



EUROPEAN COMMISSION

**Integrated Pollution Prevention and Control**

Reference Document on  
Best Available Techniques on

# **Emissions from Storage**

July 2006

This document is one of a series of foreseen documents as below (at the time of writing, not all documents have been drafted):

<b>Reference Document on Best Available Techniques...</b>	<b>Code</b>
Large Combustion Plants	LCP
Mineral Oil and Gas Refineries	REF
Production of Iron and Steel	I&S
Ferrous Metals Processing Industry	FMP
Non Ferrous Metals Industries	NFM
Smitheries and Foundries Industry	SF
Surface Treatment of Metals and Plastics	STM
Cement and Lime Manufacturing Industries	CL
Glass Manufacturing Industry	GLS
Ceramic Manufacturing Industry	CER
Large Volume Organic Chemical Industry	LVOC
Manufacture of Organic Fine Chemicals	OFC
Production of Polymers	POL
Chlor – Alkali Manufacturing Industry	CAK
Large Volume Inorganic Chemicals - Ammonia, Acids and Fertilisers Industries	LVIC-AAF
Large Volume Inorganic Chemicals - Solid and Others industry	LVIC-S
Production of Speciality Inorganic Chemicals	SIC
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector	CWW
Waste Treatments Industries	WT
Waste Incineration	WI
Management of Tailings and Waste-Rock in Mining Activities	MTWR
Pulp and Paper Industry	PP
Textiles Industry	TXT
Tanning of Hides and Skins	TAN
Slaughterhouses and Animals By-products Industries	SA
Food, Drink and Milk Industries	FDM
Intensive Rearing of Poultry and Pigs	ILF
Surface Treatment Using Organic Solvents	STS
Industrial Cooling Systems	CV
<i>Emissions from Storage</i>	ESB
<b>Reference Document...</b>	
General Principles of Monitoring	MON
Economics and Cross-Media Effects	ECM
Energy Efficiency Techniques	ENE

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## EXECUTIVE SUMMARY

The horizontal BAT (Best Available Techniques) Reference Document (BREF), entitled ‘Emissions from storage’ reflects an information exchange carried out under Article 16(2) of Council Directive 96/61/EC (IPPC Directive). This executive summary – which is intended to be read in conjunction with the BREF preface’s explanation of objectives, usage and legal terms – describes the main findings, a summary of the principal BAT conclusions and the associated emission/consumption levels. It can be read and understood as a stand alone document but, as a summary, it does not present all the complexities of the full BREF text. It is therefore not intended as a substitute for the full BREF text as a tool in BAT decision making.

### Scope

The issue ‘emissions from storage of bulk or dangerous materials’ has been identified as a horizontal issue for all activities described in Annex I of the IPPC Directive. It means that this document covers the storage, transfer and handling of liquids, liquefied gases and solids, regardless of the sector or industry. It addresses emissions to air, soil and water, however, most attention is given to emissions to air. Information about air emissions from the storage and handling/transfer of solids focuses on dust.

### General information, substances and classifications

Chapter 1, General information, provides general information on the environmental relevance of storage and handling of bulk and dangerous substances and the emission situation at storage installations by identifying, in general, the most important sources of emission to air and water and waste. Chapter 2, Substances and classifications, addresses the different classification systems of substances and the different categories of substances such as toxicity, flammability and harmfulness for the environment. For solids in bulk, it also addresses the dispersiveness class.

### Applied storage, transfer and handling techniques, and techniques to be considered in the determination of BAT

Chapter 3, Applied storage, transfer and handling techniques, describes the techniques applied in the storage, transfer and handling of liquids, liquefied gases and solids. Chapter 4 describes techniques to be considered in the determination of BAT, again related to liquids, liquefied gases and solids. First, the liquids and liquefied gases related topics will be summarised, followed by the solids related topics.

### *Liquids and liquefied gases*

For the storage of liquids and liquefied gases, the following modes are described in Chapter 3:

- open top storage tanks
- external floating roof tanks
- (vertical) fixed roof tanks
- aboveground horizontal storage tanks (atmospheric)
- horizontal storage tanks (pressurised)
- vertical storage tanks (pressurised)
- spheres (pressurised)
- mounded storage (pressurised)
- lifter roof (variable vapour space) tanks
- refrigerated storage tanks
- underground horizontal storage tanks
- containers and the storage of containers
- basins and lagoons
- mined caverns (atmospheric)
- mined caverns (pressurised)
- salt leached caverns, and
- floating storage.

Equipment such as vents; gauging, sample and access hatches; still wells and guide poles; drains; sealing elements and valves, and common issues are addressed for tanks and other storage modes, together with issues such as design, commissioning and decommissioning, economics, management and operation are also addressed.

For the transfer and handling of liquids and liquefied gases equipment, such as vents, drains, sealing elements and pressure relief devices and the following techniques or operations are described:

- aboveground open and closed piping transfer systems
- underground piping transfer systems
- loading and unloading of transporters
- gravity flow
- pumps and compressors
- inert gases
- flanges and gaskets, and
- valves and fittings.

For each storage mode and for each transfer and handling operation, the relevant operational activities, such as filling, emptying, breathing, cleaning, draining, pigging, purging, connecting/disconnecting, and possible events/incidents, such as overfill and leakages, which potentially result in an emission, are listed. This forms the basis for describing the possible emissions by mode and activity. In particular, the potential emission sources from storage modes and transfer and handling operations, are selected for further analyses using a risk matrix approach. In this approach a scoring system is applied, calculating emission scores from operational sources by multiplying emission frequency by emission volume for each single storage mode and transfer and handling operation. All potential emission sources with a score of 3 or more are considered relevant and therefore emission control measures, further called ECM, to prevent or reduce the potential emissions from these sources are discussed in Chapter 4, Techniques to be considered in the determination of BAT.

Chapter 4 provides information on the possible ECM for each storage mode discussed in Chapter 3, which includes an assessment of relevant safety, operational aspects and economic considerations. Tanks are used for the storage of a wide range of substances, such as manure,

cooling water, and all sorts of chemicals and petrochemicals. In the petrochemical industry, where large volumes of chemical and oil products are stored in tanks, a lot of experience has been gained on preventing and reducing emissions and, therefore, an important part of the information in this BREF is related to the storage of petrochemical products in tanks.

In respect of emissions from the normal operation of a tank, the following ECM, which are not solely techniques, but also operation and management tools, are discussed and assessed:

- tank design
- inspection, maintenance and monitoring
- emissions minimisation principle
- floating, flexible and fixed covers
- domes
- tank colour
- solar shields
- natural tank cooling
- external and internal floating roofs and the roof seals
- pressure and vacuum relief valves
- draining systems
- vapour balancing and treatment, and
- mixing and sludge removal.

This chapter also provides a general methodology tool for assessing the ECM for tanks for specific cases (specific product, location and storage tank) and provides a number of case studies.

ECM for potential emissions from tanks due to incidents and (major) accidents that are discussed and assessed are:

- safety and risk management
- operational procedures and training
- low level indicator in external floating roof tanks
- leakage and overfill, e.g.:
  - leakage due to corrosion and erosion
  - instrumentation and automation to prevent overfill and detect leakage
  - impervious barriers and tank bunds
  - double wall tanks
- fire protection, fire-fighting equipment and containment.

The storage techniques described in Chapter 3 for packaged dangerous materials are storage cells, storage buildings and storage yards. Operational emissions from packaged materials do not occur; the only possible emissions are from incidents and (major) accidents and ECM discussed and assessed in Chapter 4 are:

- safety and risk management
- construction and ventilation
- segregation and separation policies
- containment of leakage and contaminated extinguishant, and
- fire protection and fire-fighting equipment.

In industry, basins and lagoons are most commonly used to hold cooling water, fire-fighting water and treated and untreated waste water. In agriculture, they are widely used for storing manure. ECM discussed and assessed in Chapter 4 for basins and lagoons are floating and plastic or rigid covers, impervious barriers and protection for overfill due to rainfall.

The types of caverns identified are mined caverns that can be atmospheric, but more often than not are pressurised, and salt leached caverns. Caverns are typically used for the storage of hydrocarbons, such as crude oil, gasoline, diesel fuel, fuel oil and liquefied petroleum gas (LPG). Emissions from normal operations of pressurised mined caverns and from salt leached caverns are considered as not significant and ECM are, therefore, not identified. However, for atmospheric mined caverns, vapour balancing is discussed and assessed as an ECM for emissions from normal operation. ECM for emissions from incidents and (major) accidents that are discussed for the different types of caverns, where appropriate, are:

- safety and risk management
- monitoring
- intrinsic safety properties
- maintaining hydrostatic pressure
- cement injection
- interlock-system, and
- automated overfill protection.

Floating storage, i.e. ships, are sometimes used to provide additional, temporary storage capacity at a marine terminal. These ships are normally ex-trading vessels. Pressure and vacuum relief valves; tank colour; and vapour balancing, collection or treatment are similar to ECM identified for storage tanks. Some ECM for emissions from incidents and (major) accidents are identified, however, further information on these has not been submitted.

For the transfer and handling of liquids and liquefied gases, compared to the storage of these substances, far less ECM are identified and discussed, and the most important are: some management tools, prevention of internal and external corrosion and vapour balancing, and treatment for loading (and unloading) of transporters. For product handling, high performance valve and pump types, such as bellows valves and valves with a diaphragm and seal-less pumps and dual pressurised or unpressurised seals for pumps, are discussed and assessed.

### *Solids*

Chapter 3 also describes the techniques applied in the storage, transfer and handling of solids in bulk. Different types of open storage, which is an important potential source of dust emissions, are described, and so is storage in sacks and bulk bags, silos and bunkers, and packaged dangerous solids. The actual handling of solid bulk material is another, and compared to storage an even greater potential source of dust emissions, and several loading, unloading and conveying techniques are described, and they are:

- grabs
- discharge hoppers
- tubs
- suction air conveyors
- mobile loading devices
- dump pits
- fill pipes and tubes
- cascade tubes
- chutes
- thrower belts
- belt conveyors
- bucket elevator
- chain and screw conveyors
- pressure air conveyors, and
- feeders.

Chapter 4, Techniques to be considered in the determination of BAT, describes ECM, and their assessment, for preventing dust emissions from the storage, transfer and handling of solids. The three dust preventing approaches that are identified to minimise dust from storage and handling are: pre-primary approaches, primary approaches and secondary approaches. Pre-primary approaches are part of the production or extraction process and, therefore, outside the scope of this document. Primary approaches are approaches to prevent dust formation and they can be divided into organisational, technical and constructional approaches, of which the latter one is only applicable to storage and not to handling. Secondary approaches are abatement techniques to limit the distribution of dust where the formation of dust could not be prevented. For the storage of solids, the approaches and techniques to prevent and limit dust emissions are listed in Table 1.

Approaches and techniques to reduce dust emissions from the storage of solids		
Primary	Organisational	• monitoring
		• layout and operation of storage places (by planning and operating personnel)
		• maintenance (of prevention/reduction techniques)
		• reduction of wind attack areas
	Constructional	• large volume silos
		• sheds or roofs
		• domes
		• self-erecting covers
		• silos and hoppers
		• wind protection mounds, fences and/or plantings
Technical	• use of wind protection	
	• covering of open storage	
	• moistening of open storage	
Secondary	• water spraying/water curtains and jet spraying	
	• extraction of storage sheds and silos	

**Table 1: Approaches and techniques to reduce dust emissions from the storage of solids**

All these techniques are described and assessed in Chapter 4. For the handling of solids, the approaches and techniques to prevent and limit dust emissions are listed in Table 2. These techniques are also described and assessed in Chapter 4.

Approaches and techniques to reduce dust emission from the transfer and handling of solids		
Primary	Organisational	Weather conditions
		Measures (for the crane operator) when using a grab: <ul style="list-style-type: none"> <li>• reduction of the drop height when the material is discharged</li> <li>• total closing of the grab/jaws after material pick-up</li> <li>• leaving the grab in the hoppers for a sufficient time after discharge</li> <li>• stopping of grab operations when the wind is strong.</li> </ul>
		Measures (for the operator) when using a belt conveyor: <ul style="list-style-type: none"> <li>• suitable conveyor speed</li> <li>• avoiding loading the belt up to its edges.</li> </ul>
		Measures (for the operator) when using a mechanical shovel: <ul style="list-style-type: none"> <li>• reducing the drop height when the material is discharged</li> <li>• choosing the right position during discharging into a truck.</li> </ul>
		Layout and operation of storage sites (by the planner and the operating personnel) <ul style="list-style-type: none"> <li>• reduction of transport distances</li> <li>• adjusting the speed of vehicles</li> <li>• roads with hard surfaces</li> <li>• reduction of wind attack areas</li> </ul>
	Technical	Optimised grabs
		Use of closed conveyors (e.g. tube belt conveyors, screw conveyors)
		Conveyor belt without support pulleys
		Primary measures on conventional conveyor belts
		Primary measures on transfer chutes
		Minimising speed of descent
		Minimisation of free fall heights (e.g. cascade hoppers)
		Use of dust barriers on dump pits and hoppers
		Low dust bunker
Chassis of vehicles with round tops		
Secondary	Screens for open conveyor belts	
	Housing or covering of the emission sources	
	Applying covers, aprons or cones on fill tubes	
	Extraction systems	
	Filter systems for pneumatic conveyors	
	Dump pits with suction equipment, housing and dust barriers	
	Optimised discharge hoppers (in ports)	
	The techniques of water spraying/water curtains and jet spraying	
	Cleaning conveyor belts	
	Fitting trucks with mechanical/hydraulic flaps	
	Cleaning of roads	
	Cleaning of vehicle tyres	

**Table 2: Approaches and techniques to reduce dust emission from transfer and handling of solids**

### Best available techniques

The following paragraphs summarise Chapter 5, Best available techniques, by describing the techniques, approaches or activities from which conclusions on BAT are achieved. These relate to the most relevant environmental issues, namely emissions from normal operation to air and soil on the storage and handling of liquids and dust emissions from the storage and handling of solids. In some situations BAT conclusions on emissions from incidents and (major) accidents are also reported. These paragraphs should not be read instead of the ‘Best available techniques’ chapter. Evenso, the BAT chapter should not be read in isolation from the rest of the BREF, and for this reason cross references are made in each BAT conclusion to the relevant sections in other chapters.



The BAT conclusions in Chapter 5 are grouped as follows. Firstly, BAT conclusions are listed on the storage of liquids and liquefied gases, addressing the general principles to prevent and reduce emissions, which are:

- inspection and maintenance
- location and layout
- tank colour
- emission minimisation principle in tank storage
- monitoring of VOC, and
- dedicated systems.

This is followed by tank specific BAT conclusions on emissions from normal operation, addressing all the types of tanks that are described in Chapter 4, logically followed with BAT conclusions on (potential) emissions that do not result from normal tank operations, namely on the prevention of incidents and (major) accidents, addressing:

- safety and risk management
- operational procedures and training
- leakage due to corrosion and/or erosion
- operational procedures and instrumentation to prevent overflow
- instrumentation and automation to detect leakage
- risk-based approach to emissions to soil below tanks
- soil protection around tanks (containment)
- flammable areas and ignition sources
- fire protection
- fire-fighting equipment, and
- containment of contaminated extinguishant.

The BAT conclusions on tank storage are followed by the BAT conclusions on the other storage techniques, namely:

- storage of packaged dangerous substances
- basins and lagoons, and
- mined and salt leached caverns.

It is concluded that floating storage is not BAT.

Secondly, BAT conclusions on the transfer and handling of liquids and liquefied gases are listed, also starting with the general principles to prevent and reduce emissions, which in this case are:

- inspection and maintenance
- leak detection and repair programme
- emissions minimisation principle in tank storage
- safety and risk management, and
- operational procedures and training.

BAT conclusions on specific techniques are achieved on piping systems addressing aboveground and underground piping systems, on abatement of emissions from loading and unloading activities, on the joints in the piping systems and the prevention of corrosion, on valves, on pumps and compressors, and on sampling connections.

Thirdly, BAT conclusions on dust emissions from open and enclosed storage and the storage of packaged materials are listed, ending with a BAT conclusion on safety and risk management.

Finally the BAT conclusions on dust emissions from the transfer and handling of solids are listed, starting with conclusions on the following general approaches to minimise dust emissions:

- scheduling the transfer activities
- continuous transport
- reduction measures when applying discontinuous transport, which are:
  - cleaning of roads and vehicle tyres
  - moistening of the product
  - minimising the speed of descent, and
  - minimising the free fall height.

The BAT conclusions on general approaches are followed by conclusions on minimising dust emissions from the transfer techniques grabs and conveyors.

### Concluding Remarks

In Chapter 7 – Concluding Remarks – the reader will find information on:

- which pieces of information were submitted by the TWG are the cornerstones of this BREF
- the level of consensus reached on the BAT conclusions
- the recommendations for future work, and
- the topics suggested for future R&D projects.

It is concluded that a high level of consensus was reached, because on the total of 110 BAT conclusions 5 split views were reported. These split views are regarding some BAT conclusions in the sections on storage and handling of liquids and liquefied gases. On the BAT conclusions regarding the storage and handling of solids, no split views were reported. The split views are on the following topics:

- the assessment methodology (ECM methodology)
- the requirement of applying a vapour treatment installation for the storage of certain volatile substances regarding three different tank types, and
- the tool that can be used for quantifying VOC emissions.

At the Information Exchange Forum (IEF) meeting in December 2004, a general split view from a few Member States on the emphasis on determining BAT on a case by case basis was recorded and added to Chapter 5.

Recommendations for the future review of the BREF address the following topics:

- the development of a European classification system for air pollutants
- the separation of the storage and handling of liquids and liquefied gases and the storage and handling of solids which are two completely different areas and, therefore, require different expertise
- the monitoring of VOC emissions and tools to validate the emission calculation methods
- updating the list of techniques to prevent or reduce emissions from tanks to the soil
- collecting data on the loading and unloading of transporters concerning volatile substances, and
- collecting feedback on the assessment methodology.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are, therefore, invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).

## PREFACE

### 1. Status of this document

Unless otherwise stated, references to “the Directive” in this document means the Council Directive 96/61/EC on integrated pollution prevention and control. As the Directive applies without prejudice to Community provisions on health and safety at the workplace, so does this document.

This document forms part of a series presenting the results of an exchange of information between EU Member States and industries concerned on best available technique (BAT), associated monitoring, and developments in them. It is published by the European Commission pursuant to Article 16(2) of the Directive, and must therefore be taken into account in accordance with Annex IV of the Directive when determining “best available techniques”.

### 2. Relevant legal obligations of the IPPC Directive and the definition of BAT

In order to help the reader understand the legal context in which this document has been drafted, some of the most relevant provisions of the IPPC Directive, including the definition of the term ‘best available techniques’, are described in this preface. This description is inevitably incomplete and is given for information only. It has no legal value and does not in any way alter or prejudice the actual provisions of the Directive.

The purpose of the Directive is to achieve integrated prevention and control of pollution arising from the activities listed in its Annex I, leading to a high level of protection of the environment as a whole. The legal basis of the Directive relates to environmental protection. Its implementation should also take account of other Community objectives such as the competitiveness of the Community’s industry thereby contributing to sustainable development.

More specifically, it provides for a permitting system for certain categories of industrial installations requiring both operators and regulators to take an integrated, overall look at the polluting and consuming potential of the installation. The overall aim of such an integrated approach must be to improve the management and control of industrial processes so as to ensure a high level of protection for the environment as a whole. Central to this approach is the general principle given in Article 3 that operators should take all appropriate preventative measures against pollution, in particular through the application of best available techniques enabling them to improve their environmental performance.

The term ‘best available techniques’ is defined in Article 2(11) of the Directive as ‘the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.’ Article 2(11) goes on to clarify further this definition as follows:

‘techniques’ includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;

‘available’ techniques are those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;

‘best’ means most effective in achieving a high general level of protection of the environment as a whole.

Furthermore, Annex IV of the Directive contains a list of ‘considerations to be taken into account generally or in specific cases when determining best available techniques ... bearing in mind the likely costs and benefits of a measure and the principles of precaution and prevention’. These considerations include the information published by the Commission pursuant to Article 16(2).

Competent authorities responsible for issuing permits are required to take account of the general principles set out in Article 3 when determining the conditions of the permit. These conditions must include emission limit values, supplemented or replaced where appropriate by equivalent parameters or technical measures. According to Article 9(4) of the Directive, these emission limit values, equivalent parameters and technical measures must, without prejudice to compliance with environmental quality standards, be based on the best available techniques, without prescribing the use of any technique or specific technology, but taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In all circumstances, the conditions of the permit must include provisions on the minimisation of long-distance or transboundary pollution and must ensure a high level of protection for the environment as a whole.

Member States have the obligation, according to Article 11 of the Directive, to ensure that competent authorities follow or are informed of developments in best available techniques.

### **3. Objective of this Document**

Article 16(2) of the Directive requires the Commission to organise ‘an exchange of information between Member States and the industries concerned on best available techniques, associated monitoring and developments in them’, and to publish the results of the exchange.

The purpose of the information exchange is given in recital 25 of the Directive, which states that ‘the development and exchange of information at Community level about best available techniques will help to redress the technological imbalances in the Community, will promote the worldwide dissemination of limit values and techniques used in the Community and will help the Member States in the efficient implementation of this Directive.’

The Commission (Environment DG) established an information exchange forum (IEF) to assist the work under Article 16(2) and a number of technical working groups have been established under the umbrella of the IEF. Both IEF and the technical working groups include representation from Member States and industry as required in Article 16(2).

The aim of this series of documents is to reflect accurately the exchange of information which has taken place as required by Article 16(2) and to provide reference information for the permitting authority to take into account when determining permit conditions. By providing relevant information concerning best available techniques, these documents should act as valuable tools to drive environmental performance.

### **4. Information Sources**

This document represents a summary of information collected from a number of sources, including in particular the expertise of the groups established to assist the Commission in its work, and verified by the Commission services. All contributions are gratefully acknowledged.

### **5. How to understand and use this document**

The information provided in this document is intended to be used as an input to the determination of BAT in specific cases. When determining BAT and setting BAT-based permit conditions, account should always be taken of the overall goal to achieve a high level of protection for the environment as a whole.

The rest of this section describes the type of information that is provided in each section of the document.

Chapter 1 provides information on the storage and handling of bulk and dangerous substances in general.

Chapter 2 addresses the relevant classification of substances, such as toxicity, flammability and harmfulness for the environment. For solids in bulk it also addresses the dispersiveness class.

Chapter 3 describes the various modes used to store liquids and gases, as well as possible emissions resulting from storage and transfer facilities both above and below ground. For each storage and transfer category, relevant operational activities and possible events/incidents are listed. Emission scorecards are developed and show which emissions are relevant and which therefore are discussed in more detail in Chapter 4.

This chapter also describes the storage and handling of solids in bulk. Heaps of bulk material such as cereals and coals in the open air are a potential source of dust emissions. Different types of heaps are described. Because the actual handling of solid bulk material is another potential source of dust emissions, several loading, unloading and conveying techniques are described.

Chapter 4 provides basic information on the possible Emission Control Measures (the so-called ECM) which, for liquids and gases, includes an assessment of relevant safety and operational aspects and economic considerations. ECM for preventing dust emissions from the storage and handling of solids are also described and assessed, but this assessment is less comprehensive than for liquids and gases. This chapter also provides for a general methodology for making the appropriate assessment of ECM for specific cases (specific product, storage mode and site) and providing a number of case studies. The purpose is thus to provide a general methodology to be applied to the storage and handling of substances to assist in the determination of BAT-based permit conditions. It should be noted, however, that the methodology presented in Chapter 4 will not necessarily be appropriate for all installations.

Chapter 5 focuses on the selection and description of BAT. It should be stressed, however, that this document does not propose emission limit values. The determination of appropriate permit conditions will involve taking account of local, site-specific factors such as the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. For existing installations, the economic and technical viability of upgrading them also needs to be taken into account. Even the single objective of ensuring a high level of protection for the environment as a whole will often involve making trade-off judgements between different types of environmental impact, and these judgements will often be influenced by local considerations.

Since the best available techniques change over time, this document will be reviewed and updated as appropriate. All comments and suggestions should be made to the European IPPC Bureau at the Institute for Prospective Technological Studies at the following address:

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# Best Available Techniques Reference Document on Emissions from Storage

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## SCOPE

This horizontal BAT Reference Document (BREF), entitled ‘Emissions from storage’, covers the storage and the transfer/handling of liquids, liquefied gases and solids, regardless of the sector or industry.

It addresses emissions to air, soil and water. However, most attention is given to emissions to air. Energy and noise are also addressed but to a lesser extent.

Of the following storage modes applied for the storage of liquids and liquefied gases, a short description is given and their main emission sources are identified:

Tanks:

- open top tank
- external floating roof tank
- fixed roof tank
- aboveground horizontal storage tanks (atmospheric)
- horizontal storage tanks (pressurised)
- vertical storage tanks (pressurised)
- spheres (pressurised)
- mounded storage tank (pressurised)
- lifter roof (variable vapour space) tank
- refrigerated storage tank
- underground storage tank.

Other storage modes:

- containers and the storage of containers
- basins and lagoons
- mined caverns
- salt leached caverns
- floating storage.

And, in particular for the storage of solids:

- heaps
- sacks and bulk bags
- silos and bunkers
- packaged dangerous solids.

For the transfer and handling of liquids and liquefied gases, techniques such as piping systems and loading and unloading equipment are addressed, such as valves, pumps, compressors, flanges and gaskets, etc.

For the transfer and handling of solids, techniques such as mobile unloading devices, grabs, dump pits, fill pipes, thrower belts, conveyors and feeders are described, and in each case the emission sources are identified.

For all significant emissions sources from the storage and transfer/handling of liquids and liquefied gases, emission reduction techniques are described, such as management tools and techniques, e.g., bunds, double wall tanks, level control instrumentation, seals, vapour treatment and fire protection.

## Scope

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Information about air emissions from the storage and handling/transfer of solids focuses on dust. Techniques to prevent or reduce dust such as water spraying, covers, enclosed storage and handling facilities are described, together with some operational tools.

The storage and handling of gas is also in the scope of this document, however it is not described further in this document as no information was submitted. The main reason for this is that at most times gas is stored under pressure, as liquefied gas. The storage and handling of liquefied gases is described together with that of liquids, since similar techniques are applied.

## 1. GENERAL INFORMATION

[18, UBA, 1999]

Storage is an activity which occurs in connection with practically all industrial activities, including, in particular, those industrial activities cited in Article 1 of the IPPC Directive. The techniques or systems described in this document could be applied to basically all categories of industrial activities.

### 1.1. Environmental relevance of storage

The environmental relevance of storage is essentially dependent on its potential to pollute the environment and on the physico-chemical properties of the stored substances. It is important to note that there is a difference between hazard (the inherent properties of a chemical) and risk (the probability of the hazardous properties of the chemical causing harm to people or the environment). Different substances create very different risks because of their hazards. It is therefore important that applied emission control measures are based on an understanding of the physico-chemical properties of the substances concerned. A risk-based approach is commonly applied and is hence also used in this document.

An example of this risk-based approach is the storage of solids. The danger of solids (immobile) polluting groundwater during storage is, as a rule, smaller than that of liquid (mobile) substances. However, in this context it is also necessary to consider possible accident scenarios. For example, in the event of a fire with solids which may not be hazardous themselves, dangerous gases may be produced. In this way, substances which are immobile and/or are considered to be harmless can still cause air pollution and may contaminate soil and waters e.g. through the fire-extinguishing water and the wasting out of the combustion gases. In addition, extinguishing additives, which serve as solvents, can dissolve substances adsorbed on soot particles, which when in the extinguishing water pathway, poses a hazard to water.

Hence it is not possible to come up with generally applicable statements about environmental significance, which cover all substances for storage in connection with industrial activities. Nevertheless, almost all substances are capable of adversely changing the physical, chemical and biological characteristics of the environment.

Concerning dust, several epidemiological studies (e.g. by the American 'Environmental Protection Agency') have shown that an adverse health impact can be discerned even at the airborne dust concentrations normally found in the open air. Increased particle intake raises the likelihood of respiratory ailments, disorder of the cardiovascular system and the general impairment of lung performance. The extent of the adverse impact on health depends on – over and above the individual constitution and susceptibility – the composition of the dust, their concentration, the exposure time and the particle size distribution.

A special significance is attached to particles smaller than 10  $\mu\text{m}$ . The designation  $\text{PM}_{10}$  (particulate matter < 10  $\mu\text{m}$ ) is used in the corresponding EU regulations. Analogous terminology is used for other particle sizes (e.g.  $\text{PM}_{2.5}$  for particle diameters less than 2.5  $\mu\text{m}$ ).

Fine dust can penetrate deep into the lungs, reach the alveoli and accumulate there or may cross the alveolus wall to enter into the bloodstream. This applies in particular to particles less than 10  $\mu\text{m}$ . Particles with an aerodynamic diameter of 10  $\mu\text{m}$  are 1.3 % alveolus penetrative, particles of 5  $\mu\text{m}$  30 %, of 4  $\mu\text{m}$  50 % and 1  $\mu\text{m}$  penetrates at a rate of 97 %. A proportion of smaller particles are exhaled. Specific causality investigations have shown that amongst the particles that penetrate the alveoli, the fine particles (2 to 4  $\mu\text{m}$ ) and the ultra-fine particles (less than 0.1  $\mu\text{m}$ ) exhibit the highest rate of deposition. In relation to the effect of fine particles (2 to 4  $\mu\text{m}$ ) a dose effect relationship is assumed, whereby the mass of particles remaining in the respiratory system is the decisive factor.

Apart from the potential adverse impact on health from dust, the impairment of water quality and the risk for explosion and fire are other examples of potential effects of the storage and handling of solids.

The consumption of energy during storage, for example:

- for the warm storage of special substances (warm ‘cupboards’ for various containers or heat generating covers in the case of stationary tanks)
- if applicable, for the heating of buildings in container depots
- for the operation of pumps, exhaust ventilators, etc.
- for cooling, if applicable.

These are generally not factors which significantly influence the capacity of various techniques to protect the environment. Quantitative details on this subject are, therefore, only possible in separate cases: e.g. if waste heat from production installations which cannot be used otherwise as an energy source can be used for the heating of tanks.

## **1.2. Emission situation at storage installations**

The following emissions could occur during the operation of storage modes:

- emissions from normal operating conditions (including transferring substances in and out of storage and cleaning)
- emissions from incidents and (major) accidents.

The aforementioned emissions can be:

- emissions to air
- emissions (discharges) to water (direct/indirect)
- noise emissions
- waste emissions.

### **1.2.1. Emissions to air**

Important emissions to air from the storage of liquid and liquefied gases during normal operation are differentiated as follows:

- emissions during entry and evacuation i.e. transferring substances in and out of storage (filling and emptying)
- emissions during tank breathing, i.e. emissions due to temperature increases resulting in vapour space expansions and subsequent emissions
- fugitive emissions from flange seals, fittings and pumps
- emissions during sampling
- emissions from cleaning operations.

The following categories of emissions from dusty bulk materials may be distinguished and are addressed in this document:

- emissions during loading of the material
- emissions during discharge of the material
- emissions during conveyance of the material
- emissions during storage of the material.

### 1.2.2. Emissions to water

Emissions which occur into water (direct or indirect via canalisation and sewage or purification plants) and that are addressed in this BREF include the following:

- waste water from chemical warehouses, tanks, seepage water, etc.
- discharge from drainage facilities (precipitation from secondary containment)
- waste water from leaching
- waste water from cleaning
- fire-fighting water.

### 1.2.3. Noise emissions

Noise emissions in storage installations essentially occur only during transfer in and out of storage.

- emissions from pumps in tank installations
- vehicle traffic (stacker) and air vent valves in containers installations
- emissions from transferring solids, such as conveyors.

Noise emissions are generally of secondary importance in establishing optimal storage techniques and are, therefore, not addressed in great detail in this document.

### 1.2.4. Waste aspects

Typical waste products that can arise in an operating storage facility are:

- residues from containers or products of a substandard quality
- waste from installations which treat exhaust gases (e.g. activated carbon)
- used containers
- (oil) sludges
- if applicable, cleaning agents, which may contain chemicals or oil.

In discussing the different storage modes and different handling and transfer techniques, any possible waste arising is addressed. The treatment of these wastes, however, is not addressed in this document.

### 1.2.5. Incidents and (major) accidents

Apart from emissions during normal operating conditions, possible emissions from incidents and (major) accidents are addressed. Emissions from incidents and (major) accidents usually occur within a relatively short time frame but with a much greater intensity than emissions which occur under normal operating conditions.

The control of major accident hazards involving dangerous substances is covered by the Seveso II Directive (Council Directive 96/82/EC of 9 December 1996), which requires companies to take all measures necessary to prevent and limit the consequences of major accidents. Companies must in any case have a 'major accident prevention policy' (MAPP) and a safety management system to implement the MAPP. Companies holding large quantities of dangerous substances, so-called upper tiered establishments, must also draw up a safety report and an on-site emergency plan and also maintain an up-to-date list of substances.

In this document, techniques to prevent emissions from incidents and (major) accidents are addressed, ranging from e.g. techniques to prevent a tank overflow to a complete tank rupture. However, the range of incidents and accidents is not exhaustive and does not distinguish between small or major accidents.





## 2. SUBSTANCES AND CLASSIFICATION

### 2.1. Nature and classification of dangerous materials

The classification of dangerous substances is the process of identifying their hazardous properties by using appropriate test methods and then allocating them to one or more hazard classes by comparing the results of the tests with the classification criteria. Preparations or mixtures may be classified either by testing or by applying calculation methods based upon the concentration of their hazardous components.

The list in Table 2.1 shows an overview of the relevant categories of substances with their danger characteristics and hazard symbols. Furthermore, the R-Phrases can appear separately or in combination. In Annex 8.2 the symbols and R-Phrases are explained in detail.

Hazard	Symbol	R-Phrases
Explosive	E	1, 2, 3
Oxidising	O	7, 8, 9
Extremely flammable	F+	12
Highly flammable	F	11
Flammable	-	10
Reacts strongly with water	-	14
Reacts strongly with water producing extremely flammable gases	-	15
Forms poisonous gases in contact with water	-	29
Very toxic	T+	26, 27, 28 (-39)
Toxic	T	23, 24, 25 (-39, -48)
Harmful	Xn	20, 21, 22, 65 (-48)
Corrosive	C	34, 35
Irritant	Xi	36, 37, 38
Sensitising	-	42, 43
Carcinogenic	-	40, 45, 49
Toxic for reproduction	-	60, 61, 62, 63, 64
Mutagenic	-	46
Dangerous for the environment	N	50, 51, 52, 53, 58, 59
VOC <sup>1)</sup>	-	-
Dust <sup>1)</sup>	-	-
<sup>1)</sup> <i>Dangerous according to Annex 3 of the IPPC Directive</i>		

**Table 2.1: Categories of dangerous substance according to Directive 67/548/EEC**

The following subjects are also addressed in detail in Annex 8.2 – Dangerous substances and classification:

- regulatory classification systems (European Union supply legislation; transport legislation)
- scope of regulatory classification systems (European supply system; UN RTDG transport system)
- hazard communication within regulatory classification systems
- physico-chemical hazards:
  - explosive hazards (EU system; UN RTDG transport system)
  - oxidising and organic peroxide hazards (EU system; UN RTDG transport system)
  - flammability hazards
  - EU system (liquids; solids; gases; pyrophoric/self-heating; water reactive evolving flammable gases; other physico-chemical properties)
  - UN RTDG transport system (liquids; solids; gases; self-reactive and related substances; desensitised explosives; pyrophoric/self-heating; water reactive evolving flammable gases)
  - physico-chemical properties (EU system; UN RTDG transport system)

- health hazards:
  - acute toxicity (EU system; UN RTDG transport system)
  - sub-acute, sub-chronic or chronic toxicity (very serious irreversible effects by a single exposure; very serious irreversible effects by repeated or prolonged exposure)
  - corrosive and irritant (EU system – corrosive; UN RTDG transport system; EU system – irritant)
  - sensitisation
  - specific effects on health
  - other health effects (EU system; UN RTDG transport system)
- environmental hazards (EU system; UN RTDG transport system).

It should be noted that the classification systems described in detail in Annex 8.2 do not necessarily cover all the criteria required for dangerous goods storage legislation in all Member States of the European Union. For example, in parts of Belgium, storage legislation covers flashpoints up to 250 °C.

Classification leads to hazard communication, of which there are two forms: immediate information on the label of the packaging containing the dangerous goods and more detailed information on, for example, an attached safety data sheet.

In several MS there are existing classification systems related to emissions to air and water, e.g. in the TA Luft in Germany (see <http://www.umweltbundesamt.de/wgs/vwvws.htm>) and in the NER in the Netherlands (see <http://www.infomil.nl/lucht/index.htm>).

## 2.2. Classification of packaged substances

In reference [HSE, 1998 #35] the UN RTDG transport system (explained in Annex 8.2 – Dangerous substances and classification) is used in expressing the compatibility of packaged substances. See Annex 8.3 where the compatibility of substances is given in a table.

This principle of separation and segregation is not only relevant for the storage of packaged substances, but is also relevant for storage in tanks.

## 2.3. Dispersiveness classes of solid bulk material

[InfoMil, 2001 #15]

The following classification, based on the susceptibility of a material to be dispersed and the possibility of dealing with the problem by wetting, is used for non-reactive products:

- S1: highly drift sensitive, not wettable**
- S2: highly drift sensitive, wettable**
- S3: moderately drift sensitive, not wettable**
- S4: moderately drift sensitive, wettable**
- S5: not or very slightly drift sensitive.**

Dispersiveness classes of solid bulk materials shows a long list of different solid materials and their respective dispersiveness class; see Annex 8.4.

The storage and transfer of toxic and/or reactive products is disregarded here because, when these products are loaded for transport or storage in bulk, they are handled in closed system or in packaged form and not as loose material.

## 2.4. How to use classification systems in this document

The classification systems described in Section 2.1 are very comprehensive and rather complex, but usually only part of the hazardous properties (e.g. flammability) really influences the design mode and the operation of a storage unit. Conversely some properties are ignored, or virtually ignored, by the classification system although they can have a major influence on the design and operation of the storage unit; examples of this may be the freezing and boiling points, vapour pressure and data on suitable construction materials. This is because the classification criteria of the dangerous substances are based on their intrinsically hazardous properties and are not based on risk.

The classification system by themselves do not include all data necessary to define BAT for the storage of a given substance, but include hazardous properties data which is necessary to perform a risk analysis. The classification data of a given substance are, therefore, useful when considering the determination of BAT.

In any situation, the precautions needed to achieve a reasonable standard of control will vary, but they must always take into account the properties of the substance to be stored. This is especially important as different substances can create very different risks because of their hazards. Interaction between different substances, especially those which are incompatible, may create additional hazards. Although this statement is made in the context of packaged dangerous substances in warehouses, it is also valid for dangerous substances in bulk.



### 3. APPLIED STORAGE, TRANSFER AND HANDLING TECHNIQUES

This chapter describes applied storage, transfer and handling techniques for liquids and liquefied gases, and solids. Storage of liquids and liquefied gases and all that is related to storage is described in Section 3.1. The transfer and handling of liquids and liquefied gases is described in Section 3.2. The storage of solids is described in Section 3.3 and transfer and handling of solids in Section 3.4.

#### 3.1. Storage of liquids and liquefied gases

In this section the following storage modes are considered:

Type of storage mode	Atmospheric, pressurised, refrigerated	Sections
Open top storage tank	Atmospheric	Section 3.1.1
External floating roof tanks	Atmospheric	Section 3.1.2
(Vertical) fixed roof tanks	Atmospheric	Section 3.1.3
Horizontal storage tanks (aboveground)	Atmospheric	Section 3.1.4
Horizontal storage tanks (underground)	Atmospheric	Section 3.1.11
Variable vapour space tanks	Atmospheric	Section 3.1.9
Spheres	Pressurised	Section 3.1.7
Horizontal storage tanks	Pressurised	Section 3.1.5
Vertical cylindrical tanks	Pressurised	Section 3.1.6
Mounded storage	Pressurised	Section 3.1.8
Refrigerated storage tanks	Refrigerated	Section 3.1.10
Caverns	Atmospheric	Section 3.1.15
Caverns	Pressurised	Section 3.1.16
Caverns – salt leached		Section 3.1.17
Containers and storage of containers		Section 3.1.13
Basins and lagoons	Atmospheric	Section 3.1.14
Floating storage	Atmospheric	Section 3.1.18

**Table 3.1: Cross-references of storage modes for liquids and liquefied gases**

The flow chart in Figure 3.1 identifies the possible gaseous and liquid emissions and residues, resulting from the storage of liquid materials. The base case for any of the storage modes described assumes that there are no emission control measures installed, e.g. a fixed roof tank will be assumed to have only open vents, the shell will not be painted a light colour, etc. For each storage category, the relevant operational activities and possible events/incidents which can result in an emission are listed. This forms the basis for describing the possible emissions by mode and activity.

In particular, the possible emission sources from storage facilities for liquids and liquefied gases are selected for further analyses, using a risk matrix approach as shown in Figure 3.2.

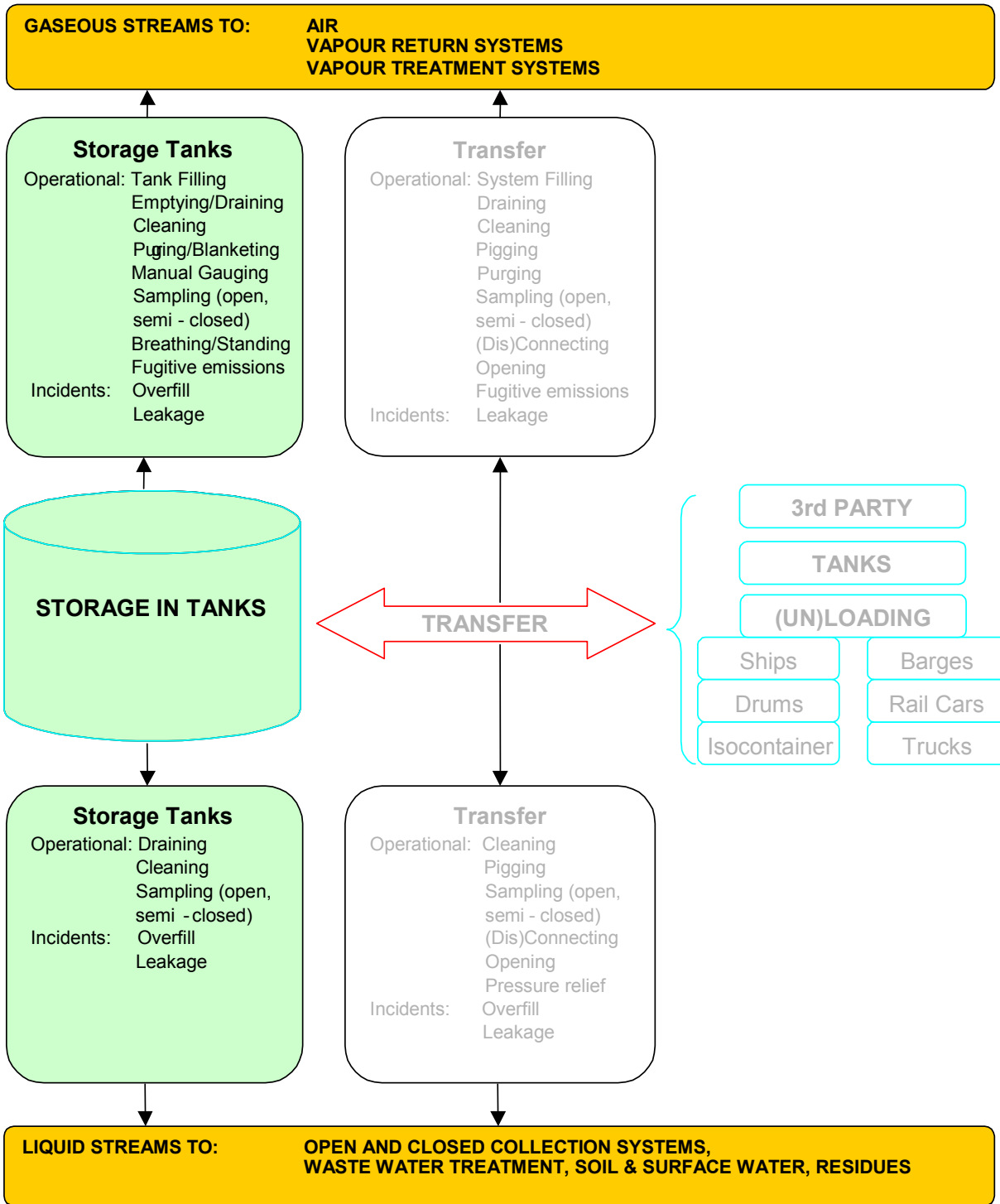


Figure 3.1: Flow chart with potential emissions resulting from aboveground and underground storage facilities

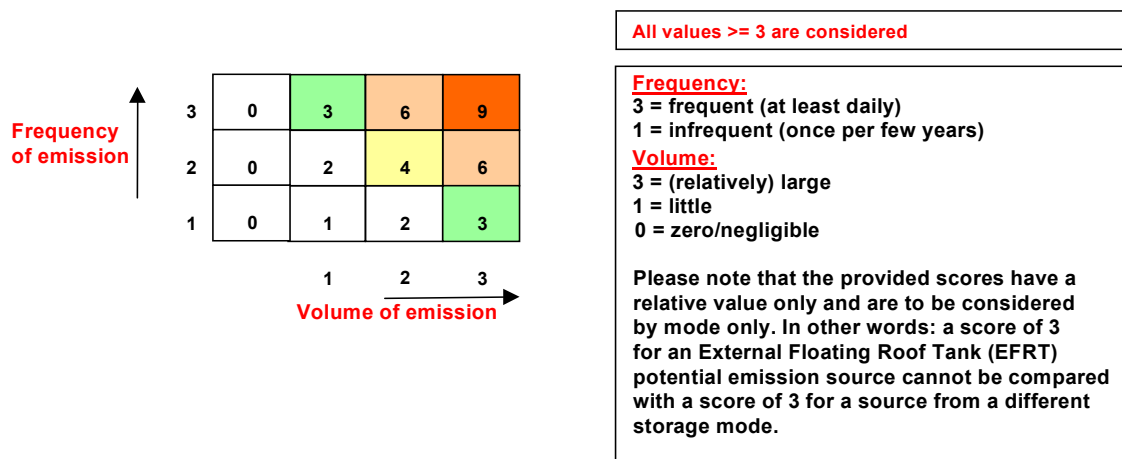


Figure 3.2: Risk matrix for emissions from storage of liquids and liquefied gases

**Remarks:**

1. The classification term N/A (Not Applicable) indicates that a particular emission source will not be considered (not applicable or not relevant, etc.) due to the specific nature of the storage mode described.
2. A clear distinction will be made between emissions from 'operational sources' and emission from 'incidents'.
3. The emission scores (from 'operational sources') are calculated by multiplying emission frequency by emission volume. This methodology is commonly applied in risk assessment approaches such as the one used for risk based inspection (as will be further explained in the BREF). All scores above 3 are considered: e.g. all 'high' frequencies (score = 3), 'large' volumes (score = 3) and the 'medium/medium' frequency/volume emission sources (where frequency and volume both score 2).

The different types of storage tanks used are described in various sections as shown in Table 3.1. To prevent repetition, all the common technical issues, such as commissioning, decommissioning and equipment, are described in separate sections. Where relevant, cross-referencing, as an instrument to link the related issues, is used to ease the search for those related issues. Other storage modes such as, e.g. warehouses, basins, lagoons and caverns, have less or no common technical issues and are, therefore, only described in separate sections.

### 3.1.1. Open top storage tanks

#### A. Description

Open top tanks are normally used for storing manure slurry and are made from curved steel panels or concrete sections. Some concrete panel tanks may be partly below ground. All tanks are built on a properly designed reinforced concrete base. In all tank designs, the thickness of the base plate and the suitability of the seal at the joint of the wall and the tank base are very important features to prevent leaking.

A typical system has a reception pit with a grid cover next to the main store. Open top tanks are filled via a pipe with an opening above or below the slurry surface. The main store may have a valved outlet to allow emptying back to the reception pit or it may be emptied using a pump located in the store.

An open top tank may be covered with a natural or artificial layer of floating matter (such as granulated materials, straw chaff or floating membrane) or with a firm cover (such as a canvas or concrete roof) to keep rainwater out and to reduce emissions (e.g. ammonia from manure slurry). The fitting of a firm cover permits the collection and treatment of emissions.

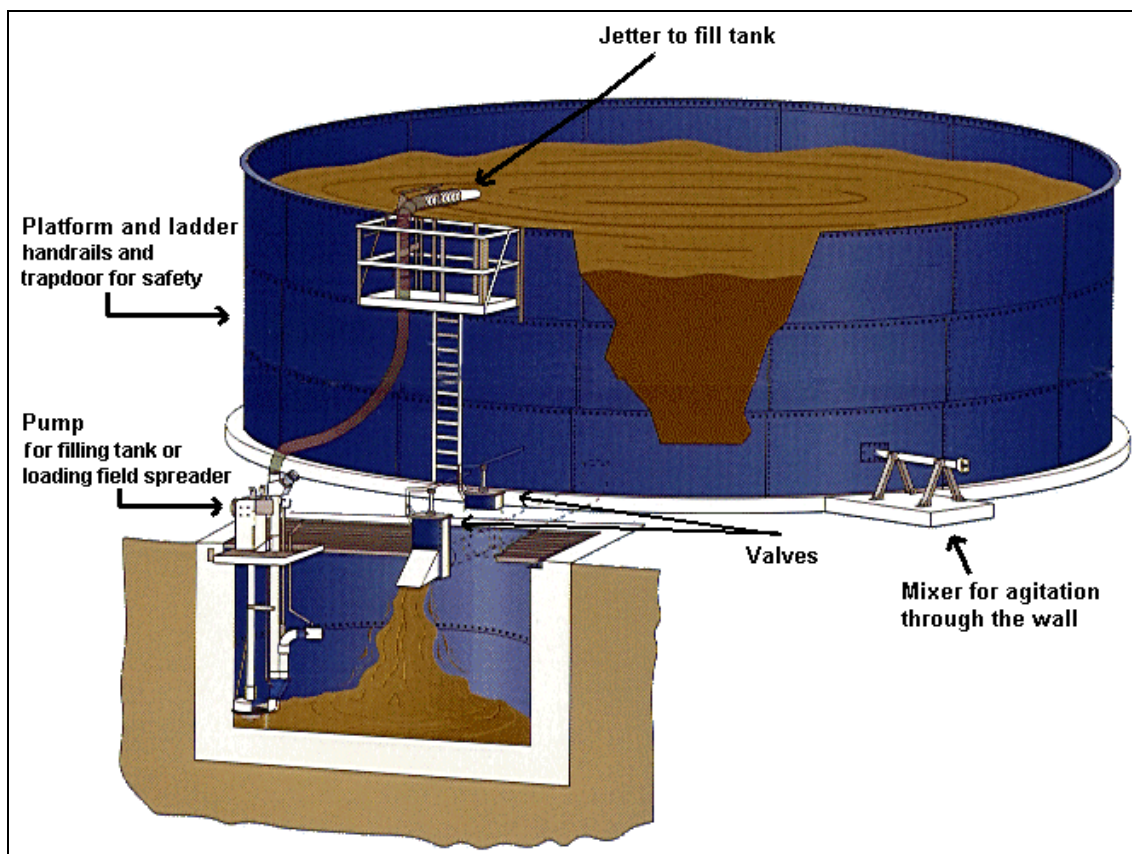


Figure 3.3: Example of an open top slurry tank with underground receiving pit [119, EIPPCB, 2001]



## B. Relevant tank equipment and other considerations

		Section
3.1.12.7 Equipment for tanks	Instrumentation	3.1.12.7.4
	Drains	3.1.12.7.6
	Mixers	3.1.12.7.7
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
3.1.12 Considerations related to tanks		

**Table 3.2: Cross-references for open top tanks**

## C. Possible emission sources (open top tanks)

Table 3.3 and Table 3.4 show the emission scores for the potential emission sources for open top tanks. Section 3.1, Figure 3.2 explains the methodology for calculating the emission score. Sources with an emission score of 3 or more will be addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	3	6
Standing	3	3	9
Emptying	2	1	2
Cleaning	1	2	2
Blanketing			N/A
Manual gauging			N/A
Sampling			N/A
Fugitive			N/A
Draining			N/A

**Table 3.3: Possible emissions to air from ‘operational sources’ with open top storage tanks [113, TETSP, 2001]**

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	1	3	3
Sampling	2	0	0

**Table 3.4: Possible liquid emissions to water or waste from ‘operational sources’ with open top storage tanks [113, TETSP, 2001]**

Apart from operational losses, infrequent emissions can also occur from incidents and (major) accidents such as overflow and leaks. These emissions are also addressed in Chapter 4.

### 3.1.2. External floating roof tanks (EFRT)

#### A. Description

[84, TETSP, 2001], [41, Concawe, 1999] [66, EPA, 1997] [114, UBA, 2001]

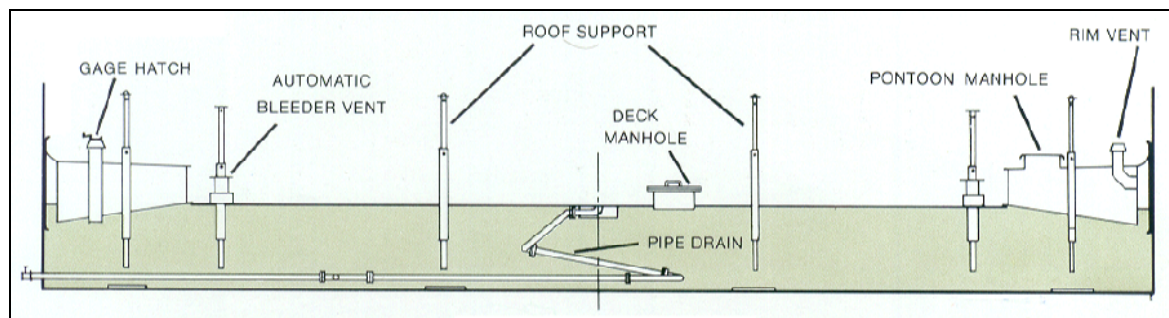
A typical EFRT consists of an open topped cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid. The floating roof consists of a deck, fittings, and a rim seal system. With all types of EFRT, the roof rises and falls with the rise and fall of the liquid level in the tank. External floating decks are equipped with a rim seal system, which is attached to the deck perimeter and contacts the tank wall. The purpose of the floating deck and rim seal system is to reduce emissions to air (and loss of product) of the stored liquid. The seal system slides against the tank wall as the roof is raised and lowered. The floating deck is also equipped with fittings that penetrate the deck and serve operational functions. The external floating roof design is such that evaporative losses from the stored liquid are limited to losses from the rim seal system and deck fittings (standing storage loss) and from any liquid left on the inner tank shell as the roof falls (withdrawal loss).

An EFRT can be fitted with a geodesic dome roof. These dome roofs are primarily installed to prevent water ingress to the product or to reduce snow load on the floating roof. A dome roof, however, also reduces the wind effects on the roof seals system and thus reduces emissions. A dome roof is thus an emission control device and a such is described in Section 4.1.3.5.

There are three main types of floating roof:

#### *Pontoon-type floating roofs*

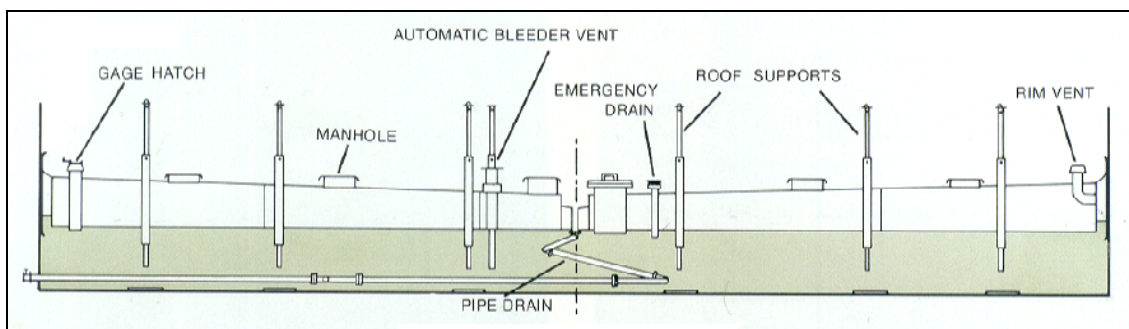
For these roofs, the buoyancy is supplied by an annular pontoon that covers approximately 20 to 25 % of the total roof area. The centre deck is able to carry about 250 mm rainfall over the total roof area. The annular pontoon is compartmentalised and the flotation is designed in such a way that the roof will still float even if two adjacent pontoon compartments and the centre deck are punctured.



**Figure 3.4: Typical floating roof tank with pontoon floating roof**  
[185, UBA Germany, 2004]

#### *Double-deck floating roofs*

For these roofs the entire roof area is provided with a double deck, making the roof more rigid than the pontoon roof. Water does not accumulate on the upper deck, which is above the level of the stored product as it is immediately discharged via the roof drain (via drain or hose system and via a ground level shell drain valve). However, it is also common practise to accumulate rainwater before the shell drain valve at the outlet of the drain system is opened. Double-deck roofs can be fitted with emergency drains, which discharge any accumulation into the stored product. Double-deck roofs are generally fitted to large diameter tanks (e.g. > 50 m diameter). They are structurally stronger and prevent wind problems, which can occur in the centre decks of large pontoon roofs.



**Figure 3.5: Typical floating roof tank with double-deck floating roof [185, UBA Germany, 2004]**

### *Special buoy-type and radially reinforced roofs*

The buoy-type roof is a pontoon roof with a relatively small annular pontoon, but with the exception that it has in addition a number of small-diameter circular buoys spread over the centre deck to provide additional buoyancy. Radially reinforced roofs have a pontoon ring and a buoy in the middle of the centre deck. These roofs are built with a certain slope to force rainwater to the drains at the centre of the deck, thus preventing water accumulation. Radial stiffeners are applied to maintain the slope when the roof floats. These roofs are vulnerable to collapse when landing on the support legs. These types of roofs are mainly applied for large diameter roofs, but they are rarely built anymore nowadays, as double-deck roofs perform much better in large diameter tanks.

## **B. Relevant tank equipment and other considerations**

		<b>Section</b>
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Gauging and sample hatches	3.1.12.7.2
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Mixers	3.1.12.7.7
	Heating systems	3.1.12.7.8
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
3.1.12 Considerations related to tanks		

**Table 3.5: Cross-references for EFRT**

## **C. Possible emission sources (EFRT)**

Table 3.6 and Table 3.7 show the emission scores for the potential emission sources of EFRTs. Figure 3.2 explains the methodology for calculating the emission score. Sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling (until roof floats on liquid)	1	3	3
Standing	3	1	3
Emptying (shell film)	2	1	2
Emptying (roof landing)	1	1	1
Blanketing			N/A
Cleaning	1	2	2
Manual gauging	2	1	2
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	1	2

**Table 3.6: Possible emissions to air from ‘operational sources’ with EFRT [84, TETSP, 2001]**

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Roof draining	2	0	0
Cleaning	1	3	3
Sampling	2	0	0

**Table 3.7: Possible liquid emissions to water or waste from ‘operational sources’ with EFRT [84, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow and leakages. These emissions are also addressed in Chapter 4.

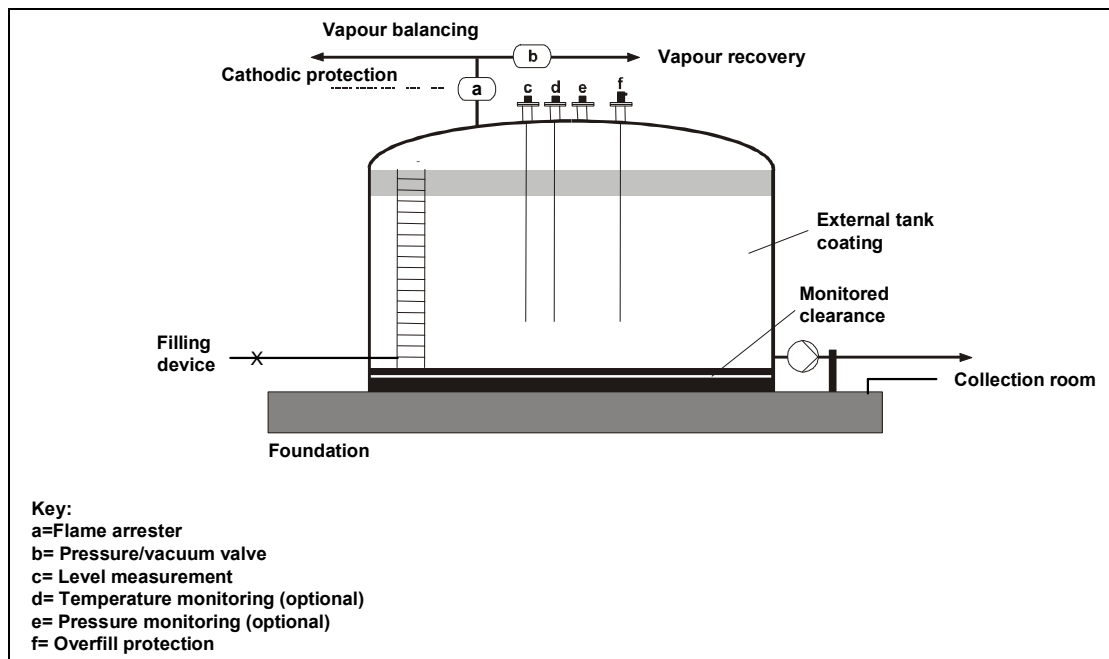
### 3.1.3. (Vertical) fixed roof tanks (FRT)

#### A. Description

[84, TETSP, 2001] [66, EPA, 1997]

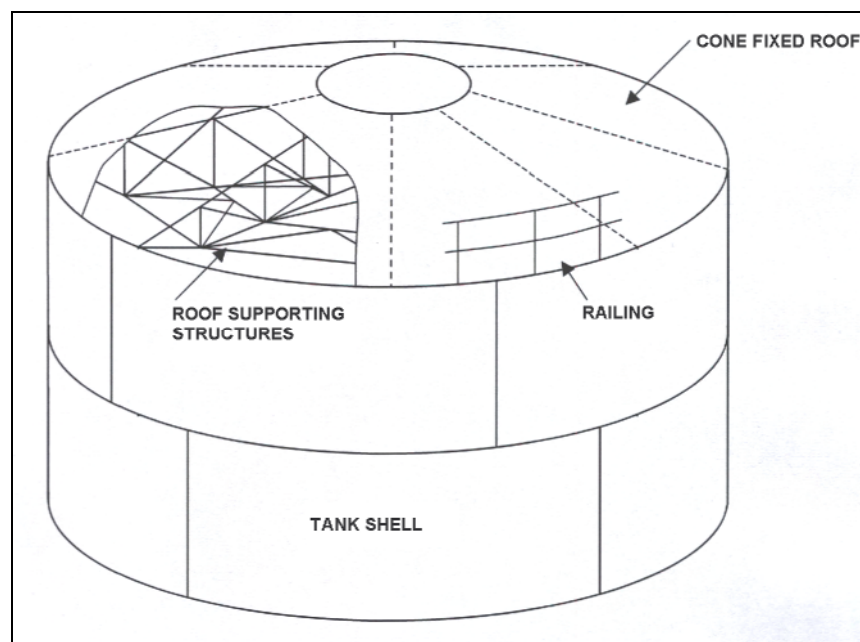
Fixed roof tanks are designed as atmospheric tanks (free vented), low pressure tanks (to approx. 20 mbar internal pressure) or – so-called – ‘high pressure’ tanks (to approx. 56 mbar internal pressure). Non-pressure fixed roof tanks are suitable for storage at atmospheric pressure and therefore have open vents (although designed to withstand internal pressures up to 7.5 mbar and a vacuum of 2.5 mbar). Both low pressure and high pressure fixed roof tanks are provided with pressure/vacuum relief valves (PVRVs), which are fully open at the design pressure/vacuum. All of these tank types must also meet additional requirements such as stability. Anchor systems may be necessary to prevent uplifting of the tank near the periphery due to the combined load of internal pressure and wind loads.

Tanks fitted with PVRVs can be ‘blanketed’ (see Section 4.1.6.2.1). In this technique, an inert gas (e.g. nitrogen) is introduced into the vapour space above the product to replace the possibly flammable air/vapour mixture for safety reasons. This is not an emissions control measure as the product will still evaporate. A blanketing control system requires careful design to ensure that the pressure within the system stays within the setting of the tank pressure relief valve. As the average pressure within the tank vapour space is higher than in a non-blanketed tank, breathing due to thermal expansion of the vapour space will result in greater emissions to the atmosphere.



**Figure 3.6: Vertical fixed roof tank with some emission control equipment installed**  
[18, UBA, 1999]

Figure 3.7 shows a conical shaped roof, which is typical for larger diameter fixed roof tanks. The roof has a roof support structure, which may be constructed from beams, trusses or rafters. Self-supporting roofs can be of conical or dome shape, but are generally only used for smaller diameter tanks.



**Figure 3.7: Typical example of a fixed roof tank**  
[166, EEMUA, 2003]

Table 3.8 shows the different design ratings for the different types of FRT.

Type of fixed roof tank	Design rating for pressure and vacuum
Atmospheric	+ 7.5 mbar - 2.5 mbar Note that these tanks are usually open vented
'Low' pressure	+ 20 mbar - 6 mbar
'High' pressure	+ 56 mbar - 6 mbar

**Table 3.8: Design ratings for the different types of fixed roof tanks**  
[113, TETSP, 2001]

### B. Relevant tank equipment and other considerations

		Section
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Gauging and sample hatches	3.1.12.7.2
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Mixers	3.1.12.7.7
	Heating systems	3.1.12.7.8
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
3.1.12 Considerations related to tanks		

**Table 3.9: Cross-references for FRT**

### C. Possible emission sources (FRT)

Table 3.10 and Table 3.11 show the emission scores for the potential emission sources for FRT. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value and should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	3	6
Breathing	3	2	6
Emptying	2	1	2
Cleaning	1	2	2
Blanketing	3	2	6
Manual gauging	2	1	2
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	1	2

**Table 3.10: Possible emissions to air from 'operational sources' with FRT**  
[84, TETSP, 2001]

Table 3.10 shows that the two significant types of emissions from fixed roof tanks are breathing and working losses. The working loss is the combined loss from filling and emptying. Breathing loss is the expulsion of vapour from a tank by vapour expansion and contraction, which are the results of changes in temperature and barometric pressure. This loss occurs without any liquid level change in the tank.

Emissions occur during filling operations as a result of an increase in the liquid level in the tank. As the liquid level increases, the pressure inside the tank exceeds the relief pressure and vapours are expelled from the tank. Emissions occur during emptying when air drawn into the tank during liquid removal becomes saturated with organic vapour and expands, thus exceeding the capacity of the vapour space.

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	1	3	3
Sampling	2	0	0

**Table 3.11: Possible liquid emissions to water or waste from ‘operational sources’ with FRT [84, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow and leakage. These emissions are also addressed in Chapter 4.

### 3.1.4. Aboveground horizontal storage tanks (atmospheric)

#### A. Description

[66, EPA, 1997] [84, TETSP, 2001] [18, UBA, 1999]

Horizontal fixed roof tanks are constructed for both aboveground and underground service and generally have a capacity of less than 150 m<sup>3</sup>. Horizontal tanks are usually equipped with pressure/vacuum relief vents (PVRVs), gauge hatches, sample wells and manholes to provide access. The maximum diameter is usually determined by factors such as design pressure, fabrication possibilities, post-weld heat treatment requirements, transport limitations, foundation criteria and economy of the design. The maximum allowable length is usually determined by the support structure, foundation criteria, size of available site and the economics of the design.

The construction material may be steel, steel with a fibreglass overlay, or fibreglass-reinforced polyester. Older tanks may be of riveted or bolted construction. All tanks are designed to be both liquid and vapour tight.

Figure 3.8 shows an aboveground horizontal storage tank with some emission control equipment installed.

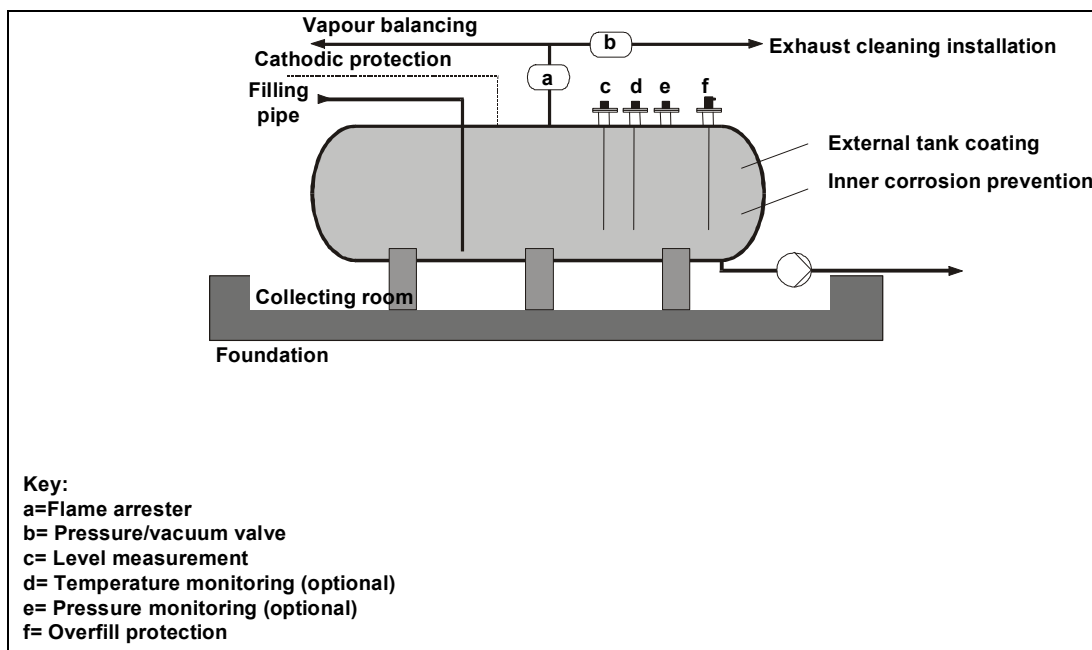


Figure 3.8: Aboveground horizontal tank with some emission control equipment installed [18, UBA, 1999]

Details of underground horizontal storage tanks are given in Section 3.1.11.

### B. Relevant tank equipment and other considerations

		Section
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Gauging and sample hatches	3.1.12.7.2
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Mixers	3.1.12.7.7
	Heating systems	3.1.12.7.8
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
3.1.12 Considerations related to tanks		

Table 3.12: Cross references for aboveground horizontal tanks

### C. Possible emission sources (aboveground horizontal storage tanks)

Table 3.13 and Table 3.14 show the emission scores for the potential emission sources for the aboveground horizontal storage tank. Figure 3.2 explains the methodology for calculating the emission score. Sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.



Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	3	6
Breathing	3	2	6
Emptying	2	1	2
Cleaning	1	2	2
Blanketing	3	2	6
Manual gauging	2	1	2
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	1	2

**Table 3.13: Possible emissions to air from ‘operational sources’ with aboveground horizontal storage tanks**  
[113, TETSP, 2001]

Potential source for liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	1	2	2
Sampling	2	0	0

**Table 3.14: Possible liquid emissions to water or waste from ‘operational sources’ with aboveground horizontal storage tanks**  
[113, TETSP, 2001]

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow and leakages. These emissions are also addressed in Chapter 4.

### 3.1.5. Horizontal storage tanks (pressurised)

#### A. Description

[66, EPA, 1997] [18, UBA, 1999]

Two classes of pressure tanks are in general use: low pressure (170 to 1030 mbar) and high pressure (higher than 1030 mbar). Pressure tanks are generally used for storing organic liquids and gases with high vapour pressures and occur in many sizes and shapes, depending on the operating pressure of the tank. Generally they are horizontally oriented and bullet or spherically shaped (see Section 3.1.7) to maintain structural integrity at high pressure. High pressure storage tanks can be operated so that virtually no evaporative or working losses occur.

The level of emission control equipment used depends on the substance that is stored, e.g. for the storage of propane or butane normally single walled storage tanks are applied.

Figure 3.9 shows some horizontal pressurised tanks with some emission control equipment installed.

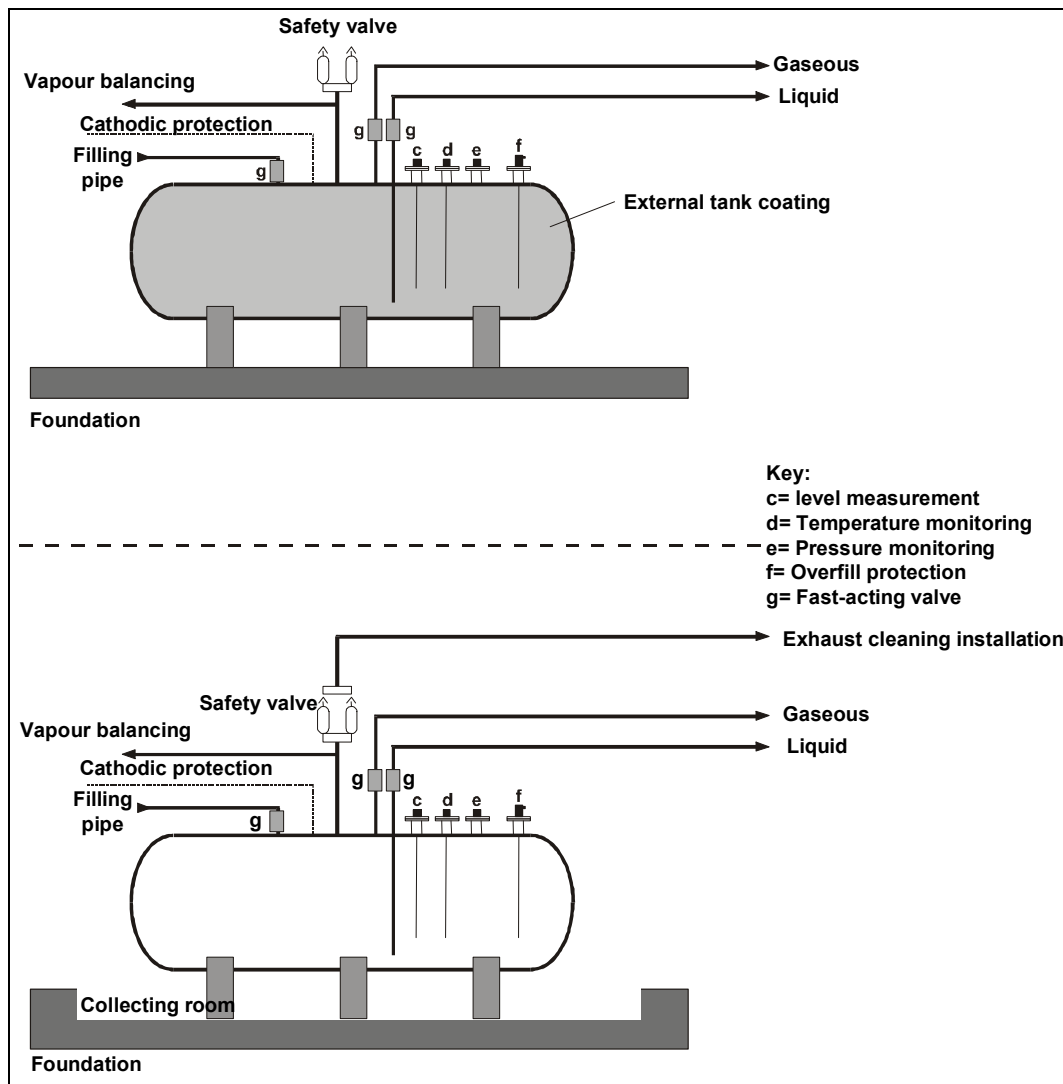


Figure 3.9: Horizontal storage tanks (pressurised) with some emission control equipment installed [18, UBA, 1999]

**B. Relevant tank equipment and other considerations**

		Section
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Mixers	3.1.12.7.7
	Heating systems	3.1.12.7.8
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
	3.1.12 Considerations related to tanks	

Table 3.15: Cross-references for horizontal storage tanks (pressurised)

**C. Possible emission sources (horizontal storage tanks (pressurised))**

Table 3.16 and Table 3.17 show the emission score for the potential emission sources for pressurised horizontal storage tanks. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	1	2
Breathing			N/A
Emptying			N/A
Cleaning	1	2	2
Blanketing (Inerting)	2	1	2
Gauging			N/A
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	2	4

**Table 3.16: Possible emissions to air from ‘operational sources’ with horizontal storage tanks (pressurised)**  
[113, TETSP, 2001]

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	0	0
Cleaning	1	1	1
Sampling	2	0	0

**Table 3.17: Possible liquid emissions to water or waste from ‘operational sources’ with horizontal storage tanks (pressurised)**  
[113, TETSP, 2001]

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow/overpressure and leakages. These emissions are also addressed in Chapter 4.

### 3.1.6. Vertical storage tanks (pressurised)

#### A. Description

[113, TETSP, 2001]

See Section 3.1.5 for the general description of aboveground pressurised tanks. Vertical storage tanks are generally used where space is limited and large capacity vessels are not required. Although there are no practical limitations on size, the economic break-even point for constructing alternative storage, such as spheres, is likely to limit the size of vertical tanks. Normally vertical tanks are limited to 10 metres diameter and to 25 metres height (approximately 1750 m<sup>3</sup> capacity). For units of the same capacity, vertical tanks require less space than horizontal tanks but are more demanding in terms of the foundation work required. The design pressure for vertical tanks is dependent on the relationship between temperature and the vapour pressure of the product in stock.

Provisions to cope with vacuum conditions are required in applications where ambient temperatures can be expected to reach the point where the vapour may start to condense or where very high liquid withdrawal rates are applied without an adequate vapour return system. In these cases, the tank should be designed for full vacuum.

Nozzles are possible sources of leakage. Therefore the number of nozzles on a tank, particularly below the liquid level, is usually minimised to reduce the risk of leakage.

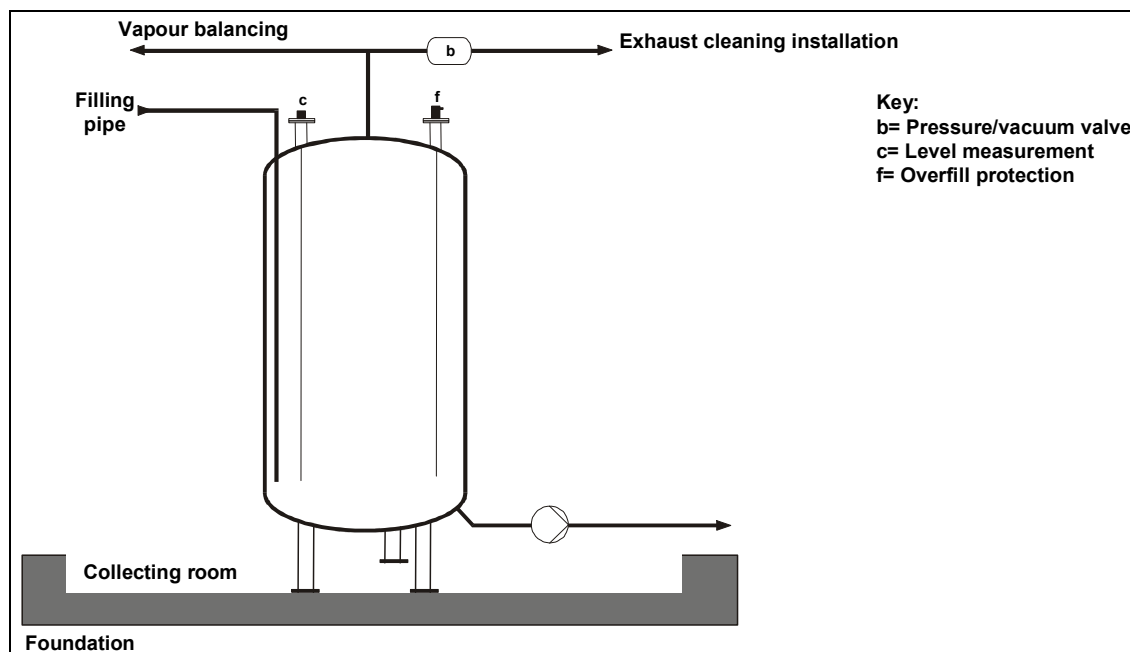


Figure 3.10: Vertical pressurised tank with some emission control equipment installed [18, UBA, 1999]

### B. Relevant tank equipment and other considerations

		Section
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Mixers	3.1.12.7.7
	Heating systems	3.1.12.7.8
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
	3.1.12 Considerations related to tanks	

Table 3.18: Cross-references for relevant tank equipment and fitting for vertical storage tanks (pressurised)

### C. Possible emission sources (vertical storage tanks (pressurised))

Table 3.19 and Table 3.20 show the emission scores for the potential emission sources for pressurised vertical storage tanks. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	1	2
Breathing			N/A
Emptying			N/A
Cleaning	1	2	2
Blanketing (Inerting)	2	1	2
Gauging			N/A
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	2	4

**Table 3.19: Possible emissions to air from ‘operational sources’ with vertical storage tanks (pressurised)**  
[113, TETSP, 2001]

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	0	0
Cleaning	1	1	1
Sampling	2	0	0

**Table 3.20: Possible liquid emissions to water or waste from ‘operational sources’ with vertical storage tanks (pressurised)**  
[113, TETSP, 2001]

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow/overpressure and leakages. These emissions are also addressed in Chapter 4.

### 3.1.7. Spheres (pressurised)

#### A. Description

[113, TETSP, 2001]

Spherical tanks normally have a larger capacity than horizontal or vertical pressurised tanks because of the more favourable economies of scale. Approximately 3500 m<sup>3</sup> may be considered as the practical upper limit. These tanks are usually erected on-site from preformed plates and shop fabricated sub-assemblies. The design pressure for spherical tanks is dependent on the relationship between temperature and the vapour pressure of the product in stock.

The number of nozzles on a spherical tank, particularly below the liquid level, is usually minimised to reduce the risk of leakage.

#### B. Relevant tank equipment and other considerations

		Section
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
3.1.12 Considerations related to tanks		

**Table 3.21: Cross-references for spheres (pressurised)**

### C. Possible emission sources (spheres (pressurised))

Table 3.22 and Table 3.23 show the emission scores for the potential emission sources for pressurised spheres. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	1	2
Breathing			N/A
Emptying			N/A
Cleaning	1	2	2
Blanketing (Inerting)	2	1	2
Gauging			N/A
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	2	4

**Table 3.22: Possible emissions to air from ‘operational sources’ with spheres (pressurised)**  
[113, TETSP, 2001]

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	0	0
Cleaning	1	1	1
Sampling	2	0	0

**Table 3.23: Possible liquid emissions to water or waste from ‘operational sources’ with spheres (pressurised)**  
[113, TETSP, 2001]

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow/overpressure and leakages. These emissions are also addressed in Chapter 4.

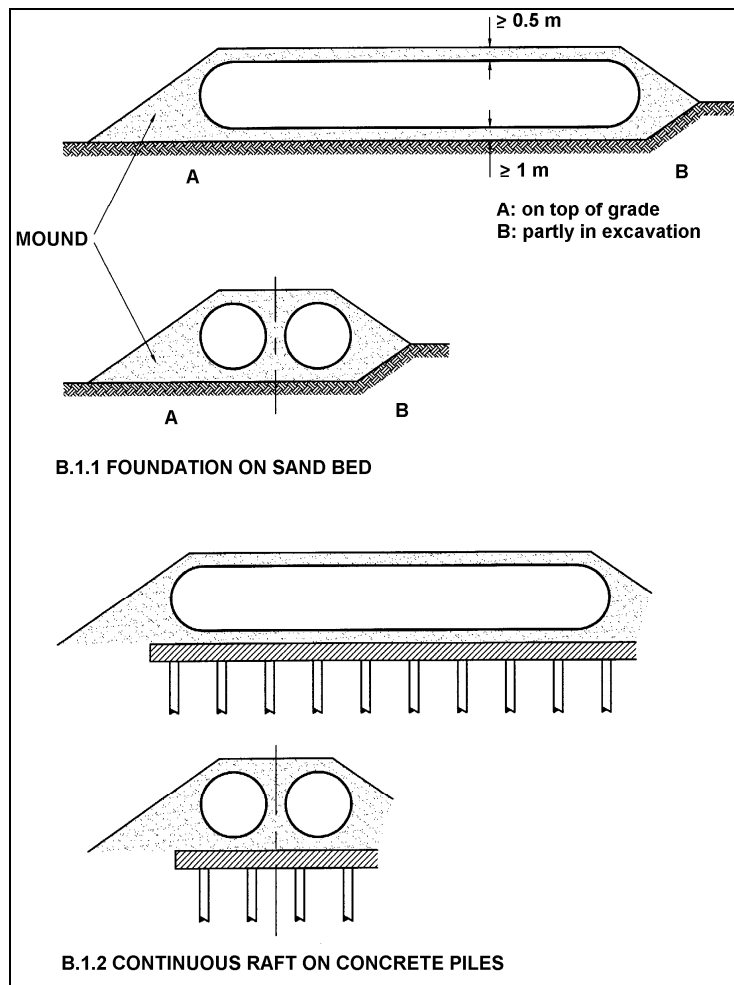
### 3.1.8. Mounded storage (pressurised)

#### A. Description (Figure 3.11)

[84, TETSP, 2001]

Mounded storage is the term given to the pressurised storage at ambient temperatures of liquefied petroleum gases in horizontal cylindrical tanks placed at or just below ground level and completely covered with suitable backfill. Several tanks may be placed side-by-side under one ‘mound’. Tanks in open underground vaults and excavations are normally not considered to be ‘mounded storage’.

The design aspects of mounded storage projects are in general more complicated than those for aboveground spheres or bullets. Attention should be paid to the interaction between the tank and soil, and to corrosion protection to avoid leakages. As it is not intended that mounded tanks will be externally inspected during their lifetimes, attention needs to be given to the external coating and application of a cathodic protection system to minimise the risk of (undetected) corrosion. The tanks need to be installed above the highest known water table level, and the soil cover, therefore, usually protrudes above ground level as an earth mound – hence the term ‘mounded storage’.



**Figure 3.11: Mounded storage**  
[EEMUA Pub 190]

If more than one tank is placed in a single mound, then the minimum distance between the tanks depends on construction activities such as welding, coating, backfilling and compaction of the backfill material. A distance of 1 m is considered to be a practical minimum.

The maximum diameter is usually determined by factors such as design pressure, fabrication possibilities, post-weld heat treatment requirements, transport limitations, subsoil conditions and economy of the design (a tank diameter of 8 m may be regarded as a practical upper limit). The maximum allowable length is usually determined by the support structure and/or subsoil conditions (especially if differential settlement is expected), size of available site and economy of the design. For tanks which are founded on a sand-bed, the length of the tank is generally no more than eight times the diameter, in order to prevent the design shell thickness being governed by longitudinal bending of the tank due to possible differential settlement or construction tolerances of tanks and foundations. The maximum volume of a tank is normally approximately 3500 m<sup>3</sup> gross; there is no minimum size of tank, except for practical considerations.

From an external safety point of view, mounded storage for flammable liquefied gases could be considered as fire protection (to prevent 'boiling liquid expanding vapour explosion' (BLEVE) from happening).

**B. Relevant tank equipment and other considerations**

		<b>Section</b>
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
3.1.12 Considerations related to tanks		

**Table 3.24: Cross-references for mounded storage****C. Possible emission sources (mounded storage/pressurised)**

Table 3.25 and Table 3.26 show the emission scores for the potential emission sources for mounded storage. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

<b>Potential source of emissions to air</b>	<b>Emission frequency</b>	<b>Emission volume</b>	<b>Emission score</b>
Filling	2	1	2
Breathing			N/A
Emptying			N/A
Cleaning	1	2	2
Blanketing (Inerting)	2	1	2
Manual gauging			N/A
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	2	4

**Table 3.25: Possible emissions to air from ‘operational sources’ with pressurised mounded storage [84, TETSP, 2001]**

<b>Potential source of liquid emissions to water or waste</b>	<b>Emission frequency</b>	<b>Emission volume</b>	<b>Emission score</b>
Draining	2	0	0
Cleaning	1	1	1
Sampling	2	0	0

**Table 3.26: Possible liquid emissions to water or waste from ‘operational sources’ with pressurised mounded storage [84, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow/overpressure and leakages. These emissions are also addressed in Chapter 4.



### 3.1.9. Variable vapour space tanks

#### A. Description

[87, TETSP, 2001]

Variable vapour space tanks are equipped with expandable vapour reservoirs to accommodate vapour volume fluctuations attributable to temperature and barometric pressure changes. The two most common types of variable vapour space tanks are lifter roof tanks and flexible diaphragm tanks. Lifter roof tanks are used to store a product whereas flexible diaphragm tanks are only used to store vapour at, or very close to, atmospheric pressure. The latter are usually connected to a number of tanks to reduce breathing emissions and are thus an emission control measure (ECM): see Section 4.1.3.13.

Lifter roof tanks have a telescoping roof that fits loosely around the outside of the main tank wall. The space between the roof and the wall is closed by either a wet seal, which is a trough filled with liquid, or a dry seal, which uses a flexible coated fabric.

The use of a water seal necessitates manual checking or automatic control of the seal level. Use during cold weather requires protection against freezing. Fabric seals have to be checked regularly for wear or damage which will result in vapour loss. Lifter roof tanks are very rarely used in Europe for petroleum product storage.

Lifter roof tank losses occur during tank filling when vapour is displaced by liquid and the tank's vapour storage capacity is exceeded.

#### B. Relevant tank equipment and other considerations

		Section
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Gauging and sample hatches	3.1.12.7.2
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
3.1.12 Considerations related to tanks		

**Table 3.27: Cross-references for lifter roof tanks**

#### C. Possible emission sources (lifter roof tanks)

Table 3.28 and Table 3.29 show the emission scores for the potential emission sources for lifter roof tanks. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	3	6
Breathing	3	0	0
Emptying	2	1	2
Cleaning	1	2	2
Blanketing			N/A
Manual gauging	2	1	2
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	1	2

**Table 3.28: Possible emissions to air from ‘operational sources’ with lifter roof tanks [87, TETSP, 2001]**

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	1	3	3
Sampling	2	0	0

**Table 3.29: Possible emissions to water or waste from ‘operational sources’ with lifter roof tanks [87, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow/overpressure and leakages. These emissions are also addressed in Chapter 4.

### 3.1.10. Refrigerated storage tanks

#### A. Description

[84, TETSP, 2001]

There are three types of refrigerated storage systems:

- single containment
- double containment
- full containment.

The selection of the type of storage system will be considerably influenced by the location, the operational conditions, the adjacent installations, loadings and environmental considerations.

From an external safety point of view, refrigerated storage could be considered for large scale storage of liquefied gases such as ammonia, chlorine, liquefied petroleum gas, etc.

#### *Single containment*

Either a single or double wall tank designed and constructed so that only the containing element in contact with the refrigerated product is required to meet the low temperature ductility requirements for storage of the product. The outer shell (if any) of a single containment storage system is primarily for the retention and protection of insulation and is not designed to contain liquid in the event of product leakage from the inner container. A single containment tank will usually be surrounded by a traditional low bund wall to contain any leakage.

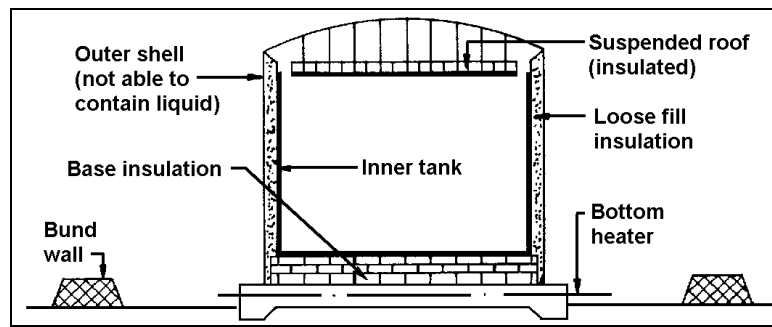


Figure 3.12: Typical example of a single containment refrigerated tank [EEMUA Pub 147]

### *Double containment*

A double wall tank is designed and constructed so that both inner tank and outer shell are capable of containing the refrigerated liquid stored. The inner tank stores the refrigerated liquid under normal operating conditions. The outer shell is able to contain any refrigerated liquid product leakage from the inner tank. The outer shell is not designed to contain vapour released due to product leakage from the inner tank.

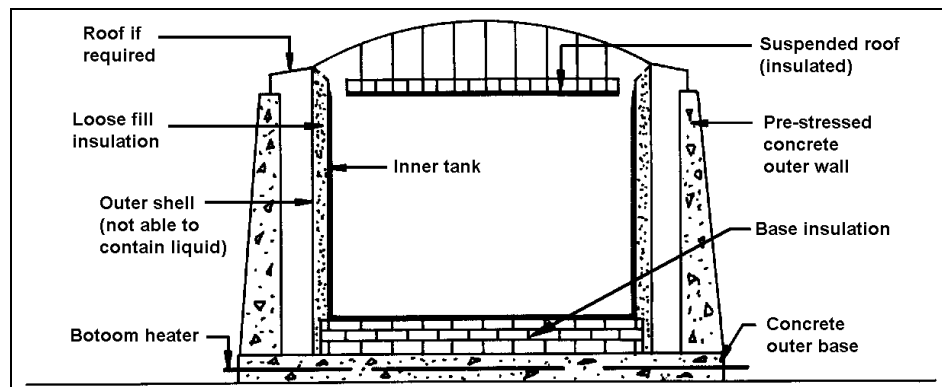


Figure 3.13: Typical example of a double containment refrigerated tank [EEMUA Pub 147]

### *Full containment*

A double wall tank designed and constructed so that both inner and outer tanks are capable of containing the refrigerated liquid (e.g. ammonia) stored. The outer wall is approximately 1 to 2 metres distant from the inner wall. The inner tank stores the refrigerated liquid under normal operating conditions. The outer roof is supported by the outer wall. The outer tank is capable of containing the refrigerated liquid and vapour resulting from product leakage from the inner tank.

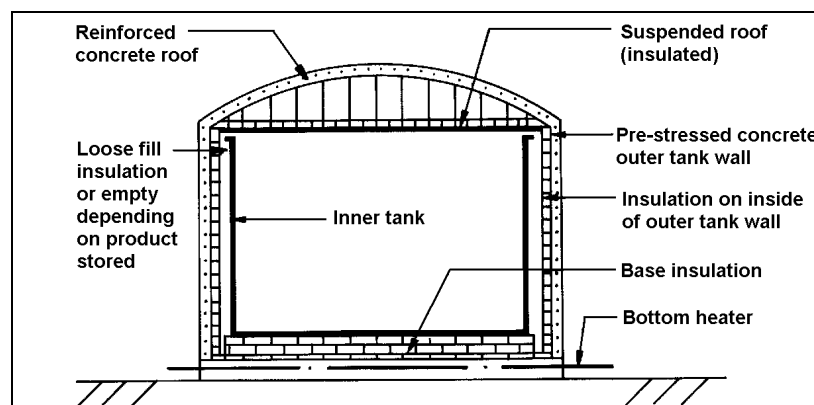


Figure 3.14: Typical example of a full containment refrigerated tank [EEMUA Pub 147]

## B. Relevant tank equipment and other considerations

		Section
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Gauging and sample hatches	3.1.12.7.2
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
3.1.12 Considerations related to tanks		

**Table 3.30: Cross-references for refrigerated storage tanks**

## C. Possible emission sources (refrigerated storage tanks)

Table 3.31 and Table 3.32 show the emission scores for the potential emission sources for aboveground refrigerated storage. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	1	2
Breathing			N/A
Emptying			N/A
Cleaning	1	2	2
Blanketing	2	1	2
Manual gauging			N/A
Sampling	2	1	2
Fugitive	2	1	2
Draining			N/A

**Table 3.31: Possible emissions to air from ‘operational sources’ with refrigerated storage [84, TETSP, 2001]**

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining			N/A
Cleaning			N/A
Sampling			N/A

**Table 3.32: Possible liquid emissions to water or waste from ‘operational sources’ with refrigerated storage [84, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow and leakages. These emissions are also addressed in Chapter 4.

### 3.1.11. Underground horizontal storage tanks

#### A. Description

[18, UBA, 1999] [132, Arthur D. Little Limited, 2001]

Horizontal tanks can be – apart from aboveground – buried or mounded. For details on mounded storage see Section 3.1.8. Underground (buried) storage tanks are often used for the storage of gasoline, diesel and other fuels and typically have a capacity of less than 50 m<sup>3</sup>. They can be made of steel or fiberglass reinforced polymers. See Section 3.1.4 for the general description of atmospheric horizontal tanks. See Section 3.1.5 for the general description of pressurised horizontal tanks.

In addition, underground tanks are protected from corrosion on the outside, for example with cathodic corrosion protection or by insulation, e.g. bitumen. The tanks can be double walled and equipped with a leakage detector, but can also be single walled in combination with a containment. The level of emission control equipment is of course dependent on the substance that is stored.

For underground tanks it is important that the construction proceeds in such a way so as to prevent damage from aboveground activities. When containing combustible substances, the tank is normally completely surrounded by a layer of non-combustible substance that cannot damage the insulating layer, e.g. sand.

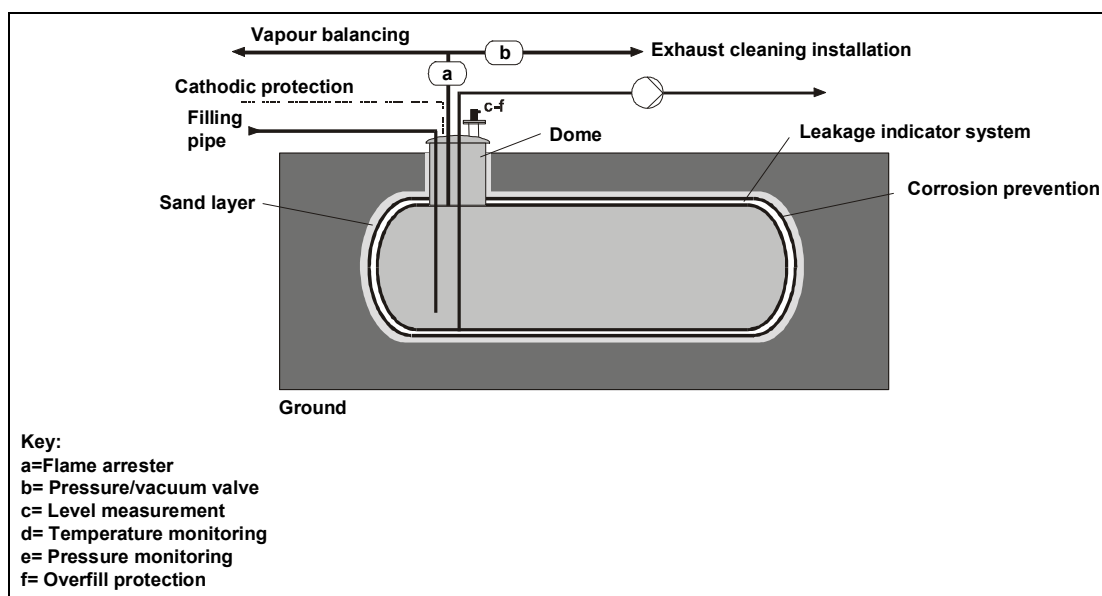


Figure 3.15: Underground double wall tank with some emission control equipment installed [18, UBA, 1999]

See Annex 8.6, for a summary of Member State requirements for underground storage in general from reference [132, Arthur D. Little Limited, 2001], a study commissioned by the European Commission on the storage of gasoline containing methyl-tertiary-butyl-ether (MBTE).

## B. Relevant tank equipment and other considerations

		Section
3.1.12.7 Equipment for tanks	Instrumentation	3.1.12.7.4
	Drains	3.1.12.7.6
	Sealing elements	3.1.12.7.9
	Valves	3.1.12.7.10
3.1.12 Considerations related to tanks		

Table 3.33: Cross-references for underground horizontal storage tanks

## C. Possible emission sources (underground horizontal storage tanks)

Table 3.34 and Table 3.35 show the emission scores for the potential emission sources for underground horizontal storage tanks. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	3	6
Breathing	2	1	2
Emptying	2	1	2
Cleaning	1	2	2
Blanketing	3	1	3
Manual gauging	2	1	2
Sampling	2	1	2
Fugitive	3	1	3
Draining			N/A

Table 3.34: Possible emissions to air from ‘operational sources’ with underground horizontal storage  
[84, TETSP, 2001]

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	1	1	1
Cleaning	1	2	2
Sampling			N/A

Table 3.35: Possible liquid emissions to water or waste from ‘operational sources’ with underground horizontal storage  
[84, TETSP, 2001]

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow and leakages. These emissions are also addressed in Chapter 4.

### 3.1.12. Considerations related to tanks

#### 3.1.12.1. Economics

The costs of designing, constructing and operating storage tanks very much depend upon the type of tank (e.g. EFRT, fixed roof tank), the size of the tank, the design features (e.g. type of foundation, external coating, type of safety and environmental protection measures), the requirements set by the product to be stored (e.g. internal coating, stainless steel versus mild steel, vapour control system), the operating conditions, the required inspection and maintenance activities and, linked to the latter, the envisaged technical lifetime. It is very difficult to give for certain tank types, typical costs in euro per cubic metre of maximum storage volume. It is important, therefore, to focus on the ‘total cost of ownership’ (TCO) of a storage tank, for example by considering all the elements shown in Table 3.38.

Cost elements which are typically considered when determining unit rate cost	Cost elements which are not always considered when determining unit rate cost	Cost elements which are typically not often considered when determining unit rate cost
<ul style="list-style-type: none"> <li>- design</li> <li>- construction and installation</li> <li>- commissioning</li> </ul>	<ul style="list-style-type: none"> <li>- inspection/maintenance</li> <li>- re-design</li> <li>- documentation</li> <li>- operation/handling</li> </ul>	<ul style="list-style-type: none"> <li>- downtime or non-availability due to inspection/maintenance period</li> <li>- training</li> <li>- safety and environmental impact</li> <li>- performance/breakdowns</li> <li>- obsolescence</li> <li>- demolition</li> </ul>

**Table 3.36: Cost elements for storage tanks**  
[113, TETSP, 2001]

#### 3.1.12.2. Design and construction

**Description:** The material of the whole tank should comply with internally recognised standards: EN 14015, API 650, BS 2654, DIN 4119, NEN 3850<sup>1</sup>, CPR9-3, BS 2594 or BS 4994 or any other national or international standard that provides an equivalent level of safety. (See Annex 8.1 International Codes, for an overview of the standards). Furthermore, the constructed facilities, including tanks and foundations, need to be or are usually constructed in such a way that displacements and slopes, which pose a danger to the safety and tightness of the installation, are excluded. The raw materials, production process, dimensions, applied monitoring and quality-proofing of the tanks and all their equipment need to be appropriate for the technical purpose.

The distances between tanks and from the tanks to walls and other construction components are sufficient to allow malfunctions to be detected and fires to be contained. These distances are kept or protective walls are constructed to minimise danger to neighbouring facilities or buildings. For more details on distances, see Section 4.1.2.3.

A summary of important aspects and considerations for the design and construction requirements of tanks are given below.

#### A. Benefits of a proper design

Most technical measures, related to the reduction or elimination of the consequences of ‘abnormal’ conditions are taken at the design stage. The risks resulting from a loss of containment are assessed at this stage and technical safety measures are defined accordingly. In essence, the best industrial knowledge about the substance to be stored is used at this phase to

<sup>1</sup> In cases when the liquid stored has a specific gravity  $\leq 1$  and the pressure above the liquid is more or less equal to atmospheric pressure.

select suitable technical storage options based on either some kind of risk analysis or ‘cost to benefit’ analysis. Defining and implementing the safety measures at the design phase is undoubtedly the best and cheapest option. The efficiency of the safety measures also need to be maintained over time. This can only be ensured by carrying out regular checks on the operation of safety devices e.g. relief valves, interlocks, on/off valves, etc. The management system should be organised in such a way that these check-ups can be dealt with properly.

At first the designer should consider the level of appropriate operational measures to be followed by the operators. Operational measures, e.g. clear instructions given to the operators, are the primary requirements for preventing overfills, overpressure and/or leakage. A few examples demonstrate how efficient these operational measures can be:

- instruments used for controlling the normal operation of the storage system, such as level or pressure indicators, inform the operator when a process parameter is at risk of exceeding its pre-set limit. The operator will then be able to react quickly
- during regular inspections, the operators are able to react after observation of parameters exceeding their pre-set limits (e.g. vibration of a pipe, noise of a pump, unusual odour). They can then check for leaks and can detect small leaks before they result in uncontrolled releases, etc.
- whilst a vessel which is not equipped with level instrumentation and/or alarms is being loaded, the presence of the operator prevents overfilling.

The efficiency of these measures needs to be maintained. This is – amongst others – the role of the management systems, which normally facilitates:

- regular training of the operators
- updating of the operating instructions
- calibration of instruments on a regular basis.

Environmental inspections of the storage facility must be considered at this stage. These play a major role in determining possible emission sources. Regular checks should be performed to ensure that the emissions remain within the permitted limits. Moreover they can inform the operator when the performance is becoming unacceptable. For more details see Section 4.1.2.2.

Carrying out mechanical inspections of the storage facility can play a key role in the prevention of incidents. The basis of an inspection plan is usually drawn up at the design stage with the selection of the components. In general these components, or the total storage facility itself, will be based on experience with:

- the substance
- the component
- the component/substance combination.

Examples are:

- suitability of construction materials and of proven assembly (e.g. welding) procedures
- selection of equipment manufacturers
- proper specification of equipment such as pumps, valves, instruments and gaskets
- site layouts, e.g. checking easy access to equipment.

The management system carries the responsibility of the inspection plan. This inspection plan aims to fix rules in order to define inspection frequencies, acceptance criteria of defects etc.



## B. Design requirements

Design requirements depend on the following aspects (not shown in any order of importance):

- purpose of the storage tank(s), e.g. is the tank part of a manufacturing process or is the tank a standalone unit providing storage space for short or a longer term
- other requirements set by the owner/operator and/or customer (e.g. storage volume, accessibility, optimal inspection intervals during the operating period by the choice of 'better' materials or by adding corrosion allowances on design thickness of components, type of mixer, etc.)
- national codes and guidelines, together with more specific local legislative requirements, (e.g. fire regulations, the minimum distances between tanks, etc.)
- type of products to be stored and the corresponding (appropriate) storage condition (i.e. atmospheric, pressurised or refrigerated condition)
- vapour pressure of the product, which determines the need for atmospheric or low pressure rated storage, e.g. an EFRT or FRT, or pressurised storage
- both safety (systems and type of instrumentation) and environmental requirements (emission controls)
- requirements determining the location, e.g. other facilities in the neighbourhood (safety distances), distance to the jetty or truck loading racks, distance to facilities or residential areas outside the boundary fence, etc.
- specific design requirements predicted by climatic conditions or specific soil conditions.

Determining the correct design in general should also include a consideration of the foundation type and bearing capacity of the underlying soil. Bearing capacity aspects normally include the settlement potential, taking account of the effects of cyclic loading due to the tank being successively filled and emptied. Large, uneven settlements can cause excessive ovaling of floating roof tank shells which can cause the roof to jam, reducing safety and leading to additional air emissions.

## C. Construction requirements

Construction requirements depend on the following aspects, but are not limited to:

- type and size of the tank
- selected tank material (e.g. mild steel, stainless steel, aluminium, or synthetic materials)
- number of appendages and fittings, extent of automated operations by means of instruments
- location of the tank within a specific location (e.g. accessibility, level of safety precautions/distances, available working time)
- allowable construction time
- availability of construction expertise at the site (e.g. type of tank erection method)
- availability of construction equipment at the location (e.g. cranes)
- requirements set by the (local) authorities, e.g. building permits, local building codes, etc.

## D. Codes, standards and guidelines

Some examples of international codes, standards and guidelines are given below. For a more complete overview, see Annex 8.1 International Codes.

Aboveground storage: EN 14015, API 650, API 652, DIN 4119, BS 2654, EEMUA 180, EEMUA 183, EMC 1980, CODRES 1991, CPR 9-2/3.

Underground storage: API 1615, ASTM D4021-92, DIN 6600, DIN EN 976, BS EN 976, AFNOR NF EN 976, CPR 9-1.

Pressurised storage: ASME Section II, ASME Code Cases: BPV, BS PD 5500, PD 6497, EEMUA 190, CODAP 95, Rules for Pressure Vessels (Dutch code).

Refrigerated storage: EN 14620, API 620, NFPA 57, NFPA 59, BS 7777, EEMUA 147, IP Model Code of Safe Practice Volume 1-Part 9, CPR 13.

### **3.1.12.3. Commissioning**

[113, TETSP, 2001]

Commissioning or re-commissioning after a tank turn-around requires a full inspection to be undertaken, both inside and outside the tank, to ensure any mechanical and electrical work has been completed and that all equipment is safe. This inspection will cover at least the following:

- foundations, bund walls, floors and drainage systems
- all electrical bonding and earthing, cathodic protection and electrical fittings
- ladders, walkways, and railings
- emission control measures
- any mixers, vents and pressure/vacuum relief valves
- instrumentation including level and temperature gauges and all alarms
- all suction, discharge and drainage valves
- fire fighting systems, including foam injection
- safety systems.

Before operation, all tools, debris and waste materials need to be removed from the tank, both internally and externally, with all the valves (with the exception of the roof drain valve on EFRTs) left in the closed position. All roof fittings are also in a closed position. Normally a final inspection of the inside is made before closure of the access hatch.

### **3.1.12.4. Management**

[113, TETSP, 2001]

The main operations to be considered in this document are those likely to create a release of material from the tank and these are described in Figure 3.1.

These operations can be sorted into routine operations (e.g. filling, emptying, level gauging, sampling, etc.) and non-routine operations prior to maintenance and inspection. The management systems have to cope with both types, but the means are different; instrumented control systems often assist the operators when they deal with routine operations, while non-routine operations are often performed manually, following special operating instructions.

### **3.1.12.5. Operation**

[113, TETSP, 2001]

Operation of a tank means the normal utilisation of that tank to store liquids or liquefied gases and the main activities which permit its safe use (e.g. management, maintenance, inspection, etc.). The measures to ensure the proper operation of tanks are described in Section 4.1.2.

### 3.1.12.6. Decommissioning and demolition

[37, HSE, 1998] [113, TETSP, 2001]

#### *Decommissioning*

In decommissioning, tanks which are to be taken out of service are made safe. The method will vary with the location of the tank, the product it has contained and whether it is to be taken out of use permanently or only temporarily. Common practice is that a risk assessment is carried out at the planning stage to identify any hazards that decommissioning may incur. The preliminary steps in the decommissioning process (which apply also to pipework) are:

- isolation of the tanks from any process, plant or storage vessel by either removing pipe sections or fitting spade pieces. Shut-off valves by themselves are not adequate
- emptying the tanks as much as possible
- opening access hatches to assist venting.

Tanks which are being decommissioned permanently are made safe by thorough cleaning and gas freeing. Any entry points (access hatches, etc) should be physically closed or barred to prevent unauthorised access. Alternatively large door sections of the tank shell can be removed to make the development of an unsafe atmosphere impossible. Tanks that are being decommissioned temporarily are made safe by thorough cleaning as above or by filling with water or an inert gas such as nitrogen. If inert gas is used, the tank is labelled to make it clear that it contains a gas which could cause suffocation if the tank is entered. As above, any entry points should be physically closed. Regular inspection ensures that the tanks remain in a safe condition. Carbon steel tanks which have been filled with water for some time will be subject to internal corrosion; when emptied of water the inner surface of the tank will rapidly rust (oxidise) resulting in dangerous oxygen depletion of the tank atmosphere.

In several Member States, the work needs to be covered by a permit-to-work or similar authorisation procedure. Such a permit specifies:

- the area to which the permit applies
- the work to be undertaken and the method to be used
- the time limit on the permit
- the precautions to ensure that all flammable materials have been removed and cannot be accidentally reintroduced.

#### *Demolition*

The demolition of tanks that have contained flammable or other hazardous liquids is potentially (very) dangerous. Hot work might cause an explosion if it is undertaken before the tanks and pipework have been adequately drained and cleaned. Tanks that have contained flammable liquids need special preparation to remove flammable vapours or associated liquids and sludges. Residues that can emit flammable vapours when heated may be present on the walls and underside of the roof. It may, at times, even be advisable to use a special tank demolition company with the relevant expertise and equipment.

### 3.1.12.7. Tank equipment

[67, Rentz et al, 1998]

The following equipment may be installed on a storage tank, depending upon the mode for which it is designed: vents, access hatches, gauge float wells, gauge-hatches/sample wells, rim vents, roof drains, roof legs, unslotted guidepole wells, slotted guidepole/sample wells and vacuum breakers. These fittings accommodate the structural support or provide certain operational functions. They can be a source of emissions to air because they require penetrations in the roof.

As an example, fittings for external floating roofs include: access hatches, guidepole wells, roof legs, vacuum breakers, and automatic gauge float wells.

#### **3.1.12.7.1. Vents**

[113, TETSP, 2001] [41, Concawe, 1999] [84, TETSP, 2001] [3, CPR, 1984, 37, HSE, 1998]

Normal relief can be provided by the following types of vents, depending on the type of tank:

##### ***Open vents***

Storage tanks which operate purely at atmospheric pressure (i.e. without pressure or vacuum conditions existing in the tank) are equipped with open roof vents. These air vents cannot be shut. The open air vents are designed to ensure that under the conditions of the highest vapour flow (i.e. when the supply pumps are operating at maximum capacity and ambient conditions simultaneously produce maximum rates of breathing) no dangerous under- or overpressure can occur.

##### ***Pressure/vacuum relief valves (PVRVs)***

Pressure relief valves prevent excessive pressure build-up, and vacuum valves prevent the tank collapsing due to a negative pressure in the tank. These functions may be combined in a pressure/vacuum relief valve (PVRV), also known as a breather valve. In the standard BS 2654 (International Codes), these valves are recommended for use on atmospheric fixed roof tanks in which a product with a flashpoint below 38 °C is stored and for use on tanks containing a product that is heated above its flashpoint. Table 3.8 shows the three basic types of fixed roof tanks, together with their pressure and vacuum design ratings.

Liquefied gas tanks are always fitted with pressure relief valves. In certain designs, for example in the case of refrigerated tanks, vacuum relief valves are also fitted. These valves protect the tank against pressure excursions due to process malfunctions or fire conditions.

##### ***Bleeder vents***

Floating roof tanks can be fitted with automatic bleeder vents (also called vacuum breakers) to release air and vapour from under the floating roof during initial filling, and to allow in breathing if the tank is emptied so that the roof lands on its legs. Normally they open automatically before the roof lands on its legs, thus stopping vacuum conditions arising, but under normal circumstances these vents are closed. The size of the bleeder vent/vacuum breaker is based on the product (and hence vapour) flowrate when filling the tank. It is important to have the bleeder vent pipe supports, which open the vent valve, designed in a similar way to the roof support legs, i.e. to have an operational and a maintenance setting. The change of roof support leg adjustment should always include a similar change to the bleeder vent support setting to prevent malfunction of the whole system.

##### ***Rim seal vents***

On external floating roof tanks a rim seal vent is required for seals that have a 'vapour space' under the primary rim seal, for example vapour mounted seals and the mechanical shoe type seals. The liquid mounted seals do not require a rim vent. The main function of the rim vent is to allow pockets of vapour, which become pressurised, to escape from under the rim seal to the atmosphere. Vapour pockets can form under the floating roof deck and then find their way into the rim space. Overpressure inside the rim space may damage the rim seal material and hence reduce the efficiency of the seal.

Emergency relief may be provided by:

- larger or additional vents
- access hatches or hatch covers which lift under abnormal internal pressure
- purpose-built relief devices, e.g. on pressurised tanks.

Another possible option is that tanks with a fixed roof containing flammable liquids, can be constructed in such a way that, in the event of an explosion, the roof will tear at the top of the tank. The weld between the roof and the tank-wall is, therefore, weaker than the weld between the bottom and the tank-wall.

#### **3.1.12.7.2. Gauging and sample hatches**

Products in atmospheric storage tanks are usually dipped or ullaged from a gauging or still well. The gauge measures parameters such as: height, mass, temperature, density and/or pressure. To prevent emissions to air the gauge or still well is closed with a lid during normal circumstances. Self-closing foot-operated hatches that are vapour tight are commonplace. Automatic gauging is possible and has the advantage over manual dipping that it allows determination of the quantity of liquid without opening the tank.

Dipsticks are potential sources of ignition in that they may produce frictional heating, sparking or static electricity. Normally they are made of non-sparking alloys and are earthed as described, e.g. in BS 5958 (see Annex 8.1 International Codes). Dip tapes may be an alternative to measure depth.

For an EFRT, access to the roof itself during operation is not recommended without breathing apparatus and assistance.

#### **3.1.12.7.3. Still wells and guide poles**

[114, UBA, 2001] [41, Concawe, 1999]

Still wells and guide poles are installed to:

- enable access for measuring the liquid level
- enable access for measuring the temperature of the liquid
- enable access for sampling the liquid
- prevent the roof from rotating.

For an EFRT at least one still well is recommended. If two are used, (one for the automatic level gauge, and another for manual dipping) they are normally adjacent and fixed to the tank (preferably to the floor) in the same way. If manual and automatic gauging are carried out from the same still well, then a method of winding the automatic gauge out of the way is necessary to allow safe sampling and gauging and to minimise the likelihood of spillage.

#### **3.1.12.7.4. Instrumentation**

[41, Concawe, 1999] [18, UBA, 1999] [3, CPR, 1984] [113, TETSP, 2001]

Local or remote instrumentation should be in accordance with appropriate standards; the Institute of Petroleum (IP) Petroleum Measurement Manual and IP Electrical Safety Code will provide specific advice, as well as other codes, standards and guidelines in this field; see Annex 8.1 – International Codes.

#### ***Level control and overflow protection***

During filling procedures, usually it is insufficient to control and record only the filling level. Because there is a danger of overfilling and consequent soil and water pollution, storage tanks can be equipped with overflow protection so that filling procedures can be interrupted automatically before the maximum authorised level of liquid is reached. Where the filling procedure is not carried out automatically, e.g. when it is carried out manually, the tank is normally equipped with an alarm to indicate when the maximum authorised level of liquid is reached. When the alarm goes off, personnel can stop the filling procedure in time.

### ***Flame arrester***

Atmospheric storage tanks containing volatile products may have a flammable atmosphere above the liquid. To prevent these vapours being ignited by an external source (e.g. lightning) open (air) vents can be fitted with flame arresters. However, these can become partially or fully blocked (e.g. by ice, dirt, polymerised product, wax, etc.). As the open vent is designed and fitted to prevent the tank becoming either over- or under-pressurised, the installation of these arresters can compromise the tank integrity unless they are regularly inspected and maintained.

Pressure relief valves are normally designed so that the vapour flow out of the valve exceeds the flame propagation speed in the vapour, thus preventing flame ingress into the tank. Due to the problems of blockage with flame arresters described above, these are not normally fitted in series with PVRVs – see API 650 (Annex 8.1 – International Codes).

### ***Leak and gas detection***

Instruments and/or analysers are used to detect liquid and/or gaseous leaks and spillages. A particular case is the verification of the safe working level of contamination in vessels before internal maintenance. The following is a non-exhaustive list of some typical techniques used:

- gas leaks can be detected by explosimeters, general purpose organic vapours analysers (OVA) or specific gas analysers
- liquid leaks can be detected in the spillage collection systems. Level or interface level sensors can be used for insoluble organics, while pH meters and conductivity meters can be used when, for example, acids or bases are handled.

#### **3.1.12.7.5. Access hatches**

[41, Concawe, 1999] [113, TETSP, 2001]

For aboveground vertical atmospheric tanks, access hatches at the base of the tank allow access during a shut-down of the tank and to fulfil gas freeing of the tank. This is also the access route where any solids left in the tank are removed during cleaning operations. For safety reasons, tanks greater than 25 metres in diameter require at least two access hatches.

An access hatch is also usually provided for horizontal tanks (both atmospheric and pressurised) on the top of the tank.

#### **3.1.12.7.6. Drains**

[41, Concawe, 1999] [37, HSE, 1998] [113, TETSP, 2001] [3, CPR, 1984]

For atmospheric tanks, a drain allows the removal of water that may accumulate at the base of the tank. This is best achieved by an internal water draw-off sump and line leading to an external, valved outlet. In the case of flammable liquids it is common practice to blank off the valves when not in use. Strict operational control is required to prevent accidental draining of the tank contents due to leaving the valve open after starting to drain water.

An EFRT requires a second type of drain. This is to provide drainage for the roof to cater for rainwater. The water is drained via an internal articulated pipe or flexible hose with a valve at the end, at the base of the tank. A non-return valve near the roof end is recommended to prevent any leakage into the drain from the product reaching the roof and evaporating. Normally the roof drain at the base is closed to prevent any product leakage. However, this must be complemented by a programme of regular draining, particularly during or after rainstorms, otherwise there is a potential serious risk of sinking the roof and causing substantial emissions. Reference, [3, CPR, 1984] however, states that the drain should always be opened. In this case leakage of the product into the roof drain line would result in a spill.

For pressurised storage tanks, the drain systems are normally provided with two manual shut-off ball valves that are separated by at least 600 mm of adequately supported piping with a fall towards the outlet. The two drain valves are positioned to enable simultaneous operation of both valves by a single operator. The downstream valve is normally a quick-acting spring-loaded type (spring to close) valve that will operate as a dead man's handle. The drain outlet point can be lined up to a vapour treatment (i.e. thermal oxidiser) via a vapour knock out vessel.

#### **3.1.12.7.7. Mixers**

[41, Concawe, 1999]

Mixers are used in blending tanks and also to prevent the accumulation of solids and sludges in the tank bases. They are normally capable of being maintained without the need to shut down the tank. Consideration could be given to the installation of warning devices to indicate failures of bearings or mechanical seals, especially where the operation is unattended for long periods. This will ensure action can be taken quickly for a problem that could escalate into a safety or environmental incident.

#### **3.1.12.7.8. Heating systems**

[3, CPR, 1984] [37, HSE, 1998] [113, TETSP, 2001] [18, UBA, 1999]

For the heating of the products stored in tanks (e.g. to ease pumping for reasons of viscosity), pipework is installed inside the tank through which steam, heated water or heated oil is pumped for heat exchange. Standards for the construction of heated tanks and their associated heating equipment are, e.g. BS 799, BS 5410 or BS 806 (See Annex 8.1 International Codes).

Normally the outlet pipe is located above the heating coil or element to prevent exposure of any internal heated surface or any temperature control sensor. A second drain pipe is fitted at a lower level so that the tank can be completely emptied when necessary. A locked closed valve or a blank flange will prevent this drain pipe from being used during normal operations. An alternative is to fit a low liquid level alarm linked to a heater cut-out or an alarm to identify important changes. In any event, a heating system can be equipped with different levels of instrumentation, dependent upon product specifications and operational requirements.

The temperature and/or the pressure of the product stored are monitored when it is necessary because of operating conditions or characteristics of the substances, e.g. with heated tanks or if gas blanketing is required.

#### **3.1.12.7.9. Sealing elements**

[149, ESA, 2004]

The primary purpose of a seal is to contain the liquid or liquefied gases and prevent or reduce emissions. A significant proportion of fugitive emissions are losses from unsealed sources, including storage tanks, open-ended (non blanketed) lines, pressure-relief valves, vents, flares, blow-down systems and spills. In other cases, these losses may be caused by leaks in the sealing elements of particular items of equipment, such as:

- agitators/mixers
- compressors
- flanges
- pumps
- tank lids
- valves.

Some important causes of leaking losses are:

- ill-fitting internal or external sealing elements
- installation or construction faults
- wear and tear
- equipment failure
- pollution of the sealing element
- incorrect process conditions.

### **3.1.12.7.10. Valves**

Valves are part of both the tank and the transfer system. They are described in Section 3.2.2.6.

### **3.1.13. Containers and the storage of containers**

#### **A. Description**

[7, CPR, 1992, 36, HSE, 1998, 116, Associazione Italiana Commercio Chimico, 2001]

Containers are classed as:

- glass bottles up to 5 litres
- plastic bottles or drums up to 60 litres
- metal canisters up to 25 litres
- steel or GRP (glass-fibre reinforced polyester) drums up to 300 litres
- paper (solids only) or plastic bags
- intermediate bulk containers (IBC).

The material of the container must be perfectly compatible with the chemico-physical properties of the liquid to ensure that no interaction occurs which might cause a reaction or leakage. In International Codes, the most important codes are listed. For dangerous substances the containers must be of an appropriate UN performance tested type. For liquid substances, to avoid product dispersion, it is mandatory to respect a filling percentage of the container depending on the characteristics of the products. The containers need to be robust and have well-fitting lids or tops to resist spillage if knocked over.

Several types of containers are normally used to transport and store chemical products:

#### ***Glass containers***

Glass bottles do not normally exceed a capacity of 5 litres and often do not exceed a capacity of 2.5 litres. In most cases glass bottles are intended for immediate use e.g. in a laboratory.

#### ***Drums***

These are, normally, cylindrical containers with a flat top and bottom. However, the shape depends on the product that is stored. The drums can be made of steel, plastic, wood, cardboard or other materials.

#### ***Plastic composite containers***

These types of containers are made of an internal plastic container and an external (cardboard, wood, etc.) package. Once put together, they cannot be re-divided.

#### ***Composite containers***

This type of containers is made of an internal glass, porcelain or earthenware container and an external (cardboard, wood, etc.) package. After implementation this kind of container cannot be re-divided. Most of these containers can be 'reconditioned' if the used containers have been checked under official procedures.



**Big containers (IBCs)**

These types of containers can have different shapes, sizes and capacities, but with the following upper capacity limits:

- 3 m<sup>3</sup> for hard IBCs
- 1.5 m<sup>3</sup> for flexible IBCs.

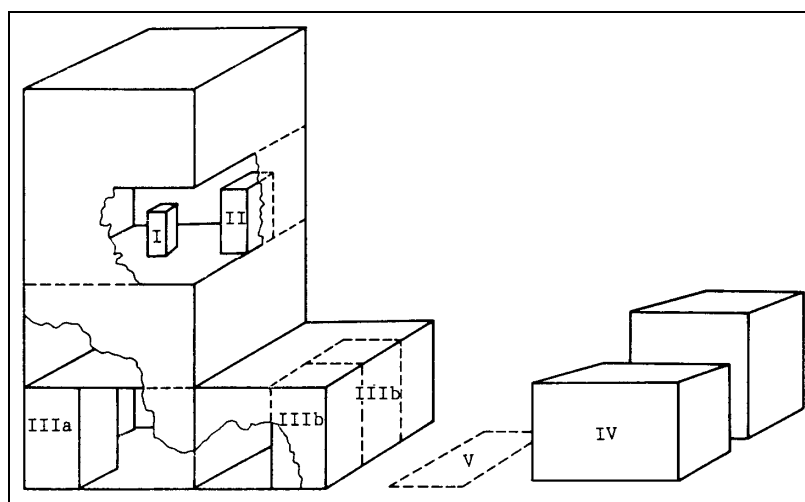
IBCs commonly used are:

- metallic IBCs: completely made of metallic material, i.e. both the container and the ancillary equipment.
- flexible IBCs: made of textile, film or other flexible material, (eventually also composite material) and ancillary equipment.
- hard plastic IBCs: have hard plastic bodies, with or without a skeleton for the mechanical support and ancillary equipment.

Containers can, of course, be used to store all kinds of materials in all different types of industries. In this section only the storage by containers of dangerous materials is considered.

Figure 3.16 shows that containers with dangerous materials can be stored in (I) loose cabinets, (II) fitted cabinets, (IIIa) storage cells in a multistorey building, (IIIb) storage cells in a single-storey building in (IV) storage buildings and in (V) storage yards. Cabinets are very small units and are not further described. The latter three are described in the following sections.

Even more important than a proper storage facility concerning dangerous materials is the determination whether compartmenting is necessary. In principle, each category of dangerous material shall be stored separately from other dangerous materials. Compatible and incompatible combinations of dangerous materials are shown in Annex 8.3.



**Figure 3.16: Possible locations for the storage of dangerous materials in containers**  
[7, CPR, 1992]

**B. Possible emission sources (containers)**

Operational losses do not occur in storing packaged dangerous materials. The only possible emissions are from incidents and (major) accidents. These emissions are addressed in Chapter 4.

### **3.1.13.1. Storage cells**

#### **A. Description**

[7, CPR, 1992, 36, HSE, 1998]

A storage cell containing hazardous materials in containers will normally be located on the ground floor. A storage cell in a multistorey building will normally not contain more than 500 litres of hazardous materials, where one in a single-storey building will normally contain a maximum of 2500 litres of dangerous materials. When the storage cell has direct access to a workroom in which activities constituting a fire hazard usually take place, the cell is fitted with a self-closing door. A storage cell may contain a fitted or loose cabinet for separately storing hazardous materials (compartmenting) that may react with other stored substances to produce dangerous gases or fumes or which may cause hazardous situations such as explosions, the spray-release of dangerous materials or excessive heat.

#### **B. Possible emission sources (storage cells)**

Operational losses do not occur in storing packaged dangerous materials. The only possible emissions are from incidents and (major) accidents. These emissions are addressed in Chapter 4.

### **3.1.13.2. Storage buildings**

#### **A. Description**

[HSE, 1998 #35; CPR, 1991 #8; CPR, 1992 #7, [43, Austria, 1991, 45, Vlaanderen, ] [117, Verband Chemiehandel, 1997, 127, Agrar, 2001]

Storage buildings are used for storing all kinds of substances, from drums with flammable liquids, cylinders with pressurised gas, to packaged products such as chemicals and pesticides or chemical wastes awaiting disposal. They can be a standalone building or be part of another building.

Good design and construction of storage buildings containing dangerous materials focuses on events such as fire, explosion and releases of dangerous substances, in particular to prevent or control them as much as possible. Also good management practices and operational procedures are important; these are described in Chapter 4.

Between MSs many different standards for fire resistance, compartment size and also means of escape and assistance to the fire brigade concerning storage buildings exist. The differences in these standards are related to issues such as, how much and which dangerous materials are stored. This means that the descriptions of storage buildings given in this section are general and thus serve only as some examples.

Normally storage buildings are constructed of non-combustible materials, however, not always. The degree of fire-resistance offered by the building determines the minimum distances from boundaries and other buildings that need to be observed. With a sufficient degree of fire-resistance the storage building can also be part of another establishment.

Compartmenting the spaces intended for storing dangerous materials separately can be carried out by means of utilising partition walls or by incorporating a storage-free zone. Some warehouses have an inbuilt store within the main warehouse. This interior store can be used to store particular hazardous materials, for example highly flammable liquids and gases, or peroxides. Compatible and incompatible combinations of hazardous materials are shown in Annex 8.3.

The floor(s) of the building is usually made of non-combustible material, is liquid-tight and will be resistant to the stored substances.

The roof of the building is resistant to wind-blown fires, with the roof structure being of a fire-resistant construction to prevent fire coming into the store. The degree of fire-resistance depends on different factors such as, how close the store is to the border or other buildings and the type of substances stored.

A storage building is normally equipped with adequate ventilation to prevent an explosive mixture forming because of, e.g. leakage and to extract any harmful or unpleasant fumes.

The use of electrical equipment can generate sparks that might ignite a fire in the storage building, therefore it is important to use explosion-protected electrical equipment. However, proper earthing of the steel structure will usually suffice in most cases.

The level of fire prevention and fire-fighting measures depend on many factors, such as the flammability of the stored substances, the flammability of the packaging and the quantity stored. If a fire breaks out in a storage facility, part of the stored substances may be released. As, when polluted extinguishant is produced, provisions are normally taken to prevent these materials from entering the soil, sewerage systems or surface water. Systems for collecting the extinguishant can be constructed in several ways, see Section 4.1.7.5 for more detailed information. The capacity of the collection system depends on the type and amount of substances stored and is described in further detail in Section 4.1.7.5.

#### **B. Possible emission sources (storage buildings)**

Operational losses do not occur in storing packaged dangerous materials. The only possible emissions are from incidents and (major) accidents. These emissions are addressed in Chapter 4.

### **3.1.13.3. Outside storage (storage yards)**

#### **A: Description**

[7, CPR, 1992, 8, CPR, 1991, 35, HSE, 1998]

In principle, measures and provisions for storing dangerous (packaged) materials outside do not differ from those for storage inside a building (see Section 3.1.13.2). The amount and type of substances stored determines the minimum distances from boundaries and buildings to be observed. To protect the storage from direct sunlight and rain, the storage may be equipped with a roof.

The collecting provisions normally applied for spilled substances and the eventually occurring extinguishant are the same as those applied in storage buildings and are described in Section 3.1.13.2. When the storage is not covered with a roof, provisions for the controlled discharge of (possibly polluted) rainwater are normally in place.

The level of fire prevention and fire-fighting measures depend on many factors, such as the flammability of the stored substances, the flammability of the packaging and the quantity stored.

#### **B. Possible emission sources (storage yards)**

Operational losses do not occur in storing packaged dangerous materials. The only possible emissions are from incidents and (major) accidents. These emissions are addressed in Chapter 4.

### 3.1.14. Basins and lagoons

#### A. Description

[113, TETSP, 2001]

Basins and lagoons are used in industry and in agriculture. In industry, they are most commonly used to hold water of all types, including cooling and fire-fighting water, untreated waste water and treated water. They can also be used to hold brine. In agriculture, they are widely used for storing and treating manure and silage. They are not used for volatile petroleum products or chemicals.

The distinction between basins and lagoons is not strictly defined and the terms are often interchanged. Other terms, such as pond, are also used for this storage mode. There are two types: naturally occurring and man-made.

The size and shape of a basin or lagoon is a site-specific issue. Rectangular basins of length to width ratios of 3:1 or less are typical. Depths are again site-specific but are typically in the range of 2 to 6 metres.

**Construction:** Where the site topography and the ground and soil are suitable, earth-banked containment basins or lagoons can provide cost effective storage for non-hazardous substances such as firewater or treated waste water. Lagoons may be constructed either above or below the surrounding ground level with the formation level often being determined by the economic advantages of balancing cut and fill. (See Pollution Prevention Guidance 18 Note published by the Environment Agency, UK).

Where groundwater pollution is seen to be a risk, the lagoon should be substantially impermeable, with either a clay or a synthetic membrane liner or a concrete layer being applied.

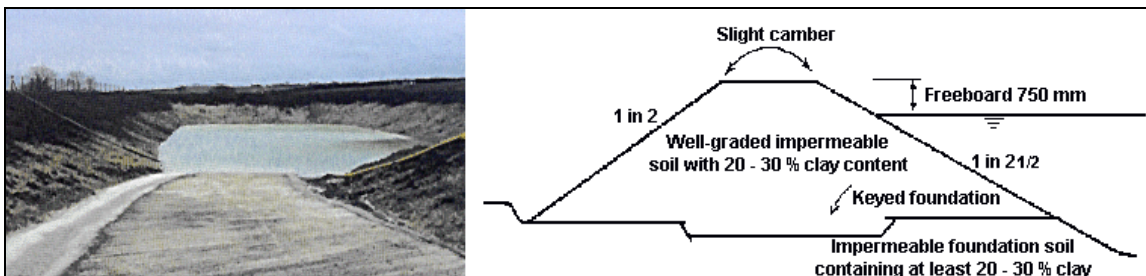


Figure 3.17: Example of an earth-banked slurry store and design features

#### B. Possible emission sources (basins and lagoons)

Table 3.37 and Table 3.38 show the emission scores for the potential emission sources for basins and lagoons. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	3	6
Standing	3	3	9
Emptying	2	1	2
Cleaning	1	2	2
Blanketing			N/A
Manual gauging			N/A
Sampling			N/A
Fugitive			N/A
Draining			N/A

**Table 3.37: Possible emissions to air from ‘operational sources’ with basins and lagoons [87, TETSP, 2001]**

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	1	3	3
Sampling	2	0	0

**Table 3.38: Possible emissions to water or waste from ‘operational sources’ with basins and lagoons [87, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents such as overflow and leakages. These emissions are also addressed in Chapter 4.

### 3.1.15. Mined caverns (atmospheric)

See Section 3.1.16 for details on pressurised mined caverns and Section 3.1.17 for salt leached caverns. The following general description applies to atmospheric as well as pressurised mined caverns. It is important to note that most mined caverns are of the pressurised type. [150, Geostock, 2002]

In building a rock mined cavern, there are three main factors to be taken into account:

1. the hydrocarbon product stored must be lighter than water
2. the bedrock must be sufficiently hard and homogenous
3. rock mined caverns must be excavated below the groundwater level to a depth where the groundwater pressure around the cavern is higher than any pressure inside the cavern.

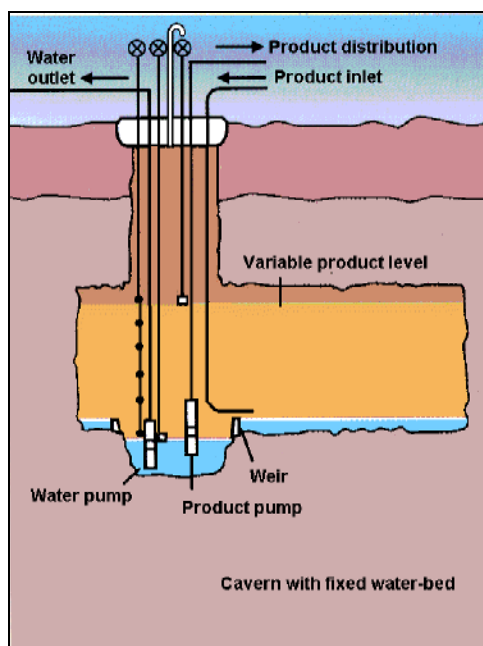
The difference in specific gravity between the hydrocarbon product stored and water, together with the location of the caverns deep enough below the groundwater table, ensure that the hydrostatic pressure of the groundwater surrounding the rock cavern is greater than that of the stored hydrocarbon, thus preventing the liquid and gas from escaping. Seepage water, entering the cavern through fractures and joints in the rock mass, collects in the water-bed and is pumped out. There are several alternative varieties of acceptable bedrock, including intrusive rocks, metamorphic rocks, limestone, certain sedimentary rocks and even in some cases volcanic rocks. [81, Neste Engineering, 1996]

**A. Description** [81, Neste Engineering, 1996]

There are two main types of mined cavern storage principles:

***Caverns with a fixed waterbed***

A layer of water, usually less than a metre deep, is maintained at the bottom of the cavern. The water level is kept constant with a pump pit weir. Caverns built on the fixed waterbed principle can store, for example, crude oil, LPG, gasoline, diesel fuel, light fuel oil and heavy fuel oil. See Figure 3.18.



**Figure 3.18: Schematic of a cavern with a fixed waterbed**  
[81, Neste Engineering, 1996]

***Caverns with a fluctuating waterbed***

In this type of rock cavern, the level of the hydrocarbon product stored is kept at a nearly constant height by varying the depth of the water layer. The cavern is always full and the amount of water is at a minimum when the hydrocarbon product totally fills the cavern. Conversely, when there is no hydrocarbon product in the cavern, it is full of water. See Figure 3.19.

Caverns constructed with a fluctuating waterbed are used, for example, for storing gasoline. Heavy oils to be stored at elevated temperatures, and other hydrocarbon products requiring great outlet pumping capacity, are stored in caverns utilising a dry pump room at the bottom level of one or more of the caverns.

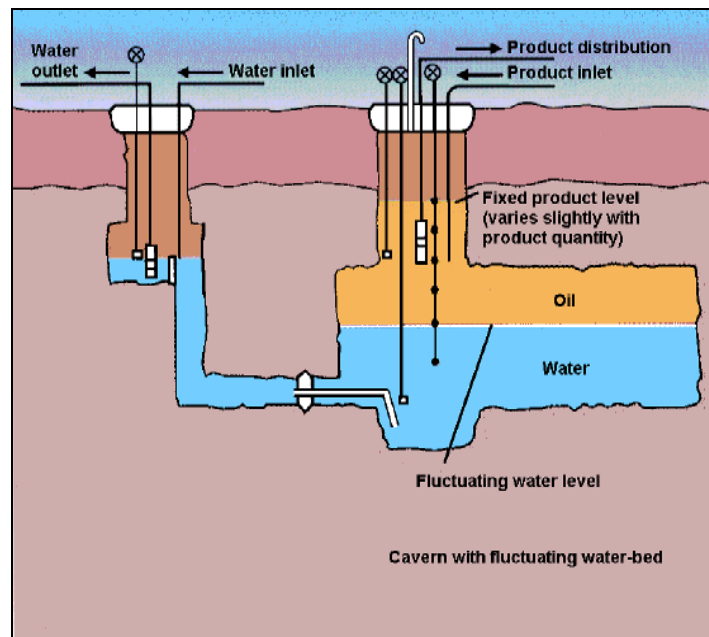


Figure 3.19: Schematic of a cavern with a fluctuating waterbed [81, Neste Engineering, 1996]

Typical volumes of this type of cavern range from 50000 to 580000 m<sup>3</sup>. However, regional LPG pressurised mined cavern storages can be as small as 8000 m<sup>3</sup>, as for example the LPG Sennecey storage in France; see Section 3.1.16.

The Porvoo Refinery in Finland uses caverns of the fixed waterbed type because they need less water and thus less water treatment.

The depth at which a cavern is situated differs according to the presence of suitable rock and the hydrocarbon product stored. Typical depths range from 40 to 170 metres. At the Porvoo Refinery, for example, a pressurised cavern containing LPG is situated 140 metres below the groundwater level, see Figure 3.20.

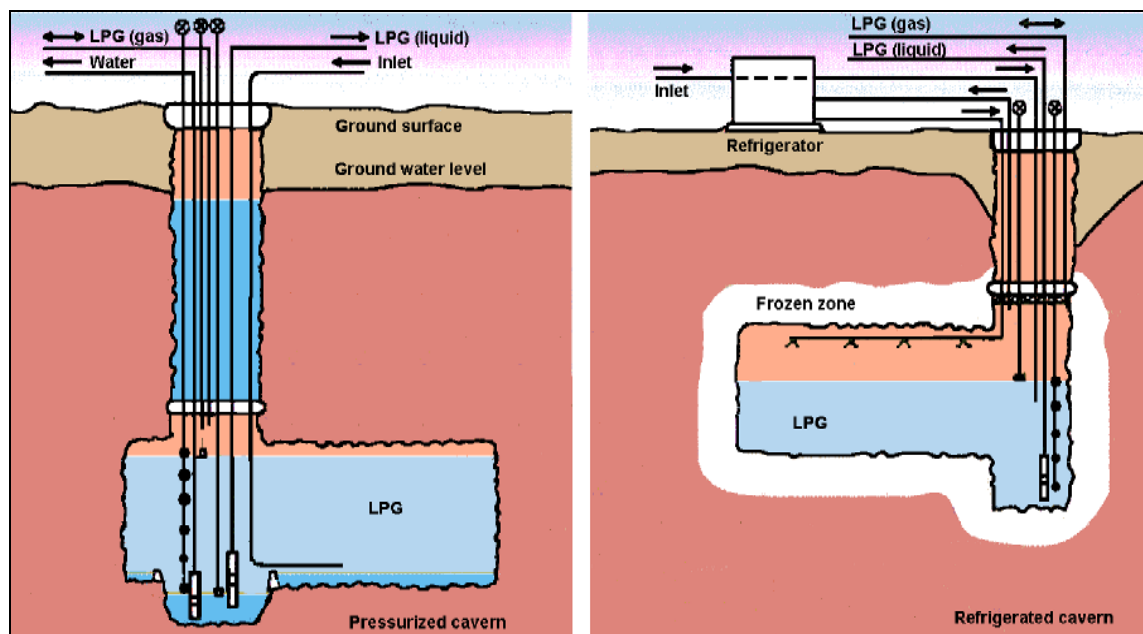


Figure 3.20: Schematics of a pressurised cavern and a refrigerated cavern for the storage of LPG [81, Neste Engineering, 1996]

### **Construction**

[81, Neste Engineering, 1996, 150, Geostock, 2002]

The construction of economically viable rock caverns is highly dependent on favourable rock and groundwater conditions. Site studies are made to determine rock quality, solidity, discontinuities, direction of schistosity and other valuable information. These are collected and analysed in order to establish excavation plans. The bedrock structure is studied by means of outcrop mapping, seismic refraction soundings, percussion drilling and diamond core drilling. It is also good working practice to measure the initial stress of the bedrock and to carry out hydrocarbon product/rock compatibility tests at this stage. Groundwater conditions are studied by well observations and pumping tests. After this study, the exact location and the longitudinal direction of the caverns can be chosen.

### **Economics**

[81, Neste Engineering, 1996]

The major factors affecting construction costs are:

- the quality of the bedrock
- the groundwater conditions
- the size and dimensions of storage caverns
- the number of storage units and the total volume of the project
- the type of hydrocarbon product to be stored and the method of storage
- the amount of reinforcing and grouting needed
- requirements for purifying seepage water and the need to replace groundwater
- design loads of concrete structures
- types of inlet and discharge facilities
- the equipment and degree of automatic and remote control
- the value of the excavated stone, which can be used for levelling, road construction, etc.

The largest cost item is excavating the cavern out of the rock, amounting to at least half of the total investment costs. Installation costs, and the costs for reinforcement and concrete structures are in the range of 10 % each. All costs depend greatly on local conditions. The marginal cost of a rock mined cavern is very small in relation to its volume, favouring the storage of large quantities of hydrocarbon product. In cost comparisons with aboveground steel tanks, the break-even point at this particular location in Finland is generally 50000 m<sup>3</sup>. For LPG the figure is considerably lower (approximately 10000 m<sup>3</sup>). Figure 3.21 shows the relative investment costs for oil storage in surface tanks and unlined rock caverns under Finnish conditions. Figure 3.22 shows the relative investment costs for LPG storage alternatives under Finnish conditions. The operation and maintenance costs of underground caverns, for example at the Porvoo Refinery, are no more than one-sixth of those for steel tanks on the surface. This figure is based on daily operations of 5 million m<sup>3</sup> of underground caverns and 2 million m<sup>3</sup> of aboveground steel tanks. However, costs for decommissioning the site can be significant and will depend on many aspects such as the substances that have been stored and the quality of the bedrock.



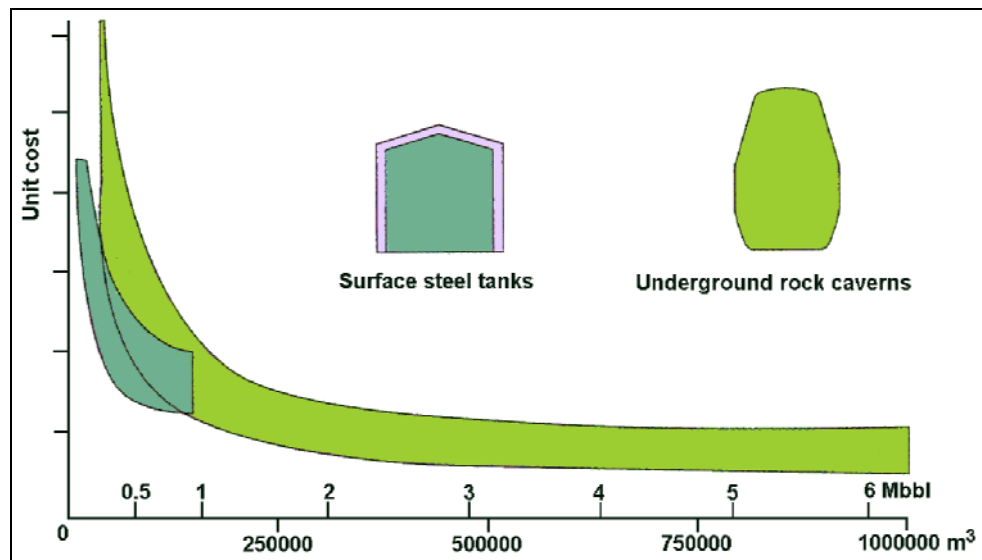


Figure 3.21: Relative investment costs for oil storage in surface tanks and unlined rock caverns at a refinery location in Finland [81, Neste Engineering, 1996]

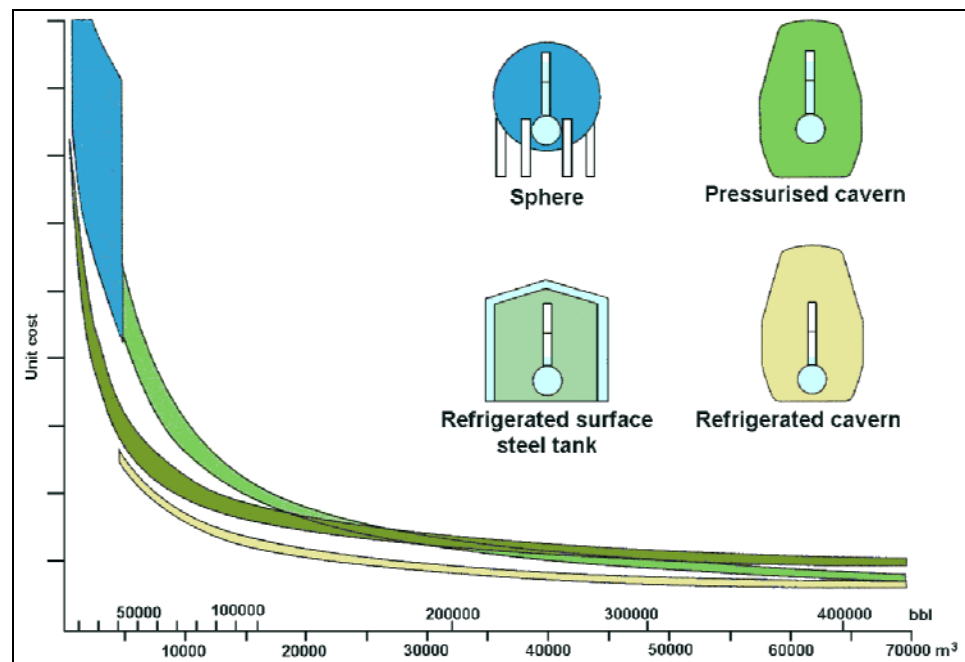


Figure 3.22: Relative investment costs for LPG storage alternatives at a refinery location in Finland [81, Neste Engineering, 1996]

### Emission and consumption

[81, Neste Engineering, 1996] [150, Geostock, 2002]

An underground storage unit is protected against external forces and threats. The risk of gas explosions is minimal and under no circumstances can the hydrocarbon product catch fire underground due to the absence of oxygen. Emissions to air are low, due to stable temperatures and the possibility of storing the hydrocarbon product under pressure. Since the entire storage cavern is practically invisible, the landscape above remains untouched and free for other industrial purposes.

By its very nature, underground storage provides high intrinsic resistance to earthquakes.

The main consumers of energy are the pumps used for filling and emptying the caverns. The energy consumption for filling and emptying aboveground storage tanks is lower than that for filling and emptying caverns. On the other hand, under Finnish climate conditions, the energy consumption for heating certain types of substances in aboveground storage tanks is higher compared with storage in caverns.

There might be some sediment accumulation at the bottom of the caverns where crude is stored, but at the Porvoo Refinery, in the 30 years of operating the caverns, there has been no need to take wastes from the caverns. The only wastes that arise are the spare parts of the pumps which have to be changed in the case of malfunction and maintenance.

A disadvantage of mined caverns in general is the oily seepage water, which is pumped out and treated in a waste water treatment plant.

Caverns of the fixed waterbed type need less water (and thus less water treatment) than the caverns of the fluctuating waterbed type.

**B. Relevant equipment and other considerations**

[81, Neste Engineering, 1996]

The pipes and instruments of an underground mined cavern are generally installed in a vertical shaft constructed from the cavern to the surface. Caverns are mostly equipped with complete instrumentation to control pressure, surface levels and temperature and to check the operation of the equipment.

In general, the pumps used in caverns are submersible motor pumps suspended (hanging) from discharge pipes, located in the vertical shaft leading to the cavern. Pumps can also be installed in a dry pump room located at the bottom level of the cavern and separated from it, see Figure 3.23. Conventional centrifugal pumps are used in this type of design.

Generally the control and operation of cavern storage facilities are carried out in a remote control room. Due to their remote and partly automatic operation, cavern sites are sometimes unmanned.

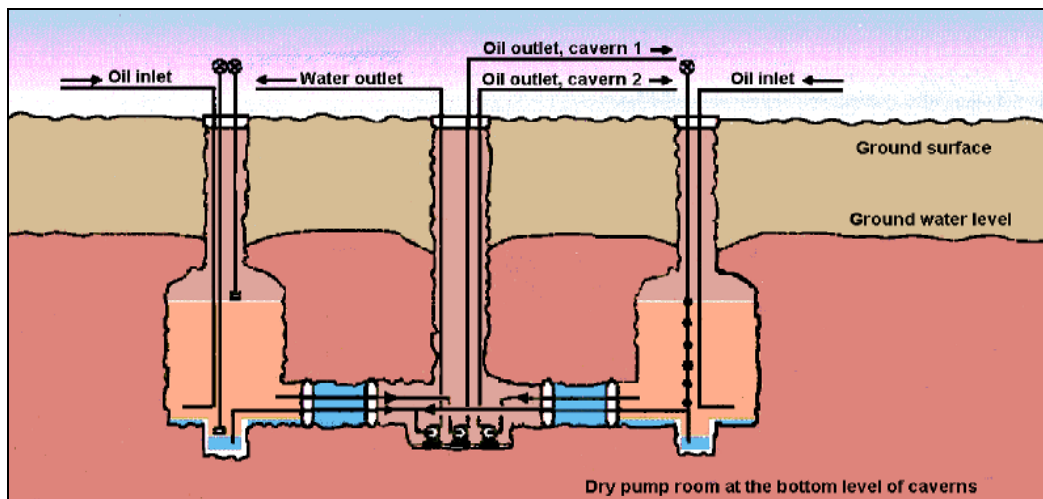


Figure 3.23: Scheme of a dry pump room at the bottom level of caverns [81, Neste Engineering, 1996]

### C. Possible emission sources (atmospheric mined caverns)

Table 3.39, Table 3.41 and Table 3.42 show the emission scores for the potential emission sources for atmospheric mined caverns. The tables show that for a cavern with a fluctuating waterbed the emissions to air due to filling are very low, because the gas level in the cavern is kept more or less constant during filling by pumping out water. Also the breathing emission is lower because, with the help of the water level, the gas volume is kept as small as possible. However, the pumping out of water may create an emission to water.

Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	3	6
Breathing	2	1	2
Emptying	2	1	2
Cleaning			N/A
Blanketing			N/A
Manual gauging	2	1	2
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	1	2

**Table 3.39: Possible emissions to air from ‘operational sources’ with atmospheric mined caverns of the fixed waterbed type [87, TETSP, 2001]**

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	1	1	1
Breathing	1	1	1
Emptying	2	1	2
Cleaning			N/A
Blanketing			N/A
Manual gauging	2	1	2
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	1	2

**Table 3.40: Possible emissions to air from ‘operational sources’ with atmospheric mined caverns of the fluctuating waterbed type [176, EIPPCB Ineke Jansen, 2004]**

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning			N/A
Sampling	2	0	0

**Table 3.41: Possible emissions to water or waste from ‘operational sources’ with mined caverns (atmospheric) [87, TETSP, 2001]**

Apart from operational losses, emissions from mined caverns could also eventually occur from incidents such as overflow and leakages. These emissions are also addressed in Chapter 4.

### **3.1.16. Mined caverns (pressurised)**

#### **A. Description**

[113, TETSP, 2001, 150, Geostock, 2002]

See Section 3.1.15 for the general description of mined cavern storage. Pressurised liquefied gas may also be stored in mined rock caverns or salt leached caverns (for salt leached caverns see Section 3.1.17).

The principle of mined rock cavern storage is that the caverns are set at such a depth below ground level that the static head of the water table is greater than the pressure of the stored hydrocarbon product. There is, therefore, a pressure gradient towards the inside of the cavern and leakage of the product to the rock strata is avoided.

The vapour space in pressurised mined caverns contains no air and, as mentioned in Section 3.1.15, under no circumstances can the hydrocarbon product catch fire underground due to the absence of oxygen. During filling operations, the pressurised mined caverns are usually designed and operated in such a way so as to ensure that the vapour condenses into liquid, thus avoiding any pressure rise in the cavern and potential release to the atmosphere.

Groundwater inflow is collected in a water pit on the cavern floor and then pumped to the surface. The liquefied gas is discharged by means of submerged pumps.

#### **B. Relevant equipment and other considerations**

[150, Geostock, 2002]

The relevant equipment, fittings, etc. for pressurised mined caverns are similar to the ones used for atmospheric mined caverns (see Section 3.1.15). In this field, major design improvements have taken place over the last 30 years, particularly with respect to safety issues. For example, recently constructed pressurised mined caverns are equipped with downhole fail-safe valves which totally isolate the stored hydrocarbon product from the surface in case of emergency or gas detection, see Figure 3.24. Such types of safety and environmental measures are also sometimes retrofitted on existing caverns. Other additional equipment which improve operation and safety are:

- redundant level measurement
- automated overflow detection devices
- emergency water injection
- specific design features for safe maintenance.

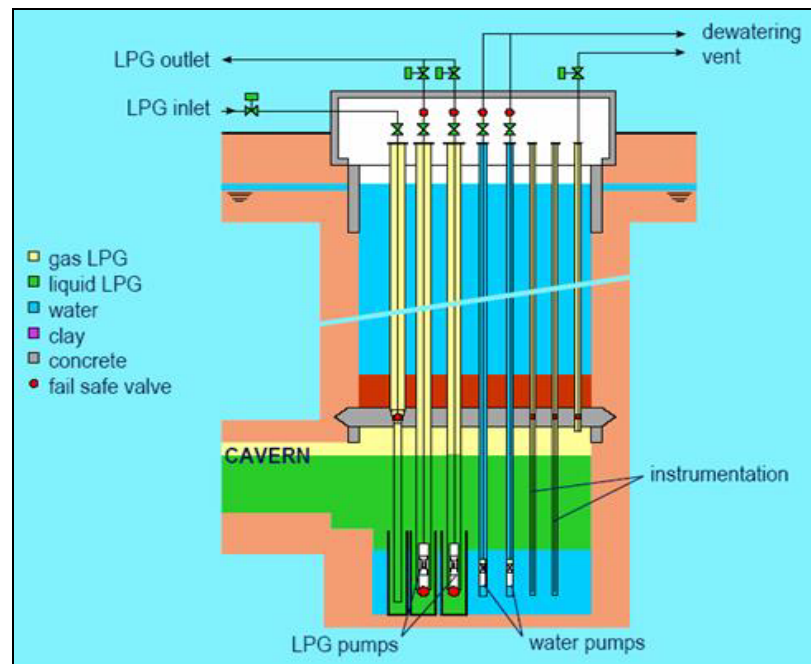


Figure 3.24: LPG underground storage operation shaft with instrumentation [175, TWG, 2003]

### C. Possible emission sources (pressurised mined caverns)

Table 3.42 and Table 3.43 show the emission scores for the potential emission sources for pressurised caverns. Section 3.1, Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value and should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	1	2
Breathing			N/A
Emptying	2	1	2
Cleaning			N/A
Blanketing			N/A
Manual gauging			N/A
Sampling			N/A
Fugitive	2	1	2
Draining			N/A

Table 3.42: Possible emissions to air from 'operational sources' with mined caverns (pressurised) [87, TETSP, 2001, 150, Geostock, 2002]

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining			N/A
Cleaning			N/A
Sampling			N/A

Table 3.43: Possible emissions to water or waste from 'operational sources' with mined caverns (pressurised) [87, TETSP, 2001]

Apart from small operational losses, infrequent emissions also occur from incidents and (major) accidents such as overfill and leakages. Only the latter ones are addressed in Chapter 4.

### **3.1.17. Salt leached caverns**

#### **A. Description**

[113, TETSP, 2001, 150, Geostock, 2002]

See Section 3.1.15 for the general description of mined cavern storage and Section 3.1.16 for pressurised mined caverns. Liquid hydrocarbons and liquefied pressurised gases may also be stored in caverns leached from salt deposits.

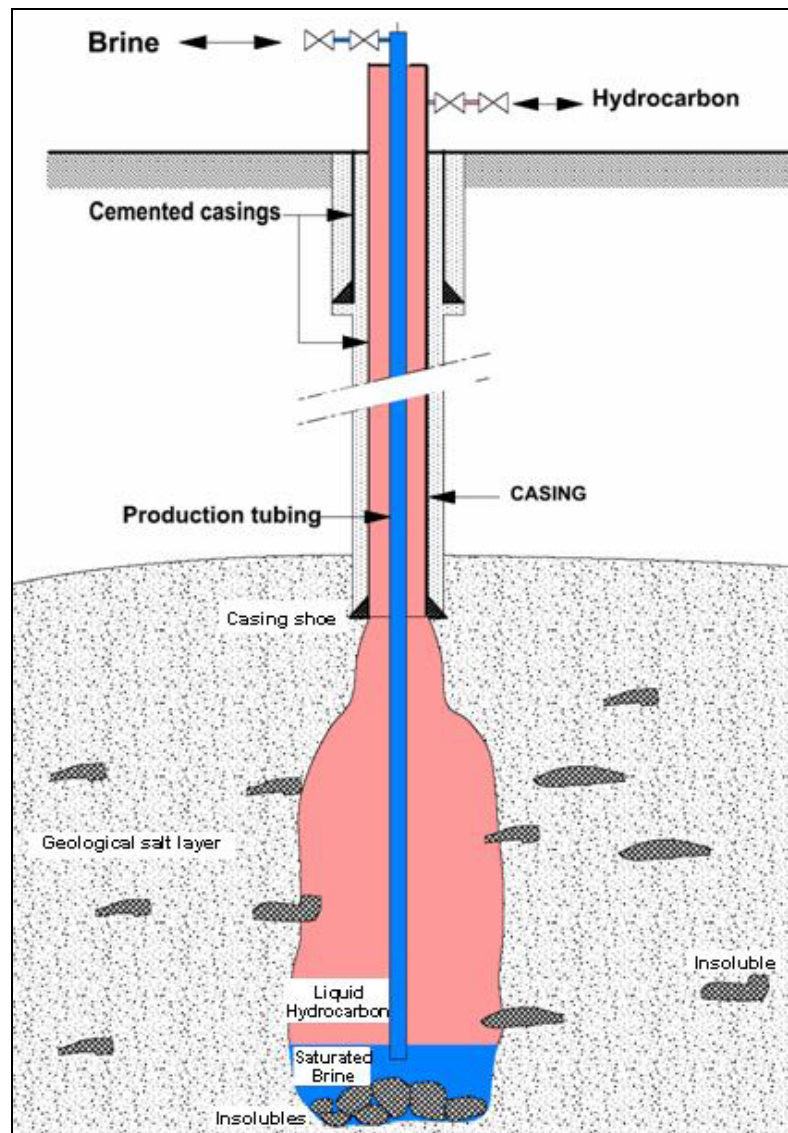
Salt leached caverns are created by drilling a well into the salt formation, circulating fresh or low salinity water in the well, and withdrawing the brine from the cavern. The salt in the formation dissolves, thus enlarging the well bore until the target volume is reached.

In salt leached caverns the liquids and liquefied gases are stored above a brine solution. On filling, the hydrocarbon product is pumped into the upper part of the cavern and displaces the brine. After passing through a decanting or degassing process the brine is stored in a lined pond or lagoon (see Section 3.1.14). The hydrocarbon product is stored under pressure at depth due to the static weight of the brine and of the hydrocarbon itself. The hydrocarbon product is generally discharged by brine displacement. However, for shallow salt caverns, this can be by means of submerged pumps.

Salt is intrinsically impermeable and physically and chemically inert with respect to hydrocarbons. In addition, cracks and faults in the salt are healed by the viscoplastic behaviour of the salt under the geostatic pressure. This ensures that there are no emissions to soil.

Typical salt leached cavern depths vary from approximately 300 m to 1200 m. Cavern sizes vary according to the site location, but for example at the Geosel site in France, typical cavern volumes range from 90000 to 450000 m<sup>3</sup> for a total capacity of approximately 6 million m<sup>3</sup> (26 storage caverns for crude oil, diesel oil, gasoline, naphtha, etc.).

The ponds or lagoons used to store the brine required to export the hydrocarbon product are, in general, designed so as to blend into the landscape.



**Figure 3.25: Example of a salt leached cavern in operation**  
[175, TWG, 2003]

### **B. Relevant equipment and other considerations**

[150, Geostock, 2002]

The salt leached caverns are connected to the surface via concentric tubing strings (similar to those used for oil and gas production wells) for moving the hydrocarbon product in and out of the cavern. At the surface level the well-head, equipped with valves, occupies a very limited space, and all associated piping is buried underground.

The pumping facilities, metering equipment and related support facilities such as control buildings and fire protection systems are centralised into a single area thus ensuring minimal land occupation and environmental impact.

### **C. Possible emission sources (salt leached caverns)**

Table 3.44 and Table 3.45 show the emission scores for the potential emission sources for salt domes. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value and should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	1	2
Breathing			N/A
Emptying	2	1	2
Cleaning			N/A
Blanketing			N/A
Manual gauging			N/A
Sampling			N/A
Fugitive	2	1	2
Draining			N/A

**Table 3.44: Possible emissions to air from ‘operational sources’ with salt leached caverns [150, Geostock, 2002]**

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining			N/A
Cleaning			N/A
Sampling			N/A

**Table 3.45: Possible emissions to water or waste from ‘operational sources’ with salt leached caverns [150, Geostock, 2002]**

Apart from small operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow and leakages. Only the latter ones are addressed in Chapter 4.

### 3.1.18. Floating storage

#### A. Description

[113, TETSP, 2001]

Ships are sometimes used to provide additional, temporary storage capacity at a marine terminal. Note that this storage mode does not include the tanks of ships that are loading or discharging at a terminal.

The supply and discharge pipework of the floating storage facility are permanently connected to the on-shore product transfer systems. The connecting pipework must be provided with flexible sections to take account of wave or tidal motion. Careful consideration should be given to containing any spill or leakage of liquid into the surrounding water. As the ships are ex-trading vessels they will have been built to the International Maritime Organization regulations in place at the time that the keel of the ship was laid down. The vessels will need to maintain compliance with these regulations if they travel to shipyards for inspection, hull maintenance, etc.



## B. Relevant equipment and other considerations

		Section
3.1.12.7 Equipment for tanks	Vents	3.1.12.7.1
	Gauging and sample hatches	3.1.12.7.2
	Still wells and guide poles	3.1.12.7.3
	Instrumentation	3.1.12.7.4
	Access hatches	3.1.12.7.5
	Drains	3.1.12.7.6
	Mixers	3.1.12.7.7
	Heating systems	3.1.12.7.8
	Sealing elements	3.1.12.7.9
	Valves	3.2.2.6
3.1.12 Considerations related to tanks		

**Table 3.46: Cross references for floating storage**

## C. Possible emission sources (floating storage)

Table 3.47 and Table 3.48 show the emission scores for the potential emission sources for floating storage. Figure 3.2 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each storage mode in isolation.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	3	6
Breathing	3	2	6
Emptying	2	1	2
Cleaning	1	2	2
Blanketing	3	2	6
Manual gauging	2	1	2
Sampling	2	1	2
Fugitive	3	1	3
Draining	2	1	2

**Table 3.47: Possible emissions to air from ‘operational sources’ with floating storage [113, TETSP, 2001]**

Potential source of liquid emissions to water or waste	Emission frequency	Emission volume	Emission score
Draining	2	0	0
Cleaning	1	3	3
Sampling	2	0	0

**Table 3.48: Possible emissions to water or waste from ‘operational sources’ with floating storage [113, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents such as overflow and leakages. These emissions are also addressed in Chapter 4.

### 3.2. Transfer and handling of liquids and liquefied gases

Transfer systems refer to the pipework, including all the valves and fittings, connected to the storage tank and the flexible hose or a loading arm for connection to road tankers, rail tankers and ships. Handling techniques refer to the means of moving the product (e.g. pumps) through the pipework into and out of the storage tanks.

The following transfer modes, handling techniques and related issues are considered:

<b>Transfer modes</b>	<b>Section number</b>
Aboveground closed piping transfer	3.2.1.1
Aboveground open piping transfer	3.2.1.2
Underground closed piping transfer	3.2.1.3
Loading and unloading of transporters	3.2.1.4
<b>Handling techniques</b>	<b>Section number</b>
Gravity flow	3.2.2.1
Pumps	3.2.2.2
Compressors	3.2.2.3
Inert gases	3.2.2.4
Flanges and gaskets	3.2.2.5
Valves and fittings	3.2.2.6
<b>Considerations related to transfer and handling</b>	3.2.3
<b>Equipment and fittings</b>	3.2.4
<b>Transfer and handling of packaged goods</b>	3.2.5

**Table 3.49: Cross-references of transfer and handling modes for liquids and liquefied gases**

The flow chart in Figure 3.26 identifies the possible gaseous and liquid emissions and residues, resulting from the transfer and handling of liquid materials and liquefied gases. The base case for any of the transfer and handling modes described assumes that there are no emission control measures installed. For each transfer category, the relevant operational activities and possible events/incidents which can result in an emission, are listed. This forms the basis for describing the possible emissions by transfer and handling activities.

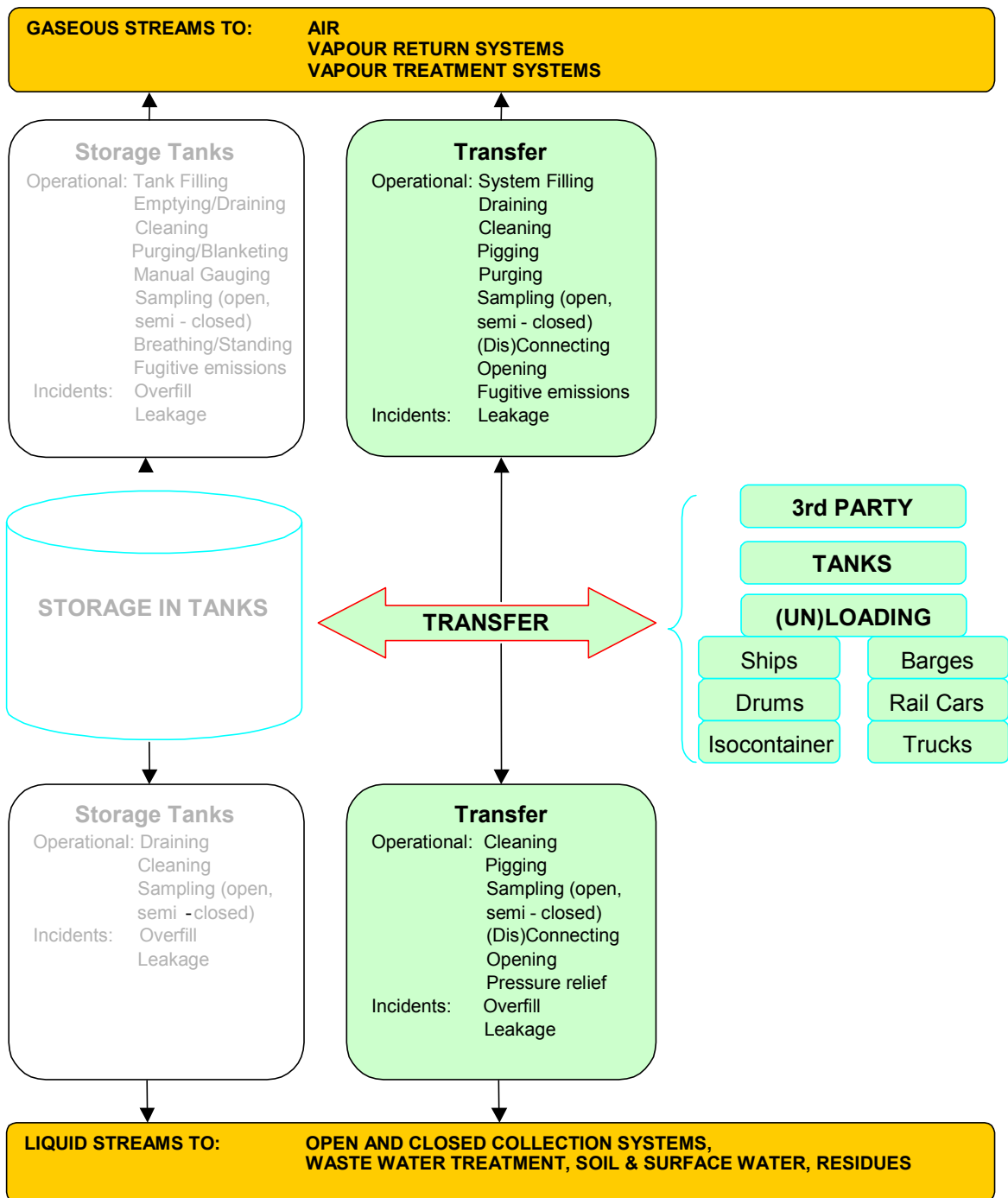


Figure 3.26: Flow chart of the potential emissions resulting from transfer and handling facilities

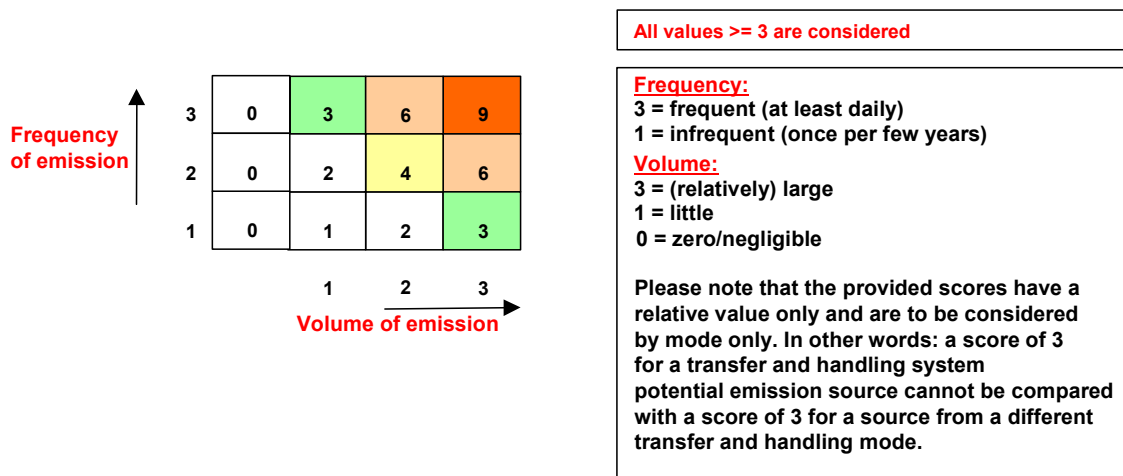


Figure 3.27: Risk matrix for emissions from handling and transfer of liquid and liquefied gases

<b>Remarks:</b>	
1.	The classification term N/A (Not Applicable) indicates that a particular emission source will not be considered (not applicable or not relevant etc.) due to the specific nature of the transfer or handling technique described.
2.	A clear distinction will be made between emissions from ‘operational sources’ and emission from ‘incidents’.
3.	The emission scores are calculated by multiplying the emission frequency by the emission volume. This methodology is commonly applied in risk assessment approaches such as the one used for risk based inspection (as will be further explained in the BREF). All scores above 3 are considered: e.g. all ‘high’ frequencies (score = 3), ‘large’ volumes (score = 3) and the ‘medium/medium’ frequency/volume emission sources (where frequency and volume both score 2).

The possible emission sources from transfer and handling operations for liquids and liquefied gases are selected for further analyses, using a risk matrix approach as described in Figure 3.27.

### 3.2.1. Product transfer

#### 3.2.1.1. Aboveground closed piping transfer systems

[113, TETSP, 2001]

##### A. Description

Aboveground closed piping systems are normally designed to transport liquids, refrigerated gases (liquefied), pressurised gases (as liquids) or vapours. The design varies with the intended service and products to be transported. Aboveground piping systems are the most common form of handling system within storage facilities.

Normally transport-piping systems for storage applications are designed for low to moderate operating pressures, unless specific circumstances dictate otherwise.

The design, construction, operation and maintenance of pipelines usually comply with statutory and internationally accepted standards and guidelines (e.g. ASME, API, DIN, NEN, etc).

Piping systems usually consist of pipelines, valves (ball, gate, needle, butterfly, etc.) and fittings (e.g. instrumentation connections) and pump stations. Emissions generally only occur as a result of leakage through seals and/or cleaning/purging operations.

**B. Relevant transfer equipment:** See Section 3.2.4.

### C. Possible emission sources (aboveground closed piping transfer system)

Table 3.50 and Table 3.51 show the emission scores for the potential emission sources for an aboveground closed piping technique. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for transfer modes.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	2	4
Cleaning	1	2	2
Pigging	2	1	2
Purging	1	2	2
Sampling	2	1	2
(Dis)connecting	2	1	2
Opening	1	2	2
Fugitive	3	1	3
Emptying/draining	2	1	2

**Table 3.50: Possible emissions to air from ‘operational sources’ with aboveground closed piping transfer systems [113, TETSP, 2001]**

Potential source of liquid emissions	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	1	2	2
Sampling	2	1	2
Pigging	2	1	2
(Dis)connecting	2	1	2
Pressure relief	2	1	2
Opening	2	1	2

**Table 3.51: Possible liquid emissions to soil/groundwater from ‘operational sources’ with aboveground closed piping transfer systems [113, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents such as overflow and leakages. These emissions are also addressed in Chapter 4.

#### 3.2.1.2. Aboveground open piping transfer systems

##### A. Description

[113, TETSP, 2001]

Aboveground open piping transfer systems are (atmospheric) systems either designed to collect (rain) water or spillage, to protect these from polluting the subsoil or surface water. Open systems are only suitable for non-hazardous low volatility products. They are used, for example, to collect contaminated water run-off from bunded facilities. Some common examples are:

- gutters
- open drains
- drip pans around pumps.

The systems usually allow gravity drainage to a central collection pit, from where the liquids are pumped into a buried or aboveground piping system or into a mobile vessel.

**B. Relevant transfer equipment:** Not relevant.

**C. Possible emission sources (open piping)**

Table 3.52 and Table 3.53 show the emission scores for the potential emission sources for an aboveground open piping technique. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for transfer modes.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	3	6
Cleaning	2	2	4
Pigging			N/A
Purging			N/A
Sampling			N/A
(Dis)connecting			N/A
Opening			N/A
Fugitive			N/A
Emptying/draining			N/A

**Table 3.52: Possible emissions to air from ‘operational sources’ with aboveground open piping transfer systems [113, TETSP, 2001]**

Potential source of liquid emissions	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	2	2	4
Sampling	2	1	2
Pigging			N/A
(Dis)connecting			N/A
Pressure relief			N/A
Opening			N/A

**Table 3.53: Possible liquid emissions to soil/groundwater from ‘operational sources’ with aboveground open piping transfer systems [113, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents such as leakages. These emissions are also addressed in Chapter 4.

### 3.2.1.3. Underground piping transfer systems

#### A. Description

[113, TETSP, 2001, 156, ECSA, 2000]

Underground piping systems are normally designed to transport liquids, refrigerated gases (liquefied), pressurised gases (as liquids) or vapours underground (road crossings or long sections through dedicated piping channels). The design varies with the intended service and products to be transported, for example, underground piping systems are rarely used for transporting chlorinated solvents and if used, they are constructed as a jacketed pipe system with a leakage alarm system for the outer space.

Normally transport-piping systems for storage applications are designed for low to moderate operating pressures unless specific circumstances dictate otherwise. The design, construction, operation and maintenance of pipelines comply with statutory and internationally accepted standards and guidelines (e.g. ASME, API, DIN, NEN etc).

Piping systems usually consist of fully welded pipeline, with limited valves and fittings (e.g. instrumentation connections). Pump stations are normally installed aboveground. Emissions can occur as a result of leakage through seals and/or cleaning/purging operations.

Buried pipelines can be affected by external corrosion due to salty landfill and the formation of corrosion cells in the surrounding ground or from stray electrical currents.

**B. Relevant transfer equipment:** See Section 3.2.4.

#### C. Possible emission sources (underground piping)

Table 3.54 and Table 3.55 show the emission scores for the potential emission sources for an underground closed piping technique. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for transfer modes.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	2	4
Cleaning	1	2	2
Pigging	2	1	2
Purging	1	2	2
Sampling	2	1	2
(Dis)connecting	2	1	2
Opening	1	2	2
Fugitive	3	1	3
Emptying/draining	2	1	2

**Table 3.54: Possible emissions to air from ‘operational sources’ with underground closed piping transfer systems**

[113, TETSP, 2001]

Potential source of liquid emissions	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	1	2	2
Sampling	2	1	2
Pigging	2	1	2
(Dis)connecting			N/A
Pressure relief	2	1	2
Opening	1	1	1

**Table 3.55: Possible liquid emissions to soil/groundwater from ‘operational sources’ with underground piping transfer systems [113, TETSP, 2001]**

Apart from operational losses, infrequent emissions also occur from incidents such as leakages. These emissions are also addressed in Chapter 4.

#### 3.2.1.4. Loading and unloading of transporters

##### A. Description

[156, ECSA, 2000] [157, VDI, 2001] [184, TETSP, 2004]

Road tankers, rail tankers and ships are connected to the loading/unloading point by a flexible hose or a loading arm. Rigid pipelines cannot be used.

Flexible hoses are normally reinforced by steel spirals or meshed steel. Both the material of the hose and the type of hose construction must be suitable for the product being handled.

Product loading arms are fitted with swivel joints to allow the connection to move with the transport unit. The swivel joint is fitted with a seal to prevent leakage. The material of the loading arm, and particularly of the seal, must be suitable for the product being handled.

Where it is necessary to collect vapours from the transport unit during liquid loading, the vapours displaced must be collected through pipework either fitted on the transporter or through modified loading arms. The method of collection depends upon whether they are top loaded through an open hatch or loaded through fixed pipework upon the tanker. During top loading, vapours can be collected by the use of special loading arms which seal against the loading hatch and incorporate vapour collection pipework. Otherwise, the tankers require vapour vent valves to be installed in each product tank (or ‘compartment’) which is connected by vapour collection pipework on the tanker to a vapour connector, located at working height on road and rail tankers. This vapour connector can be connected to a flexible hose or arm at the loading facility similar to that used for loading product.

Some ships, particularly chemical tankers, are fitted with vapour collection pipework systems which have connection points to permit coupling to shore-side facilities where this is appropriate to the characteristics of the product(s) being handled. However, most general purpose petroleum product carriers operating in EU waters do not have vapour collection systems (AEAT report, Rudd and Hill, ‘Measures to Reduce Emissions of VOCs during Loading and Unloading of Ships in the EU’ August 2001).

See Figure 3.28 for an example of a bulk unloading system.



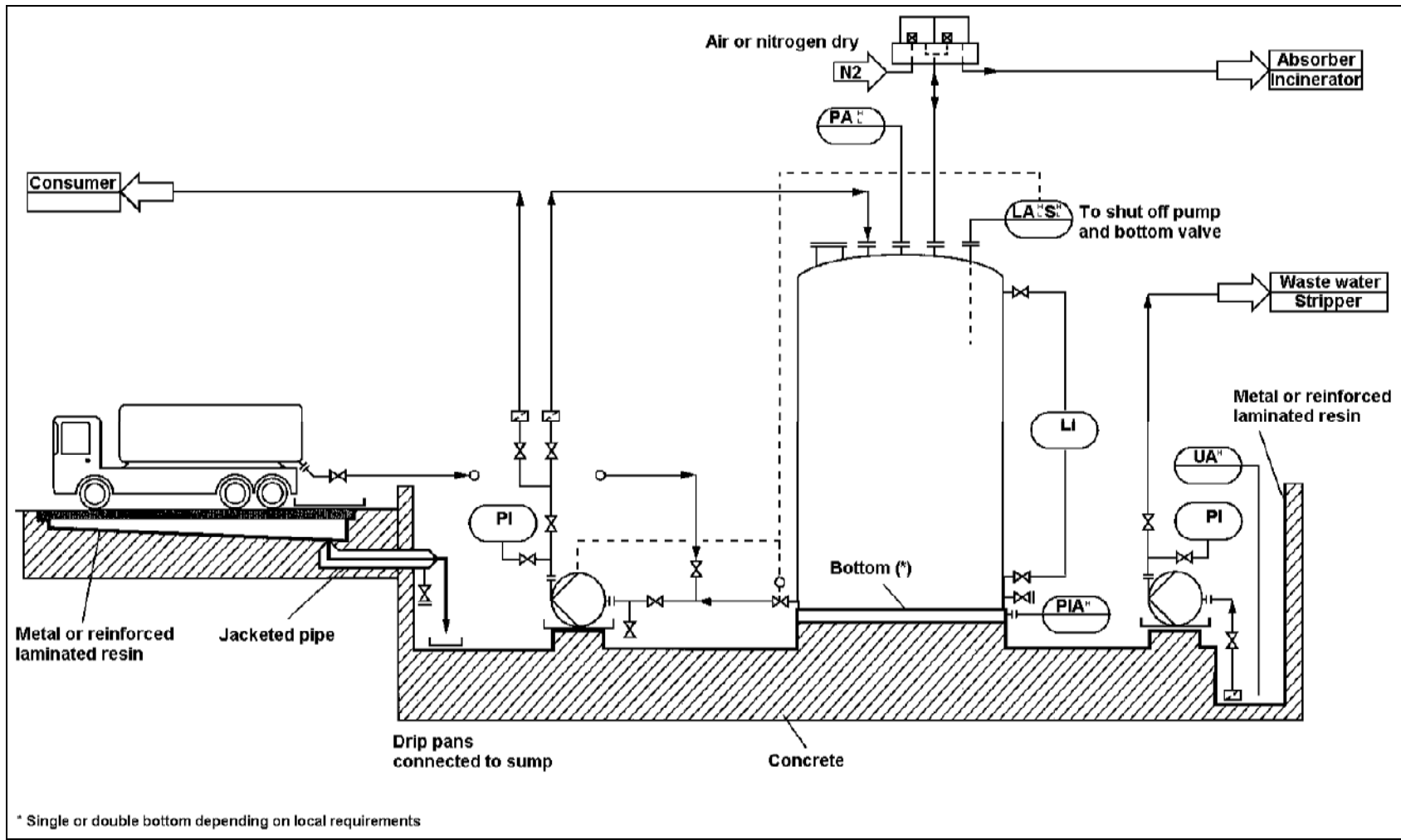


Figure 3.28: Example of bulk unloading and storage system for chlorinated solvents [156, ECSA, 2000]

**B. Relevant transfer equipment:** Not relevant.

**C. Possible emission sources (flexible hose or loading arm)**

Table 3.56 and Table 3.57 show the emission scores for the potential emission sources for unloading hoses and pipelines. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for transfer modes.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	2	4
Cleaning	1	2	2
Pigging	2	1	2
Purging	1	2	2
Sampling	2	1	2
(Dis)connecting	3	2	6
Opening	1	2	2
Fugitive	3	1	3
Emptying/draining	2	1	2

**Table 3.56: Possible emissions to air from ‘operational sources’ with flexible hoses or loading arms**  
Source: EIPPCB

Potential source of liquid emissions	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	1	2	2
Sampling	2	1	2
Pigging	2	1	2
(Dis)connecting	3	1	3
Pressure relief	2	1	2
Opening	2	1	2

**Table 3.57: Possible liquid emissions to soil/groundwater from ‘operational sources’ with flexible hoses or loading arms**  
Source: EIPPCB

Apart from operational losses, infrequent emissions also occur from incidents such as leakages. These emissions are also addressed in Chapter 4.

### 3.2.2. Product handling

[113, TETSP, 2001]

Several product handling or displacement methods are available which can be distinguished by their use of:

- gravity
- pumps
- compressors
- inert gas.

They are addressed in Section 3.2.2.1 through to Section 3.2.2.4.

Other types of equipment applied in product handling are:

- flanges and gaskets
- valves and fittings
- sealing elements
- vents, drains and sample points
- instrumentation
- pressure relief devices.

These are addressed in Sections 3.2.2.5 and 3.2.2.6 and also in Section 3.2.4.

The economics, design and construction, and commissioning and decommissioning aspects are addressed in Section 3.2.3.

### 3.2.2.1. Gravity flow

#### A. Description

Gravity flow is only applicable under atmospheric conditions or between pressurised vessels with either common vapour space, or when operating at the saturated vapour pressure of the stored liquid.

**B. Relevant handling equipment:** See Section 3.2.4.

#### C. Possible emission sources (displacement methods)

Table 3.58 and Table 3.59 show the emission scores for the potential emission sources for product handling in general. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for product handling techniques.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling	2	0	0
Cleaning	1	0	0
Pigging			N/A
Purging			N/A
Sampling			N/A
(Dis)connecting			N/A
Opening	1	1	1
Fugitive	3	1	3
Emptying/draining	2	0	0

**Table 3.58: Possible emissions to air from ‘operational sources’ with product handling [113, TETSP, 2001]**

Potential source of liquid emissions	Emission frequency	Emission volume	Emission score
Draining	2	1	2
Cleaning	1	1	1
Sampling			N/A
Pigging			N/A
(Dis)connecting			N/A
Pressure relief			N/A
Opening	1	1	1

**Table 3.59: Possible liquid emissions to soil/groundwater from ‘operational sources’ with product handling**  
[113, TETSP, 2001]

Apart from small operational losses, infrequent emissions also occur from incidents and (major) accidents. These emissions are not addressed in Chapter 4, because no information has been made available.

### 3.2.2.2. Pumps

#### A. Description

[157, VDI, 2001] [156, ECSA, 2000]

Pumps are used to displace all types of products under atmospheric, pressurised or refrigerated conditions. Two types of pumps are generally used: positive displacement pumps or centrifugal pumps.

Positive displacement pumps comprise reciprocating pumps (piston or diaphragm types) or rotary gear pumps. These are often used as dosing pumps to provide small accurate flowrates.

Pumps normally require seals: see Section 3.2.4.1. Some centrifugal pumps and rotating displacement pumps that do not need a shaft seal are:

- centrifugal pump with magnetic transmission
- canned centrifugal
- diaphragm
- peristaltic.

For handling oil products, centrifugal pumps are commonly applied, although in special situations displacement pumps may be used. Centrifugal pumps with magnetic transmission are commonly applied for handling chlorinated solvents.

**B. Relevant handling equipment:** See Section 3.2.4.

#### C. Possible emission sources (product handling)

Table 3.58 and Table 3.59 show the emission scores for the potential emission sources for product handling in general. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value and should only be considered for product handling techniques.

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents. These emissions are also addressed in Chapter 4.

### 3.2.2.3. Compressors

#### A. Description

[156, ECSA, 2000]

Compressors have many similar features to pumps and are used to displace gases or refrigerated products. Two types of rotodynamic compressor will be discussed in this section. The first grouping is lower velocity, positive displacement designs, operating typically at 50/60 cycle synchronous speeds. They are used with many different types of gases but are commonly used in smaller refrigeration cycle services. The same technology is applied on some process gases. The shaft bearing assemblies are at either end of the shaft and mounted inboard of the seal assembly. Equipment leakage losses occur mainly where the rotating shaft penetrates the casing.

The second grouping typically operates at much higher velocities to achieve their performance efficiencies and are the centrifugal process compressors. These are commonly applied on VOC gases. The shaft bearing assemblies are at either end of the shaft and mounted outboard of the seal assembly. Equipment leakage losses occur mainly where the rotating shaft penetrates the casing at its drive and non-drive ends.

**B. Relevant handling equipment:** See Section 3.2.4; the sealing technologies employed are discussed in Section 3.2.4.1.

#### C. Possible emission sources (product handling)

Table 3.58 and Table 3.59 show the emission scores for the potential emission sources for product handling in general. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for each product handling technique in isolation.

Apart from operational losses, infrequent emissions also occur from incidents and (major) accidents. These emissions are also addressed in Chapter 4.

### 3.2.2.4. Inert gases

#### A. Description

Inert gases may be used to displace a product, either because of quality or safety issues. This system is generally only used for small product volumes.

**B. Relevant handling equipment:** Not relevant.

#### C. Possible emission sources (product handling)

Table 3.58 and Table 3.59 show the emission scores for the potential emission sources for product handling in general. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for product handling.

Apart from small operational losses, infrequent emissions also occur from incidents and (major) accidents. These emissions are also addressed in Chapter 4.

### 3.2.2.5. Flanges and gaskets

#### A. Description

[156, ECSA, 2000]

A gasket is used to create and retain a static seal between two stationary flanges, which may connect a series of mechanical assemblies in an operating plant, including the storage area. These static seals aim to provide a complete physical barrier against the fluid contained within, and so block any potential leakage path. To achieve this, the gasket must be able to flow into (and fill) any irregularities in the mating surfaces being sealed, while at the same time be sufficiently resilient to resist extrusion and creep under operating conditions.

The seal is affected by the action of force upon the gasket surface, which compresses the gasket, causing it to flow into any flange imperfections. The combination of contact pressure between the gasket and flanges, and densification of the gasket material, prevents the escape of the contained fluid from the assembly. As such, gaskets are vital to the satisfactory operation of a broad range of industrial equipment and must be regarded as an integral design element of the whole plant.

Historically, compressed asbestos fibre sheet material (CAF) has been the material of choice for 'soft' gasket materials. It was regarded as easy to use and very tolerant of abuse, for which it was recognised as very 'forgiving'. Consequently, the material was used to seal almost all common applications, and usually gave a satisfactory performance. A broad experience of the material was established over many years amongst manufacturers and users alike.

More recently, with the ban on the use of asbestos fibres, a new generation of asbestos-free substitutes has been developed by the sealing industry. These provide improved levels of sealing performance, although they are usually more application specific than the earlier asbestos materials. Equally, handling of these new materials requires more care in general. Overall, these new materials can outperform their asbestos predecessors, but are usually less forgiving; users must exercise more care in selecting the right material for the job and assembling the seal.

Over time, alternative gasket styles have been developed, especially for more severe services, and these include the 'hard' gasket types, primarily of metallic or semi-metallic construction.

Individual flanges generally do not have very large leaking losses but, since many flanges are utilised in transfer and handling, they can make a major contribution to the overall leaking losses.

**B. Relevant handling equipment:** Not relevant.

#### C. Possible emission sources (product handling)

Table 3.58 and Table 3.59 show the emission scores for the potential emission sources for product handling in general. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for product handling.

Apart from small operational losses, infrequent emissions also occur from incidents and (major) accidents. These emissions are also addressed in Chapter 4.

### 3.2.2.6. Valves and fittings

#### A. Description

[149, ESA, 2004] [18, UBA, 1999]

Leaking losses are generally higher from dynamic equipment (compared to static equipment) and from older equipment. Valves are considered to account for approximately 50 – 60 % of fugitive emissions in the chemical and petrochemical industries. Furthermore, the major proportion of fugitive emissions comes from only a small fraction of sources (e.g. less than 1 % of valves in gas/vapour service can account for more than 70 % of the fugitive emissions in a refinery).

Some valves are more likely to leak than others, e.g. valves with rising stems (gate valves, globe valves) are likely to leak more frequently than quarter-turn type valves such as ball and plug valves. Valves which are operated frequently, such as control valves, may wear quickly and allow emission paths to develop. However, newer, low-leak control valves provide good fugitive emissions control performance.

Types of valves are:

- control valves
- needle valves
- globe valves
- gate valves
- plug valves
- ball valves
- butterfly valves
- relief valves
- check valves.

Commonly used valves within a piping system are ball, gate or butterfly valves. Other types (e.g. control valves, needle valves) may be used in specific circumstances. Valves can be bolted or, for smaller sizes, threaded or welded in the piping system.

Except for cast iron and plastic valves, each valve meets the minimum requirements of API 6D or equivalent. A valve should not be used under operating conditions that exceed the applicable pressure-temperature ratings contained in those requirements and it should have a maximum service pressure rating for temperatures that equal or exceed the maximum service temperature to avoid malfunction.

All except the relief valve and check valve are activated through a valve stem. This stem requires a seal to isolate the product inside the valve from the atmosphere. Since a check valve has no stem, this is not considered a source of fugitive emissions.

Because they open and close frequently, control valves are more prone to leakage than shut-off valves. Using rotating control valves instead of rising stem control valves can help reduce fugitive emissions. However, it is not always possible to interchange these two types of valves. At the design stage, the use of variable speed pumps may offer an alternative to control valves.

Leaks from valve stems can be caused by the use of poor quality packing material, inaccurate machining of the stem or packing housing, improper assembly of the valve, ageing of the packing, inadequate compression of the packing, corrosion, abrasion of the packing by dirt, etc. Bellows valves have no stem emissions as this type of seal incorporates a metal bellow that forms a barrier between the valve disc and the valve body.

High quality packed valves are available that have very low fugitive emissions. To achieve low emissions, these valves use improved packing systems, are built according to stringent tolerances, and are carefully assembled.

It is common practice that valves (fittings) are easily accessible and operated and that they are, with respect to raw materials, production, dimension, monitoring and proof of quality, appropriate for the technical purpose. The casing of valves consists of tough raw materials. Valves sited underneath the level of the liquids can, in special cases, be designed 'fire-safe' to delay failure in the event of a fire.

**B. Relevant transfer and handling equipment:** Not relevant.

### **C. Possible emission sources (product handling)**

Table 3.58 and Table 3.59 show the emission scores for the potential emission sources for product handling in general. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for product handling.

Apart from small operational losses, infrequent emissions also occur from incidents and (major) accidents. These emissions are also addressed in Chapter 4.

### **3.2.3. Considerations related to transfer and handling systems**

#### **3.2.3.1. Economics**

[113, TETSP, 2001]

The costs of designing, constructing and operating transfer and handling techniques will very much depend on the type of system (e.g. closed or open, aboveground or underground), its size, the design features (e.g. soil foundation, external coatings, type of safety and environmental protection measures, etc.), the requirements set by the product to be transferred or handled (e.g. stainless steel versus mild steel, type of seals, etc.) the operating conditions, the required inspection and maintenance activities and, linked to the latter, the envisaged technical lifetime.

It is recommended, therefore, to focus on the total cost of ownership (TCO) of a transfer or handling system by considering the elements shown in Section 3.1.12.1.

#### **3.2.3.2. Design and construction**

It goes beyond the scope of this document to provide here a comprehensive summary of the design and construction requirements, but nevertheless some important aspects and considerations are described below.

##### ***Benefits of a proper design***

Most technical measures, allowing for the elimination or reduction of the consequences of abnormal conditions, are taken at the design stage when the risks resulting from a loss of containment are assessed and technical safety measures defined accordingly. In essence the best of the industrial knowledge about the substance to be transferred and handled is used at this phase to select suitable technical options based on a risk analysis or a cost to benefit analysis. Defining and implementing the safety measures at the design phase is undoubtedly the best and cheapest option. The efficiency of the safety measures also has to be maintained over time and this can only be ensured if regular checks are made of the safety devices. A suitable management system is required to deal with the latter.



It is common practise that the designer first considers the level of appropriate operational measures that need to be taken by the operators. The efficiency of these measures needs to be maintained over time. To ensure this, a management system can be implemented that, for example, addresses the regular training of the operators, the updating of the operating instructions, etc. Environmental inspection can be considered at this phase. It also plays a major role in determining the emission sources, in ensuring that over time the releases remain within the permitted limits and in informing the operator when the performance is no longer acceptable.

Mechanical inspection plays a key role in the prevention of incidents. The definition of an inspection plan starts at the design phase with the selection of the components of the installation based on experience: experience of the substance, experience of the component, experience of the component with the substance, experience of storage activities. These have to be carefully checked.

### ***Codes, standards and guidelines***

Reference is made to international codes/standards/guidelines. Some typical examples are:

#### **Piping, valves and fittings**

- ANSI/API 574 1-JUN-1998: inspection practices for piping system components
- ASTM volume 01.01 2000: ASTM book of standards volume 01.01: iron and steel products: steel - piping, tubing, fittings
- ASTM A961-99 10-MAR-1999: standard specification for common requirements for steel flanges, forged fittings, valves, and parts for piping applications
- ASME B31.5-1992 01-JAN-92: refrigeration piping
- ASME B31.8-1995 01-DEC-95: gas transmission distribution and piping systems
- ASME B31.3-1999 01-JAN-99: process piping
- NACE RP0190-95 1-MAR-1990: standard recommended practice - external protective coatings for joints, fittings, and valves on metallic underground or submerged pipelines and piping systems
- NFPA 54: national fuel gas code, 1999 edition
- DIN EN 1092-1 1-NOV-1994: flanges and their joints - part 1: circular flanges for pipes, valves, fittings and accessories – German only
- ISO 12092 1-OCT-2000: fittings, valves and other piping system components made of unplasticised poly(vinyl chloride) (PVC-U), chlorinated poly(vinyl chloride) (PVC-C), acrylonitrile-butadiene-styrene (ABS) and acrylonitrile-styrene-acrylester (ASA) for pipes under pressure – resistance to internal pressure
- BS EN 558-1 1996: industrial valves - face-to-face and centre-to-face dimensions of metal valves for use in flanged pipe systems - part 1: PN-designated valves
- EEMUA 153/96: EEMUA supplement to ASME B31.3: date 1996 edition, process piping (& amendments N° 1, May 97 and N° 2, Mar 98)
- EEMUA 196: valve purchasers' guide to the European pressure equipment Directive - date 1999
- NEN 1091: 1994 NL: safety requirements for steel gas transport pipelines operating at design pressures greater than 1 bar and not exceeding 16 bar
- NEN 3650: 1998 EN: requirements for steel pipeline transportation systems NEN-EN 10208-1: 1997 EN: steel pipes for pipelines for combustible fluids - technical delivery conditions - part 1: pipes of requirement class A
- NEN-EN 10208-2: 1996/C1: 1997 EN: steel pipes for pipe lines for combustible fluids - technical delivery conditions - part 2: pipes of requirements class B.

## Pumps

- ASME PTC8.2-1990: centrifugal pumps
- BS EN 25199 1992: technical specification for centrifugal pumps, class II
- EEMUA 164: seal-less centrifugal pumps, class 1; date 1993
- NEN-EN-ISO 5199: 1999 ONTW.: technical specifications for centrifugal pumps, class II
- API 676 amendment 1 15-JUN-1999: positive displacement pumps – rotary
- HI S112 1994: rotary pump test - ANSI/HI 3.6
- NFPA 20 1999: standard for the installation of stationary fire pumps for fire protection, 1999.

### 3.2.3.3. Commissioning and decommissioning

[113, TETSP, 2001]

The sections below generally apply to closed piping systems. Open piping systems are normally not tested for leakages, but part of these systems (e.g. the pumps and the interface with a closed piping system) are normally tested for functional requirements and leakages.

#### *Pre-commissioning*

It is essential that pipelines are pressure-tested after construction work to prove the mechanical integrity of welded joints and to assure leak tightness prior to commissioning. The test is a hydrostatic leak test in accordance with the chosen design code. Sometimes, for example when a hydrostatic leak test would damage the internal lining or insulation or could contaminate a process, a pneumatic test is carried out in accordance with a recognised design code.

#### *Cleaning*

Before a pipeline can be considered ready for service, it should be cleaned internally. Cleaning may be performed by water washing or by passing pigs through completed sections of the pipeline. This may form part of the testing procedure. Drying of the pipeline may be appropriate depending on the product being carried after commissioning.

#### *Commissioning*

Commissioning refers to the work required to bring a pipeline system into operation after completion of its construction. Normally a commissioning procedure document is prepared which systematically sets out the commissioning operations.

Where a pipeline has undergone a complete hydrostatic test with many fittings removed, or where radiographed joints have been made, but not yet proof tested, an in-service leak test of all connections and fittings is applied using a soap test to search for leaks.

### 3.2.4. Equipment and fittings

[113, TETSP, 2001, 152, TETSP, 2002]

The main potential emission source in transfer and handling systems is ‘fugitives’. Fugitive emissions are defined here as vapour leaking from seals and packings and from flanges and connections that should normally be tight. These emissions depend on the pressure within the system. With the exception of pressurised storage, the pressure within transfer and handling systems is relatively low compared to pipework within a process plant. Thus fugitive emissions within handling and transfer systems for atmospheric storage tanks are significantly lower than process plant equipment leaks.

It is important that each component of a pipeline should be able to withstand design pressures and other anticipated loadings to avoid incidents and/or accidents.

### 3.2.4.1. Sealing elements

[149, ESA, 2004], [157, VDI, 2001]

#### *Seals for pumps*

The products transferred can leak at the point of contact between the moving pump shaft and the stationary casing. To isolate the interior of the pump from the atmosphere all pumps, except the seal-less types require a seal at the point where the shaft penetrates the housing. The sealing technologies employed are:

- gland packing
- gland packing with a barrier flush
- single mechanical seals
- single mechanical seals with a mechanical containment seal and leakage collection (dual unpressurised seals)
- double seals with a separate barrier fluid (dual pressurised seals)
- seal-less drive systems.

The most commonly used seals are packed and mechanical seals. With packed seals lubrication is required to prevent build-up of frictional heat. If the liquid being pumped provides this lubrication, then emissions can occur if the packing or shaft face degrades. Mechanical seals can be of the single or double type – these also require lubrication, but much less than for packed seals.

Double mechanical seals can be arranged back-to-back, in tandem, or face-to-face. The two seals form a closed cavity through which a barrier fluid is circulated. Because this fluid surrounds the dual seal and lubricates both sets of seal faces, the seal life characteristics of the dual seal are much better than a single seal. Depending on the seal arrangement, the barrier fluid may be at a higher or lower pressure than the product. If it is higher, then leakage of the barrier fluid may occur into the product being pumped, which means that the barrier fluid must be compatible with both it and the environment. If it is at a lower pressure than the product, then the product may mix with the barrier fluid, which means that any emissions from the barrier fluid reservoir may need control, e.g. treatment of the gas in a vapour treatment system.

See Table 3.60 for the average emissions from seals in pumps in normal operation when handling mineral oils.

Seal system	Average emissions to air during normal operation	Remarks
Improved single mechanical seal	Average: 1g/h per seal (1) Range: 0.42 – 1.67 g/h (2)	Diameter shaft = 50 mm p = 10 bar n = 3000 min <sup>-1</sup>
Dual unpressurised seals and leakage collection	Close to zero (1) Below 0.01 g/h and 10 ppm (2)	
Dual pressurised seals	No emissions (technically closed) (1) Not measurable (2) < 0.5 g/day (2)	Nitrogen barrier
Seal-less pumps	No emissions (technically closed) (1, 2)	
<i>Note: (1): [157, VDI, 2001] (2): [149, ESA, 2004]</i>		

**Table 3.60: Average emissions from seals in process pumps when handling mineral oils [157, VDI, 2001] [149, ESA, 2004]**

### ***Seals for compressors***

Sealing technologies employed in low velocity compressors are:

- single mechanical seals
- single mechanical seals with an energised containment seal
- single mechanical seals with a mechanical containment seal and leakage collection (dual unpressurised seals)
- double seals with a separate barrier fluid (dual pressurised seals).

Lower speed, positive displacement compressors are typically sealed by a barrier oil-lubricated mechanical seal and emissive leakage is low; containment sealing arrangements are used in many services and the oil is separated and recycled.

Centrifugal process compressors typically operate at much higher velocities. Sealing technologies employed are:

- labyrinth seals
- single mechanical seals
- single mechanical seals with a mechanical containment seal and leakage collection (dual unpressurised seals)
- tandem mechanical seals with a mechanical containment seal and leakage collection (triple seals)
- double seals with a separate barrier fluid (dual pressurised seals).

Centrifugal compressors are traditionally sealed by labyrinth seals (fixed or floating carbon bushings) or oil-lubricated mechanical seals for positive displacement compressors. Labyrinth seals have high leakage and are commonly exchanged for mechanical seal assemblies, such as gas-lubricated single seals with an outer containment seal. This has enabled improved reliability and the management of primary seal emissive leakage to a flare or recovery system.

Various externally supplied gas purges are used with both types of machinery. Regular control and maintenance is indispensable to reduce emissions.

#### **3.2.4.2. Vents, drains and sample points**

[113, TETSP, 2001]

Generally all lines are provided with vents on all high points and drains on all low points. Vents and drains that are required to be opened while the line is operating (e.g. sampling connections) normally are valved and shown on the piping and instrument diagram. Vents and drains on high pressures (> 40 bar), or liquefied petroleum gases are normally equipped with a double block and bleed valves. The bleed discharge can go to a high vent or to a safe disposal arrangement.

All temporary vents and drain valves on pipelines carrying hazardous materials used for pressure testing are removed prior to commissioning of the piping system. All double block or single valve plugs/caps should be tightly closed and 100 % sealed off with appropriate welding to prevent leaks.

#### **3.2.4.3. Instrumentation on piping systems**

The instrumentation on piping systems is usually limited to pressure and/or temperature measuring devices. Usually instrumentation is either installed between flanged connections or at a branch connection from the main piping.

### 3.2.4.4. Pressure relief devices

Pressure relief devices are normally installed on lines, compressors, or pumping stations as a means of relieving abnormal pressures and for emergency situations. If a closed pipeline containing liquid is heated, the pressure within the pipe can exceed the maximum allowable working pressure of the line. Relief devices and systems, and valves are normally designed to API 520 (Part 1 and 2), API 521 and API 526 respectively (or equivalent).

### 3.2.5. Transfer and handling of packaged goods

#### A. Description

[18, UBA, 1999] [156, ECSA, 2000]

The means of transport for loading and unloading dangerous packaged substances, e.g. a stacker, must be designed to suit the characteristics of the substances. If, e.g. drums containing highly flammable liquids are loaded and unloaded an explosion-prevention design is necessary.

Stackers can be equipped with diesel motors, however nowadays in most storage installations electrically-operated vehicles are used. Stacker drivers must be carefully selected and trained in order to avoid accidents.

To dispense liquids, e.g. chlorinated solvents, a portable tank on wheels or a skid is sometimes used. This unit normally has its own permanently mounted pump, used exclusively for solvent transfer and an adequate pressure relief valve. A drip retaining basin is normally applied.

Small containers (to about 25 kg) can be readily emptied by hand. Removing the contents of 200 litre drums can be achieved either by gravity or by using a pump. Under no circumstances should a drum be emptied by using air pressure as the drum may burst. To avoid soil contamination the drum to be emptied can be put on a collector pan, such as a metal grating over a metal drip pan or a collector pan of prefabricated polymer concrete.

**B. Relevant transfer and handling equipment:** Not applicable.

#### C. Possible emission sources (transfer and handling of packaged goods)

Table 3.61 and Table 3.62 show the emission scores for the potential emission sources for transfer and handling of packaged goods. Figure 3.27 explains the methodology for calculating the emission score. The sources with an emission score of 3 or more are addressed in Chapter 4.

It should be noted that the scores have a relative value only and thus should only be considered for packaged goods.

Potential source of emissions to air	Emission frequency	Emission volume	Emission score
Filling			N/A
Cleaning			N/A
Pigging			N/A
Purging			N/A
Sampling			N/A
(Dis)connecting	1	1	1
Opening	1	1	1
Fugitive	1	1	1
Emptying	1	1	1

**Table 3.61: Possible emissions to air from 'operational sources' with transfer and handling of packaged goods**  
[113, TETSP, 2001]

Potential source of liquid emissions	Emission frequency	Emission volume	Emission score
Draining			N/A
Cleaning			N/A
Sampling			N/A
Pigging			N/A
(Dis)connecting	2	1	2
Pressure relief			N/A
Opening	1	1	1
Emptying	2	1	2

**Table 3.62: Possible liquid emissions to soil/groundwater from ‘operational sources’ with transfer and handling of packaged goods [113, TETSP, 2001]**

Apart from small operational losses, infrequent emissions also occur from incidents and (major) accidents. These emissions are also addressed in Chapter 4.

### 3.3. Storage of solids

The different modes of storing solids are described in the sections as shown in Table 3.63.

Type of storage mode	Sections
Open storage	Section 3.3.1
Sacks and bulk bags	Section 3.3.2
Silos and bunkers	Section 3.3.3
Packaged dangerous solids	Section 3.3.4

**Table 3.63: Storage modes for solids and reference to the sections**

#### 3.3.1. Open storage

[17, UBA, 2001] [116, Associazione Italiana Commercio Chimico, 2001] [24, IFA/EFMA, 1992]

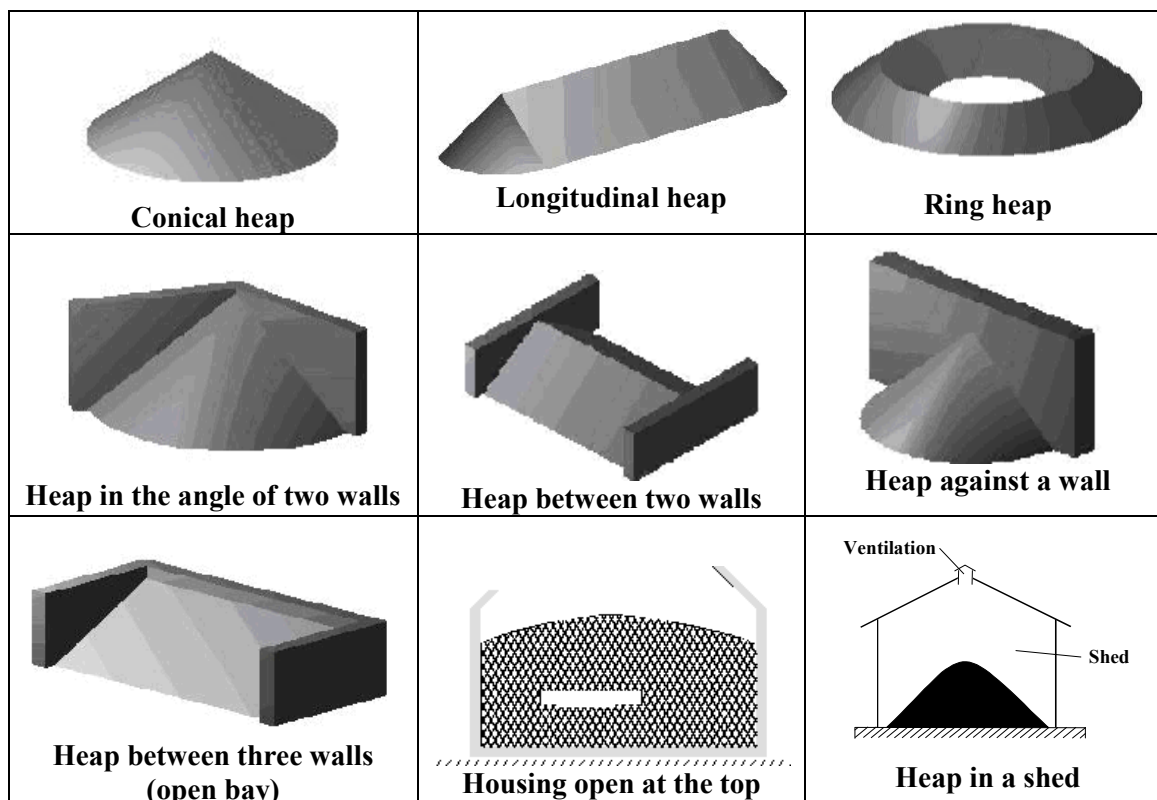
Storage in heaps outdoors or in buildings is used for larger quantities of bulk materials. It serves:

- to stockpile between the place of extraction and the processing plant
- as a buffer between different operations, which work at different times or with different amounts of the material
- to mix different bulk materials
- to homogenise the mass flow
- as a means of transfer from continuous to discontinuous conveying systems and vice versa.

Open storage is suitable for bulk materials such as coal, gypsum, ore, scrap and sand because these are not seriously affected by the weather. The bottom of the storage area can be sealed to protect the material against dirt. In most cases concrete is used. When solid fuels are stored, the support surface is normally waterproof. An outdoor storage facility for limestone (calcium carbonate) is normally fitted with a rainwater collection system.

**Description:** Open storage can be used for short-term or long-term storage and, in general, the heaps are longitudinal or ring-shaped. Depending on the requirements (e.g. if different materials have to be stocked in one place), storage can be up against one or several walls. For example fertiliser is stockpiled against three walls, also called an open bay, or in dedicated sheds.

Table 3.66 shows the various constructions together with the name of the technique and Figure 3.29 shows different shapes of heaps, except the situation where a heap is placed against another heap made of the same or different material, for example, a gypsum heap against a fly ash heap.



**Figure 3.29: Shapes of heaps**  
[17, UBA, 2001, 91, Meyer and Eickelpasch, 1999]

Table 3.64 gives the criteria for the selection of the storage shape.

Longitudinal storage places	Ring-shaped storage places
<ul style="list-style-type: none"> <li>• are suitable for very high capacities (up to millions of tonnes)</li> </ul>	<ul style="list-style-type: none"> <li>• are suitable for capacities of up to 100000 tonnes</li> </ul>
<ul style="list-style-type: none"> <li>• are suitable when the storage may be extended at a later date</li> </ul>	<ul style="list-style-type: none"> <li>• are suitable if no extension is planned or necessary</li> </ul>
<ul style="list-style-type: none"> <li>• are preferred on lengthy sites</li> </ul>	<ul style="list-style-type: none"> <li>• are preferred on squarer sites</li> </ul>
<ul style="list-style-type: none"> <li>• are suitable when long-term heaps are positioned next to short-term heaps</li> </ul>	

**Table 3.64: Criteria for the selection of longitudinal and ring-shaped storage places**  
[17, UBA, 2001]

### 3.3.2. Sacks and bulk bags

[17, UBA, 2001] [24, IFA/EFMA, 1992]

Storage in sacks and bulk bags has no relevance to dust emissions, however, empty bulk bags and sacks that cannot be re-used are waste. It is used especially for quality reasons and in cases in which very dusty goods are handled. In most cases the opening of sacks and bulk bags containing dusty materials is carried out in specialised installations with suitable suction installations within the production sheds. The type of bags used, their size and construction, will depend on the frequency and method of handling climatic conditions and market requirements. For fertilisers polythene bags are often used because these are resistant to water and oil.



### 3.3.3. Silos and bunkers

[17, UBA, 2001] [24, IFA/EFMA, 1992, 116, Associazione Italiana Commercio Chimico, 2001]

In some industrial branches silos are also called bunkers. Silos are normally used for the storage of dry and/or fine materials such as cement and grain. Bunkers are normally used for the storage of material composed of larger particles. The top of bunkers and silos can be open or closed. The open ones are relevant for emissions by wind erosion: emissions from closed ones only appear during loading and unloading.

Silos can be made of concrete, metal or plastic. The capacity of concrete silos can range up to tens of thousands of tonnes, the metal and plastic silos are of a more moderate size. Depending on the product (e.g. clinker or cement), silos are equipped with a fabric filter, sometimes with fabric sleeves that can stand temperatures of up to 150 – 160 °C. For example, fertiliser is stored in closed plastic silos or in open bunkers.

### 3.3.4. Packaged dangerous solids

In Section 3.1.13 the different types of containers and the storage of packaged dangerous substances are described for liquids and liquefied gases. However, this is also valid for the storage of packaged dangerous solids. In practice packaged solids and liquids are often stored together in warehouses. Therefore, a reference is made to the different sections in Chapter 3 that are also applicable for packaged dangerous solids.

Section 3.1.13 Containers and the storage of containers

Section 3.1.13.1 Storage cells

Section 3.1.13.2 Storage buildings

Section 3.1.13.3 Outside storage (storage yards).

### 3.4. Transfer and handling of solids

The different techniques for the transfer and handling of solids are described in the sections as shown in Table 3.65.

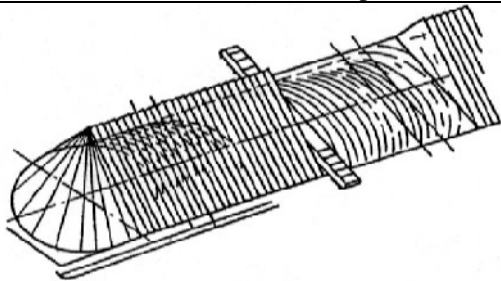
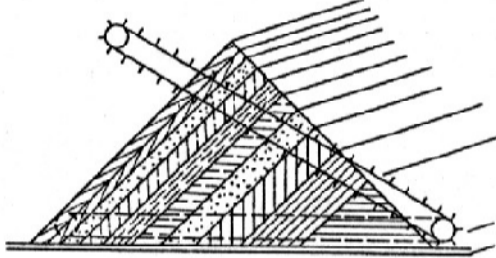
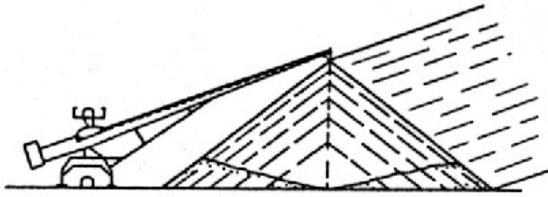
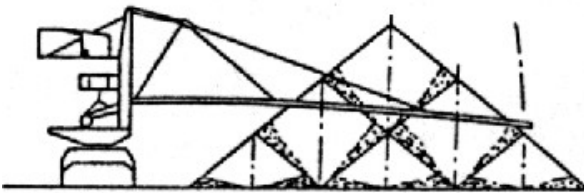
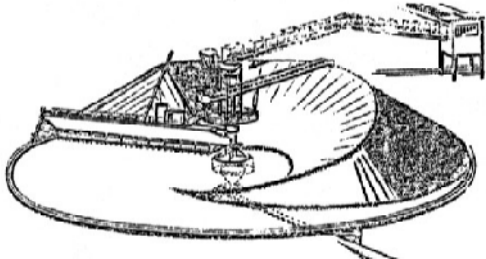
<b>Techniques</b>		<b>Sections</b>
The construction and reclaiming of heaps		Section 3.4.1
Grabs	Batch process	Section 3.4.2.2
Discharge hoppers	Batch process	Section 3.4.2.3
Tubs	Batch process	Section 3.4.2.4
Suction air conveyors	Continuous process	Section 3.4.2.5
Mobile loading devices	Batch process	Section 3.4.2.6
Wagon and truck emptying	Batch process	Section 3.4.2.7
Dump pits	Batch process	Section 3.4.2.8
Fill pipes	Continuous process	Section 3.4.2.9
Fill tubes	Continuous process	Section 3.4.2.10
Cascade tubes	Continuous process	Section 3.4.2.11
Chutes	Continuous process	Section 3.4.2.12
Thrower belts	Continuous process	Section 3.4.2.13
Belt conveyors	Continuous process	Section 3.4.2.14
Bucket elevators	Continuous process	Section 3.4.2.15
Trough chain conveyors	Continuous process	Section 3.4.2.16.1
Scraper conveyors	Continuous process	Section 3.4.2.16.2
Screw conveyors	Continuous process	Section 3.4.2.17
Pressure air conveyors	Continuous process	Section 3.4.2.18
Feeders		Section 3.4.2.19

**Table 3.65: Techniques for the transfer and handling of solids, with section references**

### 3.4.1. The construction and reclaiming of heaps

[17, UBA, 2001]

There are several techniques to construct and reclaim a heap.

Structure of the heap	Technique	Explanation
	Cone-shell	Heaps with a conical profile that are constructed/reclaimed with a drivable conveyor (longitudinal heaps) or a rotating conveyor (ring-shaped heaps)
	Strata	Heaps built up in lateral sloping layers with a drivable conveyor that can be raised, lowered, slewed or telescoped
	Chevron	Heaps with sloping layers pitched like a roof and built up with a conveyor that can be raised and lowered
	Windrow	Heaps in rows which are built up in layers (like the chevron) with a drivable conveyor that can be raised, lowered, slewed or telescoped
	Chevcon	Mixture of cone-shell and chevron (roof-like sloping layers)

**Table 3.66: Typical techniques to construct a heap**  
[17, UBA, 2001]

Machines especially elaborated for the construction of heaps are dumpers, such as tipper trucks or wagons and, for the reclaiming of heaps, back-loading devices such as bridge scrapers, lateral scrapers and portal scrapers.

Tripper cars throw the bulk material onto the heap from its side. Depending on the requirements, tripper cars can be equipped with a slewing belt or a transverse belt. Using the same principle a heap can be filled directly from the wagon above the heap.

Belt dischargers are conveyor belts which throw the bulk material over the heap. Depending on the type of heap, these systems are fitted to rotating or running jibs/booms or supporting beams.

Depending on the type of construction chosen, the band discharger can be slewed or adjusted in height and – should the situation require – be telescoped or traversed.

The system has to be flexible in cases where a mixing and homogenisation of the bulk material (so-called mixing heaps) is required in addition to the storage function.

### **3.4.2. Loading and unloading devices**

[17, UBA, 2001]

Section 3.4.2.1 describes the general emission aspects of loading and unloading. Section 3.4.2.2 to Section 3.4.2.13 describe the techniques for the material pick-up and discharge. Sections 3.4.2.14 to 3.4.2.18 describe the techniques for conveyance. A clear distinction between the pick-up and discharge techniques and the conveyance techniques cannot be made and, therefore, all the techniques are described in this Section 3.4.2. Feeders are described in the final section, Section 3.4.2.19.

#### **3.4.2.1. General emission sources from transfer and handling**

In principle, transfer and handling comprises three types of operations, the dust relevance of which is determined by the material itself and the techniques used. The techniques of material pick-up and discharge can be classified as continuous and batch processes, which is shown in Table 3.65.

##### **1. material pick-up, e.g.**

- the unloading from ships or wagons by grabs
- the mechanical unloading from ships or wagons by bucket elevators
- the pneumatic unloading from ships by siphons
- the grabbing of material by bucket loaders.

##### **2. material conveyance, e.g.**

- the slewing of the filled grab with the crane beam
- the conveying by bucket conveyors, elevators, belt conveyors
- the conveying by pneumatic transport
- the transport of material in a filled bucket of a bucket loader.

##### **3. material discharge, e.g.**

- discharge of the material by the opening of the filled grab onto a loading area, into a hopper or onto a heap
- discharge from a conveyor belt onto a loading area, a heap or another conveying system
- the loading of a truck, wagon or ship by a fill pipe or a fill tube
- the discharge of the material from a bucket loader from a dump truck
- pneumatic or atmospheric (gravity) discharge of silo trucks.

There is a worldwide trend towards using continuous systems for unloading specific bulk materials. This is especially valid for sea transport but also for the pneumatic unloading of silo trucks or wagons. The growing significance of continuous unloading systems in sea transport is caused by two factors. One is the relatively rapid and efficient unloading, which is important to save on high ship berthing costs. Secondly, continuous systems create less dust and noise and it is possible to reduce material losses in comparison to grab techniques. The use of continuous ship unloaders is limited by the size of the free ship load area. If the opening of the hold is too small (e.g. with converted tankers), mechanical systems such as bucket elevators or screw conveyors are often not practical. In these cases grabs are more favourable, with frontloading shovels for the trimming.

Dust is emitted while loading if:

- the motion of the mass flow is changed (change of direction or velocity)
- the size of surface particles is reduced by crushing or friction
- the moisture of the material is decreased by climatic conditions.

Closely related to the process of loading is the trimming of the material. This process is necessary when:

- any compacted material has to be loosened before the grab can pick it up
- the jib boom of the unloader is too short and the material must be taken to a central point
- the grabbing apparatus is too clumsy
- the remaining material around the edges has to be removed.

Other procedures to clean up residues from the wagons and trucks are:

- mechanical procedures, e.g. vibrators if dumpers are used, or brushes
- hydraulic procedures, e.g. truck washing, direct water jet
- pneumatic procedures, e.g. industrial vacuum cleaners.

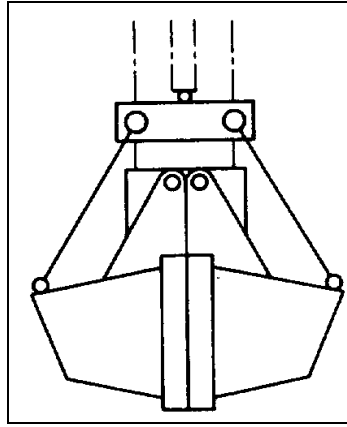
In many cases, frontloaders are used to trim the remaining material and to clean the ship's hold. Cleaning is normally only necessary when different bulk materials are being handled. Two methods of gathering and disposing of solid waste from ships are described in: 'Übereinkommen über die Sammlung, Abgabe und Annahme von Abfällen in der Rhein- und Binnenschifffahrt, Anlage 2, Anhang III Entladestandards und Abgabe-/Abnahmevorschriften für die Zulässigkeit der Einleitung von Wasch-, Niederschlags, und Ballastwasser mit Ladungsrückständen; Zentralkommission für die Rheinschifffahrt'.

The use of continuous conveying systems is dependent on:

- the properties of the material, such as bulk density and angle of the heap, particle size, adhesion and cohesion properties and moisture sensitivity
- the sensitivity of the material to mechanical handling and its thermal and chemical properties
- the required throughput
- the economy.

### 3.4.2.2. Grabs

**Description:** Grabs are technical installations with two or more controlled shells which penetrate the bulk material in an open condition, pick up the material by closing and discharge it by opening. In general, the capacity of grabs – dependent on the type of grab, its weight and size – is limited to 2000 to 2500 t/h. Grabs are normally only used to pick up the material; belt conveyors are used for further transport. Figure 3.30 shows a two-shell grab.



**Figure 3.30: Two-shell grab**  
[17, UBA, 2001, 91, Meyer and Eickelpasch, 1999]

Grabs are the most commonly used tools in loading and unloading processes because:

- they are versatile
- they can be easily swapped when another type of bulk material is to be handled
- their capital cost is relatively low
- they can load and unload at the same rate.

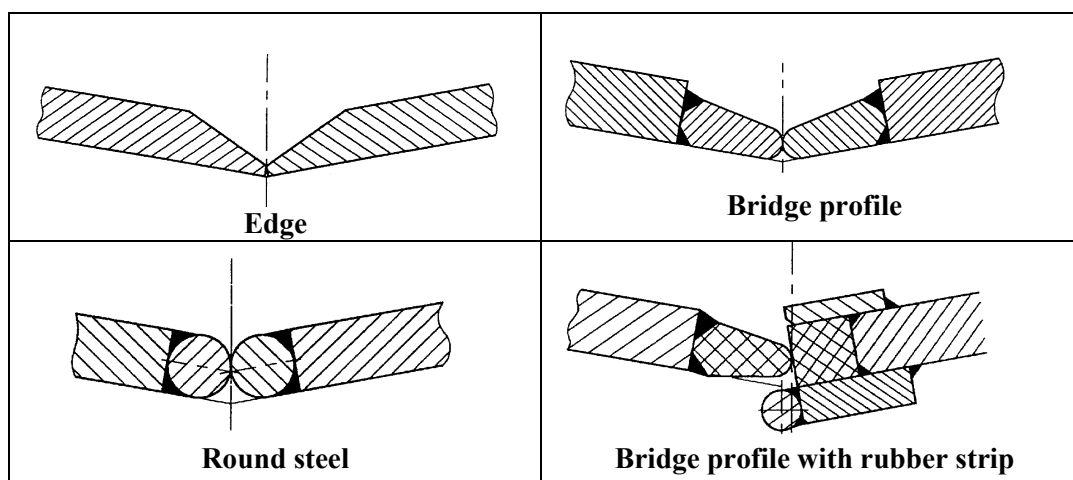
Potential disadvantages of the grab technique may be:

- the strong dependence on the correct operating technique
- the slightly disadvantageous ratio between the nominal capacity and the effective capacity compared to continuous unloading techniques
- the weight of the grab shells themselves.

The controlling of the grabs is normally carried out mechanically with cables. The option of controlling the grabs hydraulically with motors is rarely used for bulk materials. A wire grab takes 10 seconds to close the shells, whereas a motor grab takes 20.

The shape of the edges of the grab is important to control dust emissions.

Figure 3.31 shows different shapes of grab edges.



**Figure 3.31: Different shapes of grab edges**  
[17, UBA, 2001] with reference to MB Kröger Greifertechnik GmbH

The rubber joint is particularly suitable for very fine flowing bulk materials, e.g. fish-meal. For lumpy bulk materials like iron and ores, rubber joints are not strong enough and are therefore not used. Rubber joints need to be cleaned and maintained regularly, if they are to be effective.

If different materials are handled, joints with two round steel edges are commonly used. Precise fitting of the grab edges is vital for optimal closing and minimum dust emission. Problems with the precise fittings can arise from the constant abrasion of the edges. Edges which overlap prove not to be suitable in practice because they are especially sensitive to damage.

**Emissions:** Emission-relevant process steps are:

- dumping of the material (dust formation depends on the fall height)
- overloading or not totally closing the grab shells (the material spills)
- slewing of the grabs (dust emissions arise from drifting).

**Applicability:** Grabs are used for transport from ship to ship as well as from ship to storage and/or to wagon and also for the move from storage to processing plants. Grabs are applicable for nearly all bulk materials, including those with a high moisture content (which is not the case with e.g. pneumatic systems). However, their use should be avoided for dry drift sensitive bulk materials because of the potential dust emissions.

#### 3.4.2.3. Discharge hoppers

**Description:** Discharge hoppers are devices which take the discharged product (from grabs or from belts) and deliver it in a jet onto the load area of a vehicle (truck or wagon), onto another conveyor system or into the storage system. Discharge hoppers are often fitted with gratings or lamellae in order to ensure an even flow of material and to prevent larger pieces of material blocking the flow; the lamellae require the bulk material to be fairly fluid. Feeders are used for even delivery to the next conveying device. Hoppers can be equipped with a height adjustable fill tube and with a dust apron when they are used, e.g. for loading vehicles.

**Applicability:** Loading and unloading of bulk materials in ports, e.g. ship unloading by grabs or discharge onto a belt after silo unloading to load a truck or a wagon. A hopper is suitable for nearly all bulk materials (up to a particular size); e.g. grain, fertilisers, coal, non-iron metal ores or concentrates, raw materials of the cement industry.

#### 3.4.2.4. Tubs

**Description:** Tubs are used to load as well as to transport. Tubs are transportable vessels with at least one gate. They cannot pick up the material but are normally filled from the top. In order to empty the tubs a bottom plate is swung aside (bottom emptying tub), the tub is tilted (tilting tub) or gates open (a gate tub similar to the grab). Tubs are normally not suitable for dusty goods. Figure 3.32 shows different tub types.

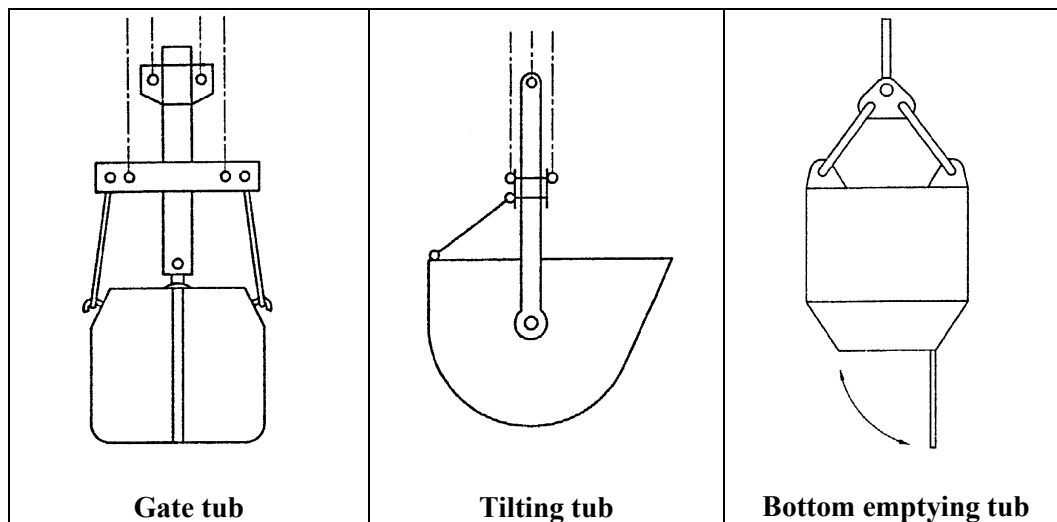


Figure 3.32: Different tub types [17, UBA, 2001] with reference to DIN 30800-3

### 3.4.2.5. Suction air conveyors

**Description:** Pneumatic conveyors, such as suction air conveyors, transport the material in closed pipes by streaming air, with the air compressor arranged at the end of the process chain. There are suction and pressure installations and Figure 3.33 shows the process principle of a suction system. The pressure system, which is not an unloading but a transfer device, is described in Section 3.4.2.18.

Suction air conveyors may be installed as mobile or stationary installations. Mobile systems are suitable if different port activities take place at the same point or if the installation is only needed from time to time. Stationary installations are growing in number because the transport of goods is steadily increasing together with the number of suitable specialised terminals.

The material is sucked by a nozzle and is then transported under vacuum to the separator which separates the airflow and material flow. The conveyed material is discharged in most cases over cell-wheel gates. At this point the vacuum is separated from atmospheric pressure. The discharged material is then transferred to continuous conveying systems.

The installation is very flexible by:

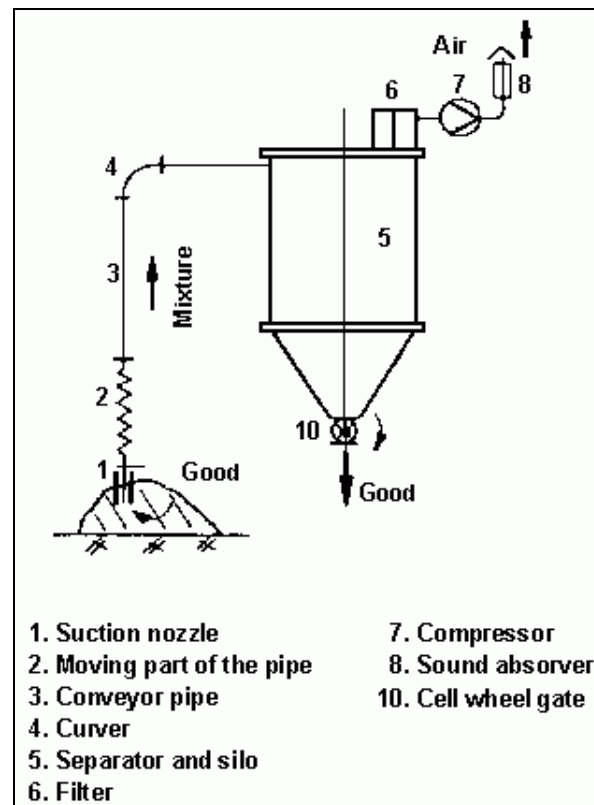
- the rotating and the kick-in/kick-out movement of the suction head
- the bending and the telescopic manner of the vertical suction pipe
- the mostly drivable concept of the installation.

Nearly every area of the ship which needs to be unloaded can be reached. At the end of the unloading time the material layer gets too thin and it is more practical to use, e.g. a frontloading shovel to trim the remaining material.

The throughput of pneumatic conveyors is influenced by the material type, the cross-section of the pipe, the air pressure and the route. For example, grain can have a throughput of 500 - 600 tonnes per hour and aluminium oxide a throughput of 1000 tonnes per hour.

The essential advantages are the prevention of dust because of the closed system and dust control by filters, the simple construction, the long lifetime and the fact that no movable parts are used in the load room. The investment is relatively low. An essential disadvantage is the often high energy consumption.





**Figure 3.33: Function principle of a suction air conveyor**  
[17, UBA, 2001] with reference to Pfeifer, 1989

**Applicability:** Suction air conveyors are suitable for bulk materials where the specific density is less than  $1.2 \text{ g/cm}^3$ . They are used in many industrial fields, typically in agriculture, mining, chemicals and food industries, for materials such as grain, aluminium oxide, petroleum coke, cement, limestone, lime and clay, potash, sodium sulphates and similar chemicals, fertilisers, salt and some plastics. They are used for the unloading of ships, wagons and trucks.

**Emission:** Additional textile filters may be installed behind the separator to remove dust from the emitted air. Dust emission levels of  $5 \text{ mg/Nm}^3$  can be achieved, but the filters are dimensioned for a dust emission level of 20 to  $25 \text{ mg/Nm}^3$  in order to reduce investment.

Like all pneumatic systems, suction air conveyors have a very high energy consumption: for light materials such as agricultural products, a value of 1 kWh per tonne and for heavy materials like clay or cement, a value of 2 kWh per tonne. In comparison, values between 0.3 and 0.8 kWh per tonne can be assumed for mechanical conveyor systems.

### 3.4.2.6. Mobile loading devices

**Description:** Mobile loading devices are excavators and frontloaders. They are used:

- to work on small heaps
- to load vehicles
- to bring the material to bins or boxes
- to feed hoppers
- to trim the material in ships.

**Emissions:** Emissions arise from the lifting of the bucket, from wind drifting or from dumping. The open handling favours dust formation.

### 3.4.2.7. Wagon and truck emptying

**Description:** Wagons and trucks are used to transport grain, fertiliser, coal, sand or ores. Table 3.67 shows the typical bulk material wagons and trucks used in Germany.

Types	Principle	Bulk material
1. open wagon/truck	<ul style="list-style-type: none"> <li>wagon/truck open at the top</li> <li>not self-unloading (partly by grabs or by special tilt equipment)</li> </ul>	Coal, briquettes, scrap, ores, stone, gypsum and minerals
2. open wagon/truck with gravity unloading – dosable	<ul style="list-style-type: none"> <li>loading space with several juxtaposed hoppers</li> <li>dosed lateral material unloading by gravity through dosable openings</li> </ul>	Gravel, sand, and stone chippings
3. open wagon/truck with gravity unloading – instantaneous	<ul style="list-style-type: none"> <li>wagon/truck open at the top</li> <li>saddle-shaped bottom</li> <li>instantaneous material unloading through side-gates (also with bottom unloading)</li> </ul>	Gravel, sand, stone chippings and gypsum
4. tipper wagon/truck	<ul style="list-style-type: none"> <li>wagon/truck with a pit, tipping over the side (for trucks also over the front) and driven by a pneumatic ram</li> <li>separated valves (the lower valve serves as a chute)</li> </ul>	Building waste, building material and gypsum
5. wagon/truck for pressure unloading	<ul style="list-style-type: none"> <li>closed wagon/truck</li> <li>emptying by pipes into silos</li> </ul>	Cement, lime flour, quartz sand, soda, aluminium oxide, sugar, flour, semolina and salt
6. covered wagon/truck with gravity unloading – dosable	<ul style="list-style-type: none"> <li>like 2, but with a slewable roof</li> </ul>	Moisture-sensitive bulk materials, e.g. grain
7. covered wagon/truck with gravity unloading – abruptly	<ul style="list-style-type: none"> <li>like 3, but with a slewable roof</li> </ul>	Moisture-sensitive bulk materials, e.g. gypsum

**Table 3.67: Survey of typical wagons/trucks for bulk materials [17, UBA, 2001]**

The emptying of wagons/trucks is carried out via lateral discharge openings or at the bottom of the wagon/truck. With lateral emptying, the material is led via special gutters to the next handling device or directly onto belts/bands. It is similar in principle to the bulk gutter unloading of road vehicles and is often used for fertiliser. Unloading stations are generally roofed or partly enclosed (particularly when handling moisture-sensitive bulk materials). Totally closed housing is not usual for railway unloading.

In seaports, it is common practice to unload wagons/trucks over the side onto belts; the material is conveyed either to a subsequent means of transport (truck or ship) or to a storage system (heap, shed or silo). Figure 3.34 shows a rear tipping and a side tipping truck, Figure 8.1 in Annex 8.8 shows some wagon types used by the German railway, with different unloading techniques.

**Emissions:** The loading (by grabs, loading pipes or discharge from conveyor belts) and unloading of the wagons are the two relevant process steps. Capsulation or suction systems can be installed.

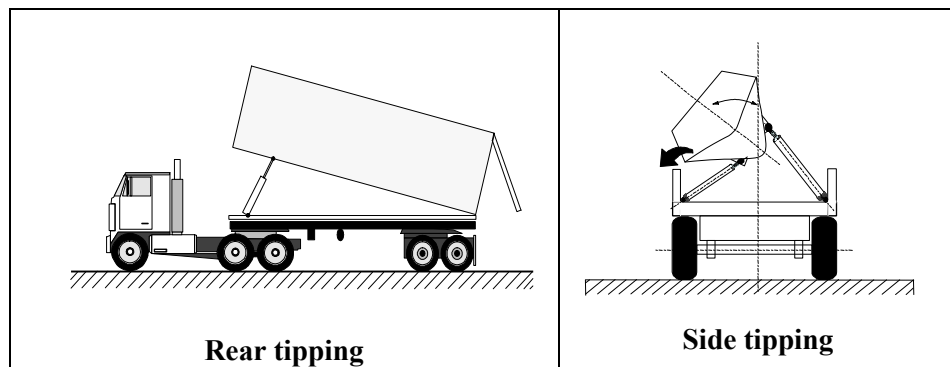


Figure 3.34: Dump trucks  
[17, UBA, 2001, 91, Meyer and Eickelpasch, 1999]

### 3.4.2.8. Dump pits

**Description:** Dump pits are ground excavations covered with a grid into which the material is tipped at high velocity. Dump pits are normally used to unload tipper wagons (e.g. with grain).

Dump pits can be equipped with so-called dust barriers. These lamellae open when the material is fed in. The dust that comes up is held back either by the following material or, when the mass flow stops, by the closing dust barriers. Dump pits can also be equipped with a suction system. Apart from dust barriers or a suction system, the reception area can be housed. Another possibility is the housing of the vehicle and pit area by a movable curtain system.

**Applicability:** Dump pits were developed for the unloading of grain, but are in principle applicable for all free-flowing bulk materials.

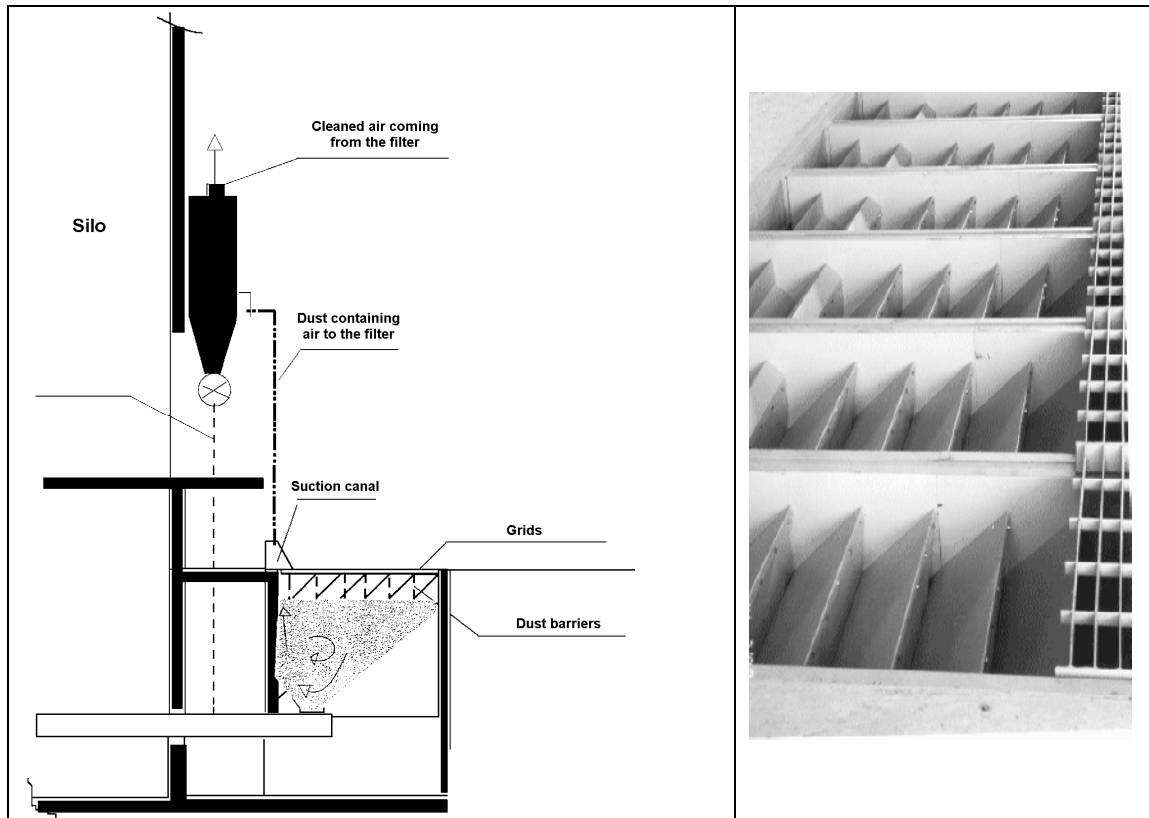
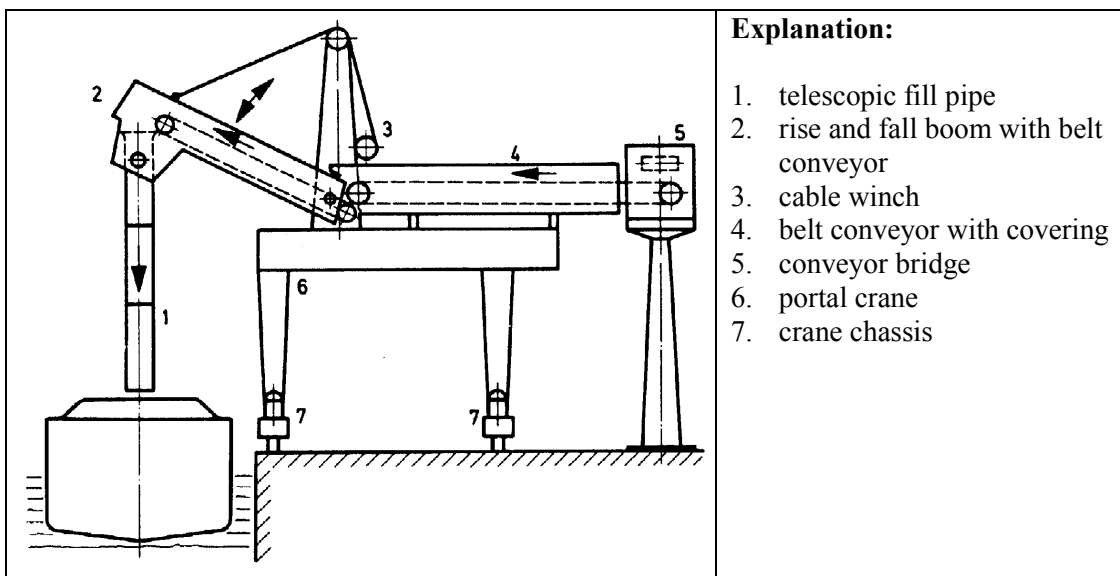


Figure 3.35: Dump pits with suction and dust barriers  
[17, UBA, 2001] with reference to Franz Rubert and Co. GmbH, 2000 (left picture) and Raiffeisen Hauptgenossenschaft Nord AG, 2000 (right picture)

**Emissions:** Dump pits without dust barriers can cause high dust emissions; when grain is unloaded, dust can shoot up three metres high and be dispersed over the surrounding area. Sometimes dump pits are equipped with suction equipment.

### 3.4.2.9. Fill pipes

**Description:** With fill pipes, the material slides or falls down a pipe under gravity. There are several variations of fill pipes. Synonyms are 'loading pipe' and 'down pipe'. Figure 3.36 shows a ship loader for bulk materials with a fill pipe.



**Figure 3.36: Ship loader with fill pipe**  
[17, UBA, 2001] with reference to Pfeifer, 1989

Fill pipes are available as a rigid pipe or as a vertical and/or horizontal movable pipe. The movability is achieved by lifting devices with ropes, telescopic booms and kick-in/kick-out installations. With a movable fill pipe the fall height can be (automatically) regulated and loading heads can be installed at the end of the pipe to regulate the output volume. A movable fill pipe can also be composed of an upper pipe and a lower pipe; they are joined with a seal and the lower one is telescoped by sliding pieces or pulleys. In very long pipes, baffles are installed to reduce the fall velocity.

**Applicability:** Fill pipes are used to load containers, trucks, trains and ships.

### 3.4.2.10. Fill tubes

**Description:** Fill tubes (also called loading tubes) can be used for closed and open loading. For open loading of bulk materials onto open trucks, ships or heaps, covers or aprons are fixed at the end of the tube to minimise the spreading of dust. For closed loading in silo trucks or containers, a cone with a fill alarm is fixed at the end of the tube so that dust cannot be emitted. The tube is composed of an inner and an outer tube and is made of plastic or of a tough woven plastic textile.

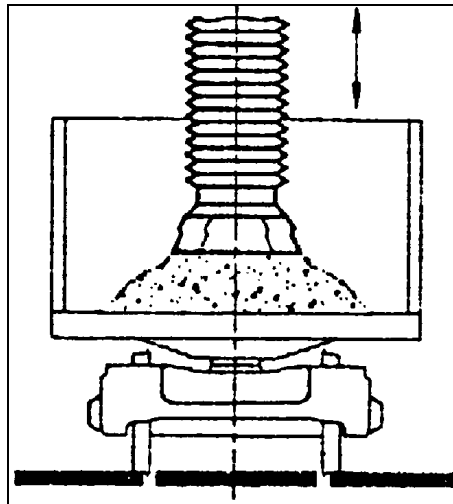


Figure 3.37: Fill tube  
[17, UBA, 2001] with reference to DIN 30800-3

**Applicability:** Fill tubes are used to load containers, trucks, wagons and ships.

**Emissions:** Similar to the fill pipe (Section 3.4.2.9), a fill tube minimises the free surface in order to achieve a nearly dustless loading.

#### 3.4.2.11. Cascade tubes

**Description:** A cascade tube is a fill tube where a cascade is put in; see Figure 3.38. The material slides and falls alternately. The low fall heights and the changes of the direction mean that there is scarcely any dust formation during loading and the material is treated more carefully.

Cascade tubes with throughputs of 30 to 5000 m<sup>3</sup>/h are available. They are coated with extremely high density polyethylene, sintered aluminium, ceramic brick and steel, which are all resistant to abrasion.

Installing a level sensor enables the tube to automatically maintain an appropriate distance from the surface of the material.

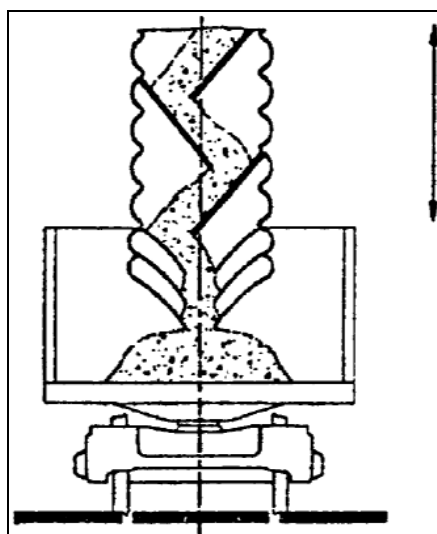


Figure 3.38: Cascade tube  
[17, UBA, 2001] with reference to DIN 30800-3

**Applicability:** Cascade tubes are used to load containers, silos, trucks, wagons and ships, and for transfer between conveyor belts. Suitable bulk materials are: powdery to coarse flowing bulk materials, e.g. potash, phosphate, grain, coal, coke, heavy sodium, aluminium oxide, cement, sodium phosphate, maize and animal feed. The technique has a relatively simple construction and only needs simple maintenance and cleaning.

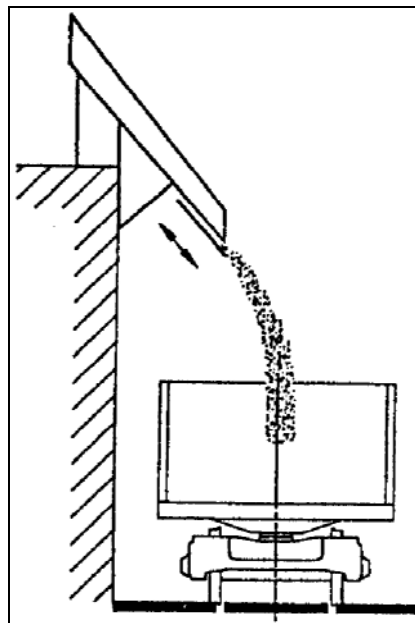
**Emission:** The cascade tube not only minimises the free surface at the discharge point, but also reduces the velocity of the material in order to achieve a nearly dustless loading.

**Economics:** A positive effect is the reduction of quality loss of the handled material.

**Reference plants:** Kali Transport Hamburg, the ports of Wismar, Lübeck and Philippstal, Germany.

### 3.4.2.12. Chutes

**Description:** Chutes are bulk material conveyors where the material slides downwards in an open or closed sloping groove. Chutes are used as loading tools or as transfer devices between two conveyors. There are rigid and movable chutes. Movable chutes can be vertical and horizontal slewable or drivable either backwards and forward or diagonally.



**Figure 3.39: Loading of a wagon by a chute** [17, UBA, 2001] with reference to DIN 30800-3

A minimum slope angle is required that varies with the specific flow properties of the conveyed material. Although a low friction and/or high abrasion resistance coating can be used to protect the chute, wear will still take place, at a rate dependent on:

- the chute length
- the angle of the slope
- the specific area load
- the slide velocity
- the frictional properties of the chute material.

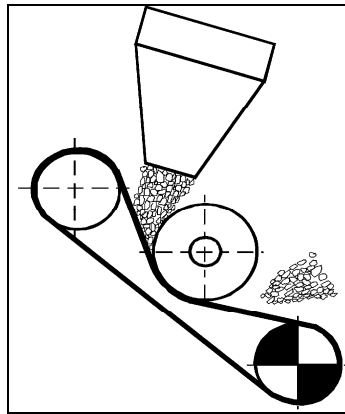
**Applicability:** Generally, chutes are suitable for non-caking materials and for dry operations. Because of the dust emissions, chutes are not applicable for fine powdery materials.

**Emissions:** The finer the material, the more dust will form.

### 3.4.2.13. Thrower belts

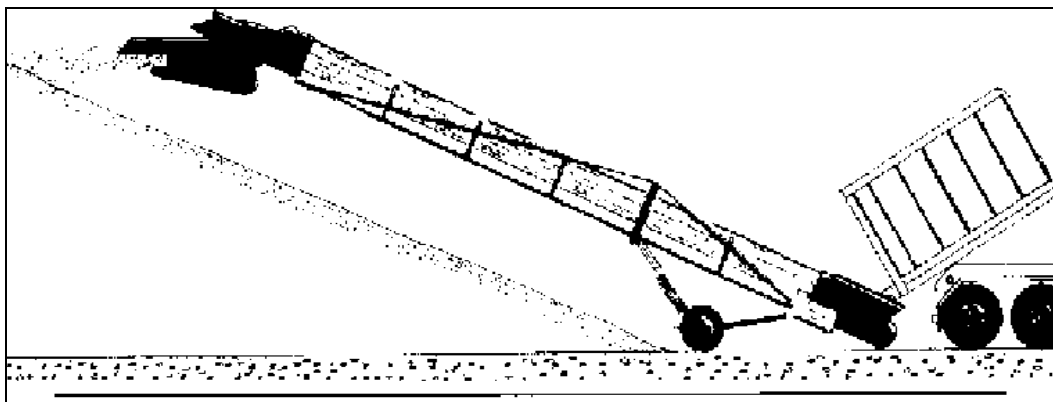
**Description:** Thrower belts are short rubber belt conveyors which reach very high conveyor velocities of 10 to 20 m/s. They are used as the last part of a loading chain if, for local reasons, the conveyor or loading system cannot be installed near enough to the discharge point. Examples are:

- ship loading in combination with vertical loaders if the loading bridge is not long enough



**Figure 3.40: Thrower belt**  
[17, UBA, 2001, 91, Meyer and Eickelpasch, 1999]

- to feed smaller heaps if the material properties mean that only flat heap angles can otherwise be achieved.



**Figure 3.41: Thrower belt used for constructing heaps**  
[17, UBA, 2001, 91, Meyer and Eickelpasch, 1999]

**Applicability:** Thrower belts are used in situations where the conveyor or loading system cannot be installed near enough to the discharge point.

**Emissions:** Thrower belts cause a lot of dust emissions.

**3.4.2.14. Belt conveyors**

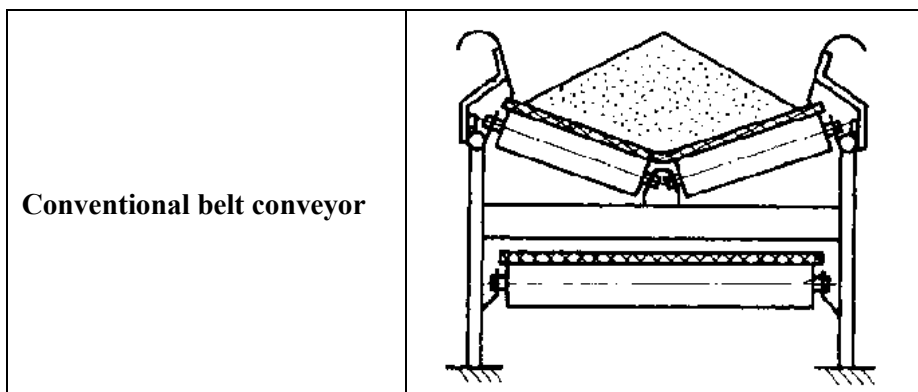
[17, UBA, 2001] [137, suppliers information, 2002] [139, suppliers information, 2001] [138, suppliers information, 2001] [78, DCMR Milieudienst Rijnmond, 1995]

**Description:** Belt conveyors are the most used and the best-known continuous conveyor systems. On belt conveyors the conveyed material is transported on an endless belt on support pulleys, slide strips or on an air film, made of rubber or plastic. Types of belt conveyors are:

***Belt conveyors***

With belt conveyors, the material is transported on the top side of an endless rubber belt with wire reinforcement. They are used as mobile systems or as part of stationary installations. A characteristic of the conveyor belts is that they are concave.

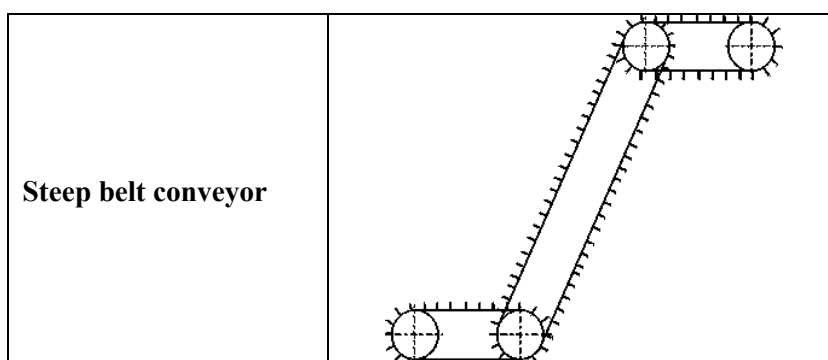
**Emissions from belt conveyors:** With open outdoor conveying systems, dust emissions are caused by the wind, an effect exacerbated by the vibrations of unsupported conveyor belts. Dust emissions also occur when caked-on material falls off while the belt is running back after the discharge. Dust emission from the material that is fed onto the belt can occur if the feed velocity does not match the belt velocity. Another source of emissions are when the belt is overloaded and the material falls off.



**Figure 3.42: Conventional belt conveyor**  
[91, Meyer and Eickelpasch, 1999]

***Steep belt conveyors***

Steep belt conveyors are similar to the conventional belt conveyor. In order to overcome slopes, the band is reinforced with profiles or small side-belts.



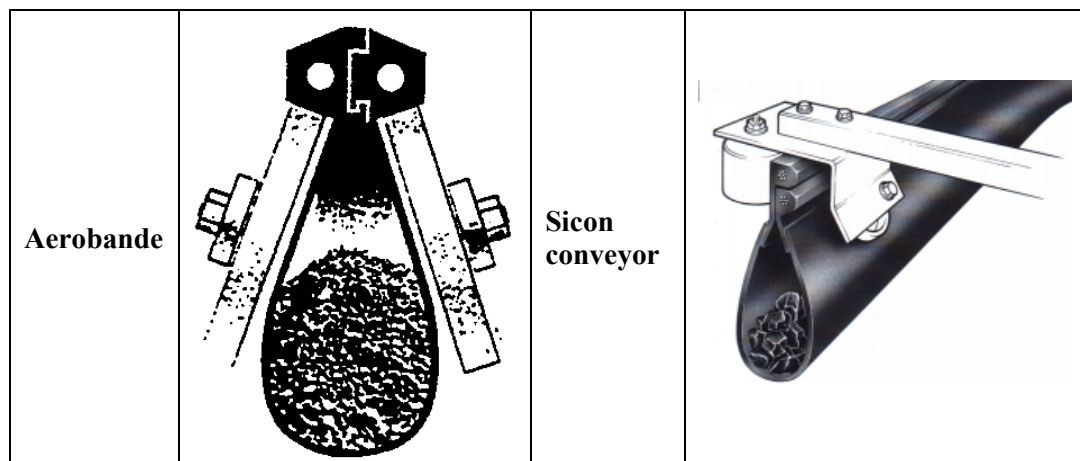
**Figure 3.43: Principle of a steep belt conveyor**  
[17, UBA, 2001]



### ***Hanging belt (or loop belt) conveyors***

Hanging belt conveyors are a relatively new kind of belt conveyor which are not often used, because of the high cost. The belt is formed as a loop by pressure and support pulleys. The belt is opened in order to discharge the material. With this type of conveyor, extremely tight curves (up to 0.4 m) are possible.

The most recent innovation in the field of continuous vertical conveying is a belt in the (patented) shape of pockets that make all hinges unnecessary. Belt speeds of up to 6 m/s are possible. These types of conveyors in shaft applications reach volume flows of 1000 m<sup>3</sup>/h at a vertical lift of 500 metres. For self-unloading vessels they can achieve volume flows of 5000 m<sup>3</sup>/h at a lift of 35 metres. All kind of material can be conveyed in a vertical path since different rubber qualities are available to suit different requirements as, e.g. heat resistance or oil resistance. Due to the simple construction with less rotating parts, this type of system offers the further advantage of energy saving by lower frictional losses.



**Figure 3.44: Examples of hanging belt conveyors**  
[78, DCMR Milieudienst Rijnmond, 1995]

### ***Tube belt (or pipe belt) conveyors***

Tube belt conveyors are a special type of the conventional belt conveyor. After the feed-path, the conveyor belt forms a nearly circular cross-section, the belt edges overlap and form a closed tube. The material is conveyed in the inner side of the band, which is rolled by (3 to 5) drive pulleys. The material is protected against the weather and dust emissions are minimised. At the – usually housed – discharge point, the belt is opened to discharge the material.

Belt conveyors of this type are suitable for fine and for lumpy materials up to a size of one third of the tube diameter. They are used to overcome long distances (and steep inclines of up to 60°), e.g. in mines and iron and steel works, because the system allows curves so that intermediate transfer points are not necessary. Other applications are in the cement, fertiliser, food and chemicals industries, to transport materials such as ores, coal, coke, limestone, broken stones, cement, gypsum, copper ore concentrate, ash and salt.

The belt speed ranges from 60 m/min to 300 m/min, roughly the same as a conventional belt conveyor. With regard to the handling capacity, a pipe conveyor can transport the same amount of material as a belt conveyor with a belt width which is three times the pipe diameter.

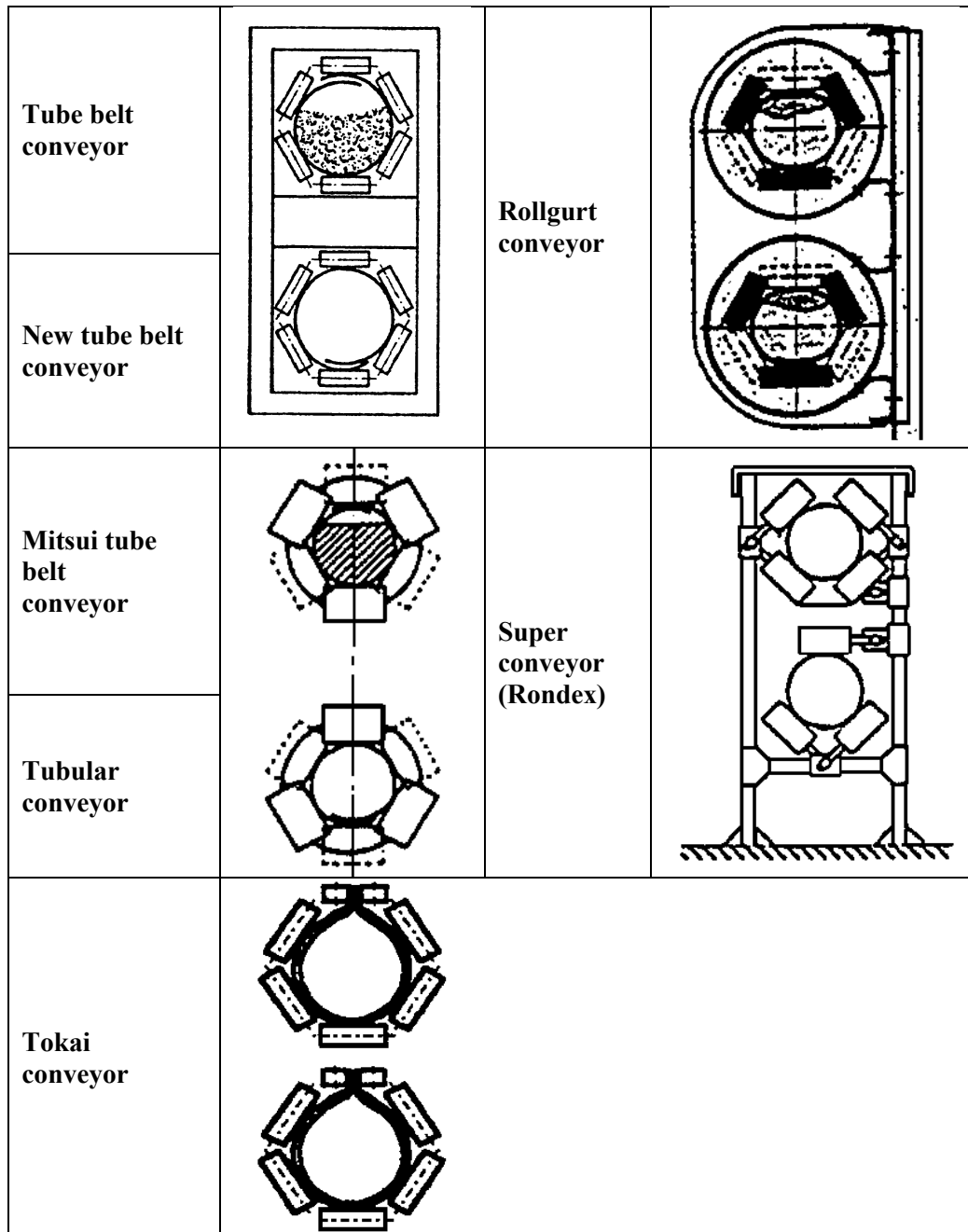


Figure 3.45: Different designs of tube belt conveyors [78, DCMR Milieudienst Rijnmond, 1995]

**Double belt conveyors**

Double belt conveyors use two conveying belts, normally a support (or carry) belt and a cover belt, which are brought together in the sloping or vertical part of the installation. The support band has raised edges and cross-profiles which support the material during vertical transport. At the bottom, the belt system is led over a drum, from which it picks up the material while moving downwards. The wedge effect between the two belts carries the material upwards to the transfer point, which may be a hopper.

This technique requires a relatively even particle size. Generally, materials between fine and coarse are suitable, but not powdery or lumpy materials or those that tend to cake on. This type of belt is especially suitable for products vulnerable to deterioration or degradation. A disadvantage of the sandwich or twin belt conveyor is that it cannot make curves.

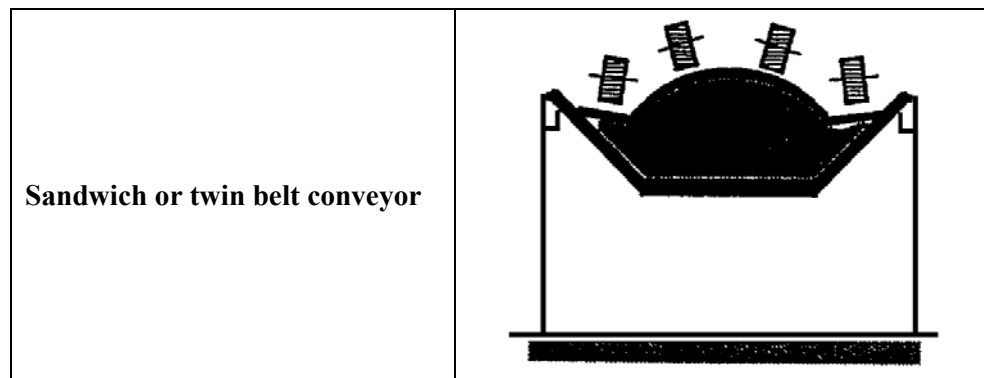


Figure 3.46: Example of a double belt conveyor  
[78, DCMR Milieudienst Rijnmond, 1995]

***Folding belt conveyors***

With folding belt conveyors, the belt is folded with the help of support pulleys in such a way that the product is completely enclosed.

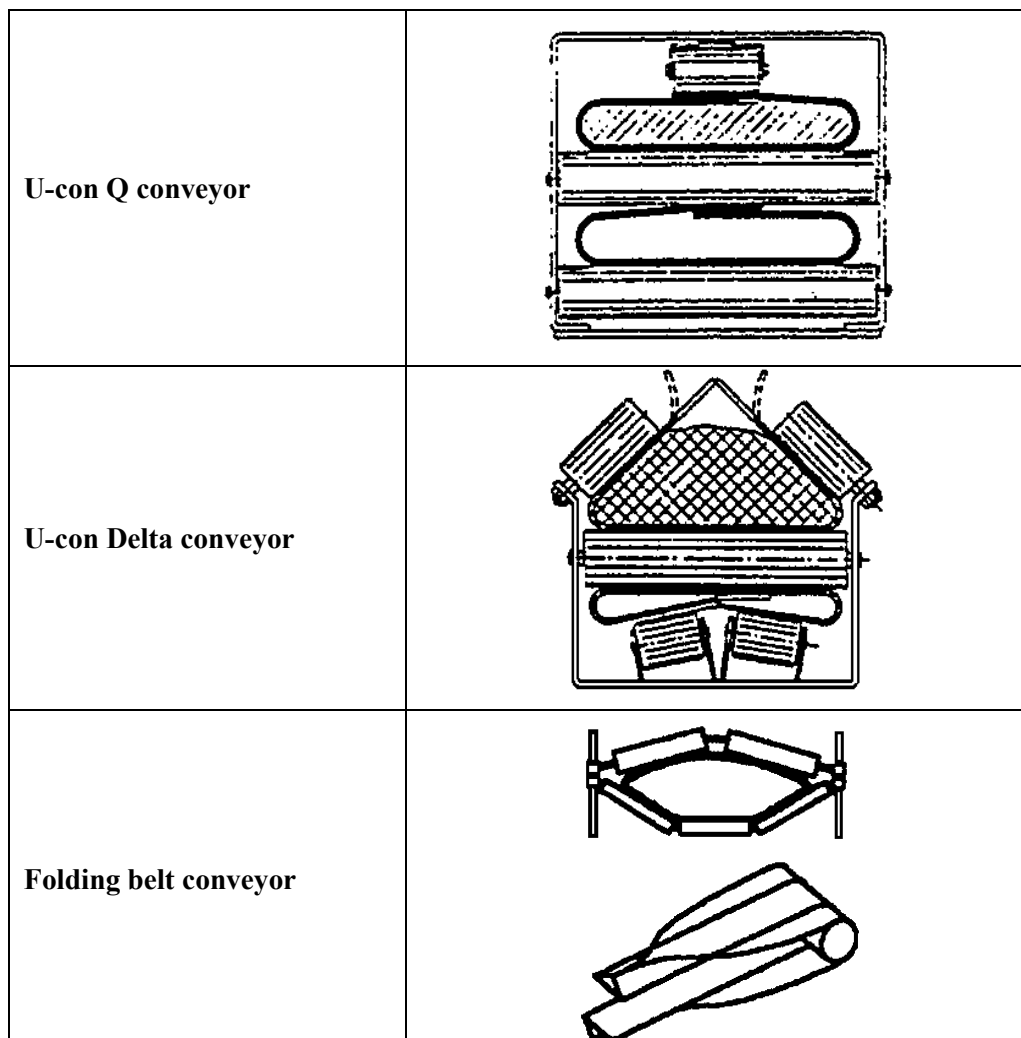
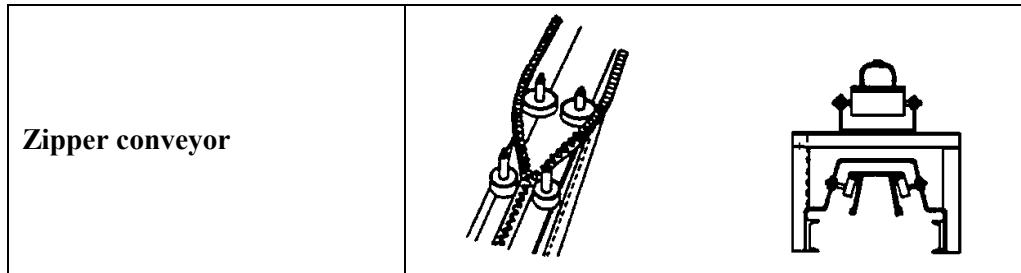


Figure 3.47: Examples of folding belt conveyors  
[78, DCMR Milieudienst Rijnmond, 1995]

**Zipper conveyors**

With zipper conveyors the product is completely enclosed by the belt because the edges of the belt are connected to each other by means of a zipper.



**Figure 3.48: Zipper conveyor**  
[78, DCMR Milieudienst Rijnmond, 1995]

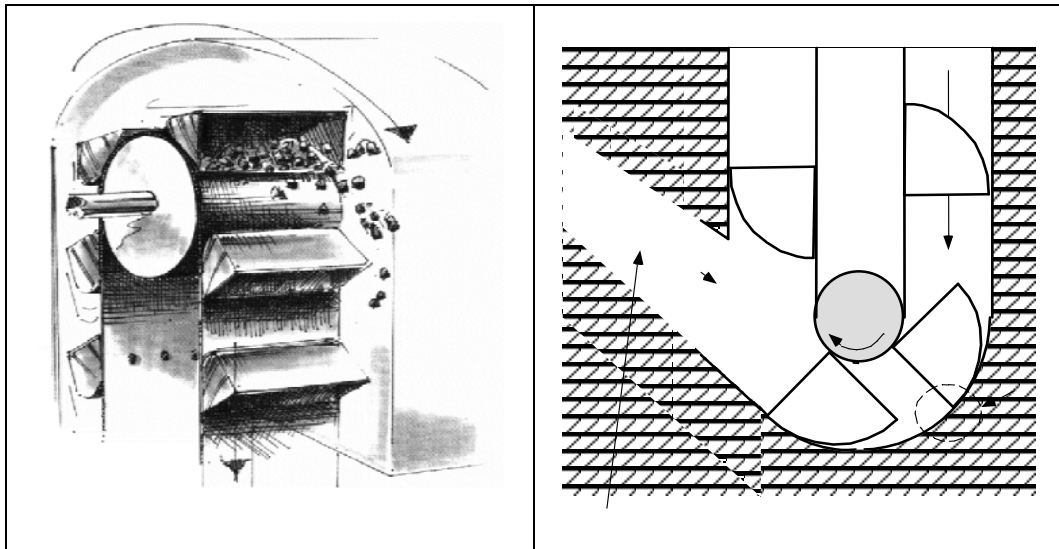
**3.4.2.15. Bucket elevator**

**Description:** Bucket elevators are conveyors where the buckets that pick up the material are fixed to a drive mechanism such as a chain or a conveyor belt. The shape and material of the buckets depend on the material that is to be conveyed. Bucket elevators are used for vertical transport, as they can lift to great heights, but are also used as continuous ship unloaders to convey the material horizontally and vertically in one device. In these cases, the conveyor foot is L-shaped. The advantage of the L-shaped foot is that the bulk material can be picked up fairly close to floor level and out of the corners of the ship’s hold, which reduces the need for trimming. The flexible conveyor shoe can be adapted by hydraulic systems to the geometry of the hold, enabling optimum filling of the buckets.

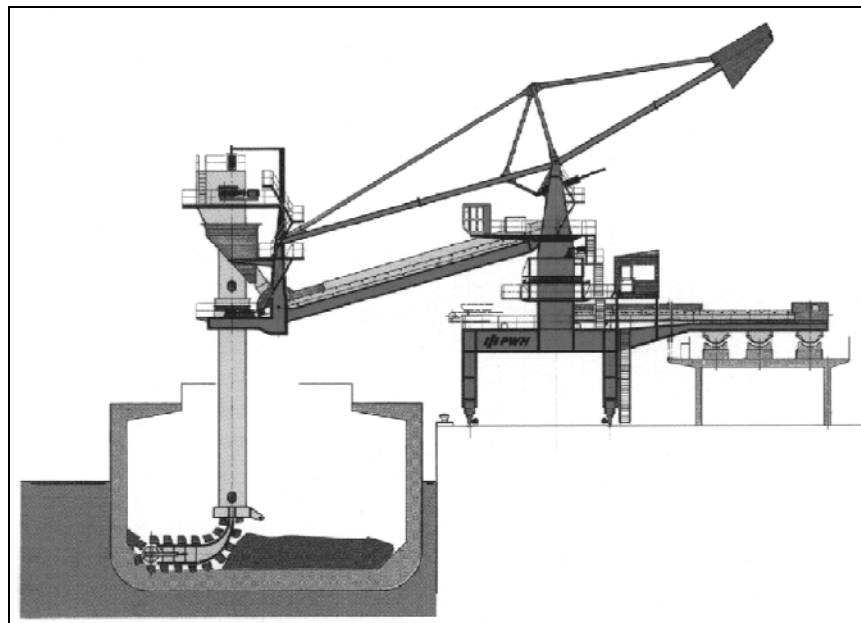
The fill factor is the proportion between the design volume of the bucket and the actual fill and is dependent on:

- shape and velocity of the bucket elevator
- type of the bulk material being handled
- relative position of the buckets to the bulk material surface
- relative position of the buckets which are in contact with the bulk material.

The discharge of the material takes place at the head of the bucket elevator either by gravity unloading (with slowly running conveyor systems) or by centrifugal force (with fast running conveyor systems). The conveyor velocity is 0.3 to 1.6 m/s with steel chains and 1.5 to 4 m/s with conveyor belts. Conveyor heights of 110 m are achievable with a belt and 60 m with a chain. The maximum throughput may be up to 3000 t/h on average to 4000 t/h peak.



**Figure 3.49: Construction and function principle of a bucket elevator**  
[17, UBA, 2001, 91, Meyer and Eickelpasch, 1999]



**Figure 3.50: Continuous ship unloader with bucket elevator technique and L-shaped pick-up foot**  
[17, UBA, 2001] with reference to Krupp Fördertechnik GmbH, 2000

**Applicability:** Bucket elevators are suitable for the conveying of bulk materials from powdery to moderately lumpy (up to 60 mm particle size) which do not have caking-on and no strongly abrasive properties, e.g. flour, corn and pulses, sand, coal, limestone, cement or ash.

**Emissions:** The bucket elevator is encased and can be equipped with a suction system, so little or no dust emissions will occur. The material pick-up and discharge are potential sources of dust emissions.

**Reference plants:** Bucket elevators with the L-shaped pick-up foot are applied in European steelworks such as Riva Acciai in Taranto, Italy, Sidmar Steelwork in Gent, Belgium, Ferrol, Spain and in Dillinger Hüttenwerke AG, Vereinigte Elektrizitätswerke Westfalen AG, Germany.

**Economics:** For the specific case of Dillinger Hüttenwerke the investment was around DEM 8 million (about EUR 4 million). The capacity of this ship unloader varies between 1200 and 1500 t/h, depending on the material conveyed. The alternative of two grab unloading stations would have required a similar investment of DEM 7 – 8 million (reference year 2000), but has only one third of the capacity.

The energy and maintenance costs are one-third lower than for conventional grab unloading. Two persons are needed for the operation of the bucket elevator, but four persons are needed for the operation of two grabs.

### 3.4.2.16. Chain conveyors

**Description:** The chain conveyor is a closed and heavy-duty conveyor with one or more continuous drive chains. The chains are moved over sprockets; chain tensioners are used to stop the chains from sagging. Chain conveyors are characterised by a generally low energy consumption; some units show values of 0.006 kWh per tonne and metre conveyor height. The chain velocity is mostly under 1 m/s with a throughput of up to 1000 t/h. Damaged chain elements can be changed relatively easily.

Two types of chain conveyors are presented in the following sections: the trough chain conveyor (Section 3.4.2.16.1) and the scraper conveyor (Section 3.4.2.16.2).

#### 3.4.2.16.1. Trough chain conveyors

**Description:** In a trough chain conveyor the chains run in a closed trough, as shown in Figure 3.51. The shape of the collector is chosen to suit the type of material being handled and the conveyor path:

- for horizontal and gently sloping conveyor paths, flat, rectangular or L-shaped collectors are used
- for steeply sloping and vertical paths, U-shaped, fork- or ring-formed collectors are suitable.

The pick-up and discharge of the material are fairly easily accomplished and the material can be conveyed vertically. This technique has a relatively low space demand and has low or no dust emissions. Disadvantages are the high wear and the relatively high energy demand. The throughputs vary between 10 and 2000 m<sup>3</sup>/h, with a maximum conveyor length of 50 to 150 m.

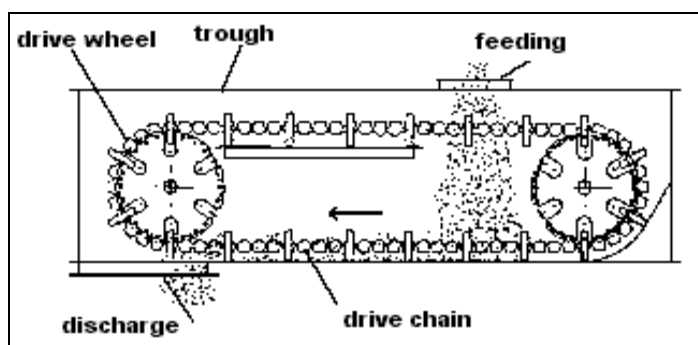


Figure 3.51: Principle of a trough chain conveyor [17, UBA, 2001, 91, Meyer and Eickelpasch, 1999]

**Application:** Trough chain conveyors are typically used in bunkers and silos for loading and unloading powdery and moderately lumpy materials that have no caking-on properties. Because the trough chain conveyor is a closed system, it is used especially for grain, oil seeds, food and feed, coal, cement, chemical products and minerals.

**Emissions:** If the feed and discharge areas are enclosed or housed, no dust emissions arise.

#### 3.4.2.16.2. Scraper conveyors

**Description:** A scraper conveyor is similar to a trough chain conveyor, but without a trough. The conveying is carried out by collectors attached to chains. The collectors push the material. The pick-up and discharge of the material can be made at any chosen point on the conveyor.

**Application:** Scraper conveyors are mostly used to feed and to reclaim heaps of ore, coal and salt.

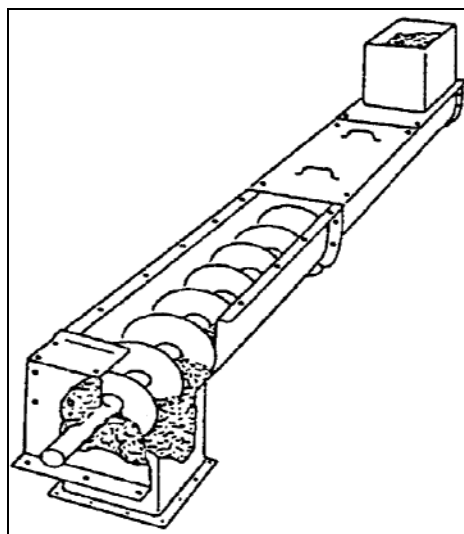
**Emissions:** Dust is emitted during the pick-up and transport of the material. Friction effects between the material and the walls and bottom of the conveyor can cause crushing of the material. The dust formation from this effect can be minimised by dampening the material.

#### 3.4.2.17. Screw conveyors

**Description:** Screw conveyors are bulk material conveyors in which the material is driven along a stationary trough or pipe by a rotary conveyor worm, whether horizontal or sloping up to 30°. Vertical movement is also possible, but requires a totally different construction of the conveyor. With horizontal movement, the material is pushed forward along the bottom of the trough; with vertical movement, the material runs with the worm around the pipe.

With horizontal screws, the material can be picked-up and discharged at several points. The openings to discharge are directed with flights. Vertical screw conveyors have a lower material pick-up point and an upper material discharge point. The maximum fill degree in relation to the screw cross-section is 40 % for trough screw conveyors and up to 80 % for pipe screw conveyors.

The maximum throughput performance of a vertical screw conveyance is 1000 to 1200 t/h. A higher performance is technically possible, but is very expensive.



**Figure 3.52:** Scheme of a trough screw conveyor [17, UBA, 2001] with reference to VDI 3971

**Application:** Screw conveyors are especially suitable for conveying very dusty materials, e.g. aluminium oxide powder, cement, grain, gypsum, fertilisers, coal, lime and phosphates.

Screw conveyors are also suitable for animal by-products and sugar beet pulp at rates of up to 900 tonnes per hour with diameters of up to 2 metres.

Screw conveyors are used for the transport of materials ranging from those containing powdery, fine particles to lumpy bulk materials over relatively short distances (up to 40m). They are unsuitable for abrasive materials or those that tend to cake-on.

These devices are compact and – because of the kick-in/kick-out device – can reach areas that are otherwise difficult to access, although they are not suitable for ships with small hatches. Because of its versatility the screw conveyor is used in many fields.

**Emissions:** Vertical screw conveyors are always closed, whereas horizontal conveyors can be open or closed. In all cases dust is emitted at the points where the material is picked up and discharged, unless the transfer points are enclosed.

**Cross-media effects:** The energy consumption is relatively high due to the high driving power of the screw.

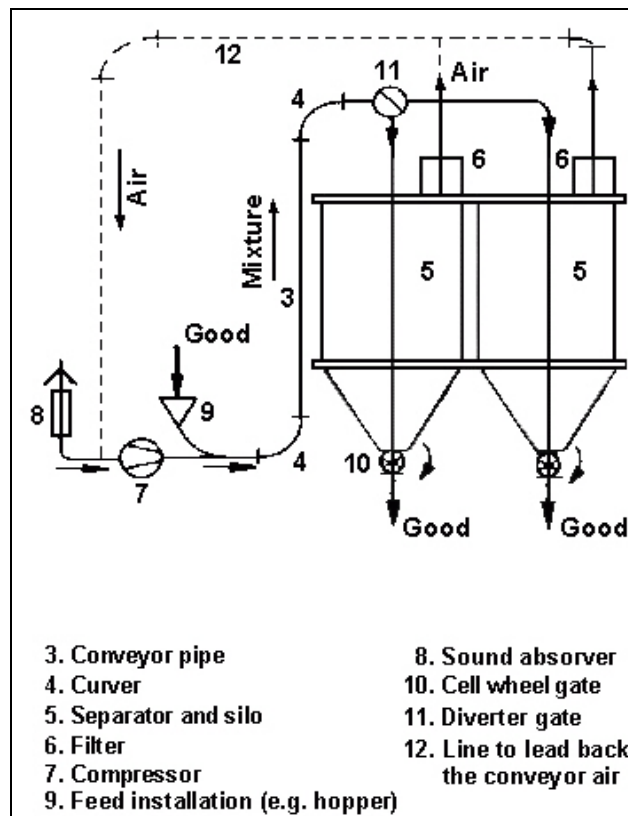
**Reference plant:** Stadtwerke Flensburg; Port of Borugas Ltd., Bulgaria; Kingsnorth Power Station, England; Calibra S.A. Lisbon, Portugal.

#### **3.4.2.18. Pressure air conveyors**

**Description:** Pressure air conveyors are mainly used for dust-free conveying in closed systems. The principle of a pressure air conveyor is the same as the suction air conveyor described in Section 3.4.2.5, except that the compressor is at the beginning of the unloading system.

The conveyed material is introduced into the conveyor pipe system via a feed mechanism (cell-wheel gate, screw or feed hopper) by injector effect. The conveyor pipe system is run at over-pressure. The next steps in the process are the same as those for suction air conveyors (see Section 3.4.2.5).





**Figure 3.53: Function principle of a pressure air conveyor**  
[17, UBA, 2001] with reference to Pfeifer, 1989

**Applicability:** Pressure air conveyors are suitable for fine particle crystalline bulk materials like cement, lime or gypsum and are applied, e.g. for unloading silo trucks.

**Emissions:** There is scarcely any dust emission from the closed conveying system using a back venting line. Systems without a back venting line and equipped with a filter system have low emissions. The material pick-up can be the only dust relevant step in the process.

Pressure air conveyors, as all pneumatic systems, have a very high energy consumption.

### 3.4.2.19. Feeders

**Description:** The feed and discharge points are the most significant for the formation of dust from continuous conveyor systems. Some typical feeders are:

#### *Belt feeders*

Belt feeders are rectangular hoppers. The bulk material falls from the storage unit over the hopper onto the conveyor system behind it. Such hoppers are available as enclosed types, with optional suction or sprinkling systems.

#### *Roll feeders*

Roll feeders are openings from bunkers or silos. The material is fed onto a rotating roller. The roll conveys the material to a conveyor system behind it. The feed velocity varies with the rotation speed of the roll.

#### *Screw feeders*

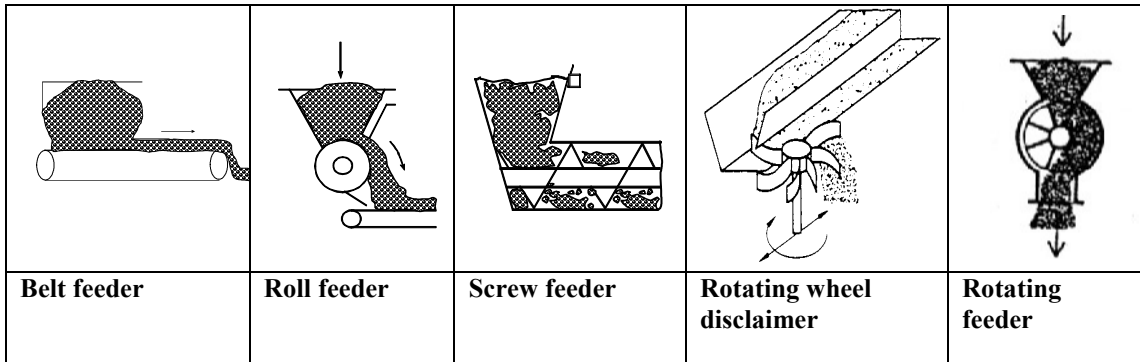
Screw feeders correspond to the classic screw conveyors. By the rotation of the conveyor screw in a trough, material is transported in a controlled way from a longitudinal feed opening to the conveyor or storage unit behind it.

**Rotating wheel disclaimers**

Rotating wheel disclaimers are used to feed bunkers or silos. The material slides over a bevelled ground plate from the storage system in a discharge slot. A discharge carriage moves along the slot opening. At the discharge carriage, a rotating bucket wheel is fixed which removes the material from the slotted outlet to the conveyor installation behind it.

**Rotating feeders**

Rotating feeders are also used to feed the material to conveyor belts from bunkers or silos. The discharge is effected by cells. The cells with lamellae on a rotating axis are housed in a kind of cylinder with openings at the top and the bottom; these openings are sealed to the silo or bunker and to the conveyor system behind it.



**Figure 3.54: Feeders**

[91, Meyer and Eickelpasch, 1999] [17, UBA, 2001] with reference to DIN 15201 part 2

**Emissions:** Dust emissions arise particularly from feeders which are not housed. Overfilling can occur if the feed system is not adapted to the storage or conveyor system, e.g. because the feed velocity is too high.

**3.4.3. Transfer and handling of packaged good**

See Section 3.2.5 – Transfer and handling of packaged goods.

## 4. TECHNIQUES TO CONSIDER IN THE DETERMINATION OF BAT

### 4.1. Storage of liquid and liquefied gas

In Chapter 3 most of the different storage modes for liquids and liquefied gases are described and the potential emission sources of each storage type are identified and are given an emission score. Scoring the emission sources is a simple and reliable means for identifying the most important emission sources, although, it should be noted that the scores have a relative value and should only be considered for each storage mode in isolation. The sources with an emission score of 3 and more are addressed here in Chapter 4.

ECM scorecards (Emission Control Measures) have been prepared for all storage modes and are shown in Annex 8.9 – ECM Scorecards for storing liquid and liquefied gas. Each scorecard provides information on typical ECM for gaseous and/or liquid emissions and/or waste. The cards also show the emission score of each potential emission source.

Annex 8.9 shows that ECM for fourteen types of storage modes for operational emissions are to be discussed and assessed. This chapter contains an overview of the various ECM that might be applied to all or some of the storage modes. Each discussed ECM is – where possible – assessed by:

- description
- achieved environmental benefit
- operability
- applicability
- safety aspects
- energy/waste/cross-media, and
- economics.

#### 4.1.1. ECM assessment methodology for the storage of liquid and liquefied gas

**Description:** TETSP (Technical European Tank Storage Platform) has defined a practical methodology for assessing the ECM described here in Chapter 4 in order to define which ECM, or combination of ECM perform best in the storage of liquid and liquefied gas in a specific situation. This methodology is based on the principles of a risk-based approach for selecting and qualifying emission points (see Chapter 3), followed by the definition of ECM. TETSP developed this tool, because in their view, it is recognised within the BREF that almost all tanks are different due to their design, their location and the product stored, etc. and it would, therefore, be virtually impossible to define a generic BAT for a certain type of tank.

ECM can denote technical measures and/or operational measures and/or management measures. These measures do not focus just on end-of-pipe techniques with their achievable emissions and costs, but also cover measures such as good operating procedures, adequate training and sound maintenance procedures.

The methodology is based on an assessment matrix, which is used with information about specific storage modes and their main sources of emissions. The assessment matrix uses a scoring system to determine the best performing ECM. The scores relate to:

- the emission reduction potential or the ‘emission control efficiency’ of the ECM being considered. The emission reduction potential scoring system for the ECM being considered will be storage tank dependent. The emission reduction potential weighting factors will depend upon the properties of the product stored, and on-site-specific factors (proximity to habitation), etc. and must be agreed between the operator and the permit writer at the outset
- the ‘operational features’ of the ECM, e.g. the operability, applicability, safety and energy/waste/cross-media issues for the ECM as outlined in this chapter
- the economics of the ECM, i.e. the cost to install the ECM and the operating costs.

The assessment matrix for an external floating roof tank, is shown in Annex 8.12 as an example, and a full explanation showing how to complete the assessment matrix is given in Annex 8.11.

To qualify the emission sources, scores are given depending on the frequency and volume of the emissions from a specific tank type; these form the ECM scorecards and they are shown in Annex 8.9 for each tank type that is addressed in this document. The scores have a relative value only, as these scores are only meant to indicate the emission differences within a storage mode. For example, a score of 3 for an external floating roof tank may not be compared with a score of 3 for a fixed roof tank. The relevant emission control measures (i.e. with a score of 3 or higher) are then put into the assessment matrix.

The ECM scorecards are set up independently of the product stored. The reason for this is that when comparing the sources of emissions to air from a specific tank type with the aim of defining the main sources, the type of product does not influence the relative ranking of the sources.

Examples for the situations below are included in Annex 8.13:

- 100000 m<sup>3</sup> storage of crude oil in an external floating roof tank (EFRT); Annex 8.13.1
- 10000 m<sup>3</sup> storage of naphtha (not gasoline) in a fixed roof tank (FRT) for two different operating conditions; Annex 8.13.2 and Annex 8.13.3
- 1000 m<sup>3</sup> storage of acrylonitrile in a fixed roof tank; Annex 8.13.4
- 100 m<sup>3</sup> storage of acrylonitrile in a fixed roof tank; Annex 8.13.5.

The case studies deal with a single ‘standalone’ tank storing a product. However, it is often the case that a multiple number of tanks will be used for the same product. In this case an economy of scale of implementing an ECM may start to dominate the cost evaluation. For example, consideration of a single tank may show that BAT is met by installing an internal floating roof, but if there are 10 tanks used for the same product then possibly some form of vapour treatment may become a more economic measure to meet BAT.

Annex 8.11, dealing with the use of the assessment matrices, indicates that this is an iterative approach until the combination of ECM that give the highest overall score meets BAT. When no combination of ECM meet the BAT criteria, or any stricter locally applicable legislation, the process should be restarted by changing the basic data, e.g. by reducing the inventory to be stored, or by changing the storage mode.

**Applicability:** In this BREF, the methodology of the assessment matrix was developed in such a way that it could provide the permit writer with a tool that will enable the identification of ECM that meet BAT in any specific case. This is the most appropriate use of the methodology, as the product will be already known, as will the site-specific circumstances.

It is anticipated that other Technical Working Groups will be able to use this methodology to decide what will normally be considered as BAT for storage activities in any specific industry sector, albeit that this will vary to some extent when taking into account site-specific circumstances.

The method can be used for the assessment of ECMs on a single tank or for a number of similar tanks and it can be applied for new and existing storage facilities.

However, several Member States have serious concerns on the use of this method in permitting processes, and the reasons given are:

- the methodology has not yet been tested in permitting process practices on an administrative level
- the methodology would be too complex for permit writers
- with this approach, the decision on BAT would be completely shifted to a conclusion at local level
- BREF documents should give a clear description of BAT and, therefore, specific measures are preferred
- it is not clear how the method takes into account the number of tanks emitting vapours in an installation.

#### **4.1.2. ECM for tanks – general**

##### **4.1.2.1. Tank design**

**Description:** The design of a new storage facility or the retrofit of an existing one for a given substance or preparation is a multi-step approach. The initial steps are aimed at considering all the storage modes and at eliminating those that are not acceptable. This elimination is based essentially on the thorough examination of the important physical and dangerous properties of the substance, the inventory of the substances to be stored and also the operational modes of the tank.

In the next step, the ECM suitable for selected storage modes are analysed to enable identification of the available techniques that allow BAT to be reached. When no combination of ECM meet the BAT criteria, the process should be restarted by changing the basic data, e.g. by reducing the inventory to be stored, or by changing the storage mode.

A proper design must take many factors into account including:

- physico-chemical properties of the substance being stored
- how the storage is operated, what level of instrumentation is needed, how many operators are required, and what their workload will be
- how the operators are informed of deviations from normal process conditions (alarms)
- how the storage is protected against deviations from normal process conditions (safety instructions, interlock systems, pressure relief devices, leak detection and containment, etc.)
- what equipment has to be installed, largely taking account of past experience of the product (construction materials, quality of valves, types of pumps, etc.)
- which maintenance and inspection plan needs to be implemented and how to ease the maintenance and inspection work (access, layout, etc.)
- how to deal with emergency situations (distance to other tanks, facilities and to the boundary, fire protection, access for emergency services such as the fire brigade, etc.).

For a practical checklist for the design of a product storage tank in a chemical plant facility see Annex 8.19.

**Reference literature:** [113, TETSP, 2001] [176, EIPPCB Ineke Jansen, 2004]

#### 4.1.2.2. Inspection, maintenance and monitoring

According to national regulations there are different approaches to perform inspection work and they are:

##### *Official surveillance*

**Description:** Official surveillance is, in principle, restricted to general control activities and is based on:

- internal company control (control by the operator) and
- supplementary surveillance by officially recognised experts (independent third parties).

The main objective of official surveillance is to ensure that:

- control by the operator and surveillance by experts are both carried out properly
- any deficiencies found in these activities are corrected, and
- any damage which cannot be excluded is detected quickly and reliably at internal company level and those concerned, including the authorities, are subsequently informed by the operator immediately and the necessary remedial measures are carried out by the operator.

Accordingly, official surveillance mainly involves the following tasks:

- evaluation of installations within the framework of legal obligations of operators concerning authorisation and notification
- maintenance of an installation register for the registration of installations and for the inspection reports forwarded by commissioned experts
- stipulation and enforcement of provisions governing the recognition of experts
- stipulation of essential benchmarks for internal control by the operator
- stipulation of essential benchmarks for surveillance by experts
- ensuring that any deficiencies identified by commissioned experts are remedied properly
- issue of official orders, if necessary
- random checks of companies, in the framework of official inspections carried out according to a concrete inspection programme, with respect to, *inter alia*, environmental management and proper control of installations by the operator
- stipulation of essential requirements for reporting and handling of incidents or accidents causing damage.

##### *Surveillance by experts*

**Description:** Surveillance by officially recognised experts generally presents an independent inspection on a high quality level and is a detailed technical control activity which is based on:

- the experts' own investigations and checks
- evidence and documentation provided by the operators, by authorities or by other competent bodies
- measures to assure the quality of the experts' activities
- stipulations made by the authorities.

The main objective is to ensure that:

- the installation and its components have been manufactured and erected properly
- the installation and its components remain in an appropriate condition
- possible deficiencies are identified.

Accordingly, surveillance by experts mainly involves the following tasks:

- initial assessment of the conformity of the installation and its components
- assessment of the conformity of the erection work carried out
- regularly recurring assessment of the conformity of the installation and its components according to stipulations made by the authorities
- assessment of possible repair measures
- assessment of organisational measures taken by the operator.

The assessment of the conformity of the installation and its components extends, above all, to those parts which directly come into contact with the materials stored (e.g. containers, piping, fittings, joint sealings, pumps) as well as to safety devices (leak indicators, overfill prevention devices, containment areas) and precautionary technical measures (e.g. sealed surfaces in the case of filling operations).

#### ***Internal company control (control by the operator)***

**Description:** In keeping with the operator's responsibility, control by the operator is the technically most intensive and most time-consuming form of surveillance of storage facilities. Surveillance by experts and official surveillance are complementary.

Control by the operator is based on:

- the design, layout and assessment of the installations concerned
- an up-to-date installations register
- up-to-date operating instructions and checking rules including service warnings, alarms and action plans as well as appropriate auxiliaries for incidents or accidents causing damage.

The main objective of control by the operator is to ensure that:

- the installations are safe at any time and meet the applicable requirements
- irregularities and disturbances are detected quickly and reliably
- releases of dangerous materials are detected quickly and reliably and effective measures are taken if any damage which cannot be prevented does occur, so that there are no reasons to suspect any negative effects on the environment.

Accordingly, control by the operator may involve the following tasks:

- recording of installations in an installations register which is updated on a case-by-case basis
- performance of an initial safety check, if such a check has not yet been carried out, and, most importantly, identification of those components of the installation which may pose a particular risk (weak-point analysis) such as joining elements, pumps, fittings, filling and emptying devices
- preparation and updating of operating instructions, checking plans and measuring programmes for continuous surveillance and servicing while taking into account the results of the weak-point analysis
- implementation of control by the operator according to schedule
- documentation of the results
- informing the authorities where required
- continual recording and documentation of derogations from the operation of the installation according to its intended purpose
- immediate correction of identified deficiencies
- additional commissioning of officially recognised experts within the prescribed time limits, where required by the authorities
- immediately informing all parties concerned, including the authorities, if any damage has occurred and implementation of the necessary remedial measures.

#### 4.1.2.2.1. Risk and Reliability Based Maintenance (RRM)

The application of risk-based tools for the optimisation of maintenance and inspection activities follows the trend in worldwide industry to move away from a time based maintenance approach to a condition based maintenance approach. Such risk based tools have already proven to work for static refinery equipment, e.g. installations, heat exchangers, pressure vessels, piping, etc. Recently, it has been recognised that such risk based tools are also applicable to the total maintenance approach of conventional storage tanks.

The 2003 revision of EEMUA 159, see reference [166, EEMUA, 2003], contains elaborated information on how the RRM approach and its underlying methodologies can be used within the total philosophy of tank maintenance. The RRM approach as described in this section is a tool to determine proactive maintenance plans and to develop risk based inspection plans. It is based on two existing underlying methodologies: risk based inspection (RBI) and reliability centred maintenance (RCM).

The inspection system may include the following areas:

- tank data records
- analysis of tank duty (the probability of a tank failure and consequences of failure should be established and a risk assessment carried out so that the inspection frequency matches the hazards)
- planning
- responsibility schedule
- execution
- review.

Inspection of fully refrigerated anhydrous liquid ammonia storage tanks is a compromise between a need for knowledge about the tank conditions and the negative effects of opening the tank for inspection, which will cause thermal stress and ingress of oxygen. The need for inspection and the method, type and scope of inspection, therefore, have to be evaluated dependent upon the risk and consequence of a failure. Applying RBI means that these factors can be considered and the inspection programme can be established for each individual tank. RBI is one element of an overall inspection strategy for each individual tank and application of RBI to an ammonia tank requires an evaluation of the following:

##### *Failure probability*

- operating experience
- additional stress, internal and external (settling, snow or similar)
- leak before break properties
- pipe connections
- stress corrosion cracking
- other materials degradation phenomena
- plate and weld material properties
- pre-commissioning control
- repairs
- commissioning and recommissioning procedure (inert purging, cooling rate).

##### *Failure consequences*

- single versus double wall tank
- extra external safety (bund wall or dike)
- location of the tank.

Shot peening and cathodic protection are considered to be non-proven technology for low temperature ammonia tanks and are, therefore, excluded from the RBI evaluation.



#### 4.1.2.2.2. In-service and out-of-service inspections

Inspections can be categorised as regular in-service inspections or as regular out-of-service inspections. An in-service inspection may be a simple, regular walk around the tank using a checklist (see International Codes, e.g. API RP 575, Appendix C). An out-of-service inspection is a detailed inspection of the complete tank structure using a standard checklist (see International Codes, e.g. API RP 575, Appendix C). (EEMUA N° 183, 1999) and is discussed below.

It is common to consider an inspection hierarchy with a number of levels of detail, e.g:

- routine inspections
- in-service external inspections
- out-of-service internal inspections.

During all types of inspection, particular attention is paid to areas where the storage duty or tank construction type may increase any risk of leakage. For example, insulated tanks are checked for ingress of moisture in the lagging which may increase the possibility of tank corrosion.

##### *Routine inspections*

**Description:** The operations personnel make frequent visits to the tanks under their control. They should be alert to any signs of deterioration or change to the tank or its surrounds, especially of leakage or indications of over or under pressure and of the malfunction of ancillary equipment such as drains or roof ladders. Normally, a system is in place for the operator to record these observations and to convey them to the inspection engineer for further evaluation.

Frequent observations will usually detect a rapid change of condition but are prone to miss slow changes or not to be aware of a condition that has become an accepted practice. The effects of slowly changing conditions are more likely to be observed during a dedicated inspection examination.

##### *In-service inspections*

**Description:** An in-service inspection of a tank consists basically of a review of the tank's operational and inspection history followed by a walk round the tank bund and then the tank pad before climbing the tank stairs to view the roof. The inspections are usually organised and led by the site inspection engineer but there is benefit in personnel from the site maintenance and operations groups being involved.

During the in-service inspection, the tank and ancillaries are examined to detect any signs of deterioration or change since the previous inspection. Such inspections identify potential problems before they have a chance to become serious and identify maintenance work which, when carried out early, will eliminate the need for more extensive work at a later date. The inspection also aims to detect defective safety items such as blocked vents or drains, defective stairways or breached bund walls. With a proper inspection, any leakage from the tank shell or bottom is observed and its significance evaluated. Changes in paint condition can be noticed and recorded.

The inspection normally also includes an examination of the bund wall and all equipment within the bund of the tank under review, as well as the main structure of the tank, all connecting pipework, pumps and valves, etc. To prevent accidents, the means of access to the tank should be shown to be safe. The tank roof will be viewed, including roof seals, drains, pressure/vacuum devices, roof ladders, etc. The condition of shell and roof coatings are to be assessed as well.

On many sites there are a large number of tanks to be inspected; in these situations the task is routine and can become tedious. To reduce the problems that can result from this, it is advisable that the in-service inspections follow a checklist thus giving greater assurance that all relevant features will be noticed. A suggested checklist with explanations is included in EEMUA publication 159.

Dependent upon the visual condition of the tank and its inspection history the routine inspection may be extended to include ultrasonic thickness gauging of the tank shell and acoustic emission examination of the tank floor. Both of these techniques can be applied to an in-service tank if suitable precautions are taken.

Gauging of ancillary pipework may also be carried out. Checks can be made on cathodic protection systems. It is common practice to have written confirmation that all instruments associated with the tank have been checked and are functioning as required.

Some inspection techniques are available for internal inspections from the outside, such as acoustic emission and long range ultrasonic measurements on annular plates (LORUS). These techniques, however, do not specify actual plate thicknesses of bottom plates, but may be used to prioritise tanks from a group containing the same products.

For low temperature (ammonia) storage the non-intrusive inspection technique used for the internal inspection to check on 'stress corrosion cracking' should be applicable at -33 °C.

### ***Out-of-service internal inspections***

**Description:** An out-of-service inspection is the prime means of confirming that the tank is fit to be in service for a projected period of time. It assesses the condition of the tank and ancillaries, measuring how they have performed under the service they have experienced since the previous major out-of-service inspection and identifies the work that is necessary to bring the tank back to good condition. It confirms that the tank is safe to return to service and predicts the length of time it can remain in service before another major shutdown will be required.

A major shutdown, when the tank is isolated, gas freed and cleaned for inspection and maintenance, is a significant piece of work for a site to carry out and needs to be carefully scheduled to avoid undue interruption to operations and unnecessary expenditure. EEMUA publication 159 describes a risk based approach to the development of inspection plans. The interval between inspections for any particular tank normally takes into account:

- relevant mandatory regulations
- company and industry experience of the type of tank
- the operating conditions of the tank
- the inspection and operating history of the tank.

When opened, gas freed and cleaned, the tank can be entered and the shell, roof, floor and internal drains, etc. inspected. Viewing the interior shell and roof means that there is a much better opportunity to detect local deterioration than there is during an external examination. Great attention is paid to detecting small patches or areas of deep corrosion or corrosion pitting of the shell, especially if it is in the form of vertical grooves or could subsequently extend to become a groove.

The only time that the floor can be physically examined is when the tank is clean and empty. A visual examination can be reinforced by floor scanning, using a magnetic flux core leakage or an ultrasonic device. Both of these will give information concerning the underside of the floor. The once common practice of cutting floor plates, in order to assess the condition of the underside of the floor, is not carried out by many companies. It is considered that the newer inspection tools have rendered the technique obsolete and that it presents a now unnecessary hazard.

A visual examination can confirm the validity of any diagnosis that has been made by an acoustic emission examination. The observations made and the conclusions reached during an out-of-service inspection are normally accurately recorded in a history file peculiar to the tank. This record will provide much of the information needed to determine the service time through RRM principles that defines the next major inspection.

**Operability:** Inspection types are directly related to the storage types. External shell inspections present no difficulties. Bottom inspections of vertical storage are usually executed with a tank out of service and top side only. Types of inspection modes are given in EEMUA 159/183 etc.

**Applicability:** The principle of inspection/maintenance is applicable for all types of storage.

**Safety aspects:** These are dependent on type of product, mode of storage and type of inspection/maintenance works. Entry onto, under and within floating roofs should be strictly controlled, and additional safety precautions have to be taken to avoid accidents.

**Energy/waste/cross-media:** Wastes are generated when draining, cleaning and grit blasting the tank. For fully refrigerated anhydrous liquid ammonia storage tanks it is known that opening the tanks for inspection could increase the potential for 'stress corrosion cracking'.

**Economics:** The costs involved are medium to high with a few exceptions (e.g. visual inspection).

**Reference literature:** [86, EEMUA, 1999] [175, TWG, 2003]

#### 4.1.2.2.3. Monitoring

**Description:** Another common aspect of inspections is the monitoring of diffuse emissions to air and the monitoring of leakages. The monitoring of leakages is described in Section 4.1.6.1.7.

Emissions to air from storage tanks and loading/unloading operations are usually calculated based on general emission factors. Calculation methodologies are published by API, US EPA and CEFIC/EVCM (European Council of Vinyl Manufacturers). For measuring emissions to air, the DIAL (Differential Infrared Absorption Laser) technique can be applied.

DIAL is commonly used in Sweden for monitoring VOC emissions from tanks storing hydrocarbon products at refineries and oil terminals. Results in Sweden have shown that calculated emissions underestimate measured emission values to a great extent, by a factor of 2 – 5. However, reference [16, Concawe, 1995] states that the differences between calculations and measurements are within 10 %.

**Applicability:** Calculation methodologies are commonly applied. DIAL is not commonly applied, because in Europe only a limited number of DIAL facilities capable of detecting a wide spectrum of hydrocarbons exist.

**Economics:** Calculation methodologies represent low cost. DIAL represents very high cost (approximately EUR 100000/week) due to its complexity.

**Reference literature:** [16, Concawe, 1995] [178, Länsstyrelsen Västra Götaland, 2003] [158, EIPPCB, 2002]

#### 4.1.2.2.4. Gas detection techniques

**Description:** In addition to general inspection techniques, some specific gas-leak detection techniques exist as gas detection systems (either manually by ‘sniffers’ – e.g. Drager tubes – or automatically). Gas detection systems are not a means of preventing leakage but are a safety feature.

Liquid leak detection systems are described in detail in Section 4.1.6.1.7.

**Operability:** The principle of monitoring is applicable for all storage tanks.

**Applicability:** The principle of monitoring is applicable for all types of storage.

**Safety aspects:** Dependent on type of product, mode of storage and type of inspection.

**Energy/waste/cross-media:** None.

**Economics:** Depending on the technique, monitoring costs vary greatly. Visual inspection and the use of ‘sniffers’ is at the lower end of the scale.

#### 4.1.2.3. Location and layout

**Description:** The location and layout of a storage installation have to be selected with care. Tanks may be located aboveground, underground or in mounds. Each location has different advantages and disadvantages. Storage at ground level, in the open air, has advantages because leaks are more readily detected and contained and any vapour produced will normally be dissipated by natural ventilation. Examinations, modifications and repairs are also easier and corrosion can be more readily identified and controlled. However, underground or mounded tanks give better fire protection, save space and have less emissions from tank breathing.

For tanks containing flammable liquids or liquefied gases it is important that they are sited in a well-ventilated position separated from the site boundary, occupied buildings, sources of ignition, loading and unloading activities and process areas. For safety reasons, the layout of the tanks should always take into account the accessibility needed for the emergency services.

Separation is an important means of providing protection for tanks containing flammable liquids or liquefied gases. Separation has particular advantages because not only does it protect people and property from the effects of a fire at the tank, but it also protects the tank from fires which may occur elsewhere on-site. In Annex 8.18 – Examples of applied distances for the storage of flammable liquid in tanks, applied in the Netherlands and UK are shown.

Under certain circumstances it may be necessary to increase the separation distances or provide additional fire protection. Such circumstances may include:

- where there are problems with the local (fire) water supply
- where the site is remote from external help
- where the tank is close to a heavily populated area.

For the storage of liquid chlorine (pressure or low pressure) in an aboveground tank, a safe distance of 25 m from public roads or main railway lines, to eliminate the risk of damage to the storage in the event of an accident, is reported. The distance from the boundary of the factory is 10 m and a sufficient distance between adjacent stock tanks is required to give good access to the vessels.

In the UK, the minimum recommended separation distance from any underground tank to any building line is at least 2 m to avoid undermining the building foundations, and it is thought advisable to increase this distance to 6 m for a basement or pit to minimise the risk of vapour accumulation. In the Netherlands the distance of 0.75 m from a tank to a building is thought to be sufficient and the recommended distances between two underground tanks is at least 1/3 of the diameter of the largest tank. This example shows the different approaches in the MS.

**Reference literature:** [18, UBA, 1999] [37, HSE, 1998] [1, CPR, 1993, 37, HSE, 1998] [50, EuroChlor, 1993, 51, EuroChlor, 1996]

### 4.1.3. ECM for tanks – operational – gas emissions

#### 4.1.3.1. Emissions minimisation principle in tank storage

**Description:** The principle of ‘emissions minimisation in tank storage’ is that – within a certain time frame – all emissions from the tank storage, transfer and handling will be abated before they are emitted. This includes the following emissions arising from normal operational activities and from incidents:

- emissions to air
- emissions to soil
- emissions to water
- energy consumption
- waste.

**Achieved environmental benefits:** Unabated operational emissions from the tanks and from transfer and handling are negligible. However, unabated emissions from incidents and (major) accidents could still occur.

**Operability:** For soil, the aim is that new pollutions will be avoided and that existing pollutions will not pose any risk to the environment. Existing pollutions have to be controlled or removed to prevent further dispersion. To avoid emissions, organisational measures and proper technical measures have to be applied to tanks with a potential risk for new soil pollutions.

For water, the aim is to not discharge unabated waste water and to reduce the use of water. Prevention has priority over later treatment and can be achieved by:

- technical measures to prevent waste water arising
- organisational measures, training of personnel, implementing an environmental management system
- additional measures for problematic substances
- providing sufficient storage capacity for contaminated fire water.

For waste, the aim is to first prevent any waste arising but to recycle or re-use any waste that does arise. This can be achieved by organisational measures and optimising the maintenance regime. Technical measures include, e.g. efficient stripping and (grit) blasting of tanks.

For energy, the aim is to reduce the use of energy. Possible measures include the use of low energy equipment, the re-use of waste heat, utility sharing and the appropriate training of personnel. However, applying waste water treatment facilities or vapour recovery systems might increase the use of energy.

For measures that can be applied to prevent or abate emissions to air, safety considerations might impose restrictions on possible emission reduction.

**Applicability:** The ‘emissions minimisation in tank storage’ principle has been developed for tank terminals, but is also applicable to tank storage in general.

**Energy/waste/cross-media:** All media are considered.

**Economics:** This strongly depends on the prevention and reduction measures currently applied.

**Reference literature:** [159, DCMR/VOPAK, 2000]

#### 4.1.3.2. Floating covers

**Description:** Floating covers are applied to open top tanks, basins and lagoons to prevent vapours and particularly odours being emitted to the atmosphere. The types of covers normally fitted into vertical fixed roof tanks are described in Section 4.1.3.10.

For open top tanks, different types of floating covers are available, such as:

- light gravel
- straw
- peat
- rapeseed oil
- plastic pellets
- blankets and foil.

**Operability:** Inspection underneath may present difficulties. Maintenance during operation is usually not possible.

**Applicability:** Although the results from using floating covers vary widely, they are generally good enough to make their application to slurry tanks an attractive option. The following observations from tests were reported:

##### *Rape oil*

Rape oil (or derivations with high percentages of rape oil) is very easy to apply and does not mix easily with pig slurry. However, it is biodegradable, loses its surface integrity with time and greatly increases methane emissions. Material that floats well and does not have to be added every year may have the disadvantage of being blown away and may need an additional cover. Very low-density minerals absorb water, are rapidly blown away by wind or are dusty and unpleasant to use. An example is expanded polystyrene (EPS).

##### *Light expanded clay aggregate (LECA)*

LECA is suitable for tanks and lagoons. LECA granules are heavier than EPS. Observations were reported that it tends to sink to the bottom of the store and has to be added again, but other sources do not report this. Because of its higher density, however, LECA does not have its entire layer floating on top of the slurry surface. To get LECA in place and evenly distributed may be difficult with large tanks and lagoons and could be achieved by mixing it with water or slurry and pumping it onto the surface.

Peat mixes with slurry during stirring, becomes waterlogged and has to be renewed after each stirring. However, peat is a natural product and does not create a waste problem.

The filling outlet should be very close to the bottom of the tank to avoid clogging.

**Safety aspects:** There is a potential risk in building up high concentrations of hazardous and noxious vapours immediately below the surface.

**Energy/waste/cross-media:** The primary objective for covering manure slurry has been the reduction of odour, but evaporation of ammonia is reduced at the same time. Other effects due to a reaction between a floating cover and slurry may increase emissions of methane (rape oil by about 60 %). In the case of rapeseed oil, anaerobic reactions may produce surfaces with a strong, rancid odour.

**Economics:** A medium to low cost option. Costs for floating sheets for open top tanks with diameters of 15 – 30 m are reported to range from EUR 15 – 36/m<sup>2</sup> (year 1999). Costs of LECA are EUR 225 – 375 per tonne (year 1999). Costs of other floating covers have not been reported.

**Reference literature:** [119, EIPPCB, 2001] [113, TETSP, 2001]

#### 4.1.3.3. Flexible covers or tent covers

**Description:** Open top tanks can be covered with flexible covers or tent covers which have a central supporting pole with spokes radiating from the top. A fabric membrane is spread over the spokes and is tied to a rim-bracing. This is a circular pipe that is located on the outside around the circumference just below the top of the store. By evenly spaced vertical straps between rim-bracing and the tent-rim, the cover is tightened over the store.

Pole and spokes are designed to withstand wind and snowloads. Vents are applied to release gases that build up under the cover and the cover is further applied with an opening for an inlet pipe and a hatch that can be opened for inspecting the store's contents.

**Achieved environmental benefits:** In covering a manure slurry store, reductions of ammonia emissions of 80 – 90 % have been reported.

**Operability:** Tent covers can be fitted to existing concrete stores with diameters of under 30 m without modifications, but a technical survey is recommended beforehand.

With the storage of manure slurry, the development of H<sub>2</sub>S may cause corrosion that affects the construction.

**Applicability:** From a UK survey amongst farms, it appeared that tent type covers can be applied to 50 – 70 % of existing steel type stores with modest modifications, if these consist of fitting an additional stiffening angle strip around the rim of the store. It is important to calculate the required strength of the construction to withstand wind and snowloads for both store and store with cover. The larger the diameter, the more difficult the application will be, as the cover must be evenly taut in all directions to avoid uneven load.

**Safety aspects:** Development of toxic gases may occur. They may not have environmental relevance, but must be considered for safety reasons.

**Energy/waste/cross-media:** Development of gases under closed (plastic) covers is common, hence the necessity for vents. The gases may be used in a biogas installation, but efficiency and economics depend largely on factors such as daily gas production, distance to biogas installation and use.

**Economics:** Cost for tent covers for stores with diameters of 15 – 30 m have been reported to be about EUR 54 – 180/m<sup>2</sup> (1999).

**Reference farms in EU:** Applications have been reported in the UK.

**Reference literature:** [119, EIPPCB, 2001]

#### 4.1.3.4. Fixed/rigid covers

**Description:** Rigid covers are tight concrete covers or fibreglass panels with a flatdeck or conical shape. They fully cover the product surface, preventing rain and snow from entering. If the cover is made of lighter material, the span can be larger than for concrete covers exceeding 25 m and can have a central support. The use of rigid covers permits emissions to be collected and treated; see Section 4.1.3.15.

**Achieved environmental benefits:** In the storage of pig slurry, the effect on the emissions is not clear. Dilution of manure occurs in uncovered manure pits due to rain lowering contents of solid matter and nutrients. Differences in nitrogen content in covered and uncovered stores were reported to be small and thus there is doubt whether a solid roof would affect the evaporation of ammonia. Emission reductions of 95 – 98 % have been reported.

**Operability:** Covering of small stores is more general than covering of large ones.

**Applicability:** Rigid covers are usually installed at the same time as the store. Retrofitting it to an existing store is reported to be expensive. The minimum life of these covers is 20 years.

**Energy/waste/cross-media:** Development of toxic gases may occur. They may not have an immediate environmental relevance, but must be considered for safety reasons.

**Economics:** Cost indications were reported in a farm survey, carried out in the UK. For concrete stores with diameters of 15 – 30 m storing pig slurry, the cost range is EUR 150 – 225/m<sup>2</sup> (year 1999). For rigid covers made of glass fibre-reinforced plastic (GRP) costs range between EUR 145 and 185/m<sup>2</sup> (year 1999).

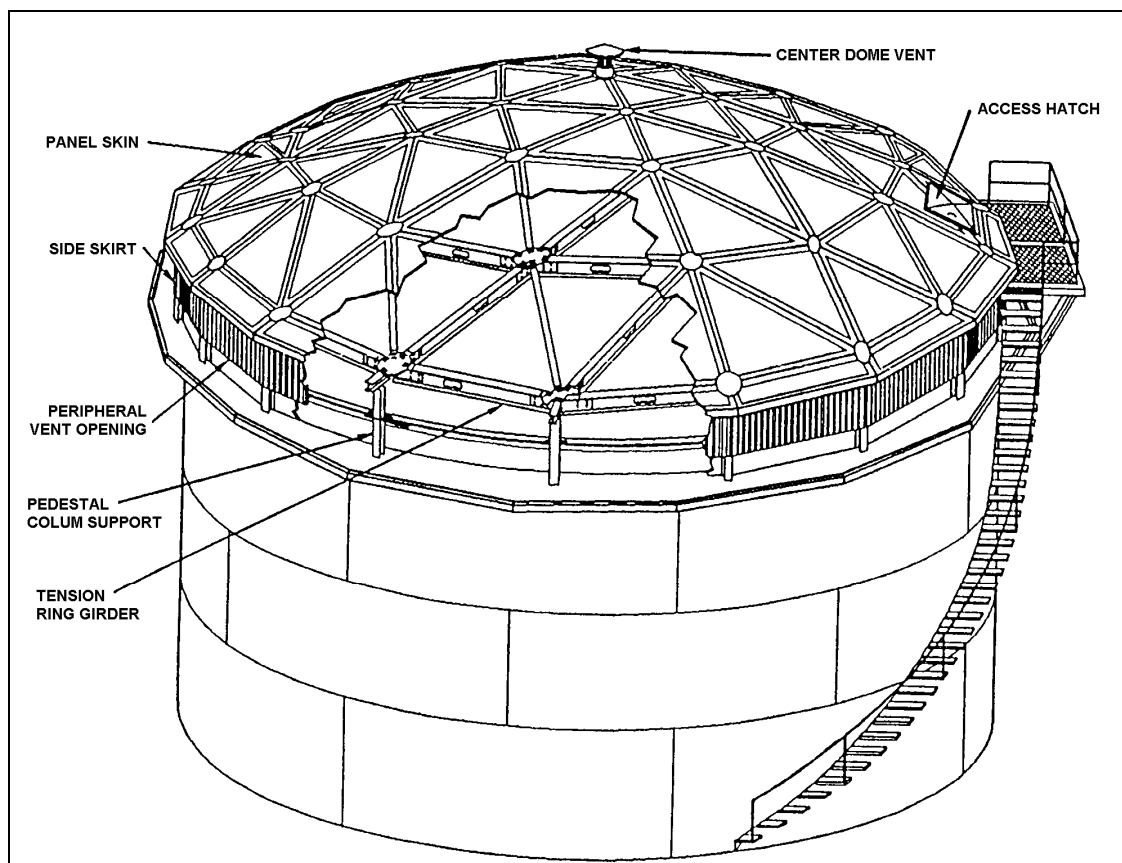
**Reference literature:** [119, EIPPCB, 2001]

#### 4.1.3.5. Domes

**Description.** Retrofitting an EFRT with a fixed or domed roof will reduce the emissions into the air. The typical aluminium (geodesic) dome roof structures, introduced in the mid 1970s as weather covers over water treatment facilities, are now also used for some storage tanks in the petrochemical industry. In addition to the prevention of snow accumulation on top of floating roofs, it was realised that dome roofs are also advantageous in the prevention of rainwater accumulation. The elimination of wind on top of the floating roof is another important feature.

The aluminium geodesic domes are generally available in a range from approximately 6 m up to 80 m diameter. The dome is, in general, composed of prefabricated aluminium I-shaped beams and panels. The beams are linked/bolted together, forming triangular spaces, which are closed by the pre-cut aluminium panels clamped on top of the beams. The domes can be prefabricated within the tank and lifted into position or assembled outside the tank and lifted into position by a crane. However, the diameter/size of the dome is then limited by the available crane capacity. The dome structure requires a tension ring to handle the outward radial thrust. This tension ring can be either integrated with the primary wind girder at the top of the tank shell or as integral section of the dome structure itself. The latter (self supporting dome) is the most cost effective solution and does not require a lot of hot work on the tank shell. Special care has to be taken when domes are installed without a tension ring to ensure that the tank shell top section has adequate horizontal support.





**Figure 4.1: External floating roof tank equipped with a geodesic aluminium dome**  
[166, EEMUA, 2003]

**Achieved environmental benefits:** The emission reductions (estimated using the EPA AP-42 method) achieved in an EFRT case study is given in Annex 8.13.1. For the conditions of product, tank size, wind speed, etc. considered, the installation of a dome achieved an estimated reduction in emissions of 93 %. The effectiveness of a dome primarily depends on the average annual wind speed and the existing rim seal system installed, and is thus site-specific.

**Operability:** The confined space presents difficulties in access for, e.g. maintenance of the dome and the floating roof (former EFR). The actual emission reduction depends on the effectiveness of the seals fitted on the existing floating roof.

**Applicability:** The construction of a dome on an existing tank usually requires design review and modification of the tank. On larger tanks the construction of a dome is even more difficult.

**Safety aspects:** A dome introduces the potential for a flammable atmosphere between the floating roof and the dome and makes fire fighting very difficult. The confined space gives rise to entry and escape problems.

**Energy/waste/cross-media:** None.

**Economics:** Installing a dome is a high cost option, particularly in retrofit. Significant costs are involved on a site-specific basis.

**Reference literature:** [84, TETSP, 2001] [113, TETSP, 2001]

#### 4.1.3.6. Tank colour

**Description:** The tank colour influences the amount of thermal or light radiation absorbed by aboveground tanks and, therefore, the temperature of the liquid and vapour contents inside. This measure is applicable for all types of aboveground tanks. The impact of the tank colour is limited if the tank is already fitted with a floating roof.

For storage tanks in a ship (floating storage) painting the ship deck, which is the tank top, in a light colour also reduces the amount of absorption of thermal or light radiation.

**Achieved environmental benefits:** Table 4.1 shows the paint factors used in the aboveground atmospheric storage tank loss equation as given in AP-42.

Paint colour	Paint shade or type	Paint factor good condition	Paint factor poor condition
Aluminium	Specular	0.39	0.49
Aluminium	Diffuse	0.60	0.68
Grey	Light	0.54	0.63
Grey	Medium	0.68	0.74
Red	Primer	0.89	0.91
White	N/A	0.17	0.34

**Table 4.1: Paint factors**  
[41, Concawe, 1999], with reference to EPA AP-42

Table 4.2, from reference VDI 3479 (Verein Deutscher Ingenieure), shows the heat radiant reflectance percentage of different colours on tanks.

Denomination of the colour	Heat radiant total reflectance, %
Black	3
Machine grey	10
Browne	12
Mouse grey	13
Green	14
Blue	19
Silver grey	27
Pebbly grey	38
Red	43
Light grey	51
Ivory coloured	57
Alu-silver	72
Cream white	72
White	84

**Table 4.2: Heat radiant reflectance of different tank colours**  
Source: VDI 3479 Emission control: Marketing Installation Tank Farms

From these tables, it can be concluded that a white painted tank has the lowest emission level compared with other paint colours.

The emission reductions (estimated using the EPA AP-42 method) achieved with changing tank paint colour in five case studies are given in Annex 8.13. For the range of tank types, sizes, turnover, thermal or light radiation, products, etc. considered, the reduction potential for changing the tank colour from medium grey to white for a base case tank (i.e. with no other ECM installed) is in the range of 15 – 82 %. This shows that the effectiveness is very specific to the storage conditions, and in particular to the amount of thermal or light radiation and number of tank turnovers.

**Operability:** Requires maintenance for visual impact issues.

**Applicability:** Widely applicable, also for tanks on a ship (floating storage). Stainless steel would not require painting as an ECM.

**Safety aspects:** None.

**Energy/waste/cross-media:** Wastes, such as grit blast and paint containers during and after application have to be disposed of. Paint based on organic solvents generate VOC emissions during application.

**Economics:** As part of the repainting schedule, painting the tank in another colour with higher heat reflectance properties is a low cost ECM. Additional costs are incurred if undertaken outside of the maintenance cycle of the tank.

**Reference literature:** [41, Concawe, 1999] [87, TETSP, 2001] [113, TETSP, 2001] and VDI 3479

#### 4.1.3.7. Solar shields

**Description:** A rather new development is the application of sunscreens or sunshields around vertical storage tanks. This technique has been used on horizontal liquefied gas tanks. This approach focuses mainly on the idea that one will reduce/prevent an increase in temperature of the vapour/product within the tank and this in turn will lead to the potential for lower emissions. The shields are positioned to minimise the solar impact onto the roof and shell of the tank. There is some space left between shield and tank.

**Achieved environmental benefits:** The emission reductions (estimated using the EPA AP-42 method) achieved by installing solar shields in two case studies are given in Annex 8.13.4 and Annex 8.13.5 respectively. For the two FRT sizes considered, the reduction potential for installing a solar shield for a base case tank (i.e. with no other ECM installed and with a mid grey tank) is in the range of 44 – 49 %. The effectiveness would have been decreased if the tanks had been painted white.

**Operability:** Only a viable option for smaller storage tanks. Inspection under the solar shield can be difficult. The shields require very low maintenance.

**Applicability:** Only currently used for small tanks or vessels in areas of high solar incidence. Restricted access onto the shield may be required if a lightweight material or construction method has been used. In addition, access between the shield and the tank should be restricted because of the possibility of vapour being present in a semi-enclosed, poorly ventilated atmosphere, which can cause accidents.

**Safety aspects:** To avoid accidents, the area underneath needs to be well ventilated and access to the shield should be restricted.

**Energy/waste/cross-media:** None.

**Economics:** The costs vary greatly depending on size and construction. Low cost materials could be used for the shield itself.

**Reference literature:** [113, TETSP, 2001]

#### 4.1.3.8. Natural tank cooling

**Description:** To run a storage tank with low liquid temperatures is an important measure of emission prevention, especially when storing mixtures of hydrocarbon liquids with high portions of lightweight molecules, such as gasoline, naphtha or crude oil.

In order to keep the storage temperature under a certain limit, also during summer conditions, it is advantageous to use all natural possibilities for cooling the tank. Floating roof tanks do have the best chance of keeping the liquid temperature at a low level, as there is no heated-up air volume between a tank roof and the stored liquid. Furthermore, it is advantageous to keep a certain quantity of rainwater on top of the floating roof during the summer period. Evaporation of this water will result in lower storage temperatures and lower emissions.

Together with the use of solar shields (see Section 4.1.3.7), cooling with water films or water sprays are possibilities to reduce the product temperature and the emissions. These and other possibilities of passive emission prevention are not yet used to their maximum.

**Operability:** Industry is reluctant to apply natural cooling. They try to keep EFRs clear of water to minimise corrosion, but more importantly to minimise the risk of the roof sinking due to rainwater accumulation during storms. Also, although water cooling is acceptable on fixed roof tanks as an emergency measure, the increased corrosion and resultant maintenance due to operating a tank for long periods with a water deluge in operation, is considered unacceptable for the operator particularly if brackish or saline water is used.

**Energy/waste/cross-media:** The use of water may be unacceptable in regions with a shortage of fresh water, especially in summer periods, e.g. Southern Europe.

**Economics:** An increase in costs will occur because the tank needs to be inspected more frequently.

**Reference literature:** [113, TETSP, 2001] [114, UBA, 2001] [175, TWG, 2003]

#### 4.1.3.9. Roof seals for external and internal floating roofs

##### 4.1.3.9.1. Rim seals

**Description:** The rim seal system is designed to fill the gap between the outer pontoon of the floating roof and the tank shell (rim space) and, therefore, minimise emissions to air. All EFRs have such a seal as part of their construction to prevent vapour egress to the atmosphere and this is called the primary seal. To reduce emissions even further, a secondary seal can be mounted above the primary seal. New seal designs are available with integrated primary and secondary seals. Here, the working elements of independent primary and secondary seals are integrated into one construction, with one or two sealing curtains connected to the floating roof.

The effectiveness of a seal is dependent on the 'roundness' of the tank. This depends primarily on the settlement of the tank and hence upon the tank foundation design (see Section 4.1.2.1)

##### *Primary seals*

The three basic types of primary seals used on external floating roofs are:

- vapour mounted, see Figure 4.2
- liquid and foam mounted, see Figure 4.3
- mechanical (metallic) shoe, see Figure 4.4.

Some primary seals on external floating roofs are protected by a weather shield. Weather shields may be of metallic, elastomeric, or composite construction and prolong the life of the primary seal by protecting the primary seal fabric from deterioration due to exposure to weather, debris and sunlight. Weather shields are less effective than rim mounted secondary seals in reducing emissions, primarily due to the unsealed radial joints.

Two types of materials are commonly used to make the wipers. One type consists of a cellular, elastomeric material tapered in cross-section with the thicker portion at the mounting. Rubber is a commonly used material; urethane and cellular plastic are also available. All radial joints in the blade are joined. The second type of material that can be used is a foam core wrapped with a coated fabric. Polyurethane on nylon fabric and polyurethane foam are common materials. The core provides the flexibility and support, while the fabric provides the vapour barrier and wear surface.

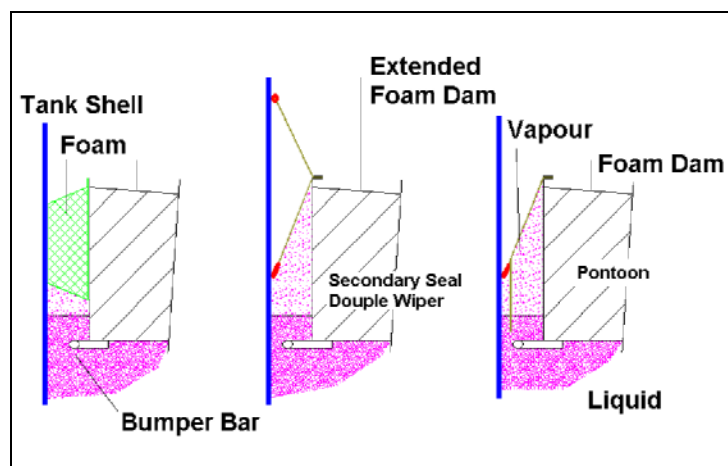


Figure 4.2: Vapour mounted seals (typical)  
[84, TETSP, 2001, 166, EEMUA, 2003]

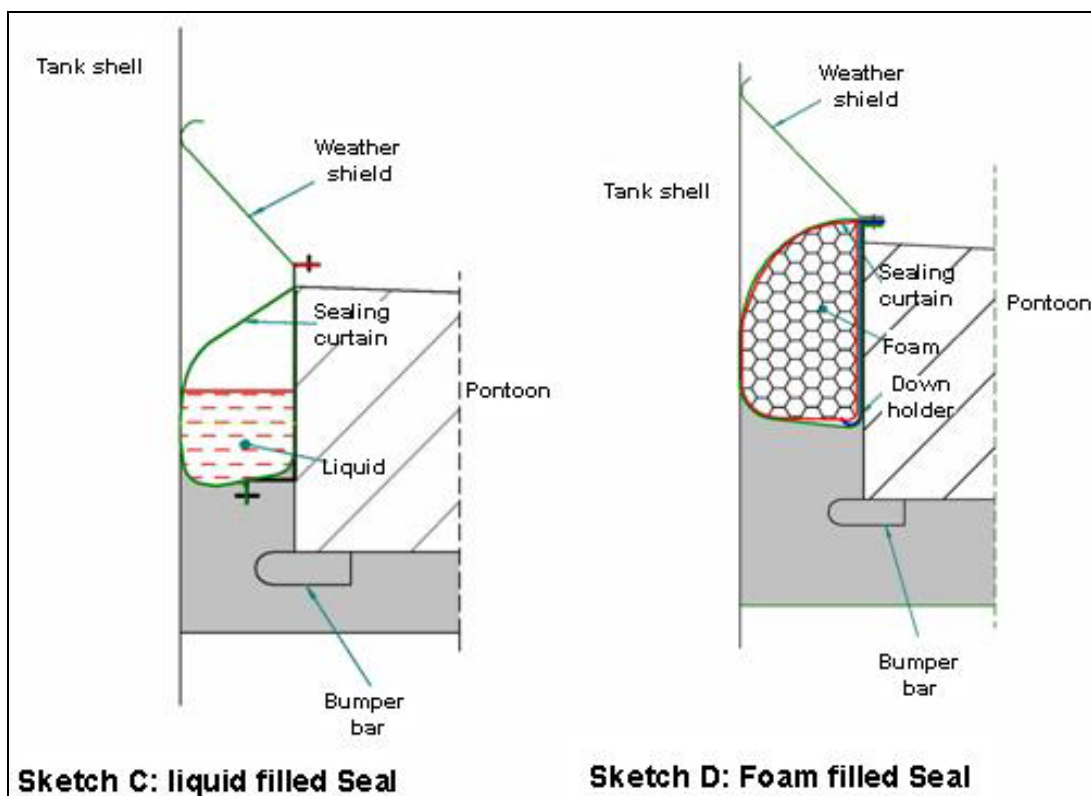


Figure 4.3: Sketches of a liquid mounted seal (left) and a foam mounted seal (right)  
[185, UBA Germany, 2004]

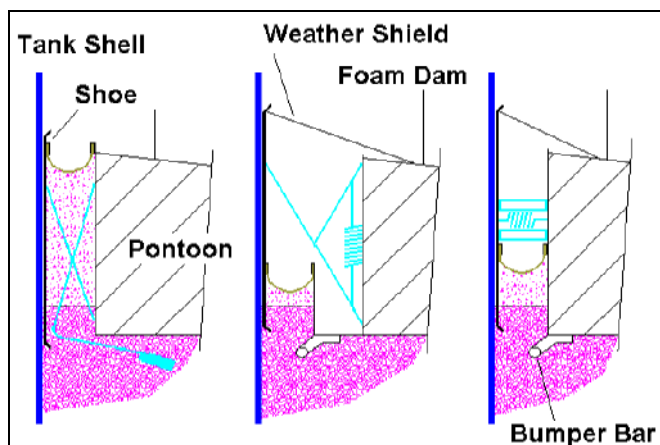


Figure 4.4: Liquid mounted mechanical shoe seals (typical)  
[84, TETSP, 2001, 166, EEMUA, 2003]

### Secondary seals

Secondary seals can be flexible wiper seals or resilient filled seals. For external floating roof tanks, two configurations of secondary seals are available: shoe mounted and rim mounted, as shown in Figure 4.5. Rim mounted secondary seals are more effective in reducing losses than shoe mounted secondary seals because they cover the entire rim vapour space. The mechanical shoe design is more durable.

For some external floating roof tanks, however, using a secondary seal further limits the tank's operating capacity because of the need to keep the secondary seal in contact with the tank shell when the tank is filled. However, the integrated seal designs have reduced working heights and have almost no effect on the tank's operating capacity.

Secondary seals with water absorbing contact elements are available. The retailer claims that these seals can drain off all rainwater from the inner tank wall. The application of such seals, however, is limited to the storage of 'white' products (semi-refined or refined products without paraffin wax). This allows water sensitive products to be stored in floating roof tanks. At the same time, discharge from the tank bottom and corrosion of the tank bottom is substantially reduced.

Assuming all seals are in good condition, mechanical shoe and liquid mounted resilient filled seals offer better control of emissions to air, as reflected by the API derived rim seal loss factors.

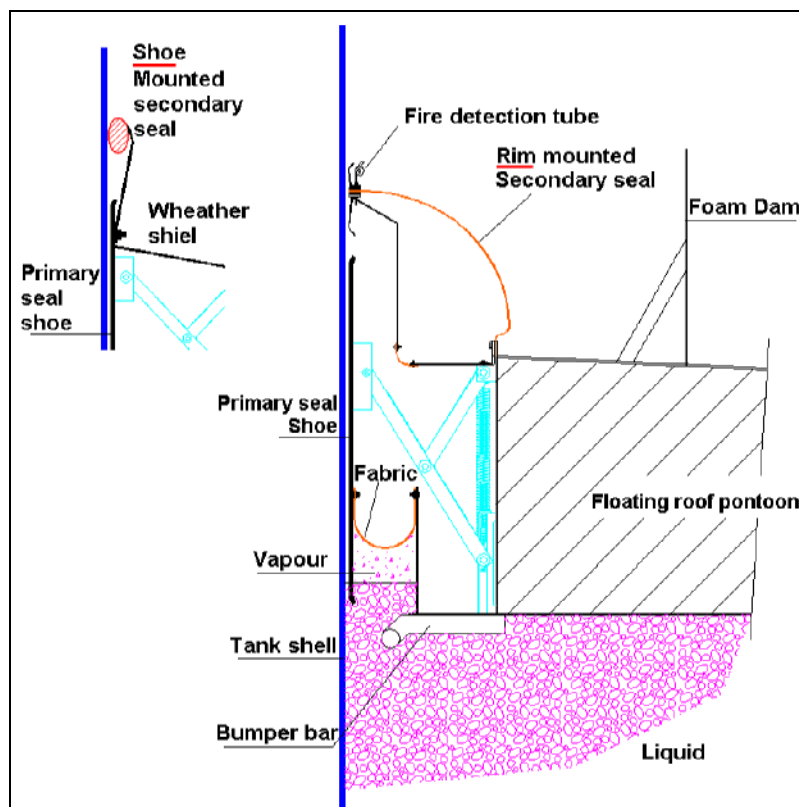


Figure 4.5: Liquid mounted mechanical shoe seal with a shoe mounted and a rim mounted secondary seal (typical)  
[166, EEMUA, 2003]

**Achieved environmental benefits:** For EFRs, an emission reduction of at least 97 % can be achieved (compared to a fixed roof tank without measures) when over at least 95 % of the circumference the gap between roof and wall is less than 3.2 mm and the seals are liquid mounted, preferably of the mechanical shoe type.

The emission reductions (estimated using the EPA AP-42 method) achieved by installing different types of roof seals in five case studies are given in Annex 8.13. For the EFRT considered, the incremental reduction potential for changing from a vapour mounted primary seal to a liquid mounted primary seal was 84 %. There was a further 5 % increase in emission reduction potential by fitting a rim mounted secondary seal.

By installing liquid mounted primary seals and rim mounted secondary seals to an external floating roof tank storing crude oil and which has, on average, 12 turnovers a year, a reduction in air emissions of up to 99.5 % can be achieved, compared to a fixed roof tank without measures.

For the four fixed roof tank case studies, the incremental emission reduction potential by changing from a vapour mounted primary to a liquid mounted primary seal if an internal floating roof (IFR) is installed is very small. The incremental emission reduction potential estimated for a secondary seal on the IFR is also small.

The API (American Petroleum Institute) has carried out generic testing for emissions from EFRTs based on the following combinations of seals: mechanical shoe seal, resilient filled seal (both vapour mounted and liquid mounted), along with combinations of these seals with rim mounted secondary seals. The testing concluded that utilisation of a liquid mounted primary seal (e.g. metallic shoe seal, or liquid mounted resilient filled seal) in combination with a rim mounted secondary seal provided a significant reduction in emissions when compared to primary seals alone. For more detailed information see the API Manual of Petroleum

Measurement Standards Chapter 19.1 and 19.2 (formerly API standard API 2517 and API 2519). In Annex 8.22, the performances of different seal systems, according to this API manual, are shown in a graphic.

The efficiency of an EFR is very dependent on the product that is stored, the turnover rate per year and the diameter of the tank. In Annex 8.20, calculations of efficiencies, according to the above mentioned API manual, are shown for different tank sizes and a variable number of filling actions when storing gasoline, and in Annex 8.21, the same calculation is shown, but now comparing the efficiency of the EFR when storing gasoline with the efficiency when storing crude oil.

**Operability:** For EFRTs, seals are easy to operate and install but cause potential problems for the inspection of seal gaps and the condition of primary seals. As the seal adds 'height' to the roof, it lowers the usable capacity of the tank.

For IFRs, there are difficulties in inspecting and maintaining primary seals. These are made worse by the installation of secondary seals.

Replacement of secondary seals on EFRTs is necessary about every 10 years, although the period of replacement strongly depends on the condition of the tank shell, atmospheric conditions and quality of seal material.

The choice of seal type is related to the reliability of the seal, e.g. shoe seals are preferred for longevity and, therefore, for high turnovers.

**Applicability:** Widely applicable. However, there is not much practical experience with secondary seals with water absorbing contact elements.

The European Parliament and Council Directive 94/63/EC of 20 December 1994 on the control of volatile organic compound emissions resulting from the storage of petrol and its distribution from terminals to service stations, requires, amongst others, that tanks with external floating roofs must be equipped with a primary and a secondary seal.

In the Netherlands, the condition for when to apply an EFR that can achieve an emission reduction of at least 97 % is when the substance has a vapour pressure of 1 kPa (at 20 °C) and the tank has a volume of  $\geq 50 \text{ m}^3$ . However, this is not valid for toxic volatile substances, for which the tank needs to be connected to a vapour treatment installation and a type of tank that is compatible with such a treatment installation is, therefore, required.

In Germany, the TA Luft requires for new installations and for substances with a vapour pressure of more than 1.3 kPa (at 20 °C) or specifically classified substances (see Section 4.1.3.15.), that points of emissions should be connected to a vapour treatment installation, a vapour collection pipe or a vapour recovery unit. However, crude oil to be stored in storage tanks with a volume of more than 20000  $\text{m}^3$  may also be stored in a floating roof tank sealed effectively at their edges or in fixed roof tanks with an internal floating roof if emissions are reduced by at least 97 % as compared to a fixed roof tanks without an internal floating roof. Furthermore, a floating roof can also be used in existing installations, provided that the tank contains no substances from the carcinogenic/mutagenic/reproductive-toxic category and the emission reduction efficiency should be at least 97 %.

**Safety aspects:** The risk of fire is minimised by installing an adequate earthing of the tank roof. Fire fighting foam shields, which are only applied on EFRTs, will be needed to help douse any rim fires. Access for maintenance and inspection will require confined space precautions.



**Energy/waste/cross-media:** Secondary seals reduce water ingress into the tank, thus decreasing tank draining and the associated emissions from waste water treatment systems. For tanks containing ‘white’ products, secondary seals with water absorbing contact elements are claimed by the retailer to offer the following advantages:

- no damage of the stored liquid by rainwater
- no water drainage from the tank bottom is required
- reduced corrosion of the tank bottom
- reduced quantities of spoiled water with necessity of waste water treatment.

**Economics:** Generally low to medium cost. For EFRTs, the value of emissions savings alone sometimes offers little incentive to change to secondary seals but, when a seal requires replacement, the additional cost of fitting secondary seals is usually justified. Besides this, secondary seals not only generate a reduction of emissions to air, but also offers other advantages – as mentioned above – that will save costs in, e.g. maintenance or waste water treatment.

However, adding a secondary seal to an IFR is not economically viable and adds major inspection problems.

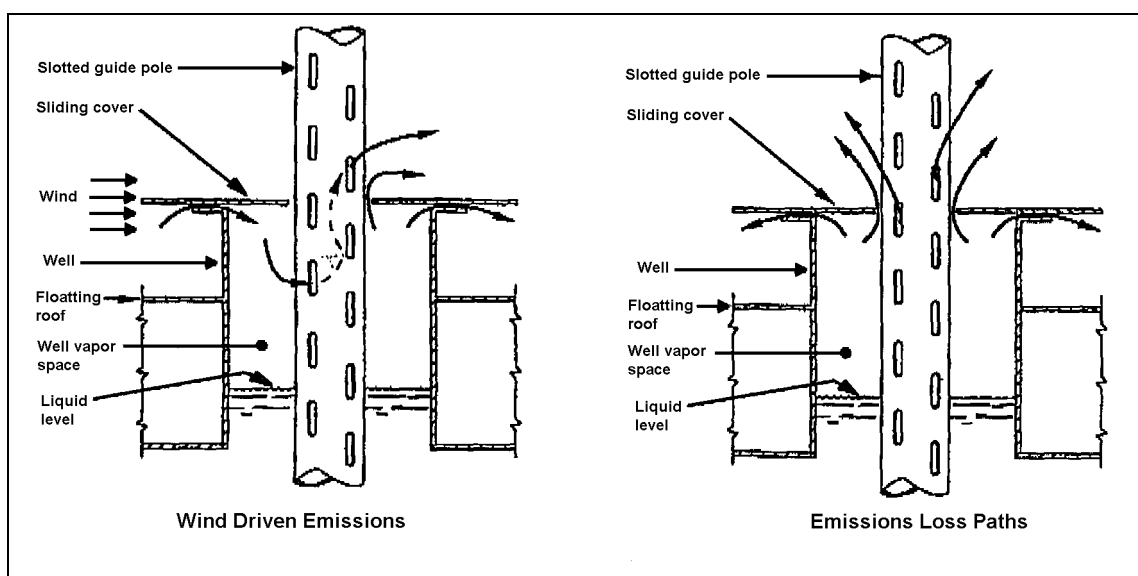
**Reference literature:** [113, TETSP, 2001] [114, UBA, 2001] [41, Concawe, 1999] [66, EPA, 1997] [131, W-G Seals Inc., 2002] [58, KWS2000, 1991] [87, TETSP, 2001] [175, TWG, 2003]

#### 4.1.3.9.2. Still wells and guide poles

**Description:** Emissions can occur through fittings on both floating and fixed roof tanks where there are pathways for vapours to escape. Such fittings are slotted still wells and roof legs on EFRTs. Details of emission controls for these fittings are given below.

##### *Slotted still wells*

Still wells using large size well openings are a major source of emissions on tanks with a floating roof. With products such as gasoline, slotted still wells give rise to emissions of several tonnes per year depending on the wind speed conditions experienced at the site. Figure 4.6 shows the wind-escalated emissions and normal emissions, including their pathways.



**Figure 4.6: Emissions from still wells**  
[41, Concawe, 1999]

Figure 4.7 shows a typical design of still wells, which incorporates the following features:

- **well gasket:** a gasket which seals the gap between the sliding cover and the fixed covers on the guide pole well. The sliding cover permits a degree of movement for the tank roof
- **pole sleeve:** the sleeve is attached to the sliding cover and surrounds the guide pole extending downward into the liquid product, thereby creating a barrier between the well vapour space and the guide pole
- **pole wiper:** this is a rubber seal attached to the top of the sliding cover and extending over the annular gap between the guide pole and the sleeve. The wiper not only eliminates losses through the gap, but also reduces the amount of stock clinging to the pole, during times when the tank level is lowered, by wiping the outside of the guide pole, reducing the tank working losses
- **float and float wiper:** this combination will reduce the emissions from inside the still well.

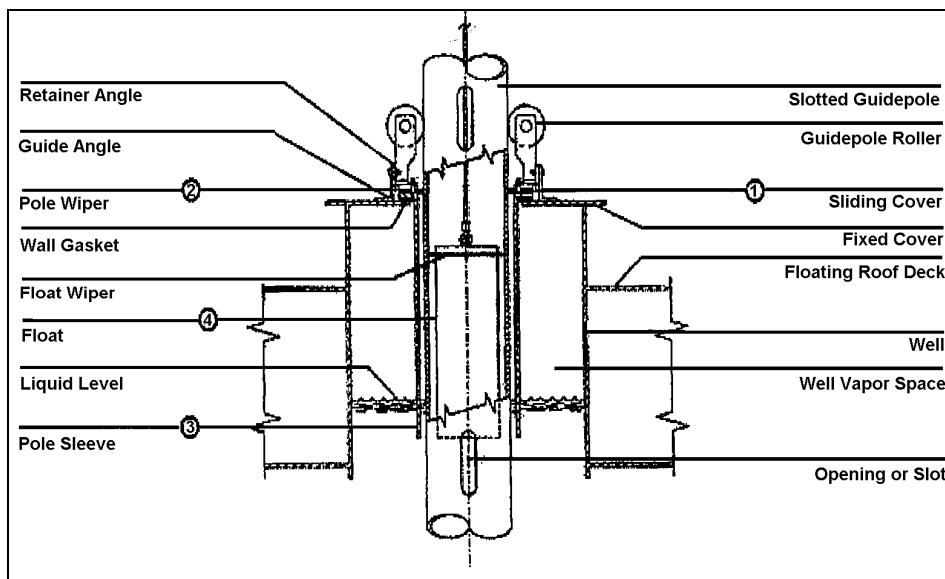


Figure 4.7: Design for emission reduction from still wells  
[41, Concawe, 1999]

Other still well controls have been developed, an example of which is shown in Figure 4.8 consisting of a fabric sleeve on the outside.

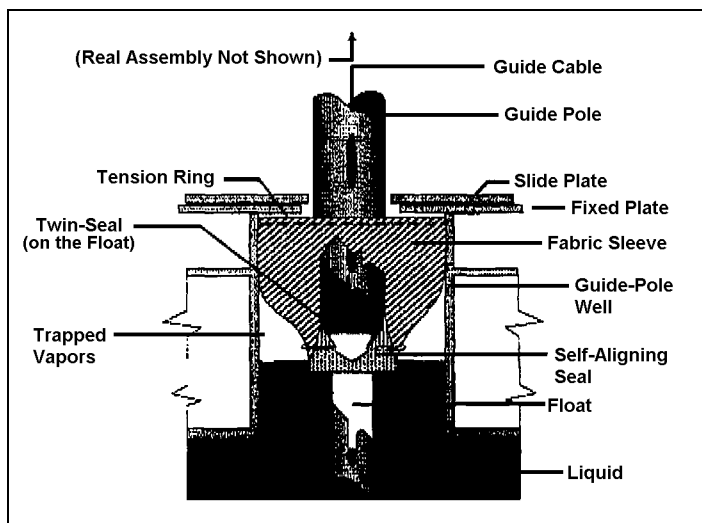


Figure 4.8: Design with fabric sleeve for emission reduction from still wells  
[41, Concawe, 1999]

**Roof support legs**

Support leg emissions are individually relatively low compared to those from other tank roof fittings. Bagging of legs can be achieved cheaply using rim seal material. A cheaper alternative, but perhaps only temporary, would be to tape up all the gaps on the legs. These techniques could virtually eliminate this source of emission. Like other control measures, their effectiveness relies on regular inspection, and in the case of support legs, this can usually be carried out visually.

**Achieved environmental benefits:** The emission reductions (estimated using the EPA AP-42 method) achieved in an EFRT case study are given in Annex 8.13.1. When different ECM were added to the base case tank, the emission reduction potentials estimated were:

- 4 % for the installation of a float in a slotted still well
- 6 % for the installation of a sleeve over a slotted still well
- 0.3 % for the bagging of roof support legs.

This shows that roof fittings are only minor sources of emissions from the base case EFRT considered. When these ECM were added to a tank equipped with liquid mounted primary seals and rim-mounted secondary seals, the emission reduction potentials estimated were:

- 39.4 % for additionally installing a float in the slotted still well
- 54.8 % for additionally installing a sleeve over the slotted still well
- 3.0 % for additional bagging of roof support legs.

**Operability:** Easy to operate and install but potential problems for inspection of seal gaps. Floats in still wells present problems if the still well is used for sampling. Long-term durability is unproven.

**Applicability:** Widely applicable.

**Safety aspects:** Access for maintenance and inspection will require confined space precautions.

**Energy/waste/cross-media:** None.

**Economics:** Very low cost for new tanks and still low when retrofitted.

**Reference literature:** [113, TETSP, 2001] [114, UBA, 2001]

**4.1.3.10. Internal floating roof (IFR)**

**Description:** An internal floating roof tank (IFRT) has both a permanent fixed roof and a floating roof (or deck) inside. The deck in an IFRT rises and falls with the liquid level and either floats directly on the liquid surface (contact deck) or rests on pontoons several centimetres above the liquid surface (non-contact deck). Contact floating roofs can be:

- aluminium sandwich panels that are bolted together, with a honeycomb aluminium core
- pan steel decks with or without pontoons
- resin-coated, fibreglass reinforced polyester (FRP), buoyant panels.

The majority of direct contact floating roofs currently in service are aluminium sandwich panel-type or pan steel-type. The FRP decks are less common. The panels of pan steel decks are usually welded together.

Non-contact decks are the most common type currently in use. Typical non-contact decks are constructed of an aluminium deck and an aluminium grid framework supported above the liquid surface by tubular aluminium pontoons or some other buoyant structure covered with thin aluminium sheets or panels, usually sealed and bolted or riveted together.

Both contact and non-contact decks incorporate rim seals and deck fittings for the same purposes previously described for EFRTs. Emissions from floating roofs may come from deck fittings, non-welded deck seams, and the annular space between the deck and tank wall.

Tanks fitted with an IFR may be freely vented by circulation vents at the edge and top of the fixed roof to minimise the possibility of vapour accumulation in the tank vapour space in concentrations approaching the flammable range. The effectiveness of a pressure and vacuum relief valve (PVRV), as an ECM in this case, is considerably reduced.

**Achieved environmental benefits:** For fixed roof tanks larger than 50 m<sup>3</sup>, containing products with a vapour pressure > 1 kPa at working temperature, the installation of an internal floating roof can achieve an emission reduction of at least 90 %. An emission reduction of at least 97 % can be achieved (compared to a fixed roof tank without measures) when over at least 95 % of the circumference the gap between roof and wall is less than 3.2 mm and the seals are liquid mounted, preferably of the mechanical shoe type.

The emission reductions (estimated using the EPA AP-42 method) achieved by installing an IFR in four FRT case studies are given in Annex 8.13. For the range of tank sizes, turnover, solar radiation, products, etc. considered, the reduction potential for installing an IFR with a primary seal ranged from 62.9 – 97.4 % as the tank diameter increased from 4 – 33 metres. The efficiency of an IFR is not only dependent on the diameter of the tank, but also on the product that is stored and the turnover rate per year. In Annex 8.23 calculations of efficiencies, according to the above-mentioned EPA method, are shown for different tank sizes, equipped with a shoe type primary seal, and a variable number of filling actions when storing gasoline. See also Section 4.1.3.9 on roof seals.

**Operability:** The storage capacity is reduced and there is a need to consider flammable atmosphere problems as part of the design. The stability of the roof during filling also needs consideration as a sudden high rate of fill may introduce instability. Once installed, it is easy to operate, but difficult to inspect and maintain.

**Applicability:** In the Netherlands, the condition for when to apply an IFR is when the substance has a vapour pressure of 1 kPa (at 20 °C) and the tank has a volume of  $\geq 50$  m<sup>3</sup>. However, this is not valid for toxic volatile substances, for which the tank needs to be connected to a vapour treatment installation (see Section 4.1.3.15.)

In Germany, the TA Luft requires for new installations and for substances with a vapour pressure of more than 1.3 kPa (at 20 °C) or specifically classified substances, that points of emissions should be connected to a vapour treatment installation, a vapour collection pipe or a vapour recovery unit (for more detail see Section 4.1.3.15). However, crude oil to be stored in storage tanks with a volume of more than 20000 m<sup>3</sup> may also be stored in a floating roof tank sealed effectively at their edges or in fixed roof tanks with an internal floating roof if emissions are reduced by at least 97 % as compared to a fixed roof tanks without an internal floating roof. Furthermore, a floating roof may also be used for existing installations, provided that the tank contains no substances from the carcinogenic/mutagenic/reproductive-toxic category and the efficiency should be at least 97 %. Fixed roof tanks with a volume below 300 m<sup>3</sup> need not be connected to a vapour collection pipe or a vapour treatment installation with regard to liquid organic substances with a vapour pressure of the product more than 1.3 kPa (at 20 °C) which do not meet any of the criteria of the specific classified substances and specified limit values.

IFRs are widely used in the petroleum industry, however, they are only applicable to vertical fixed roof tanks. An IFR is less effective in tanks with a small diameter because of the poor effectiveness of the rim seal in small tanks.

There are possible compatibility issues between stored products and the IFR construction materials, e.g. aluminium sheets/pontoons and gasket/sealing materials. In situations where caustic treatment is included in plants run downstream of the process, such as in refineries, corrosion on the IFR might give rise to problems of applicability.

Floating suction in existing tanks, high filling rate regimes, mixers and other protuberances all present difficulties in retrofits.

**Safety aspects:** There is a potential for a flammable atmosphere. An IFR also has a negative effect on fire fighting. Confined space entry problems and escape issues also need consideration.

**Energy/waste/cross-media:** None.

**Economics:** Medium cost options particularly in retrofit situations. Adding a secondary seal to an IFR is not economically viable and adds major inspection problems.

**Reference literature:** [41, Concawe, 1999], [66, EPA, 1997], [84, TETSP, 2001, 113, TETSP, 2001] [110, KWS2000, 1992] [179, UBA Germany, 2004]

#### 4.1.3.11. Pressure and vacuum relief valves (PVRV)

**Description:** The valves, installed as a safety device to fixed roof tanks, prevent either over-pressure or the pulling of a vacuum, also provide a useful function in limiting vapour emissions to atmosphere. They are useful in limiting filling losses and, particularly, breathing losses. When a blanketing gas is used, it has to be ensured that the pressure inside the tank does not counter the settings of the PVRV.

**Achieved environmental benefits:** The emission reductions (estimated using the EPA-42 method) achieved by installing PVRV in four case studies are given in Annex 8.13. For the range of tank sizes, turnover, solar radiation, products, etc. considered, the reduction potentials are:

- for the addition of low pressure PVRV to a base case FRT (i.e. no additional ECM installed) in the range of 5 – 13 %
- for the upgrading and addition of ‘high’ pressure (56 mbar) PVRV to a base case FRT in the range of 12 – 31 %.

This shows that the effectiveness of an PVRV is very specific to the storage conditions.

Other data are reported in a study carried out in the Netherlands. For low pressure valves a possible reduction in the range of 30 – 50 % and for high pressure valves a possible reduction in the range of 65 – 85 % are reported. [129, VROM and EZ, 1989]

**Operability:** The PVRVs require low maintenance and are easy to install as new or as a retrofit.

**Applicability:** Broadly applicable, also on tanks of ships – the so-called floating storage – as described in Section 3.1.18. However, blockage of the PVRV can result in tank failure. Therefore, when polymerisation, condensation or icing is anticipated, process measures adapted to the substance being stored have to be put in place. Such measures may include:

- tracing, heating, or insulation to avoid polymerisation, condensation or icing
- gas bleed or liquid flushing to avoid the presence of the substance in the PVRV.

Pressure relief valves set at the highest possible value consistent with the tank design criteria are common practice for tanks with a volume < 50 m<sup>3</sup>.

**Safety aspects:** PVRV need to be well designed to match all the design scenarios such as maximum filling and breathing rates. Zone rating of the area could change. The possibility of blockage or icing requires regular inspections.

**Energy/waste/cross-media:** None.

**Economics:** Very low cost particularly when installed as new. In retrofit, this measure is also cheap, but may have implications on uprating tank operating pressures.

**Reference literature:** [113, TETSP, 2001]

#### 4.1.3.12. Closed drain systems

**Description:** For atmospheric vessels, drains can be routed to a recovery vessel from which the material will usually be recovered and recycled, otherwise treated as a waste. For pressurised storage, drains can be routed through a local pressure vessel to a compressor system for reliquifying (e.g. ammonia storage) or to a vapour treatment (usually thermal oxidation).

**Operability:** The drains do not impose particular difficulties, the effectiveness of the measure fully depends on the subsequent treatment system.

**Applicability:** This technique is generally applicable for most products. However, the vapour treatment will be both site and product specific. Difficulties may arise due to blockage of the draining lines by, for example, solids or sludge. A proper design of the lines (absence of low points, correct slopes, etc.) usually solves this problem.

**Safety aspects:** Closed draining systems need more pieces of equipment compared to conventional draining systems and their design is, therefore, more complex. Especially for draining pressurised vessels, care must be taken that the drainage flow does not exceed the capacity of the recovery system and that the downstream pressure remains within acceptable limits. Also when liquefied gas storage is being drained, the risk of blockage of the drain valves by ice and hydrates has to be considered.

**Energy/waste/cross-media:** Energy usage can be high and depending on the treatment can generate waste (liquid or solid) and other gas emissions.

**Economics:** This technique is an expensive option that requires detailed technical evaluation. The costs are very dependent on the product that is stored.

**Reference literature:** [113, TETSP, 2001]

#### 4.1.3.13. Vapour balancing

**Description:** Vapour balancing consists of collecting the vapours which are displaced during a liquid transfer from the 'receiving tank' and returning them to the tank from which the product is delivered, the 'delivery tank'. Such balancing systems require the receiving and delivery tanks to be of the fixed roof type to permit vapour collection and transfer.

The objective of the balancing system is to reduce emissions to the atmosphere from liquid displacement operations by transferring the vapours from the receiving tank to the delivery tank. The volume of product removed from the delivery tank is replaced by vapours instead of by air drawn into the tank through the vents from the atmosphere. Evaporation is thus reduced, depending on the level of saturation of the returned vapours. The maximum achievable efficiency is thus limited to approximately 80 % for such applications, depending on the number of tank turnovers, etc.

The balancing principle requires vapour tight pipework between the receiving tank and delivery tank vapour spaces. The connection pipe for gas balancing is not shut during filling to prevent undue overpressure in the tank. The system is designed in such a way that at maximum vapour flowrate (i.e. at maximum liquid fill and breathing rates) the increase in pressure in the delivery tank does not result in an emission from the tank pressure relief valves. The vapour balancing system must be safeguarded against the hazards of handling potentially explosive air/hydrocarbon mixtures, mixing of incompatible components, and excessive differential pressures between the receiving and delivery tanks.

**Achieved environmental benefits:** Vapour balancing reduces emissions due to filling. The maximum achievable efficiency is limited to approximately 80 %, for tanks with a very high number of tank turnovers. The lower the number of tank turnovers, the lower the efficiency.

**Operability:** The technique is reasonably easy to operate, but it requires increased inspections of detonation arresters and PVRVs, and vapour leak tests. It should be possible to isolate individual tanks to achieve proper sampling, maintenance and inspection. Condensates may collect in low points in the vapour piping system and in arrester bodies and this presents a potential removal problem.

**Applicability:** Vapour balancing is only applicable to atmospheric pressure storage modes with a vapour space between the liquid and the 'roof', e.g. FRT. The pressure rating of the tanks that are connected to the vapour balancing system, needs to be of an adequate level to make the system work. Possible cross-contamination of the stored liquids has to be considered. Vapour balancing is commonly used on fixed roof tanks containing chemicals.

Vapour balancing is also applicable to floating storage (see Section 3.1.18). If the tank on the ship is connected to a shore-side balancing system, the vapour pipework must incorporate flexible sections to take account of wave and tidal motion.

**Safety aspects:** Vapour balancing introduces a potential for high hazards that increase asymptotically with the number of tanks, particularly the risk of fire. There is also the potential for blockage of detonation arresters. Design issues are paramount, e.g. tanks must be fitted with vacuum relief valves.

**Energy/waste/cross-media:** None.

**Economics:** Installing vapour balancing is a medium to high cost option. Significant costs are site-specific because this depends on the layout of the existing storage tanks.

**Reference literature:** [18, UBA, 1999, 113, TETSP, 2001]

#### 4.1.3.14. Vapour holders – flexible diaphragm tanks

**Description:** Vapour holders or holding tanks (VHTs) are used in a tank vapour balanced system to store the vapours produced by storage tank ‘out-breathing’ due to a rise in the temperature of the tank vapour space. These vapours are then released back to the storage tank when the temperature reduces again. The majority of VHTs are aboveground vertical tanks. It is also possible to retrofit spherical tanks or horizontal tanks, either above- and underground, for vapour holding duty.

In a VHT a flexible diaphragm is installed, fixed at its periphery around the tank shell at the mid height of the tank. The diaphragm is weighted to provide stability as it moves within the tank shell.

The diaphragm material should be sufficiently conductive to prevent static electricity generation as it rubs against the tank shell. Normally it has a permeation rate as low as is cost-effective for the installation.

An aboveground vertical tank, used as a VHT is normally constructed to API 650 or equivalent, for vapour – and not liquid – service, with a weak seam between roof and shell. A VHT should be treated as a normal storage tank when considering safety distances to other tanks and other potential sources of ignition, see Section 4.1.6. A VHT does not need to be located in a bund as it does not contain any liquid.

Roof vents are provided in accordance with recognised standards e.g. API 2000, (see International Codes) assuming the vapour flow is equivalent to the liquid product flow into a normal tank. A roof access manway should be provided to permit inspection and maintenance.

A pressure/vacuum valve (P/V valve) should be installed, connected to the vapour space beneath the diaphragm to prevent overpressure when the tank is full. The pressure valve venting capacity must cope with the maximum design vapour flowrate into the tank plus thermal expansion.

**Achieved environmental benefits:** The emission reductions (estimated using the EPA AP-42 method) achieved by installing a vapour holding tank in four FRT case studies are given in Annex 8.13. For the range of tank sizes, turnover, solar radiation, products, etc. considered, the reduction potential for installing a vapour holding tank to base case tanks (i.e. with no other ECM installed) is in the range of 33 – 100 %. The efficiency depends on the amount of emissions due to breathing relative to the total emissions. Thus VHTs are very efficient where the breathing losses are a very high proportion of the total, e.g. where the number of tank turnovers are very small. The effectiveness is, therefore, very specific to the storage operating conditions and the amount of solar radiation.

**Operability:** The technique is reasonably easy to operate, but it requires increased inspections of detonation arresters. It should be possible to isolate individual tanks for proper sampling, maintenance and inspection. Condensates may collect in low points in the vapour piping system and in arrester bodies and present a potential removal problem. Pressure limits need to be strictly adhered to, to prevent damage to the diaphragm. An inspection programme is required for the diaphragm integrity.

**Applicability:** Vapour holders are used for some petroleum product vapours. The pressure rating of the tanks that are connected to the vapour balancing system, needs to be of an adequate level to make the system work.

Vapour holders are also applicable to floating storage (see Section 3.1.18). If the tank on the ship is connected to a shore-side system, the vapour pipework must incorporate flexible sections to take account of wave and tidal motion.



**Safety aspects:** Moving vapours provide potential for high hazards, particularly if the vapours are flammable. Hazards increase asymptotically with the number of tanks. Design issues are paramount. There is also the potential for blockage of detonation arresters. Static electricity particularly associated with the diaphragm needs to be considered.

**Energy/waste/cross-media:** None.

**Economics:** Installing a vapour holder is a medium to high cost option. Significant costs are site-specific because this depends on the layout of the existing storage tanks.

**Reference literature:** [113, TETSP, 2001]

#### 4.1.3.15. Vapour treatment

**Introduction:** Vapour treatment systems are described in detail in the BREF on common waste water and waste gas treatment and management in the chemical sector (CWW BREF), see reference [147, EIPPCB, 2002]. The control technologies that are applicable to gasoline tank emission controls, their application limits and normalised costs, as given in the CWW BREF, are listed in Table 4.3.

In this introduction, the application limits and the costs quoted for the techniques listed in Table 4.3 are compared with the technologies currently available to control VOC emissions from gasoline storage tanks.

##### *Application limits for gasoline vapour*

Vapours vented from gasoline or gasoline component storage tanks can be up to the saturation concentration – a VOC concentration in air of up to 40 % by volume, equivalent to about 1200 g/m<sup>3</sup> by weight.

Vapour flow from a fixed roof tank is caused by displacement as the tank is filled and by breathing, which is primarily due to solar heating, and hence expansions of the tank vapour space.

Typical storage tank fill rates from a ship are about 600 m<sup>3</sup>/h. Pipeline fill rates can be higher.

An approximate estimation of breathing rates for a white painted tank can be calculated from:

$$F = 0.1 V/6 \quad (F \text{ is the breathing rate in m}^3/\text{h and } V \text{ is the tank vapour space in m}^3)$$

Thus for an almost empty 10000 m<sup>3</sup> tank which is being filled on a day with uninterrupted sunshine, the likely maximum vapour vent flows could be in the order of 600 m<sup>3</sup>/h due to filling and 170 m<sup>3</sup>/h due to breathing, totalling 770 m<sup>3</sup>/h.

##### *Comparison with CWW BREF technology application limits*

Comparison of the above calculated flows with the data in Table 4.3, indicates that the only technologies that would suit the range of conditions of flow and concentration for gasoline tank vapour emission controls are selective membrane separation and possibly condensation and absorption. However, all of the technologies listed in Table 4.3 are available for gasoline vapour emission controls.

##### *Comparison with CWW BREF technology cost data*

The cost data in the CWW BREF are normalised, i.e. the cost in euros is given per m<sup>3</sup>/h vapour flowrate, assuming that the system costs are directly proportional to the flowrate, and with no relationship to concentration.

In practice, for gasoline vapour recovery systems the cost versus flowrate curve is not a straight line that passes through 'zero'. Typically, the cost of a system is proportional to the maximum flowrate to the power 0.65. Oil industry experience with installing vapour recovery units to comply with European regulations has shown that the capital cost versus size curve for VRUs tends towards about EUR 300000 as flow tends to zero. Installation costs depend on site-specific issues but can be of the same order of magnitude as the unit cost.

Thus normalising the costs can be misleading if cost data have been obtained from very high throughput systems. The costs for conventional condensation and absorption systems quoted in Table 4.3 are at least an order of 100 too low for gasoline applications. This could be due to the base case costs used being for a very high flowrate system of a very low stream concentration.

Because of the considerations above, only referring to the CWW BREF is not sufficient. The CWW BREF provides good technical background information on waste gas emissions control technologies and their selection. However, it would appear that the majority of applications considered for waste gas treatment in the CWW BREF are for much higher flow and/or much lower VOC concentration conditions than occur in vents from gasoline storage tanks. Reference to the applicability and costs for the different control technologies in the CWW BREF is not, therefore, appropriate when considering storage tank emission control.

Recovery operation and processes for VOCs	Range of VOC stream concentration considered applicable by volume	Range of VOC stream concentration considered applicable by mass	Range of VOC stream flow considered applicable Nm <sup>3</sup> /h	Investment Cost EUR/m <sup>3</sup> /h
<b>Selective membrane separation</b>	Up to 90 %	<i>Up to 2700 g/m<sup>3</sup></i> <i>1)</i>	Dependent on membrane area, but up to 3000 reported	300 (for 200 m <sup>3</sup> /h system)
<b>Conventional condensation</b>	more or less saturated	± 1200 g/m <sup>3</sup>	100 to 100000	5
<b>Cryogenic condensation</b>	Not given	Not given	Up to 5000	500
<b>Adsorption</b>	Up to 25 % Lower Explosive Limit (LEL)	<i>Up to 12 g/m<sup>3</sup></i> <i>1)</i>	100 to 100000	240 (including regeneration system)
<b>Absorption (Scrubbing)</b>	Not given	Not given	50 to 500000	7 to 37 for packed bed (highest cost system)
<b>Straight thermal oxidation</b>	Up to 25 % Lower Explosive Limit (LEL)	<i>Up to 12 g/m<sup>3</sup></i> <i>1)</i>	900 to 86000	3 to 65
<b>Flare</b>	0 to 100 % LEL with safety engineering	<i>Up to 50 g/m<sup>3</sup></i> <i>1)</i>	Up to 1800000	9 to 625 for elevated flare

*Note 1): data in italics are derived from the figures in the CWW BREF using a value for gasoline vapour density of 3 kg/m<sup>3</sup>*

**Table 4.3: Emission Control Technologies – applicability limitations and normalised costs as given in the CWW BREF**  
[153, TETSP, 2002] [147, EIPPCB, 2002]

**Description and applicability:** End-of-line vapour treatment systems require the vapours to be collected and fed to a thermal oxidiser or vapour recovery unit (VRU) via pipework. Vapour treatment is only applicable where emissions can be collected and routed to the treatment system, e.g. from fixed roof tank vents. This pipework requires the same consideration as for vapour balancing systems (see Section 4.1.3.13).

Vapour treatment is also applicable to floating storage (see Section 3.1.18). If the tank on the ship is connected to a shore-side vapour treatment system, the vapour pipework must incorporate flexible sections to take account of wave and tidal motion.

Technologies for the abatement of VOC emissions to atmosphere from storage operations are:

- oxidation of the vented vapours in process heaters, specially designed incinerators, gas engines or flares
- hydrocarbon recovery of the vented vapour in a vapour recovery unit (VRU) utilising technologies such as adsorption, absorption, membrane separation and condensation.

With application of vapour recovery the hydrocarbons in the air/hydrocarbon vapour mixture displaced during loading operations are recovered for subsequent re-use. The technologies of vapour recovery involve two processes:

- separation of the hydrocarbons from air
- liquefaction of the separated hydrocarbon vapours.

The separation processes that may be used to separate hydrocarbon vapours from the air are:

- pressure swing adsorption on activated carbon
- absorption by washing in a low volatility absorbent fluid
- selective membrane separation
- condensation by cooling or compression (this is a special case because separation and liquefaction are combined in a single process).

The liquefaction processes applicable for separated hydrocarbon vapours are:

- reabsorption, normally into their own product
- condensation on a cold surface
- compression.

The following are the most commonly used VRU systems:

- adsorption in twin bed pressure swing operation
- cold liquid absorption in a lean oil stream
- indirect liquid condensing in a refrigerant heat exchanger
- membrane separation by passage through a hydrocarbon selective surface.

**Achieved environmental benefits:** The efficiency of the different technologies is product dependent, e.g. the adsorption efficiency of activated carbon is much higher for butane than it is for methane. Increased overall emission reduction efficiency can be achieved by having two systems in series, e.g. a membrane first stage treatment unit followed by a thermal oxidiser as a second stage to further control the emissions from the first stage. However, the incremental reduction in emissions may be small compared to operating only a single stage process. For example, gasoline single stage VRUs can achieve an average efficiency of 99 %. Adding a second stage would remove another 0.9 %. The capital and operating costs of the second stage, therefore, result in a very poor cost per tonne emission abated effectiveness. In addition, second stage units produce additional air emissions, e.g. indirect CO<sub>2</sub> due to electricity consumption or NO<sub>x</sub> from a thermal oxidiser, that need to be reviewed in relation to the amount of VOC emission reduction achieved.

**Operability:** The German TA Luft requires that points of emission should be connected to a vapour treatment installation, a vapour collection pipe, or a vapour recovery unit for the storage and handling of the following specified liquids:

- liquid products with organic substances with a vapour pressure of more than 1.3 kPa (at 20 °C), or
- specific classified substances above specified limit values:
  - mass content of more than 1 % organic substances such as phenol, tetrachlorethylene, ethene and chloropropene
  - mass content of more than 1 % carcinogenic substances such as acrylamide, acrylonitrile, benzene and 1,3-butadiene
  - mass content of 1 % reproductive toxic substances others than those mentioned in the first two bullets
  - mass content of more than 10 mg/kg of carcinogenic substances such as, benzo(a)pyrene, cadmium and arsenic
  - mass content of more than 10 mg/kg of mutagenic substances others than those mentioned above, or
  - some specific dioxins and furans.

The emissions of a vapour treatment installation should meet the limits as shown in Table 4.4

Category	Example substance	Emission limit for sum of all substances of each category	
		mass stream (g/h)	concentration (mg/m <sup>3</sup> )
VOCs	Methanol	500	50 mg TOC/m <sup>3</sup>
	Tetrachlorethylene	100	20 mg substances/m <sup>3</sup>
	1,1,1-trichlorethane	500	100 mg substances/m <sup>3</sup>
<b>Carcinogenic/mutagenic/reproductive</b>			
	Benzo(a)pyrene	0.15	0.05
	Acrylonitrile	1.5	0.5
	Benzene	2.5	1
<b>Dioxin/furan</b>			
	Dioxin	0.25 µg/h	0.1 ng/m <sup>3</sup>

**Table 4.4: Substances treated in a vapour treatment installation [179, UBA Germany, 2004]**

The Dutch Guidelines for air emissions are similar to the German TA Luft regulation, however, based on considerations of cost-effectiveness, vapour treatment should only be applied when the emission is qualified as significant. An emission is significant when on a yearly basis the emissions of a discontinuous source exceeds 1000-fold the value of the hourly mass stream. For example, for substances in the category of the least toxic VOCs, such as methanol, the emission limit is 500 g/hr and the corresponding yearly value, that qualifies the emission as being significant, is 500 kg/yr. For extremely hazardous substances such as dioxins and furans, an emission limit of 0.1 ngTEQ/m<sup>3</sup> is set when the mass stream is 20 mg/yr or more.

**Reference literature:** [113, TETSP, 2001, 153, TETSP, 2002] [147, EIPPCB, 2002] [179, UBA Germany, 2004] [180, Netherlands, 2004]

#### 4.1.3.15.1. Thermal oxidation

**Description:** Thermal oxidisers convert hydrocarbon molecules through oxidation to CO<sub>2</sub> and H<sub>2</sub>O. This can be achieved either by thermal oxidation at high temperature (950 °C), in flare systems or furnaces or by catalytic oxidation at low temperature (450 °C). Catalytic incineration is more applicable for low concentration hydrocarbon flows. The residence time of the vapour within the oxidiser is an important factor for both systems.

The oxidation of hydrocarbons needs a support fuel to sustain the process, thereby generating additional emissions to air (e.g. CO<sub>2</sub> and NO<sub>x</sub>).

In certain circumstances, the application of oxidation can be the only effective technology available to abate emissions to the atmosphere. This applies specifically where vapours from different sources can be combined which may otherwise cause a mixture of incompatible components. The possibility of producing a recoverable heat source may compensate the environment pollutants and cost elements.

**Operability:** This technique is reasonably easy to operate. Limitations in turndown ratio need to be observed. A support fuel is necessary.

**Applicability:** The design of the system needs to cater for a safe range from workspace, borders and other parts of the plant. The technique can be used for a large variety of products simultaneously and a wide variety of flowrates, but the flame stability is sensitive to flow variations.

**Safety aspects:** The technique involves a potential for high hazard from the ignition source being present at the end of the vapour line. Safety devices need to be highly reliable. A potential blockage with detonation arresters requires specialist design.

**Energy/waste/cross-media:** Thermal oxidation generates light, heat and noise together with CO<sub>2</sub>, NO<sub>x</sub> and other products of combustion. There is also a small but continuous need for support fuel.

**Economics:** Thermal oxidation is a medium to high cost option. Significant costs are involved on a site-specific basis, which may include the cost of a support fuel system.

**Reference literature:** [113, TETSP, 2001, 153, TETSP, 2002] [147, EIPPCB, 2002]

#### 4.1.3.15.2. Adsorption

**Description:** In the adsorption process the hydrocarbon molecules adhere physically to activated sites on the surface of solids, like activated carbon or zeolite. As the carbon has limited adsorption capacity it is necessary for a continuous process to have two vessels ('beds') containing activated carbon which cycle, normally on a time basis, between adsorption and regeneration modes. Regeneration of the carbon activity can be done by:

- steam regeneration
- air vacuum regeneration with a vacuum pump
- air vacuum regeneration with a vacuum pump and roots blower.

Using low pressure steam, followed by a drying process, the carbon activity can be fully restored. However, in principle the carbon again becomes hyperactive, which could result in an excessive release of the 'heat of adsorption' during operation and the formation of 'hot-spots'. To avoid temperature rises to unsafe levels, the carbon requires a process of wetting to achieve safe operation conditions after completion of steam regeneration. This aspect makes this principle of regeneration less suitable for twin bed pressure swing applications in storage tank vapour recovery systems.

Air vacuum regeneration using a single liquid ring pump, removes the majority, but not all of the hydrocarbon molecules from the saturated active carbon. This partial regeneration of the carbon activity ensures that it does not become hyperactive avoiding problems of hot-spot formation. Using straight lobe compressors in series with a vacuum pump can provide assisted air regeneration. This achieves a much lower absolute pressure in the system and, therefore, a deeper stripping of the hydrocarbons from the saturated active carbon. However, with this deep regeneration, the active carbon can become more sensitive to overheating if certain non-compatible vapours, e.g. ketones, are fed to the freshly regenerated carbon.

The adsorption process has a number of valves, which automatically open and close in sequence, generally on a time basis of every 12 to 15 minutes. The units, therefore, require daily inspection to ensure continued efficient operation and routine maintenance.

**Operability:** This technique is an unmanned automatically controlled process but requires trained personnel for operations and maintenance.

**Applicability:** The applicability is limited due to exothermic reactions with some products. Other fluids such as crude oil containing H<sub>2</sub>S have potential problems with by-product formation in the bed. It is applicable for a wide variety of flowrates and can be designed for a wide, but compatible range of products.

**Safety aspects:** The technique provides a potential for hazards from uncontrolled exothermic reactions.

**Energy/waste/cross-media:** There is a potential for waste generation in the regeneration process. The energy usage is high and involves generation of CO<sub>2</sub>. Carbon replacement is required on an infrequent but regular basis.

**Economics:** Adsorption is a high cost option – both capex and opex.

**Reference literature:** [113, TETSP, 2001, 153, TETSP, 2002] [147, EIPPCB, 2002]

#### 4.1.3.15.3. Absorption ('washing')

**Description:** In the absorption process, the incoming vapour is absorbed in a stream of low volatility ('lean') absorbent. The absorbent used depends on the composition of the vapours and the recovery efficiency required. Thus the absorbent may need to be cooled to reduce its volatility and hence its absorbing qualities. For example, for gasoline applications the absorbent used is kerosene at a temperature of about -25 to -30 °C. Cold gasoline could be used as an absorbent, but its volatility would result in a low efficiency of operation.

With absorbent streams operating below 0 °C, there is a potential problem of blockage due to ice formation where water vapour may be present in the vapour. Methanol injection can be used to overcome this problem.

Depending on the process, it may be necessary to split the vapour from the absorbent. In gasoline applications this is undertaken by heating the kerosene/recovered gasoline mix in a heat exchanger and then reabsorbing the rich gasoline vapour in a stream of gasoline.

**Achieved environmental benefits:** A cleaning fluid containing terpenes has been reported to absorb VOCs with an efficiency of 99 %. The fluid is also quite effective in absorbing odours, and works at ambient temperatures (between -10 and 40 °C).

**Operability:** It is an unmanned automatically controlled process but requires specially trained personnel for operations and maintenance. There is a range of designs covering anything from simple scrubbers to mechanically complex high maintenance systems. A mobile installation is also available and is especially suitable for the cleaning of tanks, trucks and tankers.

**Applicability:** Absorption is applicable for a wide variety of flowrates and can be designed for a wide, but compatible range of products.

**Safety aspects:** None other than the handling of vapour unless potentially hazardous chemicals as absorbents are used.

**Energy/waste/cross-media:** There is a potential for waste generation in the process, e.g. contaminated water effluent stream. Absorption can also involve a high energy usage (with indirect generation of CO<sub>2</sub>), although the absorption of VOCs as described above demands less energy than incineration or deep cooling. Absorbent replacement is required on a regular basis.

**Economics:** Absorption is a medium to high cost option – depending on the complexity of the process. The VOC absorption fluid mentioned above can be separated from the absorbed substances and can be recycled a number of times, depending on the use. The recovered VOCs can (in the case of a single stream) be reintroduced into the process or returned to the storage facility.

**Reference literature:** [113, TETSP, 2001, 153, TETSP, 2002] [147, EIPPCB, 2002] [176, EIPPCB Ineke Jansen, 2004]

#### 4.1.3.15.4. Condensation

**Description:** In the condensation process, the vapours are condensed on the surface of a cold heat exchanger. The temperature of this exchanger will be dependent on the boiling point of the product and the recovery efficiency required. For example, for gasoline the condenser temperature is typically about -80 °C. To increase the efficiency a second stage (e.g. a cryogenic condenser using liquid nitrogen) can be used to recover the hydrocarbons in the ‘tail gas’.

There are also systems available that apply, together with the cryogenic condensation with liquid nitrogen, an integrated heat transfer fluid which allows recovery of a wide variety of VOCs. With this technique, a direct heat exchange between the liquid nitrogen and the treated vapours would result in operational problems in the recovery unit due to solidification of most of the hydrocarbons at extremely low temperatures. To avoid this problem, a heat transfer fluid is used as the intermediate between both the liquid nitrogen and cargo vapours. The temperature of the heat transfer fluid is adjusted as a function of the nature of the compound to be liquefied.

**Operability:** It is an unmanned automatically controlled process, but it requires specially trained personnel for operations and maintenance. Designs are mechanically complex high maintenance systems.

**Applicability:** Systems are available that can be applied in the refining, pharmaceutical and chemical industry to treat vapour losses incurred during loading, unloading, storage and handling of organic compounds.

Flow variance has to be avoided to ensure efficient condensation. Problems with frosting/defrosting might arise in systems without applying a heat transfer fluid. The range of products that can be treated is limited to the design temperature limits of the equipment.

**Safety aspects:** None other than the handling of vapour. Use of equipment at very low temperatures can result in injury to personnel if exposed to the coolant (e.g. liquefied nitrogen) or the recovered product in case of a leak. Many light hydrocarbons form solid hydrates at sub-ambient temperatures which can cause blockage of the condenser and associated pipework. Polymerisation problems may also need to be addressed.

**Energy/waste/cross-media:** There is a potential for waste generation in the process, e.g. contaminated water effluent stream from defrost and refrigerant losses. It can also involve a high energy usage (with indirect generation of CO<sub>2</sub>) which might be even higher if cryogenics are used. Refrigerant make up is required on a regular basis. Some refrigerants are ozone depleting substances.

However, systems are available where secondary pollution such as acid gases, CO<sub>2</sub> emissions, waste water, nitrogen oxides, dioxins, etc. are not created. The nitrogen vapours generated during the vapour recovery process can be used for inerting or blanketing.

**Economics:** Condensation is a high cost option – depending on the complexity of the process.

**Reference literature:** [113, TETSP, 2001, 153, TETSP, 2002] [147, EIPPCB, 2002] [162, GRS Europe, 2002]

#### 4.1.3.15.5. Membrane separation

**Description:** With membrane technology, the hydrocarbon molecules are separated from air by passing the vapour/air mixture over a membrane through which the hydrocarbons have preferential permeability. The efficiency of the separation process is dependent on the differential pressure across the membrane. A compressor is used to provide a higher pressure at the inlet to the membrane unit and a vacuum pump is used to obtain a low pressure on the permeate side of the membrane.

Membrane separation technology has high operating costs as it requires a double set of vapour moving equipment, i.e. a liquid ring vacuum pump and a compressor. This technology is well suited to systems with large vapour volumes because of the use of a compressor at the inlet to the membrane unit. It is, therefore, suitable for use with fixed roof storage tank vapour balancing systems.

**Operability:** It is an unmanned automatically controlled process with the use of relatively new technology, but requires high maintenance.

**Applicability:** Large upstream – fixed – vapour volumes are required because of the need to have an upstream compressor. The range of products that can be treated is limited to the design of the membrane.

**Safety aspects:** As the membrane unit uses an inlet compressor, vapour systems require protection against vacuum.

**Energy/waste/cross-media:** There is a potential for very high energy usage (indirect generation of CO<sub>2</sub>).

**Economics:** Membrane separation is a medium to high cost option, both capex and opex.

**Reference literature:** [113, TETSP, 2001, 153, TETSP, 2002] [147, EIPPCB, 2002]

#### 4.1.3.16. Compatibility of ECM for gas emissions – operational

Not all of the emission control measures described in Section 4.1.3 can be used together. For example, a dome can only be considered for an EFRT and is thus not compatible with an ECM used for a FRT, such as an internal floating roof. The compatibility of the ECM is shown below in Table 4.5. Table 4.6 shows typical ECM for different storage modes.



Notes	Operational procedures/training	Design/inspection/maintenance	PVRV	Instrumentation	Floating covers	Flexible or tent covers	Fixed/rigid covers	Tank paint	Solar shields	Natural tank cooling	EFR rim seals	EFR roof fittings	IFR primary seals	IFR secondary seals	Domes	Closed drain systems	Vapour balancing	Vapour holders	Vapour treatment	Uprate tank to 56 mbar
Y) – can be used together N) – cannot be used together  1) not assessed yet	Y	Y	Y	Y	Y	Y	Y	Y	Y	1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	Y	Y	Y	Y	1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
			Y	N	N	N	N	Y	Y	1	N	N	N	N	N	Y	Y	Y	Y	Y
				N	N	N	N	Y	Y	1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
					N	N	N	Y	Y	1	N	N	N	N	N	N	N	N	N	N
						N	N	Y	Y	1	N	N	N	N	N	N	N	N	Y	N
								Y	Y	1	N	N	N	N	N	N	N	N	Y	N
									Y	1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
										1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
											1	1	1	1	1	1	1	1	1	1
												Y	N	N	Y	Y	N	N	N	N
													N	N	Y	Y	N	N	N	N
														Y	N	Y	N	N	N	N
															N	Y	N	N	N	N
																Y	N	N	N	N
																	Y	Y	Y	Y
																			Y	Y
																				Y

Table 4.5: ECM compatibility  
[154, TETSP, 2002]

	Notes 1. rarely used in Europe 2. not applicable 3. if fitted with cover  P) Pressurised storage mode; pressure relief valve required for safety Y) – can be used together N) – cannot be used together		Operational procedures/training	Design/inspection/maintenance	PV valve	Instrumentation	Floating covers	Flexible or tent covers	Fixed/rigid covers	Tank paint	Solar shields	Natural tank cooling	EFR rim seals	EFR roof fittings	IFR	Domes	Closed drain systems	Vapour balancing	Vapour holders	Vapour treatment	Uprate tank to 56 mbar
Aboveground	<b>Open top tank</b>	<b>Atmospheric</b>	Y	Y	N	Y	Y	Y	Y	Y	N	?	N	N	N	N	Y	N	N	3	N
	<b>External floating roof tank</b>	<b>Atmospheric</b>	Y	Y	N	Y	N	N	N	Y	1	1	Y	Y	N	Y	Y	N	N	N	N
	<b>Vertical fixed roof tank</b>	<b>Atmospheric</b>	Y	Y	Y	Y	N	N	N	Y	1	1	N	N	Y	N	Y	Y	Y	Y	Y
	<b>Horizontal storage tank</b>	<b>Atmospheric</b>	Y	Y	Y	Y	N	N	N	Y	1	?	N	N	N	N	Y	Y	Y	Y	Y
	<b>Lifter roof tank</b>	<b>Atmospheric</b>	Y	Y	Y	Y	N	N	N	Y	1	1	N	N	N	N	Y	Y	N	Y	Y
	<b>Sphere</b>	<b>Pressurised</b>	Y	Y	P	Y	N	N	N	Y	N	?	N	N	N	N	Y	Y	N	Y	N
	<b>Horizontal storage tank</b>	<b>Pressurised</b>	Y	Y	P	Y	N	N	N	Y	Y	Y	N	N	N	N	Y	Y	N	Y	N
	<b>Vertical cylindrical tank</b>	<b>Pressurised</b>	Y	Y	P	Y	N	N	N	Y	1	?	N	N	N	N	Y	Y	N	Y	N
	<b>Refrigerated storage tank</b>	<b>Pressurised</b>	Y	Y	P	Y	N	N	N	N	N	?	N	N	N	N	Y	Y	N	Y	N
Underground	<b>Horizontal storage tank</b>	<b>Atmospheric</b>	Y	Y	Y	Y	N	N	N	N	2	?	N	N	N	N	Y	Y	Y	Y	N
	<b>Cavern</b>	<b>Atmospheric</b>	Y	Y	Y	Y	N	N	N	N	2	?	N	N	N	N	Y	Y	Y	Y	N
	<b>Mounded storage</b>	<b>Pressurised</b>	Y	Y	P	Y	N	N	N	N	2	?	N	N	N	N	Y	Y	N	Y	N
	<b>Cavern</b>	<b>Pressurised</b>	Y	Y	P	Y	N	N	N	N	2	?	N	N	N	N	Y	Y	N	Y	N
Other storage	<b>Warehouse</b>	<b>Atmospheric</b>	Y	Y	2	N	N	N	N	2	2	?	N	N	N	N	N	N	N	N	N
	<b>Basin and lagoon</b>	<b>Atmospheric</b>	Y	Y	2	N	Y	Y	Y	2	2	?	N	N	N	N	N	N	N	N	N
	<b>Floating storage</b>	<b>Atmospheric</b>	Y	Y	Y	Y	N	N	N	Y	2	?	N	N	N	N	N	Y	Y	Y	N

Table 4.6: Possible ECM by storage mode  
[154, TETSP, 2002]

#### 4.1.4. ECM for tanks – operational – liquid emissions

Liquid emission control measures divide into two main groups: ECM for potential releases to soil from planned activities and those for unplanned releases. This section considers the ECM for potential releases from regular operations such as draining and cleaning. Section 4.1.6 deals with ECM for the infrequent unplanned releases such as tank overflow.

##### 4.1.4.1. Manual draining

**Description:** Tanks can be drained successfully manually with due care and attention. Care should be taken during draining of tanks, particularly where tanks have bottoms coned down to the centre and a fixed draw-off pipe. In this case the draw-off pipe will be full of oil (or other product stored) as the last of the water is removed and subsequent water withdrawals must first displace the product.

An alternative technology is automation of this process, as this will limit the stock carry-over and can be achieved by the installation of automatic or semi-automatic tank drain valve systems.

Water drained from a tank is usually captured in a drainage or sewerage system for further treatment of the water. Draining directly to the ground is not acceptable practice.

The rate of water draw-off can influence emissions. Rapid valve opening and high flowrates may create a vortex which will pull both water and oil into the drain. At many sites tank drain valves are operated manually, with visual inspection of the drained liquid to determine when to stop draining. Draining is normally stopped at a stage where the water contains less than 10 % oil. However, this limit can be exceeded, allowing significant quantities of oil into the effluent system.

Careful manual draining is still a viable option at many sites that store crude oil. However, it can be an extremely time consuming process. And it is practically impossible to eliminate all trace pollution of the water however well operated. Indirectly, emissions of hydrocarbon will result from the operation of draining water bottoms to air. Tests have shown that 30 % of hydrocarbons entering drainage systems will be lost through evaporation. As such, minimising product lost in drained water will result in lower emissions from drains.

**Operability:** It is not difficult to manually drain tanks but this requires time and care.

**Applicability:** Manually draining of tanks is widely applicable.

**Safety aspects:** Any tank draining, however carried out, has the potential to release large quantities of liquid product into the sewer or tank bund if not undertaken properly or checked regularly.

**Energy/waste/cross-media:** Potential risk of high waste and potential cross-media issues.

**Reference literature:** [41, Concawe, 1999] [113, TETSP, 2001]

##### 4.1.4.2. Semi-automatic tank drain valves

**Description:** Semi-automatic tank drain valves are categorised as such because they need to be reset at the start of each draining operation. Commercial designs are available for products that have a significantly different density to water; this density difference is exploited to terminate draining operations.

The designs generally consist of a small chamber with an inlet from the tank drain line and an outlet to the sewer system and a float. When the inlet valve is opened, the chamber fills with the water from the tank bottom causing the float (constructed of a hollow steel float ballasted with oil) to rise. The operator can then leave the operation unattended. Winterisation of these valves will be necessary in some climates.

When the product starts to enter the chamber, the float will fall into a ring seal, shutting off the valve.

An alternative methodology is to use a hydrocarbon sensor instead of a float. However, this element requires replacement after every draining and is therefore more suited to tanks that require infrequent draining.

**Operability:** Potential problems are:

- cleanliness: the float can become jammed if debris enters the float chamber. This is a serious drawback if the valve sticks open releasing the product to the drainage system
- premature closure: the valve can shut early if vortexing draws down the product before draining is finished or if the flow drops.

**Applicability:** Semi-automatic tank draining is widely applicable, but for a good performance, this technique requires a clean product with sufficiently different density to water.

**Safety aspects:** Any tank draining, however carried out, has the potential to release large quantities of liquid product into the sewer or tank bund if not undertaken properly or checked regularly.

**Energy/waste/cross-media:** Potential risk of high waste and potential cross-media issues.

**Economics:** Semi-automatic tank drain valves are not powered and incur minimal installation costs. They present the least expensive alternative to manual draining.

**Reference literature:** [41, Concawe, 1999] [113, TETSP, 2001]

### 4.1.4.3. Fully automatic tank drain valves

**Description:** Fully automatic drain valves are designed to require minimal operator intervention and, as such, are significantly more expensive than semi-automatic systems. A power source at the tank is also needed.

There are several different types with different characteristics. Correct selection is, therefore, crucial.

#### *Electromagnetic radiation probes*

An electromagnetic radiation probe is used to measure the hydrocarbon content of the water to be drained. The probe sends microwaves into the fluid and measures how much energy is absorbed by the fluid. Since water absorbs microwaves more, it is possible to quantify the concentration of hydrocarbons. The technology can be used as a portable unit, a single source probe or a double probe, in which one probe is located at the drain outlet point and the other at about 600 mm above the tank floor (or at a prescribed level). Basically, when the upper probe detects water, the drain valve opens; when the lower probe detects oil, the drain valve closes.

#### *Measurement of dielectric constant*

A capacitance probe is mounted in a circulating chamber in the tank drain. When the oil content reaches a preset value, the valve automatically closes. There are potential problems with detection due to layerings. A well-defined interface is necessary for satisfactory operation.

**Measurement of refractive index**

The refractive index is measured using fibre optics. There is little experience with this system in Europe.

**Operability:** Layering within the product might give rise to problems when applying this technique.

**Applicability:** Fully automatic tank draining is widely applicable, but dependant on the product that is stored.

**Safety aspects:** Any tank draining, however carried out, has the potential to release large quantities of liquid product into the sewer or tank bund if not undertaken properly or checked regularly.

**Energy/waste/cross-media:** Potential risk of high waste and potential cross-media issues.

**Economics:** Automatic drain valves are high cost items and costs for retrofit are extremely high.

**Reference literature:** [41, Concauwe, 1999, 113, TETSP, 2001]

**4.1.4.4. Dedicated systems**

**Description:** In ‘dedicated systems’, tanks and equipment are dedicated to one group of products. This means no changes in products. This makes it possible to install and use technologies specifically tailored to the products stored (and handled), thereby preventing and abating emissions efficiently and effectively.

**Operability:** Especially for terminals, where many different products are stored, this is a relevant emission control measure.

**Applicability:** The applicability depends on the type of storage operations and is generally not applicable to storage facilities where tanks are used for short to medium-term storage of different products.

**Energy/waste/cross-media:** Because cleaning activities will be largely reduced, subsequently emissions to air and waste will also be reduced.

**Reference literature:** [130, VROM, 2002]

**4.1.5. ECM for tanks – waste****4.1.5.1. Tank mixing**

**Description:** Sludge is a loose term for a semi-solid mixture of product, water and solids such as sand, scale and rust particles. Crude sludge can contain all of the above, including wax crystals, in varying quantities.

Sludge deposition in storage tanks occurs by the mechanisms of molecular diffusion, gravity and chemical reactivity and depends on operating conditions. Sludge deposition is not usually even and does not necessarily build at the same rate.

The amount of sludge depends on some or all of the following factors:

- temperature
- product type
- standing time
- mixer capacity
- type of tank bottom
- method of receipt (tanker, pipeline).

Mixing offers the best technology for reducing sludge. Turbulent mixing occurs when fluid particles move past each other at different speeds setting up shear stresses forming eddies. The speed at which this occurs determines the mixing rate.

There are two types of mixers used:

- impeller mixers
- jet mixers.

To prevent sludge deposition the mixer position has to be such that a maximum economical flow is applied across the tank bottom. The best operation is to use mixers where the swivel angle can be changed. Multiple mixers are necessary in larger tanks. Where multiple mixers are in use, the recommended separation is between 22.5 and 45°, with all mixers located within a 90° quadrant in order to minimise sludge deposition.

In the past, and even still today, air was used to homogenise liquids. If these liquids contain volatile compounds, this results in extra emissions to the air as the air 'strips' the volatile compounds. Therefore, the use of air to homogenise liquids cannot be considered BAT.

**Applicability:** Impeller mixers are more commonly used, however, jet mixers tend to be more efficient.

**Economics:** Impeller mixers tend to be cheaper to purchase but more expensive to operate (up to four times tank side entry mixers as these require minimum power to develop a fluid motion necessary for the mixing process to commence). Jet mixers tend to be more efficient and have lower running costs.

**Reference literature:** [41, Concawe, 1999] [176, EIPPCB Ineke Jansen, 2004]

### 4.1.5.2. Sludge removal

**Description:** Where sludge depth in tanks becomes unacceptably high and cannot be reduced by mixing technologies (see Section 4.1.5.1), tank cleaning will be necessary. A number of methods have been developed which eliminate the need to open the tank and will re-suspend deposits, and thus minimise losses. Chemical additives, centrifuging or product circulation form the basis for these methods.

Current practice for the removal of sludge build up in crude oil storage tanks involves withdrawal from operational service and after the discharging of stored stock, purging the interior of any hazardous atmosphere. The sludge bottom is then removed manually and disposed of in a safe manner (e.g. incineration).

**Reference literature:** [41, Concawe, 1999]

## 4.1.6. ECM for tanks – incidents and (major) accidents

### 4.1.6.1. Safety and risk management

The Seveso II Directive (Council Directive 96/82/EC of 9 December 1996 on the control of major accident hazards involving dangerous substances) requires companies to take all measures necessary to prevent and limit the consequences of major accidents. They must, in any case, have a major accident prevention policy (MAPP) and a safety management system to implement the MAPP. Companies holding large quantities of dangerous substances, the so-called upper tiered establishments, must also draw up a safety report and an on-site emergency plan and maintain an up-to-date list of substances.

**Description:** The safety management system gives shape to the MAPP. A safety management system includes:

- a statement of tasks and responsibilities
- an assessment of the risks of major accidents
- a statement of procedures and work instructions
- plans for responding to emergencies
- the monitoring of the safety management system
- the periodical evaluation of the policy adopted.

However, plants that do not fall under the scope of the Seveso II Directive also often apply individual risk management policies that are developed for premises that, e.g. store flammable liquids in tanks, see reference [37, HSE, 1998], or other premises used to store packaged dangerous substances. The degree of detail in these policies is clearly dependent on various factors such as:

- quantities stored
- specific hazards of the substances
- location of the storage.

An important tool is the risk assessment that is an organised viewing at the activities on-site using the following five steps:

- |               |  |
|---------------|--|
| <b>Step 1</b> | identify the hazards   |
| <b>Step 2</b> | decide who and/or what may be harmed (and/or damaged and/or contaminated and how seriously)                                  |
| <b>Step 3</b> | evaluate the risks arising from the hazards and decide whether existing precautions are adequate or if more needs to be done |
| <b>Step 4</b> | record significant findings  |
| <b>Step 5</b> | review assessment from time to time and revise it if necessary.  |

Concerning the storage of flammable liquids in tanks, the assessment includes the risks arising from the tank and risks to the tank from external sources. The aims of the assessment are to:

- minimise the risk of a spillage of flammable liquid
- minimise the risk of a fire or explosion occurring at the tank itself
- mitigate the consequences of such an incident, particularly with regard to humans and the environment
- protect the tank from fires occurring elsewhere.

Factors that are important when assessing a storage installation include:

- storage capacity
- location of the tank, in relation to site boundaries, buildings, process areas and fixed sources of ignition
- design standards for the installation
- quantities and locations of other flammable liquids
- quantities and locations of other dangerous substances
- activities on adjacent premises
- training and supervision of site operatives
- frequency of deliveries
- loading and unloading operations
- inspection and maintenance.

The Dutch government developed a software program – PROTEUS – for determining the environmental risks of accidental chemical spillage onto surface water. PROTEUS includes the program SERIDA, which is a database for information on substances dangerous to humans and the environment. The substances included in SERIDA were selected from the safety reports of Dutch establishments, the Seveso II list, the black lists of either the EU or the Netherlands, and the International Rhine Committee list.

**Operability:** The level and detail of safety management systems as described above depends on the amount of substances stored, their specific hazard and the location of the store. The storage of multi-hazard goods together is a high risk activity demanding high level management considerations and highly qualified personnel.

**Applicability:** Applied all over Europe.

**Economics:** Cannot be specified.

**Reference literature:** [120, VROM, 1999] [35, HSE, 1998] [36, HSE, 1998] [37, HSE, 1998] [118, RIVM, 2001] [121, CIWM, 1999]

**Internet links:** <http://www.rivm.nl/serida/> <http://www.riskanalysis.nl/proteus/>

### 4.1.6.1.1. Operational procedures and training

**Description:** Adequate organisational measures are important for safe and responsible operation of the installation. It is common practice that:

- emergency response plans and communication plans for internal purposes and to/for external locations are available and kept up to date. They allow swift intervention of internal and external rescue/support teams and, therefore, might reduce any negative consequences caused by an accident
- operating instructions are available and followed. They contain information pertaining to the operation of the installation, e.g. plans for monitoring and maintenance, for precautions against malfunctions and for dealing with any that occur
- the company has, in its possession, relevant records and documentation on the storage mode (e.g. design data/drawings, inspection and maintenance records, etc.
- training and instruction of employees are both carried out on a regular basis. Employees are informed, among other things, about hazards to the workforce and potential consequences for the environment.



A typical training schedule includes:

- hazards and properties of the liquids being stored and handled
- safe operating procedures for the installation and its associated equipment
- the purpose of the safety features, including the importance of not removing or tampering with them
- the action to be taken if a fault in the equipment is detected
- dealing with minor leaks and spills
- the importance of good housekeeping and preventive maintenance
- emergency procedures.

**Operability:** The level and detail of operational procedures and training as described above depends on the amount of substances stored, their specific hazard and the location of the store. The storage of multi-hazard goods together is a high risk activity demanding high level management considerations and highly qualified personnel.

**Applicability:** Applied all over Europe.

**Reference literature:** [18, UBA, 1999] [87, TETSP, 2001] [37, HSE, 1998] [35, HSE, 1998]

#### 4.1.6.1.2. Low level indicator in EFRT

**Description:** Instrumentation to measure and warn for a low level of the content of a tank is needed to prevent an external floating roof from landing in an emptying mode, potentially causing damage and loss. The nature of the instrumentation is either by level gauge with alarm settings only or automatic closing of valves to stop the unloading of the tank; see Section 4.1.6.1.6 for high level content alarm systems.

**Operability:** A standalone alarm requires manual intervention and appropriate procedures. Automatic valves would need to be integrated into the downstream process design to ensure no consequential effects of closure. Regular inspection/maintenance of either is an essential requirement.

**Applicability:** Alarms are widely applicable but the need for automatic valves needs to be evaluated at each location.

**Safety aspects:** With automatic valves there is a potential for failure of downstream systems due to, e.g. the 'water hammer' effect (see Glossary).

**Energy/waste/cross-media:** None.

**Economics:** For tanks with an automatic gauging system, the installation of an alarm does not require a major investment. Tanks that are manually gauged require the installation of an automatic gauging system with an alarm or a level alarm only. Automatic shut-off valves are more costly. If the alarm system is attached to a local control room, the costs are site-specific.

**Reference literature:** [113, TETSP, 2001]

#### 4.1.6.1.3. Leakage and overflow

**Description:** (Secondary) containment refers to additional protection against storage tank releases over and above the inherent protection provided by the tank container itself. There are two major types of secondary containment for leakages, namely those that are part of the tank construction, such as, double tank bottoms (only for aboveground tanks), double skin and double wall tanks and impervious barriers which are placed upon the soil surface below the tanks.

Tank farm bunds and cup-tanks are designed to contain large spills from aboveground tanks, such as caused by a shell rupture or a large overflow. Also underground tanks can be equipped with containment. All techniques are described in the sections below.

Operational procedures and training, and instrumentation and automation are important tools to prevent overflow. Corrosion and erosion are also important sources for leakage to soil or to air. These are also discussed below.

**Reference literature:** [41, Concauwe, 1999], [113, TETSP, 2001]

#### 4.1.6.1.4. Corrosion and erosion

##### *Aboveground storage tanks*

Corrosion is one of the main causes of equipment failure. It can occur both internally and externally on any exposed metal surface. Corrosion is generally avoided by the selection of resistant construction materials and proper construction methods. The resistant material may be the base material (e.g. stainless steel), a coating or a cladding on a mechanically resistant sheet.

Storage vessels for the storage of, e.g. phosphoric acid are normally constructed of mild steel completely lined with rubber including the ceiling, because the acid is corrosive to mild steel and many metals under the formation of (the highly explosive) hydrogen. The rubber can be natural or synthetic (butyl) or preferably multiple layers of either. Low carbon stainless steel can be used at temperatures below about 60 °C, provided no risk of corrosion due to chlorides or other impurities is present. Stainless steel tanks fitted with anodic protection is another possible option, this technique can only be used at temperatures below 70 °C. The standard type of material for the storage of anhydrous ammonia at low temperatures is certified carbon manganese steel.

Paints or other coatings generally provide a good protection. Chemically resistant coatings or paints are available. Annex 8.2 – International Codes, shows an overview of various methods that may be used.

Internal corrosion may result from the accumulation of water in the tank. A means to remove such water can be appropriate (see Sections 4.1.4.1 to 4.1.4.3).

Corrosion may go unnoticed under thermal insulation or lagging. Corrosion under lagging has to be addressed as part of the planned preventive maintenance schedule for the tanks.

Cathodic protection is an option to prevent corrosion on the inside of aboveground tanks. Cathodic protection is achieved by placing sacrificial anodes in the tank that are connected to an impressed current system or by using galvanic anodes in the tank. Internal cathodic protection is no longer widely used in the petroleum industry, due to corrosion inhibitors that are now found in most refined petroleum products.

Abrasion may occur when moving solids, which are present in the liquid, are in contact with components of the storage system. There are few ways to avoid this difficult to predict phenomenon, e.g. reduce the velocity of the solids through design measures, or use harder or softer construction materials when the effect is detected.

##### *Underground storage tanks*

It is common practice that underground tanks constructed of material vulnerable to corrosion (such as steel) are protected by:

- a corrosion resistant coating (such as bitumen)
- plating
- a cathodic protection system.

See also Annex 8.6 for a summary of MS requirements on underground tanks.

***Stress corrosion cracking***

Stress corrosion cracking is a phenomenon which can occur in metals exposed to a combination of stress and corrosive environment. Stress corrosion cracking is a problem specifically for pressure vessels that may occur over a wide range of temperatures and pressures. Stress corrosion cracking has been observed in pressure storage bullets (spheres), semi-refrigerated storage tank and some fully refrigerated tanks at temperatures of -33 °C or below, containing ammonia. The cracks are mainly formed in welds and the heat affected zones around the welds.

Based on experience from findings and extensive international research work, it appears that the commissioning, and to an even greater extent recommissioning, are critical phases in the formation of cracks. This is due to, primarily, the potential for increased oxygen levels inside the tank and temperature variations causing increased stress levels.

Stress relieving by post-weld heat treatment of the heat affected zones is reported to be the only reliable method to avoid stress corrosion cracking in ammonia tanks.

**Reference literature:** [86, EEMUA, 1999] [25, IFA/EFMA, 1990] [41, Concawe, 1999] [3, CPR, 1984, 26, UNIDO-IFDC, 1998, 28, HMSO, 1990, 37, HSE, 1998, 113, TETSP, 2001]

**4.1.6.1.5. Operational procedures and training to prevent overflow**

**Description:** Clear operational procedures undertaken by the operators are the first level of protection against overflowing. These procedures, for example, can establish the actions to ensure that:

- sufficient ullage is available to receive a batch filling
- the instruments used for controlling the normal operation of the storage system, such as the level or pressure indicators, inform the operator that there is a risk of the process parameter being exceeded before an overflowing occurs
- during their regular rounds of the storage facility the operators observe abnormal levels or pressure conditions in a tank
- no overflow occurs during a tank filling operation.

The effectiveness of these measures needs to be maintained over time. This is one of the roles of management systems. A proper management system includes: regular training of the operators, the updating of the operating instructions, the calibration of the instruments on a scheduled basis, safety reviews, and incorporation of lessons learnt from incident analysis.

**Reference literature:** [113, TETSP, 2001]

**4.1.6.1.6. Instrumentation and automation to prevent overflow**

**Description:** To prevent the overflowing of a tank, high level instrumentation is required. This can be a level gauge with alarm settings and/or auto closing of valves.

**Operability:** A standalone alarm requires manual intervention and appropriate procedures. Automatic valves would need to be integrated into the upstream process design to ensure no consequential effects of closure. There is a potential for pipeline pressure surge problems. Valve closure time together with inspection requirements and calibration are all crucial in preventing emissions.

**Applicability:** Alarms are widely applicable but automatic valves need to be evaluated at each location for specific problems such as surge and overpressure. Also for underground tanks, alarms to prevent overflowing are commonly applied.

**Safety aspects:** With automatic valves, there is a potential for failure of upstream systems.

**Energy/waste/cross-media:** None.

**Economics:** Tanks that are manually gauged, require only the installation of automatic gauging and/or level alarm, which involves only low costs. If alarms are attached to a local control room then costs are site-specific. Automatic shut-off valves are a more costly item. Pressure surge protection and pipe upgrading are very costly measures.

For example, an electronic sensor for overfill protection costs EUR 500 to 2000 (year 1999). These costs exclude installation and inter connection to safeguarding systems but are site-specific. It is possible to have alternative sensors with the same measuring principle and comparable environment protection capacity. The costs do not differ considerably.

**Reference literature:** [113, TETSP, 2001] [18, UBA, 1999] [132, Arthur D. Little Limited, 2001]

#### 4.1.6.1.7. Instrumentation and automation to detect leakage

**Introduction:** Four different basic techniques can be used to detect leaks and are described in this section. These are:

- A. Release prevention barrier system
- B. Inventory checks
- C. Acoustic emissions method
- D. Soil vapour monitoring

##### *A. Release prevention barrier system (RPBS)*

**Description:** Where a double tank bottom or impervious barriers are installed, any leakage from the tank bottom can be lead to the perimeter of the tank. The simplest detection method is to undertake a regular visual inspection for the presence of product at the ‘tell tale’ leak detection points. For volatile products, gas sensing at the ‘tell tales’ can be carried out.

Another technique applicable for a double tank bottom is that the space between the floors is kept under a vacuum that is continuously monitored. Any leak in the floors will dissipate the vacuum and trigger an alarm. For impervious liners, a detection cable can be placed between the tank bottom and the liner. The electrical properties of this cable change when it is in contact with the stored product. This can be used to indicate a potential leak.

For a double wall tank or a cup-tank, a sensor system can be placed in between the two walls of a double wall tank or between the single wall of a tank and its containment.

**Operability:** These methods do not affect the operation of the tank.

**Applicability:** Widely applicable.

**Safety aspects:** None.

**Energy/waste/cross-media:** None for the simple visual systems. Other systems require power for instrumentation.

**Economics:** Low cost if installed with a new tank, a new double wall or a new double bottom. Costs can be very high in retrofit situations.

**Reference literature:** [114, UBA, 2001, 132, Arthur D. Little Limited, 2001] [151, TETSP, 2002]

## B. Inventory checks

**Description:** These checks are either based on:

- a) the level of the product in the tank (level check), or
- b) the mass of the product in the tank under static conditions (mass check), or
- c) the difference between the volumes of product pumped in and out of the tank over long periods compared to the change in the stored volume.

Check methods a) and b) are both known as the static volumetric methods and c) is known as the enhanced inventory check.

### Static volumetric methods

- a) **Level check** – the basic concept is that the liquid volume, and hence level, of a tank should remain constant if the thermal expansion of the tank and stored product is accounted for. Errors are introduced by thermal gradients in the stored product, changes in tank shape due to thermal and internal pressure changes, wind effects and variations in both ambient temperature and solar radiation.
- b) **Mass check** – the concept is to force gas into two tubes; one near the bottom of the tank and the other in the vapour space above the product. The differential pressure corresponds to the mass of product above the lower measuring point and should be independent of the changes in liquid level caused by thermal expansion.

Both volumetric methods require an out-of-service period of 24 to 48 hours to conduct the tests. Leak sensitivity is improved as the test period increases. To reduce thermal effects, the test should be undertaken with low levels of stored product (< 3 m) and during the night.

- c) **Enhanced inventory check** – the concept is that all flows into and out of the tank are summed and the net difference is compared to the volumetric change in the tank. This method has the same limitations as the static volumetric check. The inlet and outlet flowmeters introduce additional instrument errors.

**Operability:** Both ‘static volumetric methods’ require the tank to be out-of-service for one to two days with the product at low level. These methods require precision instrumentation. The ‘enhanced inventory check’ does not affect the operation of the tank. It requires long test periods during which flows are measured with well calibrated instruments and data logged for later reconciliation.

**Applicability:** All techniques are widely applicable to atmospheric storage tanks, but the ‘static volumetric methods’ cannot be used for EFRTs. The ‘enhanced inventory check’ has the advantage that existing instrumentation can be used.

**Safety aspects:** None.

**Energy/waste/cross-media:** None.

**Economics:** ‘Static volumetric methods’ are low cost techniques. ‘Enhanced inventory checks’ are medium cost techniques.

**Reference literature:** [151, TETSP, 2002]

### ***C. Acoustic emissions method***

**Description:** This method detects a leak by listening for the characteristic noises created by a leak from the bottom of a static tank. Sophisticated equipment is required to permit the very low intensity noises to be detected and analysed. A number of noise sources can result in spurious leak detections such as the movement of a floating roof, high winds and thermal movement of the tank shell.

**Operability:** This method requires the tank to be taken out of service for 4 to 8 hours and also requires specialised measurement and data analysis equipment.

**Applicability:** This technique is widely applicable to atmospheric storage tanks.

**Safety aspects:** None.

**Energy/waste/cross-media:** None.

**Economics:** The 'acoustic emissions method' is a medium cost technique.

**Reference literature:** [151, TETSP, 2002]

### ***D. Soil vapour monitoring***

**Description:** This method depends on the testing of vapours either diffusing or being drawn with a vacuum pump from the soil below a tank. The number of sampling points required depends on the tank diameter and soil permeability. A survey of the soil should be undertaken before any leak occurs to ascertain if any background emissions are detected. The basic method does not work where the stored product is non-volatile or there is a water bottom below the product in the tank.

To improve detection capability, a marker can be added to the stored product. The marker needs to be volatile, non-toxic and non-flammable, different to any product stored on the site and not contaminate the stored product. Markers that have been successfully used are perfluorocarbons, injected at a rate of 1 to 10 ppm.

**Operability:** This technique can be undertaken with the tank in service. The use of markers requires a test over several hours to weeks. These also require specialised gas detection monitors.

**Applicability:** 'Soil vapour monitoring' is widely applicable to atmospheric storage tanks.

**Safety aspects:** None.

**Energy/waste/cross-media:** The marker system requires addition of a substance to the stored product.

**Economics:** This technique is a medium cost item for small diameter tanks and a high cost item for large diameter tanks.

**Reference literature:** [151, TETSP, 2002]

#### 4.1.6.1.8. Risk-based approach for emissions to soil below tanks

A risk-based methodology is described below for emissions to soil below tanks. A methodology for emissions to soil surrounding tanks is considered in Section 4.1.6.1.11.

**Description:** The risk-based approach for emissions to soil from an aboveground flat-bottom and vertical, storage tank containing liquids with a potency to pollute soil, is that soil protection measures are applied at such a level that there is a ‘negligible risk’ for soil pollution because of leakage from the tank bottom or from the seal where the bottom and the wall are connected.

In the Netherlands, industry and authorities have together developed a methodology to define what a sufficient risk level is. Does it have to be a ‘negligible risk level’ or is an ‘acceptable risk level’ sufficient? It can also be determined how a certain risk level can be achieved. The methodology is explained below:

A combination of good design, proper construction and a proper inspection and maintenance level, together with certain technical measures can achieve a ‘negligible risk’ for soil pollution. Table 4.7 shows measures that, in proper combination, can achieve a negligible risk. In this methodology, only combinations that score 100 points or more can achieve this result.

A negligible risk for soil pollution can only be achieved by applying the following technical combinations:

- a thickness of the tank bottom of at least 6 mm, together with an impervious barrier between the tank bottom and soil surface, or
- an original double tank bottom with a leak detection system and the thickness of the primary and secondary bottom of at least 6 mm, or
- a thickness of the tank bottom of at least 5 mm, together with a leak detection system in combination with an external coating system and measures to prevent rainwater and groundwater ingress, or
- a combination of other maximum measures in combination with a non-corrosive product or a tank bottom of more than 3 mm thickness.

An applied combination of techniques with a score in the range of 45 to 99 is defined in this methodology as an ‘increased risk level’, and which can be upgraded to a ‘negligible risk level’ (score  $\geq 100$ ) by implementing a risk-based inspection of the tank bottom in combination with applying a suitable management system.

An ‘increased risk level’ can be upgraded to an ‘acceptable risk level’ by monitoring the soil (and groundwater) conditions and accepting the possible necessity for cleaning, treating or removing the polluted soil.

Scoring for thickness (d) of the bottom in mm	Points scored	Remarks
$d_{\min} \geq 6$	50	
$5 \leq d_{\min} < 6$	40	
$4 \leq d_{\min} < 5$	30	
$3 \leq d_{\min} < 4$	15	
$d_{\min} < 3$	0	
Add for $d_{\min} > 6$	5	For each mm add 5 points
Annular joints and butt-welded membrane	5	
<b>Emission control measures</b>		
Impervious barrier	50	
Leak detection above or on soil surface	25	
Double tank bottom with leak detection (note 1)	50	Thickness of the outer tank bottom of at least 6 mm
External coating system	15/5	15 for coating systems applied on jacked tank  5 when coating is applied before installing the tank bottom
Measures to prevent water ingress	20	No rainwater ingress and there is a sufficient distance to groundwater course
Oilsand (note 2)	5	No points to be added when the external coating is applied on jacked tank. The oilsand has to be combined with measures to prevent rainwater ingress
Internal coating system or a (for the tank bottom) non-corrosive substance is stored	10	
Cathodic protection	No scoring identified	
<i>Notes:</i>		
1) an original double tank bottom means that the tank originally was constructed with a double bottom. Installing a second bottom on an existing tank does not achieve the same level of protection.		
2) oilsand is a special mixture of pure, dry sand and a non-corrosive oil, which is spread out right below the tank bottom area to prevent it from external corrosion.		

**Table 4.7: Scoring system to identify the risk level of emissions to soil**

[79, BoBo, 1999]

Double tank bottoms and impervious barrier systems are described in more detail in Section 4.1.6.1.9 and Section 4.1.6.1.10 respectively.

**Achieved environmental benefits:** A ‘negligible risk level’ for soil pollution can be achieved, however, there may be situations where an ‘acceptable risk level’ might be sufficient.

**Operability:** This methodology was developed to help authorities and industry agree on what risk level is sufficient for a specific site and which emission control measures need to be applied to control or influence the current risk level for soil pollution.

**Applicability:** This methodology can be used for new and existing situations and addresses the storage of crude oil, crude oil products, and chemicals in atmospheric aboveground tanks with a minimum diameter of 8 m. However, the methodology is also thought to be applicable to smaller tanks and other substances with a potential for soil pollution.

The methodology is applicable to vertical tanks with a flat bottom made of carbon steel. It is not applicable to the storage of – for the soil – non-hazardous products such as water and products that coagulate when in contact with the open air (e.g. bitumens, vegetable oils, wax and sulphur). Neither is it applicable to the storage of liquefied gases.



**Energy/waste/cross-media:** None.

**Economics:** Depends on the current risk level and on the applied techniques.

**Reference literature:** [79, BoBo, 1999]

#### 4.1.6.1.9. Double tank bottoms under aboveground tanks

**Description:** Installing a second impervious bottom to an aboveground tank provides a measure of protection against typically non-catastrophic releases due to corrosion, faulty weld joints, or flaws in the bottom material or the construction details. In addition to containment, the secondary bottom provides a means of allowing detection of a bottom leak.

Double bottoms can either be retrofitted on an existing tank or incorporated into the design of a new tank. Installing a second bottom on an existing tank does not achieve the same level of protection as a double bottom that is incorporated into the design of the tank. If retrofitted, the existing tank bottom is normally used as the secondary flooring, and sand, gravel or concrete can be installed between the new primary and secondary floors. It is common practice to keep the interstitial space to a minimum and, therefore, the secondary bottom should slope the same way as the primary bottom. The slopes to the base of tanks can be either flat, cone-up (sloping from the centre down to the tank perimeter) or cone-down (sloping downward from the tank perimeter).

Nearly all tank floors are made of carbon steel. If a double bottom is to be installed (either retrofit or new build), there are choices in material selection for the new floor. A second carbon steel floor can be utilised or a more corrosion-resistant stainless steel floor can be installed. A third choice is to use a glass fibre-reinforced epoxy coating over the steel.

Any product leak through a tank bottom can be identified by a leak detection system. Leak detection systems are described in Section 4.1.6.1.7.

The main disadvantage of double bottoms is the difficulty in determining how the tank bottom can be repaired safely when a leak is detected. It is very difficult to gas-free and clean the space between the two bottoms. This requirement should not be underestimated or neglected as this could cause serious problems to the safety of maintenance personnel. Furthermore, when evaluating the use of double bottoms, consideration should be given to changed tank design calculations, location of fittings and possible bottom corrosion.

**Applicability:** Potential corrosion, design and safe maintenance are problems for double bottoms. Some welds are not visible after installation of the double bottom. Repairs are difficult due to the narrow gap between the two bottoms.

**Safety aspects:** If a leak occurs, cleaning and making the space between the two bottoms gas-free is difficult.

**Energy/waste/cross-media:** There are potential cross-media issues when double bottoms are retrofitted to existing tanks.

**Economics:** High cost items. Extremely high as retrofit.

**Driving force for implementation:** Germany and Switzerland are two of the few countries in Europe where double bottoms are installed to meet national requirements.

**Reference literature:** [41, Concawe, 1999, 113, TETSP, 2001]

#### 4.1.6.1.10. Impervious barriers under aboveground tanks

**Description:** There are a number of ways to effectively seal the ground to prevent downward migration of spilled product. It is possible to utilise a shallow layer of low permeability clay that may occur naturally beneath the tank(s) or be imported for the purpose. The following types of clay mats exist:

- granular bentonite embedded between two layers of geotextile
- sand, bentonite and polymeric material.

Clay mats are applicable for virtually all products. However, effective sealing at joints and protrusions requires proper design (see also Section 4.1.6.1.11). Furthermore, a soft clay layer placed under the tank can exacerbate tank shell or base edge rotation as the tank settles, increasing the propensity for bottom plate failure. Clays are susceptible to shrinking and cracking under dry conditions, and so measures must be taken to ensure that they stay moist. In a dry climate it may, therefore, be preferable to install an asphalt or concrete surface, although care must be taken here to ensure that cracks do not develop over time.

An impervious flexible membrane such as a high density polyethylene (HDPE) may be laid under aboveground tank bottom structures of either the cone-up or cone-down configuration. A cone-up configuration will require an external drain around the perimeter at the footing of the tank whilst a cone-down configuration requires a collecting sump under the centre of the tank foundation with a drain pipe to an external sump/leak detection system. Flexible membranes may also be used with tanks with a concrete ring foundation.

The installation of flexible membranes does not affect the design of the tank. Furthermore, the presence of a membrane usually does not hinder jacking-up operations.

The main disadvantage of these types of liners is the necessity of adequately sealing them. Furthermore, when removing contaminated material from underneath the tank after leakages utmost care must be taken not to damage the membrane which may lead to replacing the membrane. Although membranes are suitable for almost all products, the stored product resistance of membranes may present problems for tanks with varying contents.

**Operability:** All liner systems have maintenance and testing issues. Removing material and/or repairing the primary system for a leak, presents difficulties in ensuring that the integrity of the secondary system is not broken.

**Applicability:** These techniques may be applicable for new builds, but for retrofitting they are much more difficult. Compatibility with stored products is an issue in choosing the barriers' material. Climatic conditions (e.g. freezing, large daily temperature changes, very high ambient temperatures) may be an issue. Drying out of clay mats may be a potential problem.

Applying any type of barrier system is commonly based on a risk evaluation (see also Section 4.1.6.1.11).

**Safety aspects:** After any leak has occurred, exposure or undetected risk to personnel from the product may be an issue. Leaked flammable product presents a fire hazard.

**Energy/waste/cross-media:** There are potential cross-media issues when retrofitting impervious barriers.

**Economics:** High cost items. Extremely high as retrofit.

**Reference literature:** [113, TETSP, 2001]

#### 4.1.6.1.11. Tank bunds and liner systems

**Description:** Whereas double bottoms or impervious liners under a tank protect against the small but persistent leak, a tank farm bund (or dike) is designed to contain large spills, such as that caused by a shell rupture or a large overflow. The purpose of bunding is not only to prevent contamination of land and watercourses, but also to:

- prevent the flammable liquid from reaching ignition sources
- prevent the liquid entering the drainage or water systems where it may spread to uncontrolled ignition sources
- allow the controlled recovery or treatment of the spilled material
- minimise the surface area of the liquid and so reduce the size of any fire that may occur
- prevent the spread of burning liquids which could present a hazard to other plants or personnel both on and off-site.

The bund consists of a wall around the outside of the tank (or tanks) to contain any product in the unlikely event of a spill. The bund is typically constructed of well compacted earth or reinforced concrete. The volume is normally sized to accommodate the contents of the largest tank within the bund.

A substantially impervious barrier within the bund wall can prevent infiltration of the product into the ground. This barrier can comprise a full barrier, covering the bund floor and walls, or a partial barrier around the bottom of the tank shells. A partial barrier is sized to contain any product spilled due to a small overflow or from minor leaks from tank side valves, etc.

Any liner system design needs to accommodate tank settlements such that integrity is maintained throughout the operational lifetime of the tank. Tank settlements can be large over their lifetime (e.g. > 1 m for large crude oil tanks), especially where the foundation soils comprise soft estuarine silts and clays.

In Europe, most legislation dealing with land contamination, or potential land contamination, is risk-based. Risk-based approaches account for the significance of any harm or damage to human health or the environment and is commonly applied. Hence, the risk from any tank release needs to be judged. Spilled liquids can permeate downward and groundwater flow can then allow migration of the dissolved components of the product under the bund. The propensity for this is dependent upon the product type, the ambient temperature and the ground type. With the risk-based approach, the following six steps are normally considered:

- (1) review spill volumes against spill frequency; this usually shows, in relative terms, higher chances of many very small spills compared with very low chances of larger spills
- (2) consider potential for infiltration of the spill into the ground of a bund without a barrier – dependent upon product type, ambient temperature, ground type and time of emergency action to recover ‘accessible’ spilled product
- (3) combine (1) and (2) to give probability for occurrence of different ‘volumes’ of contaminated land due to releases
- (4) consider the risks to receptors from the volumes of contamination derived previously – examines fate and transport and this includes the potential for certain organic products to degrade under some conditions
- (5) repeat steps (2) to (4) for different barrier conditions
- (6) make sensitivity analyses allowing judgement of significance of risk for different barrier extent, product and ground type combinations as an aid to decision making.

**Operability:** Issues that influence the operability are:

- handling of the spilled liquid
- drainage of rainwater captured in the bund
- potential damage to the bund liner from maintenance activities
- maintenance and testing of the liner system
- repairing the liner after damage.

**Applicability:** Containment of overflow is applicable to new build tanks. Retrofitting is more difficult because of sealing around the existing pipelines/drainage infrastructure. The fitting of a containment system needs to be balanced with reduction in spill potential from improving operational systems, training and record keeping, and installing instrumentation and/or alarms.

When different substances are stored in the same bund, the compatibility of potential spilled substances has to be considered to avoid accidents; see Annex 8.3. Climatic conditions (e.g. freezing, large daily temperature changes, very high ambient temperatures) may be an issue to consider. The selection of a barrier system may be determined using a risk-based approach. This approach may also be used to inform on the extent of any barrier. Cost/benefit considerations may show that it is beneficial only to put a barrier on the area close to the tank rather than the full bund. This provides protection against damage from the potential higher frequency but lower volume spills.

Unprotected concrete surfaces, including watertight concrete, are not impervious to chlorinated hydrocarbon solvents.

**Safety aspects:** After a spill, exposure of personnel to the product is an important aspect. Flammable liquids present fire hazards. Removing the spilled material can cause damage to the containment system. After removal of the spilled material, the barrier requires a thorough integrity inspection.

**Energy/waste/cross-media:** There are some waste and potential cross-media issues. For bunds with a barrier a drainage system must be installed to handle the captured rainwater, which would have otherwise percolated into the soil. Good practice at refineries is to segregate this clean tank farm storm-water from potentially contaminated storm-water (such as might be generated at pipeline manifold or process areas) in order to minimise the amount of waste water processed through the facility's oily water treatment system.

**Economics:** High costs are involved with retrofitting a barrier in an existing tank farm; the costs involved when building new tanks are lower.

**Reference literature:** [41, Concawe, 1999] [113, TETSP, 2001] [37, HSE, 1998] and UK Energy Institute: 'A risk-based framework for assessing secondary containment of hydrocarbon storage facilities, January 2005'.

#### 4.1.6.1.12. Laminated concrete containment under aboveground tanks

**Description:** For chlorinated hydrocarbon solvents (CHC), concrete containment requires the application of surface protection, allowing the covering of capillary cracks, to render it impervious. For CHC-proof laminates, a suitable quality of concrete is required. CHC-proof laminates are based on:

- phenolic resins, or
- furan resins.

In addition, one form of epoxy resin ('Concretin') has passed the rigorous tests for CHC-proof laminate.

**Operability:** Furan resin laminates may contain chemical modifiers to overcome cracking by improving their plasticity. However, modifiers reduce chemical durability; this is of special importance with methylene chloride. Furan resins cannot be used as sealing materials in joints due to their limited plasticity. To obtain sufficient durability, phenolic or furan resins have to be combined with glass fibre mats. Elastic intermediate layers are required to cover and fill cracks in the concrete such as:

- layers of elastomers (e.g. polyisobutylene and several rubber products)
- layers on bituminous basis
- so-called liquid foils, which are poured on the concrete and when hardened will form an elastic layer (e.g. polyurethane).

The CHC-impervious laminate is then applied on the top of the elastic intermediate layer. If resistance to considerable mechanical wear is required of this laminate, then a cover can be applied, e.g. of tiles in a mortar bed.

**Applicability:** This technique is commonly applied where CHC is stored in single wall tanks or containers.

**Reference literature:** [156, ECSA, 2000]

#### 4.1.6.1.13. Aboveground double wall tanks

**Description:** Different designs exist of double wall tanks. See Figure 4.9 that shows a double wall on the outside with a distance to the inner wall of about 100 – 150 mm, a double wall adjacent to the inner wall and a double wall placed inside the tank. The double wall is normally applied in combination with a double tank bottom and leak detection for the storage of flammable and non-flammable substances and substances that are non hazardous up to very hazardous to surface water.

With the double wall on the outside, it is important that the construction is sufficient to withstand the pressure of a full containment. A double wall on the inside supports the tank wall and increases the total strength of the tank.

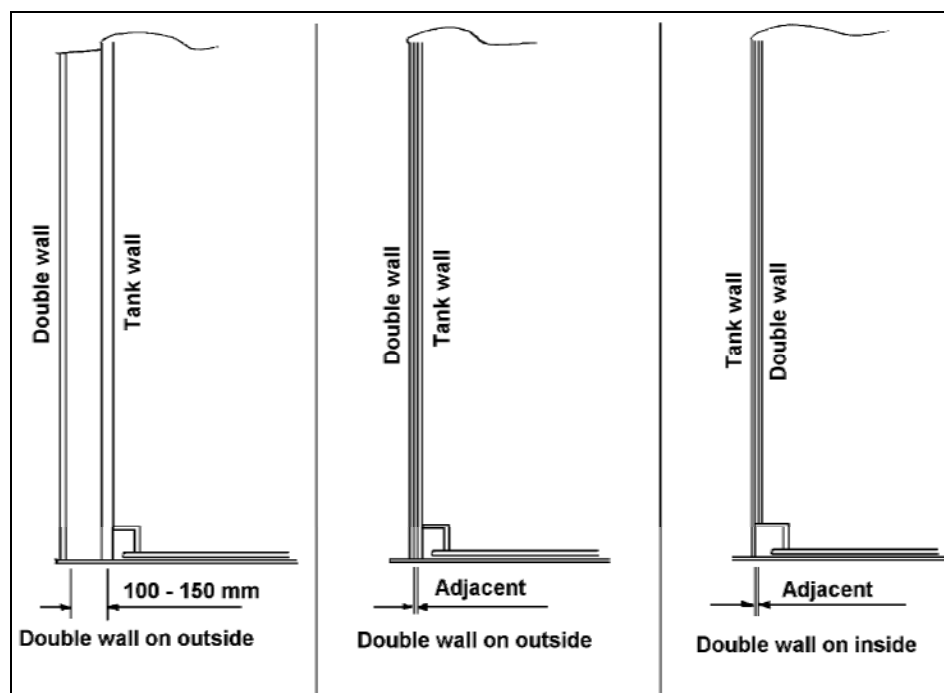


Figure 4.9: JPM double wall tanks, a patented system  
[122, JPM Ingenieurstechnik GMBH, 2002]

**Operability:** A double wall tank takes less space than e.g. a cup-tank. The patented system applies to the German rules for containing extinguishant. The double skin insulates e.g. pressurised storage because of the ‘thermos flask’ effect. Inspection and maintenance of the space between the double wall is difficult.

**Applicability:** This tank type is applied in Germany for flammable and non flammable substances and substances that are non hazardous to surface water up to very hazardous to surface water.

**Safety aspects:** Double wall tanks have a higher resistance to fire than single wall tanks. However, if a fire occurs, it might be difficult to fight the fire between the double wall.

**Energy/waste/cross-media:** The insulating effect can save energy. Rainwater is prevented from entering between the double wall and the tank wall.

**Economics:** This technique is more costly than upgrading existing bund facilities around existing tanks, however, costs are very site-specific.

**Reference literature:** [122, JPM Ingenieurstechnik GMBH, 2002] [175, TWG, 2003]

**4.1.6.1.14. Cup-tanks**

**Description:** With a cup-tank, a second tank is built around a single wall tank with a distance of about 1.5 m. The cup has the same strength as the tank itself and is constructed to contain all of the liquid stored. Equipment like pumps and valves are placed in the cup to prevent leakage from the tank and the equipment entering into the soil. The rainwater that enters in the cup is discharged via one or more oil-skimmers.

This type of tank is used for the storage of products such as crude oil, petrol and domestic fuel oil. The tank itself can be equipped with a double bottom under vacuum with leak detection.

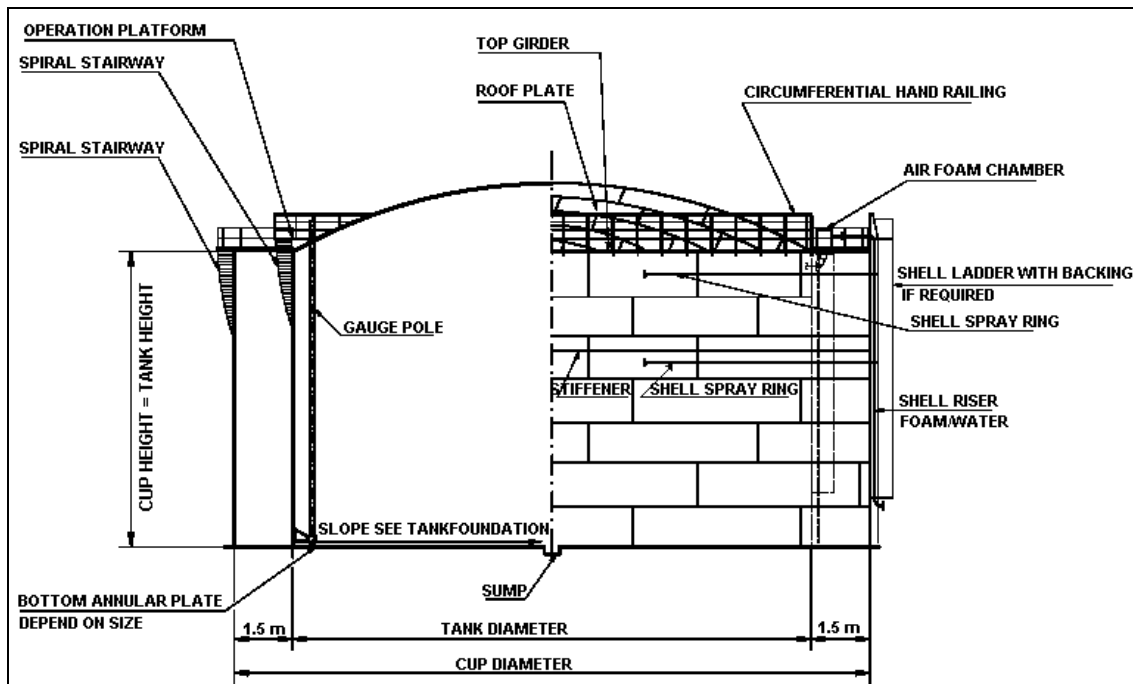


Figure 4.10: Example of a cup-tank [125, Oiltanking, 2002]

**Operability:** Cup-tanks are widely applied, e.g. in Gera, Germany, at a terminal of Oiltanking.

**Safety aspects:** Calculations on the heat radiation show that cup-tanks have a higher resistance to fire than single wall tanks. Normally (petrol) tanks are equipped with a sprinkler system to prevent flames from a fire nearby spreading to the tank.

Each tank has its dedicated containment for leakage, which makes the question of storing compatible substances in the same containment superfluous, compared to several single wall tanks in one containment.

**Energy/waste/cross-media:** Rainwater entering into the cup is contaminated and has to be treated before it is discharged.

**Reference literature:** [124, Oiltanking, 2002] [123, Provincie Zeeland, 2002]

#### 4.1.6.1.15. Aboveground double wall tank with monitored bottom discharge

**Description:** In preventing emissions to soil and/or surface water, the two alternative systems used are the ‘single wall tank in a pit or bund’ or ‘double wall tank equipped with a leak detection device’. However, double wall tanks should have no penetrations below the permissible filling degree to avoid leakage and, therefore, are normally equipped with a top discharge.

A pit will prevent water pollution in case the tank leaks, but because of its large surface, vaporisation, especially of flammable liquids, will be hastened and mixture limits for the appearance of explosions might be exceeded. This will not happen with a double wall tank.

Due to sophisticated measuring and analysing techniques combined with a fail-safe system of redundantly arranged shut-off valves, the horizontal and vertical double wall tank with bottom outlets, a patented system, was approved by the Deutsches Institut für Bautechnik for the storage of water polluting flammable and non-flammable liquids.

Another system with bottom discharge approved by the Deutsches Institut für Bautechnik for the storage of water polluting flammable and non-flammable liquids, is a double wall steel tank with monitored bottom discharge via two separate simultaneously opening and closing valves. See Figure 4.11: the two valves after the opening represent the inner and outer wall of the tank. The tightness of both valves in a closed position is continuously monitored with the leak detection device, and this is in addition to the leak detection of the secondary containment of the tank itself. The double wall valve is patented and is described in more detail in Section 4.2.9.7.

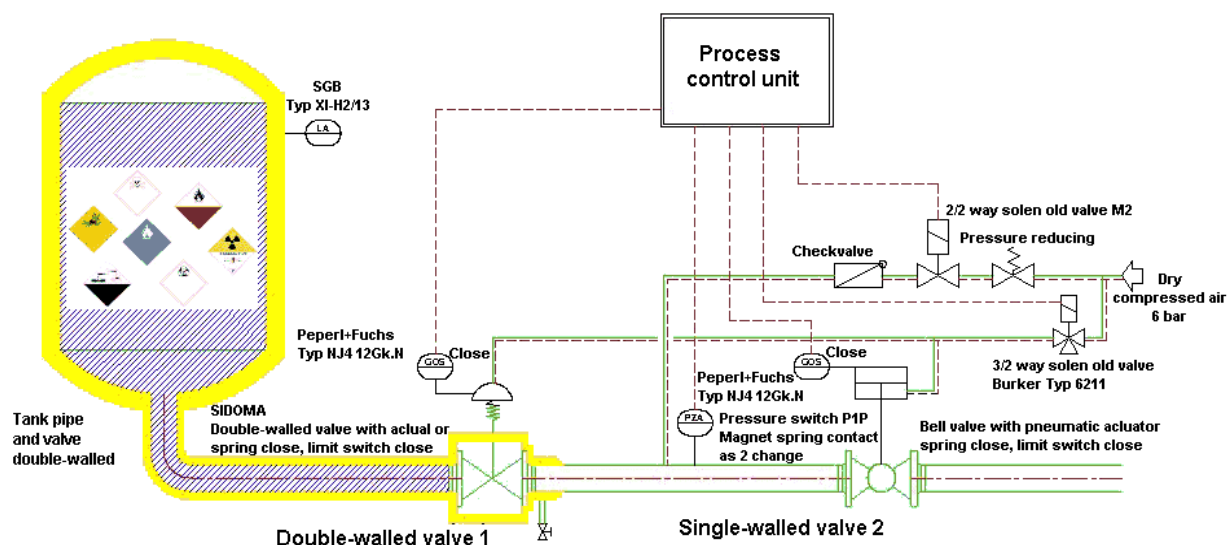


Figure 4.11: Double wall tank with bottom outlet and patented double wall valve [160, Sidoma Systeme GmbH, 2003]

**Energy/waste/cross-media:** None.

**Applicability:** Applied in Germany for the storage of water polluting flammable and non-flammable liquids.

**Economics:** When all the costs of an appropriate pit and other protection measures of a single wall tank are taken into account, a double wall tank with bottom outlet will often be less expensive. The same goes for maintenance and upkeep.

For building new tanks, the system with the double valve is cheaper compared to a vertical single wall tank in an appropriate pit and more expensive than a vertical double wall tank with top-discharge.

**Reference literature:** [126, Walter Ludwig, 2001] [160, Sidoma Systeme GmbH, 2003]

#### 4.1.6.1.16.            **Underground double wall tanks**

**Description:** Figure 3.15 shows a typical double wall tank. Tanks containing gasoline (with MBTE) or other fuels are normally double walled (or single walled with containment, see Section 4.1.6.1.17) and equipped with a leakage detector.

**Operability:** Retrofitting an existing single wall tank into a double wall tank is not possible.

**Applicability:** The need for applying a double wall tank is of course dependent on the substance that is stored. For gasoline containing MBTE, a substance which is highly polluting to groundwater, a double wall tank (or a single wall tank with containment) is common practice, but, e.g. for the storage of propane or butane normally single wall storage tanks are applied.

**Safety aspects:** None.

**Energy/waste/cross-media:** The leakage might be recycled or else it has to be properly disposed of.

**Reference literature:** [18, UBA, 1999] [132, Arthur D. Little Limited, 2001]

#### 4.1.6.1.17.            **Underground single wall tanks with secondary containment**

**Description:** An alternative to the double wall tank described in Section 4.1.6.1.16 is to equip the single wall tank with a secondary containment with additional leak detection to monitor liquid ingress into the containment. The secondary containment is coated with an impermeable material to prevent leaks. The secondary containment has the same height as the maximum liquid level or it is also reported that the containment has a total capacity 25 % greater than the capacity of the associated tank.

**Operability:** Retrofitting an existing single wall tank is possible.

**Applicability:** The need for applying containment is, of course, dependent on the substance that is stored. For gasoline containing the substance MBTE, which is highly polluting to groundwater, containment (or a double wall tank) is common practice.

**Safety aspects:** None.

**Energy/waste/cross-media:** The leakage might be recycled or else it has to be properly disposed of.

**Reference literature:** [132, Arthur D. Little Limited, 2001] [114, UBA, 2001]



#### 4.1.6.2. Fire protection, fire-fighting equipment and containment

##### 4.1.6.2.1. Flammable areas and ignition sources

**Description:** In certain areas, flammable atmospheres may occur either during normal operation or due to accidental spills or leakages. These areas are called hazardous areas and measures to prevent these areas or, if this is not possible, control the introduction of sources of ignition are required. Classifying these areas is a method for identifying areas where flammable concentrations of gases or vapours are likely to be present. There are three classes of zone and their definition is given in the following table:

Zone	Definition
Zone 0	An area in which an explosive gas mixture is continuously present or present for long periods
Zone 1	An area in which an explosive gas mixture is likely to occur in normal operation
Zone 2	An area in which an explosive gas mixture is not likely to occur in normal operation, and, if it does occur, it is likely to do so only infrequently and will exist for a short period only.

**Table 4.8: Definition of zones**  
[37, HSE, 1998]

For more details see the ATEX Directive 1999/92/EC on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres.

Measures to prevent explosive gas mixtures are:

- prevent a vapour-air mixture above the stored liquid, e.g. by applying a floating roof
- lower the amount of oxygen above the stored liquid by replacing it with an inert gas (blanketing)
- store the liquid at a safe temperature to prevent the gas-air mixture from reaching the explosion limit.

The next step is to record the locations of the zones on a plan. This may then be used to prevent the introduction of sources of ignition into hazardous areas. Common ignition sources include:

- unprotected electrical equipment
- naked flames including welding and cutting equipment
- smoking materials
- vehicles (or vapour processing units) with internal combustion engines
- hot surfaces
- frictional heating or sparking
- static electricity.

In general, static electricity can be prevented or decreased by measures such as:

- a low velocity of the liquid in the tank
- adding antistatic additives to increase the electrical conduction properties of the liquid.

**Reference literature:** [3, CPR, 1984] [37, HSE, 1998]

#### 4.1.6.2.2. Fire protection

**Description:** It is common practice, in order to prevent mutual influence between tanks in case of a fire, to keep sufficient separation distances between tanks, fences and buildings. Several national codes exist that provide guidance for distances that are regarded as safe; for an example see Annex 8.18.

It may be necessary to provide fire protection measures where the storage conditions are less than ideal, such as where it is difficult to achieve adequate separation distances. Fire protection measures can be provided by:

- fire resistant claddings or coatings
- firewalls (only for smaller tanks)
- water cooling systems.

To prevent a tank from collapsing it is important to prevent the overheating of tank supports, e.g. by insulating and/or equipping them with water deluge facilities.

**Reference literature:** [3, CPR, 1984] [28, HMSO, 1990, 37, HSE, 1998]

#### 4.1.6.2.3. Fire-fighting equipment

**Description:** The fire-fighting equipment for the bulk storage of flammable liquids depends on the quantity and type of liquid and on the conditions of storage. MS apply different very detailed guidelines and it goes beyond the scope of this document to deal with this issue in such detail. In this section, only general principles are addressed. The decision on the adequate level of fire-fighting equipment has to be made on a case by case base in agreement with the local fire brigade.

Dry powder or foam fire extinguishers are suitable to deal with fires from small leaks of flammable liquid. CO<sub>2</sub> extinguishers are used for electrical fires. Good practice is to have extinguishers grouped in pairs to guard against equipment failure.

Facilities to deal with larger fires include an adequate water supply for fire brigade use and to provide cooling for tanks exposed to heat from a nearby fire.

Fixed water sprays or portable monitors are an advantage, but are normally only applied where the storage conditions are less than ideal, such as where it is difficult to achieve adequate separation distances.

**Reference literature:** [37, HSE, 1998] [3, CPR, 1984]

#### 4.1.6.2.4. Containment of contaminated extinguishant

**Description:** The fire water run-off can be huge and interceptors or special draining systems may be applied to minimise the risk of contamination of local watercourses. The capacity for containing contaminated extinguishant depends on the local circumstances such as, which substances are stored and is the storage close to watercourses and/or situated in a water catchment area. Below, two examples from reference [28, HMSO, 1990] are given on when full containment needs to be applied in the UK:

- a tank containing toluene diisocyanate is located in full containment bunds which are totally isolated from water drains
- a tank containing vinyl chloride monomer requires fire protection to prevent overheating and collapse so it is insulated and/or equipped with water deluge facilities. The tank is located in a containment area with walls less than 1 m high so that vapour does not accumulate, and graded so that liquid leakage does not remain beneath the tank. The containment area is also capable of retaining any fire-fighting water.

Such a collecting provision can, if appropriate, and if, e.g. vapour collection is not an issue, be a tank that can be clearly distinguished from tanks used to store products, as can be seen at a terminal of Oiltanking in Kotka, Finland.

**Operability:** Proper containment for contaminated extinguishant requires professional engineering.

**Applicability:** Containment can be applied in new and existing plants and is applied throughout Europe. Note, however, that specific regulations for some products differ between MS.

**Safety aspects:** Containment of a released product may reduce the risk of fire spread.

**Energy/waste/cross-media:** Contaminated extinguishant is waste that needs to be treated and/or disposed of dependent on the contamination. Biological treatment and incineration are possible options.

**Economics:** Cannot be specified.

**Reference literature:** [28, HMSO, 1990] [37, HSE, 1998] [175, TWG, 2003]

#### 4.1.7. ECM for storing containers – incidents and (major) accidents

Operational losses do not occur in storing packaged dangerous materials. The only possible emissions are from incidents and (major) accidents. There are three main events which individually or jointly have the potential to cause significant harm or damage. See Table 4.9 where these events are listed together with some examples of how these events could occur.

Event	Examples causing the event
Fire	<ul style="list-style-type: none"> <li>• ignition following a spill or release</li> <li>• self-combustion</li> <li>• arson</li> <li>• electrical faults – heaters, cookers, motors, etc.</li> <li>• hazardous activities – welding, shrink-wrapping, smoking, battery charging, etc.</li> <li>• external events – lightning, impact, fire in an adjacent property.</li> </ul>
Explosion	<ul style="list-style-type: none"> <li>• fire</li> <li>• spills of incompatible chemicals or flammable substances.</li> </ul>
Release of dangerous substances	<ul style="list-style-type: none"> <li>• containment failure</li> <li>• impact by vehicles or other objects</li> <li>• operator error – filling, discharging, etc.</li> </ul>

**Table 4.9: Main potential events concerning the storage of packaged dangerous materials [35, HSE, 1998]**

Possible ECM not only include building and engineering design and installation standards, but also good management practices and operational procedures and are discussed in the following sections.

#### 4.1.7.1. Safety and risk management

**Description:** Storage of dangerous packaged substances can also fall into the scope of the Seveso II Directive (Council Directive 96/82/EC of 9 December 1996 on the control of major accident hazards involving dangerous substances). See Section 4.1.6.1 which is also appropriate to storage of dangerous substances in containers.

Normally a person (e.g. a senior staff member) is made responsible for safe warehouse operations, which includes responsibility for the identification, assessment, handling and storage of all the dangerous goods held on-site. Adequate training and knowledge of the properties of dangerous substances are essential for their safe storage. Persons responsible for the operation of the store need specific training in emergency procedures and periodic retraining will normally be necessary. Other staff on the site need to be informed about the risks of storing packaged dangerous substances and the precautions necessary to safely store substances that have different hazards.

Normally, written operating procedures are developed and usually form the basis for training the personnel. They might include:

- the types of dangerous goods stored, their properties, incompatibilities and hazards, including hazard label recognition and understanding of the contents of material safety data sheets
- general procedures for safe handling
- (use of protective clothing) and procedures for dealing with leaks and spills
- housekeeping and record keeping of substances stored
- reporting of faults and incidents, including minor leaks and spills
- emergency procedures, including raising the alarm and the use of appropriate fire-fighting equipment.

**Operability:** The level and detail of operational procedures and training as described above depends on the amount of substances stored, their specific hazard and the location of the store. The storage of multi-hazard goods together is a high risk activity demanding high level management considerations and highly qualified personnel.

**Applicability:** Applied all over Europe.

**Reference literature:** [35, HSE, 1998]

#### 4.1.7.2. Construction and ventilation

**Description:** See Figure 4.12 that shows a general layout of an external storage area for containers, and Figure 4.13 and Figure 4.14 showing general layouts of storage buildings. For a proper design of storage buildings and storage cells, several norms are applicable. Cabinets are not addressed.

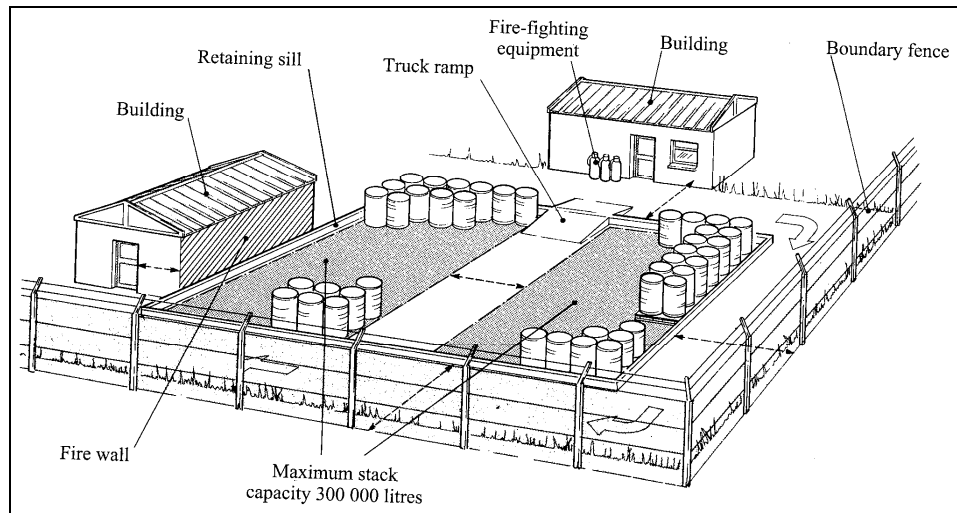


Figure 4.12: General layout of an external storage area for containers [36, HSE, 1998]

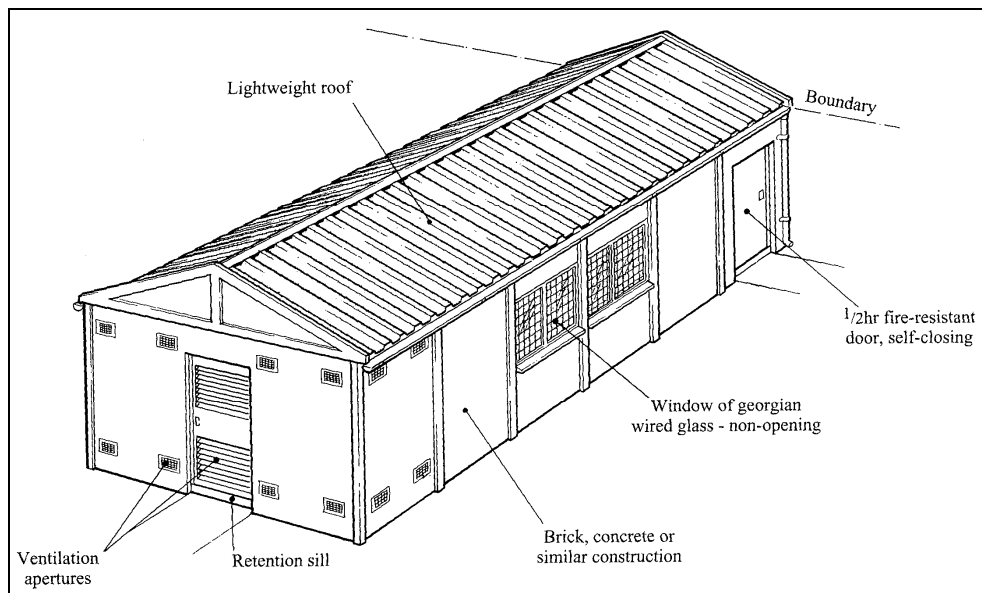


Figure 4.13: Example of a fire-resistant external storage building [36, HSE, 1998]

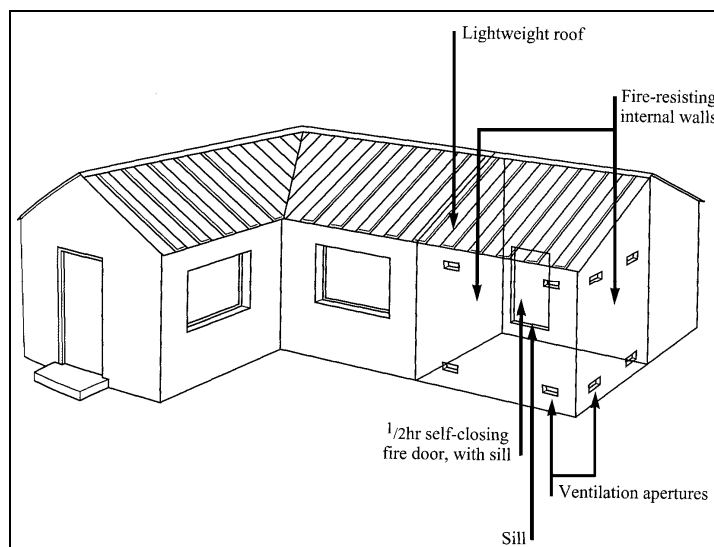


Figure 4.14: Example of an internal storage building [36, HSE, 1998]

### ***Storage buildings and areas***

The floor of the building is made of non-combustible material, is liquid-tight and resistant to the stored substances. It has no apertures connecting directly onto any sewerage system or surface water other than a provision in connection with the collection or the controlled discharge of extinguishant or spilled materials. The floors, walls, and any thresholds of a storage building have liquid-tight reservoirs that are discussed in Section 4.1.7.5. The floor of the storage building (or area) where gases are stored with a specific gravity larger than air, has the same height as the surrounding buildings.

Storage buildings normally have a roof constructed of lightweight materials. This allows the roof to act as explosion relief while leaving the remaining storage building structure intact. [36, HSE, 1998] Instead of a lightweight roof an intentionally weak spot can also be incorporated at another place, however it has to be located so as to prevent any hazard or damage to the surroundings in the event of an explosion. An alternative to explosion relief is to use mechanical exhaust ventilation that needs to be designed for every specific situation.

To prevent dangerous concentrations of flammable vapours accumulating in a building or storage area as result of a leak, the space needs to be adequately ventilated. Containers stored in the open air allow for any vapours to be dispersed effectively by natural ventilation and leaks or releases can be quickly seen. In a storage building the number of air changes in the room depends on the nature of the stored materials and the layout of the room. For example, if the room contains materials in the form of powder, the minimum number of air changes is one per hour. In the case of (highly) flammable liquids and highly volatile toxic materials, the number of air changes is minimal four to five per hour. Ventilation openings are normally not installed in any partitions designed to be fire-resistant. Where this is unavoidable, such openings are required to self-close in a fire situation. Several norms give advice on ventilation principles and designing for (natural) ventilation in buildings, however, advice from a competent ventilation engineer is normally necessary.

For protecting the outdoor storage from direct sunlight and rain, the storage can be equipped with a roof, however, in certain cases the erection of a roof may cause structural problems or it may hinder fire fighting. Compared to indoor storage, it is especially important for outdoor storage that the packaging of any dangerous material can withstand all possible climatic conditions.

To ensure adequate ventilation in an outdoor storage area, a firewall is normally only provided on one side of a container stack.

### ***Storage cells***

Floors, walls and partition walls for compartmenting are made of non-flammable materials and are resistant to the substances stored. At a certain place in the storage cell, an intentionally weak spot is incorporated that will collapse in the event of an explosion while leaving the remaining structure of the storage cell intact.

To prevent dangerous concentrations of flammable vapours accumulating in a storage cell, the cell will have adequate ventilation to the open air through diametrically opposed ventilation apertures in a wall near the floor (but above the liquid-tight reservoir) and near the top of a wall or in the top cover. Provisions are made to prevent ignition of the flammable liquids from outside through the ventilation apertures, e.g. self-closing.

**Operability:** An outdoor storage is easier to operate because it is naturally ventilated, leaks or releases can be seen quicker and has a simpler construction than a storage building.

**Applicability:** Buildings, cells and outdoor storage are applied all over Europe. An outdoor storage is easier to construct, but requires more space than a building or a storage cell.

Storage cells are normally used for storing small quantities of dangerous substance up to 2500 kilos or litres.

**Safety aspects:** Proper construction and ventilation is essential for the safe storage of dangerous substances.

**Energy/waste/cross-media:** A naturally ventilated storage facility requires less energy than forced ventilated alternatives.

**Economics:** Cannot be specified.

**Reference literature:** [7, CPR, 1992, 8, CPR, 1991, 35, HSE, 1998, 36, HSE, 1998, 45, Vlaanderen, ]

#### 4.1.7.3. Separation policy

**Description concerning outdoor storage facilities:** It is good practice to store flammable liquids well away from other processes and general storage areas. A physical distance best achieves this, but alternatively a physical barrier such as a wall or partition can be used. The recommended minimum separation distances are dependent on the quantity of flammable liquid stored. The distances shown in Table 4.10 are based on what is considered to be good practice in the UK and have been widely accepted by industry.

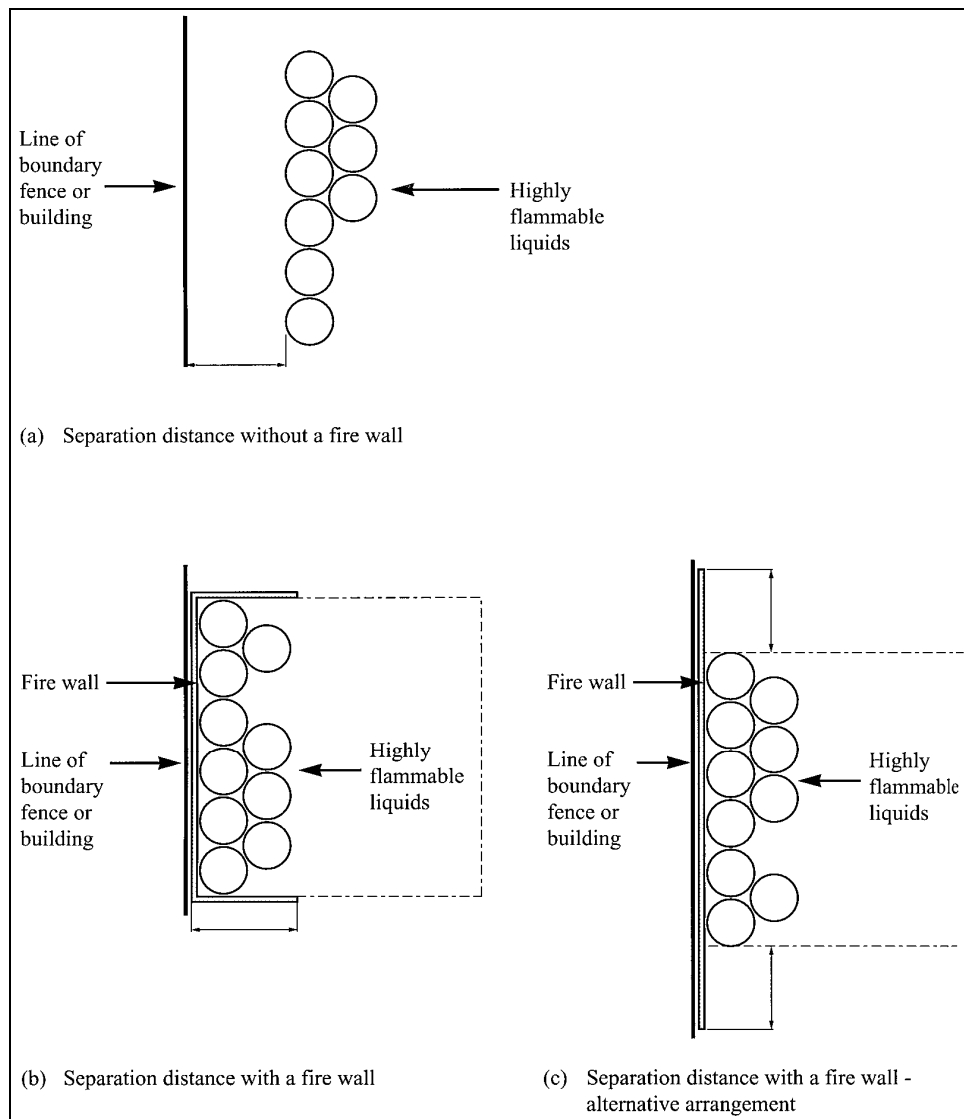
Quantity stored outdoors in litres	Distance (in metres) from occupied buildings, boundaries, process units, flammable liquid storage tanks or fixed ignition sources
up to 1000	2
1000 – 100000	4
above 100000	7.5
<i>Notes:</i> 1) the maximum stack size is 300000 litres, with at least 4 metres between stacks 2) containers are not stored within the bund of a fixed flammable liquid storage tank or within 1 metre of the tank bund wall	

**Table 4.10: Minimum separation distances of an outdoor storage with flammable liquid [36, HSE, 1998]**

Additional protective measures can be passive, such as a firewall, or they can be active, such as water deluge systems, for example sprinklers or monitors. Where such features are installed, a reduction in the minimum separation distances quoted above may be justified.

In the UK, a firewall is described as an imperforate wall, screen or partition providing at least 30 minutes fire resistance. It protects containers of flammable liquid from the effects of radiated heat from a nearby fire. A firewall can also ensure an adequate dispersion distance from buildings, boundaries, sources of ignition, etc. for flammable liquid or vapour leaking from any container. Concrete, masonry or brick constructions are applied. In the Netherlands, fire-resistance of doors, hatches and window constructions are determined in accordance with a Dutch NEN-norm. And as a last example, in Flanders, Belgium, a firewall is made of masonry with a thickness of at least 18 centimetres or concrete with a thickness of at least 10 centimetres, or it is made of a material with a thickness that achieves the same fire-resistance.

Separation distances for highly flammable liquids in drums and similar portable containers stored outside are shown in Figure 4.15.



**Figure 4.15: Separation distances for highly flammable liquids in drums and similar portable containers stored outside (view from above)**  
[36, HSE, 1998]

In the Netherlands, an outdoor storage facility for hazardous materials or pesticides with a capacity of more than 10 tonnes is situated at least 10 metres from flammable vegetation and to the storage of flammable materials. A minimum of 3 metres applies for the distance to the storage of other goods; this distance may be reduced to 2 metres if the firewall has a resistance of at least 60 minutes.

For the storage of packaged hazardous materials below 10 tonnes in the Netherlands, the following distances are applied:



Amount of hazardous material, chemical waste or pesticide stored in kilograms or litres	Distance from site boundary (m)	Distance from any building forming part of the establishment (m)
up to 1000	3	5
more than 1000	5	10

*Note: The scope of references [7, CPR, 1992] and [8, CPR, 1991] is limited to the following categories of substances:*

- *oxidants, with the exception of organic peroxides and nitrous fertiliser*
- *highly flammable substances, with the exception of substances which, under normal temperatures and without the addition of energy, can increase in temperature and finally ignite, substances which in gaseous form, at normal pressure, are flammable with air, or substances which, in contact with water or humid air, develop highly flammable gases in dangerous quantities*
- *flammable substances*
- *very poisonous substances*
- *poisonous substances*
- *corrosive substances*
- *harmful substances*
- *irritant substances*

**Table 4.11: Minimum separation distances of an outdoor storage with hazardous substances [7, CPR, 1992, 8, CPR, 1991]**

The distances mentioned in Table 4.11, may be reduced by erecting a firewall or a similar provision.

An outdoor storage facility with more than 1000 kilograms or litres highly flammable hazardous substances, chemical waste or pesticides is normally located at a distance of at least 15 metres from any other outdoor storage facility. This distance can also be less if a firewall or similar provision is erected.

In Flanders, guidelines are also developed concerning safe distances and safe combinations for storing gases in an outdoor storage area. Distances depend on the type of gas and the amount that is stored and varies from 2 and 7.5 metres. By erecting a firewall as with the previous two examples, these distances can reduce. See Table 8.32 in Annex 8.17.

**Description concerning storage buildings:** For an external storage building containing flammable liquids in the UK, the same distances as mentioned in Table 4.10 are valid. The use of a firewall can also be considered for any part of a building located within the separation distances to the boundary or another building, namely:

- the wall of the building on the boundary side is a firewall, and
- either the wall of the building at right angles to the boundary are firewalls for at least 4 metres from the boundary, or the firewall extends along the boundary for at least 4 metres beyond the store on either side.

Constructing the store as a fire-resistant building providing 30 minutes fire resistance can reduce these distances. See Figure 4.13 and Figure 4.14 that show examples of an external and an internal fire-resistant storage building respectively. Walls of the storage building forming part of another establishment normally have a fire-resistance of 60 minutes.

Also in Flanders the same distances are applied for an outdoor storage area or a storage building where gas cylinders are stored. By erecting a firewall these distances can reduce. See Table 8.31 in Annex 8.17.

If in excess of 10 tonnes dangerous substances or pesticide are stored in a building with a wall having a fire-resistance of at least 60 minutes, the distance applied in the Netherlands to flammable vegetation and/or the storage of flammable substances is 5 metres.

**Description concerning storage cells:** Floors, walls and partition walls for compartmenting in storage cells are made of non-flammable materials and are resistant to the substances stored. The floors, walls and roof have a fire resistance of at least 60 minutes.

**Applicability:** Fire-resistant walls can be applied in new and existing situations. Applying proper distances without firewalls can be a problem for existing sites.

**Safety aspects:** Applying proper distances and/or proper fire-resistant walls is essential for the safe storage of dangerous substances.

**Economics:** Cannot be specified.

**Reference literature:** [7, CPR, 1992, 8, CPR, 1991, 35, HSE, 1998, 36, HSE, 1998, 45, Vlaanderen, ] [6, CPR, 1992]

#### 4.1.7.4. Segregation and separation policy for incompatible materials

**Description:** The intensity of a fire, or its rate of growth, may be increased if incompatible materials are stored together. For example, oxidising agents will greatly increase the severity of a flammable liquid fire. In addition, a fire may grow and involve dangerous substances that in themselves are not combustible. It is the segregation policy that prevents these types of escalation. Depending on the nature of the stored materials, certain partitioning (sections) may be realised by means of:

- aisles at least 3.5 metres wide (3 metres in reference [35, HSE, 1998])
- a physical partition with fire-resistance of 30 minutes based solely on the criterion of flame-tightness
- a wall with a fire-resistance of at least 30 minutes
- using a storage cell or cabinet inside the storage area, building or cell.

Annex 8.3 shows recommendations for the segregation of dangerous substances according their hazard classification.

In Flanders distances depend on the type of gas and the amount that is stored and varies from 2 to 7.5 metres for incompatible gases and nothing for compatible gases. By erecting a firewall as with the previous two examples, these distances can reduce. See Table 8.31 and Table 8.32 in Annex 8.17: Distances for the storage of gas cylinders.

In the Netherlands maximum section sizes and maximum floor area of the storage facility are recommended as a prevention measure. The size of a section that is realised by one of the means mentioned earlier, used to store flammable solids or liquids is not greater than 300 m<sup>2</sup> and the floor area of a whole storage facility is not greater than 2500 m<sup>2</sup>. However, if substances with a flame-point lower than 100 °C are stored, a smaller section and floor area is recommended. For existing installations the maximum floor area can have a maximum of 4000 m<sup>2</sup>.

**Operability:** To apply a proper segregation and separation policy requires well educated and trained personnel.

**Applicability:** This policy can be applied in new and existing plants and is applied throughout Europe.

**Safety aspects:** Applying the segregation and separation policy is essential for safe storage of dangerous substances.

**Economics:** Cannot be specified.

**Reference literature:** [8, CPR, 1991, 45, Vlaanderen, ] [35, HSE, 1998]

#### 4.1.7.5. Containment of leakage and contaminated extinguishant

**Description:** The floors, walls, and any thresholds of a storage building have liquid-tight reservoirs that can contain all or a part (depending on the substance) of the liquid stored above or in such a reservoir. These reservoirs can be internal bunded areas, in-rack bunds or drip trays under each pallet and connected to an appropriate drainage system. Only after controls are made, spills and accumulated precipitation water is pumped out and discharged or disposed of in an appropriate way. The arrangement of spillage reservoirs must consider material segregation to prevent spillages from running into areas where incompatible materials are stored.

The floors of each compartment in a storage cell are fitted with a liquid-tight reservoir that can contain at least 100 % of the dangerous liquids stored in the storage cell.

If fire breaks out in a storage facility, not only part of the stored substances may be released, but also polluted extinguishant is produced. To prevent these materials from entering the soil, public drainage systems or surface water provisions are installed to collect these. If the same collecting system is used for collecting both the extinguishant and stored substances, the total collecting capacity required is determined by the sum of the product collecting capacity and extinguishant collecting capacity. Because of their storage capacity storage cells are not normally equipped with an extinguishant collection capacity.

For determining the collecting capacities several norms and regulations exist; see Annex 8.1 International Codes. The capacity depends on several parameters such as, the package material, the toxicity and harmfulness of the stored substances, the presence of (highly) flammable substances and the available fire-fighting equipment. In situations where, e.g. (highly) toxic or substances harmful to the environment are stored together with (highly) flammable substances, the collecting capacity not only depends on the amount of substances stored, but the accident in November 1986 in Basel (Sandoz) learned that in those situations the polluted extinguishant also has to be collected.

For outdoor storage the normally applied collecting provisions for spilled substances and the eventually occurring extinguishant are equal to those applied in storage. When the storage is not covered with a roof, provisions for the controlled discharge of (possibly polluted) rainwater are normally in place.

An extinguishant collecting provision shall be of watertight construction to prevent any polluted extinguishant from entering into soil, public drainage systems or surface waters. Polluted extinguishant is regarded as a waste product and should be disposed of as such.

The following possibilities exist for realising adequate extinguishant collecting provisions:

- containment within the storage facility
- a cellar under the storage facility
- an underground cellar outside the storage facility
- a reservoir completely or partly aboveground.

Such a collecting provision can be a tank that can be clearly distinguished from tanks used to store products, as can be seen e.g. at Oiltanking in Kotka, Finland. Although this site is a terminal and not a chemical warehouse, the principle is the same. Also a specially reserved part of a waste water treatment plant can be used as collecting provision.

**Operability:** The installation of a proper containment for leakage and contaminated extinguishant requires professional engineering.

**Applicability:** Containment can be applied in new and existing plants and is applied throughout Europe.

**Safety aspects:** Applying containment is essential for a safe storage of dangerous substances.

**Reference literature:** [8, CPR, 1991, 35, HSE, 1998, 117, Verband Chemiehandel, 1997]

#### 4.1.7.6. Fire protection and fire-fighting equipment

**Description:** Protection levels of fire prevention and fire-fighting measures in connection with the storage of packaged hazardous materials and chemical waste in excess of 10 tonnes, or the storage of pesticides can be ranged as follows:

1. (semi)-automatic extinguishing system or fire-fighting system with company fire brigade, fire detection, extinguishant collecting provision and preventive measures
2. fire detection, extinguishant collecting provision and preventive measures
3. preventive measures.

Protection level 1 entails fast detection in the event of fire section that can be deployed (semi-) automatically and will be operative within a few minutes. At protection level 2, controlling and extinguishing the fire must also be possible through an operationally reliable and well prepared fire fighting action. However, in this case it is acceptable if the fire-fighting action commences slightly later and is not deployed automatically. Level 3 is based on the virtual absence of any fire-fighting scenario; in these situations the preventive measures such as, separation and segregation, proper collecting systems and the below mentioned precautions against ignitions, are expected to provide sufficient safeguard.

Fire-resistant storage facilities for smaller quantities (< 10 tonnes) are normally equipped with one or more fire extinguishers.

Depending on the flammability of the stored product, the flammability of the packaging, the quantity stored and the category into which a material or a combination of materials is classified (e.g. toxic or harmful to the environment), a certain protection level will be applicable to each storage facility and has to be decided together with the local fire brigade on a case by case base.

**Reference literature:** [8, CPR, 1991]

##### 4.1.7.6.1. Preventing ignition

**Description:** There are many potential sources of ignition and they include: [35, HSE, 1998]

- smoking and smokers' materials
- maintenance work, particularly involving hot work
- electrical power supplies
- storage close to hot pipes or light fittings
- arson
- heating systems incorporating open flames
- warehouse vehicles and battery charging facilities
- LPG fuelled shrink-wrapping machines.

##### *Smoking*

Smoking and smokers' materials have caused many fires. The only possible measure is to prohibit smoking in the actual storage areas, and provide designated areas where smoking cannot give rise to any risk.

**Hot work**

Precautions that are current practice are:

- clearing, as far as practicable, all flammable or combustible materials away from the work area
- checking the flammability or combustion properties of material on one side of a partition or wall when work is to take place on the other side
- having suitable fire extinguishers at hand and maintaining a careful watch for fire during the work
- protecting combustible material that cannot be cleared by providing suitable screens or partitions
- examining the area thoroughly for some time after the work has finished to make sure there is no smouldering material present
- stopping all hot work by a safe period before the end of the working day.

**Electrical equipment**

Good practice is applying a main switch and distribution board in a separate fire-resisting room, located at the main store entrance, or preferably accessible directly from the outside. If electrical equipment is installed within the store, for example lighting, ignitable materials are not stored close to them. Normally electrical equipment located in a hazardous environment is constructed or protected so as to prevent danger and can be achieved by selecting equipment built to an explosion-protected standard (e.g. a British Standard or NEN-norm).

**Vehicles**

Vehicles that have to operate within the hazardous areas need to be protected to an appropriate standard to avoid ignition of any flammable vapours.

**Heating systems**

Normally indirect heating is used because this is not an ignition source, for example a radiator fed remotely by hot water pipes.

**Shrink-wrapping operations**

Ideally, heat shrink-wrapping operations are not carried out in the storage area but takes place either in a separate building or in a specifically designed bay within the building. An alternative to shrink-wrapping which is much safer is stretch-wrapping, however, in a few situations the latter cannot replace the shrink-wrapping method.

**Operability:** All measures to prevent ignition are simple and easy to operate.

**Applicability:** These prevention measures can be applied in new and existing plants and are applied throughout Europe.

**Safety aspects:** Applying prevention measures is essential for the safe storage of dangerous substances.

**Economics:** Cannot be specified, although none of these prevention measures are very expensive.

**Reference literature:** [8, CPR, 1991, 35, HSE, 1998]

#### 4.1.7.6.2. Fire-fighting systems

**Description:** The following fire-fighting systems are considered realistic and acceptable in storage facilities for hazardous materials and chemical waste storing > 10 tonnes, or storing pesticides:

1. automatic sprinkler system
2. automatic deluge system
3. automatic gas extinguishing system
4. local fire brigade with dry deluge system
5. automatic hi-ex system
6. company fire brigade with manually operated deluge system
7. company fire brigade with dry deluge system
8. company fire brigade extinguishing *in situ* (internal assault).

The characteristics of these systems are described in Annex 8.16, Characteristics of fire-fighting systems.

**Operability:** This depends on the applied system.

**Safety aspects:** Applying prevention measures is essential for the safe storage of dangerous substances.

**Energy/waste/cross-media:** With the use of fire-fighting equipment the arising of (chemical) waste is unavoidable.

**Reference literature:** [8, CPR, 1991]

#### 4.1.8. ECM for basins and lagoons – operational – gas emissions

##### 4.1.8.1. Floating covers

**Description:** Floating covers are applied to tanks, basins and lagoons to prevent vapours and particularly odours being emitted to the atmosphere. See Section 4.1.3.2 where floating covers are described for usage on open top tanks.

**Achieved environmental benefits:** In storing pig slurry, a reduction of ammonia emissions and odour can be achieved. An ammonia emission reduction of about 95 % or more was reported. Application of LECA reduced ammonia emissions by 82 %.

**Applicability:** Floating covers are commonly applied.

**Energy/waste/cross-media:** Stirring of the substance stored, e.g. slurry, would mix the slurry and its LECA layer, which increases (ammonia) emissions temporarily. It was observed that the LECA cover re-established itself very quickly after stirring and that emissions dropped again to the reduced level.

In the specific situation of storing pig manure slurry, covering will reduce or (in the case of plastic covering) eliminate oxygen transfer from air to slurry and raise the temperature of the slurry by about 2 °C. These effects create an anaerobic condition in which methane will rapidly be formed. Mixing and stirring of slurry increase emissions of methane. The lack of oxygen reduces nitrification (and consequently) denitrification and hence nitrous oxide emissions could be significantly reduced or prevented. With LECA, oxygen can still enter, which means that the (de)nitrification process and increased emission of nitrous oxide are likely to occur.

**Economics:** Costs of floating covers are likely to be EUR 15 – 25/m<sup>2</sup> (year 1999) of exposed substance surface. Costs of LECA are EUR 225 – 375 per tonne (year 1999). Additional costs will be incurred on sites where modifications are needed to the structure, or to emptying and agitation methods. Rainwater management determines differences in running costs, where LECA covered lagoons may coincide with higher slurry application costs. With plastic covering, net costs depend on possibilities for re-use of water, e.g. for irrigation.

**Reference literature:** [119, EIPPCB, 2001]

#### 4.1.8.2. Plastic or rigid covers

**Description:** Covers for lagoons are based on flexible impermeable UV-stabilised plastic sheets that are secured at the banktops and supported on floats. Plastic covers could effectively increase the capacity of a lagoon by a possible 30 % by keeping rainwater out.

**Achieved environmental benefits:** In storing pig slurry, reduction of ammonia emissions and odour can be achieved. An ammonia emission reduction of about 95 % or more was reported. The use of covers also permits emissions to be collected and treated, see Section 4.1.3.15.

**Operability:** Rigid covers are more commonly applied on smaller concrete basins.

**Applicability:** Purpose-designed covers can be fitted to existing (pig slurry) lagoons, unless:

- access is very poor
- a lagoon is very large (cost)
- banks are uneven.

An existing lagoon must be emptied completely to allow fitting of the cover. Wind damage is not a problem if the cover is well fixed on the sides and if some rainwater is kept on top to weigh it down.

Durability of 10 years for covers has been reported, but the vulnerability to wear and damage (from grazing animals) is unknown.

**Energy/waste/cross-media:** For covering a lagoon a large amount of plastic is needed that can measure up to 70 % more than the actual lagoon surface area and depends on the depth and inclination of the edges. The cover can be re-used.

In the specific situation of storing pig manure slurry, covering will reduce or eliminate oxygen transfer from air to slurry and raise the temperature of the slurry by about 2 °C. These effects create an anaerobic condition in which methane will rapidly be formed. Mixing and stirring of slurry increase emissions of methane. The lack of oxygen reduces nitrification (and consequently) denitrification and hence nitrous oxide emissions could be significantly reduced or prevented.

**Economics:** Additional costs will be incurred on sites where modifications are needed to the structure, or to emptying and agitation methods. Rainwater management determines differences in running costs. With plastic covering, net costs depend on possibilities for re-use of water, e.g. for irrigation. The use of biogas (methane) in case slurry is stored, depends on the purpose (heating or engine) and on the installation requirements. It could be profitable, but the cost recovery period may be quite long (over 20 years).

**Reference literature:** [119, EIPPCB, 2001]

#### **4.1.9. ECM for basins and lagoons – operational – emissions to soil and water**

##### **4.1.9.1. Impervious barriers**

**Description:** Where groundwater pollution is seen to be a risk, the lagoon should be substantially impermeable. The choice lies between either a clay or a synthetic membrane liner. If clay is used, it should contain at least 20 – 30 % clay to be sufficiently impermeable.

The clay needs to be compacted to a minimum of one metre thickness and a maximum permeability of  $1 \times 10^{-9}$  m/s. Liners need to be applied by a specialist contractor to ensure no damage during installation. Concrete basins are also an option.

**Reference literature:** [119, EIPPCB, 2001] [113, TETSP, 2001]

#### **4.1.10. ECM for basins and lagoons – operational – waste**

No information has been submitted.

#### **4.1.11. ECM for basins and lagoons – incidents and accidents**

Basins and lagoons are not used for storing hazardous substances so major accidents are not expected. A possible incident or accident is overflowing due to rainfall in situations where the basin or lagoon is not covered.

##### **4.1.11.1. Protection for overflow due to rainfall**

**Description:** For lagoons used for storing slurry, a freeboard of 750 mm is common practice. See Figure 3.17.

**Operability:** Is commonly applied in agriculture.

**Applicability:** Easy to apply.

**Safety aspects:** None.

**Energy/waste/cross-media:** Decreases the storage capacity.

**Economics:** Low cost measure.

**Reference literature:** [119, EIPPCB, 2001]

#### **4.1.12. ECM for mined caverns (atmospheric) – operational – gas emissions**

##### **4.1.12.1. Vapour balancing**

**Description:** Vapour balancing is used on atmospheric mined cavern sites with a fixed waterbed when storing liquid hydrocarbons. These sites contain a number of caverns which are connected to each other. As one cavern is filled, the displaced vapour is transferred to other caverns in order to avoid rapid pressure rises in the cavern being filled. Rigorous stock control planning is required in order to ensure that caverns are always available to receive displaced vapour.



**Operability:** Used mainly on large sites equipped with a number of caverns.

**Applicability:** Easy to apply on large sites.

**Safety aspects:** Require a strict respect of operating procedures and/or a high level of automation (safety alarms, emergency shutdown systems, etc.)

**Energy/waste/cross-media:** None.

**Economics:** Can eventually lead to hydrocarbon product declassification from a high value to a low value product in case of product mixing.

**Reference literature:** [150, Geostock, 2002]

### 4.1.13. ECM for mined caverns (atmospheric) – incidents and (major) accidents

#### 4.1.13.1. Safety and risk management

See Section 4.1.6.1 where the Seveso Directive is discussed for storing large quantities of dangerous materials in tanks. However, the same is valid for storage in caverns or any other type of storage for large quantities of dangerous substances.

#### 4.1.13.2. Monitoring

**Description:** It is common practice to carry out monitoring throughout the operational life of a cavern to ensure stability and successful hydraulic containment of the cavern. A typical monitoring programme includes:

- monitoring of the hydraulic flow pattern around the caverns by means of groundwater measurements, piezometers and/or pressure cells, seepage water flowrate metering
- assessment of cavern stability by seismic monitoring
- water quality follow-up procedures by regular sampling and analysis
- corrosion monitoring, including periodic casing evaluation.

Monitoring also requires a regular periodic evaluation.

**Operability:** All mined caverns are monitored.

**Applicability:** Applicable to all types of mined caverns – atmospheric and pressurised

**Safety aspects:** Safety procedures and monitoring programmes have to be established and strictly followed by qualified personnel.

**Reference literature:** [150, Geostock, 2002]

#### 4.1.13.3. Intrinsic safety properties

**Description:** The main safety principle adopted is to always ensure that the hydrocarbon product cannot catch fire underground due to the absence of oxygen. This is intrinsically the case for, amongst other types, atmospheric caverns designed with a fluctuating waterbed.

Rock mined caverns provide high intrinsic resistance to earthquakes.

**Applicability:** Applying mined rock caverns is highly dependent on the bedrock structure and groundwater conditions.

**Safety aspects:** By their intrinsic nature, caverns are by far the safest way of storing large quantities of hydrocarbon products.

**Energy/waste/cross-media:** Groundwater (seepage water) pumped from the cavern needs to be treated. Caverns of the fixed waterbed type need less water (and thus less waste water treatment) than the caverns of the fluctuating waterbed type.

**Economics:** The economical break-even point for applying a mined rock cavern is dependent on the hydrocarbon product stored and the site geology, but is generally from a capacity of 50000 m<sup>3</sup>.

**Reference literature:** [150, Geostock, 2002]

#### 4.1.13.4. Blanketing

**Description:** With heavier oils, such as diesel, bacterial growth on the oil/water interface may occur resulting in an accumulation of methane in the empty space. In these situations, for safety reasons, nitrogen blanketing is commonly applied.

When emptying a cave containing highly flammable products, having a high vapour pressure such as, e.g. petrol, the product will evaporate and the empty space will be filled with a mixture of hydrocarbon gases until it reaches a level above the upper explosion limit. When filling the cave again, the pressure will rise and the hydrocarbons will condensate. When applying nitrogen for blanketing in these situations, venting the nitrogen containing VOCs to the atmosphere will be necessary when filling the cave again. For this reason, blanketing is not commonly applied on highly flammable products. However, in certain fixed bed atmospheric caverns, according to the hydrocarbon product stored, nitrogen blanketing is used to make absolutely sure that no ignition is possible inside of the cavern.

However, for safety reasons when taking a cavern into use for the first time, it is important to purge the cave with nitrogen before filling it with product.

When crude oils are stored, there may be methane or ethane building up in the empty space in the cavern. Upon filling, these vapours will not (easily) return into the oil. For these situations the caverns are commonly connected for balancing ('breathing') these vapours. When one cavern is filling, the gases flow to the other caverns, using all available empty space. With time these gases move back into the oil and blanketing and venting into the atmosphere is not necessary.

**Applicability:** Blanketing is widely applied when storing heavier oils. In certain fixed bed atmospheric caverns, nitrogen blanketing is commonly applied to make absolutely sure that no ignition is possible.

**Energy/waste/cross-media:** For safety reasons, blanketing might be necessary for highly flammable products, accepting the consequence of venting the nitrogen to the atmosphere.

**Reference literature:** [176, EIPPCB, 2004]

#### 4.1.13.5. Maintaining hydrostatic pressure

**Description:** For preventing the stored hydrocarbon product from escaping out of the cavern, the cavern is designed in such a way, that at the depth at which it is situated, the hydrostatic pressure of the groundwater surrounding the cavern is always greater than that of the stored hydrocarbon product.

**Operability:** All unlined mined caverns are designed in this manner.

**Applicability:** This technique requires an appropriate design and monitoring throughout the operational life of the facility to ensure cavern stability and successful hydraulic containment of the cavern.

**Safety aspects:** None if the cavern is designed and monitored correctly.

**Energy/waste/cross-media:** The groundwater (seepage water) is, in most cases, not miscible with the hydrocarbon product being stored and accumulates at the bottom of the cavern prior to being pumped out. However, in the case of very light hydrocarbons (e.g. propane), the hydrocarbon product may contain traces (ppms) of water and may have to be dried in order to meet the appropriate quality standards.

**Reference literature:** [150, Geostock, 2002]

#### 4.1.13.6. Cement injection

**Description:** Cement injection of the roof and walls of caverns help to minimise the amount of seepage water.

The seepage water entering the cavern is pumped out and treated in a waste water treatment system. Porvoo Refinery has two waste water treatment plants; an active sludge plant (chemical and biological treatment) and an active carbon plant (adsorption/regeneration sections), which are both well suited for oily waters. At the Porvoo Refinery, the amount of waste water discharged is about 1 m<sup>3</sup>/day concerning a volume of 5000 m<sup>3</sup> oil, this equals 6 – 8 litres of seepage water/m<sup>3</sup> of cavern volume/year. The achieved emission level of VOC in the treated waste water that is discharged into the sea is typically below 1 mg/l.

**Operability:** The amount of cement required is dependent on the rock geology at the cavern depth.

**Applicability:** It is easy to apply to all mined caverns.

**Safety aspects:** Cement injection does not generate particular safety problems apart from the strict respect of safety standards and procedures required for all underground civil works.

**Economics:** This technique is a low cost measure.

**Reference literature:** [150, Geostock, 2002] [81, Neste Engineering, 1996]

#### 4.1.13.7. Interlock-system

**Description:** An interlock-system prevents overfilling; this system closes the inlet line valve if the level in the cavern is too high.

**Operability:** It is common practice to install an interlock-system.

**Applicability:** An interlock-system is easy to apply to all mined caverns.

**Safety aspects:** Applying an interlock-system is a minimum safety measure. More sophisticated overfill protection measures are available.

**Economics:** Interlock-systems are low cost items.

**Reference literature:** [150, Geostock, 2002] [81, Neste Engineering, 1996]

#### 4.1.13.8. Automated overfill protection

**Description:** Overfill protection devices can be connected to automated emergency shutdown systems which close down all the filling line equipment (pumps, valves, etc.).

**Operability:** For recently mined cavern facilities it is common practice to include sophisticated overfill protection devices which are built into the emergency shutdown system.

**Applicability:** Overfill protection devices connected to automated emergency shutdown systems are easy to apply for new facilities. They can sometimes be retrofitted on existing facilities. This system requires a strict respect of operating procedures and/or a high level of automation (safety alarms, emergency shutdown systems, etc.). It is applicable to all mined caverns.

**Safety aspects:** The safety standard is high. However, with automatic valves there is a potential for failure of upstream systems due to the 'water hammer' effect.

**Economics:** Sophisticated emergency shut down systems can be costly for new facilities, but these are usually justified for safety reasons resulting in positive environmental benefits. Retrofit, where feasible, is a very high cost option.

**Reference literature:** [150, Geostock, 2002]

#### 4.1.14. ECM for mined caverns (pressurised) – incidents and (major) accidents

##### 4.1.14.1. Safety and risk management

See Section 4.1.6.1 where the Seveso Directive is discussed for storing large quantities dangerous materials in tanks. However, the same is valid for storage in caverns or any other type of storage for large quantities of dangerous substances.

##### 4.1.14.2. Monitoring

Section 4.1.13.2 is also applicable to pressurised mined caverns.

#### 4.1.14.3. Intrinsic safety properties

**Description:** Pressurised caverns by their very nature, cannot catch fire underground due to the absence of oxygen at depth.

Rock mined caverns provide high intrinsic resistance to earthquakes.

**Applicability:** Applying mined rock caverns is highly dependent on the bedrock structure and groundwater conditions. Most mined caverns are of the pressurised type.

**Safety aspects:** By their intrinsic nature, caverns are by far the safest way of storing large quantities of hydrocarbon products.

**Energy/waste/cross-media:** Groundwater (seepage water) pumped from the cavern needs to be treated.

**Economics:** The economical break-even point for applying a mined rock cavern is dependent on the hydrocarbon product stored and the site geology, but is generally from a capacity of 50000 m<sup>3</sup>. For LPG in typical European conditions, the figure is considerably lower (approximately 10000 m<sup>3</sup>).

**Reference literature:** [150, Geostock, 2002]

#### 4.1.14.4. Fail-safe valves

**Description:** Downhole fail-safe valves, and other safety measures, ensure that the hydrocarbon product cannot escape in the event of a surface emergency event.

**Operability:** Recently designed caverns are equipped with these safety measures.

**Applicability:** Applicable to new mined caverns, but also existing caverns are sometimes retrofitted.

**Reference literature:** [150, Geostock, 2002]

#### 4.1.14.5. Maintaining hydrostatic pressure

Section 4.1.13.5 is also applicable to pressurised mined caverns.

#### 4.1.14.6. Cement injection

Section 4.1.13.6 is also applicable to pressurised mined caverns.

#### 4.1.14.7. Interlock-system

Section 4.1.13.7 is also applicable to pressurised mined caverns.

#### 4.1.14.8. Automated overflow protection

Section 4.1.13.8 is also applicable to pressurised mined caverns.

#### 4.1.15. ECM for salt leached caverns – incidents and (major) accidents

##### 4.1.15.1. Safety and risk management

See Section 4.1.6.1 where the Seveso Directive is discussed for storing large quantities of dangerous materials in tanks. However, the same is valid for storage in caverns or any other type of storage for large quantities of dangerous substances.

##### 4.1.15.2. Monitoring

**Description:** Cavern monitoring and inspection are key issues for safety and performance. Periodic controls are recommended, including the control and shape of the cavern, which can be modified if undersaturated brine is used, as well as casing integrity checks (logging and/or test) to prevent any risk of leakage due to cemented casing corrosion. A typical monitoring programme includes:

- assessment of cavern stability by seismic monitoring
- corrosion monitoring, including periodic casing evaluation
- carrying out of regular sonar evaluations to monitor eventual shape variations, particularly if undersaturated brine is used.

Monitoring also requires a regular periodic evaluation.

**Operability:** All salt leached caverns are regularly monitored and undergo a periodic inspection throughout the operating life of the facility.

**Applicability:** Applicable to all types of salt leached caverns.

**Safety aspects:** Safety procedures and monitoring programmes have to be established and strictly followed by qualified personnel.

**Reference literature:** [150, Geostock, 2002]

##### 4.1.15.3. Intrinsic safety properties

**Description:** Salt leached caverns by their very nature, cannot catch fire underground due to the absence of oxygen at depth.

**Applicability:** Applying salt leached caverns is highly dependent on the geographic conditions.

**Safety aspects:** By their intrinsic nature, caverns are by far the safest way of storing large quantities of hydrocarbon products.

**Energy/waste/cross-media:** The main consumers of energy are the pumps used for filling and emptying the caverns. Small traces of hydrocarbon may be present at the brine/hydrocarbon interface. For liquid hydrocarbons, especially at the end of a filling process, these hydrocarbons may be separated out in a brine treatment unit. As most salt leached cavern sites are isolated, these need to be collected and disposed of accordingly.

**Economics:** Where the geology of the site makes this mode of storage feasible, the relative cost per cubic metre of salt leached cavern storage to other modes is low.

**Reference literature:** [150, Geostock, 2002]

#### **4.1.16. ECM for floating storage – operational – gas emissions**

##### **4.1.16.1. Pressure and vacuum relief valves (PVRV)**

Section 4.1.3.11 is also applicable to floating storage.

##### **4.1.16.2. Tank colour**

Section 4.1.3.6 is also applicable to floating storage.

##### **4.1.16.3. Vapour balancing, collection or treatment**

Sections 4.1.3.13, 4.1.3.14 and 4.1.3.15 are also applicable to floating storage.

#### **4.1.17. ECM for floating storage – operational – emissions to water**

Cleaning of the tanks is the most important source of emissions to water. Normally residues from tank cleaning are piped ashore and treated in the same manner as those from tanks on shore. However, no further information was submitted.

#### **4.1.18. ECM for floating storage – incidents and (major) accidents**

##### **4.1.18.1. Safety and risk management**

**Description:** See Section 4.1.6.1 where the Seveso Directive is discussed for storing large quantities of dangerous materials in tanks. The same principles can be applied for floating storage.

**Reference literature:** [113, TETSP, 2001]

##### **4.1.18.2. Inspection and maintenance of the hull**

**Description:** As ships float on water, particular attention is normally paid to the inspection and maintenance of the hull.

**Reference literature:** [113, TETSP, 2001]

##### **4.1.18.3. Prevention of overfill**

**Description:** Overfills can be prevented by the use of high-level instrumentation and pump shutdown procedures.

**Reference literature:** [113, TETSP, 2001]

## 4.2. Transfer and handling of liquid and liquefied gas

In Section 3.2, the potential emissions from transfer and handling systems are listed in Tables Table 3.50 and Table 3.51 for aboveground closed piping transfer systems, Table 3.52 and Table 3.53 for aboveground open piping transfer systems, Table 3.54 and Table 3.55 for underground closed piping transfer systems, Table 3.56 and Table 3.57 for unloading hoses and Table 3.58 and Table 3.59 for handling systems.

These identify that the most significant potential emission sources, on a mode-by-mode basis, are filling of piping systems, cleaning of open systems and fugitives from all modes.

The scorecards in Annex 8.10 identify the emission control measures (ECM) for these potential emission sources.

Sections 4.2.2 through to Section 4.2.7 describe ECM systems for the transfer of liquids and liquefied gases, i.e. the different piping systems, and Section 4.2.8 describes ECM for the loading and unloading of transporters. ECM for the handling systems of the product such as the valves, flanges, pumps and seals are described in Section 4.2.9. Section 4.2.1 deals with several management tools that are applicable to transfer and handling in general.

### 4.2.1. Management tools for transfer and handling

#### 4.2.1.1. Operational procedures and training

**Description:** Procedures and training are important aspects in minimising emissions during the filling of all transfer systems; see Section 4.1.6.2.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.1.2. Inspection, maintenance and monitoring

**Description:** See Section 4.1.2.2.

#### 4.2.1.3. Leak detection and repair (LDAR) programme

**Description:** A LDAR programme consists of checking components for leaks and then repairing any identified leaking components. The leakage check is performed according to the US EPA reference method EPA 21, at a predefined sampling frequency. Inaccessible components are, in practice, not monitored (e.g. for reasons of insulation or height).

**Operability:** LDAR is a commonly used tool for situations most likely to cause emissions, such as when handling gas and light liquids, pressurised systems and where higher temperatures are applied.

**Reference literature:** [158, EIPPCB, 2002]

#### 4.2.1.4. Safety and risk management

See Section 4.1.6.1 where the Seveso Directive is discussed for storing large quantities of dangerous materials in tanks. However, the same is valid for transfer and handling of dangerous substances.



## 4.2.2. ECM for aboveground closed piping – operational – gas emissions

### 4.2.2.1. Reduction in number of flanges and connectors

**Description:** Bolted flanges and gasket-sealed joints are used wherever pipes, pumps, or valves may require isolation or removal.

A primary cause of flange leakage is thermal stress, which causes deformation of the seal between the flange faces. Thus piping systems in cyclic thermal service are likely to have higher flange leak rates.

Leaks from flanges may also be caused by misalignment and can be reduced by increased attention to the bolting technique. The flange rating and the type and material of the gasket need to be adequate for the service. For example, spiral wound gaskets to reduce risk of failure on gas systems and primary liquid shutoff valves.

Minimising the number of flanges by replacement with welded connections can be considered, compatible with the operations and maintenance requirements of the plant.

Threaded connectors may leak if the threads become damaged or corroded or if tightened without sufficient lubrication or torque. Pipeline standards should set a minimum size of branch pipeline which can be attached to a main pipeline to protect against mechanical damage, as it is easy to damage a very small pipeline attached to a very large pipeline.

**Achieved environmental benefits:** Each flange or flange assembly should meet the design code requirements to make sure that each flange assembly is able to withstand the maximum pressure at which the pipeline is to be operated. Meeting the design code requirements also ensures that the flange will be able to maintain its physico-chemical properties at any temperature to which it is anticipated that it might be subjected to in service.

**Operability:** Bolted and gasketed flanges are required wherever pipes, pumps, or valves may require isolation or removal. It is thus not possible to remove all flanges and connectors from a transfer and handling system.

**Applicability:** Widely applicable, within the limitation of operational requirements for equipment maintenance or transfer system flexibility.

**Safety aspects:** None.

**Energy/waste/cross-media:** None.

**Economics:** Minimising the number of flanges by replacement with welded connections, compatible with the operations and maintenance requirements of the plant, is a low cost option for new systems. Retrofitting is medium to high cost.

**Reference literature:** [152, TETSP, 2002]

### 4.2.2.2. Selection and maintenance of gaskets

**Description:** Correct selection of the gasket and regular maintenance (e.g. controlled tightening of the flange), are very important to prevent emissions. The regular control and replacement of the gaskets is also necessary, especially for those gaskets exposed to temperature fluctuation or vibration (where gasket load may be lost).

Primarily, a proper selection must be based upon:

- compatibility with the operating medium (process fluid)
- operating temperature and pressure
- variations of operating conditions (for example, during cycling)
- the type of joint involved.

Gaskets can be defined into three main categories:

- soft (non-metallic)
- semi-metallic
- metallic.

The mechanical characteristics and sealing performance capabilities of these categories will vary extensively, depending on the type of gasket selected and the materials from which it is manufactured. Obviously, mechanical and sealing properties are important factors when considering gasket design, but the selection of a gasket is usually influenced primarily by:

- temperature and pressure of the medium to be contained
- chemical nature of the medium
- mechanical loading affecting the gasket
- sealing characteristics of the gasket.

***Soft gaskets (non-metallic)*** Often composite sheet materials, suitable for a wide range of general and corrosive chemical applications. Generally limited to low to medium pressure applications. Types include: fibre reinforced sheet, exfoliated graphite, sheet PTFE (polytetrafluoroethylene) in various forms (including blow-out resistant forms based upon orientation of the PTFE) and high temperature sheet materials based upon forms of mica.

***Semi-metallic gaskets*** Composite gaskets consisting of both metallic and non-metallic materials, the metal generally providing the strength and resilience of the gasket. Suitable for both low and high temperature and pressure applications. Types include: covered serrated metal cored, covered metal jacketed, covered corrugated metal, metal eyelet, metal jacketed, metal reinforced soft gaskets (including tanged graphite and wire reinforced fibre materials), corrugated metallic and spiral wound gaskets.

***Metallic gaskets*** Can be fabricated from a single metal or a combination of metallic materials, in a variety of shapes and sizes. Suitable for high temperature and pressure applications. Types include: lens rings, ring type joints and weld rings.

A good performing gasket must be resistant to deterioration from the fluids being sealed, and it must be compatible chemically and physically. For metallic gaskets, consideration must be given to electrochemical (or 'galvanic') corrosion, which can be minimised by selecting gasket and flange metals which are close together on the electrochemical series.

Gaskets cut from sheets perform best when using the thinnest material that the flange arrangement will allow, but thick enough to compensate for unevenness of the flange surfaces, their parallelism, surface finish and rigidity, etc. The thinner the gasket, the higher the bolt load that the gasket can withstand, the less the loss of bolt stress due to relaxation, and hence the longer the service life of the gasket. Also, the lower the gasket area which will be exposed to attack from the internal pressure and aggressive media.

Once assembled, a gasket must be capable of overcoming minor alignment and flange imperfections, such as:

- non-parallel flanges
- distortion troughs/grooves
- surface waviness
- surface scorings
- other surface imperfections.

When assembled, a flange gasket seal is subject to compressive pressure between the faces of the flanges, usually achieved by bolts under tension. In order to ensure the maintenance of the seal throughout the lifetime of the assembly, sufficiently high pressure must remain on the gasket surface to prevent leakage. Under operating conditions, this pressure will be relieved by hydrostatic end thrust, the force produced by internal pressure which acts to separate the flanges. The gasket itself is also subject to a side load due to the internal fluid pressure tending to extrude it through the flange clearance space. To maintain seal integrity, the effective compressive pressure on the gasket (that is, the assembly load minus the hydrostatic end thrust) must be greater than the internal pressure by some multiple, dependent upon the gasket type, manufacturing process involved and level of tightness required.

For spiral wound gaskets in particular, the flatness and parallelism of the flanges are important factors for good sealing performance.

For soft gaskets, there must also be adequate friction between the gasket and flange faces to help prevent extrusion (blow-out) of the gasket from the joint. To allow for any relaxation of gasket compressive pressure which is normally inevitable, a factor of at least two is usually recommended between the compressive pressure on the assembly and that required to maintain a seal.

A proper assembly procedure is important for a good sealing performance; detailed guidance on this can be found in reference: [149, ESA, 2004]

Gaskets are normally not re-used because they may have been modified dramatically under operating conditions and might not achieve the normal level of sealing performance. Anyhow, the costs for new gaskets are very low.

High-integrity gaskets are, e.g. spiral wound, kammprofile or ring joints.

Exfoliated graphite and processed PTFE sealing materials have proved to be very successful when applied to a whole range of gasket styles providing the user with sealing performance way beyond that of the original asbestos-based gaskets.

**Reference literature:** Guidelines for safe seal usage – Flanges and Gaskets (ESA publication no. 009/98), available in several language versions. [149, ESA, 2004]

#### **4.2.2.3. Improved flanges**

**Description:** For installations with a high potential for environmental pollution, flanges with tongue and groove or with projection and recess, or special seals such as those with metal or grooved seals, are common practice.

**Reference literature:** [18, UBA, 1999]

#### 4.2.2.4. Vapour collection

**Description:** Vapours displaced during pipeline filling can be collected and either ‘balanced’ back to the tank from which the product was delivered, or treated in a vapour treatment system. For more details see Section 4.2.8 – ECM for the loading and unloading of transporters.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.3. ECM for aboveground closed piping – incidents and (major) accidents

##### 4.2.3.1. Internal corrosion and erosion

Internal corrosion may be caused by the corrosive nature of the product being transferred. Primarily the selection of the correct construction material would minimise corrosion.

Erosion is caused by mechanical wear of the inside of the pipeline due to excessively high flowrates, gas entrainment in the liquid, or by solid contamination of the liquid. Erosion may be controlled by a combination of flow management, corrosion inhibitors, internal lining and frequent pigging.

Deviations from designed conditions may impact corrosion and/or erosion rates and are normally examined through a management procedure, such as the ‘management of change procedure’, prior to making such changes.

An internal coating may be applied according to a strict quality specification to achieve a high quality protection. If pipes are to be joined by welding such that metal is exposed, then the area of the weld must also be coated to achieve a high level of protection. If this is not possible, then corrosion inhibitors could be considered.

If internally coated lines are to be pigged, then careful selection of the pig to prevent damage to the lining is essential.

**Reference literature:** [152, TETSP, 2002]

##### 4.2.3.2. External corrosion – aboveground piping

**Description:** To prevent the piping from atmospheric corrosion, the system is normally painted with a one, two or three layer coating system. The coating system needs to take the site-specific conditions into account (e.g. close to sea, etc). Coating is normally not applied to plastic or stainless steel pipelines.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.4. ECM for aboveground open piping – operational – gas emissions

##### 4.2.4.1. Replacement with closed piping systems

**Description:** See Section 3.2.1.1 for the general description of the closed piping system. In the Sections 4.2.2 and 4.2.3 emission reduction measures for closed piping systems are described.

**Operability:** Closed piping systems are normally used for the transfer of volatile liquids and liquefied gases because they can give rise to gaseous emissions. Open systems are only suitable for non-hazardous low volatility products.

**Applicability:** Applicable to all liquids and liquefied gases.

**Safety aspects:** None.

**Energy/waste/cross-media:** None.

**Economics:** Closed piping systems are a low cost item for new systems, they are a medium to high cost item for retrofit installations, depending on the current system design.

**Reference literature:** [152, TETSP, 2002]

#### **4.2.4.2. Reduced length**

**Description:** Reducing the length of aboveground open piping systems such as guttering, reduces the possible emissions.

**Operability:** The length should be kept as short as practicable.

**Applicability:** Applicable to all new systems. The applicability in retrofit situations depends on the local circumstances.

**Safety aspects:** None.

**Energy/waste/cross-media:** None.

**Economics:** For new installations this is a low cost item; for retrofit installations costs depend on the current system design.

**Reference literature:** [152, TETSP, 2002]

#### **4.2.5. ECM for aboveground open piping – incidents and (major) accidents**

The same ECM as for aboveground closed piping transfer systems; see Section 4.2.3.

#### **4.2.6. ECM for underground closed piping – operational – gas emissions**

The same ECM as for aboveground closed piping transfer systems; see Section 4.2.2.

#### **4.2.7. ECM for underground closed piping – incidents and (major) accidents**

The same ECM as for aboveground closed piping transfer systems; see Section 4.2.3, except for external corrosion, which is described below.

#### 4.2.7.1. External corrosion – underground piping

It is a commonly applied technique to protect underground piping systems by a combination of external coating and cathodic protection.

##### *External coating*

External coatings for buried pipelines should have suitable mechanical and electrical properties to exhibit strong resistance to local corrosive soils and strong adhesive characteristics. Factory applied external coatings are preferred. Coal tar or bitumen are common coatings applied to piping with reinforced fibre as an aid to bonding. Polyethylene, epoxy powder and other resins may also be used.

Every buried pipe has to have some field applied coatings where sections have been welded and where fittings connect with main pipelines. Field wrapping of these exposed sections could be applied under supervision to secure bonding and compatibility with the main pipeline coating and the cathodic protection system. External coatings are normally designed and applied in accordance with internationally accepted standards such as NACE RP-02-75, RP-01-69-92 and ASME B31.1, B31.3, B31.4, B31.8.

##### *Cathodic protection*

This is a technique that can be used to protect underground pipelines. It is only commonly used for large diameter pipelines which cannot be protected in some other way.

An undetected fault in the coating of a pipeline may become serious because any corrosive currents present in the soil environment will concentrate at this point. This potential problem is addressed by the application of a cathodic protection system. The design of cathodic protection systems is a specialised field and a corrosion engineer should be consulted for an optimal result.

**Reference literature:** [113, TETSP, 2001]

#### 4.2.8. ECM for the loading and unloading of transporters

**Description:** Vapours displaced during the loading of road tankers, rail tankers and ships may be freely vented to atmosphere, or as an alternative for products where the vapours have a significant negative environmental effect, may be ‘balanced’ back to the tank from which the product is being delivered, or treated in a vapour treatment system. Vapour balancing and treatment are also ECM for tank filling – see Sections 4.1.3.13 and 4.1.3.15. There are no emissions from the transporter during unloading as the product is replaced by air or vapour (if a vapour balance system is installed).

##### 4.2.8.1. Vapour balancing for the loading and unloading of transporters

**Description:** Vapour balancing can be used for both the loading and unloading of transporters. During loading, the vapours displaced from the transporter are collected through pipework installed on the transporter (or through specially designed loading arms) and displaced via vapour balancing pipework back to the storage tank from which the products are pumped. During unloading, the vapours move in the opposite direction, being displaced from the storage tank by the rising level of product in the tank to the transporter from which the product was unloaded. For balancing during unloading, the transporter must have vapour pipework installed ‘onboard’ the transporter to connect the vapour pipe from the storage tank to the transporter tank (or ‘compartment’ on a road tanker). The vapour balancing system requires non-pressurised storage tanks to be of the fixed roof type.

The balancing principle requires vapour tight pipework between the storage tank and the transporter. A vapour connection system is required at the loading point to connect the facility and the transporter. The system should be designed in such a way that at maximum vapour flowrate (i.e. at maximum liquid fill plus any tank breathing occurring during tank filling) the increase in pressure in the tank being filled (either the storage tank or transporter tank) does not result in an emission from the tank pressure relief valves. Conversely, both tanks should be designed so that the vacuum induced in the tank from which the product is pumped out does not result in the opening of the vacuum relief valves on the tank. This would result in air being drawn into the tank and effective vapour balancing not being achieved. Design considerations include minimising the potential for liquid locking of the vapour system due to liquid condensation collecting at low points in the pipework.

Where non-dedicated transporters are used (in particular, ship and rail loading where the transporters are used in international trade) there may be problems of ensuring that transporters have vapour collection pipework installed 'onboard'. In addition, where pipework is installed there may be compatibility issues between the size and location of the vapour connectors on the transporter and those installed on the loading facility. As the maintenance of the pipework, valves and connectors installed 'onboard' the transporter are generally not within the control of the operator of the storage facility, these may not be as effective as those installed within the facility itself.

The system must be safeguarded against the hazards of handling potential explosive air/hydrocarbon mixtures, mixing of incompatible components and excessive differential pressures between the storage tank and transporter.

Where a number of tanks are connected to a common vapour collection system, the system must be carefully designed to ensure that the liquid/vapour connections are always established to the same tank, and to minimise the risk of multiple tank involvement in any incidents.

**Achieved environmental benefits:** The emission reduction potential is limited by leakage within the vapour connection systems, both 'onboard' the transporter and within the facility. Efficiencies in excess of 95 % can be achieved. The efficiency decreases if top loading vapour collection arms, nominally sealed against an open hatch, are used due to increased potential for leakage around the hatch seal and because of emissions from the open hatch before and after loading.

**Operability:** The technique is reasonably easy to operate but requires increased inspections of detonation arresters and PVRVs, and of tests for vapour leaks. Condensates may collect in low points in the vapour piping system and in detonation arrester bodies and present a potential removal problem.

**Applicability:** Vapour balancing of non-pressurised storage tanks and transporters is only applicable to fixed roof tanks (FRT). Transporters require vapour collection systems to be installed 'onboard' except where modified top loading takes place. Only a limited number of general purpose sea-going tankers are fitted with vapour collection pipework.

The pressure rating of both the storage tanks and the transporter tanks needs to be of an adequate level to make the balancing system work and not cause emissions through PVRVs due to excessive pressures or vacuums. Where vapour balancing is undertaken during loading of a transporter, the possible cross-contamination of the stored liquid with the vapour from the previously carried cargo displaced from the transporter has to be considered. Where vapour balancing is undertaken during unloading, the owner of the transporter has to consider the effect on the next cargo to be loaded into the transporter. This may result in the transporter being purged (possibly uncontrolled e.g. ship tank purging off-shore) prior to the next loading.

**Safety aspects:** Vapour balancing introduces a potential for high hazards, particularly the risk of fire and explosion. There is the potential for blockage caused by rust particles, etc. or damage caused by poor maintenance to detonation arresters. Design issues are paramount e.g. both storage and transporter tanks must be fitted with PVRVs. Serious tank and transporter collapses due to vacuum incidents have occurred when the vapour balance lines have become blocked, or have not been correctly opened. Fire and explosion incidents have occurred due to maloperation of vapour balance systems, or lack of adequate maintenance of detonation arrester systems.

**Energy/waste/cross-media:** None.

**Economics:** Installing vapour balancing is a medium to high cost option. Significant costs are site-specific to the facility because this depends on the layout of the existing storage tanks and the distance between the tanks and the loading facility. Costs are not only incurred by the facility. Vapour collection systems are generally required on transporters. The costs to install these, particularly for ships which do not have inert gas systems installed, are high.

#### 4.2.8.2. Vapour treatment for the loading of transporters

**Description:** Vapour treatment requires the vapours to be collected during the loading of a transporter and fed to a vapour treatment system via pipework.

The vapour treatment systems for the loading of transporters are the same as those used for tank filling. These are described in Section 4.1.3.15.

The considerations of vapour collection from the transporter being loaded are the same as for vapour balancing described in Section 4.2.8.1.

**Achieved environmental benefits:** The emission reduction potential is limited to:

- the efficiency of the vapour collection system, and
- the efficiency of the vapour treatment system.

Leakage can occur within the vapour connection systems, both ‘onboard’ the transporter and within the facility. Vapour collection efficiency decreases if top loading vapour collection arms are used due to increased potential for leakage around the hatch seal and because of emissions from the hatch which has to be open before and after loading.

The efficiency of the vapour treatment system depends upon the technology used and the product vapour being treated. Although increased overall emission reduction can be achieved by having two systems in series, the incremental reduction in emissions may be small compared to operating only a single stage process. For example, gasoline single stage vapour recovery units (VRUs) can achieve an average efficiency of 99 %. Adding a second stage may remove another 0.9 %. The capital and operating costs of the second stage, therefore, result in a very poor cost per tonne of emission abated. In addition, second stage units produce additional air emissions e.g. indirect CO<sub>2</sub> due to electricity consumption or NO<sub>x</sub> from a thermal oxidiser, that need to be reviewed in relation to the amount of VOC emission reduction achievable.

**Operability:** The operability depends upon the treatment technique applied (see Sections 4.1.3.15.1 to 4.1.3.15.5). In general processes are unmanned and automatically controlled but may have high maintenance requirements. Specially trained personnel are needed for operation and maintenance.

**Applicability:** Emissions from loading and unloading are discontinuous and the significance of these emissions depend on the substance and the volume that is emitted. In the Netherlands, for example, an emission of methanol is significant and, therefore, needs to be abated, when over 500 kg/yr is emitted. However, no further information was made available for the TWG to decide on when to qualify an emission as being significant.



Vapour balancing or treatment of vapours displaced during loading activities is commonly applied and techniques are available for a wide range of products, but may be sensitive to flow or concentration fluctuations or contaminants (e.g. H<sub>2</sub>S poisoning of carbon beds). Water vapour causes problems with systems operating at low temperatures.

**Safety aspects:** Each technique needs to be reviewed for individual safety aspects, e.g. potential for uncontrolled exothermic reactions within adsorption systems.

**Energy/waste/cross-media:** Most treatment systems have a high energy usage with corresponding CO<sub>2</sub> emissions. There is the potential for waste generation in many systems (spent carbon from adsorption systems, contaminated water effluent streams, etc.) Thermal oxidation results in combustion products. Refrigeration systems may use ozone depleting substances.

**Economics:** Vapour recovery is a high cost option both for capital and operating costs. A recent report produced for the European Commission, DG Environment (AEAT, Rudd and Hill, Measures to Reduce Emissions of VOCs during Loading and Unloading of Ships in the EU, August 2001) concluded that ‘the costs per tonne abated of measures on ship-loading are higher than the most expensive measures that Member States are likely to implement in order to comply with national emission ceilings...’.

**Reference literature:** [176, EIPPCB Ineke Jansen, 2004, 180, Netherlands, 2004] [184, TETSP, 2004]

#### 4.2.9. ECM for product handling systems – operational – gas emissions

The main sources of fugitive emissions in a storage transfer and handling system are valve stems, flanges, connections and open ends, sampling points and pump seals.

Technical ECM for each of these potential sources are described below.

##### 4.2.9.1. High quality equipment

**Description:** In many cases, using better quality equipment can result in reductions of emissions. For new systems, this generally does not lead to a large increase in investment costs. However, for existing systems, replacing existing equipment with equipment of improved quality is often not economically justifiable.

For example, high quality packed valves are available that have very low fugitive emissions. To achieve low emissions, these valves use improved packing systems, are built according to stringent tolerances and are carefully assembled.

**Operability:** Use of better quality equipment can reduce downtime and maintenance requirements.

**Applicability:** Widely applicable.

**Safety aspects:** None.

**Energy/waste/cross-media:** None.

**Economics:** Low cost for new systems. High cost if equipment is retrofitted.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.9.2. Elimination of open-ended lines and valves

**Description:** Open-ended lines occur at the outlets from drains or sampling points. They are typically fitted with a valve, which is normally closed.

All drains that are not operated on a regular basis are normally fitted with a cap, blind flange or plug. If they need to be operated regularly, they are fitted with a second valve.

**Operability:** Requires more time to remove caps, blind flanges, etc.

**Applicability:** Widely applicable.

**Safety aspects:** Reduces risk of accidental spillage.

**Energy/waste/cross-media:** None.

**Economics:** This is a low cost technique.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.9.3. Bellows valves

**Description:** Bellows valves have no stem emissions as this type of seal incorporates a metal bellows that forms a barrier between the valve disc and body.

However, the resulting emission reduction compared with good quality rising stem valves is not sufficient to justify the very high additional cost on environmental grounds. These valves are used for health or safety reasons for highly toxic services (to reduce the risk of exposure of operators to toxic vapours) or highly corrosive service (to avoid risks related to corrosion of the valve components potentially leading to a loss of containment).

**Operability:** The bellows is the weak point of this type of system and service life can be quite variable. Consequently, this type of seal is normally backed up with a conventional packing gland and may be fitted with a leak detector in case of failure.

**Applicability:** Bellows valves are used for toxic or corrosive products, as the additional cost for these valves does not justify use on less hazardous products.

**Safety aspects:** None.

**Energy/waste/cross-media:** None.

**Economics:** Bellows valves are very high cost items when compared with packed valves.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.9.4. Valves with a diaphragm

**Description:** In this type of valve, a diaphragm is used to isolate the working parts of the valve from the liquid in the main body. The diaphragm may also be used to control the flow. However, emissions will occur if the diaphragm fails.

**Operability:** Advantages of this type of valve are absence of valve seating problems and no gland sealing requirements. The material of the diaphragm is normally the limiting factor to the maximum service pressure and temperature. Failure of the diaphragm causes rapid loss of integrity.

**Applicability:** Because there are no moving parts in the liquid, the valves are often used on aggressive liquids where, for example, some solid material may be present. The body itself can also be lined against corrosion.

**Safety aspects:** The potential for diaphragm rupture means that due consideration should be given to the consequence of failure, particularly if handling toxic or flammable products.

**Energy/waste/cross-media:** None.

**Economics:** For new installations this is a low cost item, for retrofit installations costs depend on the current system design.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.9.5. Rotating control valves

**Description:** Control valves open and close frequently and are, therefore, more prone to leakage than shut-off valves. Using rotating control valves instead of rising stem control valves reduces emissions to air.

**Operability:** Similar to rising stem control valves.

**Applicability:** Rotating stem control valves may not have the required flow characteristics provided by rising stem control valves for certain control applications.

**Safety aspects:** None.

**Energy/waste/cross-media:** None.

**Economics:** For new installations this is a low cost item, for retrofit installations costs depend on the current system design.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.9.6. Variable speed pumps

**Description:** Control valves open and close frequently and are, therefore, more prone to leakage than shut-off valves. Using variable speed pumps instead of rising stem control valves reduces emissions to air.

**Operability:** The operability depends on the system design but is generally similar in control complexity to an automated valve.

**Applicability:** The applicability is dependent on the overall system design.

**Safety aspects:** None.

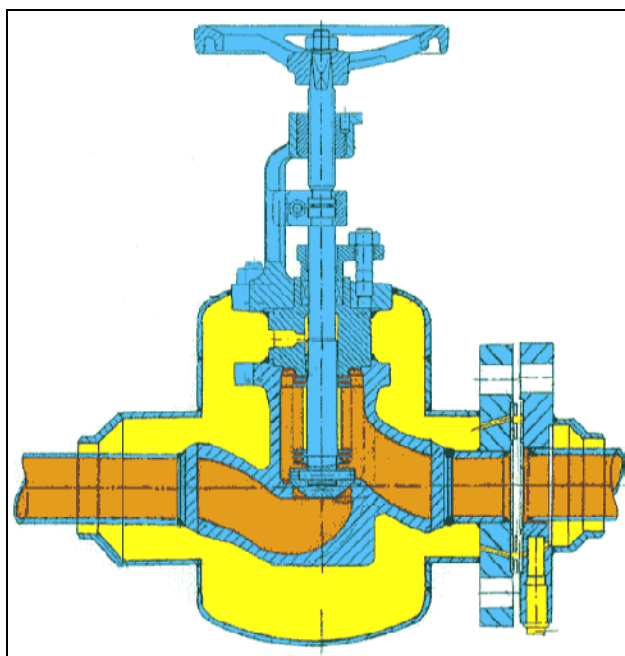
**Energy/waste/cross-media:** None.

**Economics:** Use of a variable speed pump is a low cost item for new systems. High cost if equipment is retrofitted outside of the normal replacement schedule.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.9.7. Double walled valves

**Description:** Double walled valves are available which are approved standard valves with an outer secondary containment, which hermetically encapsulate all critical parts that represent a potential point for leakage or emission. These valves are a necessary item in all monitored double wall systems and can be attached to either pipes or tanks with welded or flanged connections.



**Figure 4.16:** Scheme of a patented double wall valve  
[160, Sidoma Systeme GmbH, 2003]

**Achieved environmental benefits:** Technically zero emission can be achieved.

**Operability:** Maximum allowable pressure is 40 bar and maximum allowable temperature is 450 °C.

**Applicability:** Broadly applicable, especially for gasoline, benzene and fugitive liquids.

**Safety aspects:** None.

**Economics:** See economics for the combination of a double wall tank and bottom discharge and of a double wall valve in Section 4.1.6.1.15.

**Reference literature:** [160, Sidoma Systeme GmbH, 2003]

#### 4.2.9.8. Pressure and thermal relief valves

**Description:** Relief valves are fitted to transfer systems to avoid a build up of pressure due to solar heat absorption or in emergency situations.

The vents of relief valves can be piped back into a suitable safe point in the transfer or storage system on the other side of equipment blocked in.

Relief valves, which discharge to the atmosphere, should exhaust at a safe distance away from personnel to prevent accidents.

Thermal relief valves are designed for credible fire cases as well as thermal expansion due to ambient effects.

Similar relief systems are used for liquids that can be subject to decomposition and cannot be blocked between two closed valves.

In emergency situations, e.g. fast closure of a pipeline valve, a pressure surge may be generated that exceeds the maximum allowable pipeline working pressure. In such cases, pressure surge relief systems are designed to protect the integrity of the pipeline. Pipeline surge can be avoided or minimised by using systems to control the closure rate of valves, typically by timing a control valve or fitting a gearbox to a manual valve. Pipeline surge potential increases in proportion to length of pipeline and where suspected should be mathematically modelled to determine valve closure speeds.

**Operability:** Relief valves require regular inspection and maintenance.

**Applicability:** Widely applicable.

**Safety aspects:** Significantly reduces the risk of leakage due to excess pressure.

**Energy/waste/cross-media:** None.

**Economics:** Low to medium cost.

**Reference literature:** [152, TETSP, 2002]

#### 4.2.9.9. Seal-less pumps

**Description:** To isolate the interior of the pump from the atmosphere all pumps, except canned motor and diaphragm pumps (with magnetic drive), require a seal at the point where the shaft penetrates the housing.

In seal-less canned motor pumps, the cavity housing, the motor rotor and the pump casing are interconnected. As a result, the motor bearings run in the product being pumped and all shaft seals are eliminated. As a result, these pumps are not suitable in transferring substances containing particles.

**Operability:** Maintenance of the electrical parts of the motor requires the unit to be fully cleaned of the process fluids.

**Applicability:** Canned pumps cannot be used with products that may contain particles. A centrifugal pump with a magnetic transmission are commonly applied for handling chlorinated solvents.

**Safety aspects:** Canned pumps pose more risk of fire when transferring flammable substances.

**Energy/waste/cross-media:** Depending on system design cleaning of the unit may give additional waste by comparison to a traditional pump motor arrangement. Seal-less pumps require more energy compared to conventional pumps.

**Economics:** Medium cost for new systems and high cost for retrofit installations.

**Reference literature:** [152, TETSP, 2002] [156, ECSA, 2000]

#### 4.2.9.10. Improved single seals for pumps

**Description:** The technologies employed include highly sophisticated finite elements and other modelling techniques in the optimisation of component shapes, computational fluid dynamics, specialised material developments, improved tribological properties rubbing face surface profile adjustments and pre-set packaged assemblies to eliminate fitting errors. Another factor, in support of the enhanced performance and reliability of new seal technologies, is the performance testing capability of the seal manufacturers.

Additionally, for applications where hazard containment is required from the single seal arrangement, it is usual to include some form of external containment device to allow collection of any abnormal levels of vapour leakage and, where required, warn operators through a pressure induced alarm system. There are many kinds of secondary containment devices, including fixed or floating bushing and lip seals (spring energised or pressure energised). The space between the mechanical seal and some types of secondary containment device can be filled with a fluid to provide an environment where degradation or crystallisation of leakage is prevented.

To avoid emissions it is important that pump seals (and fitting and pipe seals) are mounted and installed so that, during operation, they are technically impervious towards the surrounding atmosphere and the seals are not forced out of place during normal operating conditions.

In selecting an appropriate sealing technique and raw materials, the following aspects are normally considered:

- the characteristics of the substance
- the mechanical, thermal and product demands
- the stability towards the medium to be transported.

**Achieved environmental benefits:** For improved single mechanical seals, leak rates of between 0.42 and 1.25 g/h are reported from one petrochemical plant in the Netherlands and between 0.63 and 1.67 g/h from a chemical plant in Germany.

This experience and data have been consolidated into the German guideline VDI 2440 which recommends that operators use 1 g/h as the mean leakage rate from single mechanical seals on process pumps.

Emission values are typically below 1 g/h under normal operating conditions in the field.

**Operability:** Single mechanical seals provide cost effective, reliable sealing for most VOC services, in line with API Standard 682 specifications, provided the following conditions are satisfied:

- process fluid specific gravity > 0.4
- vapour pressure margin in the seal chamber is sufficient for face lubrication
- process or flush fluid provides adequate lubrication and cooling of the seal faces.

Special seals may be needed for aggressive or solidifying products.

**Applicability:** Improved seals are suitable in the majority of cases though a higher degree of installation and maintenance skill is needed by comparison to packed gland pumps.

**Safety aspects:** None.

**Energy/waste/cross-media:** None.

**Economics:** A packed gland provides the most economic form of seal. A single mechanical seal provides medium cost replacement for new equipment, but can be high for retrofit as extensive pump shaft modifications may be required.

**Reference literature:** [152, TETSP, 2002, 157, VDI, 2001] [18, UBA, 1999] [149, ESA, 2004] [175, TWG, 2003]

#### 4.2.9.11. Dual unpressurised seals for pumps

**Description:** The simple sophistication of a single seal (which contains the process fluid) is to include a second mechanical seal outboard of this primary seal. The vapour leakage entering the containment chamber between the two seals can then effectively be channelled to a plant flare or vapour recovery system.

**Achieved environmental benefits:** Dual seal arrangements with unpressurised buffer liquid provide emission values typically below 0.01 g/h, achieving emission levels less than 10 ppm (< 1 g/day) when emissions are fed to a flare or vapour recovery system.

To achieve nearly complete elimination of emissions to the atmosphere, a flow of nitrogen buffer gas can be used to purge the gas lubricated, mechanical containment seal to channel them to the recovery/disposal system.

**Operability:** Normally there is a connection from the top of the reservoir to a plant flare or vapour recovery system together with an orifice and an alarm to warn of deterioration in the sealing performance of the primary seal.

**Applicability:** Commonly applied where the handled fluid is a VOC. Purging with nitrogen is applied by some operators.

**Reference literature:** [149, ESA, 2004]

#### 4.2.9.12. Dual pressurised seals for pumps

**Description:** This technique consists of two seals with a barrier fluid (liquid or gas) between them operated at a pressure greater than the process stream. Any leakage (outbound to the atmosphere or inbound to the process stream) is of the barrier fluid, and therefore, selection of a safe barrier fluid compatible with the process stream is essential.

Liquid lubricated mechanical seals typically use water or a light lubricating oil as the barrier fluid supplied from a self-contained support system and gas lubricated designs utilise a convenient plant gas source such as nitrogen managed by a control system. The simplicity and very low energy consumption of dual pressurised gas seals has been a strong driver in the growth of this technology in recent years.

**Achieved environmental benefits:** Dual pressurised systems virtually eliminate leakage of the process fluid into the environment and typically have emission values approaching zero, usually described as ‘not measurable with existing instrument technology’.

**Operability:** The potential of a failure of the barrier system to maintain a pressure greater than the process stream, although unlikely, is a scenario which must be considered. The system can be configured to warn the operator of the problem. In addition, modern dual pressurised mechanical seals can be provided with componentry which will withstand a failure of the barrier system and continue to effectively contain the process for a period of time; most international pump standards now require features which provide this capability.

**Applicability:** This type of seal arrangement is applicable to sealing process fluids with poor lubricating properties, on services where single seals are unreliable, or where the process fluids may change frequently (such as in pipeline services) and is selected when the handled fluid is particularly hazardous.

**Economics:** Double mechanical seal systems are expensive.

**Reference literature:** [113, TETSP, 2001, 149, ESA, 2004]

#### 4.2.9.13. Seals for compressors

**Description:** The issues with seals in compressors are similar to pumps (see Sections 4.2.9.10 4.2.9.11 and 4.2.9.12).

Lower velocity positive displacement compressors are typically sealed by single mechanical seals lubricated by oil which jointly flows through the inbound bearing assembly. The oil is separated and recycled. It is common practice to use an energised lip seal outbound of the primary seal to contain any oil leakage. This helps channel process contaminated oil into a suitable collection chamber.

This concept is improved by the addition of a gas lubricated mechanical containment seal. With this technique no liquid buffer is required and the transferred gas, now at atmospheric conditions in the containment chamber, itself provides the lubrication of the containment seal. Another advantage is that the containment chamber is directly connected to a plant flare or vapour recovery system with an orifice and a pressure alarm to warn of deterioration in the sealing performance of the primary seal.

A nitrogen buffer gas is occasionally used to purge the outer containment seal and assist the collection and separation of lubricating oil and the gas that is transferred.

In circumstances where the transferred gas is contaminated by a toxic impurity (e.g. H<sub>2</sub>S in a sour hydrocarbon gas), again nitrogen can be used to purge the process side of the containment seal. Where this is not practical, inert gas flush can be added.

In very high pressure services, the pressure is broken down over two primary seals and a containment seal. This triple tandem seal system has been used successfully to seal hydrogen recycle compressors.

**Economics:** Oil lubricated mechanical seals have a high capital investment. The benefits of gas lubricated mechanical seals are lower investment and operating costs.

**Reference literature:** [149, ESA, 2004]

#### 4.2.9.14. Improved sampling connections

**Description:** Sampling points can be fitted with a ram type sampling valve or with a needle valve and a block valve to minimise emissions. Safe operations must always be taken into account in the design.

Where sampling lines require purging to obtain representative samples, closed-loop sampling lines can be installed. These control emissions from the purged liquid by returning it either directly to the process line, collecting and recycling it or transporting it to a control device.

**Operability:** Training and operating procedures required.



**Applicability:** Applicable to volatile products.

**Safety aspects:** Safe operations must always be taken into account in the design.

**Energy/waste/cross-media:** None.

**Economics:** Depending on the complexity of the sampling systems, these can be low to medium cost.

**Reference literature:** [152, TETSP, 2002]

#### **4.2.10. ECM for product handling systems – incidents and (major) accidents**

##### **4.2.10.1. Flanged connections in liquid tight pits**

For underground piping it is common to install all flanged connections in liquid tight pits making them accessible from the surface.

## 4.3. Storage of solids

### 4.3.1. General – Emission Control Measures (ECM)

This section contains a general overview of the various Emission Control Measures concerning the storage of different bulk materials. Table 8.3 in the Annex shows the storage methods applied and the relevant bulk materials. Table 8.29 shows the same bulk materials in combination with selected techniques to consider in the determination of BAT. In that same table the selected techniques are assessed against the following parameters:

- dust reduction potential
- energy consumption
- cross-media effects
- investment requirement
- operating costs.

In the following sections these techniques are described in more detail. However, other ECM, which do not appear in Table 8.29 were also identified and are also discussed in the following sections. Finally, all techniques were assessed by the TWG and the TWG concluded which of these techniques are BAT.

After describing the general approaches to minimise dust from storage in Section 4.3.2, possible primary organisational approaches are described in Section 4.3.3 and in Section 4.3.4 the primary constructional techniques. Section 4.3.5 is a bit different from the other sections, because all approaches, primary and secondary, on dust prevention/reduction on heaps are put together in one table, Table 4.13. Section 4.3.6 continues with describing primary techniques to minimise dust from storage and Section 4.3.7 with the possible secondary techniques. In Section 4.3.8 attention is given to the prevention and control of explosions.

### 4.3.2. General approaches to minimise dust from storage

There are three approaches to dust reduction:

1. **Pre-primary approaches** start with the production or extraction process and reduce the material's tendency to make dust before it leaves the production plant. Pre-primary approaches are part of the production process and therefore outside the scope of this document and, apart from some examples in Section 4.4.2, are not further described.
2. **Primary approaches** are all the ways of reducing emissions during storage and can be divided into:
  - organisational primary approaches: behaviour of the operators
  - constructional primary approaches: constructions which prevent dust formation
  - technical primary approaches: techniques which prevent dust formation.
3. **Secondary approaches** are abatement techniques to limit the distribution of dust.

Table 4.12 gives an overview of approaches and techniques that can reduce dust emissions from storage together with reference to the relevant sections, if available.

**Reference literature:** [17, UBA, 2001]

Approaches and techniques to reduce dust emissions		Section	
Primary	Organisational	• monitoring	4.3.3.1
		• layout and operation of storage places (by planning and operating personnel)	
		• maintenance (of prevention/reduction techniques)	
		• reduction of wind attack areas	
	Constructional	• large volume silos	4.3.4.1
		• sheds or roofs	4.3.4.2
		• domes	4.3.4.3
		• self-erecting covers	4.3.4.4
		• silos and hoppers	4.3.4.5
		• wind protection mounds, fences and/or plantings	4.3.5
Technical	• use of wind protection	4.3.5; 4.3.6.2	
	• covering of open storage	4.3.5; 4.3.6.3	
	• moistening of open storage	4.3.6.1	
Secondary	• water spraying/water curtains and jet spraying	4.4.6.8; 4.4.6.9	
	• extraction of storage sheds and silos	4.3.7	
<i>Note: The boundary between primary and secondary approaches is not always clear; e.g. a water curtain limits the spread of dust emissions and is – at the same time – a means of dust binding.</i>			

**Table 4.12: Approaches and techniques to reduce dust emission from storage and cross-reference [17, UBA, 2001]**

It is important to note that the selection of a storage system type and ECM to reduce dust emissions depend on the properties of the product. Especially for end-products, where customer specifications are crucial, selection of storage equipment and ECM are based on many factors such as, the product resistance to attrition, the ability to break, crush, flow, and cake-on, the chemical stability, and sensitivity to moisture.

### 4.3.3. Primary organisational approaches to minimise dust from storage

#### 4.3.3.1. Monitoring dust emissions from open storage

**Description:** Regular or continuous visual inspections to see if dust emissions from open storage occurs and to check if preventive measures are in good conditions are necessary to be able to react quickly and to undertake adequate measures. Measuring of concentrations of dust in the air at and around large sites is used as a method for controlling and monitoring and can be carried out continuously or discontinuously. Measuring the levels of dust also allows for checking if air quality levels are respected.

See for more information on monitoring the reference document on the general principles of monitoring [158, EIPPCB, 2002].

**Operability:** In the Netherlands, at the three largest sites for storage and handling of coal and ore, systems for continuous monitoring are in use. At Corus, IJmuiden, a steel producer that produces more than six million tonnes of steel products a year, continuous monitoring of dust concentrations around the location has been applied since 1990. At two other large storage sites in the Rotterdam-Rijnmond area a sophisticated measuring network for continuous monitoring is applied with measuring points on site and downwind outside the site. At these two sites even different levels of dust emissions can be detected between different shifts. At one of the sites seven monitor devices are installed.

To be able to anticipate weather conditions, and especially on increasing wind speed or troublesome wind direction at the Corus site, the person who is responsible for spraying the heaps, is also made responsible for following the weather forecast. Following the weather forecast by, e.g. using meteorological instruments on site, will help to identify when moistening of heaps is necessary and will prevent unnecessary use of resources for moistening the open storage.

**Economics:** One continuous monitoring device costs EUR 7000. The operational costs such as data processing and maintenance are larger.

**Reference literature:** [134, Corus, 1995] [176, EIPPCB Ineke Jansen, 2004]

### 4.3.4. Primary constructional techniques to minimise dust from storage

#### 4.3.4.1. Large volume silos

**Description:** A large volume silo has a flat bottom and a central discharge installation in which the silo content is stacked in horizontal layers. Within the silo there is a spreader, a telescopic pipe and a screw system. The screw system consists of a distribution screw and a dust barrier screw. The screw system is attached to the spreader by wires and guides in order to keep the screw system constantly on the surface of the stored material.

By the use of filtering installations in the telescopic pipe and at the transfer points, an under-pressure is generated and dust is prevented from escaping from the silo.

There are different construction types:

##### *Centre flow*

With centre flow, unloading is from the bottom; the material forms its own centre flow channel by gravity. The surface of the material forms a hopper. In order to bring the material into the centre of the silo, the screws rotate in opposition. The velocity of the screws determines the amount of material conveyed.

##### *Centre flow with centre column*

A centre column supports the silo roof. The function principle is similar to the centre flow principle. It is used for large storage capacities.

##### *Disc column*

With a disc column, an artificial centre flow column is formed. The centre column consists of several discs. The system is suitable for bulk materials that are not free-flowing and for those with changeable flow characteristics.

**Applicability:** Silos are generally used to protect the product against external input (e.g. rain) or to avoid losing valuable product. They are also commonly applied when the solid material is a powder or contains a sufficient quantity of dust which can cause a significant environmental impact. Examples of bulk materials that are stored in silos when they are in powder or pulverised forms are: FGD-gypsum, potato starch, finely crushed limestone, fly ash, fertiliser and pulverised coal.

**Economics:** The costs vary from installation to installation. Beside normal cost factors such as investment and maintenance, losses of quality and quantity of the stored materials must be considered.

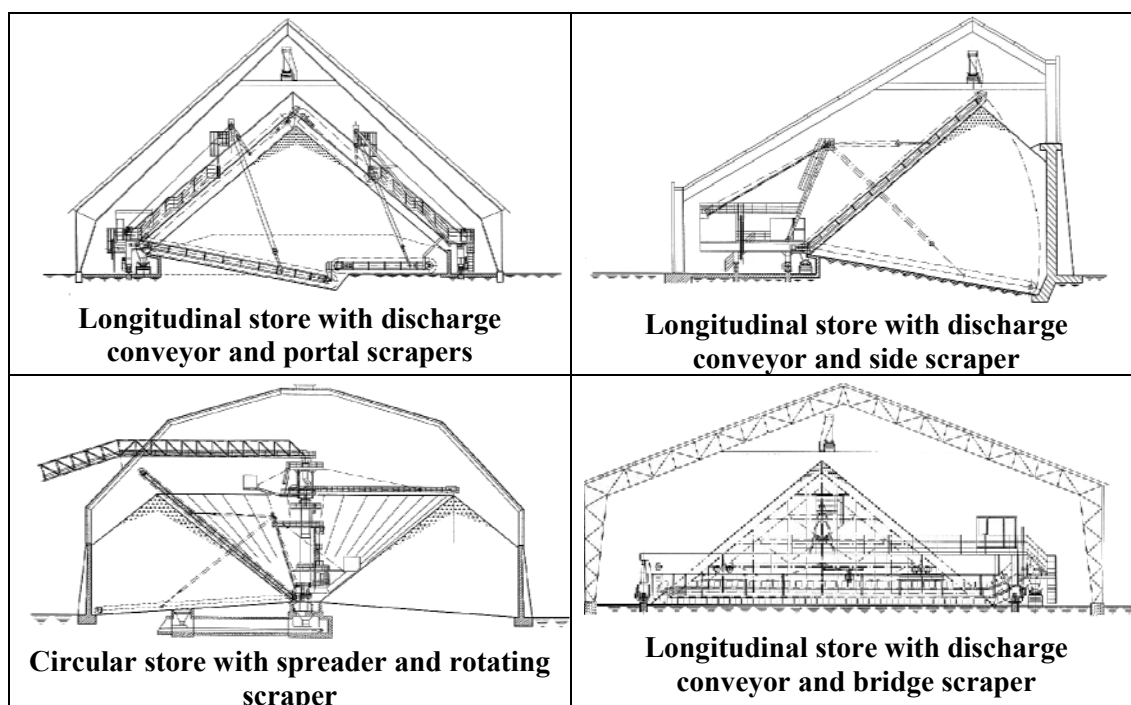
**Driving force for implementation:** The use of silo systems is suitable in those cases where only small storage areas are available, the storage capacities are limited and the requirements for preventing emissions are relatively high.

**Reference plants:** Power station Tiefstack (HEW) for hard coal and FGD-gypsum, Deuben (MIBRAG), Chemnitz and Lippendorf (VEAG) for FGD-gypsum.

**Reference literature:** [17, UBA, 2001] [175, TWG, 2003]

#### 4.3.4.2. Sheds or roofs

**Description:** A shed or a roof above a heap can reduce the emissions to air. In fact dust is formed by the same processes that operate on storage in the open air, but it can only exit via the shed openings. Shed openings are doors for mobile loading machines and openings for venting systems. Dust emissions coming from shed openings are relatively low if the ventilation is correctly dimensioned. The dusty air that is extracted by fans can be led through suitable filter systems. The sheds can reach sizes of 70 to 90 m diameter and capacities of up to 100000 m<sup>3</sup>. The following figure shows some examples:



**Figure 4.17: Examples of sheds**  
[17, UBA, 2001] with reference to Schade, Maschinenbau GmbH

Another example is the hangar-type shed with bridge cranes equipped with buckets. They are sturdy concrete structures, roofed and fitted with ventilation and lighting openings in their high walls. These openings are generally screened against the wind. This type of store is very compact and very versatile, as it can be subdivided into cells of different capacities. These cells can be put to different uses with relative ease. The bridge crane is generally run by an operator, but remote automated control of the crane has become popular very recently.

The automated depot can reach capacities of up to tens of thousands of tonnes and is suited not only for storage, but also for mixing batches of one material or different materials. These depots are fitted with automatic machines for constructing and reclaiming heaps. The heaps are linear or circular, and are constructed by depositing several layers of material. Reclamation from the front of the heap is carried out by rotary bucket machines; for the side of the heap, scrapers are used. Automated depots typically use rubber conveyor belts for construction and reclamation. The various material transfer points are protected with conventional fabric filters.

The roof is generally complete and devoid of openings; the side-walls have doors for worker and machinery access.

**Operability:** In the production of hydraulic binders, automated depots and depots with bridge cranes are used for storing clinker and solid fuels.

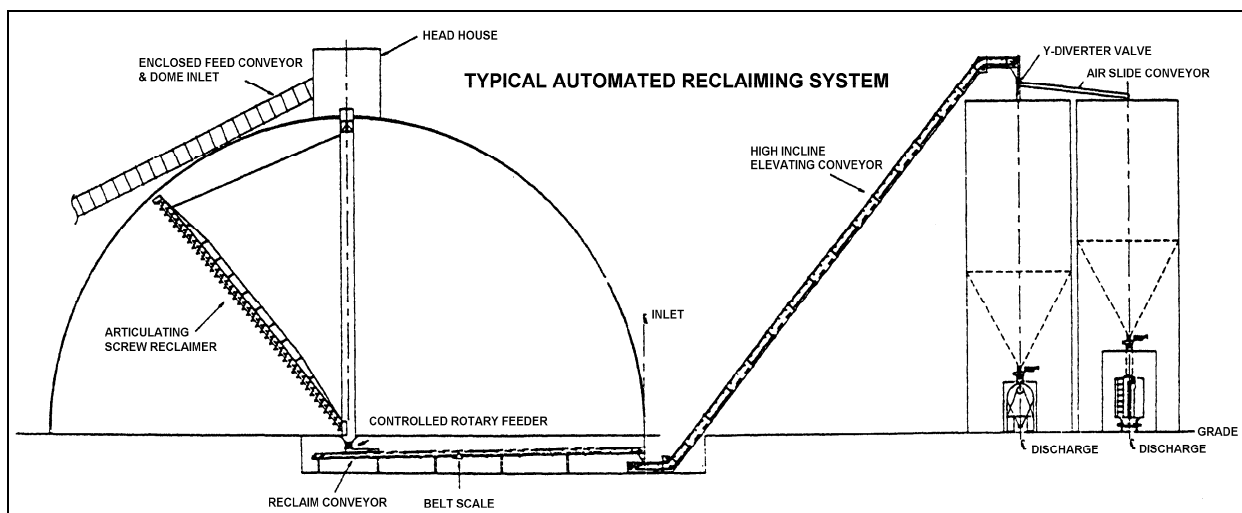
**Applicability:** Sheds are in current use, e.g. for the homogenisation and storing of moisture sensitive or very dusty goods. Depots with bridge cranes are suited to handling very small or large quantities of all types of materials, including clinker and solid fuels.

**Cross-media effects:** Because of the closed structure, any noise is confined to the interior where, in the case of automated depots, no staff are continuously present.

**Reference literature:** [89, Associazione Italiana Technico Economica del Cemento, 2000] [17, UBA, 2001]

#### 4.3.4.3. Domes

**Description:** Figure 4.18 shows an example of a dome. Special techniques have been developed for dome construction; in most cases a mould (a special inflatable round shape) is used, onto which concrete is sprayed. They can be constructed in a short time and have a reasonable capacity (e.g. 4000 tonnes). Advantage of this technique is the absence of pillars and the ability to control the climate.



**Figure 4.18: Example of a dome**  
[78, DCMR Milieudienst Rijnmond, 1995]

**Applicability:** Domes are used fairly widely and for different types of products such as coal and fertiliser.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.3.4.4. Self-erecting covers

**Description:** The self-erecting cover is an alternative for storage of cereals in the open air and is applied in the US. With this technique the product is stacked from the top under a closed cover (tarpaulin); the heap grows under the cover. To prevent the tarpaulin from inflating, a continuous under-pressure under the tarpaulin is created by using fans (two fans of 40 kW each). The self-erecting cover was developed in order to:

- prevent product loss by wind action
- minimise the cost of cereal storage
- to achieve good aeration of the cereals.

The cover has to be removed when reclaiming of the heap is started. It cannot be put back, which means that the whole heap has to be reclaimed in a short time to prevent weather damage to the product.

The lifetime of the cover/tarpaulin is rather short; the supplier gives a 5-year guarantee.

**Achieved environmental benefits:** There is less product loss than with the storage of cereals in the open air, in which the top layer of the cereal heap has to be treated to prevent it from being blown around, thereby making it unsuitable for consumption.

**Applicability:** This technique has been developed for storing cereals with a maximum capacity of 50000 m<sup>3</sup> and for a long period. To date it has only been used for the storage of cereals, but might be applicable for other products provided that the products have good flow properties and are permeable to air (comparable to cereals).

**Cross-media effects:** Maintaining the under-pressure demands the use of energy.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.3.4.5. Silos and hoppers

**Description** Silos are mainly cylindrical containers with a conical discharge section. Smaller (intermediate) hoppers are often also rectangular, with a pyramid shaped discharge section. The residence time of solids bulk in these containers can be very short; sometimes a couple of minutes only, e.g. in dosage hoppers. However, in storage silos it can last also some days or weeks.

From the perspective of environmental and health and safety issues, five critical issues are seen:

- design of the silo or hopper from the perspective of stability
- design of the silo or hopper from the perspective of easy discharge of the bulk material
- elimination of dust explosion
- dust elimination when the silo or hopper is filled
- dust elimination when the silo or hopper is emptied.

Silos are normally designed, from the perspective of stability according DIN 1055 part 6. The peculiarity of silos is that the biggest tension in the silo material occurs at the transition between the conical and cylindrical part. High tensions occur when the silo is filled or emptied. The silo wall thickness has to take this into account to prevent the silo from collapsing. According to DIN 1055 the design of the silo is mainly determined by the physical properties of the bulk material to be stored, such as:

- bulk density
- wall friction angle
- inner effective friction angle
- horizontal load value
- bottom load factor
- discharge factor.

Vibration is the most dangerous situation for silos, leading to possible cracking of the welding seams. Vibrations are caused by material with a so-called ‘slip stick effect’, an uneven flow behaviour. This effect can be determined by a careful investigation of the flow behaviour in shear tester.

It is expected that the bulk material, once filled into a silo, may be discharged easily. In case the bulk material solidifies or may not be discharged by inappropriate design, it has to be removed manually with all the consequences concerning possible dust explosion, or with hazardous material.

The easy discharge of bulk material depends on the geometry of the cone and of the discharge nozzle diameter, which has to be designed according the wall friction angle of the bulk material on the cone material and on the cohesiveness (unconfined yield stress) of the bulk material. These properties are measured in Jenike or, the so-called ring shear tester according to the recommendations of the Institution of Chemical Engineers.

Commonly, dust filters are installed to prevent emissions during filling and emptying; see Section 4.3.7.

**Achieved environmental benefits:** Compared to storage in heaps, emission levels are very low especially when equipped with dust filters.

**Applicability:** Silos and hoppers are broadly applied.

**Safety aspects:** Explosion resistant silos are available; see Section 4.3.8.3.

**Cross-media effects:** None.

**Reference literature:** [163, Cefic, 2002] and:

DIN 1055: Lastannahmen für Bauten, part 6: Lasten in Silozellen. Beuth Verlag, Berlin, 1987.

Jenike, A.W.: Storage and flow of solids Bull. No. 123, Engng. Exp. St., Univ. of Utah, Salt Lake City, 1964.

Schwedes, J.: Fließverhalten von Schüttgütern in Bunkern, Verlag Chemie, Weinheim, 1968.

Standard Shear Testing Technique for Particulate Solids Using the Jenike Shear Cell, The Institution of Chemical Engineers, Rugby, 1989.

### 4.3.5. Dust prevention/reduction techniques and measures applied to open storage

Generally the most effective approach to prevent or reduce dust emissions from open storage is closed storage in sheds, bunkers or silos, but this is not always possible for economic, technical and/or logistical reasons. This section discusses the many prevention and reduction techniques available for open storage, starting with Table 4.13: Dust reduction approaches to open storage and their limitations. In Sections 4.3.6.1, 4.4.6.8 and 4.4.6.9 the different techniques for water spraying are described.



Reduction approach	Comment	Relevant heap type
Longitudinal axis of the heap parallel with the prevailing wind	possible limitations on implementation: <ul style="list-style-type: none"> <li>• unfavourable geographic situation (in valleys/river courses)</li> <li>• unfavourable infrastructure (roads and rails cannot be diverted)</li> <li>• ownership (size and shape of the available site)</li> </ul>	Long-term and short-term storage
Protective plantings, windbreak fences (see Section 4.3.6.2) or upwind mound to lower the wind velocity	<ul style="list-style-type: none"> <li>• protective plantings are less effective in winter, because of the leaf fall, at the time when the wind velocities are particularly high</li> </ul>	Long-term and short-term storage
Moistening of the heap surface by a sprinkler system (see Section 4.3.6)	possible restrictions: <ul style="list-style-type: none"> <li>• moisture sensitivity of the material</li> <li>• no water resources</li> <li>• groundwater charges</li> <li>• not useful during stormy weather</li> <li>• not useful during frosty weather</li> <li>• danger of spoiling the goods (loss of quality)</li> </ul>	Long-term and short-term storage
Only one heap instead of several heaps as far as possible; with two heaps storing the same amount as one, the free surface increases with 26 % [91, Meyer and Eickelpasch, 1999]	<ul style="list-style-type: none"> <li>• not appropriate for storing different bulk materials together</li> <li>• shape and size of the site must be considered</li> <li>• suitable heap construction devices are necessary</li> </ul>	Long-term and short-term storage
If it is erected as a cone heap, the optimal slope angle $\alpha = 55^\circ$	<ul style="list-style-type: none"> <li>• slope angles are dependent on the properties of the bulk material and are difficult to influence. The optimal slope angle quoted is the ideal. Slope angles achieved in practice are between 20 and 45°.</li> </ul>	Long-term and short-term storage
If it is erected as a truncated cone, the optimal proportion of the radius of the upper flat part to the side length of the truncated cone is 0.55	<ul style="list-style-type: none"> <li>• with this proportion an optimal minimisation of the free surface can be reached</li> </ul>	Long-term and short-term storage

<b>Reduction approach</b>	<b>Comment</b>	<b>Relevant heap type</b>
With regard to the free surface of heaps, a circular cross-sectional area is preferable to ring or longitudinal heaps  Open ring-shaped heaps are more unfavourable than closed ring-shaped heaps	<ul style="list-style-type: none"> <li>• circular heaps require special conveyors (e.g. long reach)</li> <li>• closed ring-shaped heaps can only be used for long-term storage; heaps which are constantly being constructed and reclaimed are always open</li> </ul>	Long-term storage
Storage with retaining walls reduces the free surface, leading to a reduction of diffuse dust emissions. This reduction is maximised if the wall is placed upwind of the open storage	<ul style="list-style-type: none"> <li>• this is useful for small and medium heaps, but not for big heaps</li> <li>• the walls can restrict access to the heap</li> <li>• retaining walls require extra investment</li> </ul>	Long-term and short-term storage
Placing retaining walls close together	<ul style="list-style-type: none"> <li>• increases the height of the heap</li> </ul>	Long-term and short-term storage
Covering the surface with tarpaulins (4.3.4.4) or solidification of the surface or grassing-over	<ul style="list-style-type: none"> <li>• only relevant for long-term storage</li> </ul>	Long-term storage
Use of durable dust-binding substances (4.3.6.1)	<ul style="list-style-type: none"> <li>• the binding substance may damage the goods</li> <li>• normally only relevant for long-term storage</li> </ul>	Long-term (to short-term) storage
Not carrying out construction or reclamation during adverse weather (e.g. long dry periods, frosty periods, high wind velocities)	<ul style="list-style-type: none"> <li>• considerable potential disruption to operations</li> </ul>	Short-term storage

**Table 4.13: Dust reduction approaches to open storage and their limitations**  
[17, UBA, 2001]

### 4.3.6. Primary techniques to minimise dust from storage

#### 4.3.6.1. Spraying of water with or without additives

**Description:** This is a spraying system that uses water mostly in combination with additives. There are several additives on the market, including products that are readily biodegradable (that means that after 20 days, 80 % of the ecologically harmful substance is biodegraded).

The additives can have the following functions:

***The moistening function*** The moistening function gives the solution or emulsion which is sprayed, the property to penetrate deep into the stored product. The additive can lower the surface tension of the emulsion or solution. An advantage of moistening with use of an additive is that dust emissions are also reduced in the subsequent handling of the product.

***The foaming function*** Dust is formed by the smaller particles in the bulk material. By adding a foaming additive that forms very small bubbles (0.1 – 50 µm), these small particles will be embedded in the bubbles. The quality of the foam and the consequent dust emission reduction potential depend on the size of the bubbles and the stability of the foam.

***The binding function*** The binding function is a combination of the ability to bind the moisture and an adhesive function. For better moisture binding, the calcium oxide or magnesium oxide is mixed with the additive. Vegetable or mineral oils improve the adhesion between small particles.

Special adhesives are the so-called crust-forming substances. An example is the use of water-based latex polymers on coal heaps in the open air. Crust is formed by polymerisation of the product at the storage pile's surface so that the wind is unable to disturb individual particles, see Figure 4.19.

Some materials, such as gypsum, form a crust just with water and without using additives. In these situations water alone can be used as a crust-forming agent.



**Figure 4.19: Crust-forming of the surface of a storage heap**  
[134, Corus, 1995]

**Achieved environmental benefits:** A lower quantity of water is needed. The dust preventing effect of crust-forming is better compared to the use of only water.

The effectiveness of spraying with water mixed with additives is very dependent on how the technique is operated and the method, frequency and maintenance of the treatment. The effectiveness is estimated at 90 – 99 % (in comparison with an effectiveness of 80 – 98 % when spraying with only water).

Disadvantages are that the additives may affect the material quality and additional devices for the mixing of water and the additives are necessary.

**Operability:** The additive used in Port Nordenham is ECS 89 and is used in the constant proportion of 1:3750. At Corus an emulsion with 3 – 5 % latex is used on heaps of coals.

At Corus, research was also undertaken to find the most suitable method of applying the latex solution. This resulted in construction of a special spraying truck with a hydraulically controlled spray arm 20 metres in length, see Figure 4.20. It was found that uniform spraying of the storage heap's surface is very important for the formation of a good crust. However, a so-called spray gun was not satisfactory. For preparation of the spray solution, a mixing station was constructed with tanks for storing the concentrate delivered by tankers. The mixture was then pumped into the truck's spray tank. Weather conditions during spraying operations are very important for obtaining a good crust. Spraying is not carried out when it is raining, when there is frost or when wind speeds are above 6 m/s. When it has been hot for a long time, the heap is first sprayed with water before the crust-forming agent is applied. Spraying with the crust-former is carried out as soon as a storage or blending heap has been formed. Also after a heap has been partially dug away, the new front is given a crust-forming coating. As long as a storage heap remains untouched, there is no need to repeat the spraying. Crust-forming agents have been in use at Corus since 1990.



**Figure 4.20: Uniform spraying is extremely important for the formation of a good crust [134, Corus, 1995]**

**Applicability:** This system is used on stones, ores, hard and brown coal, bauxite, slags and building wastes, in heap construction, the unloading of wagons and trucks and the loading of ships. It is sometimes integrated in a frontloader, in mobile loading devices or scraper conveyors. However, crust-forming is only applicable on heaps.

**Economics:** The running costs for Port Nordenham (energy, water and additive) are DEM 0.03 per tonne of sprayed substance (about EUR 0.02) (reference year 2000).

**Reference plants:** Port Nordenham, Germany; Corus, Netherlands.

**Reference literature:** [17, UBA, 2001] [134, Corus, 1995] [78, DCMR Milieudienst Rijnmond, 1995] [175, TWG, 2003]

#### 4.3.6.2. Wind protection methods

**Description:** A windshield can be a fence or a net at the boundary of the storage site. The purpose of a windshield is to lower the wind speed and thus lower the dust emissions. The layout of the windshields is very site-specific; research with the use of wind-tunnels can be useful.

The concept of storage with an embankment was developed in the Netherlands in the eighties in combination with the bridge and landing type reclaimers. The reclaimer rides on top of the embankment, which makes it possible for the top of the storage heap to stay below the level of the bridge or landing. An important difference between an embankment protecting only the storage heap and one acting as a windshield around the borders of the whole storage site is that with the latter one the handling and transport on the site is also protected.

**Achieved environmental benefits:** Research in Japan on the effect of nets as a windshield for the storage of coal has shown a 50 % reduction in wind velocity. The same reduction is achieved with an embankment of a rectangular heap in combination with a bridge reclaimer.

The embankment of storage heaps (without using a bridge reclaimer) has an estimated nett efficiency of 20 – 40 %. This is a nett figure because, although the erosion of the heaps is reduced by more than 50 %, the emissions from handling and transportation (with belt conveyors) increases in comparison with storage without a reduction technique.

**Operability:** The embankment technique is used on a terminal for imported coals (17 different qualities) with a capacity of 8 million tonnes per year. They coals were imported by sea in ships with capacities of 40000 to 150000 tonnes. In the terminal the coals were loaded into wagons and/or other ships.

**Applicability:** These techniques can be applied to any quantity of any type of product.

**Cross-media effects:** There is a risk that birds get trapped in the nets.

**Driving force for implementation:** This system was developed to achieve:

- a reduction of dust emission
- a reduction of operational cost by automating the process
- a reduction of losses due to heating
- optimised facility to mix the different qualities of coal.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.3.6.3. Tarpaulins or nets

**Description:** Tarpaulins or fine-mesh nets are used on open storage for:

- reducing dust emission
- reducing the nuisance caused by birds
- (for tarpaulins) protecting the material from getting wet.

The disadvantages of the use of nets or tarpaulins are:

- there is no reduction of dust emission during stacking or reclaiming
- the installation and removal are very labour-intensive
- their lifetime is very short.

**Applicability:** They are used for long-term open storage of very easily dispersed substances, where e.g. moistening is not enough to prevent dust emissions. This technique is not often used.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.3.7. Secondary techniques to minimise dust from storage – dust filters on silos and hoppers

**Description:** Closed storages such as silos and sheds are normally equipped with filter systems to filter the displaced air during loading, e.g. using a fabric filter. To prevent all the air in a shed being extracted, extraction only is carried out at those places with loading and or unloading activities.

Different filter systems are described and compared in the BREF on Common Waste Water and Waste Gas with reference: [147, EIPPCB, 2002].

##### *Dust filters on silos and hoppers*

Silos and hoppers are normally equipped with a dust filter, because mainly with fine bulk powders a significant amount of dust is generated when the silo or hopper is filled. Candle or cartridge filters on top of the silo are the common way to eliminate this dust.

Cartridge filters herewith are disposable filters, consisting of a filter material, commonly paper, and a support, e.g. steel or plastic. Cartridge filters have to be deposited when full.

In contrary, the body of candle filters is covered with a cloth as filter medium. This cloth may be woven; uni- or multifilament cloths may be felt. Polypropylene or polyester is a common cloth material. Candle filters are cleaned by vibration or by a back pulse. The cleaning step is initiated after a filtration mode cycle time or by the limit of allowed pressure drop over the filter.

Dust is also generated when the silo or hopper is emptied. Commonly bulk powder is discharged via a rotary feeder into a pneumatic conveying line or directly into a screw feeder. The dust generated at the discharge can be separated generally by cartridge or candle filters as described above.

Often there are measures taken also by the supplier of the bulk material to avoid dust generation, such as:

- screening or classifying of the bulk material. A common cut size for the fines to be separated is 100  $\mu\text{m}$
- coating the bulk solids with a thin, adhesive layer making those very fine particles stick to coarser particles.

Very often the particle size distribution is part of the specification. As particles  $< 10 \mu\text{m}$  have to be minimised, this amount of particles in the bulk is normally specified separately.

**Achieved environmental benefits:** Dust filters on silos and hoppers commonly achieve emission levels for particles in the range of 1 – 10  $\text{mg}/\text{m}^3$ , depending on the nature/type of substance stored.

**Operability for silos and hoppers:** The required filter area depends on the volume of gas displaced or the volume of gas needed for the pneumatic conveying of the bulk solids into the silo. Commonly a velocity of 1 – 2  $\text{m}/\text{min}$  is maintained. The common maximum pressure drop, before cleaning, ranges from 4 – 10  $\text{kPa}$ .

**Applicability for silos and hoppers:** The decision, whether cartridge or candle filters are used, depends on the amount of dust to be removed. With coarser material and short silo filling cycles cartridge filters are more convenient. With continuous filling and discharge of fine powders, using a hopper, candle filters are more appropriate. The type of abatement technique only can be decided on a case-by-case basis.

**Safety aspects with silos and hoppers:** In general, with the handling and storage of fine powders of organic material, there is the danger of dust explosion. Silos containing fine, organic material are purged with nitrogen. Measures to avoid dust explosion are described, i.e. in 'VDI Richtlinie 2263, Staubbrände und Staubexplosionen'.

**Reference literature:** [148, VDI-Verlag, 1994] [147, EIPPCB, 2002, 163, Cefic, 2002] and: Löffler, F: Staubabscheiden, Stuttgart, Thieme Verlag, New York, 1988. VDI 2263, Staubbrände und Staubexplosionen', in VDI Richtlinie zur Reinhaltung der Luft, vol. 6, VDI Verlag, Düsseldorf.

### 4.3.8. Measures to prevent incidents and (major) accidents

In many industries, organic – solid – bulk materials are stored and handled. These organic solids are flammable in situations where oxygen and an ignition source are available; dust from organic solids can even be explosive.

Ignition sources are described in Section 4.1.6.2.1 – Flammable areas and ignition sources.

Section 4.3.8.2 shows the conclusions of a survey that was conducted in the UK into large fires in warehouses and other storage areas involving solid materials only. In Sections 4.3.8.3 and 4.3.8.4 some techniques to prevent and control explosions are described.

#### 4.3.8.1. Safety and risk management

See Section 4.1.6.1 where the Seveso Directive is discussed for storing dangerous liquids or liquefied gases in tanks. The same is valid for storing and handling dangerous solid substances, disregarding the type of storage.

#### 4.3.8.2. Warehouse fires involving solid materials

**Description:** An analysis of 290 fires involving solid material stored in warehouses in the UK has been undertaken. The results have identified specific categories of materials (see Table 4.14) the common ignition sources (see Table 4.15), the presence of sprinkler systems and the contribution of arson to the statistics.

The types of solid materials involved were categorised by their type and end use. The categories reflect a broad spectrum of materials found in storage.

As shown in Table 4.14, packaging materials are the items most frequently involved in storage fires. Currently the focus is mainly on the goods stored in them.

Material	Number of times the material was involved in the incidents <sup>*)</sup>	Percentage of total
Paper (not packaging materials)	53	11.0
Textiles	64	13.2
Foodstuffs	28	5.8
Furniture	51	10.6
Plastics	60	12.4
Chemicals	27	5.6
Domestic goods	42	8.7
Timber	25	5.2
General packaging	133	27.5

<sup>\*)</sup> More than one material was present in a number of fires

**Table 4.14: Materials involved in the 290 fires**  
[135, C.M. Bidgood and P.F. Nolan, 1995]

The cause of each fire (where known) has been noted in order to identify the types of ignition sources responsible for warehouse fires and are shown in Table 4.15.

Ignition source	Number of incidents	Percentage of total
Malicious	84	29.0
Electrical fault	27	9.3
Smoking materials	26	9.0
Space heaters	12	4.1
Children with matches	4	1.4
Hot work	11	3.8
Cold work	4	1.4
Fluorescent lamps	5	1.7
Burning refuse	9	3.1
Spontaneous combustion	7	2.4
Other	19	6.5
Unknown	82	28.3

**Table 4.15: Ignition sources**  
[135, C.M. Bidgood and P.F. Nolan, 1995]

The survey showed that 86 % of the storage buildings were not fitted with active fire protection systems and about 3 % had sprinkler systems installed but these were turned off at the time of the fire.

The incidence of arson attacks in industrial and commercial premises has increased greatly during the past 20 years and is now a major problem to which warehouses are particularly susceptible. Arson is the largest single cause of warehouse fires, responsible for 29 % of all incidents.

**Reference literature:** [135, C.M. Bidgood and P.F. Nolan, 1995]



#### 4.3.8.3. Explosion resistant silos

**Description:** An example of an explosion resistant silo is installed at Firma Bissinger GmbH, Zaberfeld, for the storage and loading and unloading of cornflour, and it has the following characteristics:

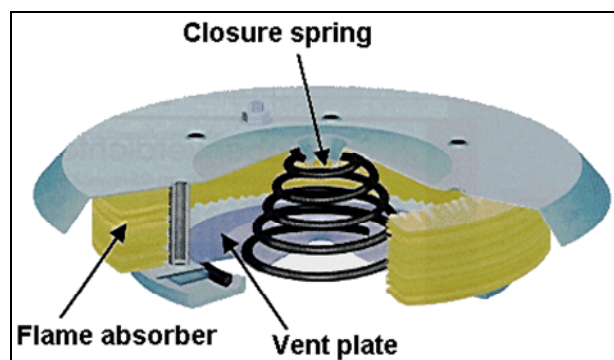
- the highest possible, but economically viable, reduction of the possibility of an explosion through constructive measures
- prevention of the attached vehicle during loading/unloading and of other attached equipment when an explosion occurs and preventing the relevant surroundings for the energy that is released during an explosion
- secure detection system for explosions
- automatic blanketing with an inert substance at all possible substance levels.

The construction of the silo is able to absorb the energy from the explosion, without reaching the attached vehicle during loading or unloading. All the equipment of the silo is pressure resistant and made of antistatic material, including the filter installation.

**Reference literature:** [143, suppliers information, 2001]

#### 4.3.8.4. Relief vents

**Description:** Explosions are characterised by a very rapid increase of pressure and temperature and a proper working relief vent should be resistant to both. The relief valve will open when the pressure – due to the explosion – increases with 0.05 bar over-pressure, or in special cases already with 0.01 bar over-pressure. The waste gases will flow radially through the vent that is also equipped with a flame-absorber preventing the flames escaping from the tank or silo. In contrary to conventional relief vents, the vent shown in Figure 4.21 (a patented design) closes rapidly after the explosion to prevent oxygen entering the silo or tank which can cause a secondary fire.



**Figure 4.21: Example of a relief vent (patented design)**  
[145, Hoerbicher, 2001]

**Operability:** In the following situations where an explosion occurred, the valve has proven to function well:

- on tanks and silos where a dust-explosion occurred while storing grain
- on tanks and silos storing flammable solids
- extraction equipment used in industry
- on places where coal is ground
- on installations for drying.

This type of relief vent does not need maintenance after an explosion.

**Applicability:** The relief valve shown in Figure 4.21 can be applied on new and existing silos and tanks. Over 150000 valves of this design are applied at installations such as where dust-explosions or explosions from oil-dust might happen.

**Cross-media effects:** None.

**Safety aspects:** No negative safety aspects. Relief valves prevent the tank or silo from exploding.

**Reference literature:** [145, Hoerbicher, 2001]

#### **4.3.9. Leaching to soil or surface water**

No information has been submitted.

## 4.4. Handling of solids

### 4.4.1. General – Emission Control Measures (ECM)

This section contains a general overview of the various Emission Control Measures for the handling of different bulk materials. Table 8.4 in the Annex shows the applied handling techniques and the relevant bulk materials. Table 8.30 shows the same bulk materials in combination with the selected techniques to consider in the determination of BAT. In that same table the selected technique is assessed against the following parameters:

- dust reduction potential
- energy consumption
- cross-media effects
- investment requirement
- operating costs.

In the following sections these techniques are described in more detail. However, other ECM, which do not appear in Table 8.30 were also identified and are also discussed in the following sections. Finally all techniques were assessed by the TWG and the TWG concluded on which of these techniques are BAT.

General approaches to minimise dust emissions are described in Section 4.4.2 and possible primary organisational approaches are described in Section 4.4.3. In Section 4.4.5 the possible primary techniques and in Section 4.4.6 quite a number of possible secondary techniques are described. Section 4.4.7 addresses the handling of packaged solids and in Section 4.4.8 attention is given to the prevention and control of explosions.

### 4.4.2. General approaches to minimise dust from handling

There are several approaches to dust minimisation:

1. **Pre-primary approaches** start with the production or extraction process and reduce the material's tendency to make dust before it leaves the production plant. Pre-primary approaches are part of the production process and, therefore, outside the scope of this document and, apart from the following examples, are not further described:

#### *Production of pellets or briquettes*

- fine ores with particle sizes of 100 µm and smaller are formed (with additives) into small balls and are hardened by fire
- pellets might be produced, e.g. of some fertiliser products, or briquettes in case of moist materials, with the explicit objective to reduce the surface and the tendency of the bulk material to make dust during loading and unloading processes.

#### *Spraying*

- by spraying the limestone with water and additives, a durable binding of dust particles with the limestone can be reached. The spraying is carried out in the limestone quarry itself in order to reduce dust formation during the local operations of crushing, classification, conveying and filling
- mined mineral salts are processed by crushing and grinding directly in the quarry. 'Sticked powder' (= finest salt particles with sizes < 0.2 mm) is separated by passing through a sieve or by air classification. The result is a product that scarcely forms any dust during loading and processing.

The application of pre-primary means has its limitations when it influences the properties of the products that are required by the buyer. For example, there are processes to reduce the dust tendency of grains by a treatment with rape oil or chemical preservatives (e.g. with urea and propionic acid). However, the treatment considerably reduces the marketing and application options, because flour from grains which is treated with rape oil can no longer be used for baking.

2. **Primary approaches** are all the ways of reducing emissions during handling and can be divided into:

- organisational primary approaches: behaviour of the operators
- technical primary approaches: techniques which prevent dust formation.

3. **Secondary approaches** are abatement techniques to limit the distribution of dust.

Table 4.16 gives an overview of approaches and techniques to reduce dust emissions from loading and unloading, and where information was submitted, these are detailed in the sections mentioned in the same table.

It is important to note that the selection of handling system types and ECM to reduce dust emissions depend on the properties of the product. Especially for end-products, where customer specifications are crucial, selection of storage equipment and ECM are based on many factors such as the product resistance to attrition, the ability to break, crush, flow, and cake-on, the chemical stability, and sensitivity to moisture.

**Reference literature:** [17, UBA, 2001, 175, TWG, 2003]

<b>Approaches and techniques to reduce dust emission</b>		<b>Section</b>	
<b>Primary</b>	<b>Organisational</b>	Weather conditions	4.4.3.1
		Measures (for the crane operator) when using a grab: <ul style="list-style-type: none"> <li>reduction of the drop height when the material is discharged</li> <li>total closing of the grab/jaws after material pick-up</li> <li>leaving the grab in the hoppers for a sufficient time after the material discharge</li> <li>stopping of grab operations when the wind is strong.</li> </ul>	4.4.3.2
		Measures (for the operator) when using a belt conveyor: <ul style="list-style-type: none"> <li>suitable conveyor speed</li> <li>avoiding loading the belt up to its edges.</li> </ul>	4.4.3.3
		Measures (for the operator) when using a mechanical shovel: <ul style="list-style-type: none"> <li>reducing the drop height when the material is discharged</li> <li>choosing the right position during discharging into a truck.</li> </ul>	4.4.3.4
		Layout and operation of storage sites (by the planner and the operating personnel) <ul style="list-style-type: none"> <li>reduction of transport distances</li> <li>adjusting the speed of vehicles</li> <li>roads with hard surfaces</li> <li>reduction of wind attack areas</li> </ul>	4.4.3.5
	<b>Technical</b>	Optimised grabs	4.4.5.1
		Use of closed conveyors (e.g. tube belt conveyors, screw conveyors)	4.4.5.2
		Conveyor belt without support pulleys	4.4.5.3
		Primary measures on conventional conveyor belts	4.4.5.4
		Primary measures on transfer chutes	4.4.5.5
		Minimising speed of descent	4.4.5.6
		Minimisation of free fall heights (e.g. cascade hoppers)	4.4.5.7
		Use of dust barriers on dump pits and hoppers	4.4.5.8
		Low dust bunker	4.4.5.9
	Chassis of vehicles with round tops	4.4.5.10	
	<b>Secondary</b>	Screens for open conveyor belts	4.4.6.1
		Housing or covering of the emission sources	4.4.6.2
		Applying covers, aprons or cones on fill tubes	4.4.6.3
		Extraction systems	4.4.6.4
Filter systems for pneumatic conveyors		4.4.6.5	
Dump pits with suction equipment, housing and dust barriers		4.4.6.6	
Optimised discharge hoppers (in ports)		4.4.6.7	
The techniques of water spraying/water curtains and jet spraying		4.4.6.8	
		4.4.6.9	
Cleaning conveyor belts		4.4.6.10	
Fitting trucks with mechanical/hydraulic flaps		4.4.6.11	
Cleaning of roads		4.4.6.12	
Cleaning of vehicle tyres	4.4.6.13		
<i>Note: The boundary between primary and secondary approaches is not always clear; e.g. a water curtain limits the spread of dust emission and is – at the same time – a method of dust binding.</i>			

**Table 4.16: Approaches and techniques to reduce dust emissions from loading and unloading [17, UBA, 2001, 134, Corus, 1995] [91, Meyer and Eickelpasch, 1999]**

### 4.4.3. Primary organisational approaches to minimise dust from handling

#### 4.4.3.1. Weather conditions

**Description:** Preventing dust dispersion due to loading and unloading in the open air by suspending transfer activities during high winds, depending on the local situation and wind direction. In the Netherlands, for example, transfer activities are suspended if, considering the dispersiveness class, the wind speed exceeds the following values:

- classes S1 and S2 8 m/s (wind force 4; moderate breeze)
- class S3 14 m/s (wind force 6; strong breeze)
- classes S4 and S5 20 m/s (wind force 8; fresh gale).

Explanation of the dispersiveness classes, see also Annex 8.4:

- S1: highly drift sensitive, not wettable
- S2: highly drift sensitive, wettable
- S3: moderately drift sensitive, not wettable
- S4: moderately drift sensitive, wettable
- S5: not or very slightly drift sensitive.

**Operability:** This measure has an impact on the plant operations due to suspension during poor weather conditions.

**Applicability:** This measure can be applied more easily when building heaps than when loading or unloading transporters. However, it is also more difficult if the heap building is part of a continuous process.

**Safety aspects:** None.

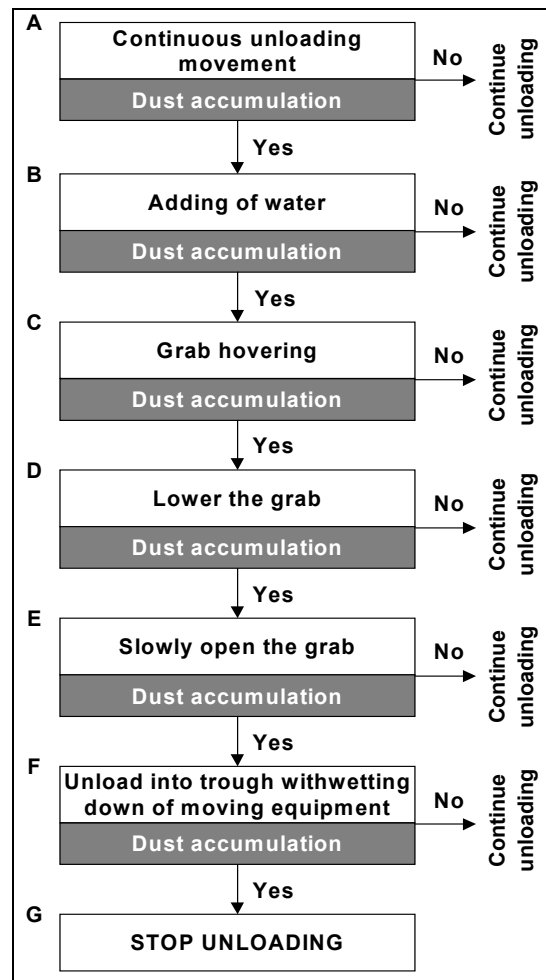
**Cross-media effects:** None.

**Economics:** Suspending transfer activities may be extremely costly when ships have to be blocked entailing large demurrage fines (surestaries), which is also valid for trucks, trains, idle personnel, etc.

**Reference literature:** [15, InfoMil, 2001, 175, TWG, 2003]

#### 4.4.3.2. Measures for the crane operator when using a grab

**Description:** See Figure 4.22 on the next page.



**Figure 4.22: Decision diagram for a crane driver to prevent accumulation of dust [134, Corus, 1995]**

In addition to the above shown diagram, loading and unloading of materials belonging to the dispersiveness classes S1, S2, S3 and possibly S4 take place with grabs kept in good condition and covered at the top. The grab may only be opened during unloading after it has descended below the edge of the hopper, or, alternatively, below the edge of the wind screens.

Other important measures are closing the grab/jaws completely after the material pick-up and leaving the grab in the hoppers for a sufficient time after the material discharge.

**Applicability:** Can always be applied. Operating the grab carefully might take more time.

**Safety aspects:** None.

**Economics:** This is a very low cost measure.

**Reference plant:** Corus, the Netherlands.

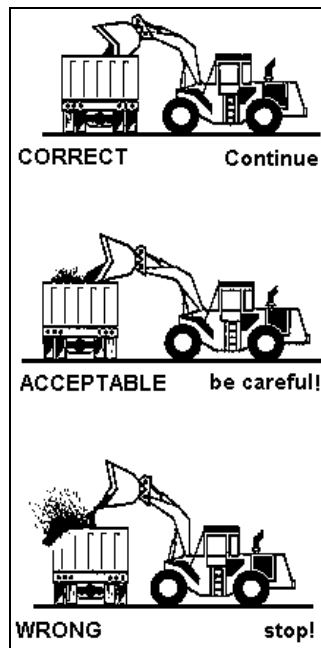
**Reference literature:** [17, UBA, 2001] [15, InfoMil, 2001]

#### 4.4.3.3. Measures (for the operator) when using a belt conveyor

No information has been submitted.

#### 4.4.3.4. Measures (for the operator) when using a mechanical shovel

**Description:** Reducing the drop height and choosing the right position during discharging into a truck using a mechanical shovel are important factors in preventing dust accumulation.



**Figure 4.23:** Illustration on how to prevent the accumulation of dust using a mechanical shovel [134, Corus, 1995]

**Applicability:** Can always be applied. Operating the mechanical shovel carefully might take more time.

**Safety aspects:** None.

**Economics:** This is a very low cost measure.

**Reference plant:** Corus, the Netherlands.

**Reference literature:** [134, Corus, 1995]

#### 4.4.3.5. Layout and operation of storage sites (by the planner and the operating personnel)

##### 4.4.3.5.1. Reduction of discontinuous transport and transport distances

**Description:** In deciding the layout of a site dealing with dusty materials, an important measure to decrease dust emissions is to make the transport distances as short as possible to minimise the number of traffic movements on-site.

Also substances that are not drift sensitive because of their humidity, can contribute to dust emissions when the material is torn to pieces by vehicles running over it and swirling it up.

Discontinuous transport (shovel, truck) in general generates more dust emissions than continuous transport such as conveyors. Conveyors can relatively easily be covered, as where emission reduction measures for trucks and shovels are mostly less effective.



**Applicability:** A layout which minimises the number of traffic movements can be applied to new to build plants, but for existing plants this might be difficult to achieve.

**Safety aspects:** None.

**Economics:** Continuous transport modes can be applied on new sites, changing over from discontinuous transport modes to continuous transport modes on existing sites might be expensive.

**Reference literature:** [15, InfoMil, 2001] [148, VDI-Verlag, 1994] [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.4.3.5.2. Adjusting the speed of vehicles

**Description:** To reduce the amount of dust that is swirled up, vehicles have to be driven at walking pace. Installing e.g. speed bumps may possibly stimulate this.

**Operability:** Easier to require this from personnel working on the site than from third parties.

**Applicability:** Can be applied everywhere.

**Safety aspects:** None.

**Cross-media effects:** None.

**Economics:** None.

**Reference plant:** Several plants in Duisburg, Germany.

**Reference literature:** [15, InfoMil, 2001, 52, Staatliches Umweltamt Duisburg, 2000]

#### 4.4.3.5.3. Roads with hard surfaces

**Description:** The problem caused by dust collecting on vehicles driving on sandy roads and land can be resolved by using roads with hard surfaces of, for example, concrete or asphalt. The advantage of these roads is that they can be cleaned easily, see Section 4.4.6.12. It might be useful to border the roads to prevent vehicles from driving on sandy surfaces, or to put azobe mats on the verges.

Another advantage of hard surfaced roads is that it prevents the pollution of soil.

**Applicability:** Roads with hard surfaces are commonly applied where trucks and cars are driving, however, where big shovel vehicles are used or when the roads are only temporary, the roads are normally not fitted with a hard surface.

**Safety aspects:** None.

**Reference plant:** Corus, the Netherlands and several plants in Duisburg, Germany

**Reference literature:** [52, Staatliches Umweltamt Duisburg, 2000, 134, Corus, 1995, 148, VDI-Verlag, 1994] [15, InfoMil, 2001] [183, EIPPCB, 2004]

#### 4.4.4. Primary constructional techniques to minimise dust from loading and unloading

##### 4.4.4.1. Loading and unloading in a closed building

**Description:** Loading and unloading can take place in closed buildings, e.g. a shed. To prevent dust from escaping, the shed can be equipped with automatically opening and closing doors or curtains. This can be applied to loading/unloading activities from trucks, trains and (small) ships.

**Applicability:** Can be applied to new and existing installations and for all kind of materials. However, it will more commonly be applied with materials that are susceptible to weather conditions to avoid loss of quality, e.g. in the food industry.

**Safety aspects:** Explosive dust/air mixtures can appear when extraction systems are not applied or not properly applied.

**Economics:** High cost alternative.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.4.5. Primary techniques to minimise dust from handling

##### 4.4.5.1. Optimised grabs

**Description:** The essential properties of a dust preventing grab are:

- it is closed at the top to avoid any influence from the wind
- its geometric shape and its optimal load capacity which avoid overloading
- the grab volume should always be higher than the volume that is given by the grab curve (the grab curve is the curve that is described by the grab jaws while subsiding into the material)
- the surface should be smooth to avoid material adhering
- the closure capacity of the grab during permanent operation.

The closed jaw construction with a hopper-shaped opening has all the above-mentioned properties.

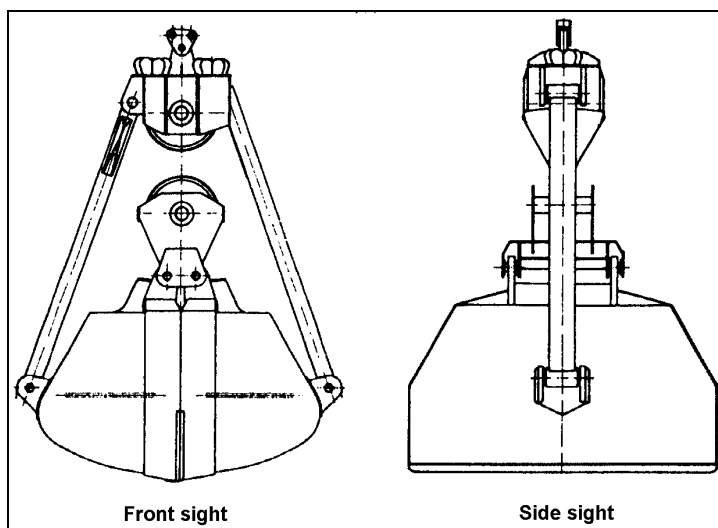


Figure 4.24: Closed grab jaw construction with a hopper-shaped opening (front and side view) [17, UBA, 2001] with reference to MB Kröger Greifertechnik GmbH

**Achieved environmental benefits:** A closed construction minimises the formation of dust emissions, but dust emissions and spillages may still cause considerable material losses of 2 to 5 %.

**Economics:** As a rough guide, a grab with a capacity of 13 m<sup>3</sup> costs DEM 83000 (about EUR 42000). Additional costs, e.g. for the crane installation, have to be considered.

**Reference plants:** These types of grabs are used in several sea and river ports, such as Neuss or Orsoy.

**Reference literature:** [17, UBA, 2001]

#### 4.4.5.2. Closed conveyors

**Description:** The following closed conveyors are described in Chapter 3:

- pneumatic conveyors; see Section 3.4.2.18
- trough chain conveyors; see Section 3.4.2.16.1
- screw conveyors; see Section 3.4.2.17.

A special type of closed belt conveyor is one where the belt itself or a second belt locks in the material and they are described in Section 3.4.2.14.

- loop belt conveyors
- tube belt conveyors
- double belt conveyors
- folding belt conveyors
- zipper conveyors.

Further details on these conveyors, except for the zipper conveyor, are given in Table 4.17.

	Loop belt	Tube belt	Double belt	Folding belt
<b>Developed for a specific situation</b> See note 1)	Yes	Yes	Yes	Yes
<b>Disadvantages</b>	See note 2)	Length < 5000 m	See note 2)	See note 2)
<b>Applicability</b>	Applied	Often applied	Applied	Not often applied
<b>Capacity</b>	400 t/h	Till 3000 t/h	Till 4000 t/h; theoretically 15000 t/h	Practised on 1500 t/h; theoretically not known
<b>Materials transported</b>	Pieces < 100 mm	Not too big pieces	Not too big pieces	Not too big pieces

**Table 4.17: Comparison of different closed belt conveyors**  
[78, DCMR Milieudienst Rijnmond, 1995]

**Note 1):** Conveyors of this type are developed because:

- less spillage and dust appear
- the quality of the product is not influenced by the weather
- steep to very steep inclines are possible
- very tight curves are possible (except for double belt).

**Note 2):** With conveyors of the tube belt and hanging belt type, inclines of 20 to 40 degrees (up to 60 degrees) are possible. With the double belt conveyor and folded belt conveyor inclines of 90 degrees are possible. However, this is always dependent on the product being transported.

All conveyors, except the double belt conveyor, are capable of making curves which prevents the necessity of transfer points and thus potential emission sources. The tightness of the curves differs from type to type; with tube belt conveyors the radius of the curve can be up to several hundreds of metres, where folded belt conveyors and hanging belt conveyors only need a few metres (as little as 0.4 metres for loop belt conveyors).

**Achieved environmental benefits:** The reference to compare with is an encapsulated conventional conveyor belt, transporting cereals. For a closed belt conveyor, with the same number of transfer points, in general a dust emission reduction of 80 – 90 % can be achieved. In the situation where two transfer points can be avoided this efficiency is estimated to be as high as 95 – 98 %.

In comparison with the same reference technique, this time transporting coal or ore and with the same number of transfer points, the achievable dust emission reduction is estimated to be 95 – 98 %. Avoiding two transfer points the efficiency is estimated to be as high as 98 – 99 %.

Transfer points are an important source of dust emissions and the achievable emission reduction depends on the possibility to avoid transfer points by applying closed belt conveyors because of their ability to make curves. The emission from transfer points depends on the type of material and the design of the transfer point, but, as an indication it can be said that the emission of a simple and closed transfer point concerning coal and ore will be about 0.3 – 2 grams per tonne. For cereals this might be less.

A study on the energy efficiency of a 10 km conventional overland conveyor belt at BHP Gregory/Crinum, Australia, has shown that significant energy savings can be achieved by combining:

- a good conveyor design, including idlers and idler spacing
- an accurate installation tolerance, and
- a belt with a special low rolling resistance pulley cover.

**Applicability:** Tube belt conveyors are very often applied. Double belt and hanging belt conveyors are commonly applied. Folded belt conveyors are less often applied.

**Safety aspects:** None.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995] [17, UBA, 2001] [140, suppliers information, 2001]

### 4.4.5.3. Conveyor belt without support pulleys

A main source of dust emissions from belts is when the returning part of the belt comes into contact with the support pulleys. Avoiding the use of support pulleys can prevent these emissions. Techniques without support pulleys are:

- aerobelt
- low friction conveyor
- conveyor with diabolos.

An advantage of belts without support pulleys is that these are more suitable to close them in. The argument for this is that they need less maintenance than a conventional conveyor belt so the disadvantage of being less accessible for maintenance is cancelled out by a lesser need for maintenance.

#### 4.4.5.3.1. Aerobelt

**Description:** The belt carrying the material is moving on top of a sheet with small holes where air is blown through. An air-film is created between the sheet and the belt that is carrying the belt.

**Achieved environmental benefits:** The estimated emission reduction, compared with a conventional, closed belt conveyor is 60 – 90 %.

**Operability:** The maximum length of an aerobelt is 300 metres. The width varies from 300 – 1800 mm. The capacity is about 3400 m<sup>3</sup> per hour.

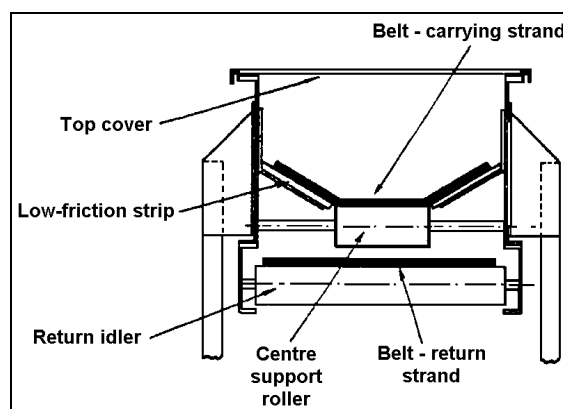
**Applicability:** The technique is often applied, especially with very dusty products that cannot be wetted, because this type of conveyor can be easily enclosed. It can be used for the transport of all kind of materials.

**Safety aspects:** None.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.4.5.3.2. Low friction conveyor

**Description:** With a low friction conveyor, the belt is troughed and glides on a slide strip with low resistance; see Figure 4.25.



**Figure 4.25: Low friction conveyor**  
[78, DCMR Milieudienst Rijnmond, 1995]

**Achieved environmental benefits:** The estimated emission reduction, compared with a conventional, enclosed belt conveyor is 60 – 90 %.

**Operability:** With the low friction conveyor, the belt partly glides over a plate or sheet. This gives a higher resistance than with the conventional conveyors and therefore this technique is only used on short distances and with lower capacity. The maximum length of this belt is 300 metres. The width varies from 300 – 1800 mm. The capacity is about 3400 m<sup>3</sup> per hour.

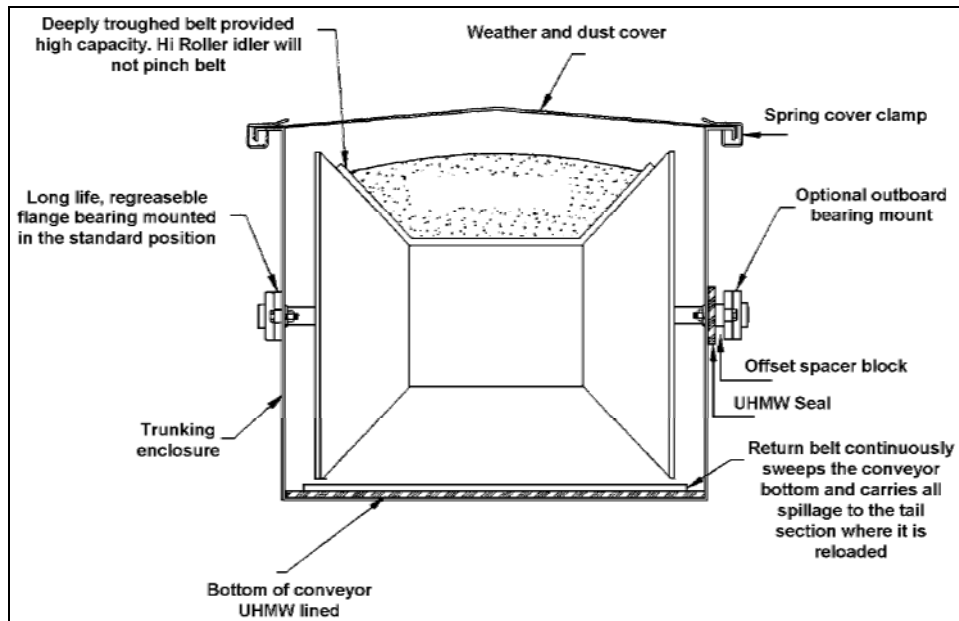
**Applicability:** The technique is often applied, especially with very dusty products that cannot be wetted, because this type of conveyor can be easily enclosed. It can be used for the transport of all kind of materials.

**Safety aspects:** None.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.4.5.3. Conveyor with diablo

**Description:** With this type of conveyor, the belt adapts the diablo-form of the roller; see Figure 4.26.



**Figure 4.26: Belt conveyor with diabolos**  
[78, DCMR Milieudienst Rijnmond, 1995]

**Achieved environmental benefits:** The estimated emission reduction, compared with a conventional, enclosed belt conveyor is 60 – 90 %.

**Operability:** The velocity of the surface of the diabolos does not match with the velocity of the belt everywhere and this is because of the form of the diablo. This can cause serious wearing of the belt. This can be prevented by increasing the tension of the belt to avoid contact with the diablo in the middle. The wearing will increase with the increase of capacity and length of the belt. The maximum length of this belt is 300 metres. The width varies from 300 – 1800 mm and the capacity is about 3400 m<sup>3</sup> per hour.

**Applicability:** The technique is often applied, especially with very dusty products that cannot be wetted, because this type of conveyor can be easily enclosed. It can be used for the transport of all kind of materials.

**Safety aspects:** None.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.4.5.4. Primary measures on conventional conveyor belts

**Description:** To avoid dust coming from the top of the conveyor belt, the following measures are applied:

- increase the belt tension
- place the support pulleys closer to each other
- place a plate or a sheet below the belt at the loading point
- decrease the belt speed
- increase the belt width
- make the belt more concave.

To avoid dust coming from below the conveyor belt, the following measures are applied:

- type of belt (prevents material caking on)
- put an additive on the belt for the prevention of caking on (e.g. a water film on the belt when transporting 'raw' sugar).

**Safety aspects:** None.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995]

#### 4.4.5.5. Primary measures on transfer chutes (e.g. on belt conveyors)

**Description:** The design of conveyor to conveyor transfer chutes plays a very important role in trying to achieve that:

- the transfer generates zero spillage
- the transfer chute loads onto the receiving conveyor centrally and without bias so that the tracking of the receiving conveyor is not affected
- the transfer chute aims to achieve a material flow onto the receiving belt at or about the speed of the receiving conveyor
- problems due to constraints such as excessive or insufficient drop height, existing head chute width and height, chute extension width, length etc., are managed efficiently
- material degradation caused by the transfer are to be minimised so as to minimise dust generation.

These objectives can be achieved by accurately calculating the material trajectory off the delivering conveyor and steering the material through the transfer at low angles of incidence so as to induce a 'free flow' of material through the transfer. A modelling process is available to generate detailed designs.

A company in the US adapted the principles of soft loading transfer chutes (using the above mentioned 'free flow' technology) to develop transfer stations that fully control/contain all the dust inherent in many transfer chute applications. This has been achieved without the use of baghouses or similar devices, i.e. the system is a 'passive' dust control system. This is a patented technology that manages the flow of air through a series of chambers to cause backpressure and a unique air stilling process to agglomerate the dust and return it to the main material flow.

**Operability:** The basis of the process is parametric design, and for most transfer applications the whole process, once the key 20 – 25 parameters have been detailed by a customer (and in the case of an existing transfer – the structural details of the current installation) can be carried out in 6 – 8 hours.

**Applicability:** The calculating process can be applied to new or existing transfers that need to be upgraded.

**Safety aspects:** None.

**Cross-media effects:** None.

**Economics:** Compared to conventional transfer chute design no additional costs are involved.

**Reference literature:** [142, Martin Engineering, 2001]

#### 4.4.5.6. Minimising the speed of descent of the loaded material

**Description:** When the speed of the descending material is too high, particles will separate and small dust particles are released. Furthermore, air is forced to the bottom with the falling material and carries out dust at the exit of the discharger. The impact of the bulk material can also cause additional dust emissions. The emission of dust depends on the length of the fall.

The speed of descent of the material can be decreased by:

- installing baffles inside long pipes (e.g. in long fill pipes)
- applying a loading head at the end of the pipe to regulate the output volume
- applying a cascade (e.g. cascade tube and cascade hopper)
- applying a minimum slope angle (e.g. with chutes).

A cascade has the advantaged combination of low fall heights and decreasing velocity because the material slides and falls alternately (see Figure 3.38).

**Safety aspects:** None.

**Cross-media effects:** None.

**Reference literature:** [17, UBA, 2001]

#### 4.4.5.7. Minimisation of free fall heights

**Description:** To minimise dust emissions from loading trucks, trains or transport units or from constructing a heap, the outlet of the discharger (e.g. a fill pipe) should reach down onto the bottom of the cargo space or onto the material already piled up. Automatically adjusting the height is the most accurate way.

**Applicability.** Hoppers, (see Section 3.4.2.3), fill pipes (see Section 3.4.2.9), fill tubes (see Section 3.4.2.10), and cascade tubes (see Section 3.4.2.11) can achieve very low fall heights when operated properly.

For substances with dispersiveness class S5, the fall height is not that critical.

**Safety aspects:** None.

**Cross-media effects:** None.

**Reference literature:** [15, InfoMil, 2001, 133, OSPAR, 1998]

#### 4.4.5.8. Dump pits with dust barriers

**Description:** See Section 3.4.2.8 and Figure 3.35 where a dump pit with dust barriers is described and shown. A dump pit equipped with dust barriers, suction equipment and (partly) housing of the reception area is described in Section 4.4.6.6.

**Operability:** Care has to be taken of the fact that the dust barriers reduce the flow capacity which can lead to dust emissions if the flow capacity is smaller than the unloading capacity of the truck or wagon.

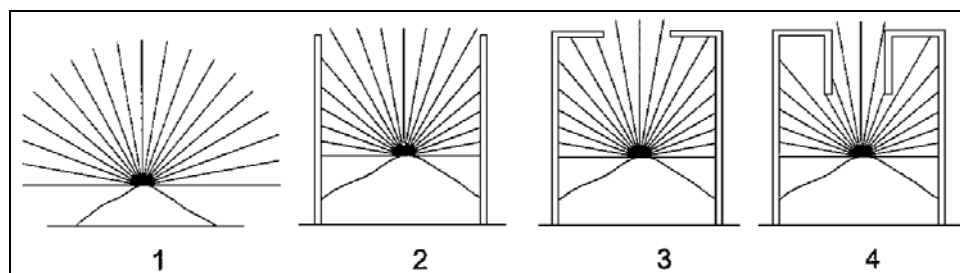
**Applicability:** Dump pits were developed for the unloading of grain, but are in principle applicable for all free-flowing bulk materials.

**Reference literature:** [17, UBA, 2001]



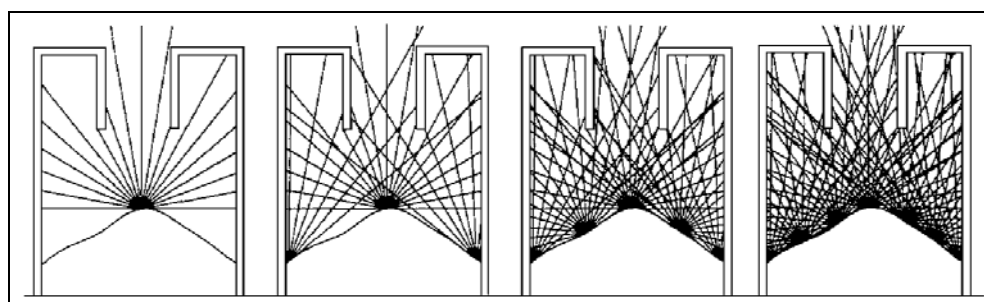
#### 4.4.5.9. Low dust bunker

**Description:** In the reference [91, Meyer and Eickelpasch, 1999] research had shown that for dust emissions from the discharge of materials with a grab into a bunker, the construction of the receiving bunker is an important factor. See Figure 4.27 showing four different constructions that are compared. Bunker number 3 and 4, show the lowest emission.



**Figure 4.27: Dust-emission from bunkers with different constructions**  
[91, Meyer and Eickelpasch, 1999]

Comparing bunker number 3 and 4 in more detail (i.e. more emission points), shows that bunker number 4, with the sophisticated reduced opening, has the highest emission reduction. See Figure 4.28, showing detailed dust emissions from bunker number 4 from 1, 3, 5 and 7 points, and Table 4.18, showing the results from bunker number 3 and 4.



**Figure 4.28: Detailed dust emissions from bunker number 4**  
[91, Meyer and Eickelpasch, 1999]

	Number of emission points considered			
	1	3	5	7
Reduction (%) in bunker 3	84	86	85	85
Reduction (%) in bunker 4	84	92	91	90

**Table 4.18: Emission reduction in bunker number 3 and 4**

**Operability:** No practical data available.

**Applicability:** No practical data available.

**Reference literature:** [91, Meyer and Eickelpasch, 1999]

#### 4.4.5.10. Chassis of vehicles with round tops

**Description:** The chassis of trucks transporting bulk solid materials can be equipped with round tops, so material cannot accumulate.

**Applicability:** For vehicles owned by the same company this can be realised, but for vehicles belonging to third parties this will be difficult.

**Reference literature:** [134, Corus, 1995]

#### 4.4.6. Secondary techniques to minimise dust from handling

Besides handling techniques which generate less dust – the primary means – there are secondary techniques to reducing emissions, such as:

- housing of the dust source, possibly combined with a suction system
- use of dust separators
- use of sprinkling plants.

For open conveyor systems in open air, placing screens or a roof is an alternative. In transporting powdery products a secondary means to prevent emissions is covering the load.

In the sections below these emission control measures are discussed in more detail.

**Reference literature:** [17, UBA, 2001] [15, InfoMil, 2001] [52, Staatliches Umweltamt Duisburg, 2000, 134, Corus, 1995]

##### 4.4.6.1. Screens for open conveyor belts

**Description:** Open conveyor systems in the open air can be protected from the effects of wind by means of:

- longitudinal screens
- transverse screens.

Also the intake and discharge sides of the conveyor can be provided with barriers in the form of wind reduction screens (or sprinklers).

**Safety aspects:** None.

**Reference literature:** [15, InfoMil, 2001]

##### 4.4.6.2. Housing or covering of the emission source

**Description:** Transfer points, hoppers, bucket elevators and other potential dust sources are housed in order to prevent dust spreading and/or to protect the material against the weather. Housing is normally a precondition for air suction. There are two types of housings: a closed type and a half-open type, where the emission source is open at one side. The type of housing and its quality determine the success of the dust limitation and influence the effectiveness of the dedusting units used.

It is also possible to cover – completely or partly – the whole conveyor path with (half-round) covers made of sheet metal or plastic.

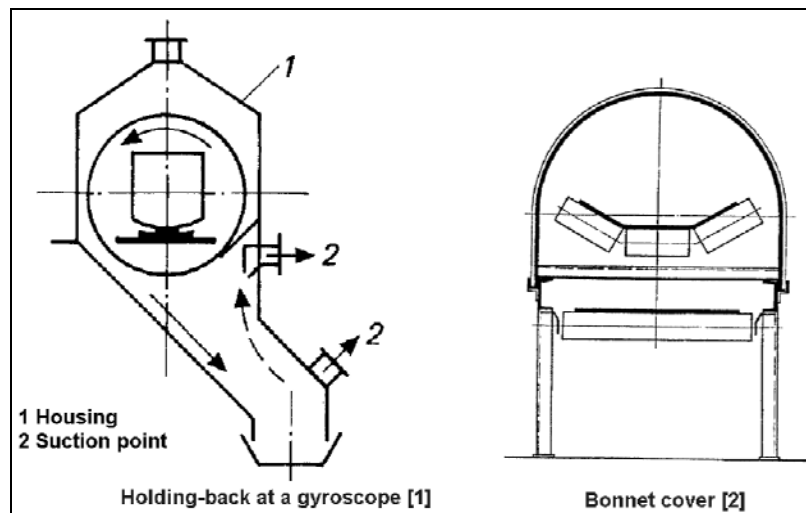


Figure 4.29: Construction types of housings [17, UBA, 2001] with reference to VDI 3929 and VDI 3606 (draft)

**Applicability:** Sometimes covers are not used because the mass flow cannot be observed. The design should take into consideration aspects such as fall height, belt width and belt velocity.

**Reference literature:** [17, UBA, 2001]

#### 4.4.6.3. Applying covers, aprons or cones on fill tubes

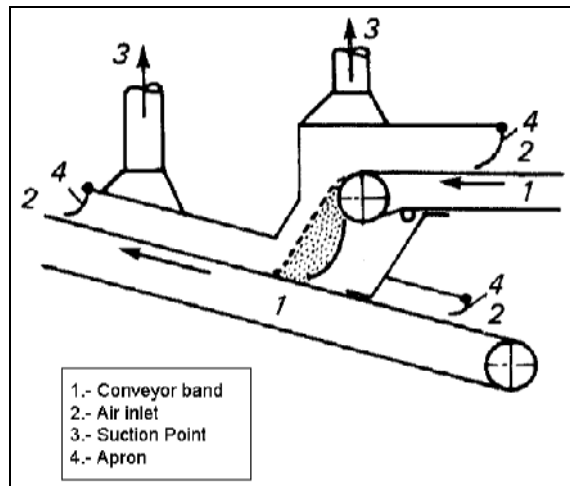
**Description:** In Section 4.4.5.6 – Minimising the speed of descent of the loaded material, primary techniques to minimise dust emissions from, amongst others, fill tubes are discussed. In addition to these, covers or aprons can be fixed at the end of the tube to minimise the spreading of dust.

For closed loading in solo trucks or containers, a cone with a fill alarm is fixed at the end of the tube so that no dust can be emitted.

**Reference literature:** [17, UBA, 2001]

#### 4.4.6.4. Extraction systems

**Description:** The use of extraction systems is common practice, whether as a central dedusting plant or several single dedusting units. In any case it is important to adjust the extraction system in such a way that no material is drawn into the air-stream; so, the extractors should be installed in the vicinity of the dust source, but not directly at it. Suction velocities of 1 to 2 m/s are normally adequate. If the dust/air stream contains too many particles, a centrifugal force separator can be installed.



**Figure 4.30: Housing and extraction at a belt transfer point**  
[17, UBA, 2001] with reference to VDI 3929

Normally filtering separators such as textile filters are used for the separation of the dust from the air-stream; they have the following advantages:

- broad application spectrum
- high separating performance
- high availability
- long filter element life
- simple construction
- not expensive with regard to investment and operating costs.

Different types of filter elements are offered, such as tube, pocket and cartridge filters. Different types of cleaning processes are: cleaning by mechanical shaking, blast cleaning and jet stream cleaning.

**Applicability:** Single units are often used when the distances between the dust sources are too great or when the dust consists of abrasive or explosive material.

**Economics:** A central dedusting plant is, in general, less expensive than several single dedusting units with regard to the investment and the operating and maintenance costs. The investment costs for a central dedusting plant vary between DEM 60000 and 400000, reference year 2000 (about EUR 30000 – 200000).

**Reference literature:** [17, UBA, 2001]

#### 4.4.6.5. Lamellae filters for pneumatic conveyors

**Description:** Filter systems for pneumatic conveyors have to operate under difficult situations. Usually they are directly connected with the conveying system and thus have to operate at an under-pressure of up to 0.5 bar. The airflow can be up to 700 m<sup>3</sup>/h, dependent on the layout of the system and the type of material that is conveyed. A sinter lamella filter is a suitable filter in these circumstances.

**Achieved environmental benefits:** The achievable emission level is < 1 mg/Nm<sup>3</sup>.

**Applicability:** This type of filter is often applied.

**Safety aspects:** Sinter lamellae filters are available in antistatic versions as well.

**Cross-media effects:** The filter is washable, it can be recycled and regenerated. However, end-of-pipe techniques always go together with energy consumption.

**Reference literature:** [146, suppliers information, 2001] [147, EIPPCB, 2002]

#### 4.4.6.6. Dump pits with suction equipment, housing and dust barriers

**Description:** Dump pits can be equipped with so-called dust barriers. These are valves or lamellae which open when the material is fed in. The dust that comes up is held back either by the following material or, when the mass flow stops, by the closing dust barriers. Dump pits can also be equipped with a suction system. Apart from dust barriers and/or a suction system, the reception area can be housed. Another possibility is the housing of the vehicle and pit area by a movable curtain system. Sometimes dump pits are equipped only with suction equipment. The disadvantage of this approach is high energy consumption and low effectiveness in dust reduction.

**Achieved environmental benefits:** The combination of a suction system and dust barriers has the advantage that the suction performance needed is considerably lower with dust barriers than without dust barriers; a reduction of 60 % is reported.

In the paragraph below, two possible combinations of dust reducing measures that are practised are compared on their efficiency, safety issues and economics.

Combination 1: suction of the dump pit, installation of dust barriers and housing of the whole reception area results in an almost total prevention of diffuse dust emissions.

Combination 2: suction of the dump pit, installation of dust barriers and housing of the vehicle and pit area by a movable curtain system results in no visible dust leaving the housing.

**Operability:** For suction equipment, a difficulty might be to adjust the suction capacity precisely to avoid the risk of sucking the product itself as well.

A possible problem of applying dust barriers might be the reduced flow capacity which can lead to dust emissions if the flow capacity is smaller than the unloading capacity of the truck or wagon.

In practice, closed (or housed) dump pits are not very effective because the gates are not held closed.

**Safety aspects:** A disadvantage of closed dump pits is that the vehicle – as an ignition source – stays within the housed area where the formation of explosive dust/air mixtures is possible. With combination 2 this is not the case.

**Cross-media effects:** Suction systems generate noise and have a high energy consumption.

**Economics:** Example 1: A new dump pit with a capacity of 7500 kg, with a fixed housing and suction, but without dust barriers, required an investment of DEM 450000 (about EUR 225000), reference year 2000.

Example 2: The retrofitting to an existing grain reception point, with a capacity comparable to example 1, of dust barriers, suction and a movable housing required an investment of DEM 200000 (about EUR 100000), reference year 2000.

The lower energy consumption for dump pits with dust barriers is an economic advantage.

**Reference plants:**

- combination 1: several in Germany
- combination 2: Raiffeisen Bezugsverein e. G., Süderbrarup; ATR Landhandel, Leezen (Germany). (This combination is not allowed in some German Länder).

**Reference literature:** [17, UBA, 2001]

**4.4.6.7. Optimised discharge hoppers (in ports)**

**Description:** The following characteristics – which also can be combined – are relevant for dust prevention on hoppers:

- suction hoppers; dust/air mixtures are drawn through a dust filter
- closed hoppers; hoppers equipped with high side-walls with the following effects:
  - wind disturbance is prevented by the wall
  - dust distribution is locally limited by the hopper wall and the grab (when the grab stays long enough within the walled area)
  - any suction system installed is more effective (40 % less suction capacity is required in comparison to open hoppers)
- hoppers equipped with (primary) techniques such as baffles or a louvre-type grid closure with the effect that dust-air mixtures are held back; these installations require the bulk material to be fairly fluid.

**Operability:** Hoppers with high side-walls hinder the crane operator's view. Additionally, the dust-reducing effect of high side-walls is essentially dependent on the crane operator's technique.

**Economics:** An example is an investment of DEM 90000 (about EUR 46000) for a silo hopper with:

- 55° hopper slope angle
- a discharge gate of 400 mm
- a cylinder top of 3 m
- a diameter of 5 m
- dust valves (as dust barriers) with suction (7500 m<sup>3</sup>/h)
- an antistatic filter
- control equipment.

**Reference plants:** Louvre-type grid closure with suction is applied in port Neuss, Norddeutsche Affinerie Hamburg and the port of Hamburg. Louvre-type grid without suction is applied in Raiffeisen Hauptgenossenschaft Nord, Uelzen (only for fertilisers).

**Reference literature:** [17, UBA, 2001]

**4.4.6.8. The techniques of water spraying/water curtains**

**Description:** The moistening of bulk materials by sprinkler irrigation is a practically proven technique to prevent dust formation from loading/unloading activities. The spraying can be carried out by using a permanent installation or mobile containers (e.g. tankers).

Water curtains are, e.g. used to keep dust in the hopper when grabs are opened above the water curtain. Another example is the tipping to stockpiles made through chutes equipped with wet suppression systems.

Efforts have been made to produce finer drops for binding the fine dust particles. These have involved the development of special nozzles for use with compressed air and the use of additives.

See Section 4.3.6.1 – Spraying of water with or without additives and Section 4.4.6.9 – Jet spraying, where the techniques described are applicable to storage and loading and unloading activities in the open air.

**Achieved environmental benefits:** When spraying with water only, the estimated effectiveness is 80 – 98 %.

**Applicability:** The technique of water spraying is simple, but application is limited to bulk material that is not sensitive to moisture. Spraying is particularly suitable for existing plants where the space for installing extraction equipment is not sufficient and water resources are available.

**Cross-media effects:** The water consumption is relatively high and the sprinkling can make the material too wet to handle. Sometimes the material needs to be dried later, which can lead to increased energy consumption. The collected run-off water may need to be treated.

**Economics:** To give a general idea of cost, water spraying plants require – depending on the number of transfer points – an investment of DM 10000 to 15000 (reference year 2000, about EUR 5000 to 7500).

**Reference plant:** Weser Engineering GmbH, Germany.

**Reference literature:** [17, UBA, 2001] [78, DCMR Milieudienst Rijnmond, 1995] [133, OSPAR, 1998] [74, Corus, 2002]

#### 4.4.6.9. Jet spraying

**Description:** Air with a constant pressure of 2 bar and water with a variable pressure between 0.5 and 1.5 bar are used to generate a fine water fog. The user can select a cone-shaped or a fan-shaped fog. The size of the water drops is between 1 and 50  $\mu\text{m}$  (mostly between 1 and 10  $\mu\text{m}$ ), depending on the nozzle size and the water and air pressure. Machines are available with a variety of consumption rates, e.g. 10 l/h, 25 l/h and 55 l/h. In practice 1 litre is needed per tonne of treated material.

The use of this technique requires complete coverage in order to guarantee optimal dust reduction. If only a lateral capsulation is carried out, the effect is reduced to 50 %. The capsulation normally has sizes of 600 mm height and 2500 mm to 4000 mm length. Per nozzle 0.5 to 1 m<sup>3</sup> capsulated space is calculated.

The technique of spraying with fine water fog prevents the material from getting too wet. No additives and no antifreeze is needed. The disadvantages are that complete coverage and a compressor are needed.

**Applicability:** Jet spraying, which is a mean to suppress dust formation, can be used on heaps, for the loading/unloading of heaps and tip bunkers, the loading of ships with telescopic hoppers and the loading of trucks from silos.

**Cross-media effects:** Water and energy are needed and the compressor generates noise.

**Economics:** In comparison to conventional dust reduction measures, the investment is lower, particularly if water, air and compressed air connections exist. The costs for a nozzle vary between DEM 1500 and 4000 (about EUR 760 – 2000) including controls and pipes, and DEM 800 – 900 (about EUR 400 – 460) not including controls and pipes. The investment cost for all the equipment needed is DEM 20000 (about EUR 10000).

**Reference plants:** Power station Mannheim, Braunschweigische coal-mining work AG – power station Offleben, VEAG Brown coal power station Jänschwalde, HKW Pforzheim, Energy supply Nordthüringen – HKW Erfurt, Energy supply Schwaben – Heilbronn.

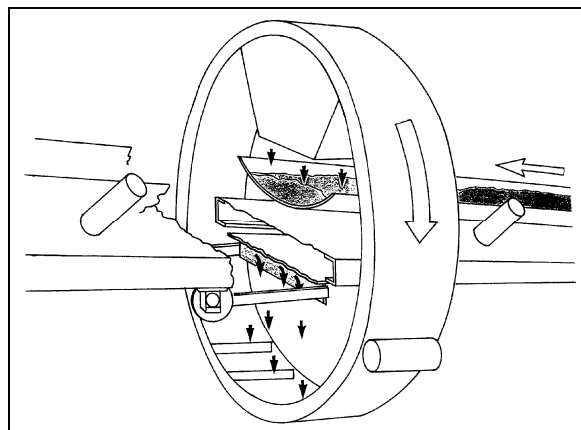
**Reference literature:** [17, UBA, 2001]

#### 4.4.6.10. Cleaning conveyor belts

**Description:** To avoid dust emissions from conveyor belts the following techniques to clean the belt are applied:

- scraping off, eventually with a rotating elevator to collect the material that is scraped off (see Figure 4.31)
- washing with water
- blowing air
- knocking or trembling
- suction below the belt
- turning the belt when it is running back
- a self-cleaning tray below the belt.

The rotating elevator shown below is installed on those parts of the belt where much material is falling off the belt. The slowly rotating elevator collects the material and throws the material back on the belt. This technique is mainly developed for existing belt conveyors where a lot of material falls from the belt.



**Figure 4.31: Rotating elevator to collect material that is scraped off of the conveyor belt [78, DCMR Milieudienst Rijnmond, 1995]**

At the Martha Hill Mine on the north island of New Zealand, ore and waste are both conveyed on conventional conveyor belts. The ore and waste are a mixture of fine clays mixed with volcanic ash and hard rock. The clays have a moisture content of 41 % and are extremely sticky. In order to clean the belt an elaborated belt cleaning system is installed. The belt cleaning system includes a primary belt scraper and a secondary belt scraper on the head pulley, a pair of high pressure fan jet water sprayers that are mounted slightly behind the head pulley, and a series of rollers that are provided to squeeze the last of the water/waste slurry off the belt. The water delivery is sufficient to slurry any material carried back and the water from this system is collected in dams where the solids are settled and the water is then recycled.

**Achieved environmental benefits:** Estimated efficiency is 20 – 40 %, but this will highly depend on the material and the number of elevators.



**Operability:** The experience of Corus with some of these techniques is not very positive because they are considered not to be very effective. Belt scrapers at the head drum are subject to wear and require continuous maintenance. Belt turning and belt washing installations can only be used limitedly and belt washing installations require frequent maintenance.

Commissioning the conveyor facility at Martha Hill Mine included a number of detail revisions, mostly as a consequence of handling the sticky waste material causing problems with chute blockages. After a number of minor alterations the system operation achieved the required performance level. However, no information from the customer was made available to confirm the level of operability and performance of this equipment.

**Applicability:** The combination, spraying with water, scraping off and automatic belt turning is applied where ore is transported.

The rotating elevator is not suitable for very dusty materials.

**Safety aspects:** None.

**Reference plants:** Corus and Ertsoverslagbedrijf Europoort c.v. (an ore-transshipment company), the Netherlands.

**Reference literature:** [78, DCMR Milieudienst Rijnmond, 1995, 134, Corus, 1995, 141, suppliers information, 2001]

#### 4.4.6.11. Fitting trucks with mechanical/hydraulic flaps

**Description:** Trucks hauling powdery products are fitted with mechanical/hydraulic flaps which cover the cargo.

**Safety aspects:** None.

**Reference plant:** Corus, the Netherlands.

**Reference literature:** [52, Staatliches Umweltamt Duisburg, 2000, 134, Corus, 1995]

#### 4.4.6.12. Cleaning of roads

**Description:** Roads with hard surfaces of, for example, concrete or asphalt can be cleaned to avoid dust being swirled up by vehicles, using various sweepers, such as:

- Technique 1. wet sweeper trucks equipped with a wetting system, rotary brush and a suction nozzle of 0.5 m
- Technique 2. dry sweeper trucks equipped with a rotary brush, enclosed suction unit with a suction nozzle of 0.5 m
- Technique 3. dry sweeper trucks equipped with a rotary brush enclosure suction, high suction rate and a nozzle of 2.4 m, and a drying machine
- Technique 4. wet sweeper trucks without rotary brush, a water pressure of 120 bar, high suction rate and a nozzle of 2.4 m.

**Achieved environmental benefits:** All techniques had been tested at Corus, the Netherlands (a steel producer); technique 1 had a very poor performance, because the amount of dust was only reduced by 12 %. Technique 2 had a better performance and reduced the amount of dust by 38 %. Technique 3 showed very good results by reducing the amount by 93 % and technique 4 performed even better by reducing the amount of dust by 98 %.

Technique number	1	2	3	4
Total dust reduction (%)	12	38	93	98

**Table 4.19: Efficiency of various sweepers**  
[134, Corus, 1995]

The frequency of cleaning roads depends on many factors and can only be decided on a case-by-case basis.

**Operability:** Technique number 4 showed the disadvantage that dirty water had to be discharged into a water-cleaning unit (settling tank). This requires additional investment if there is not a suitable water-cleaning unit available.

**Safety aspects:** None.

**Reference plant:** Corus, the Netherlands.

**Reference literature:** [52, Staatliches Umweltamt Duisburg, 2000, 134, Corus, 1995]

#### 4.4.6.13. Cleaning of vehicle tyres

**Description:** To prevent motor vehicles from collecting dust on their tyres, different techniques for cleaning the tyres are available. This can be as simple as just a pool of water where the vehicle is forced to pass through.

A more sophisticated technique is a pool in combination with cleaning of the tyres' running surface with clean water where the dust is removed from the dirty water in a settling tank and the water is re-used as washing water (see Figure 4.32). When a vehicle is approaching the installation, the water automatically sprinkles on higher speed to minimise the amount of water and energy used.

In case washing water has to be discharged, it is common practise to treat the water before release and to recycle the collected materials, particularly in the primary non-ferrous metal industry to avoid release of metals.



**Figure 4.32: A pool of water in combination with running water for the tyres' running surface**  
[134, Corus, 1995]

Besides using water for cleaning, dry cleaning techniques are also available, however, no further information was made available on these techniques.

**Operability:** To assure that the vehicles are cleaned by the washing installation before leaving the site, fences are placed to force the drivers to take the route where the cleaning installation is situated.

**Applicability:** The cleaning of vehicle tyres is often applied. The choice of technique – a simple pool or ‘high tech’ equipment – depends on several circumstances such as:

- the appearance of fine dust on site (when sprinkling the fine dust on the streets, a fine sludge will be formed, but cleaning just by simply driving through a pool of water is sufficient)
- having to deal with sticky soil (the washing installation has to deal with more difficult circumstances because sticky soil is more difficult to remove from the tyre tread)
- the dust containing dangerous substances
- the distance to neighbouring houses and other sensitive objects
- the number of vehicles is of minor relevance for the decision whether a cleaning installation is necessary.

**Safety aspects:** None.

**Reference plant:** Corus in the Netherlands and several other plants in Duisburg, Germany.

**Reference literature:** [52, Staatliches Umweltamt Duisburg, 2000] [134, Corus, 1995] [133, OSPAR, 1998]

#### **4.4.7. Measures to prevent emissions from handling packaged good**

See Section 4.1.7.

#### **4.4.8. Safety and risk management in handling solids**

See Section 4.1.6.1 where the Seveso Directive is discussed for storing dangerous liquids or liquefied gases in tanks. The same is valid for storing and handling dangerous solid substances.



## 5. BEST AVAILABLE TECHNIQUES

In understanding this chapter and its contents, the attention of the reader is drawn back to the preface of this document and in particular the fifth section of the preface: ‘How to understand and use this document’. The techniques and associated emission and/or consumption levels, or ranges of levels, presented in this chapter have been assessed through an iterative process involving the following steps:

- identification of the key environmental issues for the sector; emissions to air and soil from the storage, transfer and handling of liquids and liquefied gases and of dust from the storage and handling of solids. Also safety issues are addressed
- examination of the techniques most relevant to address these key issues
- identification of the best environmental performance levels, on the basis of the available data in the European Union and worldwide
- examination of the conditions under which these performance levels were achieved; such as costs, cross-media effects, main driving forces involved in implementation of the techniques
- selection of the best available techniques (BAT) and the associated emission and/or consumption levels in a general sense, all according to Article 2(11) and Annex IV of the Directive.

Expert judgement by the European IPPC Bureau and the storage Technical Working Group (TWG) has played a key role in each of these steps and in the way in which the information is presented here.

On the basis of this assessment, techniques, and as far as possible emission and consumption levels associated with the use of BAT, are presented in this chapter that are considered to be appropriate to the relevant storage, transfer and handling systems and in many cases reflect current performance of some installations applied. Where emission or consumption levels ‘associated with best available techniques’ are presented, this is to be understood as meaning that those levels represent the environmental performance that could be anticipated as a result of the application of the techniques described, bearing in mind the balance of costs and advantages inherent within the definition of BAT. However, they are neither emission nor consumption limit values and should not be understood as such. In some cases it may be technically possible to achieve better emission or consumption levels but due to the costs involved or cross-media considerations, they are not considered to be appropriate as BAT for the relevant storage or transfer and handling system. However, such levels may be considered to be justified in more specific cases where there are special driving forces.

The emission and consumption levels associated with the use of BAT have to be seen together with any specified reference conditions (e.g. averaging periods).

The concept of ‘levels associated with BAT’ described above is to be distinguished from the term ‘achievable level’ used elsewhere in this document. Where a level is described as ‘achievable’ using a particular technique or combination of techniques, this should be understood to mean that the level may be expected to be achieved over a substantial period of time in a well maintained and operated installation using those techniques.

Where available, data concerning costs have been given together with the description of the techniques presented in the previous chapter. These give a rough indication about the magnitude of costs involved. However, the actual cost of applying a technique will depend strongly on the specific situation regarding, for example, taxes, fees, and the technical characteristics of the installation concerned. It is not possible to evaluate such site-specific factors fully in this document. In the absence of data concerning costs, conclusions on economic viability of techniques are drawn from observations on existing installations.

It is intended that the general BAT in this chapter are a reference point against which to judge the current performance of an existing installation or to judge a proposal for a new installation. In this way they will assist in the determination of appropriate 'BAT-based' conditions for the installation or in the establishment of general binding rules under Article 9(8). It is foreseen that new installations can be designed to perform at or even better than the general BAT levels presented here. It is also considered that existing installations could move towards the general BAT levels or do better, subject to the technical and economic applicability of the techniques in each case.

While the BAT reference documents do not set legally binding standards, they are meant to give information for the guidance of industry, Member States and the public on achievable emission and consumption levels when using specified techniques. The appropriate limit values for any specific case will need to be determined taking into account the objectives of the IPPC Directive and the local considerations.

In a horizontal approach it is assumed that the environmental aspects of the applied techniques and the associated reduction measures can be assessed and that generic BAT can be identified that are independent of the industry in which these techniques are applied.

However, it is recognised that tanks differ due to design, product stored, location etc., and therefore a methodology has been developed for assessing the emission control measures (ECM) described in Chapter 4. This methodology is a tool that can be used by the permit writer and the operator in order to define which ECM, or combination of ECM, that meet the generic BAT levels or do better, performs best in the storage of liquid and liquefied gas in a specific situation, and is described in Section 4.1.1.

There is a split view from some Member States, that the ECM methodology is neither practical nor suitable for determining BAT in their view (see Section 4.1.1). Specifically, the methodology:

- is not BAT and this was agreed upon in the TWG. Furthermore, the methodology does not conform with the requirements on BAT according the BREF Outline and Guide
- has not been practically tested in practice by the permitting authorities
- does not allow any European or sectoral conclusions on BAT for substances with certain properties, and
- does not offer a possibility for the harmonisation of BAT techniques in Europe.

A few Member States do not agree with the BAT conclusions in Chapter 5 because, in their view, there is too much emphasis on the determination of BAT on a case by case basis at a local level. In their view, the BREF does not contain clear European BAT conclusions which would contribute more to harmonisation of standards at the European level. They would prefer, in particular, that such standards are based upon the hazardous potential and the amount of materials being handled.

## 5.1. Storage of liquids and liquefied gases

### 5.1.1. Tanks

#### 5.1.1.1. General principles to prevent and reduce emissions

##### Tank design

BAT for a proper design is to take into account at least the following:

- the physico-chemical properties of the substance being stored
- how the storage is operated, what level of instrumentation is needed, how many operators are required, and what their workload will be
- how the operators are informed of deviations from normal process conditions (alarms)
- how the storage is protected against deviations from normal process conditions (safety instructions, interlock systems, pressure relief devices, leak detection and containment, etc.)
- what equipment has to be installed, largely taking account of past experiences of the product (construction materials, valve quality, etc.)
- which maintenance and inspection plan needs to be implemented and how to ease the maintenance and inspection work (access, layout, etc.)
- how to deal with emergency situations (distances to other tanks, facilities and to the boundary, fire protection, access for emergency services such as the fire brigade, etc.).

See Annex 8.19 for a typical checklist.

##### Inspection and maintenance

BAT is to apply a tool to determine proactive maintenance plans and to develop risk-based inspection plans such as the risk and reliability based maintenance approach; see Section 4.1.2.2.1.

Inspection work can be divided into routine inspections, in-service external inspections and out-of-service internal inspections and are described in detail in Section 4.1.2.2.2.

##### Location and layout

For building new tanks it is important to select the location and the layout with care, e.g. water protection areas and water catchment areas should be avoided whenever possible. See Section 4.1.2.3.

BAT is to locate a tank operating at, or close to, atmospheric pressure aboveground. However, for storing flammable liquids on a site with restricted space, underground tanks can also be considered. For liquefied gases, underground, mounded storage or spheres can be considered, depending on the storage volume.

##### Tank colour

BAT is to apply either a tank colour with a reflectivity of thermal or light radiation of at least 70 %, or a solar shield on aboveground tanks which contain volatile substances, see Section 4.1.3.6 and 4.1.3.7 respectively.

##### Emissions minimisation principle in tank storage

BAT is to abate emissions from tank storage, transfer and handling that have a significant negative environmental effect, as described in Section 4.1.3.1.

This is applicable to large storage facilities allowing a certain time frame for implementation.

## **Monitoring of VOC**

On sites where significant VOC emissions are to be expected, BAT includes calculating the VOC emissions regularly. The calculation model may occasionally need to be validated by applying a measurement method. See Section 4.1.2.2.3.

There is a split view from three Member States, because in their view, on sites where significant VOC emissions are to be expected (e.g. refineries, petrochemical plants and oil terminals), BAT is to calculate the VOC emissions regularly with validated calculation methods, and because of uncertainties in the calculation methods, emissions from the plants should be monitored occasionally in order to quantify the emissions and to give basic data for refining calculation methods. This can be carried out by using DIAL techniques. The necessity and frequency of emission monitoring needs to be decided on a case-by-case basis.

## **Dedicated systems**

BAT is to apply dedicated systems; see Section 4.1.4.4.

Dedicated systems are generally not applicable on sites where tanks are used for short to medium-term storage of different products.

### **5.1.1.2. Tank specific considerations**

#### ***Open top tanks***

Open top tanks are used for the storage of, e.g. manure slurry in agricultural premises and water and other non-flammable or non-volatile liquids in industrial facilities, see Section 3.1.1.

If emissions to air occur, BAT is to cover the tank by applying:

- a floating cover, see Section 4.1.3.2
- a flexible or tent cover, see Section 4.1.3.3, or
- a rigid cover, see Section 4.1.3.4.

Additionally, with an open top tank covered with a flexible, tent or a rigid cover, a vapour treatment installation can be applied to achieve an additional emission reduction, see Section 4.1.3.15. The type of cover and the necessity for applying the vapour treatment system depend on the substances stored and must be decided on a case-by-case basis.

To prevent deposition that would call for an additional cleaning step, BAT is to mix the stored substance (e.g. slurry), see Section 4.1.5.1.

#### ***External floating roof tank***

External floating roof tanks are used for the storage of, e.g. crude oil; see Section 3.1.2.

The BAT associated emission reduction level for a large tank is at least 97 % (compared to a fixed roof tank without measures), which can be achieved when over at least 95 % of the circumference the gap between the roof and the wall is less than 3.2 mm and the seals are liquid mounted, mechanical shoe seals. By installing liquid mounted primary seals and rim mounted secondary seals, a reduction in air emissions of up to 99.5 % (compared to a fixed roof tank without measures) can be achieved. However, the choice of seal is related to reliability, e.g. shoe seals are preferred for longevity and, therefore, for high turnovers. See Section 4.1.3.9.



BAT is to apply direct contact floating roofs (double-deck), however, existing non-contact floating roofs (pontoon) are also BAT. See Section 3.1.2.

Additional measures to reduce emissions are (see Section 4.1.3.9.2):

- applying a float in the slotted guide pole
- applying a sleeve over the slotted guide pole, and/or
- applying ‘socks’ over the roof legs.

A dome can be BAT for adverse weather conditions, such as high winds, rain or snowfall. See Section 4.1.3.5.

For liquids containing a high level of particles (e.g. crude oil), BAT is to mix the stored substance to prevent deposition that would call for an additional cleaning step, see Section 4.1.5.1.

### ***Fixed roof tanks***

Fixed roof tanks are used for the storage of flammable and other liquids, such as oil products and chemicals with all levels of toxicity, see Section 3.1.3.

For the storage of volatile substances which are toxic (T), very toxic (T+), or carcinogenic, mutagenic and reproductive toxic (CMR) categories 1 and 2 in a fixed roof tank, BAT is to apply a vapour treatment installation.

There is a split view from industry, that this technique is not BAT because in their view:

- a) *there is no definition of ‘volatile’ in this BREF*
- b) *there is no test of environmental significance*
- c) *products which may be dangerous to the environment, but not classed as toxic, are not captured*
- d) *it can be demonstrated that other emission control measures may provide a higher level of environmental protection taking into account the costs and advantages of the various techniques*
- e) *there are no commonly understood performance criteria for a vapour treatment installation*
- f) *this does not take into account the cost, or advantages of other techniques*
- g) *this does not provide the flexibility to take into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions*
- h) *there is no proportionality in this conclusion.*

For other substances, BAT is to apply a vapour treatment installation, or to install an internal floating roof (see Sections 4.1.3.15 and 4.1.3.10 respectively). Direct contact floating roofs and non-contact floating roofs are BAT. In the Netherlands, the condition for when to apply these BAT is when the substance has a vapour pressure (at 20 °C) of 1 kPa and the tank has a volume of  $\geq 50 \text{ m}^3$ . In Germany, the condition for when to apply these BAT is when the substance has a vapour pressure (at 20 °C) of 1.3 kPa and the tank has a volume of  $\geq 300 \text{ m}^3$ .

For tanks  $< 50 \text{ m}^3$ , BAT is to apply a pressure relief valve set at the highest possible value consistent with the tank design criteria.

The selection of the vapour treatment technology is based on criteria such as cost, toxicity of the product, abatement efficiency, quantities of rest-emissions and possibilities for product or energy recovery, and has to be decided case-by-case. The BAT associated emission reduction is at least 98 % (compared to a fixed roof tank without measures). See Section 4.1.3.15.

The achievable emission reduction for a large tank using an internal floating roof is at least 97 % (compared to a fixed roof tank without measures), which can be achieved when over at least 95 % of the circumference of the gap between the roof and wall is less than 3.2 mm and the seals are liquid mounted, mechanical shoe seals. By applying liquid mounted primary seals and rim mounted secondary seals, even higher emission reductions can be achieved. However, the smaller the tank and the smaller the number of turnovers the less effective the floating roof is, see Annex 8.22 and Annex 8.23 respectively.

Also the case studies in Annex 8.13 show that achievable emission reductions depend on several issues such as the substance that is actually stored, meteorological circumstances, number of turnovers and diameter of the tank. The calculations show that with an internal floating roof an emission reduction in the range 62.9 – 97.6 % can be achieved (compared to a fixed roof tank without measures); where 62.9 % refers to a tank of 100 m<sup>3</sup> equipped with only primary seals and 97.6 % refers to a tank of 10263 m<sup>3</sup> equipped with primary and secondary seals.

For liquids containing a high level of particles (e.g. crude oil) BAT is to mix the stored substance to prevent deposition that would call for an additional cleaning step, see Section 4.1.5.1.

### *Atmospheric horizontal tanks*

Atmospheric horizontal tanks are used for the storage of flammable and other liquids, such as oil products and chemicals in all levels of flammability and toxicity, see Section 3.1.4. Horizontal tanks are different to vertical tanks, e.g. since they can inherently operate under higher pressures.

For the storage of volatile substances which are toxic (T), very toxic (T+), or CMR categories 1 and 2 in an atmospheric horizontal tank, BAT is to apply a vapour treatment installation.

There is a split view from industry, that this technique is not BAT because in their view:

- a) *there is no definition of 'volatile' in this BREF*
- b) *there is no test of environmental significance*
- c) *products which may be dangerous to the environment, but not classed as toxic, are not captured*
- d) *it can be demonstrated that other emission control measures may provide a higher level of environmental protection taking into account the costs and advantages of the various techniques*
- e) *there are no commonly understood performance criteria for a vapour treatment installation*
- f) *this does not take into account the costs or advantages of other techniques*
- g) *this does not provide the flexibility to take into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions*
- h) *there is no proportionality in this conclusion.*

For other substances, BAT is to do all, or a combination, of the following techniques, depending on the substances stored:

- apply pressure vacuum relief valves; see Section 4.1.3.11
- up rate to 56 mbar; see Section 4.1.3.11
- apply vapour balancing; see Section 4.1.3.13
- apply a vapour holding tank, see Section 4.1.3.14, or
- apply vapour treatment; see Section 4.1.3.15.

The selection of the vapour treatment technology has to be decided on a case-by-case basis.

***Pressurised storage***

Pressurised storage is used for storing all categories of liquefied gases, from non-flammable up to flammable and highly toxic. The only significant emissions to air from normal operation are from draining.

BAT for draining depends on the tank type, but may be the application of a closed drain system connected to a vapour treatment installation, see Section 4.1.4.

The selection of the vapour treatment technology has to be decided on a case-by-case basis.

***Lifter roof tanks***

For emissions to air, BAT is to (see Sections 3.1.9 and 4.1.3.14):

- apply a flexible diaphragm tank equipped with pressure/vacuum relief valves, or
- apply a lifter roof tank equipped with pressure/vacuum relief valves and connected to a vapour treatment installation.

The selection of the vapour treatment technology has to be decided on a case-by-case basis.

***Refrigerated tanks***

There are no significant emissions from normal operation, see Section 3.1.10.

***Underground and mounded tanks***

Underground and mounded tanks are used especially for flammable products, see Sections 3.1.11 and 3.1.8 respectively.

For the storage of volatile substances which are toxic (T), very toxic (T+), or CMR categories 1 and 2 in an underground or mounded tank, BAT is to apply a vapour treatment installation.

There is a split view from industry, that this technique is not BAT because in their view:

- a) *there is no definition of 'volatile' in this BREF*
- b) *there is no test of environmental significance*
- c) *products which may be dangerous to the environment, but not classed as toxic, are not captured*
- d) *it can be demonstrated that other emission control measures may provide a higher level of environmental protection taking into account the costs and advantages of the various techniques*
- e) *there are no commonly understood performance criteria for a vapour treatment installation*
- f) *this does not take into account the costs or advantages of other techniques*
- g) *this does not provide the flexibility to take into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions*
- h) *there is no proportionality in this conclusion.*

For other substances, BAT is to do all, or a combination, of the following techniques, depending on the substances stored:

- apply pressure vacuum relief valves; see Section 4.1.3.11
- apply vapour balancing; see Section 4.1.3.13
- apply a vapour holding tank, see Section 4.1.3.14, or
- apply vapour treatment; see Section 4.1.3.15.

The selection of the vapour treatment technology has to be decided on a case-by-case basis.

### 5.1.1.3. Preventing incidents and (major) accidents

#### **Safety and risk management**

The Seveso II Directive (Council Directive 96/82/EC of 9 December 1996 on the control of major accident hazards involving dangerous substances) requires companies to take all measures necessary to prevent and limit the consequences of major accidents. They must, in any case, have a major accident prevention policy (MAPP) and a safety management system to implement the MAPP. Companies holding large quantities of dangerous substances, the so-called upper tiered establishments, must also draw up a safety report and an on-site emergency plan and maintain an up-to-date list of substances. However, plants that do not fall under the scope of the Seveso II Directive can also cause emissions from incidents and accidents. Applying a similar, maybe less detailed, safety management system is the first step in preventing and limiting these.

BAT in preventing incidents and accidents is to apply a safety management system as described in Section 4.1.6.1.

#### **Operational procedures and training**

BAT is to implement and follow adequate organisational measures and to enable training and instruction of employees for safe and responsible operation of the installation as described in Section 4.1.6.1.1.

#### **Leakage due to corrosion and/or erosion**

Corrosion is one of the main causes of equipment failure and can occur both internally and externally on any metal surface, see Section 4.1.6.1.4. BAT is to prevent corrosion by:

- selecting construction material that is resistant to the product stored
- applying proper construction methods
- preventing rainwater or groundwater entering the tank and if necessary, removing water that has accumulated in the tank
- applying rainwater management to bund drainage
- applying preventive maintenance, and
- where applicable, adding corrosion inhibitors, or applying cathodic protection on the inside of the tank.

Additionally for an underground tank, BAT is to apply to the outside of the tank:

- a corrosion-resistant coating
- plating, and/or
- a cathodic protection system.

Stress corrosion cracking (SCC) is a specific problem for spheres, semi-refrigerated tanks and some fully refrigerated tanks containing ammonia. BAT is to prevent SCC by:

- stress relieving by post-weld heat treatment, see Section 4.1.6.1.4, and
- applying a risk based inspection as described in Section 4.1.2.2.1.

### **Operational procedures and instrumentation to prevent overflow**

BAT is to implement and maintain operational procedures – e.g. by means of a management system – as described in Section 4.1.6.1.5, to ensure that:

- high level or high pressure instrumentation with alarm settings and/or auto closing of valves is installed
- proper operating instructions are applied to prevent overflow during a tank filling operation, and
- sufficient ullage is available to receive a batch filling.

A standalone alarm requires manual intervention and appropriate procedures, and automatic valves need to be integrated into the upstream process design to ensure no consequential effects of closure. The type of alarm to be applied has to be decided for every single tank. See Section 4.1.6.1.6.

### **Instrumentation and automation to detect leakage**

The four different basic techniques that can be used to detect leaks are:

- release prevention barrier system
- inventory checks
- acoustic emission method
- soil vapour monitoring.

BAT is to apply leak detection on storage tanks containing liquids that can potentially cause soil pollution. The applicability of the different techniques depends on the tank type and is discussed in detail in Section 4.1.6.1.7.

### **Risk-based approach to emissions to soil below tanks**

The risk-based approach to emissions to soil from an aboveground flat-bottom and vertical, storage tank containing liquids with a potency to pollute soil, is that soil protection measures are applied at such a level that there is a ‘negligible risk’ for soil pollution because of leakage from the tank bottom or from the seal where the bottom and the wall are connected. See Section 4.1.6.1.8 where the approach and the risk levels are explained.

BAT is to achieve a ‘negligible risk level’ of soil pollution from bottom and bottom-wall connections of aboveground storage tanks. However, on a case-by-case basis, situations might be identified where an ‘acceptable risk level’ is sufficient.

### **Soil protection around tanks – containment**

BAT for aboveground tanks containing flammable liquids or liquids that pose a risk for significant soil pollution or a significant pollution of adjacent watercourses is to provide secondary containment, such as:

- tank bunds around single wall tanks; see Section 4.1.6.1.11
- double wall tanks; see Section 4.1.6.1.13
- cup-tanks; see Section 4.1.6.1.14
- double wall tanks with monitored bottom discharge; see Section 4.1.6.1.15.

For building new single walled tanks containing liquids that pose a risk for significant soil pollution or a significant pollution of adjacent watercourses, BAT is to apply a full, impervious, barrier in the bund, see Section 4.1.6.1.10.

For existing tanks within a bund, BAT is to apply a risk-based approach, considering the significance of risk from product spillage to the soil, to determine if and which barrier is best applicable. This risk-based approach can also be applied to determine if a partial impervious barrier in a tank bund is sufficient or if the whole bund needs to be equipped with an impervious barrier. See Section 4.1.6.1.11.

Impervious barriers include:

- a flexible membrane, such as HDPE
- a clay mat
- an asphalt surface
- a concrete surface.

For chlorinated hydrocarbon solvents (CHC) in single walled tanks, BAT is to apply CHC-proof laminates to concrete barriers (and containments), based on phenolic or furan resins. One form of epoxy resin is also CHC-proof. See Section 4.1.6.1.12.

BAT for underground and mounded tanks containing products that can potentially cause soil pollution is to:

- apply a double walled tank with leak detection, see Section 4.1.6.1.16, or
- to apply a single walled tank with secondary containment and leak detection, see Section 4.1.6.1.17.

### **Flammable areas and ignition sources**

See Section 4.1.6.2.1 together with ATEX Directive 1999/92/EC.

### **Fire protection**

The necessity for implementing fire protection measures has to be decided on a case-by-case basis. Fire protection measures can be provided by applying, e.g. (see Section 4.1.6.2.2):

- fire resistant claddings or coatings
- firewalls (only for smaller tanks), and/or
- water cooling systems.

### **Fire-fighting equipment**

The necessity for implementing fire-fighting equipment and the decision on which equipment to apply has to be taken on a case-by-case basis in agreement with the local fire brigade. Some examples are given in Section 4.1.6.2.3.

### **Containment of contaminated extinguishant**

The capacity for containing contaminated extinguishant depends on the local circumstances, such as which substances are stored and whether the storage is close to watercourses and/or situated in a water catchment area. The applied containment therefore has to be decided on a case-by-case basis, see Section 4.1.6.2.4.

For toxic, carcinogenic or other hazardous substances, BAT is to apply full containment.

## 5.1.2. Storage of packaged dangerous substances

### Safety and risk management

Operational losses do not occur in storing packaged dangerous materials. The only possible emissions are from incidents and (major) accidents. Companies that fall under the scope of the Seveso II Directive are required to take all measures necessary to prevent and limit the consequences of major accidents. They must, in any, case have a major accident prevention policy (MAPP) and a safety management system to implement the MAPP. Companies in the high risk category (Annex I of the Directive) must also draw up a safety report and an on-site emergency plan and maintain an up-to-date list of substances. However, companies storing dangerous substances not falling under the scope of the Seveso II Directive can also cause emissions from incidents and accidents. Applying a similar, maybe less detailed, safety management system is the first step in preventing and limiting these.

BAT in preventing incidents and accidents is to apply a safety management system as described in Sections 4.1.6.1.

The degree of detail of the system is clearly dependent on various factors such as: the quantities of substances stored, specific hazards of the substances and the location of the storage. However, the minimum level of BAT is to assess the risks of accidents and incidents on the site using the five steps described in Section 4.1.6.1

### Training and responsibility

BAT is to appoint a person or persons who is or are responsible for the operation of the store.

BAT is to provide the responsible person(s) with specific training and retraining in emergency procedures as described in Section 4.1.7.1 and to inform other staff on the site of the risks of storing packaged dangerous substances and the precautions necessary to safely store substances that have different hazards.

### Storage area

BAT is to apply a storage building and/or an outdoor storage area covered with a roof, as described in Section 4.1.7.2. For storing quantities of less than 2500 litres or kilograms dangerous substances, applying a storage cell as described in Section 4.1.7.2 is also BAT.

### Separation and segregation

BAT is to separate the storage area or building of packaged dangerous substances from other storage, from ignition sources and from other buildings on- and off-site by applying a sufficient distance, sometimes in combination with fire-resistant walls. MSs apply different distances between the (outdoor) storage of packaged dangerous substances and other objects on- and off-site; see Section 4.1.7.3 for some examples.

BAT is to separate and/or segregate incompatible substances. For the compatible and incompatible combinations see Annex 8.3. MSs apply different distances and/or physical partitioning between the storage of incompatible substances; see Section 4.1.7.4 for some examples.

### Containment of leakage and contaminated extinguishant

BAT is to install a liquid-tight reservoir according to Section 4.1.7.5, that can contain all or a part of the dangerous liquids stored above such a reservoir. The choice whether all or only a part of the leakage needs to be contained depends on the substances stored and on the location of the storage (e.g. in a water catchment area) and can only be decided on a case-by-case basis.

BAT is to install a liquid-tight extinguishant collecting provision in storage buildings and storage areas according to Section 4.1.7.5. The collecting capacity depends on the substances stored, the amount of substances stored, the type of package used and the applied fire-fighting system and can only be decided on a case-by-case basis.

### **Fire-fighting equipment**

BAT is to apply a suitable protection level of fire prevention and fire-fighting measures as described in Section 4.1.7.6. The appropriate protection level has to be decided on a case-by-case basis in agreement with the local fire brigade.

### **Preventing ignition**

BAT is to prevent ignition at source as described in Section 4.1.7.6.1.

## **5.1.3. Basins and lagoons**

Basins and lagoons are used for the storage of, e.g. manure slurry in agricultural premises and water and other non-flammable or volatile liquids in industrial facilities.

Where emissions to air from normal operation are significant, e.g. with the storage of pig slurry, BAT is to cover basins and lagoons using one of the following options:

- a plastic cover; see Section 4.1.8.2
- a floating cover; see Section 4.1.8.1, or
- only small basins, a rigid cover; see Section 4.1.8.2.

Additionally, where a rigid cover is used, a vapour treatment installation can be applied to achieve an extra emission reduction, see Section 4.1.3.15. The need for and type of vapour treatment must be decided on a case-by-case basis.

To prevent overfilling due to rainfall in situations where the basin or lagoon is not covered, BAT is to apply a sufficient freeboard, see Section 4.1.11.1.

Where substances are stored in a basin or lagoon with a risk of soil contamination, BAT is to apply an impervious barrier. This can be a flexible membrane, a sufficient clay layer or concrete, see Section 4.1.9.1.

## **5.1.4. Atmospheric mined caverns**

### **Emissions to air from normal operation**

Where a number of caverns with a fixed waterbed storing liquid hydrocarbons are present, BAT is to apply vapour balancing, see Section 4.1.12.1.

### **Emissions from incidents and (major) accidents**

By their intrinsic nature, caverns are by far the safest way of storing large quantities of hydrocarbon products. BAT for storing large quantities of hydrocarbons is, therefore, to apply caverns wherever the site geology is suitable, see Sections 3.1.15 and 4.1.13.3.

BAT, in preventing incidents and accidents, is to apply a safety management system as described in Section 4.1.6.1.



BAT is to apply, and then regularly evaluate, a monitoring programme which at least includes the following (see Section 4.1.13.2):

- monitoring of the hydraulic flow pattern around the caverns by means of groundwater measurements, piezometers and/or pressure cells, seepage water flowrate metering
- assessment of cavern stability by seismic monitoring
- water quality follow-up procedures by regular sampling and analysis
- corrosion monitoring, including periodic casing evaluation.

For preventing the stored product from escaping out of the cavern, BAT is to design the cavern in such a way that at the depth at which it is situated, the hydrostatic pressure of the groundwater surrounding the cavern is always greater than that of the stored product, see Section 4.1.13.5.

For preventing seepage water entering the cavern, BAT is, apart from a proper design, to additionally apply cement injection, see Section 4.1.13.6.

If seepage water that enters the cavern is pumped out, BAT is to apply waste water treatment before discharge, see Section 4.1.13.3.

BAT is to apply automated overflow protection, see Section 4.1.13.8.

### **5.1.5. Pressurised mined caverns**

#### **Emissions from incidents and (major) accidents**

By their intrinsic nature, caverns are by far the safest way of storing large quantities of hydrocarbon products. BAT for storing large quantities of hydrocarbons is, therefore, to apply caverns wherever the site geology is suitable, see Sections 3.1.16 and 4.1.14.3.

BAT, in preventing incidents and accidents, is to apply a safety management system as described in Section 4.1.6.1.

BAT is to apply, and then regularly evaluate a monitoring programme which at least includes the following (see Section 4.1.14.2):

- monitoring of the hydraulic flow pattern around the caverns by means of groundwater measurements, piezometers and/or pressure cells, seepage water flowrate metering
- assessment of cavern stability by seismic monitoring
- water quality follow-up procedures by regular sampling and analysis
- corrosion monitoring, including periodic casing evaluation.

For preventing the stored product from escaping out of the cavern, BAT is to design the cavern in such a way that at the depth at which it is situated, the hydrostatic pressure of the groundwater surrounding the cavern is always greater than that of the stored product, see Section 4.1.14.5.

For preventing seepage water entering the cavern, BAT is, apart from a proper design, to additionally apply cement injection, see Section 4.1.14.6

If seepage water that enters the cavern is pumped out, BAT is to apply waste water treatment before discharge, see Section 4.1.14.3.

BAT is to apply automated overflow protection, see Section 4.1.14.8.

BAT is to apply fail-safe valves in the event of a surface emergency event, see Section 4.1.14.4.

### **5.1.6. Salt leached caverns**

#### **Emissions from incidents and (major) accidents**

By their intrinsic nature, caverns are by far the safest way of storing large quantities of hydrocarbon products. BAT for storing large quantities of hydrocarbons is, therefore, to apply caverns wherever the site geology is suitable. For more detail see Sections 3.1.17 and 4.1.15.3.

BAT, in preventing incidents and accidents, is to apply a safety management system as described in Section 4.1.6.1.

BAT is to apply, and then regularly evaluate a monitoring programme which at least includes the following (see Section 4.1.15.2):

- assessment of cavern stability by seismic monitoring
- corrosion monitoring, including periodic casing evaluation
- carrying out of regular sonar evaluations to monitor eventual shape variations, particularly if undersaturated brine is used.

Small traces of hydrocarbons may be present at the brine/hydrocarbon interface due to filling and emptying the caverns. If this is the case, BAT is to separate these hydrocarbon products in a brine treatment unit and to collect and dispose of them safely.

### **5.1.7. Floating storage**

Floating storage is not BAT, see Section 3.1.18.

## **5.2. Transfer and handling of liquids and liquefied gases**

### **5.2.1. General principles to prevent and reduce emissions**

#### **Inspection and maintenance**

BAT is to apply a tool to determine proactive maintenance plans and to develop risk-based inspection plans such as, the risk and reliability based maintenance approach; see Section 4.1.2.2.1.

#### **Leak detection and repair programme**

For large storage facilities, according to the properties of the products stored, BAT is to apply a leak detection and repair programme. Focus needs to be on those situations most likely to cause emissions (such as gas/light liquid, under high pressure and/or temperature duties). See Section 4.2.1.3.

#### **Emissions minimisation principle in tank storage**

BAT is to abate emissions from tank storage, transfer and handling that have a significant negative environmental effect, as described in Section 4.1.3.1.

This is applicable to large storage facilities, allowing a certain time frame for implementation.

#### **Safety and risk management**

BAT in preventing incidents and accidents is to apply a safety management system as described in Section 4.1.6.1.

## **Operational procedures and training**

BAT is to implement and follow adequate organisational measures and to enable the training and instruction of employees for safe and responsible operation of the installation as described in Section 4.1.6.1.1.

### **5.2.2. Considerations on transfer and handling techniques**

#### **5.2.2.1. Piping**

BAT is to apply aboveground closed piping in new situations, see Section 4.2.4.1. For existing underground piping it is BAT to apply a risk and reliability based maintenance approach as described in Section 4.1.2.2.1.

Bolted flanges and gasket-sealed joints are an important source of fugitive emissions. BAT is to minimise the number of flanges by replacing them with welded connections, within the limitation of operational requirements for equipment maintenance or transfer system flexibility, see Section 4.2.2.1.

BAT for bolted flange connections (see Section 4.2.2.2.) include:

- fitting blind flanges to infrequently used fittings to prevent accidental opening
- using end caps or plugs on open-ended lines and not valves
- ensuring gaskets are selected appropriate to the process application
- ensuring the gasket is installed correctly
- ensuring the flange joint is assembled and loaded correctly
- where toxic, carcinogenic or other hazardous substances are transferred, fitting high integrity gaskets, such as spiral wound, kammprofile or ring joints.

Internal corrosion may be caused by the corrosive nature of the product being transferred, see Section 4.2.3.1. BAT is to prevent corrosion by:

- selecting construction material that is resistant to the product
- applying proper construction methods
- applying preventive maintenance, and
- where applicable, applying an internal coating or adding corrosion inhibitors.

To prevent the piping from external corrosion, BAT is to apply a one, two, or three layer coating system depending on the site-specific conditions (e.g. close to sea). Coating is normally not applied to plastic or stainless steel pipelines. See Section 4.2.3.2.

#### **5.2.2.2. Vapour treatment**

BAT is to apply vapour balancing or treatment on significant emissions from the loading and unloading of volatile substances to (or from) trucks, barges and ships. The significance of the emission depends on the substance and the volume that is emitted, and has to be decided on a case-by-case basis. For more detail see Section 4.2.8.

For example, according to Dutch regulations, the emission of methanol is significant when over 500 kg/yr is emitted.

### 5.2.2.3. Valves

BAT for valves include:

- correct selection of the packing material and construction for the process application
- with monitoring, focus on those valves most at risk (such as rising stem control valves in continual operation)
- applying rotating control valves or variable speed pumps instead of rising stem control valves
- where toxic, carcinogenic or other hazardous substances are involved, fit diaphragm, bellows, or double walled valves
- route relief valves back into the transfer or storage system or to a vapour treatment system.

See Sections 3.2.2.6 and 4.2.9.

### 5.2.2.4. Pumps and compressors

#### **Installation and maintenance of pumps and compressors**

The design, installation and operation of the pump or compressor heavily influence the life potential and reliability of the sealing system. The following are some of the main factors which constitute BAT:

- proper fixing of the pump or compressor unit to its base-plate or frame
- having connecting pipe forces within producers' recommendations
- proper design of suction pipework to minimise hydraulic imbalance
- alignment of shaft and casing within producers' recommendations
- alignment of driver/pump or compressor coupling within producers' recommendations when fitted
- correct level of balance of rotating parts
- effective priming of pumps and compressors prior to start-up
- operation of the pump and compressor within producers' recommended performance range (The optimum performance is achieved at its best efficiency point.)
- the level of net positive suction head available should always be in excess of the pump or compressor
- regular monitoring and maintenance of both rotating equipment and seal systems, combined with a repair or replacement programme.

#### **Sealing system in pumps**

BAT is to use the correct selection of pump and seal types for the process application, preferably pumps that are technologically designed to be tight such as canned motor pumps, magnetically coupled pumps, pumps with multiple mechanical seals and a quench or buffer system, pumps with multiple mechanical seals and seals dry to the atmosphere, diaphragm pumps or bellow pumps. For more details see Sections 3.2.2.2, 3.2.4.1 and 4.2.9.

#### **Sealing systems in compressors**

BAT for compressors transferring non-toxic gases is to apply gas lubricated mechanical seals.

BAT for compressors, transferring toxic gases is to apply double seals with a liquid or gas barrier and to purge the process side of the containment seal with an inert buffer gas.

In very high pressure services, BAT is to apply a triple tandem seal system.

For more detail see Sections 3.2.3 and 4.2.9.13.

**5.2.2.5. Sampling connections**

BAT, for sample points for volatile products, is to apply a ram type sampling valve or a needle valve and a block valve. Where sampling lines require purging, BAT is to apply closed-loop sampling lines. See Section 4.2.9.14.

## 5.3. Storage of solids

### 5.3.1. Open storage

BAT is to apply enclosed storage by using, for example, silos, bunkers, hoppers and containers, to eliminate the influence of wind and to prevent the formation of dust by wind as far as possible by primary measures. See Table 4.12 for these primary measures with cross-references to the relevant sections.

However, although large volume silos and sheds are available, for (very) large quantities of not or only moderately drift sensitive and wettable material, open storage might be the only option. Examples are the long-term strategic storage of coal and the storage of ores and gypsum.

BAT for open storage is to carry out regular or continuous visual inspections to see if dust emissions occur and to check if preventive measures are in good working order. Following the weather forecast by, e.g. using meteorological instruments on site, will help to identify when the moistening of heaps is necessary and will prevent unnecessary use of resources for moistening the open storage. See Section 4.3.3.1.

BAT for long-term open storage are one, or a proper combination, of the following techniques:

- moistening the surface using durable dust-binding substances, see Section 4.3.6.1
- covering the surface, e.g. with tarpaulins, see Section 4.3.4.4
- solidification of the surface, see Table 4.13
- grassing-over of the surface, see Table 4.13.

BAT for short-term open storage are one, or a proper combination, of the following techniques:

- moistening the surface using durable dust-binding substances, see Section 4.3.6.1
- moistening the surface with water, see Sections 4.3.6.1
- covering the surface, e.g. with tarpaulins, see Section 4.3.4.4.

Additional measures to reduce dust emissions from both long and short-term open storage are:

- placing longitudinal axis of the heap parallel with the prevailing wind
- applying protective plantings, windbreak fences or upwind mounds to lower the wind velocity
- applying only one heap instead of several heaps as far as possible; with two heaps storing the same amount as one, the free surface increases with 26 %
- applying storage with retaining walls reduces the free surface, leading to a reduction of diffuse dust emissions; this reduction is maximised if the wall is placed upwind of the heap
- placing retaining walls close together.

See Table 4.13 for more details.

### 5.3.2. Enclosed storage

BAT is to apply enclosed storage by using, for example, silos, bunkers, hoppers and containers. Where silos are not applicable, storage in sheds can be an alternative. This is, e.g. the case if apart from storage, the mixing of batches is needed.

BAT for silos is to apply a proper design to provide stability and prevent the silo from collapsing. See Sections 4.3.4.1 and 4.3.4.5.

BAT for sheds is to apply proper designed ventilation and filtering systems and to keep the doors closed. See Section 4.3.4.2.

BAT is to apply dust abatement and a BAT associated emission level of 1 – 10 mg/m<sup>3</sup>, depending on the nature/type of substance stored. The type of abatement technique has to be decided on a case-by-case basis. See Section 4.3.7.

For a silo containing organic solids, BAT is to apply an explosion resistant silo (see Section 4.3.8.3), equipped with a relief valve that closes rapidly after the explosion to prevent oxygen entering the silo, as described in Section 4.3.8.4.

### **5.3.3. Storage of packaged dangerous solids**

For details regarding BAT for the storage of packaged dangerous solids, see Section 5.1.2.

### **5.3.4. Preventing incidents and (major) accidents**

#### **Safety and risk management**

The Seveso II Directive (Council Directive 96/82/EC of 9 December 1996 on the control of major accident hazards involving dangerous substances) requires companies to take all measures necessary to prevent and limit the consequences of major accidents. They must in any case have a major accident prevention policy (MAPP) and a safety management system to implement the MAPP. Companies holding large quantities of dangerous substances, so-called upper tiered establishments, must also draw up a safety report and an on-site emergency plan and maintain an up-to-date list of substances. However, plants that do not fall under the scope of the Seveso II Directive can also cause emissions from incidents and accidents. Applying a similar, maybe less detailed, safety management system is the first step in preventing and limiting these.

BAT in preventing incidents and accidents is applying a safety management system as described in Section 4.1.7.1.

## **5.4. Transfer and handling of solids**

### **5.4.1. General approaches to minimise dust from transfer and handling**

BAT is to prevent dust dispersion due to loading and unloading activities in the open air, by scheduling the transfer as much as possible when the wind speed is low. However, and taking into account the local situation, this type of measure cannot be generalised to the whole EU and to any situation irrespective of the possible high costs. See Section 4.4.3.1.

Discontinuous transport (e.g. shovel or truck) generally generates more dust emissions than continuous transport such as conveyors. BAT is to make transport distances as short as possible and to apply, wherever possible, continuous transport modes. For existing plants, this might be a very expensive measure. See Section 4.4.3.5.1.

When applying a mechanical shovel, BAT is to reduce the drop height and to choose the best position during discharging into a truck; see Section 4.4.3.4.

While driving, vehicles might swirl up dust from solids spread on the ground. BAT then is to adjust the speed of vehicles on-site to avoid or minimise dust being swirled up; see Section 4.4.3.5.2.

BAT for roads that are used by trucks and cars only, is applying hard surfaces to the roads of, for example, concrete or asphalt, because these can be cleaned easily to avoid dust being swirled up by vehicles, see Section 4.4.3.5.3. However, applying hard surfaces to the roads is not justified when the roads are used just for big shovel vehicles or when a road is temporary.

BAT is to clean roads that are fitted with hard surfaces according to Section 4.4.6.12.

Cleaning of vehicle tyres is BAT. The frequency of cleaning and type of cleaning facility applied (see Section 4.4.6.13) has to be decided on a case-by-case basis.

Where it neither compromises product quality, plant safety, nor water resources, BAT for loading/unloading drift sensitive, wettable products is to moisten the product as described in Sections 4.4.6.8, 4.4.6.9 and 4.3.6.1. Risk of freezing of the product, risk of slippery situations because of ice forming or wet product on the road and shortage of water are examples when this BAT might not be applicable.

For loading/unloading activities, BAT is to minimise the speed of descent and the free fall height of the product; see Sections 4.4.5.6 and 4.4.5.7 respectively. Minimising the speed of descent can be achieved by the following techniques that are BAT:

- installing baffles inside fill pipes
- applying a loading head at the end of the pipe or tube to regulate the output speed
- applying a cascade (e.g. cascade tube or hopper)
- applying a minimum slope angle with, e.g. chutes.

To minimise the free fall height of the product, the outlet of the discharger should reach down onto the bottom of the cargo space or onto the material already piled up. Loading techniques that can achieve this, and that are BAT, are:

- height adjustable fill pipes
- height adjustable fill tubes, and
- height adjustable cascade tubes.

These techniques are BAT, except when loading/unloading non drift sensitive products, for which the free fall height is not that critical.

Optimised discharged hoppers are available and described in Section 4.4.6.7

### **5.4.2. Considerations on transfer techniques**

#### **Grabs**

For applying a grab, BAT is to follow the decision diagram as shown in Section 4.4.3.2 and to leave the grab in the hopper for a sufficient time after the material discharge.

BAT for new grabs, is to apply grabs with the following properties (see Section 4.4.5.1):

- geometric shape and optimal load capacity
- the grab volume is always higher than the volume that is given by the grab curve
- the surface is smooth to avoid material adhering, and
- a good closure capacity during permanent operation.



### **Conveyors and transfer chutes**

For all types of substances, BAT is to design conveyor to conveyor transfer chutes in such a way that spillage is reduced to a minimum. A modelling process is available to generate detail designs for new and existing transfer points. For more details see Section 4.4.5.5.

For non or very slightly drift sensitive products (S5) and moderately drift sensitive, wettable products (S4), BAT is to apply an open belt conveyor and additionally, depending on the local circumstances, one or a proper combination of the following techniques:

- lateral wind protection, see Section 4.4.6.1
- spraying water and jet spraying at the transfer points, see Sections 4.4.6.8 and 4.4.6.9, and/or
- belt cleaning, see Section 4.4.6.10.

For highly drift sensitive products (S1 and S2) and moderately drift sensitive, not wettable products (S3) BAT for new situations, is to:

apply closed conveyors, or types where the belt itself or a second belt locks the material (see Section 4.4.5.2), such as:

- pneumatic conveyors
- trough chain conveyors
- screw conveyors
- tube belt conveyor
- loop belt conveyor
- double belt conveyor

or to apply enclosed conveyor belts without support pulleys (see Section 4.4.5.3), such as:

- aerobelt conveyor
- low friction conveyor
- conveyor with diabolos.

The type of conveyor depends on the substance to be transported and on the location and has to be decided on a case-by-case basis.

For existing conventional conveyors, transporting highly drift sensitive products (S1 and S2) and moderately drift sensitive, not wettable products (S3), BAT is to apply housing; see Section 4.4.6.2. When applying an extraction system, BAT is to filter the outgoing air stream; see Section 4.4.6.4.

To reduce energy consumption for conveyor belts (see Section 4.4.5.2), BAT is to apply:

- a good conveyor design, including idlers and idler spacing
- an accurate installation tolerance, and
- a belt with low rolling resistance.

See Annex 8.4 for the disperseveness classes (S1 – S4) of solid bulk materials.



## 6. EMERGING TECHNIQUES

### 6.1. Handling of solids

#### 6.1.1. Screw conveyor

**Description:** The screw conveyor considered here is a continuous ship unloader with a screw pick-up device and a conveyor shaft. The unloading is done horizontally or by slewing the beam. The discharge is carried out layer by layer. The material is picked up by a digging screw, conveyed through a pipe screw and delivered at the top to the conveyor shaft. The screw has a length of 4 m, so the need for intermediate storage is negligible. The digging heads stick into the material, so dust emissions are prevented.

The conveyor shaft consists of four conveyor belts (gate belt, cover belt and two lateral top belts) which form a closed shaft. The gate belt and cover belt are separately driven at the same velocity (1 m/s). The gates are made of metal, but high-molecular plastics are also possible. The bulk material slides over the sloping gates on the boom belt. The transfer points are fitted with air extractors or have rubber lips in order to minimise dust emissions.

In order to trim the remaining material, additional equipment can be fixed to the screw pick-up or a grab can be used.

The maximum throughput capacity is 1000 - 1200 tonnes per hour, but capacities of 2000 tonnes per hour can probably be achieved in future. The minimum throughput capacity is 300 tonnes per hour.

#### **Advantages:**

- not noisy, not dusty, low weight
- relatively low specific energy consumption (use of gate belt conveyor as vertical conveyor)
- compact construction by combination of screw conveyor and gate belt
- simple gravity unloading
- no intermediate storage needed
- can also be used for the loading of ships.

#### **Disadvantages:**

- so far used only as a prototype in the port of Nürnberg
- additional equipment needed for trimming remaining material
- suitable only for ships with wide hatches.

**Applicability:** This technique is especially suitable to unload river ships that transport coal to a power station with a port connection. The following options are available for existing plants:

- to replace a grab unloader by a screw conveyor so a higher unloading capacity can be achieved without increasing the load on the quay
- to expand an existing transshipment plant by a screw conveyor; the ship unloading goes faster and dust emissions are reduced.

Suitable bulk materials consist of dry and fine particles, especially coal, but also grain and fertilisers.

**Reference plant:** Until now this technique has been used (and with success) only in the port of Nürnberg to unload coal.

**Economics:** The investment depends on the ship size, the water height, the lifting height of the device and the dimensions of the quay.

The operating costs can be estimated at 2 to 3 %, but have to be specified for the individual case.

**Cross-media effect:** The energy consumption for the vertical conveyance only is 0.0088 kWh per tonne at a given lifting height of 1 metre. For all the driven equipment, the energy consumption for coal is estimated at 0.02 kWh per tonne over 1 metre, 0.037 kWh per tonne over 1 metre for zinc ore concentrate and 0.047 kWh per tonne over 1 metre for lead ore concentrate.

**Reference literature:** [17, UBA, 2001].

### 6.1.2. Low-dust dock transshipment containers without negative pressure extraction

**Description:** The intake opening of the transshipment container is fitted with laminas. As the loaded grab enters the opening, the air thereby displaced is recirculated to the emptied grab. Hence negative pressure is automatically generated in the container by the bulk material as it is offloaded into a truck. The underpressure prevents dust escaping through any gaps in the seal between the grab and the intake opening. The material can thus be transferred from the grab to the container without the release of dust and without any additional energy input.

It is intended to fit the transshipment container with a height adjustable discharge pipe, so that the dump height is continually adjusted to the changing height of the material pile on the truck loading bed. The discharge pipe will be double walled, so that displaced air – particularly when filling tankers – can be returned to a recirculation pipe. The displaced air is hence channelled back to the transshipment container. Due to the properties of the material (in this case fertilisers), all parts in direct contact with the material are made of stainless steel.

The low-emission transshipment containers (e.g. hoppers) that are currently on the market are very expensive. They are equipped with air extraction and filter systems and have a high energy consumption. There is an unmet need for technologically appropriate transshipment containers within the price range of small and medium-sized enterprises that operate with low/no energy requirements and have a minimum dust emission. For this reason the dock transshipment container (bulk carrier) described above is being developed for fertilisers, designed to minimise diffuse emissions without any additional energy input. The development is sponsored by the Bundesstiftung Umwelt (National Environment Foundation).

**Advantages:** It is anticipated that diffuse emissions will be minimised by optimisation of the best currently available technologies (transshipment containers with high side panels, negative pressure extraction and dust traps). The key advantage would lie in a 100 % reduction in the energy requirement compared to currently available techniques.

Investment and operating costs are projected below those of available handling hoppers (with comparable dust reduction capability), as no dust precipitator is required and no additional energy costs have to be considered.

**Applicability:** This system is being developed initially for handling fertilisers in medium-sized enterprises. Applications are anticipated for this technology in handling other free-flowing bulk materials.

**Reference literature:** [17, UBA, 2001]

### 6.1.3. Screw conveyor for non-ferrous ores and concentrates

**Description:** Copper ores and concentrates and other non-ferrous ores and concentrates, especially lead and zinc, are at present handled with grabs. Due to their properties (toxic constituents such as cadmium), the handling process needs to be further optimised by the development of improved pick-up devices.

Investigations have indicated that enclosed, continuous (on/off) loaders such as screw conveyors represent one possible solution. Trial runs with zinc and lead concentrates have already been carried out with a combined screw pick-up conveyor and vertical belt conveyor shaft.

The tendency of the concentrates to cake is problematic. This can result in deposition and ultimately blockages in the screw conveyor. More research is therefore required to identify a more suitable structural or coating material for the screw.

**Reference literature:** [17, UBA, 2001]



## 7. CONCLUDING REMARKS

### 7.1. Timing of the work

The work on this BREF document started with the first plenary meeting of the TWG in December 1999. A partial first draft addressing the storage, transfer and handling of liquids and liquefied gases was sent out to the TWG for consultation in May 2001. The part addressing the storage and handling of solids was sent out to the TWG for consultation in September 2001. The comments were assessed and integrated into the document and a complete second draft, including proposals for BAT conclusions, was sent out in July 2003. The final plenary meeting of the TWG was held in May 2004. After the final meeting, there were short consultation periods on the revised BAT Chapter, the revised Chapters 1 through to 4, the introductory paragraph on the methodology in Chapter 5, the Concluding Remarks chapter and the Executive Summary. Following these consultations, the final redrafting took place.

### 7.2. Sources of information

Several reports from industry and MS authorities were used as sources of information in the drafting of this BREF. The reports submitted by TETSP [84, TETSP, 2001, 113, TETSP, 2001] and Germany [18, UBA, 1999] can be considered to be the building blocks of the storage tank sections. TETSP developed and provided a methodology for assessing emission control measures. For the storage of packaged dangerous materials, existing guidelines were received from the Netherlands [3, CPR, 1984, 8, CPR, 1991] and the UK [35, HSE, 1998, 36, HSE, 1998] and for the storage in caverns, much of the information was received from industry, namely Neste [81, Neste Engineering, 1996] and Geostock [150, Geostock, 2002]. The report submitted by Germany [17, UBA, 2001] is the cornerstone for the storage and handling of solids, supplemented with information from the Netherlands [15, InfoMil, 2001, 164, DCMR, 2003], from industry [74, Corus, 2002] and from suppliers. These reports, guidelines and additional information were supplemented by information received during meetings, usually in combination with site visits to Spain, Finland, Netherlands, Germany, Belgium, UK and France. The formal consultations on the draft document also prompted the submission of new and additional information, as well as providing the opportunities for the TWG to verify information already submitted.

### 7.3. Degree of consensus reached

The conclusions of the work were agreed at the final plenary meeting in May 2004 and on most of the topics discussed consensus was reached. The main issues discussed at the final meeting were:

- the assessment methodology (ECM methodology) versus concrete BAT conclusions
- VOC monitoring
- internal and external floating roofs and sealing systems
- vapour treatment and balancing on emissions from tanks
- vapour treatment and balancing on emissions from loading and unloading activities
- risk-based approach to emissions to soil from tanks
- prevention of dust emissions concerning long and short-term outdoor storage
- spraying of roads and spraying during unloading/loading activities
- fall height and speed of solid materials during unloading/loading activities.

In the discussion on the assessment methodology, TETSP proposed that, because almost all tanks are different due to their design, product stored, location, etc. the detailed BAT conclusions should be replaced by a statement that BAT can be determined by applying the assessment methodology. In the view of some other TWG members, applying the assessment methodology is not appropriate for defining general BAT and the BREF should provide clear descriptions of BAT. At the concluding meeting, the TWG agreed that the BAT conclusions provided in the BREF should be clear descriptions of techniques or approaches and that the assessment methodology should be described in Chapter 4, with an introductory paragraph in Chapter 5. It was clearly concluded that the methodology as such is not BAT. However, it can be used as a tool for permit writers and operators for assessing the emission control measures (ECM) described in Chapter 4 and for which generic BAT levels are reported in Chapter 5, in order to define which ECM, or combination of ECM that meet the generic BAT levels or do better, performs best in the storage of liquid and liquefied gas in a specific situation. Some MS expressed severe concerns on the proposed assessment methodology by written and oral comments before and at the concluding TWG meeting and these resulted in a split view on the methodology in Chapter 5.

After the second meeting, the new section in Chapter 4 on the assessment methodology, together with the concerns that were voiced on this methodology, and the introductory paragraph in Chapter 5 were submitted to the TWG to ascertain whether these changes reflected the discussion that took place at the concluding meeting. The majority of the TWG agreed that these changes reflected the discussion in the meeting, however, some MS did not agree, since in their opinion their comments were not reflected properly and completely, and wanted the introductory paragraph in Chapter 5 to be deleted and their concerns on the methodology to be literally repeated in Chapter 4. However, the EIPPCB has the responsibility to validate information and views and to process this into the BREF by reporting objective facts and statements and to make sure the BREF is consistent. For this reason, it cannot be accepted that a provided text is literally repeated in the BREF, unless it is a split view. The reported split view about the assessment methodology is the following:

“There is a split view from some MS that the ECM methodology is neither practical nor suitable for determining BAT in their view. Specifically, the methodology:

- is not BAT and this was agreed upon in the TWG. Furthermore, the methodology does not conform with the requirements on BAT according to the BREF Outline and Guide
- has not been practically tested in practice by the permitting authorities
- does not allow any European or sectoral conclusions on BAT for substances with certain properties, and
- does not offer the possibility for the harmonisation of BAT techniques in Europe.”

Another split view reported and supported by three MS, regarding the BAT conclusion on monitoring VOC emissions, is the fact that DIAL can be used as a tool to measure VOC emissions and this is not specifically mentioned in the conclusions. The BAT conclusion in Chapter 5 is that: “On sites where significant VOC emissions are to be expected, BAT includes calculating the VOC emissions regularly. The calculation model may need to be occasionally validated by applying a measurement method. See Section 4.1.2.2.3.” It is only in this Section 4.1.2.2.3 that reference to DIAL is made.



The last three identical split views are from industry on three similar BAT conclusion, that BAT is to apply a vapour treatment installation for the storage of volatile substances which are toxic (T), very toxic (T+), or CMR categories 1 and 2. This BAT is relevant for three different tank types, namely the fixed roof tank, the atmospheric horizontal tank and the underground and mounded tanks. In their view this technique cannot be BAT because:

- a) *there is no definition of 'volatile' in this BREF*
- b) *there is no test of environmental significance*
- c) *products which may be dangerous to the environment, but not classed as toxic, are not captured*
- d) *it can be demonstrated that other emission control measures may provide a higher level of environmental protection taking into account the costs and advantages of the various techniques*
- e) *there are no commonly understood performance criteria for a vapour treatment installation*
- f) *this does not take into account the costs or advantages of other techniques*
- g) *this does not provide the flexibility to take into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions*
- h) *there is no proportionality in this conclusion.*

The other 110 BAT conclusions were all agreed by the TWG, and no further split views were reported. Especially on the storage and handling of solids, all BAT conclusions were agreed by the TWG. Thus on the whole it can be concluded that a high level of consensus was reached.

However, at the Information Exchange Forum (IEF) meeting of 20 – 21 December 2004 in Brussels, it was agreed to add the following general split view: “A few MS do not agree with the BAT conclusions in Chapter 5 because, in their view, there is too much emphasis on the determination of BAT on a case by case basis at a local level. In their view, the BREF does not contain clear European BAT conclusions which would contribute more to harmonisation of standards at the European level. They would prefer, in particular, that such standards are based upon the hazardous potential and the amount of materials being handled.”

## 7.4. Recommendations for future work

From the start of this BREF process it was clear that addressing the storage of all dangerous substances that are stored in the wide range of industries falling in the scope of the IPPC Directive would be eased if some kind of classification system could be adopted and used in the development of this BREF. However, Europe has no standard classification system for air pollutants. Although Germany and the Netherlands provided examples of classification systems used in their country, the TWG did not succeed in coming to a consensus on how to use this information regarding the storage and handling of liquid and liquefied gases. However, the classification system on dispersiveness classes of solids used in the Netherlands was agreed on to be used in this BREF, which helped the discussion and the formation of BAT conclusions considerably.

Whilst it would be beyond the scope of a BREF review to establish an agreed European air pollutant classification system, such a system would have considerable value in the development of BAT on emissions from storage. Such a system would be very helpful in identifying when an emission can be qualified as ‘significant’, because this depends on the quantity that is emitted in relation with the properties of the substance. This is one example why this TWG could not come to a consensus of opinion on the BAT conclusions for which emissions the application of some sort of vapour treatment is BAT. Although it is recognised that such an exercise would be complex and time-consuming, a recommendation is made to the Environment DG to consider such an initiative.

During the development of this BREF, it became clear that the storage and handling of liquids and liquefied gases and the storage and handling of solids are two completely different areas and requires different expertise. When reviewing this BREF, it is recommended to separate these subjects in order to encourage more efficient meetings and a more efficient exchange of information.

In this TWG, no consensus could be achieved on how to monitor VOC emissions and how to validate this. Normally these emissions are calculated and the calculating model can be validated by applying a measurement method, e.g. DIAL. DIAL is used commonly in Sweden for monitoring emissions from tanks storing hydrocarbon products at refineries and oil terminals, but there is not enough information on the use of DIAL on other sites and other countries. For the review of this BREF, it is recommended that more information is collected on the monitoring of VOC emissions.

In Section 4.1.6.1.8 the risk-based approach to emissions to soil below tanks is discussed and the TWG agreed that this approach is BAT. However, it was agreed in the concluding meeting that it would be highly desirable to update the techniques mentioned in Table 4.5 where the techniques to prevent or reduce emissions are listed. In practise, this is a request to the Netherlands, as this approach and the table were both provided by them.

The current text in Section 4.2.8 on loading and unloading of transporters was submitted by TETSP after the concluding meeting and, therefore, the possibilities for peer review by the whole TWG was limited. During and after the meeting no consensus could be reached on the BAT conclusion on this issue, however, it was recognised that the loading and unloading of transporters is a potential source of emissions that needs to be assessed. It is, therefore, recommended that for the review of this BREF more information on this activity is gathered, especially on emission data, cost and economics and also on the techniques applied.

It is recognised by the TWG that the assessment methodology described in Section 4.1.1 has not been tested in practice by the permitting authorities. It is, therefore, recommended that feedback, especially from the permitting authorities, on the use of the methodology is needed for the future review of this BREF.

### **7.5. Suggested topics for future R & D projects**

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are, therefore, invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).

The following topics might be considered for future research and development projects:

- economical measurement methods for VOC emissions
- closed transportation systems.

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## GLOSSARY

### Definition of materials

#### Combustible material:

A material that will continue to show a combustive reaction with air of normal composition and pressure even after the source of ignition is removed.

#### Carcinogenic material:

A material that is known to cause cancer in man.

#### Corrosive material:

A material that in contact with the skin can have a destructive effect on living tissue.

#### Explosive material:

A material that may explode when brought into contact with a flame or that is more sensitive to impact or friction than nitrobenzene.

#### Irritant material:

A material that through direct, prolonged or repeated contact with the skin or the mucous membranes can cause infection.

#### Highly flammable material:

A material that:

- when exposed to the atmosphere at normal temperature, can rise in temperature and finally ignite without the addition of energy;
- in solid form, when subjected to an ignition source for a short period of time, can be easily ignited and will continue to burn or smoulder after removal of the ignition source;
- in liquid form, has a flashpoint below 21° C;
- in gaseous form, at normal pressure, can be ignited with air, or
- in contact with water or humid air, will develop highly flammable gases in dangerous quantities (a material that develops highly flammable gases when brought into contact with water).

#### Environmentally harmful material:

A material that can cause acute or chronic effects in ecosystems; the classification of environmentally harmful materials takes place in accordance with the agreements included in the 67/548/EEC Directive.

#### Mutagenic material:

A material that is known to affect the structure of DNA.

#### Flammable material:

A material that in liquid form has a flashpoint of at least 21 °C and not higher than 55 °C.

#### Oxidant:

A material that can react highly exothermically when brought into contact with other materials, flammables in particular.

#### Harmful material:

A material that by inhalation or entry via the mouth or skin can cause disorder of a limited nature.

#### Teratogenic material:

A material that is known to be teratogenic to man.

Toxic material:

A material that by inhalation or entry via the mouth or skin, can cause serious acute or chronic dangerous disorders or even death.

Highly toxic material:

A material by inhalation or entry via the mouth or skin can cause very serious acute or chronic dangerous disorders or even death.

Drift (for solid material):

The ability to be dispersed by the wind

## Definitions related to storage and handling of liquids and liquefied gases

**Operational:** Emissions occurring due to normal operational activities. Frequency, volumes and loads are usually known up-front or can be estimated and some can be scheduled. The above can be used for determining best ratio of investment vs. efficiency when prioritising investments and determining best applicable emission reduction technique. Fugitive emissions and pressure relief are considered to be operational since they occur under normal operational circumstances.

**Incidents:** Emissions due to incidents are those, which result from failure of protection systems and/or human error. Volumes and frequencies cannot be predicted and only mitigating measures can be provided.

**Standing:** Product volume in tank not circulated and/or pumped in or out.

**(Out)Breathing:** Gaseous emission due to ambient temperature change, usually daytime heating of contents of storage tanks (out breathing due to volume increase of gas and evaporation of liquid). Inbreathing due to cooling of contents (night-time volume decrease of gas and condensation of vapour) is not considered an emission source.

**Filling:** Liquid stream replacing vapour contents of a system.

**(Tank)Emptying:** Removing (part of) the liquid contents of a system (e.g. relevant for EFRT).

**Purging:** Replacement of gaseous contents of system by air or inert gases.

**Manual Gauging:** A method for measuring the liquid height of a tank, usually done by lowering a weighted tape through an opening in the tank roof.

**Sampling:** Removing a small representative volume of liquid from the contents of system for test purposes. Usually done by opening valves directly connected to the main system and collecting liquid in a (semi)closed or open sample system.

**Overfill:** Liquid spill due to filling of system beyond maximum contents caused by failure of overfill prevention systems.

**Leakage:** Gaseous or Liquid spills out of system/equipment due to system/equipment failures.

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Cleaning:	Removing of liquid and/or vapour contents of system by draining, flushing, scraping, purging etc. in order to prepare the system for maintenance/inspection activities or other products. Usually creates (small) waste liquid stream.
Pigging:	Removing of contents of piping systems by means of a device pushed by an inert media or product which scrapes the contents of the system out of the system. Possible liquid and gaseous spillages at outlet of system.
(Dis)Connecting:	Connecting transfer system to tanks, (un)loading system or other transfer system by means of removable connections (spool pieces etc.). Possible liquid and gaseous emissions when installing connection and removing connection.
(Un)Coupling:	Connecting transfer system to tanks or other (un)loading system (liquid or gas containment systems, e.g. trucks, vessels, isocontainers etc.) by means of purpose-designed loading arms and/or hoses. Possible liquid and gaseous emissions when installing connection and removing connection.
Fugitive Emissions:	Gaseous emission from system components (pump seals, mechanical seals, gaskets etc.) usually by permeation of gases through a bolted connection.
Draining:	Emptying of liquid contents of system to collection system or other storage system creating a possible liquid waste stream.
Pressure relief:	A system which prevents a liquid (or gas) system from overpressure due to ambient temperature changes, usually releasing some liquid contents of system to a collection system due to ambient temperature rise in daytime.
Ullage:	The space above the product within a storage tank.
Water hammer:	Water hammer (or hydraulic shock) is the momentary increase in pressure, which occurs in a water system when there is a sudden change of direction or velocity of the water. When a rapidly closed valve suddenly stops water flowing in a pipeline, pressure energy is transferred to the valve and pipe wall. Shock waves are set up within the system. Pressure waves travel backward until encountering the next solid obstacle, then forward, then back again. The pressure wave's velocity is equal to the speed of the sound; therefore it 'bangs' as it travels back and forth, until dissipated by friction losses. See for more detail: <a href="http://www.nesc.wvu.edu/ndwc/articles/OT/WI03/Water_Hammer.html">http://www.nesc.wvu.edu/ndwc/articles/OT/WI03/Water_Hammer.html</a>

## Definitions – general

Demurrage:	Failure to load or discharge a chartered ship within the time agreed with the owner; the rate or amount payable to the owner by the charterer in respect of such failure. ('surestaries' in French)
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## Abbreviations

AP-42:	U.S. EPA publication: 'Compilation of Air Pollutant Emission Factors', available through the EPA website: <a href="http://www.epa.gov/ttn/chief/index.html">http://www.epa.gov/ttn/chief/index.html</a> . Chapter 7 of AP-42 is on storage and the EPA TANKS software contains the algorithms in that chapter
BAT:	Best Available Techniques
BLEVE:	Boiling Liquid Expanding Vapour Explosion
CAPEX:	Capital Expenditure
CEFIC:	European Chemical Industry Council
CONCAWE:	Oil Companies Organisation for Health, Safety, and Environment
CMR:	Carcinogenic, Mutagenic and Reproductive toxic
CWW BREF:	BREF on common waste water and waste gas treatment and management in the chemical sector
EFR:	External Floating Roof
EFRT:	External Floating Roof Tank
ECM:	Emission Control Measures
EPA:	U.S. Environmental Protection Agency
FECC:	Federation Association of Chemical Distribution
FETSA:	Federation of European Tank Storage Association
FGD:	Flue Gas Desulphurisation
FRP:	Fibreglass Reinforced Polyester
FRT:	Fixed Roof Tank
HDPE:	High Density Polyethylene
IFR:	Internal Floating Roof
IFRT:	Internal Floating Roof Tank
LECA:	Light Expanded Clay Aggregate
LPG:	Liquefied Petroleum Gas
MBTE:	Methyl-Tertiary-Butyl-Ether
OPEX:	Operational Expenditure
PTFE:	Poly-Tetra-Fluoro-Ethylene
PVRV:	Pressure/Vacuum Relief Valve
TEQ:	Toxic Equivalents
TETSP:	Technical European Tank Storage Platform; members are: CEFIC, CONCAWE, FETSA, and FECC
VDI:	Verein Deutscher Ingenieure
VOC:	Volatile Organic Compound
VRU:	Vapour Recovery Units

## Common units, measurements and symbols

TERM	MEANING
atm	normal atmosphere (1 atm = 101325 N/m <sup>2</sup> )
bar	bar (1.013 bar = 1 atm)
barg	bar gauge (bar + 1 atm)
°C	degree Celsius
cm	centimetre
d	day
g	gram
GJ	gigajoule
h	hour
J	Joule
K	kelvin (0 °C = 273.15 K)
kcal	kilocalorie (1 kcal = 4.19 kJ)
kg	kilogram (1 kg = 1000 g)
kJ	kilojoule (1 kJ = 0.24 kcal)
kPa	kilopascal
kt	kilotonne
kWh	kilowatt-hour (1 kWh = 3600 kJ = 3.6 MJ)
l	litre
m	metre
m <sup>2</sup>	square metre
m <sup>3</sup>	cubic metre
mbar	millibar (1 mbar = 10 <sup>-3</sup> bar)
mg	milligram (1 mg = 10 <sup>-3</sup> gram)
MJ	megajoule (1 MJ = 1000 kJ = 10 <sup>6</sup> joule)
mm	millimetre (1 mm = 10 <sup>-3</sup> m)
m/min	metres per minute
mmWG	millimetre water gauge
Mt	megatonne (1 Mt = 10 <sup>6</sup> tonne)
Mt/yr	megatonnes per year
MW <sub>e</sub>	megawatts electric (energy)
MW <sub>th</sub>	megawatts thermal (energy)
ng	nanogram (1 ng = 10 <sup>-9</sup> gram)
Nm <sup>3</sup>	normal cubic metre (101.325 kPa, 273 K)
Pa	pascal
ppb	parts per billion
ppm	parts per million (by weight)
s	second
t	metric tonne (1000 kg or 10 <sup>6</sup> gram)
t/d	tonnes per day
t/yr	tonne(s) per year
V	volt
vol-%	percentage by volume. (Also % v/v)
W	watt (1 W = 1 J/s)
wt-%	percentage by weight. (Also % w/w)
yr	year
~	around; more or less
µm	micrometre (1 µm = 10 <sup>-6</sup> m)
µg	microgram (1 µg = 10 <sup>-6</sup> g)
% v/v	percentage by volume. (Also vol-%)
% w/w	percentage by weight. (Also wt-%)



## 8. ANNEXES

### 8.1. International Codes

#### STORAGE of LIQUID PRODUCTS

#### OVERVIEW of INTERNATIONAL CODES, STANDARDS and GUIDELINES

By Main Storage Mode (January 2001)

No.	Item
	Introduction
	- Codes, Standards and Guidelines (and Countries) considered
	- Storage Modes considered
	- Applicability
	- Questions
1	Aboveground Storage
2	Underground Storage
3	Pressurised Storage
4	Refrigerated Storage
5	ISO Containers or IBC's
6	Caverns for LPG Pressurised Storage or Mineral Oil
7	Example for Chemical Distribution – Storage of Packed product

## INTRODUCTION

### Codes, Standards and Guidelines (and Countries) considered

The overview is limited to codes, standards and guidelines published in the following countries:

- United States of America
- Germany
- United Kingdom
- France
- the Netherlands.

Please note that some of the codes and standards have been listed under a specific country since that country adopts them in this form; other countries may have used this code and used a unique number.

In alphabetical order, the following codes, standards and guidelines, amongst others, have been included: ABS, AFNOR, AMCA, AMD, ANSI, API, ARI, AS, ASME, ASTM, AWMA, AWS, BS, CAS, CEN, CGA, CODAP, CODRES, CPR, DIN, EEMUA, EIA, EMC, EN, ENV, FED, GPA, IEC, IEEE, IP, ISO, NACE, NFPA, PD, PEI, UL.

Please note that this is an overview that might not contain all available references yet. All readers are encouraged to list additional (inter)national codes, standards and guidelines, which can then be incorporated in this reference list.

### Storage modes considered

Six storage modes for bulk liquids (and one example for storage of packed product) have been considered:

1. Above ground storage tanks
2. Underground storage tanks
3. Pressurised storage
4. Refrigerated Storage
5. ISO Containers or IBC's
6. Caverns for LPG pressurised storage or mineral oil
7. A typical example has been included for: Chemical distribution: Storage buildings for packaged storage (UK based).

### Applicability

The attached preliminary overview comprises a listing of codes, standards and guidelines with respect to:

- design
- construction
- inspection and maintenance
- and, where possible, environmental prevention techniques of various storage modes for liquid products.

Several listed codes, standards and guidelines are applicable for the same storage mode and for other storage modes as well. No qualification is made on the suitability and/or applicability.



## 1. ABOVE GROUND STORAGE

### 1.0 General

**EN 14015, 2004** Specification for the design and manufacture of site built, vertical, cylindrical, flat bottomed, above ground, welded, metallic tanks for the storage of liquids at ambient temperature and above. Part 1: Steel Tanks

The following normative references are quoted in **EN 14015**:

**EN 287-1** Approved testing of welders for fusion testing. Part 1: Steels

**EN 288-1** Specification and approval of welding procedures for metallic materials. Part 1: General rules for fusion welding

**EN 288-2** Specification and approval of welding procedures for metallic materials. Part 2: Welding procedure specification for arc welding

**EN 288-3** Specification and approval of welding procedures for metallic materials. Part 3: Welding procedure tests for the arc welding of steels

**EN 444** Non-destructive testing. General principles for radiographic examination of metallic material by X-ray and Gamma-rays

**EN 462-1** Image quality indicators (wire type). Determination of image quality value

**EN 462-2** Image quality indicators (step/hole type). Determination of image quality value

**EN 473** General principles for the qualification and certification of NDT personnel

**EN 571-1** Non-destructive testing, Penetrant testing. Part 1: General principles

**EN 970** Non-destructive examination of fusion welds, visual inspection

**EN 1092-1** Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designed. Part 1: Steel flanges

**EN 1290** Non-destructive examination of welds. Magnetic particle testing of welds

**EN 1418** Welding personnel. Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanised and automatic welding of metallic materials.

**EN 1435** Non-destructive examination of welds. Radiographic examination of welded joints

**EN 1714** Non-destructive examination of welds. Ultrasonic examination of welded joints

**prEN 1759-1** Flanges. Part 1: Class designated circular steel flanges NPT ½" to 24"

**EN 10025** Hot rolled products of non-alloy structural steels. Technical delivery conditions

**EN 10028-2** Flat products made of steels for pressure purposes. Part 2: Non-alloy and alloy-steels with specified elevated temperature properties

- EN 10028-3** Flat products made of steels for pressure purposes. Part 3: weldable grain steels, normalised
- EN 10029** Hot rolled steel plates 3mm thick or above. Tolerances on dimensions, shape and mass
- EN 10045-1** Metallic materials, Charpy impact test. Part 1: Test method
- EN 10088-1** Stainless steels. Part 1: List of stainless steels
- EN 10088-2** Stainless steels. Part 2: Technical delivery conditions for steel sheet/plate and strip for general purposes
- EN 10088-3** Stainless Steels. Part 3: Technical delivery conditions for semi-finished products, bars, rods and sections for general purposes
- EN 10113-2** Hot rolled products in weldable fine grain structural steels. Part 2: Delivery conditions for normalised/normalised rolled steels
- EN-10113-3** Hot rolled products in weldable fine grain structural steels. Part 3: Delivery conditions for thermomechanical rolled steels
- EN 10204** Metallic products. Types of inspection documents
- EN 10210-1** Hot finished structural hollow sections of non-alloy and fine grain structural steels. Part 1: Technical delivery conditions
- prEN 10216-1** Seamless steel tubes for pressure purposes, technical delivery conditions. Part 1: Non-alloy steel tubes with specified room temperature properties
- prEN 10216-5** Seamless steel tubes for pressure purposes, technical delivery conditions. Part 5: Stainless steel tubes
- prEN 10217-1** Welded steel tubes for pressure purposes, technical delivery conditions. Part 1: Non-alloy steel tubes with specified room temperature properties
- prEN 10217-7** Seamless steel tubes for pressure purposes, technical delivery conditions. Part 7: Stainless steel tubes
- prEN 12874** Flame arresters. Specification requirements and test procedures
- EN 26520** Classifications of imperfections in metallic fusion welds, with explanations
- ENV 1991-2-1** Eurocode 1: Basis of design and actions on structures. Part 2-1: Actions on structures – Densities, self-weight and imposed loads
- ENV 1991-2-3** Eurocode 1: Basis of design and actions on structures. Part 2 - 3: Actions on structures – Snow loads
- ENV 1993-1-1** Eurocode 3: Design of steel structures. Part 1-1: General rules and rules for buildings
- prEN ISO 14122** Safety of machinery. Permanent means of access to machines and industrial plants
- EN 485** Aluminium and aluminium alloys. Sheet, strip and plate

EN 754 Aluminium and aluminium alloys. Cold drawn rod/bar and tube

EN 755 Aluminium and aluminium alloys. Extruded rod/bar, tube and profiles

## 1.1 United States of America

**API 048 (RS)** 1-DEC-1989 The Net Social Cost of Mandating Out-of-Service Inspections of Aboveground Storage Tanks in the Petroleum industry

**API 065 (RS)** 1-SEP-1992 Estimated Costs and Benefits of Retrofitting Aboveground Petroleum Industry Storage Tanks with Release Prevention Barriers

**ANSI/API 12B** 1-FEB-1995 Specification for Bolted Tanks for Storage of Production Liquids

**ANSI/API 12D** 1-NOV-1994 Specification for Field Welded Tanks for Storage of Production Liquids

**ANSI/API 12F** 1-NOV-1994 Specification for Shop Welded Tanks for Storage of Production Liquids

**ANSI/API 2610** 1-JUL-1994 Design, Construction, Operation, Maintenance, and Installation of Terminal and Tank Facilities

**API 1629** 10-OCT-1993 Guide for Assessing and Remediating Petroleum Hydrocarbons in Soils

**API 2000** 1-APR-1998 Venting Atmospheric and Low pressure Storage Tanks: Non-refrigerated and Refrigerated

**API 2015** 1-MAY-1994 Safe Entry and Cleaning of Petroleum Storage Tanks, Planning and Managing Tank Entry From Decommissioning Through Recommissioning

**API 2021A** 1-JUN-1998 Interim Study Prevention and Suppression of Fires in Large Aboveground Atmospheric Storage Tanks

**API 2202** 1991 Dismantling and Disposing of Steel from Aboveground Leaded Gasoline Storage Tanks

**API 2350** 1996 Overfill Protection for Petroleum Storage Tanks

**API 2517D** 1-MAR-1993 Documentation File for API Publication 2517, Evaporation Loss from External Floating-Roof Tanks

**API 2519D** 1-MAR-1993 Documentation File for API Publication 2597, Evaporation Loss from Internal Floating-Roof Tanks

**API 301** 1991 Aboveground Tank Survey: 1989, 1991

**API 306** 1991 An Engineering Assessment of Volumetric Methods of Leak Detection in Aboveground Storage Tanks

**API 307** 1991 An Engineering Assessment of Acoustic Methods of Leak Detection in Aboveground Storage Tanks

**API 322** 1994 An Engineering Evaluation of Acoustic Methods of Leak Detection in Aboveground Storage Tanks

- API 323** 1994 An Engineering Evaluation of Volumetric Methods of Leak Detection in Aboveground Storage Tanks
- API 325** 1-MAY-1994 An Evaluation of a Methodology for the Detection of Leaks in Aboveground Storage Tanks
- API 327** 1-SEP-1994 Aboveground Storage Tank Standards: A Tutorial
- API 334** 1-SEP-1995 A Guide to Leak Detection for Aboveground Storage Tanks
- API 340** 1-OCT-1 997 Liquid Release Prevention and Detection Measures for Aboveground Storage Facilities
- API 341** 1-FEB-1998 A Survey of Diked-Area Liner Use at Aboveground Storage Tank Facilities
- API 351** 1-APR-1999 Overview of Soil Permeability Test Methods
- API 579** 2000 Recommended Practice for Fitness-for-Service
- API 620** 1-FEB-1996 Design and Construction of Large, Welded, Low pressure Storage Tanks, Ninth Edition
- API 650** 1-NOV-1998 Welded Steel Tanks for Oil Storage
- ANSI/API 651** 1-DEC-1 997 Cathodic Protection of Aboveground Petroleum Storage Tanks
- ANSI/API 652** 1-DEC-1997 Lining of Aboveground Petroleum Storage Tank Bottoms
- API 653** 1-DEC-1995 Tank Inspection, Repair, Alteration, and Reconstruction
- API 910** 1-NOV-1997 Digest of State Boiler, Pressure Vessel, Piping, and Aboveground Petroleum Storage Tank Rules and Regulations
- API MPMS Chapter 19.2** 1-APR-1997 Evaporative Loss Measurement: Documentation File for API Manual of Petroleum Measurement Standards Chapter 19.2 – Evaporative Loss from Floating Roof Tanks
- API MPMS Chapter 19.3C** 1-JUL-1998 Evaporative Loss Measurement - Part C: Weight Loss Test Method for the Measurement of Rim-Seal Loss Factors for Internal Floating-Roof Tanks
- API MPMS Chapter 7.4** 1993 Static Temperature Determination Using Fixed Automatic Tank Thermometers
- API RP 575** 1-NOV-1995 Inspection of Low pressure Storage Tanks
- AWMA 91.15.5** 1-JUN-1991 Detection of Leaks in the Floor of Aboveground Storage Tanks by Means of a Passive Acoustic Sensing System
- ANSI/AWWA D110-95** 1995 Wire-wound Circular Prestressed Concrete Water Tanks (includes addendum D110a-96)
- UL 142** 1992 Steel Aboveground Storage Tanks for Flammable and Combustible Liquids
- NFPA 30A** Code for Motor Fuel Dispensing Facilities and Repair Garages, 2000 Edition

**NFPA 22** Standard for Water Tanks for Private Fire Protection, 1998 Edition

**NFPA 395** Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites, 1993 Edition

## 1.2 Germany

**DIN 4119-1** 1-JUN-1979 Aboveground Cylindrical Flat-Bottomed Tank Installations of Metallic Material – Fundamentals, Design, Tests, Standard

**DIN 4119-2** 1-FEB-1980 Aboveground Cylindrical Flat-Bottom Tank Installations of Metallic Material – Calculation

**DIN 6600** 1-SEP-1989 Steel Tanks for the Storage of Flammable and Non-Flammable Water Polluting Liquids; Concepts and Inspection

**DIN 6601** -OCT-1990 Material resistance of steel tanks against liquids (positive list) (+ DIN 6601/A1 Revision)

**DIN 6616** -SEP-1989 Horizontal steel tanks, single and double wall, for aboveground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6618-1** -SEP-1989 Vertical steel tanks, single wall, for aboveground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6618-2** -SEP-1989 Vertical steel tanks, double wall, without leak detection system for aboveground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6618-3** -SEP-1989 Vertical steel tanks, double wall, with leak detection system for aboveground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6618-4** -SEP-1989 Vertical steel tanks, double wall, without leak detection system, with external sucking pipe for aboveground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6623-1** -SEP-1989 Vertical steel tanks, single wall, with less than a volume of 1000 litre for aboveground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6623-2** -SEP-1989 Vertical steel tanks, double wall, with less than a volume of 1000 litre for aboveground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6624-1** -SEP-1989 Horizontal steel tanks, single wall, with a volume of 1000 to 5000 litre for aboveground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6624-2** -SEP-1989 Horizontal steel tanks, double wall, with a volume of 1000 to 5000 litre for aboveground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 11622** -JUL-1994 Silos for ferment feed and liquid manure tanks (6 parts)

**DIN EN 617 -MAY-2002** Continuous handling equipment and systems – Safety and EMC requirements for the equipment for the storage of bulk materials in silos, bunkers, bins and hoppers

**DIN EN 12285-2 -FEB-2002** Workshop fabricated steel tanks – Part 2: Horizontal cylindrical single skin and double skin tanks for the aboveground storage of flammable and non-flammable water polluting liquids

**DIN EN 12573-1 -DEC-2000** Welded static non-pressurised thermoplastic tanks. Part 1: General principles

**DIN EN 12573-2 -DEC-2000** Welded static non-pressurised thermoplastic tanks. Part 2: Calculation of vertical cylindrical tanks

**DIN EN 12573-3 -DEC-2000** Welded static non-pressurised thermoplastic tanks. Part 3: Design and calculation for single skin rectangular tanks

**DIN EN 12573-4 -DEC-2000** Welded static non-pressurised thermoplastic tanks. Part 4: Design and calculation of flanged joints

**DIN EN 13121-1 -AUG-1998** GRP tanks and vessels for use above ground. Part 1: Raw materials - Specification conditions and acceptance conditions

**DIN EN 13121-2 -AUG-1998** GRP tanks and vessels for use above ground. Part 2: Composite materials, chemical resistance

**DIN EN 13121-3 -AUG-1998** GRP tanks and vessels for use above ground. Part 3: Calculation, construction and design

**DIN EN 13121-4 -AUG-1998** GRP tanks and vessels for use above ground. Part 4: Delivery, installation and maintenance

**DIN EN 13352 -DEC-1998** Specification for the performance of automatic tank contents gauges

**DIN EN 13530-1 -AUG-2002** Cryogenic Vessels – Large transportable vacuum insulated vessels. Part 1: Fundamental requirements

**DIN EN 13530-2 -JUL-1999** Cryogenic Vessels – Large transportable vacuum insulated vessels. Part 2: Design, fabrication, inspection and testing

**DIN EN 13575 -AUG-1999** Overfill Prevention Devices for tanks for liquid petroleum

**DIN EN 13617-1 -SEP-1999** Petrol Filling Station. Part 1: Construction and performance of metering pumps, dispenser and remote pumping units

**DIN EN 14015-1 -JAN-2001** Specification for the design and manufacture of site build, vertical, cylindrical, flat-bottomed, aboveground, welded, metallic tanks for the storage of liquids at ambient temperature and above. Part 1: Steel tanks

**DIN EN 14398-2 -APR-2002** Cryogenic vessels - Large transportable non-vacuum insulated vessels. Part 2: Design, fabrication, inspection and testing

**DIN EN ISO 17654 -JUN-2000** Destructive tests on welds in metallic materials – Resistance welding – Pressure test on resistance seam welds

**DIN EN ISO 17654 -JUN-2000** Petroleum and related products – Determination of the flammability characteristics of fluids in contact with hot surfaces – Manifold ignition test

### 1.3 United Kingdom

**BS 2654** 1989 Specification for Manufacture of Vertical Steel Welded Non-Refrigerated Storage Tanks with Butt-Welded Shells for the Petroleum Industry

**BS 2654 Amendment 1** 1997 Amendment 1 – Specification for Manufacture of Vertical Steel Welded Non- Refrigerated Storage Tanks with Butt-Welded Shells for the Petroleum Industry

**BS 8007** 1987 Code of practice for design of concrete structures for retaining aqueous liquids

**EEMUA 154** Guidance to Owners on Demolition of Vertical Cylindrical Steel Storage Tanks

**EEMUA 159** 1994 Users' Guide to the Maintenance and Inspection of Aboveground Vertical Cylindrical Steel Storage Tanks

**EEMUA 180** 1996 Guide for Designers and Users on Frangible Roof Joints for Fixed Roof Storage Tanks

**EEMUA 183** 1999 Guide for the Prevention of Bottom Leakage from Vertical, Cylindrical, Steel Storage Tanks

**EMC** 1980 European model code of safe practice in the storage and handling of petroleum products, part II, design, layout and construction

**IP 34/99** Determination of Flashpoint – Pensky-Martens closed cup method IP-ASTM Joint Method ASTM D 93-97

**IP 35/63 (86)** Determination of open flash and fire point – Pensky-Martens method Equivalent Standards: BS 2000: Part 35: 1993

**IP 36/84 (89)** Determination of Open Flash and Fire Point – Cleveland Method IP-ASTM Joint Method ASTM D 92-97

**IP 170/99** Petroleum products and other liquids – Determination of flashpoint – Abel closed cup method Equivalent Standards: BS 2000: Part 170: 1998; BS EN ISO 13736: 1998; ISO 13736: 1997

**IP 303/83 (88)** Determination of closed flashpoint – mini equilibrium method IP-ASTM Joint Method ASTM D 3828-97

**IP 304/80** Determination of Flashpoint Closed Cup Equilibrium Method

**IP 378/87** Storage Stability at 43°C of Distillate Fuel IP-ASTM Joint Method ASTM D 4625-92 (98)

**IP 403/94** Petroleum products – Determination of flash and fire points – Cleveland open cup method Equivalent Standards: BS 2000: Part 403: 1994; BS EN 22592: 1994; ISO 2592: 1973

**IP 404/94** Petroleum products and lubricants – Determination of flashpoint – Pensky-Martens closed cup method Equivalent Standards: BS 2000: Part 404: 1994; BS EN 22719: 1994; ISO 2719: 1988

**IP PM CE/1996** Determination of flashpoint – transparent liquids – Pensky-Martens closed tester Obsolete; Proposed Method

**IP PM CH/99** Determination of the hot storage stability of modified bituminous binders Proposed Method

**IP Model Code of Safe Practice, part 19** Fire precautions at petroleum refineries and bulk storage installations

**IP Code of Practice, 1994** Internal floating roofs for oil storage tanks

#### 1.4 France

**CODRES 1991** Code Français de construction des réservoirs cylindriques verticaux en acier avec tôles de robe soudées bout à bout, pour stockage de produits pétroliers liquides. – FRENCH

#### 1.5 The Netherlands

**Rules for Pressure Vessels** Dutch Code for Construction of Unfired Pressure Vessels. Section G. Sections G801, G802 and G803

**CPR 9-2 1985** Vloeibare aardolieproducten. Bovengrondse opslag, kleine installaties – DUTCH

**CPR 9-3 1984** Vloeibare aardolieproducten. Bovengrondse opslag, grote installaties – DUTCH

**CPR 9-6 25 mei 1998 Nr. 98/88** De opslag van vloeibare aardolieproducten

**CPR 9-6 19 juli 1999 Nr. 99/135** Richtlijn voor opslag tot 150 m<sup>3</sup> van brandbare vloeistoffen met een vlammpunt van 55 tot 100 °C in bovengrondse tanks

**CPR 12E Nr. 98/11 3 februari 1998** Berekeningsmethoden voor opstellen risicoanalyse gevaarlijke stoffen

**CPR-12 Nr. 97/13128 juli 1997** Methoden voor het bepalen en verwerken van kansen

**CPR 12E 1 November 1999 Nr. 99/194** Methods for determining and processing probabilities

**CPR 14E Nr. 97/13128 juli 1997** Methods for the calculation of physical effects

**CPR 14E 1 November 1999 Nr. 99/194** Methods for the calculation of physical effects

**CPR 15-1 1994**Richtlijn 15-1 van de CPR, getiteld ‘Opslag gevaarlijke stoffen in emballage; Opslag van vloeistoffen en vaste stoffen (0 ton tot 10 ton)’, tweede druk, uitgave 1994

**CPR 15-2 1991**Richtlijn 15-2 van de CPR, getiteld ‘Opslag gevaarlijke stoffen, chemische afval stoffen en bestrijdingsmiddelen in emballage; opslag van grote hoeveelheden’, eerste druk, 1991



**CPR-16 Nr. 97/13128 juli 1997** Methoden voor het bepalen van mogelijke schade aan mensen en goederen

**CPR 16E 1 November 1999 Nr. 99/194** Methods for the determination of possible damage

**CPR 18E 1 November 1999 Nr. 99/194** Guidelines for quantitative risk assessment

**CPR 20 31 januari 2000 Nr. 2000/013** RIB, Rapport Informatie-eisen BRZO'99

**NEN-EN 14015, 2000 (draft version only available)** Specification for the design and manufacture of site built, vertical, cylindrical, flat bottomed, aboveground, welded, metallic tanks for the storage of liquids at ambient temperature and above, Part 1: Steel Tanks (see also CEN/TC 265 under section General)

## 1.6 Austria

**OENORM C 2115:** 1981 01 01 (Standard), Liegende Behälter aus Stahl; einwandig und doppelwandig für oberirdische Lagerung von Flüssigkeiten

**OENORM C 2116-1:** 1984 06 01 (Standard), Stehende zylindrische Behälter aus Stahl-einwandig-für oberirdische Lagerung von Flüssigkeiten

**OENORM C 2116-2:** 1984 06 01 (Standard), Stehende zylindrische Behälter aus Stahl-doppelwandig-mit Unterdruck-Leckanzeige für oberirdische Lagerung von Flüssigkeiten

**OENORM C 2116-3:** 1984 06 01 (Standard), Stehende zylindrische Behälter aus Stahl-doppelwandig-mit Flüssigkeits-Leckanzeige für oberirdische Lagerung von Flüssigkeiten

**OENORM C 2117-1:** 1982 03 01 (Standard), Standortgefertigte prismatische Behälter aus Stahl für oberirdische Lagerung von Flüssigkeiten; Ausführung

**OENORM C 2117-2:** 1982 03 01 (Standard), Standortgefertigte prismatische Behälter aus Stahl für oberirdische Lagerung von Flüssigkeiten; Berechnung

**OENORM C 2118:** 1985 04 01 (Standard), Liegende Behälter aus Stahl; Nenninhalt 1m<sup>3</sup> bis 5m<sup>3</sup>; einwandig und doppelwandig für oberirdische Lagerung von Flüssigkeiten

## 2. UNDERGROUND STORAGE

### 2.1 United States of America

**API 1604** 1-MAR-1996 Closure of Underground Petroleum Storage Tanks

**API 1615** 1-MAR-1996 Installation of Underground Petroleum Storage Systems

**API 1621** 1-MAY-1993 Bulk Liquid Stock Control at Retail Outlets

**API 1629** 10-OCT-1993 Guide for Assessing and Remediating Petroleum Hydrocarbons in Soils

**API 1631** 1-OCT-1997 Interior Lining of Underground Storage Tanks

**API 1632** 1-MAY-1996 Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems

**API 1650** 1989 Set of Six API Recommended Practices on Underground Petroleum Storage Tank Management

**API 1663A** Underground Storage Tank Installation Training Module – SET – Includes API 1663B, 1663C, 1663D, and 1663E

**API 1663B** Underground Storage Tank Installation Training Module

**API 1663C** Underground Storage Tank Installation Workbook/Exhibit Book Set To accompany API 1663B

**API 1663D** Underground Storage Tank Removal Training Module

**API 1663E** Underground Storage Tank Removal Workbook/Exhibit Book Set To accompany API 1663D

**API 2000** 1-APR-1998 Venting Atmospheric and Low pressure Storage Tanks: Non-refrigerated and Refrigerated

**ASTM D4021-92** 15-JUN-1992 Standard Specification for Glass-Fibre-Reinforced Polyester Underground Petroleum Storage Tanks

**ASTM E1430-91** 6-SEP-1991 Standard Guide for Using Release Detection Devices with Underground Storage Tanks

**ASTM E1526-93** 15-MAR-1993 Standard Practice for Evaluating the Performance of Release Detection Systems for Underground Storage Tank Systems

**ASTM EI 990-98** 10-OCT-1998 Standard Guide for Performing Evaluations of Underground Storage Tank Systems for Operational Conformance with 40 CFR, Part 280 Regulations

**ASTM G158-98** 10-SEP-1998 Standard Guide for Three Methods of Assessing Buried Steel Tanks

**NACE RP0285-95** 1995 Standard Recommended Practice – Corrosion Control of Underground Storage Tank Systems by Cathodic Protection

**NFPA (fire) 326** 1999 Safe Entry of Underground Storage Tanks

**PEI RP100** 1997 Recommended Practices for Installation of Underground Liquid Storage Systems

**PEI RP 100-2000** Recommended Practices for Installation of Underground Liquid Storage Systems

**UL 1316** 1994 Glass Fibre Reinforced Plastic Underground Storage Tanks for Petroleum Products, Alcohols, and Alcohol -Gasoline Mixtures

**UL 1746** 1993 External Corrosion Protection Systems for Steel Underground Storage Tanks

**UL 1746** Amendment 1 3-NOV-1997 External Corrosion Protection Systems for Steel Underground Storage Tanks

**UL 1746** Amendment 2 24-SEP-2000 External Corrosion Protection Systems for Steel Underground Storage Tanks

**UL 1746** Amendment 3 16-MAY-2000 External Corrosion Protection Systems for Steel Underground Storage Tanks

## 2.2 Germany

**DIN 6600** 1-SEP-1989 Steel Tanks for the Storage of Flammable and Non-Flammable Water Polluting Liquids; Concepts and Inspection

**DIN EN 1918-5** JUL-1998 Gas supply systems – Underground gas storage. Part 5: Functional recommendations for surface facilities

**DIN EN 976-1** 1-SEP-1997 Underground Tanks of Glass-Reinforced Plastics (GRP)-Horizontal Cylindrical Tanks for the Non-Pressure Storage of Liquid Petroleum Based Fuels. Part 1: Requirements and Test Methods for Single Wall Tanks – GERMAN

**DIN EN 976-2** 1-SEP-1997 Underground Tanks of Glass-Reinforced Plastics (GRP) – Horizontal Cylindrical Tanks for the Non-Pressure Storage of Liquid Petroleum Based Fuels. Part 2: Transport, Handling, Storage and Installation of Single Wall Tanks – GERMAN

**DIN EN 977** 1-SEP-1997 Underground Tanks of Glass-Reinforced Plastics (GRP) – Method for One Side Exposure to Fluids – GERMAN

**DIN EN 978** 1-SEP-1997 Underground Tanks of Glass-Reinforced Plastics (GRP) – Determination of Creep Factor and Factor – GERMAN

**DIN 6607** -JAN-1991 Corrosion protection – Coatings of underground tanks: requirements and testing

**DIN 6608-2** -SEP-1989 Horizontal steel tanks, double wall, for underground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6619-2** -SEP-1989 Vertical steel tanks, double wall, for underground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN 6626** -SEP-1989 Domes of steel for tanks for underground storage of flammable and not flammable liquids and liquids hazardous to waters

**DIN EN 976-3** -OCT-1997 Underground tanks of Glass-Reinforced Plastics (GRP) – Horizontal cylindrical tanks for the non-pressure storage of liquid petroleum based fuels. Part 3: Requirements and test methods of double walled tanks

**DIN EN 976-4** -OCT-1997 Underground tanks of Glass-Reinforced Plastics (GRP) – Horizontal cylindrical tanks for the non-pressure storage of liquid petroleum based fuels. Part 4: Transport, handling, intermediate storage and installation of double walled tanks

**DIN EN 12917** -OCT-1997 Underground tanks of Glass-Reinforced Plastics (GRP) – Horizontal cylindrical tanks for the non-pressure storage of liquid petroleum based fuels – conformity assessment according EN 976-1 and 976-3

**DIN EN 13160-1** -MAY-1998 Leak detection systems. Part 1: General principles

**DIN EN 13160-2** -MAY-1998 Leak detection systems. Part 2: Pressure and vacuum systems

**DIN EN 13160-3** -MAY-1998 Leak detection systems. Part 3: liquid systems

**DIN EN 13160-4** -MAY-1998 Leak detection systems. Part 4: Liquid and/or vapour sensor systems for use in leakage containments or interstitial spaces

**DIN EN 13160-5** -MAY-1998 Leak detection systems. Part 5: Tank content sensor systems

**DIN EN 13160-6** -MAY-1998 Leak detection systems. Part 6: Sensors in monitoring wells

**DIN EN 13160-7** -MAY-1998 Leak detection systems. Part 7: General requirements and test methods for interstitial spaces, leak protecting linings and leak protecting jackets

**DIN EN 13636** -OCT-1999 Cathodic corrosion protection of underground metallic tanks and their pipes

**DIN EN 14125** -MAY-2001 Underground pipes for petrol filling stations

**DIN EN 14129** -JUL-2001 Safety valves for tanks for liquified gases

### 2.3 United Kingdom

**BS 2594** 1975 Specification for Carbon Steel Welded Horizontal Cylindrical Storage Tanks

**BS EN 1918-1** 1998 Gas Supply Systems – Underground Gas Storage – Functional Recommendations for Storage in Aquifers

**BS EN 1918-2** 10-JAN-1998 Gas Supply Systems – Underground Gas Storage – Functional Recommendations for Storage in Oil and Gas Fields

**BS EN 1918-5** 1998 Gas Supply Systems – Underground Gas Storage – Functional Recommendations for Surface Facilities

**BS EN 976-1** 1997 Underground Tanks of Glass-Reinforced Plastics (GRP) – Horizontal Cylindrical Tanks for the Non-Pressure Storage of Liquid Petroleum Based Fuels. Part 1: Requirements and Test Methods for Single Wall Tanks – ENGLISH

**BS EN 976-2** 1997 Underground Tanks of Glass-Reinforced Plastics (GRP) – Horizontal Cylindrical Tanks for the Non-Pressure Storage of Liquid Petroleum Based Fuels. Part 2: Transport, Handling, Storage and Installation of Single Wall Tanks – ENGLISH

**BS EN 977** 1-SEP-1997 Underground Tanks of Glass-Reinforced Plastics (GRP) – Method for One Side Exposure to Fluids – ENGLISH

**BS EN 978** 1-SEP-1997 Underground Tanks of Glass-Reinforced Plastics (GRP) – Determination of Creep Factor and Factor – ENGLISH

**IP 34/99** Determination of Flashpoint – Pensky-Martens closed cup method IP-ASTM Joint Method ASTM D 93-97

**IP 35/63(86)** Determination of open flash and fire point – Pensky-Martens method Equivalent Standards: BS 2000: Part 35: 1993

**IP 36/84 (89)** Determination of Open Flash and Fire Point – Cleveland Method IP-ASTM Joint Method ASTM D 92-97

**IP 170/99** Petroleum products and other liquids – Determination of flashpoint – Abel closed cup method Equivalent Standards: BS 2000: Part 170: 1998; BS EN ISO 13736: 1998; ISO 13736: 1997

**IP 303/83 (88)** Determination of closed flashpoint – mini equilibrium method IP-ASTM Joint Method ASTM D 3828-97

**IP 304/80** Determination of Flashpoint Closed Cup Equilibrium Method

**IP 403/94** Petroleum products – Determination of flash and fire points – Cleveland open cup method Equivalent Standards: BS 2000: Part 403: 1994; BS EN 22592: 1994; ISO 2592: 1973

**IP 404/94** Petroleum products and lubricants – Determination of flashpoint – Pensky-Martens closed cup method Equivalent Standards: BS 2000: Part 404: 1994; BS EN 22719: 1994; ISO 2719: 1988

## 2.4 France

**AFNOR NF EN 976-1** 1-SEP-1997 Underground Tanks of Glass-Reinforced Plastics (GRP)-Horizontal Cylindrical Tanks for the Non-Pressure Storage of Liquid Petroleum Based Fuels. Part 1: Requirements and Test Methods for Single Wall Tanks – FRENCH

**AFNOR NF EN 976-2** 1-SEP-1997 Underground Tanks of Glass-Reinforced Plastics (GRP) – Horizontal Cylindrical Tanks for the Non-Pressure Storage of Liquid Petroleum Based Fuels. Part 2: Transport, Handling, Storage and Installation of Single Wall Tanks – FRENCH

**AFNOR NF M 88-514** 1-MAR-1980 Dual Material Tanks for Underground Storage of Liquid Petroleum Products. Steel Exterior Tank. Plastic Interior Tank

**AFNOR NF M 88-550** 1979 Storage Tanks in Reinforced Plastic. Underground Tanks for Liquid Petroleum Products.

## 2.5 The Netherlands

**CPR 9-1** 1983 Vloeibare aardolieproducten. Ondergrondse opslag – DUTCH

**CPR 12E Nr. 98/11 3 februari 1998** Berekeningsmethoden voor opstellen risicoanalyse gevaarlijke stoffen

**CPR-12 Nr. 97/13128 juli 1997** Methoden voor het bepalen en verwerken van kansen

**CPR 12E 1 November 1999 Nr. 99/194** Methods for determining and processing probabilities

**CPR 14E Nr. 97/13128 juli 1997** Methods for the calculation of physical effects

**CPR 14E 1 November 1999 Nr. 99/194** Methods for the calculation of physical effects

**CPR 15-1 1994** Richtlijn 15-1 van de CPR, getiteld ‘Opslag gevaarlijke stoffen in emballage; Opslag van vloeistoffen en vaste stoffen (0 ton tot 10 ton)’, tweede druk, uitgave 1994

**CPR 15-2 1991** Richtlijn 15-2 van de CPR, getiteld 'Opslag gevaarlijke stoffen, chemische afval stoffen en bestrijdingsmiddelen in emballage; opslag van grote hoeveelheden', eerste druk, 1991

**CPR-16 Nr. 97/13128 juli 1997** Methoden voor het bepalen van mogelijke schade aan mensen en goederen

**CPR 16E 1 November 1999 Nr. 99/194** Methods for the determination of possible damage

**CPR 18E 1 November 1999 Nr. 99/194** Guidelines for quantitative risk assessment

**CPR 20 31 januari 2000 Nr. 2000/013** RIB, Rapport Informatie-eisen BRZO'99

## 2.6 Austria

**OENORM C 2110:** 1990 07 01 (Standard), Liegende Behälter aus Stahl; einwandig und doppelwandig, für unterirdische Lagerung von Flüssigkeiten

**OENORM C 2121:** 1986 01 01 (Standard), Stehende Behälter aus Stahl; einwandig und doppelwandig für unterirdische Lagerung von Flüssigkeiten

**OENORM C 2122:** 1992 06 01 (Standard), Domschächte aus Stahl für Behälter zur unterirdischen Lagerung von Flüssigkeiten

**OENORM C 2123:** 1992 09 01 (Standard), Domschachtkragen aus Stahl bei Domschächten in Massivbauweise für Behälter zur unterirdischen Lagerung von Flüssigkeiten

**OENORM EN 12285:** 1996 03 01 (Draft Standard), Werksfertige Tanks aus metallischen Werkstoffen – Liegende ein- und doppelwandige Tanks zur unterirdischen Lagerung v. brennbaren u. nichtbrennbaren wassergefährdenden Flüssigkeiten

**OENORM EN 12917:** 1997 09 01 (Draft Standard), Unterirdische Tanks aus textilglasverstärkten Kunststoffen (GFK) – Liegende, zylindrische Tanks für die drucklose Lagerung von flüssigen Kraftstoffen auf Erdölbasis – Konformitätsbewertung nach EN 976-1 und 976-3

**OENORM EN 14075:** 2001 02 01 (Draft Standard), Static welded steel cylindrical tanks, serially produced for the storage of Liquefied Petroleum Gas (LPG) having a volume not greater than 13 m<sup>3</sup> and for installation underground – Design and manufacture

**OENORM EN 976-1:** 1998 04 01 (Standard), Unterirdische Tanks aus textilglasverstärkten Kunststoffen (GFK) – Liegende, zylindrische Tanks für die drucklose Lagerung von flüssigen Kraftstoffen auf Erdölbasis

**OENORM EN 976-2:** 1998 04 01 (Standard), Unterirdische Tanks aus textilglasverstärkten Kunststoffen (GFK) – Liegende, zylindrische Tanks für die drucklose Lagerung von flüssigen Kraftstoffen auf Erdölbasis

**OENORM EN 976-3:** 1997 09 01 (Draft Standard), Unterirdische Tanks aus textilglasverstärkten Kunststoffen (GFK) – Liegende, zylindrische Tanks für die drucklose Lagerung von flüssigen Kraftstoffen auf Erdölbasis. Teil 3: Anforderungen und Prüfverfahren für doppelwandige Tanks

**OENORM EN 976-4:** 1997 09 01 (Draft Standard), Unterirdische Tanks aus textilglasverstärkten Kunststoffen (GFK) – Liegende, zylindrische Tanks für die

drucklose Lagerung von flüssigen Kraftstoffen auf Erdölbasis. Teil 4: Transport, Handhabung, Zwischenlagerung und Einbau doppelwandiger Tanks

**OENORM EN 977:** 1998 04 01 (Standard), Unterirdische Tanks aus textilglasverstärkten Kunststoffen (GFK) – Prüfanordnung zur einseitigen Beaufschlagung mit Fluiden

**OENORM EN 978:** 1998 04 01 (Standard), Unterirdische Tanks aus textilglasverstärkten Kunststoffen (GFK) – Bestimmung des Faktors Alpha und des Faktors Beta

### **3. PRESSURISED STORAGE**

#### **3.1 United States of America**

**API 520-1** 2000 Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries. Part 1 – Sizing and Selection

**AS 1210 Amendment 1** 1-FEB-1998 Unfired Pressure Vessels – Advanced Design and Construction

**AS 1210 Supplement 1** 1990 Unfired Pressure Vessels – Advanced Design and Construction – Remains current as supplement for 1997 edition

**AS 1210 Supplement 1 - Amd 1** 5-SEP-1995 Unfired Pressure Vessels – Advanced Design and Construction (Amendment 1 to Supplement 1)

**AS 1210 Supplement 1 - Amd 2** 1-JUL-1997 Unfired Pressure Vessels – Advanced Design and Construction (Amendment 2 to Supplement 1)

**ASME Section IIA** 1-JAN-98 ASME Boiler and Pressure Vessel Code, Section 11: Materials. Part A: Ferrous Material Specifications

**ASME Section IIB** 1-JAN-98 ASME Boiler and Pressure Vessel Code, Section 11: Materials. Part B: Nonferrous Material Specifications

**ASME Section IIC** 1-JAN-98 ASME Boiler and Pressure Vessel Code, Section 11: Materials. Part C: Specifications for Welding Rods, Electrodes and Filler Metals

**ASME Section IID** 1-JAN-98 ASME Boiler and Pressure Vessel Code, Section 11: Materials. Part D: Properties

**ASME Section V** 1-JAN-98 ASME Boiler and Pressure Vessel Code, Section V: Non-destructive Examination

**ASME Section VIII-DIV 1** 1998 ASME Boiler and Pressure Vessel Code, Section VIII, Division 1: Pressure Vessels

**ASME Section VIII-DIV 2** 1998 ASME Boiler and Pressure Vessel Code, Section VIII, Division 3: Alternative Rules

**ASME Section VIII-DIV 3** 1998 ASME Boiler and Pressure Vessel Code, Section VIII, Division 3: Alternative Rules for Construction of High Pressure Vessels

**ASME Section X** 1-JAN-98 ASME Boiler and Pressure Vessel Code, Section X: Fibre-Reinforced Plastic Pressure Vessels

**ASME CodeCases: BPV 01-JUL-98** ASME Boiler and Pressure Vessel Code – Code Cases: Boilers and Pressure Vessels

**NACE RP0285-95** 1995 Standard Recommended Practice – Corrosion Control of Underground Storage Tank Systems by Cathodic Protection

**NFPA (fire) 326** 1999 Safe Entry of Underground Storage Tanks

**PEI RP100** 1997 Recommended Practices for Installation of Underground Liquid Storage Systems

**UL 1746** 1993 External Corrosion Protection Systems for Steel Underground Storage Tanks

**UL 1746** Amendment 1 3-NOV-1997 External Corrosion Protection Systems for Steel Underground Storage Tanks

**UL 1746** Amendment 2 24-SEP-2000 External Corrosion Protection Systems for Steel Underground Storage Tanks

**UL 1746** Amendment 3 16-MAY-2000 External Corrosion Protection Systems for Steel Underground Storage Tanks

### 3.2 United Kingdom

**BS 5276-1-1984** Pressure vessel details (dimensions). Specification for davits for branch covers of steel vessels

**BS EN 286-1** 1998 Simple Unfired Pressure Vessels Designed to Contain Air or Nitrogen – Pressure Vessels for General Purposes

**BS PD 5500** 15-NOV-1999 Specification for unfired fusion welded pressure vessels

**BS 7005-1988** Specification for design and manufacture of carbon steel unfired pressure vessels for use in vapour compression refrigeration systems

**AMD 10830** Amendment to PD 5500:2000. Specification for unfired fusion welded pressure vessels

**Enquiry Case 5500/33:2000** Enquiry case to PD 5500:2000. Specification for unfired fusion welded pressure vessels

**Enquiry Case 5500/119:2000** Enquiry case to PD 5500:2000. Specification for unfired fusion welded pressure vessels

**Enquiry Case 5500/127:2000** Enquiry case to PD 5500:2000. Specification for unfired fusion welded pressure vessels

**PD 6497-1982** Stresses in horizontal cylindrical pressure vessels supported on twin saddles: a derivation of the basic equations and constants used in G.3.3 of BS 5500:1982

**PD 6550-1-1989** Explanatory supplement to BS 5500:1988 Specification for unfired fusion welded pressure vessels, section three Design. Domed ends (heads)

**PD 6550-2-1989** Explanatory supplement to BS 5500:1988 Specification for unfired fusion welded pressure vessels, section three Design. Openings and branch connections



**PD 6550-3-1989** Explanatory supplement to BS 5500:1988 Specification for unfired fusion welded pressure vessels, section three Design. Vessels under external pressure

**BS TH42069** 1993 Pressure Vessels – Germany

**BS TH42070** 1993 Pressure Vessels – France

**EEMUA 190 2000** Guide for the Design, Construction and Use of Mounded Horizontal Cylindrical Vessels for Pressurised Storage of LPG at Ambient Temperature

**IP 34/99** Determination of Flashpoint – Pensky-Martens closed cup method IP-ASTM Joint Method ASTM D 93-97

**IP 35/63(86)** Determination of open flash and fire point – Pensky-Martens method Equivalent Standards: BS 2000: Part 35: 1993

**IP 36/84 (89)** Determination of Open Flash and Fire Point – Cleveland Method IP-ASTM Joint Method ASTM D 92-97

**IP 170/99** Petroleum products and other liquids – Determination of flashpoint – Abel closed cup method Equivalent Standards: BS 2000: Part 170: 1998; BS EN ISO 13736: 1998; ISO 13736: 1997

**IP 303/83 (88)** Determination of closed flashpoint – mini equilibrium method IP-ASTM Joint Method ASTM D 3828-97

**IP 304/80** Determination of Flashpoint Closed Cup Equilibrium Method

**IP 403/94** Petroleum products - Determination of flash and fire points – Cleveland open cup method Equivalent Standards: BS 2000: Part 403: 1994; BS EN 22592: 1994; ISO 2592: 1973

**IP 404/94** Petroleum products and lubricants – Determination of flashpoint – Pensky-Martens closed cup method Equivalent Standards: BS 2000: Part 404: 1994; BS EN 22719: 1994; ISO 2719: 1988

**IP 410/99** Liquefied petroleum products – Determination of gauge vapour pressure – LPG method

### 3.3 France

**CODAP 95** French Code for Construction of Unfired Pressure Vessels

### 3.4 The Netherlands

**Rules for Pressure Vessels** Dutch Code for Construction of Unfired Pressure Vessels. Section D.

**CPR 12E Nr. 98/11 3 februari 1998** Berekeningsmethoden voor opstellen risicoanalyse gevaarlijke stoffen

**CPR-12 Nr. 97/13128 juli 1997** Methoden voor het bepalen en verwerken van kansen

**CPR 12E 1 November 1999 Nr. 99/194** Methods for determining and processing probabilities

**CPR 13-1** Ammonia, Storage and Loading

**CPR 14E Nr. 97/13128 juli 1997** Methods for the calculation of physical effects

**CPR 14E 1 November 1999 Nr. 99/194** Methods for the calculation of physical effects

**CPR 15-1 1994** Richtlijn 15-1 van de CPR, getiteld 'Opslag gevaarlijke stoffen in emballage; Opslag van vloeistoffen en vaste stoffen (0 ton tot 10 ton)', tweede druk, uitgave 1994

**CPR 15-2 1991**Richtlijn 15-2 van de CPR, getiteld 'Opslag gevaarlijke stoffen, chemische afval stoffen en bestrijdingsmiddelen in emballage; opslag van grote hoeveelheden', eerste druk, 1991

**CPR 16 Nr. 97/13128 juli 1997** Methoden voor het bepalen van mogelijke schade aan mensen en goederen

**CPR 16E 1 November 1999 Nr. 99/194** Methods for the determination of possible damage

**CPR 17-1 Nr. 98/88 25 mei 1998** De richtlijn aardgas-afleverstations voor motorvoertuigen

**CPR 17-2 11 januari 1999Nr. 99/001** Richtlijn voor het veilig stellen en repareren van motorvoertuigen

**CPR 17-3 16 maart 1999 Nr. 99/038** Concept richtlijn voor installaties voor de in pandige aflevering van gecomprimeerd aardgas aan motorvoertuigen (Concept CPR 17-3)

**CPR 18E 1 November 1999 Nr. 99/194** Guidelines for quantitative risk assessment

**CPR 20 31 januari 2000 Nr. 2000/013** RIB, Rapport Informatie-eisen BRZO'99

#### **4. REFRIGERATED STORAGE**

##### **4.1 United States of America**

**API 620** 1-FEB-1996 Design and Construction of Large, Welded, Low pressure Storage Tanks, Ninth Edition – Appendix Q Liquids down to -168 °C

**API 620** 1-FEB-1996 Design and Construction of Large, Welded, Low pressure Storage Tanks, Ninth Edition – Appendix R Liquids down to -51 °C

**API 2000** 1-APR-1998 Venting Atmospheric and Low pressure Storage Tanks: Non-refrigerated and Refrigerated

**NFPA 50** Standard for Bulk Oxygen Systems at Consumer Sites, 1996 Edition

**NFPA 50A** Standard for Gaseous Hydrogen Systems at Consumer Sites, 1999 Edition

**NFPA 50B** Standard for Liquefied Hydrogen Systems at Consumer Sites, 1999 Edition

**NFPA 57** Liquefied Natural Gas (LNG) Fuel Systems Code, 1999 Edition

**NFPA 59** Standard for the Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants, 1998 Edition

**NFPA 59A** Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG). 1996 Edition

**UL 641** 1994 Type L Low-Temperature Venting Systems

**UL 873** 1994 Temperature-Indicating and -Regulating Equipment

#### 4.2 United Kingdom

**BS 5429-1976** Code of practice for safe operation of small-scale storage facilities for cryogenic liquids

**BS 6364-1984** Specification for valves for cryogenic service

**BS EN 1160-1997** Installations and equipment for liquefied natural gas. General characteristics of liquefied natural gas

**BS 7777-1** 1993 Flat-Bottomed, Vertical, Cylindrical Storage Tanks for Low Temperature Service. Part 1: Guide to the General Provisions Applying for Design, Construction, Installation, and Operation

**BS 7777-2** 1993 Flat-Bottomed, Vertical, Cylindrical Storage Tanks for Low Temperature Service. Part 2: Specification for the Design and Construction of Single, Double and Full Containment Metal Tanks for the Storage of Liquefied Gas at Temperatures Down to 165 °C

**BS 7777-3** 1993 Flat-Bottomed, Vertical, Cylindrical Storage Tanks for Low Temperature Service. Part 3: Recommendations for the Design and Construction of Prestressed and Reinforced Concrete Tanks and Tank Foundations, and Design and Installation of Tank Insulation, Liners and Coatings

**BS 7777-4** 1993 Flat-Bottomed, Vertical, Cylindrical Storage Tanks for Low Temperature Service. Part 4: Specification for the Design and Construction of Single Containment Tanks for the Storage of Liquid Oxygen, Liquid Nitrogen and Liquid Argon

**EEMUA 147** Recommendations for the Design and Construction of Refrigerated Liquefied Gas Storage Tanks

**IP 34/99** Determination of Flashpoint – Pensky-Martens closed cup method IP-ASTM Joint Method ASTM D 93-97

**IP 35/63(86)** Determination of open flash and fire point - Pensky-Martens method Equivalent Standards: BS 2000: Part 35: 1993

**IP 36/84 (89)** Determination of Open Flash and Fire Point – Cleveland Method IP-ASTM Joint Method ASTM D 92-97

**IP 170/99** Petroleum products and other liquids – Determination of flashpoint – Abel closed cup method Equivalent Standards: BS 2000: Part 170: 1998; BS EN ISO 13736: 1998; ISO 13736: 1997

**IP 251/76** Static Measurement of Refrigerated Hydrocarbon Liquids Published as Part XII Section 1 of the IP Petroleum Measurement Manual

**IP 252/76** Static Measurement of Refrigerated Hydrocarbon Liquids Published as Part XIII Section 1 of the IP Petroleum Measurement Manual

**IP 264/72 (85)** Determination of Composition of LPG and Propylene Concentrates – Gas chromatography Method IP-ASTM Joint Method ASTM D 2163-91 (96)

**IP 303/83 (88)** Determination of closed flashpoint – mini equilibrium method IP-ASTM Joint Method ASTM D 3828-97

**IP 304/80** Determination of Flashpoint Closed Cup Equilibrium Method

**IP 317/95** Determination of residues in liquefied petroleum gases (LPG) – Low temperature evaporation method IP-ASTM Joint Method ASTM D 2158-92 Equivalent Standards: BS 2000: Part 317: 1995

**IP 337/78 (95)** Composition of Non-associated Natural Gas – Quantitative Gas Chromatography Method

**IP 345/80** Composition of Associated Natural Gas – Gas Chromatography Method

**IP 395/98** Liquefied petroleum gases – Assessment of the dryness of propane – Valve freeze method IP-ASTM Joint Method ASTM D 2713-91 (95) Equivalent Standards: BS 2000: Part 395: 1997; BS EN ISO 13758: 1997; ISO 13758: 1996

**IP 403/94** Petroleum products – Determination of flash and fire points – Cleveland open cup method Equivalent Standards: BS 2000: Part 403: 1994; BS EN 22592: 1994; ISO 2592: 1973

**IP 404/94** Petroleum products and lubricants – Determination of flashpoint – Pensky-Martens closed cup method Equivalent Standards: BS 2000: Part 404: 1994; BS EN 22719: 1994; ISO 2719: 1988

**IP 405/94** Commercial propane and butane – Analysis by gas chromatography Equivalent Standards: BS 2000: Part 405: 1994; BS EN 27941: 1994; ISO 7941: 1988

**IP 410/99** Liquefied petroleum products – Determination of gauge vapour pressure – LPG method Equivalent Standards: BS 2000: Part 410: 1998; BS EN ISO 4256: 1998; ISO 4256: 1996

**IP 432/2000** Liquefied petroleum gases – Calculation method for density and vapour pressure Equivalent Standards: BS 2000: Part 432: 1999; BS EN ISO 8973: 1999; ISO 8973: 1997

**IP PM CD/96** Determination of the composition of liquefied petroleum gases – gas chromatography method. Proposed Method

**IP Model Code of Safe Practice** LPG, Volume 1, Part 9 Large bulk pressure Storage and refrigerated LPG

#### 4.3 Germany

**EN 14620** Specification for the design and manufacture of site built, vertical, cylindrical, flat bottomed, metallic tanks for the storage of liquefied gases at temperatures between - 5 °C and -165 °C.

#### 4.4 The Netherlands

**Rules for Pressure Vessels** Dutch Code for Construction of Unfired Pressure Vessels. Section G. Sections G804 and G805

**CPR 8-3** Distributiedepots voor LPG – Dutch.

**CPR 11-6 Nr. 98/88 25 mei 1998** Propana. Vulstations voor spuitbussen met propana, butaan en demethyl-ether als drijfgas

**CPR 12E Nr. 98/11 3 februari 1998** Berekeningsmethoden voor opstellen risicoanalyse gevaarlijke stoffen

**CPR-12 Nr. 97/13128 juli 1997** Methoden voor het bepalen en verwerken van kansen

**CPR 12E 1 November 1999 Nr. 99/194** Methods for determining and processing probabilities

**CPR 13 Nr. 99/137 21 juli 1999** Richtlijnen voor opslag en verlading van ammoniak en voor de toepassing van ammoniak als koudemiddel in koelinstallaties en warmtepompen

**CPR 13-1 Nr. 98/88 25 mei 1998** De opslag en verlading van ammoniak

**CPR 13-1 Nr. 99/137 21 juli 1999** Ammoniak; opslag en verlading

**CPR 13-2 Nr. 99/137 21 juli 1999** Ammoniak; toepassing als koudemiddel in koelinstallaties en warmtepompen

**CPR 14E Nr. 97/13128 juli 1997** Methods for the calculation of physical effects

**CPR 14E 1 November 1999 Nr. 99/194** Methods for the calculation of physical effects

**CPR 15-1 1994** Richtlijn 15-1 van de CPR, getiteld ‘Opslag gevaarlijke stoffen in emballage; Opslag van vloeistoffen en vaste stoffen (0 ton tot 10 ton)’, tweede druk, uitgave 1994

**CPR 15-2 1991** Richtlijn 15-2 van de CPR, getiteld ‘Opslag gevaarlijke stoffen, chemische afval stoffen en bestrijdingsmiddelen in emballage; opslag van grote hoeveelheden’, eerste druk, 1991

**CPR-16 Nr. 97/13128 juli 1997** Methoden voor het bepalen van mogelijke schade aan mensen en goederen

**CPR 16E 1 November 1999 Nr. 99/194** Methods for the determination of possible damage

**CPR 18E 1 November 1999 Nr. 99/194** Guidelines for quantitative risk assessment

**CPR 20 31 januari 2000 Nr. 2000/013** RIB, Rapport Informatie-eisen BRZO’99

## **5. ISO CONTAINERS OR IBC’S**

### **5.1 United States of America**

**AS/NZS 3833-1998 5-SEP-1998.** The Storage and Handling of Mixed Classes of Dangerous Goods in Packages and Intermediate Bulk Containers

**ABS 13-1998** 1998 Rules for Certification of Cargo Containers

**AMCA 99** 1986 Standards Handbook

- ANSI MH26.1-1998** 1998 Specifications for Industrial Metal Containers
- ANSI MH5.1.3M-1992** 1992 Requirements for Tank Containers for Liquids and Gases
- ANSI MH5.1.5-1990** 1990 Road/Rail Closed Dry Van Containers
- ANSI MH5.1.9-1990** 1990 Freight Containers – Automatic Identification
- ANSI PRD1-1998** 1998 Pressure Relief Devices for Natural Gas Vehicle (NGV) Fuel Containers
- ARI Guideline K (1997)** 1997 Containers for Recovered Fluorocarbon Refrigerators
- ARI Guideline N (1995)** 1995 Assignment of Refrigerant Container Colours
- AS 2278-1986** 1986 Metal Aerosol Containers
- AS 2278-1986 Amendment 1** 1-JUN-1988 Metal Aerosol Containers
- ASTM C148-00** 2000 Standard Test Method for Polariscope Examination of Glass Containers
- ASTM C149-86(1995)** 31-JAN-1986 Standard Test Method for Thermal Shock Resistance of Glass Containers
- ASTM C224-78(R1999)** 27-JAN-1978 Standard Practice for Sampling Glass Containers
- ASTM C225-85(R1999)** 26-JUL-1985 Standard Test Methods for Resistance of Glass Containers to Chemical Attack
- ASTM D2463-95** 10-NOV-1995 Standard Test Method for Drop Impact Resistance of Blow-Moulded Thermoplastic Containers
- ASTM D2561-95** 10-NOV-1995 Standard Test Method for Environmental Stress-Crack Resistance of Blow-Moulded Polyethylene Containers
- ASTM D2659-95** 10-NOV-1995 Standard Test Method for Column Crush Properties of Blown Thermoplastic Containers
- ASTM D2684-95** 10-NOV-1995 Standard Test Method for Permeability of Thermoplastic Containers to Packaged Reagents or Proprietary Products
- ASTM D3074-94** 15-NOV-1994 Standard Test Method for Pressure in Metal Aerosol Containers
- ASTM D3694-95** 15-FEB-1995 Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents
- ASTM D3844-96** 10-JUN-1996 Standard Guide for Labelling Halogenated Hydrocarbon Solvent Containers
- ASTM D4306-97** 10-DEC-1997 Standard Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
- ASTM D4728-95** 10-NOV-1995 Standard Test Method for Random Vibration Testing of Shipping Containers

- ASTM D4991-94(R1999)** 15-JUN-1994 Standard Test Method for Leakage Testing of Empty Rigid Containers by Vacuum Method
- ASTM D6063-96** 10-DEC-1996 Standard Guide for Sampling Drums and Similar Containers by Field Personnel
- ASTM D997-80(R1986)** 3-MAR-1980 Standard Test Method for Drop Test for Loaded Cylindrical Containers
- ASTM D998-94** 15-MAY-1994 Standard Test Method for Penetration of Liquids into Submerged Loaded Shipping Containers
- ASTM D999-96** 10-FEB-1996 Standard Methods for Vibration Testing of Shipping Containers
- ASTM ES26-93** 28-JUL-1993 Emergency Standard Specification for Cautionary Labelling for Plastic Five-Gallon Open-Head Containers (Buckets)
- ASTM F1115-95** 10-SEP-1995 Standard Test Method for Determining the Carbon Dioxide Loss of Beverage Containers
- ASTM F1615-95** 10-SEP-1995 Standard Specification for Cautionary Labelling for Five-Gallon Open-Head Plastic Containers
- ASTM F302-78(R1989)** 25-AUG-1978 Standard Practice for Field Sampling of Aerospace Fluids in Containers
- ASTM F926-85** 23-AUG-1985 Standard Specification for Cautionary Labelling of Portable Kerosene Containers for Consumer Use
- EIA 556B** 1-NOV-1999 Outer Shipping Container Bar Code Label Standard
- EIA JEP130** 1-AUG-1997 Guidelines for Packing and Labelling of Integrated Circuits in Unit Container Packing
- IEC 60096-1 Amendment 2** 25-JUN-1993 Amendment No. 2
- IEC 60249-1 Amendment 4** 13-MAY-1993 Amendment No. 4
- IEC 60249-2-10 Amendment 3** 18-MAY-1993 Amendment No. 3
- IEC 60249-2-11 Amendment 2** 18-MAY-1993 Amendment No. 2
- IEC 60249-2-12 Amendment 2** 18-MAY-1993 Amendment No. 2
- IEC 60249-2-14 Amendment 3** 18-MAY-1993 Amendment No. 3
- IEC 60249-2-5 Amendment 3** 13-MAY-1993 Amendment No. 3
- IEC 60249-2-6 Amendment 2** 13-MAY-1993 Amendment No. 2
- IEC 60249-2-7 Amendment 2** 13-MAY-1993 Amendment No. 2
- IEC 60249-2-9 Amendment 3** 18-MAY-1993 Amendment No. 3
- IEC 60264-1** 31-DEC-1969 Packaging of winding wires. Part 1: Containers for round winding wires

- IEC 60344 Amendment 1** 1985 Amendment No. 1
- IEC 60390A** 1976 First supplement
- IEC 60708-1 Amendment 3** 1988 Amendment No. 3
- IEC 60804 Amendment 1** 15-SEP-1989 Amendment No. 1
- IEC 60804 Amendment 2** 21-SEP-1993 Amendment No. 2
- IEEE C135.1-1999** 30-DEC-1999 Galvanized Steel, Bolts and Nuts for Overhead Line Construction
- UL 147B Amendment 1** 1-MAR-1999 Non-refillable (Disposable) Type Metal Container Assemblies for Butane
- UL 2003 Outline** 28-AUG-1992 Proposed Standard – Portable LP Gas Container Assemblies
- CGA G-6.7** 1996 Safe Handling of Liquid Carbon Dioxide Containers That Have Lost Pressure
- FED A-A-1235A** 6-DEC-1984 Containers, Plastic, Moulded (For Liquids, Pastes, and Powders)
- FED A-A-2597A** 25-JUL-1996 Dishpan (Food Container Pan)
- FED A-A-30132A** 18-MAY-1987 Disposable Container, Hypodermic Needle and Syringe
- FED A-A-50019B** 18-MAR-1988 Racks, Milk Container, Mobile and Racks, Egg Container, Mobile
- FED A-A-50486A** 23-NOV-1992 Container, Insulated, Shipping
- FED A-A-51625B** 24-NOV-1989 Disposal Container, Hypodermic Needle and Syringe (Non-Needle Removal)
- FED A-A-51703(DM)** 13-OCT-1986 Container and Pump, Dental (Mouth rinse)
- FED A-A-52193A** 18-JUL-1994 Food Container, Insulated, with Inserts
- FED A-A-52486** 13-DEC-1984 Mount, Shipping Container, Resilient: Shock and Vibration Damping
- FED A-A-58041** 15-MAR-1995 Trailer, LD-3 Container, Side Transfer, Turntable
- FED A-A-59209** 15-APR-1998 Paperboard, Ammunition Container
- FED O-F-1044B** 24-FEB-1975 Fuel, Engine Primer: Cold Starting, In Pressurised and Non-pressurised Containers
- FED RR-C-550D** 8-APR-1991 Containers, Fluid, for Paint Spray Equipment
- FED RR-C-550D Amendment** 19-FEB-1993 Amendment 1 – Containers, Fluid, for Paint Spray Equipment



## 5.2 Germany

**DIN 30823** MAR 1999 (draft) Intermediate bulk containers – Rigid IBC – Metal, rigid plastics and composite intermediate bulk containers; dimension, design, requirements, marking

**DIN 55461-1** FEB 1990 Large size packages; flexible IBC; concepts, forms, dimensions, testing of dimensions

**DIN 55461-2** JUL 1991 Large size packages; flexible IBC; dimensions

**DIN 10955** 1-APR-1983 Sensory Analysis - Testing of Container Materials and Containers for Food Products

**DIN 168-1** 1-DEC-1979 External Screw Threads. Part 1: Especially for Glass Containers – Thread Sizes

**DIN EN ISO 15867** NOV 1997 (draft) Intermediate bulk containers (IBC) for non-dangerous goods – Terminology

**ISO/DIS 11895** JAN 1996 (draft) Specification for flexible intermediate bulk containers for non-dangerous goods

**98/714098 DC** APR 2000 (draft) Pallet borne flexible intermediate bulk containers (PB FIBCs) for non-dangerous goods

**ISO 10327** 1-FEB-1995 Aircraft-Certified Aircraft Container for Air Cargo-Specification and Testing

**ISO 10374** 1-OCT-1991 Freight containers – Automatic identification

**ISO 11242** 1-JUN-1996 Aircraft-Pressure Equalization Requirements for Cargo Containers

**ISO 11418-1** 1-OCT-1996 Containers and accessories for pharmaceutical preparations. Part 1: Drop-dispensing bottles

**ISO 11418-2** 1-OCT-1996 Containers and accessories for pharmaceutical preparations. Part 2: Screw-neck bottles for syrups

**ISO 11418-4** 1-OCT-1996 Containers and accessories for pharmaceutical preparations. Part 4: Tablet bottles

**ISO 11418-5** 1-OCT-1997 Containers and accessories for pharmaceutical preparations. Part 5: Dropper assemblies

**ISO 1161** 1984 Series 1 Freight Containers – Corner Fittings – Specification

**ISO 1496-1** 1990 Series 1 Freight Containers – Specification and Testing. Part 1: General Cargo Containers for General Purposes – Includes Amendments 1(1993) and 2 (1998)

**ISO 1496-1/AMD1** 1-OCT-1993 Amendment 1 to ISO 1496-1:1990 1AAA and 1BBB containers

**ISO 1496-2** 1996 Series 1 Freight Containers – Specification and Testing. Part 2: Thermal Containers - Includes Technical Corrigendum 1:1997

- ISO 1496-3** 1995 Series 1 Freight Containers – Specification and Testing. Part 3: Tank Containers for Liquids, Gases and Pressurised Dry Bulk
- ISO 1496-4** 1991 Series 1 Freight Containers – Specification and Testing. Part 4: Non-Pressurised Containers for Non-Bulk
- ISO 1496-4/AMD1** 1-OCT-1994 AMENDMENT 1 to ISO 1496-4:1991 1AAA and 1BBB containers
- ISO 1496-5** 1991 Series 1 Freight Containers – Specification and Testing. Part 5: Platform and Platform-Based Containers
- ISO 1496-5/AMD1** 1-OCT-1993 Amendment 1 to ISO 1496-5:1991 1AAA and 1BBB containers
- ISO 2308** 1972 Hooks for Lifting Freight Containers of Up To 30 Tonnes Capacity – Basic Requirements
- ISO 3871** 1-FEB-1980 (HISTORICAL ITEM) Labelling of Containers for Petroleum or Non-Petroleum Base Brake Fluid
- ISO 3874** 1988 (HISTORICAL ITEM) Series 1 Freight Containers – Handling and Securing
- ISO 3874** 1-OCT-1997 Series 1 freight containers – Handling and securing
- ISO 4118** 1-APR-1996 Non-Certified Lower Deck Containers for Air Transport- Specification and Testing
- ISO 4128** 1-SEP-1985 Air Mode Modular Containers
- ISO 6346** 1995 Freight Containers – Coding, Identification, and Marking
- ISO 668** 1995 Series 1 Freight Containers – Classification, Dimensions and Ratings
- ISO 6967** 1-SEP-1994 Wide Body Aircraft Main Deck Container/Pallet Loader-Functional Requirements
- ISO 6968** 1-SEP-1994 Wide Body Aircraft Lower Deck Container/Pallet Loader-Functional Requirements
- ISO 7458** 1984 Glass Containers - Internal Pressure Resistance - Test Methods
- ISO 7459** 1984 Glass Containers – Thermal Shock Resistance and Thermal Shock Endurance – Test Methods
- ISO 8106** 1985 Glass Containers – Determination of Capacity by Gravimetric Method – Test Method
- ISO 8162** 1985 Glass Containers – Tall Crown Finishes – Dimensions
- ISO 8163** 1985 Glass Containers – Shallow Crown Finishes – Dimensions
- ISO 8164** 1990 Glass Containers – 520 ml Euro-form Bottles – Dimensions
- ISO 8167** 1-OCT-1989 Projections for resistance welding

**ISO 830** 1981 (HISTORICAL ITEM) Freight Containers – Terminology

**ISO 830** 1-OCT-1999 Freight containers – Vocabulary

**ISO 8323** 1995 Freight Containers – Air/Surface (Intermodal) General Purpose Containers – Specification and Tests

**ISO 90-2** 1-OCT-1997 Light gauge metal containers – Definitions and determination of dimensions and capacities. Part 2: General use containers

**ISO 9009** 1991 Glass Containers – Height and Non-Parallelism of Finish with Reference to Container Base – Test Methods

**ISO 9056** 1990 Glass Containers – Series of Pilferproof Finish – Dimensions

**ISO 9057** 1991 Glass Containers – 28 mm Tamper-Evident Finish for Pressurised Liquids – Dimensions

**ISO 9058** 1992 Glass Containers – Tolerances

**ISO 9100** 1-OCT-1992 Wide-mouth glass containers – Vacuum lug finishes – Dimensions

**ISO 9669** 1990 Series 1 Freight Containers – I Interface Connections for Tank Containers

**ISO 9711-1** 1990 Freight Containers – Information Related to Containers on Board Vessels. Part 1: Bay Plan System

**ISO 9711-2** 1990 Freight Containers – Information Related to Containers on Board Vessels. Part 2: Telex Data Transmission

**ISO 9897** 1-OCT-1997 Freight containers – Container equipment data exchange (CEDEX) – General communication codes

**ISO/IEC 2258** 31-DEC-1976 Printing ribbons – Minimum markings to appear on containers

**ISO/TR 15070** 1996 Series 1 Freight Containers – Rationale for Structural Test Criteria

### 5.3 United Kingdom

**BS 1133-7.7** 1990 Packaging Code – Paper and Board Wrappers, Bags and Containers – Composite Containers

**BS 3951-2 Section 2.5** 1992 Freight Containers. Specification and Testing of Series 1 Freight Containers. Platform and Platform-Based Containers

**BS 5045-1 Amendment 1** 1-AUG-1986 Amendment 1 – Transportable Gas Containers. Part 1: Specification for Seamless Steel Gas Containers above 0.5 Litre Water Capacity

**BS 5045-1 Amendment 2** 1991 Amendment 2 – Transportable Gas Containers. Part 1: Specification for Seamless Steel Gas Containers above 0.5 Litre Water Capacity

**BS 5045-1 Amendment 3** 1-NOV-1993 Amendment 3 – Transportable Gas Containers. Part 1: Specification for Seamless Steel Gas Containers above 0.5 Litre Water Capacity

**BS 5045-1 Amendment 4** 1997 Amendment 4 – Transportable Gas Containers. Part 1: Specification for Seamless Steel Gas Containers above 0.5 Litre Water Capacity

**BS 5045-1 Amendment 5** 15-SEP-1997 Amendment 5 – Transportable Gas Containers. Part 1: Specification for Seamless Steel Gas Containers above 0.5 Litre Water Capacity

**BS 5045-5** 1986 Transportable Gas Containers – Specification for Aluminium Alloy Containers Above 0.5 Litre up to 130 Litres Water Capacity with Welded Seams

**BS 5045-6** 1987 Transportable Gas Containers – Specification for Seamless Containers of Less than 0.5 Litre Water Capacity

**BS 5430-1** 31-MAY-1990 Periodic Inspection, Testing and Maintenance of Transportable Gas Containers (Excluding Dissolved Acetylene Containers). Specification for Seamless Steel Containers of Capacity 0.5 Litres and Above

**BS 5430-2** 31-DEC-1990 Periodic Inspection, Testing and Maintenance of Transportable Gas Containers (Excluding Dissolved Acetylene Containers). Specification for Welded Steel Containers of Water Capacity 0.5 L up to 150 L

**BS 5430-3** 31-DEC-1990 Periodic Inspection, Testing and Maintenance of Transportable Gas Containers (Excluding Dissolved Acetylene Containers). Specification for Seamless Aluminium Alloy Containers of Water Capacity 0.5 Litres and Above

**BS 5430-6** 15-JUL-1994 Periodic Inspection, Testing and Maintenance of Transportable Gas Containers (Excluding Dissolved Acetylene Containers). Specification for Seamless Steel and Aluminium Alloy Containers Having a Water Capacity of Less Than 0.5 Litre

**BS 7320 Amendment 1** 15-MAY-1994 Specification for Sharps Containers

**BS 7864** 1997 Specification for Plastics Containers for Surface Coatings

**BS EN 20090-2** 1993 Light Gauge Metal Containers – Definitions and Determination Methods for Dimensions and Capacities. Part 2: General Use Containers

**BS EN 20090-2 Amendment 1** 1-MAR-1993 Amendment 1 – Light Gauge Metal Containers – Definitions and Determination Methods for Dimensions and Capacities. Part 2: General Use Containers

**BS EN 28362-1** 1993 Injection Containers for Injectables and Accessories. Part 1: Injection Vials Made of Glass Tubing

**BS EN 28362-2** 1993 Injection Containers for Injectables and Accessories. Part 2: Closures for Injection Vials

**BS EN 28362-3** 1993 Injection Containers for Injectables and Accessories. Part 3: Aluminium Caps for Injection Vials

**BS EN 28362-4** 1993 Injection Containers for Injectables and Accessories. Part 4: Injection Vials Made of Moulded Glass

#### 5.4 France

**AFNOR NF M 88-610** 1970 Petroleum Industry. Calibration Identification Plate for Containers

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**6. CAVERNS FOR LPG PRESSURISED STORAGE OR MINERAL OIL****6.1 United States of America**

**API 1114** 1-JUN-1994 Design of Solution-Mined Underground Storage Facilities

**API 1115** 1-SEP-1994 Operation of Solution-Mined Underground Storage Facilities

**6.2 United Kingdom**

**BS EN 1918-3** 1998 Gas Supply Systems – Underground Gas Storage – Functional Recommendations for Storage in Solution-mined Salt Cavities

**BS EN 1918-4** 1998 Gas Supply Systems – Underground Gas Storage – Functional Recommendations for Storage in Rock Caverns

**BS EN 1918-5** 1998 Gas Supply Systems – Underground Gas Storage – Functional Recommendations for Surface Facilities

**CAS Z341-98** 1-DEC-1998 Storage of Hydrocarbons in Underground Formulations

## 7. Chemical Distribution – Standards, codes and regulations – A typical example in the UK

Series no	Title	Publ.	ISBN
	Chemical Industry:		
HSG71	Chemical warehousing – Storage of packaged dangerous substances (Revised)	1998	0 7176 1484 0
	Other Accident/Incident reports:		
	Fire and explosions at BandR Hauliers, Salford 25-9-82	1983	0 11 883702 8
	Fire at Allied Colloids, Bradford on 21 July 1992	1994	0 7176 0707 0
	Fire at Hickson and Welch	1994	0 7176 0702 X
	A report of the investigations into the fires and explosions at BP Oil, Grangemouth and Dalmeny, 13 and 22 March and 11 June 1987	1989	0 11 885493 3
	A report of the HSE investigation into the chemical release and fire at the Associated Octel Comp. Ltd.	1996	0 7176 0830 1
	The explosion and fires on the Pembroke Cracking Company plant at the Texaco refinery, Milford Haven on 24 July 1994	1997	0 7176 1413 1
HSG51	The storage of flammable liquids in containers	1998	0 7176 1471 9
HSG135	Storage and handling of industrial nitrocellulose	1995	0 7176 0694 5
HSG71	Chemical warehousing – Storage of packaged dangerous substances (Revised)	1998	0 7176 1484 0
HSG158	Flame arresters – Preventing the spread of fires and explosions in equipment that contains flammable gases and vapours	1996	0 7176 1191 4
HSG176	The storage of flammable liquids in tanks	1998	0 7176 1470 0
HSG186	The bulk transfer of dangerous liquids and gases between ship and shore	1999	0 7176 1644 4
INDG230	Storage and handling ammonium nitrate	1996	Single copy available
CS3	Storage and use of sodium chlorate and other similar strong oxidants	1998	0 7176 1500 6
CS15	Cleaning and gas freeing of tanks containing flammable residues	1985	0 7176 1365 8
CS18	Storage and handling of ammonium nitrate	1986	0 11 883937 3
CS21	Storage and handling of organic peroxides	1991	0 7176 2403 X

## 8.2. Dangerous substances and classification

[84, TETSP, 2001]

**Warning to the reader:** the contents of this annex reflects the status of the regulations at April 1<sup>st</sup>, 2001. This annex will need to be updated in the future according to the changes, which will occur to the regulation on classification of dangerous substances after this date.

### 1 Background

The classification of dangerous substances is the process of identifying their hazardous properties by using appropriate test methods, and allocating them to one or more hazard classes by comparing the results of the tests with the classification criteria. Preparations or mixtures may be classified either by testing or by applying calculation methods based upon the concentration of their hazardous components.

It should be noted that the classification systems described in this chapter do not necessarily cover all the criteria required for dangerous goods storage legislation in all Member States of the European Union. For example, in parts of Belgium, storage legislation covers flashpoints up to 250 °C.

### 2 Regulatory classification systems

In Europe there are two main regulatory classification systems that provide information that may be relevant to the storage of dangerous goods and the nature of their hazards.

#### 2.1 European Union supply legislation

There are two primary Directives;

- 67/548/EEC – Dangerous Substances Directive as amended
- 1999/45/EC – Dangerous Preparations Directive as amended.

A further relevant Directive is 91/155/EEC Safety Data Sheet Directive as amended.

#### 2.2 Transport legislation

The basis for transport legislation worldwide is the United Nations Recommendations on the Transport of Dangerous Goods (UN RTDG), commonly known as the ‘Orange Book’. These are recommendations, not regulations, and as such have no legal force. However they are implemented by international transport modal regulations as follows;

- sea , global: IMDG Code
- air, global: ICAO Technical Instructions
- road, Europe: ADR Agreement
- rail , Europe: RID Agreement.

In Europe, ADR and RID are implemented at national level through the following Directives;

- road: 94/55/EC on the approximation of the laws of the Member States with regard to the transport of dangerous goods by road. (ADR Framework Directive)
- rail: 96/49/EC on the approximation of the laws of the Member States with regard to the transport of dangerous goods by rail. (RID Framework Directive).

As there are differences in the level of risk encountered in each transport mode, the international transport modal regulations do not fully replicate the UN RTDG. Therefore there are slight differences between them. For the purposes of this chapter, any references regarding transport are to the UN RTDG unless otherwise stated.

### 3 Scope of regulatory classification systems

Classification systems classify dangerous goods into three distinct groups of hazards;

- physico-chemical hazards
- health hazards
- environmental hazards.

Within each of these groups of hazards, there are individual hazard classes and further differentiation into levels of hazard. The scope of the two regulatory systems differs.

#### 3.1 European supply system

The European Supply system classifies dangerous goods into the following hazard classes:

physico-chemical hazards:

- explosive
- oxidising
- flammable.

health hazards:

- acute toxicity - lethal and irreversible effects after a single exposure
- sub-acute, sub-chronic or chronic toxicity
- corrosive and irritant
- sensitising
- specific effects on health:
  - carcinogenicity
  - mutagenicity
  - reproductive toxicity.

environmental hazards:

- aquatic environment
- non-aquatic environment.

Environmental Hazards for the non-aquatic environment includes substances listed in Annex I to Council Regulation (EC) No 2037/2000 on substances that deplete the ozone layer, and preparations containing them. Currently there are no classification criteria for Environmental Hazards for the non-aquatic environment in the primary Directives.

Annex V of the Dangerous Substances Directive 67/548/EEC contains the tests and procedures for classification.

There is differentiation into levels of hazard in a number of the hazard classes.



### 3.2 UN RTDG transport system

The UN RTDG Transport system covers substances, mixtures (preparations) and also articles such as batteries (articles are not covered by the EU supply system). It deals with immediate hazards arising from a single exposure, and therefore health hazards in this system only include acute effects. All dangerous goods that are classified are assumed to be environmentally hazardous, but at present there are no separate criteria for this hazard. The ADR and RID modal regulations do contain criteria for aquatic toxicity and covers substances that are not otherwise classified. This is based on a subset of the EU supply criteria. The IMDG Code has its own system that can classify any substance as a severe marine pollutant or marine pollutant, but mixtures can only be classified as a marine pollutant. The UN RTDG Transport system also includes other hazards not covered by the EU supply system, i.e. gases that are compressed, liquefied, refrigerated or in solution, biological hazards and radioactive materials. The UN RTDG is also more comprehensive than the EU supply system in describing physico-chemical hazards.

The UN RTDG Transport system classifies into the following hazard classes and ‘Divisions’ of hazard classes as follows:

#### Class 1 - Explosives

- Division 1.1 substances and articles, which have a mass explosion hazard
- Division 1.2 substances and articles, which have a projection hazard but not a mass explosion hazard;
- Division 1.3 substances and articles, which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard. This comprises substances and articles:
  - (i) which give rise to considerable radiant heat; or
  - (ii) which burn one after another, producing minor blast or projection effects or both;
- Division 1.4 substances and articles which present no significant hazard
- Division 1.5 very insensitive substances which have a mass explosion hazard
- Division 1.6 extremely insensitive articles which do not have a mass explosion hazard

#### Class 2 - Gases

- Division 2.1 flammable gases
- Division 2.2 non-flammable, non-toxic gases (includes oxidising gases)
- Division 2.3 toxic gases (includes corrosive gases)

#### Class 3 - Flammable liquids

#### Class 4 - Flammable solids; substances liable to spontaneous combustion; substances which, in contact with water, emit flammable gases

- Division 4.1 flammable solids, self-reactive and related substances and desensitised explosives
- Division 4.2 substances liable to spontaneous combustion
- Division 4.3 substances which in contact with water emit flammable gases

#### Class 5 - Oxidising substances and organic peroxides

- Division 5.1 oxidising substances
- Division 5.2 organic peroxides

## **Class 6 - Toxic and infectious substances**

Division 6.1 toxic substances

Division 6.2 infectious substances

## **Class 7 - Radioactive material**

## **Class 8 - Corrosive substances**

## **Class 9 - Miscellaneous dangerous substances and articles (includes environmental hazards for dangerous goods not already classified in classes 1 to 8).**

The UN RTDG Manual of Tests and Criteria contains the test methods, procedures and criteria for the classification of dangerous goods for transport.

In most hazard classes there is differentiation into hazard levels, called packing groups. Packing groups are also used to determine the standard of packaging required, but because of the properties of explosives, self-reactive substances and organic peroxides, the packing group does not reflect the level of hazard of these.

### **4 Hazard communication within regulatory classification systems**

Hazard communication within the two main regulatory systems described in this chapter also differs.

In the EU supply system, the immediate hazard communication is by a label, and there are rules by which the requirements for most of the following label elements are determined:

- chemical name of a substance or the trade name or designation of a preparation
- chemical name of substances present in a preparation
- danger symbol(s) (pictogram in a square box on an orange background)
- indication(s) of danger
- risk phrases (R phrases)
- safety advice (S phrases)
- nominal quantity (nominal mass or nominal volume) if for sale to the general public
- EC Number for substances
- name, address and telephone number to contact for emergency information.

In the EU supply system, more detailed information is contained in the safety data sheet. The safety data sheet should always be considered as the primary source of hazard communication information for all purposes, and, in particular, storage.

In the UN RTDG, the label, UN number and proper shipping name on the packaging containing the dangerous goods provide the immediate information. The label is a diamond shape (a square on its point) containing a pictogram in the upper half. The colour of the label varies according to the hazard class. The IMDG Code has a marine pollutant label, a triangle (top half of the transport diamond) on a horizontal base. The UN RTDG lists UN numbers and the rules for deriving the proper shipping name. The proper shipping name is usually the name of the chemical, or the main chemicals leading to the classification, but the European road and rail regulations, ADR and RID, do not require this. In transport, there are different means of providing the more detailed information, but ADR and RID usually provide it in the form of a TREMcard (TRANSPORT EMERGENCY card). Emergency services make use of the transport label and UN number as a primary source of immediate information.

## 5 Physico-chemical hazards

### 5.1 Explosive hazards

#### 5.1.1 EU system

Explosives are assigned the danger symbol below and the indication of danger ‘explosive’:



One of the following risk phrases is obligatory;

- R2 risk of explosion by shock, friction, fire or other sources of ignition  
 R3 extreme risk of explosion by shock, friction, fire or other source of ignition.

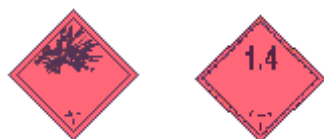
#### 5.1.2 UN RTDG transport system

Part I of the UN RTDG Manual of Tests and Criteria contains further tests, grouped into seven series, to determine the correct division in Class 1 for explosives.

Explosives are defined as:

- (a) explosive substance is a solid or liquid substance (or a mixture of substances) which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings. Pyrotechnic substances are included even when they do not evolve gases
- (b) pyrotechnic substance is a substance or a mixture of substances designed to produce an effect by heat, light, sound, gas or smoke or a combination of these as the result of non-detonative self-sustaining exothermic chemical reactions
- (c) explosive article is an article containing one or more explosive substances.

Substances classified as explosives of Divisions 1 to 3 are assigned a label containing a bomb symbol, and Substances of Divisions 4 to 6 are assigned a label without the ‘bomb’ symbol, but containing the Division number as per the following label examples:



### 5.2 Oxidising and organic peroxide hazards

#### 5.2.1 EU system

This classification covers organic peroxides, inorganic peroxides and other oxidising substances. For organic peroxides, the tests and criteria in Annex V of the Dangerous Substances Directive 67/548/EEC can be used to determine their explosive properties, but not their oxidising properties. Organic peroxide substances not classified as explosive are classified on the basis of their structure, and preparations are classified using a calculation method based on the percentage of active oxygen. Any organic peroxide or preparation is classified as oxidising, if the peroxide or its formulation contains:

- more than 5 % of organic peroxides, or
- more than 0.5 % available oxygen from the organic peroxides, and more than 5 % hydrogen peroxide.

They are assigned the danger symbol below and the indication of danger ‘oxidising’;



One of the following risk phrases is obligatory;

- R7 may cause fire
- R8 contact with combustible material may cause fire
- R9 explosive when mixed with combustible material.

### 5.2.2 UN RTDG transport system

The UN RTDG classifies oxidising substances and organic peroxides separately.

#### (a) Division 5.1 *Oxidising substances*

These are defined as substances that, while in themselves are not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other material.

Classification distinguishes between solids, liquids and gases. For solids and liquids only, three levels of hazard are differentiated. The oxidising ability of gases is determined either by tests or by calculation methods adopted by ISO.

#### (b) Division 5.2 *Organic peroxides*

These are defined as Organic substances which contain the bivalent -O - O- structure and may be considered to be derivatives of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals.

Organic peroxides are thermally unstable substances, which may undergo exothermic self-accelerating decomposition. In addition, they may have one or more of the following properties:

- be liable to explosive decomposition
- burn rapidly
- be sensitive to impact or friction
- react dangerously with other substances
- cause damage to the eyes.

Classification distinguishes between Solids and Liquids, and seven levels of hazard (Types A to G) are differentiated, but Type G is not regulated for transport.

Both oxidising substances and organic peroxides of types A to F are assigned the same label, which is a flame over an ‘O’;



Some organic peroxides may be subject to temperature control requirements or may have been desensitised by the use of compatible diluents, such as organic liquids or solids, inorganic solids or water so that, in case of spillage or fire, the organic peroxide will not concentrate to a dangerous extent.

### 5.3 Flammability hazards

#### 5.3.1 EU system

##### Liquids

Classification differentiates into three hazard levels:

- (a) extremely flammable liquids having a flashpoint lower than 0 °C and boiling point or initial boiling point lower than or equal to 35 °C

They are assigned the symbol below and the indication of danger 'extremely flammable':



The following risk phrase is obligatory: R12 extremely flammable.

- (b) highly flammable liquids having a flashpoint below 21 °C and not classified as extremely flammable

They are assigned the symbol below and the indication of danger 'highly flammable':



The following risk phrase is obligatory: R11 highly flammable.

- (c) Flammable liquids having a flashpoint equal to or greater than 21 °C, and less than or equal to 55 °C. However, preparations do not have to be classified as flammable if the preparation does not support combustion and there is no reason to fear risks to those handling the preparations or to other persons.

There is no symbol or indication of danger.

The following risk phrases is obligatory: R10 flammable.

##### Solids

There is a single hazard level for solids which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition.

They are assigned the symbol below and the indication of danger 'highly flammable':



The following risk phrase is obligatory: R11 highly flammable.

### **Gases**

There is a single hazard level for gases that are flammable in contact with air at ambient temperature and pressure.

They are assigned the symbol below and the indication of danger ‘extremely flammable’:



The following risk phrase is obligatory: R12 extremely flammable.

### **Pyrophoric/self heating**

There is a single hazard level for dangerous goods which may become hot and finally catch fire in contact with air at ambient temperature without any input of energy.

They are assigned the symbol below and the indication of danger ‘highly flammable’:



The following risk phrase is obligatory: R17 spontaneously flammable in air.

### **Water reactive evolving flammable gases**

There is a single hazard level for water reactive dangerous goods that, in contact with water or damp air, evolve extremely flammable gases at a minimum rate of one litre per kilogram per hour.

They are assigned the symbol below and the indication of danger ‘highly flammable’:



The following risk phrase is obligatory: R15 contact with water liberates extremely flammable gases.

## **5.3.2 UN RTDG transport system**

### **Liquids**

Flammable liquids are defined as liquids, or mixtures of liquids, or liquids containing solids in solution or suspension, e.g. paints, which give off a flammable vapour at temperatures of not more than 60.5 °C, closed-cup test, or not more than 65.6 °C, open-cup test, normally referred to as the flashpoint.

Classification differentiates into three hazard levels:

- (a) high danger – packing group I

Flammable liquids having a boiling point or initial boiling point lower than or equal to 35 °C.

- (b) medium danger – packing group II

Flammable liquids having a boiling point or initial boiling point greater than 35 °C and a flashpoint below 23 °C

- (c) low danger – packing group III.

Flammable liquids having a boiling point or initial boiling point greater than 35 °C, and a flashpoint equal to or greater than 23 °C, and less than or equal to 60.5 °C. However, such liquids with a flashpoint of more than 35 °C which do not sustain combustion may not have been classified as flammable liquids. Liquids are considered to be unable to sustain combustion (i.e. they do not sustain combustion under defined test conditions) if:

- (i) they have passed a suitable combustibility test (see UN RTDG Manual of Tests and Criteria)
- (ii) their fire point according to ISO 2592:1973 is greater than 100 °C, or
- (iii) they are water miscible solutions with a water content of more than 90 % by mass.

All hazard levels of flammable liquids are assigned the same label:



Note: In the UN RTDG due to various derogations, the packing group is not always a true guide as to the flammability or flashpoint range of preparations/mixtures for storage purposes.

- (a) there are provisions in the UN RTDG allowing viscous liquid mixtures having a flashpoint of less than 23 °C to be placed in the low danger category, packing group III. This is usually on the basis of a combination of some of the following conditions:
- the viscosity expressed as the flow time in seconds
  - the closed-cup flashpoint
  - less than 3 % of the clear solvent layer separates in a solvent separation test, and
  - no content of any substance classified for acute toxicity in Division 6.1 or corrosivity in class 8.
- (b) in the UN RTDG, viscous preparations/mixtures in the low danger category, packing group III, may not have been regulated if:
- the flashpoint of 23 °C or above and less than or equal to 60.5 °C
  - they are not also classified for acute toxicity in Division 6.1 or corrosivity in Class 8
  - they contain no more than 20 % nitrocellulose provided the nitrocellulose contains no more than 12.6 % nitrogen by dry mass, and
  - they are packed in receptacles of less than 450 l capacity.

and:

- less than 3 % of the clear solvent layer separates in a solvent separation test, and
- the flow time in the viscosity test with a jet diameter of 6 mm is equal to or greater than:
  - 60 seconds, or
  - 40 seconds if the viscous preparations/mixture contains not more than flammable liquids.

**Note:** These provisions are not applied consistently across all the modal regulations.

### **Solids**

Flammable solids are defined as readily combustible solids which are powdered, granular, or pasty substances which are dangerous if they can be easily ignited by brief contact with an ignition source, such as a burning match, and if the flame spreads rapidly. The danger may come not only from the fire but also from toxic combustion products. Metal powders are especially dangerous because of the difficulty of extinguishing a fire since normal extinguishing agents such as carbon dioxide or water can increase the hazard.

Solids which may cause fire through friction are also defined as flammable solids and are classified by analogy with existing entries (e.g. matches).

Classification differentiates into two hazard levels:

- (a) medium danger – packing group II
- (b) low danger – packing group III.

Both hazard levels of flammable solids are assigned the same label:



### **Gases**

Flammable gases are defined as gases which at 20 °C and standard pressure of 101.3 kPa:

- are ignitable when in a mixture of 13 per cent or less by volume with air, or
- have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit.

Flammability is generally determined by tests or by calculation in accordance with methods adopted by ISO (see ISO 10156:1996). For transport this classification includes aerosols and small receptacles containing gas.

Hazard levels of gases are not differentiated. They are assigned the label below:





### **Self-reactive and related substances**

Self-reactive substances are defined as thermally unstable substances liable to undergo a strongly exothermic decomposition even without participation of oxygen. Substances are not considered to be self-reactive substances if:

- they are explosives
- they are oxidising
- they are organic peroxides
- their heat of decomposition is less than 300 J/g, or
- the self-accelerating decomposition temperature is greater than 75 °C for a 50 kg package.

Substances related to self-reactive substances are defined as having a self-accelerating decomposition temperature greater than 75 °C. They can undergo a strongly exothermic decomposition and are liable, in certain packagings, to meet the criteria for explosives.

The decomposition of self-reactive substances can be initiated by heat, contact with catalytic impurities (e.g. acids, heavy-metal compounds, bases), friction or impact. The rate of decomposition increases with temperature and varies with the substance. Decomposition, particularly if no ignition occurs, may result in the evolution of toxic gases or vapours. For certain self-reactive substances, the temperature has to be controlled. Some self-reactive substances may decompose explosively, particularly if confined. This characteristic may be modified by the addition of diluents or by the use of appropriate packagings. Some self-reactive substances burn vigorously. Self-reactive substances are, for example, some compounds of the types listed below:

- aliphatic azo compounds (-C-N=N-C-)
- organic azides (-C-N<sub>3</sub>)
- diazonium salts (-CN<sub>2</sub>+Z-)
- N-nitroso compounds (-N-N=O), and
- aromatic sulphohydrazides (-SO<sub>2</sub>-NH-NH<sub>2</sub>).

Classification differentiates into seven levels of hazard (types A to G), but type G is not regulated for transport.

Types A to F are assigned the label below:



Some self-reactive substances may be desensitised through the use of a diluent. Diluents should not allow a self-reactive substance to concentrate to a dangerous extent in the event of leakage. The diluent has to be compatible with the self-reactive substance. Compatible diluents are those solids or liquids which have no detrimental influence on the thermal stability and hazard type of the self-reactive substance.

Some self-reactive substances may be subject to temperature control requirements. Liquid diluents in liquid formulations requiring temperature control have to have a boiling point of at least 60 °C and a flashpoint not less than 5 °C. The boiling point of the liquid has to be at least 50 °C higher than the control temperature of the self-reactive substance.

**Desensitised explosives**

Desensitised explosives are substances which are wetted with water or alcohols or are diluted with other substances to suppress their explosive properties.

They are assigned the label below:

**Pyrophoric/self heating**

Pyrophoric and self-heating substances are defined as:

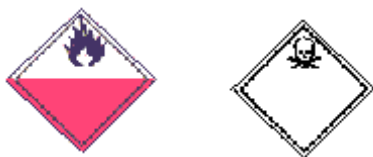
- pyrophoric substances are liquid or solid dangerous goods which even in small quantities ignite within five minutes of coming into contact with air. These are liable to spontaneous combustion
- self-heating substances are liquid or solid dangerous goods, other than pyrophoric substances, which in contact with air without energy supply are liable to self-heating. These substances will ignite only when in large amounts (kilograms) and after long periods of time (hours or days) and are called self-heating substances.

Self-heating of dangerous goods, leading to spontaneous combustion, is caused by reaction of the substance with oxygen and the heat developed not being conducted away rapidly enough to the surroundings. Spontaneous combustion occurs when the rate of heat production exceeds the rate of heat loss and the auto-ignition temperature is reached.

Classification differentiates into three hazard levels:

- |     |               |                   |                          |
|-----|---------------|-------------------|--------------------------|
| (a) | high danger   | packing group I:  | pyrophoric substances    |
| (b) | medium danger | packing group II  | self-heating substances  |
| (c) | low danger    | packing group III | self-heating substances. |

All hazard levels of pyrophoric and self-heating substances are assigned the same labels:

**Water reactive evolving flammable gases**

These are defined as substances which in contact with water may emit flammable gases that can form explosive mixtures with air. Such mixtures are easily ignited by all ordinary sources of ignition, for example naked lights, sparking hand tools or unprotected light bulbs. The resulting blast wave and flames may endanger people and the environment.

Classification differentiates into three hazard levels based on the rate of evolution of the flammable gases:

(a) high danger packing group I

Evolution of flammable gases at a minimum rate of ten litres per kilogram per minute.

(b) medium danger packing group II

Evolution of flammable gases at a minimum rate of twenty litres per kilogram per hour.

(c) low danger packing group III

Evolution of flammable gases at a minimum rate of one litre per kilogram per hour.

All hazard levels of these water reactive substances are assigned the same label:



## 5.4 Other physico-chemical properties

### 5.4.1 EU system

The EU system uses additional risk phrases that are applicable to dangerous goods, which are already classified. These risk phrases do not represent a classification. They are:

R1 explosive when dry

For explosive dangerous goods put on the market in solution or in a wetted form, e.g. nitrocellulose with more than 12.6 % nitrogen.

R4 forms very sensitive explosive metallic compounds

For dangerous goods which may form sensitive explosive metallic derivatives, e.g. picric acid, styphnic acid.

R5 heating may cause an explosion

For thermally unstable dangerous goods not classified as explosive, e.g. perchloric acid > 50 %.

R6 explosive with or without contact with air

For dangerous goods which are unstable at ambient temperatures, e.g. acetylene.

R7 may cause fire

For reactive dangerous goods, e.g. fluorine, sodium hydrosulphite.

R14 reacts violently with water

For dangerous goods which react violently with water, e.g. acetyl chloride, alkali metals, titanium tetrachloride.

R16 explosive when mixed with oxidising substances

For dangerous goods which react explosively with an oxidising agent, e.g. red phosphorus.

R18 in use, may form flammable/explosive vapour-air mixture

For preparations not classified as flammable, which contain volatile components which are flammable in air.

R19 may form explosive peroxides

For dangerous goods which may form explosive peroxides during storage, e.g. diethyl ether, 1,4-dioxan.

R30 can become highly flammable in use

For preparations not classified as flammable, but which may become flammable due to the loss of non-flammable volatile components.

R44 risk of explosion if heated under confinement

For dangerous goods not classified as explosive, but which may nevertheless display explosive properties in practice if heated under sufficient confinement. For example, certain substances which would decompose explosively if heated in a steel drum do not show this effect if heated in less-strong containers.

#### 5.4.2 UN RTDG transport system

##### Corrosivity to metal

**Note:** There is no equivalent criteria in the EU system.

This is defined as exhibiting a corrosion rate on steel or aluminium surfaces exceeding 6.25 mm a year at a test temperature of 55 °C.

For the purposes of testing steel, type P235 (ISO 9328 (II):1991) or a similar type, and for testing aluminium, non-clad types 7075-T6 or AZ5GU-T6 shall be used. An acceptable test is prescribed in ASTM G31-72 (Reapproved 1990).

Only one hazard level, packing group III is differentiated, which is assigned the same level as for corrosive to living tissue;



##### Gases

The UN RTDG also classifies gases in other physical forms as listed below:

- compressed gas - a gas (other than in solution) which when packaged under pressure for transport is entirely gaseous at 20 °C
- liquefied gas - a gas which when packaged for transport is partially liquid at 20 °C
- refrigerated liquefied gas - a gas which when packaged for transport is made partially liquid because of its low temperature, or
- gas in solution - compressed gas which when packaged for transport is dissolved in a solvent.

This covers: compressed gases; liquefied gases; gases in solution; refrigerated liquefied gases; mixtures of gases; mixtures of one or more gases with one or more vapours of substances of other classes; articles charged with a gas; tellurium hexafluoride; aerosols.

## 6 Health hazards

### 6.1 Acute toxicity

#### 6.1.1 EU system

Three routes of exposure are considered:

- oral
- dermal
- inhalation.

and these are differentiated into three levels of hazard:

- very toxic
- toxic
- harmful.

### **Oral toxicity**

The criteria for the highest level of hazard, 'very toxic', are:

- LD50 oral, rat < 25 mg/kg
- less than 100 % survival at 5 mg/kg oral, rat by the fixed dose procedure, or high mortality at doses < 25 mg/kg oral, rat, by the acute toxic class method.

The following risk phrase is obligatory: R28 very toxic if swallowed.

The criteria for the second level of hazard, 'toxic' are:

- LD50 oral, rat: 25 < LD50 < 200 mg/kg
- Discriminating dose, oral, rat, 5 mg/kg: 100 % survival but evident toxicity, or
- high mortality in the dose range > 25 to < 200 mg/kg oral, rat, by the acute toxic class method.

The following risk phrase is obligatory: R25 toxic if swallowed.

There are two different criteria for the lowest level of hazard, 'harmful', which are:

(i) 'acute oral toxicity':

- LD50 per oral, rat: 200 < LD50 < 2000 mg/kg
- discriminating dose, oral, rat, 50 mg/kg: 100 % survival but evident toxicity
- less than 100 % survival at 500 mg/kg, rat oral by the fixed dose procedure, or
- high mortality in the dose range > 200 to < 2000 mg/kg oral, rat, by the acute toxic class method.

The following risk phrase is obligatory: R22 harmful if swallowed.

(ii) 'aspiration hazard'

This is defined as liquid substances and preparations presenting an aspiration hazard in humans because of their low viscosity:

- (a) for substances and preparations containing aliphatic, alicyclic and aromatic hydrocarbons in a total concentration equal to or greater than 10 % and having either:
- a flow time of less than 30 sec. in a 3 mm ISO cup according to ISO 2431 (April 1996/July 1999 edition) relating to 'Paints and varnishes - Determination of flow time by use of flow cups'

- a kinematic viscosity measured by a calibrated glass capillary viscometer in accordance with ISO 3104/3105 of less than  $7 \times 10^{-6} \text{ m}^2/\text{sec}$  at  $40 \text{ }^\circ\text{C}$  (ISO 3104, 1994 edition, relating to 'Petroleum products - Transparent and opaque liquids - Determination of kinematic viscosity and calculation of dynamic viscosity'; ISO 3105, 1994 edition, relating to 'Glass capillary kinematic viscometers - Specifications and operating instructions'), or
- a kinematic viscosity derived from measurements of rotational viscometry in accordance with ISO 3219 of less than  $7 \times 10^{-6} \text{ m}^2/\text{sec}$  at  $40 \text{ }^\circ\text{C}$  (ISO 3219, 1993 edition, relating to 'Plastics – Polymers/resins in the liquid state or as emulsions or dispersions - Determination of viscosity using a rotational viscometer with defined shear rate')
- Note that substances and preparations meeting these criteria need not be classified if they have a mean surface tension greater than  $33 \text{ mN/m}$  at  $25 \text{ }^\circ\text{C}$  as measured by the du Nouy tensiometer or by the test methods shown in Annex V Part A.5.

(b) for substances and preparations, based on practical experience in humans.

The following risk phrase is obligatory: R65 harmful: may cause lung damage if swallowed.

### **Dermal toxicity**

The criteria for the highest level of hazard, 'very toxic', is:

- LD50 dermal, rat or rabbit:  $< 50 \text{ mg/kg}$ .

The following risk phrase is obligatory: R27 very toxic in contact with skin.

The criteria for the second level of hazard, 'toxic', is:

- LD50 dermal, rat or rabbit:  $50 < \text{LD50} < 400 \text{ mg/kg}$ .

The following risk phrase is obligatory: R24 toxic in contact with skin.

The criteria for the lowest level of hazard, 'harmful', is:

- LD50 dermal, rat or rabbit:  $400 < \text{LD50} < 2000 \text{ mg/kg}$ .

The following risk phrase is obligatory: R21 harmful in contact with skin.

### **Inhalation toxicity**

The criteria for the highest level of hazard, 'very toxic', is:

- LC50 inhalation, rat, for aerosols or particulates:  $< 0.25 \text{ mg/litre/4hr}$
- LC50 inhalation, rat, for gases and vapours:  $< 0.5 \text{ mg/litre/4hr}$ .

The following risk phrase is obligatory: R26 very toxic by inhalation.

The criteria for the second level of hazard, 'toxic', is:

- LC50 inhalation, rat, for aerosols or particulates:  $0.25 < \text{LC50} < 1 \text{ mg/litre/4hr}$ ,
- LC50 inhalation, rat, for gases and vapours:  $0.5 < \text{LC50} < 2 \text{ mg/litre/4hr}$ .

The following risk phrase is obligatory: R23 toxic by inhalation.

The criteria for the lowest level of hazard, 'harmful', is:

- LC50 inhalation, rat, for aerosols or particulates:  $1 < LC50 < 5$  mg/litre/4hr,
- LC50 inhalation, rat, for gases or vapours:  $2 < LC50 < 20$  mg/litre/4hr.

The following risk phrase is obligatory: R20 harmful by inhalation.

Acute Health Effects are assigned danger symbols and indications of danger as below:

Hazard level 1 is assigned the indication of danger 'very toxic' and the danger symbol:



Hazard level 2 is assigned the indication of danger 'toxic' and the danger symbol:



Hazard level 3 is assigned the indication of danger 'harmful' and the danger symbol:



### 6.1.2 UN RTDG transport system

The UN Transport system only classifies dangerous goods as posing health hazards when the effect is from a single exposure. Toxic dangerous goods are defined as substances liable either to cause death or serious injury or to harm human health if swallowed or inhaled or by skin contact. Except for Gases, these are differentiated into three levels of hazard.

- |       |                   |  |
|-------|-------------------|--|
| (i)   | packing group I   | substances and preparations presenting a very severe toxicity risk     |
| (ii)  | packing group II  | substances and preparations presenting a serious toxicity risk         |
| (iii) | packing group III | substances and preparations presenting a relatively low toxicity risk. |

For inhalation toxicity, vapours, dusts and mists (Division 6.1) are treated differently to gases (Division 2.3).

#### **Oral toxicity**

The criteria for classification are currently:

- |       |                            |                        |
|-------|----------------------------|------------------------|
| (i)   | packing group I            | LD50 < 5 mg/kg         |
| (ii)  | packing group II           | 5 < LD50 < 50 mg/kg    |
| (iii) | packing group III, solids  | 50 < LD50 < 200 mg/kg  |
| (iv)  | packing group III, liquids | 50 < LD50 < 500 mg/kg. |

**Dermal toxicity**

The criteria for classification are currently:

- |       |                           |                          |
|-------|---------------------------|--------------------------|
| (i)   | packing group I           | LD50 < 40 mg/kg          |
| (ii)  | packing group II          | 40 < LD50 < 200 mg/kg    |
| (iii) | packing group III, solids | 200 < LD50 < 1000 mg/kg. |

**Inhalation toxicity – dusts and mists**

The criteria for classification are currently:

- |       |                           |                             |
|-------|---------------------------|-----------------------------|
| (i)   | packing group I           | LC50 < 0.5 mg/litre/1hr     |
| (ii)  | packing group II          | 0.5 < LC50 < 2 mg/litre/1hr |
| (iii) | packing group III, solids | 2 < LC50 < 10 mg/litre/1hr. |

Whereas the corresponding EU supply criteria is based on 4 hour exposure figures, the corresponding UN RTDG, criteria for inhalation toxicity of dusts and mists are based on LC50 data relating to 1 hour exposures. Where only LC50 data relating to 4 hours exposures are available, these figures are multiplied by four and the product substituted in the above criteria, i.e. LC50 (4 hours) × 4 is considered the equivalent of LC50 (1 hour).

**Inhalation toxicity –vapours**

In the UN RTDG system the volatility of liquids is taken into account in the classification criteria. Liquids having toxic vapours are assigned to the following packing groups, where 'V' is the saturated vapour concentration in millilitres per cubic metre of air at 20 °C and at standard atmospheric pressure:

- |       |                   |   |
|-------|-------------------|---|
| (i)   | packing group I   | if $V > 10 LC50$ and $LC50 < 1000 \text{ ml/m}^3$   |
| (ii)  | packing group II  | if $V > LC50$ and $LC50 < 3000 \text{ ml/m}^3$ , and not meeting the criteria for packing group I             |
| (iii) | packing group III | if $V > 1/5 LC50$ and $LC50 < 5000 \text{ ml/m}^3$ , and not meeting the criteria for packing groups I or II. |

Whereas the corresponding EU supply criteria is based on mg/litre 4 hour exposure figures, the corresponding UN RTDG, criteria for inhalation toxicity of vapours are based on LC50 data relating to 1 hour exposures expressed as millilitres per cubic metre. Where only LC50 data relating to 4 hours exposures are available, these figures are multiplied by two and the product substituted in the above criteria, i.e. LC50 (4 hours) × 2 is considered the equivalent of LC50 (1 hour).

**Inhalation toxicity –gases**

There is no differentiation into hazard levels and the criteria covers when the LC50 value is equal to or less than 5000 ml/m<sup>3</sup> (ppm)

Hazard communication for toxic substances in the UN RTDG

All physical states and hazard levels of toxic dangerous goods are assigned the same label:





## 6.2 Sub-acute, sub-chronic or chronic toxicity

**Note:** These hazards are not covered in the UN RTDG Transport system

### 6.2.1 Very serious irreversible effects by a single exposure

Three routes of exposure are considered:

- (i) oral
- (ii) dermal
- (iii) inhalation

and these are differentiated into three levels of hazard:

- (i) very toxic
- (ii) toxic
- (iii) harmful.

The criteria is that there is strong evidence that irreversible damage other than Carcinogenic, Mutagenic or Reproductive toxic (CMR) effects are likely to be caused by a single exposure by an appropriate route, generally in the same dose range as the equivalent for acute toxicity.

The following risk phrases are obligatory:

For hazard level one 'very toxic' and hazard level two 'toxic': R39 danger of very serious irreversible effects.

For Hazard Level three 'harmful': R40 (R68 from 30/07/2002) possible risk of irreversible effects.

In order to indicate the route of exposure, these risk phrases are used in combinations with the relevant acute toxicity risk phrase(s): R39/26, R39/27, R39/28, R39/26/27, R39/26/28, R39/27/28, R39/26/27/28, R39/23, R39/24, R39/25, R39/23/24, R39/23/25, R39/24/25, R39/23/24/25, R40/20, R40/21, R40/22, R40/20/21, R40/20/22, R40/21/22, R40/20/21/22.

Hazard level 1 is assigned the indication of danger 'very toxic', and hazard level 2 is assigned the indication of danger 'toxic' and both are assigned the danger symbol:



Hazard level 3 is assigned the indication of danger 'harmful', and the danger symbol:



### 6.2.2 Very serious irreversible effects by repeated or prolonged exposure

Three routes of exposure are considered:

- (i) oral
- (ii) dermal

(iii) inhalation

and these are differentiated into two levels of hazard:

(i) toxic

(ii) harmful.

The criteria is that there is serious damage (clear functional disturbance or morphological change which have toxicological significance) that is likely to be caused by repeated or prolonged exposure by an appropriate route.

Classification is as harmful when these effects are observed at levels of the order of:

- oral, rat < 50 mg/kg (bodyweight)/day
- dermal, rat or rabbit < 100 mg/kg (bodyweight)/day
- inhalation, rat < 0.25 mg/l, 6h/day.

These guide values are applied directly when severe lesions have been observed in a sub-chronic (90 days) toxicity test. When the results of a sub-acute (28 days) toxicity test have been used these figures are increased approximately three fold. If chronic (two years) toxicity test is available they are evaluated on a case-by-case basis. If results of studies of more than one duration are available, then those from the study of the longest duration are normally used. Classification is as at least as toxic when these effects are observed at levels of one order of magnitude lower (i.e. 10-fold) than those for harmful.

The following risk phrases are obligatory: For both hazard levels, the following risk phrase is obligatory: R48 danger of serious damage to health by prolonged exposure

In order to indicate the route of exposure, these risk phrases are used in combinations with the relevant Acute Toxicity risk phrase(s): R48/23, R48/24, R48/25, R48/23/24, R48/23/25, R48/24/25, R48/23/24/25, R48/20, R48/21, R48/22, R48/20/21, R48/20/22, R48/21/22, R48/20/21/22.

The highest hazard level is assigned the indication of danger 'toxic' and the danger symbol:



The lowest hazard level is assigned the indication of danger 'harmful', and the danger symbol:



### 6.3 Corrosive and irritant

**Note:** The UN RTDG Transport system only covers corrosive effects

#### 6.3.1 EU system - corrosive

Corrosive is defined as being if during the test when applied to healthy intact animal skin, full thickness destruction of skin tissue on at least one animal is produced.

Two levels of hazard are differentiated.

The criteria for the most severe hazard level is if, when applied to healthy intact animal skin, full thickness destruction of skin tissue occurs as a result of up to three minutes exposure.

The following risk phrase is obligatory: R35 causes severe burns.

The criteria for the less severe hazard level is if, when applied to healthy intact animal skin, full thickness destruction of skin tissue occurs as a result of up to four hours exposure.

The following risk phrase is obligatory: R34 causes burns.

Both hazard levels are assigned the indication of danger 'corrosive' and the danger symbol:



### 6.3.2 UN RTDG transport system

Corrosive dangerous goods are defined as substances which, by chemical action, will cause severe damage when in contact with living tissue.

**Note:** Although the definition refers to destruction of living tissue, the criteria only refers to destruction of skin tissue. Refer to physico-chemical hazards for corrosivity to metal.

Three levels of hazard are differentiated:

packing group I	is assigned to substances that cause full thickness destruction of intact skin tissue within an observation period up to 60 minutes starting after the exposure time of three minutes or less
packing group II	is assigned to substances that cause full thickness destruction of intact skin tissue within an observation period up to 14 days starting after the exposure time of more than three minutes but not more than 60 minutes
packing group III	is assigned to substances that cause full thickness destruction of intact skin tissue within an observation period up to 14 days starting after the exposure time of more than 60 minutes but not more than 4 hours.

The following label is assigned:



### 6.3.3 EU system - irritant

#### Skin

Dangerous goods are considered to be irritant if they cause significant inflammation of the skin which persists for at least 24 hours after an exposure period of up to four hours determined on the rabbit according to the cutaneous irritation test method, or if they cause significant

inflammation of the skin, based on practical observations in humans on immediate, prolonged or repeated contact.

The following risk phrase is obligatory: R38 irritating to skin.

### **Eyes**

Two hazard levels are differentiated.

- (i) serious damage to eyes (higher hazard level)
- (ii) irritating to eyes (lower hazard level).

Dangerous goods are classified if, when applied to the eye of the animal, cause significant ocular lesions which occur within 72 hours after exposure and which persist for at least 24 hours, or if they cause significant ocular lesions, based on practical experience in humans.

**Note:** When a substance or preparation is classified as corrosive and assigned R34 or R35, the risk of severe damage to eyes is considered implicit and R41 is not included in the label.

The following risk phrases are obligatory:

- (i) (higher hazard level) R41 risk of serious damage to eyes
- (ii) (higher hazard level) R36 irritating to eyes.

### **Respiratory system**

A single hazard level is differentiated.

Dangerous goods are classified based on:

- practical observation in humans
- positive results from appropriate animal tests.

The following risk phrase is obligatory: R37 irritating to respiratory system.

All these hazard levels and routes of exposure hazard levels are assigned the indication of danger 'irritant' and the danger symbol:



## **6.4 Sensitisation**

**Note:** These hazards are not covered in the UN RTDG transport system

### **Sensitisation by inhalation**

A single hazard level is differentiated.

Dangerous goods are classified as sensitising by inhalation:

- if there is evidence that they can induce specific respiratory hypersensitivity
- where there are positive results from appropriate animal tests, or
- if it is an isocyanate, unless there is evidence that the specific isocyanate does not cause respiratory hypersensitivity.

Evidence that the dangerous goods can induce specific respiratory hypersensitivity will normally be based on human experience. In this context hypersensitivity is normally seen as asthma, but other hypersensitivity reactions such as rhinitis and alveolitis are also considered. The condition will have the clinical character of an allergic reaction. However, immunological mechanisms do not have to be demonstrated.

The following risk phrase is obligatory: R42 may cause sensitisation by inhalation.

This is assigned the indication of danger 'harmful', and the danger symbol:



### **Sensitisation by skin contact**

A single hazard level is differentiated.

Dangerous goods are classified as sensitising by skin contact:

- if practical experience shows the dangerous goods to be capable of inducing a sensitisation by skin contact in a substantial number of persons, or
- where there are positive results from an appropriate animal test.

The following risk phrase is obligatory: R43 may cause sensitisation by skin contact.

This is assigned the indication of danger 'irritant', and the danger symbol:



## **6.5 Specific effects on health**

**Note:** These hazards are not covered in the UN RTDG transport system.

These are commonly known as CMR (Carcinogenic, Mutagenic and Reproductive toxic) effects). Each are differentiated into three levels of hazard. For the purpose of classification and labelling, and having regard to the current state of knowledge, they are divided into three categories. The placing into category 1 is done on the basis of epidemiological data; placing into categories 2 and 3 is based primarily on animal experiments.

Category 1 known to be CMR to man. There is sufficient evidence to establish a causal association between human exposure to a substance and the development of CMR effects

- Category 2 should be regarded as if they are CMR to man. There is sufficient evidence to provide a strong presumption that human exposure may result in the development of CMR effects, generally on the basis of:
- appropriate long-term animal studies
  - other relevant information
- Category 3 cause concern for man owing to possible CMR effects but in respect of which the available information is not adequate for making a satisfactory assessment. There is some evidence from appropriate animal studies, but this is insufficient to place the substance in category 2.

### **Carcinogenic**

The following risk phrases are obligatory:

- (i) (Category 1 and 2) R45, may cause cancer, or R49 may cause cancer by inhalation
- (ii) (Category 3) R40 limited evidence of a carcinogenic effect.

### **Mutagenic**

The following risk phrases are obligatory:

- (i) (Category 1 and 2) R46 may cause heritable genetic damage
- (ii) (Category 3) R68

### **Reproductive Toxic**

Reproductive toxic effects are considered for two different types of effects:

- fertility
- development.

The following risk phrases are obligatory:

#### **Fertility**

- (i) (Category 1 and 2) R60 may impair fertility
- (ii) (Category 3) R62 possible risk of impaired fertility.

#### **Development**

- (i) (Category 1 and 2) R61 may cause harm to the unborn child
- (ii) (Category 3) R63 possible risk of harm to the unborn child.

Dangerous goods which are classified as toxic to reproduction and which also cause concern due to their effects on lactation are in addition labelled with R64.

For each CMR effect of category 1 and 2 the following danger symbol is assigned:



For each CMR effect of category 3 the following danger symbol is assigned:



## 6.6 Other health effects

### 6.6.1 EU system

The EU system uses additional risk phrases that are applicable to dangerous goods, which are already classified. These risk phrases do not represent a classification. They are:

R29 Contact with water liberates toxic gas

For dangerous goods which in contact with water or damp air, evolve very toxic/toxic gases in potentially dangerous amounts.

R31 Contact with acids liberates toxic gas

For dangerous goods which react with acids to evolve toxic gases in dangerous amounts.

R32 Contact with acids liberates very toxic gas

For dangerous goods which react with acids to evolve very toxic gases in dangerous amounts.

R33 Danger of cumulative effects

For dangerous goods when accumulation in the human body is likely and may cause some concern.

R64 May cause harm to breastfed babies

For dangerous goods which are absorbed by women and may interfere with lactation or which may be present (including metabolites) in breast milk in amounts sufficient to cause concern for the health of a breastfed child.

R66 Repeated exposure may cause skin dryness or cracking

For dangerous goods which may cause concern as a result of skin dryness, flaking or cracking but which do not meet the criteria for R38 based on either:

- practical observation after normal handling and use, or
- relevant evidence concerning their predicted effects on the skin.

R67 Vapours may cause drowsiness and dizziness

For volatile dangerous goods containing substances which cause clear symptoms of central nervous system depression by inhalation and which are not already classified with respect to acute inhalation toxicity (R20, R23, R26, R68/20, R39/23 or R39/26).

### 6.6.2 UN RTDG transport system

The UN RTDG system classifies hazards that are not covered under the two prime EU Directives.

Division 6.2 Infectious substances

Infectious substances are defined as those substances known or reasonably expected to contain pathogens. Pathogens are defined as micro-organisms (including bacteria, viruses, rickettsia,

parasites, fungi) or recombinant micro-organisms (hybrid or mutant), that are known or reasonably expected to cause infectious disease in animals or humans.

They are classified on the basis of their allocation to one of three risk groups based on criteria developed by the World Health Organisation (WHO) and published in the WHO 'Laboratory Biosafety Manual, second edition (1993)'.

#### Class 7 Radioactive Materials

Radioactive materials are defined as any material containing radionuclides where both the activity concentration and the total activity in the consignment exceed the values specified in paragraphs 401 - 406 of the Regulations for the Safe Transport of Radioactive Material, (1996 Edition) IAEA Safety Standards Series No.ST-1.

### 7 Environmental hazards

#### 7.1 EU system

##### Aquatic toxicity

Substances classification is usually on the basis of experimental data for acute aquatic toxicity, degradation, and log Pow (or BCF if available). Classification of preparations is normally made by a calculation method based on the individual concentration limits of the components.

Classification differentiates into three hazard levels:

(a) very toxic

(i) acute aquatic toxicity criteria are:

- acute toxicity 96 hr LC50 (for fish) < 1 mg/l
- acute toxicity 48 hr EC50 (for Daphnia) < 1 mg/l, or
- acute toxicity 72 hr IC50 (for algae) < 1 mg/l.

The following risk phrase is obligatory: R50 very toxic to aquatic organisms.

(ii) acute/chronic aquatic toxicity

- acute toxicity 96 hr LC50 (for fish) < 1 mg/l
- acute toxicity 48 hr EC50 (for Daphnia) < 1 mg/l, or
- acute toxicity 72 hr IC50 (for algae) < 1 mg/l

and:

- the substance is not readily degradable, or
- the log Pow (log octanol/water partition coefficient) > 3.0 (unless the experimentally determined BCF < 100).

The following risk phrases are obligatory: R50 very toxic to aquatic organisms; and R53 may cause long-term adverse effects in the aquatic environment.

They are assigned the symbol below and the indication of danger 'dangerous for the environment'.





## (b) toxic - acute/chronic aquatic toxicity

- acute toxicity      96 hr LC50 (for fish)      1 mg/l < LC50 < 10 mg/l
- acute toxicity      48 hr EC50 (for Daphnia)      1 mg/l < EC50 < 10 mg/l, or
- acute toxicity      72 hr IC50 (for algae)      1 mg/l < IC50 < 10 mg/l

and:

- the substance is not readily degradable, or
- the log Pow (log octanol/water partition coefficient) > 3.0 (unless the experimentally determined BCF < 100).

The following risk phrases are obligatory: R51 toxic to aquatic organisms; and R53 may cause long-term adverse effects in the aquatic environment.

They are assigned the symbol below and the indication of danger 'dangerous for the environment'.



## (c) harmful

## (i) acute aquatic toxicity criterium is:

Substances not falling under the criteria listed above, but which on the basis of the available evidence concerning their toxicity may nevertheless present a danger to the structure and/or functioning of aquatic ecosystems.

The following risk phrase is obligatory: R52 harmful to aquatic organisms.

## (ii) acute/chronic aquatic toxicity:

- acute toxicity      96 hr LC50 (for fish)      10 mg/l < LC50 < 100 mg/l
- acute toxicity      48 hr EC50 (for Daphnia)      10 mg/l < EC50 < 100 mg/l, or
- acute toxicity      72 hr IC50 (for algae)      10 mg/l < IC50 < 100 mg/l

and

- the substance is not readily degradable

This criterion applies unless there exists additional scientific evidence concerning degradation and/or toxicity sufficient to provide an adequate assurance that neither the substance nor its degradation products will constitute a potential long-term and/or delayed danger to the aquatic environment.

The following risk phrases are obligatory: R52 harmful to aquatic organisms, and R53 may cause long-term adverse effects in the aquatic environment.

## (iii) chronic aquatic toxicity

Substances not falling under the criteria listed above in this chapter, but which, on the basis of the available evidence concerning their persistence, potential to accumulate, and predicted or observed environmental fate and behaviour may nevertheless present a long-term and/or delayed danger to the structure and/or functioning of aquatic ecosystems.

The following risk phrase is obligatory: R53 may cause long-term adverse effects in the aquatic environment.

### **Non-aquatic toxicity**

Dangerous goods are classified on the basis of the available evidence concerning their toxicity, persistence, potential to accumulate and predicted or observed environmental fate and behaviour may present a danger, immediate or long-term and/or delayed, to the structure and/or functioning of natural ecosystems. Detailed criteria is to be elaborated later.

One or more of the following risk phrases is obligatory as appropriate:

- R54 toxic to flora
- R55 toxic to fauna
- R56 toxic to soil organisms
- R57 toxic to bees
- R58 may cause long-term adverse effects in the environment.

Similarly regarding danger for the atmosphere, dangerous goods are classified on the basis of the available evidence concerning their properties and their predicted or observed environmental fate and behaviour may present a danger to the structure and/or the functioning of the stratospheric ozone layer. This includes the substances which are listed in Annex I to Council Regulation (EC) No 2037/2000 on substances that deplete the ozone layer (OJ No L 244, 29.9.2000, p.1) and its subsequent amendments.

The following risk phrases is obligatory: R59 dangerous for the ozone layer.

All of these are assigned the symbol below and the indication of danger ‘dangerous for the environment’.



## **7.2 UN RTDG transport system**

Currently the UN RTDG has no criteria for environmentally hazardous dangerous goods, although there is a placeholder for them in class 9 of the UN RTDG. In Europe the road and rail transport regulations classify for environmental hazards utilising the very toxic and toxic hazard levels from the EU system. This applies to substances and mixtures that are not otherwise classified for transport. The UN RTDG class 9 label is used to communicate this hazard.

For sea transport, the IMDG code classifies substances as either severe marine pollutants or marine pollutants, but mixtures can only classified as marine pollutants based on a content of 1 % or more of severe marine pollutants or 10 % or more of marine pollutants. The IMDG code system applies irrespective of whether the substances or mixtures are already classified for transport or not. This is essentially not a self-classification system for substances as IMO has a group of scientific experts, GESAMP, who have overall responsibility for the criteria and substance classifications. The label that is used is reproduced below (Note: in IMDG parlance this is called a mark rather than a label).



### 8.3. Compatibility of hazardous substances

		CLASS	2	3	4	5	6	8									
		<b>CLASS</b>															
COMPRESSED GASES	2.1 Flammable		KEEP APART	Segregate from DR KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	ISOLATE	Segregate from	Segregate from	KEEP APART	KEEP APART
	2.2 Non-Flammable/ non-toxic		KEEP APART	KEEP APART	KEEP APART	Separation may not be necessary	Segregate from	Separation may not be necessary	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
	2.3 Toxic		Segregate from DR KEEP APART	KEEP APART	Segregate from	KEEP APART	Segregate from	KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
FLAMMABLE LIQUIDS	3		Segregate from	KEEP APART	Segregate from	Segregate from	KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
FLAMMABLE SOLIDS	4		Segregate from	Separation may not be necessary	KEEP APART	KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
4.1 Readily combustible	4		Segregate from	Separation may not be necessary	KEEP APART	KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
4.2 Spontaneously combustible			Segregate from	Segregate from	Segregate from	Segregate from	KEEP APART	KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
4.3 Dangerous when wet			Segregate from	Separation may not be necessary	KEEP APART	Segregate from	Segregate from	KEEP APART	KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
OXIDISING SUBSTANCES	5		Segregate from	Separation may not be necessary	Separation may not be necessary	Segregate from	Segregate from	Segregate from	KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
5.1 Oxidising substances	5		Segregate from	Separation may not be necessary	Separation may not be necessary	Segregate from	Segregate from	Segregate from	KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
5.2 Organic peroxides			ISOLATE	Segregate from	Segregate from	ISOLATE	Segregate from	ISOLATE	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from	Segregate from
TOXIC SUBSTANCES	6		KEEP APART	Separation may not be necessary	Separation may not be necessary	KEEP APART	KEEP APART	KEEP APART	KEEP APART	Separation may not be necessary	KEEP APART	KEEP APART	KEEP APART	KEEP APART	KEEP APART	KEEP APART	KEEP APART
CORROSIVE SUBSTANCES	8		KEEP APART	KEEP APART	KEEP APART	KEEP APART	Separation may not be necessary	KEEP APART	KEEP APART	KEEP APART	KEEP APART	KEEP APART	KEEP APART	KEEP APART	KEEP APART	KEEP APART	KEEP APART

## 8.4. Dispersiveness classes of solid bulk materials

	Product (specification)	Dispersion class
Alum earth		S1
Baryta		S3
Baryla (ground)		S1
Bauxite	Calcined	S1
	China calcined	S1
	Raw bauxite	S5
Bimskies		S4
Blast furnace slag		S4
Borax		S3
Calcium carbide		S1
Carborundum		S5
Cement		S1
	Clinker bricks	S4
Clay	Bentonite, chunks	S3
	Bentonite, ground	S1
	Chamotte clay, chunks	S4
	Chamotte clay, ground	S1
	Kaoline (China) clay, chunks	S3
	Kaoline (China) clay, ground	S1
Coal	Anthracite	S2
	Brown coal, briquettes	S4
	Coal	S4
	Coal	S2
	Powder coal	S1
Cokes	Coal cokes	S4
	Fluid cokes	S1
	Petroleum coke, calcined	S1
	Petroleum coke, coarse	S4
	Petroleum coke, fine	S2
Derivates and related products	Alfalfa pellets	S3
	Almond flour	S3
	Apple pulp pellets	S3
	Babassu pellets	S3
	Barley meal	S1
	Barley pellets	S3
	Bone meal	S1
	Brewer's grain pellets	S3
	Buckwheat flour	S1
	Cassava pellets, hard	S3
	Cassava root	S3
	Cattle feed pellets	S3
	Citrus pellets	S3
	Cocoa beans	S3 <sup>3)</sup>
	Coffee pulp pellets	S3
	Compound feed pellets	S3
	Copra	S5
	Copra cakes	S3
	Copra chips	S3
	Copra pellets	S3
	Corn distiller grain flour	S3
	Corn distiller grain pellets	S3

	<b>Product (specification)</b>	<b>Dispersion class</b>
Derivates and related products	Corn plant pellets	S3
	Corncob pellets	S3
	Cottonseed pellets	S3
	D.F.G. pellets (maize sprout pellets)	S3
	Extracted babossu	S3
	Extracted bone	S3
	Extracted copra	S3
	Extracted cottonseed	S3
	Extracted groundnuts	S3
	Extracted kapok seed	S3
	Extracted kardi seed	S3
	Extracted linseed	S3
	Extracted macoja	S3
	Extracted mango	S1
	Extracted olive fruit	S3
	Extracted palm pit	S3
	Extracted rapeseed	S3
	Extracted safflower seed	S3
	Extracted salseed	S1
	Extracted sesame seed	S3
	Extracted sorghum seed	S3
	Extracted soyameal	S3
	Extracted sunflower seed	S3
	Extracted tucum	S3
	Groundnut pellets	S3
	Groundnuts	S5
	Hominecy chop pellets	S3
	Kapok seed pellets	S3
	Leaf meal pellets	S3
	Linseed pellets	S3
	Lucerne pellets	S3
	Macoja pellets	S3
	Macuno meal	S3
	Maize flour	S3
	Maize gluten meal	S3
	Maize gluten pellets	S3
	Malt sprout pellets	S3
	Malt sprout pellets	S3
	Mango pellets	S3
	Mill run pellets	S3
	Milo flour	S3
	Milo gluten pellets	S3
	Oat pellets	S3
	Oatmeal	S1
	Olive pulp pellets	S3
	Palm pit cakes	S3
	Palm pit pellets	S3
	Palm pits	S5
	Peanut hull pellets	S3
	Pineapple pellets	S3
	Pollard pellets	S3
	Potato flour	S1
	Potato slices	S3

	<b>Product (specification)</b>	<b>Dispersion class</b>	
Derivates and related products	Quar bean meal	S3	
	Quar bean meal pellets	S3	
	Rapeseed pellets	S3	
	Rice bran	S1	
	Rice hull pellets	S3	
	Rice husk pellets	S3	
	Rye meal	S1	
	Rye pellets	S3	
	Safflower seed pellets	S3	
	Salseed extraction pellets	S3	
	Sesame seed pellets	S3	
	Soiulac pellets	S3	
	Sorghum seed pellets	S3	
	Sorghum seed pellets	S3	
	Soya chips	S3	
	Soya flour	S3	
	Soya pellets	S3	
	Splent grain pellets	S3	
	Sugar beet pulp pellets	S3	
	Sugar cane pellets	S3	
	Sunflower seed pellets	S3	
	Sweet potato pellets	S3	
	Tapioca chips	S1	
	Tapioca cubes	S1	
	Tapioca pellets, hard	S3	
	Tapioca pellets, natives	S1	
	Tea pellets	S3	
	Wheat meal	S1	
	Wheat pellets	S3	
	Hominecy chop meal	S3	
	Dolomite	Chunks	S5
		Ground	S1
	Feldspar		S5
Ferrochromium, chunks		S5	
Ferromanganese, chunks		S5	
Ferro-phosphorus, chunks		S5	
Ferrosilicon, chunks		S3	
Fertiliser	Ammonium sulphate nitrate	S3	
	Di ammonium phosphate	S1	
	Double super-phosphate, granules	S3	
	Double super-phosphate, powder	S1	
	Lime ammonium nitrate	S3	
	Sulphuric ammonia	S3	
	Triple super-phosphate, powder	S1	
Fluorspor		S5	
Fly ash		S2	
Glass waste		S5	

	Product (specification)	Dispersion class
Grain	Barley	S3
	Buckwheat	S3
	Groats	S3
	Kafi corn	S3
	Linseed screenings	S3
	Maize	S3
	Malt	S3
	Milicorn	S3
	Oat screenings	S3
	Oats	S5
	Rapeseed screenings	S3
	Rice	S5
	Rice husk	S3
	Rye	S3
	Sorghum seed	S3
	Soya grits	S3
	Wheat	S3
Gravel		S5
Gypsum	Gypsum	S4
	Calcined gypsum (plaster)	S1
Heavyspar		S5
Household refuse		
Iron ore	Beeshoek, fine ore	S5 <sup>1)</sup>
	Beeshoek, lump ore	S5 <sup>1)</sup>
	Bomi Hill, lump ore	S4
	Bong Range concentrate	S4 <sup>2)</sup>
	Bong Range pellets	S5 <sup>1)</sup>
	Broz. Nat. ore	S4
	Carol Lake concentrate	S4 <sup>2)</sup>
	Carol Lake pellets	S5 <sup>1)</sup>
	Cassinga pellets	S5
	Cassinga, fine ore	S4
	Cassinga, lump ore	S5 <sup>1)</sup>
	Cerro Bolivar ore	S4
	Coto Wagner ore	S5 <sup>2)</sup>
	Dannemora ore	S4
	El Poo, fine ore	S4
	Fabrica pellets	S5 <sup>1)</sup>
	Fabrica Sinter Feed	S5
	Fabrica Special pellet ore	S5
	F'Derik Ho	S4
	Fire Lake pellets	S5 <sup>1)</sup>
	Grbngesberg ore	S4
	Homersley Pebble	S5 <sup>1)</sup>
	Itabira Run of Mine	S5 <sup>1)</sup>
	Itabiro Special sinter feed	SS
	Kiruna B, fine ore	S5
	Kiruna pellets	S5 <sup>1)</sup>
	Ilmenite ore	S5
	Malmberg pellets	S5
	Manoriver Ho	S4
	Menera, fine ore	S5

	Product (specification)	Dispersion class
Iron ore	Migrolite	S4
	Mount Newman pellets	S4
	Mount Wright concentrate	S4 <sup>2)</sup>
	Nimba ore	S4
	Nimba, fine ore	S5
	Pyrite ore	S4
	Robe River, fine ore	S5 <sup>1)</sup>
	Samarco pellets	S5 <sup>1)</sup>
	Sishen, fine ore	S5 <sup>1)</sup>
	Sishen, lump ore	S5 <sup>1)</sup>
	Svappavaaro ore	S4
	Svoppavaara pellets	S4
	Sydvaranger pellets	S5 <sup>1)</sup>
	Tazadit, fine ore	S5 <sup>1)</sup>
Kyanite		S4
Lime	Chunks	S5
	Ground	S1
Lime salt		S5
Nepheline		S3
Olivin stone		S4
Ore	Chromium ore	S4
	Copper ore	S4
	Emery ore, chunks	S5
	Iron ore (see Iron ore)	
	Lead ore	S2
	Manganese ore	S5 <sup>1)</sup>
	Tantalite ore	S4
	Titanium ore (see Titanium)	
Zinc blend	S4	
Phosphate	Moisture-free content > 4 weight %	S4
Phosphate	Moisture-free content < 1 weight %	S1
Pig iron		S4
Polymer products	Plastic powder	S1
Potash		S3
Pulse	Beans	S3
	Guar split	S3
	Horse beans	S3
	Lentil	S3
	Lupine seed	S3
	Peas	S3
	Soya bean husk	S3
	Soya beans	S3
	Soya screenings	S3
Vetch	S3	
Pumice		S5
Pyrietas		S2
Pyrite cinder		S2
Pyrolusite		S2
Quicklime		S1
Road salt		S5



	<b>Product (specification)</b>	<b>Dispersion class</b>
Sand	Coarse sand	S4
	fine sand	S3
	Olivin sand	S4
	Rutile sand (see Titanium)	
	Silver sand	S3
	Zircon sand	S3
Scoria, slag		S4
Scrap, metal		S4
Seeds and related products	Canary seed	S5
	Dariseed	S3
	Kardiseed	S3
	Linseed	S5
	Millite seed	S5
	Mustard seed	S5
	Oilseed rape	S3
	Paricum seed	S3
	Poppy seed	S5
	Rapeseed	S5
	Safflower seed	S5
	Sesame seed	S5
	Sorghum seed	S5
	Sunflower seed	S5
	Tamorin seed	S3
Sillimanite		S5
Sinter magnesite		S3
Soda		S3
Soot		S1
Sugar		S5
Sulphur	Coarse	S4
	Fine	S1
Talk	Crushed	S3
	Ground	S1
Tapioca (see Derivates)		
Titanium	Ilmenite	S5
	Rutile	S3
	Rutile sand	S3
	Rutile slag	S5
Urea		S3
Vanadium slag		S4
Vermiculite	Chunks	S3
	Ground	S1
Wollastonite		S5
1) Applies to storage; loading and unloading S4. 2) Applies to storage; loading and unloading S5. 3) Temporary classification.		





## 8.6. Summary of MS requirements on underground tank storage modes and equipment for liquids

Country	Double walled or single + containment	Use of corrosion-resistant materials	Leak detection systems	Specifications for pipes and hydrocarbon separators
Austria	S	S	S	S
Belgium, Brussels	S	S	S	S
Belgium, Flanders	S	S	S	S
Belgium, Wallonia	S	S	S	S
Denmark	R	S	S	S
Finland	R	S	R	S
France	S	S	S	S
Germany	S	S	S	S
Greece	N	R	R	N
Ireland	S	S	G	G
Italy	S	S	S	N
Luxembourg	S	S	S	S
Netherlands	S	S	S	S
Portugal	S	S	R	R
Spain	S	S	S	S
Sweden	R	S	R	N
United Kingdom	G	G	G	G
Key: <b>S</b> : primary or statutory requirement under national legislation for all systems <b>R</b> : required for specific situations or recommended wherever practicable by national legislation <b>G</b> : good practice cited by competent authorities <b>N</b> : no information available at time of study				
Note: As indicated in the table, all MS now have some form of published requirement for underground systems, whether issued as part of the sovereign legislation (e.g. Italy or Portugal) or as guidelines for good practice (e.g. UK and the Republic of Ireland). There are very few gaps in these requirements when assessed against the four keys areas of construction and operation listed in the table, indicating a level of national awareness of the problems associated with gasoline underground tank systems and groundwater contamination.				

**Table 8.2: Summary of MS requirements on underground tanks**  
[132, Arthur D. Little Limited, 2001]

## 8.7. Storage modes and relevant solid bulk materials

	Grain	Pit-coal	Brown-coal	Pit-coal coke	Iron ores and concentrates	Copper ores and concentrates	Other non-iron metal ores and concentrates	Calcined gypsum	Gypsum	Fertilisers
<b>Open storage (outdoor)</b>	X	X	X	X	X	X	X		X	X
<b>Heap in shed/under roof</b>	X	X	X	X	X	X	X		X	X
<b>Bunker</b>			X						X	X
<b>Silo</b>	X	X	X					X	X	X
<b>Packed (sack, big-bags)</b>								X	X	X

Table 8.3: Storage modes and relevant bulk materials  
[17, UBA, 2001]

## 8.8. Handling techniques and relevant solid bulk material

	Grain	Pit-coal	Brown-coal	Pit-coal coke	Iron ores and concentrates	Copper ores and concentrates	Other non-iron metal ores and concentrates	Calcined gypsum	Gypsum	Fertilisers
Grab	X	X		X		X	X		X	X
Hopper	X	X		X		X	X		X	X
Tube							X		X	X
Mobile loading device	X	X	X	X	X	X	X		X	X
Silo (truck or train)	X	X	X					X	X	X
Tilting cart (truck or train)	X	X	X	X	X				X	X
Dump pit	X	X		X	X				X	X
Gravity conveyor	X	X	X	X	X	X	X		X	X
Cascade chute	X	X					X		X	X
Band conveyor	X	X	X	X	X	X	X	X	X	X
Double belt conveyor	X							X	X	X
Scraper conveyor	X	X	X		X			X	X	X
Trough chain conveyor	X		X						X	X
Chain conveyor (as unloader)	X								X	X
Screw conveyor	X	X						X	X	X
Bucket conveyor	X	X			X			X	X	X
Bucket elevator (ship unloader)		X			X				X	
Pneumatic conveyor	X	X	X					X	X	X

Table 8.4: Loading and unloading techniques and relevant bulk materials

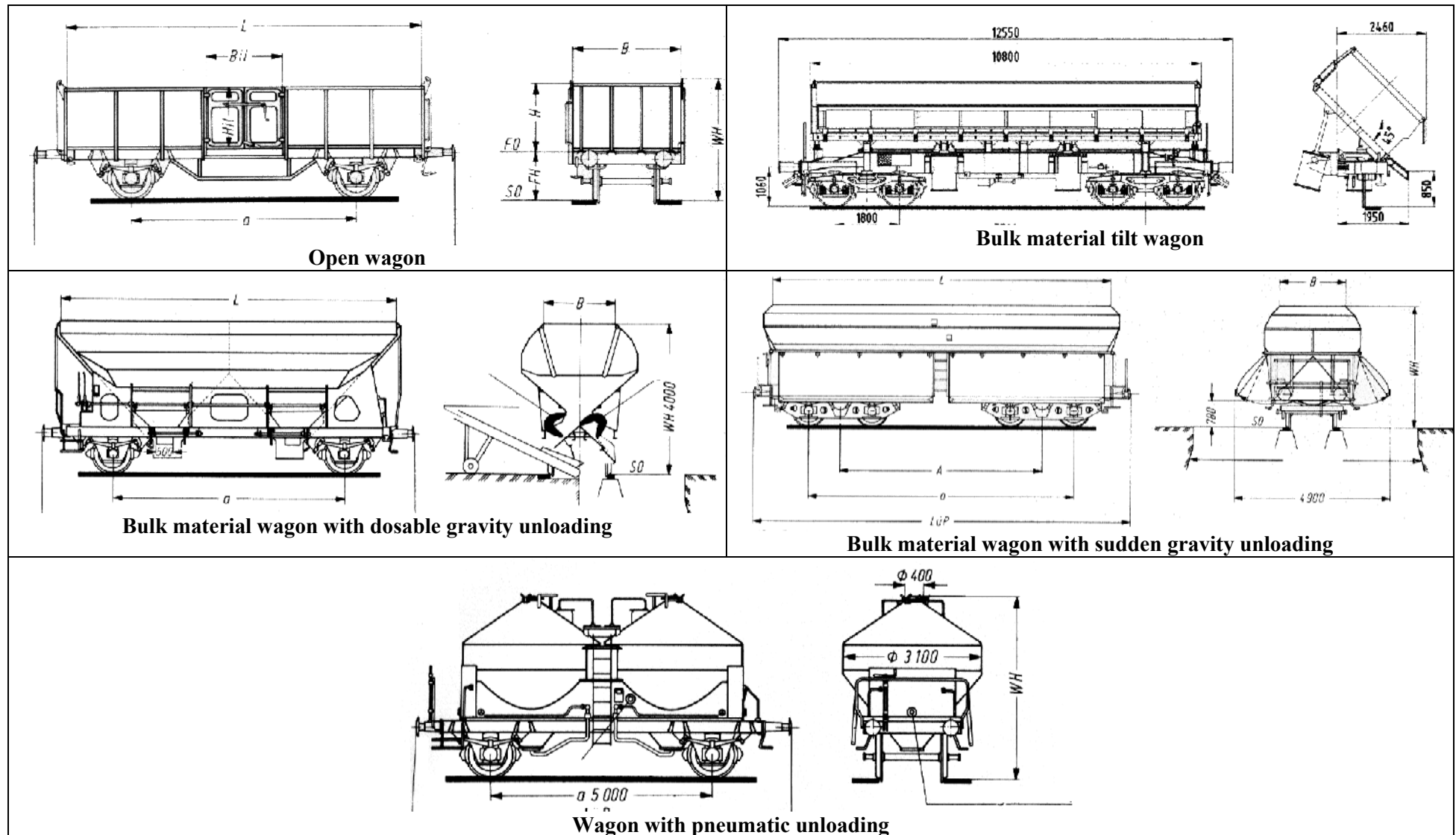


Figure 8.1: Wagons for transporting solid bulk materials, used in Germany [17, UBA, 2001] with reference to Railway Wagons, 1994

## 8.9. ECM Scorecards for storing liquid and liquefied gas - operational

Aboveground Atmospheric Storage: Open Top Tank				
Operational emissions				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
Potential Emission Source	Emission Frequency Note 1	Emission Volume Note 2	Emission Score	POSSIBLE ECM
<b>Gas Emissions</b>				
Filling	2	3	6	Floating covers
				Flexible or tent covers
				Fixed/rigid covers
				Vapour treatment (if covered)
Standing	3	3	9	Paint colour
				Floating covers
				Flexible or tent covers
				Fixed/rigid covers
				Sun covers/heat shields
				Vapour treatment (if covered)
Emptying	2	1	2	Floating covers
				Flexible or tent covers
				Fixed/rigid covers
				Vapour treatment (if covered)
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system
				Fixed, closed drain system
<b>Liquid Emissions</b>				
Draining	2	1	2	Operating procedures/training
				Fixed, closed drain system
Cleaning	1	3	3	Operating procedures/training
Sampling	2	0	0	Operating procedures/training
				Liquid tight sampling system
				Containment

Table 8.5: ECM-cards operational emissions; Aboveground Open Top Tank



<b>Aboveground Atmospheric Storage: External Floating Roof</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling	1	3	3	Operating procedures/training
(until roof floats on liquid)				Instrumentation
Standing	3	1	3	Shell/roof paint colour
				Dome roof
				Pontoon roof
				- with vapour mounted primary seal
				- with liquid mounted primary seal
				- with mechanical shoe seal
				- with secondary seal
				Double deck roof
				- with vapour mounted primary seal
				- with liquid mounted primary seal
				- with mechanical shoe seal
				- with secondary seal
				Sealing roof penetrations
				- guide pole
				- roof legs
				- still well cover
Emptying	2	1	2	Inner shell coating
(film of product left on shell)				Shell scrapers (e.g. for crudes)
Emptying	1	1	1	Operating procedures/training
(after roof lands on legs)				Instrumentation
				Secondary seal
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system
Blanketing				N/A
Manual gauging	2	1	2	Semi-closed gauging system (sealing still well openings)
				Instrumentation
Sampling	2	1	2	Semi-closed sampling system
				Shell-side sampling
Fugitive	3	1	3	Inspection/maintenance (including roof-shell seal tightness)
Draining	2	1	2	Semi-automatic water draw-off
<b>Liquid Emissions</b>				
Draining	2	1	2	Operating procedures/training
				Automatic drain valve
				Fixed, closed drain system
Roof draining	2	0	0	Operating procedures/training
				Fixed, closed drain system
Cleaning	1	3	3	Operating procedures/training
Sampling	2	0	0	Operational procedures/training
				Closed sampling system
				Containment

**Table 8.6: ECM-cards operational emissions; Aboveground Atmospheric Storage: External Floating Roof Tank**

<b>Aboveground Atmospheric Storage: Fixed Roof Tank</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling	2	3	6	Pressure Vacuum Relief Valve (PVRV)
				Innerfloat/internal floating roof (IFR)
				- with primary seal
				- with secondary seal
				Vapour collection
				- balancing
				- treatment
Breathing	3	2	6	PVRV
				Paint colour
				Sun covers/heat shields
				Innerfloat/IFR
				- with primary seal
				- with secondary seal
				Vapour collection
				- vapour holding tank
				- treatment
Emptying	2	1	2	PVRV
				Innerfloat/IFR
				- with primary seal
				- with secondary seal
				Vapour collection
				- balancing
				- treatment
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system
Blanketing	3	2	6	PVRV
				Vapour collection
				- treatment
Manual gauging	2	1	2	Mechanical gauging system
				Instrumentation
Sampling	2	1	2	Semi-closed sampling system
				(NB: only with PVRV with high pressure settings)
				Shell-side sampling
Fugitive	3	1	3	Inspection/maintenance
Draining	2	1	2	Semi-automatic water draw-off
				Fixed, closed drain system
<b>Liquid Emissions</b>				
Draining	2	1	2	Operating procedures/training
				Fixed, closed drain system
Cleaning	1	3	3	Operating procedures/training
Sampling	2	0	0	Operating procedures/training
				Liquid tight sampling system
				Containment

**Table 8.7: ECM-cards operational emissions; Aboveground Atmospheric Storage: Fixed Roof Tank**

<b>Aboveground Atmospheric Storage: Horizontal Storage Tank</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling	2	3	6	Pressure Vacuum Relief Valve (PVRV)
				Vapour collection
				- balancing
				- treatment
Breathing	3	2	6	PVRV
				Paint colour
				Sun covers/heat shields
				Vapour collection
				- vapour holding tank
				- treatment
Emptying	2	1	2	PVRV
				Vapour collection
				- balancing
				- treatment
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system
Blanketing	3	2	6	PVRV
				Vapour collection
				- treatment
Manual gauging	2	1	2	Mechanical gauging system
				Instrumentation
Sampling	2	1	2	Semi-closed sampling system
				(NB: only with PVRV with high pressure settings)
				Shell-side sampling
Fugitive	3	1	3	Inspection/maintenance
Draining	2	1	2	Operating procedures/training
				Fixed, closed drain system
<b>Liquid Emissions</b>				
Draining	2	1	2	Operating procedures/training
				Fixed, closed drain system
Cleaning	1	2	2	Operating procedures/training
Sampling	2	0	0	Operating procedures/training
				Liquid tight sampling system
				Containment

**Table 8.8: ECM-cards operational emissions; Aboveground Atmospheric Storage: Horizontal Storage Tank**

<b>Aboveground Pressurised Storage: Spheres</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling	2	1	2	Control filling rate (non-condensables vented)
Breathing				N/A
Emptying				N/A
Cleaning	1	2	2	Operating procedures/training Closed cleaning system
Blanketing	2	1	2	Vapour collection - treatment
Gauging				N/A
Sampling	2	1	2	Vapour collection - treatment
Fugitive	3	1	3	Inspection/maintenance
Draining	2	2	4	Fixed, closed drain system (connected to vapour treatment)
<b>Liquid Emissions</b>				
Draining	2	0	0	
Cleaning	1	1	1	Operating procedures/closed cleaning procedures
Sampling	2	0	0	

**Table 8.9: ECM-cards operational emissions; Aboveground Pressurised Storage: Spheres**

<b>Aboveground Pressurised Storage: Horizontal Storage Tank</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling	2	1	2	Control filling rate (non-condensables vented)
Breathing				N/A
Emptying				N/A
Cleaning	1	2	2	Operating procedures/training Closed cleaning system
Blanketing	2	1	2	Vapour collection - treatment
Gauging				N/A
Sampling	2	1	2	Vapour collection - treatment
Fugitive	3	1	3	Inspection/maintenance
Draining	2	2	4	Fixed, closed drain system (connected to vapour treatment)
<b>Liquid Emissions</b>				
Draining	2	0	0	
Cleaning	1	1	1	Operating procedures/closed cleaning procedures
Sampling	2	0	0	

**Table 8.10: ECM-cards operational emissions; Aboveground Pressurised Storage: Horizontal Storage Tank**

<b>Aboveground Refrigerated Storage</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling	2	1	2	Normally closed system (non-condensables vented)
Breathing				N/A (failure of refrigeration not considered)
Emptying				N/A
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system
Blanketing	2	1	2	Vapour collection
				- treatment
Gauging				N/A
Sampling	2	1	2	Vapour collection
				- treatment
Fugitive	2	1	2	Inspection/maintenance
Draining				N/A
<b>Liquid Emissions</b>				
Draining				N/A
Cleaning				N/A
Sampling				N/A

Table 8.11: ECM-cards operational emissions; Aboveground Refrigerated Storage

<b>Underground Atmospheric Storage: Horizontal Storage Tank</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling	2	3	6	Pressure Vacuum Relief Valve (PVRV)
				Vapour collection
				- balancing
				- treatment
Breathing	2	1	2	PVRV
Emptying	2	1	2	PVRV
				Vapour collection
				- balancing
				- treatment
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system
Blanketing	3	1	3	PVRV
				Vapour collection
				- treatment
Gauging	2	1	2	Mechanical gauging system
				Instrumentation
Sampling	2	1	2	Semi-closed sampling system
				(NB: only with PVRV with high pressure settings)
Fugitive	3	1	3	Inspection/maintenance
Draining				N/A
<b>Liquid Emissions</b>				
Draining	1	1	1	Fixed, closed drain system
				Operating procedures/training
Cleaning	1	2	2	Operating procedures/training
Sampling				N/A

Table 8.12: ECM-cards operational emissions; Underground Tank

<b>Underground Atmospheric Storage: Caverns</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling	2	3	6	Pressure Vacuum Relief Valve (PVRV)
				Vapour collection
				- balancing
				- treatment
Breathing	2	1	2	PVRV
Emptying	2	1	2	PVRV
				Vapour collection
				- balancing
				- treatment
Cleaning				N/A
Blanketing				N/A
Gauging	2	1	2	Mechanical gauging system
				Instrumentation
Sampling	2	1	2	Semi-closed sampling system
				(NB: only with PVRV with high pressure settings)
Fugitive	3	1	3	Inspection/maintenance
Draining	2	1	2	Fixed, closed drain system
<b>Liquid Emissions</b>				
Draining	2	1	2	Maintain sufficient water bottom by means of automation
Cleaning				N/A
Sampling	2	0	0	

Table 8.13: ECM-cards operational emissions; Atmospheric Cavern



<b>Underground Atmospheric Storage: Salt Domes</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
Potential Emission Source	Emission Frequency Note 1	Emission Volume Note 2	Emission Score	POSSIBLE ECM
<b>Gas Emissions</b>				
Filling				? - to be investigated
Breathing				N/A
Emptying				? - to be investigated
Cleaning				? - to be investigated
Blanketing				N/A
Gauging				? - to be investigated
Sampling				? - to be investigated
Fugitive				? - to be investigated
Draining				? - to be investigated
<b>Liquid Emissions</b>				
Draining	2	1	2	Maintain sufficient water bottom by means of automation
Cleaning				N/A
Sampling	2	0	0	

Table 8.14: ECM-cards operational emissions; Atmospheric Salt Dome

<b>Underground Pressurised Storage: Caverns</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
Potential Emission Source	Emission Frequency Note 1	Emission Volume Note 2	Emission Score	POSSIBLE ECM
<b>Gas Emissions</b>				
Filling	2	1	2	Control filling rate (non-condensables vented)
Breathing				N/A
Emptying				N/A
Cleaning				N/A
Blanketing				N/A
Gauging				N/A
Sampling	2	1	2	Vapour collection - treatment
Fugitive	2	1	2	Inspection/maintenance
Draining	2	1	2	Fixed, closed drain system
<b>Liquid Emissions</b>				
Draining				Maintain sufficient water bottom by means of automation
Cleaning				N/A
Sampling				N/A

Table 8.15: ECM-cards operational emissions; Pressurised Cavern

<b>Aboveground Atmospheric Storage: Lagoons and Basins</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling (lagoon)	2	3	6	None
Filling (basin)	2	3	6	Floating cover
Standing (lagoon)	3	3	9	None
Standing (basin)	3	3	9	Floating cover
				Fixed cover
Emptying	2	1	2	N/A
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system (NB: only if cover installed)
Blanketing				N/A
Manual gauging				N/A
Sampling				N/A
Fugitive				N/A
Draining				N/A
<b>Liquid Emissions</b>				
Draining	2	1	2	Fixed, closed drain system
				Operating procedures/training
Cleaning	1	3	3	Operating procedures/training
Sampling	2	0	0	

Table 8.16: ECM-cards operational emissions; Lagoon and Basin

<b>Floating Storage</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Filling	2	3	6	Pressure Vacuum Relief Valve (PVRV)
				Vapour collection
				- balancing
				- treatment
Breathing	3	2	6	PVRV
				Paint colour deck
				Vapour collection
				- vapour holding tank
				- treatment
Emptying	2	1	2	PVRV
				Vapour collection
				- balancing
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system
Blanketing	3	2	6	PVRV
				vapour collection
				- treatment
Gauging	2	1	2	Mechanical gauging system
				Instrumentation
Sampling	2	1	2	Semi-closed sampling system
				(NB: only with PVRV with high pressure settings)
Fugitive	3	1	3	Inspection/maintenance
Draining	2	1	2	Fixed, closed drain system
<b>Liquid Emissions</b>				
Draining	2	0	0	
Cleaning	1	3	3	Operating procedures/training
Sampling	2	0	0	

Table 8.17: ECM-cards operational emissions; Floating Storage

<b>Aboveground Atmospheric Storage: Lifter Roof Tank</b>				
<b>Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 0 - 3: 3 = largest, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM</b>
<b>Gas Emissions</b>				
Breathing	3	0	0	N/A
Filling	2	3	6	PVRV
				Vapour collection
				- treatment
Emptying	2	1	2	PVRV
				Vapour collection
				- treatment
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system
Blanketing	3	2	6	PVRV
				Vapour collection
				- treatment
Manual gauging	2	1	2	Mechanical gauging system
				Instrumentation
Sampling	2	1	2	Semi-closed sampling system
				(NB: only with PVRV with high pressure settings)
				Shell-side sampling
Fugitive	3	1	3	Inspection/maintenance
Draining	2	1	2	Semi-automatic water draw-off
				Fixed, closed drain system
<b>Liquid Emissions</b>				
Draining	2	1	2	Operating procedures/training
				Fixed, closed drain system
Cleaning	1	3	3	Operating procedures/training
Sampling	2	0	0	Operating procedures/training
				Liquid tight sampling system
				Containment

Table 8.18: ECM-cards operational emissions; Lifter Roof Tank

## 8.10. ECM Scorecards for transfer and handling of liquid and liquefied gas

<b>Aboveground Transfer Systems: Closed Piping; Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 1 - 3: 3 = large, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM's</b>
<b>Gas Emissions</b>				
Filling	2	2	4	Operating procedures/training
				Vapour collection
				- treatment
				- balancing
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system (etc.)
Pigging	2	1	2	operating procedures/training
				Vapour collection
				- treatment
				- balancing
Purging	1	2	2	Operating procedures/training
				Vapour collection
				- treatment
				- balancing
Sampling	2	1	2	Semi-closed sampling system
(Dis)connecting	2	1	2	Operating procedures/training
Opening	1	2	2	Operating procedures/training
Fugitive	3	1	3	Inspection/maintenance
Emptying/draining	2	1	2	Operating procedures/training
<b>Liquid Emissions</b>				
Draining	2	1	2	Operating procedures
				Fixed, closed drain systems
				Containment
Cleaning	1	2	2	Operating procedures/training
Sampling	2	1	2	Operating procedures/training
Pigging	2	1	2	Operational procedures
				Containment
(Dis)connecting	2	1	2	Operational procedures
				Containment
Pressure relief	2	1	2	Operational procedures
				Closed relief system
				Containment
Opening	2	1	2	Operational procedures
				Containment

**Table 8.19: ECM-cards operational emissions; Aboveground Transfer Systems: Closed Piping**

<b>Aboveground Transfer Systems: Open Piping; Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 1 - 3: 3 = large, 0 = zero or negligible			
	These scores are relative values and are to be considered only for each storage mode			
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM's</b>
<b>Gas Emissions</b>				
Filling (incl. Standing)	2	3	6	Operating procedures/training Closed system (where applicable)
Cleaning	2	2	4	Operating procedures/training Closed system (where applicable)
Pigging				N/A
Purging				N/A
Sampling				N/A
(Dis)connecting				N/A
Opening				N/A
Fugitive				N/A
Emptying/draining				N/A
<b>Liquid Emissions</b>				
Draining	2	1	2	Operating procedures/training
Cleaning	2	2	4	Operating procedures/training
Sampling	2	1	2	Operating procedures/training
Pigging				N/A
(Dis)connecting				N/A
Pressure relief				N/A
Opening				N/A

**Table 8.20: ECM-cards operational emissions; Aboveground Transfer Systems: Open Piping**

<b>Underground Transfer Systems: Closed Piping; Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 1 - 3: 3 = large, 0 = zero or negligible			
These scores are relative values and are to be considered only for each storage mode				
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM's</b>
<b>Gas Emissions</b>				
Filling	2	2	4	Operating procedures/training
				Vapour collection
				- treatment
				- balancing
Cleaning	1	2	2	Operating procedures/training
				Closed cleaning system (etc.)
Pigging	2	1	2	Operating procedures/training
				Vapour collection
				- treatment
				- balancing
Purging	1	2	2	Operating procedures/training
				Vapour collection
				- treatment
				- balancing
Sampling	2	1	2	Semi-closed sampling system
(Dis)connecting	2	1	2	Operating procedures/training
Opening	1	2	2	Operating procedures/training
Fugitive	3	1	3	Inspection/maintenance (valve pits etc.)
Emptying/draining	2	1	2	Operating procedures/training
<b>Liquid Emissions</b>				
Draining	2	1	2	Operating procedures
				Fixed, closed drain systems
Cleaning	1	2	2	Operating procedures/training
Pigging	2	1	2	Operational procedures
(Dis)connecting				N/A
Pressure relief	2	1	2	Operational procedures
				Closed relief system
Opening	1	1	1	Operational procedures
Sampling	2	1	2	Operating procedures/training

**Table 8.21: ECM-cards operational emissions; Underground Transfer Systems: Closed Piping**

<b>Product Handling Methods: Pumps &amp; Compressors; Operational emissions</b>				
Note 1:	Emission Frequency Score 1 - 3: 3 = frequent (daily), 1 = infrequent (once per few years)			
Note 2:	Emission Volume Score 1 - 3: 3 = large, 0 = zero or negligible			
These scores are relative values and are to be considered only for each storage mode				
<b>Potential Emission Source</b>	<b>Emission Frequency Note 1</b>	<b>Emission Volume Note 2</b>	<b>Emission Score</b>	<b>POSSIBLE ECM's</b>
<b>Gas Emissions</b>				
Filling	2	0	0	N/A
Cleaning	1	0	0	N/A
Pigging				N/A
Purging				N/A
Sampling				N/A
(Dis)connecting				N/A
Opening	1	1	1	Operating procedures/training
Fugitive	3	1	3	Inspection/maintenance
				Secondary seals or canned pumps
Emptying/draining	2	0	0	N/A
<b>Liquid Emissions</b>				
Draining	2	1	2	Fixed, closed drain systems
				Operational procedures
				Containment
Cleaning	1	1	1	Operating procedures/training
Sampling				N/A
Pigging				N/A
(Dis)connecting				N/A
Pressure relief				N/A
Opening	1	1	1	Operational procedures
				Containment

**Table 8.22: ECM-cards operational emissions; Product Handling Methods: Pumps & Compressor**



## 8.11. Methodology for completion of the ECM Assessment Table

The methodology to complete an ECM Assessment Table (as shown in Annex 8.12) is outlined below. The method can be used iteratively to establish if a combination of ECM can be considered to meet BAT.

It is assumed that non-hardware type ECM e.g. operational procedures, inspection and maintenance, etc. are already in place.

The method can be used for the assessment of ECM for a single tank or for a number of similar tanks on compatible products. The steps outlined below assume only one tank is to be assessed, but the methodology is the same for a group of tanks.

The methodology can be used for a planned new tank or an existing tank. The methodology differs slightly.

This methodology requires emission estimation to be undertaken. For the majority of ECM installed on atmospheric pressure tanks, this estimation can be undertaken using available models e.g. API, US EPA, TNO. However for pressurised tanks there are no equivalent models and emission estimates have to be undertaken using operating data, best engineering judgement, etc.

Four case studies are given in Annex 8.13.

### **Initial Assessment of ECM**

**Step 1:** Estimate the annual average emissions from the ‘base case’ tank for the tank location. For all atmospheric fixed roof tanks, the base case is an FRT of the same diameter and shell height and fitted with open vents. For EFRTs two cases should be considered – the ‘uncontrolled case’ and the base case. The ‘uncontrolled case’ is an FRT of equivalent size to the EFRT; the base case should be taken as an EFRT with the roof fitted with a vapour mounted primary seal. Base case for other storage tank modes must be agreed between all parties involved in the assessment of ECM for the tank.

Emissions calculations should be undertaken using an estimation method that is acceptable to the local authorities.

**Step 2:** For an existing tank, if the tank already has an ECM installed estimate the annual average emissions from the tank as existing.

**Step 3:** Compare the emissions from an existing tank with those from the base case tank (or ‘uncontrolled case’ for EFRTs) and calculate the emission reduction efficiency as a percentage from:

*For FRT:*  $[(\text{Base case tank emissions} - \text{Existing tank emissions}) \times 100] \div (\text{Base case tank emissions})$

*For EFRT:*  $[(\text{Uncontrolled case tank emissions} - \text{Existing tank emissions}) \times 100] \div (\text{Uncontrolled case tank emissions})$

If the emission reduction efficiency meets BAT then no further emission reduction measures are considered necessary. Otherwise, continue as below.

**Step 4:** Identify the ECM for the particular storage mode that have an emissions score of 3 or more in the relevant table in Chapter 3 (showing the possible emissions to air from ‘operational sources’) and from Annex 8.9.

**Step 5:** Undertake separate emission estimations for the base case tank fitted with each of the ECM identified.

**Step 6:** From the emission estimations determine the percentage efficiency at reducing the emissions relative to the base case for the ECM being considered using:

$$\frac{[(\text{Emissions from base case tank} - \text{Emissions from tank with an ECM installed}) \times 100] \div \text{Emissions from base case tank}}$$

**Step 7:** From the efficiencies obtained, determine a score rating system that covers 0 to 100 % in five ranges. The score rating system should take account of the properties of the material scored, site-specific factors, etc.

For example, where the product is considered to be reasonably environmentally benign, the ERP score rating system could be agreed (between the operators and permit writer) to be:

Score	Emission Reduction Potential (Efficiency of ECM)
1	0 to < 20 %
2	20 to < 40 %
3	40 to < 60 %
4	60 to < 80 %
5	80 to 100 %

Alternatively, where the product is considered to be very hazardous to the environment, the score rating system could be agreed to be:

Score	Emission Reduction Potential (Efficiency of ECM)
1	0 to < 95 %
2	95 to < 98 %
3	98 to < 99 %
4	99 to < 99.5 %
5	99.5 to 100 %

Examples are given in the case studies (Annex 8.13). The score rating system used needs to be agreed upon by all parties involved in the assessment for the tank.

**Step 8:** Complete the Emission Reduction Potential column of the ECM Assessment Table using scores of 1 to 5 (where 1 is the lowest and 5 is the highest efficiency) from the emission reduction efficiency data in **Step 6**.

**Step 9:** From the information in Chapter 4 and from previous experience with the product and storage mode complete the four ‘Operation Aspects’ columns in the Assessment Table (i.e. Operability, Applicability, Safety aspects, Energy/waste/cross-media).

The scoring is 1 to 5, with a score of 5 meaning:

- **Operability:** the easiest to operate;
- **Applicability:** most applicable for the widest range of products;
- **Safety:** safest to use by operators, and
- **Energy/waste/cross-media:** requires the least energy consumption, produces the least waste and has the lowest cross-media effects.

**Step 10:** Establish the approximate costs of procuring and installing the possible ECM. These will vary depending upon whether the tank is a planned new tank or an existing tank with the ECM being retrofitted. The costs for retrofitted ECM should, where appropriate, include all measures required to ensure safe installation e.g. tank cleaning/gas freeing.

**Step 11:** From the range of costs obtained, determine a score rating system that covers the lowest to the highest costs in 5 ranges – examples are given in the case studies.

**Step 12:** Complete the CAPEX column in the ranges 1 to 5, where 5 is the lowest and 1 is the highest installed cost, from the cost data in **Step 10**.

**Step 13:** Establish the approximate costs of operating the possible ECM over a ten-year period. These should include both the cost of utilities to operate the ECM (e.g. the electricity used by a VRU), the training costs and the maintenance costs.

**Step 14:** From the range of costs obtained, determine a score rating system that covers the lowest to the highest costs in 5 ranges - examples are given in the case studies.

**Step 15:** Complete the OPEX column in the ranges 1 to 5, where 5 is the lowest and 1 is the highest operating cost, from the cost data in **Step 13**.

**Step 16:** Calculate the ‘Operational Score’, ‘Cost Score’ and ‘Overall Score’ as outlined in Annex 8.12.

**Step 17:**

1. For a new tank, the initial assessment of ECM is the tank fitted with the ECM with the highest overall score.
2. For an existing tank, compare the emissions from the base case tank fitted with the ECM determined with the highest score in 1) with those from the tank as existing (from Steps 1 and 2). If the existing tank has lower emissions, then the initial assessment of ECM is the tank with ECM(s) as installed.

Compare the emissions from the tank configuration with BAT associated emission levels and other legislative requirements. If the tank meets these requirements then no further emission reduction measures are considered necessary. Otherwise, continue with an iterative process as outlined below.

**Second Round Assessment of ECM**

**Step A:** From the ECM compatibility table in Section 4.1.3.16 determine what ECM are compatible with that established in **Step 17(1)** above (or those fitted to an existing tank if this is deemed initially to meet BAT in **Step 17(2)** above).

**Step B:** From the initial ECM Assessment Table establish which of the compatible ECM had a medium to high overall score – as an example ECM could be considered which have an overall score in excess of 50 % of the overall score for the initial identified ECM.

**Step C:** Draw up a new ECM Assessment Table to include the ECM with the highest score and the compatible ECM – an example is given in the case studies.

**Step D:** Estimate the emissions from the tank with the highest scoring ECM installed plus one of the available compatible ECM. Repeat for the highest scoring ECM with each compatible ECM.

**Step E:** From the emission calculations determine the incremental efficiency at reducing emissions relative to the initial ECM assessment case, using:

((Emissions from tank fitted with highest scoring ECM – Emissions from tank with highest scoring ECM plus another compatible ECM) × 100) - (Emissions from tank fitted with highest scoring ECM)

**Step F:** From the incremental emission reduction efficiencies obtained, determine a score rating system that covers 0 to 100 % in five ranges.

**Step G:** Complete the Emission Reduction Potential column of the ECM Assessment Table using scores of 1 to 5 (where 1 is the lowest and 5 is the highest incremental efficiency) from the incremental emission reduction efficiency data in **Step E**.

**Step H:** From the information in Chapter 4 and from previous experience with the product and storage mode complete the four ‘Operation Aspects’ columns in the Assessment Table (i.e. Operability, Applicability, Safety aspects, Energy/waste/cross-media). These scores will be as in **Step 9**.

**Step J:** Determine the CAPEX and OPEX costs for the additional ECM being considered. These will be as in Steps 10 and 13. From the range of costs obtained, determine a score rating systems that covers the cheapest to the highest costs in 5 ranges – examples are given in the case studies.

**Step K:** Complete the CAPEX and OPEX columns.

**Step L:** Calculate the ‘Operational Score’, ‘Cost Score’ and ‘Overall Score’ as outlined in Annex 8.12.

The second round assessment of ECM is the tank fitted with the combination of ECM with the highest overall score.

A third round of assessment can be carried out if deemed necessary. This would review the ECM from the second round assessment table that had medium to high overall scores – as an example ECM could be considered which have an overall score in excess of 50 % of the overall score for the second round highest scoring ECM combination.

## 8.12. Gaseous and liquid emission control measure assessment matrix

Aboveground Atmospheric Storage: External Floating Roof														
Operational emissions														
Potential Emission Source Only scores >= 3 are considered	POSSIBLE ECM	Emission reduction potential	Operability	Applicability	Safety aspects	Cross-media	Operational Score	CAPEX (new)	CAPEX (retrofit)	OPEX (Utilities)	OPEX (Ops and Main)	Cost score (new)	Cost score (retrofit)	Overall score
<b>Gas Emissions</b>														
		A	B	C	D	E	=B+C+D+E	F	G	H	I	=F*(H+I)	=G*(H+I)	
filling	operating procedures/training													
(until roof floats on liquid)	instrumentation													
standing	shell/roof paint colour													
	dome roof													
	pontoon roof													
	- with vapour mounted primary seals													
	- with liquid mounted primary seals													
	- with mechanical shoe seal													
	- with secondary seals													
	double deck roof													
	- with vapour mounted primary seals													
	- with liquid mounted primary seals													
	- with mechanical shoe seal													
	- with secondary seals													
	sealing roof penetrations													
	- guide pole													
	- roof legs													
	- still well cover													
fugitive	inspection/maintenance													
	(incl. roof-shell seal tightening)													
<b>Liquid Emissions</b>														
cleaning	operational procedures/training													
<b>Scoring definitions:</b>														
All scores range from 1 to 5														
5-score on emission reduction potential indicates the highest reduction potential														
5-score on operability means easiest to operate														
5-score on applicability indicates that the ECM is suitable for the widest range of products														
5-score on safe to use indicates safest to use for operators														
5-score on Amount of Waste produced indicates the lowest amount of (additional) waste produced														
5-score on all CAPEX/OPEX columns indicates lowest costs														

## 8.13. Case studies for ECM assessment methodology

This annex provides five case studies that show how the ECM assessment methodology outlined in Annex 8.11 is undertaken for atmospheric pressure storage modes.

The case studies are for the following tank modes and stored products:

1. 100000 cubic metre capacity EFR tank storing crude oil
2. and 2a. 10000 cubic metre capacity FRT tank storing light naphtha
3. 1000 cubic metre capacity FRT tank storing acrylonitrile (ACN)
4. 100 cubic metre capacity FRT tank storing ACN

These case studies are provided only to demonstrate the methodology and, as such, should not be used to draw conclusions for the tank types or products used. The ECM assessment needs to be undertaken taking account of site location, tank operations, local cost factors, etc.

### 8.13.1. Case study number 1; existing EFRT

**Tank type:** Existing EFR, storing crude oil with a Reid Vapour Pressure of 34 kPa

**Location:** Northern Europe – average annual temperature 10 °C, average annual solar radiation 120 W/m<sup>2</sup>, average annual wind speed 4 m/s.

**Details:**

- Double deck type EFR with primary vapour mounted seal
- Welded shell, colour mid grey, good condition.
- Internal shell has light rust
- Size: diameter 90 m, height 16 m, capacity 101787 m<sup>3</sup>
- Fitted with slotted still well/guide pole
- Turnovers: average 12 per year

#### Case study number 1 - Initial ECM Assessment

**Step 1:** Emission estimates are undertaken. In the example below these were made using the US EPA Tanks 4 software.

Base case for an EFR is a mid-grey painted tank with the floating roof fitted only with a vapour mounted primary seal. If a guide pole or still well is installed, the base case should take the type installed without emission control devices fitted. The existing tank is, therefore, equivalent to the base case.

a) 'Uncontrolled Case' (FRT of same capacity) emissions = 518187 kg/year

b) Base Case (in this case: existing tank) emissions = 24425 kg/year

**Step 2:** Not required as existing EFRT has no additional ECM over base case.

**Step 3:** Percentage reduction over 'uncontrolled case' = 95.3 %

As this is an example, it will be assumed that further controls are deemed necessary.

**Step 4:** The emission sources with a score of 3 or more are given in Table 3.6. The ECM to control these emissions are shown in the scorecard in the Annex in Table 8.6.

The ECM to be considered to control standing emissions are:

- Change primary seal to mechanical shoe type
- Change primary seal to liquid mounted type
- Change seal to liquid mounted primary and rim-mounted secondary
- Install 'socks' over roof legs
- Install float in slotted still well
- Install sleeve over slotted still well
- Change tank paint colour to white
- Install domed roof over tank.

The effect of these ECM can be determined by using the Tanks 4 software.

In addition, to control filling emissions (until roof floats on liquid surface), level-measuring instrumentation is identified as an ECM. The effectiveness of this ECM at controlling emissions has to be determined from the reduction in the number of times that the EFR would be landed on its legs per year and the total volume and concentration of vapour expelled during subsequent filling before the roof re-floats.

**Steps 5 and 6:** The emission estimation results and the calculated emissions reduction efficiencies are shown below.

Case	Total Emissions (kg)	ECM Efficiency (%)
Base	24425	0
Base case with tank paint colour changed to white	20749	15.0
Base case with domed roof installed over tank	1580	93.5
Change primary seal to mechanical shoe type	7688	68.5
Change primary seal to liquid mounted type	3870	84.2
Change seal to liquid mounted primary and rim-mounted secondary	2673	89.1
Base case plus float in slotted guide pole	23372	4.3
Base case plus sleeve over slotted guide pole	22960	6.0
Base case plus 'socks' over roof legs	24345	0.3

**Step 7:** The score rating system to be used is established as:

Score	Emission Reduction Potential (Efficiency of ECM)
1	0 to < 50 %
2	50 to < 75 %
3	75 to < 85 %
4	85 to < 95 %
5	95 to 100 %

**Step 8:** The ECM ratings are therefore:

ECM	Emission Reduction Potential Rating
Instrumentation	1
Base case with tank paint colour changed to white	1
Base case with domed roof installed over tank	4
Change primary seal to mechanical shoe type	2
Change primary seal to liquid mounted type	3
Change seal to liquid mounted primary and rim-mounted secondary	4
Base case plus float in slotted still well	1
Base case plus sleeve over slotted still well	1
Base case plus 'socks' over roof legs	1

**Step 9:** From the information in Chapter 4 and from best judgement, the ratings for the ‘operation aspects’ are:

ECM	Operability	Applicability	Safety	Waste, etc.
Instrumentation	5	5	5	5
Base case with tank paint colour changed to white	5	4	5	3
Base case with domed roof installed over tank	2	2	1	4
Change primary seal to mechanical shoe type	5	5	4	5
Change primary seal to liquid mounted type	5	5	4	5
Change seal to liquid mounted primary and rim-mounted secondary	4	5	4	5
Base case plus float in slotted still well	2	5	4	5
Base case plus sleeve over slotted still well	4	5	4	5
Base case plus ‘socks’ over roof legs	5	5	4	5

**Step 10:** The cost data to retrofit these ECM are determined. The costs to retrofit the ECM fall within the range EUR 5500 to 746000.

**Step 11:** The score rating system to be used is established:

Score	CAPEX (EUR)
5	< 10000
4	10000 to < 50000
3	50000 to < 100000
2	100000 to < 500000
1	Equal or > 500000

Note that a proportional system was not used, as this would not have differentiated between the ECM costing below 100000 EUR

**Step 12:** Completed assessment table is given in **step 15**

**Step 13:** The operating cost data for the ECM are determined for a ten-year period. The OPEX costs fall within a range 1000 EUR to 32000 EUR

**Step 14**

The score rating system to be used is established:

Score	OPEX (EUR)
5	< 5000
4	5000 to < 10000
3	10000 to < 15000
2	15000 to < 20000
1	Equal or > 20000

**Steps 15 and 16:** The completed assessment table is shown in Table 8.23.

**Step 17:** The ECM with the highest overall score is the liquid mounted primary with rim mounted secondary seal.



From **steps 5 and 6** above it can be seen that the estimated emissions with this ECM are 2673 kg/year compared with 24425 kg/year for base case. Note that this is 99.5 % of the ‘uncontrolled case’.

The result of the initial assessment of ECM for this tank, therefore, is that the seal should be changed from a vapour-mounted primary to a liquid-mounted primary with a rim mounted secondary seal system, further called the ‘initial ECM’.

If necessary the assessment can be re-iterated using the same methodology. As an example, a further round of iteration is given below.

### **Case Study 1 - Second Round of ECM Assessment**

**Step A:** The compatibility table indicates that the following ECM are compatible with the initial ECM:

- Install ‘socks’ over roof legs
- Install float in slotted still well
- Install sleeve over slotted still well
- Change tank paint colour to white
- Install domed roof over tank

**Step B:** The initial assessment table (Table 8.23) shows that only roof leg socks had an overall score of more than 50 % of the seal system with the highest overall score (the initial ECM). The still well float and sleeve had scores of about 40 %. The assessment would have continued with a re-assessment of these three ECM relative to the initial ECM.

As this is an example case study, however, it will continue with an assessment of all the compatible ECM to control standing losses.

**Step C:** The new assessment table is shown in **Step K**

**Steps D and E:** The emission estimation results and the calculated incremental efficiencies are shown below:

Case	Total Emissions (kg)	Incremental Efficiency (%)
Initial ECM: Change seal to liquid mounted primary and rim-mounted secondary	2673	0
Initial ECM with tank paint colour changed to white	2336	12.6
Initial ECM with domed roof installed over tank	643	75.9
Initial ECM plus float in slotted still well	1621	39.4
Initial ECM plus sleeve over slotted still well	1208	54.8
Initial ECM plus ‘socks’ over roof legs	2593	3.0

**Step F:** The score rating system to be used is established as:

Score	Incremental Emission Reduction Potential (Efficiency of ECM)
1	0 to < 20 %
2	20 to < 40 %
3	40 to < 60 %
4	60 to < 80 %
5	> 80 %

Note that as the incremental efficiencies are well spaced between 0 and 100 %, a proportional scoring system is used (i.e. steps of 20 %)

**Step G:** The completed Incremental Emission Reduction Potentials are shown in the table in **Step K**

**Steps H:** The scoring for the 'Operation Aspects' for the ECM are the same as in **Step 9** above

**Step J:** The CAPEX and OPEX costs for the ECM are the same as determined in **Steps 10 and 13** above. The same score rating systems are also used.

**Step K:** The completed second round assessment table is shown in Table 8.24.

**Step L:** The combined ECM with the highest overall score are the liquid mounted primary with rim mounted secondary seal and the still well sleeve.

The result of the second round assessment of ECM for this tank, therefore, is that the seal should be changed from a vapour-mounted primary to a liquid-mounted primary with a rim mounted secondary seal system and a sleeve fitted over the slotted still well.

A further round of assessment could be carried out if deemed necessary considering the ECM with medium to high overall scores relative to that scored by the second round ECM combination (i.e. still well float and roof leg socks).

When in the end no arrangement of ECM meet the BAT criteria, the process should be restarted by changing the basic data e.g. by reducing the inventory to be stored, or by changing the storage mode.

### 8.13.2. Case study number 2; new FRT

**Tank type:** Planned new FRT, storing light naphtha with a Reid Vapour Pressure of 68 kPa

**Location:** Southern Europe – average annual temperature 20 °C, average annual solar radiation 175 W/m<sup>2</sup>

**Details:**

- Cone roof, welded shell.
- Size: diameter 33 m, height 12 m, capacity 10263 m<sup>3</sup>
- Turnovers: average 12 per year

#### Case Study 2 - Initial ECM Assessment

**Step 1:** Emission estimates are undertaken. In the example below these were made using the US EPA Tanks 4 software.

Base case for a FRT is a mid-grey painted tank with open vents.

a) Base Case emissions = 318856 kg/year

**Steps 2 and 3:** Not required as tank is newly planned.

**Step 4:** The emission sources with a score of 3 or more are given in Table 3.10. The ECM to control these emissions are shown in the scorecard in the Annex in Table 8.7.

The ECM to be considered to control emissions are:

- Paint tank shell white
- Install breather (PVRV) valve
- Up rate tank to 56 mbar
- Install an IFR with primary seal only
- Install an IFR with secondary seal

The effect of these ECM can be determined from using the Tanks 4 software. In addition,

- Vapour balancing
- Connect to a vapour holding tank (VHT)
- Connect to a vapour recovery unit (VRU),

are also identified as ECM. The effects of these have to be determined from the emission estimates, specification of the systems and best engineering judgement.

**Steps 5 and 6:** The emission estimation results and the calculated emissions reduction efficiencies are shown below.

Case	Total Emissions (kg)	ECM Efficiency (%)
Base	318856	0
Base case with tank paint colour changed to white	174750	45.2
Base case with breather valve	302660	5.1
Base case with tank up-rated to 56 mbar	280320	12.1
Base case with IFR with primary mechanical shoe seal	10945	96.6
Base case with IFR with vapour mounted primary seal	11489	96.4
Base case with IFR with liquid mounted primary seal	8410	97.4
Base case with primary plus rim mounted secondary seal	7806	97.6
Base case with vapour balancing (assumed 80 % reduction in filling emissions)	176398	44.7
Base case with vapour holding tank (VHT)	178073	44.2
Base case with VRU (assumed 98 % efficiency)	6377	98.0
Base case with VRU and VHT	3561	98.9

**Step 7:** The score rating system to be used is established as:

Score	Emission Reduction Potential (Efficiency of ECM)
1	0 to < 75 %
2	75 to < 85 %
3	85 to < 95 %
4	95 to < 99 %
5	99 to 100 %

**Step 8:** The ECM ratings are:

ECM	Emission Reduction Potential Rating
Base case with tank paint colour changed to white	1
Base case with breather valve	1
Base case with tank up-rated to 56 mbar	1
Base case with vapour balancing	1
Base case with a VHT	1
Base case with a VRU	4
Base case with an IFR with primary seal	4
Base case with an IFR with secondary seal	4

**Step 9:** From the information in Chapter 4 and from best judgement, the ratings for the ‘operation aspects’ are:

ECM	Operability	Applicability	Safety	Waste, etc.
Shell paint colour	5	4	5	3
Breather valve	3	3	4	5
Up rate to 56 mbar	5	1	5	4
Vapour balancing	3	2	1	4
VHT	3	5	4	5
VRU	1	5	1	1
IFR with primary seal	4	5	2	5
IFR with secondary seal	4	4	2	5

**Step 10:** The cost data to fit these ECM are determined. The costs to fit the ECM fall within the range 1500 EUR to 650000 EUR.

**Step 11:** The score rating system to be used is established:

Score	CAPEX (EUR)
5	< 5000
4	5000 to < 25000
3	25000 to < 125000
2	125000 to < 625000
1	Equal or > 625000

Note that a proportional system was not used, as this would not have differentiated between the ECM costing below 125000 EUR (if 625000 divided into 5 steps).

**Step 12:** Completed assessment table given in **step 15**

**Step 13:** The operating cost data for the ECM are determined for a ten-year period. The OPEX costs fall within a range of EUR 500 to 20000.

**Step 14:** The score rating system to be used is established:

Score	OPEX (EUR)
5	< 5000
4	5000 to < 10000
3	10000 to < 15000
2	15000 to < 20000
1	Equal or > 20000

**Steps 15 and 16:** The completed assessment table is shown in Table 8.25.

**Step 17:** The ECM with the highest overall score is the IFR with primary seal.

The result of the initial assessment of ECM for this tank, therefore, is that the tank should be fitted with an internal floating deck; the initial ECM.

A second round of assessment could be undertaken. Only one ECM (secondary seal) has a high overall score relative to the initial ECM. Changing paint colour has a medium score. These two ECM would be re-evaluated using the methodology above against the initial ECM.

When in the end no arrangement of ECM meet the BAT criteria, the process should be restarted by changing the basic data e.g. by reducing the inventory to be stored, or by changing the storage mode.

### 8.13.3. Case study number 2a; new FRT

**Tank type:** as for case study 2, but FRT, storing light naphtha, to be used for strategic storage (i.e. tank kept full without turnovers)

**Location:** Southern Europe – average annual temperature 20 °C, average annual solar radiation 175 W/m<sup>2</sup>.

**Details:**

- Cone roof, welded shell
- Size: diameter 33 m, height 12 m, capacity 10263 m<sup>3</sup>
- Turnovers: zero per year.

#### Case Study 2a - Initial ECM Assessment

**Step 1:** Emission estimates are undertaken. In the example below these were made using the US EPA Tanks 4 software.

Base case for a FRT is a mid-grey painted tank with open vents.

a) Base Case emissions = 74790 kg/year

**Steps 2 and 3:** Not required as tank is newly planned

**Step 4:** The emission sources with a score of 3 or more are given in Table 3.10. The ECM to control these emissions are shown in the scorecard in the Annex in Table 8.7.

The ECM to be considered to control emissions are:

- Paint tank shell white
- Install breather (PVRV) valve
- Up rate tank to 56 mbar
- Install an IFR with primary seal only
- Install an IFR with secondary seal

The effect of these ECM can be determined from using the Tanks 4 software. In addition,

- Connect to a vapour holding tank (VHT)
- Connect to a vapour recovery unit (VRU)

are also identified as ECM. The effects of these have to be determined from the emission estimates, specification of the systems and best engineering judgement. Note that vapour balancing is not considered as the tank is on strategic storage duty.

**Steps 5 and 6:** The emission estimation results and the calculated emissions reduction efficiencies are shown below.

Case	Total Emissions (kg)	ECM Efficiency (%)
Base	74790	0
Base case with tank paint colour changed to white	13216	82.3
Base case with breather valve	66186	9.2
Base case with tank up-rated to 56 mbar	54318	27.4
Base case with IFR with primary mechanical shoe seal	10917	85.4
Base case with IFR with vapour mounted primary seal	11461	84.7
Base case with IFR with liquid mounted primary seal	8382	88.8
Base case with primary plus rim mounted secondary seal	7778	89.6
Base case with vapour holding tank (VHT)	0	100.0
Base case with VRU (assumed 98 % efficiency)	1496	98.0
Base case with VRU and VHT	0	100.0

**Step 7:** The score rating system to be used is established as:

Score	Emission Reduction Potential (Efficiency of ECM)
1	0 to < 75 %
2	75 to < 85 %
3	85 to < 95 %
4	95 to < 99 %
5	99 to 100 %

**Step 8:** The ECM ratings are:

ECM	Emission Reduction Potential Rating
Base case with tank paint colour changed to white	2
Base case with breather valve	1
Base case with tank up-rated to 56 mbar	1
Base case with a VHT	5
Base case with a VRU	4
Base case with an IFR with primary seal	3
Base case with an IFR with secondary seal	3

**Step 9:** From the information in Chapter 4 and from best judgement, the ratings for the 'operation aspects' are:

ECM	Operability	Applicability	Safety	Waste, etc.
Shell paint colour	5	4	5	3
Breather valve	3	3	4	5
Up rate to 56 mbar	5	1	5	4
VHT	3	5	4	5
VRU	1	5	1	1
IFR with primary seal	4	5	2	5
IFR with secondary seal	4	4	2	5

**Step 10:** The cost data to fit these ECM are determined. The costs to fit the ECM fall within the range of EUR 1500 to 650000.

**Step 11:** The score rating system to be used is established:

Score	CAPEX (EUR)
5	< 5000
4	5000 to < 25000
3	25000 to < 125000
2	125000 to < 625000
1	Equal or > 625000

Note that a proportional system was not used, as this would not have differentiated between the ECM costing below 125000 EUR (if 625000 divided into 5 steps).

**Step 12:** Completed assessment table given in **step 15**

**Step 13:** The operating cost data for the ECM are determined for a ten-year period. The OPEX costs fall within a range of EUR 500 to 20000.

**Step 14:** The score rating system to be used is established:

Score	OPEX (EUR)
5	< 5000
4	5000 to < 10000
3	10000 to < 15000
2	15000 to < 20000
1	Equal or > 20000

**Steps 15 and 16:** The completed assessment table is shown in Table 8.26.

**Step 17:** The ECM with the highest overall score is shell and roof paint colour.

The result of the initial assessment of ECM for this tank, therefore, is that the tank should be painted white; the initial ECM.

A second round of assessment could be undertaken. Only two ECM (IFR with and without a secondary seal) have a high overall score relative to the initial ECM. These two ECM would be re-evaluated using the methodology above against the initial ECM.

When in the end no arrangement of ECM meet the BAT criteria, the process should be restarted by changing the basic data e.g. by reducing the inventory to be stored, or by changing the storage mode.

#### 8.13.4. Case study number 3; new FRT

**Tank type:** New 1000 cubic metre capacity FRT tank storing acrylonitrile (ACN).

**Location:** Northern Europe – average annual temperature 10 °C, average annual solar radiation 120 W/m<sup>2</sup>

**Details:**

- Standard FRT
- Cone roof.
- Size: diameter 12.5 m, height 9 m, capacity 1000 m<sup>3</sup>
- Turnovers: average 12 per year

**Step 1:** Emission estimates are undertaken. In the example below these were made using the US EPA Tanks 4 software.

Base case for an FRT is a free-vented tank, painted mid-grey.

Base Case emissions = 4777 kg/year

**Step 2:** Not required, as this is a new tank.

**Step 3:** Not required, as this is a new tank.

**Step 4:** The emission sources with a score of 3 or more are given in Table 3.10. The ECM to control these emissions are shown in the scorecard in the Annex in Table 8.7.

The ECM to be considered to control emissions are:

- Change tank paint colour to white
- Install solar shield over tank
- Install a breather (P/V) valve on the tank
- Up-rate the tank design pressure to 56 mbar
- Install an IFR with primary seal
- Install an IFR with secondary seal

The effect of these ECM can be determined from using the Tanks 4 software. The effectiveness of the solar shield has to be established to permit solar radiation reduction to be introduced into the estimation methodology. In addition,

- Vapour balancing
- Connect to a vapour holding tank (VHT)
- Connect to a vapour recovery unit (VRU)

are also identified as ECM. The effects of these have to be determined from the emission estimates, specification of the systems and best engineering judgement.

**Steps 5 and 6:** The emission estimation results and the calculated emissions reduction efficiencies are shown below.

Case	Total Emissions (kg)	ECM Efficiency (%)
Base	4777	0
Base case with tank paint colour changed to white	2662	44.3
Base case with solar shield installed over tank	2444	48.8
Base case with breather (P/V) valve	4161	12.9
Base case with PV valve at 56 mbar	3312	30.7
Base case with IFR with primary seal	300	93.7
Base case with primary and rim mounted secondary seal	172	96.4
Base case with vapour balancing (80 % reduction assumed in filling emissions)	2561	46.3
Base case with vapour holding tank	2770	32.8
Base case with VRU (assumed 98 % efficiency)	96	98.0



**Step 7:** The score rating system to be used is established as:

Score	Emission reduction potential (Efficiency of ECM)
1	0 to < 80 %
2	80 to < 95 %
3	95 to < 98 %
4	98 to < 99.5 %
5	99.5 to 100 %

**Step 8:** The ECM ratings are therefore:

ECM	Emission reduction potential rating
Shell paint colour	1
Breather (PV) valve	1
Up-rate to 56 mbar	1
Solar shield	1
Vapour balancing	1
Vapour holding tank	1
Vapour recovery unit	4
IFR with primary seal	2
IFR with secondary seal	3

**Step 9:** From the information in Chapter 4 and from best judgement, the ratings for the ‘operation aspects’ are:

ECM	Operability	Applicability	Safety	Additional waste generation
Shell paint colour	5	4	5	3
Breather PV Valve	3	4	4	5
Up-rate to 56 mbar	5	4	5	4
Solar shield	5	2	5	5
Vapour balancing	3	2	1	4
Vapour holding tank	3	1	4	5
Vapour recovery unit	1	5	1	1
IFR with primary seal	4	5	2	5
IFR with secondary seal	4	3	2	5

**Step 10:** The cost data to fit or retrofit these ECM are determined. The costs for this example vary within a range of EUR 1000 to 100000.

**Step 11:** The score rating system to be used is established:

Score	CAPEX (EUR)
5	< 5000
4	5000 to < 15000
3	15000 to < 40000
2	40000 to < 100000
1	Equal or > 100000

**Step 12:** Completed **assessment** table is given in **Step 15**

**Step 13:** The operating cost data for the ECM are determined for a ten-year period. The OPEX costs fall within a range up to 20000 EUR

**Step 14:** The score rating system to be used is established:

Score	OPEX (EUR)
5	< 5000
4	5000 to < 10000
3	10000 to < 15000
2	15000 to < 20000
1	Equal or > 20000

**Steps 15 and 16:** The completed assessment table is shown in Table 8.27.

**Step 17:** The ECM with the highest overall score is the IFR with primary seal. However, an IFR with primary and secondary seal has a very close score.

From **steps 5 and 6** above it can be seen that the estimated emissions with this latter ECM are 172 kg/year compared with 4777 kg/year for base case. Note that this is 96.4 % of the base case.

Thus installing an IFR with primary and secondary seals is considered to be the initial ECM.

If further emission reductions are required a second round of ECM determination can be undertaken using as initial ECM an IFR installed on a free-vented FRT, having both primary and secondary seals.

When in the end no arrangement of ECM meet the BAT criteria, the process should be restarted by changing the basic data e.g. by reducing the inventory to be stored, or by changing the storage mode.

#### 8.13.5. Case study number 4; new FRT

**Tank type:** New 100 cubic metre capacity FRT tank storing acrylonitrile (ACN).

**Location:** Northern Europe – average annual temperature 10 °C, average annual solar radiation 120 W/m<sup>2</sup>.

**Details:**

- Standard FRT
- Cone roof
- Size: diameter 4 m, height 8 m, capacity 100 m<sup>3</sup>
- Turnovers: average 12 per year

**Step 1:** Emission estimates are undertaken. In the example below these were made using the US EPA Tanks 4 software.

Base case for an FRT is a free-vented tank, painted mid-grey.

Base case emissions = 346 kg/year

**Step 2:** Not required, as this is a new tank.

**Step 3:** Not required, as this is a new tank.

**Step 4:** The emission sources with a score of 3 or more are given in Table 3.10. The ECM to control these emissions are shown in the scorecard in the Annex in Table 8.7.

The ECM to be considered to control emissions are:

- Change tank paint colour to white
- Install solar shield over tank
- Install a breather (P/V) valve on the tank
- Up-rate the tank design pressure to 56 mbar
- Install an IFR with primary seal
- Install an IFR with secondary seal

The effect of these ECM can be determined from using the Tanks 4 software. The effectiveness of the solar shield has to be established to permit solar radiation reduction to be introduced into the estimation methodology. In addition,

- Vapour balancing
- Connect to a vapour holding tank (VHT)
- Connect to a vapour recovery unit (VRU)

are also identified as ECM. The effects of these have to be determined from the emission estimates, specification of the systems and best engineering judgement.

**Steps 5 and 6:** The emission estimation results and the calculated emissions reduction efficiencies are shown below.

Case	Total emissions (kg)	ECM efficiency (%)
Base	346	0
Base case with tank paint colour changed to white	222	36.0
Base case with solar shield installed over tank	194	43.8
Base case with breather valve	317	8.4
Base case with PV valve at 56 mbar	277	20.1
Base case with IFR with primary mechanical shoe seal	128	62.9
Base case with IFR with primary and rim mounted secondary seal	87	74.8
Base case with vapour balancing (assumed 80 % reduction in filling emissions)	145	58.1
Base case with vapour holding tank	251	48.2
Base case with VRU (assumed 98 % efficiency)	7	98

**Step 7:** The score rating system to be used is established as:

Score	Emission reduction potential (Efficiency of ECM)
1	0 to < 80 %
2	80 to < 95 %
3	95 to < 98 %
4	98 to < 99.5 %
5	99.5 to 100 %

**Step 8:** The ECM ratings are therefore:

ECM	Emission reduction potential rating
Shell paint colour	1
Breather PV Valve	1
Up-rate to 56 mbar	1
Solar shield	1
Vapour balancing	1
Vapour holding tank	1
Vapour recovery unit	4
IFR with primary seal	1
IFR with secondary seal	1

**Step 9:** From the information in Chapter 4 and from best judgement, the ratings for the ‘operation aspects’ are:

ECM	Operability	Applicability	Safety	Additional waste generation
Shell paint colour	5	4	5	3
Breather PV Valve	3	4	4	5
Up-rate to 56 mbar	5	5	5	4
Solar shield	5	2	5	5
Vapour balancing	3	3	1	4
Vapour holding tank	3	1	4	5
Vapour recovery unit	1	5	1	1
IFR with primary seal	4	2	2	5
IFR with secondary seal	4	2	2	5

**Step 10:** The cost data to fit or retrofit these ECM are determined. The costs for this example vary within a range of EUR 500 to 50000.

**Step 11:** The score rating system to be used is established:

Score	CAPEX (EUR)
5	< 2500
4	2500 to < 7500
3	7500 to < 20000
2	20000 to < 50000
1	Equal or > 50000

**Step 12:** Completed assessment table given in **step 15**.

**Step 13:** The operating cost data for the ECM are determined for a ten-year period. The OPEX costs fall within a range of EUR 0 to 10000 EUR

**Step 14:** The score rating system to be used is established:

Score	OPEX (EUR)
5	< 2500
4	2500 to < 5000
3	5000 to < 7500
2	7500 to < 10000
1	Equal or > 10000

**Steps 15 and 16:** The completed assessment table is shown in Table 8.28.

**Step 17:** The ECM with the highest overall score is a breather PV valve (at 20 mbar), closely followed by the up-rate to 56 mbar.

From **steps 5 and 6** above it can be seen that the estimated emissions with the latter ECM are 277 kg/year compared with 346 kg/year for base case. Note that this is 20.1 % of the ‘uncontrolled case’.

Up-rating the design of the new tank to 56 mbar is considered the initial ECM.

If further emission reductions are required a second round of ECM determination can be started using as initial ECM a PV valve set at 56 mbar installed on a FRT.

When in the end no arrangement of ECM meet the BAT criteria, the process should be restarted by changing the basic data e.g. by reducing the inventory to be stored, or by changing the storage mode.

Technique	Emission reduction potential	Operability	Applicability	Safety	Waste, energy, cross-media	Operational score	Score CAPEX (retro)	Score opex	Financial score RETRO	Overall score RETRO
	A	B	C	D		$O = A * (B+C+D+E)$	F	H	$Cr = F*H$	$OS = O*Cr$
Instrumentation	1	5	5	5	5	20	4	3	12	240
Shell/Roof colour	1	5	4	5	3	17	3	5	15	255
Dome Roof	4	2	2	1	4	36	1	3	3	108
Primary Seal - Mechanical Shoe	2	5	5	4	5	38	3	4	12	456
Primary Seal - Liquid Mounted (LM)	3	5	5	4	5	57	3	4	12	684
LM Primary + Secondary Seal	4	4	5	4	5	72	3	4	12	864
Still Well Float	1	2	5	4	5	16	5	4	20	320
Still Well Sleeve	1	4	5	4	5	18	5	4	20	360
Roof Leg Socks	1	5	5	4	5	19	5	5	25	475

Table 8.23: Case study number 1 – Initial ECM Assessment

Technique	Incremental emission reduction potential	Operability	Applicability	Safety	Waste, energy, cross-media	Operational score	Score CAPEX (retro)	Score opex	Financial score RETRO	Overall score RETRO
	A	B	C	D	E	$O = A * (B+C+D+E)$	F	H	$Cr = F*H$	$OS = O*Cr$
Initial ECM + Shell/Roof colour	1	5	4	5	3	17	3	5	15	255
Initial ECM + Dome Roof	4	2	2	1	4	36	1	3	3	108
Initial ECM + Still Well Float	2	2	5	4	5	32	5	4	20	640
Initial ECM + Still Well Sleeve	3	4	5	4	5	54	5	4	20	1080
Initial ECM + Roof Leg Socks	1	5	5	4	5	19	5	5	25	475

Table 8.24: Case study number 1 – Second Round of ECM Assessment

Technique	Emission reduction potential	Operability	Applicability	Safety	Waste, energy, cross-media	Operational score	Score CAPEX (new)	Score opex	Financial score NEW	Overall score NEW
	A	B	C	D	E	$O = A * (B+C+D+E)$	F	H	$C_n = F*H$	$OS = O*C_n$
Shell paint colour	1	5	4	5	3	17	5	5	25	425
PV Valve	1	3	3	4	5	15	3	5	15	225
Uprate to 56 mbar	1	5	1	5	4	15	4	5	20	300
Vapour balancing	1	3	2	1	4	10	3	5	15	150
Vapour holding tank	1	3	5	4	5	17	2	3	6	102
Vapour recovery unit	4	1	5	1	1	32	1	1	1	32
IFR with primary seal	4	4	5	2	5	64	3	5	15	960
IFR with secondary seal	4	4	4	2	5	60	3	5	15	900

Table 8.25: Case study number 2 – Initial ECM Assessment

Technique	Emission reduction potential	Operability	Applicability	Safety	Waste, energy, cross-media	Operational score	Score CAPEX (new)	Score opex	Financial score NEW	Overall score NEW
	A	B	C	D	E	$O = A * (B+C+D+E)$	F	H	$C_n = F*H$	$OS = O*C_n$
Shell paint colour	2	5	4	5	3	34	5	5	25	850
PV Valve	1	3	3	4	5	15	3	5	15	225
Uprate to 56 mbar	1	5	1	5	4	15	4	5	20	300
Vapour holding tank	5	3	5	4	5	85	2	3	6	510
Vapour recovery unit	4	1	5	1	1	32	1	1	1	32
IFR with primary seal	3	4	5	2	5	48	3	5	15	720
IFR with secondary seal	3	4	4	2	5	45	3	5	15	675

Table 8.26: Case study number 2a – Initial ECM Assessment

Technique	Emission reduction potential	Operability	Applicability	Safety	Waste, energy, cross-media	Operational score	Score CAPEX (new)	Score opex	Financial score NEW	Overall score NEW
	A	B	C	D	E	$O=A * (B+C+D+E)$	F	H	$C_n = F * H$	$OS = O * C_n$
Shell Paint colour	1	5	4	5	3	17	5	5	25	425
Breather (PV) Valve	1	3	4	4	5	16	5	5	25	400
Up-rate to 56 mbar	1	5	4	5	4	18	5	5	25	450
Solar shield	1	5	2	5	5	17	4	5	20	340
Vapour balancing	2	3	2	1	4	20	3	5	15	300
Vapour holding tank	1	3	1	4	5	13	2	3	6	78
Vapour recovery unit	4	1	5	1	1	32	1	1	1	32
IFR with primary seal	2	4	5	2	5	32	4	5	20	640
IFR with secondary seal	3	4	3	2	5	42	3	5	15	630

Table 8.27: Case study number 3 – Initial ECM Assessment

Technique	Emission reduction potential	Operability	Applicability	Safety	Waste, energy, cross-media	Operational score	Score CAPEX (new)	Score opex	Financial score NEW	Overall score NEW
	A	B	C	D	E	$O=A * (B+C+D+E)$	F	H	$C_n = F * H$	$OS = O * C_n$
Shell paint colour	1	5	4	5	3	17	4	5	20	340
PV Valve	1	3	4	4	5	16	5	5	25	400
Uprate to 56 mbar	1	5	5	5	4	19	4	5	20	380
Solar shield	1	5	2	5	5	17	4	5	20	340
Vapour balancing	1	3	3	1	4	11	3	5	15	165
Vapour holding tank	1	3	1	4	5	13	2	4	8	104
Vapour recovery unit	4	1	5	1	1	32	1	1	1	32
IFR with primary seal	1	4	2	2	5	13	3	5	15	195
IFR with secondary seal	1	4	2	2	5	13	3	5	15	195

Table 8.28: Case study number 4 – Initial ECM Assessment

## 8.14. ECM Scorecards for the storage of solids

- *Dust reduction potential*

- ++ very high or virtually complete prevention of diffuse emissions
- + clear reduction of diffuse emissions
- 0 no significant reduction of diffuse emissions or no clear conclusion possible

- *Energy consumption*

- + low energy consumption
- 0 normal energy consumption or no reliable data is available
- high energy consumption

- *Cross-media effects*

(e.g. additional impact in the hydrological cycle or on ground and surface water, increase in waste production, increase of noise impact.)

- + reduction of dust emissions without cross-media effect
- 0 no significant impact or no reliable data available
- cross-media effect

- *Investment requirement*

- + low investment required
- nd no data available
- high investment required

- *Operating costs*

- + low
- nd no data available
- high operating costs



**Table 8.29: ECM Scorecard for the storage of solids**  
[17, UBA, 2001]

General comment: [15, InfoMil, 2001]    **S1 = highly drift sensitive, not wettable**  
**S2 = highly drift sensitive, wettable**  
**S3 = moderately drift sensitive, not wettable**  
**S4 = moderately drift sensitive, wettable**  
**S5 = not or very slightly drift sensitive**

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs	Cross-reference
<b>Cereals</b> • wheat: S3 • rye: S3 • maize: S3	6.4b	Silo	++	0	0	nd	nd	

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs	Cross-reference
<b>Brown coal: S4</b>	1.1/1.3/1.4/3.1/3.5	Open storage with sprinklers, possibly with wind protection walls	+	0	0	+	nd	
<b>Black coal: S4</b>	1.1/1.3/1.4/3.1/3.5	Open storage with sprinklers, possibly with wind protection walls *)	+	0	0	+	nd	
		Enclosed storage	++	0	0	-	-	
		Large capacity silo	++	0	0	-	-	

\*) Note: for long-term storage of coal compacted multi-layer accretion is recommended for safety (flammability) and quality reasons. With fine coal dumps (particle size < 10 mm), it is common practice to apply a covering layer of gravel, earth or other material or cover with a tarpaulin or to spray the material with a binding agent.

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs	Cross-reference
Coke: S1-S4	1.1/1.3/2.1/2.2/2.4/2.5a	Enclosed storage	+	0	0	nd	nd	
		Open storage	+	0	-	nd	nd	

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs	Cross-reference
Iron ores and concentrates • pellets: S5 • rock ore: S5 • ore dust: S4-S5	2.1/2.2	Open storage with sprinkler systems, possibly with wind protection walls	+	0	0	+	+	
		Copper ores and concentrates: S4	2.5a	Enclosed storage	++	+	+	nd
Miscellaneous non-ferrous ores and concentrates: S2-S5	2.5a/2.5b	Open storage and sprinkling with a chalk suspension	0	+	0	nd	nd	
		Enclosed storage in halls	++	+	+	nd	nd	

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs	Cross-reference
Gypsum: S4	1.1/3.1/3.3/3.5/4.3	Large capacity silo	++	+	+	-	nd	
		Bunker	++	+	+	nd	+	
		Open storage	+	+	0	+	+	
		In shed/under roof	++	0	+	-	nd	

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs	Cross-reference
Fertiliser: S1-S3	4.3							

## 8.15. ECM Scorecards for the handling of solids

- *Dust reduction potential*

- ++ very high or virtually complete prevention of diffuse emissions
- + clear reduction of diffuse emissions
- 0 no significant reduction of diffuse emissions or no clear conclusion possible

- *Energy consumption*

- + low energy consumption
- 0 normal energy consumption or no reliable data is available
- high energy consumption

- *Cross-media effects*

(e.g. additional impact in the hydrological cycle or on ground and surface water, increase in waste production, increase of noise impact.)

- + reduction of dust emissions without cross-media effect
- 0 no significant impact or no reliable data available
- cross-media effect

- *Investment requirement*

- + low investment required
- nd no data available
- high investment required

- *Operating costs*

- + low
- nd no data available
- high operating costs

**Table 8.30: ECM Scorecard on the handling of solids**  
[17, UBA, 2001]

General comment: [15, InfoMil, 2001] **S1 = highly drift sensitive, not wettable**  
**S2 = highly drift sensitive, wettable**  
**S3 = moderately drift sensitive, not wettable**  
**S4 = moderately drift sensitive, wettable**  
**S5 = not or very slightly drift sensitive**

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs
<b>Cereals</b> <ul style="list-style-type: none"> <li>• wheat: S3</li> <li>• rye: S3</li> <li>• maize: S3</li> </ul>	6.4b	Fill pipe with automatic height adjustment and loading head	++	+	0	nd	nd
		Discharge tube with height adjustment and dust apron	+	+	0	nd	nd
		Discharge tube with sealing cone and level sensor	++	+	0	nd	nd
		Cascade chute	++	+	0	nd	nd
		Reduced emission grabs	+	0	0	+	nd
		Hopper at negative pressure	++	-	0	-	-
		Chutes enclosed at negative pressure	++	-	+	-	-
		Screw conveyor	++	-	0	-	+
		Chain conveyor	+	0	0	nd	nd
		Fully enclosed conveyor belt	++	0	0	nd	nd

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs
<b>Black coal: S4</b>	1.1/1.3/1.4/3.1/3.5	Fill pipe with height adjustment without loading head	+	0	0	+	+
		Cascade chute	++	+	0	-	nd
		Reduced emission grabs	+	0	0	+	nd
		Dedusted hopper *)	++	0	0	+	-
		Bucket elevator	+	+	0	-	+
		Screw conveyor	++	-	0	-	+
		Open belt conveyors, entrenched with lateral wind protection	+	0	0	+	+
		Enclosed belt conveyor	++	0	0	-	-
		Tube belt conveyor	++	0	0	nd	nd
Sprinkler systems for conveyor transfer points	++	0	+	nd	+		
<b>Brown coal: S4</b>	1.1/1.3/1.4/3.1/3.5	Open belt conveyor with water sprayed conveyor transfer points	++	0	0	nd	nd
		Open belt conveyor with negatively pressured conveyor transfer points	+	-	0	nd	nd
		Pneumatic conveyor **)	++	-	0	-	+
		Water jets/fine sprays at conveyor transfer points ***)	++	+	+	nd	+
		Spraying with water and tensides at conveyor transfer points ***)	++	+	-	nd	-

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs
Coke: S1-S4	1.1/1.3/2.1/2.2/2.4/2.5a	Reduced emission grabs	+	0	0	+	nd
		Dedusted hopper *)	++	0	0	+	nd
		Open belt conveyor, entrenched and with lateral wind protection	+	0	0	nd	nd
		Enclosed belt conveyor	++	0	0	-	nd
*) Note: dedusted means hoppers with high traverse walls and usually with dust filters							

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs
Iron ores and concentrates  • pellets: S4 • rock ore: S4 • ore dust: S4	2.1/2.2	Fill pipe with height adjustment without loading head	+	+	0	nd	+
		Reduced emission grabs	+	0	0	+	nd
		Dedusted hopper *)	++	0	0	+	nd
		Bucket elevator	++	+	0	-	+
		Open belt conveyors, embedded and with lateral wind protection	+	0	0	+	+
		Water jets, possibly with additives at appropriate conveyor transfer points	++	+	0	nd	+
Copper ores and concentrates: S4	2.5a	Emission optimised grabs	+	0	0	+	nd
		Dedusted hopper *)	++	0	0	nd	nd
		Enclosed belt conveyor	++	0	0	nd	nd
Miscellaneous non-ferrous ores and concentrates: S2-S4	2.5a/2.5b	Reduced emission grabs	+	0	0	+	nd
		Dedusted hopper *)	++	0	0	+	nd
		Enclosed belt conveyor	++	0	0	nd	nd
		Spraying with tensides	++	+	-	nd	nd
*) Note: dedusted means hoppers with high traverse walls and usually with dust filters; they are not necessarily used for handling iron pellets, because of the barely perceptible dust generation							

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs
Gypsum: S4	1.1/3.1/3.5/4.3	Emission optimised grabs	++	+	+	-	nd
		Reduced emission hopper not under negative pressure	++	-	0	nd	-
		Screw conveyor	++	-	+	+	-
		Pneumatic conveyor systems	++	-	+	+	-
		Tube belt conveyor	++	0	+	nd	+
		Cascade chute	++	+	0	-	nd
		Fill pipe with height adjustment and dust apron	+	+	0	nd	nd
		Fill pipes with sealing cone and level sensor	++	-	0	nd	-
Bucket elevator							

Relevant bulk material and inherent dustiness	Relevant IPPC activities (No. of appendix on IPPC Directive)	ECM	Dust reducing potential	Energy use	Cross-media effect	Investment costs	Operating costs
Fertiliser: S1-S3	4.3	Emission optimised grabs	+	0	0	+	nd
		Reduced emission hopper not under negative pressure	++	+	0	+	+
		Screw conveyor	-	-	0	+	nd
		Pneumatic conveyor systems	++	-	0	+	-
		Tube belt conveyor	++	0	+	nd	+
		Cascade chute	++	+	0	-	nd
		Fill pipe with height adjustment and dust apron	+	+	0	nd	nd
		Fill pipe with sealing cone and level sensor	++	+	0	nd	nd
Bucket elevator							

## 8.16. Characteristics of fire-fighting systems

Source: [8, CPR, 1991]

### 1) Automatic sprinkler system:

- heat detection at all times
- water or foam may be used as extinguishant
- a maximum storage floor area of 2500 m<sup>2</sup>
- the system requires no special structural provisions
- when the extinguishing system is activated only the area below the indicated sprinkler heads will be sprinkled
- the use of smoke and heat extraction systems is not allowed
- if (highly) flammable liquids are stored, only foam may be used as extinguishant.

### 2) Automatic deluge system

- any detection method may be used
- water or foam (medium or heavy) may be used as extinguishant
- a maximum storage floor area of 2500 m<sup>2</sup>
- the system requires no special structural provisions
- when the extinguishing system is activated, an entire section (number and size depending on the design) will be sprinkled; the sprinkled area is determined by the size of the section or partition
- if (highly) flammable liquids are stored, only foam may be used as extinguishant.

### 3) Automatic gas extinguishing system:

- any detection method may be used
- CO<sub>2</sub> is used as extinguishant
- a maximum storage floor area of 600 m<sup>2</sup> applies
- the walls, doors and ceilings of the storage room is completely fire-resistant for 30 minutes
- the use of smoke and heat extraction systems is not allowed.

### 4) Local fire brigade with dry deluge system

- a fast detection method is used (not heat detection); in the event of fire, detection must also take place for rooms adjoining the storage room (alternatives for fire detection may be formulated in the technical/organisational plan, and needs to be assessed by the competent authorities)
- water or foam may be used as extinguishant
- a maximum storage floor area of 500 m<sup>2</sup>
- the storage room is completely fire-resistant for 60 minutes; if a local fire brigade can be shown to be deployable within 6 minutes, a structure with a fire-resistance of 30 minutes will suffice for an existing storage room
- the storage room is subdivided into sections of no more than 100 m<sup>2</sup>; the sections are separated by walls with a fire-resistance of at least 30 minutes or by an aisle of at least 3.5 metres width
- if (highly) flammable liquids are stored, only foam may be used as extinguishant.



**5) Automatic hi-ex system**

- a fast detection method shall be used (not heat detection)
- light foam with an expansion factor between 500 and 1000 is used as extinguishant
- the maximum floor area of the storage room is 1500 m<sup>2</sup>
- the doors, walls and ceilings of the storage room is completely fire-resistant for 30 minutes
- when the system is activated, the entire room shall be completely filled with foam
- the use of a smoke and heat extraction system is required.

**6) Company fire brigade with manually operated deluge system**

- a fast detection method shall be used (not heat detection)
- water or foam (medium or heavy) may be used as extinguishant
- the maximum floor area of the storage room is 2500 m<sup>2</sup>
- the doors, walls and ceilings of the storage room is completely fire-resistant for 30 minutes
- when the extinguishing system is activated, an entire section will be sprinkled
- if (highly) flammable liquids are stored, only foam may be used as extinguishant.

**7) Company fire brigade with dry deluge system**

- a fast detection method shall be used (not heat detection)
- water or foam (medium or heavy) may be used as extinguishant
- the maximum floor area of the storage room is 2500 m<sup>2</sup>
- the doors, walls and ceilings of the storage room is completely fire-resistant for 30 minutes
- when the extinguishing system is activated, an entire section will be sprinkled
- if (highly) flammable liquids are stored, only foam may be used as extinguishant.

**8) Company fire brigade extinguishing *in situ* (internal assault)**

- a fast detection method shall be used (not heat detection)
- water or foam (medium or heavy) may be used as extinguishant
- the maximum floor area of the storage room is 1500 m<sup>2</sup>
- the storage room is subdivided in sections of no more than 300 m<sup>2</sup>
- the storage room is completely fire-resistant for 60 minutes; a construction with a fire-resistant of 30 minutes will suffice for existing storage rooms
- the use of a smoke and heat extraction system is required
- if (highly) flammable liquids are stored, only foam may be used as extinguishant.

## 8.17. Distances for the storage of gas cylinders

Distance	Group 1°, a)	Group 1°, b)	Group 1°, c)	Group 2°, a)	Group 2°, b)	Group 3°, a)	Group 3°, b)	Group 4°
Group 1° a	-	0	5	0	5	1) 5 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	0
Group 1° b	0	-	5	0	5	1) 5 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	0
Group 1° c	5	5	-	5	5	1) 5 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	0
Group 2° a	0	0	5	-	0	0	0	0
Group 2° b	5	5	5	0	-	0	0	0
Group 3° a	1) 5 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	0	0	-	0	0
Group 3° b	1) 5 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	0	0	0	-	0
Group 4°	0	0	0	0	0	0	0	-
Distance to borders	1) 3 2) 5 3) 7.5	7.5	7.5	7.5	7.5	2	7.5	2
To buildings without open fire	1) 3 2) 5 3) 7.5	5	7.5	7.5	7.5	5	7.5	2
Storage of flammable substances	5	5	5	2	5	5	5	2
Storage of liquids with flame point >55 °C	5	5	5	2	5	5	5	2
Storage combustible liquids with flame point < 55 °C	7.5	7,5	7.5	2	7.5	7.5	7.5	2
Storage combustible liquids	2	2	2	0	0	0	0	0
Tank liquefied oxygen	1) 5 2) 7.5 3) 7.5	1) 5 2) 7.5 3) 7.5	1) 5 2) 7.5 3) 7.5	2	2	2	2	2
Tank liquefied nitrogen or argon	2	2	2	2	2	2	2	2
Tank liquefied hydrogen	1) 5 2) 7.5 3) 75	1) 5 2) 7.5 3) 7.5	1) 5 2) 7.5 3) 7.5	2	7.5	7.5	7.5	2
<p>Note:  the distances mentioned under 1) are the minimum distances for a storage capacity of maximum 1000 l.  the distances mentioned under 2) are the minimum distances for a storage capacity between 1000 and 5000 l.  the distances mentioned under 3) are the minimum distances for a storage capacity of more than 5000 l.</p> <p>Those storage capacity are related to the group of gases concerned and not the whole storage capacity.</p>								

**Table 8.31: Distances for closed storage of gas cylinders**  
[45, Vlaanderen, ]

Distance	Group 1°, a)	Group 1°, b)	Group 1°, c)	Group 2°, a)	Group 2°, b)	Group 3°, a)	Group 3°, b)	Group 4°
Group 1° a	-	0	5	0	5	1) 2 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	0
Group 1° b	0	-	5	0	5	1) 2 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	0
Group 1° c	5	5	-	5	5	1) 2 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	0
Group 2° a	0	0	5	-	0	0	0	0
Group 2° b	5	5	5	0	-	0	0	0
Group 3° a	1) 2 2) 5 3) 7.5	1) 2 2) 5 3) 7.5	1) 2 2) 5 3) 7.5	0	0	-	0	0
Group 3° b	1) 5 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	1) 5 2) 5 3) 7.5	0	0	0	-	0
Group 4°	0	0	0	0	0	0	0	-
Distance to borders	1) 3 2) 5 3) 7.5	7.5	7.5	7.5	7.5	2	7.5	2
To buildings without open fire.	1) 3 2) 5 3) 7.5	5	7.5	7.5	7.5	5	7.5	2
Storage flammable substances	5	5	5	2	5	5	5	2
Storage liquids flame point > 55 °C	5	5	5	2	5	5	5	2
Storage combustible liquids flame point < 55 °C	7.5	7.5	7.5	2	7.5	7.5	7.5	2
Storage combustible liquids	2	2	2	0	0	0	0	0
Tank with liquefied oxygen	1) 5 2) 7.5 3) 7.5	1) 5 2) 7.5 3) 7.5	1) 5 2) 7.5 3) 7.5	2	2	2	2	2
Tank with liquefied nitrogen or argon	2	2	2	2	2	2	2	2
Tank liquefied hydrogen	1) 5 2) 7.5 3) 7.5	1) 5 2) 7.5 3) 7.5	1) 5 2) 7.5 3) 7.5	2	7.5	7.5	7.5	2
<p>Note:  the distances mentioned under 1) are the minimum distances for a storage capacity of maximum 1000 l.  the distances mentioned under 2) are the minimum distances for a storage capacity between 1000 and 5000 l.  the distances mentioned under 3) are the minimum distances for a storage capacity of more than 5000 l.</p> <p>Those storage capacity are related to the group of gases concerned and not the whole storage capacity.</p>								

**Table 8.32: Distances for open storage of gas cylinders**  
[45, Vlaanderen, ]

## 8.18. Examples of applied distances for the storage of flammable liquid in tanks

K <sub>1</sub> , K <sub>2</sub> and crude	Floating Roof Tanks						Fixed Roof Tanks
	10 – 40	41 – 60	61 – 80	81 – 100	101 – 180	181 – 240	10 – 40
Storage capacity in 1000 m <sup>3</sup>							
Block-capacity versus storage capacity	%	%	%	%	%	%	%
1 tank	100	100	100	100	100	100	100
2 tanks	80	80	80	80	80	80	80
3 tanks	70	80	80	80	80	80	70
4 tanks or more	60	80	80	80	80	80	70
Containment of the bund: capacity of the biggest tank + 10 % of all other tanks in the same bund. Maximum 4 tanks with a total capacity of 60000 m <sup>3</sup> or one tank with a capacity higher than 60000 m <sup>3</sup> (floating roof) in one bund							
Minimum distance from a tank to the foot of the bund or wall:							
	2 m	2.5 m	3 m	4 m	5 m	6 m	2 m
Minimum distance from a tank to another K <sub>1</sub> or K <sub>2</sub> tank with a separate containment							
	½ D	½ D	½ D	½ D	½ D	½ D	½ D
	6 m	10 m	15 m	17.5 m	20 m	25 m	6 m
Minimum distance from a tank within the same containment: ½ D, minimum 6 m							
<b>K<sub>3</sub></b>							
Minimum distance of a K <sub>3</sub> -tank to another K <sub>3</sub> -tank in the same containment: 1/3 D							
Minimum distance of a K <sub>3</sub> -tank to another K <sub>3</sub> -tank in a separate containment: ¼ D or 3 – 13 m.							
Note: K <sub>0</sub> : this is the category of flammable liquids with a vapour pressure, at 37.8 °C, of 1 bar or more K <sub>1</sub> : this is the category of flammable liquids, not being K <sub>0</sub> , with a flashpoint (determined with the Abel-Pensky instrument) at 1 bar, below 21 °C K <sub>2</sub> : this is the category of flammable liquids with a flashpoint (determined with the Abel-Pensky instrument) at 1 bar, below 55 °C but not below 21 °C K <sub>3</sub> : this is the category of flammable liquids with a flashpoint (determined with the Abel-Pensky instrument) at 1 bar, of 55 °C or higher, but not above 100 °C							

**Table 8.33: Distances for the aboveground storage of K<sub>1</sub>, K<sub>2</sub>, K<sub>3</sub> and crude applied in the Netherlands [3, CPR, 1984]**

<b>Factor</b>	<b>Minimum separation from any part of the tank</b>
Between adjacent fixed roof tank	Equal to the smaller of the following: the diameter of the smaller tank half the diameter of the larger tank 15 m but not less than 10 m
Between adjacent floating roof tank	10 m for tanks up to and including 45 m diameter 15 m for tanks over 45 m diameter The spacing is determined by the size of the larger tank
Between a floating roof tank and a fixed roof tank	Equal to the smaller of the following: the diameter of the smaller tank half the diameter of the larger tank 15 m but not less than 10 m
Between a group of small tanks and any tank outside the group	15 m
Between a tank and the site boundary, any designated non-hazardous area, process area or any fixed source of ignition	15 m

**Table 8.34: Distances for the aboveground storage of flammable liquids in ‘large’ tanks applied in the UK [37, HSE, 1998]**

## 8.19. Typical checklist for the design of a product storage tank in a chemical plant facility

### Physical properties of primary concern

- At ambient conditions - gas/liquid/solid
- Normal boiling point - °C
- Freezing point - °C
- Vapour pressure at ambient conditions - kPa
- State in the storage conditions - gas/liquid/solid/possible change of state
- Possible storage conditions - pressure: atmospheric/other  
- temperature: ambient/other
- Special cases - e.g. need to cool, heat....
- Hygroscopic features - need prevention to moisture contact

### Dangerous properties of primary concern

- Flammability - explosive limits/flashpoint
- Chemical stability - need to add stabilizers  
- effect of temperature
- Compatibility with usual agents - air, water, usual construction materials
- Corrosivity - avoided/recommended materials at storage temperature
- Acute toxicity for man - for man-qualitative data sufficient (e.g. MAC values)
- Long term toxicity for man - for man-qualitative data sufficient (e.g. MAC values)

### Product quality aspects

- Is the storage - dedicated  
- multi products/with or without incompatibilities
- Fate of off spec product - if present in storage  
- if returned from shipment
- Risk of pollution of product - by common vent collection system  
- by the mobile vessels  
- by the transfer lines
- Need of special operations - filtration, drainage of unwanted by-products, mixing etc

**Inventory (commercial aspects)**

- Total inventory - in volume, in mass, in weeks production, yearly turnovers
- Number of tanks - how to cope with regulatory inspections

**First selection of storage mode**

- In any case - operating pressure/temperature  
- construction materials  
- unit volume  
- total volume
- Inconvenient storage mode - list/main reasons
- Storage modes to be considered - list/main reasons

**Environmental issues of each storage mode**

- To surface water
- To groundwater
- Wastes

**Analysis of ECM applicable to each storage mode**

- Prevention of air pollution - recommended combination of ECM
- Prevention of surface water pollution - recommended combination of ECM
- Prevention of groundwater pollution - recommended combination of ECM
- Prevention of waste formation - recommended combination of ECM
- Incompatibilities between the combinations
- Cross-media aspects
- Economic aspects

**Solutions considered satisfactory**

- Industrial experience - with same/slightly different product
- Compliance with regulation
- Cost

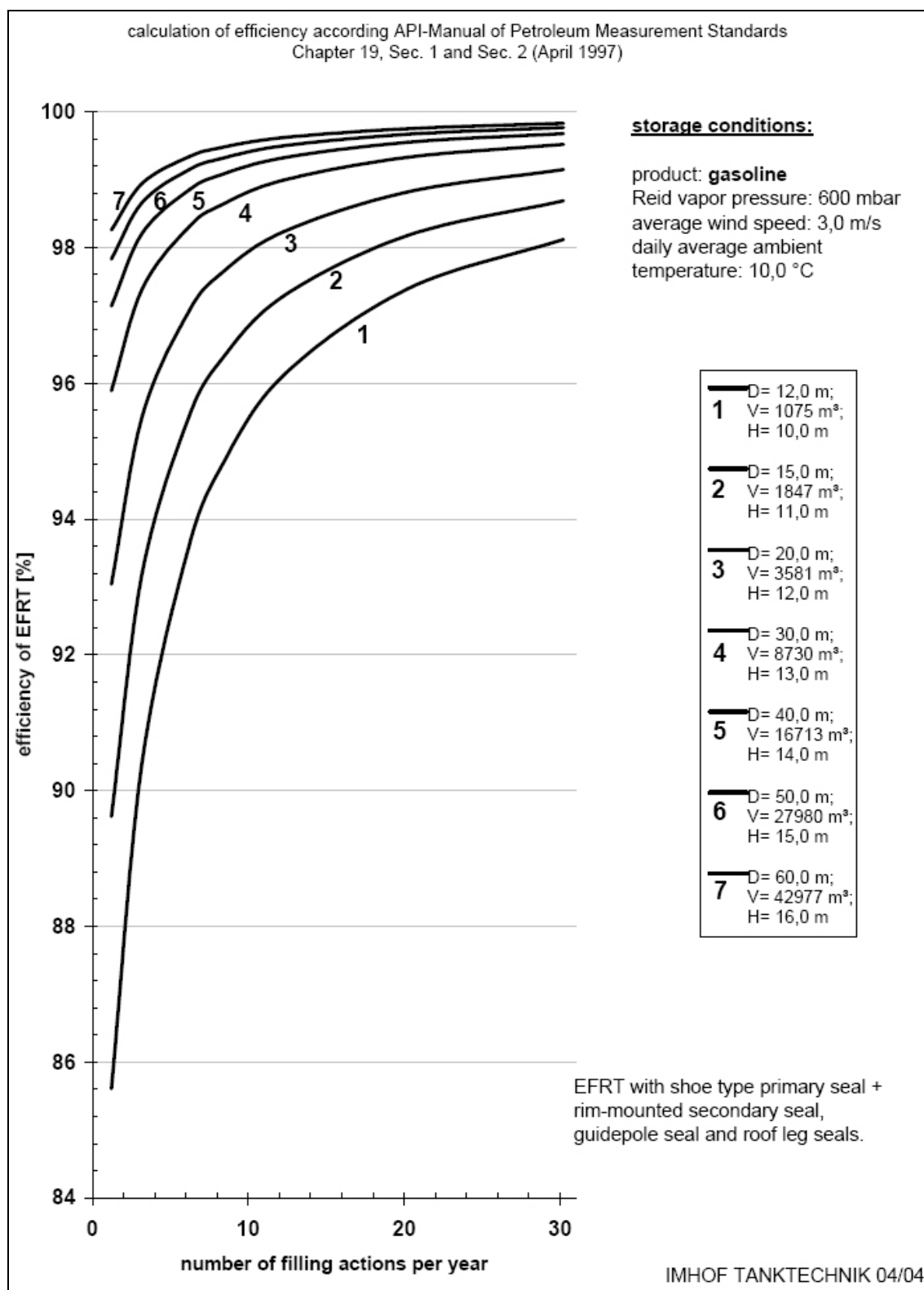
**Selection of solution(s) to develop****Refinement of design to cope with the other dangerous properties, when relevant**

**Final solution:**

- Design
- Environmental performances
- Cost

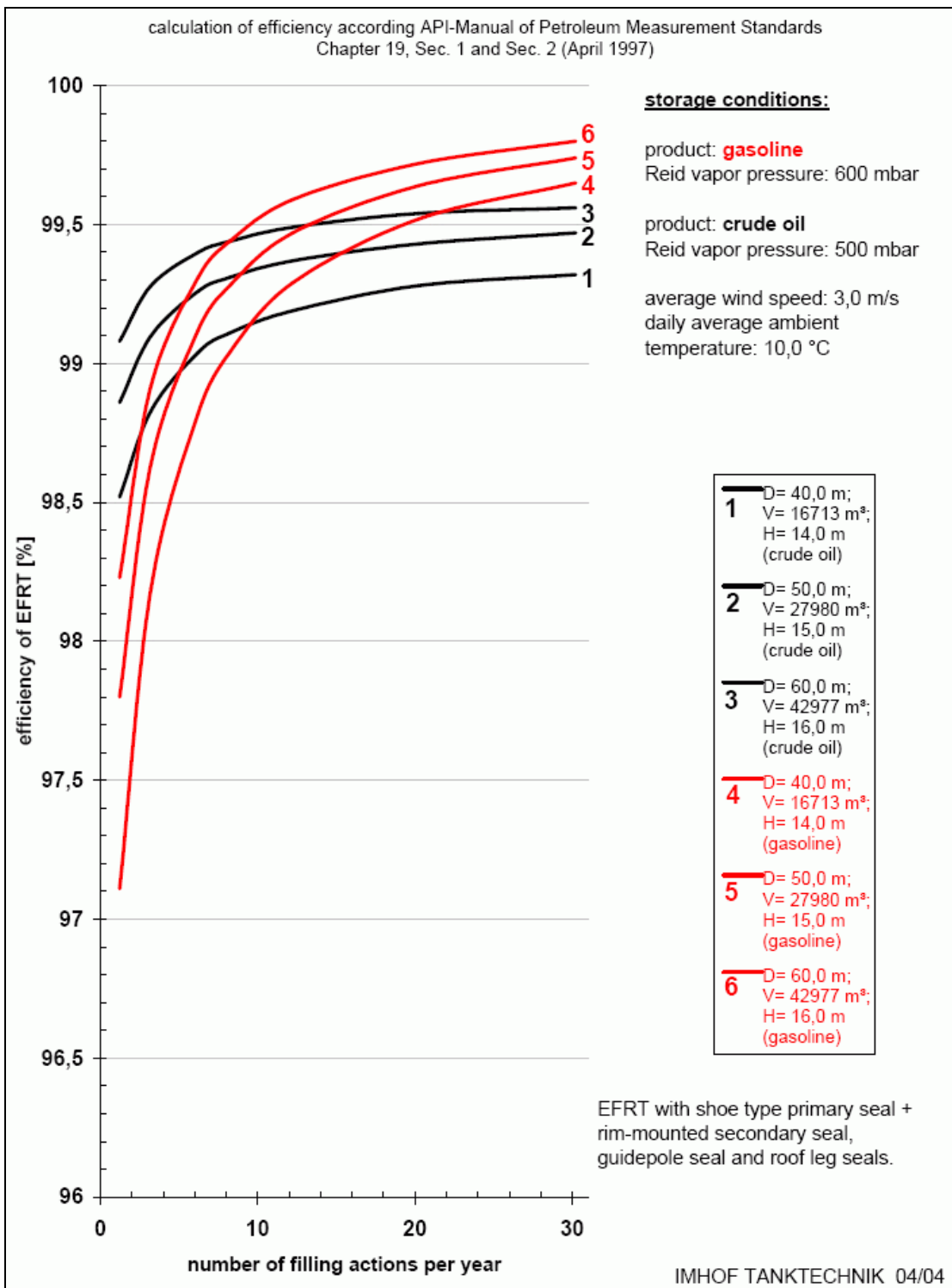


## 8.20. Efficiency of an EFRT depending on the number of filling cycles per year and tank



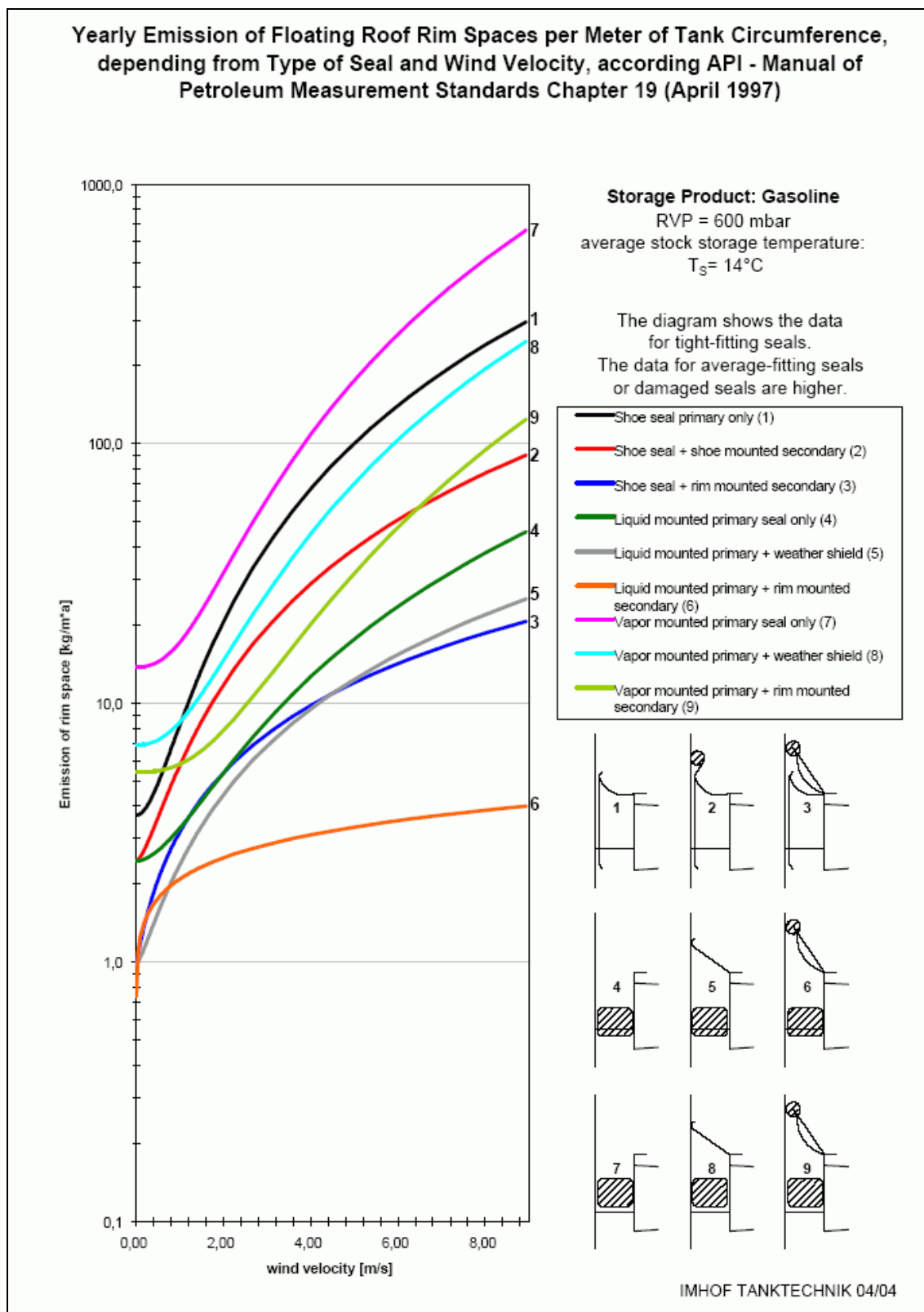
[185, UBA Germany, 2004]

## 8.21. Efficiency of an EFRT depending on the turnover rate per year and tank diameter for crude oil and gasoline



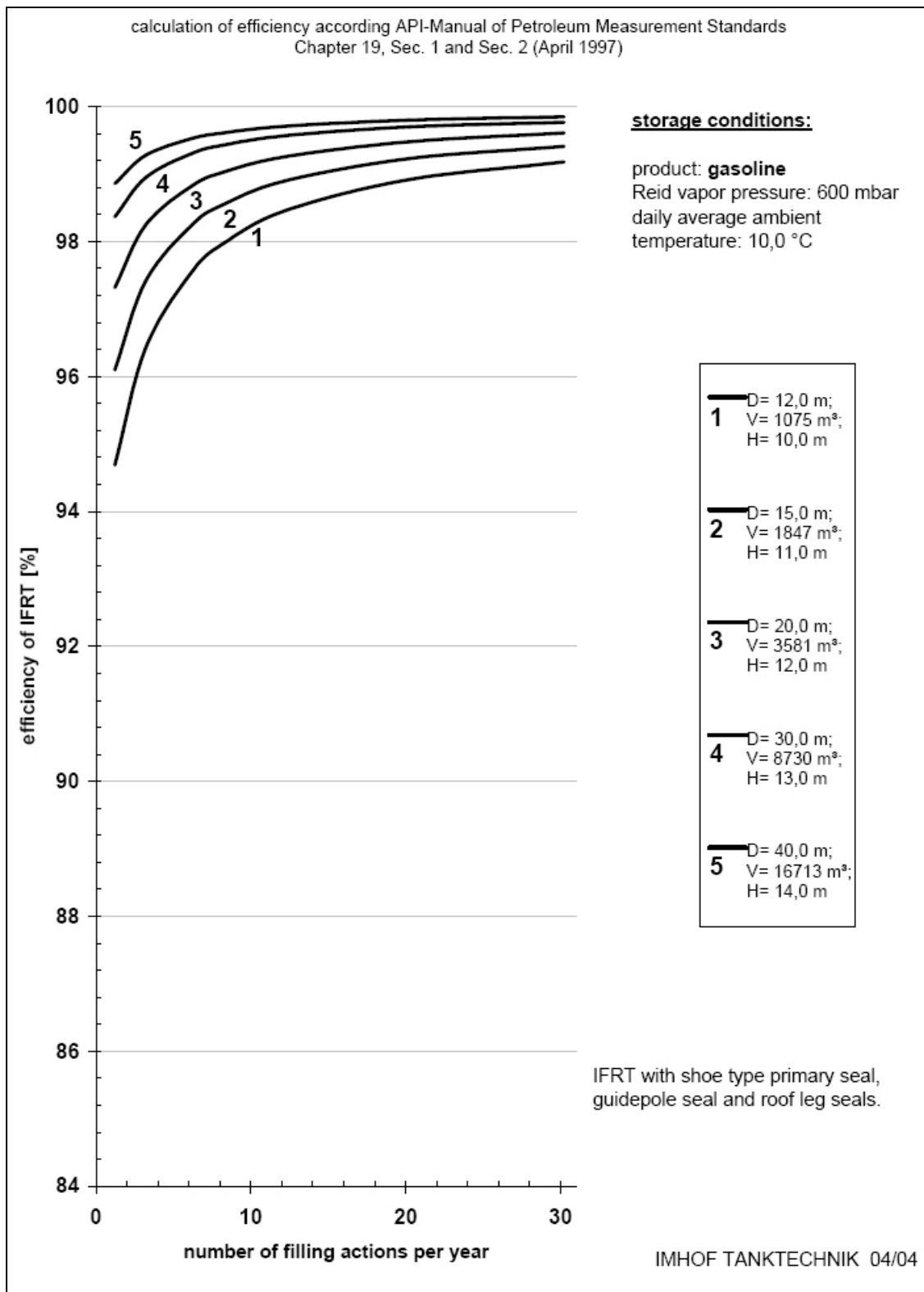
[185, UBA Germany, 2004]

## 8.22. Efficiency of different types of floating roof seals



[185, UBA Germany, 2004]

## 8.23. Efficiency of an IFRT depending on the number of filling cycles per year and the tank diameter



[185, UBA Germany, 2004]