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Inland Transport Committee

Working Party on the Transport of Dangerous Goods

Joint Meeting of Experts on the Regulations annexed to the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN) (ADN Safety Committee)

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Proposals for amendments to the Regulations annexed to ADN

Ventilation requirements

Transmitted by the European Barge Union (EBU)

TRANSAFE
GET A GRIP ON SAFETY

Report

Report of study investigating the effectiveness of the ADN measurement and ventilation standards on container ships carrying hazardous substances.

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Assignment SPB/EICB en Ministerie van Infrastructuur en Milieu

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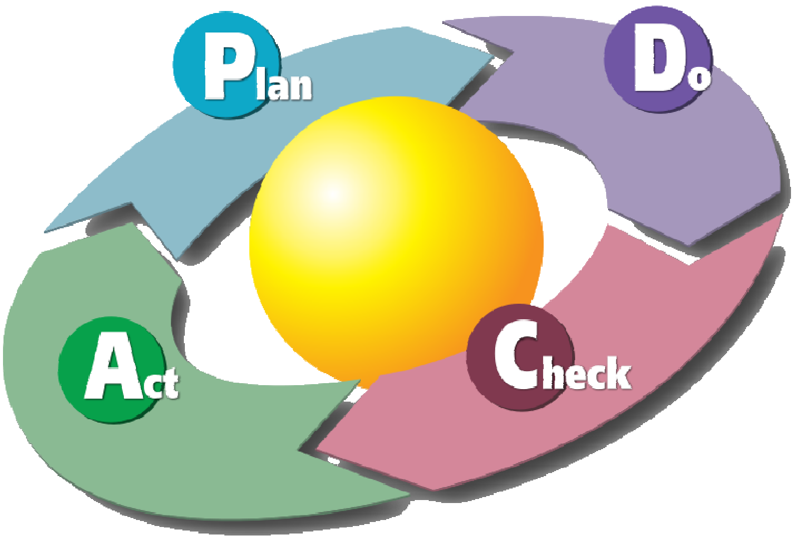
1. Introduction

Transafe has been asked to test the current requirements as described in the ADN for feasibility. Transafe is an assessors' office which deals with the daily practice of inland navigation. One of the main activities carried out by Transafe is fulfilling the role of safety advisor for ships which transport hazardous substances and for the waterfront side of storage companies. In addition, Transafe is in charge of safety and quality inspections, alcohol and drug testing, making up a Risk Inventory and Evaluation, Safety Management Systems, guidance relating to absence (safety, health and welfare), setting up Task Risk Analyses, a "help desk" for questions about safety and legislation, courses (ADN, safety, etc.).

Transafe's role as safety advisor makes it all the more precarious to state that the regulations must be simplified or dropped. That is why the various aspects regarding safety and the effects of changing the legislation in different scenarios have been considered carefully and extensively.
In the conclusions of the report, the practice and the direct safety of the people involved in transportation have been prioritised.
Transafe sees this study into the improvement process according to the Plan-Do-Check-Act "Deming circle", as follows:



“"Deming circle" (source: wikipedia)

The Deming quality circle is an aid for quality/safety management. The circle describes 4 activities (steps; Plan-Do-Check-Act) where there is constant attention for improving the quality/safety. This can also be used to test the legislation and explore the alternatives.

In the past, the criteria for required qualifications were recorded in the ADNR, as shown in the “Plan” step. When these changes were implemented, it became compulsory to work with this; the "Do" step. In this study, Transafe has been in charge of the "Check" section; testing whether the regulations are feasible. In order to carry the results of the study of the improvement cycle through to the next step, "Act", Transafe has made a proposal for changing the text of the regulations in the recommendations in Chapter 8.3.

With the results from this study, we hope to provide a good contribution to more manageable and effective regulations for safety in practice.

A "standard" container ship "Jordy-M" with the dimensions 110m long x 11.45m wide, 208 TEUs (4 layers).

2. Table of Contents

Appendices:

3. Summary

Transafe has been asked to investigate whether the current regulations for the measurement and ventilation on-board container ships are applicable. This concerns the regulations described in the ADN.Ch.7.1.4.12.2 and Ch.7.1.6.12. AND. Ch.7.1.4.12.2. describes a general standard; measurement and ventilation has to be done in the event of suspicion of leakage. In Ch. 7.1.6.12 the “VE-standards” are describes. In table A of Ch. 3.2. of the AND for each dangerous cargo is indicated whether a VE-standard is applicable (and which one), referring to Ch. 7.1.6.12. Both regulations describe methods of measuring for hazardous substances and, if these are present, for ventilating the holds.

In addition to carrying out the above-mentioned study, we have been asked to set out and compare a number of alternatives using a Risk Inventory.
Transafe has investigated the reliability of the mandatory measurements, the effectiveness of the ventilation, loaders' compliance with the duty of care and the number and nature of incidents involving containers filled with hazardous substances.

The study shows that it is not possible, with the current state of technology and instruction, to have the ship's crew carry out a fully reliable and representative measurement. This, because a simple and effective instrument which is able to detect all the products that are being transported, does not exist. The main problem is that it is not known which container is leaking and which product should be detected. Besides crosssensivities and deviations within the measurement of toxicity should be taken into account. The ADN does not prescribe how and where the measurement should be carried out; it appears that there is currently no unilateral answer to this. In practice, the above reasons often lead to the crew not carrying out measurements.

The study shows that incidents involving containers releasing hazardous substances are relatively rare. In most cases, there was already a leak in the container before this was loaded onto the barge; every now and then, another container is damaged by the actions of the crane engineer during loading. Very rarely, a leak occurs in the container during travel.

Transafe has considered the alternative situations in relation to the present regulations based on the following scenarios:

-1) keep the current situation the same

-2) only measure in case of a suspected leakage

-3) never measure

-4) only measure in case of a suspected leakage, using specialists, a good ship emergency response plan and guaranteed cooperation with terminals, authorities and specialists in case of a (suspected) leak in a container filled with hazardous substances.

Based on scenario 4, Transafe suggests a text change in the above-mentioned articles in Ch.7.1. of the ADN. In doing so, the emphasis will be mainly on the importance of checking the containers before they are loaded onto the ship and on ensuring the safe handling of a situation where there is a leakage in a container filled with hazardous substances, by taking control measures. In this context, the situation is discussed in broader terms than just the shipping side, since there are always several parties involved in the transportation.

Container ships loaded with "5 layers" of containers.

4. Problem definition

4.1. The Process

Barges are used to transport containers on inland waterways. In a number of cases, these containers may be filled with hazardous substances. There are also tank containers, where a storage tank is hung in the frame of a container.
The ships are loaded and unloaded using a crane. The crew does not need to do anything with the cargo (in contrast with a tanker); loading and unloading is done by a crane at the loading/unloading terminal.

Many loaded (full) containers are supplied by ships in the seaports. The seaport container terminals take over the containers and these are stored at the terminal. At a later stage, the containers are loaded by barges and brought to receiving terminals. The same process exists the other way around with empty containers, but also with full containers. There are also loading/unloading terminals where companies fill or empty the containers themselves (e.g. BASF, Bayer).
During the study, it appeared that the probability of a container springing a leak on-board a barge is minimal; the biggest probability of a container springing a leak is when it is being transshipped, where the inherent bumping and shaking of loading, occasionally with an added mistake made by the crane engineer, can damage the container. It appears that it is extremely rare that a container will leak whilst being transported on the barge.

It is also possible that a damaged container is loaded onto the ship without the loader being aware of this. To control this process, "Safety duties for those involved" are included in the ADN in H.1.4. for all parties participating in the transportation process (sender, loader, transporter, packager/filler, receiver). In short, all parties are responsible for taking the necessary measures in order to guarantee safe transportation. Among the things that need to be checked are: whether the container is in any way damaged, whether it has been labelled correctly, etc.

Example of labelling on a container.

4.2. The current VE standards

In the ADN (known as "ADNR" prior to 1-1-2011), H.7. ("Regulations for the loading, transport, unloading and any other handling of the cargo") contains the regulations on measuring and ventilation:

7.1.4.12 *Ventilation*

…

7.1.4.12.2 On-board the ships which only transport hazardous substances in containers in open cargo holds, the ventilation systems do not need to be built-in, but they must be transported on board. ***When there is suspected damage to the container or when there are grounds for suspecting that the contents within the container have been released, the cargo hold must be ventilated so that the gas concentration of the flammable gases coming from the cargo is below 10% of the lower explosive limit or so that, in case of toxic gases or vapours coming from the cargo, the cargo holds are free of every important concentration.***

7.1.6 Additional requirements.

7.1.6.12 *Ventilation*

The following additional requirements must be met, if they are mentioned in 3.2, Table A, Column 10:

VE01: ***Cargo holds which contain this substance must ventilate at full power, should the measurement determine that the gas concentration coming from the gases in the cargo is above 10% of the lower explosive limit. This measurement must be carried out directly after loading***. A repeat measurement must be carried out after one hour. The results of these measurements must be recorded in writing.

VE02: ***Cargo holds which contain this substance must ventilate at full power if, following measurement, it is established that the cargo holds are not free of the gases coming from the cargo. This measurement must be carried out directly after loading.*** A repeat measurement must be carried out after one hour.The results of these measurements must be recorded in writing.

VE03: Spaces such as cargo holds, cabins and engine rooms which are next to a cargo hold containing this substance, must be ventilated.
The cargo holds which have contained this substance must be mechanically ventilated after unloading.
After ventilation, the gas concentration in these cargo holds must be measured.
The results of these measurements must be recorded in writing.

VE04 If spray cans are transported in accordance with Particular standard 327 of chapter 3.3 for the reuse or for removal purposes, particular standards VE01 and VE02 apply.

In relation to the subject of the study; "Evaluating the current VE standards" the first problem is in the regulations of 7.1.4.12, "Ventilation". After investigating the ventilation (see chapter 5.1) the effect of the ventilation by mechanical extraction of the holds appears to have little to no effect and only has a minimal effect in the most ideal theoretical conditions.In relation to standards VE01/02/04 we distinguish: the substances to which the VE01 standard applies in ADN Ch.3.2. Table "A" in column 10 ("Ventilation") are generally flammable and can release explosive vapours.
The substances to which the VE02 standard applies are generally toxic substances which may release toxic vapours.
There are also substances to which both the VE01 and VE02 standards apply; this is generally the case for flammable, toxic substances that can release explosive as well as toxic vapours.

7.1.4.12.2. states that, when suspecting the damage to the containers or release of the substances in the container(s), the cargo holds must be ventilated so that the atmosphere in the holds comes to a maximum value of 10% from the lower explosive limit (“10% L.E.L.") after measurement and free of every important concentration. In order to achieve this, the following must be functioning:

1) The ventilation must be effective

2) The crew must be able to carry out a measurement which is representative of the atmosphere in the hold. There must be measurements for explosion and "every important" concentration.

VE standards 7.1.6.12. state that:

-VE01: a measurement must be carried out after loading. If it is established that the hold atmosphere amounts to more than 10% of the explosion limit, ventilation must be applied. In this case, a repeat measurement must be carried out after one hour.

-VE02: a measurement must be carried out after loading. If it is established that the hold atmosphere is not free of the gases coming from the cargo, ventilation must be applied. In this case, a repeat measurement must be carried out after one hour.

The study also shows that measuring the holds (see chapter 5.2.) causes problems, making it impossible in many cases to generate a reliable, representative measurement result.

Therefore, neither the regulations of 7.1.4.12. nor the VE standards of 7.1.6.12 contribute to increasing the safety. Using the Risk Inventory, we will discuss some alternatives in Ch. 7.

4.3. Risks

The purpose of regulations 7.1.4.12 and 7.1.6.12 is: to carry out a measurement in order to establish whether there is an explosive or toxic atmosphere in the cargo holds, and to ventilate these if there is, so that this atmosphere is controlled and remains below the values indicated. By measuring the atmosphere in the hold according to 7.1.6.12, leakages from a container should be discovered in time to prevent any negative consequences.

Various risks are associated to complying with these regulations, in relation to measuring:

- Apparent safety: if the measurements are not carried out or interpreted correctly, or if they are carried out in the wrong place, this can lead to a false sense of security. The assumption could be made that the hold is a safe area, when it is not.
- Danger of falling; discrepancy with the Arbo-Wet (Dutch Occupational Health and Safety Law); to carry out a representative measurement, a number of points in the hold must be measured; to be able to measure the centre of the hold, the crew must climb on the containers, which creates a danger of falling. This is inadvisable.

- Danger of falling overboard: to carry out the "measuring" action one needs to use both hands. Because climbing on the containers is not permitted, the measurements must be carried out from a position around the hold. This means that measurements may only be carried out from the gangway, (80 m long, 80 cm wide.) and from the deck between the cabin(s) and the hold (and possibly from the midship section). In the gangway, it is not possible to hold on to the railing because the measurement must be carried out with both hands, increasing the risk of falling overboard.

Various risks are associated to complying with these regulations, in relation to ventilation:

- Excessive load for the crew with regards to lifting; the ventilation systems often weigh more than 35 kg.
- Danger of falling; (discrepancy with the Dutch Occupational Health and Safety Law); in order to place the ventilation systems and extraction hose in the right location in the hold, the crew must climb on containers in a number of cases, which creates a danger of falling. This is inadvisable.
- For the mobile ventilation systems, the explosion safety would have to be examined further. The ventilation systems themselves must be EX proofed, however it appears that most only have a 3 meter long cord, meaning extension leads/connectors would have to be laid out on the containers and on deck. The "exhaust pipe" of the ventilation system will expel explosive vapours on deck when extracting these.
- Exposure of the crew to explosive and/or toxic vapours near the exhaust pipe of the ventilation system. The crew has not been trained or educated in how to deal with this. By independently carrying out this extraction from the hold, the crew runs an increased risk of exposure. There is also an increased risk that the vapours will enter the cabin(s) and the captain's cabin through mechanical ventilation.

4.4. Practice

During Transafe's regular inspections on container ships and from the explicit interviews of the crews of 33 ships (see Chapter 5.4.2), the following things occur in practice:

- How, what and where to measure is seen as a big problem by the crew. The knowledge of the crew is often not sufficient to make a reliable and accurate measurement. In addition, in a number of cases there are no measurement methods available. This is discussed in more detail in Chapter 5.2.
- The results of the measurement of the hold are recorded on the measurement list. In 9 out of 10 cases, the measurement list is filled in without a measurement taking place. This is to avoid a fine or "trouble with the water police". In practice, measurements are usually not carried out.

- In practice, incidents with leaky containers happen very rarely. (See Chapter 5.4).
- If a leakage occurs in a container, it is very difficult for the crew to determine which container it is. In many cases, the container is not clearly visible because there other containers on top of or around it.
- In reality, ventilation is only applied in an emergency.
- The ventilation systems cannot practically be applied in all locations in the hold. This is discussed further in Chapter 5.1.

Barge Name:

Date start trip:

Gas measurement records in accordance with ADN 7.1.6.12												
After loading, before departure:												
	% to LEL	Time	Date	By :	% to LEL							
Section 1 t/m 5												
Section 6 t/m 11												
After 1 hour ventilation (only if measured gas level is >10 at departure)												
	% to LEL	Time	Date	By:	% to LEL	Time	Date	By:	% to LEL	Time	Date	By:
Section 1 t/m 5												
Section 6 t/m 11												
After unloading of substances with the code VE 03												
	% to LEL	Time	Date	By:	% to LEL	Time	Date	By:	% to LEL	Time	Date	By :
Section 1 t/m 5												
Section 6 t/m 11												
Engine room Front												
Engine room Back												
Living Quarters Front												
Wheelhouse												

Example of a measuring form/measurement list.

4.5. Reference to literature

The study of Transafe has been set up, in which Chapter 2 of the study report "Study into substantive compliance costs" of Berenschot, dated 17-03-2010 has been included. Although the emphasis of the report of Berenschot, after indicating the problems, mainly discusses the expenses, Transafe largely draws its conclusions from the report. However, the emphasis of Transafe's study is on the safety aspects for crew members and third parties. Transafe endorses the opinion that the legislation is not strong and clear enough in outlining the obligations of the parties involved, as named in H.1.4. of the ADN.

5. Description of Study

5.1. Ventilation

5.1.1. Description of the ventilation practice

Most container ships are equipped with 2 or more mobile ventilation systems. The ventilation systems are powered by electricity and are explosion proof (EX). On most ships, the ventilation system comes with a hose which needs to be attached to the ventilation system. The extraction opening of the hose must then be placed in the hold. Because the ventilation system uses suction, it extracts air from the hold and blows this outside through the opening at the back of the ventilation system. No other facilities have been fitted here, such as a hose to extract the air, a baffle plate, etc. There are ships which do not work with hoses, but which are equipped with fixed shafts.

Mobile ventilation system and extraction hose which have been placed on deck above the back of the hold.

The same situation, the other side of the extraction hose lies on the dummy in the hold. In any case, this hose is too short to reach the bottom of the hold. The ventilation system's outlet blows in the direction of the cabin.

EX indication of the ventilation system in accordance with ATEX guidelines

On a number of ships, shafts have been built into the front and rear bulkheads, which have openings at the bottom of the hold and one on deck, which is closed with a hatch. By opening the hatch, the top of the shaft becomes visible and a mobile ventilation system can also be set up here, so that air can be extracted from the hold through the shaft.


Example of a built-in ventilation shaft coming from the stern (deck) coming out in the hold. Most ships are not equipped with fixed shafts but instead have loose, mobile units.

On ships that have a mobile ventilation system with an extraction hose, as well as those which have been equipped with ventilation shafts, the ventilation systems must be placed in the correct position by the crew. The study shows that the ventilation systems weigh > 35 kg and are therefore not easily moved. As described in the Occupational Health and Safety Law (Arbo-law) objects weighing more than 25 kg may not be lifted by one person. Moving the ventilation systems therefore requires 2 people. In practice, it is highly inadvisable to walk along the narrow gangway carrying this large and heavy item, as it increases the risk of falling overboard. During Transafe's regular inspections on-board container ships, as well as during interviews held with crew members, it came to light that the ventilation systems are stored away in an engine room, and sometimes stored so well that the crew doesn't remember where to find them.

5.1.2. Inventory of ventilation equipment on-board ships

To discuss the different kinds of ventilation equipment and its ventilation capacity, Transafe has presented its clients with container ships with a written survey. The crews of the ships in question completed the survey. The following format is used for the inventory:

Questionnaire data from container ships in relation to the study on ventilation/measurement:

Ship name	
Hold contents	
Does the hold have dividing walls?	
Number of hold ventilation systems per ship	
Ventilation system capacity in m3/hour	
Diameter of extraction hose(s)	
What type of measuring equipment do you have on board?	
If you do have a toxic gas meter, which test tubes do you have on board?	
What type of respiratory protection do you have on board?	
Any comments:	

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Appendix 5.1.2. contains a complete overview of the inventory, which fully outlines the outcomes. The outcomes of 31 ships have been considered (including lighter cargo barges, which are transported in barge combination with the motorized barges). The ship names have not been indicated.

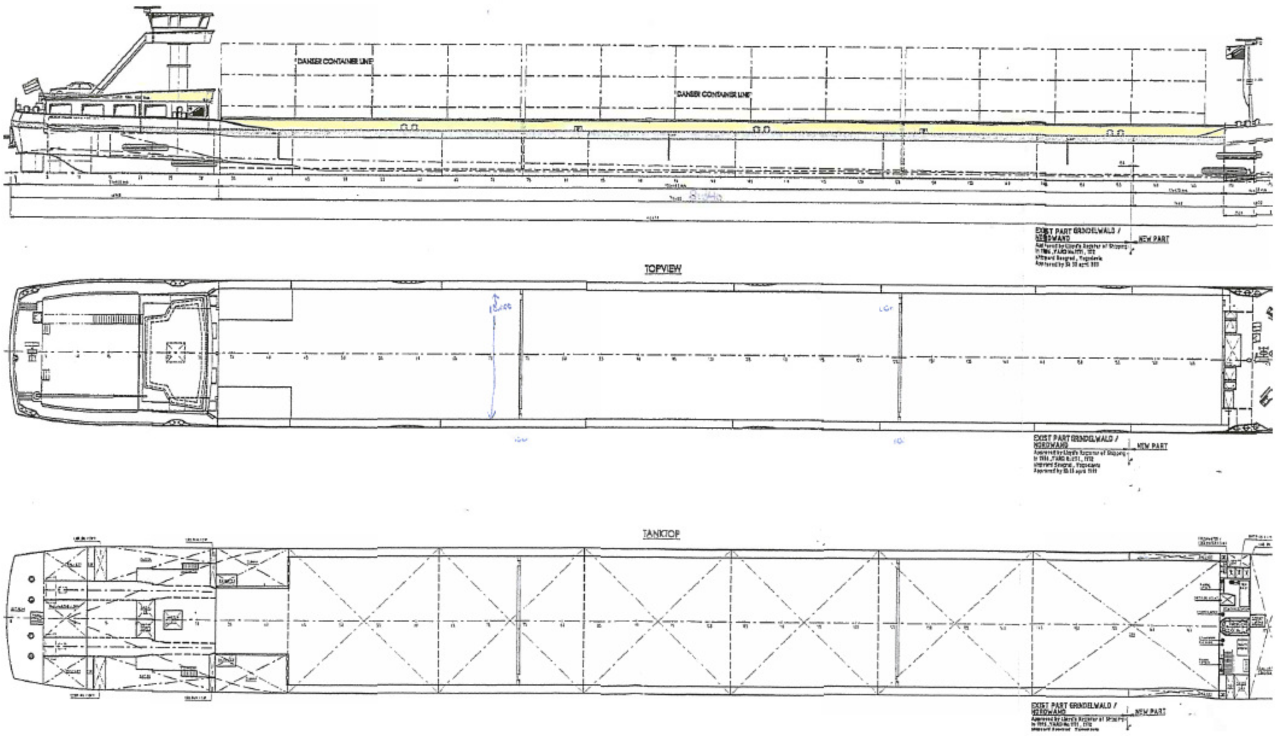
After the inventory, the following values appear relevant in relation to any further study:

Number of respondents:	31 ships
Average number of ships with loose ventilation systems/hoses:	86.66% (26/31)
Average number of ships with fixed ventilation shafts:	12.90% (4/31)
Average number of ships without ventilation:	3.22 % (1/31)
Average ventilation capacity:	8459.76 m3/hour
Mostly common ventilation capacity:	8500 m3/hour
Average diameter of extraction hose:	47.76 cm
Mostly common diameter of extraction hose:	50 cm

5.1.3. CFD air-flow analysis

Assuming an "average" container ship of 110 m in length x 11.40 m in width, the dimensions of the hold are approx. 80 m x 10 m. Assuming that the average ventilation system capacity is 8500 m3/hour (without the resistance that occurs in the curves of the hose) we started to further examine the effectiveness of the ventilation. We have assumed an average width of 4.8 cm between the containers.

Transafe has given the company Bunova Development B. V. (abbr: "Bunova") the task of calculating the effectiveness of the ventilation. Bunova is a mechanical and process technology engineering company, specialised in modelling chemical and physical processes. Through a CFD simulation (Computational Fluid Dynamics) Bunova has made an air-flow analysis to determine the effect of ventilation.



Drawing (general plan) of an example "standard" container ship. Hold dimensions 81.84 m x 10.00 m x 4.00 m   Source: Danser Container line

The task for Bunova is divided into 2 variants:

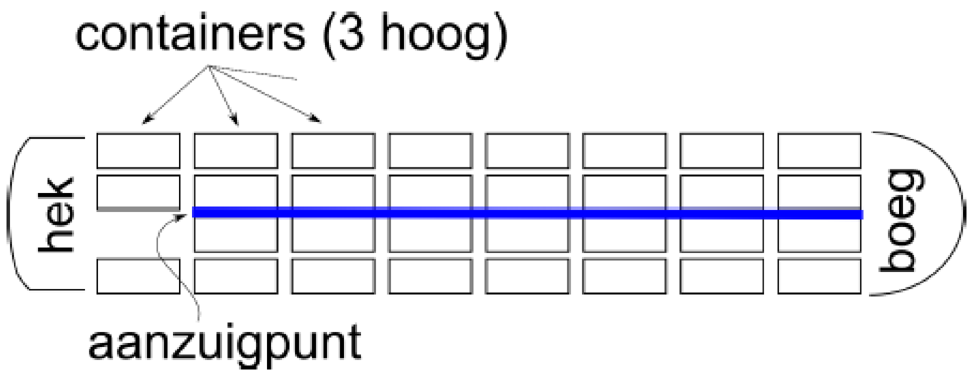
- Variant 1; ventilation set-up in the most ideal (far from realistic) circumstances.

Because the ventilation system extraction hose does not fit into a completely filled hold, which is of course filled with containers, one column of containers has been left clear, in the back row.

This is where air is extracted towards the front between 2 rows of containers in the longitudinal axis of the ship.

To achieve optimal results, the extraction hose should, in theory, be connected to a sealed manifold, at the height of 1 container, in the opening between the containers, so that all air is extracted from the opening. In theory, the openings between the containers which are placed further forwards should be sealed. The calculation assumes that the sides of the containers are smooth, in order to determine the effect of ventilation in the most optimal conditions. In practice, this is an impossible situation.

- Variant 2; ventilation set-up in the most feasible practical situation. Because the ventilation system extraction hose does not fit in a completely filled hold - because it is filled with containers - one row of containers has been left clear, the back row. This is where air is extracted towards the front between 2 rows of containers in the longitudinal axis of the ship. The hose has been placed in the most ideal position, in the most suitable corner and in front of the opening between the containers, at the bottom of the hold. Appendix 05-02 contains Bunova's complete report.



Sketch of set-up of the ventilation system extraction hose at the bottom of the hold. Air is extracted lengthways from the opening between the containers
(blue line). Source: Bunova report "Extraction in the hold of a container ship", 16-05-2011.

The CFD analysis shows that in "variant 1" air is extracted from up to 2 containers in front, where there is only 1% of the flow compared to the ventilation capacity. In practice, this ideal situation is not possible, for various reasons.

The CFD analysis shows that in "variant 2" hardly any air is actually extracted from the opening (1.5%). Most air is sucked in from above and behind the opening of the extraction hose.

5.1.4. Practical problems

During the study, we determined various practical problems for ventilation, which undermine the feasibility of effective ventilation:

- The vapours from most hazardous substances are denser than air; extraction must therefore be carried out at as low a height as possible. Usually, a container ship is fully loaded; so the bottom layer will be full of containers, which are placed back to back. This leaves no room to place an extraction hose in the hold and a column of containers (in its entire height) would have to be removed before this could be done.

- The ventilation systems are heavy (> 35 kg), and must be carried over the gangway by 2 people, increasing the danger of falling (overboard).

- The hoses are too short to be able to extract air from all areas. In accordance with the Dutch Occupational Health and Safety Law (Arbo-Wet), climbing on containers is not permitted; therefore the ventilation system can only be placed around the hold, in the gangways or in front of and behind the holds on deck. From the gangway, the hose first has to go up by 1 meter (over the den), then down by 4 meters and in the worst case, when there is a leaky container in the centre, it has to be moved at least another 5 meters to one side in order to be placed between the middle rows, on the longitudinal axis of the ship. This is assuming that we are dealing with a situation on the bottom layer. If the hose first had to be moved upwards over the 3rd, 4th or possibly 5th layer of containers, the hose would have to be much longer still. In these cases, the height makes it impossible to even put the hose in place.

- As it is not permitted to just enter the hold (ADN 7.1.3), especially in case of a leak, and climbing on containers is not permitted (Occupational Health and Safety (ARBO)), it is often impossible for the crew to get the nozzle of the extraction hose in the right place.

- For ships with fixed built-in ventilation shafts ventilation with a full hold is possible because there is no need for a hose to be placed in the hold, however the shaft offers no possibility of reaching the right place.

- A loose cable with a plug is attached to the ventilation systems for power. In order to power the ventilation system in all areas, loose cables, reels, etc. must be used on deck. This is inadvisable, particularly in combination with possible explosive vapours.

Example of a loaded container ship, measuring 135m x 17.42m Ships of these dimensions load 6 rows in the width. This makes it practically impossible to place an extraction hose which goes from the gangway to the bottom of the hold.

5.1.5. Sub-conclusion on ventilation

The study shows that, in practice, effective ventilation as described in the ADN is practically impossible. In addition to the practical impediments to getting the ventilation systems to the right places, the CFD analysis shows that there is no effect, even in the most ideal conditions. In short, according to the current regulations and in the present situation, ventilation is pointless.

The same loaded container ship which clearly shows that the extraction hose of the ventilation systems cannot be placed by the crew without climbing on the containers.

5.2. Measuring

5.2.1. Available measuring techniques to be applied

Container ships which transport hazardous substances are usually fitted with an oxygen/explosion meter and a toxic gas or PID meter.

Table A, column 9 ("required equipment") of Chapter 3.2. of the ADN indicates for each product to be transported which required equipment is mandatory to have on board in order to be permitted to transport this product, referring to Chapter 8.1.5 ("Special equipment"). For most flammable products to which the VE01 standard applies according to column 10 "Ventilation", the explosion meter is mandatory. For most toxic products to which the VE02 standard applies according to column 10, a toxic gas meter is also required. For substances for which the combination of flammability and toxicity applies, and both the VE01 and VE02 standards apply, both meters must be on board.

In order to be allowed to enter the hold (ADN chapter 7.1.3.1.6.) when handling goods of class 2, 3, 5.2, 6.1 and 8, oxygen levels must also be measured. In practice, crew members rarely enter the hold and usually only when the ship is empty.

To comply with the legislation, most container ships are equipped with the specified measuring instruments.

Oxygen/explosion meter:

Measuring the danger of explosion is usually done using a combined oxygen/explosion meter. This is an electronic device. Carrying out such a measurement is relatively simple in most cases. Most oxygen/explosion meters are equipped with a self-priming pump. In order to be able to measure the hold, the hose must be guided with one hand until it is at the correct height within the hold, whilst the measurer holds on to the railing of the gangway with the other hand and also holds the meter so that it can be read. In practice, this increases the danger of falling overboard, despite the fact that most meters are equipped with a strap. The result of the measurement can be read from the meter immediately, not much can go wrong with that.

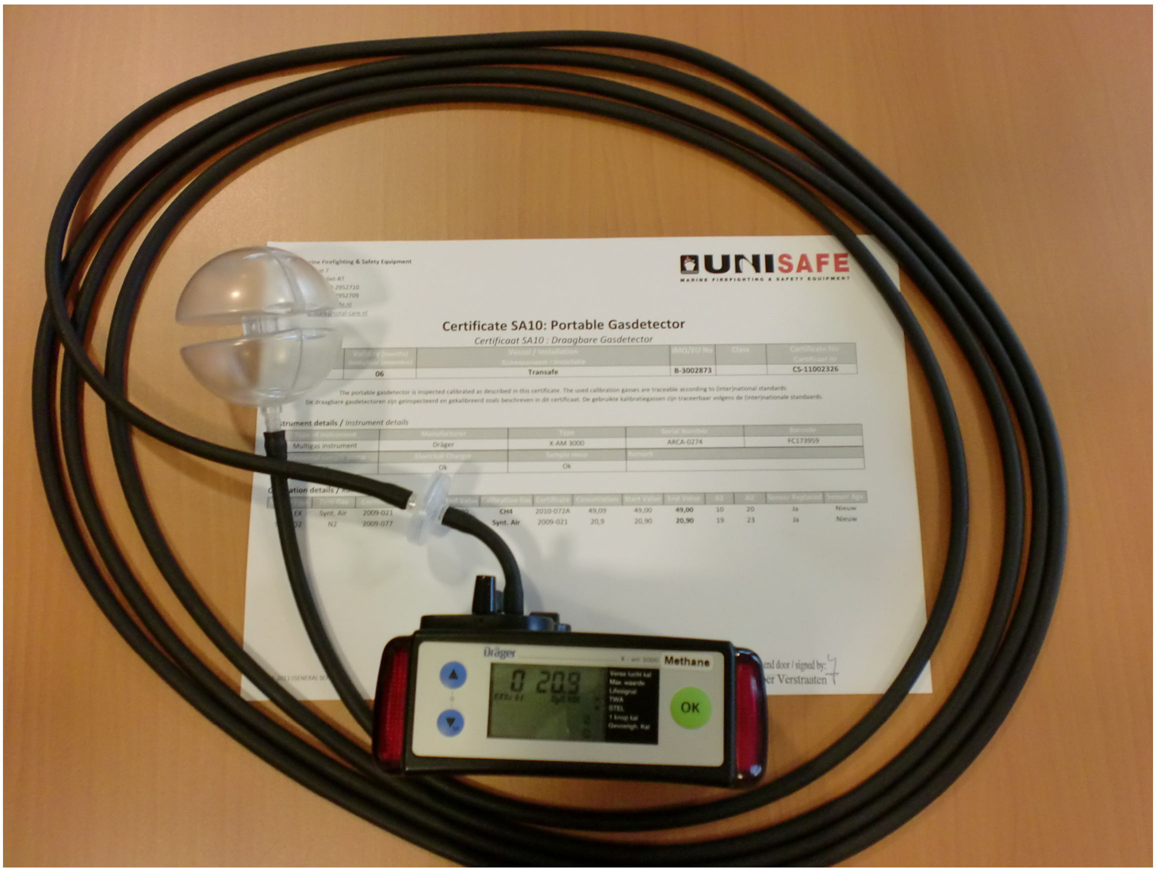


Photo of a combined oxygen/explosion meter with Certificate.

Toxic gas meter: Measuring toxic substances is mainly done using a toxic gas meter: a portable hand pump with a hose and "toxi-tubes". Separate tubes are available for most products. There are also poly-test tubes, which can detect a broad range of products. The possibility cross sensitivities of the test tubes must be considered (they sometimes react to more than one substance). By making the prescribed number of pump strokes by hand, the necessary quantity of air flows through the tube, allowing it to react. A chemical reaction takes place in the tube. The tube can only be used once.
In practice, in order to carry out a measurement of toxicity, the box of tubes will be opened on the gangway and the tops of the glass measuring tubes will be broken off. The measuring tube must be put in the sleeve at the bottom of the hose and the hose must be hung in the right place in the hold.

All these actions require the use of both hands at the same time, meaning one cannot hold on to the hand rail, creating an increased danger of falling overboard for the crew member carrying out the measurement.

After the number of pump strokes, the test tube will show the result by a discolouration. This measurement is largely inaccurate, as it depends on the humidity and temperature, among other things. An additional practical problem is that the measurer does not know what they are measuring for. If the ship would transport a single cargo, such as UN 1114, benzene, it would be easy to determine whether vapours of this product were present. In a cargo hold containing up to 150 different products at the same time, it is impossible to check for all the vapours that could be found there and to find out whether there are any cross sensitivities for the required test tubes. In addition, despite the fact that more than 250 kinds of test tubes are available and that there are programmes for finding which tubes to use for which products, there are still substances that cannot be measured.

In addition to this, the measurement result of the toxic gas meter is difficult to read in the dark, as it does not light up, as opposed to most oxygen/explosion meters and PID meters.

The kind of "poly-test" tube that works for several products can be used. The disadvantage of this is that even after the measurement, we do not know what has been measured. You could say that if it measures something, then we can assume that one of the containers is leaking.

Photo of a toxic gas meter (hand pump) with a number of boxes containing various test tubes and certificate.

"PID" meter:

The PID meter (Photo Ionization Detector) is an electronic measuring instrument that is very similar in its use to the oxygen/explosion meter. In addition to being able to regularly measure the oxygen and explosion concentration, the PID meter measures concentrations of ppm (parts per million) of different substances. Only a part of the (aromatic) hydrocarbons can be measured with this instrument. There is also a part of the (aromatic) hydrocarbons that can be measured, but where the lower measurement limit lies above the value of the limit. Substances other than the above-mentioned cannot be measured using a PID meter.

The PID meter is often used in combination with oxygen and explosion measurement. To interpret the values that the PID meter read, one must know what kind of ionisation lamp the device uses.

The kind of lamp that has been placed inside the device is indicated in the manual. After obtaining the value on the display, the user must convert this to the correct value using a correction table. It is important in this case that the user knows what substance he will be measuring.
The oxygen/explosion meter, the toxic gas meter and the PID meter must be tested by an expert according to the instructions of the manufacturer (every six months or annually). Following the testing, a certificate will be delivered which will be kept on board.

Photo of an example of a PID meter and certificate, which also measures oxygen, explosion, H2S and CO.

The current state of technology is therefore not able to measure all substances directly at this moment. For instance, various products with chlorine compounds are not directly detectable.

Some examples of substances which are not immediately measurable:
-UN 1026 Cyanogen VE01/VE02
-UN 1069 Nitrosyl chloride VE02
-UN 1308 Zirconium, dissolved in flammable liquid VE01
-UN 2013 Strontium phosphide
-UN 3246 Methanesulfonyl chloride

5.2.2. Advantages and disadvantages of different measuring instruments.
As described in 5.2.1., there is no single meter available that can measure everything that needs to be measured in a relatively simple and reliable way. The table below indicates the advantages and disadvantages of the most common measuring devices. With regards to the costs, we refer to the "study into substantive compliance costs" report of the Berenschot company; this explains the purchase costs of the measuring equipment.

Table overview of the effectiveness of measuring instruments on board container ships

Measuring device Aspects for use:	combined oxygen/explosion meter	toxic gas meter with product tube and poly-test	PID- meter
User-friendly control	+	-	+
Reliable measurement outcome	+	-	+
Costs	+	-	+
Range of different substances	+	-	+/-
Availability (tubes)	n/a	-	n/a
Suitable for one substance	+	+	+/-
Suitable for possible multiple, (unknown) substances present	+	-	+/-

\+ satisfactory; costs relatively low whilst in use
+/- yes, but not in all cases, depends on the substance
\- to some extent; costs relatively high whilst in use

5.2.3 .The knowledge of the crew in relation to measuring

On-board ships which transport hazardous substances, at least one of the crew members must have passed the ADN (basic) certificate. The ADN certificate demonstrates specialist knowledge of the ADN. In accordance with ADN chapter 8.2.1.3. the following requirement has been adopted for measurement as the examination target for the ADN basic examination:

Measuring techniques (ADN 8.2.2.3.1.1.):

- Measuring toxicity, oxygen level and explosiveness

The ADN certificate is valid for 5 years. A refresher course must be completed every 5 years, where the subject of "measuring" will be dealt with in a half day course. By taking part in the refresher course, the certificate can be extended by 5 years.

The crew must know how to measure for toxicity, oxygen content and explosiveness. The outcome of the measurements made by the crews must be seen purely as indicative. When it comes to interpreting the measurement data about limits for instance, or declaring something "protected from fire/hot work" a gas expert should be appointed (popularly called a "gas doctor"). Only the gas expert is qualified to declare a tank ship gas free when it is going to the shipyard.

5.2.4. Practical problems in relation to measurement.

Assuming that the right equipment is available onboard the ship to measure the substances for which the VE01 and VE02 regulations are prescribed, the crew must measure the hold atmosphere immediately after loading for the risk of explosion (VE01) and “gases emitted by the cargo” (VE02).

The ADN does not state how and where measurements should be carried out. It is not permitted for unrestricted access to be granted to the hold (ADN 7.1.3.1.6) in order to carry measurements on the spot; the hold has to be measured, etc., first before such can take place.

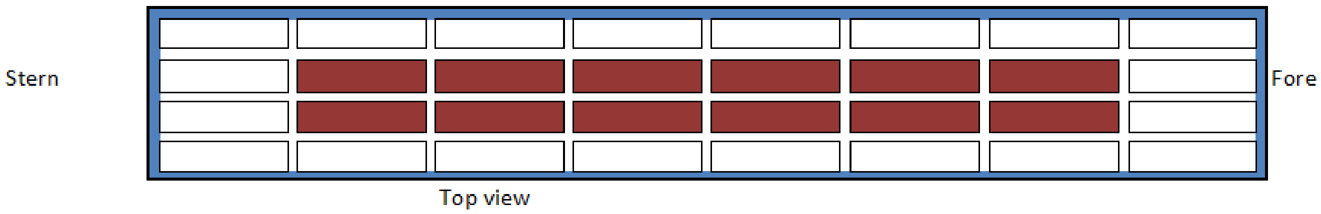
How and where measurements should take place raises numerous questions. Measurement immediately after loading of a container, for example, for which the VE01 regulations apply, would in practice mean:

1) The immediate interruption of any further loading.

2) Depending on where the container is placed, the crew would have to get as close to the container as possible, however there is only around the edge of the hold for measurements to be carried out in the hold.

Thus only containers that are in the stacks around the edges can be reached. The crew are on the gangway/foredeck and afterdeck and lower the hose of the oxygen/explosion gauge down into the hold next to the container. The diagram below shows the locations which can be reached safely by the crew; apart from the outermost containers, the other containers cannot be measured.

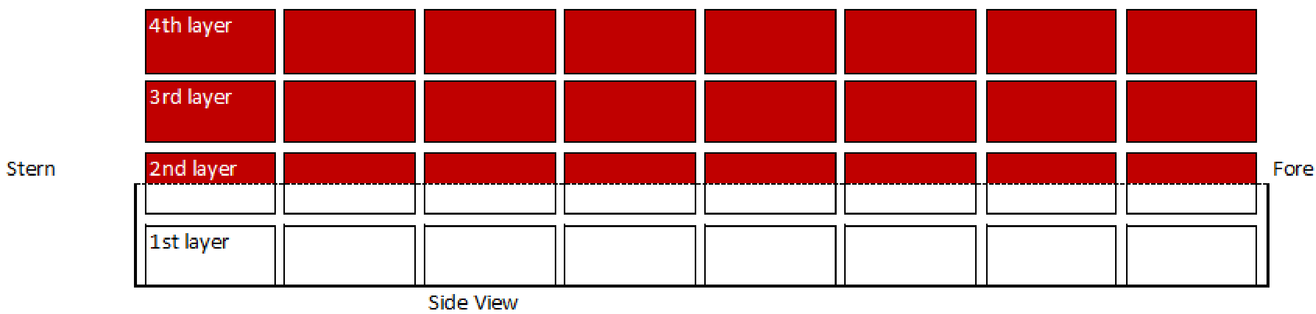
Diagram showing accessibility of ship's hold for measurement of containers



Blue: accessible for measurement of containers on one side
Red: containers inaccessible for measurement

It is therefore not practically possible for measurements to be carried out near all containers. The containers shaded in red cannot be measured at all without entering the hold or without climbing on top of the containers. In this example, the containers on the 1st and 2nd layer shown in white in the diagram can be measured on one side. From the 3rd layer upwards, the containers are higher than the bulkhead of the ship. It can be assumed that the wind would blow away most of any gases or vapours emitted, so there would not be much point in carrying out a measurement.

Diagram of containers above deck level



In the diagram above, it can be seen that for most ships the bulkhead of the ship would be level with the middle of the second layer of containers.

A separate study would have to be carried out to show how effective it is to try to measure these containers, although the practical problems concerning where and how containers at a higher level can be measured mean that this would be totally pointless;

- as with the bottommost 2 layers; measurements can only be carried out on one side of the outermost containers;
- the third or fourth and/of fifth layers are completely outside of the enclosed environment of the hold, and are affected much too much by the wind;
- containers at higher levels cannot be reached, and thus the crew cannot carry out measurements for them.

3) If one wants to carry out measurements “around a container” with hazardous substances with a toximeter, 4 tubes are necessary in order to carry out the measurements from all sides as required under the VE02 regulations. This means 4 times as many tubes have to be kept onboard, and 4 times as much time will be needed to carry out the measurements (see the Berenschot report).

4) In order to carry out a measurement, one has to be able to stand on a gangway 60cm wide, and to be able to carry out measurements without having to hold onto anything.

Measuring from the gangway,in this example there is a barge alongside, which means the danger of falling overboard is mitigated on this side, but in most cases (and on the other side of the ship) there is not a barge, and there is a high risk of falling overboard.
Photo: Hazardous cargo 23-12-2010 (Article Mr. Ing.R. Tieman).

5.2.5. Effectiveness of the measurements

Because in practice containers are loaded and unloaded quickly after one another, every loading situation is unique. In order to carry out effective measurements, a study would have to be carried out into how measurements should be carried out at different stages of loading, and when a container which is leaking gas and/or vapours has been placed in different locations. In light of the variables involved in this scenario, there is no feasible way of doing this. Is not clear to the crew where measurements have to be carried out.
All the problems described above mean in many cases it is not possible for the crew to carry out an effective and reliable measurement.

5.2.6. Sub-conclusion measurement

Due to the limitations with regard to the currently available measurement equipment, it is not possible to properly measure the toxicity of every substance that is transported, and which is subject to the VE02 regulations. Furthermore, it is not possible in any case to measure those containers which are not on the outermost stacks. There is a high risk of incorrect measurement due to abnormalities in the toxicology tubes, cross-contamination, and possible human error in the performance of the measurements and the interpretation of the measured values. The measurement of toxicity is therefore not realistically possible in practice.
The same applies in relation to the explosion concentration measurements; it is not possible to reach all locations. However, it is significantly easier to measure explosion concentrations, and therefore these measurements are more reliable. If a study was carried out that could show where it was possible to take a good ‘average’ measurement of the atmosphere in a hold when it was loaded, this might present an alternative solution. When a ship is totally empty, it is easy to carry out a measurement of the hold around the bulkhead. If a study showed that by following a certain measurement protocol the atmosphere of a hold of an empty ship could be measured, this could result in a recommendation. In practice, however, the hold of a container ship is rarely empty.

5.3. Study compliance obligation to act with due care of loader

5.3.1. Regulations on obligation to act with due care ADN

In the ADN, chapter 1.4. "Safety obligations of those concerned", amongst other things the obligations of a loader with regard to the safe transport of hazardous substances in containers is described. In accordance with the definitions of chapter 1.2. of the ADN, the terminal where the ships are loaded with the containers is “the loader”;

“Loader”: the undertaking that

a) loads packaged hazardous goods, small containers, or transport tanks in or on a means of transport or container;

b) loads a large container, bulk container, MEGC, tank container, or transport tank on a means of transport;

c) loads a vehicle or a wagon in or on a ship.

ADN 1.4.3. Obligations of other parties:

1.4.3.1 Loader
1.4.3.1.1 In the context of 1.4.1, the loader has in particular the following duties:
The loader:
a) may only present hazardous goods to the carrier if they are allowed to be transported under the ADN;
b) ***must check to make sure whether or not there is damage to the packaging of hazardous substances***, or the unclean empty packaging, **presented for transportation. It may only present a consignment for transportation, of which the packaging is damaged, especially if it is leaking and the hazardous substance is escaping outside, after the defect has been rectified;** the same also applies for empty packaging that has not yet been cleaned;
c) must comply with the specific regulations for the loading and handling of hazardous goods when loading such in ships, vehicles, wagons, and small or large containers;
d) **must comply with the regulations concerning labelling for hazardous substances after the loading of hazardous goods in a container in accordance with 5.3;**
e) must observe the prohibition on combined loading when loading the consignments, also taking into account the hazardous substances that might already be in the ship, on the vehicle, or in the large container. Furthermore, it must comply with the regulations for the separation of foodstuffs, other articles of consumption, and animal feed;
f) must guarantee that suitable provisions are available, both in the vicinity of the fore and the stern, to exit the ship, including in emergencies;
g) reserved

5.3.2. Survey container handling terminals

In order to study how container handling companies observe the obligations referred to in ADN 1.4., Transafe carried out a number of interviews with the people responsible for safety at six container terminals. Several terminals were visited and the other terminals were contacted by telephone and via e-mail. Interviews were held at two Rhine terminals in Germany, two inland waterway terminals, and two seaport terminals. One of the seaport terminals did not want to react towards the survey.The content of the interviews is available in a depersonalized form. This report deals exclusively with the findings of the survey.

Particular issues that were identified by the survey include:

- The terminals are aware of the obligations imposed under ADN 1.4., and primarily check the incoming containers.
- The seaport terminals have the most facilities and resources for dealing with leaking containers. They usually have measurement equipment, such as EX/OX and Toximeters, but this is only used in emergencies or if a container is opened at the request of a customer or customs. At some Rhine terminals there is no measurement equipment, and they do not open the containers.
- If there are any incidents involving containers, they usually called in external help from specialised companies.
- A number of staff are trained at most terminals in the handling of hazardous substances and emergency management.

5.3.3. Practice of loading and unloading

During normal inspections carried out by Transafe on-board container ships, as well as in the interviews which were held with the crews of 33 container ships, in relation to the practice of loading and unloading, the following is apparent:

- loading and unloading takes place very quickly. Containers are not checked by the terminal during loading and unloading. The speed of loading and unloading does not allow any room for such. Presumably the terminals carry out checks at a different time, such as on arrival.
- it is relatively rare for a damaged container to be loaded onboard, or a container without (the correct) labelling
- if this happens, and the crew has notified such to the terminal, in most cases it is not a problem for the container to be left on the quayside or to be unloaded again. However, crews do occasionally have to argue to make sure this happens.
- the biggest problem for crews in relation to the distribution of cargo in the hold is that it is not always known in advance if a particular container which has been put on the manifest by a shipping agent for loading contains hazardous substances or not.
- especially the companies where loading takes place onsite, who work with hazardous substances themselves, and who load and/or unload the containers themselves, are very circumspect when checking the good condition of the containers and the labelling (e.g., Bayer, BASF).

Photograph of a container ship under a crane ready for unloading.

5.4. Incidents with containers

5.4.1. Result of survey with government organisations and institutes (IVW, RWS, DCMR, Deltalinqs, RPA, the Regional Safety Authority Rijnmond (fire department), and the Dutch Safety Board).
Transafe contacted the above organisations to ask for information about incidents with containers with hazardous substances. Under ADN H.1.8.1, “incidents involving dangerous goods” have to be reported by the terminal, the loader, the carrier, or the consignee. They have to submit a report to the competent authority within 6 months after the incident. In the Netherlands, the IVW manages the central register of accidents involving the transport of hazardous substances. In order to obtain a full picture, we also asked the Directorate-General for Public Works and Water Management, DCMR, Deltalinqs, RPA, the Regional Safety Authority Rijnmond, and the Dutch Safety Board to provide us with information on this subject. Most other organisations referred us to the IVW. We were issued confidential information by the IVW and the RPA. The Dutch Safety Board is not allowed to provide any other information than that contained in its published reports. In the published reports, one accident was described with a tank container (LBC Rotterdam 27-10-2007, exposure to heat of a tank container containing Divinylbenzene).

Because this incident involved mistakes made during the handling of the load, it was not included in this report because it did not relate to transport.

The survey of the organisations in question revealed that leaks are usually caused:

- in normal containers; because the load in the container has not been secured properly, started to move around during the transport over sea, and this caused a leak.
- leaks in tank containers are usually due to problems with seals (gaskets) in the stop valve. On one occasion a leaking valve was reported, but it subsequently turned out to be drops of water condensation from the air.

The reports of leaking containers in the information from both the IVW and the RPA made available to us primarily concerned containers transported by seagoing vessels. This would seem to be logical, since the occasional violent nature of maritime transport overseas can have an impact on the container contents (storms, high waves, etc.). In most cases it concerned leaking seals, which were repaired by specialists and the spillage was cleaned up.

Furthermore, Transafe used the experience it has gained playing an advisory role in relation to safety aspects, including with incidents and accidents. While working as a safety adviser, over the last 10 years Transafe was involved in two incidents involving leaking containers with hazardous substances on inland waterway ships. On one occasion it subsequently turned out to be condensation dripping from the valve of a tank container, which was originally identified as a leak. On the other occasion, a product was leaking from the valve of a tank container.

5.4.2 Findings survey container ship crews

During normal inspections carried out by Transafe on-board container ships, as well as in the interviews which were held with the crews of 33 container ships, Transafe looked at how often there were incidents involving leaks from containers.

The full findings of the survey are set out in appendix 5.4.2.

The findings of the survey provide a general average; on-board the 33 ships, the people interviewed had a combined total of 181 years of experience in container shipping. During this 181 years of experience there were:

- 3 known incidents involving leaks from a container with hazardous substances,
- 4 known incidents involving leaks from a container without hazardous substances.

On average, it can therefore be said that one would be likely to experience an incident involving a leak from a container containing hazardous substances once every 60.3 years, and an incident involving a leak from a container without hazardous substances once every 45.25 years.

5.4.3 Information found on the internet

Information about leaks from containers was also collected from the internet. There were several reports concerning a leak at a terminal. One report concerned a collision between seagoing vessels, and one concerned a collision between a seagoing vessel and an inland shipping vessel, whereby the hull of the inland shipping vessel was damaged and a number of containers went overboard. Since these fall outside the scope of this study, no additional relevant information was found on the Internet. No information was found concerning specific leaks during loading, unloading, or during sailing of inland waterway shipping.

Loading of a barge combination at the sea port container terminal.
(Source: the sea port container terminal)

6. Conclusions study current situation

With regard to the current situation concerning the measurement, ventilation, the obligation of due care of the loader, and the identified number of reports of incidents with containers with hazardous substances, as described in chapter 5 “Description of the Study”, we can draw the following conclusions in relation to the current situation:

Ventilation:

The ventilation in the current situation as identified in the study is ineffective and does not enhance safety. In practice, the help of safety advisers, shipping agents, chartering operators, government organizations, and loading/unloading terminals is called upon in the event of incidents. The crews do not have the resources themselves to effect a solution without help from outside.

Measurement:

The measurement of a container hold which might contain various hazardous substances is subject to numerous practical problems:

- poor transparency; which container is leaking, where is it, and how do you know what is leaking?
- access to the relevant location in order to carry out a measurement (health and safety regulations concerning working at heights mean measurements can only take place around the hold perimeter, and thus there is usually no way whatsoever of measuring containers in the middle)
- limited measurement resources; a user-friendly “multi-purpose measurement device” is not yet available on the market. Some products cannot be measured anyway, and measurement devices have their limitations. Furthermore, the crews onboard ships cannot be expected to be technically proficient in all these areas. In practice, there is therefore likely to be an element of human error.

In relation to oxygen an explosion measurements, we can state that if one could measure at the right location then this would presumably give reliable measurements.

In relation to the measurement of toxicity, in light of the above factors no reliable/representative measurements can be expected to be carried out and interpreted by the crew.

Obligation to act with due care of loader:

The survey found that loaders appears to take the obligation to act with due care seriously in most cases. If a leak or missing labels are discovered by the ship's crew, the relevant container is usually removed from the ship at the instigation of the crew.

Incidents with containers containing hazardous substances:

The questions put to official organizations and the survey of terminals and shipping crews revealed that considering the huge volume of containers shipped, there were relatively few incidents involving the release of hazardous substances. In most cases a leak was discovered when containers arrived on seagoing vessels.

7. Description and comparison of alternatives

7.1. The current Risk Assessment and Evaluation (RI&E)

The industry RI&E standard, which was drawn up by Kantoor Binnenvaart (Inland Shipping Office) (03-2008) and approved by the Ministerie van Sociale Zaken en Werkgelegenheid (Ministry of Social Affairs and Employment) is used to identify the general risks associated with hazardous substances onboard inland shipping vessels. The most relevant questions in this RI&E in relation to the measurement and ventilation of the hold are used to define the risks compared to alternative regulations:

- Are sufficient guarantees provided to ensure harmful gases, vapours, or substances do not leak from the cargo and can be inhaled?
- Are there sufficient measures to prevent exposure to toxic, corrosive, or other hazardous substances?
- Have sufficient safety precautions been taken in situations where gases vapours, or substances can be released?

7.1.1. Substances to be transported

In H.3.2. Table A of the ADN, there is a numerical list of the hazardous substances which can be transported in dry cargo ships. This concerns around 2000 different substances, and VE regulations have been prescribed for around 400 of these substances. Products in the following danger categories are transported:

1	Explosive substances and objects
2	Gases
3	Flammable liquids
4.1	Flammable solids
4.2	Substances susceptible to spontaneous combustion
4.3	Substances that produce flammable gases on contact with water
5.1	Oxidising substances
5.2	Organic peroxides
6.1	Toxic substances
6.2	Infectious substances
7	Radioactive substances
8	Corrosive substances
9	Environmentally hazardous substances

7.1.2. Company emergency response plans and risks in relation
to the substances to be transported.

In order to be able to take effective action in the event of a disaster, the crew must be aware of the dangers associated with the different categories of substances.

In ADN 1.3, it prescribes “instruction of persons who are involved in the transport of dangerous substances”.

Looking at the products that are to be transported from the viewpoint of the RI&E, the biggest risk for the crew is exposure to flammable and/or toxic gases or vapours. This would consequently also expose them to the risk of fire, explosion, and/or poisoning.

There are also risks associated with the regular performance of measurements, namely the risk of falling overboard, and thus also the risk of being crushed between the quayside and the ship, hypothermia, and drowning.

Because most vapours (except for some gases in category 2) are heavier than air, the vapours will be concentrated low down near the floor of the hold.

If there is any wind, the vapours will be blown around the hold, but with a fully-loaded ship the effect of this natural form of ventilation will be minimal. Hydrostatic differences in pressure can also form an aspect of natural ventilation. A separate study would need to be carried out to identify the effects of the spreading of gases and vapours in the ship's hold, the effect of the wind, and so on, in fully-loaded ships, half-loaded ships, and empty ships.

7.2. Description of alternatives and risk matrix

In order to make a comparison between the effects with respect to the three scenarios, as specified in the research assignment, the aspects associated with safety were calculated using the basic risk model of Fine & Kinney. The risks are assessed by making a calculation: the risk = effect x exposure x probability. Transafe added its own detailed 4th scenario, which goes further than just the amendment in the wording of the ADN, which also looks at the possibility of taking safe action in the event of a disaster.

The risk model of "FINE & KINNEY" (R = E x D x P)

P	Probability of the risk
10	Can almost definitely be expected
6	very likely
3	unlikely, but possible
1	only possible in the long-term
0,5	very unlikely
0,2	almost impossible
0,1	virtually impossible

D	Duration of exposure to risk
10	continious
6	daily during working hours
3	weekly or incidental
2	monthly
1	several times per year
0,5	very rarely

E	Effect (consequence)
100	catastrophic (e.g., multiple fatalities-enviroment disaster)
40	disastrous (several fatalities-loss of ship-environmental damage)
15	very serious (fatality-loss of ship-environmental damage)
7	considerable (permanent damage-ship/environment)
3	important (employment disability-damage)
1	significant (first aid-minor damage)

R	Risk	Nature of the action to be taken
> 320	very high	stopping all work
160 - 320	high	immediate action necessary
70-160	substantial	correction is necessary
20 - 70	possible	attention necessary
< 20	low	possibly acceptable

In the comparison based on the risk model of Fine & Kinney, we used the following situation:

- the crew uses the available equipment to take measurements in two locations in the hold from the gangway.
- not all substances can be detected with the equipment that is currently available.
- the measurement and interpretation of the measurement values by the crew can lead to incorrect conclusions being drawn with respect to safety, and thus represents an additional risk. An inaccurate or non-representative measurement can lead to a false sense of safety; the measurement could be interpreted as "safe" while there might still be vapours elsewhere which cannot be detected.
- the measurement procedure itself can therefore lead to a greater risk of exposure, particularly if an attempt is made to locate the source (and people get too close to a leaking container), without the appropriate precautions being taken, such as the use of suitable personal protection equipment.

The following scenarios were described for this situation:

Sc-A: The VE regulations are complied with, in other words measurements are always taken, and the decision to ventilate/not to ventilate is taken based on the measurement results; the current situation. Compliance with the current regulations, in the knowledge that the measurements are often not effectively carried out and that ventilation might not have an effect. In practice, measurements are hardly carried out at all. The assumption is that these regulations would lead to a greater level of safety.

Sc-B: Measurement only carried out if there is a suspicion of a leak. The quality of the measurements which the crew carries out, should be considered. Ventilation only with positive measuring results. The quality of the measurements carried out by the crew under operational circumstances (in accordance with the VE regulations) compared to the ideal situation, in which the measurements are carried out by professional companies. In practice this more or less reflects the current situation; it was apparent from the interviews that measurements were seldom carried out. In cases where there is a suspicion of a leak, measurements are carried out more accurately and more deliberately.

Sc-C: Never measure and never ventilate

Sc-D: Measurement in the event of suspicion. The crew must be aware of the possible risks associated with leaking containers containing hazardous substances, and the measures that need to be taken in relation to such. In the event of a suspicion of a leak, a comprehensive ship emergency plan should be set in motion, whereby each person knows what they have to do. With optimal help from government organizations, terminals, and support specialists, incidents can be managed in a professional, safe, and effective way. This will control the risk of fire, explosion, and poisoning.
The dangers are the release of hazardous substances and the associated risk of explosion, fire, and poisoning. The quality of the measurements can lead to a false sense of security, which can increase the risks in the above situations if the wrong decisions are taken.

The risk model of Fine & Kinney : (Risk = effect x exposure x probability)

Comparison current situation A with alternative scenarios B, C and D

Situation	Loading of hazardous substances in (tank)containers
Place	In the hold of a ship
Explanation	The hold is seen as "the protected zone" comparable with zone 1/2. The scenarios vary concerning the degree of measurement and effectiveness.
Remarks	The statutory regulations are aimed at (preventing) an emergency situation

Situation	Risk leaks of hazardous substance:	Effect/Damage	E	W	B	R
SC-A	risk of explosion (category 2 and 3)	injury/death of crew, damage to ship and cargo, fire	15	0,5	0,5	3,75
(baseline situation)	risk of fire (category 2 and 3)	injury/death of crew, damage to ship and cargo	7	0,5	0,5	1,75
	risk of poisoning (category 6.1)	respiratory problems, illness, possible fatalities	15	0,5	0,5	3,75
	risk of false sense of safety/unrepresentive measurement	incorrect assessment safety situation: see item 3 above	15	6	6	540
SC-B	risk of explosion (category 2 and 3)	injury/death of crew, damage to ship and cargo, fire	15	0,5	0,5	3,75
measurement only	risk of fire (category 2 and 3)	injury/death of crew, damage to ship and cargo	7	0,5	0,5	1,75
in the event of	risk of poisoning (category 6.1)	respiratory problems, illness, possible fatalities	15	0,5	0,5	3,75
suspicion	risk of false sense of safety/unrepresentive measurement	incorrect assessment safety situation: see item 3 above	15	1	6	90
SC-C	risk of explosion (category 2 and 3)	injury/death of crew, damage to ship and cargo, fire	15	0,5	0,5	3,75
never measure	risk of fire (category 2 and 3)	injury/death of crew, damage to ship and cargo	7	0,5	0,5	1,75
	risk of poisoning (category 6.1)	respiratory problems, illness, possible fatalities	15	0,5	0,5	3,75
	risk of false sense of safety/unrepresentive measurement	incorrect assessment safety situation: see item 3 above	15	6	10	900
SC-D	risk of explosion (category 2 and 3)	injury/death of crew, damage to ship and cargo, fire	15	0,5	0,5	3,75
measurement only	risk of fire (category 2 and 3)	injury/death of crew, damage to ship and cargo	7	0,5	0,5	1,75
in the event of	risk of poisoning (category 6.1)	respiratory problems, illness, possible fatalities	15	0,5	0,5	3,75
suspicion support	risk of false sense of safety/unrepresentive measurement	incorrect assessment safety situation: see item 3 above	15	0,5	0,2	1,5
experts						

Risk matrix table comparison scenarios, based on the Fine & Kinney model

7.3. Sub-conclusion comparison of alternatives

The risk matrix shows that the biggest danger is associated with the quality of the measurements carried out by the crew, because of the high risk of a false sense of security, which is a dangerous situation in of itself, and can lead to a greater risk of the associated dangers. In chapter 5, a number of incidents with containers with hazardous substances are described. In light of the low frequency of occurrence, and the poor reliability of the measurements that can lead to a false sense of safety, scenario “D” would provide the biggest contribution towards safety. Scenario “B” would lead to a lower level of exposure because it assumes that if there is a suspicion of a leak, the crew will be more alert to

the possibility and presence of gases and vapours, and will take precautions in relation to such, such as the use of personal protection equipment, etc.

The standard measurements that are supposed to be carried out now, if they are carried out, are seen as “red tape” where “nothing is ever found anyway”. The matrix also shows that the probability and the level of exposure to released gases and vapours from the cargo is identical in all cases. The carrying out of measurements will not make any difference to this, and emphasises how important it is for loaders to follow the procedures carefully.

8. Conclusions and recommendations

8.1. Explanation

Chapter 5 describes the study into the effect of ventilation, measurement, compliance with the obligation to act with due care by the loader, and the number and nature of the incidents with containers with hazardous substances. In chapter 6, a conclusion based on the practical situation is set out, taking into account the current regulations laid down in ADN 7.1.4.12 and 7.1.6.12. In chapter 7, a number of alternatives compared to the current situation are outlined and the effect of such calculated in the risk matrix.

8.2. Conclusions

The ventilation on-board container ships in the prescribed way has a negligible effect.

The findings of the measurements which have to be carried out by the crew are unreliable and very probably not representative for the atmosphere in the entire hold.

Furthermore, measurement equipment is not available for all products. The measurement of toxicity of substances is the biggest problem. As it is not known which container is leaking and where the measurement should take place. Besides cross sensivities and deviation should be taken into account. The measurement of the risk of explosion is easier and more reliable in terms of instrumentation, but there is still a problem in terms of where measurements should be carried out, and whether they are representative for the entire atmosphere in the hold.

The current regulations as laid down in ADN 7.1.4.12 and 7.1.6.12 (see chapter 4.2) are not relevant due to the poor reliability of the measurements and a negligible effect of mechanical ventilation, and both aspects definitely do not increase safety and can even create a false sense of safety. The crew is forced to carry out more or less pointless activities which also involve considerable costs (see the Berenschot report).

There is not always an effective company emergency response plan, and thus the crews on container ships are not always adequately prepared for an incident involving the release of hazardous substances. Because the crews are not convinced about the usefulness of ventilation and measurement, and because relatively few incidents occur, in practice the crew often do not know how to respond, and specialists are called in such as the shipping agents, safety advisers, terminals, authorities, gas experts, etc.

In the current situation, there are no procedures for how to respond in the event of an incident involving the release of hazardous substances, except for the obligation to report such to the authorities. There is no standard procedure in the shipping industry for how to respond in the event of an incident with hazardous substances, which also describes the role of emergency services and government organisations. Collaboration in this area would lead to a general increase in safety for all parties concerned.

8.3. Recommendations:

In order to increase the level of safety onboard container ships and to avoid unnecessary activities and costs, the ADN regulations on measurement and ventilation should be modified;

- the regulations should be changed in accordance with that described in H.6 “Scenario D”;

Measurements should only be carried out in the event of a suspicion of leaks or damage. Furthermore, extra attention should be paid to raising the awareness of crews concerning the risk and consequences of a leak from the container with hazardous substances.

We would propose the following changes to the text (changes in red):

7.1.4.12 ***~~Ventilation~~ Alertness during the loading of containers with hazardous substances***

…

7.1.4.12.2

Onboard of ships, that only carry hazardous substances in containers in open cargo hold, ventilation systems do not have to be permanently installed, however they must be carried on board.

The crew must be aware of the fact that when there are hazardous substances in containers there is a risk that gases and vapours can build up in the hold, which can be flammable, explosive, or toxic.

During loading and unloading, suitable personal protection equipment for the substances being transported must be made ready for immediate use.

During loading, the crew must visually inspect the condition of the containers coming on board. If there is any doubt about the condition of a container, the completeness of the labelling, or a suspicion of a leak, the loading terminal must remove the container from the ship immediately at the direction of the crew, so that it can be inspected further by the terminal. If there is a suspicion that the contents of a container has leaked, the ship's emergency response plan must come into effect. The crew must wear the appropriate personal protection equipment. The loading terminal must take responsibility for the safe management of the incident.

The crew can carry out a provisional measurement, however a measurement must be carried out by a gas expert in order to show whether or not there is a dangerous situation, or to confirm that no gases or vapours of hazardous substances have been released.
If during the voyage there is a suspicion that a container has been damaged or that the contents of the container has leaked, the ship's emergency response plan will come into effect. The crew can carry out a provisional measurement, however a measurement must be carried out by a gas expert in order to show whether or not there is a dangerous situation, or to confirm that no gases or vapours of hazardous substances have been released.

~~7.1.6. Additional requirements~~ Delete as well as the associated column 10 of Table A, H.3.2.
~~7.1.6.12 *Ventilation*~~

~~VE01: *Cargo holds which contain this substance must ventilate at full power, should the measurement determine that the gas concentration coming from the gases in the cargo is above 10% of the lower explosive limit. This measurement must be carried out directly after loading.* A repeat measurement must be carried out after one hour. The results of these measurements must be recorded in writing.~~

~~VE02: *Cargo holds which contain this substance must ventilate at full power if, following measurement, it is established that the cargo holds are not free of the gases coming from the cargo. This measurement must be carried out directly after loading.* A repeat measurement must be carried out after one hour.
The results of these measurements must be recorded in writing.~~

~~VE03: Spaces such as cargo holds, cabins and engine rooms which are next to a cargo hold containing this substance, must be ventilated.
The cargo holds which have contained this substance must be mechanically ventilated after unloading.
After ventilation, the gas concentration in these cargo holds must be measured.
The results of these measurements must be recorded in writing.~~

~~VE04 If spray cans are transported in accordance with Particular standard 327 of chapter 3.3 for the reuse or for removal purposes, particular standards VE01 and VE02 apply.~~

- Research the possibility of developing realistic emergency scenarios which detail the help to be given by terminals, government organisations, and specialists. In a scenario involving a leaking container in the hold of a ship, the crew can do very little itself. To guarantee safety onboard the ship, the container must be removed from the ship as quickly as possible. In such a situation, it is likely that any vapours released from a container would still remain in the hold even after unloading. With optimal help from terminals, government organisations, and support specialists, incidents can be handled in a professional, safe, and effective way. This will ensure effective management of the risks of fire, explosion, and poisoning.

- The study did not look at how hazardous substances that have
leaked from containers move around in a hold. This study was based on the assumption that most vapours are heavier than air, and therefore concentrated around the floor of the hold. In order to gain more insight into the behaviour of gases and vapours in a hold, both when loaded, partially loaded, and empty (when there is more space in the hold), and in a situation where a leaking container that is on the 3rd layer or higher (see the situation described in H.5.2.4), a study would have to be carried out into if, and how much, vapour would build up in the hold. Furthermore, the behaviour of vapours after a leaking container has been removed from a ship would also need to be studied. This will also provide more insight into where measurements should be taken for the risk of explosion, for example. A more detailed CFD analysis calculation for the above scenarios would generate useful information on these subjects.

9. Consulted literature, consulted authority/companies, and list of abbreviations

9.1. Consulted literature.

During the study, the following literature was consulted:

- ADN regulations 2011
- Report "*Onderzoek inhoudelijke nalevingskosten*" of Berenschot 17-03-2009.
- Report "*Veiligheid*: *gevoel versus werkelijkheid*" (study into simplification procedures for berthing and mooring of ships) of Oranjewoud version 13-03-2006.
- Internet; Google/ Wikipedia
- IMDG code

9.2. Consulted authorities and companies.

For the collection of information, the following authorities and companies were consulted:

IVW Ministry of Transport, Public Works and Water Management, Merchant Shipping Inspectorate

Directorate-General for Public Works and Water Management, Traffic and Merchant Shipping Agency

Port of Rotterdam Authority

DCMR Environment Agency Rijnmond

Regional safety authority / fire department Rotterdam Rijnmond

Deltalinqs

Crews/owners of 33 container ships/container barges

2 Seaport container terminals, 2 inland shipping container terminals, and 2 Rhine container terminals in Germany

Unisafe B.V.

Dutch Safety Board

TRANSAFE
GET A GRIP ON SAFETY

9.3. List of abbreviations

ADN: *Accord européen relatif au transport international des marchandises dangereuses par voies de navigation intérieures*; European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways, before 1-1-2011 referred to as "ADNR".

TEU: the designation used for the dimensions of containers; Twenty feet Equivalent Unit.
1 TEU is a container with the following dimensions: 20 feet long, 8 feet wide, and 8 feet high.
2 TEU equals two containers of this size or a single container of 40 feet long

ARBO : Working Conditions Act; this law is aimed at guaranteeing the health, safety, and well-being of employees, and preventing accidents and illness at work. The Arbo Act lays down obligations for both employees and employers in relation to such. The Act moreover comprises the Working Conditions Decree (*Arbobesluit*), the health and safety regulations (*Arboregeling*), and the health and safety policy rules (*Arbobeleidsregel*).

RI&E: Risk Assessment & Evaluation: a standard procedure to ensure health and safety at work as described in the Arbo Act.

CFD: Computational Fluid Dynamics

Appendices:

Appendix 5.1.2. Inventory hold ventilation systems container ships:

Appendix 5.1.3. CFD Analysis Bunova effectiveness of air extraction between containers separately in attached PDF.

Appendix 5.4.2. Findings of survey on experience with incidents involving leaks from a container with hazardous substances.

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Anlage 5.1.2. Bestandsaufnahme der Ventilatoren im Laderaum von Containerschiffen Transafe 28.04.2011

Schiffsname	Volumen m³	Laderaum-Zwischenwände	Zahl loser Ventilatoren	Zahl fester Ventilatoren	Leistung (m³/h)	Durchmesser Saugschlauch in cm	Durchmesser Schacht in cm
mcs	2631	nein	4	0	7500	40	
mcs	2360	nein	4	0	7500	40	
mcs	4940	nein	2	0	13154	50	
mcs	3600	nein	0	0	0		
mcs	6620 (3507 + 3113)	ja (1)	0	4	7000		43
mcs	6960	ja (1)	0	4	7960		43
mcs	9600	ja (3), Unters. offen	0	4	115.200		?
mcs	3500	nein	2	0	9000	40	
mcs	7700	nein	2	0	10.000	50	
mcs	7800	nein	2	0	9000	45	
mcs	3625	nein	2	0	unbekannt	50	
mcs	7300	nein	0	4	unbekannt		unbekannt
mcs	3000	nein	2	0	9.000	40	
mcs	9000	ja (1; midherft)	3	0	10080	65	
mcs	7200	nein	2	0	8500	40	
mcs	7500	ja (offen)	2	0	unbekannt	60	
mcs	7290	nein	2	0	8500	40	
mcs	2880	nein	2	0	5000	50	
bak	2400	nein	2	0	5000	50	
mcs	3500	nein	2	0	8300	42	
mcs	5100	nein	2	0	10000	40	
mcs	3600	ja 2 (offen)	2	0	8500	50	
bak	2678	ja 1 (offen)	2	0	8500	50	
mcs	3600	ja 2 (offen)	2	0	8500	50	
bak	2678	ja 1 (offen)	2	0	8500	50	
mcs	3600	ja 2 (offen)	2	0	8500	50	
bak	2678	ja 1 (offen)	2	0	8500	50	
mcs	3600	ja 2 (offen)	2	0	8500	50	
bak	2678	ja 1 (offen)	2	0	8500	50	
mcs	3600	ja 2 (offen)	2	0	8500	50	
bak	2678	ja 1 (offen)	2	0	8500	50	
Durchschnittlich:	4706,3				8459,76	47,76	

Befragte:	31 Schiffe
Durchschnittliche Anzahl der Schiffe mit losen Ventilatoren/Schläuchen:	86,66 % (26/31)
Durchschnittliche Anzahl der Schiffe mit festen Lüftungsschächten:	12,90 % (4/31)
Durchschnittliche Anzahl der Schiffe ohne Lüftung:	3,22 % (1/31)
Durchschnittliche Leistung der Ventilatoren:	8459,76 m3/h
Häufigste Leistung der Ventilatoren:	8500 m3/h
Durchschnittlicher Durchmesser des Saugschlauchs:	47,76 cm
Häufigster Durchmesser des Saugschlauchs:	50 cm

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Appendix 5.4.2. Overview telephone survey clientsof Transafe (dry cargo) experience of leaking containers

Explanation: the person conducting the survey calls the ships/the ship owners detailed below by telephone and askes if they had the experience of leaking (tank)containers with hazardous substances. Th
results are set out in the table below:

Ship name	Date telephone call	Details of experience of crew with leaking containers	Years of experience	Leacks HS	Leacks no HS
MCS	18-5-2011	No experience last 4 years	4		
MCS 5 articulated barge (10 units)	18-5-2011	1 x in 8 years with 5 articulated barges, leaking tank container during the voyage on the Rhine. Immediately unloaded at the next terminal. 1 x in 8 years a molasses/pulp tank container from the third layer fell off in the hold, whereby pulp leaked (non HS). The container was dislodged by the crane operator with another container.	40	1	1
MCS	18-5-2011	No experience. The measurement reports are purely drawn up for the police.	0		
MCS	25-5-2011	In 19 years no experience.	19		
MCS	18-5-2011	No experience last 7 years.	7		
MCS 3 Ships	18-5-2011	In 14 years on 3 ships no experience. Bayer is very careful about the way it loads containers. Empty containers are usually loaded in the ports on this route.	14		
MCS 2 Ships	18-5-2011	Altogether in 20 years 1 x experience with leak of non HS.	20		1
MCS Ship + Barge	25-5-2011	By ECT a stack of containers was once knocked over, and a valve was broken on a tank container. This was immediately removed and the hold was sprayed down (badly loaded), no HS.	6		1
MCS Ship + Barge	25-5-2011	Regularly sailed on voyages with containers for many years, no experience of such	5		
MCS		No experience in 15 years of leaks with hazardous substances.	15		
MCS 2 Ships + Barge	25-5-2011	2 ships in 10 years 2 x experience, 1 x with hazardous substances (leaking tank container) 1 x vegetable oil.	20		1
		Ship + barge, 1 x experience in the last 20 years.	20		
MCS Ship + Barge	25-5-2011	Last 3 years, never experienced an incident. Hoechst inspects containers very thoroughly.	3		
MCS Ship + Barge	25-5-2011	Last 3 years, never experienced an incident.	5		
MCS	25-5-2011	Last 3 years, never experienced an incident, although often damaged containers.	3		
		Totaal:	181	1	4

33 Ships (units)

Total with hazardous substances: 2x
Total with non hazardous substances: 4x

In the survey there were 181 years of experience in depreciates, and 3 x experience with a leaking container with hazardous substances, and 4 x with a container without hazardous substances.