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DESIGN GUIDELINES AND OPERATIONAL RECOMMENDATIONS FOR VENTILATION SYSTEMS IN RO-RO CARGO SPACES

PART 1 DESIGN GUIDELINES FOR VENTILATION SYSTEMS IN RO-RO CARGO SPACES

Table of contents and Introduction

1 The Maritime Safety Committee, at its fifty-fourth session (27 April to 1 May 1987), included an item on ventilation of vehicle decks in the work programme on the Sub-Committee on Ship Design and Equipment.

2 The Sub-Committee on Ship Design and Equipment, at its thirty-eighth session (23 to 27 January 1995), prepared, subject to review by the Sub-Committee on Fire Protection with regard to fire safety aspects, the draft Design Guidelines and Operational Recommendation for Ventilation Systems in Ro-Ro Cargo Spaces. The guidelines and operational recommendations are based on the SIS 150 "Cleaner air in ro-ro cargo spaces" and ISO 9785, and are intended to address the ventilation of ro-ro cargo spaces during loading, unloading and during voyage in order to maintain an adequate level of air quality in these spaces.

3 The Sub-Committee on Fire Protection, at its fortieth session (17 to 21 July 1995), reviewed the draft design guidelines and operational recommendations and prepared the final text of the guidelines and recommendations for approval by the Committee.

4 The Maritime Safety Committee, at its sixty-sixth session (28 May to 6 June 1996), approved the design guidelines and operational recommendations as contained in the annex and invited Member Governments to bring them to the attention of the designers, shipyards, ship owners and personnel employed on board and to apply the design guidelines to new ships and the operational recommendations to new and existing ships.

ANNEX

PART 1 DESIGN GUIDELINES FOR VENTILATION SYSTEMS IN RO-RO CARGO SPACES

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INTRODUCTION

This document provides general guidelines for the design of suitable ventilation systems for vehicle decks on ro-ro ships, car carriers and car ferries.

Exhaust gas composition

Exhaust gases from motor vehicles contain hazardous substances. Carbon monoxide (CO) from petrol engines, and nitric oxide (NO) and nitrogen dioxide (NO₂) from diesel engines are the substances whose health hazards are discussed in this document. These hazardous substances can affect people in many different ways. Certain substances have a tangible, immediate effect. Others only show injurious effects after a person has

been exposed to them for some time. The effect of a substance normally depends on how long a person has been exposed to them and the quantity inhaled.

Carbon monoxide (CO) is a colourless and odourless gas which, to a lesser or greater extent, inhibits the ability of the blood to absorb and transport oxygen. Inhalation of the gas can cause headaches, dizziness and nausea and in extreme cases causes weakness, rapid breathing, unconsciousness and death.

Nitric oxide (NO) and nitrogen dioxide (NO₂) are compounds of nitrogen and oxygen, together commonly referred to as oxides of nitrogen or NO_x. NO, a colourless gas, is the main oxide of nitrogen formed in the combustion process. NO itself is not of great concern as regards health effects; however, a proportion of the NO formed will combine with oxygen to form NO₂, which is of concern from the point of view of human health. NO₂ is a brown gas which has a stinging, suffocating odour. It exerts a detrimental effect on the human respiratory system. Asthmatics in particular are susceptible to exposure.

Measures

Measures should be considered as follows:

- A reduction in exhaust gas emissions;
- Provision of an adequate ventilation system; and
- Prevention of exposure to the gases.

PART 1 DESIGN GUIDELINES FOR VENTILATION SYSTEMS IN RO-RO CARGO SPACES

1 REQUIREMENTS

1.1 Definition of exposure limits

"An exposure limit value" means the highest acceptable average concentration (time-weighted mean value) of a substance or, in some cases, of a mixture of substances in the air breathed by the occupants. The concentrations are usually given in parts per million (ppm) or mg/m³. An exposure limit value refers either to a long-term exposure level or a maximum limit value. Short-term exposure level is also used.

"Long-term exposure level", means the exposure limit value for exposure during the entire working day (normally 8 hours).

"Maximum exposure level", means the highest concentration reached .

"A short-term exposure level" means the time-weighted mean exposure value over a short period of 10 or 15 minutes, dependent on the national occupational exposure standards.

1.2 Pollutants of interest

The exhaust gases generated by internal combustion engines contain hundreds of chemical substances. The main part of them are nitrogen (N₂), carbon dioxide (CO₂), oxygen (O₂), carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO₂) aldehydes such as formaldehyde, polyaromatic hydrocarbons such as benzo(a)pyrene and organic and particulate bound lead.

Among the pollutants emitted in the exhaust gases of petrol and diesel engines, CO is generally of the most significant concern for petrol engines and NO_x for diesel engines. Lead and benzo(a)pyrene are also of a significant concern.

Knowledge of the effects of other pollutants to the health is at present insufficient. However considerable research is being undertaken.

Monitoring of occupational hygiene should be planned and its results should be assessed by a qualified expert, with special training in this field. The studies should be carried out in co-operation with the monitoring staff, the management of the ship concerned and the relevant Administrations.

1.3 Rate of air change

Regulations II-2/37, 38 and 53 of the 1974 SOLAS Convention, as amended, provides requirements for rate of air changes which are intended to limit maximum concentration of pollutants during loading and unloading and also to prevent a build-up of hazardous gases in the ro-ro cargo spaces when the ship is at sea with a cargo of motor vehicles. These regulations provide the minimum acceptable standards for ventilation.

1.4 Noise levels

Noise effects the utilization of the ventilation system. Efforts should be made to minimize noise at the design stage.

Noise level limits are laid down in the requirements of the respective maritime authorities who also publish guidelines for measuring noise.

2 VENTILATION

2.1 Ventilation on board ship

Ventilation systems for ro-ro cargo spaces on board ship generally operate according to the principle of dilution ventilation, whereby the supply air flow to the area is sufficient for the exhaust gases to mix thoroughly with the air and be removed.

There are two main types of dilution ventilation: exhaust air ventilation and supply air ventilation. Briefly, in exhaust air ventilation, fans remove air from a ro-ro cargo space, and this is then replaced by outdoor air entering through open ramps, doors and other openings. Exhaust air ventilation is employed when sub-atmospheric pressure is required in the ro-ro cargo space. The sub-atmospheric pressure prevents the pollution from spreading to adjacent areas.

Supply air ventilation works in the opposite way. Fans deliver outdoor air into the ro-ro cargo space and the air is then exhausted through ramps and other openings. Supply air ventilation usually creates slight pressurisation of the ro-ro cargo space. If supply air ventilation is used exclusively, pollutants may mix with the supply air, be pushed up the internal ramps and contaminate other decks. However, if sufficient mixing with supply air does not occur, contaminants may remain on the deck in question. Particularly hazardous conditions may occur on lower decks.

Ventilation systems on board ship often combine these two principles. The fans can then be reversible, so that they can either supply air into the ro-ro cargo space or exhaust air from it.

2.2 Air pollutant dispersion

Exhaust gas dispersion will depend upon air flow patterns within the vehicle deck. These will not be uniform but will be dependent upon the capacity, design and mode of operation of the ventilation system; volume and configuration of the cargo space; natural ventilation patterns and the number and location of vehicles on the vehicle deck.

Although the overall rate of air change on vehicle decks may be high, areas with low rates of air change may remain. High velocity air jets are

sometimes installed in an attempt to "stir" the air so that the supply air will be evenly distributed throughout the vehicle space.

2.3 Conditions and guidelines for calculating air requirements

The function of a ventilation system in a ro-ro cargo space is to dilute and remove the vehicle exhaust gases and other hazardous gases, to protect persons working in the area from being exposed to a hazardous or disagreeable level of air pollution. The basic particulars necessary for calculating the supply air required are contained in Appendix 1. These may be used as reference in the planning of new installations or in the assessments of the capacity of existing installations.

The formula given in Appendix 1 is similar to that used for calculating the supply air required for ro-ro cargo spaces in ships. However, the formula also takes into account the fact that the outdoor air supplied contains a certain amount of pollutant and also includes a dilution factor. The latter takes into account the degree of estimated or possible dilution of the pollutants in the air (see Appendix 1, paragraph 6).

In addition to the supply air required to dilute and remove the exhaust gases, it is also important to ensure air circulation in the ro-ro cargo space.

2.4 Air flow distributions

It is not possible to draw up or recommend any universal solutions for the distribution of air flow in different types of vessel. Duct runs and the location of supply air and exhaust air openings must be made to suit the design of the individual ship, the estimated vehicle handling and exhaust emissions in areas occupied by the crew and other workers. The following generally applies:

- The air flow should reach all parts of the ro-ro cargo space. However ventilation should be concentrated in those areas in which the emissions of exhaust gases are particularly high and which are occupied by the crew or other workers.
- Consideration should be given to the likelihood of unventilated zones being screened behind an object, and also to the fact that exhaust gases readily accumulate in low-lying spaces under the vehicles and in decks beneath the one being unloaded. Furthermore, depending on air flow patterns, it may be possible for contaminants to move into decks above the one actually being off-loaded.
- The air flow on vehicle deck should be suited to the height of the deck.
- The air flow will follow the path of least resistance, and most of the air will thus flow in open spaces, such as above the vehicles etc.
- Polluted air from ro-ro cargo spaces must be prevented from being dispersed into adjacent spaces, for instance accommodation and engine rooms.
- Whenever possible, places which are sheltered from the airflow should be indicated on the plan. The actual locations of such spaces on the deck should be painted in a conspicuous manner to indicate that personnel should not stand on that part of the deck, and signs should be hung on the bulkhead to provide a backup warning.

2.5 Determination of air flow requirements

To assess the number of vehicles which may be in operation at the same time in a cargo space without the occupants being exposed to a hazardous or discomforting level of pollution the guidance contained in Appendix 1 for estimating the flow of outdoor air required to dilute and remove the gases exhausted by a vehicle should be followed.

Consideration should be given to the fact that the exhaust gases may not mix completely with the outdoor air supplied, that the exposure limit values must not be reached and that the outdoor air itself will contain a certain level of pollution.

This guidance applies to vehicles with a normal emission of exhaust gases, operating under normal conditions. It must be remembered that the measured or estimated air flow may deviate from the actual air flow and that the concentration of pollutants in the exhaust gases can vary widely.

The guidance specifies the supply air requirement per vehicle, to ensure that the level of pollution is kept below the exposure limit. Nevertheless, subjective (individual) symptoms of discomfort may be felt, particularly from diesel exhaust gases, with supply airflows at or above the recommended levels.

3 TESTING THE VENTILATION SYSTEM

3.1 General

Testing the ventilation system when the ship is delivered is primarily aimed at confirming that the design supply air flow is obtained. The test results apply to empty vehicle deck and the weather prevailing at the time of testing.

The values recorded during testing are neither representative of nor equivalent to those that need to be applied during loading and unloading of the various types of vehicles under varying weather conditions.

To utilise the ventilation system in the ro-ro cargo spaces on a ship most effectively, knowledge must be acquired of its capacity from experience and through simple tests. It is important that guidelines, rules and routines be established for using the ventilation system in typical loading and unloading conditions. It is also important that experience gained will be documented and passed on, to provide guidance for the ship's crew.

The factors that need to be determined are the quantities of air supplied to and exhausted from the ro-ro cargo spaces and the circulation of air within the vehicle deck. Guidelines for suitable testing are contained in Appendix 2.

By systematic use of visible smoke, it is possible to assess the air circulation in a ro-ro cargo space, and an anemometer can be used for determining the rate of flow of supply air. If the results are compared with detailed documentation of actual conditions, they can be used to provide a firm foundation for effective measures.

It is important that the conditions prevailing at the time of the test, which are likely to influence the results, are carefully documented since air flow patterns will vary according to loading conditions. The test results are obviously only applicable to the conditions existing at the time of the tests.

3.2 Determining the rate of air change

The rate of air change is governed by the flow of supply air admitted to the ro-ro cargo spaces through the supply air openings. The flow of air can be determined using a direct reading of anemometer or other instrument of equivalent reliability.

Since the velocity profile of the air entering the vehicle deck through supply air openings on ships is generally highly unstable and fluctuates widely, the air flow should be measured by someone experienced in such measurements. However, after some training, responsible members of the crew should also be able to make these measurements.

Even when the measurements are made by competent personnel, allowance should be made for deviations of at least 20% from the actual air flow, when readings are taken by means of anemometers.

A description of air flow measurement procedures is given in appendix 2. Note that a high air change rate does not guarantee low contaminant levels. Poor mixing within the deck could lead to high contaminant levels and potentially high exposures, even though the fans appear to be providing a large amount of air. Once the ventilation system has been fully characterized, spot checks of the system should be made during actual loading or off-loading operations to ensure that the system is operating as expected. Further guidance is provided in Operational Recommendations for Minimizing Air Pollution in Ro-Ro Cargo Spaces (Part 2).

3.3 Smoke and gas for tracing the air distribution

To improve the quality of the air at the workplace knowledge must be gained of how the pollution from the vehicles is diffused through the air in the ro-ro cargo space.

Visual tests using visible smoke do not provide any direct readings of the rate of air change or air distribution in a ro-ro cargo space, although they often provide sufficient indication of a satisfactory picture to be obtained of the air circulation, the existence of any stagnant or screened zones and the rate at which pollutants are removed by the ventilation system. Recommended methods using visible smoke or tracer gas are given in appendix 2.

The visible smoke method is simple and can readily be carried out by the officer responsible for ro-ro cargo space ventilation.

The use of tracer gas will give a more reliable picture of air changes and the air circulation in the ro-ro cargo space. However, the procedure for using tracer gas is more complicated. As the same measurement points are used, it is expedient to use tracer gas in combination with stationary monitoring of pollutant concentration in a ro-ro cargo space.

4 DOCUMENTATION

4.1 Operation manual

An operation manual should be supplied and should include a plan of the ventilation system, showing fans, supply air and exhaust air openings and doors, ramps, hatches, etc. The location of the control panel for the ro-ro cargo space ventilation system should also be marked.

The plan should show the various options for operation of the ventilation system. It should include details of the design air flow and of the estimated number of different types of vehicles in the different ro-ro cargo spaces under various loading and unloading conditions.

The plan should be periodically revised and/or supplemented on the basis of the experience gained from the normal vehicle loading and unloading conditions. A number of blank drawings should therefore be kept on board.

On the basis of such experience, it should also be possible to draw up guidelines for the maximum number of vehicles that should be allowed to operate simultaneously.

Whenever possible, places which are sheltered from the air flow should be indicated on the plans.

The air flow should be indicated in colour on the plan in accordance with the following recommended standard taken from ISO 5571, Identification Colours for Schemes for Ventilation Systems:

Supply air, natural ventilation - Yellow

Exhaust air, natural ventilation - Brown

Supply air, mechanical ventilation - Green

Exhaust air, mechanical ventilation - Grey

The operation manual should include guidance for the service and maintenance of the systems.

4.2 Control panels

The control panel on the ship should be installed in a convenient location.

A plan of the ship's ro-ro cargo spaces, showing the location of fans and openings, should be kept at the control panel. Each fan should be given an individual designation.

Indications as to which fans should be used for a given ro-ro cargo space under various loading conditions should also be on display at the control panel.

For safety reasons and to facilitate control of the ventilation system, the control panel should include means of indicating which fans are running.

The individual control and indicator lights should be marked with the same designation as the fans to which they relate.

As far as possible, indicator lights and controls for fans that normally operate simultaneously should be located in groups. This will help to make the function of the controls readily apparent and will therefore facilitate correct use of the controls.

Reference is made to the IMO Code on Alarms and Indicators.

Appendix 1 - Ventilation of ro-ro cargo spaces - Requirements and basic calculations

1 Scope and field of application

This appendix specifies conditions and basic calculations for ventilation in ro-ro cargo spaces in ships where vehicles with internal combustion engines operate. The purpose of the ventilation is to dilute and remove exhaust gases generated by the vehicles in order to protect crews, shore personnel and passengers from being exposed to harmful levels of pollutants.

Regulations which relate to ventilation in ro-ro cargo spaces should also be considered. For example requirements for a minimum number of air changes with regard to vehicles and other cargo, such as dangerous goods, and stipulations for maximum permitted noise levels should be met.

2 References

Appropriate national occupational exposure limit values should be stated.

3 Supply air requirements

The ventilation plant should be dimensioned to meet the following requirements.

- (a) A minimum number of air changes according to SOLAS reg. II-2/37, 38, 53; and

(b) The supply air requirements stipulated in the tables below.

Supply air requirements based on short-term exposure levels

Type of vehicle	Operating cycle	Supply air required per vehicle
Cars on ferries and ro-ro ships	Normal operating cycle, starting from cold engine	7 - 8 m ³ /s
	Idling, starting from cold engine	5 - 6 m ³ /s
Long-distance lorries on ferries and ro-ro ships	Normal operating cycle, starting from cold engine	6 - 7 m ³ /s
	Charging of compressed air systems for brakes, starting from cold engine (engine being idled at high speed)	7 - 8 m ³ /s

Supply air requirements based on long-term exposure levels

Type of vehicle	Operating cycle	Supply air required per vehicle
Cars on ferries and ro-ro ships	Normal operating cycle, starting from cold engine	10 - 12 m ³ /s
	Idling, starting from cold engine	7 - 9 m ³ /s
Long-distance lorries on ferries and ro-ro ships	Normal operating cycle, starting from cold engine	16 - 18 m ³ /s
	Charging of compressed air systems for brakes, starting from cold engine (engine being idled at high speed)	17 - 19 m ³ /s
Large loader trucks used for ro-ro ships	Normal operating cycle, warm engines	22 - 24 m ³ /s
Small diesel trucks on ro-ro ships	Normal operating cycle, warm engine	3 - 4 m ³ /s
Cars on car carriers	Normal operating cycle, starting from cold engine	8 - 9 m ³ /s
	Normal operating cycle, warm engine	6 - 7 m ³ /s
	Normal operating cycle idling, starting from cold engine	4 - 5 m ³ /s

4 Calculations of supply air requirements

For calculating the supply air requirement either of the formulas shown below, may be used.

Formula 1

$$q = F/(a(k-b))$$

where

q = required outdoor air, m³/s

F = pollution, mg/s

K = exposure limit value, mg/m³

a = dilution factor (see paragraph 6)

b = pollution content of the outdoor air

For the purposes of calculation it is understood that there is a complete mixture of air and pollutant.

The pollution content of the outdoor air (b) is assumed to be 1/40 of the exposure limit value - in the absence of any other information.

Formula 2

$$C = ((G-Ge)/Q') \exp(-(\lambda t)/v)$$

C = concentration of contaminant

G = rate of generation of contaminant, or rate per car times the number of cars in motion during the specified period

e = 2.71828

Q' = effective rate of ventilation, or actual rate (Q) divided by a safety factor of 3

t = time in minutes

V = volume of ventilated space

5 Calculation of vehicle pollution

For calculation of pollution quantity it is important to know the type of engine in the vehicles (diesel, petrol), size, operation cycle (activity on board) and the number of vehicles in operation simultaneously. This varies according to the size and type of the ship and to the design of the forwarding routes and if there are hoists or other arrangements on board which delay the traffic (queuing, idling). The calculation of pollution

quantity must, therefore, be based on this and on expected cargo handling operations and the way in which these are organized. Information on the anticipated vehicle mix and operational requirements should be obtained by the designer.

When estimating the pollution generation the ro-ro cargo spaces should be regarded as separate volumes. Places where a particularly high generation of exhaust gas could be expected and areas with limited airflow, must be taken into consideration.

The maximum number of vehicles that may be operated simultaneously should be determined from the amount of pollution generated by the vehicle(s) being operated, when considering the adequacy of the ventilation system.

CO, NO₂ and HC in vehicle exhausts are given in paragraph 7 for different modes of operation.

When designing a ventilation system for the dilution and removal of exhaust gases generated by vehicles, it should be noted that CO will be the most significant exhaust gas where petrol engines predominate. Whereas NO_x will be most where diesel engines predominate. However exposures should be kept well below the NO_x and CO exposure limits to protect against exhaust gas components for which occupational exposure limits are unavailable.

6 Dilution factor

The factor of dilution takes into consideration the estimated dilution of the air pollution, and ranges from 0.9 for a well ventilated deck with well defined loading and ventilation patterns to 0.3 for a poorly ventilated deck with poorly defined uses and operational procedures.

7 The quantity of pollution in exhaust gases

The quantity shown below of carbon monoxide (CO), nitric oxide (NO_x), hydrocarbons (HC) and nitrogen dioxide (NO₂) in exhaust gases generated by petrol and diesel engines, applies to engines without exhaust gas purifier. Stated values are average values and are to be considered representative of a large group of vehicles.

7.1 Petrol engines, cylinder volume 1 000 - 2 000 cm³

Example of vehicle: Passenger cars

Pollution in mg/s */			
Operating cycles	CO	NO _x	HC
Idling (600 - 1000 r/min)	100-150	1-2	10-15
Constant speed, 15 km/h	200-250	3,3-3,5	15-20
Constant speed, 30 km/h	250-300	7-8,5	15-20
Acceleration, 0,6 m/s ² , (0-15 km/h)	250-300	5-6,5	15-20
Motor breaking 0,6 m/s ² , (15-0 km/h)	110-140	1	28-33

*/ Applies to warm engine. At cold start and with the choke in use the pollution increases by 100% or more. Engines in cars, 1977 and later, emit up to 50% smaller quantity of CO, 15 - 20% smaller quantity of HC and 20 - 25% smaller quantity of NO_x.

7.2 Diesel engines

7.2.1 Turbo-charged diesel engine, approximately 150 Kw

Examples of vehicles: Larger lorries, loaders and larger trucks

Pollution in mg/s */				
Operating cycles	CO	NO _x	HC	NO ₂
Idling	20-30	17-25	15-25	5-8
Lift 2 500 r/min	170	10-100	100	5-50
Transport 2 260 r/min	150	600-700	130	25-30

**/ Applies to warm diesel engine. Engines that are cold started and run with an increased number of revolutions per minute emit about 100% more carbon monoxide (CO) and hydrocarbon (HC). The quantity of nitrogen dioxide (NO₂) is unchanged.

7.2.2 Suction fed diesel engine, with air storage chamber, approximately 150 Kw

Pollution in mg/s */				
Operating cycles	CO	NO _x	HC	NO ₂
Idling	20-25	25-30	2-4	8-9
Lift 2 150 r/min	50-60	10-130	10-15	5-65
Transport 2000 r/min	130-150	100-225	15-35	4-9

*/ Applies to warm diesel engine. Engines that are cold started and run with an increased number of revolutions per minute emit about 100% more carbon monoxide (CO) and hydrocarbon (HC). The quantity of nitrogen dioxide (NO₂) is unchanged.

7.2.3 Suction fed diesel engine without air storage chamber, approximately 130 Kw

Examples of vehicles: Lorries, loaders and buses

Pollution in mg/s */				
Operating cycles	CO	NO _x	HC	NO ₂
Idling	20-25	15-20	10-15	5-6

Lift 2 200 r/min	50-60	22-26	40-60	10-15
Transport 2 200 r/min	170-200	136-150	10-15	5-6

*/ Applies to warm diesel engine. Engines that are cold started and run with an increased number of revolutions per minute emit about 100% more carbon monoxide (CO) and hydrocarbon (HC). The quantity of nitrogen dioxide (NO₂) is unchanged.

7.2.4 Suction fed diesel engine without air storage chamber, approximately 74 Kw

Examples of vehicles: Fork lift trucks and passenger cars

Pollution in mg/s */				
Operating cycles	CO	NO _x	HC	NO ₂
Idling	3-5	2-5	1	0,5-1,5
Lift 3 000 r/min	50-60	5-10	30-40	2.5-5
Transport 3 000 r/min	60-70	40-50	10-20	1,5-2,5

*/ Applies to warm diesel engine. Engines that are cold started and run with an increased number of revolutions per minute emit about 100% more carbon monoxide (CO) and hydrocarbon (HC). The quantity of nitrogen dioxide (NO₂) is unchanged.

8 Dimensioning pollution in exhaust gases

Below are some examples of frequently occurring operating cycles and an average value of the quantity of pollution in exhaust gases produced by vehicles with internal combustion engines running in ro-ro cargo spaces.

8.1 Ro-ro ships

For loading and unloading of trailers from ro-ro ships, larger trucks and loaders are generally used. Type of engine: Turbo-charged diesel engine, approximately 150 Kw.

The number of trucks operating simultaneously is highly dependent on the size of the ship, the number of decks, the design of the ramp and ease of access etc. are of great importance. A normal operating cycle for vehicles consists of lift (about 45 s), transport and idling.

For the local vehicle handling on board ro-ro ships smaller diesel powered trucks are used as a rule. Type of motor: Suction fed diesel engine, approximately 74 Kw.

The number of smaller trucks operating simultaneously is dependent on the size of the vehicle deck. A normal operating cycle for smaller trucks is short and consists of lift, transport and idling.

Exhaust gas generation from buses, lorries and passenger vehicles on ro-ro ships is comparable with the one for vehicles on ferries (see paragraph 8.2).

8.2 Ferries

The vehicle mix on board ferries varies seasonally from the main part (70 - 80%) of the vehicle capacity being occupied by long-distance lorries and the rest by passenger vehicles, to the opposite proportions. For most of the year the former applies on most routes.

For passenger vehicles the cargo handling is quick. A vehicle deck with up to 300 cars can, if the traffic conditions are good, be discharged in 15 minutes. Such a quick discharging can mean that many vehicles may have their engines running at the same time during the discharging.

A normal operating cycle for passenger vehicles on board ferries consists of running at a low speed, acceleration, motor braking and idling. Type of motor: Petrol engine 1,000 - 2,200 cm³.

A normal operating cycle for larger lorries and buses on board ferries consists of charging the compressed air system for the brakes, acceleration and running at a low speed. Type of motor: Turbo-charged diesel engine, approximately 150 Kw.

8.3 Car carriers

On car carriers the cargo handling is normally carried out without any queuing. The turnover of the cargo is about 350 cars per hour. There are generally 6 - 10 cars in continuous operation and it can be supposed that 4 of them are on the vehicle deck.

A normal operating cycle for a passenger car on board car carriers consists of running at a moderate speed and a smaller part of idling. Type of motor: Petrol engine 1,000 - 2,200 cm³.

Appendix 2 - Ventilation of ro-ro cargo spaces - Air flow testing procedures

1 Scope and field of application

This appendix gives directions for measuring nominal air change and air distribution in connection with testing of ventilation plants in ro-ro ships cargo spaces where running of vehicles with internal combustion engines occurs.

The nominal air change is measured by calculation of the air flow in supply air and exhaust air terminal devices. The air distribution is normally estimated visually with visible smoke, or by measuring with tracer gas.

2 Nominal air change

In order to verify that the calculated quantity of air is supplied to the ro-ro cargo spaces, the air flow rate shall be measured in each supply air and, where appropriate, exhaust air terminal device.

2.1 Instruments for Measurement of Air Flow

Although alternative techniques, such as the pilot traverse method are available, anemometers are generally employed for low velocity air flow measurements. There are two general types of anemometers:

(a) The direct-reading anemometer of the electronic type which registers the air velocity almost instantaneously. This has a distinct non-uniform airflow as any instability or random changes of velocity are immediately seen and the true mean of the velocity at a point can be judged. It is also very quick to use.

(b) The mechanical type of direct reading anemometer with a rotating vane. The movement is a rotary deflection against the action of a spring. These types of anemometer are small and compact, easy to read and use, give reasonably steady readings and any fault or inconsistency developing is usually quite apparent. Where a correction chart is supplied with an anemometer the correction factors should be applied to the measured velocities before comparing them. With a good quality instrument in proper repair used by an experienced operator, the probable error on the comparative value obtained will range from a maximum of +/-2% when comparing similar velocities to a maximum of +/-5% when comparing widely differing velocities.

2.2 Air Flow Measurement Procedure *

* Abstracted from the Chartered Institute of Building Services, Commissioning Codes, Series A, Air Distribution, CIBS, London, 1971.

For supply or extract grilles the anemometer is used as follows:

The gross grille area is divided into 150-300 mm squares, depending upon the size of grille and variation in the velocity pattern. The anemometer is held at the centre of each square with the back of the instrument touching the louvres which must be set without deflection. The instrument will give an immediate reading of the indicated velocity at each square and this reading should be recorded. When the indicated velocities at the centre of all squares have been recorded, the average value of these velocities should be calculated; this average value should be taken as the 'indicated velocity' for the whole grille.

This method will normally provide repeatable results. In practice the only inconsistency which is necessary to consider appears where the grille damper is well closed down, causing the air to strike the anemometer vanes in separate jets rather than with uniform velocity. In this case a hood may have to be used with the anemometer.

2.3 Calculations

The air flow rate at each supply-extract grille is calculated as follows:

Air flow rate (m³/s) = 'indicated velocity' (m/s) x area of supply/extract grille (m²)

The global rate of air change per hour achieved by the vehicle deck system(s) is subsequently calculated as follows:

Air changes per hour = sum (Air flow rates at extract grilles (m³/s) x 60 x 60) / (Volume of vehicle deck (m³))

2.4 Report

A report should be drawn up in accordance with paragraph 4 of this appendix.

3 Air distribution

3.1 Visual study with visible smoke

In order to assess air change rate the movement of air and the existence of poorly ventilated areas, visible smoke can be released into the space. With the ventilation system operating, the movement of air and the dissipation of smoke can be studied and the air change rate estimated.

3.2 Measurement with tracer gas

By use of tracer gas it is possible to estimate air change rate and air distribution in chosen points in the ro-ro cargo space.

Measurement with tracer gas involves mixing a gaseous component with the air. The atmosphere in the space is examined to determine how dilution of the tracer gas is tracked at chosen points in the ro-ro cargo space whilst the ventilation system is operational.

This method should be carried out with and without vehicles.

3.2.1 Test procedures

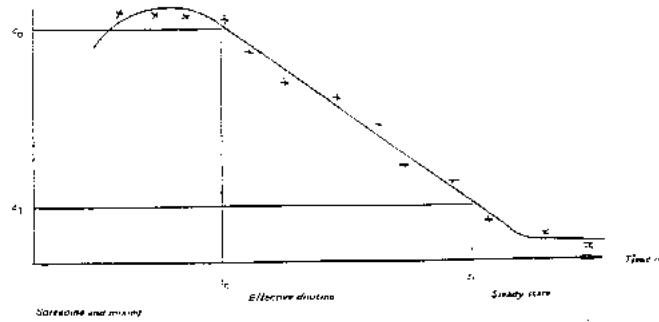
The placing of the measurement probes shall be chosen with regard to the purpose of the measurement. The probes are not to be placed near to the supply air terminal devices or at places where a so-called ventilation shadow can be expected, such as behind pillars, webs etc. As a rule the probes are placed at the head height and in the vicinity of persons working on the deck.

The tracer gas should be spread and mixed in the air as completely as possible. The mixing may be done by the ordinary ventilation plant or with help of external fans. In order to reach an adequate accuracy, the concentration of the tracer gas ought to reach at least 50 times the detection limit of the analytical instrumentation.

When the tracer gas concentration is adequate the ventilation plant as well as the measurement equipment should be started. Tracer gas concentration should be recorded until the detection level is reached.

3.2.2 Calculation

With a dilution ventilation system the logarithm of the concentration of tracer gas will be linear with regard to time (see figure below).



The logarithm of the concentration of tracer gas

The relation between the concentration of tracer gas and time (the inclination of the graph) is a straight measure of the effect to the ventilation expressed in number of air changes according to the following formula:

$$N = (\ln (C_0/C_1))/(t_1 - t_0)$$

where

N = number of changes

C₀ = the concentration at the beginning of the effective dilution

C₁ = the concentration at the end of the effective dilution

t₀ = the point of time at the beginning of the effective dilution

t₁ = the point of time at the end of the effective dilution

3.3 Alternatives

As an alternative to the tests in paragraph 3.1 and 3.2, air flow distribution in the ro-ro cargo space may be evaluated by use of an anemometer.

4 Report

A written report should be provided containing the following information:

Ship's data	Including, ship name, register, number, length, breadth, draught, GT, owner, shipyard, name of contractor carrying out the test.
Weather conditions	Wind speed and direction in general and in relation to the longitudinal of the ship during measurements.
Vehicle deck measurements	Deck length, breadth, height, and volume.
Ventilation	A plan of the deck indicating the location of supply and exhaust fans, together with information on grille surface area, design capacity and actual capacity of each unit. The use of additional air mixing equipment (e.g. dirigent) should also be noted. An indication of the status of all other openings to the deck during sampling should also be provided.
Activity	Details of loading and unloading should be included. These should comprise the time taken for each loading/unloading operation, the number of personnel working, the number and type of vehicles present.
Measurements	Time and date of the measurements
	Instrumentation
	Calibration
	Measurement procedure
	Sample locations
	Details of sample analysis
Results	Measurement results
	Calculation of occupational exposure

Conclusions/Recommendations

In addition to the statement of results the report should contain a plan of the ro-ro cargo space with supply air and exhaust air ducts shown. Where appropriate the measurement points, type and number of vehicles, etc., should be indicated. Notes should be made regarding circumstances that affect the ventilation systems and/or air flow patterns on the deck.

When conducting a visual study with visible smoke, a detailed description of discharge and dissipation of the smoke as well as lapse of time should be given.

PART 2 OPERATIONAL RECOMMENDATIONS FOR MINIMIZING AIR POLLUTION IN RO-RO CARGO SPACES

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INTRODUCTION

The operational recommendations contained in this document are primarily directed at those involved with cargo handling in cargo spaces on ro-ro ships or working in similar environments. The main purpose of the recommendations is to suggest ways in which exposure to exhaust gas emissions can be restricted, but the hazards associated with pollution from exhaust gases are also dealt with. A copy of the recommendations should be kept on board the ship.

Exhaust gas composition

Exhaust gases from motor vehicles contain hazardous substances. Carbon monoxide (CO) from petrol engines, and nitric oxide (NO) and nitrogen dioxide (NO₂) from diesel engines are the substances whose health hazards are discussed in this document. These hazardous substances can affect people in many different ways. Certain substances have a tangible, immediate effect. Others only show injurious effects after a person has been exposed to them for some time. The effect of a substance normally depends on how long a person has been exposed to them and the quantity inhaled.

Carbon monoxide (CO) is a colourless and odourless gas which, to a lesser or greater extent, inhibits the ability of the blood to absorb and transport oxygen. Inhalation of the gas can cause headaches, dizziness and nausea.

Nitric oxide (NO) and nitrogen dioxide (NO₂) are compounds of nitrogen and oxygen, commonly referred to as oxides of nitrogen or NO_x. NO, a colourless gas, is the main oxide of nitrogen formed in the combustion process. NO itself is not of great concern as regards health effects; however, a proportion of the NO will combine with oxygen to form NO₂, which is of concern from the point of view of human health. NO₂ is a brown gas which has a stinging, suffocating odour. It exerts a detrimental effect on the human respiratory system. Asthmatics in particular are susceptible to exposure.

Measures

Measures should be considered as follows:

- reduction in exhaust gas emissions;
- provision of an adequate ventilation system; and
- prevention of exposure to the gases.

1 REQUIREMENTS

1.1 Definition of exposure limits

"An exposure limit value" means the highest acceptable average concentration (time-weighted mean value) of a substance or, in some cases, of a mixture of substances in the air breathed by the occupants. The concentrations are usually given in parts per million (ppm) or mg/m³. An exposure limit value refers either to a long term exposure level or a maximum limit value. Short-term exposure level is also used.

"Long-term exposure level" means the exposure limit value for exposure during the entire working day (normally 8 hours).

"Maximum exposure level" means the highest concentration reached.

"A short-term exposure level" means the time-weighted mean exposure value over a short period of 10 or 15 minutes, dependent upon national occupational exposure standards.

1.2 Pollutants of interest

The exhaust gases generated by internal combustion engines contain hundreds of chemical substances. The main part of them are nitrogen (N₂), carbon dioxide (CO₂), oxygen (O₂), carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO₂) aldehydes such as formaldehyde, polyaromatic hydrocarbons such as benzo(a)pyrene and organic and particulate bound lead.

Among the pollutants emitted in the exhaust gases of petrol and diesel engines, CO is generally of most significant concern for petrol engines and NO_x for diesel engines. Lead and benzo(a)pyrene are also of a significant cause for concern.

Knowledge of the effects of other pollutants to the health is at present insufficient. However considerable research is being undertaken.

Monitoring of occupational hygiene should be planned and its results should be assessed by a qualified expert, with special training in this field. The studies should be carried out in co-operation with the monitoring staff, the management of the ship concerned and the relevant Administrations.

1.3 Rate of air change

Regulations II-2/37, 38 and 53 of the 1974 SOLAS Convention, as amended, provide requirements for rate of air changes which are intended to limit maximum concentration of pollutants during loading and discharging and also to prevent a build-up of hazardous gases in the ro-ro cargo space when the ship is at sea with a cargo of motor vehicles. These regulations provide the minimum acceptable standards for ventilation.

1.4 Noise levels

Noise affects the utilization of the ventilation system. Efforts should be made to minimize noise at the design stage.

Noise level limits are laid down in the requirements of the respective maritime authorities who also publish guidelines for measuring noise.

2 TRAINING AND INFORMATION

Personnel should be properly trained, possess the necessary skills and follow established procedures.

In order to improve/monitor air quality on vehicle decks a process should be established to record and investigate complaints where persistently poor air quality is perceived by shoregang and crew.

Drivers should be given appropriate instructions for embarkation/disembarkation. These should be aimed at minimizing the air pollution generation.

Training and information should be reviewed following a significant change in the operation of the vessel.

3 INSPECTION, MAINTENANCE AND REPAIRS

Inspection, maintenance and repairs should be carried out in a professional manner. Owners should ensure that this is done and that the necessary skills, equipment and spares are available.

Annual testing of the vehicle space ventilation system should be conducted by the ship's safety delegate.

Third party testing of the vehicle space ventilation system should be undertaken before entry into service of a new ship and at periodical intervals of 5 years thereafter.

4 VENTILATION

4.1 Ventilation on board ship

Ventilation systems for ro-ro cargo spaces on board ship generally operate according to the principle of dilution ventilation, whereby the supply air flow to the area is sufficient for the exhaust gases to mix thoroughly with the air and be removed.

There are two main types of dilution ventilation: exhaust air ventilation and supply air ventilation. Briefly, in exhaust air ventilation, fans remove air from a ro-ro cargo space, and this is then replaced by outdoor air entering through open ramps, doors and other openings. Exhaust air ventilation is employed when sub-atmospheric pressure is required in the ro-ro cargo space. The sub-atmospheric pressure prevents the pollution from spreading to adjacent areas.

Supply air ventilation works in the opposite way. Fans deliver outdoor air into the ro-ro cargo space and the air is then exhaust through ramps and other openings. Supply air ventilation usually creates slight pressurisation of the ro-ro cargo space. If supply air ventilation is used exclusively, pollutants may mix with the supply air, be pushed up the internal ramps and contaminate other decks. However, if sufficient mixing with supply air does not occur, contaminants may remain on the deck in question. Particularly hazardous conditions may occur on lower decks.

Ventilation systems on board ship often combine these two principles. The fans can then be reversible, so that they can either supply air into the ro-ro cargo space or exhaust air from it.

4.2 Air pollutant dispersion

Exhaust gas dispersion will depend upon air flow patterns within the vehicle deck. These will not be uniform but will be dependent upon the capacity, design and mode of operation of the ventilation system; volume and configuration of the cargo space; natural ventilation patterns and the number and location of vehicles on the vehicle deck.

Although the overall rate of air change on vehicle decks may be high, areas with low rates of air change may remain. High velocity air jets are sometimes installed in an attempt to "stir" the air so that the supply air will be evenly distributed throughout the vehicle space.

4.3 Air flow distributions

It is not possible to draw up or recommend any universal solutions for the distribution of the air flow in different types of vessel. Duct runs and the location of supply air and exhaust air openings must be made to suit the design of the individual ship, the estimated cargo handling and exhaust emissions in areas occupied by the crew and other workers.

The following generally applies:

- The air flow should reach all parts of the ro-ro cargo space. However ventilation should be concentrated in those areas in which the emissions of exhaust gases are particularly high and which are occupied by the crew or other workers.
- Areas in front of ducts that should not be obstructed should be identified by painting a line around the area on the deck and labelling "Keep area clear for proper ventilation".
- Consideration should be given to the likelihood of unventilated zones being screened behind an object, and also to the fact that exhaust gases readily accumulate in low-lying spaces under the vehicles and in decks beneath the one being unloaded. Furthermore, depending on air flow patterns, it may be possible for contaminants to move into decks above the one actually being off-loaded.
- The air flow on vehicle deck should be suited to the height of the deck.
- The air flow will follow the path of least resistance, and most of the air will thus flow in open spaces, such as above the vehicles etc.
- Polluted air from ro-ro cargo spaces must be prevented from being dispersed into adjacent spaces, for instance accommodation and engine rooms.
- Whenever possible, places which are sheltered from the air flow should be indicated. For example, the deck should be painted in a conspicuous manner to indicate that personnel should not stand on that part of the deck, and signs should be hung on the bulkhead to provide a backup warning.

5 TESTING THE VENTILATION SYSTEM

5.1 General

Testing the ventilation system when the ship is delivered is primarily aimed at confirming that the design supply air flow is obtained. The test results apply to empty vehicle deck and the weather prevailing at the time of testing.

The values recorded during testing are neither representative nor equivalent to those that need to be applied during loading and unloading of the various types of vehicles under varying weather conditions.

To utilise the ventilation system in the ro-ro cargo spaces on a ship most effectively, knowledge must be acquired of its capacity from experience and through simple tests. It is important that guidelines, rules and routines be established for using the ventilation system in typical loading and unloading conditions. It is also important that experience gained will be documented and passed on, to provide guidance for the ship's crew.

By systematic use of visible smoke, it is possible to assess the air circulation in a ro-ro cargo space, and an anemometer can be used for determining the rate of flow of supply air. If the results are compared with detailed documentation of actual conditions, they can be used to provide a firm foundation for effective measures.

It is important that the conditions prevailing at the time of the test, which are likely to influence the results, are carefully documented since air flow patterns will vary according to loading conditions. The test results are obviously only applicable to the conditions existing at the time of the tests.

5.2 Determining the rate of air change

The rate of air change is governed by the flow of supply air admitted to the ro-ro cargo spaces through the supply air openings. The flow of air can be determined using a direct reading of anemometer or other instrument of equivalent reliability.

Since the velocity profile of the air entering the vehicle deck through supply air openings on ships is generally highly unstable and fluctuates widely, the air flow should be measured by someone experienced in such measurements. However, after some training, responsible members of the crew should also be able to make these measurements.

Even when the measurements are made by competent personnel, allowance should be made for deviations of at least 20% from the actual air flow, when readings are taken by means of anemometers.

A description of air flow measurement procedures is given in Appendix 2. Note that a high air change rate does not guarantee low contaminant levels. Poor mixing within the deck could lead to high contaminant levels and potentially high exposures, even though the fans appear to be providing a large amount of air. Once the ventilation system has been fully characterized, spot checks of the system should be made during actual loading or off-loading operations to ensure that the system is operating as expected.

5.3 Smoke and gas for tracing the air distribution

To improve the quality of the air at the workplace knowledge must be gained of how the pollution from the vehicles is diffused through the air in the ro-ro cargo space.

Visual tests using visible smoke do not provide any direct readings of the rate of air change or air distribution in a ro-ro cargo space, although they often provide sufficient indication of a satisfactory picture to be obtained of the air circulation, the existence of any stagnant or screened zones and the rate at which pollutants are removed by the ventilation system.

The visible smoke method is simple and can readily be carried out by the officer responsible for ro-ro cargo space ventilation.

The use of tracer gas will give a more reliable picture of air changes and the air circulation in the ro-ro cargo space. However, the procedure for using tracer gas is more complicated. As the same measurement points are used, it is expedient to use tracer gas in combination with stationary monitoring of pollutant concentration in a ro-ro cargo space.

5.4 Correct use of the ventilation system

When examining the ventilation in a ro-ro cargo space, options that are available should be borne in mind. It is by no means certain that the greatest effect will be achieved with all the fans operating at maximum speed at the same time or with all doors, hatches and the like open. This may have the opposite effect. In some circumstances, when the wind direction and strength are favourable, the opening of suitable doors may provide effective natural ventilation.

5.5 Testing of the air quality

When a new ship is put in operation, the air quality should be tested by a competent qualified person with specialist training in occupational exposure. The tests should be carried out in consultation with the ship's safety delegate and any other relevant authorities.

Vessel owners should consider testing the air quality in conjunction with tests of the ventilation system to ensure proper maintenance and functioning of the ventilation system. Situations which indicate the necessity to conduct air quality monitoring include worker complaints (e.g. headache, dizziness, stinging of the eyes or respiratory system), indications that the ventilation system itself has deteriorated, and changes in vessel operation which are substantially different from that for which the original ventilation system was verified.

All test results verifying the adequacy of the ventilation system should be documented and kept with the ship's records. Appendix 3 provides recommendations for conducting air quality monitoring in ro-ro cargo spaces.

6 SHIPS IN OPERATION

6.1 Loading and unloading

Even if the cargo handling on a ship is well planned and the ventilation system is well suited to the planned traffic density, this may still not be enough to ensure that acceptable air quality is maintained under all vehicle handling conditions. It is extremely important that the ventilation system is operated in the most effective manner under the prevailing operational and weather conditions.

The personnel responsible for loading and unloading of vehicles should consult with the officer responsible for vehicle deck ventilation to familiarize himself with the ventilation system on board (the supply and exhaust air openings and the design air flow) and decide whether the ventilation is adequate in the light of the traffic density, vehicle type and other considerations on a given occasion.

It is important that the supply air has free passage to the ro-ro cargo spaces and ventilation openings should not be unnecessarily obstructed.

If auxiliary air-jet systems have been installed, vehicles should be stowed in such a way that the air jets are allowed to operate at maximum effectiveness for as long as possible.

6.2 Documentation

An operation manual should be supplied based on these operational recommendations and should include a plan of the ventilation system, showing fans, supply air and exhaust air openings and doors, ramps, hatches, etc. The location of the control panel for the ro-ro cargo space ventilation system should also be marked.

The plan should show the various options for operation of the ventilation system. It should include details of the design air flow and of the estimated number of different types of vehicles in the different ro-ro cargo spaces under various loading and unloading conditions.

The plan should be periodically revised and/or supplemented on the basis of the experience gained from the normal vehicle loading and unloading conditions. A number of blank drawings should therefore be kept on board.

On the basis of such experience, it should also be possible to draw up guidelines for the maximum number of vehicles that should be allowed to operate simultaneously.

The air flow should be indicated in colour on the plan in accordance with the following recommended standard taken from ISO 5571, Identification Colours for Schemes for Ventilation Systems:

Supply air, natural ventilation - Yellow

Exhaust air, natural ventilation - Brown

Supply air, mechanical ventilation - Green

Exhaust air, mechanical ventilation - Grey

The operation manual should include guidance for the service and maintenance of the systems.

6.3 Control panels

The control panel on the ship should be installed in a convenient location.

A plan of the ship's ro-ro cargo spaces, showing the location of fans and openings, should be kept at the control panel. Each fan should be

given an individual designation.

Indications as to which fans should be used for a given ro-ro cargo space under various loading conditions should also be on display at the control panel.

For safety reasons and to facilitate control of the ventilation system, the control panel should include means of indicating which fans are running.

The individual control and indicator lights should be marked with the same designation as the fans to which they relate.

As far as possible, indicator lights and controls for fans that normally operate simultaneously should be located in groups. This will help to make the function of the controls readily apparent and will therefore facilitate correct use of the controls.

Reference is made to the IMO Code on Alarms and Indicators.

6.4 Limitation of exhaust emission production

The most effective way of reducing exhaust emissions is to ensure that vehicles spend as little time as possible on board with their engines running. This applies not only to cargo-handling vehicle (trucks, tractors, etc.) but also to vehicles being carried as cargo (cars, buses, long-distance trucks, etc.). The speed at which the vehicles are driven on board should also be appropriate to the prevailing conditions.

Exhaust emissions are greatly influenced by driving techniques and the temperature at which an engine is running. Smooth and steady driving of a vehicle with a warm engine will generate the lowest exhaust gas emissions. Sudden and heavy acceleration will cause a substantial and often unnecessary rise in the pollution level. This is particularly true when an engine is cold. Since slow speeds and slow acceleration produce significantly lower levels of air pollutants than high speeds and quick accelerations, vehicles should be accelerated very slowly and kept at low speeds.

The essential points to note include the following:

- condition of the engines;
- driving techniques;
- organization of the work (as few engines as possible running at the same time);
- ensuring that drivers do not start their engines sooner than necessary; and
- ensuring that the traffic flows steadily (thereby eliminating heavy acceleration and high speeds). Exhaust emission control equipment for both diesel and petrol engines may influence air quality during embarkation. However, this is likely to have little effect during disembarkation due to cold starting of engines.

6.5 Limitation of exposure

The car decks on ferries are usually equipped with exhaust air ventilation. The supply air is generally admitted through the ramp and the air is removed by exhaust air fans at the other end of the car deck. A person carrying out heavy manual work uses up twice as much air as a person doing light work. As a result, he will inhale a correspondingly higher proportion of pollutants. Consequently, the work should be organized so that heavy physical work is avoided in areas where the pollution level is high. Nobody should be unnecessarily exposed to hazardous concentrations of exhaust gases.

6.6 Recommendations for specific ship types

6.6.1 Car ferries

During disembarkation at peak times, the highest average concentration of pollution (exhaust gases) in the vehicle deck will occur furthest away from the ramp, in the proximity of the exhaust air fans. Work on the car deck should therefore be organized to eliminate the need for personnel occupying the area of the car deck in which the pollution concentration is highest.

The embarkation and disembarkation should be organized so that no direct queues form inside the ship or in the ramp opening. The embarkation rate should be suited to the capacity of the fans and the flow of outdoor air supplied.

Embarkation should be organized so that ventilation openings, or air jets in an auxiliary system, are not unnecessarily obstructed.

Drivers should be given printed instructions for embarkation/disembarkation. A suitable leaflet could be given to drivers when the tickets are issued or notices posted for examples: Exhaust fumes constitute a health hazard. Don't start your engine before the signal is given and obey instructions.

On enclosed vehicle decks, instructions to start engines should not be given until doors leading to the ramps are open.

6.6.2 Ro-ro ships carrying heavy vehicles

Most of the cargo on ro-ro ships is handled by vehicles. Large trucks and tractors are used for cargo loading and unloading. Trucks of various sizes are used to stow the cargo in the ro-ro cargo spaces. On enclosed vehicle decks, instructions to start engines should not be given until doors leading to the ramps are open.

It is important to eliminate unnecessary exhaust emissions during cargo handling. The vehicles must be kept moving and queues should not be allowed to form. Avoid having vehicles standing with their engines idling. This applies particularly to any waiting during loading and unloading on board and to vehicles on lifts. At these times the ro-ro cargo spaces should be well ventilated.

It is also important to ensure that supply air and exhaust air openings are kept clear and are not obstructed unnecessarily. Failure to observe this can result in the ventilation system not performing effectively.

Attention should be drawn to the fact that exhaust gases can accumulate in poorly ventilated areas and in low-lying areas. A cold engine

discharges twice as much pollution as a warm engine.

6.6.3 Car carriers

Owing to the general uniformity of cargo on car carriers, effective organisation of embarkation/disembarkation should be possible, thereby avoiding the formation of queues and the resulting unnecessary exhaust emissions.

Drivers should be given printed instructions for driving techniques and should be informed of the importance of not running the engines more than necessary. A vehicle driven slowly and with slower acceleration will emit much less pollutant than a vehicle driven faster and with higher acceleration. Furthermore, a cold engine will often emit twice as much pollutant as a warm engine.

It is therefore recommended that engines be warmed up before the vehicles are driven on board. Vehicles with engines running should not be permitted in the vicinity of the "lashing gang".

7 PERSONAL SAFETY EQUIPMENT

The use of personal safety equipment should always be seen as a last resort, only to be adopted when all else has failed. As regards exhaust gases, the practical possibilities are limited, since all of the pollutants contained in the emissions are difficult to filter out, which generally rules out the use of masks and the like. Consequently, if the problem is to be solved using personal safety equipment, breathing apparatus must be used. Such apparatus is inconvenient in practice because the oxygen must come either from cylinders carried or worn on the back of the user or through a hose.

Appendix 1 - Example of general arrangement of ventilation systems in ro-ro cargo spaces

The general arrangement of the ventilation system is illustrated in the attached figure.

The lower deck (the tank-top) is served by eight fans: four supply air fans in the forward part of the deck, and four exhaust air fans aft. Each duct has two openings, one at about deck level and one at the deckhead. An auxiliary system of directing air jets is included for mixing the air. The supply air capacity is 84 m³/s, which should be fully adequate for the relevant cargo handling (3 or 4 trucks).

The part of the deck immediately aft of the lift can constitute a stagnant or screened area when the lift is descending, as there will then be an opening in the main deck.

Two supply air fans and two exhaust air fans provide the ventilation at sea, giving six air changes per hour when the cargo space is empty according to regulation II-2/53 of SOLAS 74, as amended.

The intermediate deck (the main deck) is served by eight supply air fans at the forward end. Each duct has two openings, one at deck level and one at the deckhead. The exhaust air is removed by natural ventilation through the ramp in the stern. An auxiliary system is included for mixing the air. The supply air capacity is 168 m³/s, which will normally be fully adequate during cargo handling (6-8 trucks). Two exhaust air fans, primarily intended for ventilation of the hold when the ship is under way, are located at the stern.

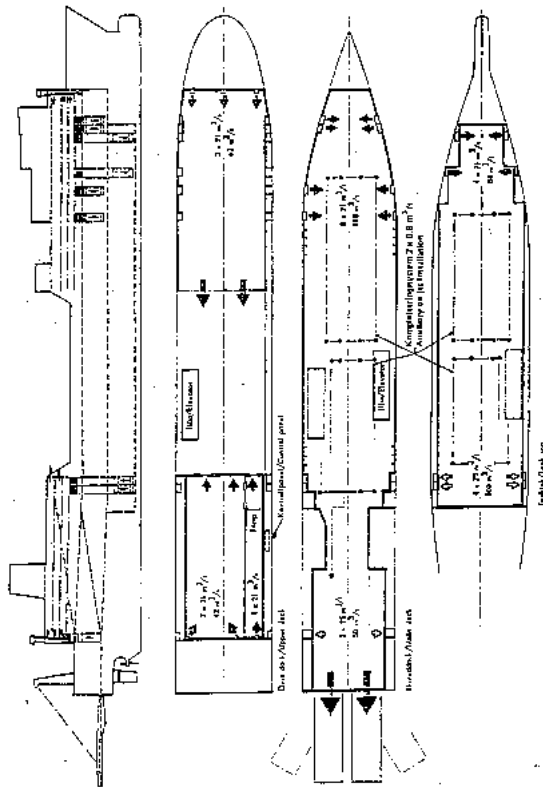
When the ship is under way, ventilation giving six air changes per hour when the ro-ro cargo space is empty is provided by two supply air fans and the two exhaust air fans in the stern.

Each of the deck garages (weather decks) is served by three supply air fans. Each duct has three openings with a facility for directing the air to the area in which cargo handling is in progress. The supply air capacity of 64 m³/s should be adequate to cope with the exhaust emissions from 6-8 cars or from 2 or 3 trucks handling the cargo. The exhaust air is discharged through an opening into the weather deck. The aft deck garage has exhaust air openings in the forward bulkhead for ventilation of the ro-ro cargo space when the ship is under way.

Ventilation at sea, giving six air changes per hour in an empty ro-ro cargo space, is provided by one supply air fan.

Figure

Example of arrangement of ventilation systems of ro-ro cargo spaces



Appendix 2 - Measurement of Air flow

1 Instruments for Measurement of Air Flow

Although alternative techniques, such as the pilot traverse method are available, anemometers are generally employed for low velocity air flow measurements. There are two general types of anemometers:

(a) The direct-reading anemometer of the electronic type which registers the air velocity almost instantaneously. This has a distinct advantage when measuring at terminals where there is unstable or non-uniform airflow as any instability or random changes of velocity are immediately seen and the true mean of the velocity at a point can be judged. It is also very quick to use.

(b) The mechanical type of direct reading anemometer with a rotating vane. The movement is a rotary deflection against the action of a spring.

These types of anemometer are small and compact, easy to read and use, give reasonably steady readings and any fault or inconsistency developing is usually quite apparent. Where a correction chart is supplied with an anemometer the correction factors should be applied to the measured velocities before comparing them. With a good quality instrument in proper repair used by an experienced operator, the probable error on the comparative value obtained will range from a maximum of +/-2% when comparing similar velocities to a maximum of +/-5% when comparing widely differing velocities.

2 Air Flow Measurement Procedure *

* Abstracted from the chartered Institutions of Building Services, Commissioning Codes, Series A, Air Distribution, CIBS, London, 1971.

For supply or extract grilles the anemometer is used as follows:

The gross grille area is divided into 150-300 mm squares, depending upon the size of grille and variation in the velocity pattern.

The anemometer is held at the centre of each square with the back of the instrument touching the louvres which must be set without deflection. The instrument will give an immediate reading of the indicated velocities at the centre of all squares have been recorded, the average value of these velocities should be calculated; this average value is the 'indicated velocity' for the whole grille.

This method will normally provide repeatable results. In practice the only inconsistency it is necessary to consider is where the grille damper is well closed down, thereby causing the air to strike the anemometer vanes in separate jets rather than with uniform velocity. In this case a hood may have to be used with the anemometer.

3 Calculations

The air flow rate at each supply-extract grille is calculated as follows:

$$\text{Air flow rate (m}^3\text{/s)} = \text{'indicated velocity' (m/s)} \times \text{area of supply/extract grille (m}^2\text{)}$$

The global rate of air change per hour achieved by the vehicle deck ventilation system(s) is subsequently calculated as follows:

$$\text{Air changes per hour} = \text{sum (Air flow rates at extract grilles (m}^3\text{/s)} \times 60 \times 60) / (\text{Volume of vehicle deck (m}^3\text{)})$$

Appendix 3 - Recommendations for the evaluation of air quality in ro-ro cargo spaces

1. General

Air quality testing should be planned and results evaluated by competent persons with specialist training in air quality evaluation and occupational exposure. Tests should be carried out in consultation with the ship's safety delegate and any other relevant authorities.

The duration of the tests will depend on the operating cycles and working practices on board the vessel. Monitoring should be carried out during

several 'normal' cycles, i.e. with representative vehicles, activities and ventilation practices.

Both short-term and long-term (over the working day) exposure to air pollutants should be investigated. Either static or personal samplers or ideally a combination of both techniques should be used in order to provide the most accurate picture of contaminant concentrations and occupational exposure.

2. Air quality measurements

Air quality measurements should be representative of all exposed persons.

Pollutants

The concentrations of the following pollutants should be determined; nitric oxide (NO), nitrogen dioxide (NO₂), carbon monoxide (CO). In addition concentrations of benzene, toluene, xylene and suspended particulate matter (SPM) should also be determined whenever possible.

There are two general approaches to air quality sampling that can be adopted. Static site monitoring, typically involving continuous monitoring techniques and personal sampling which employs both passive and active methods. Static site monitoring usually includes the more accurate and sensitive techniques, but as the sampling site is fixed the measurements are not entirely representative of exposure. Personal samplers are worn by a representative sub-set of exposed individuals throughout the sampling period. Personal sampling techniques are not usually as sensitive or accurate. Ideally, personal sampling methods should be validated using more sophisticated techniques at regular intervals.

The following methods are recommended.

Static site monitoring	
Pollutant	Sampling and analysis method
Nitrogen dioxide analysis	Chemiluminescence, reagent tube, grab sampling/laboratory
Nitric oxide analysis	Chemiluminescence, reagent tube, grab sampling/laboratory
Carbon monoxide sampling/laboratory	Non-dispersive infra red absorption, reagent tube, grab analysis
Benzene	Real time gas chromatography
Toluene	Real time gas chromatography
Xylene	Real time gas chromatography
Suspended particulates *	Dual beam radiation absorption,
	Tapered Element Oscillating
	Microbalance, gravimetric

* Suspended particulate matter can be sampled as total suspended particulate matter, PM₁₀, respirable dust (<= 5 micro m).

Personal monitoring	
Pollutant	Sampling and analysis method
Nitrogen dioxide	Passive (badge) sampler-ion chromatography
Nitric oxide	Electrochemical*
Carbon monoxide	Electrochemical*

* Electrochemical methods are susceptible to interference, therefore it is recommended that these methods are regularly validated by intercomparison with other techniques in the test environment.

Benzene	Passive badge sampler-gas chromatography/ FID (Flame Ionisation Detection)
	Passive badge sampler-gas chromatography/FID
Toluene	Passive badge sampler-gas chromatography/FID
Xylene	Passive badge sampler-gas chromatography/FID
Suspended particulates **	Personal sampler, gravimetric

** Suspended particulate matter can be sampled as total suspended particulate matter or respirable dust (<= 5 micro m).

Supplementary measurements of local air velocity, temperature and relative humidity should also be undertaken.

3 Calculation of occupational exposure to air pollutants

Long-term Reference Period

The occupational exposure over a 24-hour period is determined by treating the cumulative exposure over 24 hours as equivalent to a single uniform exposure. This is generally converted to an 8-hour time-weighted average (TWA) exposure and is represented mathematically by:

$$(C_1T_1 + C_2T_2 + \dots + C_nT_n)/8$$

where C_n is the occupational exposure and T_n is the associated exposure time in hours in any 24-hour period.

Short-Term Reference Period

The short-term reference period generally relates to a period of 10 or 15 minutes, dependent upon the national occupational exposure standards. Exposure is therefore recorded as the average over a 10 or 15 minute reference period. Where the exposure period is less than 10 or 15 minutes, the measurement result is averaged over 10 or 15 minutes. Where the exposure period exceeds the short term reference period, results are averaged for the 10 or 15 minutes period during which maximum exposure occurs.

4. Reporting

A written report should be provided containing the following information:

Ship's data	Including, ship name, register number, length, breadth, draught, GT, owner, shipyard, name of contractor carrying out the test.
Weather conditions	Wind speed and direction in general and in relation to the longitudinal of the ship during measurements.
Vehicle deck measurements	Deck length, breadth, height, and volume.
Ventilation	A plan of the deck indicating the location of supply and exhaust fans, together with information on grille surface area, design capacity and actual capacity of each unit. The use of additional air mixing equipment (e.g. dirivent) should also be noted. An indication of the status of all other openings to the deck during sampling should also be provided.
Activity	Details of loading and unloading should be included. These should comprise the time taken for each loading/unloading operation, the number of personnel working, the number and type of vehicles present.
Measurements	Time and date of the measurements
	Instrumentation
	Calibration
	Measurement procedure
	Sample locations
	Details of sample analysis
Results	Measurement results
	Calculation of occupational exposure

Conclusions/Recommendations
