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Ships and marine technology — Ventilation of cargo spaces where vehicles with internal combustion engines are driven — Calculation of theoretical total airflow required

Navires et technologie maritime — Ventilation des espaces cargaison des navires dans lesquels des véhicules à moteur à combustion interne sont utilisés — Calcul du débit d'air total théorique exigé

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 9785 was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 3, *Piping and machinery*.

This second edition cancels and replaces the first edition (ISO 9785:1990), which was revised for continued consistency with International Marine Organization provisions for calculating required ventilation in cargo spaces where vehicles with internal combustion engines may be driven.

Annex A forms a normative part of this International Standard. Annex B is for information only.

Introduction

The purpose of this International Standard is to ensure that exposure to substances hazardous to health should be kept as low as is reasonably practicable in work areas in cargo spaces in ships. This can, as a rule, be achieved by limiting exhaust gas emissions as far as possible (by controlling the traffic) and by providing a high flow of air in the cargo spaces. For further information and guidance regarding good practice, please refer to recent guidelines developed by the International Maritime Organization which are contained in the IMO Maritime Safety Committee Circular 729 (MSC Circ. 729), *Guidelines and Operational Recommendations for Ventilation Systems in RO-RO Cargo Spaces*.

Ships and marine technology — Ventilation of cargo spaces where vehicles with internal combustion engines are driven — Calculation of theoretical total airflow required

1 Scope

This International Standard specifies methods of calculating the theoretical quantity of outdoor air required in cargo spaces of ships where vehicles with internal combustion engines are driven, in order to dilute the polluted air to within the permitted occupational exposure limits.

Annex A specifies average values of the amounts of pollutants in exhaust gases from vehicles with internal combustion engines driven in cargo spaces in ships.

Annex B gives general information and guidance as to good practice for the ventilation of cargo spaces in ships where vehicles with internal combustion engines may be driven.

Users of this International Standard should note that, while observing the requirements of the standard, they should at the same time ensure compliance with such statutory requirements, rules, and regulations as may be applicable to the individual ship concerned. Users should also refer to guidelines developed by the International Maritime Organization (IMO) contained in the Maritime Safety Committee Circular 729 (MSC Circ. 729), *Guidelines and Recommendations for Ventilation systems in RO-RO Cargo Spaces*.

2 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

2.1
cargo space
space used for cargo where vehicles may be driven

2.2
occupational exposure limit
highest airborne concentrations averaged over a specified period of time (time-weighted average or TWA) of substances hazardous to health for employees at work

NOTE An occupational exposure limit refers either to a long-term exposure limit or to a short-term exposure limit as determined by the appropriate authority.

2.3
working area
area occupied by employees at work

3 Airflow calculation

3.1 Volume of space

The volume of total cargo spaces shall be the gross volume with no deduction for the cargoes or for frames, webs, pillars, ducts, etc. In the case of lining or insulation of cargo spaces, the volume shall be calculated from the inside of the lining or insulation.

3.2 Supply airflow

3.2.1 General

The outdoor-supply airflow to the cargo spaces shall be calculated using whichever of the following criteria gives the highest value:

— minimum number of air changes according to applicable statutory requirements;

— required outdoor-supply airflow to maintain the occupational-exposure limit-value.

3.2.2 Supply airflow to maintain the occupational-exposure-limit value

3.2.2.1 Introduction

The sum of the required outdoor-supply airflows per vehicle in operation to maintain the occupational-exposure-limit value is calculated in accordance with 3.2.2.2 or 3.2.2.3 for normally polluted outdoor air or highly polluted outdoor air, respectively.

3.2.2.2 Normally polluted outdoor air

The required outdoor-supply airflow, q_p, per vehicle in operation for normally polluted outdoor air, in cubic metres per second (m^3/s), is given by the equation

$$q_p = \frac{q_m}{ac}$$

where

q_m is the pollution per vehicle in operation, in milligrams per second (see clause 4);

a is the factor of dilution (see clause 5);

c is the occupational-exposure-limit value, in milligrams per cubic metre.

(See typical examples of application in B.2.)

NOTE The pollution contents of normally polluted outdoor air can be taken to be less than 1/40 of the occupational-exposure-limit value.

3.2.2.3 Highly polluted outdoor air

The required outdoor-supply airflow, q_p, per vehicle in operation for highly polluted outdoor air, in cubic metres per second, is given by the equation:

$$q_p = \frac{q_m}{a(c - c')}$$

where

q_m, a and c are as defined in 3.2.2.2;

c' is the content of the pollutant in question in outdoor air, in milligrams per cubic metre.

4 Pollution from vehicles

The purchaser shall specify the type of engine in the vehicles, the engine size, operation cycles (activity on board) and the anticipated number of vehicles normally in operation simultaneously in each working area.

Where specific data on the amount of pollutants (substances hazardous to health) generated by these vehicles are not available, the data according to A.1 shall be used. If the operation cycles are not the same as in A.1, quantities calculated according to A.2 shall apply.

5 Factors of dilution

The factor of dilution indicates the degree of estimated or possible dilution of the air pollution in the cargo spaces.

The purchaser shall specify the factor of dilution taking into account any legal requirements. In the absence of such a specification, the following factors shall apply:

— 0,8 in general cargo spaces;

— 0,4 in cargo spaces in car carriers;

— 0,8 in cargo spaces in ferries with a ventilation system in which the air is supplied at one end and exhausted at the opposite end of the space.

NOTE Guidelines for factors of dilution are given in B.4.

Annex A
(normative)

Pollutants from vehicles in cargo spaces in ships

A.1 Assessment of pollutants in exhaust gases generated by vehicles on board ships

A.1.1 Average values of pollutants

Average values of the amount of pollutants in question in exhaust gases generated by vehicles with internal combustion engines running in ship's cargo holds are given in A.1.2 to A.1.6.

A.1.2 Larger trucks

These are used for loading and unloading of Ro/Ro cargo ships.

Normal operating cycle:	lift (45 s), transport, and some idling
Average amount of NO_2 generated:	≈ 36 mg/s
Type of motor:	— turbo-charged compression-ignition (diesel) engine — power ≈ 150 kW

A.1.3 Smaller trucks

These are used for local cargo handling on board ships.

Normal operating cycle:	lift, transport, and idling
Average amount of NO_2 generated:	≈ 3 mg/s
Average amount of CO generated:	≈ 50 mg/s
Type of motor:	— suction-fed compression-ignition engine — power ≈ 74 kW

A.1.4 Larger ferries and coaches

These may be driven on board ferries and Ro/Ro ships.

Normal operating cycle:	charging the compressed air systems for the brakes, acceleration and running at low speed
Average amount of NO_2 generated:	≈ 45 mg/s at cold start
Type of motor:	— turbo-charged compression-ignition engine — power ≈ 150 kW

A.1.5 Passenger cars (low speed)

The following conditions are specified when these are driven on-board ferries.

Normal operating cycle: running at low speed, moderate acceleration, motor braking, and idling

Average amount of CO generated: ≈ 350 mg/s at cold start

Type of motor: spark-ignition of 1 000 cm^3 to 2 200 cm^3

A.1.6 Passenger cars (moderate speed)

The following conditions are specified when these are driven on board ferries.

Normal operating cycle: running at a moderate speed and a shorter period of idling

Average amount of CO generated: ≈ 250 mg/s for new cars

≈ 350 mg/s for older cars

Type of motor: spark-ignition of 1 000 cm^3 to 2 200 cm^3

A.2 Quantity of pollutants in exhaust gases

A.2.1 Typical quantities of pollutants

Clauses A.2.2 and A.2.3 reference tables of carbon monoxide (CO), oxides of nitrogen (NO_x), hydrocarbons (HC) and nitrogen dioxide (NO_2) in exhaust gases generated by spark-ignition and compression-ignition engines, that apply to engines without an exhaust gas purifier. The stated values are average values and shall be considered representative of a large group of vehicles.

A.2.2 Spark-ignition engine cylinder volume 1 000 cm^3 to 2 200 cm^3

Table A.1 indicates the pollutants for spark-ignition engines of cylinder volume 1 000 cm^3 to 2 200 cm^3 (example of vehicle: passenger cars). The figures apply to a warm engine.

At cold start and with the choke in use, the pollution increases by 100 % or more.

Engines in modern cars (1977 and newer), emit up to 50 % lower quantity of CO, 15 % to 20 % lower quantity of HC and 20 % to 25 % lower quantity of NO_x.

A.2.3 Compression-ignition (diesel) engines

A.2.3.1 Turbo-charged compression-ignition engine, approximately 150 kW

Table A.2 indicates the pollutants for these turbo-charged compression-ignition engines of approximately 150 kW power (examples of vehicles: larger lorries and larger trucks). The figures apply to a warm engine.

Engines that are cold-started and run with an increased number of revolutions per minute emit about 100 % more CO and HC, while the quantity of NO_2 is unchanged.

A.2.3.2 Suction-fed compression-ignition engine with air storage chamber, approximately 150 kW

Table A.3 indicates the pollution for these suction-fed compression-ignition engines with an air storage chamber, of approximately 150 kW power (examples of vehicles: larger lorries and coaches). The figures apply to a warm engine.

Engines that are cold and run with an increased number of revolutions per minute emit about 100 % more CO and HC, while the quantity of NO_2 is unchanged.

A.2.3.3 Suction-fed compression-ignition engine without air storage chambers, approximately 130 kW and 74 kW

Table A.4 indicates the pollution for warm, suction-fed compression-ignition engines, without air storage chambers, of approximately 130 kW power (examples of vehicles: lorries, loaders and buses).

Table A.5 indicates the pollution for these suction-fed compression-ignition engines without an air storage chamber, of approximately 74 kW power (examples of vehicles: fork trucks and passenger cars). The figures apply to a warm engine.

Engines that are cold and run with an increased number of revolutions per minute emit about 100 % more CO and HC, while the quantity of NO_2 is unchanged.

Table A.1 — Typical spark-ignition engine for passenger car

Operating cycle	Pollutants mg/s		
	CO	NO_x	HC
Idling (800 r/min to 1 000 r/min)	100 to 150	1 to 2	10 to 15
Constant speed, 15 km/h	200 to 250	3,3 to 3,5	15 to 20
Constant speed, 30 km/h	250 to 300	7 to 8,5	15 to 20
Acceleration, 0,8 m/s^2 (0 km/h to 15 km/h)	250 to 300	5 to 8,5	15 to 20
Engine braking, 0,6 m/s^2 (15 km/h to 0 km/h)	110 to 140	1	28 to 33

Table A.2 — Turbo diesel engine, approximately 150 kW

Operating cycle	Pollutants mg/s			
	CO	NO_x	HC	NO_2
Idling	20 to 30	17 to 25	15 to 25	5 to 8
Lift, 2 500 r/min	170	10 to 1 000	$\approx$ 100	5 to 55
Transport, 2 800 r/min	150	600 to 700	$\approx$ 130	25 to 30

Table A.3 — Suction-fed diesel engine with air storage chamber, approximately 150 kW

Operating cycle	Pollutants mg/s			
	CO	NO_x	HC	NO_2
Idling	20 to 25	25 to 30	2 to 4	5 to 9
Lift, 2 150 r/min	50 to 60	10 to 130	10 to 15	5 to 55
Transport, 2 000 r/min	130 to 150	100 to 225	15 to 35	4 to 9

Table A.4 — Suction-fed diesel engine without air storage chamber, approximately 130 kW

Operating cycle	Pollutants mg/s			
	CO	NO_x	HC	NO_2
Idling	20 to 25	15 to 20	10 to 15	5 to 6
Lift, 2 200 r/min	50 to 60	22 to 25	40 to 50	10 to 15
Transport, 2 200 r/min	170 to 200	135 to 150	10 to 15	6 to 9

Table A.5 — Suction-fed diesel engine without air storage chamber, approximately 74 kW

Operating cycle	**Pollutants** mg/s			
	CO	NO_x	HC	NO_2
Idling	3 to 5	2 to 5	1	0,5 to 1,0
Lift, 2 200 r/min	50 to 60	2 to 10	30 to 40	2,5 to 5
Transport, 3 000 r/min	60 to 70	40 to 50	10 to 20	1,5 to 2,5

Annex B
(informative)

General information and guidance as to good practice

B.1 Constituents of exhaust gases from internal combustion engines

The exhaust gases generated by internal combustion engines contain hundreds of chemical substances. Most of these are nitrogen (N_2), oxygen (O_2), carbon monoxide (CO), oxides of nitrogen (NO), nitrogen dioxide (NO_2), aldahydes such as formaldahyde, polyaromatics such as benzo[*a*]pyrane, organic and particle-shaped lead, etc. Oxides of nitrogen and nitrogen dioxide are, as a rule, put together as oxides of nitrogen and are denominated NO_x.

The air pollutants that are of immediate interest when estimating the injurious effects to health of exhaust gases generated by spark-ignition and compression-ignition vehicles are above all carbon monoxide, oxides of nitrogen, and nitrogen dioxide. Lead and benzo[*a*]pyrane are also of interest.

Carbon monoxide and nitrogen dioxide are taken as the limiting substances when dimensioning a ventilation plant for diluting and removing exhaust gases generated by vehicles with internal combustion engines.

Where spark-ignition vehicles are concerned, CO is the limiting substance. Where compression-ignition vehicles are concerned, NO_2 is the limiting substance. The correlation between these and other hazardous substances contained in exhaust gases is usually such that, when the concentrations of CO and NO_2 are below the specified limits, the concentration of other hazardous substances will also be at an acceptable level.

B.2 Airflow calculation

Pollution is generated by different types of vehicles that can either form the ship's cargo or be used for cargo-handling operations on the vessel. The required outdoor-supply airflow to the cargo space is calculated according to clause 3.

When the ship is at sea and when no vehicles are in operation, the ventilation can be reduced to an outside-supply airflow according to statutory requirements.

The required outdoor airflow for every vehicle should be calculated separately: by summation, for all the vehicles in operation simultaneously, the required outdoor airflow for the cargo space or working area in question is obtained.

When assessing the generation of pollution, the cargo holds should be regarded as separate volumes. Working areas, where an especially high generation and concentration of exhaust gas can be expected, have to be given special consideration.

For the purposes of this International Standard, it may be assumed that normal operational conditions, that is, the number of vehicles operating at any one time, will be one of the following for each circumstance shown:

— one large and three smaller trucks in operation in general cargo spaces;

— five cars in operation in cargo spaces in car carriers;

— eight cars in operation in cargo spaces in ferries (embarkation);

— twenty cars in operation in cargo spaces in ferries (disembarkation).

NOTE The last specified operational condition is to be used only in the case where there is a necessity for employees to work within the cargo space during the disembarkation.

Typical examples of the results of applying the equation in 3.2.2.2 are given in B.3.1 and B.3.2, and should be regarded as the minimum airflow per vehicle. The pollution is in accordance with clause 4 and A.1 and the factor of dilution is in accordance with clause 5.

B.3 Typical calculations

B.3.1 Long-term exposure

Typical values of required ventilation based on long-term exposure limits, where the occupational-exposure-limit value, c, is taken as 40 mg/m^3 for CO for spark-ignition engines and 4 mg/m^3 for NO_2 for compression-ignition engines, are:

— larger trucks for loading and unloading of Ro-Ro cargo ships, starting from warm engines: 30 m^3/s;

— smaller trucks for local handling on board ships, starting from warm engines: 4 m^3/s;

— larger lorries and coaches on board ferries starting from cold engines: 14 m^3/s;

— larger lorries and coaches on board Ro-Ro ships, starting from cold engines: 38 m^3/s;

— passenger cars on board ferries, starting from cold engines: 11 m^3/s;

— new passenger cars on board car carriers starting from cold engines: 16 m^3/s;

— new passenger cars starting from warm engines: 9 m^3/s.

NOTE The indicated values are per vehicle.

B.3.2 Short-term exposure

Typical values of required ventilation based on short-term exposure limits, where c is taken as 120 mg/m^3 for CO for spark-ignition engines and 8 mg/m^3 for NO_2 for compression-ignition engines, are:

— passenger cars on board ferries, starting, from cold engines: 4 m^3/s;

— larger lorries and coaches on board ferries, starting from cold engines: 7 m^3/s.

B.4 Factor of dilution

The following can be used as a guideline when specifying the factor of dilution.

In most cases, a dilution factor of 0,7 to 0,8 can be adopted. If too many difficulties are encountered in the layout and arrangements of air ducts, and if the ship's structure and cargo can be expected to involve large obstructions to air circulation, the dilution factor should be reduced. In the most unfavourable cases, it may reach half the above values. If it can be shown, through modelling or simulation, that the ventilation system design provides substantially superior circulation, the dilution factor may be increased to a maximum value of 1,0.

B.5 General considerations for ventilation system and ducting

Duct runs and the location of supply air and exhaust air openings have to be made to suit the design of the particular ship, the estimated cargo handling and the exhaust emission in working areas. The following generally applies.

— Supply air and exhaust air openings should be located so that the ventilation will be concentrated to those areas in which the emissions of exhaust gases are particularly high and in which employees work.

— Supply air and exhaust air openings should also be located, wherever possible, where they will not be obstructed by the cargo or screened by web-plates, frames, etc.

— Supply air and exhaust air openings should be designed so that the maximum air velocity in the opening does not exceed 10 m/s.

— Consideration should be given to the likelihood of there being unventilated zones screened behind objects, and also to the fact that exhaust gases readily accumulate in low-lying spaces and under the vehicles.

— The airflow will follow the path of least resistance, and most of the air will thus flow in open spaces, such as above the cargo, vehicles, etc.

— Measures should be taken to prevent polluted air from cargo spaces from dispersing into adjoining spaces where people can be exposed, such as accommodation, engine-room, etc.

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