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Shipbuilding — Ventilation of cargo spaces where internal combustion engine vehicles may be driven — Calculation of theoretical total airflow required

Construction navale — Ventilation des espaces cargaison des navires dans lesquels des véhicules à moteur à combustion interne peuvent être utilisés — Calcul du débit d'air total théorique exigé

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Foreword

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International Standard ISO 9785 was prepared by Technical Committee ISO/TC 8, *Shipbuilding and marine structures*.

Annex A forms an integral part of this International Standard. Annex B is for information only.

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Shipbuilding — Ventilation of cargo spaces where internal combustion engine vehicles may be 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 internal combustion engine vehicles are driven, in order to dilute the polluted air to within the permitted occupational exposure limits.

Annex A gives average values of the amounts of pollutants in exhaust gases from internal combustion engine vehicles 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 internal combustion engine vehicles may be driven.

NOTE 1 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.

2 Definitions

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

2.1 cargo space: Space used for cargo where vehicles may be driven.

2.2 working area: Area occupied by employees at work.

2.3 occupational exposure limit: Highest air-borne concentrations averaged over a specified period of time (time-weighted average or TWA) of substances hazardous to health for employees at work.

NOTE 2 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.

3 Airflow calculation

3.1 Volume of space

The volume of the cargo spaces shall be the gross volume with no deduction for the cargoes or for frames, webs, pillars, ducts, etc.

In 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 space shall be calculated using whichever of the following criteria gives the highest value:

a) minimum number of air changes according to applicable statutory requirements;

b) required outdoor supply airflow to maintain the occupational exposure limit value.

3.2.2 Supply airflow to maintain occupational exposure limit value

The sum of the required outdoor supply airflows per vehicle in operation to maintain the occupational exposure limit value is calculated in accordance with 3.2.2.1 or 3.2.2.2 for normally polluted outdoor air or highly polluted outdoor air respectively.

3.2.2.1 Normally polluted outdoor air

The required outdoor supply airflow, q_v, per vehicle in operation for normally polluted outdoor air, in cubic metres per second, is given by the equation

$$q_v = \frac{q_m}{\alpha \cdot c}$$

where

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

α 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 clause B.2.)

NOTE 3 The pollution contents of normally polluted outdoor air can be taken to be less than 1/40 of the occupational exposure limit value.

3.2.2.2 Highly polluted outdoor air

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

$$q_v = \frac{q_m}{\alpha(c - c')}$$

where

q_m, α and c are as defined in 3.2.2.1;

c' is the content of the pollutant in question in the 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, data according to clause A.1 shall be used. If the operation cycles are not the same as in clause A.1, quantities calculated according to clause A.2 shall apply.

5 Factor 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 specification the following factors shall apply:

a) 0,3 in general cargo spaces;

b) 0,4 in cargo spaces in car carriers;

c) 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 4 See clause B.3.

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

Average values of the amount of the pollutants in question in exhaust gases generated by vehicles with internal combustion engines running in ship's cargo holds are given in A.1.1 to A.1.5.

A.1.1 Larger trucks

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

Normal operating cycle:

lift (about 45 s), transport and some idling.

Average NO_2 amount generated: ≈ 36 mg/s.

Type of motor:

- turbo-charged compression-ignition (diesel) engine;
- power: ≈ 150kW.

A.1.2 Smaller trucks

These are used for local cargo handling on board ships.

Normal operating cycle:

lift, transport and idling.

Average NO_2 amount generated: ≈ 3 mg/s.

Average CO amount generated: ≈ 50 mg/s.

Type of motor:

- suction-fed compression-ignition engine;
- power: ≈ 74 kW.

A.1.3 Larger lorries and coaches

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

Normal operating cycle:

charging the compressed air system for the brakes, acceleration and running at a low speed.

Average NO_2 amount generated: ≈ 45 mg/s at cold start.

Type of motor:

- turbo-charged compression-ignition engine;
- power: ≈ 150 kW.

A.1.4 Passenger cars (low speed)

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

Normal operating cycle:

running at a low speed, moderate acceleration, motor braking and idling.

Average CO amount generated: ≈ 340 mg/s at cold start.

Type of motor:

- spark-ignition engine of 1 000 cm^3 to 2 200 cm^3 capacity.

A.1.5 Passenger cars (moderate speed)

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

Normal operating cycle:

running at a moderate speed and a shorter period of idling.

Average CO amount generated:

≈ 250 mg/s for new cars;

≈ 320 mg/s for older cars;

both of them at cold start.

Type of motor:

- spark-ignition engine of 1 000 cm^3 to 2 200 cm^3 capacity.

A.2 Quantity of pollutants in exhaust gases

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

A.2.1 Spark-ignition engine, cylinder volume 1 000 cm^3 to 2 200 cm^3

Table A.1 indicates the pollutants for these 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 later), 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.2.2 Compression-ignition engines

A.2.2.1 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.2.2.2 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 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.2.2.3 Suction-fed compression-ignition engine without air storage chamber

Table A.4 indicates the pollution for these suction-fed compression-ignition engines without air storage chamber (examples of vehicles: 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.2.2.4 Suction-fed compression-ignition engine without air storage chamber, approximately 74 kW

Table A.5 indicates the pollution for these suction-fed compression-ignition engines without 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

Operating cycle	Pollutants, mg/s		
	CO	NO_x	HC
Idling (600 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, 0,6 m/s² (0 km/h to 15 km/h)	250 to 300	5 to 6,5	15 to 20
Engine braking, 0,6 m/s² (15 km/h to 0 km/h)	110 to 140	1	28 to 33

Table A.2

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, 2 550 r/min	170	10 to 100	≈ 100	5 to 50
Transport, 2 260 r/min	150	600 to 700	≈ 130	25 to 30

Table A.3

Operating cycle	Pollutants, mg/s			
	CO	NO_x	HC	NO_2
Idling	20 to 25	25 to 30	2 to 4	8 to 9
Lift, 2 150 r/min	50 to 60	10 to 130	10 to 15	5 to 65
Transport, 2 000 r/min	130 to 150	100 to 225	15 to 35	4 to 9

Table A.4

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 26	40 to 50	10 to 15
Transport, 2 200 r/min	170 to 200	135 to 150	10 to 15	5 to 6

Table A.5

Operating cycle	Pollutants, mg/s			
	CO	NO_x	HC	NO_2
Idling	3 to 5	2 to 5	1	0,5 to 1,5
Lift, 3 000 r/min	50 to 60	5 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

The purpose of the main body 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.

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), nitric oxide (NO), nitrogen dioxide (NO_2), aldehydes such as formaldehyde, polyaromatics such as benzo[a]pyrene, organic and particle-shaped lead, etc. Nitric oxide and nitrogen dioxide are as a rule put together as nitric oxides 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 (CO), nitric oxide (NO) and nitrogen dioxide (NO_2). Lead and benzo[a]pyrene are also of interest.

Carbon monoxide (CO) and nitrogen dioxide (NO_2) 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 which 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 a specially 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 — number of vehicles operating at any one time on each deck — will be one of the following:

- 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 5 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 embarkation.

Typical examples of application of the equation in 3.2.2.1 are given below, and should be regarded as minimum airflow per vehicle. The pollution is in accordance with clause 4 and clause A.1 and the factor of pollution accords with clause 5.

a) Long-term exposure limits, where the occupational exposure limit value, c, is taken as 40 mg/m³ for CO for spark-ignition engines and 4 mg/m³ for NO_2 for compression-ignition engines:

- larger trucks for loading and unloading of Ro/Ro cargo ships, starting from warm engine: 30 m³/s
- smaller trucks for local handling on board ships, starting from warm engines: 4 m³/s
- larger lorries and coaches on board ferries, starting from cold engine: 14 m³/s
- larger lorries and coaches on board Ro/Ro ships, starting from cold engine: 38 m³/s
- passenger cars on board ferries, starting from cold engine: 11 m³/s
- new passenger cars on board car carriers

  starting from cold engine: 16 m³/s

  starting from warm engine: 9 m³/s

b) Short-term exposure limit where *c* is taken as 120 mg/m³ for CO for spark-ignition engines and 8 mg/m³ for NO_2 for compression-ignition engines:

- passenger cars on board ferries, starting from cold engine: 4 m³/s
- larger lorries and coaches on board ferries, starting from cold engine: 7 m³/s

B.3 Factor of dilution

The following can be used as a guide-line when specifying the factor of dilution.

In most cases a dilution factor of 0,7 to 0,9 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.

B.4 Ventilation system and ducting: general considerations

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 cargo or screened by webplates, 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 persons can be exposed, such as accommodation, engine-room, etc.