9.3.3.22 ***Cargo tank openings***

9.3.3.22.1 (a) Cargo tank openings shall be located on deck in the cargo area.

(b) Cargo tank openings with a cross-section of more than 0.10 m^2 and openings of safety devices for preventing overpressures shall be located not less than 0.50 m above deck.

9.3.3.22.2 Cargo tank openings shall be fitted with gastight closures capable of withstanding the test pressure in accordance with 9.3.3.23.2.

9.3.3.22.3 Closures which are normally used during loading or unloading operations shall not cause sparking when operated.

9.3.3.22.4 Each cargo tank or group of cargo tanks connected to a common venting piping shall be fitted with:

Open Type N:

– Devices to prevent unacceptable overpressures or vacuums and constructed so as to prevent any accumulation of water and penetration of water into the cargo tank.

Open Type N with flame arresters:

– Devices to prevent unacceptable overpressures or vacuums, equipped with flame arresters capable of withstanding steady burning and constructed so as to prevent any accumulation of water and penetration of water into the cargo tank.

Closed Type N:

(a) A connection for the safe return ashore of gases expelled during loading;

(b) A safe depressurization device for the cargo tanks, on which the position of the shut-off valve indicates clearly whether it is open or shut;

(c) Safety valves for preventing unacceptable overpressures or vacuums;

The opening pressure of the safety valves shall be marked indelibly on the valves;

(d) If the list of substances on the vessel according to 1.16.1.2.5 is going to include substances that require explosion protection in accordance with column (17) of Table C of Chapter 3.2, then:

– At the connection to each cargo tank, the venting piping shall be equipped with a flame arrester capable of withstanding a detonation;

– The vacuum valve and the safe depressurization device for cargo tanks shall be deflagration safe. The deflagration safety may also be ensured by a flame arrester; and

– The pressure relief device shall be designed as a high velocity vent valve, with the gases discharged upwards;

The setting of the pressure relief valves shall be such that during the transport operation they do not blow off until the maximum permissible working pressure of the cargo tanks is reached;

The autonomous protection systems shall be chosen according to the explosion groups/subgroups of the substances listed in the list of substances on the vessel (see column (16) of Table C of Chapter 3.2);

If the high velocity vent valve, the vacuum valve, the flame arresters and the venting piping are required to be heatable for carriage, the safety devices concerned shall be suitable for the relevant temperature;

The opening pressure of the pressure relief valves, the vacuum valve and the high velocity vent valves shall be marked indelibly on the valves;

If a shut-off device is to be mounted between the venting piping and the cargo tank, it shall be placed between the cargo tank and the flame arrester, and each cargo tank shall be equipped with its own safety valves;

(e) The outlets of the pressure relief devices/high velocity vent valves shall be located not less than 2.00 m above the deck and at a distance of not less than 6.00 m from the openings of the accommodations, the wheelhouse and the service spaces outside the cargo area. This height may be reduced to 1.00 m when there is no equipment and no work is being carried out within a radius of 1.00 m around the pressure relief valve outlet. This area shall be marked as a danger zone.

9.3.3.22.5 ***Venting piping***

(a) When two or more cargo tanks are connected to common venting piping, it is sufficient that the equipment according to 9.3.3.22.4 (safety valves to prevent unacceptable overpressures and vacuums, high velocity vent valve, vacuum valve protected against deflagrations, safe pressure relief device for cargo tanks protected against deflagrations) is installed on the joint venting piping (see also 7.2.4.16.7);

(b) When each cargo tank is connected to its own venting piping, each cargo tank or the associated venting piping shall be equipped according to 9.3.3.22.4.

9.3.3.22.6 9.3.3.22.2 and 9.3.3.22.5 do not apply to open type N with flame-arrester and to open type N.

9.3.3.22.7 9.3.3.22.3 does not apply to open type N.

9.3.3.23 ***Pressure tests***

9.3.3.23.1 The cargo tanks, residual cargo tanks, cofferdams, piping for loading and unloading, with the exception of discharge hoses shall be subjected to initial tests before being put into service and thereafter at prescribed intervals.

Where a heating system is provided inside the cargo tanks, the heating coils shall be subjected to initial tests before being put into service and thereafter at prescribed intervals.

9.3.3.23.2 The test pressure for the cargo tanks and residual cargo tanks shall be not less than 1.3 times the design pressure. The test pressure for the cofferdams and open cargo tanks shall be not less than 10 kPa (0.10 bar) gauge pressure.

9.3.3.23.3 The test pressure for piping for loading and unloading shall be not less than 1,000 kPa (10 bar) gauge pressure.

9.3.3.23.4 The maximum intervals for the periodic tests shall be 11 years.

9.3.3.23.5 The procedure for pressure tests shall comply with the provisions established by the competent authority or a recognised classification society.

9.3.3.24 ***Regulation of cargo pressure and temperature***

9.3.3.24.1 Unless the entire cargo system is designed to resist the full effective vapour pressure of the cargo at the upper limits of the ambient design temperatures, the pressure of the tanks shall be kept below the permissible maximum set pressure of the safety valves, by one or more of the following means:

(a) a system for the regulation of cargo tank pressure using mechanical refrigeration;

(b) a system ensuring safety in the event of the heating or increase in pressure of the cargo. The insulation or the design pressure of the cargo tank, or the combination of these two elements, shall be such as to leave an adequate margin for the operating period and the temperatures expected; in each case the system shall be deemed acceptable by a recognised classification society and shall ensure safety for a minimum time of three times the operation period;

(c) other systems deemed acceptable by a recognised classification society.

9.3.3.24.2 The systems prescribed in 9.3.3.24.1 shall be constructed, installed and tested to the satisfaction of the recognised classification society. The materials used in their construction shall be compatible with the cargoes to be carried. For normal service, the upper ambient design temperature limits shall be:

air: +30 °C;
water: +20 °C.

9.3.3.24.3 The cargo storage system shall be capable of resisting the full vapour pressure of the cargo at the upper limits of the ambient design temperatures, whatever the system adopted to deal with the boil-off gas. This requirement is indicated by remark 37 in column (20) of Table C of Chapter 3.2.

9.3.3.25 ***Pumps and piping***

9.3.3.25.1 (a) Pumps and accessory loading and unloading piping shall be located in the cargo area;

(b) Cargo pumps shall be capable of being shut down from the cargo area and from a position outside the cargo area;

(c) Cargo pumps situated on deck shall be located not less than 6.00 m from entrances to, or openings of, the accommodation and service spaces outside the cargo area.

9.3.3.25.2 (a) Piping for loading and unloading shall be independent of any other piping of the vessel. No cargo piping shall be located below deck, except those inside the cargo tanks and inside the cargo pump room;

(b) The piping for loading and unloading shall be arranged so that, after loading or unloading operations, the liquid remaining in these pipes may be safely removed and may flow either into the vessel's cargo tanks or the tanks ashore;

(c) Piping for loading and unloading shall be clearly distinguishable from other piping, e.g. by means of colour marking;

(d) *(Reserved)*

(e) The shore connections shall be located not less than 6.00 m from the entrances to, or openings of, the accommodation and service spaces outside the cargo area;

(f) Each shore connection of the venting piping and shore connections of the piping for loading and unloading, through which the loading or unloading operation is carried out, shall be fitted with a shut-off device. However, each shore connection shall be fitted with a blind flange when it is not in operation;

(g) *(Deleted)*

(h) Piping for loading and unloading, and venting piping, shall not have flexible connections fitted with sliding seals.

9.3.3.25.3 *(Deleted)*

9.3.3.25.4 (a) Every component of the piping for loading and unloading shall be electrically connected to the hull;

(b) The piping for loading shall extend down to the bottom of the cargo tanks.

9.3.3.25.5 The stop valves or other shut-off devices of the piping for loading and unloading shall indicate whether they are open or shut.

9.3.3.25.6 The piping for loading and unloading shall have, at the test pressure, the required elasticity, leakproofness and resistance to pressure.

9.3.3.25.7 The piping for loading and unloading shall be fitted with pressure gauges at the outlet of the pumps. The permissible maximum overpressure or vacuum value shall be indicated on each measuring device. Readings shall be possible in all weather conditions.

9.3.3.25.8 (a) When piping for loading and unloading are used for supplying the cargo tanks with washing or ballast water, the suctions of these pipes shall be located within the cargo area but outside the cargo tanks;

Pumps for tank washing systems with associated connections may be located outside the cargo area, provided the discharge side of the system is arranged in such a way that suction is not possible through that part;

A spring-loaded non-return valve shall be provided to prevent any gases from being expelled from the cargo area through the tank washing system.

(b) A non-return valve shall be fitted at the junction between the water suction pipe and the cargo loading pipe.

9.3.3.25.9 The permissible loading and unloading flows shall be calculated.

Calculations concerning the permissible maximum loading and unloading flows for each cargo tank or each group of cargo tanks, taking into account the design of the ventilation system. These calculations shall take into consideration the fact that in the event of an unforeseen cut–off of the vapour return piping of the shore facility, the safety devices of the cargo tanks will prevent pressure in the cargo tanks from exceeding the following values:

over–pressure: 1.15 times the opening pressure of the pressure relief valve/high velocity vent valve;

vacuum pressure: not more than the design pressure, but not exceeding a vacuum of 5 kPa (0.05 bar).

The main factors to be considered are the following:

1. Dimensions of the ventilation system of the cargo tanks;

2. Gas formation during loading: multiply the largest loading flow by a factor of not less than 1.25;

3. Density of the vapour mixture of the cargo based on 50% volume vapour of 50% volume air;

4. Loss of pressure through ventilation pipes, valves and fittings. Account will be taken of a 30% clogging of the mesh of the flame-arresters;

5. Chocking pressure of the safety valves.

Instructions concerning the permissible maximum loading and unloading flows for each cargo tank or for each group of cargo tanks shall be carried on board.

9.3.3.25.10 Compressed air generated outside the cargo area can be used in the cargo area subject to the installation of a spring-loaded non-return valve to ensure that no gases can escape from the cargo area through the compressed air system into accommodation, wheelhouse or service spaces outside the cargo area.

9.3.3.25.11 If the vessel is carrying several dangerous substances liable to react dangerously with each other, a separate pump with its own piping for loading and unloading shall be installed for each substance. The piping shall not pass through a cargo tank containing dangerous substances with which the substance in question is liable to react.

9.3.3.25.12 9.3.3.25.1 (a) and (c), 9.3.3.25.2 (a), last sentence and (e) and 9.3.3.25.4 (a) do not apply to type N open unless the substance carried has corrosive properties (see column (5) of Table C of Chapter 3.2, hazard 8).

9.3.3.25.4 (b) does not apply to open type N.

9.3.3.25.2 (f), last sentence, 9.3.3.25.8 (a), last sentence and 9.3.3.25.10 do not apply to oil separator and supply vessels.

9.3.3.25.9 does not apply to oil separator vessels.

9.3.3.25.2 (h) does not apply to supply vessels.

9.3.3.26 ***Residual cargo tanks and receptacles for residual products***

9.3.3.26.1 When vessels are provided with tanks for residual products or receptacles for residual products, they shall be located in the cargo area and comply with the provisions of 9.3.3.26.2 and 9.3.3.26.3. Receptacles for residual products shall be located only in the cargo area on deck and not less than a quarter of the vessel's breadth from the outer shell.

9.3.3.26.2 Tanks for residual products shall be equipped with:

In the case of an open system:

– An ullage opening;

– Connections, with stop valves, for pipes and hose assemblies;

– A device for ensuring pressure equilibrium.

In the case of an open system with flame arrester:

– An ullage opening;

– Connections, with stop valves, for pipes and hose assemblies;

– A device for ensuring pressure equilibrium, fitted with a flame arrester capable of withstanding steady burning.

In the case of a closed system:

(a) A level indicator;

– Connections, with stop valves, for pipes and hose assemblies;

– A vacuum valve and a pressure relief valve;

The pressure relief valve shall be sized so that, during the transport operation, it does not open when in normal operation. This condition is met when the opening pressure of the valve meets the conditions required in column (10) of Table C of Chapter 3.2 for the substance to be carried;

(b) If the list of substances on the vessel according to 1.16.1.2.5 is going to include substances that require explosion protection in accordance with column (17) of Table C of Chapter 3.2, then the pressure relief valve shall be a high velocity vent valve and the vacuum valve shall be deflagration safe. The deflagration safety may also be ensured by a flame arrester;

The high velocity vent valve and the deflagration safe vacuum valve shall be chosen according to the explosion groups/subgroups of the substances listed in the list of substances on the vessel (see column (16) of Table C of Chapter 3.2).

The maximum permissible capacity is 30 m^3.

9.3.3.26.3 The receptacles for residual products shall be equipped with:

– A possibility of indicating the degree of filling;

– Connections, with stop valves, for pipes and hose assemblies;

A connection enabling gases released during filling to be evacuated safely.

9.3.2.26.4 *(Deleted)*

9.3.3.26.5 9.3.3.26.1, 9.3.3.26.2 (final sentence) and 9.3.3.26.3 do not apply to oil separator vessels.

9.3.3.27 ***Refrigeration system***

9.3.3.27.1 The refrigeration system referred to in 9.3.3.24.1 (a) shall be composed of one or more units capable of keeping the pressure and temperature of the cargo at the upper limits of the ambient design temperatures at the prescribed level. Unless another means of regulating cargo pressure and temperature deemed satisfactory by a recognised classification society is provided, provision shall be made for one or more stand-by units with an output at least equal to that of the largest prescribed unit. A stand-by unit shall include a compressor, its engine, its control system and all necessary accessories to enable it to operate independently of the units normally used. Provision shall be made for a stand-by heat-exchanger unless the system's normal heat-exchanger has a surplus capacity equal to at least 25% of the largest prescribed capacity. It is not necessary to make provision for separate piping.

Cargo tanks, piping and accessories shall be insulated so that, in the event of a failure of all cargo refrigeration systems, the entire cargo remains for at least 52 hours in a condition not causing the safety valves to open.

9.3.3.27.2 The security devices and the connecting lines from the refrigeration system shall be connected to the cargo tanks above the liquid phase of the cargo when the tanks are filled to their maximum permissible degree of filling. They shall remain within the gaseous phase, even if the vessel has a list up to 12 degrees.

9.3.3.27.3 When several refrigerated cargoes with a potentially dangerous chemical reaction are carried simultaneously, particular care shall be given to the refrigeration systems so as to prevent any mixing of the cargoes. For the carriage of such cargoes, separate refrigeration systems, each including the full stand-by unit referred to in 9.3.3.27.1, shall be provided for each cargo. When, however, refrigeration is ensured by an indirect or combined system and no leak in the heat exchangers can under any foreseeable circumstances lead to the mixing of cargoes, no provision need be made for separate refrigeration units for the different cargoes.

9.3.3.27.4 When several refrigerated cargoes are not soluble in each other under conditions of carriage such that their vapour pressures are added together in the event of mixing, particular care shall be given to the refrigeration systems to prevent any mixing of the cargoes.

9.3.3.27.5 When the refrigeration systems require water for cooling, a sufficient quantity shall be supplied by a pump or pumps used exclusively for the purpose. This pump or pumps shall have at least two suction pipes, leading from two water intakes, one to port, the other to starboard. Provision shall be made for a stand-by pump with a satisfactory flow; this may be a pump used for other purposes provided that its use for supplying water for cooling does not impair any other essential service.

9.3.3.27.6 The refrigeration system may take one of the following forms:

(a) Direct system: the cargo vapours are compressed, condensed and returned to the cargo tanks. This system shall not be used for certain cargoes specified in Table C of Chapter 3.2. This requirement is indicated by remark 35 in column (20) of Table C of Chapter 3.2;

(b) Indirect system: the cargo or the cargo vapours are cooled or condensed by means of a coolant without being compressed;

(c) Combined system: the cargo vapours are compressed and condensed in a cargo/coolant heat-exchanger and returned to the cargo tanks. This system shall not be used for certain cargoes specified in Table C of Chapter 3.2. This requirement is indicated by remark 36 in column (20) of Table C of Chapter 3.2.

9.3.3.27.7 All primary and secondary coolant fluids shall be compatible with each other and with the cargo with which they may come into contact. Heat exchange may take place either at a distance from the cargo tank, or by using cooling coils attached to the inside or the outside of the cargo tank.

9.3.3.27.8 When the refrigeration system is installed in a separate service space, this service space shall meet the requirements of 9.3.3.17.6.

9.3.3.27.9 For all cargo systems, the heat transmission coefficient as used for the determination of the holding time (7.2.4.16.16 and 7.2.4.16.17) shall be determined by calculation. Upon completion of the vessel, the correctness of the calculation shall be checked by means of a heat balance test. The calculation and test shall be performed under supervision by the recognized classification society which classified the vessel.

The heat transmission coefficient shall be documented and kept on board. The heat transmission coefficient shall be verified at every renewal of the certificate of approval.

9.3.3.27.10 A certificate from a recognised classification society stating that 9.3.3.24.1 to 9.3.3.24.3, 9.3.3.27.1 and 9.3.3.27.4 above have been complied with shall be submitted together with the application for issue or renewal of the certificate of approval.

9.3.3.28 ***Water-spray system***

When water-spraying is required in column (9) of Table C of Chapter 3.2, a water-spray system shall be installed in the cargo area on deck for the purpose of cooling the tops of cargo tanks by spraying water over the whole surface so as to avoid safely the activation of the pressure relief valves/high velocity vent valves at 10 kPa or as regulated.

The spray nozzles shall be so installed that the entire cargo deck area is covered and the gases released are precipitated safely.

The system shall be capable of being put into operation from the wheelhouse and from the deck. Its capacity shall be such that when all the spray nozzles are in operation, the outflow is not less than 50 litres per square metre of deck area and per hour.

9.3.3.29 and 9.3.3.30 (*Reserved*)

9.3.3.31 ***Engines***

9.3.3.31.1 Only internal combustion engines running on fuel with having a flashpoint above 55 °C are allowed. This provision does not apply to internal combustion engines which are part of propulsion and auxiliary systems. These systems shall meet the requirements of Chapter 30 and Annex 8, Section II, Chapter 1, and Section III, Chapter 2 of the European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN) as amended.[2]

9.3.3.31.2 Ventilation inlets of the engine room and, when the engines do not take in air directly from the engine room, air intakes of the engines shall be located not less than 2.00 m from the cargo area.

9.3.3.31.3 and 9.3.3.31.4 *(Deleted)*

9.3.3.31.5 The ventilation in the closed engine room shall be designed so that, at an ambient temperature of 20 °C, the average temperature in the engine room does not exceed 40 °C.

9.3.3.31.6 9.3.3.31.2 above does not apply to oil separator or supply vessels.

9.3.3.32 ***Oil fuel tanks***

9.3.3.32.1 Where the vessel is provided with hold spaces, the double bottoms within these spaces may be arranged as oil fuel tanks, provided their depth is not less than 0.6 m.

Oil fuel pipes and openings of such tanks are not permitted in the hold space.

9.3.3.32.2 The open ends of the air pipes of each oil fuel tanks shall extend to not less than 0.5 m above the open deck. These open ends and the open ends of overflow pipes leading to the deck shall be fitted with a protective device consisting of a gauze diaphragm or a perforated plate.

9.3.3.33 (*Reserved*)

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2 *As available on the website of the Comité Européen pour l'Élaboration de Standards dans le Domaine de Navigation Intérieure – CESNI, https://www.cesni.eu/en/documents/es-trin/.*

9.3.3.34 ***Exhaust pipes***

9.3.3.34.1 Exhaust shall be evacuated from the vessel into the open air either upwards through an exhaust pipe or through the shell plating. The exhaust outlet shall be located not less than 2.00 m from the cargo area. The exhaust pipes of engines shall be arranged so that the exhausts are led away from the vessel. The exhaust pipes shall not be located within the cargo area.

9.3.3.34.2 Exhaust pipes shall be provided with a device preventing the escape of sparks, e.g. spark arresters.

9.3.3.34.3 The distance prescribed in 9.3.3.34.1 above does not apply to oil separator or supply vessels.

9.3.3.35 ***Bilge pumping and ballasting arrangements***

9.3.3.35.1 Bilge and ballast pumps for spaces within the cargo area shall be installed within such area.

This provision does not apply to:

– double-hull spaces and double bottoms which do not have a common boundary wall with the cargo tanks;

– cofferdams, double-hull, double bottom and hold spaces where ballasting is carried out using the piping of the fire-fighting system in the cargo area and bilge-pumping is performed using eductors which are installed in the cargo area.

9.3.3.35.2 Where the double bottom is used as a liquid oil fuel tank, it shall not be connected to the bilge piping system.

9.3.3.35.3 Where the ballast pump is installed in the cargo area, the standpipe and its outboard connection for suction of ballast water shall be located within the cargo area but outside the cargo tanks.

9.3.3.35.4 A cargo pump room below deck shall be capable of being drained in an emergency by an installation located in the cargo area and independent from any other installation. The installation shall be provided outside the cargo pump room.

9.3.3.36 to 9.3.3.39 (*Reserved*)

9.3.3.40 ***Fire-extinguishing arrangements***

9.3.3.40.1 A fire-extinguishing system shall be installed on the vessel. This system shall comply with the following requirements:

– It shall be supplied by two independent fire or ballast pumps, one of which shall be ready for use at any time. These pumps and their means of propulsion and electrical equipment shall not be installed in the same space. When an unmanned pushed barge has only one energy source and the second energy source needs to be supplied by another manned vessel, the approval certificate shall indicate under number 13, Additional obligations, that: "When dangerous goods are carried, the fire extinguishing system shall be permanently supplied with energy by another vessel alongside its own energy source.";

– It shall be provided with a water main fitted with at least three hydrants in the cargo area above deck. Three suitable and sufficiently long hoses with jet/spray nozzles having a diameter of not less than 12 mm shall be provided. Alternatively one or more of the hose assemblies may be substituted by directable jet/spray nozzles having a diameter of not less than 12 mm. It shall be possible to reach any point of the deck in the cargo area simultaneously with at least two jets of water which do not emanate from the same hydrant;

A spring-loaded non-return valve shall be fitted to ensure that no gases can escape through the fire-extinguishing system into the accommodation, wheelhouse or service spaces outside the cargo area;

– The capacity of the system shall be at least sufficient for a jet of water to have a minimum reach of not less than the vessel's breadth from any location on board with two spray nozzles being used at the same time;

– The water supply system shall be capable of being put into operation from the wheelhouse and from the deck;

– Measures shall be taken to prevent the freezing of fire-mains and hydrants.

9.3.3.40.2 In addition the engine room, the pump room and all spaces containing essential equipment (switchboards, compressors, etc.) for the refrigeration equipment, if any, shall be provided with a fixed fire-extinguishing system meeting the following requirements:

9.3.3.40.2.1 *Extinguishing agents*

For the protection of spaces in engine rooms, boiler rooms and pump rooms, only permanently fixed fire-extinguishing systems using the following extinguishing agents are permitted:

(a) CO_2 (carbon dioxide);

(b) HFC 227 ea (heptafluoropropane);

(c) IG-541 (52% nitrogen, 40% argon, 8% carbon dioxide);

(d) FK-5-1-12 (dodecafluoro 2–methylpentane–3–one);

(e) (*Reserved*)

(f) K_2CO_3 (potassium carbonate).

Other extinguishing agents are permitted only on the basis of recommendations by the Administrative Committee.

9.3.3.40.2.2 *Ventilation, air extraction*

(a) The combustion air required by the combustion engines which ensure propulsion should not come from spaces protected by permanently fixed fire-extinguishing systems. This requirement is not mandatory if the vessel has two independent main engine rooms with a gastight separation or if, in addition to the main engine room, there is a separate engine room installed with a bow thruster that can independently ensure propulsion in the event of a fire in the main engine room;

(b) All forced ventilation systems in the space to be protected shall be shut down automatically as soon as the fire-extinguishing system is activated;

(c) All openings in the space to be protected which permit air to enter or gas to escape shall be fitted with devices enabling them to be closed rapidly. It shall be clear whether they are open or closed;

(d) Air escaping from the pressure–relief valves of the pressurised air tanks installed in the engine rooms shall be evacuated to the open air;

(e) Overpressure or negative pressure caused by the diffusion of the extinguishing agent shall not destroy the constituent elements of the space to be protected. It shall be possible to ensure the safe equalisation of pressure;

(f) Protected spaces shall have a facility for extracting the extinguishing agent and the combustion gases. Such facilities shall be capable of being operated from positions outside the protected rooms and which must not be made inaccessible by a fire within such spaces. If there are permanently installed extractors, it shall not be possible for these to be switched on while the fire is being extinguished.

9.3.3.40.2.3 Fire alarm system

The space to be protected shall be monitored by an appropriate fire alarm system. The alarm signal shall be audible in the wheelhouse, the accommodation and the space to be protected.

9.3.3.40.2.4 *Piping system*

(a) The extinguishing agent shall be routed to and distributed in the space to be protected by means of a permanent piping system. Piping installed in the space to be protected and their fittings shall be made of steel. This shall not apply to the connecting nozzles of tanks and compensators provided that the materials used have equivalent fire–retardant properties. Piping shall be protected against corrosion both internally and externally;

(b) The discharge nozzles shall be so arranged as to ensure the regular diffusion of the extinguishing agent. In particular, the extinguishing agent must also be effective beneath the floor.

9.3.3.40.2.5 *Triggering device*

(a) Automatically activated fire-extinguishing systems are not permitted;

(b) It shall be possible to activate the fire-extinguishing system from a suitable point located outside the space to be protected;

(c) Triggering devices shall be so installed that they can be activated also in the event of a fire, and that the required quantity of extinguishing agent can still be provided in the space to be protected in the event of a fire or of damage caused by a fire or an explosion.

Systems which are not mechanically activated shall be supplied from two energy sources independent of each other. These energy sources shall be located outside the space to be protected. The control lines located in the space to be protected shall be so designed as to remain capable of operating in the event of a fire for a minimum of 30 minutes. The electrical installations are deemed to meet this requirement if they conform to the IEC 60331–21:1999 standard.

When the triggering devices are so placed as not to be visible, the component concealing them shall carry the "Fire-fighting system" symbol, each side being not less than 10 cm in length, with the following text in red letters on a white ground:

Fire-extinguishing system

(d) If the fire-extinguishing system is intended to protect several spaces, it shall comprise a separate and clearly–marked triggering device for each space;

(e) The instructions shall be posted alongside all triggering devices and shall be clearly visible and indelible. The instructions shall be in a language the master can read and understand and if this language is not English, French or German, they shall be in English, French or German. They shall include information concerning:

(i) the activation of the fire-extinguishing system;

(ii) the need to ensure that all persons have left the space to be protected;

(iii) the correct behaviour of the crew in the event of activation and when accessing the space to be protected following activation or diffusion, in particular in respect of the possible presence of dangerous substances;

(iv) the correct behaviour of the crew in the event of the failure of the fire-extinguishing system to function properly.

(f) The instructions shall mention that prior to the activation of the fire-extinguishing system, combustion engines installed in the space and aspirating air from the space to be protected, shall be shut down.

9.3.3.40.2.6 *Alarm device*

(a) Permanently fixed fire-extinguishing systems shall be fitted with an audible and visual alarm device;

(b) The alarm device shall be set off automatically as soon as the fire-extinguishing system is first activated. The alarm device shall function for an appropriate period of time before the extinguishing agent is released; it shall not be possible to turn it off;

(c) Alarm signals shall be clearly visible in the spaces to be protected and their access points and be clearly audible under operating conditions corresponding to the highest possible sound level. It shall be possible to distinguish them clearly from all other sound and visual signals in the space to be protected;

(d) Sound alarms shall also be clearly audible in adjoining spaces, with the communicating doors shut, and under operating conditions corresponding to the highest possible sound level;

(e) If the alarm device is not intrinsically protected against short circuits, broken wires and drops in voltage, it shall be possible to monitor its operation;

(f) A sign with the following text in red letters on a white ground shall be clearly posted at the entrance to any space the extinguishing agent may reach:

Warning, fire-extinguishing system!
Leave this space immediately when the ... (description)
alarm is activated!

9.3.3.40.2.7 *Pressurised tanks, fittings and piping*

(a) Pressurised tanks, fittings and piping shall conform to the requirements of the competent authority or, if there are no such requirements, to those of a recognized classification society;

(b) Pressurised tanks shall be installed in accordance with the manufacturer's instructions;

(c) Pressurised tanks, fittings and piping shall not be installed in the accommodation;

(d) The temperature of cabinets and storage spaces for pressurised tanks shall not exceed 50 °C;

(e) Cabinets or storage spaces on deck shall be securely stowed and shall have vents so placed that in the event of a pressurised tank not being gastight, the escaping gas cannot penetrate into the vessel. Direct connections with other spaces are not permitted.

9.3.3.40.2.8 *Quantity of extinguishing agent*

If the quantity of extinguishing agent is intended for more than one space, the quantity of extinguishing agent available does not need to be greater than the quantity required for the largest of the spaces thus protected.

9.3.3.40.2.9 *Installation, maintenance, monitoring and documents*

(a) The mounting or modification of the system shall only be performed by a company specialised in fire-extinguishing systems. The instructions (product data sheet, safety data sheet) provided by the manufacturer of the extinguishing agent or the system shall be followed;

(b) The system shall be inspected by an expert:

(i) before being brought into service;

(ii) each time it is put back into service after activation;

(iii) after every modification or repair;

(iv) regularly, not less than every two years.

(c) During the inspection, the expert is required to check that the system conforms to the requirements of 9.3.3.40.2;

(d) The inspection shall include, as a minimum:

(i) an external inspection of the entire system;

(ii) an inspection to ensure that the piping is leakproof;

(iii) an inspection to ensure that the control and activation systems are in good working order;

(iv) an inspection of the pressure and contents of tanks;

(v) an inspection to ensure that the means of closing the space to be protected are leakproof;

(vi) an inspection of the fire alarm system;

(vii) an inspection of the alarm device.

(e) The person performing the inspection shall establish, sign and date a certificate of inspection;

(f) The number of permanently fixed fire-extinguishing systems shall be mentioned in the vessel certificate.

9.3.3.40.2.10 *Fire-extinguishing system operating with CO_2*

In addition to the requirements contained in 9.3.3.40.2.1 to 9.3.3.40.2.9, fire-extinguishing systems using CO_2 as an extinguishing agent shall conform to the following provisions:

(a) Tanks of CO_2 shall be placed in a gastight space or cabinet separated from other spaces. The doors of such storage spaces and cabinets shall open outwards; they shall be capable of being locked and shall carry on the outside the symbol "Warning: danger", not less than 5 cm high and "CO_2" in the same colours and the same size;

(b) Storage cabinets or spaces for CO_2 tanks located below deck shall only be accessible from the outside. These spaces shall have an artificial ventilation system with extractor hoods and shall be completely independent of the other ventilation systems on board;

(c) The degree of filling* of CO_2 tanks shall not exceed 0.75 kg/l. The volume of depressurised CO_2 shall be taken to be 0.56 m^3/kg;

(d) The concentration of CO_2 in the space to be protected shall be not less than 40% of the gross volume of the space. This quantity shall be released within 120 seconds. It shall be possible to monitor whether diffusion is proceeding correctly;

(e) The opening of the tank valves and the control of the diffusing valve shall correspond to two different operations;

(f) The appropriate period of time mentioned in 9.3.3.40.2.6 (b) shall be not less than 20 seconds. A reliable installation shall ensure the timing of the diffusion of CO_2.

9.3.3.40.2.11 *Fire-extinguishing system operating with HFC-227 ea (heptafluoropropane)*

In addition to the requirements of 9.3.3.40.2.1 to 9.3.3.40.2.9, fire-extinguishing systems using HFC-227 ea as an extinguishing agent shall conform to the following provisions:

(a) Where there are several spaces with different gross volumes, each space shall be equipped with its own fire-extinguishing system;

(b) Every tank containing HFC-227 ea placed in the space to be protected shall be fitted with a device to prevent overpressure. This device shall ensure that the contents of the tank are safely diffused in the space to be protected if the tank is subjected to fire, when the fire-extinguishing system has not been brought into service;

(c) Every tank shall be fitted with a device permitting control of the gas pressure;

(d) The degree of filling* of tanks shall not exceed 1.15 kg/l. The specific volume of depressurised HFC-227 ea shall be taken to be 0.1374 m^3/kg;

(e) The concentration of HFC-227 ea in the space to be protected shall be not less than 8% of the gross volume of the space. This quantity shall be released within 10 seconds;

(f) Tanks of HFC-227 ea shall be fitted with a pressure monitoring device which triggers an audible and visual alarm in the wheelhouse in the event of an unscheduled loss of propellant gas. Where there is no wheelhouse, the alarm shall be triggered outside the space to be protected;

* *As this text has been taken from ES-TRIN, the definition of 'Degree of filling' provided in 1.2.1 of these Regulations is not applicable.*

(g) After discharge, the concentration in the space to be protected shall not exceed 10.5% (volume);

(h) The fire-extinguishing system shall not comprise aluminium parts.

9.3.3.40.2.12 *Fire-extinguishing system operating with IG-541*

In addition to the requirements of 9.3.3.40.2.1 to 9.3.3.40.2.9, fire-extinguishing systems using IG-541 as an extinguishing agent shall conform to the following provisions:

(a) Where there are several spaces with different gross volumes, every space shall be equipped with its own fire-extinguishing system;

(b) Every tank containing IG-541 placed in the space to be protected shall be fitted with a device to prevent overpressure. This device shall ensure that the contents of the tank are safely diffused in the space to be protected if the tank is subjected to fire, when the fire-extinguishing system has not been brought into service;

(c) Each tank shall be fitted with a device for checking the contents;

(d) The filling pressure of the tanks shall not exceed 200 bar at a temperature of +15 °C;

(e) The concentration of IG-541 in the space to be protected shall be not less than 44% and not more than 50% of the gross volume of the space. This quantity shall be released within 120 seconds.

9.3.3.40.2.13 *Fire-extinguishing system operating with FK-5-1-12*

In addition to the requirements of 9.3.3.40.2.1 to 9.3.3.40.2.9, fire-extinguishing systems using FK-5-1-12 as an extinguishing agent shall comply with the following provisions:

(a) Where there are several spaces with different gross volumes, every space shall be equipped with its own fire-extinguishing system;

(b) Every tank containing FK-5-1-12 placed in the space to be protected shall be fitted with a device to prevent overpressure. This device shall ensure that the contents of the tank are safely diffused in the space to be protected if the tank is subjected to fire, when the fire-extinguishing system has not been brought into service;

(c) Every tank shall be fitted with a device permitting control of the gas pressure;

(d) The degree of filling* of tanks shall not exceed 1.00 kg/l. The specific volume of depressurized FK-5-1-12 shall be taken to be 0.0719 m^3/kg;

(e) The volume of FK-5-1-12 in the space to be protected shall be not less than 5.5% of the gross volume of the space. This quantity shall be released within 10 seconds;

(f) Tanks of FK-5-1-12 shall be fitted with a pressure monitoring device which triggers an audible and visual alarm in the wheelhouse in the event of an unscheduled loss of extinguishing agent. Where there is no wheelhouse, the alarm shall be triggered outside the space to be protected;

(g) After discharge, the concentration in the space to be protected shall not exceed 10.0%.

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* *As this text has been taken from ES-TRIN, the definition of 'Degree of filling' provided in 1.2.1 of these Regulations is not applicable.*

9.3.3.40.2.14 *(Reserved)*

9.3.3.40.2.15 *Fire-fighting systems using K_2CO_3 as the extinguishing agent*

In addition to the requirements laid down in 9.3.3.40.2.1 to 9.3.3.40.2.3, 9.3.3.40.2.5, 9.3.3.40.2.6 and 9.3.3.40.2.9, fire-fighting systems using K_2CO_3 as the extinguishing agent shall comply with the following provisions:

(a) The fire-fighting system shall have a type-approval pursuant to Directive 2014/90/EU[3] or to MSC/Circ. 1270;[4]

(b) Each room shall be provided with its own firefighting system;

(c) The extinguishing agent must be stored in specially provided unpressurised tanks in the room to be protected. These tanks shall be fitted in such a way that the extinguishing agent is dispensed evenly in the room. In particular the extinguishing agent shall also work underneath the deck plates;

(d) Each tank is separately connected with the triggering device;

(e) The quantity of dry aerosol-forming extinguishing agent relative to the room to be protected shall be at least 120 g per m^3 of the net volume of this room. This net volume is calculated according to Directive 2014/90/EU[3] or to MSC/Circ. 1270.[4] It shall be possible to supply the extinguishing agent within 120 s.

9.3.3.40.2.16 *Permanently installed fire-extinguishing systems for protecting objects*

(a) Permanently installed fire-extinguishing systems for protecting objects are permitted for the protection of installations and equipment.

The action of the fire-extinguishing systems must be aimed directly at the objects to be protected. The range of action of fire-extinguishing systems may be limited in space by means of structural measures.

Permanently installed fire-extinguishing systems for protecting objects may already be structurally integrated into the objects concerned.

Permanently installed fire-extinguishing systems for protecting objects must be independent of the systems referred to in 9.3.3.40.2.2 to 9.3.3.40.2.16 in respect of their supply of extinguishing agent.

(b) The following requirements apply to permanently installed fire-extinguishing systems for protecting objects:

(i) 9.3.3.40.2.2, if the extinguishing agent used requires the range of action to be limited by structural measures;

(ii) 9.3.3.40.2.3 and 9.3.3.40.2.4;

(iii) 9.3.3.40.2.5 (b) and (c), in addition to the provisions of (c) of the present section;

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3 *Official Journal of the European Union, L 257 of 28 August 2014, p.146.*

4 *International Maritime Organization Circular MSC/Circ. 1270 and corrigenda — Revised Guidelines for the approval of fixed aerosol fire-extinguishing systems equivalent to fixed gas extinguishing systems, as referred to in SOLAS 1974, for machinery spaces — adopted on 4 June 2008.*

(iv) 9.3.3.40.2.6, (a) to (e), and at each entrance to a room or in the immediate vicinity of an encapsulated object, a suitable sign for the fire-extinguishing system for physical protection must be prominently displayed;

(v) 9.3.3.40.2.7 to 9.3.3.40.2.13;

(vi) *(Reserved)*;

(vii) 9.3.3.40.2.15, (b) to (e).

Only extinguishing agents suitable for extinguishing a fire on or in the object to be protected and which are mentioned in 9.3.3.40.2.1 may be used in permanently installed fire-extinguishing systems for protecting objects.

The competent authority may authorize exemptions concerning the extinguishing agent for permanently installed fire-extinguishing systems for protecting objects which are based on a fire protection concept.

(c) Permanently installed fire-extinguishing systems for protecting objects must be capable of being triggered manually. Manual triggering must be possible in the immediate vicinity of the protected object. They may be triggered automatically if the triggering signal is emitted by two fire detectors with different means of detection. The triggering must occur without delay. If the fire-extinguishing system is intended to protect several spaces, it shall comprise a separate and clearly-marked triggering device for each space.

The activation of the fire-extinguishing system shall be displayed in the wheelhouse and at the entrance to the room in which the object to be protected is located. In the case of encapsulated objects, the display at the room entrance can be omitted if another display is attached to the object itself.

For manual activation, operating instructions in accordance with 9.3.3.40.2.5 (e) shall be displayed next to each triggering device, taking into account the location and nature of the object.

(d) The type and place of installation of permanently installed fire-extinguishing systems for protecting objects shall be entered in the ship’s certificate.

(e) The provisions of this section do not apply to water spray systems in accordance with 9.3.1.28, 9.3.2.28 and 9.3.3.28.

9.3.3.40.3 The two hand fire–extinguishers referred to in 8.1.4 shall be located in the cargo area.

9.3.3.40.4 The fire-extinguishing agent and the quantity contained in the permanently fixed fire-extinguishing system shall be suitable and sufficient for fighting fires.

9.3.3.40.5 9.3.3.40.1 and 9.3.3.40.2 above do not apply to oil separator or supply vessels.

9.3.3.41 ***Fire and naked light***

9.3.3.41.1 The outlets of funnels shall be located not less than 2.00 m from the cargo area. Arrangements shall be provided to prevent the escape of sparks and the entry of water.

9.3.3.41.2 Heating, cooking and refrigerating appliances shall not be fuelled with liquid fuels, liquid gas or solid fuels.

The installation in the engine room or in another separate space of heating appliances fuelled with liquid fuel having a flashpoint above 55 °C is, however, permitted.

Cooking and refrigerating appliances are permitted only in the accommodation.

9.3.3.41.3 Only electrical lamps are permitted.

9.3.3.42 ***Cargo heating system***

9.3.3.42.1 Boilers which are used for heating the cargo shall be fuelled with a liquid fuel having a flashpoint of more than 55 °C. They shall be placed either in the engine room or in another separate space below deck and outside the cargo area, which is accessible from the deck or from the engine room.

9.3.3.42.2 The cargo heating system shall be designed so that the cargo cannot penetrate into the boiler in the case of a leak in the heating coils. A cargo heating system with artificial draught shall be ignited electrically.

9.3.3.42.3 The ventilation system of the engine room shall be designed taking into account the air required for the boiler.

9.3.3.42.4 Where the cargo heating system is used during loading, unloading or degassing with a concentration given off by the cargo of 10% of the LEL or above, the service space which contains this system shall fully comply with the requirements of 9.3.3.52.1. This requirement does not apply to the inlets of the ventilation system. These inlets shall be located at a minimum distance of 2 m from the cargo area and 6 m from the openings of cargo tanks or residual cargo tanks, loading pumps situated on deck, openings of high-velocity vent valves, pressure relief devices and shore connections of loading and unloading piping and must be located not less than 2 m above the deck.

The requirements of 9.3.3.52.1 are not applicable to the unloading of substances having a flashpoint of 60 °C or more when the temperature of the product is at least 15 K lower at the flashpoint.

9.3.3.43 to 9.3.3.49 (*Reserved*)

9.3.3.50 *(Deleted)*

9.3.3.51 ***Surface temperatures of installations and equipment***

(a) Surface temperatures of electrical and non-electrical installations and equipment shall not exceed 200 °C;

(b) Surface temperatures of the outer parts of engines and their air inlets and exhaust ducts shall not exceed 200 °C;

(c) If the list of substances on the vessel according to 1.16.1.2.5 is going to include substances for which the temperature classes T4, T5 or T6 are indicated in column (15) of Table C of Chapter 3.2, then the corresponding surface temperatures within the assigned zones on board shall not exceed 135 °C (T4), 100 °C (T5) or 85 °C (T6), respectively;

(d) (a) and (b) do not apply if the following requirements are met (see also 7.2.3.51.4):

(i) Accommodation, wheelhouse and service spaces where surface temperatures higher than those mentioned in (a) and (b) occur are equipped with a ventilation system according to 9.3.3.12.4 (b); or

(ii) Installations and equipment which generate surface temperatures higher than those set out in (a) or (b), respectively, must be capable of being shut down. Such installations and equipment shall be marked in red;

(e) Open Type N vessels are only required to meet the requirements of (a), (b) and (d) if the vessel remains in the immediate vicinity of or within a shoreside assigned zone.

9.3.3.52 ***Type and location of electrical installations and equipment***

9.3.3.52.1 Electrical installations and equipment shall be of at least the 'limited explosion risk' type.

This provision does not apply to:

(a) Lighting installations in the accommodation and the wheelhouse, except for switches near to the entrances;

(b) Mobile phones, fixed telephone installations, stationary and portable computers and loading instruments in the accommodation or the wheelhouse;

(c) Electrical installations and equipment which, during a stay in the immediate vicinity of or within a shoreside assigned zone:

(i) Are extinguished; or

(ii) Are placed in premises equipped with a ventilation system according to 9.3.3.12.4;

(d) To radiotelephone installations and inland AIS (automatic identification systems) stations in the accommodation and the wheelhouse, if no part of an aerial for radiotelephone installations or AIS stations is situated above or within 2.00 m of the cargo area.

9.3.3.52.2 In the cofferdams, double-hull spaces, double bottoms and hold spaces, only hermetically sealed echo sounding devices are allowed, the cables of which are led through thick-walled steel tubes with gastight connections up to the main deck.

9.3.3.52.3 The fixed electrical installations and equipment which do not meet the requirements set out in 9.3.3.51 (a), 9.3.3.51 (b) and 9.3.3.52.1 above and their switches shall be marked in red. The disconnection of such equipment shall be controlled from a centralized location on board.

9.3.3.52.4 Every insulated distribution network shall be fitted with an automatic device with a visual and audible alarm for checking the insulation level.

9.3.3.52.5 Only distribution systems without return connection to the hull are permitted. This provision does not apply to:

– Active cathodic corrosion protection;

– Certain limited sections of the installations situated outside the cargo area (e.g., connections of starters of diesel engines);

– The device for checking the insulation level referred to in 9.3.3.52.4.

9.3.3.52.6 An electric generator which is permanently driven by an engine and which does not meet the requirements of 9.3.3.52.1 above, shall be fitted with a multipolar switch capable of shutting down the generator. A notice board with the operating instructions shall be displayed near the switch.

9.3.3.52.7 Failure of the power supply for the safety and control equipment shall be immediately indicated by visual and audible signals in the wheelhouse and on the deck. The alarm must be relayed to the accommodation automatically if it has not been switched off.

9.3.3.52.8 Electrical switches, sockets and cables on deck shall be protected against mechanical damage.

9.3.3.52.9 Sockets for the connection of signal lights and gangway lighting shall be solidly fitted to the vessel close to the signal mast or the gangway. The sockets used in this area shall be designed so as to prevent connection or disconnection except when they are not live.

9.3.3.52.10 Accumulators shall be located outside the cargo area.

9.3.3.52.11 Open Type N vessels are only required to meet the requirements of 9.3.3.52.1 and 9.3.3.52.3 if the vessel remains in the immediate vicinity of or within a shoreside assigned zone.

9.3.3.53 ***Type and location of electrical and non-electrical installations and equipment intended to be used in explosion hazardous areas***

9.3.3.53.1 On board vessels covered by the classification of zones as defined in 1.2.1, electrical and non-electrical installations and equipment used in explosion hazardous areas shall meet at least the requirements for use in the area concerned.

They shall be selected on the basis of the explosion groups/subgroups and temperature classes to which the substances to be carried belong (see columns (15) and (16) of Table C of Chapter 3.2).

If the list of substances on the vessel according to 1.16.1.2.5 is going to include substances for which temperature classes T4, T5 or T6 are indicated in column (15) of Table C of Chapter 3.2, then the corresponding surface temperatures within the assigned zones shall not exceed 135 °C (T4), 100 °C (T5) or 85 °C (T6).

If the list of substances on the vessel according to 1.16.1.2.5 is going to include substances for which temperature classes T1 or T2 are indicated in column (15) of Table C of Chapter 3.2, then the corresponding surface temperatures within the assigned zones shall not exceed 200 °C.

9.3.3.53.2 Except in the case of optical fibres, electrical cables shall be armoured or placed in a metallic sheath or in protective tubes.

Electrical cables for the active cathodic protection of the shell plating shall be led through thick-walled steel tubes with gastight connections up to the main deck.

9.3.3.53.3 Movable electric cables are prohibited in the explosion danger area, except for electric cables for intrinsically safe electric circuits or for connecting:

(a) Signal lights and lighting for gangways, provided the connection point (for example, the socket) is permanently fitted to the vessel close to the signal mast or gangway;

(b) The power network on a vessel to a land-based power network; provided

– The electric cables and the power supply unit conform with a valid standard (for example, EN 15869-03: 2010);

– The power supply unit and connectors are located outside of the explosion danger area.

Connecting and disconnecting sockets/connectors shall only be possible when they are not live.

9.3.3.53.4 Electrical cables of intrinsically safe circuits shall be separated from other cables not intended for use in such circuits and shall be marked (they shall not be installed together in the same string of cables and they shall not be fixed by the same cable clamps).

9.3.3.53.5 For movable electrical cables permitted under 9.3.3.53.3, only sheathed cables of type H07RN-F in accordance with standard IEC 60245-4:2011[5] or electrical cables of at least equivalent design having conductors with a cross-section of not less than 1.50 mm^2 shall be used.

9.3.3.54 ***Earthing***

9.3.3.54.1 The metal parts of electrical installations and equipment in the cargo area which are not live, as well as the protective metal tubes or metal sheaths of cables, in normal service shall be earthed, unless they are so arranged that they are automatically earthed by bonding to the metal structure of the vessel.

9.3.3.54.2 The provisions of 9.3.3.54.1 also apply to installations with a voltage of less than 50 Volts.

9.3.3.54.3 Independent cargo tanks, metal intermediate bulk containers and tank-containers shall be earthed.

9.3.3.54.4 Receptacles for residual products shall be capable of being earthed.

9.3.3.55 (*Reserved*)

9.3.3.56 *(Deleted)*

9.3.3.57 to 9.3.3.59 (*Reserved*)

9.3.3.60 ***Special equipment***

A shower and an eye and face bath shall be provided on the vessel at a location which is directly accessible from the cargo area. The water shall meet the minimum quality requirements applicable to drinking water on board vessels.

NOTE: *Additional decontamination substances for the purpose of avoiding corrosion of eyes and skin are allowed.*

A connection of this special equipment with the area outside the cargo zone is accepted.

A spring-loaded non-return valve shall be fitted to ensure that no gases can escape through the shower and the eye and face bath system outside the cargo area.

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[5] *Identical to EN 50525-2-21: 2011.*

9.3.3.61 9.3.3.60 above does not apply to oil separator and supply vessels. If an unmanned pushed barge is not equipped with a shower and an eye and face bath in accordance with 9.3.3.60, the list of substances according to 1.16.1.2.5 may not include substances with danger 8 in column (5) of Table C of Chapter 3.2.

9.3.3.62 ***Additional vacuum valve for degassing to reception facilities***

An opening in the loading and unloading piping or in the venting piping, used at reception facilities to take in ambient air to prevent exceedance of the maximum permissible vacuum (see 7.2.3.7.2.3), shall be fitted with an additional portable vacuum valve or an additional permanently installed vacuum valve. When the intake of ambient air is done with a hose ending shoreside, the open end of the hose shall be equipped with such a valve in the same manner.

The trigger pressure of the additional vacuum valve shall be adjusted so that under normal working conditions the vacuum valve referred to in 9.3.x.22.4 is not activated during degassing.

If the vessel's substance list according to 1.16.1.2.5 contains substances for which explosion protection is required in column (17) of Table C of Chapter 3.2, the valve shall be fitted with a flame arrester capable of withstanding a deflagration. When the vessel is not degassing to a reception facility, the permanently installed valve or the opening to which a portable valve is connected shall be closed with a blind flange.

NOTE: *7.2.4.22.1 applies for the opening of this opening.*

9.3.3.63 to 9.3.3.70 *(Reserved)*

9.3.3.71 ***Admittance on board***

The notice boards displaying the prohibition of admittance in accordance with 8.3.3 shall be clearly legible from either side of the vessel.

9.3.3.72 and 9.3.3.73 *(Reserved)*

9.3.3.74 ***Prohibition of smoking, fire or naked light***

9.3.3.74.1 The notice boards displaying the prohibition of smoking in accordance with 8.3.4 shall be clearly legible from either side of the vessel.

9.3.3.74.2 Notice boards indicating the circumstances under which the prohibition is applicable shall be fitted near the entrances to the spaces where smoking or the use of fire or naked light is not always prohibited.

9.3.3.74.3 Ashtrays shall be provided close to each exit in the accommodation and the wheelhouse.

9.3.3.75 to 9.3.3.91 *(Reserved)*

9.3.3.92 On board of tank vessels referred to in 9.3.3.11.7, spaces the entrances or exits of which are likely to become partly or completely immersed in the damaged condition shall have an emergency exit which is situated not less than 0.10 m above the damage waterline. This requirement does not apply to forepeak and afterpeak.

9.3.3.93 to 9.3.3.99 *(Reserved)*

9.3.4 Alternative constructions

9.3.4.1 *General*

9.3.4.1.1 The maximum permissible capacity and length of a cargo tank in accordance with 9.3.1.11.1, 9.3.2.11.1 and 9.3.3.11.1 may be exceeded and the minimum distances in accordance with 9.3.1.11.2 a) and 9.3.2.11.7 may be deviated from provided that the provisions of this section are complied with. The capacity of a cargo tank shall not exceed 1000 m^3.

9.3.4.1.2 Tank vessels whose cargo tanks exceed the maximum allowable capacity or where the distance between the side wall and the cargo tank is smaller than required, shall be protected through a more crashworthy side structure. This shall be proved by comparing the risk of a conventional construction (reference construction), complying with the ADN regulations with the risk of a crashworthy construction (alternative construction).

9.3.4.1.3 When the risk of the more crashworthy construction is equal to or lower than the risk of the conventional construction, equivalent or higher safety is proven. The equivalent or higher safety shall be proven in accordance with 9.3.4.3.

9.3.4.1.4 When a vessel is built in compliance with this section, a recognised classification society shall document the application of the calculation procedure in accordance with 9.3.4.3 and shall submit its conclusions to the competent authority for approval.

The competent authority may request additional calculations and proof.

9.3.4.1.5 The competent authority shall include this construction in the certificate of approval in accordance with 8.6.1.

9.3.4.2 *Approach*

9.3.4.2.1 The probability of cargo tank rupture due to a collision and the area around the vessel affected by the cargo outflow as a result thereof are the governing parameters. The risk is described by the following formula:

$R = P \cdot C$

Wherein: R risk [m^2],

P probability of cargo tank rupture [ ],

C consequence (measure of damage) of cargo tank rupture [m^2].

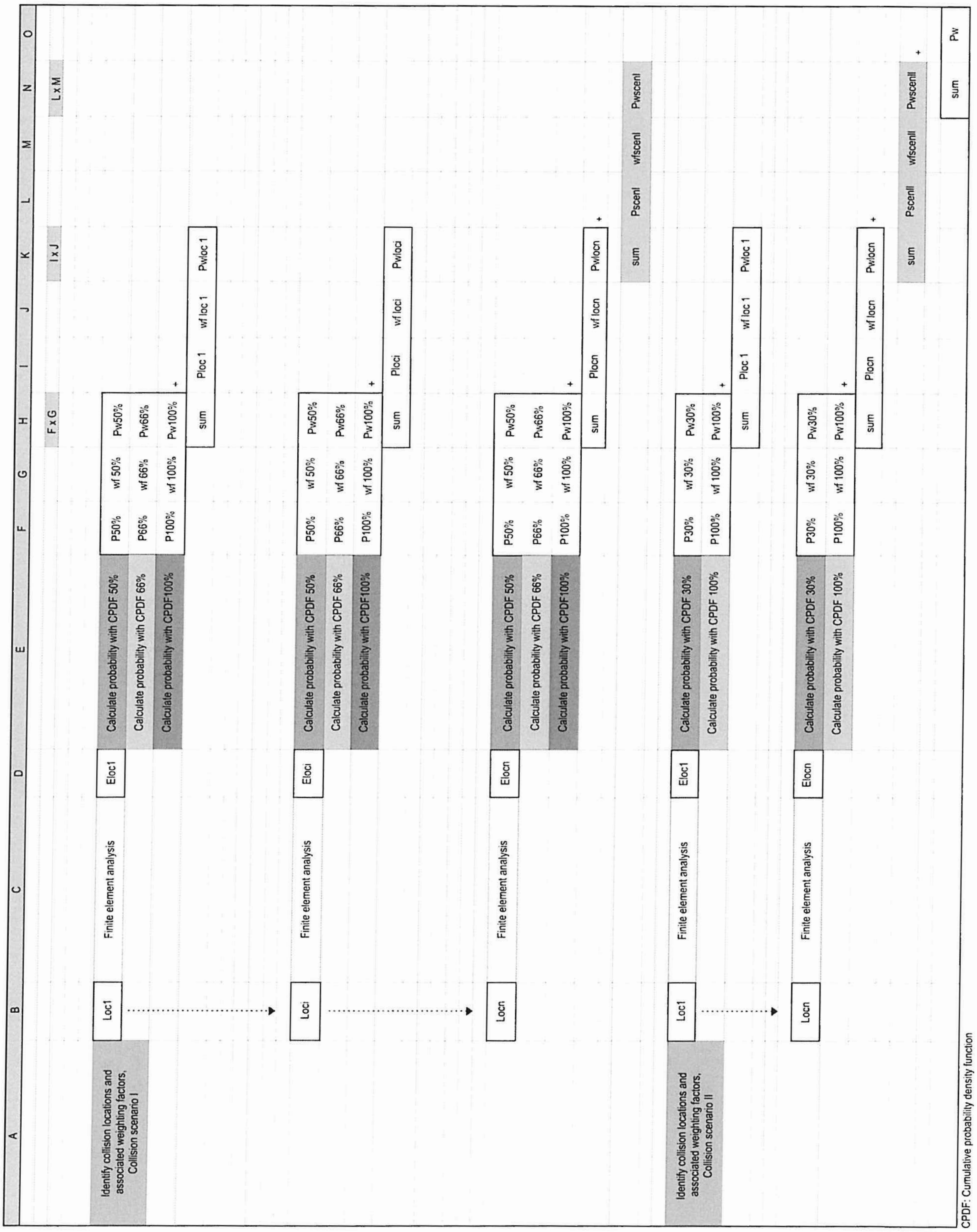
9.3.4.2.2 The probability P of cargo tank rupture depends on the probability distribution of the available collision energy represented by vessels, which the victim is likely to encounter in a collision, and the capability of the struck vessel to absorb collision energy without cargo tank rupture. A decrease of this probability can be achieved by means of a more crashworthy side structure.

The consequence C of cargo spillage resulting from cargo tank rupture is expressed as an affected area around the struck vessel.

9.3.4.2.3 The procedure according to 9.3.4.3 shows how tank rupture probabilities shall be calculated as well as how the collision energy absorbing capacity of side structure and a consequence increase shall be determined.

9.3.4.3 *Calculation procedure*

9.3.4.3.1 The calculation procedure shall follow 13 basic steps. Steps 2 through 10 shall be carried out for both the alternative design and the reference design. The following table shows the calculation of the weighted probability of cargo tank rupture:


A B C D E F G H I J K L M N O
F x G
I x J
L x M
Identify collision locations and associated weighting factors, Collision scenario I
Loc1
Loci
Locn
Finite element analysis
Eloc1
Eloci
Elocn
Calculate probability with CPDF 50%
Calculate probability with CPDF 66%
Calculate probability with CPDF100%
P50% wf 50% Pw50%
P66% wf 66% Pw66%
P100% wf 100% Pw100%
sum Ploc 1 wf loc 1 Pwloc 1
sum Ploci wf loci Pwloci
sum Plocn wf locn Pwlocn
sum PscenI wfscenI PwscenI
Identify collision locations and associated weighting factors, Collision scenario II
Calculate probability with CPDF 30%
Calculate probability with CPDF 100%
P30% wf 30% Pw30%
P100% wf 100% Pw100%
sum PscenII wfscenII PwscenII
sum Pw
CPDF: Cumulative probability density function

9.3.4.3.1.1 *Step 1*

Besides the alternative design, which is used for cargo tanks exceeding the maximum allowable capacity or a reduced distance between the side wall and the cargo tank as well as a more crashworthy side structure, a reference design with at least the same dimensions (length, width, depth, displacement) shall be drawn up. This reference design shall fulfil the requirements specified in section 9.3.1 (Type G), 9.3.2 (Type C) or 9.3.3 (Type N) and shall comply with the minimum requirements of a recognised classification society.

9.3.4.3.1.2 *Step 2*

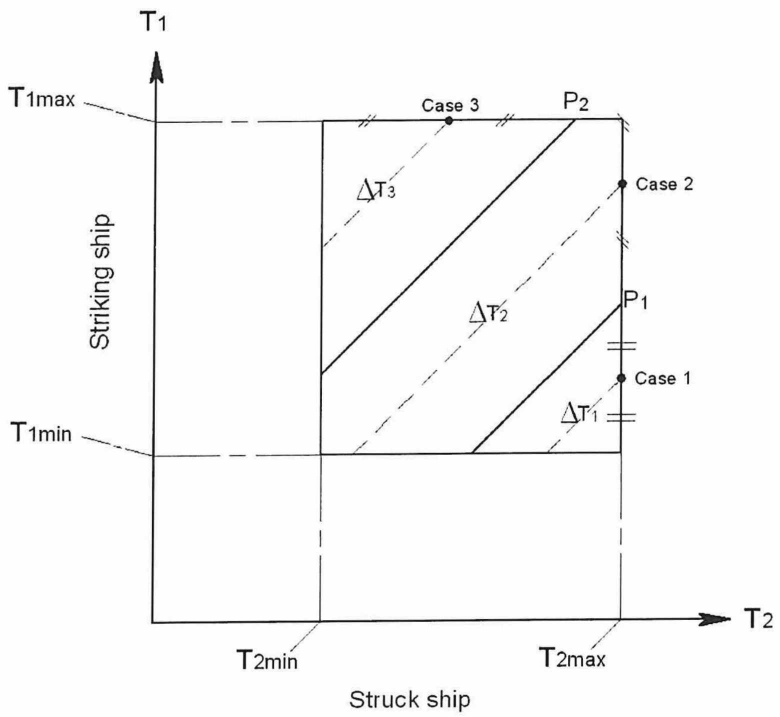
9.3.4.3.1.2.1 The relevant typical collision locations i=1 through n shall be determined. The table in 9.3.4.3.1 depicts the general case where there are 'n' typical collision locations.

The number of typical collision locations depends on the vessel design. The choice of the collision locations shall be accepted by the recognised classification society.

9.3.4.3.1.2.2 Vertical collision locations

9.3.4.3.1.2.2.1 Tank vessel type C and N

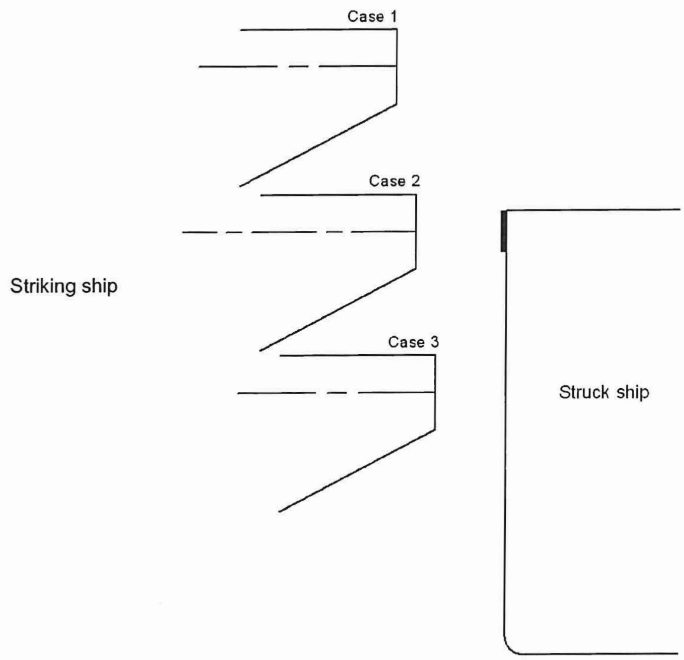
9.3.4.3.1.2.2.1.1 The determination of the collision locations in the vertical direction depends on the draught differences between striking and struck vessel, which is limited by the maximum and minimum draughts of both vessels and the construction of the struck vessel. This can be depicted graphically through a rectangular area which is enclosed by the values of the maximum and minimum draught of both striking and struck vessel (see following figure).



Definition of vertical striking locations

9.3.4.3.1.2.2.1.2 Each point in this area represents a possible draught combination. T_{1max} is the maximum draught and T_{1min} is the minimum draught of the striking vessel, while T_{2max} and T_{2min} are the corresponding minimum and maximum draughts of the struck vessel. Each draught combination has an equal probability of occurrence.

9.3.4.3.1.2.2.1.3 Points on each inclined line in the figure in 9.3.4.3.1.2.2.1.1 indicate the same draught difference. Each of these lines reflects a vertical collision location. In the example in the figure in 9.3.4.3.1.2.2.1.1 three vertical collision locations are defined, depicted by three areas. Point P_1 is the point where the lower edge of the vertical part of the pushed barge or V–bow strikes at deck level of the struck vessel. The triangular area for collision case 1 is bordered by point P_1. This corresponds to the vertical collision location "collision above deck level". Point P_2 is the point where the upper edge of the vertical part of the pushed barge or V-bow strikes the upper part of the wale plate. The area bordered by points P_1 and P_2 corresponds to the vertical collision location "collision at deck level". The triangular upper left area of the rectangle corresponds to the vertical collision location "collision below deck". The draught difference ΔT_i, i=1,2,3 shall be used in the collision calculations (see following figure).



Example of vertical collision locations

9.3.4.3.1.2.2.1.4 For the calculation of the collision energies the maximum masses of both striking vessel and struck vessel must be used (highest point on each respective diagonal ΔT_i).

9.3.4.3.1.2.2.1.5 Depending on the vessel design, the recognised classification society may require additional collision locations.

9.3.4.3.1.2.2.2 *Tank vessel type G*

For a tank vessel type G a collision at half tank height shall be assumed. The recognised classification society may require additional collision locations at other heights. This shall be agreed with the recognised classification society.

9.3.4.3.1.2.3 Longitudinal collision location

9.3.4.3.1.2.3.1 Tank vessels type C and N

At least the following three typical collision locations shall be considered:

– at bulkhead,

– between webs and

– at web.

9.3.4.3.1.2.3.2 Tank vessel type G

For a tank vessel type G at least the following three typical collision locations shall be considered:

– at cargo tank end,

– between webs and

– at web.

9.3.4.3.1.2.4 Number of collision locations

9.3.4.3.1.2.4.1 Tank vessel type C and N

The combination of vertical and longitudinal collision locations in the example mentioned in 9.3.4.3.1.2.2.1.3 and 9.3.4.3.1.2.3.1 results in 3 • 3 = 9 collision locations.

9.3.4.3.1.2.4.2 Tank vessel type G

The combination of vertical and longitudinal collision locations in the example mentioned in 9.3.4.3.1.2.2.2 and 9.3.4.3.1.2.3.2 results in 1 • 3 = 3 collision locations.

9.3.4.3.1.2.4.3 Additional examinations for tank vessels type G, C and N with independent cargo tanks

As proof that the tank seatings and the buoyancy restraints do not cause any premature tank rupture, additional calculations shall be carried out. The additional collision locations for this purpose shall be agreed with the recognised classification society.

9.3.4.3.1.3 Step 3

9.3.4.3.1.3.1 For each typical collision location a weighting factor which indicates the relative probability that such a typical collision location will be struck shall be determined. In the table in 9.3.4.3.1 these factors are named $wf_{loc(i)}$ (column J). The assumptions shall be agreed with the recognised classification society.

The weighting factor for each collision location is the product of the factor for the vertical collision location by the factor for the longitudinal collision location.

9.3.4.3.1.3.2 Vertical collision locations

9.3.4.3.1.3.2.1 Tank vessel type C and N

The weighting factors for the various vertical collision locations are in each case defined by the ratio between the partial area for the corresponding collision case and the total area of the rectangle shown in the Figure in 9.3.4.3.1.2.2.1.1.

For example, for collision case 1 (see figure in 9.3.4.3.1.2.2.1.3) the weighting factor equals the ratio between the triangular lower right area of the rectangle, and the area of the rectangle between minimum and maximum draughts of striking and struck vessels.

9.3.4.3.1.3.2.2 Tank vessel type G

The weighting factor for the vertical collision location has the value 1.0, if only one collision location is assumed. When the recognised classification society requires additional collision locations, the weighting factor shall be determined analogous to the procedure for tank vessels type C and N.

9.3.4.3.1.3.3 Longitudinal collision locations

9.3.4.3.1.3.3.1 Tank vessel type C and N

The weighting factor for each longitudinal collision location is the ratio between the “calculational span length” and the tank length.

The calculational span length shall be calculated as follows:

(a) collision on bulkhead:

0.2 • distance between web frame and bulkhead, but not larger than 450 mm,

(b) collision on web frame:

sum of 0.2 • web frame spacing forward of the web frame, but not larger than 450 mm, and 0.2 • web frame spacing aft of the web frame, but not larger than 450 mm, and

(c) collision between web frames:

cargo tank length minus the length “collision at bulkhead” and minus the length "collision at web frame".

9.3.4.3.1.3.3.2 Tank vessel type G

The weighting factor for each longitudinal collision location is the ratio between the “calculational span length” and the length of the hold space.

The calculational span length shall be calculated as follows:

(a) collision at cargo tank end:

distance between bulkhead and the start of the cylindrical part of the cargo tank,

(b) collision on web frame:

sum of 0.2 • web frame spacing forward of the web frame, but not larger than 450 mm, and 0.2 • web frame spacing aft of the web frame, but not larger than 450 mm, and

(c) collision between web frames:

cargo tank length minus the length “collision at cargo tank end” and minus the length "collision at web frame".

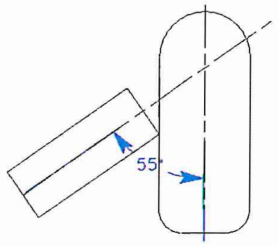
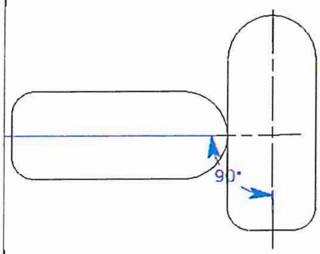
9.3.4.3.1.4 *Step 4*

9.3.4.3.1.4.1 For each collision location the collision energy absorbing capacity shall be calculated. For that matter the collision energy absorbing capacity is the amount of collision energy absorbed by the vessel structure up to initial rupture of the cargo tank (see the table in 9.3.4.3.1, column D: $E_{loc(i)}$). For this purpose a finite element analysis in accordance with 9.3.4.4.2 shall be used.

These calculations shall be done for two collision scenarios according to the following table. Collision scenario I shall be analysed under the assumption of a pushed barge bow shape. Collision scenario II shall be analysed under the assumption of a V–shaped bow.

These bow shapes are defined in 9.3.4.4.8.

Table : Speed reduction factors for scenario I or scenario II with weighting factors

<table>
<tr><td colspan="5"></td><td colspan="3">Causes</td></tr>
<tr><td colspan="5"></td><td>Communication error and poor visibility</td><td>Technical error</td><td>Human error</td></tr>
<tr><td colspan="5"></td><td>0,50</td><td>0,20</td><td>0,30</td></tr>
<tr><td rowspan="2">Worst case scenarios</td><td>I</td><td>
</td><td>Pushed barge–bow, striking angle 55°</td><td>0,80</td><td>0.66</td><td>0.50</td><td>1.00</td></tr>
<tr><td>II</td><td>
</td><td>V–shaped–bow, striking angle 90°</td><td>0,20</td><td colspan="2">0.30</td><td>1.00</td></tr>
</table>

9.3.4.3.1.5 *Step 5*

9.3.4.3.1.5.1 For each collision energy absorption capacity $E_{loc(i)}$, the associated probability of exceedance is to be calculated, i.e. the probability of cargo tank rupture. For this purpose, the formula for the cumulative probability density functions (CPDF) below shall be used. The appropriate coefficients shall be selected from the Table in 9.3.4.3.1.5.6 for the effective mass of the struck vessel.

$$P_{x\%} = C_1(E_{loc(i)})^3 + C_2(E_{loc(i)})^2 + C_3E_{loc(i)} + C_4$$

with: $P_{x\%}$ probability of tank rupture,

$C_{1\text{–}4}$ coefficients from table in 9.3.4.3.1.5.6,

$E_{loc(i)}$ collision energy absorbing capacity.

9.3.4.3.1.5.2 The effective mass shall be equal to the maximum displacement of the vessel multiplied by a factor of 1.4. Both collision scenarios (9.3.4.3.1.4.2) shall be considered.

9.3.4.3.1.5.3 In the case of collision scenario I (pushed barge bow at 55°), three CPDF formulas shall be used:

CPDF 50% (velocity 0.5 V_{max}),

CPDF 66% (velocity 2/3 V_{max}) and

CPDF 100% (velocity V_{max}).

9.3.4.3.1.5.4 In the case of scenario II (V–shaped bow at 90°), the following two CPDF formulas shall be used:

CPDF 30% (velocity 0.3 V_{max}) and

CPDF 100% (velocity V_{max}).

9.3.4.3.1.5.5 In the table in 9.3.4.3.1, column F, these probabilities are called *P50%, P66%, P100%* and *P30%, P100%* respectively.

9.3.4.3.1.5.6 Table: Coefficients for the CPDF formulas

Effective mass of struck vessel in tonnes	velocity = 1 x V_{max}				
	coefficients				
	C_1	C_2	C_3	C_4	range
14000	4.106E–05	–2.507E–03	9.727E–03	9.983E–01	$4<E_{loc}<39$
12000	4.609E–05	–2.761E–03	1.215E–02	9.926E–01	$4<E_{loc}<36$
10000	5.327E–05	–3.125E–03	1.569E–02	9.839E–01	$4<E_{loc}<33$
8000	6.458E–05	–3.691E–03	2.108E–02	9.715E–01	$4<E_{loc}<31$
6000	7.902E–05	–4.431E–03	2.719E–02	9.590E–01	$4<E_{loc}<27$
4500	8.823E–05	–5.152E–03	3.285E–02	9.482E–01	$4<E_{loc}<24$
3000	2.144E–05	–4.607E–03	2.921E–02	9.555E–01	$2<E_{loc}<19$
1500	– 2.071E–03	2.704E–02	–1.245E–01	1.169E+00	$2<E_{loc}<12$

Effective mass of struck vessel in tonnes	velocity = 0.66 x V_{max}				
	coefficients				
	C_1	C_2	C_3	C_4	range
14000	4.638E–04	–1.254E–02	2.041E–02	1.000E+00	$2<E_{loc}<17$
12000	5.377E–04	–1.427E–02	2.897E–02	9.908E–01	$2<E_{loc}<17$
10000	6.262E–04	–1.631E–02	3.849E–02	9.805E–01	$2<E_{loc}<15$
8000	7.363E–04	–1.861E–02	4.646E–02	9.729E–01	$2<E_{loc}<13$
6000	9.115E–04	–2.269E–02	6.285E–02	9.573E–01	$2<E_{loc}<12$
4500	1.071E–03	–2.705E–02	7.738E–02	9.455E–01	$1<E_{loc}<11$
3000	–1.709E–05	–1.952E–02	5.123E–02	9.682E–01	$1<E_{loc}<8$
1500	–2.479E–02	1.500E–01	–3.218E–01	1.204E+00	$1<E_{loc}<5$

Effective mass of struck vessel in tonnes	velocity = 0.5 x V_{max}				
	coefficients				
	C_1	C_2	C_3	C_4	range
14000	2.621E–03	–3.978E–02	3.363E–02	1.000E+00	$1<E_{loc}<10$
12000	2.947E–03	–4.404E–02	4.759E–02	9.932E–01	$1<E_{loc}<9$
10000	3.317E–03	–4.873E–02	5.843E–02	9.878E–01	$2<E_{loc}<8$
8000	3.963E–03	–5.723E–02	7.945E–02	9.739E–01	$2<E_{loc}<7$
6000	5.349E–03	–7.407E–02	1.186E–01	9.517E–01	$1<E_{loc}<6$
4500	6.303E–03	–8.713E–02	1.393E–01	9.440E–01	$1<E_{loc}<6$
3000	2.628E–03	–8.504E–02	1.447E–01	9.408E–01	$1<E_{loc}<5$
1500	–1.566E–01	5.419E–01	–6.348E–01	1.209E+00	$1<E_{loc}<3$

Effective mass of struck vessel in tonnes	velocity = 0.3 x V_{max} coefficients				
	C_1	C_2	C_3	C_4	range
14000	5.628E–02	–3.081E–01	1.036E–01	9.991E–01	$1<E_{loc}<3$
12000	5.997E–02	–3.212E–01	1.029E–01	1.002E+00	$1<E_{loc}<3$
10000	7.477E–02	–3.949E–01	1.875E–01	9.816E–01	$1<E_{loc}<3$
8000	1.021E–02	–5.143E–01	2.983E–01	9.593E–01	$1<E_{loc}<2$
6000	9.145E–02	–4.814E–01	2.421E–01	9.694E–01	$1<E_{loc}<2$
4500	1.180E–01	–6.267E–01	3.542E–01	9.521E–01	$1<E_{loc}<2$
3000	7.902E–02	–7.546E–01	5.079E–01	9.218E–01	$1<E_{loc}<2$
1500	–1.031E+00	2.214E–01	1.891E–01	9.554E–01	$0.5<E_{loc}<1$

The range where the formula is valid is given in column 6. In case of an E_{loc} value below the range the probability equals $P_{x\%} = 1.0$. In case of a value above the range $P_{x\%}$ equals 0.

9.3.4.3.1.6 *Step 6*

The weighted probabilities of cargo tank rupture $P_{wx\%}$ (table in 9.3.4.3.1, column H) shall be calculated by multiplying each cargo tank rupture probability $P_{x\%}$ (table in 9.3.4.3.1, column F) by the weighting factors $wf_{x\%}$ according to the following table:

Table: Weighting factors for each characteristic collision speed

			weighting factor
Scenario I	CPDF 50%	wf50%	0.2
	CPDF 66%	wf66%	0.5
	CPDF 100%	wf100%	0.3
Scenario II	CPDF 30%	wf30%	0.7
	CPDF 100%	wf100%	0.3

9.3.4.3.1.7 *Step 7*

The total probabilities of cargo tank rupture $P_{loc(i)}$ (table in 9.3.4.3.1, column I) resulting from 9.3.4.3.1.6 (step 6) shall be calculated as the sum of all weighted cargo tank rupture probabilities $P_{wx\%}$ (table in 9.3.4.3.1, column H) for each collision location considered.

9.3.4.3.1.8 *Step 8*

For both collision scenarios the weighted total probabilities of cargo tank rupture $P_{wloc(i)}$ shall, in each case, be calculated by multiplying the total tank probabilities of cargo tank rupture $P_{loc(i)}$ for each collision location, by the weighting factors $wf_{loc(i)}$ corresponding to the respective collision location (see 9.3.4.3.1.3 (step 3) and table in 9.3.4.3.1, column J).

9.3.4.3.1.9 *Step 9*

Through the addition of the weighted total probabilities of cargo tank rupture $P_{wloc(i)}$, the scenario specific total probabilities of cargo tank rupture P_{scenI} and P_{scenII} (table in 9.3.4.3.1, column L) shall be calculated, for each collision scenario I and II separately.

9.3.4.3.1.10 *Step 10*

Finally the weighted value of the overall total probability of cargo tank rupture P_w shall be calculated by the formula below (table in 9.3.4.3.1, column O):

$$P_w = 0.8 \cdot P_{scenI} + 0.2 \cdot P_{scenII}$$

9.3.4.3.1.11 *Step 11*

The overall total probability of cargo tank rupture P_w for the alternative design is called P_n. The overall total probability of cargo tank rupture P_w for the reference design is called P_r.

9.3.4.3.1.12 *Step 12*

9.3.4.3.1.12.1 The ratio (C_n/C_r) between the consequence (measure of damage) C_n of a cargo tank rupture of the alternative design and the consequence C_r of a cargo tank rupture of the reference design shall be determined with the following formula:

$$C_n/C_r = V_n / V_r$$

With C_n/C_r the ratio between the consequence related to the alternative design, and the consequence related to the reference design,

V_n maximum capacity of the largest cargo tank in the alternative design,

V_r maximum capacity of the largest cargo tank reference design.

9.3.4.3.1.12.2 This formula was derived for characteristic cargoes as listed in the following table.

Table: Characteristic cargoes

	UN No.	Description
Benzene	1114	Flammable liquid Packing group II Hazardous to health
Acrylonitrile Stabilised ACN	1093	Flammable liquid Packing group I Toxic, stabilised
n–Hexane	1208	Flammable liquid Packing group II
Nonane	1920	Flammable liquid Packing group III
Ammonia	1005	Toxic, corrosive gas Liquefied under pressure
Propane	1978	Flammable gas Liquefied under pressure

9.3.4.3.1.12.3 For cargo tanks with capacities between 380 m^3 and 1000 m^3 containing flammable, toxic and acid liquids or gases it shall be assumed that the effect increase relates linearly to the increased tank capacity (proportionality factor 1.0).

9.3.4.3.1.12.4 If substances are to be carried in tank vessels, which have been analysed according to this calculation procedure, where the proportionality factor between the total cargo tank capacity and the affected area is expected to be larger than 1.0, as assumed in the previous paragraph, the affected area shall be determined through a separate calculation. In this case the comparison as described in 9.3.4.3.1.13 (step 13) shall be carried out with this different value for the size of the affected area, t.

9.3.4.3.1.13 *Step 13*

Finally the ratio $\frac{P_r}{P_n}$ between the overall total probability of cargo tank rupture P_r for the reference design and the overall total probability of cargo tank rupture P_n for the alternative design shall be compared with the ratio $\frac{C_n}{C_r}$ between the consequence related to the alternative design, and the consequence related to the reference design.

When $\frac{C_n}{C_r} \leq \frac{P_r}{P_n}$ is fulfilled, the evidence according to 9.3.4.1.3 for the alternative design is provided.

9.3.4.4 ***Determination of the collision energy absorbing capacity***

9.3.4.4.1 *General*

9.3.4.4.1.1 The determination of the collision energy absorbing capacity shall be carried out by means of a finite element analysis (FEA). The analysis shall be carried out using a customary finite element code (e.g. LS–DYNA[6], PAM–CRASH[7], ABAQUS[8] etc.) capable of dealing with both geometrical and material non–linear effects. The code shall also be able to simulate rupture realistically.

9.3.4.4.1.2 The program actually used and the level of detail of the calculations shall be agreed upon with a recognised classification society.

9.3.4.4.2 Creating the finite element models (FE models)

9.3.4.4.2.1 First of all, FE models for the more crashworthy design and one for the reference design shall be generated. Each FE model shall describe all plastic deformations relevant for all collision cases considered. The section of the cargo area to be modelled shall be agreed upon with a recognised classification society.

9.3.4.4.2.2 At both ends of the section to be modelled all three translational degrees of freedom are to be restrained. Because in most collision cases the global horizontal hull girder bending of the vessel is not of significant relevance for the evaluation of plastic deformation energy it is sufficient that only half beam of the vessel needs to be considered. In these cases the transverse displacements at the centre line (CL) shall be constrained. After generating the FE model, a trial collision calculation shall be carried out to ensure that there is no occurrence of plastic deformations near the constraint boundaries. Otherwise the FE modelled area has to be extended.

9.3.4.4.2.3 Structural areas affected during collisions shall be sufficiently finely idealized, while other parts may be modelled more coarsely. The fineness of the element mesh shall be suitable for an adequate description of local folding deformations and for determination of realistic rupture of elements.

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9.3.4.4.2.4 The calculation of rupture initiation must be based on fracture criteria which are suitable for the elements used. The maximum element size shall be less than 200 mm in the collision areas. The ratio between the longer and the shorter shell element edge shall not exceed the value of three. The element length *L* for a shell element is defined as the longer length of both sides of the element. The ratio between element length and element thickness shall be larger than five. Other values shall be agreed upon with the recognised classification society.

9.3.4.4.2.5 Plate structures, such as shell, inner hull (tank shell in the case of gas tanks), webs as well as stringers can be modelled as shell elements and stiffeners as beam elements. While modelling, cut outs and manholes in collision areas shall be taken into account.

9.3.4.4.2.6 In the FE calculation the 'node on segment penalty' method shall be used for the contact option. For this purpose the following options shall be activated in the codes mentioned:

- "contact_automatic_single_surface" in LS–DYNA,
- "self impacting" in PAMCRASH, and
- similar contact types in other FE–programs.

9.3.4.4.3 *Material properties*

9.3.4.4.3.1 Because of the extreme behaviour of material and structure during a collision, with both geometrical and material non–linear effects, true stress–strain relations shall be used:

$$\sigma = C \cdot \varepsilon^n ,$$

where

$$n = \ln(1 + A_g) ,$$

$$C = R_m \cdot \left(\frac{e}{n}\right)^n ,$$

Ag = the maximum uniform strain related to the ultimate tensile stress Rm and

e = the natural logarithmic constant.

9.3.4.4.3.2 The values Ag and Rm shall be determined through tensile tests.

9.3.4.4.3.3 If only the ultimate tensile stress Rm is available, for shipbuilding steel with a yield stress ReH of not more than 355 N/mm² the following approximation shall be used in order to obtain the Ag value from a known Rm [N/mm²] value:

$$A_g = \frac{1}{0.24 + 0.01395 \cdot R_m}$$

9.3.4.4.3.4 If the material properties from tensile tests are not available when starting the calculations, minimum values of A_g and R_m, as defined in the rules of the recognised classification society, shall be used instead. For shipbuilding steel with a yield stress higher than 355 N/mm² or materials other than shipbuilding steel, material properties shall be agreed upon with a recognised classification society.

9.3.4.4.4 *Rupture criteria*

9.3.4.4.4.1 The first rupture of an element in a FEA is defined by the failure strain value. If the calculated strain, such as plastic effective strain, principal strain or, for shell elements, the strain in the thickness direction of this element exceeds its defined failure strain value, the element shall be deleted from the FE model and the deformation energy in this element will no longer change in the following calculation steps.

9.3.4.4.4.2 The following formula shall be used for the calculation of rupture strain:

$$\varepsilon_f(l_e) = \varepsilon_g + \varepsilon_e \cdot \frac{t}{l_e}$$

where
ε_g = *uniform strain*
ε_e = *necking*
t = *plate thickness*
l_e = *individual element length.*

9.3.4.4.4.3 The values of uniform strain and the necking for shipbuilding steel with a yield stress R_{eH} of not more than 355 N/mm^2 shall be taken from the following table:

stress states	1–D	2–D
ε_g	0.079	0.056
ε_e	0.76	0.54
element type	truss beam	shell plate

9.3.4.4.4.4 Other ε_g and ε_e values taken from thickness measurements of exemplary damage cases and experiments may be used in agreement with the recognised classification society.

9.3.4.4.4.5 Other rupture criteria may be accepted by the recognised classification society if proof from adequate tests is provided.

9.3.4.4.4.6 *Tank vessel type G*

For a tank vessel type G the rupture criterion for the pressure tank shall be based on equivalent plastic strain. The value to be used while applying the rupture criterion shall be agreed upon with the recognised classification society. Equivalent plastic strains associated with compressions shall be ignored.

9.3.4.4.5 Calculation of the collision energy absorbing capacity

9.3.4.4.5.1 The collision energy absorbing capacity is the summation of internal energy (energy associated with deformation of structural elements) and friction energy.

The friction coefficient μ_c is defined as:

$$\mu_c = FD + (FS - FD) \cdot e^{-DC|v_{rel}|},$$

with FD = *0.1,*
FS = *0.3,*
DC = *0.01*
$|v_{rel}|$ = *relative friction velocity.*

NOTE: *Values are default for shipbuilding steel.*

9.3.4.4.5.2 The force penetration curves resulting from the FE model calculation shall be submitted to the recognised classification society.

9.3.4.4.5.3 *Tank vessel type G*

9.3.4.4.5.3.1 In order to obtain the total energy absorbing capacity of a tank vessel type G the energy absorbed through compression of the vapour during the collision shall be calculated.

9.3.4.4.5.3.2 The energy E absorbed by the vapour shall be calculated as follows:

$$E = \frac{p_1 \cdot V_1 - p_0 \cdot V_0}{1 - \gamma}$$

with:

γ 1.4

(Note: The value 1.4 is the default value c_p/c_v with, in principle:

c_p = specific heat at constant pressure [J/(kgK)]

c_v = specific heat at constant volume [J/(kgK)])

p_0 = pressure at start of compression [Pa]

p_1 = pressure at end of compression [Pa]

V_0 = volume at start of compression [m^3]

V_1 = volume at end of compression [m^3]

9.3.4.4.6 Definition of striking vessel and striking bow

9.3.4.4.6.1 At least two types of bow shapes of the striking vessel shall be used for calculating the collision energy absorbing capacities:

– bow shape I: pushed barge bow (see 9.3.4.4.8),

– bow shape II: V–shape bow without bulb (see 9.3.4.4.8).

9.3.4.4.6.2 Because in most collision cases the bow of the striking vessel shows only slight deformations compared to the side structure of the struck vessel, a striking bow will be defined as rigid. Only for special situations, where the struck vessel has an extremely strong side structure compared to the striking bow and the structural behaviour of the struck vessel is influenced by the plastic deformation of the striking bow, the striking bow shall be considered as deformable. In this case the structure of the striking bow should also be modelled. This shall be agreed upon with the recognised classification society.

9.3.4.4.7 Assumptions for collision cases

For the collision cases the following shall be assumed:

As collision angle between striking and struck vessel 90° shall be taken in case of a V–shaped bow and 55° in case of a pushed barge bow; and

The struck vessel has zero speed, while the striking vessel runs into the side of the struck ship with a constant speed of 10 m/s.

The collision velocity of 10 m/s is an assumed value to be used in the FE analysis.

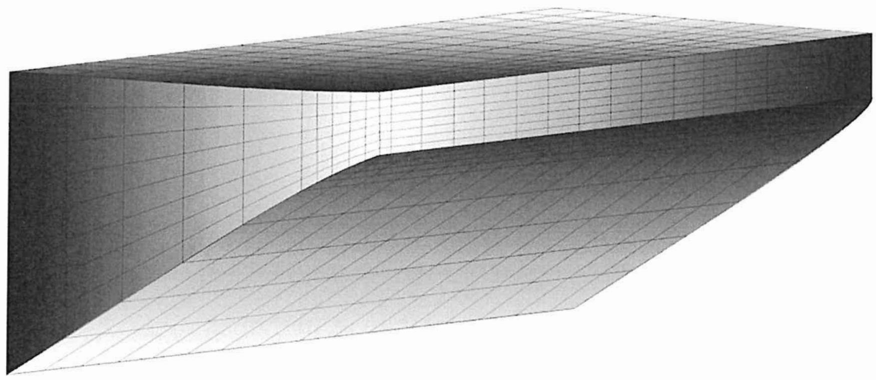
9.3.4.4.8 *Types of bow shapes*

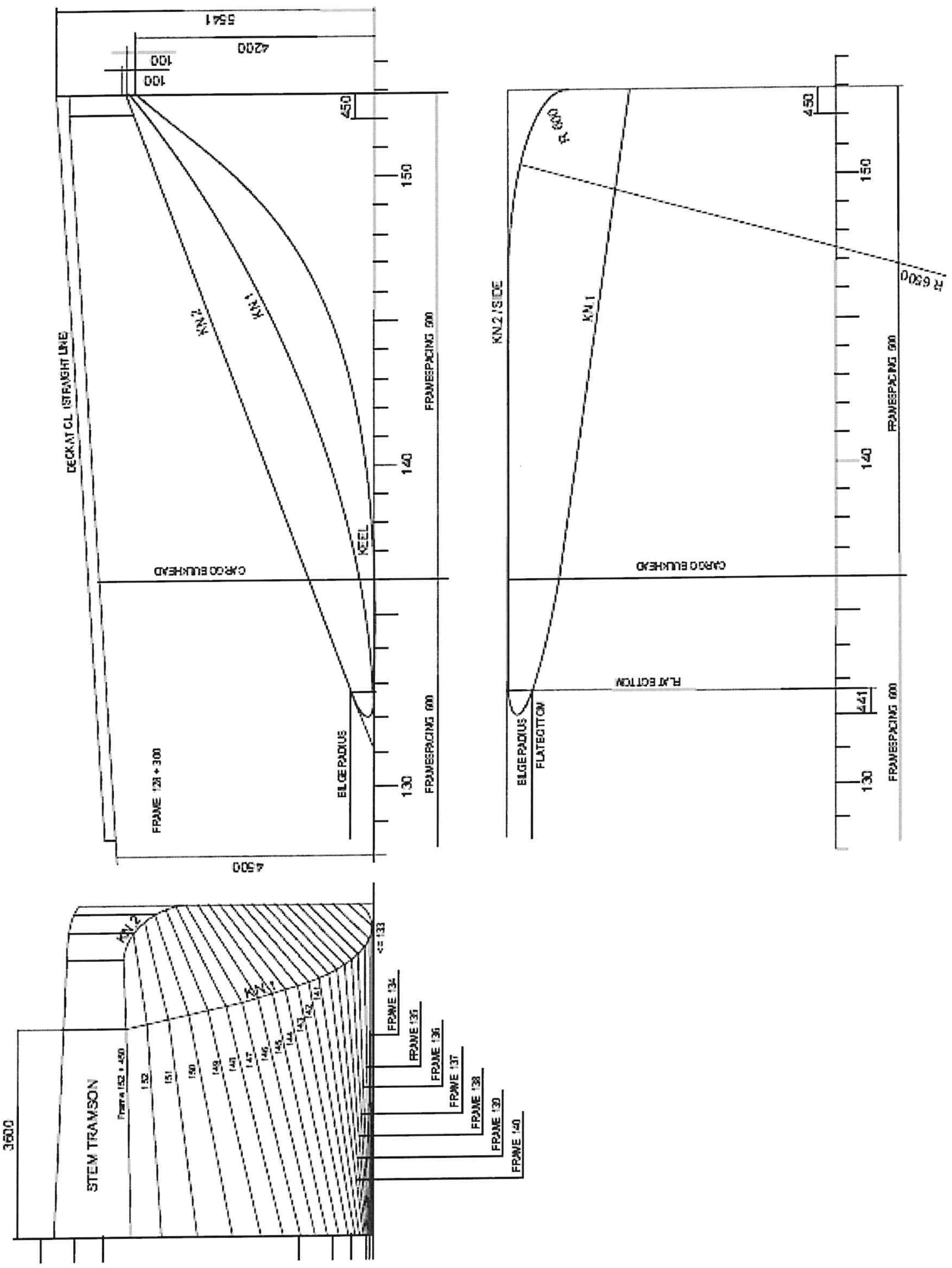
9.3.4.4.8.1 Pushed barge bow

Characteristic dimensions shall be taken from the table below:

	half breadths			heights			
fr	**Knuckle 1**	**Knuckle 2**	**deck**	**stem**	**Knuckle 1**	**Knuckle 2**	**deck**
145	4.173	5.730	5.730	0.769	1.773	2.882	5.084
146	4.100	5.730	5.730	0.993	2.022	3.074	5.116
147	4.028	5.730	5.730	1.255	2.289	3.266	5.149
148	3.955	5.711	5.711	1.559	2.576	3.449	5.181
149	3.883	5.653	5.653	1.932	2.883	3.621	5.214
150	3.810	5.555	5.555	2.435	3.212	3.797	5.246
151	3.738	5.415	5.415	3.043	3.536	3.987	5.278
152	3.665	5.230	5.230	3.652	3.939	4.185	5.315
transom	3.600	4.642	4.642	4.200	4.300	4.351	5.340

The following figures are intended to provide illustration.



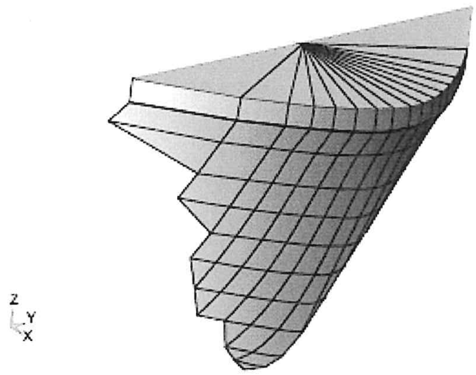

5541
4200
100
100
450
150
140
130
DECK AT CL (STRAIGHT LINE)
KN 2
KN 1
KEEL
CARGO BULKHEAD
FRAMESPACING 900
FRAMESPACING 600
BILGE RADIUS
FRAME 128 + 300
4500
R 600
R 6500
KN 2 / SIDE
FLAT BOTTOM
441
3600
STEM TRANSOM
Frame 152 + 450
FRAME 134
FRAME 135
FRAME 136
FRAME 137
FRAME 138
FRAME 139
FRAME 140
<= 133

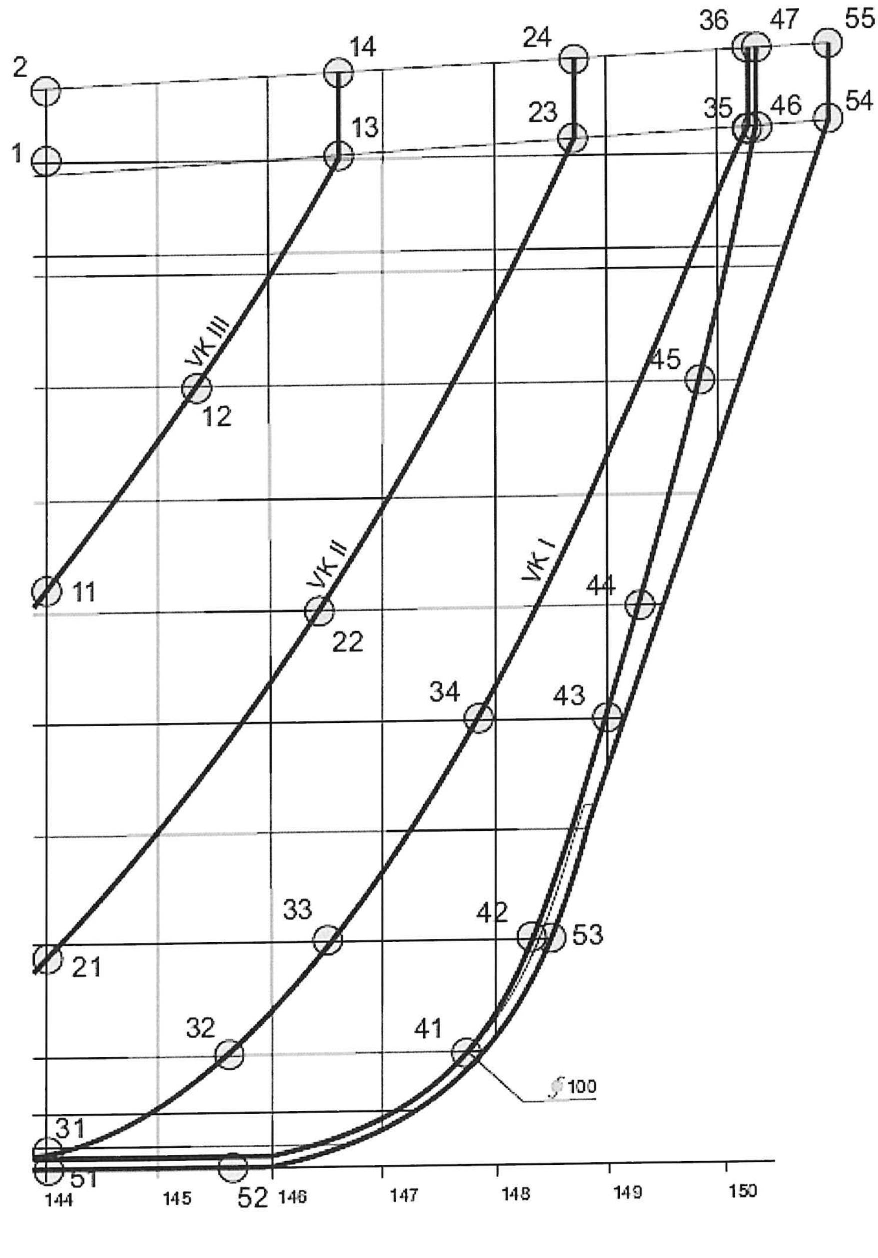
9.3.4.4.8.2 V–bow

Characteristic dimensions shall be taken from the table below:

Reference number	x	y	z
1	0.000	3.923	4.459
2	0.000	3.923	4.852
11	0.000	3.000	2.596
12	0.652	3.000	3.507
13	1.296	3.000	4.535
14	1.296	3.000	4.910
21	0.000	2.000	0.947
22	1.197	2.000	2.498
23	2.346	2.000	4.589
24	2.346	2.000	4.955
31	0.000	1.000	0.085
32	0.420	1.000	0.255
33	0.777	1.000	0.509
34	1.894	1.000	1.997
35	3.123	1.000	4.624
36	3.123	1.000	4.986
41	1.765	0.053	0.424
42	2.131	0.120	1.005
43	2.471	0.272	1.997
44	2.618	0.357	2.493
45	2.895	0.588	3.503
46	3.159	0.949	4.629
47	3.159	0.949	4.991
51	0.000	0.000	0.000
52	0.795	0.000	0.000
53	2.212	0.000	1.005
54	3.481	0.000	4.651
55	3.485	0.000	5.004

The following figures are intended to provide illustration.


Z
Y
X


2
14
24
36
47
55
1
13
23
35
46
54
VK III
12
45
11
VK II
VK I
44
22
34
43
33
42
53
21
32
41
∮100
31
51
52
144
145
146
147
148
149
150