REPORT

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Preliminary qualitative analysis for alternative design; light weight emergency generator structure on RO-RO ship

(1 appendix)

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1 Background

Flensburger Schiffbau-Gesellschaft (FSG) intend to design the emergency generator structure (referred to as “EmGen”) consisting of the emergency generator room itself and two adjacent rooms on deck 4 with steel frames and sandwich panel instead of today’s A0/A60 steel on a Ro-Ro ship. This ship will be referred to as “the Ship” in this report. The main difference introduced by the suggested design is that a non load-bearing, non-A class division material will be used in the free standing EmGen structure. The proposed sandwich panel will provide at least 60 minutes fire protection and is to a large extent made of non combustible matter. The scope of this report is to define fire hazards introduced by the new design, identify deviations from prescriptive requirements and defining trial alternative designs.

According to SOLAS Chapter II-2, Part F, Regulation 17 [1] an alternative design may be allowed provided that the design and arrangements meet the fire safety objectives and the functional requirements in SOLAS, Chapter II-2, Parts B, C, D, E or G. It is required that an engineering analysis shall be performed as described by the IMO MSC/Circ. 1002 [2].

Section 4.3.4 in IMO MSC/Circ. 1002 prescribes that an initial preliminary qualitative analysis is required that includes: the scope of the alternative design, the regulations which affect the design, possible fire scenarios, and the trial alternative designs. This analysis shall be approved by involved parties and sent to the appropriate administration for a formal approval before the quantitative analysis is started. This report contains the preliminary qualitative analysis.

2 Scope of the alternative design analysis

Current design with focus on the EmGen structure is explained and the alternative design is presented and discussed from a fire safety perspective.

2.1 The ship

An overview of the ship is given in Figure 1 below.

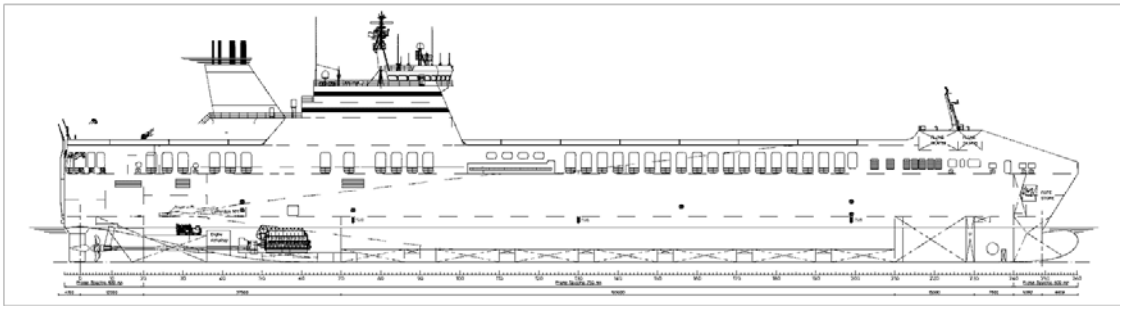

Figure 1. Lateral view of the Ship.

The EmGen structure is located at the stern of the ship on deck 4 as is indicated by the red box in figure 3 below.

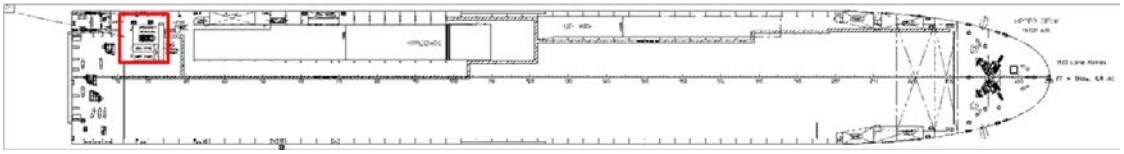

Figure 2. Deck 4 with the emergency generator structure

2.2 The emergency generator structure

A detailed view of the EmGen structure, containing emergency generator, deck store, paint store and fuel tank for the emergency generator, is presented in figure 4 and 5 below.

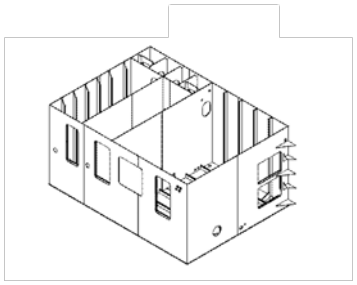

Figure 3. Emergency generator structure in the original steel design (top-down view)

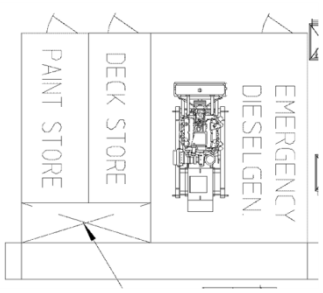

Figure 4. Emergency generator room with adjacent Deck and paint store from above

The emergency generator room and the paint store are equipped with a CO2 fire suppression system. The deck store has no fire suppression system, only local application from the outside can be applied for this room (by connecting a hose to a fire hydrant). The CO2 system must be released manually on the back wall of the room (outside). Adjacent area (the RO-RO deck) is equipped with sprinklers, but there are no sprinklers above the EmGen structure. Above the EmGen structure there is a free space of 900 mm below deck 5.

Fire detection is realised by smoke detectors connected in an alarm loop for all three rooms (one alarm for all three).

The emergency generator room is ventilated by fire flaps which only open when the generator is running.

All divisions in the prescriptive design are steel divisions (A0 - A60). The inner bulkhead (facing the deck store) one outer bulkhead, deck below and "roof" of the emergency generator room are A60 (60 minutes heat insulation to prevent fire spread). Other divisions are A0.

2.3 Definition of terms and concepts

Combustibility: A material is considered non-combustible only if it is passes the non-combustibility test (Part 1) according to the FTP code [3]. For sandwich panels used as building materials this is seldom the case since these materials generally contains a binder of some sort which will release enough energy when exposed to heat to fail the non-combustibility test.

A class divisions: According to SOLAS II-2, Reg. 3 A class divisions are those divisions formed by bulkheads and decks which comply with the following criteria:

1. they are constructed of steel or other equivalent material;
2. they are suitably stiffened;
3. they are insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any point, including any joint, rise more than 180°C above the original temperature, within the time listed below:
    a. Class A-60 60 min
    b. Class A-30 30 min
    c. Class A-15 15 min
    d. Class A-0 0 min
4. they are so constructed as to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test; and
5. the administration require a test of a prototype bulkhead or deck in accordance with the Fire Test Procedures Code to ensure that it meets the above requirements for integrity and temperature rise.

Sandwich panel: in this report, a "Sandwich panel" is a division constructed using a steel frame and a panel consisting of two metal laminates (typically steel) with a core of lightweight material, typically mineral wool. The sandwich panel is by definition considered combustible but it is not capable of producing a larger amount of energy and is typically classed A2-s1,d0 according to EN 13501-1:2007 which is the second most restrictive class for building materials. This means that the gross heat of combustion (PCS) < 4 MJ/m^2 and the total heat of combustion, (THR) < 7.5 MJ. Furthermore it prevents the spread of fire to adjacent spaces for at least 60 minutes (EI90 or EI120 according to EN 1364-1 : 1999-10 and EN 1363-1 : 1999-10). It is not known how well it prevents the passage of smoke.

2.4 Base design (alternative design)

The bulkheads and "roof" of the EmGen structure on deck 4 will be constructed using a sandwich panel as defined in section 2.3 instead of today's A0/A60 steel.

2.4.1 Fire protection of the base design

The fire safety organization and fire fighting routines on the ship will follow the requirements in SOLAS II-2. Also the fire protection systems and equipment will be in agreement with these requirements. Together with the above described sandwich panel design, this makes up the base design of the ship.

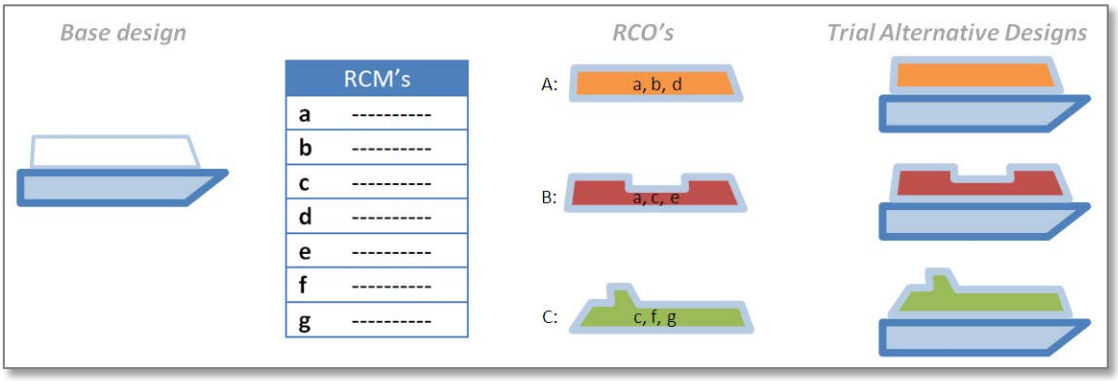

Figure 5 Illustration of the base design in relation to the trial alternative designs.

The base design might need additional risk control measures (RCM) in order to provide sufficient safety. A combination of risk control measures makes up a risk control option (RCO), which is applied to the base design in order to improve safety. Together with the base design different RCO's make up trial alternative designs, as illustrated in figure 6. A purpose with this report is to specify these trial alternative designs which will be subject to further analysis.

2.5 Affected fire safety regulations

When utilizing Regulation 17 it is possible to deviate from prescriptive fire safety requirements, but the functional requirements still need to be achieved. Compliance with the prescriptive requirements is, hence, only one way to meet the functional requirements, as stated in paragraph 6.3.2 in Circular 1002. Therefore paragraph 5.1.2 in Circular 1002 specifies that the regulations affecting the proposed alternative design and arrangements should be clearly understood and documented along with their functional requirements. It is interpreted[i] that the referred functional requirements that should be documented and achieved by the final alternative design are those listed along with the regulation objectives in the purpose statements at the beginning of each individual regulation in SOLAS II-2 (see figure 6)[ii]. The base design may thus deviate from both prescriptive requirements and regulation

[i] Comparing paragraphs 2.1, 4.3.4, 4.4, 5.1.2, 6.3.1 and 6.3.2 in Circular 1002 as well as SOLAS II-2 Regulations 2 and 17 makes it unclear as to if the fire safety objectives in SOLAS II-2/2.1, the functional requirements in SOLAS II-2/2.2 or the regulation objectives or functional requirements listed at the beginning of each individual regulation in SOLAS II-2 should be used to provide the basis when comparing safety levels.

[ii] For example, Regulation 5 in SOLAS II-2 has a purpose statement specified in SOLAS II-2/5.1. The first sentence expresses the regulations' objective: "...to limit the fire growth potential in every space of the ship." Thereafter follows three functional requirements in SOLAS II-2/5.1.1-3, that shall be achieved in order to realize the objective of this regulation. In the same way, Regulation 6 in SOLAS II-2 has a regulation objective expressed in the first sentence in SOLAS II-2/6.1: "...to reduce the hazard to life from smoke and toxic products generated during a fire in spaces where persons normally work or

functional requirements but the final alternative design must achieve the regulation functional requirements and, hence, the regulation objectives.

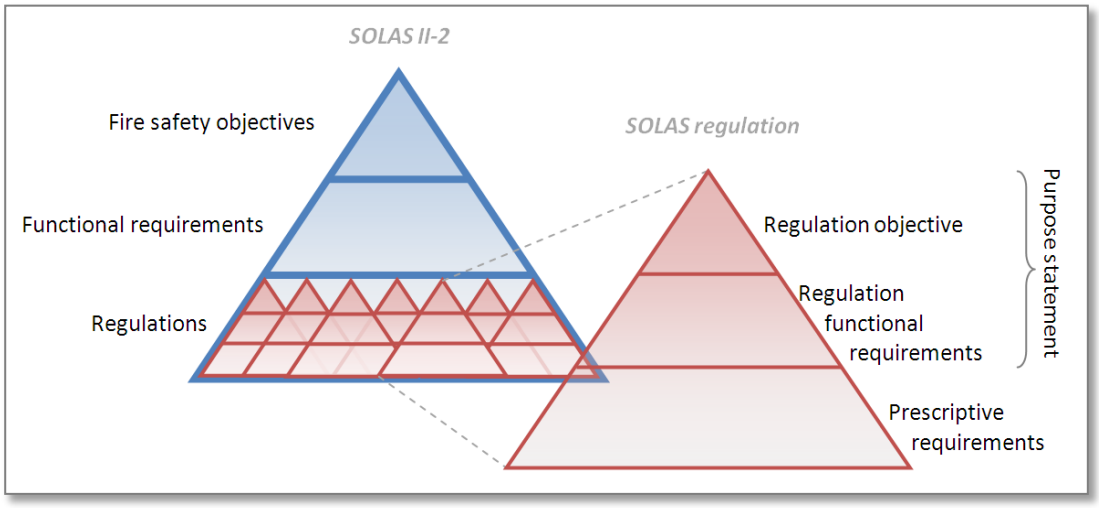

Figure 6 Each regulation in SOLAS II-2 consists of a purpose statement and prescriptive requirements. The purpose statement comprises regulation functional requirements and an individual regulation objective which sets out the purpose of the functional requirement

An evaluation of how the base design affects the fire safety regulations in SOLAS II-2 has been performed where the regulations have been divided according to above. The possibly challenged regulations and the specific deviations introduced by the base design are summarized in Table 1. Comments on compliance with regulation objectives, regulation functional requirements and the following prescriptive requirements of each regulation are also summarized. Further discussions on compliance with the fire safety regulations follow in the subsequent sections.

2.6 Regulations that affect the design

The scope of this project, constructing the EmGen structure on deck 4 using a sandwich panel instead of an A class division, constitutes a deviation from the requirement in SOLAS as the proposed sandwich panel do not meet the requirements for non-combustibility. The concerned regulations in SOLAS fire safety chapter (II-2) and the specific deviations induced by using a sandwich panel in the EmGen structure are listed in Table 1.

live." Thereafter follows the functional requirement specific for this regulation: "...the quantity of smoke and toxic products released from combustible materials, including surface finishes, during fire shall be limited." Each regulation in SOLAS II-2 has such purpose statements, where the regulation objective (RO) is defined and followed by regulation functional requirements (RFR) that shall be achieved in order to accomplish the objective.

Table 1 Non-compliance with SOLAS chapter II-2

SOLAS II-2 Part C	Regulation Objective (RO)	Regulation Functional Requirements (RFR)	Compliance and comment on how the base design affects the regulation
Reg. 9 Contain-ment of fire	Contain a fire in the space of origin	(1) Subdivide the ship by thermal and structural boundaries; (2) Boundaries shall have thermal insulation of due regard to the fire risk of the space and adjacent spaces; (3) The fire integrity of the divisions shall be maintained at openings and penetrations.	Compliance with RFR and RO but non-load-bearing walls and roof made in combustible material which is not tested for smoke containment deviates from the definition of A-class division[2] (see Reg. 9.2.2.1.1.1 and tables 9.1 and 9.2).
Reg. 11 Structural integrity	Maintain structural integrity of the ship, preventing partial or whole collapse of the ship structures due to strength deterio-ration by heat.	Materials used in the ships' structure shall ensure that the structural integrity is not degraded due to fire.	Not applicable since the generator housing is not defined as hull, superstructure, structural bulkhead, deck or deckhouse.

As can be seen from Table 1, the critical regulation concerning this design is regulation 9.

The alternative design comply with all regulations in SOLAS but Regulation 9. In regulation 9 the functional requirements and regulation objectives are fulfilled (the sandwich panel contain a fire for 60 minutes), however the sandwich panel is not tested according to SOLAS and may, to some extent, be combustible and it is thus not regarded to be an equivalent material to steel.

2.7 Additional regulation and fire analyses

The individual regulations were analyzed above, but in order to attain also the objectives and functional requirements, not fully embodied in the prescriptive requirements, the change from an A class division to sandwich panel is evaluated also through Regulation 2, which is meant to originate the following regulations.

2.7.1 The fire safety objectives and functional requirements

The fire safety objectives and functional requirements in SOLAS II-2/2 highlight the purpose of the whole fire safety chapter in SOLAS. They are thereby the framework for the following regulations, each with its own purpose statement. From Circular 1002 it can be interpreted that only these purpose statements should be used as functional requirements for an alternative design and arrangements. However, since this is unclear and due to the high degree of innovation in the base design, also the fire safety objectives and functional requirements have been evaluated.

Many of the fire safety objectives are clearly represented in functional requirements and prescriptive requirements but others are not as evident. The effects on fire safety will therefore be evaluated through a consideration of how the base design challenges the fire safety objectives and functional requirements, respectively. It also needs to be clear if the design changes will affect one or several parts, since this will influence the needs for verification.

2.7.2 Fire safety objectives

Using a sandwich panel instead of an A class division will likely affect some of the fire safety objectives. Comments concerning each fire safety objective are summarized in Table 2 and discussed below.

Table 2. A summary of the fire safety objectives in SOLAS II-2/2.1 and comments on how they are affected by the base design

The fire safety objectives in SOLAS II-2/2	Will the objective be affected?
.1 prevent the occurrence of fire and explosion;	Compliance in the same way as in a prescriptive design.
.2 reduce the risk to life caused by fire;	This objective will be affected and it is the scope of this and following analysis to ensure this objective is met
.3 reduce the risk of damage caused by fire to the ship, its cargo and the environment;	This objective will be affected similar to the above.
.4 contain, control and suppress fire and explosion in the compartment of origin; and	New structure is believed to increase the containment and control of a fire
.5 provide adequate and readily accessible means of escape for passengers and crew.	The base design will imply improved conditions for escape within the first 60 minutes.

The use of spaces and its related activities and interiors will be governed by prescriptive requirements. As a result, there will be no differences affecting the first objective. The same goes for the last objective, except that the novel design might improve the conditions in adjacent spaces during an escape.

The fourth objective insists on containing, controlling and suppressing a fire in the space of origin. This objective will most likely be achieved at least as well as by prescriptive design. The base design could also imply improvements[iii] which could be beneficial to verify.

The greatest needs for verification tend to appear in the second and third fire safety objectives. These objectives insist on reducing the risk to life, property and environment. Whilst acceptance criteria for risk to property are typically set by shipping companies, criteria for the environment and risk to life should be set by authorities.

[iii] Improved insulation might reduce the risk of fire propagation to surrounding spaces e.g. the surrounding ro-ro deck.

2.7.3 Functional requirements

In order to achieve the fire safety objectives set out in Table2, the functional requirements in Table 3 have been embodied in the regulations of SOLAS II-2. The change from an A class division to a sandwich panel will be viewed through the functional requirements in order to identify relevant differences and needs for verification. Comments concerning each functional requirement are summarized in Table 3 and discussed below.

Table 3. A summary of the functional requirements in SOLAS II-2/2.2 and comments on how they are affected by the sandwich panel design

The functional requirements in SOLAS II-2/2	Comment
.1 division of the ship into main vertical and horizontal zones by thermal and structural boundaries;	Not applicable, the EmGen structure do not constitute a main vertical or horizontal zone
.2 separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries;	Not applicable
.3 restricted use of combustible materials;	Combustible materials will be added but as a general rule not unprotected. The effects from having a sandwich panel in the structure although needs to be verified.
.4 detection of any fire in the zone of origin;	The novel design will not affect this requirement.
.5 containment and extinction of any fire in the space of origin;	The improved thermal insulation capacity implies the containment and extinction of fires will be affected, probably in a positive way.
.6 protection of means of escape and access for fire fighting;	The protection of escape routes and access for fire fighting will not be negatively affected by this minor change
.7 ready availability of fire-extinguishing appliances; and	The novel design will not affect this requirement.
.8 minimization of possibility of ignition of flammable cargo vapour.	The novel design will not affect this requirement.

The review of SOLAS II-2/2.2 enlightened some areas that will be affected by a change from an A class division to sandwich panel. The first and the second functional requirements concern the division of a ship and the separation of spaces. Differences in behaviour between an A class division and sandwich panel boundaries will affect these regulations and are therefore necessary to identify. The third functional requirement makes the usage of combustible materials topical. It invokes an evaluation of the effects from using combustible materials beyond what is permitted in prescriptive requirements. As a general rule there should not be any unprotected combustible materials added. Functional requirements five and six will be affected in similar ways as the first and second requirements. Depending on the properties of the novel material there will be effects when it comes to containment and extinction of the fire as well as the protection from and access to the fire. These and the above effects on functional requirements indicate some important needs for verification that ought to be targeted when evaluating the novel design.

3 The design team

The IMO MSC/CIRC 1002 prescribes a design team to be put together that will be responsible for the analysis and for co-ordinating the activities with regards to handling of SOLAS regulation 17. This team should mirror the complexity of the task. The selected team for the project consists of the following persons:

Table 4 The design team

	Name	Organisation	Competence
1	Markus Brinkmann	FSG	Naval architect manager steel design
2	Markus Meyendrisch	MW	Naval architect
3	Thomas Thon	RC	Composite structure production
4	Marcel Elenbaas	DSNS	Shipyard representative and composites
5	Erwan Juin	Center of Marine Technologies	Lightweight structures, FE analysis
6	Kristoffer Brinchmann	DNV	Composite structures, risk analysis and FE analysis
7	Philippe Noury	DNV	Composite structures, risk analysis and Maritime regulations
8	Tommy Hertzberg	SP Fire Technology	Coordinator and contact person. Fire technology, especially composite materials and fire protection at sea.
9	Michael Rahm	SP Fire Technology	Fire technology, risk analysis
10	Franz Evegren	SP Fire Technology	Fire technology, risk analysis
11	Jonatan Hugosson	SP Fire Technology	Fire technology, risk analysis
12	David Mattsson	Swerea/Sicomp	Mechanical properties
13	Luis Felipe Sanchez Heres	CTH	Mechanical properties
14	Jonas Ringsberg	CTH	Mechanical properties
15	Sven-Erik Hellbratt	KAB	Naval architect and WP coordinator
16	Henrik Johansson	KAB	Naval architect, composite structures

4 Development of fire scenarios

The proposed alternative design affects a small part of the ship. On some surfaces the fire resistance will be increased compared with the current design while on some surfaces the fire resistance will be about the same. The resistance to smoke may be decreased as smoke leakage in the joints between the panel sections could be more likely to occur, however only to a certain limit since it is tested for 60 minutes fire resistance.

4.1 Identification of fire hazards

In a workshop held at SP in March 2010, the design team met to discuss the specific fire hazards introduced by the new design. The result is presented in the list below which contain information about pre-fire situation, ignition sources, initial fuel, eventual secondary fuels, critical factors, for example. Also the location and extension potential of the fire hazard is classified as local if the fire is limited to a specific area; as major if the fire has a medium affect zone but still limited to the boundaries of the Ship and catastrophic if the fire spread from the Ship as defined in SOLAS. The fire hazard identification is presented in appendix 1. The locations discussed are:

1. Emergency generator room, sources for ignition include hot surfaces and oil spill, furthermore there is diesel for fuel. This fire hazard is estimated as local or major.

2. Deck store, situated next to the emergency generator room separated by a sandwich panel wall. Inside there may be combustible material such as ropes and clothes but no material that may self ignite or explode. This fire hazard is estimated as local.

3. Paint store, situated next to the deck store. Stored here there may be paint and various flammable liquids. Sources of ignition include chemical reaction and electrical failure. This fire hazard is estimated as local or major.

4. Surrounding areas are placed on deck 4 (and 5 above). Mainly trailers and cars are stored here. This fire hazard is estimated to be major in order to affect the EmGen structure.

5. Deck 3 (below). The analysis of a fire on deck 3 (A class division) is not introducing any new threats as the floor of the EmGen structure still is made out of steel. The fire hazard is estimated as major in order to affect the EmGen structure.

4.2 Emergency generator functional analysis from a fire perspective

Only if the main generator is not working will the emergency generator be of any (perhaps vital!) importance. If a fire starts at deck 4 and the main generator is working, from a fire perspective the EmGen structure is of negliable importance considering all the trailers filled with cargo on deck 4.

4.3 Selection of design fire

In Appendix 1 the fire hazard identification is presented in detail. Based on this analysis one design fire was chosen: Flash-over fire in the emergency generator room.

The aim is that the design fire captures the differences between the novel and prescriptive design. Furthermore as a worst plausible scenario it should include other less severe hazards and hazard locations. For example a fire in the deck store is less severe than a fire in the paint store which in turn is less severe than a fire in the emergency generator room. A fire starting outside, next to the EmGen structure will have to penetrate the same division as a fire inside. A fire outside the EmGen structure is likely to be very severe including several trucks before

risking to penetrate the EmGen divisions, for this scenario the Affect of the EmGen structure on the fire and overall safety is negligible (except for the fact that it may provide emergency electricity for the ship but as stated before a 60 minutes fire resistance is provided in line with, or better, than prescriptive requirements). For the reasons stated above, a flash-over fire in the Emergency generator room itself is chosen as design fire. In many ways it captures the characteristics of the plausible design fire locations stated above.

Furthermore, a fire in the deck and paint store is judged not to be affected negatively by the new design since the walls now provide 60 minutes fire resistance, and likely it would be extinguished or self extinguished during these 60 minutes due to lack of oxygen.

The fire in the emergency generator room may spread from adjacent spaces or start in the emergency generator room itself. In order for the fire to develop to a flash-over fire door or ventilation hatches need to be open and suppression system fail. If door and ventilation hatches are closed the fire is expected to self extinguish and not affect surrounding areas. If the fire suppression system (manually activated CO2) is working it is expected to extinguish the fire.

Table 5 Emergency generator fire scenario details

Fire hazard	Value
Ignition source:	Battery box Hot surfaces on engine Electrical failure; lighting, transformers, land power connection, battery charger Human error Arson Fire spread from surrounding areas
Initial fuel:	Diesel fuel Cables Dust Garbage, clothes etc
Secondary fuels:	Rubber mat Plastic material in switchboard Diesel fuel Wall paint (surface lining)
Extension potentials:	Fire spread to surrounding area Fire spread to the deck store Fire spread to fuel tank Smoke spread to adjacent spaces
Target locations:	Outer surfaces and panel joints to the deck below Structural integrity Ventilation control Smoke containment / management
Critical factors:	Door closed Ventilation hatches closed Fire/smoke detection Active fire fighting system Smoke integrity

4.3.1 Positive and negative characteristics introduced by the novel design

During the Hazard identification meeting and the whole process a list has been updated containing the pros and cons for the base design. The aim is that all pros and cons are captured by the design fire and quantified in the qualitative analysis. For pros and cons not being captured a separate analysis will be performed.

Table 6 Pros and cons introduced by the base design

Pros	Cons	Covered by design fire
60 minutes fire protection		Yes
	Combustible material added	Yes
	Possibly not leak tight / smoke tight	Yes

5 Trial alternative designs

The alternative design consists of a substantially improved fire protection compared to the requirements for ships built according to the prescriptive rules. This extended fire protection may consist of one or a combination of the following risk control measures (RCM):

1. Sandwich panel providing 60, 90 or 120 minutes fire resistance and containment
2. Surface of the panel improving reaction to fire properties
3. Automatic surveillance of closed/open doors
4. Smoke extraction system

6 Performance criteria

According to MSC/Circ.1002 performance criteria shall be defined in the quantitative analysis. Below a suggested performance criteria is presented and the final selection will be done in the quantitative analysis.

6.1 Performance criteria

Given the design fire development, the hazard identification and identified deviations from prescriptive requirements, the alternative design (constructing the EmGen structure with a sandwich panel) will be judged at least as safe as a prescriptive design if it fulfils all of the following criteria:

1. At least 60 minutes fire containment
2. Negligible smoke leakage affecting personal safety
3. For plausible flash-over fires in the emergency generator room, the added combustible material is negligible (< 5%).
4. The Sandwich panel does not contribute to the development of a fire compared with a painted steel wall.

7 Discussion and conclusions

This report contains the preliminary analysis for handling of SOLAS Regulation 17 as described by the IMO/Circ 1002.

Five different types of fire hazards have been identified and described, based on a work shop held by a designated design team of 13 professionals covering critical aspects and knowledge necessary for the task. It has been concluded by the design team that the trial design have an advantage through providing a 60 minutes fire resistance and fire containment. A disadvantage is that the sandwich panel is not an A-class division, but it is classed “A2-s0,d1” for building materials which is the second highest class for building materials. Additional safety measures to ensure safety may be the use of 90 or 120 minutes fire resistance, use of interior wall covering decreasing the fire development or the installation of automatic door surveillance.

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Appendices
A. Fire hazard analysis

[1] SOLAS, *Consolidated text of the International Convention for the Safety of Life at Sea, 1974, and its Protocol of 1988: articles, annexes and certificates*, Consolidated Edition, IMO, 2004.

[2] MSC/Circ.1002, *Guidelines on alternative design and arrangements for fire safety*, IMO, 2001.

[3]FTP Code, International Code for Aplication of Fire Test Proceedures, IMO, 1998.

Appendix A. Fire hazard analysis

	FIRE HAZARDS							
room/pre-fire situation	ignition source	initial fuel	stat/freq	secondary fuels	extension potentials	target locations	critical factors	Fire hazard enumeration
Generator room	Battery box	Diesel fuel		Rubbet mat	Fire spread to surrounding area	Outer surfaces and panel joints to the deck below	Door closed	Local or major (major if fire is spread to trailer etc outside of gen. room)
	Hot surfaces on engine	Cables		Plastic material in swichboard	Fire spread to the deck store	Structural integrity	Ventilation hatches closed	
	Electrical failure; lighting, transformers, land power connection, battery charger	Dust		Diesel fuel	Fire spread to deck above	Ventilation control	Fire/smoke detection	
	Human error	Garbage, clothes etc		Wall paint (surface lining)	Fire spread to fuel tank	Smoke containment / management	Active fire fighting system	
	Arson				Smoke spread to adjacent spaces		Smoke integrity	
	Fire spread from surrounding areas							
Deck store	Electrical failure	Clothes, ropes, etc		Clothes, ropes, etc	Fire spread to surrounding area	Outer surfaces and panel joints to the deck below	Door closed	Local or major (major if fire is spread to trailer etc outside of gen. room)
	Arson			Wall paint (surface lining)	Fire spread to paint room	Structural integrity	Fire/smoke detection?	
	Fire spread from surrounding areas				Fire spread to fuel tank	Ventilation control	Active fire fighting system	
	Human error				Fire spread to emergency generator room			
					Fire spread to deck above			
Paint store	Chemical reaction	Paint, thinners etc		Paint, thinners etc	Fire spread to surrounding area	Outer surfaces and panel joints to the deck below	Door closed	Local or major (major if fire is spread to trailer etc outside of gen. room)
	Electrical failure	Soaked clothes ets		Soaked clothes ets	Fire spread to Deck store	Structural integrity	Fire/smoke detection?	
	Arson			Wall paint	Fire spread to fuel tank	Ventilation control	Active fire fighting system	
	Fire spread from surrounding areas				Fire spread to deck above			
	Human error							
Surrounding areas	Trailer fire	N/A		Trailer (tires, plastic covers, cargo etc)	Fire spread to paint room	Outer surfaces and panel joints to the deck below	Fire/smoke detection?	Local or major
	Electrical failure				Fire spread to fuel tank	Structural integrity	Active fire fighting system	
	Arson							
	Fire spread from surrounding areas							
	Human error							
Deck below	Trailer fire	N/A		Trailer (tires, plastic covers, cargo etc)	Fire spread to surrounding area	Outer surfaces and panel joints to the deck below	Fire/smoke detection?	Local or major
	Electrical failure				Fire spread to emergency generator room	Structural integrity	Active fire fighting system	
	Arson				Fire spread to the deck store			
	Fire spread from surrounding areas				Fire spread to paint room			
	Human error				Fire spread to fuel tank			