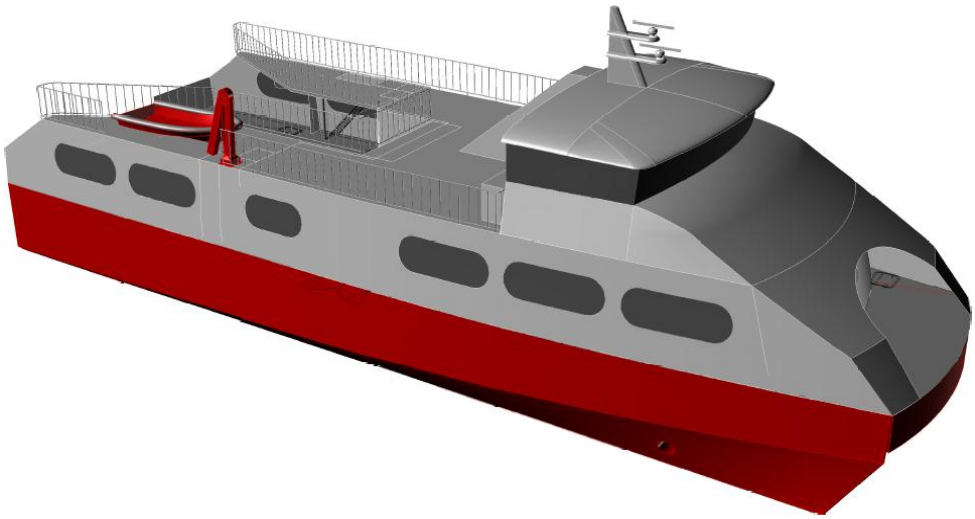
Preliminary study of the Øko-Ø-færge project

Malika Piku Amen
Franz Evegren

SP Technical Research Institute of Sweden



Fire Technology

SP Report 2012:03

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Abstract

In this study, national, European and international regulations for ship fire safety have been investigated to comprehend how these should be managed when aspiring to build island ferries in plastic composite in Sweden and Denmark. There is an opening to build ferries in plastic composite using the possibility for alternative fire safety design and arrangements, which exists in various forms in the regulations. A comparison was made between the fire safety requirements in SOLAS chapter II-2 and the European passenger directive 2002/25/EC as amended. It showed that these two directives fundamentally overlap. It was hence shown that it is possible to refer to SOLAS regulations when performing an assessment for alternative fire safety design and arrangements, both through the European directive and the national regulations of Sweden and Denmark since the latter refer to the European directive.

An investigation was also carried out to estimate the market and economic potential for ferries in plastic composite in Sweden and Denmark. A survey, responded to by ship operators, indicates great potential for building ships in plastic composite and significant economical savings potential in the long run by a change from conventional steel to plastic composite.

Key words: Plastic composite, island ferry, fire safety regulations

SP Sveriges Tekniska Forskningsinstitut
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Preface

The objective with this report is to get a further understanding of the potential and hindrances for building ships in plastic composite. National and international fire safety regulations necessary to take into concern when building passenger ships in plastic composite have been elucidated. The reader is thereby meant to get an overview of how the European fire safety regulations deviate from the international SOLAS regulations and how these regulations are affected when a ship is built in plastic composite instead of in conventional steel. This is an important first step to comprehend carrying out a fire safety assessment of a ship built in plastic composite. The work will hence be used as basis for the first part of a fire safety assessment in the Øko-Ø-færge project, where a Danish passenger ship in steel has been redesigned in plastic composite. A market investigation is also presented in the report to show if there is a potential market to build ships in plastic composite material in Sweden and Denmark.

Summary

Regulations for fire safety on passenger ships have conventionally been developed for steel ships. It was not until 2002, when a regulation for alternative fire safety design and arrangements was introduced in the international SOLAS regulations, that an opening was provided to build ships in other materials than steel, provided that the same level of fire safety could be proved. In this study, national, European and international regulations for ship fire safety have been investigated to comprehend how these should be managed when aspiring to build island ferries in plastic composite in Sweden and Denmark. The opening to build ferries in plastic composite, using the possibility to claim it's an alternative fire safety design and arrangements, exists in various forms in the regulations. A comparison was made between the fire safety requirements in SOLAS chapter II-2 and the European passenger directive 2002/25/EC as amended. It showed that these two directives fundamentally overlap. Some minor differences exist between the requirements in the European regulations and the international SOLAS regulations regarding fire safety but the former are fully based on and continuously updated in line with latter. It was hence shown that it is possible to refer to SOLAS regulations when performing an assessment for alternative fire safety design and arrangements, both through the European directive and the national regulations of Sweden and Denmark since these refer to the European directive. Furthermore, in comparison European and national regulations the structure in SOLAS was concluded far more suitable when performing a fire safety assessment of an alternative design and arrangements and will therefore be used in future evaluations of fire safety.

An investigation was also carried out to estimate the potential market and the economic potential for ferries in plastic composite in Sweden and Denmark, which is a difficult task due to validity and reliability uncertainties. A survey sent out to Swedish ship operators was responded to by a third of the recipients. The results show that about 80% of the ships are older than 20 years and that the fuel and maintenance costs correspond to an averaged total of 20%, and up to 45%, of the overall turnover. Regarding a question about whether the ship operators had considered to build ships in plastic composite only 17% of the ship operators had considered building in plastic composite and some of the answers revealed a firm and sceptical view of this relatively new material. Among the arguments about why plastic composite had not been considered as an alternative were environmental circumstances, such as that the weather conditions would not be suitable for a plastic composite material, narrow paths, regulations and economy. In conclusion, the results from the market survey indicate great potential for building ships in plastic composite and significant economical savings potential in the long run by a change from conventional steel to plastic composite. To increase the usage of plastic composite in ship building, knowledge should be spread regarding how regulations can be handled, the economic potential as well as of the properties of the material, such as durability. This will be investigated in greater detail throughout the continuation of the Øko-Ø-færge project.

1 Background

It was after a kick off meeting in the EU project MARKIS in 2010 with the headline "Light Weight Marine structures" that an industrial group in North Jutland, Denmark and SP Technical Research Institute of Sweden started to discuss production of ecological displacement ferries. This led to a Swedish-Danish consortium with the objective to open up for the construction of this type of ferry in the Swedish and Danish region. The project was given the name "Øko-Ø-færge" and a project group was formed consisting of naval architects from Sweden and Denmark, university representatives and specialists from research institutes. A project plan was drawn up for the project, were a full fire safety assessment according to SOLAS chapter II-2 Regulation 17 as well as LCC and LCA assessments were planned. An application was also sent to Västra Götalandsregionen in Sweden for financial support of a preliminary study, which is presented in this report.

2 Plastic composite for light weight ferries

Displacement ferries are traditionally made in steel or aluminium. In later years another material, plastic composite, has become an attractive alternative material in ship building. The largest benefit with using plastic composite is the possibility to reduce weight, as the material has a very high specific strength and E-modulus. Another benefit is e.g. the design freedom, as it is possible to make advanced geometries at an acceptable cost. The reduction in weight reduces fuel costs and in comparison to steel the material is not prone to corrosion, which reduces the maintenance costs for the ship operator, as illustrated in figure 1. The Swedish mine sweeping ship VIKSTEN was for instance built in plastic composite in 1974 and sections that have been cut out from this ship have shown that the ship has been very resistant towards degradation[1]. Another positive example of using plastic composite in ship building has been emphasized in the project "Tank Light Module", where it was shown that the weight of a superstructure on a tanker could be reduced by 50% by changing from steel to plastic composite and that the payback time for the new superstructure is 5-7 years [2].

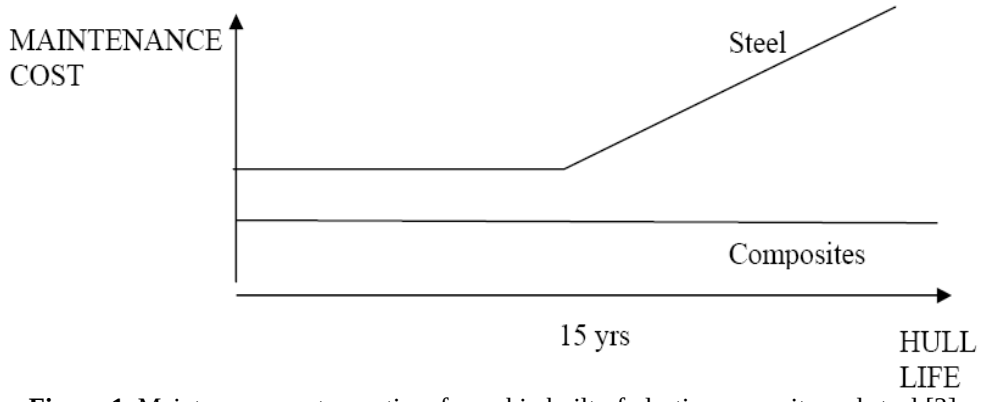

Figure 1. Maintenance cost over time for a ship built of plastic composite and steel [3].

Although the many advantages with building in plastic composite, some obstacles have prevented the usage of plastic composite in ship building, for instance limited knowledge of the relatively new material and how to design with it as well as limited knowledge of how to handle regulations regarding fire safety [1]. The conventional way of designing fire safety for displacement ferries has been to follow the prescriptive rules in SOLAS chapter II-2. However, as structural bulkheads and decks are stipulated to be built of steel or equivalent material, the ordinary procedure for evaluating fire safety cannot be used for ferries in plastic composite. In 2002 an opening was introduced for alternative design and arrangements through SOLAS chapter II-2 Regulation 17 (hereafter referred to as Regulation 17). The methodology of how to assess and demonstrate safety according to Regulation 17 is described in more detail in chapter 4 of this report.

3 Reference object

The reference case selected for this project is *Tunøfærgen* (or *the Tun island ferry* in English) which is a Ro-pax ferry class D from 1993, designed to carry about 6 cars and 200 passengers (IMO number 9107875). It is 30.5 meters in length, which is also the length of the newly designed ecological island ferry with the same capacity (hereafter referred to as the Øko-Ø-færge). The two ferries are shown in figure 2 below.

Figure 2. The present Tun island ferry to the left and the Øko-Ø-færge to the right [3].

The Tun island ferry is a displacement ferry with a speed of 9.5 knots and the Øko-Ø-færge is designed to keep the same speed. Its route is between Hov and Tunø in Denmark and the number of passengers using the ship each year is approximately 50 000. Some further comparative data is given in table 1 for the Tun island ferry, built in steel, and the future light weight Øko-Ø-færge designed in plastic composite [3].

Table 1. Weight specifications for the reference object, the Tun island ferry, and the Øko-Ø-færge

Weight item	***Tun island ferry [kg]***	***Øko-Ø-færge [kg]***
Lightweight*	250 000	77 168
Ballast	33 900	0
Fuel	18 800	10 100
Stores	1 000	1 000
Passengers	15 000	15 000
Crew	225	225
Luggage	2 000	2 000
Cars	16 000	160 00
Deck cargo	3 075	3 075
Displacement**	**340 000**	**124 568**

* The lightweight is a nautical term for the displacement of a ship (normally given in tonnes but here given in kg) without cargo, fuel, lubricating oil, ballast water, consumable stores as well as passengers, crew and their effects.
** Displacement is a nautical term for the total weight of a ship.

4 Regulations

The international, European and national regulations applicable to the Øko-Ø-færge have been scrutinized. A comparison was made between the fire safety regulations in SOLAS chapter II-2 and the European passenger directive 2002/25/EC, as amended, to see if these two directives overlap. This was done since a fire safety assessment of an alternative design and arrangements according to both regulations should be based on Regulation 17 in SOLAS. Hence, if the regulations essentially overlap, the fire safety assessment can be fully based on the SOLAS regulations.

4.1 Regulations at international level

The International Maritime Organization is a specialized agency of the United Nations that regulates safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping through international conventions. One of the most important directives for merchant ships on international waters is SOLAS (Safety of Life At Sea), adopted in 1929. The convention has latest revised in 1974 and is with its updates and amendments still the regulation of practice. SOLAS consists of twelve chapters comprising issues such as construction, life-saving appliances, safety of navigation and other measures for maritime safety. Fire safety has always been of great concern on merchant ships, which is covered by chapter II-2, describing fire protection, detection and extinction. The objectives of this chapter are the following:

1. prevent the occurrence of fire and explosion;
2. reduce the risk to life caused by fire;
3. reduce the risk of damage caused by fire to the ship, its cargo and environment;
4. contain, control and suppress fire and explosion in the compartment of origin; and
5. provide adequate and readily accessible means of escape for passengers and crew.

In order to fulfil the fire safety objectives, the following (overall) functional requirements are embedded in the following prescriptive regulations:

1. division of the ship into vertical and horizontal zones by thermal and structural boundaries;
2. separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries;
3. restricted use of combustible materials;
4. detection of any fire in the zone of origin;
5. containment and extinction of any fire in the space of origin;
6. protection of means of escape and access for fire fighting;
7. ready availability of fire-extinguishing appliances; and
8. minimization of possibility of ignition of flammable cargo vapour.

Both the fire safety objectives and the functional requirements have to be fulfilled.
This can be done either by:

- fulfilling the prescriptive requirement specified in the following chapters B, C, D, E and G in SOLAS; or
- demonstrating, in line with part F - Regulation 17, that an alternative design and arrangements is at least as safe as if it would have been designed according to prescriptive requirements [4].

An analysis according to Regulation 17 is appropriate when a ship is built in plastic composite since prescriptive rules require structural decks and bulkheads to be built in steel or other equivalent, i.e. non-combustible[i], material. The overall fire safety objectives and the functional requirements of the fire safety chapter still have to be fulfilled by the alternative design and arrangements. A guideline for how the engineering analysis should be carried out when laying claim to Regulation 17 is provided in MSC/Circ.1002 [5]. According to MSC/Circ.1002 (hereafter referred to as Circular 1002), regulations affecting the proposed alternative design and arrangements should be clearly understood and documented, both overall objectives and functional requirements as well as prescriptive requirements given in parts B, C, D, E and G [5].

The methodology for the engineering analysis required by Regulation 17 is further outlined in Circular 1002 as a two-step risk assessment. In the first step, an assembled design team is to define the scope of the analysis, identify hazards and develop design fire scenarios, which altogether needs to have a preliminary approval. This documents the requirements for the next step of the analysis, where the design fire scenarios are to be quantified and the outcomes compared with explicit criteria in SOLAS II-2 or criteria derived from a prescriptive reference design. The design team should consist in the owner, builder and designer as well as experts with the necessary knowledge and experience in fire safety, design and operation. For example operators, marine surveyors, and equipment manufacturers may also be required, depending on the alternative design and arrangements.

4.2 Regulations at European level

The latest European directive is 2010/36/EC (also called 2002/25/EC as amended in the following chapters) and regulations connected to fire safety are described in chapter II-2, fire protection, fire detection and fire extinction in the this directive. The fire safety chapter in the EU 2010/36/EC regulation is divided into chapter A Basic principles and chapter B Fire safety measures. The first part of chapter A describes the fire safety objectives which are exactly the same as those found in Regulation 2 in SOLAS chapter II-2. The fire safety objectives are followed by functional requirements which also are the same as those found in SOLAS chapter II-2.

The fire safety objectives and the functional requirements set out in the European directive can be achieved if:

1. the ship's design and arrangements, as a whole, comply with the relevant prescriptive requirements in this chapter;
2. the ship's design and arrangements, as a whole , have been reviewed and approved in accordance with part F of the revised chapter II-2 in SOLAS 1974, which applies to ships constructed on or after 1 January 2003; or
3. parts of the ship's design and arrangements have been reviewed and approved in accordance with the above mentioned part F of the revised SOLAS chapter II-2 and the remaining parts of the ship comply with relevant prescriptive requirements of the fire safety chapter in EU directive 2010/36/EU.

[i] Steel or other equivalent material means any non-combustible material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g. aluminium alloy with appropriate insulation). Plastic composite in itself is combustible (i.e. most likely to give off flammable vapours in sufficient quantity when heated to 750°C).

The European directive is continuously updated based on the SOLAS regulations. The fire safety regulations in SOLAS are therefore very similar to the ones in the EU directive, even if the SOLAS code has become better structured. It has therefore been judged more appropriate to base the analysis in the project on SOLAS. This way of carrying out an analysis is also in line with the EU directive. A more detailed description of the European fire safety regulations and a comparison of how these deviate from SOLAS are found in appendix A.

4.3 Swedish regulations

Two documents from the Swedish Transport Agency describe safety for passenger ships: SJÖFS 1970:A13 and SJÖFS 2002:17. Amendments to SJÖFS 2002:17 are given in TSFS 2011:47. Requirements applicable to national passenger ships are described in "Sjöfartsverkets meddelanden", A:13 chapter 3 from 1970 [7]. According to this chapter, ships can be built in other non-combustible materials than steel if the material has sufficient thermal isolation. Furthermore, spread of the flame shall be limited and production of toxic gases during combustion shall be restricted. The European fire safety regulations in 2010/36/EC are in general implemented in Swedish law through SJÖFS 2002:17. According to the fire safety chapter in this regulation, an analysis according to Regulation 17 (SOLAS chapter II-2 Regulation 17) can be performed for ships built after 1 January 2003. The overall fire safety objectives are exactly the same in SJÖFS 2002:17 as in SOLAS II-2 and the overall functional requirements are also the same except for one. The functional requirement to divide the ship into main horizontal zones is not mentioned amongst the overall functional requirements in SJÖFS 2002:17. However, a table is found on page 134 for structural requirements of decks, which is comparable to the prescriptive requirements for decks found in SOLAS [7, 8].

4.4 Danish guidelines on approval of risk-based ship design

The national safety regulation for relevant passenger ships in Denmark are called "Meddelelser fra Søfartsstyrelsen D - Teknisk forskrift om skibes bygning og udstyr m.v. Passagerskibe i national fart" [16] and managed by Søfartsstyrelsen, or the Danish Maritime Authority in English. As the Swedish regulation, this national regulation I fully updated in line with the regulations at EU level. Accordingly, the Danish regulation also allows for alternative fire safety design and arrangements if, which requires a safety assessment in line with SOLAS chapter II-2 Regulation 17.

Furthermore, the Danish Maritime Authority has submitted a guideline on approval of risk-based ship design to IMO. The guideline (MSC 86/5/3) can be used for instance when an analysis according to Regulation 17 is carried out. Regulation 17 refers to the guidelines of alternative design and arrangements found in Circular 1002 but the Danish guideline is a good complement for the approval process, as it describes the applicable steps in greater detail [9].

5 SOLAS regulations affected by the Øko-Ø-færge

Fire safety regulations in SOLAS affected by the alternative design in plastic composite should be taken into account in the assessment according to Regulation 17. The regulations were therefore scrutinized and the results are presented below, divided in two sections covering regulations including prescriptive requirements as well as regulations including the overall fire safety objectives and functional requirements.

5.1 Regulations including prescriptive requirements

A summary of the regulation investigation is found in table 2 on the following page. In the following paragraphs it is further discussed whether the fire safety regulations SOLAS are affected by a general change from steel to plastic composite. The purpose statements have been reproduced for each regulation, followed by comments on possible deviations.

Table 2. Regulations affected by the novel design in plastic composite material, based on [11]

Regulation	***Objective***	***Affected***
4 Probability of ignition	Prevent ignition	No
5 Fire growth potential	Limit the fire growth potential	No (however, see 5.1.3)
6 Smoke generation potential and toxicity	Reduce the hazard to life from smoke and toxic products	Yes (needs evaluation)
7 Detection and alarm	Detect a fire in the space of origin and provide for alarm	No
8 Control of smoke spread	Control the spread of smoke	No
9 Containment of fire	Contain a fire in the space of origin	Yes (thermal insulation is improved)
10 Fire fighting	Suppress and swiftly extinguish a fire in the space of origin	Yes (10.1 needs evaluation)
11 Structural integrity	Maintain structural integrity of the ship	Structural integrity depends on insulation thickness. Not worse than steel for the first 60 minutes of fire if using FRD60.
12 Notification of crew and passengers	Notify crew and passengers of a fire	No
13 Means of escape	Provide means of escape	No (may need evaluation)
14 Operational readiness and maintenance	Maintain and monitor the effectiveness of the fire safety measures	No
15 Instructions, on-board training and drills	Mitigate the consequences of fire	No
16 Operations	Provide information and instructions for proper ship and cargo handling operations	No
18 Helicopter facilities	Provide additional measures for ships fitted with special facilities for helicopters	Not applicable
19 Carriage of dangerous goods	Provide additional safety measures for ships carrying dangerous goods	No (may need evaluation)
20 Protection of vehicle, special category and ro-ro spaces	Provide additional safety measures for ships with vehicle, special category and ro-ro spaces	Not to any major content
21 Casualty threshold, safe return to port and safe areas	Establish design criteria for a ship´s safe return to port under its own propulsion after a casualty	No
22 Design criteria for systems to remain operational after a fire casualty	Design criteria for systems required to remain operational for supporting the orderly evacuation and abandonment of a ship	No
23 Safety centre on passenger ship	Provide a space to assist with management of emergency situations	No

5.1.1 Regulation 4 - Probability of ignition

Purpose statement [4]:

> *The purpose of this regulation is to prevent the ignition of combustible materials or flammable liquids. For this purpose, the following functional requirements shall be met:*
> *.1 means shall be provided to control leaks of flammable liquids;*
> *.2 means shall be provided to limit accumulation of flammable vapours;*
> *.3 the ignitability of combustible materials shall be restricted;*
> *.4 ignition sources shall be restricted;*
> *.5 ignition sources shall be separated from combustible materials and flammable liquids; and*
> *.6 the atmosphere in cargo tanks shall be maintained out of the explosive range.*

Comments: The focus of the prescriptive requirements in this regulation is connected to the risk of fire connected with usage of oil and gas. Not much is mentioned on restriction of combustible materials. Using plastic composite in the overall structure will not conflict with the prescriptive requirements of this regulation. However, the prescriptive requirement in Regulation 4.4.4 concerns the material of primary deck coverings, which should not readily ignite. This is something that needs to be taken into account, no matter what material is used in structural constructions. As plastic composites generally are covered by an insulation layer of mineral wool their ignitibility is strongly reduced.

5.1.2 Regulation 5 - Fire growth potential

Purpose statement [4]:

> *The purpose of this regulation is to limit the fire growth potential in every space of the ship. For this purpose, the following functional requirements shall be met:*
> *.1 means of control for the air supply to the space shall be provided;*
> *.2 means of control for flammable liquids in the space shall be provided; and*
> *.3 the use of combustible materials shall be restricted.*

Comments: Neither of the first two functional requirements is affected by the change to plastic composite but the functional requirement in Regulation 5.1.3 must be taken into concern. The definition of a non-combustible material is given in Regulation 3.33 in SOLAS and defines it as a material that neither burns nor gives off flammable vapours when heated to 750°C. Polyester and Vinylesters, which are materials used when building in plastic composite, are ignited below 750°C and it could therefore be argued that the amount of combustible material is increased when changing from steel to plastic composite. However, the plastic materials will be protected from fire for 60 minutes by usage of insulation on each side of the composite, forming a so called fire resistant division, FRD60. This means that the plastic composite will not add to the fire growth potential of a space within the first hour of fully developed fire. Since the purpose of the regulation is to control the fire **in** spaces, and the FRD60 construction in no way will increase the fire load in the spaces until the fire is allowed to spread to adjacent spaces after 60 minutes, compliance could be connoted. Furthermore, due to the low conductivity of plastic materials, long distance spread of fire in the ship structure caused by conductivity will be decreased in comparison with a metal structure (10, 11].
Ceilings, grounds and linings in accommodation spaces have a large impact on the spread of fire and have to be of non-combustible material even if larger parts of the ships are changed to plastic composite. In general, all surfaces in accommodation and service spaces made of combustible material must fulfil requirements of a maximum calorific value of 45 MJ/m^2 and have low flame spread characteristics according to the FTP code, which is the same for both ships.

5.1.3 Regulation 6 - Smoke generation potential and toxicity

Purpose statement [4]:

> *The purpose of this regulation is to reduce the hazard to life from smoke and toxic products generated during a fire in spaces where persons normally work or live. For this purpose, the quantity of smoke and toxic products released from combustible materials, including surface finishes, during fire shall be limited.*

Comments: The amount of combustible material and the amount of released gases will obviously be affected if the total amount of combustible material is increased and the insulation has been consumed. Toxicity may be affected depending on the selection of plastic materials and its arrangement in the space. PVC is for instance known to release HCL and CL_2 during combustion and could be avoided as construction materials in small accommodation spaces. A test should be carried out to evaluate if the produced gases from plastic composites are disproportionate or excessively toxic.

5.1.4 Regulation 7 - Detection and alarm

Purpose statement [4]:

> *The purpose of this regulation is to detect a fire in the space of origin and to provide for alarm for safe escape and fire-fighting activity. For this purpose, the following functional requirements shall be met:*
> *.1 fixed fire detection and fire alarm system installations shall be suitable for the nature of the space, fire growth potential and potential generation of smoke and gases;*
> *.2 manually operated call points shall be placed effectively to ensure a readily accessible means of notification; and*
> *.3 fire patrols shall provide an effective means of detecting and locating fires and alerting the navigation bridge and fire teams.*

Comments: This regulation is not further discussed as it is not affected.

5.1.5 Regulation 8 - Control of smoke spread

Purpose statement [4]:

> *The purpose of this regulation is to control the spread of smoke in order to minimize the hazard from smoke. For this purpose, means for controlling smoke in atriums, control stations, machinery spaces and concealed spaces shall be provided.*

Comments: This regulation is not further discussed as it is not affected.

5.1.6 Regulation 9 - Containment of fire

Purpose statement [4]:

> *The purpose of this regulation is to contain the fire in the space of origin. For this purpose the following requirements shall be met:*
> *.1 the ship shall be divided by thermal and structural boundaries;*
> *.2 thermal insulation boundaries shall have due regard to the fire risk of the space and adjacent spaces; and*
> *.3 the fire integrity of the division shall be maintained at openings and penetrations.*

Comments: This regulation describes requirements on bulkheads, windows and ventilation systems. According to Regulation 9.2.2.1.1.1, the hull, superstructure and deckhouse in passenger ships have to be divided into main vertical zones by “A-60” class divisions. According to Regulation 3 and the definition of A-class divisions, these have to be made of steel or equivalent material and keep their structural integrity when exposed

to the applicable fire test (in this case for 60 minutes). The temperature rise of the unexposed side may not exceed 140 degrees on average or 180 degrees at any point during the fire tests. As mentioned above, plastic composites ignite when exposed to fire and must be combined with thermal insulation and make up a so called fire resistant division in order to gain sufficient fire integrity, as seen in figure 3. Tests carried out by SP have demonstrated that the temperature rise at the unexposed side of a FRD60 will be as low as 45°C after 60 minutes of fire exposure (temperature rise and integrity test in accordance with the standard test for bulkheads and decks, MSC.45(65) [15]). The low conduction of heat will prevent heat from being transferred long distances through the ship structure [10, 11].

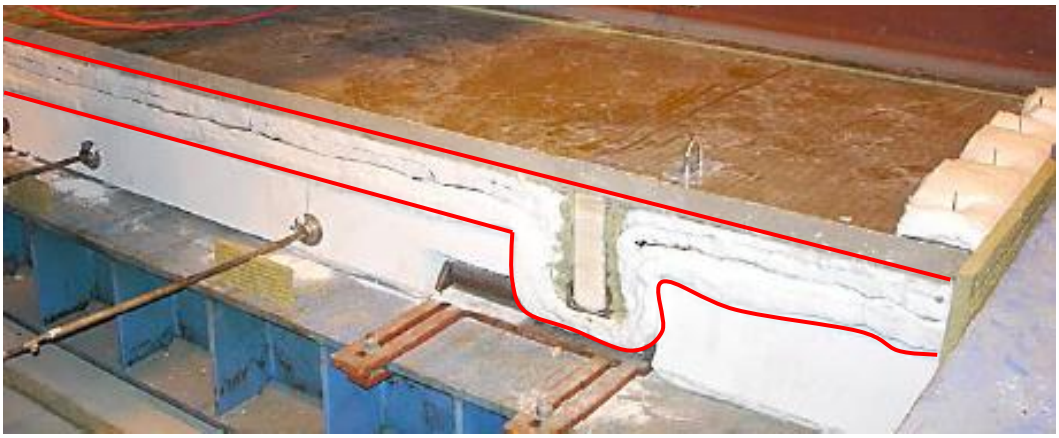

Figure 3. Plastic composite deck with insulation tested fire exposure according to MSC.45 (65) [11].

The requirements on fire resistance of decks and bulkheads in different spaces of the ship are given in table 9.1 and 9.2 in SOLAS chapter II-2/9. Decks are always made up of A-0 up to A-60 divisions, whilst bulkheads may be made of divisions with lesser fire integrity (B and C-class divisions), with or without provided insulation. Since the FRD60 construction will always be comparable with an A-60 division, the containment of fire to a space may be improved. However, the low conductivity of the plastic composite can also give rise to a faster fire development within the enclosed space. When the insulation is consumed the plastic itself will release heat that may accelerate the fire development, even if not until after 60 minutes.

5.1.7 Regulation 10 - Fire fighting

Purpose statement [4]:

> *The purpose of this regulation is to suppress and swiftly extinguish fire in the space of origin. For this purpose the following requirements shall be met:*
> *.1 fixed fire-extinguishing systems shall be installed, having due regard to the fire growth potential of the spaces; and*
> *.2 fire-extinguishing appliances shall be readily available.*

Comments: This regulation presents requirements on the active extinguishing systems and other fire extinguishing equipment. The first functional requirement states that the fixed fire extinguishing systems shall have due regard to the growth potential of the space. The fire extinguishing systems and equipment on the Øko-Ø-færge will be of at least the same standard as on the Tun island ferry. However, if the fire growth potential would differ it needs to be taken into concern for of the design of the fire extinguishing systems. For instance, vertical fire growth will happen faster on a plastic composite laminate than on a steel surface if the plastic composite is not covered with insulation. Furthermore, in the case of an open door to exteriors, it may be necessary to fix an additional sprinkler above the door, if the exterior surfaces are made of unprotected

plastic composite. Additional sprinklers may also be necessary above windows facing the outside of the plastic composite ship structure to prevent fire from an open window to be spread vertically to other decks from the outside. Hence, fire extinguishing systems and appliances should be readily available regardless of the construction material of the ship [10, 11].

5.1.8 Regulation 11 - Structural integrity

Purpose statement [4]:

> *The purpose of this regulation is to maintain structural integrity of the ship, preventing partial or whole collapse of the ship structures due to strength deterioration by heat. For this purpose, the materials used in the ships' shall ensure that the structural integrity is not degraded due to fire.*

Comments: All materials, even steel, will lose their structural strength when exposed to a large fire. Steel loses its structural strength at about 400-600°C [12] and a sandwich composite laminate may lose its bonding between core and laminate, and thereby structural performance, when heated to about 150°C[ii] (or a temperature where the bonding between core and laminate starts to soften). This is the reason why thermal insulation, as for instance mineral wool, is fixed to steel, aluminium and plastic composite, to protect the structural performance. The structural integrity in case of fire should not be worse during the first 60 minutes in a plastic composite design with FRD60[iii] divisions than in a steel design with A-60 divisions if they are all able to pass the standard test for A-60 bulkheads and decks according to MSC.45(65) [15]. On the Tun island ferry, some of the bulkheads are of A-0 or even worse fire integrity. According to the definition of A-0 class bulkheads, the average temperature rise at the unexposed side has no restrictions. On the Øko-Ø-færge, however, all bulkheads will be made in FRD60, which implies a significant improvement.

5.1.9 Regulation 12 - Notification of crew and passengers

Purpose statement [4]:

> *The purpose of this regulation is to notify crew and passengers of a fire for safe evacuation. For this purpose, a general emergency alarm system and a public address system shall be provided.*

Comment: The systems should comply with all requirements of this regulation, regardless of the material in ship structures.

5.1.10 Regulation 13 - Means of escape

Purpose statement [4]:

> *The purpose of this regulation is to provide means of escape so that persons on board can safely and swiftly escape to the lifeboat and liferaft embarkation deck. For this purpose, the following functional requirements shall be met:*
> *.1 safe escape routes shall be provided;*
> *.2 escape routes shall be maintained in a safe condition, clear of obstacles; and*
> *.3 additional aids for escape shall be provided as necessary to ensure accessibility, clear marking, and adequate design for emergency situations.*

[ii] Tommy Hertzberg, SP Technical Research institute of Sweden, 2011.

[iii] Tests of structural integrity during fire are found in the High Speed Craft (HSC) Code. The tests for deck and bulkhead constructions applying to HSC are in general the same as those prescribed for SOLAS-vessels, except from additional load bearing requirements.

Comments: To fulfil the first functional requirement, the structural integrity of for instance bulkheads and decks in accommodation spaces, corridors and staircases must be safe during at least the first 30-60 minutes of fire. An internal bulkhead between a corridor and an accommodation space of moderate fire risk (deck area of 50 m^2 or more) shall for instance be of B-15 class. If these internal bulkheads are replaced with plastic composite it may be sufficient to use a kind of bulkhead in plastic composite tested according to international standards for at least 15-20 minutes, to ensure that structural integrity of internal bulkheads is sufficient for evacuation.

5.1.11 Regulation 14 - Operational readiness and maintenance

Purpose statement [4]:

> *The purpose of this regulation is to maintain and monitor the effectiveness of the fire safety measures the ship is provided with. For this purpose the following functional requirements shall be met:*
> *.1 fire protection systems and fire-fighting systems and appliances shall be maintained ready for use; and*
> *.2 fire protection systems and fire-fighting systems and appliances shall be properly tested and inspected.*

Comments: The functional requirements are not affected by changing the structural material from steel to plastic composite. Inspection should also include detection of holes or openings in the FRD60 divisions that could affect fire resistance.

5.1.12 Regulation 15 - Instructions, on-board training and drills

Purpose statement [4]:

> *The purpose of this regulation is to mitigate the consequences of fire by means of proper instructions for training and drills of persons on board in correct procedures under emergency conditions. For this purpose, the crew shall have the necessary knowledge and skills to handle fire emergency cases, including passenger care.*

Comments: This regulation is not affected by a change from steel to plastic composite.

5.1.13 Regulation 16 – Operations

Purpose statement [4]:

> *The purpose of this regulation is to provide information and instructions for proper ship and cargo handling operations in relation to fire safety. For this purpose, the following functional requirements shall be met:*
> *.1 fire safety operational booklets shall be provided on board; and*
> *.2 flammable vapour releases from cargo tank venting shall be controlled.*

Comments: This regulation is not affected by a change from steel to plastic composite.

5.1.14 Regulation 18 - Helicopter facilities

Purpose statement [4]:

> *The purpose of this regulation is to provide additional measures in order to address the fire safety objectives of this chapter for ships fitted with special facilities for helicopters. For this purpose, the following functional requirements shall be met:*
> *.1 helideck structure shall be adequate to protect the ship from the fire hazards associated with helicopter operations;*
> *.2 fire-fighting appliances shall be provided to adequately protect the ship from the fire hazards associated with helicopter operations;*
> *.3 refuelling and hangar facilities and operations shall provide the necessary measures to protect the ship from the fire hazards associated with helicopter operations; and*
> *.4 operation manuals and training shall be provided.*

Comments: This regulation is not commented as it is not relevant for the reference object.

5.1.15 Regulation 19 - carriage of dangerous goods

Purpose statement [4]:

> *The purpose of this regulation is to provide additional safety measures in order to address the fire safety objectives of this chapter for ships carrying dangerous goods. For this purpose, the following functional requirements shall be met:*
> *.1 fire protection systems shall be provided to protect the ship from the added fire hazards associated with carriage of dangerous goods;*
> *.2 dangerous goods shall be adequately separated from ignition sources; and*
> *.3 appropriate personnel protective equipment shall be provided for the hazards associated with the carriage of dangerous goods.*

Comments: Our reference ship is designed to carry both ordinary passenger cars as well as garbage trucks and trucks loaded with oil for domestic heating. This regulations has to be taken into concern.

5.1.16 Regulation 20 - Protection of vehicle, special category and ro-ro spaces

Purpose statement [4]:

> *The purpose of this regulation is to provide additional safety measures in order to address the fire safety objectives of this chapter for ships fitted with vehicle, special category and ro-ro spaces. For this purpose, the following functional requirements shall be met:*
> *.1 fire protection systems shall be provided to adequately protect the ship from the fire hazards associated with vehicle, special category and ro-ro spaces;*
> *.2 ignition sources shall be separated from vehicle, special category and ro-ro spaces; and*
> *.3 vehicle, special category and ro-ro spaces shall be adequately ventilated.*

Comments: This regulation describes requirements for ventilation, alarm and detection systems, fire extinguishing equipment and structural requirements for spaces with vehicles. In passenger ships carrying more than 36 passengers, the boundary bulkhead or deck to the vehicle space must be A-60. The class can be reduced to A-0 if the adjacent spaces are of category 5, 9 or 10, i.e. open deck spaces, sanitary spaces or machinery spaces of minor fire risk. The reference ship has no boundaries from the vehicle space towards any of the aforementioned categories. The fixed detection and alarm systems will be the on the new ferry as if the ship would have been built in steel. It will furthermore

be designed with an approved fixed water-spraying system for the vehicle spaces and an appropriate drainage system. As on a steel ship, portable fire extinguishers will be available on both sides of the vehicle, spaced 20 meters apart, as well as three water fog applicators and a portable foam applicator.

Even if not required from prescriptive requirements, it might prove necessary from the engineering analysis to fit the new Øko-Ø-færge with additional active fire extinguishing equipment on the outside of the ship superstructure to ensure that fire does not spread from the vehicle space to the relatively close embarkation stations.

5.1.17 Regulation 21 - Casualty threshold, safe return to port and safe areas

Purpose statement [4]:

> *The purpose of this regulation is to establish design criteria for a ship´s safe return to port under its own propulsion after casualty that does not exceed the casualty threshold stipulated in paragraph 3 and also provides functional requirements and performance standards for safe areas.*

Comments: Passenger ships constructed on or after 1 July 2010 having a length of 120 m or above or having three or more main vertical zones shall comply with this regulation. As our reference ship is less than 120 meters this regulation can be overlooked.

5.1.18 Regulation 22 - Design criteria for systems to remain operational after a fire casualty

Purpose statement [4]:

> *The purpose of this regulation is to provide design criteria for systems required to remain operational for supporting the orderly evacuation and abandonment of a ship, if the casualty threshold, as defined in regulation 21.3 is exceeded.*

Comments: Passenger ships constructed on or after 1 July 2010 having a length of 120 m or above or having three or more main vertical zones shall comply with this regulation. As our reference ship is less than 120 meters this regulation can be overlooked.

5.1.19 Regulation 23 - Safety centre on passenger ships

Purpose statement [4]:

> *The purpose of this regulation is to provide a space to assist with the management of emergency situations.*

Comments: Passenger ships constructed on or after 1 July 2010 shall have a safety centre on board complying with the requirements of this regulation. Our reference ship should contain a safety centre wherefrom all fire safety systems are available, such as ventilation systems, alarm systems, fire detection and alarm system, fire and emergency pumps etc. However, this is not affected by the new design.

5.2 Overall regulations

Considering the new design with some greater perspective it can be evaluated how it will affect the overall fire safety objectives and functional requirements of the fire safety chapter in SOLAS. The analysis was based on [11] and the outcome is presented in table 3 and table 4, which hence rather summarizes the above detailed regulation analyses. Affected overall regulations does not necessarily imply a deviation or an impairment of fire safety, but merely that fire safety is affected in the area. The effects will need further evaluation in the Regulation 17 assessment.

Table 3. Fire safety objectives for the fire safety chapter in SOLAS and how they are affected when changing the structural material in a displacement ferry from steel to plastic composite

Fire safety objectives for SOLAS II-2	***How the regulation will be affected***
.1 Prevent the occurrence of fire and explosion	Will not be affected.
.2 Reduce the risk to life caused by fire	May be affected and depends on for instance the construction material properties.
.3 Reduce the risk to damage caused by fire to the ship, its cargo and the environment	May be affected and depends on for instance the construction material properties.
.4 Contain, control and suppress fire and explosion in the compartment of origin.	The containment of fire may be improved by changing to plastic composite material. The fire development within an enclosed space could be faster than if steel had been used.
.5 Provide adequate and readily accessible means of escape for passengers and crew	Should be fulfilled if the structural integrity holds the first 60 minutes.

Table 4. Functional requirements for the fire safety chapter in SOLAS and how they are affected when changing the structural material in a displacement ferry from steel to plastic composite

Functional requirements for SOLAS II-2	***How the regulation will be affected***
.1 Division of the ship into vertical and horizontal zones by thermal and structural boundaries	Thermal and structural boundaries will be used also in the new design with the same requirements as for steel. An evaluation may be necessary to evaluate the differences in structural integrity after 60 minutes in comparison to steel.
.2 separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries	A test may be required to evaluate whether plastic composite boundaries with less than 60 minutes of insulation may be sufficient for boundaries where B-15 is required.
.3 restricted use of combustible materials	The plastic composite itself is combustible but this property is mitigated by covering the plastic composite with insulations.
.4 detection of any fire in the zone of origin	Depends on alarm system, not the structural material.
.5 containment and extinction of any fire in space and origin	Containment may be improved at the initial stage of the fire. Extinction may be different from the earlier design in steel.
.6 protection of means of escape and access for fire fighting	Will not be effected as long as structural integrity holds, which should be achieved by constructing properly with FRD60, which achieves this requirement.
.7 ready availability of fire-extinguishing appliances	Will not be effected as long as structural integrity holds and fire safety routines run successfully.
.8 minimization of possibility of ignition of flammable vapours	Flammable vapours may be released from the plastic materials if exposed to considerable heat, but as long as the insulation material is not consumed, the amount of flammable vapours will not be significantly increased by the material change.

6 Market investigation

A market investigation was carried out to find out the market potential to build ferries in plastic composite in Sweden and Denmark. A question inquire was sent to 97 ship operators. The questions given to the ship operators are found in appendix 2 and the results from some of the answers are presented in the following text. Note that only 7 questions were obligatory (number 1-7, see appendix 2).

6.1 General information and ratios for relevant ship operators

Of the 97 inquiries sent out to Swedish and Danish ship operators about 24 replied, most of them from Sweden. The total number of ships in these companies were diverse and the total number of B, C, D and E ships in the investigation were 99, out of which 78% were running according to a time table. Figure 4 below shows that the number of ships belonging to the different ship operators varies from 1 to 25. Most ship operators in this investigation seem to have less than 10 ships.

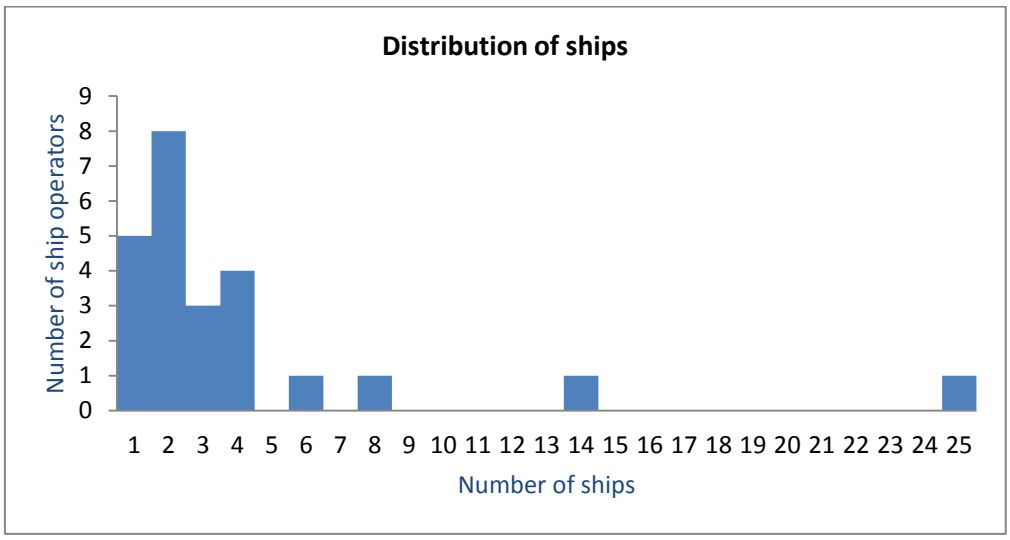

Figure 4. Distribution of the number of ships in the investigation.

The turnovers for the different ship operators span in between 1 to 330 million SEK and most of the ship operators had a turnover of less than 20 million SEK as seen in figure 5.

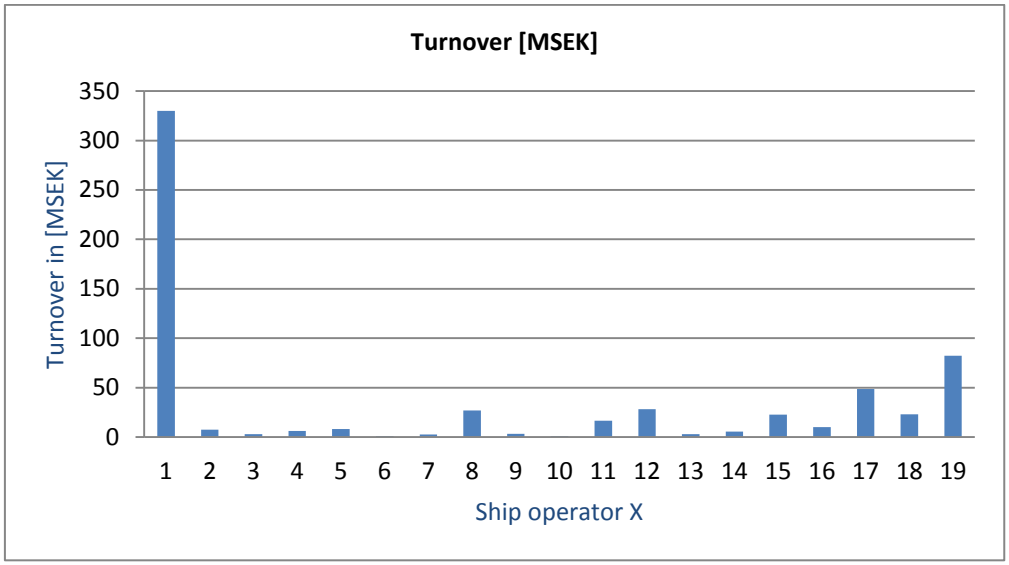

Figure 5. Diagram showing the distribution of the turnover for the ship operators participating in the study.

The operation hours per ship vary from about 200 hours to 4 600 hours per year, with an average of about 1 600 hours. Figure 6 below shows the number of operation hours per ship for the different ship operators. Not all ship operators answered this question.

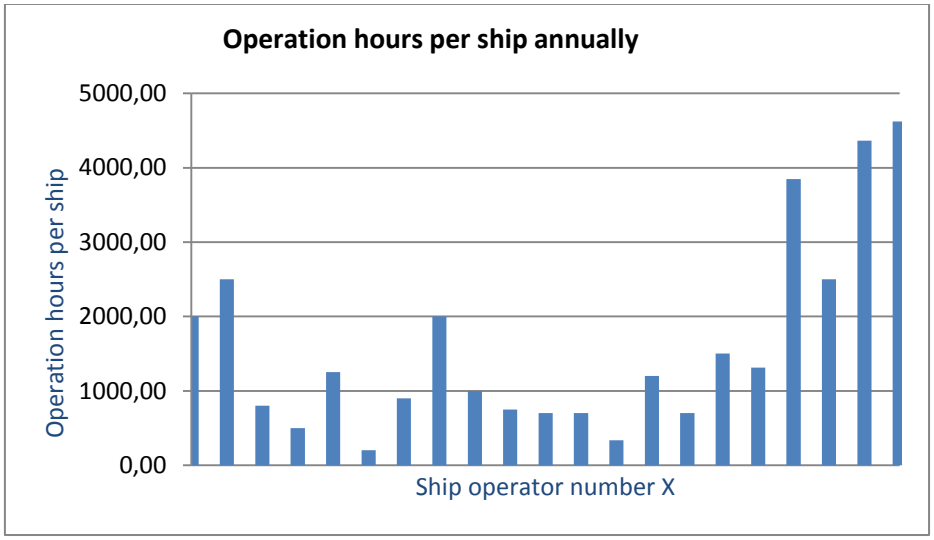

Figure 6. Distribution of average operation hours per ship for the different ship operators.

6.2 Potential market for ships in plastic composite

The lifetime of a steel ship is about 20 years and a question was therefore given about how many of the ships that were older than 20 years. Out of 99 ships there were about 73 ships that were older than 20 years. Then there was also a question about the number of ships that were planned to be replaced within the coming five years and the answers showed that only 14 of the ships were expected to be replaced within 5 years. Concerning the questions whether the ship operators had considered building a ship in plastic composite only 17% of the ship operators answered that they had considered this before, as seen in figure 7.

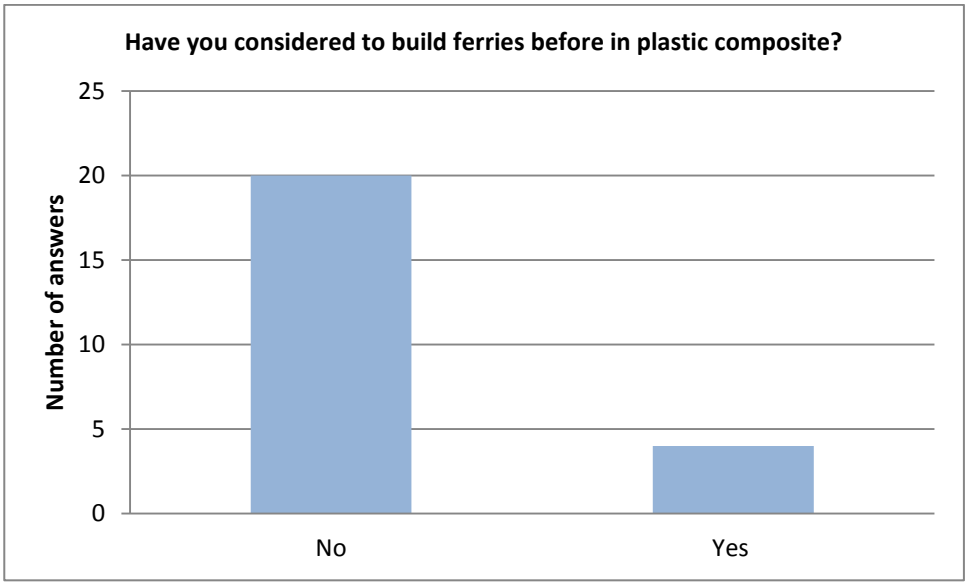

Figure 7. Diagram showing the number of ship operators that have considered to build ferries in plastic composite.

6.3 Fuel costs and maintenance costs

The average annual fuel costs for a ship in the investigation is about 300 000 SEK (median value). The average fuel costs are about 5-25% of the total turnover, with an average of 10%, based on the distribution in figure 8 below. The differences in fuel costs between ships seem to vary from 32 to 285 SEK per operational hour.

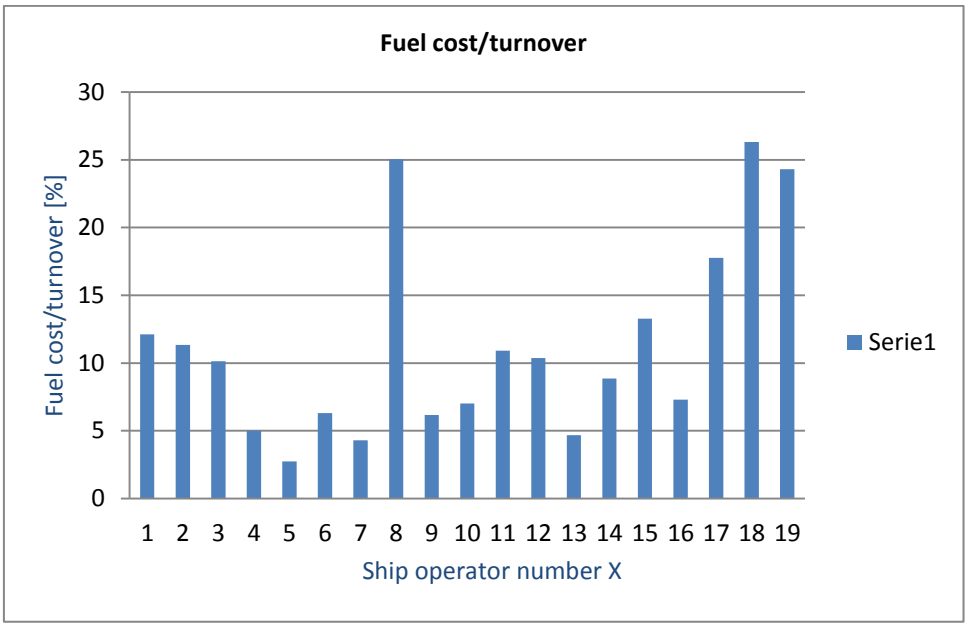

Figure 8. The total fuel costs in relation to the total turnover.

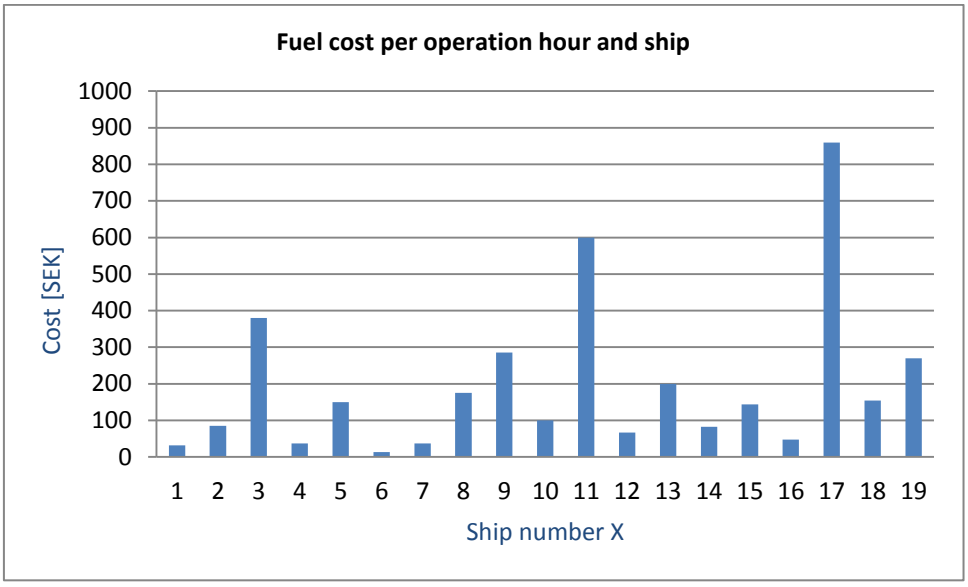

Figure 9. Average fuel cost per ship and hour for each ship operator.

The maintenance costs, as presented in figure 9, were more difficult to predict for the companies and therefore less data was obtained of this item. One ship operator meant that it varies much from year to year. The results show that the maintenance costs vary between 5-20% of the total turnover, as illustrated in figure 10.

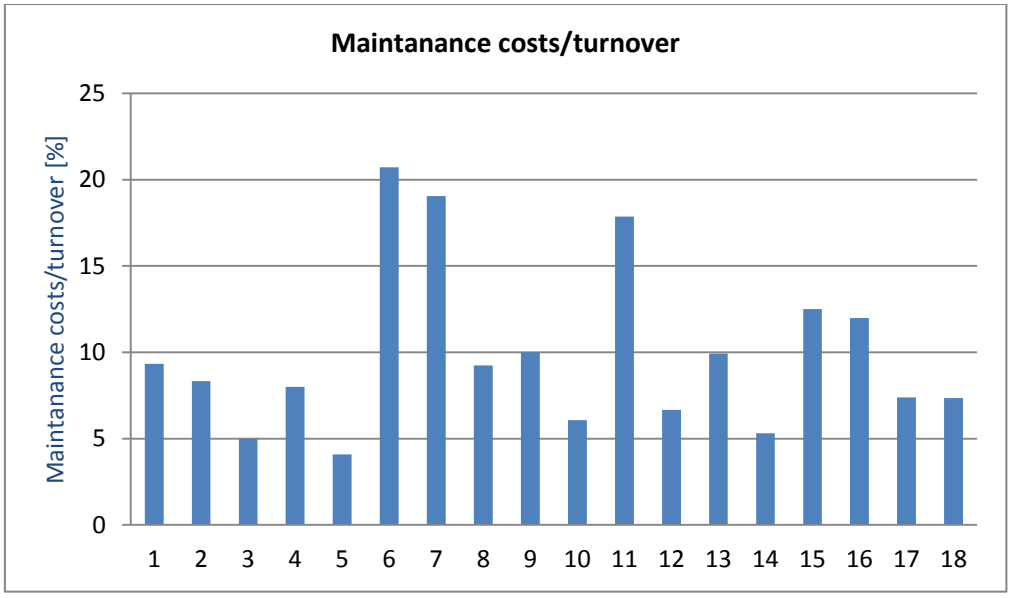

Figure 10. The total maintenance costs in relation to the total turnover.

The average maintenance costs are about 9% of the turnover and the average maintenance cost of one ship is about 300 000 per year, with some outliners as seen in figure 11.

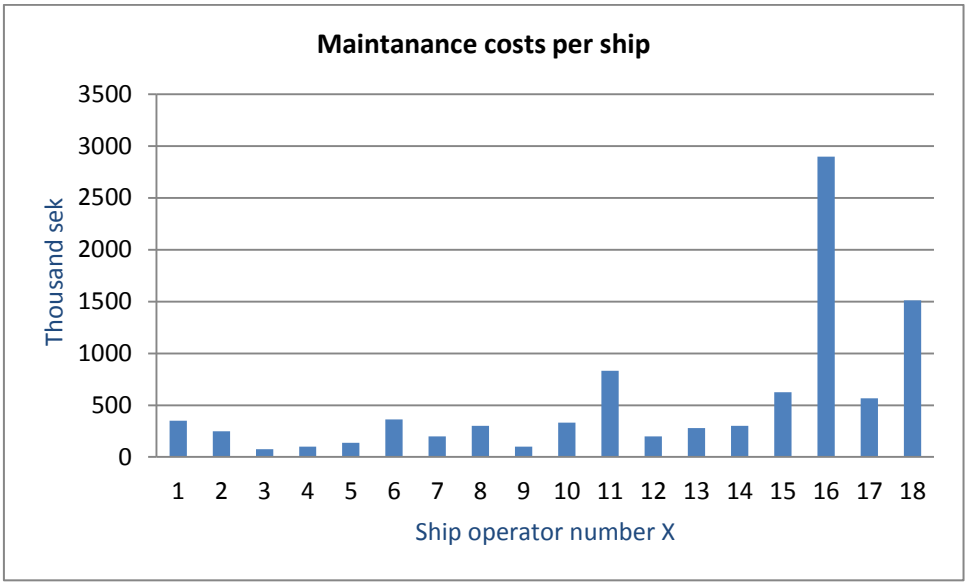

Figure 11. The average maintenance costs per ship for the various ship operators.

7 Discussion and conclusions

The results from the regulation analysis and the market investigation for ships in plastic composite are discussed below, divided in two sections.

7.1 Regulations

The results of this investigation show that it is possible to perform an engineering analysis according to SOLAS II-2/17 (Regulation 17) to evaluate fire safety in agreement with both European and national directives in Sweden and Denmark. There are some minor differences between the requirements in the European regulations and the international SOLAS regulations but it is clear that the European regulations are fully based on the SOLAS regulations. Most of the structure in the European fire safety chapter is different from SOLAS, divided in a general part A describing the requirements for fire extinguishing equipment, maintenance and safety routines while part B deals with issues related to structural requirements. The structure in the European directive could make it easier to find certain regulations. On the other hand, functional requirements to fulfil a certain fire safety goal, as for instance 'containment of fire', are not found in the EU directive. The guideline MSC/Circ.1002, point 5.1.2, requires that "the regulations affecting the proposed design and arrangements, along with their functional requirements, should be clearly understood and documented in the preliminary analysis report". This will be difficult if no functional requirements are given as fire safety goals. The coming fire safety assessment of the ecological island ferry "Øko-Ø-færge" will therefore refer to SOLAS fire safety regulations. The HSC code may also be helpful in ensuring that structural integrity is fulfilled during fire exposure, as fire test standards have been developed for light weight structures. Discussions will also be held with the Danish Maritime Authority about the approval process and using MSC86/5/3 as a tool complimentary to MSC/Circ.1002.

7.2 Market investigation

It is difficult to estimate the potential market and the economic potential for ferries in plastic composite in Sweden and Denmark. Validity and reliability uncertainties exist since perfect questions cannot be formed and since two thirds of the approached Swedish operators did not answer the survey. However, among the ship operators that answered it was shown that about 80% of their ships were older than 20 years, which indicates that there is a potential market for building ships in plastic composite in the near future. Most of the ship operators (83%) had not considered building ships in plastic composite and a few of the answers revealed a firm and sceptical view of this relatively new material. Among the arguments about why plastic composite had not been considered as an alternative were environmental circumstances, such as that the weather conditions would not be suitable for a plastic composite material, narrow paths, regulations and economy. Plastic composite is a rather new material from a historical point of view. There may hence be a need to spread information about the functionality and e.g. durability properties of plastic composite as well as about regulations in connection with ferries made in the material.

One of the biggest advantages with building ships in plastic composite is the possibility to reduce fuel and maintenance costs. The current investigation showed that fuel and maintenance costs correspond to an averaged total of 20% and up to 45% of the overall turnover. Hence there is great savings potential in the long run by a change from conventional steel to plastic composite. This will be investigated in further detail, along with demonstrations of how regulations can be handled, throughout the continuation of the Øko-Ø-færge project.

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Appendix 1 Comparison between EU and SOLAS regulations

The comparison between the regulations in the EU directive and the international SOLAS regulations for ship fire safety was based on the EU directive, where these regulations were sought in SOLAS. The investigation is presented below in two sections, dividing part A and art B of the fire safety chapter in the EU directive. All EU and SOLAS regulations refer to EU directive 2002/25/EC as amended, chapter II-2 and SOLAS chapter II-2, respectively.

Part A of the EU directive

The first part of the fire safety chapter in the EU directive covers general fire safety requirements and was first subject to scrutiny. The comparison between the EU and SOLAS regulations is summarized in table A1 below and further discussed subsequently.

Table A1. The regulations in the EU directive 2002/25/EC as amended, chapter II-2, Part A - General, and where the same topics are found in SOLAS chapter II-2

European regulation	***Corresponding SOLAS regulation***	***Objective***	***Affected by change to FRP***
Reg. 1	Reg. 2	Describing the overall fire safety object and functional requirements of the fire safety chapter	-
Reg. 2	Reg. 3	Definitions	-
Reg. 3	Reg. 10	Requirements on fire pumps, fire mains, hydrants, hoses and nozzles	No
Reg. 4	Reg. 10.4	Description of required fixed fire extinguishing systems and their maintenance	No
Reg. 5	Reg. 10.3	Description of the requirements of portable fire extinguishers	No
Reg. 6	Reg. 10.5	Fire-extinguishing arrangements in machining spaces	No
Reg. 7	Reg. 9.5	Special arrangements in machinery spaces	No
Reg. 8	Reg. 10.6	Automatic sprinkler etc.	No
Reg. 9	Reg. 7	Fixed fire detection and fire alarm systems	No
Reg. 10	Reg. 4.2	Arrangement of oil and other flammable liquids	No
Reg. 11	Reg. 10.10	Fire-fighter’s outfit	No
Reg. 12	Reg. 4.4	Miscellaneous items	No
Reg. 13	Reg. 15.2.4.1	Fire control plans	No
Reg. 14	Reg. 14.2	Operational readiness and maintenance	No
Reg. 15	Reg. 15	Instruction, on-board training and drills	No

Regulation 1 Basic principles

This regulation draws up the basic principles for the EU directive and is not applicable for this comparison.

Regulation 2 Definitions

Regulation 2 includes definitions of A, B and C bulkheads and decks, and general definitions of terms which are used frequently in the following fire safety chapter. The definitions of A, B and C divisions are the same as in SOLAS. The definitions given in regulation 3 are defined in the same way in the EU directive except in two cases: Ro-ro

spaces, which have been renamed Ro-ro cargo spaces in the EU directive, and Open ro-ro spaces, which have been renamed Open ro-ro cargo spaces in the EU directive.

Regulation 3 Fire pumps, fire mains, hydrants, hoses and nozzles

This regulation contains information about the dimension, capacity and installation of fire pumps and other installations used for fire fighting. The requirements are described in separate sections for new C and D ships, depending on the length of the ship (length over 24 meter or not). The amount of pumps and minimum pressure in fire hydrants in the EU directive is based on the number of passengers instead of tonnage as in SOLAS. This regulation is although most likely not affected by a change to plastic composite.

Regulation 4 Fixed fire-extinguishing systems

Fixed fire-extinguishing systems shall comply with the Fire Safety Systems Code [13] which implies the same requirements on fixed fire-extinguishing systems as in SOLAS. The chapter also describes requirements of fixed fire-extinguishing systems, such as fixed gas fire-extinguishing systems, low and high expansion foam and fixed pressure water systems and how these should be maintained.

Regulation 5 Portable fire extinguishers

Portable fire extinguishers shall comply with the Fire Safety Systems Code [13], as required in SOLAS regulation 10.3.

Regulation 6 Fire-extinguishing arrangements in machinery spaces

This regulation sets the requirements of fire extinguishing appliances in machinery spaces. It is not formed exactly as SOLAS regulation 10.5 but will most likely not be affected by the change from steel to plastic composite.

Regulation 7 Special arrangements in machinery spaces

This regulation describes requirements on the arrangement of doors, windows, ventilators and funnels in machinery spaces. It is based on SOLAS regulation 9.5 and is not affected by the change from steel to plastic composite.

Regulation 8 Automatic sprinkler, fire detection and fire alarm systems

This regulation describes requirements of the automatic sprinkler system which should be according to the Fire Safety Systems Code [13], as required by SOLAS regulation 10.6.

Regulation 9 Fixed fire detection and fire alarm systems

This regulation is based on regulation 7.2 and 7.7 in SOLAS. Regulation 9.5 in the EU directive is an addition to SOLAS, describing requirements of a fixed fire alarm system towards corrosion resistance, independence of other systems, electrical power supply to the system etc.

Regulation 10 Arrangement for oil fuel, lubricating oil and other flammable oils

This regulation describes the arrangement and requirements of oil fuels and how they should be maintained. This regulation is not affected by exchanging the structural material from steel to plastic composite.

Regulation 11 Firefighter's outfit

This regulation describes the number of fire-fighter's outfits that should be available and their quality.

Regulation 12 Miscellaneous items

This regulation describes requirements on miscellaneous items, such as waste receptacles, electric radiators, heated apparatus for cooking and requirements for penetration of e.g. cables and pipes through A or B class divisions. The requirements of the miscellaneous items are given in more detail in the EU directive than in the corresponding regulation 4.4 in SOLAS.

Regulation 13 Fire control plans

Regulation 13 contains requirements about information regarding the ship's general arrangement that may be of interest from a fire fighting perspective, e.g. fire sections by A and B division, the sprinkler and alarm system, fire extinguishing appliances, means of access to different compartments, ventilation system etc. For new ships constructed on or after 1 January 2003 the information provided in fire control plans and booklet shall be in accordance with the IMO resolutions A.756 (18) and A.654.

Regulation 14 Operational readiness and maintenance

This regulation contains requirements for operational readiness and maintenance and is exactly the same as regulation 14.2 in SOLAS.

Regulation 15 Instructions, on-board training and drills

This regulation is exactly the same as SOLAS regulation 15.

Regulation 16 Operations

This regulation corresponds to regulation in SOLAS.

Part B of the EU directive

The second part of the fire safety chapter in the EU directive covers more detailed fire safety requirements and was also subject to scrutiny. The comparison between the EU and SOLAS regulations is summarized in table A2 below and further discussed subsequently.

Table A2. The regulations in the EU directive 2002/25/EC as amended, chapter II-2, Part B – Fire safety measures, and where the same topics are found in SOLAS chapter II-2

European regulations	***Corresponding SOLAS regulation***	***Objective***
Reg. 1	Reg. 9,11	General structural requirements of the ships overall structures
Reg. 2	Reg. 9.2.2.1	Main vertical and horizontal zones
Reg. 3	Reg. 9.2.2.2 and Reg. 5	Bulkheads within a main vertical zone
Reg. 4	Reg. 9.2	Fire integrity of bulkhead and decks (ships more than 36 passengers)
Reg. 5	Not commented	Fire integrity of bulkhead and decks (ships more than 36 passengers)
Reg. 6	Reg. 13	Requirements needed for safe escape
Reg. 7	Reg. 9.3	Describing the requirements for the structural integrity to fire of openings, as for ex doors in A-class and B-class
Reg. 8	Reg. 9.2.2.5	Protection of stairways and lifts in accommodation and service spaces
Reg. 9	Reg. 9.7	Requirements on ventilation systems
Reg. 10	Reg. 9.4	Requirements on structural integrity of windows
Reg. 11	Reg. 5,6, 4.4	Restricted use of combustible materials
Reg. 12	Reg. 8.4	Details of construction
Reg. 13	Reg. 7 and Reg. 10	Fixed fire detection and fire alarm systems and automatic sprinkler
Reg. 14	Reg. 9.2.2 and Reg. 20	Protection of special category spaces
Reg. 15	Reg. 7.9, 12.2 ,14, 15	Patrols, detection, alarms and public address systems
Reg. 16, 17, 18	Not commented (Reg. 17 corresponds to SOLAS II-2/19)	Upgrading of existing B-class ships, carriage of dangerous goods, special requirements for helicopter facilities

Regulation 1 Structure

The general structural requirements on hull, superstructures, structural bulkheads, decks and the deckhouse imply that these should be made of steel or other equivalent material. This is the exactly same formulation as the requirement on overall structural integrity given in SOLAS regulation 11.2. Divisions must also fulfil the requirements given in the tables table 4.1 (Structural integrity of bulkheads) and 4.2 (Decks neither forming steps in main vertical zones nor bounding horizontal zones) in the EU directive. These tables are exactly the same as those found in SOLAS regulation 9 (table 9.1 and 9.2).

Regulation 2 Main vertical zones and horizontal zones

In ships carrying more than 36 passengers, the hull, superstructure and deckhouses shall be subdivided into main vertical zones by A-60 class divisions as required in SOLAS regulation 9 (.2.2.1.1.1). Table 4.2 shows that the minimum integrity of decks is exactly the same as required by table 9.2 in SOLAS (2009) and table 4.1 is identical to 9.1 in SOLAS. The classification of spaces depending on fire risk is numbered 1-14 are is the same as in SOLAS regulation 9 with the following exceptions: control stations in the EU regulations include fire-extinguishing rooms and fire recording stations (zone 1), what is

mentioned as crew corridors in the EU directive is instead lobbies in SOLAS (zone 3), and saunas are not mentioned under accommodation spaces of greater fire risk in the EU directive.

Regulation 3 Bulkheads within a main vertical zone

This regulation applies to new class B, C and D ships carrying more than 36 passengers. Divisions are allowed to be either A, B or C divisions as long as they fulfil the requirements of table 4.1 and 4.2 (regulation 9 in SOLAS). All such divisions may be faced with combustible materials according to EU regulation 11, where requirements are set on low flame-spread characteristics of surfaces and calorific content of veneers and linings. These are almost the same requirements as found in SOLAS regulation 5, paragraph 3.2.2 and 3.2.4. An extra point is that exposed surfaces on balconies are mentioned in SOLAS 3.2.4.1.3 but not in the EU directive.

Regulation 4 Fire integrity of bulkheads and decks in new ships carrying more than 36 passengers

The classification of spaces by fire risk, numbered 1-14, are the same as in SOLAS regulation 9, with the following exceptions: control stations in the EU regulations includes fire-extinguishing rooms and fire recording stations (zone 1), what is mentioned as crew corridors in the EU directive is instead lobbies in SOLAS (zone 3), and saunas are not mentioned under accommodations spaces of greater fire risk in the EU directive.

The tables describing requirements on divisions in the EU directive are, as mentioned above, exactly the same as the corresponding tables in SOLAS.

Regulation 5 Fire integrity of bulkheads and decks in new ships carrying not more than 36 passengers and existing CLASS B ships carrying more than 36 passengers

This regulation is not taken into the comparative analysis as it is not relevant for the reference object in this study.

Regulation 6 Means of escape

Regulation 6 sets out the requirements for safe evacuation and escape. For instance this regulation includes instructions of how the escape routes should be constructed. The regulation is based on regulation 13 in SOLAS.

Regulation 7 Penetration and openings in ‘A’ and ‘B’ class divisions

Openings in A-class divisions

According to the EU regulation all openings in A-class divisions shall be as effective in resisting a fire as the divisions in which they are fitted. A door shall be made of steel or equivalent material. According to SOLAS the door shall be tested according to the Fire Test Procedures Code [14] but nothing is mentioned about that the door should be tested according to the Fire Test Procedures Code [14] in the EU directive. However, it may be intuitive that the SOLAS regulations should be followed as the regulation is fully based on SOLAS, see the last line in chapter 1 General provisions in the EU directive. The general requirements of the doors are otherwise the same as in SOLAS regulation 9.

Openings in B-class divisions

The requirements on openings in B-class divisions are the same as in SOLAS. Doors and door frames shall have the same resistance as the division it is fitted in. Requirements on ventilation systems in connection to the doors are also the same as in SOLAS regulations.

Regulation 8 Protection of stairways and lifts in accommodation and service spaces

The objective with this regulation is to prevent the spread of fire through stairways and lifts. The corresponding regulation in SOLAS was not found for passenger ships, only for cargo ships in regulation 2.3.4.1.

Regulation 9 Ventilation systems

The requirements on the ventilation systems in the EU directive are very similar to SOLAS regulations. For instance, the requirements on the ducts passing A and B class divisions are the same as in SOLAS. In the EU directive a requirement is also given for the installation of a smoke extraction system in public spaces spanning three or more open decks and containing furniture and enclosed spaces such as shops and restaurants, see 32.7 in EU directive 2002/25/EC as amended. When following the SOLAS regulations this regulation may have to be extracted from the EU regulations.

Regulation 10 Windows and sidescuttles

The requirements on structural integrity of windows within and towards the outside of the ship and embarkation stations are the same as in SOLAS regulation 9.4.

Regulation 11 Restricted use of combustible material

This regulation corresponds fairly with SOLAS Regulation 5, describing how the amount of combustible materials should be restricted and requirements regarding surfaces with low flame-spread characteristics, total allowed volume of combustible facings, mouldings and veneers as well as the maximum calorific value of veneers. Nothing is mentioned in the EU regulations which cannot be found in SOLAS Regulations 4, 5 or 6. The test of low flame-spread characteristics must be carried out according to the Fire Test Procedures Code [14] according to SOLAS while no special test for flame-spread characteristics is mentioned in the EU directive.

Regulation 12 Details of construction

"In accommodation and service spaces, control stations, corridors and stairways:
.1 air spaces enclosed behind ceilings, panelling or lining shall be suitably divided by close-fitting draught stops not more than 14 meters apart.
.2 in the vertical direction such enclosed air spaces, including those behind linings of stairways, trunks, etc. shall be closed at each deck." This is the same requirements as found in Regulation 8.4 in SOLAS.

Regulation 13 Fixed fire detection and fire alarm systems and automatic sprinkler, fire detection and fire alarm system

The requirements on the fixed fire detection system, fire alarm system and automatic sprinkler are the same as in regulation 7 (.5.2) and 10 (.6.1.1) in SOLAS.

Regulation 14 Protection of special category spaces

Special category spaces are those enclosed vehicle spaces on which vehicles can be driven and to which passengers have access. This regulation sets out requirements of the structural integrity, fire-extinguishing systems, ventilation systems etc. in these spaces.

The requirements on structural integrity of special category spaces are found in SOLAS regulation 9.6 and requirements on the ventilation system in regulation 9.7 but the other requirements, on e.g. fire-extinguishing systems, were not found in SOLAS. When referring to SOLAS regulations in a fire safety assessment these EU regulations therefore need to be considered.

Regulation 15 Fire patrols, detection, alarms and public address systems

Requirements on public address systems, alarms, control of fire doors, detection and patrols are brought up in this regulation and corresponding requirements are found in SOLAS regulation 7.9, 12.2, 14 and 16.

Regulation 16 Upgrading of existing Class B ships carrying more than 36 passengers

This regulation is not commented as our reference ship is not to be upgraded.

Regulation 17 Special requirements for ships carrying dangerous goods

The requirements in SOLAS regulation 19 corresponds to this regulation applying to passenger ships carrying dangerous goods.

Regulation 18 Special requirements for helicopter facilities

This regulation is not commented as our reference ship won't have any helicopter facility. It is otherwise SOLAS regulation 18 that applies in this case. Regulations corresponding to SOLAS regulation 20, regarding protection of vehicle spaces, special category and ro-ro spaces, was not found in the EU directive.

Appendix 2 Survey questions

Below follows the content of the questionnaire given to the Swedish and Danish ship operators. Questions 8-11 were voluntary.

1. What is your annual turnover?

2. Have you previously considered building a ferry in plastic composite material?

The following questions relate to your ships in classes B, C, D and E:

3. How many ships does your shipping company have of classes B, C, D, and E?

4. How many of these ferries run according to a time table (schedule)?

5. How many of these are used for charter?

6. How many of these ferries are older than 20 years?

7. How many of the ferries do you expect to be replaced within 5 years?

The following questions are voluntary but nevertheless important to estimate the economic potential. All questions below refer to your ships in classes B, C, D and E (see question 3).

8. How large is the total fuel cost for your ferries in class B, C, D and E?

9. How many hours do your ships operate annually?

10. How large are the total annual maintenance costs for your ships?

11. How many passengers do you transport annually?

SP Technical Research Institute of Sweden

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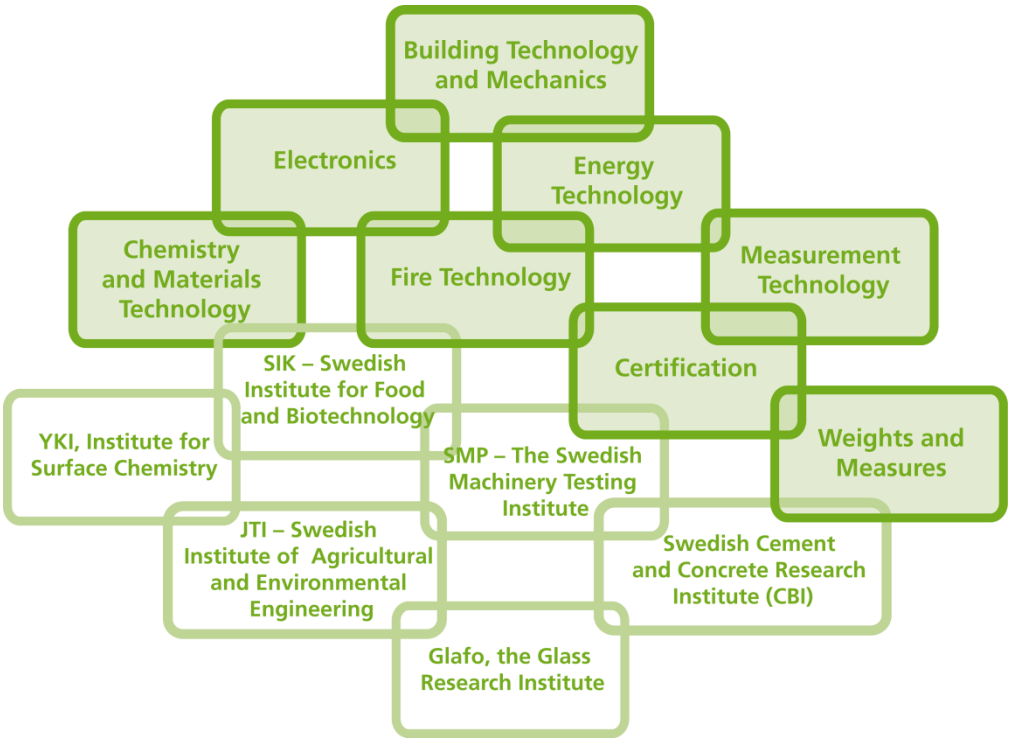

SP Technical Research Institute of Sweden
Box 857, SE-501 15 BORÅS, SWEDEN
Telephone: +46 10 516 50 00, Telefax: +46 33 13 55 02
E-mail: info@sp.se, Internet: www.sp.se
www.sp.se

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