New Fire Strategies in the Wake of Umoe Ventus

Annex D – Technical analysis

FIRE AND SECURITY

OSK-ShipTech A/S

Content

1 Fire safety objectives of the regulation

SOLAS II-2 defines the overall objectives of fire safety systems by five headlines:

- Prevent the occurrence of fire and explosion
- Reduce the risk to life caused by fire
- Reduce the risk of damage caused by fire to the ship, its cargo and the environment
- Contain, control and suppress fire and explosion in the compartment of origin
- Provide adequate and readily accessible means of escape for passengers and crew

The objectives are achieved by applying passive and active fire protection to the vessel. Passive protection is obtained by thermally insulated structural boundaries and restricted use of combustible materials. Active systems consist of fire and smoke detection and fire extinguishing systems fixed and portable.

When using FRP (fibre reinforced polymer) composites as building material a large amount of combustible material is added to the structure, which is in conflict with the before mentioned intentions. To maintain an equivalent level of safety additional fire protection is needed. For the High Speed Craft code (HSC) this is done by increasing safety in the following areas: accommodation arrangement, active safety systems, restricted area of operation, quality management and human factors engineering (education and testing of crew and management).

The lower initial safety robustness level of a HSC vessel is also supported by the infrastructure of land based rescue. The HSC vessel is not a self-sustained platform, as a conventional SOLAS vessel which can manage itself in emergency situations; a HSC vessel is dependent on rescue support from land. This is important to bear in mind when adding combustible materials to the construction as composite structures will most likely not be able to obtain equivalent level of fire safety as steel structures even though they are insulated and protected by firefighting systems. The equivalent level of safety must be obtained by other and additional means of safety.

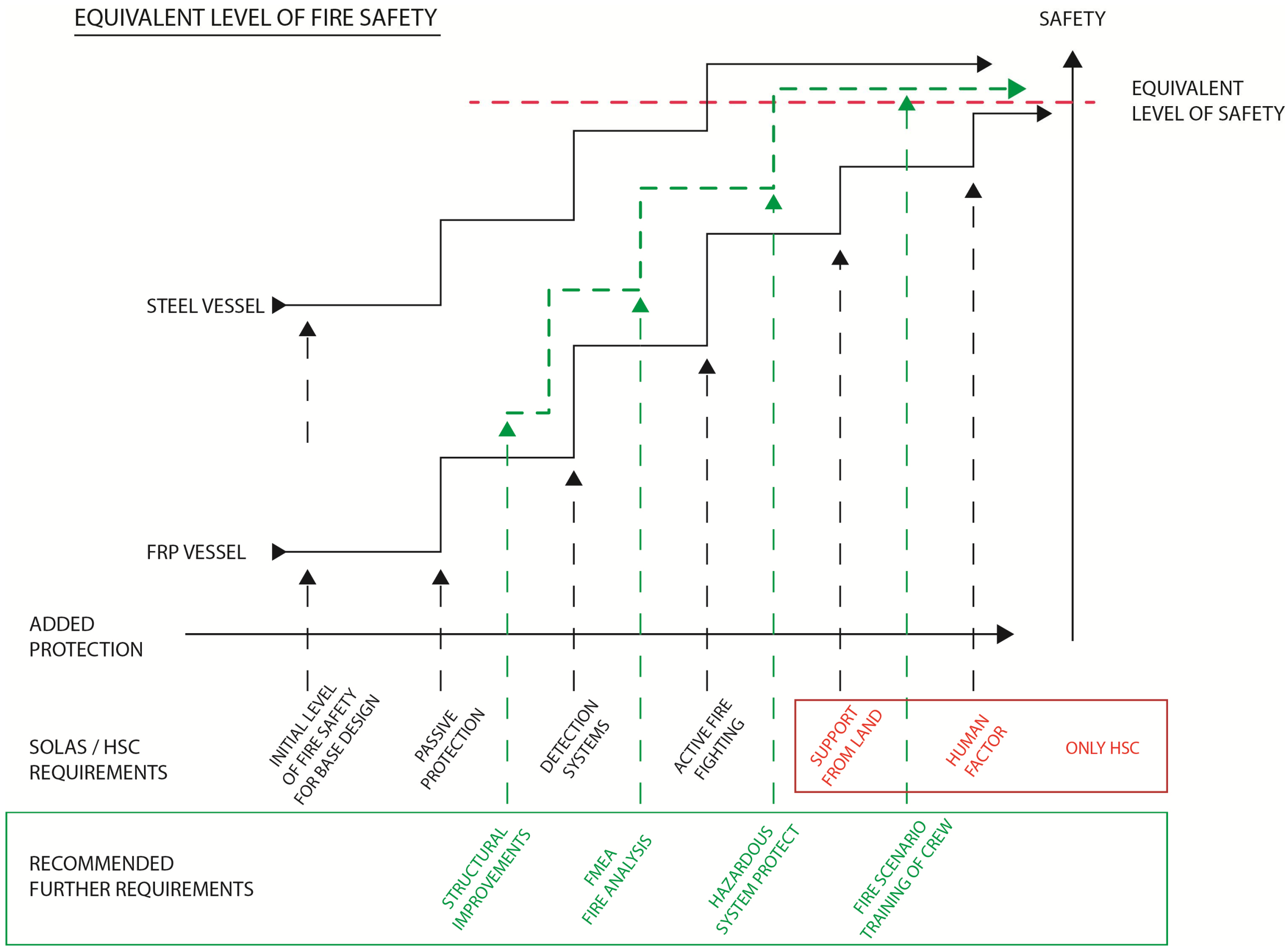

Figure 1, Equivalent level of fire safety

Figure 1 describes the principal of equivalent level of fire safety on a steel vessel compared to a composite vessel. Both types are required to improve basic safety by adding passive protection (fire insulation), fire detection systems and firefighting equipment. As the HSC code allows for the use of alternative and combustible materials, a few further requirements are added to this notation. First of all, support from land is assumed. The HSC vessel is not intended to be self-supported for a long period of time as it is expected on a SOLAS steel vessel. Therefore, rescue support from land must be available at all times.
The human factor is also considered in the HSC code to improve safety. This is done by requiring that the crew and management is trained and type rated for the specific vessel and its systems to improve the crew skills in emergency situations.

This report will recommend further improvements to the already existing requirements under the HSC code. Examples of the recommendations and the principle of their impact are shown in Figure 1 with green lines.

2 Reference Vessels and their notations

To establish a basic understanding of the fire safety on existing FRP composite vessels, we have selected four reference vessels. Three of them represents vessel types with the most commonly used notation for composite ships, the High Speed Craft code (HSC-Cargo and HSC-Passenger), and a fourth with a DMA notation D, based on EU Directive 2009/45/EC (The Ferry Directive).

HSC allows for the use of alternative materials such as polymer composites, which makes this notation the most suited for composite vessels. The code states that equivalent level of safety must be obtained by applying additional systems, procedures and fire retarded materials. The added requirements can be categorized as follows:

- Passive protection of structure and hazardous equipment
- Fire and smoke detection of areas
- Active protection of hazardous areas
- Rescue assistance from land (assisted vessel)
- Human factors engineering (training, type rating of crew and management)

As a starting point the passive protection must be robust and not dependent on other systems or equipment to maintain safety. However when using alternative materials, detection and firefighting systems are required to increase the robustness of the fire safety and reach a level of equivalent safety compared to a steel ship.

Notation D is an EU directive ratified by the Danish government based on SOLAS conventions. The notation is intended for passenger vessels in national trade. Composites can be used under notation D provided a risk-based analysis is performed proving equivalent safety is obtained (SOLAS ch. II-2 rule 17).

Reference vessel 1: Umoe Ventus, was built by the Norwegian shipyard Umoe Mandal completely in composites, in compliance with the HSC-Cargo notation. The notation allows the vessel to carry up to 12 passengers with lower requirements for systems and structural fire protection compared to a passenger vessel.

Figure 2, Umoe Ventus

Reference vessel 2: FOB SWATH 7 was built at the shipyard Danish Yachts to the HSC-Passenger code. The vessel is constructed in composites and approved to carry up to 40 passengers. The purpose of comparing reference vessel 1 and 2 is to understand the difference between cargo and passenger notation in relation to area categories and how this affects the level of safety on a cargo or passenger HSC vessel.

Figure 3, FOB SWATH 7

Reference vessel 3: Sea Gale was built by Danish Yachts to HSC-Passenger notation, approved to carry 24 passengers. The layout, in regard to area categories and uninsulated areas, are similar to ref vessel 2 (FOB SWATH 7).

Figure 4, Sea Gale

Reference vessel 4: ECO Island Ferry was a research project aimed at investigating the possibility to design a composite passenger vessel to Notice D, intended for smaller ferries in national trade. A risk analysis was performed in compliance with SOLAS ch. II-2 rule 17.

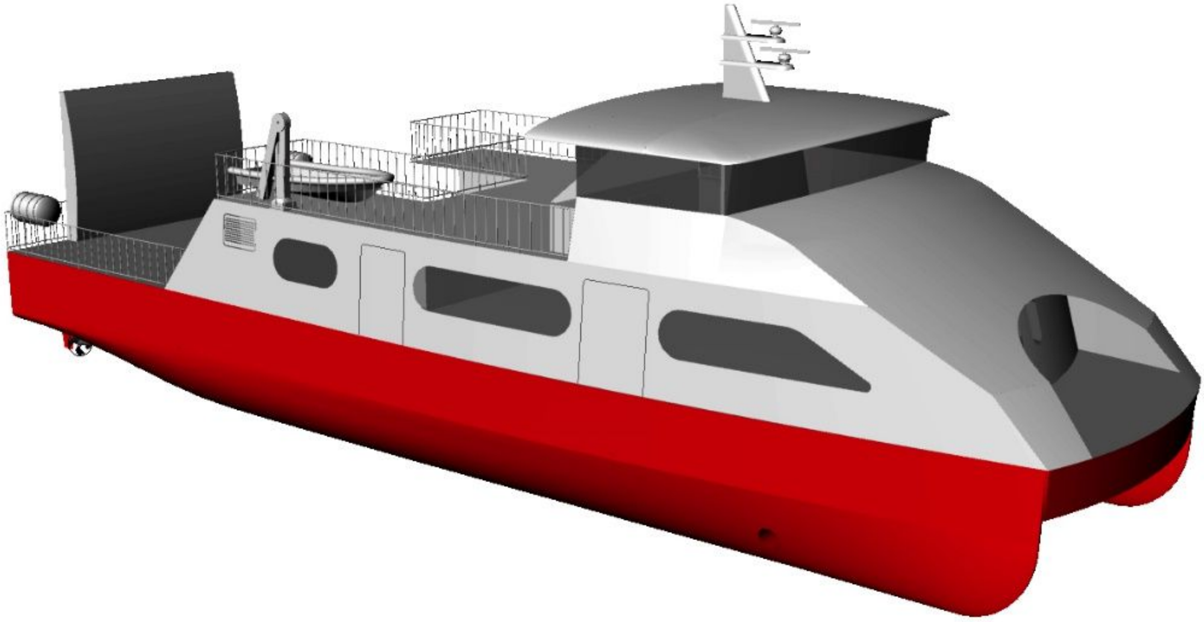

Figure 5, Eco-Island Ferry

3 Area categories

The HSC Code uses 6 area categories, A-F to determine fire risk and define corresponding fire insulation, detection and firefighting systems, see figure 4. There are two sets of area definitions dependent on whether it is a Cargo or Passenger vessel.

	A	B	C	D	E	F
Areas of major fire hazard A	60 1, 2 / 60 1, 2	30 / 60 1	3 / 60 1, 8	3, 4 / 60 1	3 / 60 1	– / 60 1, 7, 9
Areas of moderate fire hazard B		30 2 / 30 2	3 / 30 8	3, 4 / 60	3 / 30	– / 3
Areas of minor fire hazard C			3 / 3	3, 4 / 30 8, 10	3 / 3	– / 3
Control stations D				3, 4 / 3, 4	3 / 3, 4	– / 3
Evacuation stations and escape routes E					3 / 3	– / 3
Open spaces F						– / –

	A	B	C	D	E	F
Areas of major fire hazard A	60 1, 2 / 60 1, 2	30 / 60 1	3 / 60 1, 8	3, 4 / 60 1	3 / 60 1	– / 60 1, 7, 9
Areas of moderate fire hazard B		2, 6 / 2, 6	3 / 6	3, 4 / 60	3 / 6	– / 3
Areas of minor fire hazard C			3 / 3	3, 4 / 30 8	3 / 3	– / 3
Control stations D				3, 4 / 3, 4	3 / 3, 4	– / 3
Evacuation stations and escape routes E					3 / 3	– / 3
Open spaces F						– / –

Figure 6, Structural fire protection for Passenger and Cargo vessels according to HSC 7.4. Red boxes indicate differences.

The diagram above describes the categories and the red boxes indicate where there are differences between Cargo and Passenger code.

One of the differences is found in area category B. Especially category B is critical to observe as this area often contains hazardous equipment such as auxiliary engines, exhaust, electrical switchboards and motors, all equipment that has a potential to ignite a fire. The code describes the following equipment/use to be found in category B:

- Auxiliary machinery spaces
- Bond stores containing packaged beverages with alcohol content not exceeding 24 Vol-%
- Crew accommodation containing sleeping berths
- Service spaces
- Sales shops having a deck area of less than 50 m^2 containing a limited amount of flammable liquids for sale and where no dedicated store is provided separately
- Sales shops having a deck area of 50 m^2 or greater not containing flammable liquids
- Trunks in direct communication with the above spaces

The area categories are described in a simple vessel context in Figure 7 below corresponding to HSC chapter 7.3 "Classification of space use". The areas are separated by bulkheads with either A-60 or A-30 fire insulation. Between areas with minor risk, no insulation is required except between control station and other areas. Both HSC Cargo and Passenger allows areas to be unprotected if no hazardous systems are located in the specific area. This possibility should be maintained as it supports the original intention of the HSC code to construct lightweight vessels. But in a specific vessel design it should be considered if partitioning of a "minor risk" area is needed to ensure robustness in the evacuation possibilities.

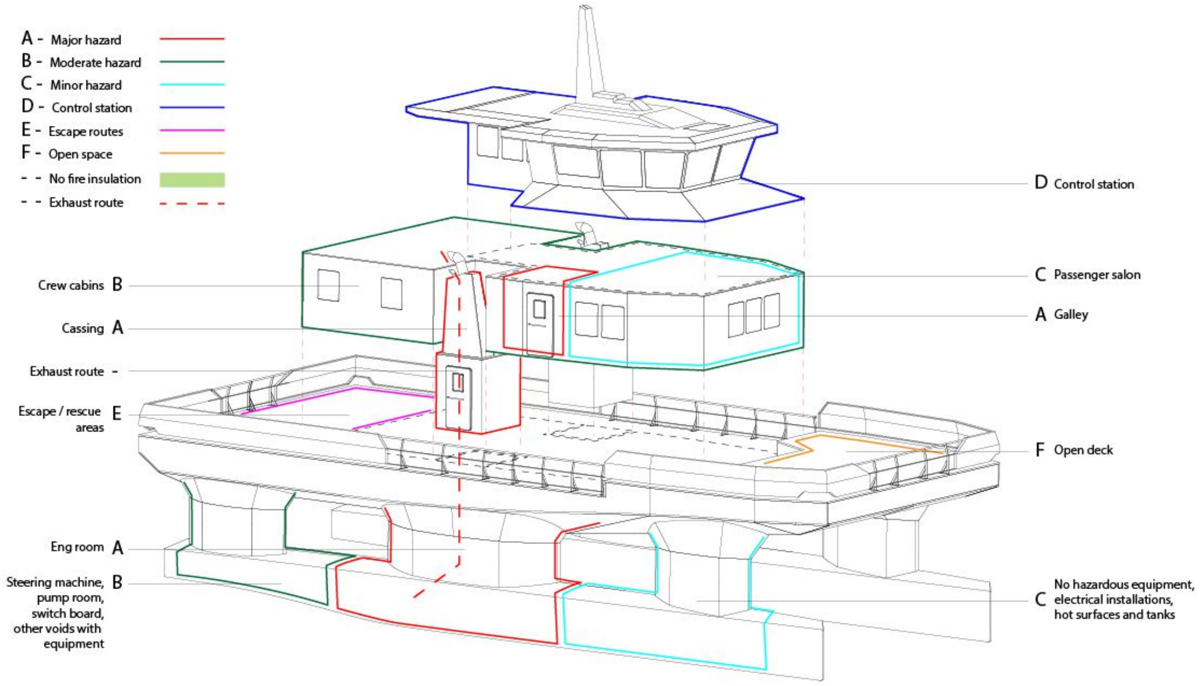

Figure 7, Area definition principle according to HSC 7.3

In reality, many of the vessels built to the HSC-Cargo notation are used for passenger transport for example in the offshore wind industry. The intension with the segregation between Cargo and Passenger area protection was not that it would be a permanent operation scenario to carry passengers on a cargo vessel. A cargo vessel is a much simpler vessel and therefore cheaper to build and operate which is good for cargo carrying operations. But if a vessel is carrying passengers on a regular basis it should comply with the Passenger notation where further safety improvements are made.

4 Protected areas

In this chapter the structural fire protection on the reference vessels is investigated and the differences in relation to the corresponding notations are compared.

The reference vessels are described in chapter 2. Figure 8 illustrates the various area classifications in the three reference vessels.

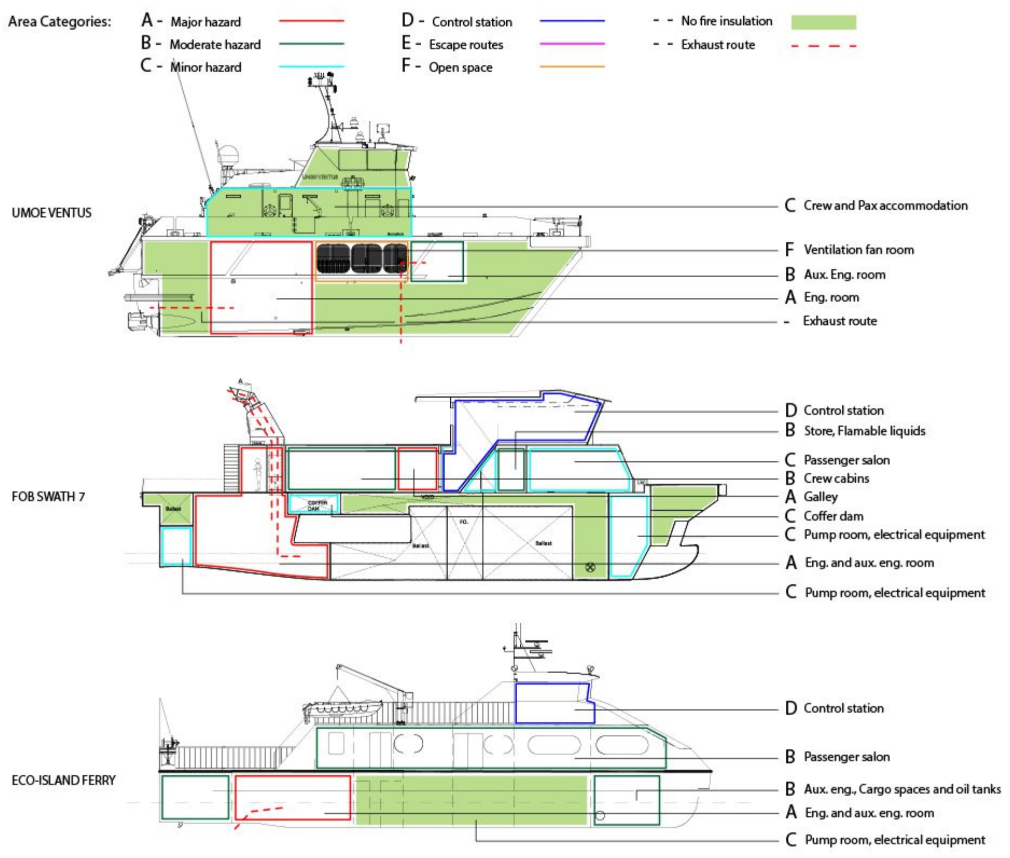

Figure 8, Insulated areas on reference vessels

4.1 Umoe Ventus

This vessel was approved based on the HSC Cargo notation. The layout is simple with only two fire-insulated areas in each hull, the main engine room and the auxiliary engine room. Figure 7 shows that both exhausts from main and auxiliary engines pass through un-insulated areas despite the exhaust being a hazardous system with potentially hot surfaces.

The un-insulated areas are categorized in compliance with the code, but it could be argued that protection of the exhaust is not in compliance with the code. Section 7.4.3.9 of the HSC code describes how exhaust gas pipes should be protected, it mentions that "risk of fire should be kept to a minimum" and "systems shall be insulated in all compartments". The pipes were partially insulated and cooled by a cooling system which supplied sufficient protection for the approval of area and system. Unfortunately the cooling system broke down or was blocked prior to the fatal fire and led to total loss of the vessel.

The area where the fire originated was categorized as open space which requires no insulation, detection or firefighting. Furthermore the area was not accessible which made it impossible for the crew to detect the fire in time or fight it.

4.2 FOB SWATH 7

This vessel was submitted to stricter area requirements due to HSC Passenger notation. Un-insulated areas can only be found in voids with minor and non-hazardous equipment. Exhaust pipes are fully protected and pass through only category A areas. Sea Gale has a similar layout and is therefore not included here.

Comparing FOB SWATH 7 with Umoe Ventus it can be seen that area category B is insulated in compliance with the HSC Passenger area requirements which provides a complete protection of the entire crew area in the deckhouse. This is a significant improvement of the fire safety level for a passenger vessel. Applying fire insulation to the passenger areas, category C, could be a further improvement as the entire deckhouse would be fire protected and not only the crew areas.

Considering the operational purpose of Umoe Ventus and many other HSC Cargo vessels operating in the offshore industry where they serve as crew transport units, compliance with HSC Passenger code would be more suitable and increase safety greatly.

4.3 ECO-ISLAND FERRY

The ferry has an area layout much similar to FOB SWATH 7. A large unprotected area (category C) can be found in the middle of each hull directly under the passenger salon. Fuel tanks are often found in area category C and are thus not fire insulated but separated from adjacent areas by cofferdams. Fuel pipes and systems are already regulated by the HSC Code, but a further protection of fuel tanks, if made of combustible material, would be advisable and could increase fire safety.

4.4 Cargo vs. Passenger notation

Comparing the three types of vessels it is obvious that the HSC Cargo vessel type has the lowest level of protection. If the vessels are used and operated by trained professionals as intended in the code, the risk would be minor. A HSC Cargo vessel should primarily be used for carrying cargo and only occasionally a few passengers. For this purpose a simpler and cheaper vessel is suitable and in the interest of the industry. However, if a vessel on a regular basis is used for crew transport, it should comply with the HSC Passenger code.

5 Systems and area categories

The area category system is the basic safety principle that insures protection of hazardous areas and systems. The HSC code describes what equipment and systems are found in each area and how it is protected with insulation, detection and fixed firefighting systems. The area categories are assumed to provide adequate safety if they are defined as intended. Definition of areas can often be interpreted differently resulting in un-intended categorization, with an increased risk as a consequence. The interpretation can be pushed by stakeholders with different interests such as commercial, weight, building time or safety perception.

The HSC code regulates the installation and design of systems with flammable fluids to prevent fire (HSC ch. 7.5). The code does not consider the danger of ignition of the structure from hot surfaces as for example an exhaust pipe. If the hot surface is located in a category B or C area on a Cargo vessel, no fire insulation is required on bulkheads decks or other structures. This could lead to dangerous situations as it did on Umoe Ventus. In this case the auxiliary exhaust passed through an area categorized as open space (F) but it was in fact a partially closed and difficult to access space with no firefighting or insulation towards surrounding spaces containing hazardous systems.

If the code (HSC 7.5) would consider hot surfaces as potential sources of ignition the before mentioned area would have been categorized as A and would be insulated and protected by detection and firefighting systems which would probably have prevented the rapid spread of the fire. A more keen attention to hazardous systems could also simplify the area categorization eliminating the before mentioned problem with interpretation of area categories.

Table 1 illustrates a simple way of highlighting the route of dangerous systems through area categories. It clearly indicates the problem of the exhaust system on Umoe Ventus. The red boxes highlights where a hazardous system passes through unprotected areas.
The yellow boxes in Table 1 mark systems or areas that are not categorized as hazardous and thus not protected. Tanks with flammable liquids on Umoe Ventus probably contributed to fuel the fire as there was no coffer dam (void space) between the ventilator room where the fire started and the fuel tank. The two areas were only separated by a composite bulkhead.

Furthermore systems that are normally considered as harmless systems can cause structures or other systems to fail and thereby develop hazardous situations. An example could be an engine room ventilation system that does not work and cause the surrounding temperature to rise with an increased risk of igniting flammable material.

Vessel:	**Umoe Ventus**						
	Areas	**A**	**B**	**C**	**D**	**E**	**F**
Systems							
Exhaust system		X		X			X
F.O. Systems		X					
Hydraulic Sys	?						
Cabin heaters	?						
Electrical Switch boards	?						
Electrical motors	?						
F.O. tanks				X			

Vessel:	FOB SWATH 7						
	Areas	**A**	**B**	**C**	**D**	**E**	**F**
Systems							
Exhaust system		X					
F.O. Systems		X					
Hydraulic Sys		X					
Cabin heaters			X				
Electrical Switch boards		X					
Electrical motors		X	X	X			
F.O. tanks				X			
Vessel:	**ECO-ISLAND FERRY**						
	Areas	**A**	**B**	**C**	**D**	**E**	**F**
Systems							
Exhaust system		X					
F.O. Systems		X					
Hydraulic Sys		X					
Cabin heaters			X				
Electrical Switch boards		X					
Electrical motors		X	X	X			
F.O. tanks				X			

Table 1, Systems passing through areas

6 Fixed firefighting systems

To improve the robustness of passive protection fixed firefighting systems are installed in selected areas defined by the code. The requirements are reduced for category A and Cargo vessels. The purpose of the system – either automatically or manually operated – is to fight fires in enclosures without crew having to enter the affected areas. Active closing mechanisms, such as fire dampers and door closers are also required to suppress the spread of fire.

Certain firefighting systems can cause great damage to the vessel and its systems. Especially saltwater, foam or powder systems are destructive to mechanical and electrical installations. The risk of damaging vital equipment can make the crew reluctant or hesitate to activate the systems if they are in doubt of the seriousness of the fire.

Gas based firefighting systems are less harmful to equipment and very effective if the area is close off efficiently and the flow of gas continues long enough. However, they can be dangerous to persons caught in areas where the gas is released and efficiency is dramatically reduced if ventilation and doors are not closed properly.

Water mist systems are somehow similar to sprinkler systems but release much less water and are therefore not as harmful to the surroundings. Water mist is very effective and can be based on fresh water reserves (with sea water as backup) reducing the potential damage even more.
If technical spaces and equipment are built to withstand water mist, such systems can be activated as soon as signs of fire are detected with no risk of damaging the vessel. The firefighting system can then be activated manually or automatically as a preventive measure for a short period of time.

7 Recommendations

Based on our technical investigations on the reference vessels, we have the following recommendations to improve fire safety on board composite vessels built to the HSC code.

- The rules regulating fire safety on composite vessels should be standardized as much as possible. This would strengthen the safety and support correct implementation of preventive measures. As a consequence only the Passenger definition of area categories should be valid, reference to HSC ch. 7.4.

- Cargo notation vessel should be used as they are intended by the code, with no passengers on board on a regular basis.

- Chapter 7.5 in the HSC code "Classification of hazardous systems" should consider protecting hot surfaces such as exhaust systems. A technical system should be considered in its entirety. Hazardous systems should not only be protected where it is dictated by the area category. Ideally, the system should be fully protected throughout the vessel.

- Risk classification and analysis of areas within the ship should be based on a detailed qualitative assessment of the actual risks in each area. The risk assessment should consider;
    1. risk of ignition (e.g. hot surfaces),
    2. fuel load (cargo, interior, structures),
    3. type of fuel (will it promote a fast or a slow fire development),
    4. importance of the area with respect to the safety of entire ship, the crew and the passengers.

- Passive safety such as insulation is the best way of protecting areas and technical systems. Fire protection of hazardous systems or areas should not be entirely dependent on active systems working.

- Easier to activate firefighting systems as an early action in areas without risking to destroy equipment. Equipment in hazardous area A should be sufficiently robust to withstand water mist for a limited period of time. Water mist systems are favourable rather than gas based systems as the crew would be more reluctant to activate a gas system.

- Type rating of crew to the specific composite vessel should include inspection rounds controlling fire insulation, training in fire development on composite structures and fighting fires. A system of check lists could be implemented similar to what is used in the aviation industry, but not as detailed.

- A system of fire scenario analysis incorporated in the FMEA procedure. This is discussed further in appendix E.

- Approval of test and trials should be defined in a way that as far as possible eliminates possibility for personal interpretations. This is to avoid negative influence on surveyors from other stakeholders such as owners, yards, crew etc.