Fire Hazards and the Maritime Scene

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ABSTRACT

IMO, the Intergovernmental Maritime Organisation, has since many years formulated fire safety regulations for maritime use. This has resulted in a number of test requirements for fire resistance and reaction to fire. IMO is currently putting all these requirements together in one single code which will greatly simplify for the user that is dealing with fire problems.

SOLAS is a prescriptive, detailed regulation, which sometimes makes it difficult to apply when unusual ship constructions are used. A stringent example was the development of high speed craft where it was found that SOLAS was not flexible enough. Therefore, a special code, the high speed craft code, HSC, was developed. The fire chapter in the HSC - code is largely expressed as requirements of performance. Modern fire calorimetry is used to identify safe products.

IMO is now starting to completely revise SOLAS in order to make it a performance based code. When this work is finished, it will be possible to introduce hazard analysis and modern fire engineering when fire safety in a ship is designed.

IMO REGULATIONS PROVIDES A BASIS FOR WORLD WIDE HARMONISATION.

International requirements for fire safety on ships are being developed by IMO (the Intergovernmental Maritime Organisation). About 135 countries are members of IMO. IMO's safety conventions have a world wide coverage, the most important have been accepted by countries representing 97% of the merchant navy. The IMO safety work has to a large extent resulted in world wide harmonisation of testing and classification of products and IMO is currently years before the EU in this process.

IMO specifications for fire safety are found in the so called SOLAS convention, (SOLAS = Safety of Life at Sea), chapter II-2. Fire regulations is the largest chapter in the convention which also covers other areas of safety, for example ship stability.

SOLAS and associated publications contain requirements on most phenomena that have an influence on the fire safety on board. SOLAS contains selection criteria for products as well as the required frequency of fire training for the crew. The first SOLAS was published in 1914 following the disaster of the Titanic. SOLAS is continuously revised and the latest edition is from 1992, with amendments from 1994. The IMO work is organised according to figure 1.

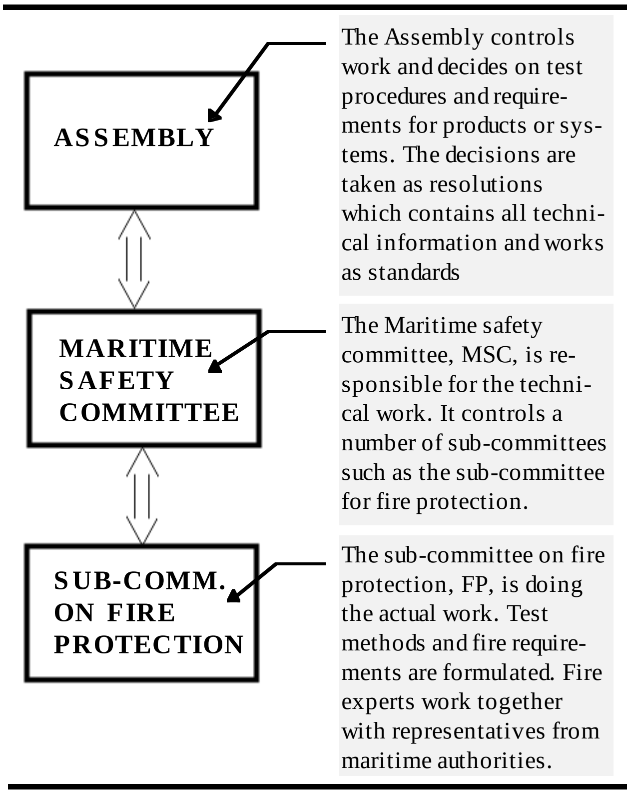

Figure 1. Organisation of fire safety work in IMO.

THE FIRE SAFETY STRATEGY USED BY IMO

The fire safety requirements are specified based on the type of ship and the space or function that needs protection. Therefore the convention is different for cargo ships, tankers and passenger ships. Most of the work is devoted to the passenger ships.

Ship areas are divided into different categories according to expected fire risk. Low risk areas are for example sanitary spaces and storage rooms. High risk areas are for example machinery spaces, passenger accommodation areas and escape routes. These areas are then given detailed fire demands. These demands have so far been formulated out of classical philosophy as for fire protection in buildings with special amendments taking account of the marine environment. Passive and active fire protection measures are required.

The requirements for passive fire protection includes fire resistance of constructions and reaction to fire of products.

As for fire resistance the ship areas are divided into fire cells separated by constructions of a certain fire integrity.

The reaction to fire demands on products are intended to minimise ignitability, flame spread , heat release and production of smoke and toxic gas species. The most important test methods for reaction to fire are listed in table 1.

Table 1. Technical fire requirements as given in the SOLAS convention for reaction to fire.

Type of product	Test method	Fire technical property
Insulation	IMO Res. A.472 (XII)	Non-combustibility
Bulkhead, wall and ceiling linings	IMO Res. A 653(16)	Flame spread, heat release
Floor coverings	IMO Res. A 653(16)	Flame spread, heat release
Primary deck coverings	IMO Res. A.687 (17)	Flame spread, heat release
Vertically supported textiles and films	IMO Res. A.471 (XII)	Ignitability
Upholstered furniture	IMO Res. A.652 (16)	Ignitability
Bedding components	IMO Res. A 688 (17)	Ignitability
Various products	MSC Res. 41 (64)	Smoke and toxicity

From table 1 it is seen that the choice of materials is governed by many test methods. Therefore IMO is now putting together a complete document on fire matters, the Fire Test Procedures Code, to be decided by the Maritime Safety Committee. This means that there will be only one document that covers all of the tests and classification criteria that IMO currently uses which will greatly simplify its use for laboratories, producers and regulators.

IMO is also preparing for a second step in developing the concept of fire safety. The intention is to change SOLAS from a prescriptive regulation to a regulation based on function. This means that hazard analysis will play an important role when fire safety is designed for a ship. The new approach by IMO is scientifically sound and the hope is that it will be successful and set an international example on how fire engineering can be used in the future. A first step towards a performance based code was taken when the fire code[1] for high speed craft was developed in 1994.

The HSC - code

Since long high speed passenger ships have been used. Relatively small ships carry passengers short distances, for example, the Danish/Swedish link between Copenhagen and Malmö. Few passengers, short trips and a crew that can monitor all spaces mitigate fire problems. However, larger ships are now being built. For example, a new high speed (40 knots) passenger ship can carry 1 500 passengers and 375 cars or 50 trailers. The dead-weight is 1 500 tons, see figure 2.

Figure 2. The Stena line high speed craft travels at 40 knots carrying 1500 passengers.

Fire protection of the new, large high speed craft is a prime issue. The bulkheads and decks cannot readily be built of traditional non-combustible materials like steel and mineral wool. The craft will be too heavy. Instead high performance polymers are used in sandwich structures. IMO prescriptive regulations require non-combustible materials only. Polymers are combustible and are therefore not allowed. However, there are polymers having excellent fire technical properties suitable for these ships. The IMO regulations therefore needed to be modernised and the so called High Speed Craft, HSC-code, was created. The HSC-code is largely formulating requirements based on performance. A certain safety level is quantified to which testing and evaluation techniques must be validated.

Two new definitions were made for products suitable for high speed craft, namely ”Fire-Resisting Divisions“ and ”Fire Restricting Materials“.

The requirements for the ”Fire-Resisting Divisions“ are similar to the traditional fire resistance testing and classification. The construction must have a certain fire endurance time, 30 or 60 minutes depending on use. The test method, IMO RES. A.754, as defined by IMO applies with some modifications. An important requirement is that the load bearing capacity must be maintained during a fire. However, all the testing and classification techniques for ”Fire-Resisting Divisions“ use traditional and well-known technology available at fire laboratories world-wide.

FIRE RESTRICTING MATERIALS

”Fire Restricting Materials“ are defined in the HSC as those materials which comply with the following requirements.

1. They are to have low flame spread characteristics.

2. They should have properties complying with standards to be developed by the organisation with respect to the following:

1. Limited heat flux. Due regard being paid to the risk of ignition of furniture in the compartment.

2. Limited rate of heat release. Due regard being paid to the risk of spread of fire to an adjacent compartment.

3. Gas and smoke should not be emitted in quantities that could be dangerous to the occupants of the craft.

The code is applicable to all sorts of materials used onboard; the most important for fire safety are linings and furniture frames/decorations.

The test standards are ISO 9705, the Room/Corner Test, and ISO 5660, the Cone Calorimeter.

A surface material or lining is considered to be a ”Fire Restricting Material“ if during a test time of 20 minutes according to ISO 9705 the criteria according to table 2 are fulfilled.

Table 2. Classification criteria for a ”Fire Restricting Material“ when tested in the Room/Corner Test according to the HSC - code.

Fire characteristic	Maximum Peak	Maximum Average
Heat Release Rate (kW)	500	100
Smoke Production Rate (m^2/s)	8.3	1.4
Flame Spread	Not further down the walls than 0.5 m from the floor	
Flaming drops or debris	not to occur outside the vicinity of the ignition source	

Large scale tests of sandwich panels have been conducted and compared to these criteria and there are polymer based constructions that fulfil them.

FIRE CALORIMETRY ARE USED TO ASSESS MATERIAL PROPERTIES

The heat Release Rate (HRR) is the single most important parameter in assessing material properties relevant to a real fire.

HRR is a direct measure of fire size and limiting the HRR from a burning product restricts the heat and radiation imposed on a person exposed to the fire.

The HRR is also closely coupled to the mass loss rate which governs the production rates of toxic gases and smoke. A high HRR generates large flames which means high radiation feedback to the surface of the product causing the rate of fire growth to increase. The HRR from a fire is measured in a fire calorimeter.

ISO 9705, the Room/Corner Test

The control values in the HSC - code relate to a large scale test where the complete assembly of the product including its mounting is tested. This is particularly important for sandwich panels with polymer foam insulation as their burning behaviour not always is truly reflected when testing small samples. For this purpose the ISO 9705-Room/Corner Test[2] is used. In this test the product is mounted on three walls and the ceiling of a small room 2.4 m by 3.6 m floor area and a ceiling height of 2.4 m, figure 3.

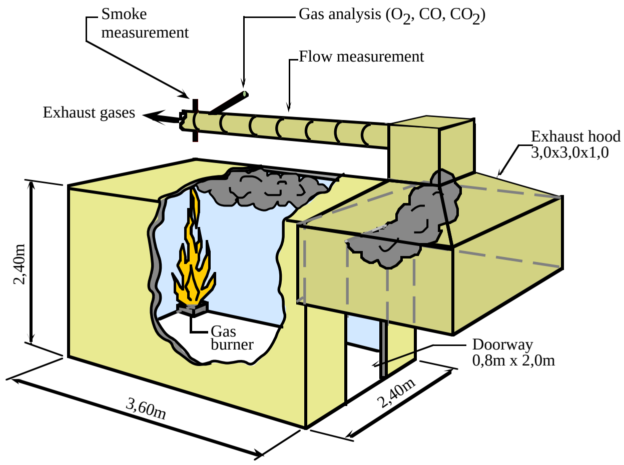

Figure 3. ISO 9705 Room Corner test is the reference scenario for testing and classifying linings as ”Fire Restricting Materials”.

The room has a door opening 0.8 m wide and 2.0 m high. The ignition source is a gas burner placed in one of the room corners. The burner heat output is 100 kW for the first ten minutes and then 300 kW for another ten minutes. The smoke gases coming out the doorway are collected by a hood. HRR is obtained by measuring the volume flow rate and the oxygen content in the exhaust duct. In a similar way the smoke production rate is obtained by measuring the smoke optical density.

A new and powerful technique for measuring a large variety of toxic gas species has been introduced, the so called FTIR (Fourier Transform InfraRed). This instrument makes infrared measurements simultaneously over the whole spectrum. NORDTEST has published a standard, NT FIRE 047[3], for FTIR measurements in fire testing. It was preceded by work done at VTT in 1990[4] and this technology was also used for measurements on upholstered furniture in the CBUF - project[5].

The FTIR technique is very promising. The concentration of a gas is measured continuously during a fire test. When combined with the heat release rate, yield data can be determined. Older techniques often only gave the time average and are time-consuming and not very suitable for routine work. An international project on further development of this technique is underway sponsored by the European Commission, the SAFIR - project.

ISO 5660, The Cone Calorimeter

The Cone Calorimeter[6] is a small-scale method where specimens sized 100 mm by 100 mm are exposed to well defined irradiance levels. These levels can be set up to 100 kW/m^2 corresponding to those of a real scale fire. As an example, the floor in a room with a fully developed fire is exposed to an irradiance in the range of 25 to 50 kW/m^2. Close to the flames on a burning wall lining the irradiance can be even higher. The surface of the specimen is heated and combustible gases are produced. The gases are then ignited by an electric spark ignitor. The smoke produced by the burning specimen is evacuated through an exhaust duct, see figure 4.

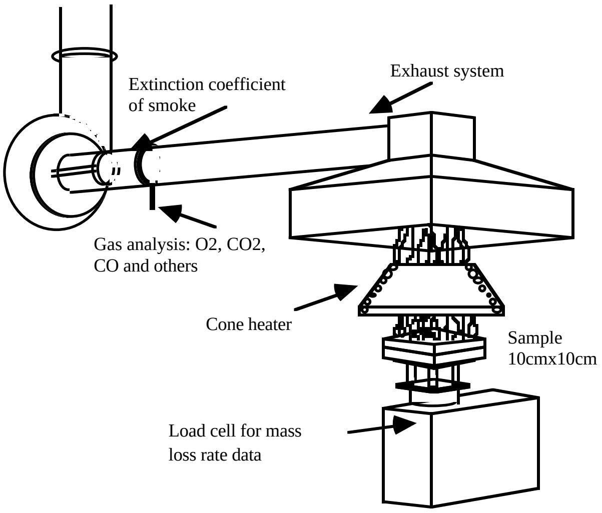

Figure 4. The Cone Calorimeter, ISO 5660.

Data reduction is the same as for the large scale Room/Corner Test. Output parameters are HRR, smoke production rate as well as toxic gas species if required.

The products used on high speed craft have high performance fire properties and experiments show that they should be tested at an irradiance of at least 50 kW/m^2. At lower levels they may not ignite or show a highly irregular behaviour which is not seen in the large scale test.

USING THE CONE CALORIMETER TO PREDICT THE BURNING BEHAVIOUR IN THE ROOM/CORNER TEST.

Testing costs can be reduced if a small scale test is used and the results for the large scale test are predicted. As the two methods are based on the same measuring principle, the same result parameters can be calculated. This offers a good point of comparison between small and full scale tests. At SP, a mathematical model[7] has been developed that uses only cone calorimeter data as input and predicts the heat release history in the ISO 9705 test. The model is currently tuned to predict the time to flashover but it might be possible to develop it into a tool for calculating the classification parameters for fire restricting materials. Table 3 shows some example calculations for some products.

Table 3. Comparison between predictions of HRR and measured values for some surface linings. The Pass/Fail condition is selected according to the HSC - code.

Product	Measured values in the Room/Corner Test			Calculated values based on data from the Cone Calorimeter		
	Peak HRR (30 s average) [kW]	Average HRR [kW]	Pass/Fail	Peak HRR (30 s average) [kW]	Average HRR [kW]	Pass/Fail
Painted gypsum paper plaster board	130	30	P	< 500	< 100	P
Plastic faced steel sheet on mineral wool	<50	<10	P	< 500	< 100	P
Melamine faced high density non-combustible board	150	15	P	< 500	< 100	P
Fire restricting material 1	250	66	P	< 500	< 100	P
Fire restricting material 2	1825	180	F	>1000	--	F

All products are classified similarly regardless whether it is based on actual data or a calculation. However, the model has the capability to be developed further to improve the confidence in the predictions of HRR parameters. To achieve a working system some actions have to be undertaken:

- The choice of Cone Calorimeter test conditions have to be optimised in order to handle modern, low weight assemblies.

- The model relating ISO 5660 to ISO 9705 classification has to be further developed on HRR and to include a prediction of the smoke production.

CONCLUSIONS

A very promising development of fire safety is taking place in the maritime area. IMO has succeeded to introduce a rather complete system for fire safety on board ships. Fire testing and classification criteria are put together into a single code that contains all necessary information. This code is expected to receive world wide recognition and provide basis for true harmonisation in the marine area.

IMO is moving towards development of a safety code based on performance. This will open possibilities for hazard analysis to be used and it is hoped that modern fire engineering principles for design of fire safety on board ships will develop. If this happens IMO will set an example on how world wide harmonisation can be achieved on a specific area using state of the art technology.

The high speed craft, HSC - code, contains requirements that partly can be said to be performance based. Fire calorimetry is used as a basis to define limitations of risk for unlimited fire growth.

For linings the Room/Corner Test is used as reference scenario. Pass/fail criteria are chosen in accordance with the performance requirements in the code. The fire growth could then preferably be predicted by a small scale test.

The Cone Calorimeter has been shown to predict the fire growth on linings without the need of any other test data. This leaves us with only two test methods for ”fire restricting materials”, ISO 9705, reference scenario, and ISO 5660, small scale.

REFERENCE LIST

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