MARITIME

Fire Risk Assessment of FRP Composite Hatch Cover for Panamax Bulk Carrier

E-LÄSS Seminar, Papenburg, Germany

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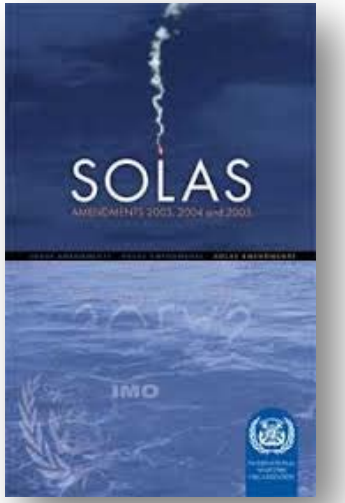
27 March 2014

CONTENT

INTRODUCTION

- Background
  - Joint development project DNV/Oshima in 2011-2012 on Eco-bulker for 2020
  - Feasibility study on FRP composite hatch cover



- Motivations
  - 35% of steel design weight
  - ↓ corrosion + ↓ fatigue = ↓ maintenance cost + ↓ risk for cargo
  - simple handling mechanism
  - simple commissioning and testing of hatches

- Objective of fire risk assessment

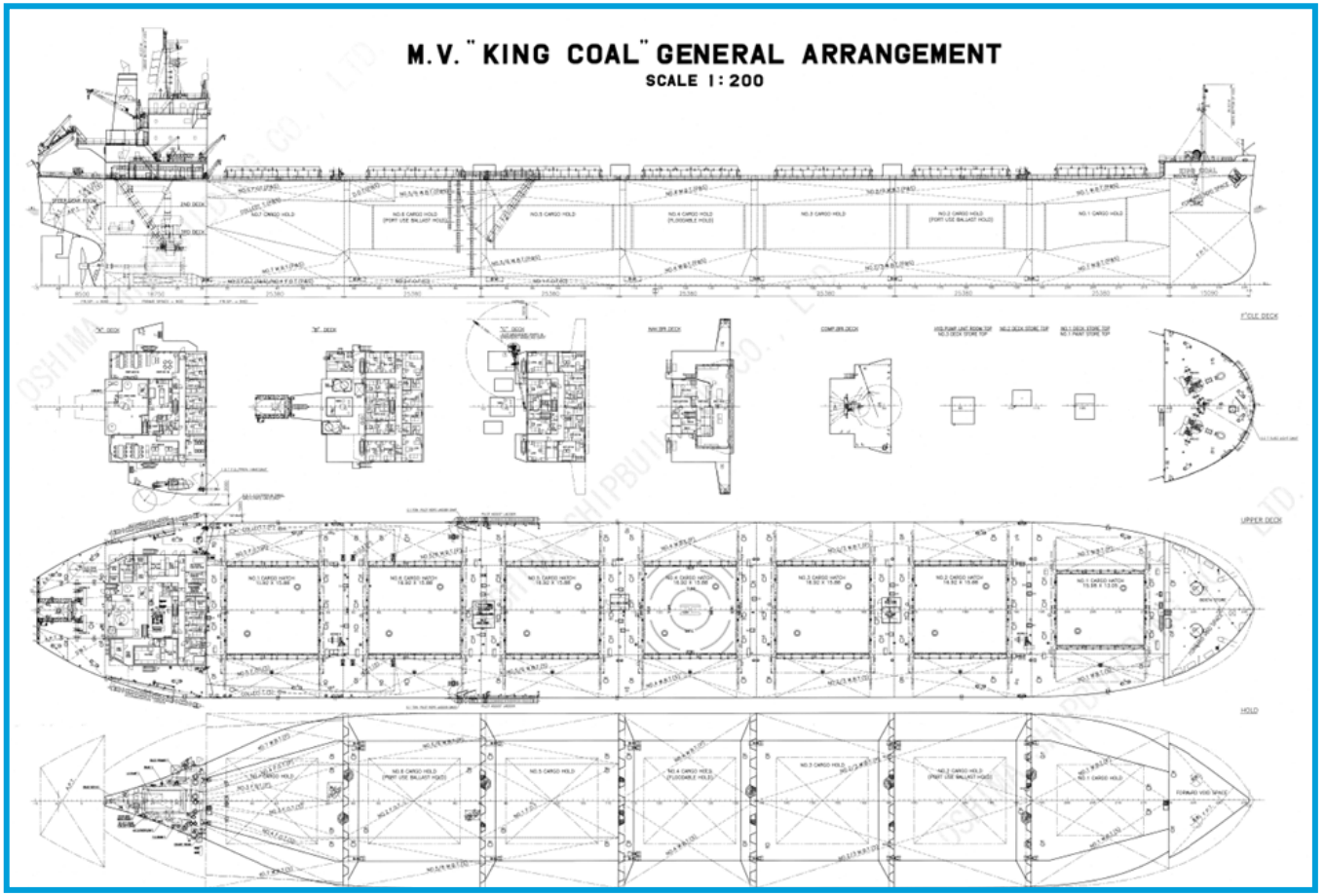
To demonstrate, in accordance with Reg.17 and the MSC/Circ.1002, that the fire risk for the novel FRP composite hatch cover for the given vessel is equivalent to that implied by the prescriptive requirements of SOLAS

SCOPE OF THE FIRE RISK ASSESSMENT

- Oshima hull
- 75,600 DWT Panamax
- 220 x 32 x 19 m

- double bottom
- single skin sides

- worldwide operations



SCOPE OF THE FIRE RISK ASSESSMENT

- Cargo types:
  - coal (all grades), grain, cement, ore
  - no deck cargo

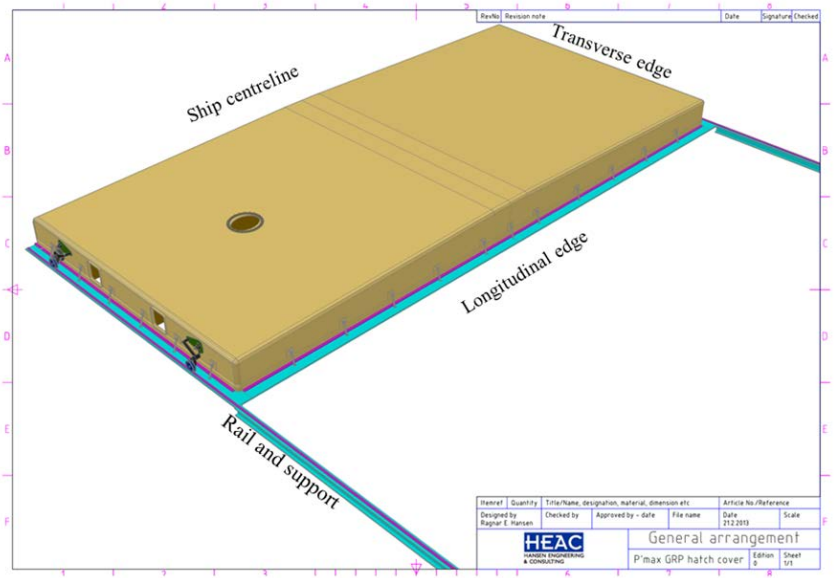
- Type of hatch cover: Side rolling with two panels per one hatch. Panels main dimensions:
  - hatch no. 1: 13.2 m x 16.2 m
  - hatches nos. 2-7: the panel size is 8.01 m x 17.10 m

- Firefighting appliances identical to those used for the prescriptive design:
  - seawater fog/jet to be connected to fire hydrant, portable fire extinguisher for helicopter landing area, fire pump, fire main/wash deck service line, fire hydrants on deck
  - Note: no firefighting and fire detection equipment in the cargo holds

DESCRIPTION OF THE ALTERNATIVE DESIGN

- Height: 800 to 1000 mm
  - i.e. typically larger than a prescriptive steel design (700 to 800 mm)

- Materials and construction: single skin GRP (E-glass fibre and polyester resin) with thicknesses ranging from 10 to 30 mm



DESCRIPTION OF THE ALTERNATIVE DESIGN

- Conformance with the recommendations of the IMO 2008 International Maritime Solid Bulk Cargoes or IMSBC Code):
  - information on cargo coal cargo characteristics (moisture content etc.)
  - cleaning of cargo spaces
  - cargo hold prepared with small openings for insertion of handheld measuring instruments (methane, oxygen, CO2, pH cargo bilge)
  - temperature measurement (from 0-100°C) at ends and bottom of tanks
  - ...

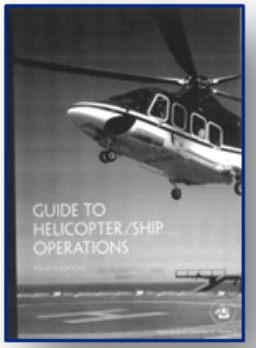
EXPERIENCED DESIGN TEAM

- The design team members were:
  - Ragnar Hansen (Oshima/HEAC Japan/Norway)
  - Kazutaka Murayama (Oshima, Japan)
  - Shinnosuke Funayama (Oshima, Japan)
  - Bjørn Høyning (FiReCo, Norway)
  - Dag McGeorge (DNV, Norway)
  - Øyvind Wilhelmesen (DNV, Norway)
  - Philippe Noury (DNV, Norway)

- Assistance of Michael Rahm and Per Blomqvist (SP, Sweden) for the quantification of the design fires

RESULTS OF THE PRELIMINARY ASSESSMENT

BASIS FOR RULES AND REGULATIONS



- This includes:
  - DNV Rules for Classification of Ships
  - IACS Common Structural Rules for Bulk Carriers
  - Pt.4 Ch.10, Fire Safety, DNV Rules for Classification of Ships
  - SOLAS Ch.II-2 Reg.9, Containment of Fire: Table 9.6
  - SOLAS Ch.II-2, Reg.10.7, Fire Fighting
  - SOLAS Ch.II-2 Reg.11, Structural Integrity
  - SOLAS Ch.II-2, Reg.17, Alternative Design and Arrangements and MSC/Circ. 1002, Guidelines on Alternative Design and Arrangements for Fire Safety
  - SOLAS Ch.II-2, Reg.18.2 and 18.3, Helicopter Facilities
  - 2008 International Maritime Solid Bulk Cargoes (IMSBC) Code, Appendix 1
  - Australian Maritime Safety Authority, Marine Orders, Part 57, Helicopter operations
  - ...

REVIEW OF SOLAS CHAPTERS AND DEVIATIONS

- Review and discussion of SOLAS fire safety objectives and functional requirements

- Aim to identify the challenges and deviations from the regulations in more details, and help to focus on the critical issues

- Produced comments on whether the safety objectives or functional requirements are fulfilled or not for the alternative design
  - Example fire safety objectives of SOLAS II-2 .5 "*provide adequate and readily accessible means of escape for passengers and crew*"
  - objective not influenced by the alternative design and hence fulfilled

IDENTIFICATION OF FIRE HAZARDS AND SCENARIOS

- Process
  - Carried out a HAZID workshop with design team
  - Systematically identified and recorded: room/pre-fire situation, ignition source, initial fuel, extension potentials, critical factors, statistics/frequencies

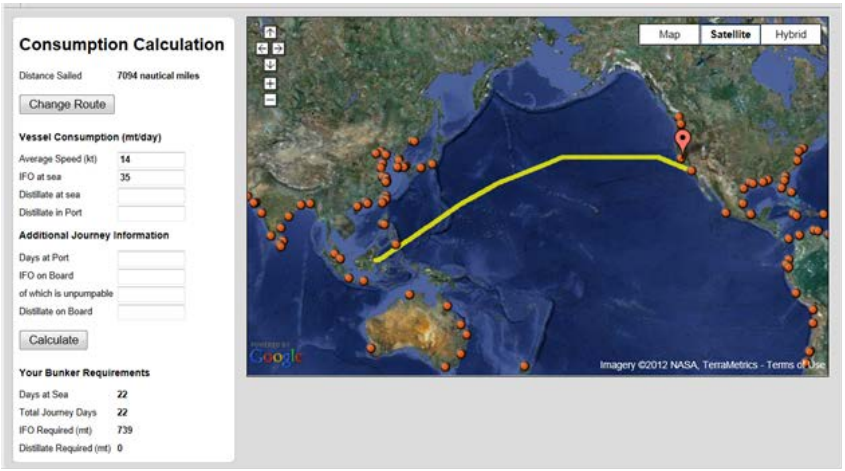
- Cargo types and combustibility
  - Cement and ore are non-combustible
  - Grain (wheat, maize etc.): Different types have different combustibility, self-combustion. Less critical than ignition risks associated with coal cargo
  - Coal: Combustible cargo that can be self-heating and self-igniting. Oxidation and combustibility characteristics vary depending on coal type. This type of cargo type is directly addressed in this analysis

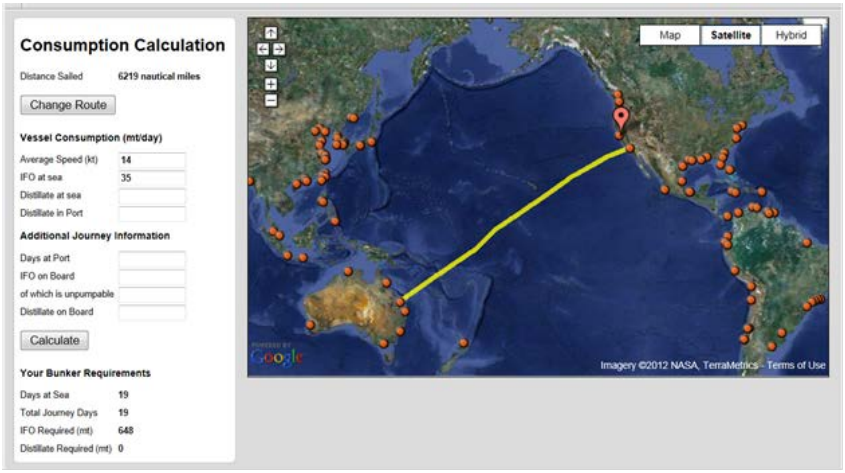
COAL FIRE

- Stage I. Slow oxidation (up to 50°C)
- Stage II. Intermediate stage of oxidation with increasing rate in temperature change: 1. Steady-state oxidation with removal of moisture (50-80°C). 2. Evolution of oxides of carbons (up to 120°C). 3. Rapid interaction with oxygen (up to 180°C). 4. Thermal decomposition (180-250°C)
- Stage III. Self-sustained combustion (200-250°C)

IDENTIFICATION OF FIRE HAZARDS AND SCENARIOS

- 2 fire scenarios (and variants) were selected
  - coal fire in the closed cargo hold a sea up to one (1) week from harbour for unloading
  - deck fire close to hatch cover at sea or at berth





SPECIFICATION OF DESIGN FIRE SCENARIOS

- Cargo hold fire scenarios with n variants:
  1. Sealed cargo hold
  2. Air leakage
  3. ...

Ignition source(s): self-ignition of cargo

Initial fuels: coal cargo (lignite coal of Indonesian origin i.e. low grade)

Secondary fuels: coal cargo, composite surface, gas, unauthorised cargo, paint, rubber gasket

Compartment of origin: cargo hold no. 5 or 6

Ventilation: No ventilation or air leak (from opened ventilation hatch or poor seal). There is no risk for other condition of ventilation to the cargo hold as there is no duct or other earlier.

Fire protection system installed: as describe

Number of occupants: 0

Assumptions: self-heating and self-ignition of coal through oxidation cannot be ruled

Control of cargo: when loading and during voyage according to procedures from of IMSBC code

SPECIFICATION OF DESIGN FIRE SCENARIOS

- Deck fire scenarios with m variants:
  1. Molotov cocktail
  2. Mooring drum
  3. Hydraulic leak
  4. ...

Ignition source(s): electrical failure, careless smoking, power cables, sun heat, Molotov cocktail, hot surface, lightning, self-ignition of e.g. oily cloth, flame cutting, grinding, welding, exhaust flakes

Initial fuels: waste basket, cable insulation, composite material, paint, paint pot, mooring ropes, wooden ladder, rubber from gasket, dust, oily liquids, hydraulic liquid

Secondary fuels: rubber gasket, composite material, mooring ropes, wooden ladder, oily liquids, unauthorised cargo

Compartment of origin: in the vicinity of any cargo hold

Ventilation: open air condition

Fire protection system installed: see Section 3.1.2

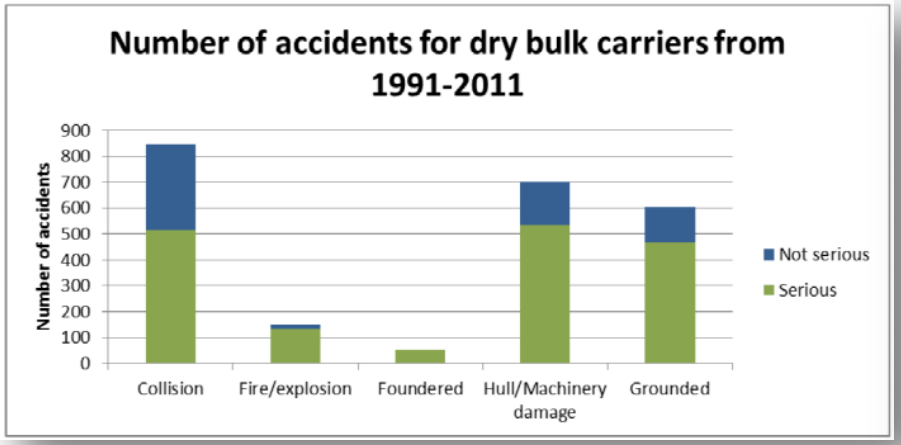
Number of occupants: 0

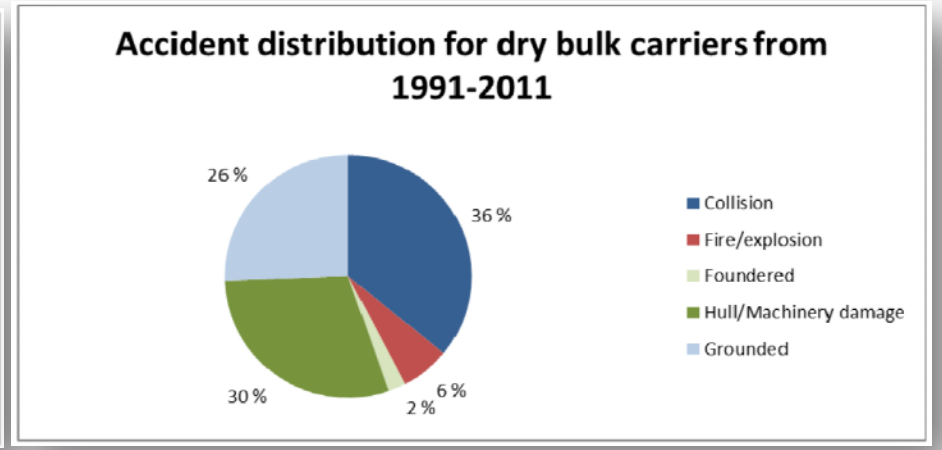
Assumptions: none

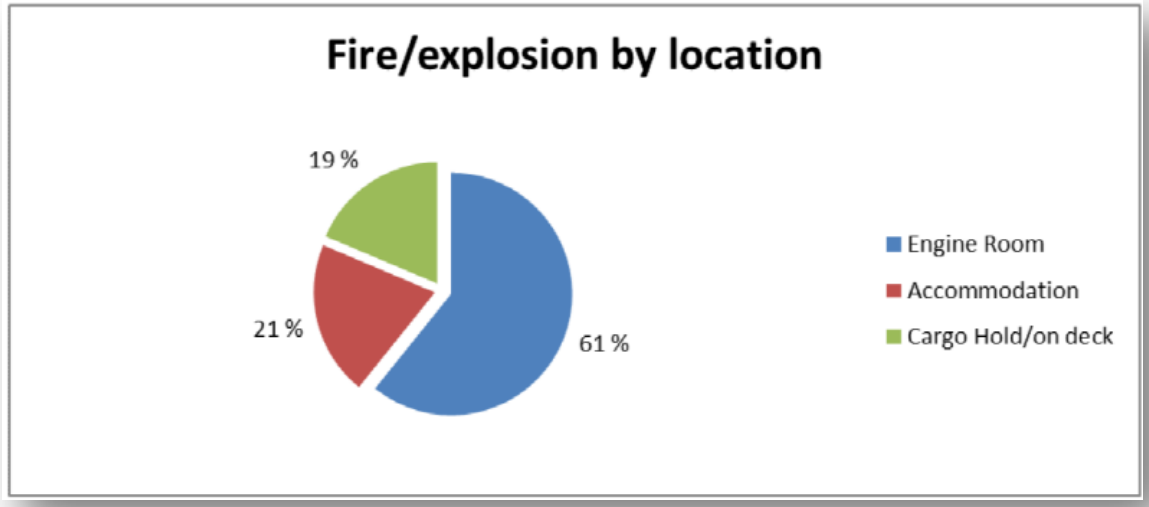
HISTORICAL AND STATISTICAL DATA

- HIS Fairplay databases
  - 56064 ships years between 1991 to 2011
- Bulk carrier in general
  - 1fire/explosion every 370 ship years
  - 1fire/explosion on deck/cargo hold every 1869 ship years.
  - 1fire on deck/cargo hold every 2803 ship years where 1 in 10 is a coal cargo fire
  - no one was killed from the 20 fires that occurred in the cargo hold/deck over 56064 ship years
- Panamax vessels or larger
  - same (or even better) trend

HISTORICAL AND STATISTICAL DATA







RESULTS OF THE PRELIMINARY ASSESSMENT

- One trial alternative design with 2 RCOs

Fire scenario	ID	Description of RCO	Goal of RCO
Cargo hold	EKS	Emergency kit for hatch cover sealing	Provide for effective control of abnormal air leakage
Deck	SES	Improved-fire-reaction surface of the GRP composite against deck fire	Prevent fire spread on external surfaces

- With these inexpensive RCMs implemented, the fire risk for the novel composite hatch cover is considered equivalent to that implied by the prescriptive requirements of SOLAS.

- To be substantiated quantitatively in the quantitative assessment

PERFORMANCE CRITERIA

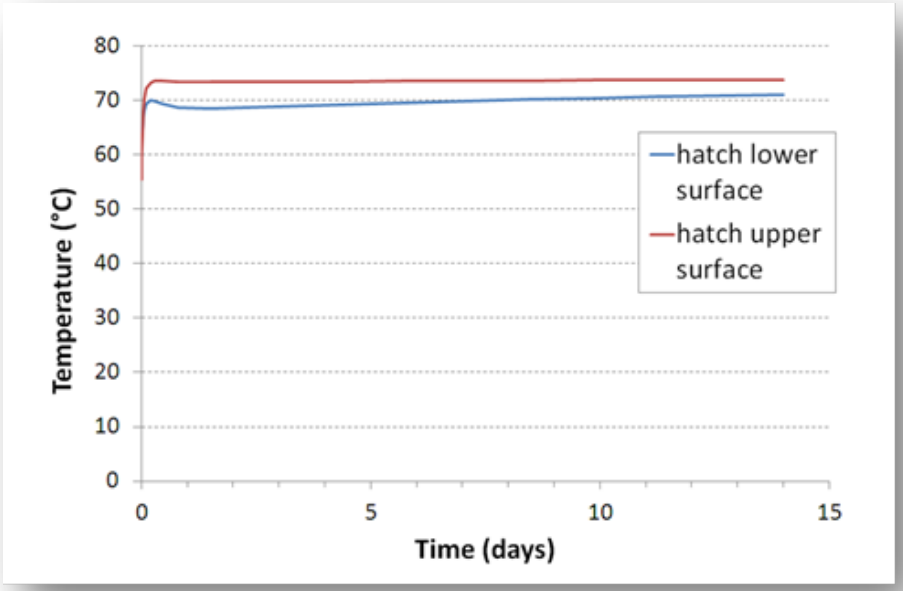
- No life shall be lost

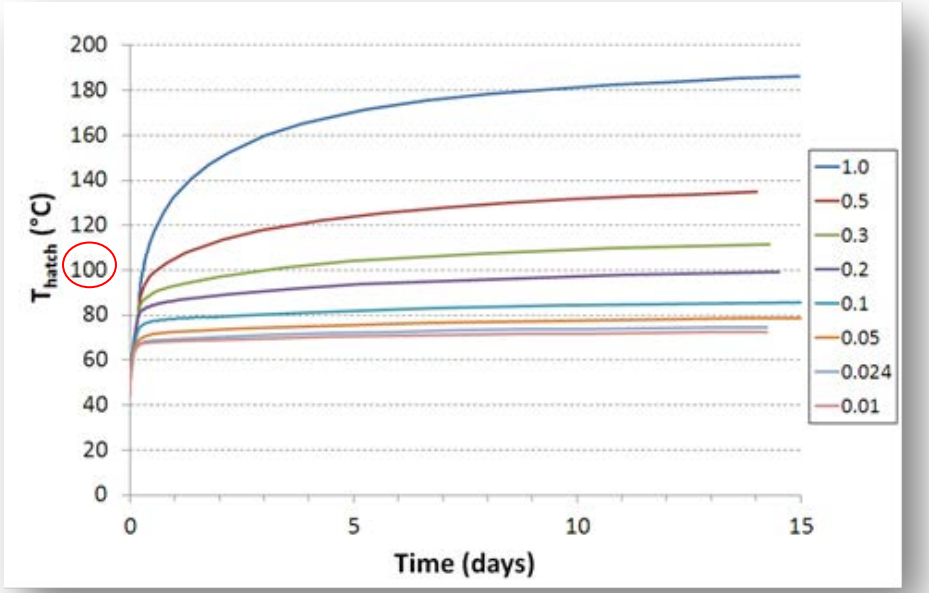
- Cargo hold fire: The hatch cover shall be capable of maintaining its structural integrity for a period of 1 week
  - i.e. to remain weather-tight with opening and closing possibilities and a structural strength up to ULS level (this, in order to control the risk of fire escalation, ensure the possibility of suppressing overheating/smouldering fire, prevent flooding and further damages or consequences)

- Deck fire: A fire on the hatch cover caused by exposure from local deck fire shall not escalate out of control

RESULTS OF THE QUANTITATIVE ASSESSMENT

CARGO HOLD FIRE





CARGO HOLD FIRE

- **Design fire scenario and consequences**
  - Max. temperature stays below 100°C during the time period the ship needs to reach harbour if the hatch is closed and sealed
  - For temperatures up to approximately 100°C, the composite hatch remains structurally unaffected by heat
  - Importance of ventilation effects for thermal load on cargo hatch but structural collapse cannot occur
  - In the unlikely case that ventilation control fails (causing a significant inflow of up to 0.2 m3/min) structure collapse will not occur due to coal combustion

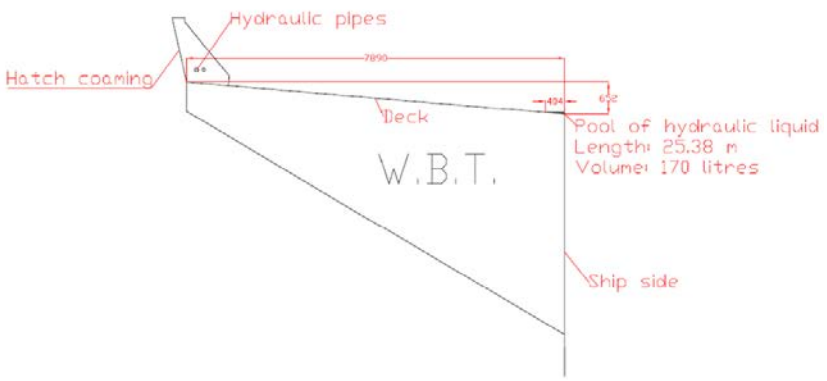
CARGO HOLD FIRE

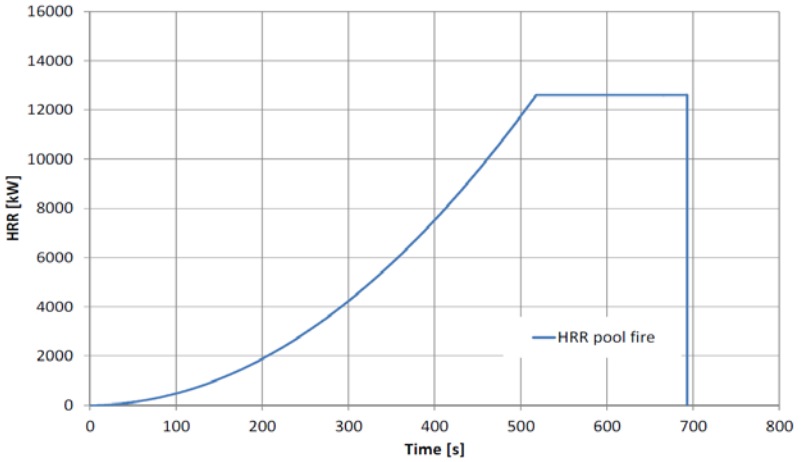
- **Performance criteria**
  - No loss of life. OK
  - The hatch cover shall be capable of maintaining its structural integrity for a period of one (1) week. OK
- **Evaluation of prescriptive (steel) design**
  - performances of the trial alternative design are equivalent to performances of the prescriptive design

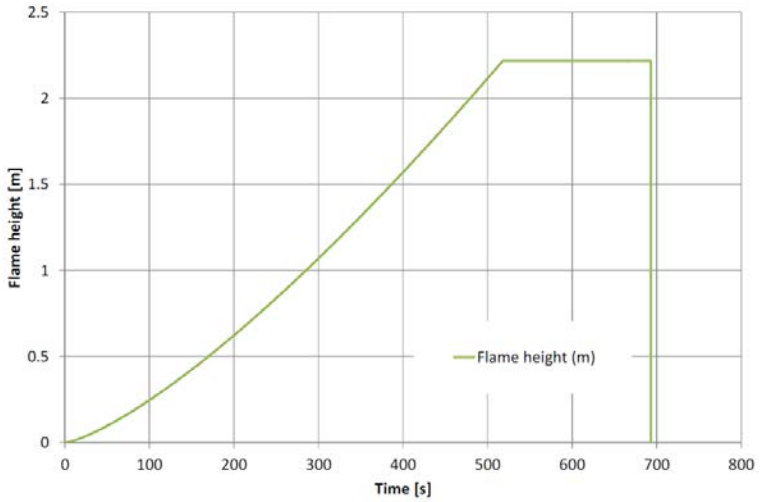
DECK FIRE - MOLOTOV COCKTAIL

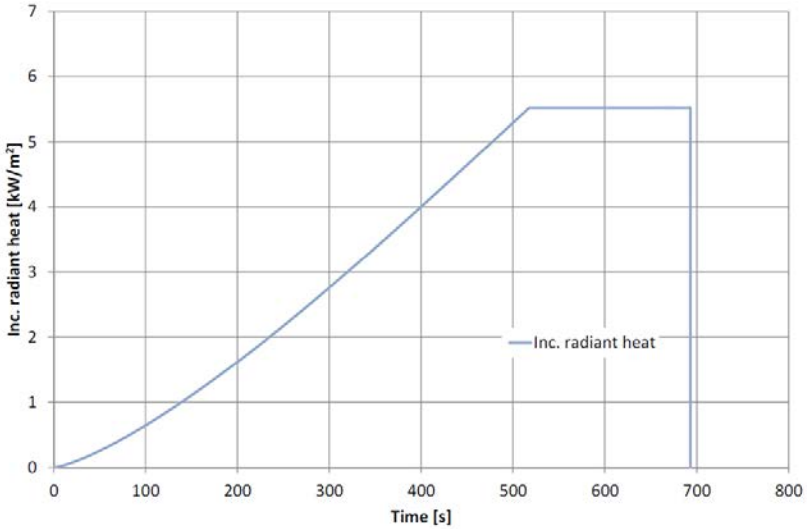
- **Design fire scenario and consequences**
  - Molotov cocktail of 750 ml of heptane produces a 2 m2 pool fire with flames of height of 2.5 m
  - Fire intensities typically low i.e. below 1000 kW and can generate a radiation level of 40 kW/m2 during 0.5 min.
  - In comparison, cone calorimeters test on GRP laminates indicates that a radiation level of 50 kW/m2 during 1 minute is necessary for ignition
  - A Molotov cocktail of 750 ml of heptane is not sufficient to ignite the FRP cargo hatch covers.

HYDRAULIC OIL POOL





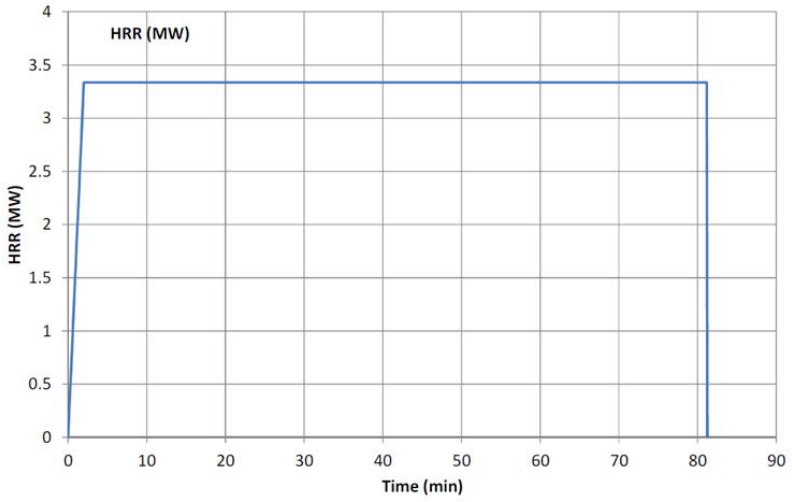


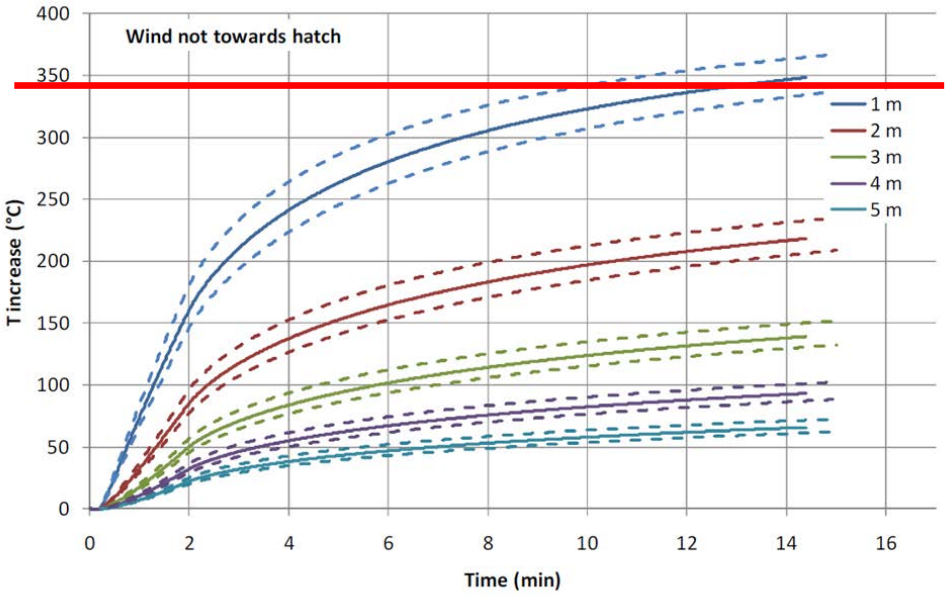


HYDRAULIC OIL POOL ALONG GUNNEL

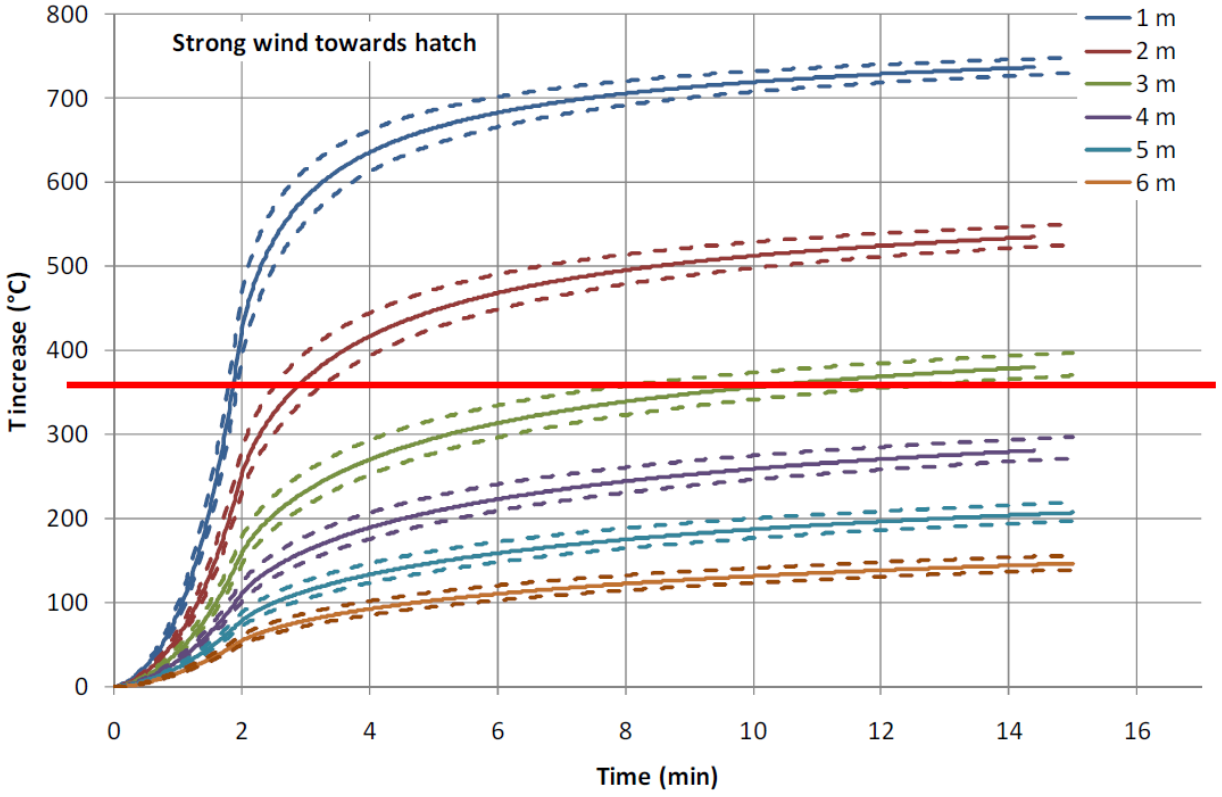
- Based on an incident radiation of 5.5 kW/m2, the surface temperature is found to be of the order of 245°C.
- This is below the ignition temperature of 346°C of such a type of GRP laminate.
- Therefore, the exposure from this pool fire scenario will not ignite the FRP regardless of how long time the pool fire is allowed to continue.

MOORING ROPE DRUM





MOORING ROPE DRUM



MOORING ROPE DRUM

Under which conditions can fire develops?

Time line?

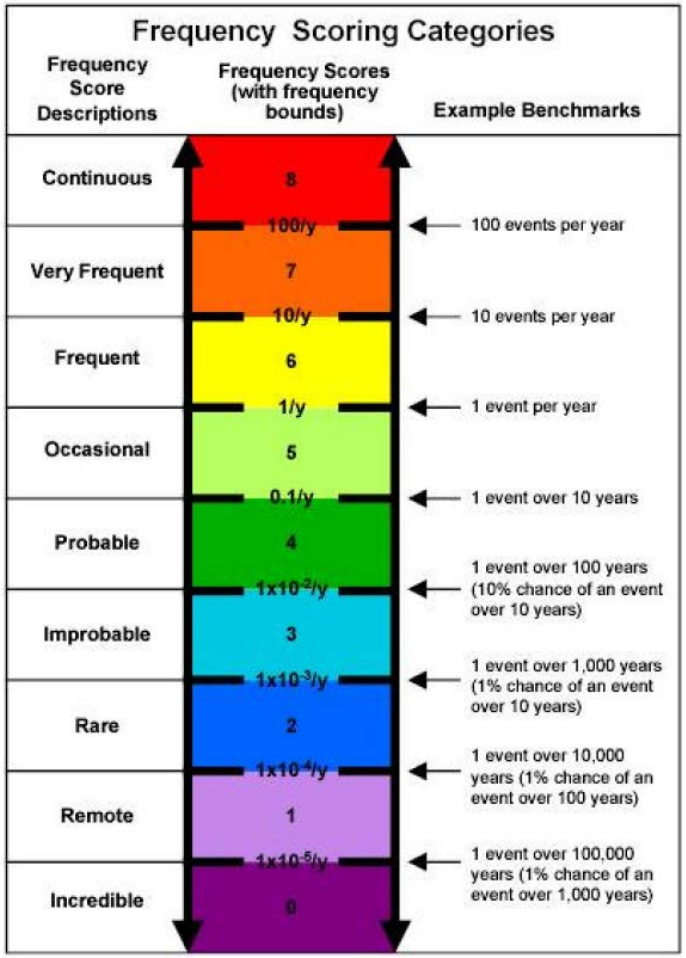
- A fire from a burning mooring rope drum, with a peak heat release of 3.3 MW and duration of 80 min, is not sufficient to ignite the FRP cargo hatch covers under most wind conditions, if positioned more than 1 m away
- If positioned 1 m away, the time from ignition of the burning rope to ignition of the FRP hatch cover is approximately 12 min under most wind conditions. This time reduces to a little less than 2 min under unfavourable wind conditions, i.e. strong winds towards the hatch cover.
- If positioned 3-4 m away, the time from ignition of the burning rope to ignition of the FRP hatch cover is a little over 2 min under unfavourable wind conditions.

MOORING ROPE DRUM

How likely is this?

- For a fire to start onto the unprotected surfaces, the following failures must occur:
  - Failure to prevent ignition of mooring drum
  - Probability of having the wind blowing towards the hatch cover
  - Failure to detect within 2 min
  - Failure to extinguish fire within 2 min plus the time necessary for the fire to develop on the mooring rope drum i.e. several minutes, with firefighting equipment located on deck.
- The total probability of fire ignition in such case is of the order of 8.5.10-7 i.e. incredible under very unfavorable conditions (1 event every 10 000 years)

Frequency categories



MOORING ROPE DRUM

But would be the consequences?

- In case of fire developing on the hatch cover:
  - fire would spread onto the surfaces of a standard GRP laminate (if not protected with improved-fire-reaction surfaces)
  - no important quantity of secondary fuel in contact with hatch cover; fire circumscribed by incombustible steel structure; local fire; normal fire intensity easily manageable with standard portable firefighting equipment
  - local fire escalation; damages limited to local surface and fittings
  - consequences of the would be minor

MOORING ROPE DRUM

- **Performance criteria**
  - No loss of life. OK
  - Fire on the hatch cover caused by exposure from local deck fire shall not escalate out of control. OK
- **Evaluation of prescriptive (steel) design**
  - performances of the trial alternative design are equivalent to performances of the prescriptive design

CONCLUSION

the fire risk for the novel composite hatch cover is considered equivalent to that implied by the prescriptive requirements of SOLAS

APPROVAL PROCESS

APPROVAL PROCESS

- related only to fire safety i.e. excludes structural integrity

- involves classification society and national authority

1. Informed the national marine authority and agreed on acceptance process
2. Delivered preliminary assessment report to DNV GL for review
3. Findings from review and recommendations from DNV GL based on the preliminary assessment were positive. Go ahead with quantitative assessment
4. Delivered quantitative assessment report to DNV GL for review
5. Findings from review and recommendations from DNV GL based on the quantitative assessment were positive, i.e. the alternative design is acceptable and documentation is complete and satisfactory
6. Real case to be sent to national maritime authority for final acceptance

Fire Risk Assessment of FRP Composite Hatch Cover for Panamax Bulk Carrier

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