Annex M

Extracts from Hawkins & Associates Ltd's report on Ignition of Hydraulic Oils by Hot Surfaces – C69/45210 dated 10 November 2010

1. INTRODUCTION

1.1 On 1 November 2010 the Marine Accident Investigation Branch (MAIB) asked Hawkins to conduct a literature survey of ignition mechanisms of hydraulic oil sprays by hot surfaces. This was in response to the possibility that the fire on the Yeoman Bontrup might have been caused by the failure of a hydraulic pipe in the vicinity of a halogen lamp. The MAIB provided the following background information regarding the hydraulic oil and the lamp.

1.2 The hydraulic pipes to ballast transfer pumps on the Yeoman Bontrup were pressurised at the time of the fire. The temperature of the oil and the pipes was reported to be around 30°C. The hydraulic oil was HySpin AWH-M15, Code 6152-UK. The MAIB provided the material safety data sheets (MSDS) for the oil that were dated 1994. The MSDS indicate that the oil had a flash point of above 140°C and an auto-ignition temperature (AIT) of above 250°C.

1.3 The MAIB had conducted investigations on the Yeoman Bridge and a sister ship and recorded surface temperatures on halogen lights of around 135°C. These lights were assumed to be the same as those in the vicinity of the seat of the fire on the Yeoman Bontrup. The MAIB asked Hawkins to comment on the possibility that a ruptured or split hydraulic pipe on the Yeoman Bontrup might have released a spray of hydraulic oil, which impinged on a halogen light and whether it was possible that this hydraulic spray could be ignited by the halogen lamp. The MAIB raised the possibility that the AIT of hydraulic oil might be reduced if the oil is highly atomised when it contacts a hot surface.

3. DISCUSSION

3.1 The available literature and review literature in terms of the Ignition Handbook and Kirks Fire Investigation, suggests that the surface temperature must greatly exceed the auto-ignition temperature for a spray of fuel oil to be ignited by that hot surface.

3.2 There is no evidence either within the scientific publications or within the general overviews that the auto-ignition of a fuel might be decreased by highly atomised sprays. The scientific publications indicate that ignition occurs in the vapour phase at some distance from the surface. Heat transfer from the surface causes evaporation of the liquid fuel, heats both the fuel vapour and the available oxygen supply and the excess energy raises the mixture to the AIT.

3.3 As such, it is necessary that the surface temperature is greatly in excess of the AIT to allow sufficient heat transfer from the surface to the liquid fuel and the vapour.

3.4 It should be noted that the residence time is critical in causing ignition of the fuel. For example, when low volatility fuels are provided with a wick, such as those used in kerosene lamps, the wick provides an environment where the fuel's evaporation is controlled and the flame can stabilise above an apparently cold fuel. This can also be observed in situations where oil soaked lagging around hot steam pipes is ignited, despite the steam pipe being below the auto-ignition temperature of the oil involved. The oil soaks into the surface of the lagging and is trapped on its surface. A slow oxidisation process occurs until ignition results at the outer surface where sufficient oxygen is available for the reaction.

3.5 There are some circumstances where the residence time of the fuel at high temperature may be increased, such as in lagging, on a wick or where high surface tension fluids are involved. In the case of the Yeoman Bontrup, it might be possible that significant quantities of granite dust existed around the halogen lamp and this provided some insulated coating on the lamp itself.

3.6 Should a sufficient granite dust have built up on the lamp, it is possible that an oil spray could have soaked into the dust and then been held in proximity to the hot surface of the lamp for an extended period. However, the significant separation of temperatures from 250°C for the quoted auto-ignition of the oil and the 135°C stated as the lamp surface temperature would appear to be too great to sustain an auto-ignition via heat transfer mechanism. Additionally, there is no evidence of a significant build-up of granite dust having covered on any of the halogen lamps, which might result in sufficient wicking affect to cause ignition of the oil.

3.7 There is no evidence in the available literature to suggest that even a highly atomised spray could have been ignited by lamp temperatures of only 135°C. As this is also below the flash point of the hydraulic oil, it is extremely unlikely that any oil landing on the halogen light would vaporise sufficiently to produce a flammable local atmosphere, which might be ignited by a secondary source.

3.8 I consider that the ignition of an oil spray on the Yeoman Bontrup might be possible had a high temperature source existed, such as an exposed halogen light bulb. However, there is no evidence that any such exposed bulb existed, that any leak of oil was observed, or that any significant quantity of oil had been lost from the water ballast transfer pump hydraulic system.

4. CONCLUSIONS

4.1 The available literature indicates that a surface temperature must greatly exceed the auto-ignition temperature of a fuel oil in order that a spray of fuel oil may be ignited by that hot surface. The available data for the halogen lamps on the sister ship, Yeoman Bridge, indicates that the surface temperatures of the lamp were around 135°C. This is below the quoted flash point and well below the auto-ignition temperature of the hydraulic oil for the water ballast tank transfer pumps.

4.2 I consider that, in the case of the Yeoman Bontrup, auto-ignition of a hydraulic spray from a failed pipe impacting the halogen lamps in the tower is extremely unlikely. Even if a significant build up of granite dust existed on the halogen lamp, the temperature of the lamp would be insufficient to create a localised flammable atmosphere that could be ignited by a secondary source, such as a spark or an open flame.

4.3 There does not appear to be any ignition mechanism available in the literature or any physical evidence that would support the suggestion that the fire on the Yeoman Bontrup was caused by the ignition of a hydraulic oil leak.

Annex N

MAIB Safety Flyer

FLYER TO SHIPPING INDUSTRY

YEOMAN BONTRUP:
RADIATION HAZARD IDENTIFIED FOLLOWING A FIRE

On 2 July 2010, a fire was discovered on the vertical cargo conveyor belt of the self-unloading bulk carrier *Yeoman Bontrup* while the cargo hopper was being repaired. The crew tackled the fire from the conveyor tunnels under the holds, but it quickly spread throughout the cargo handling area and into the accommodation. The fire also spread into the engine room by heat transfer through the bulkheads and via an open connecting door, and then to the steering gear compartment which contained a number of hydraulic systems as well as stocks of oils, greases, and ship's-use chemicals. There, the fire caused a large explosion that blasted the entire poop deck into the air and onto the funnel deck **(Figures 1 & 2)**. Fortunately, there were only minor smoke inhalation and bruising injuries.

The fire was most likely caused by hotwork repair debris falling from the cargo hopper at the top of the tower into the flammable side curtain of the vertical conveyor belt.

Figure 1

Figure 2

RADIOACTIVE ISOTOPES

Silometer devices, containing radioactive Cobalt 60 isotopes, were fitted to the cargo hopper to detect excessive build up of cargo in the self-unloading system. The silometers had not been used for 10 years, and the outer shells of the source containers were in an extremely poor condition. However, the radioactive isotopes inside them were still active. During the fire, the lead shielding around one of the radioactive source containers melted, exposing the radioactive source container itself **(Figure 3)**.


Figure 3

The onboard risk assessments did not include the risk of exposure to gamma ray radiation, and the Safety Management System did not provide any guidance on inspecting the silometers or safety precautions to be taken. Consequently: welding operations regularly took place in the hopper area without any precautions being taken to warn or protect the personnel involved; when the fire broke out none of the firefighters or salvors was warned of the potential hazard; and inspectors and surveyors investigating the cause of the fire were consequently exposed to low levels of radiation when they inspected the cargo hopper area. Fortuitously, the source containers were not breached; had this occurred the fire could have spread radioactive particles throughout the surrounding area, generating a severe risk to health.

As automation on board ships has increased, so has the use of radiation sources in control devices. This is especially so in bulk carriers and dredgers. While the Ionising Radiation Regulations 1999 apply to radioactive equipment ashore in the UK, and there are clear instructions for handling cargoes containing radioactive sources, currently there are no international regulations specifically governing radioactive sources used in ship's equipment. Consequently, the MAIB has recommended the flag state to submit proposals to the IMO to introduce standards for management of radioactive sources for use in the marine environment.

SAFETY LESSONS

- Where appropriate, ship owners and managers should ensure their Safety Management Systems provide comprehensive guidance for the control, use, inspection, maintenance and disposal of radiation sources fitted to their vessels to ensure that risks of exposure to radiation are minimised.
- Such guidance should include the potential risk to health from exposure to radiation resulting from an accident such as a fire or collision.
- Emergency plans should ensure that the presence of radiation sources is brought to the attention of attending emergency services (eg. Fire and Rescue Service) so that the radiation risk is given due consideration.

This flyer and the MAIB's investigation report are posted on our website: www.maib.gov.uk

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Annex O

New VMS Section 4.11.8 Exposure to Radiation Sources On Board

4.11.8 Exposure to Radiation Sources Onboard

The purposes of this section is to assess, monitor and where appropriate control radiation risks from shipboard sources

Radiation Types

Ionising Radiation

Ionising radiation

- occurs as either electromagnetic rays (such as X-rays and gamma rays) or particles (such as alpha and beta particles)
- represents electromagnetic waves and particles that can ionize, that is, remove an electron from an atom or molecule of the medium through which they propagate.

Ionising radiation types:-

Alpha radiation

- heavy, very short-range particle
- travels only a short distance (centimeters) in air, but is not an external hazard
- able to penetrate human skin or clothing
- can be harmful if the materials are inhaled, swallowed, or absorbed through open wounds

Beta radiation

- a light, short-range particle
- may travel several feet in air
- can penetrate human skin to the "germinal layer," where new skin cells are produced; clothing provides some protection
- If high levels of contaminants are allowed to remain on the skin for a prolonged period of time, they may cause skin injury;
- may be harmful if deposited internally (inhaled or digested)

Gamma radiation and X rays

- the most energetic electromagnetic types of radiation
- highly penetrating
- able to travel meters in air and deep in / or pass through human tissue
- clothing provides little shielding from penetrating radiation, but will prevent contamination of the skin; dense materials are needed for shielding;
- Gamma radiation and/or characteristic X rays frequently accompany the emission of alpha and beta radiation during radioactive decay

Non-ionising radiation

Optical (light) radiation (ultraviolet (UV), visible and infrared)

Risks to health are:
- damage to the eyes
- skin damage range from redness, burning and accelerated ageing through to various types of skin cancer

Electromagnetic fields (EMFs) (power frequencies, microwaves and radio frequencies)

- arise whenever electrical energy is used
- can give rise to acute health effects depending on the on the frequency of the radiation
  - at low frequencies the effects will be on the central nervous system of the body
  - at high frequencies, heating effects can occur leading to a rise in body temperature

Hazards & Health Risks Associated with Radiation Equipment

Ionising Radiation affects people by depositing energy in body tissue, which can cause cell damage or cell death. Additionally, an abnormal cell may become malignant.

Non Ionising Radiation health risks are typically associated with biological effects from heating of tissue by radio frequency / micro wave electromagnetic energy ("thermal" effects):

- skin can be affected

- eyes and the testes, are particularly vulnerable to RF heating because of the relative lack of available blood flow to dissipate the excessive heat load and prolonged exposure can damage such tissues.

Equipment onboard which may be affected

Equipment manuals onboard the vessel should be reviewed for any equipment that contains a radiation source.

Where equipment is identified as containing a radiation source, this equipment must be listed on the vessel's TEC 22 form and a copy of this kept with the Contingency Plans detailed in SEP 1.5.8. In the event of a contingency, shore responders must be notified on the presence of such equipment to avoid accidental exposure. The equipment itself must be clearly labelled as a radiation hazard.

The table below gives guidance, without being exhaustive, on possible equipment that could potentially contain ionising radiation materials and could be used as a starting point for the required onboard survey.

In all cases, the manufacturers instructions should be consulted to determine if a significant health risk is present.

Equipment	Possible radioactive elements	Type or Ionising radiation
Commercial smoke detector systems	Americium-241	gamma and alpha
Thickness gauging	Americium-241	gamma and alpha
	Cerium-144	gamma and beta
	Cesium-137	gamma
	Europium-155	gamma and beta
	Krypton-85	gamma and beta
	Strontium-90	beta
Weld inspection; detecting thickness variation and defects in castings	Cesium-137	gamma
	Cobalt-60	gamma
	Europium-155	gamma and beta
	Gadolinium-153	gamma
	Iridium-192	gamma and beta
	Samarium-145	beta and alpha
Automatic weighing equipment	Cerium-144	gamma
	Cobalt-60	gamma
	Promethium-147	beta
	Strontium-90	beta
Voltage regulators and current surge protectors	Cesium-137	gamma
	Lead-210	beta
	Nickel-63	beta

Equipment	Possible radioactive elements	Type or Ionising radiation
Glow lamps (starters for fluorescent lamps, electric blanket thermostats, etc.)	Cobalt-60	gamma
	Promethium-147	beta
	Uranium and Thorium Decay Series	alpha, beta, gamma
	Krypton-85	gamma and beta
	Nickel-63	beta
Spark gap irradiators (to enhance reliability of ignition	Cobalt-60	gamma
Studs of piston-ring and bearing wear	Chromium-51	gamma
	Copper-64	beta
	Iron-59	beta
	Nickel-63	beta
	Zinc-65	beta
Sterilization Equipment (food, medical)	Cobalt-60	gamma
Luminous signs	Hydrogen-3	beta
Electron tubes (indicator lights in electronic machines)	Hydrogen-3	beta
	Krypton-85	gamma and beta
Tungsten products (welding rods)	Thorium-228 and Thorium-232	alpha
	Uranium and Thorium Decay Series	alpha, beta, gamma
Radioluminescent products (radioluminescent gauges for equipment, clock dials, pull chains on light bulbs, switches, chamber pot lids, doorknobs, telephone dials, markers to assist movement during blackout periods.)	Promethium-147	beta
	Radium-226	gamma

The equipment listed below is common shipboard equipment that is a source of radiation. The typical risks and precautions are identified.

Marine Radars, Satellite Terminal Aerials /Dishes, Microwave Ovens

Operate in high radio frequency (RF) and emit electromagnetic radiation and microwave range emissions which are non-ionising and do not penetrate the human body.

Marine Radars precautions:

- looking directly into a radar aerial and waveguide while it is in operation or where arcing or sparking is likely to occur is to be avoided
- radar sets should generally not be operated with wave guides disconnected unless for servicing when special precautions are to be taken
- exposure near a radar scanner will also depend on
  - the distance from the scanner
  - the type of scanner or aerial
  - the presence of absorbing or scattering objects

Satellite Terminals Antennas / Dishes precautions:

- the manufacturer documentation is to be consulted for safety exposure distances / safety radius
- these are to be marked on deck and accompanied by appropriate signage
- work should not be taken within the marked safety radius of a Satellite Terminal Antenna unless its transmitter has been rendered inoperative

Microwave Ovens precautions:

- not to be operated if the oven door or its interlock is out of use, the door broken or ill-fitting or the door seals damaged

- a permanent notice should be posted to this effect

Smoke Detectors (ionising type / non optical)

Contain an artificially produced radioisotope: americium-241 (Am-241) in the form of a very small quantity of americium dioxide (AmO_2) which emits alpha particles and low energy gamma rays.

Health risks:

- the ionising radiation dose to the occupants in premises protected by such smoke detectors is very much less than that from natural background radiation
- the alpha particles are absorbed within the detector, while most of the gamma rays escape harmlessly
- swallowing radioactive material from a smoke detector is not expected to lead to significant internal absorption of Am-241

Controlling the Risks

Before any new activity involving maintenance of identified radiation equipment, a risk assessment must be completed for the purpose of identifying the measures needed to restrict the exposure of crew members to the harmful effects of radiation. The risk assessment should be based on the manufacturers' safety instructions.

All equipment must be maintained in accordance with manufacturers instructions and included within the vessel's planned maintenance system. Should the equipment require decommissioning and removal from the vessel, manufacturers recommendations must be followed.

Any equipment onboard utilising a radiation source must have appropriate warning signage to avoid accidental exposure.

Where equipment utilizing a radiation source is situated on weather exposed decks, the risk assessment must include measures to prevent damage or the equipment being lost over side.

Personal protective clothing, appropriate to the identified hazard, must be available and worn when working on equipment which contains a radiation source. Again, equipment manufacturers must give guidance on this matter. The onboard management team must supervise the correct use of such PPE.

Health Surveillance

Health surveillance is aimed to detect seafarer's work-related ill health at an early stage and acting on the results. The main aims are to safeguard the health of sea staff aboard the vessel (including identifying and protecting crew members at increased risk) and also to check the long-term effectiveness of control measures if required and put in place. This is primarily conducted ashore during medical fitness tests prior to joining vessels and onboard the vessel.

Crew members who have been engaged in work with ionising radiation equipment onboard should notify the Company doctor during periodical medicals so that appropriate health surveillance is carried out.

Onboard the vessel, health surveillance requests should be made to the Crew Manager responsible for the vessel where any risk assessment identifies that:

- A particular work activity may cause ill health;
- A crew member is displaying an adverse health condition that is related to the work;

- There is a reasonable likelihood that a disease or condition may occur in relation to particular working conditions;

If there are any concerns related to the working environment aboard the vessel, the MSQS must be consulted for further advice if risk cannot be reduced to an acceptable level aboard the vessel.

Annex P

Amended risk assessment for hopper repair work

V.Ships

Ship Name: YEOMAN BRIDGE

Record Number: V\1 **Work\Activity:** Working in Upper Hopper Areas

System\Area: Cargo Sys - Other

Last Review: 14-Sep-2010 **Review in** 12 month **Latest Review Deadline:** 14-Sep-2011

Hazard Analysis

1 **Description of Identified Hazards**

Exposure to radiation from Silometers

Likelihood 2. Unlikely
Severity 2. Moderate

Existing Control Measures

Risk Factor 2. Low Risk

Manufaturer protective casing of units

Further Risk Control Measures

Hazard No.	Further Risk Control Measures	Remedial Action Date
1 . 1	The Silometers must be switched off prior to any work near these units and the shutter closed.	14-Sep-2010
1 . 2	No hot work should be carried out in the vicinity of the units.	14-Sep-2010
1 . 3	Care should be taken not to cause any mechanical damage to the steel flasks.	14-Sep-2010
1 . 4	The manufacturers guidelines should be followed regarding working in close proximity to theses units.	14-Sep-2010

Annex Q

Amended drill schedule including SUS space fire drills – Revision 3

SAF 24 - SCHEDULE OF DRILLS

This form is to be filed in the SSTRB.

M.V.______________________   **Year ________________**

Details of training		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Note
Collision														
Grounding														
Stranding														
Technical breakdown														
Flooding														
Excessive list														
Fire														1
Fire in port or terminal														
Operational spill														2
Emergency spill														2
Enclosed space rescue inc. pumproom rescue														
Man overboard														
Bomb threat & Search														5
Terrorist / Anti-Piracy														5
Contraband/Stowaway Search														5
Other Security Drill/Training														5
Salvage														
Lifeboat/liferaft station														1
Abandoning ship / Launching of life boats (incl FPD training where appropriate)														
Steering failure/ Emergency steering														
Serious injury/medical emergency														
Heavy weather damage														
Helicopter operations														
Search and rescue														
Jettison of cargo														
Shift of cargo														4
Structural Failure														
Fire / Explosion														
OPA90 vessels only	Q.I. Drill													3
	Oil Spill Response													2
Davit-launched Liferaft Training														If fitted
Gas or Toxic Vapour Release														
Emergency Towing Equipment														

ADDITIONAL DRILLS FOR GAS TANKERS														
Details of training		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NOTE
Escape of Gas	On Deck													
	Into Void Space													
	At Terminal													
Deck Fire inv. LPG														
Emergency Discharge of cargo at sea														
Abandoning ship in presence of toxic vapours														
Cargo Containment System Failure														
Break away from jetty during Cargo transfer														
ADDITIONAL DRILLS FOR CHEMICAL TANKERS														
Escape of Chemical	On Deck													
	Into Void Space													
Deck Fire inv. Chemical														
Abandoning ship in presence of toxic vapours														

ADDITIONAL DRILLS FOR SELF-UNLOADING BULK CARRIERS														
Details of training		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NOTE
Fire Drills in SUS spaces - carried out monthly	Lift belt, loop belt, incline													
	Boom Conveyor													
	Tunnel Spaces													
	Cargo Fire on Belts													

Additional Drills Required by Flag Requirements	
Drill Type	Frequency Required

Key to Notes in Drill Schedules

1. Drills are required to be held every 14 days, 7 days if practical. It should be noted that some flag states require every 7 days.
2. Oil spills are to be held every 3 months. (i.e. SOPEP + OPA90 drills)
3. To be held every 3 months (Tankiers with VRPs only)
4. Applies to dry cargo vessels only
5. Refer to Ship Security Plan