Report on the investigation of

the fire and explosion on board

Yeoman Bontrup

Glensanda Quarry, Loch Linnhe, Western Scotland

2 July 2010

Marine Accident Investigation Branch
Mountbatten House
Grosvenor Square
Southampton
United Kingdom
SO15 2JU

Report No 5/2011
May 2011

Pursuant to the International Maritime Organization's "Code for the Investigation of Marine Casualties and Incidents", the UK Marine Accident Investigation Branch (MAIB) has co-operated with the Bahamas Maritime Authority during the course of this investigation.

Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2005 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 13(9) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

All reports can be found on our website:
www.maib.gov.uk

For all enquiries:
Email: maib@dft.gsi.gov.uk
Tel: 023 8039 5500
Fax: 023 8023 2459

CONTENTS

			Page
GLOSSARY OF ABBREVIATIONS, ACRONYMS AND TERMS			
SYNOPSIS			**1**
SECTION 1 - FACTUAL INFORMATION			**2**
1.1	Particulars of *Yeoman Bontrup* and accident		2
1.2	Background		3
	1.2.1	Vessel overview	3
	1.2.2	Operation and commercial background	3
1.3	Narrative		4
	1.3.1	Events leading up to the arrival at Glensanda Quarry	4
	1.3.2	Arrival at Glensanda Quarry to the start of hopper hotwork	5
	1.3.3	Hopper repair work	9
	1.3.4	Events leading up to the discovery of the fire	9
	1.3.5	Actions following discovery of the fire	11
	1.3.6	Consolidation	13
	1.3.7	Pre-evacuation actions	15
	1.3.8	Post-evacuation actions	16
	1.3.9	Salvage	19
1.4	Glensanda Quarry		20
	1.4.1	General	20
	1.4.2	Fire-fighting facilities	20
1.5	Environmental conditions		20
1.6	Overview of fire-related damage		20
	1.6.1	General	20
	1.6.2	Self-Unloading System (SUS)	21
	1.6.3	Engine room and adjacent compartments	22
	1.6.4	Steering gear compartment	22
	1.6.5	Other areas	24
1.7	Self-Unloading System		24
	1.7.1	General description and regulation	24
	1.7.2	Holds	25
	1.7.3	Hold conveyor belts	26
	1.7.4	Cross-conveyors	26
	1.7.5	Vertical conveyor belt	26
	1.7.6	Discharge hopper	26
	1.7.7	Boom conveyor	28
1.8	Silometers		29
	1.8.1	General description	29
	1.8.2	Operation	29
	1.8.3	V.Ships Management System (VMS) and manufacturer's safety instructions	29
	1.8.4	Survey	30

1.8.5 Condition of the source containers and warning signs on board *Yeoman Bontrup* 30
1.8.6 Condition of the source containers and warning signs on board *Yeoman Bridge* 30
1.9 Post-fire observations of the hopper 32
1.9.1 External 32
1.9.2 Internal 32
1.10 "Hardox" tile replacement procedure 35
1.11 Hydraulic systems 35
1.11.1 Shore-discharge boom slewing system 35
1.11.2 SUS hydraulic system 35
1.11.3 Forward and aft hydraulic winch power packs 35
1.11.4 Ballast system valves 36
1.12 SUS vertical conveyor belt specifications 36
1.12.1 Fitted belt specification 36
1.12.2 Spare vertical conveyor belt specification 38
1.13 Fire detection, containment and extinguishing in the cargo handling spaces 39
1.13.1 Detection 39
1.13.2 Containment 39
1.13.3 Extinguishing arrangements 39
1.14 Lighting 40
1.15 Flammability of the conveyor belts 41
1.16 Structure in the vicinity of the fire 42
1.16.1 Bulkheads 43
1.16.2 Engine room workshop/hydraulic pump space access door 43
1.17 Structural cracking 43
1.18 Designated hotwork areas and procedures 44
1.18.1 Designated hotwork areas 44
1.18.2 Procedures 44
1.19 Ship's-use chemicals 44
1.19.1 Chemical stowage 44
1.19.2 Chemical stores – housekeeping 44
1.19.3 Instructions 45
1.20 Safety management system 45
1.20.1 Risk assessments 45
1.20.2 Audits/inspections 45
1.20.3 Drills 46
1.21 External training 46
1.22 Fire testing of vertical conveyor belt materials 46
1.23 Independent investigations 48
1.23.1 Fire investigation 48
1.23.2 Investigation into the possibility of an hydraulic oil leak causing the fire 48

1.24 Self-unloading vessels 49
1.24.1 General 49
1.24.2 SUL Operators and Owners Forum 49
1.25 Similar accidents 49
1.25.1 *Yeoman Bontrup* - vertical conveyor belt fire 49
1.25.2 Canadian-registered self-unloader *Halifax* – tunnel fire 50
1.25.3 Vanuatu-registered self-unloader *Ambassador* – conveyor belt fire 50
1.25.4 Liberian-registered self-unloader *Sophie Oldendorff* – conveyor belt fire 50

SECTION 2 - ANALYSIS 51

2.1 Aim 51
2.2 Cause of the fire 51
2.2.1 Background 51
2.2.2 Vertical conveyor drive system 51
2.2.3 Electrical defects 51
2.2.4 Transfer of heat from the engine room or from the personnel elevator 51
2.2.5 Hotwork in No 4 WBT 52
2.2.6 SUS and mooring winch hydraulic systems 52
2.2.7 WBT valve hydraulic operating system 52
2.2.8 Hopper hotwork 53
2.3 Hotwork discipline 55
2.3.1 Procedural non-compliance 55
2.3.2 Company enforcement of the procedures 55
2.3.3 Complacency 56
2.4 Ship design, fire-detection, containment and fixed fire-fighting arrangements 56
2.4.1 Ship design and requirement 56
2.4.2 Detection 56
2.4.3 Containment - tunnels and vertical conveyor belt tower 57
2.4.4 Containment - engine room workshop/hydraulic pump space door 57
2.4.5 Fixed fire-fighting systems 57
2.5 Fire-fighting 58
2.5.1 Crew 58
2.5.2 Drills 58
2.5.3 Glensanda Quarry and HIFRS fire-fighting support 59
2.6 Use of passenger elevator 59
2.7 Risk assessments 59
2.8 Conveyor belt specifications 60
2.8.1 Fire risk 60
2.8.2 Regulation 60

2.9 Ship's-use chemicals 60
2.9.1 Stowage 61
2.9.2 Guidance and regulation 61
2.10 Radiation issues 61
2.10.1 Risk of exposure to radiation 61
2.10.2 Regulations 62
2.11 Housekeeping 63
2.12 Fatigue 63

SECTION 3 - CONCLUSIONS 64

3.1 Safety issues directly contributing to the accident which have resulted in recommendations 64
3.2 Other safety issues identified during the investigation also leading to recommendations 64
3.3 Safety issues identified during the investigation which have not resulted in recommendations but have been addressed 65

SECTION 4 - ACTION TAKEN 66

4.1 The Marine Accident Investigation Branch 66
4.2 V.Ships UK Limited 66
4.3 Western Bridge (Shipping) Limited and Aggregate Industries UK Limited 66

SECTION 5 - RECOMMENDATIONS 68

Figures and annexes

Figure 1 General arrangement drawing showing key features relating to the accident

Figure 2 Composite of photographs showing discharge hopper damage and wear to the "Hardox" and ceramic sacrificial protection tiles

Figure 3 Position of temporary workbench used for hotwork

Figure 4 Door between the engine room workshop and the SUS hydraulic pump space

Figure 5 Schematic of the area of the hopper work

Figure 6 Area in which the fire was discovered

Figure 7 Fire-fighting on the tower

Figure 8 Additional fire support from Glensanda Quarry's fire team

Figure 9 Fireball erupting from the SUS tower

Figure 10 Fire spread onto the conveyor boom

Figure 11 Steering gear compartment explosion

Figure 12 Fuel tanks “flaring” off

Figure 13 Extent of damage to tunnel conveyor belts

Figure 14 Example of distortion in the SUS tower

Figure 15 Engine room/SUS hydraulic pump space door

Figure 16 Exposed steering gear compartment

Figure 17 View of poop deck relocated to the funnel deck

Figure 18 Schematic of the SUS showing conveyor belt drives

Figure 19 Vertical conveyor belt arrangement

Figure 20 Internal view of the hopper “trouser leg” showing sacrificial “Hardox” and ceramic tiles

Figure 21 *Yeoman Bontrup* - starboard silometer source container

Figure 22 *Yeoman Bontrup* - port silometer source container

Figure 23 *Yeoman Bridge* - port silometer source container

Figure 24 Doubler plates fitted to the outside of the hopper carcass

Figure 25 Hopper carcass penetrations

Figure 26 Oxy-acetylene torch cutting attachment

Figure 27 Oxy-acetylene torch shank

Figure 28 Water ballast tank valves – hydraulic power pack

Figure 29 Water ballast tank valves – hydraulic distribution lines

Figure 30 500W halogen lamp fitted to *Yeoman Bridge*

Figure 31 Structural general arrangement, complete with the conveyor belt configuration

Figure 32 Fire Tests – stud and nut placed in cleat adjacent to the side curtain

Figure 33 Fire Tests – stud and nut placed in cleat adjacent to the side curtain after 10 minutes

Figure 34 Elongation of hopper carcass “Hardox” tile securing stud holes

Figure 35 Flame cut bolts similar to those used to secure the ‘Hardox’ tiles

Annexes

Annex A	Hotwork request No 15/10 for SUS hopper repair, dated 2 July 2010 and associated Safety Action Plan and risk assessment
Annex B	Hotwork request No 16/10 for No 4 WBT repair, dated 2 July 2010
Annex C	Silometer handbook – Safety Instructions, Safety Instructions for Operation and Endress + Hauser Service Report dated 18 March 2002
Annex D	Castrol Hyspin AWH-M15 – material safety data sheet
Annex E	VMS – Self-unloading Section – Sections 4.5.5 – Prevention of Conveyor Belt Fires and 4.5.6 – Dealing with Conveyor Belt Fires
Annex F	VMS – Section 4.6.7 Hotwork
Annex G	*Yeoman Bontrup* – Chemical Inventory – June 2010
Annex H	*Yeoman Bontrup* – chemical stowage arrangements – June 2010
Annex I	VMS – Section 4.4.4 Working with Dangerous or Hazardous Materials and Goods
Annex J	VMS – (Ship Safety Training and Record Book) Section 8.3Onboard Drills
Annex K	Buildings Research Establishment Fire Test report No 266-903 dated 15 November 2010 - executive summary, summary of principal outputs of the cone calorimetry tests and conclusions
Annex L	Extracts from Hawkins & Associates Ltd's Fire Investigation Report – C69/45210 dated 2 September 2010
Annex M	Extracts from Hawkins & Associates Ltd's report on Ignition of Hydraulic Oils by Hot Surfaces – C69/45210 dated 10 November 2010
Annex N	MAIB Safety Flyer
Annex O	New VMS Section 4.11.8 Exposure to Radiation Sources On Board
Annex P	Amended risk assessment for hopper repair work
Annex Q	Amended drill schedule including SUS space fire drills – Revision 3

GLOSSARY OF ABBREVIATIONS, ACRONYMS AND TERMS

AB	-	Able-bodied seaman
BA	-	breathing apparatus
BRE	-	Buildings Research Establishment
CCR	-	Cargo Control Room
CG	-	Coastguard
CO_2	-	carbon dioxide
CSL	-	Canada Steamship Lines
DfT	-	Department for Transport
DIN	-	Deutsches Institut für Normung
DPA	-	Designated Person Ashore
ECR	-	Engine Control Room
EN ISO	-	European Norm International Standards Organization
ETV	-	Emergency Towing Vessel
GRP	-	glass reinforced plastic
HIFRS	-	Highlands and Islands Fire and Rescue Service
HRR	-	Heat Release Rate
ISM Code	-	International Safety Management Code
kg	-	kilogram
kW	-	kilowatt
m	-	metre
MAHRE	-	Maximum Average Heat Release Emission
MCA	-	Maritime and Coastguard Agency
MIRG	-	Marine Incident Response Group
mm	-	millimetre

MSDS	-	Material Safety Data Sheet
MS&Q	-	Marine, Safety and Quality
PPO	-	Primary Productions Operations
SMS	-	Safety Management System
SOLAS	-	International Convention for the Safety of Life at Sea, 1974
SUL	-	Self-unloading
SUS	-	Self-unloading System
TSSR	-	Technical Superintendent Structural Repairs
UHMW	-	Ultra high molecular weight
UNC	-	Unified Course
VHF	-	Very High Frequency
VMS	-	V.Ships Management System
W	-	watt
WBT	-	water ballast tank

Class “A-0” bulkhead	A bulkhead constructed of stiffened steel or equivalent which prevents the passage of smoke and flame but is not required to satisfy heat transfer criteria
Class “A-60” bulkhead	An insulated bulkhead constructed of stiffened steel or equivalent whose unexposed side will not rise more than 140ºC, or at a single point more than 180ºC, above the original temperature for a minimum of 60 minutes
Closed cup flashpoint	A method of measuring the flashpoint of a liquid using a covered container through which an ignition source is passed to ignite vapours given off from the heated liquid
Deutsches Institut für Normung	German Institute for Standardization

Gold Command	The strategic level of the command and control structure used by the emergency services to deal with major incidents and emergencies
Half-life	The amount of time it takes for half of the atoms in a radioactive sample to decay
“Hardox”	A hard, wear-resistant steel plate used to provide protection in highly abrasive environments such as in the quarrying, construction and recycling industries
Hotwork	Work that involves burning, welding, grinding or flame-cutting resulting in the potential for an incendiary spark
Silver Command	The tactical level of the command and control structure used by the emergency services to deal with major incidents and emergencies
Tool-box talk	A briefing given on the procedures and precautions to be taken to those carrying out a specific task
Tunnel men	Crew members whose role was to monitor cargo unloading from the cargo holds to conveyor belts

Times: All times used in this report are UTC+1 unless otherwise stated

Image courtesy of FotoFlite

Yeoman Bontrup

SYNOPSIS

On 2 July 2010, a major fire and explosion occurred on board the Bahamian- registered, self-unloading (SUL) bulk carrier *Yeoman Bontrup* during cargo loading. The fire spread rapidly, resulting in significant damage to the vessel. Fortunately, injuries were minor.

A routine post-discharge survey identified the need for repairs to *Yeoman Bontrup*'s cargo discharge hopper, which required hotwork on arrival at the remote Glensanda Quarry on Loch Linnhe.

At 1519, a fire was discovered near the bottom of the vertical cargo conveyor belt. Although attempts were made to extinguish the fire, it spread to the adjacent engine room. Overwhelmed by the scale of the fire, the crew evacuated the ship. The fire spread rapidly to the accommodation and into the steering gear compartment, which contained a wide variety of ship's-use chemicals. A violent explosion followed which tore the poop deck from the ship.

The most likely cause of the fire was the ignition of the vertical conveyor belt by hot debris from the hopper repair work. Although the vessel was built to the required standards, the fire spread quickly. This was because there was no effective means of early detection, no means of dividing the large cargo handling area for containment purposes, and no fixed fire-fighting system in the cargo handling area to deal with the fire.

The investigation found that the high frequency, and therefore routine nature of hotwork repairs on board *Yeoman Bontrup* had led to violations of company procedures, which compromised safety. Furthermore, elements of the conveyor belt were highly flammable. There are currently no conveyor belt material standards specific to the marine industry.

The investigation also discovered radioactive silometers in the area of the fire. These had not been included in the list of hazardous materials on board, had not been identified during risk assessments, and were not subject to any control procedures.

The ship's manager has taken action to improve hotwork procedures compliance and risk assessment, revise ship's-use chemical stowage arrangements and widen the scope of emergency drills.

The ship's owner has established an SUL Owners and Operators Forum to review safety issues relating to the industry sector.

Recommendations have been made which are designed to:

- Review and improve standards for fire detection, containment and extinguishing in the cargo handling areas of self-unloading vessels as well as develop standards for conveyor belt systems.
- Establish international standards for the use and control of radioactive isotopes on ships.
- Review national guidance on ship's-use chemical stowage.
- Address complacency with respect to hotwork procedures.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *YEOMAN BONTRUP* AND ACCIDENT

Vessel details

Registered owner	:	Western Bridge (Shipping) Limited
Vessel operator	:	Aggregate Industries UK Ltd
Manager	:	V.Ships UK Ltd
Flag & port of registry	:	Bahamas, Nassau
Type	:	Bulk carrier – self-unloading (SUL)
Date built and builder	:	1991, Tsuneishi Shipbuilding Co Japan
IMO number	:	8912297
Classification society	:	Lloyd's Register
Construction	:	High tensile steel
Length overall, breadth	:	249.9m, 38m
Gross tonnage	:	55695
Engine type, power and propulsion	:	Single, 6 cylinder MAN-B&W 6S70MC, 2 stroke engine. Output 15402kW, service speed of 15 knots. Single fixed blade propeller, 1800kW bow thruster and 1500kW stern thruster.

Accident details

Category	:	Very serious marine casualty
Time and date	:	1519 on 2 July 2010
Location of incident	:	56º 34.1'N 005º 31.9'W, alongside the shiploader jetty at Glensanda Quarry on Loch Linnhe, Western Scotland
Persons on board	:	31 crew, one superintendent and three visitors
Injuries	:	Two cases of minor smoke inhalation, one of which also suffered bruising
Damage	:	Significant fire damage and severe distortion to: the self-unloading system; engine room; accommodation areas; and steering gear compartment. Detachment of the poop deck.

1.2 BACKGROUND

1.2.1 Vessel overview

Yeoman Bontrup and her sister ship *Yeoman Bridge* were the world's largest gravity fed self-unloading (SUL) bulk carriers. The ships were fitted with five cargo holds, totalling 89896.8m^3. A complex system of conveyor belts discharged cargo into a hopper, situated in a tower immediately forward of the accommodation block and bridge. The cargo then passed onto a boom conveyor for shore reception.

Both ships were built partly from high tensile steel, which had suffered extensive cracking, requiring long-term management with the agreement of Lloyd's Register, the ships' classification society. At the time of the accident the owner's Technical Superintendent Structural Repairs (TSSR) was on board to carry out structural surveys and oversee structural repairs.

A general arrangement drawing of *Yeoman Bontrup,* with highlighted key areas relating to the accident, is at **Figure 1**.

The ship was manned by 31 Ukrainian crew, most of whom had served with the company for many years. The manning level was well in excess of the 14 crew required by the Safe Manning Certificate. The official working language was English, but the day-to-day language spoken was Russian. The documentation was in English.

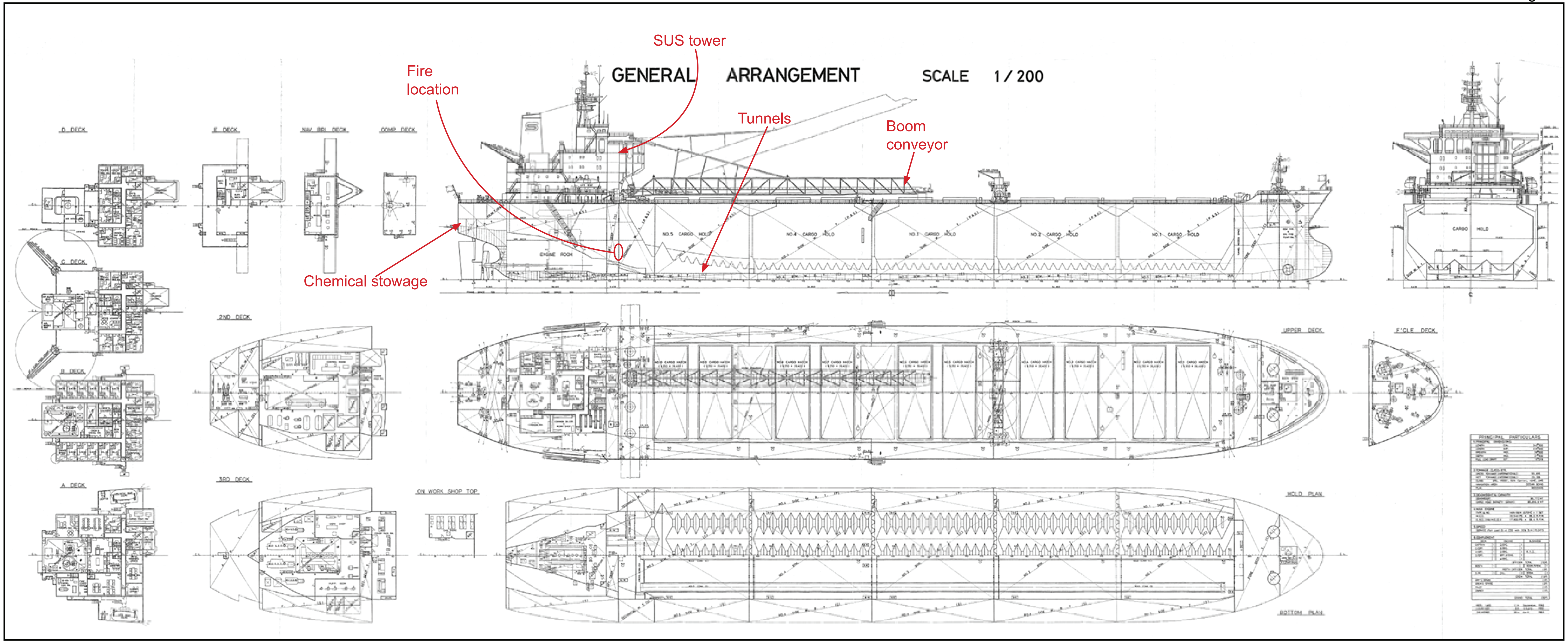
1.2.2 Operation and commercial background

Yeoman Bontrup, Yeoman Bridge and another self-unloader, *Yeoman Bank,* were operated by Foster Yeoman Limited which was part of the Aggregate Industries UK Ltd group whose shipping operations department was based in Frome, Somerset.

Both *Yeoman Bridge* and *Yeoman Bontrup* were built to a British Steel specification for carrying iron ore to supply its steel plants. Following British Steel's takeover, Corus Group used the ships until October 2000 and September 2002 respectively, when they were sold to Aggregate Industries (UK) Limited. Since then, the vessels had been used to transport stone cargoes, predominantly various grades of granite. *Yeoman Bontrup* traded on a mainly circular route. Cargoes were loaded at Aggregate Industries (UK) Limited's Glensanda Quarry on Loch Linnhe in Scotland and Bremanger Quarry at Svelgen in Norway. The cargoes were self-unloaded at North European ports, notably in Holland, Germany, Belgium and France, and at the Isle of Grain in the UK.

Glasgow-based V.Ships UK Ltd had been the ships' manager since September 2002. The crew were contracted through V.Ships' manning agency in Odessa, Ukraine.

Figure 1



General arrangement drawing showing key features relating to the accident

1.3 NARRATIVE

1.3.1 Events leading up to the arrival at Glensanda Quarry

Yeoman Bontrup arrived at Rotterdam at 1905 on 26 June 2010 to fully self-discharge a cargo of 93786 tonnes of crushed sandstone she had loaded at Bremanger Quarry. During the time alongside, following approval by the ship's manager, hotwork was carried out to repair structural cracking in No 2 water ballast tank (WBT).

Cargo operations were completed at 1850 on 29 June. The vessel sailed for Glensanda Quarry, in ballast, at 1905, and soon afterwards the self-unloading system (SUS) was washed down in preparation for its routine post-discharge inspection, which was planned for the following afternoon.

The inspection by the chief engineer and cargo engineer identified a small number of familiar defects associated with the SUS conveyor belts. It also identified that about 40 "Hardox" and 30 ceramic sacrificial tiles, fitted to the inside of the cargo discharge hopper, had been badly abraded or were missing. It was also found that the mild steel carcass of the discharge hopper had been holed in a number of places **(Figure 2)** by the hard sandstone cargo during the discharge operation. At 0807 on 1 July, the findings were reported, by e-mail, to the ship's manager and to the operator's technical manager.

Figure 2

Composite of photographs showing discharge hopper damage and wear to the "Hardox" and ceramic sacrificial protection tiles

Later that day, the cargo engineer met with the chief engineer to agree the scope of the SUS repairs. Preparatory work was also carried out that involved cleaning the hopper's defective areas and assembling the repair materials.

As a limited number of "Hardox" and ceramic tiles were available on board to effect the repairs, it was decided to use a number of "Hardox" plates to cover the larger holes. The plates were cut to shape using oxy-acetylene equipment at a temporary work bench located on the main deck at the port side of the vertical conveyor tower **(Figure 3)**.

1.3.2 Arrival at Glensanda Quarry to the start of hopper hotwork

Yeoman Bontrup arrived at Glensanda Quarry at 2135 on 1 July. Soon afterwards the bolted, hinged door[1] in the engine room workshop's forward bulkhead was opened into the SUS hydraulic pump space **(Figure 4)**. This was normal practice in harbour and provided easy access between the tower and hold tunnels, and the workshop.

Soon afterwards, the chief engineer and the chief officer agreed the risk assessments for the hotwork repairs to the SUS hopper and for No 4 WBT, which had suffered structural cracking.

At 2230, de-ballasting was started as a cargo of seven grades of granite stones was being loaded.

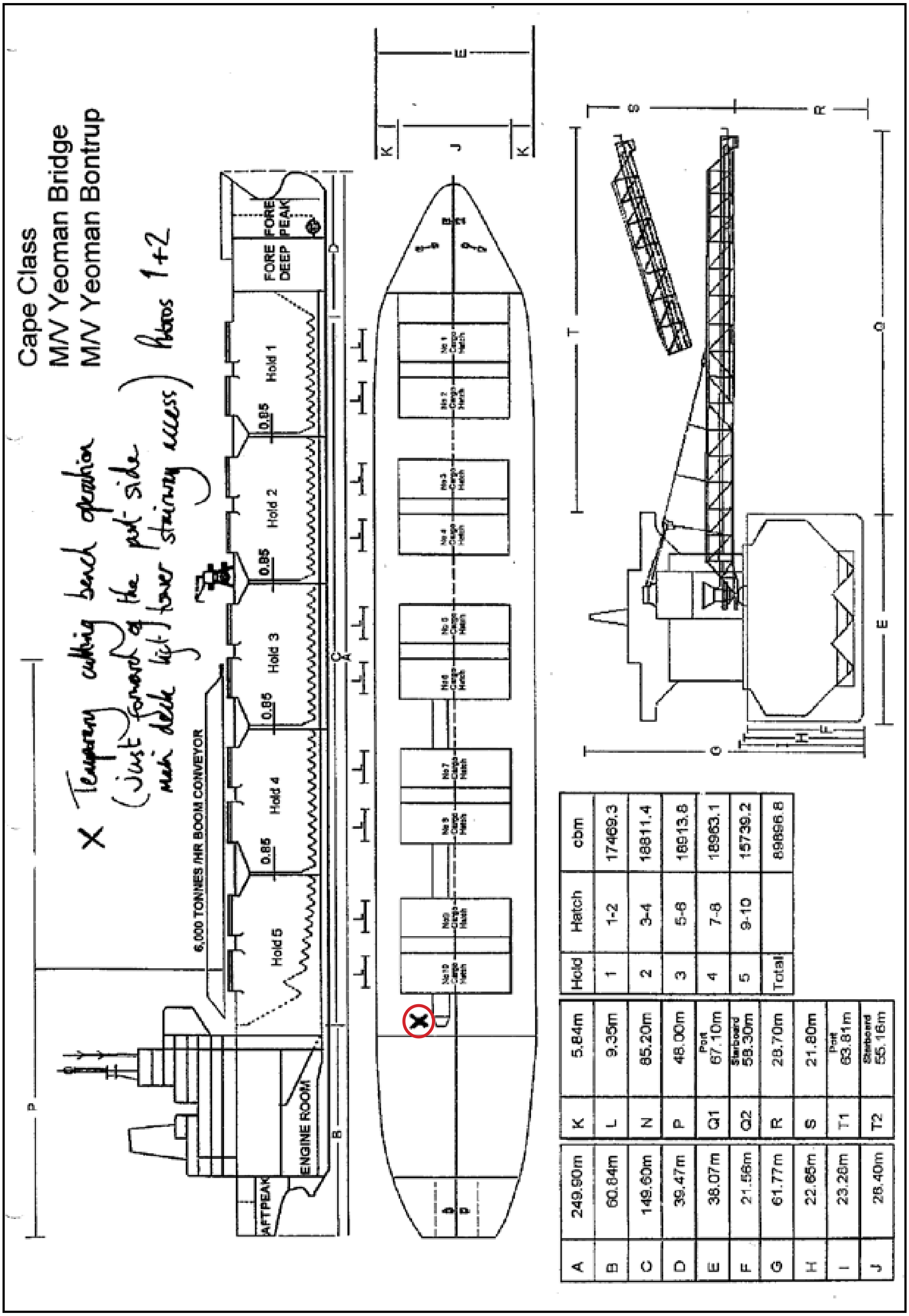
During the early morning of 2 July, the chief engineer discussed the proposed routine hotwork repairs with the master, who agreed the repairs were necessary. At 0618, hotwork request No 15/10 **(Annex A)**, together with the associated safety action plan and risk assessment, was sent to the ship's manager by e-mail. At 0753 a further hotwork request, No 16/10 **(Annex B)**, together with the supporting documentation was submitted for work in No 4 WBT. However, unbeknown to the ship's team, this request remained in the onboard computer's e-mail "outbox" and was not despatched to the ship's manager because of connectivity difficulties.

At 0700, the chief engineer carried out a "tool-box talk" with the cargo engineer and the two tunnel men who were to carry out the hopper repairs. The repair team rigged a fire hose from the pressurised fire main to deal with any potential fires resulting from the intended hotwork. Protective fire blankets were laid on the boom conveyor belt and on a plywood sheet covering the return section of the vertical conveyor belt which passed between the hopper legs. Electric arc welding leads were led from the welding machine, located in the starboard deck workshop, into the hopper chute. Oxy-acetylene hoses were run to the chute area from a portable bottle trolley positioned on the main deck to the starboard side of the conveyor tower, and an oxy-acetylene cutting attachment was also taken into the chute. A schematic of the area of the hopper work is at **Figure 5**.

[1] Although the access was a bolted, hinged plate, Lloyd's Register defined it as a "door" at build, hence the term "door" is used throughout this report.

At 0739, the ship's Designated Person Ashore (DPA), who was also the ship's manager's Senior Marine, Safety and Quality (MS&Q) Superintendent, e-mailed his approval for the hopper repairs; hotwork request No 15/10.

Figure 3



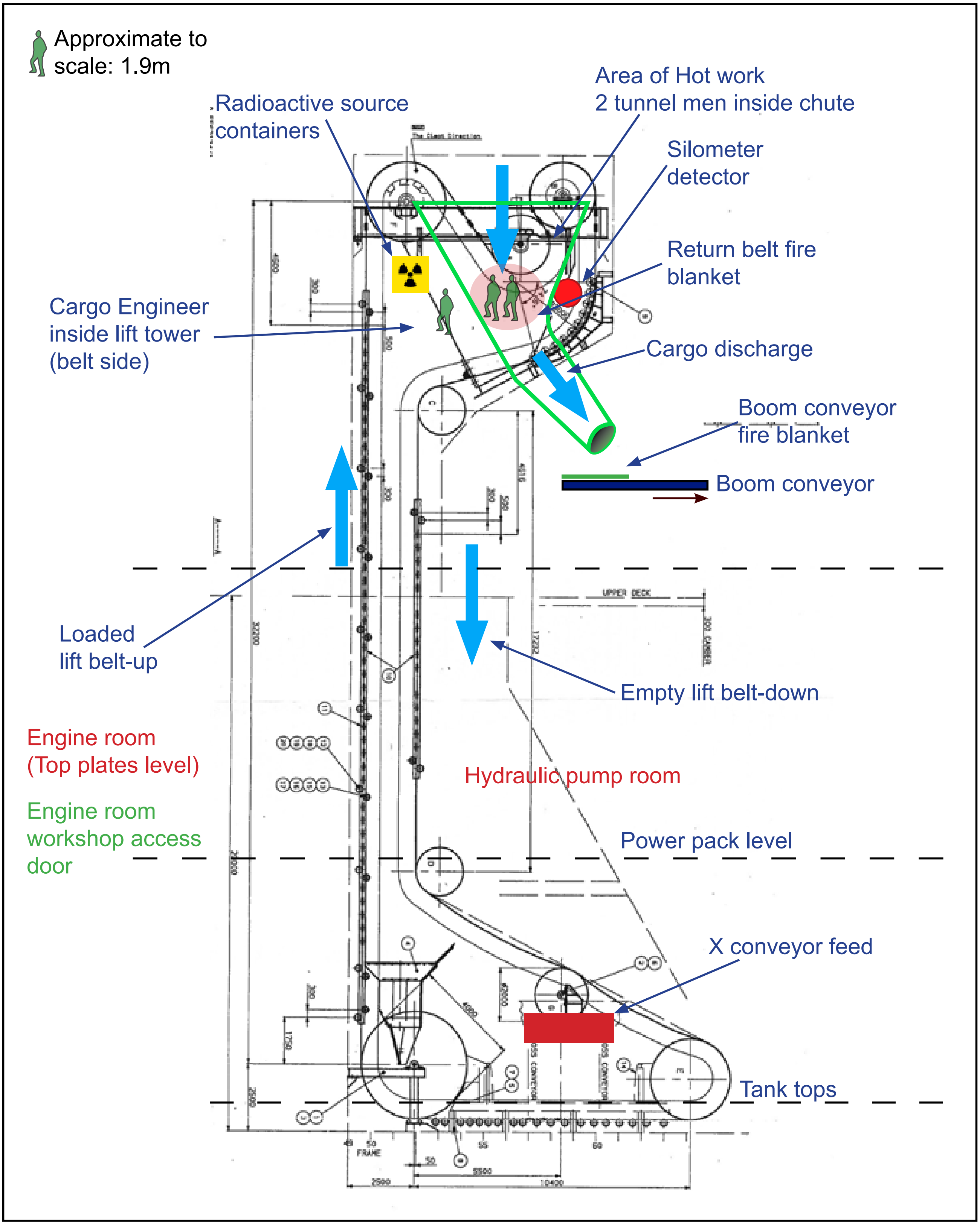
A	249.90m	K	5.84m	Hold	Hatch	cbm
B	60.84m	L	9.35m	1	1-2	17469.3
C	149.60m	N	85.20m	2	3-4	18811.4
D	39.47m	P	48.00m	3	5-6	18913.8
E	38.07m	Q1	Port 67.10m	4	7-8	18963.1
F	21.56m	Q2	Starboard 58.30m	5	9-10	15739.2
G	61.77m	R	28.70m	Total		89896.8
H	22.65m	S	21.80m			
I	23.28m	T1	Port 63.81m			
J	28.40m	T2	Starboard 55.16m			

Position of temporary workbench used for hotwork

Figure 4

Door between the engine room workshop and the SUS hydraulic pump space

Figure 5



Schematic of the area of the hopper work

1.3.3 Hopper repair work

At 0900, the chief engineer, who was the designated repair supervising officer, advised the hopper working party that hotwork request No 15/10 had been approved. He and the chief officer, who was the task-designated safety officer, met with the cargo engineer, who was in charge of the repair, in the conveyor tower to review the safety precautions that had been taken. Satisfied with the measures, the chief engineer endorsed the hotwork permit. The chief engineer and second engineer, who was also the on-watch engineer, then started the planned maintenance of the main engine exhaust valves. Meanwhile, the third engineer was in the engine room workshop carrying out a pump overhaul.

During the morning, the damaged “Hardox” and ceramic tiles were removed from the hopper. It was reported that the team used a pneumatic socket to remove the captive nuts from the “Hardox” tile studs and a pneumatic chisel for use on the ceramic tiles. At 1100 (1200 ship’s time), work was suspended for a 1-hour lunch break.

At 1200, the hopper repair work continued. The replacement “Hardox” tiles were held in position by a stud which passed through the hopper side and was fastened using a nut on the outside of the chute. The tiles were then secured together using 25mm-long tack welds. Throughout the repair, the cargo engineer kept the two fire blankets wet to guard against the risk of a fire developing from hotwork residues. At the same time, hotwork repairs were started to address the structural cracks in No 4 WBT, despite there being no approval received from the ship’s manager for the work. The welders in No 4 WBT were equipped with a VHF radio and they took their electric arc welding supplies from a control panel positioned approximately mid-way down the central tunnel. The repair was undertaken with the TSSR in attendance, who monitored and assessed the quality of the repair.

The hopper-related hotwork was suspended at 1400, at which time the afternoon break was taken. Contrary to the requirements set out in the safety action plan **(Annex A)**, a continuous fire watch was not maintained during the break period. By this time, the chief engineer had visited the site 2-3 times and had detected nothing to raise his concerns.

1.3.4 Events leading up to the discovery of the fire

The hopper repair work recommenced at about 1420-1425 with the fitting of “Hardox” plates to cover the largest holes.

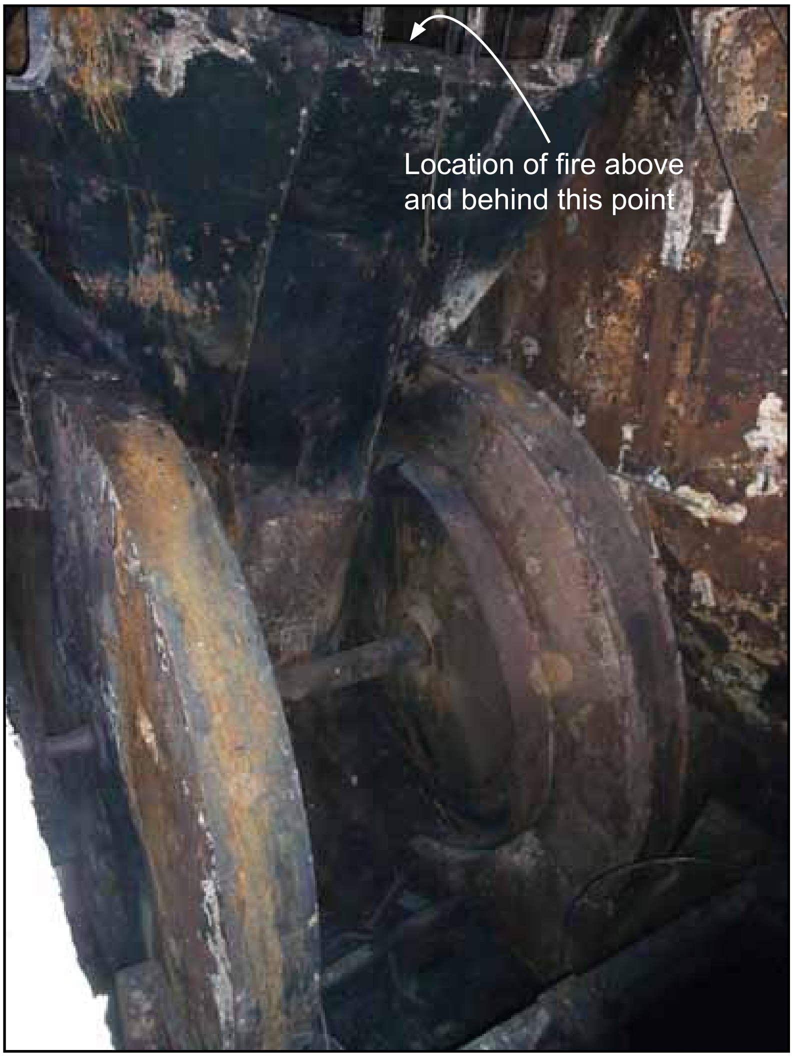
Shortly afterwards, the chief officer instructed an able-bodied seaman (AB) to remove the lid of No 3 WBT so that he could show the TSSR some structural cracks, which he had found during a routine WBT survey.

The repair to No 4 WBT was completed at 1500. The two welders involved waited in the tank for the TSSR to confirm that the repairs were satisfactory. At about the same time, the chief officer, who was in the Cargo Control Room (CCR), contacted the TSSR to discuss and examine the cracks in No 3 WBT. He also started the boom conveyor hydraulic slewing pump, to warm it up in readiness to move the boom inboard to reduce the ship's list caused by cargo loading.

At approximately 1516, the AB sent to open No 3 WBT lid took the elevator down to the engine room workshop. From there he went through into the SUS hydraulic pump space, leaving the dividing door open. He then made his way down the ladders towards the bottom of the SUS tower. At about 1518, the two welders in the SUS hopper noticed a slight wisp of smoke coming into the hopper, and warned the cargo engineer.

At 1519, the AB reached the lower platform of the vertical conveyor belt. He smelt smoke and, as he turned slightly, he saw a great deal of smoke developing and about 1.5m^2 of flame around the rising part of the vertical belt adjacent to the forward engine room bulkhead **(Figure 6)**.

Figure 6



Area in which the fire was discovered

1.3.5 Actions following discovery of the fire

The AB who discovered the fire was not equipped with a radio, so he ran back up the ladders to the CCR to alert the chief officer to the fire. On passing through the SUS hydraulic pump space, he shouted to the third engineer that there was a fire. The third engineer entered the hydraulic pump space, and on seeing large amounts of grey smoke he returned to the engine room to alert the chief and second engineers, who immediately started the three remaining fire pumps.

At about this time a number of concurrent observations were made and actions taken.

The welders in the hopper made their escape down the chute onto the boom conveyor and then onto the upper deck. Once there, they met with the cargo engineer who was already directing a fire hose into the tower's starboard doorway.

The master, who was in his office with the quarry's administration manager and two of his staff, saw smoke outside the window. As he ran to the bridge, he told the visitors to remain in the office, which overlooked the upper deck. The manager noticed that the smoke from the tower was increasing and took his staff to the gangway, where they left the ship. The manager then remained on board and contacted a number of key quarry personnel, including the harbourmaster, to alert them to the fire. By this time the TSSR had taken the elevator, which was clear of smoke, to the main deck to meet with the chief officer. On exiting the port cross alleyway onto the main deck he noticed the dense smoke from the tower.

At 1521, the ship's fire alarm sounded. It is unclear whether this was as a result of one of the tower's heat detectors activating, or either the second engineer or chief officer pressing a fire alarm button. As the master reached the bridge, he confirmed that the three remaining fire pumps were running, pressed the muster station alarm and made a broadcast advising the crew of the fire. He also contacted the Glensanda Quarry harbourmaster requesting fire-fighting assistance. The harbourmaster, in turn, advised Clyde Coastguard (CG), who alerted the Highlands and Islands Fire and Rescue Service (HIFRS) and the ambulance service. The master then advised the DPA of the situation.

On the upper deck, the cargo engineer was relieved by a crew member who continued to direct the fire hose into the tower. Immediately afterwards, at 1524, a number of additional hoses were directed at the tower **(Figure 7)**. The cargo engineer activated the tower wash-down sprays from inside the SUS hydraulic pump space in an attempt to help douse the fire. He then went to the base of the tower, where he rigged a fire-fighting hose and directed it at the fire.

By now, the chief engineer had taken the elevator, which was clear of smoke, from the engine room to the upper deck. Believing the fire might have been due to the hopper hotwork, he ran up to "B" deck level. There, he became affected by the smoke so he returned to the upper deck and went to his muster station.

Figure 7

Fire-fighting on the tower

After the AB informed the chief officer of the fire, the chief officer told the quarry staff to stop loading the cargo. He then made a general announcement about the fire on his VHF radio. The AB then ran back down the tower ladders, where he was joined by the second and third engineers, who discharged two foam extinguishers at the fire with no effect. The engineers, having heard the muster station alarm, opted to return to the Engine Control Room (ECR) through the SUS hydraulic room access, which was still open. They then went to their muster station. At the same time, the AB continued down to the lower level of the tower and joined the cargo engineer in fighting the fire.

By this time, the fire had travelled quickly up the vertical conveyor belt despite the best efforts of the cargo engineer. The cargo engineer, feeling the effects of the smoke inhalation he had suffered during his descent from the SUS hydraulic pump space, stumbled, fell onto the deck plates and bruised his ribs. However, the two welders from No 4 WBT joined him and the AB in tackling the fire using the tunnel fire hoses and the cargo engineer recovered sufficiently to assist with the fire-fighting.

At about 1527, the cargo engineer was noted to be unaccounted for at muster stations. With the agreement of the chief officer, the chief engineer went down the tunnel access space, which was forward of No 1 hold, well away from the seat of the fire. On his way there, he started the emergency fire pump. On reaching about frame 75, in the central tunnel, he could see the area of the fire and also that fire hoses were being directed at it. He also saw that the cargo engineer was with the firefighters, and reported this to the chief officer. He saw that the area, a short distance forward of the fire, where the firefighters were positioned, was relatively clear of smoke. He also noted a slight airflow as air was being drawn through the open tunnel access door and ventilators, along the tunnels and up the tower in a chimney effect, dragging the smoke with it.

1.3.6 Consolidation

Following the call to muster stations, the ship's fire organisation reacted to what was obviously a significant fire. The second engineer returned to the ECR, closing a number of engine room vents on his way there. Once back in the ECR, he stopped the fuel transfer pumps and made a number of electrical isolations, including those to the SUS hydraulic pump space, but he left power connected to the fire pumps. The third engineer also returned to the ECR, where he made sure the four fire pumps were running before rigging hoses in the vicinity of the engine room forward bulkhead. There was a conscious decision by the second engineer not to operate the emergency fuel shut-off valves from the fire control station because the generators were needed to provide power to the fire pumps.

At 1533, the Glensanda Quarry fire team arrived with its tender under the direction of the Primary Production Operations (PPO) manager, who was also the senior site manager. The team connected its fire hoses to the shore-side hydrants and supported the boundary cooling effort around the tower **(Figure 8)**.

By about 1535, a high expansion foam generator had been rigged and was discharging foam into the tower through the main deck starboard door. A 2-man breathing apparatus (BA) team, comprising an AB and the tunnel man, were dressed and equipped with two BA sets from the fire control room and a spare BA set from the forward hydraulic pump room for rescue purposes[2]. They were unable to enter the tower from the main deck because of the dense smoke levels. The 2-man BA team, accompanied by the bosun and the head tunnel man, entered the steering gear compartment and then the engine room. They were met by the second and third engineers, who were setting up boundary cooling on the forward bulkhead, which was adjacent to the fire. The engine room was becoming very smoky and hot in the vicinity of the forward bulkhead when, at about 1540, the 2-man BA team entered the open SUS hydraulic pump space door access. Once in the pump space, the team became separated in the dense smoke. The AB of the team managed to reach the lower level of the

2 The 4th BA set on board was located in the Officer's Changing Room on "D" deck and could not be accessed because of the smoke levels.

tower, where he joined the other four crew members who were fighting the fire under the direction of the chief engineer. Fortunately, the other member of the 2-man BA team managed to return through the engine room workshop into the engine room; crucially, the door to the hydraulic pump space had been left open.

It was at about this time that the second engineer noticed that the paint on the forward engine room bulkhead, on 3rd deck level, adjacent to the tower and to starboard of the elevator, was blistering. He discharged a nearby CO_2 extinguisher onto the area, but with minimal effect. It was clear that the situation was deteriorating rapidly; the smoke levels were increasing in the engine room making further occupancy untenable. The third engineer contacted the master, who by that time had evacuated from the bridge onto the starboard bridge wing, and advised him of the situation by VHF. The master immediately instructed that the engine room be evacuated, and the team made their way safely back to the upper deck.

At 1545, the Glensanda Quarry harbourmaster arranged for the company's landing barge and personnel boat to go to Rhugh Garbh, 9 miles from the quarry, to collect the HIFRS fire-tenders and firefighters as there was no road access to the remote quarry site. He also arranged for another personnel boat to go to Point Appin, about 4.5 miles away, to transport the HIFRS on-scene-commander (Silver Command) to the quarry.

Figure 8

Additional fire support from Glensanda Quarry's fire team

The chief engineer and his team felt that they were achieving some success in dealing with the fire. However, they were not aware that by that time the SUS hydraulic pump space was engulfed in fire, and that the fire had spread into the engine room workshop through the open door. Despite the chief engineer's optimism, at about 1550 part of the conveyor belt collapsed. He reported this to the master, who was in discussion with the quarry's PPO manager. The quarry staff then noticed the portable oxy-acetylene bottle stowage that was used in support of the hopper repair work. Worried about the hoses which were led to the tower, and their close proximity to the fire, they moved the stowage away from the immediate danger, having confirmed that the bottle valves were closed[3]. In doing so, one of them suffered the effects of smoke inhalation and had to be escorted off the vessel to await medical attention.

At about 1555-1600, the Glensanda harbourmaster, in consultation with the quarry PPO manager and engineering manager, strongly advised the master to evacuate the ship. By then it was clear that the situation was getting out of control, with intermittent flames coming from the tower, despite the additional support from the quarry staff. No one was able to access the accommodation block, engine room or steering gear compartment, so the internal condition of the ship was unknown. With his crew still safe and accounted for, the master decided to abandon the vessel. He instructed the chief engineer to withdraw from the tunnel and return to the deck with his 5-man fire-fighting team. The chief engineer felt he could still make progress with the three fire hoses trained on the fire, and remained with his team fighting the fire until ordered to evacuate a few minutes later by the master. Once on deck, the bosun assisted the cargo engineer ashore for medical attention because he was still suffering from the effects of smoke inhalation and bruised ribs sustained earlier.

1.3.7 Pre-evacuation actions

At about 1605, the master ordered the crew to leave the vessel once they had lashed their fire hoses to the ship's structure and directed them at the tower area to continue the boundary cooling effort. As the crew evacuated, the chief officer and chief engineer closed No 4 cargo hold hatch to help prevent any fire-fighting water from entering the holds and tunnels and impacting on the ship's stability.

The mooring winches, which were in auto-tension, were set with their brakes on to prevent the vessel moving away from the berth after the inevitable loss of electrical and hydraulic power. The chief engineer tried to operate the engine room CO_2 fire-extinguishing system, but was driven back by the heat and smoke. He did, however, manage to operate the diesel fuel service tanks emergency shut-off valves in the fire control station. The master, chief officer and chief engineer agreed they could do nothing more except to direct cooling water onto the ship from a safe distance on the quayside. Therefore, at about 1615 they left the ship.

[3] It was unclear when and by whom the bottle valves were closed.

1.3.8 Post-evacuation actions

The Glensanda Quarry personnel boat picked up the HIFRS (Silver Command) at Port Appin at 1618. It was clear from the briefing given to the Silver Commander that he had a major incident to deal with. At 1600, he contacted the HIFRS Incident Command at Inverness, which was set up to support Silver Command, and requested the expert advice of the HIFRS Marine Incident Response Group (MIRG). This was approved, and the CG set about making arrangements for the MIRG team to be transferred by helicopter from Invergordon.

At 1630, the water supply to the hoses failed as the ship's generators stopped, either through lack of fuel, or because the fire caused interruptions to the electrical supplies.

The Silver Commander arrived on scene at 1644. He considered that it was unsafe to access the ship, especially as there were 125 CO_2, 14 large O_2, 10 large acetylene and 5 small acetylene bottles in the vicinity of the fire. In addition, he was advised that there were 841 tonnes of intermediate fuel oil, 61 tonnes of diesel, 40 tonnes of lubricating oil and 2 tonnes of paint on board. He decided the only option at this point was to continue boundary cooling in an attempt to prevent the fire reaching these high-risk areas. However, as this could only be done on the starboard side, the Silver Commander requested the support of a fire-fighting tug so that the port side of the vessel could be cooled. As there were no suitable vessels available locally, the use of the Maritime and Coastguard Agency's (MCA) Emergency Towing Vessel (ETV) *Anglian Sovereign* was approved at 1755. At that time, the vessel was berthed at Stornaway and her estimated time of arrival was 0100 on 3 July.

At 1700, a doctor arrived by the personnel boat with the first of the HIFRS firefighters. The fire team immediately set up its ground monitor fire hoses to continue the boundary cooling effort. At approximately 1715, a large fireball erupted from the top of the tower **(Figure 9)** and, about 10 minutes later, the gangway fell from the ship as the after mooring lines parted. The fire continued to develop and, by 1800, it had spread to the boom conveyor **(Figure 10)**.

The HIFRS tenders arrived at 1825. The HIFRS had just established a 200m exclusion zone when a massive explosion **(Figure 11)** tore off the entire poop deck, projecting it up into the air and landing it on the port side of the funnel deck. Soon afterwards, flames were seen coming from *Yeoman Bontrup*'s stern area as the oils and chemicals stowed in the steering gear room, and the steering system's hydraulic oil charge, continued to burn.

At 2000, the HIFRS and Northern Constabulary Gold Command was established to support Silver Command. Links were established with the Highland Council Emergency Planning Officer, Scottish Ambulance Service and the Secretary of State's Representative in relation to salvage and counter pollution. A short time later, the 8-man MIRG team arrived on scene by helicopter. Still unable to access the vessel, the Silver Commander used MIRG's expertise to assess the situation and develop the tactical plan.

Figure 9

Fireball erupting from the SUS tower

Figure 10

Fire spread onto the conveyor boom

Figure 11

Steering gear compartment explosion

At about 2045, some of the crew managed to gain brief access to the ship to re-secure the after mooring lines. During this time it was noted that *Yeoman Bontrup* was trimming by the bow, and there was concern that she might touch the bottom and cause pollution. It was further suspected that back-flooding had occurred through the WBT stripping system that was in use when the fire was discovered.

At 2232, it was agreed that two of the ship's engineers and four HIFRS firefighters should go on board to try to halt the progressive trim by the bow. They took with them a portable hydraulic hand pump to close the stripping pump valves as none of the ship's valves were fitted for manual operation. At about 2300, while they still were on board, the fuel oil and oil tanks began to "flare off" **(Figure 12)**. The engineers managed to close the valve that had caused the back-flooding and left the ship at 2325. Now that the immediate danger was over and all personnel were safe and accounted for, Gold Command stood down in favour of multi-agency, on-site, briefings.

At 0055 on 3 July 2010, *Anglian Sovereign* arrived on scene and immediately began boundary cooling *Yeoman Bontrup* using her high-pressure, high-volume fire-fighting monitors. Cooling continued throughout the night and, at 0512, the MIRG team was stood down.

Figure 12

Fuel tanks “flaring” off

1.3.9 Salvage

At 0855, both the HIFRS and *Anglian Sovereign* stopped boundary cooling to allow the fire to burn itself out and to facilitate the commercial salvage team’s initial survey. At 1321, responsibility for the fire-fighting effort was transferred from the HIFRS to the salvage company. The salvage company recorded deck temperatures of over 200ºC in the accommodation area, and concluded that the engine room was too hot to enter.

The next few days were spent extinguishing small pockets of fire, allowing the ship to cool down, and making her safe to tow. As soon as she was safe to tow, *Yeoman Bontrup* was towed away from Glensanda so she did not ground during the forthcoming spring tides, and she finally arrived at Ijmuiden in the Netherlands on 28 July for detailed damage survey to determine the repair options.

1.4 GLENSANDA QUARRY

1.4.1 General

Glensanda Quarry is located on the remote western side of Loch Linnhe in Scotland. The site is inaccessible by road. The company's landing craft plies between the quarry and the company's mainland site at Rhugh Garbh, 9 miles away, where heavy machinery can be loaded. Four personnel boats operate between the quarry, Rhugh Garbh and Port Appin. There are also two mooring boats. None of the vessels had any fire-fighting resource capable of assisting a marine casualty.

The site, which is the largest of its type in Europe, commenced operations to quarry granite from the Meall na Easaiche mountain in 1986. The initial rock crusher is underground with the final, or secondary crushing plant situated close to the single-ship jetty. Cargo is loaded onto ships using the shore-side conveyor.

1.4.2 Fire-fighting facilities

Glensanda Quarry had a total of 32 trained firefighters, who were also qualified first-aiders. They were split across four shifts and included maintenance staff. Each team was led by either the shift manager or his deputy. The site's single, ex-Strathclyde Fire and Rescue Service tender, was equipped with a range of fire-fighting equipment and a water capacity sufficient for 8 minutes fire-fighting. A fire main, pressurised at 11 bar, was fitted with hydrants and ran throughout the site, including the jetty area. The teams were used as "first responders" only, to enable casualty evacuation and containment. They received annual refresher training and carried out regular drills. They were not trained in ship fire-fighting techniques or in the use of BA and so all fire-fighting was intended to be carried out in fresh air.

In the event of a marine emergency, the company had developed an emergency plan for the guidance of senior managers. This was the first marine incident that required quarry fire-fighting support in 25 years.

1.5 ENVIRONMENTAL CONDITIONS

The environmental conditions at Glensanda Quarry were recorded every 15 minutes at a weather station situated on the Shiploader Jetty. At 1515 on 2 July 2010, the wind was south-westerly (238º) force 4/5 (mean 13-19 knots). It was overcast and the air temperature was 17.3ºC. Low water was at 1525.

1.6 OVERVIEW OF FIRE-RELATED DAMAGE

1.6.1 General

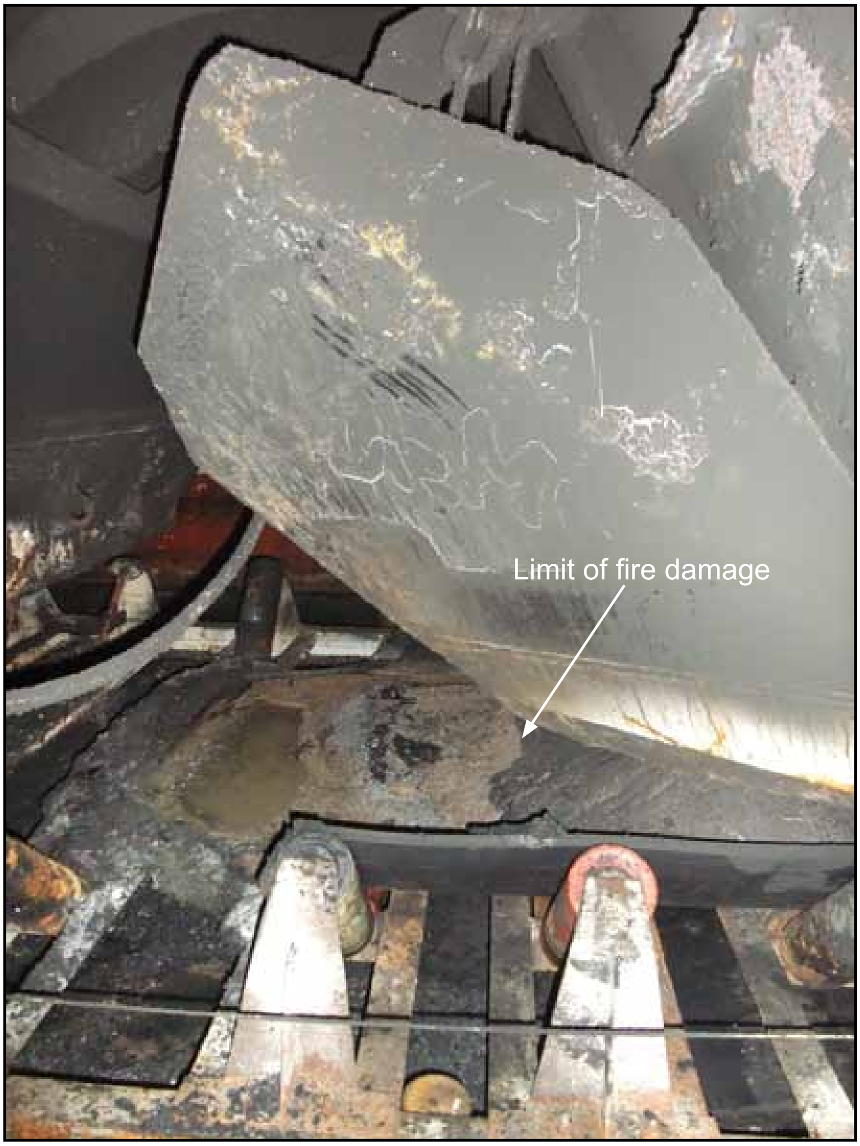
With the exception of the bridge, which suffered fairly minor heat and smoke damage, virtually the whole of the after end of *Yeoman Bontrup* was extensively damaged in the fire and explosion.

1.6.2 Self-Unloading System (SUS)

The fire damage in the hold tunnels reached as far forward as frame 167 with the port, starboard and centre hold conveyor belts being consumed from this point aft **(Figure 13)**, as were the two cross-conveyor belts. The distinct line of the limit of damage suggests that the three tunnel belts forward of this point were covered by water that had accumulated in the tunnel[4].

All flammable material in the vertical conveyor belt tower and the SUS hydraulic pump space was completely destroyed, and there was massive structural distortion to the steel doors, ladders and bulkheads **(Figure 14)**.

Figure 13



Extent of damage to tunnel conveyor belts

[4] The fire-fighting water level was deeper in the forward end of the tunnels due to the ship's increasing forward trim.

Figure 14

Example of distortion in the SUS tower

1.6.3 Engine room and adjacent compartments

The engine room workshop contents were completely consumed as the fire passed through the open SUS hydraulic pump space door **(Figure 15)**. The engine room forward bulkhead suffered distortion through heat transfer from the SUS tower. The fire consumed the ECR, electrical workshop and switchboard. The heat damage was especially severe at the upper levels of the engine room, which resulted in the overhead gantry falling to the lower level. The purifier room, situated on the starboard side, and the lower levels of the engine room escaped large-scale damage.

1.6.4 Steering gear compartment

The numerous oil drums and chemical containers in the steering gear room were largely consumed by the fire or resultant explosion. There was nothing left of the racking used to secure these items, and the transom had been set aft by about 1 metre. There was massive over-pressure damage to fittings in the compartment and to the rope store. The poop deck was torn off, leaving the steering gear exposed **(Figure 16)**. The deck areas above the port and starboard fresh water and after peak tanks suffered severe buckling and distress, and the plating at the after engine room bulkhead had split and had been torn upwards.

The poop deck itself had landed on the funnel deck, complete with its winches and mooring equipment **(Figure 17)**.

Figure 15

Engine room/SUS hydraulic pump space door

Figure 16

Exposed steering gear compartment

Figure 17

View of poop deck relocated to the funnel deck

1.6.5 Other areas

All compartments on the upper deck and in the accommodation block, including the store rooms, paint store, workshops, fire control room, cabins, galley and offices, were consumed by the fire, and many suffered severe structural distortion.

The upper deck in way of the after hold and the after hold transverse stiffeners were severely distorted.

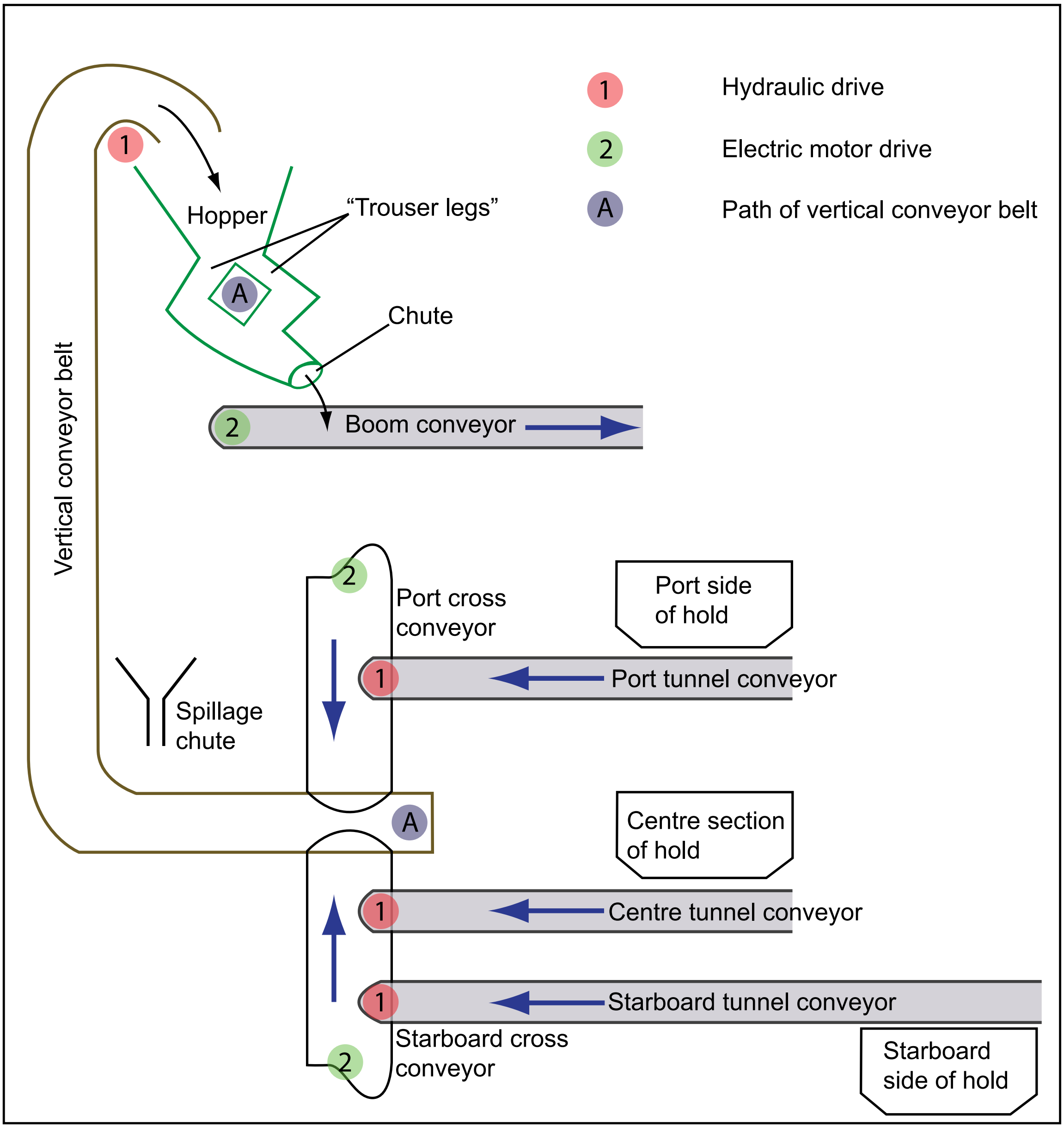
1.7 SELF-UNLOADING SYSTEM

1.7.1 General description and regulation

The SUS was designed and manufactured by Consilium BMH Marine of Enkoping, Sweden to handle stone cargoes of up to 150mm in diameter. The system was controlled from the CCR. A schematic of the SUS, including the layout of the conveyor belts and types of drive, is at **Figure 18**.

The International Convention for the Safety of Life at Sea 1974 (SOLAS), does not contain regulations covering the SUS equipment or conveyor belt requirements, and the system is not covered by classification society rules.

Figure 18



Schematic of the SUS showing conveyor belt drives

1.7.2 Holds

Each of the five holds was designed with a number of tapered sections that directed the cargo through hydraulically-operated "basket" gates onto one of three longitudinal hold conveyor belts. Each of the 181 gates was fitted with a hydraulically-operated vibrator to loosen the cargo in the event of hold-ups. To assist the gravity feed onto the belts, the holds were lined with Ultra High Molecular Weight (UHMW) polyethylene sheeting, which improved the "flow" characteristics of the cargo.

1.7.3 Hold conveyor belts

There were three hold conveyor belts identified as port, centre and starboard. Each was of a “trough” profile, 2.2m wide and 170m long, and was supported by a series of rollers against each of the outer faces of the “trough”. Each conveyor belt discharged cargo onto its respective cross-conveyor. In an emergency, the belts could be stopped by pulling on the emergency stop wire, which stretched the length of each tunnel. The belts were driven by an hydraulic motor positioned at the after end of the tunnel.

1.7.4 Cross-conveyors

There were two cross-conveyor belts positioned at right-angles to the hold conveyor belts. The port belt received cargo from the port hold conveyor belt and the starboard belt received cargo from both the centre and starboard hold conveyor belts. Each of the two belts discharged onto the vertical lift conveyor belt while it was in its horizontal plane. Each of the cross-conveyor belts was driven by an electric motor positioned at the outboard end of each belt.

1.7.5 Vertical conveyor belt

The vertical conveyor arrangement is shown at **Figure 19**. The conveyor belt, which was purchased by the previous owners in 2000, had a life-expectancy of about 10 years. This was determined by the number of fatigue related rotations. The base belt was 2.4m wide and strengthened by a matrix of zinc-coated steel wires. It was fitted with pockets, known as cleats, at 500mm intervals for carrying the cargo. Each cleat was fitted with a renewable sacrificial facing. Corrugated soft rubber side curtains, 630mm high, were fitted to the sides of the belt to prevent cargo falling from the sides of the cleat. As the belt passed over the uppermost after idler pulley, the cleats inverted and discharged cargo into the top of the hopper. Any cargo spillage from the cleats was collected in the spillage chute, located near the base of the vertical belt, and directed back onto the belt.

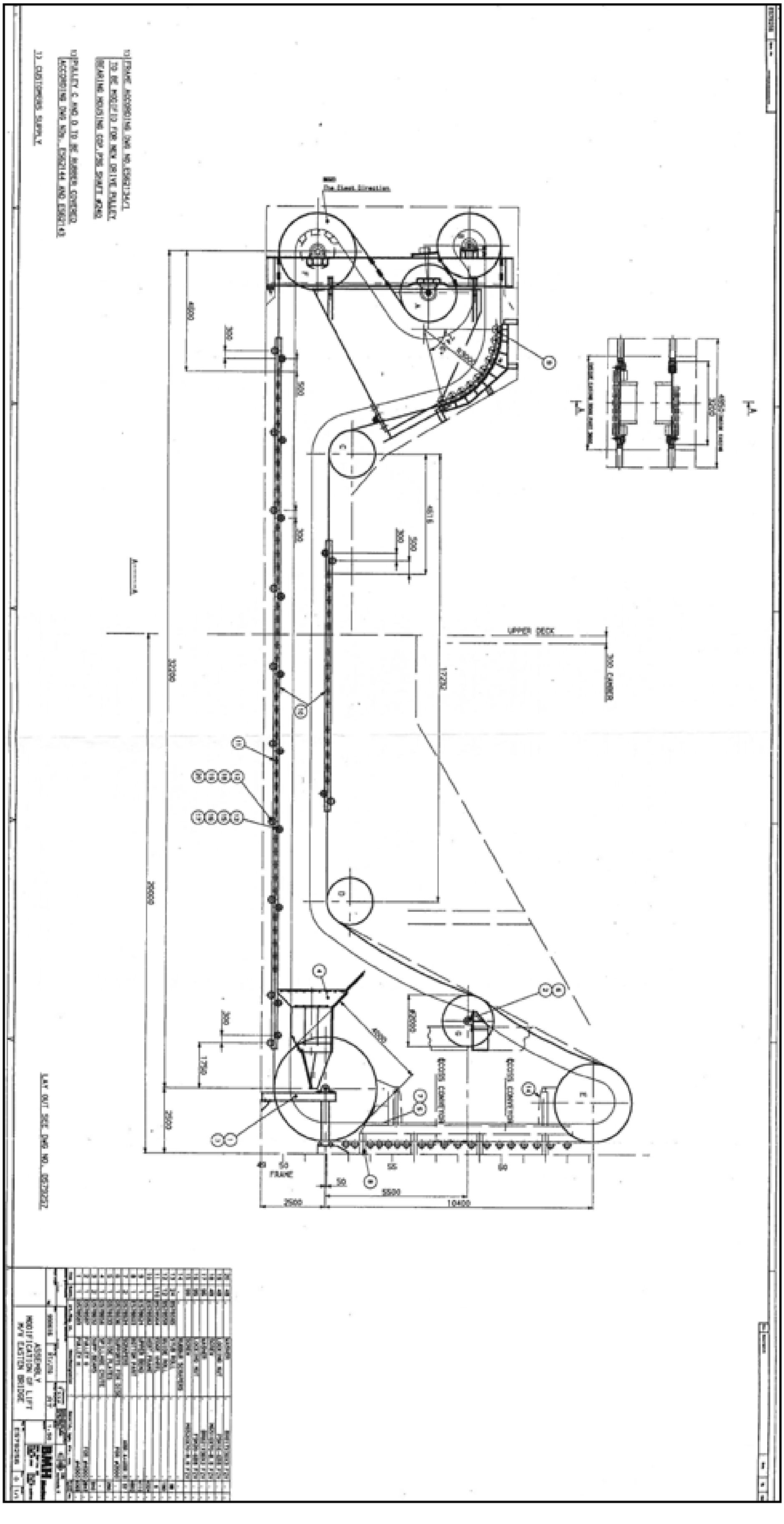
The base belt had been repaired by a specialist contractor using a recognised hot vulcanising procedure following a previous fire in November 2006. The side curtains were replaced in July 2009 after suffering cracking due to their fatigue life being exceeded.

The belt was driven by an hydraulic motor positioned at “E” deck level in the SUS tower and was supported by seven idler pulleys and two guide rollers.

1.7.6 Discharge hopper

The hopper directed the cargo through a chute and onto the boom conveyor for final discharge ashore. A short distance from the top, the hopper split into two outward angled legs known as “trouser legs”. These rejoined lower down to form the chute. The central diamond shaped section, created by the legs splitting and rejoining, formed the return path for the vertical conveyor belt.

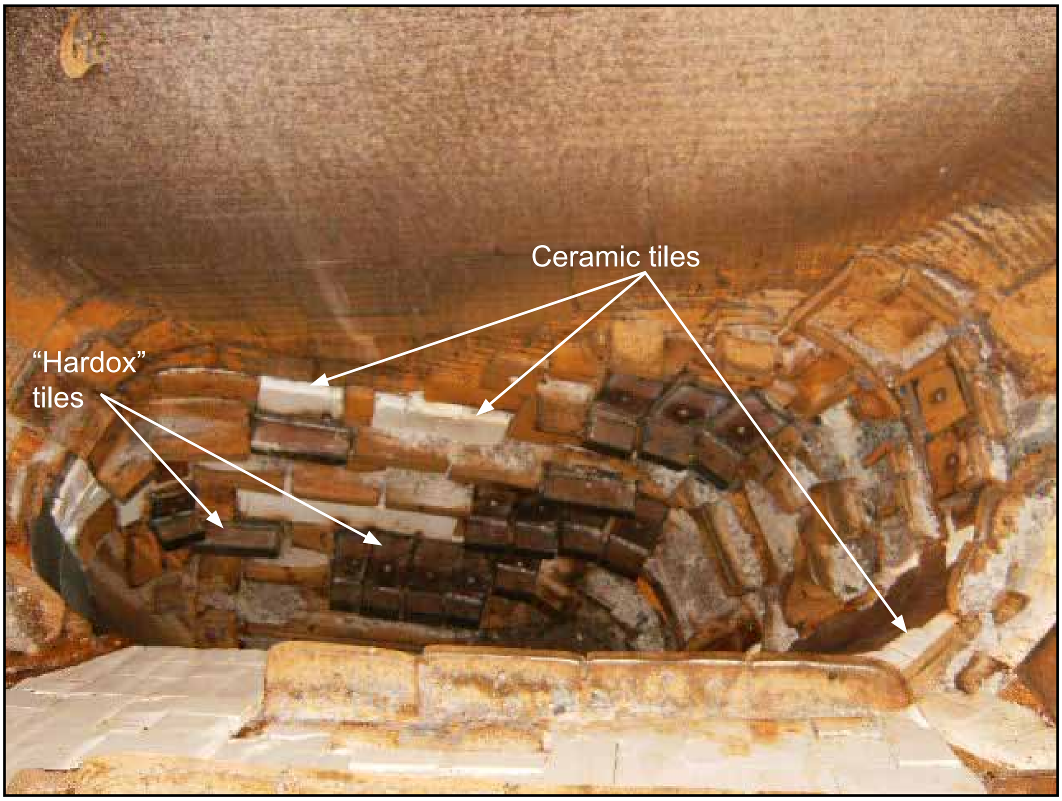
Figure 19



Vertical conveyor belt arrangement

The internal surfaces of the hopper were protected by a combination of sacrificial "Hardox" and ceramic tiles. The ceramic tiles were secured to the hopper carcass using a special adhesive while the "Hardox" tiles were secured using a nut and bolt arrangement. Both tile types **(Figure 20)** required frequent replacement. In the case of the "Hardox" tiles, this involved flame-cutting hotwork to trim the tiles and tack welding to secure the new tiles to adjacent tiles. The internal apex created by the legs was protected by right-angled "Hardox" tiles. The angle formed filled with cargo and provided a flush face to assist the cargo discharge. The system was designed for discharge rates of up to 6000 tonnes/hour. Each cargo type had an optimum discharge rate, greater or lesser rates of discharge resulted in stones impacting on the more vulnerable side of the hopper, which then required more maintenance.

Figure 20



Internal view of the hopper "trouser leg" showing sacrificial "Hardox" and ceramic tiles

1.7.7 Boom conveyor

The 2m wide, 84m long boom conveyor belt was driven by two electric motors. Cargo on the belt was protected by a glass reinforced plastic (GRP) cover. The boom could be slewed out through a range of 180º using an hydraulic pump located on the upper deck. Boom-luffing hydraulic power was provided by No 2 power pack located in the SUS hydraulic pump room.

1.8 SILOMETERS

1.8.1 General description

Cargo in the hopper of both *Yeoman Bontrup* and *Yeoman Bridge* was originally monitored by two radioactive silometers. They were designed to identify cargo blockages in the hopper and stop the SUS in a controlled manner to prevent damage. The silometers comprised a radiation source, a detector **(Figure 5)**, and an electronic process controller. While the system had not been in operation for the past 10 years, the silometers had remained on board.

The two QG100 radioactive source containers were manufactured by the Swiss company Endress + Hauser. The units were mounted at “D” deck level, on a bracket, close to the after side of the hopper’s “trouser legs”. Each unit weighed approximately 87kg and was fitted with a cobalt 60 radioactive source. The source had a half-life of 5.3 years and was surrounded by lead encased in steel, which screened the emitted gamma rays. The container was designed to accept a padlock to secure the operating handle to prevent inadvertent operation.

1.8.2 Operation

After the safety padlock was removed, a lever was turned through 180º which opened an internal shutter arrangement, allowing uni-directional measuring gamma radiation to be emitted through a narrow ray path through the hopper carcass to the Silometer detector for processing by the electronic controller. The operating lever uncovered an indicator plate which clearly showed if the unit was in the “on” or “off” position.

1.8.3 V.Ships Management System (VMS) and manufacturer’s safety instructions

The QG100 radioactive sources were not recorded on the VMS Technical Form - TEC 22 - Inventory of Potentially Hazardous Materials in the Ship’s Structure and Equipment. The form was part of the master’s emergency contingency plan documentation that was used to brief personnel responding to an emergency about the shipborne material risks. The VMS itself did not include any safety or general information relating to the radioactive source containers.

The silometer manufacturer’s handbook contained both general Safety Instructions and Safety Instructions for Operation **(Annex C)**.

In particular, the Safety Instructions stated:

> *“Observe the applying rules and national/international regulations”*

and

> *“Do not operate or store damaged or corroded devices….”*

The Safety Instructions for Operation stated:

> *“In designated use, operated under the specific ambient and operation conditions, no inspection or servicing is required”.*

However, the instructions also identified that if a unit was subjected to vibration or mechanical impact, a number of checks should be made including:

"… check regarding corrosion of housing, weld seams, outer parts of source insert, lock/padlock [sic]"

1.8.4 Survey

The units fitted to *Yeoman Bontrup* were last inspected on 3 February 2000. The inspection report implied that there were defects to the system detectors, which could not be powered up, and so the repair investigation was stopped. There was no evidence that any "wipe readings" were taken to ascertain the radiation levels on the surface of the source or in the vicinity of the source.

Yeoman Bridge was inspected on 18 March 2002. As a result of the "wipe readings", the contractor recommended **(Annex C)** that:

- Access to the walkway be restricted and/or the source holders be fitted with guards to prevent persons being in the radiation path.
- The source be switched off if anyone is required to work in the hopper.

1.8.5 Condition of the source containers and warning signs on board *Yeoman Bontrup*

The starboard container was found to be corroded but still secured to its bracket. It was not fitted with a security padlock **(Figure 21)**, but the operating lever was found to be in the "off" position.

MAIB inspectors found the port container on the floor grating near to its supporting bracket when they first accessed the SUS tower on 7 July. It was in particularly poor condition. It was heavily corroded, which had resulted in widespread destruction of the steel casing and the fire had apparently caused melting of the radioactive source lead shielding **(Figure 22)**. The operating lever was also in the "off" position but there was no security padlock fitted.

When MAIB inspectors carried out follow-up work with other specialists on 3 August, they found the source containers still in their post-fire positions. The containers were finally removed from *Yeoman Bontrup* on 19 August.

Any radioactive warning signs that might have been affixed to the area access doors or to the source containers would have been destroyed in the fire.

1.8.6 Condition of the source containers and warning signs on board *Yeoman Bridge*

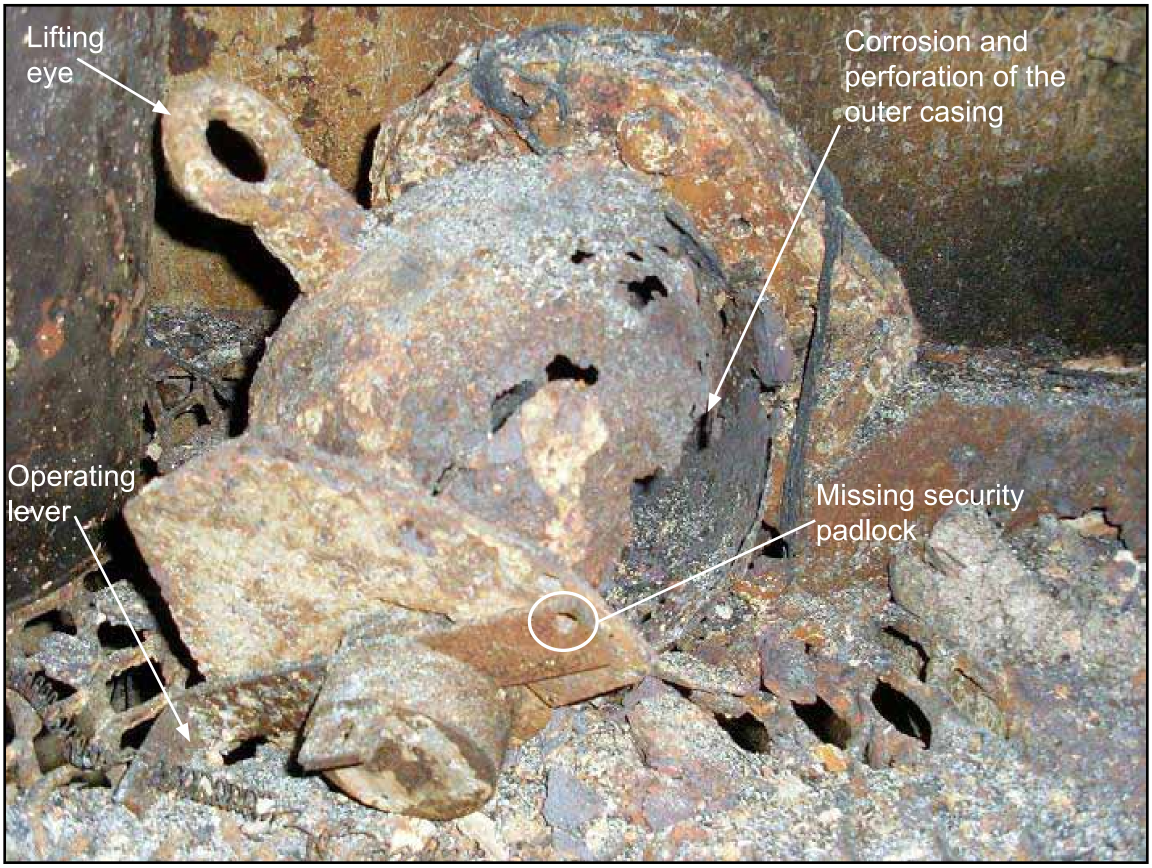
On inspection, both source containers were fixed to their supporting brackets and there was clear evidence of a build-up of surface corrosion. Neither unit was fitted with a security padlock but both operating handles were in the "off" position **(Figure 23)**. The source containers were removed from the vessel in Rotterdam on 29 January 2011.

The access doors displayed "radioactive" warning signs, but there were none on the source containers.

Figure 21

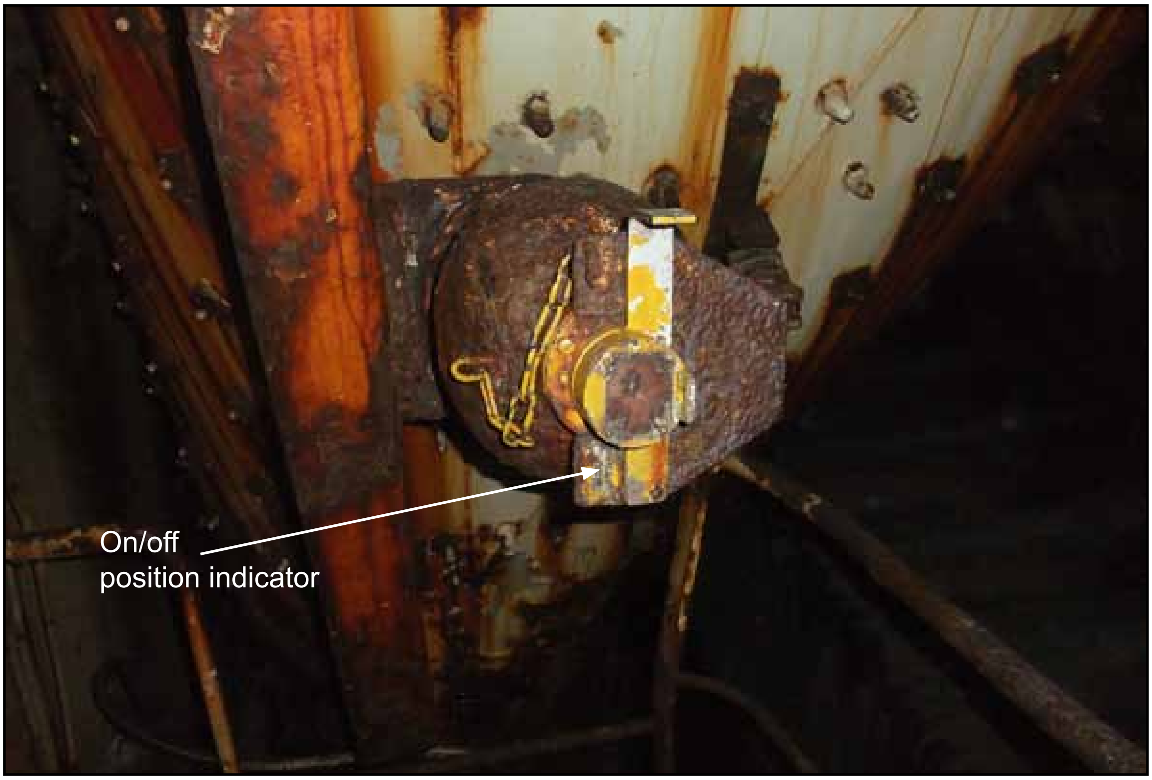
Yeoman Bontrup - starboard silometer source container

Figure 22



Yeoman Bontrup - port silometer source container

Figure 23



Yeoman Bridge - port silometer source container

1.9 POST-FIRE OBSERVATIONS OF THE HOPPER

1.9.1 External

External examination of the hopper found that many of the “Hardox” tile securing nuts were corroded, and there was a mixture of round flat washers and rectangular washers beneath the nuts. There was widespread evidence of mild steel doublers welded to the external surfaces of the carcass to cover holes probably caused by cargo abrasion **(Figure 24)**. There were also numerous examples of elongated holes burnt through the carcass using oxy-acetylene equipment. Many of these had been covered by “Hardox” tiles. There were a number of open small holes on all parts of the legs and also a much larger, 100mm hole, at the after end of the port upper leg **(Figure 25)**.

1.9.2 Internal

There was evidence of new “Hardox” tiles and temporary “Hardox” plates having been fitted in the apex area of the chute and to the port and starboard legs. There were sections of used welding rods and also new ones resting on the angular “Hardox” tiles. The remains of a pneumatic chisel were located at the port side of the apex.

The cutting attachment of an oxy-acetylene torch was found resting on the “Hardox” tiles inside the hopper at about 2.5m from the chute opening, and the shank was found with hose connections still attached[5] at the tail end of the boom conveyor **(Figures 26 and 27)**.

5 Remains of oxygen and acetylene hoses were found on the upper deck in the vicinity of the starboard side of the tower.

Figure 24

Doubler plates fitted to the outside of the hopper carcass

Figure 25

Hopper carcass penetrations

Figure 26

Oxy-acetylene torch cutting attachment

Figure 27

Oxy-acetylene torch shank

1.10 "HARDOX" TILE REPLACEMENT PROCEDURE

Abraded tiles which had not been discharged with the cargo remained connected to their ½ inch Unified Course (UNC) securing studs. Once the securing nuts were removed from the stud, the tile, complete with its stud, was drawn through into the hopper for disposal. Oxy-acetylene equipment was available to flame-cut distorted studs to ease their removal. Tile securing tack welding was removed either with a pneumatic chisel or by using oxy-acetylene equipment.

Replacement tiles[6] were offered up and cut to size using oxy-acetylene equipment. They were then drilled to take a bolt, and the hole was countersunk to allow the bolt head to sit below the surface of the tile. The countersunk recess was then filled with weld, the bolt then effectively acted as a stud. The tile was secured in place by the nut, and 25mm tack welds were used to secure it to adjacent tiles. Where studs did not align with the stud holes, the holes were elongated either by using oxy-acetylene burning equipment or by "striking" electric arc welding rods on the carcass.

1.11 HYDRAULIC SYSTEMS

There were four separate hydraulic systems, which were either in close proximity to the fire or were pressurised at the time the fire was discovered.

1.11.1 Shore-discharge boom slewing system

The hydraulic pump and associated pipework supplying the shore discharge boom slewing ram were positioned on the port side of the upper deck near to the vertical conveyor belt tower. Although the system was pressurised when the fire was discovered, none of the pipework passed through the tower.

1.11.2 SUS hydraulic system

The five SUS hydraulic power packs, located in the tower hydraulic pump space, were fully shut down at the time of the fire. Various hydraulic supplies passed in the general area of the vertical conveyor belt, including small bore pipes supplying the hold gates and vibrators.

Castrol Hyspin AWN-M32 and Castrol Hyspin AWH-M68 were used in the systems. The Material Safety Data Sheets (MSDS) listed their closed-cup flashpoints as above 190ºC and 200ºC respectively, and an auto-ignition point as above 250ºC for both oils.

1.11.3 Forward and aft hydraulic winch power packs

Both the forward and aft mooring winch hydraulic packs were pressurised at the time of the fire, with the mooring winches set to auto-tension.

The forward hydraulic packs were positioned just aft of the forecastle and all pipework was remote from the fire.

---

6 There were two sizes of "Hardox" tiles measuring about 300mm x 150mm and 150mm x 150mm and weighing 20 and 10kg respectively.

The after packs were located in the steering gear compartment. The supply and return pipework for the port mooring winch, which was positioned adjacent to the tower, passed through the upper levels of the SUS hydraulic pump space.

Castrol Hyspin AWH-100 was used in both the forward and aft systems. The MSDS listed the closed-cup flashpoint as above 200ºC and the auto-ignition point as above 250ºC.

1.11.4 Ballast system valves

A number of water ballast butterfly valves were hydraulically-operated and remotely-controlled from the CCR. The associated self-contained hydraulic system power pack was located on the starboard side, adjacent to the forward bulkhead of the engine room **(Figure 28)**.

The unit comprised a pump, with a normal operating pressure of 60 bar, and associated valves. The 250-litre capacity header tank had an operating level of 160 litres. The system was fitted with a tank low-level alarm and shut-down arrangement, which operated when the tank level dropped to 140 litres. A low pressure alarm operated at 40 bar.

An audible buzzer and red-light alarms were located in the CCR only, and were tested automatically when the unit was started.

The hydraulic oil was delivered to the ballast valves through 20mm diameter copper pipes which were located in the general vicinity of the fire. The sections of pipes were connected by brazed cup and cone couplings **(Figure 29)**. The system was pressurised at the time of the fire.

The oil used in the system was Castrol Hyspin AWH-M15. The MSDS **(Annex D)** listed the closed-cup flashpoint as above 140ºC and the auto-ignition point as above 250ºC. During normal operation, the temperatures of the supply and return oil were 30ºC and 24ºC respectively.

1.12 SUS VERTICAL CONVEYOR BELT SPECIFICATIONS

1.12.1 Fitted belt specification

The SUS vertical conveyor belt, cleats and side curtains, known as a Flexowell conveyor, were originally manufactured by the Finnish company Metso at its factory in Moers, Germany. In early 2010, conveyor belt manufacturing at the site was taken over by Continental ContiTech on its acquisition of this arm of the Metso operation.

The belt manufacturer offered various fire-resistant and self-extinguishing belt and component options in accordance with the appropriate European Norm-International Standards Organisation (EN ISO) or the Deutsches Institut für Normung (DIN).

Figure 28

Water ballast tank valves - hydraulic power pack

Figure 29

Water ballast tank valves - hydraulic distribution lines

It is understood that the specification of the original belt, identified by the manufacturer as being the same as the one involved in the fire, was agreed between the owner and shipbuilding yard. The specification confirmed that no fire-resistant properties were required. The base belt, known as "carbon black" was oil-based and was made from natural and synthetic rubber. The cleats and side curtains included natural and synthetic butylene rubbers.

Table 1 contains Continental ContiTech's interpretation of the alphanumeric data relating to the "Type/Grade and Quality" of the fitted arrangement.

Component	Type/Grade	Type/Grade/Quality interpretation
Base belt type	XST 4500	X – special i.e. marine use ST – steel cord belt 4500 – 4500 Newtons breaking strength in length direction per mm of belt width
Base belt grade	YF-L	Y – standard belt F-L – Flexowell (trade name)
Side curtain type	F 400 ES	F - Flexowell (trade name) 630[7] – height of curtain ES – over 300mm high with rubber/fabric sandwich construction
Side curtain quality	YF-L	Y – standard side curtain F-L – Flexowell (trade name)
Cleat type	TC-GS 370[8]	TC – special profile G – rubber/textile sandwich construction S – profile 360 - 360mm height
Cleat quality	YF-C	Y- standard cleat F-C - Flexowell cleat

Table 1 - Interpretation of the fitted belt specification

1.12.2 Spare vertical conveyor belt specification

Aggregate Industries UK Ltd held an option to purchase a spare vertical conveyor belt belonging to Oldendorff Carriers, another self-unloading bulk carrier operator. The belt, side curtains and cleats were manufactured to the following specification which was presented in a different manner to that of the fitted belt:

- 2400mm wide, profile F 630 ES VT, pocket profile VSF 120Y at 500mm spacing.

[7] Actual height of side curtain confirmed to be 630mm notwithstanding nomenclature.

[8] Although the specification states the figure is 370, the manufacturer confirmed this was an error and the correct figure should be 360

Table 2 contains Continental ContiTech's interpretation of the belt's data.

Component	Type/Grade	Type/Grade/Quality interpretation
Base belt	2400mm	The overall width of the base belt is 2.4m
Side curtain	F 630 ES VT	Side curtain 630mm high Extra strong Flame resistant quality
Cleat	VSF 120Y 500mm spacing	Cleat bases 120mm high in standard quality glued to the base belt Cleat pitch – 500mm

Table 2 - Interpretation of the spare belt specification

1.13 FIRE DETECTION, CONTAINMENT AND EXTINGUISHING IN THE CARGO HANDLING SPACES

1.13.1 Detection

The vertical conveyor belt tower was fitted with single-head heat detectors at "D" deck, "A" deck and "3" deck levels. The three detectors were factory-set at 57ºC to activate the alarm panels in the fire control room and on the bridge, as required by SOLAS Chapter II-2, Part C, Regulation 7, Paragraph 4. There were no heat or smoke detectors fitted in the conveyor belt tunnels.

The detectors were not annotated on the fire control plan reviewed by Lloyd's Register's Gdansk office on 27 February 2009.

Cargo unloading operations were monitored by the tunnel men and by the duty officer in the CCR using four camera displays. The cameras were directed at the conveyor belts and the images were played in real time. The system was not equipped with a recording facility.

1.13.2 Containment

Each of the three, 179m long x 9.3m wide tunnel spaces under the holds met with the 37m high vertical conveyor belt tower, effectively making the cargo handling area one large compartment. The compartment was not fitted with any form of division to contain either a fire or flood.

1.13.3 Extinguishing arrangements

Neither the tunnel spaces nor the tower were equipped with any fixed fire-fighting system. The tower itself was fitted with a fresh water dust suppression system, which was used during cargo discharge operations.

Fire hoses and nozzles were positioned throughout the tunnels and at the base of the tower.

1.14 LIGHTING

The area around the after end of the tunnel, near the vertical and cross-conveyor belts, was lit by a mix of 300W and 500W tungsten halogen lights.

Two 400W sodium lights, positioned between 2 and 3m from the vertical belt, lit the general area in which the fire was discovered. Other 20W fluorescent tube lights were also in the general area.

The surface temperature of the 500W tungsten halogen light lenses **(Figure 30)** was 135ºC with the body of the light measuring 41ºC. The temperatures measured at 100mm and 500mm from the halogen lights, in the direction of the vertical conveyor belt, were 40ºC and 26ºC respectively. The halogen lights were positioned approximately 1.3m from the vertical belt and about 2.9m from the pressured hydraulic system operating the ballast tank valves (Section 1.11.4)[9].

Figure 30

500W halogen lamp fitted to *Yeoman Bridge*

[9] This information was obtained from *Yeoman Bridge* because light fittings on board *Yeoman Bontrup* had been totally consumed in the fire.

1.15 FLAMMABILITY OF THE CONVEYOR BELTS

The high risk of fires developing in the areas of the conveyor belts was clearly recognised in the VMS.

In the "Self-Unloader Vessel Operating Instructions", which is a supplement of the VMS, the following sections emphasised the importance of correct safe working practices in relation to the hazard:

- Section 3.4.11:

  "Hotwork in the lift belt casing is extremely hazardous as hot material can lodge in the pockets."

- Section 3.4.29:

  "… adequate cover, and wetting of the belt when carrying out hotwork in its vicinity."

- Section 4.5.1:

  "Protect the conveyor belts adequately before carrying out hotwork in the vicinity.

- Section 4.5.3:

  "……….Fire rounds are to be taken at least two and six hours after completion of any hotwork in the Loop and tunnel areas [sic]."

Section 4.5.5 - Prevention of Conveyor Belt Fires, and Section 4.5.6 - Dealing with Conveyor Belt Fires, provide further guidance. The full sections are at **Annex E**. Section 4.5.5 states:

> *"Fires in the Loop and Tunnel areas are very dangerous, as the conditions are conducive to its rapid spread …."*

and

> *"**NOTE: WHEN PERFORMING HOTWORK ON THE UNLOADING GEAR, A FIRE OR WASH-DOWN HOSE UNDER PRESSURE MUST BE AT THE WORKSITE WITH ONE MAN PRESENT AS A FIRE WATCHMAN ONLY.***
>
> ***THE FIRE WATCH IS TO BE MAINTAINED DURING COFFEE AND MEAL BREAKS. THE FIREWATCH MUST BE MAINTAINED FOR 60 MINUTES AFTER HOTWORK IS COMPLETED** [sic]."*

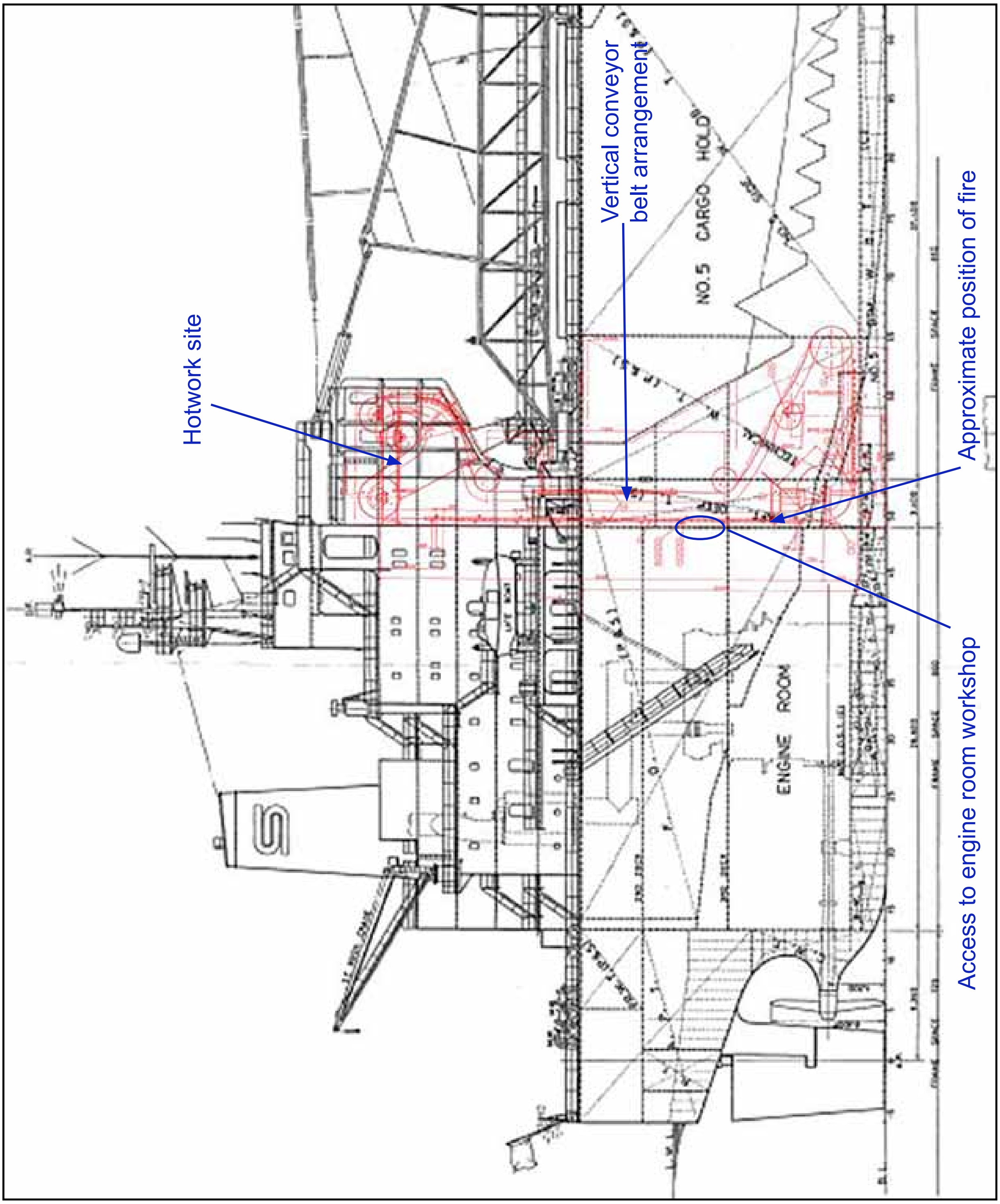
The last paragraph of the above instruction is also included in the safety action plan, in red font for emphasis.

Section 4.5.6 emphasised that smoke from conveyor belt fires is highly toxic and acrid, and that the tower acts as a high riser (chimney), encouraging the fire.

1.16 STRUCTURE IN THE VICINITY OF THE FIRE

The structural general arrangement of the aft end of *Yeoman Bontrup*, complete with the conveyor belt configuration, is shown at **Figure 31**.

Figure 31



Structural general arrangement, complete with the conveyor belt configuration

1.16.1 Bulkheads

The fire integrity requirements for bulkheads fitted to cargo ships are laid out in SOLAS, Chapter II-2, Part C, Regulation 9, Table 9.5. The engine room was designated as a “Category A Machinery Space”, the conveyor cargo handling area as an “Other Machinery Space” and the personnel elevator fell under the “Stairways” designation.

In accordance with the compartment designations, the engine room forward bulkhead was a class “A-0” bulkhead. The personnel elevator shaft, which abutted the vertical conveyor belt casing, was a class “A-60” bulkhead.

1.16.2 Engine room workshop/hydraulic pump space access door

The existence of the 26-bolt door that provided access between the engine room workshop and the SUL hydraulic pump space was known to Lloyd’s Register at build and the door was required to be watertight. However, at the owner’s request, a bolted, hinged watertight door was fitted in lieu of a sliding one. In acceding to the request for the door to be hinged, Lloyd’s Register required that a permanent notice be affixed to both sides of the door, stating:

> *“This cover is to be kept closed at all times at sea”*

Although the door was insulated to an “A-60” standard, Lloyd’s Register had no record of this. There was no requirement for the higher standard as the door was fitted to an “A-0” bulkhead.

1.17 STRUCTURAL CRACKING

Since build, *Yeoman Bontrup*’s high tensile steel structure had suffered from frequent cracking, which required a far greater amount of repair hotwork to be carried out than on a comparable mild steel hull. The cracking problem was particularly prevalent in way of the WBTs.

The owner and manager had agreed a continual survey and repair procedure with Lloyd’s Register to cover WBT repairs, but not defects to the shell plating, which required Class surveyor oversight. To provide the necessary expertise, the TSSR rotated around the owner’s three ships to carry out surveys and to monitor and assess the quality of the repairs undertaken by two coded[10] welders, who formed part of the crew, once the ship was alongside. Repairs were necessary up to about three times per month.

A full register of the defects was scrutinised and signed periodically by the Class surveyor. The register was last reviewed in mid-2010 when all the WBT special surveys were completed, with only minor deficiencies noted.

10 Welder recognised by a classification society or similar professional body as competent to undertake work on behalf of that body.

1.18 DESIGNATED HOTWORK AREAS AND PROCEDURES

1.18.1 Designated hotwork areas

The hotwork procedures were covered comprehensively in VMS Section 4.6.7 **(Annex F)**. The section identified that the engine room workshop was the only designated space that hotwork involving welding, burning, naked flame, high temperature, arc or a continuous spark process could be carried out without requiring prior approval from the ship's manager.

Welding and burning equipment was additionally stowed in the bosun's store, and in the deck store and workshop in both *Yeoman Bontrup* and *Yeoman Bridge.*

1.18.2 Procedures

Hotwork procedures fell into two categories as defined by VMS 4.6.7: those that required prior approval from the superintendent, and those that did not. For the hotwork planned for 2 July 2010, prior approval was required. The procedure required a detailed risk assessment to be completed on VMS form SAF03, which was to be agreed at a safety meeting chaired by the master.

The completed risk assessment and hotwork request were then forwarded to the MS&Q superintendent for approval. A safety action plan, which specified the requirements and precautions, was also forwarded. On receipt of the request the MS&Q superintendent was required to thoroughly review the risk assessment and discuss the requirement with the relevant technical superintendent to determine whether or not the hotwork was to be allowed. If approved, the ship then raised form SAF 04 – Hotwork Permit. In this case, the hotwork permit raised for the hopper work was destroyed in the fire.

1.19 SHIP'S-USE CHEMICALS

1.19.1 Chemical stowage

The steering gear compartment was the designated stowage for ship's-use chemicals. Good quality, secure racking was positioned at the transom, where numerous oils and chemicals, including oxidisers, were stowed. The chemicals were positioned to the port side of the centreline. Alkaline-based chemicals were stowed in racks on the port side, abutting the rope store, which was about 6m forward of the acid stowage.

Yeoman Bontrup's chemical inventory for June 2010 and a stowage sketch are at **Annexes G** and **H** respectively. The majority of the chemicals were supplied by Unitor, and the related MSDSs were held on board.

1.19.2 Chemical stores – housekeeping

On board *Yeoman Bridge,* numerous chemicals were found to have been stowed in workshops, passageways and in the engine room. These included flammable chemicals, the powerful oxidiser Dieselguard (sodium nitrate) and the corrosive Liquitreat (potassium hydroxide).

1.19.3 Instructions

VMS Section 4.4.4 – Working with Dangerous or Hazardous Materials and Goods **(Annex I)** provided guidance on the use and storage of chemicals. In particular, the instruction highlighted that chemicals having different properties and safety concerns were to be stored apart from each other, and the particular dangers of each were to be highlighted.

The MCA's publication, "Code of Safe Working Practices for Merchant Seamen (COSWP)" is carried on board numerous foreign-registered vessels, including *Yeoman Bontrup,* as a book of reference. Section 27.1.7 states:

> *"In the case of ship's stores etc, reference should be made to the manufacturer's instructions and data sheets which may be supplied with the goods. Reference may also be made where appropriate to the series of publications issued by the Health and Safety Executive under the Control of Substances Hazardous to Health (COSHH) Regulations".*

1.20 SAFETY MANAGEMENT SYSTEM

The International Safety Management (ISM) Code requires a company to develop a structured and documented system, commonly known as the Safety Management System (SMS), but in this case known as the VMS, so that its employees can implement the company's safety and environment protection policy. The VMS was a computer-based interactive system.

1.20.1 Risk assessments

Under Section 1.2.2.2 of the ISM Code, ships' managers have a responsibility to:

> *"assess all identified risks to its ships, personnel and the environment and establish appropriate safeguards…"*

Section 3.0 of the VMS covered risk assessments and critical operations. The instructions required the crew to use the onboard computer-based "ShipSure Risk Assessment Database" to carry out risk assessments and to store them for future use, review and amendment.

In the event that the "ShipSure" database was unavailable, the crew were instructed to carry out risk assessments using the paper system Form SAF 03.

1.20.2 Audits/inspections

The last external SMS audit was carried out by Lloyd's Register on 17 March 2008. No non-conformities were identified. *Yeoman Bontrup'*s Safety Management Certificate was issued on 17 March 2008 with an expiry date of 2 April 2013.

V.Ships UK Ltd conducted the last internal SMS audit on 23-24 February 2010. Although there were no non-conformities issued, five observations were made. Notably, Observation 01/10 identified that Hotwork Permits 03, 04 and 05 of 2010 were not fully completed in that the times of the safety checks and work completion were missing.

The Bahamas Maritime Authority's last inspection was carried out in Hamburg on 15 November 2009. The last port state control inspection was conducted in Florø, Norway, on 24 March 2010. Neither of the inspections identified any deficiencies.

1.20.3 Drills

Section 8.3 of the VMS - (Ship Safety Training and Record Book) **(Annex J)** stressed the importance of drills and dealt with drill management procedures. In particular it laid the responsibility for the nature and conduct of the drills on the master. The Schedule of Drills was laid out in Form SAF 24 and required fire drills to be held every 14 days, and every 7 days if practicable.

1.21 EXTERNAL TRAINING

In addition to the VMS drill requirements, SeaTec UK was contracted to provide an annual specialist 8-day training package to the Aggregate Industries UK Ltd's fleet. Training included emergency preparedness and drills, risk assessment awareness, enclosed space entry and VMS training.

1.22 FIRE TESTING OF VERTICAL CONVEYOR BELT MATERIALS

A series of fire tests was conducted on the vertical conveyor belt materials at the IMO-approved Buildings Research Establishment (BRE) test facility at Watford.

Cone calorimetry and ignitability tests were carried out on new sections of the vertical conveyor base belt, cleat and side curtain which were manufactured to the same specification as those fitted to *Yeoman Bontrup.*

Fire simulation tests were also carried out to investigate the possibility of a "Hardox" plate hot section of stud and nut, which had been cut using oxy-acetylene equipment, falling from the SUS hopper to the fire locus and igniting the components of the vertical conveyor belt.

The first series of tests involved heating the stud and nut to about 980°C and placing it at various locations on the conveyor belt arrangement. It was found that ignition did not occur at this temperature.

During the second series of tests, the stud and nut were heated to just below their melting point of 1370ºC, about the temperature that would have been reached had oxy-acetylene equipment been used. Following a 3-second delay to take into account cooling during a 21m fall[11], the hot stud and nut were placed centrally in the cleat, in the cleat and against the side curtain, and in the side curtain corrugation. The three separate tests were carried out in 0 m/s and 0.4 m/s wind speeds to simulate airflows in the SUS tower. On each occasion, the cleat ignited, smouldered and then self-extinguished. However, when the stud and nut were in contact with the side curtain, the latter readily ignited **(Figures 32 and 33)**.

[11] The 21m represents the distance from the hotwork location to the estimated position of the fire locus.

A copy of the report’s executive summary, summary of the principal outputs of the cone calorimetry tests, and conclusions is at **Annex K**.

Figure 32

Fire Tests - stud and nut placed in cleat adjacent to the side curtain

Figure 33

Fire Tests - stud and nut placed in cleat adjacent to the side curtain after 10 minutes

1.23 INDEPENDENT INVESTIGATIONS

1.23.1 Fire investigation

Hawkins & Associates Ltd, a leading forensic fire investigation company, was contracted to provide expert interpretation of the fire scene, the cause of the fire, its spread characteristics and resultant explosion.

A copy of the relevant sections of Hawkins & Associates Ltd's report is at **Annex L**[12].

The report was written before the fire tests were carried out on the vertical conveyor base belt, cleat and side curtains. The report concludes that the:

- Fire was probably caused by hot metal debris falling in the lift tower and igniting the vertical conveyor belt side curtain.
- Fire spread from the tower to the engine room and hydraulic pump space by conduction through the bulkheads and steel deck and through the open hydraulic pump space to the engine room workshop.
- Development of the fire in the engine room, coupled with failure of air lines, resulted in localised melting of the steel work and the formation of a layer of hot gases at the upper level.
- Heat build-up in the engine room transferred to the steering gear compartment and ignited combustibles there. Damage to the chemical containers stowed there, and their interaction, caused a severe localised detonation, opening up the transom/poop deck.
- Subsequent deflagration of the hydrocarbon rich (from the oils and hydraulic systems) atmosphere in the steering gear compartment caused the poop deck to be torn from the ship.

1.23.2 Investigation into the possibility of an hydraulic oil leak causing the fire

Hawkins & Associates Ltd was also contracted to research the possibility that an hydraulic oil leak from the water ballast valve operating system (Section 1.11.4) could have ignited following contact with a halogen light lens with a surface temperature of 135ºC (Section 1.14) resulting in the fire.

The report states that, for ignition to occur, the surface temperature must greatly exceed the auto-ignition temperature of the oil. It concludes that ignition of the hydraulic oil, following contact with the halogen lamp, was extremely unlikely.

A copy of the Introduction, Discussion and Conclusions of Hawkins & Associates Ltd report is at **Annex M**.

[12] Section 1 - Introduction, and some of the referenced figures, appendices, and photographs have been omitted to reduce the size of the Annex.

1.24 SELF-UNLOADING VESSELS

1.24.1 General

At the time of writing, there were 178 self-unloading bulk carriers in existence. Of these, 80 were known as “Lakers”. They were small in size and operated on the Canadian Great Lakes. Of the “Lakers”, 37 were Canadian registered and 43 were registered in the USA. Of the remaining 98 vessels, the Bahamas Maritime Authority has the largest number on its register, with 15 vessels.

Of the 98 vessels, 31 have the SUS discharge tower positioned aft, near to the high-risk engine room and accommodation area.

1.24.2 SUL Operators and Owners Forum

Concerned about the rapidity of the fire spread, *Yeoman Bontrup*’s owners established an SUL Operators and Owners Forum to discuss mutual SUL safety issues. The inaugural meeting was held at the Aggregate Industries UK Ltd’s headquarters during 13 -14 October 2010. The attendees, which represented about 90% of the SUL industry, included Canada Steamship Lines (CSL), Egon Oldendorff, Torvald Klavenes Group, Jebsens Beltships, Stema (Shipping), and Aggregate Industries UK Ltd. CSL also represented Algoma Central Corporation and Vulicia Shipping Company Limited of the United States.

The outcome of the forum’s inaugural meeting included:

- Extension of worldwide forum membership to all SUL operators and owners and holding of biannual meetings.
- Joint-funding for the fire testing of a constant air analysis fire detection system and a suitable, possibly high-density fog mist, extinguishing system.
- Production of a safety video (in conjunction with the testing above) on the dangers of conveyor belt fires for distribution to all attendee companies.
- Trial installation of a fire detection system on a CSL vessel.
- Contact with specific marine fire-fighting schools, with the purpose of developing a dedicated fire-fighting course covering the dangers of conveyor belt fires and how to effectively deal with them.

1.25 SIMILAR ACCIDENTS

1.25.1 *Yeoman Bontrup* - vertical conveyor belt fire

On 18 October 2006, a corroded scupper pipe, which was adjacent to the vertical conveyor belt was planned to be replaced. The procedure included hotwork which had not been authorised. At 1405, a fire was discovered on the vertical belt, about 2m below the work site, which the crew extinguished about 7 minutes later. The company’s investigation found that hotwork debris had become trapped between a roller and the base belt, causing the latter to ignite.

The investigation also found that non-compliance of hotwork procedures, lack of planning and a lack of effective oversight were the major contributory factors.

1.25.2 Canadian-registered self-unloader *Halifax* – tunnel fire

On 6 April 1993, a major fire broke out in the centre tunnel during post-repair testing of a hold gate's hydraulic system. A hose to a gate valve was found disconnected after the fire. The fire was successfully extinguished by the crew, but the head tunnel man lost his life.

The fire was caused when the hydraulic oil mist from the disconnected hose was ignited by a halogen lamp that was missing a protective lens cover.

1.25.3 Vanuatu-registered self-unloader *Ambassador* – conveyor belt fire

On 31 December 1994, a fire occurred on the cross-conveyor belt system, which was due to an overheating belt support roller. The fire quickly spread to the accommodation area and took 28 hours to extinguish. The subsequent investigation report by the Transport Safety Board Canada found that the fixed sprinkler system was inadequate, the containment doors could not be closed and the crew had not been properly drilled. As a result, a recommendation was made to seek support to approach the IMO to address the need for enhanced fire detection and extinguishing systems in self-unloaders. In the event, the recommendation received insufficient support and no approach was made.

1.25.4 Liberian-registered self-unloader *Sophie Oldendorff* – conveyor belt fire

The Liberian-registered vessel was self-unloading a cargo of granite on 16 June 2010 when a fire broke out on the conveyor belt system. It took 100 firefighters over 6 hours to bring it under control. At the time of writing, the cause of the fire was still being investigated by the US Coastguard.

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 CAUSE OF THE FIRE

2.2.1 Background

In determining the cause of the fire on board *Yeoman Bontrup*, which was discovered on the vertical conveyor belt, a number of possible scenarios were considered against the circumstances prevailing at the time. These particularly included the possibility of a fire starting elsewhere, from an hydraulic oil leak, and transferring to the conveyor belt.

While there was CCTV coverage in the general area of the fire, the system was only switched on during self-unloading. Consequently, no one in the CCR saw the fire start on the remote system, and there were no witnesses to the event.

It is known that when the fire was discovered, at about 1519, it was already well-established, with the flames covering an area of about 1.5m^2.

2.2.2 Vertical conveyor drive system

There have been many examples of overheating drive systems and seized supporting rollers which have caused sufficient friction to ignite conveyor belts. The SUS was shut down at the time and therefore this cause can be discounted.

2.2.3 Electrical defects

Apart from lighting systems and the cross-conveyor motors, there were no significant electrical components or distribution systems which might have ignited materials that could have then been transferred to the conveyor belt. An electrical short circuit is not considered to be the cause of the fire.

2.2.4 Transfer of heat from the engine room or from the personnel elevator

The conveyor belt was positioned about 300mm forward of the engine room bulkhead. If there had been a fire in the engine room large enough to transfer sufficient heat to ignite the belt, the smoke detector in the engine room would have raised the alarm before the conveyor belt fire was discovered.

Although there are electrical cables in the base of the elevator trunk, the chief engineer and the TSSR both used the lift after the fire was discovered. Neither noticed smoke in the lift cab or in the lift trunking.

Both these potential causes for the fire are discounted.

2.2.5 Hotwork in No 4 WBT

Hotwork had been taking place in No 4 WBT just before the fire was discovered. However, No 4 WBT is some 50m forward of the fire site, and the arc welding cables were being supplied from a welding machine forward of that point. The hotwork in No 4 WBT was not contributory to the fire.

2.2.6 SUS and mooring winch hydraulic systems

The SUS conveyor belt hydraulic drive systems were shut down and there was no evidence of leaks at the last discharge port when the system was last used. The SUS boom slewing hydraulic system was pressurised before the fire was discovered, to move the boom inboard. However, the hydraulic power pack and associated pipework were external to the conveyor tower.

The after port midships mooring winch hydraulic system supply and return pipelines passed through the upper level of the SUS hydraulic pump space. However, any oil leaking from the substantial pipework or flanges overhead would have been obvious, and none was reported. Hydraulic oil accelerants from these sources are discounted as a cause of the fire.

2.2.7 WBT valve hydraulic operating system

It is known that the WBT valve hydraulic operating system was pressurised to 60 bar at the time the fire was likely to have started. This was because the chief officer was carrying out ballast operations as the granite cargo was being loaded.

In relation to the locus of the fire, the system's bundles of 20mm copper hydraulic pipework passed within 1.6m of the conveyor belt and within 2.9m of the halogen light, which itself was 1.3m from the belt. The flashpoint of the hydraulic oil was 140ºC and the auto-ignition point was 250ºC. The nearest ignition source was the halogen light, which had a surface lens temperature of 135ºC[13]. There is no evidence that the lamp lens cover was missing. However, if it had been, the temperature of the filament would certainly have been higher than that of the lens cover, increasing the possibility of the lamp being an ignition source for the oil.

Although there were no witnesses to a leak, it is feasible that one of the hydraulic copper pipes might have "work-hardened" and developed a split, which allowed a jet, spray or fine mist to develop. However, based on Hawkins & Associates Ltd's report at **Annex M**, the halogen lamp temperature would need to have greatly exceeded 250ºC for ignition to have occurred.

In addition, when the fire was discovered, no one reported any other flames either in the area of the lamp or from the pipework. It is possible that, had a leak ignited, the power pack hydraulic tank fuel source might have been exhausted by the time the fire was discovered. Had this been the case, the audible and visual low-level warning alarms, which had automatically been tested when the hydraulic power pack was started, would have sounded in the manned CCR. None was heard.

[13] From readings taken on board *Yeoman Bridge.*

Considering the large number of contributory factors required, for which there is no evidence, and expert-opinion that the temperatures required for ignition were not achievable from an undamaged halogen lamp, it is extremely unlikely that a leak from the WBT valve hydraulic operating system was the cause of fire.

Hawkins & Associates Ltd's report at **Annex M** further concludes that:

> "*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"*

While there is insufficient evidence to support the leak theory as being the cause of this particular accident, a similar set of circumstances involving a damaged halogen lamp did occur on the self-unloading bulk carrier *Halifax* in 1993 (Section 1.25.2), which caused a fire.

2.2.8 Hopper hotwork

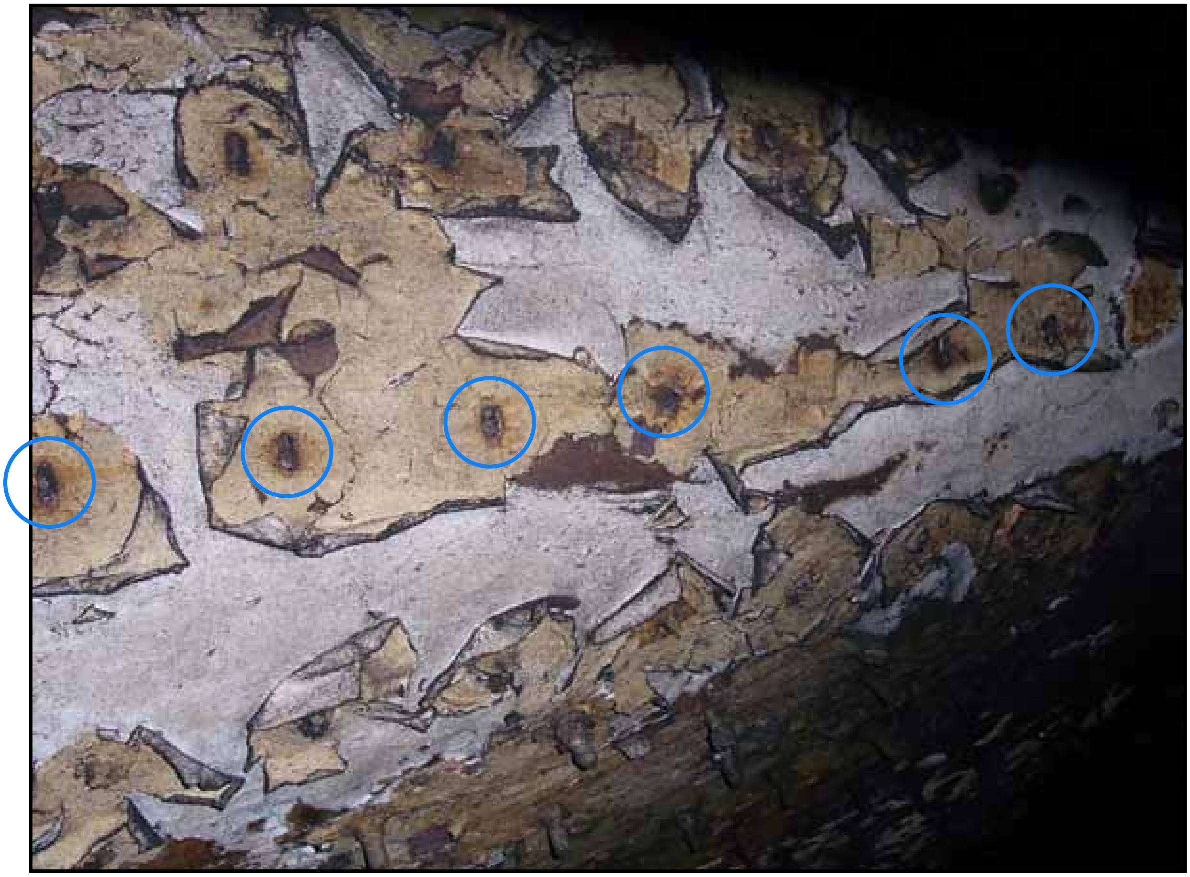
There was irrefutable evidence that hotwork was routinely carried out on the outside of the hopper:

- Doubler plates were found to have been welded on the outside of the carcass.
- There was clear evidence that studs holes had been elongated **(Figure 34)**.

It is common practice to use flame cutting equipment to burn through seized nut and bolt fastenings, as illustrated in **Figure 35**. In the harsh environment of the hopper it is reasonable to conclude that this had occurred, although the frequency is not known. The fire tests (Section 1.22) confirmed that when a low-carbon steel stud and nut fastening, similar to those shown in Figure 35, is heated to its melting point and is allowed to fall 21m, it can ignite the conveyor belt side curtain if it is in contact with it. The fire tests showed that, after about 15 minutes, the side curtain was well alight. However, it is not known how long a similar situation would have taken to develop into the 1.5m^2 area of flame that was burning when the fire was discovered. The particular circumstances would have been affected by airflows, condition of the belt and its components, and cargo residues, all of which might have had the effect of suppressing its development.

The repair party recognised the risk of hot debris falling onto the belt because the sloping area of the return belt was covered by a fire blanket. There is no doubt that there was a clear route for hot debris from the hopper to fall into cleats and land against the side curtain at the locus of the fire. Because of the concern over the veracity of the accounts, it is not certain whether or not oxy-acetylene equipment was used, for example to burn off "Hardox" studs, after 1400, the time at which all hopper hotwork was reportedly completed. Despite this, it was also stated that tack welding of the "Hardox" tiles took place after this time, when tack welding is clearly a form of hotwork.

Figure 34



Elongation of hopper carcass “Hardox” tile securing stud holes

Figure 35

Flame cut bolts similar to those used to secure the "Hardox" tiles

It is known that the repair team paid insufficient attention to the hotwork controls laid out in the VMS, which significantly increased the risk of a fire developing.

The scenario that the fire was caused when hot debris from the hotwork on the hopper came into contact with the conveyor belt below seems most likely.

This view is supported by the independent fire investigation report **(Annex L)** which concluded that the fire was probably caused by hot metal debris, from the hotwork being carried out in the hopper, falling into a pocket and igniting the side curtain.

2.3 HOTWORK DISCIPLINE

Poor hotwork discipline and a failure to follow established guidelines is a significant cause of fires in ships, many of which could have been avoided by proper oversight.

2.3.1 Procedural non-compliance

The VMS contained comprehensive instructions and procedures on how hotwork was to be controlled on board *Yeoman Bontrup*. In particular, the dangers associated with hotwork in areas adjacent to the conveyor belt system had been stressed. However, there was compelling evidence to suggest that the company's requirements in this respect had often been circumvented.

Hotwork had been carried out in unapproved areas including the bosun's store, the deck store and workshop. Additionally, oxy-acetylene cutting equipment had been employed on the upper deck and welding had taken place inside No 4 WBT without the prerequisite approval from the managers.

The VMS required that a dedicated fire watcher was used whenever hotwork was undertaken. However, the cargo engineer chose to take on this role when supervising the planned hotwork in the tower. Accordingly, it was impossible for him to monitor the condition of the conveyor and, importantly, there was no fire watch posted during the periods when there was a break taken from working in the tower. This requirement is specifically covered in the company's SMS.

2.3.2 Company enforcement of the procedures

On 18 October 2006, *Yeoman Bontrup* suffered a vertical conveyor belt fire due to poor hotwork discipline (Section 1.25.1). Following this, the ship's manager distributed a fleet-wide e-mail on 23 October 2006 emphasising the need for full compliance with the hotwork procedures and introducing the Safety Action Plan. This was followed up with a further e-mail on 27 September 2007 from the ship's manager MS&Q department, further emphasising that short-cuts to permit-to-work procedures were unacceptable and that compliance with the VMS safety procedures was mandatory.

2.3.3 Complacency

The ship's arduous trading pattern led to considerable abrasion of the hopper's sacrificial tiles and perforation of the hopper carcass, which frequently required hotwork repairs. In addition, the high tensile steel hull suffered cracking, which also required regular hotwork repair.

These factors led to much more hotwork being carried out on *Yeoman Bontrup* when compared with other conventional bulk carriers. This inevitably led to the crew regarding hotwork operations to be a routine, rather than exceptional task. As a consequence, it is apparent that a degree of complacency was evident with respect to the crew's attitude to safe working practices during hotwork operations, notwithstanding the unequivocal instructions that had been sent to the fleet about the subject.

2.4 SHIP DESIGN, FIRE-DETECTION, CONTAINMENT AND FIXED FIRE-FIGHTING ARRANGEMENTS

2.4.1 Ship design and requirement

Although the vessel was built to the required standards, this accident has identified important shortcomings that limited the crew's ability to manage a fire situation in the cargo handling areas. *Yeoman Bontrup* was designed and built with the majority of her cargo-handling facilities positioned adjacent to the engine room and fuel oil tanks. Some other self-unloading vessels using conveyor systems have their discharging systems positioned forward, away from the high-risk areas.

The design of the ship meant that early detection of a fire was essential in order for sufficient resources to be deployed to prevent its escalation. Once discovered, the need to contain a fire is paramount, as is the need to aggressively attack it, either by first-aid fire-fighting appliances or portable equipment, or to expeditiously deploy fixed systems where these are available.

It is important that these requirements are recognised, that the ship is designed to minimise the risk, and that crew are properly trained. The SUL Owners and Operators Forum (Section 1.24.2) has agreed funding to examine these points, and its initiative is a constructive step towards improving safety in the SUL industry. However, there remains a need for more formal regulation to achieve a common safety standard.

2.4.2 Detection

By the time the fire had been discovered, it was well-established on the conveyor belt, and heat transfer through the engine room bulkhead was already well developed.

Yeoman Bontrup was originally fitted with three heat detectors in the SUS tower, but no smoke detectors. This option was provided for in SOLAS because the high dust levels expected during cargo discharge operations would have risked spurious alarms and thus compromised the crew's confidence in the system. However, smoke was detected by the team working in the hopper, which was some 21m above the locus of the fire, before the alarm was raised. The conveyor belt fire tests commissioned by the MAIB proved that, once the fire became established, copious amounts of smoke would have preceded the discovery of the fire. Had suitable smoke detectors been fitted, early detection would have been possible. This would probably have led to an early attack on the fire, and may have helped prevent its spread and made success at extinguishing it more likely.

2.4.3 Containment - tunnels and vertical conveyor belt tower

The cargo tunnels and vertical conveyor belt tower represented 72% of the ship's overall length; in addition, the height of the tower was about 36m. There was no way of dividing the large space for containment purposes. Had there been, the spread of the fire would probably have been reduced.

2.4.4 Containment - engine room workshop/hydraulic pump space door

The fire transferred from the SUS tower to the engine room by conduction through the "A-0" bulkhead.

However, the fire was also able to spread into the engine room workshop, and then into the engine room, through the open hydraulic pump space access door. The door could not be easily closed, especially from the workshop side, nor could it be held in the closed position without inserting at least one of the securing bolts. As there was considerable heat build-up, and virtually no visibility in the smoke-filled area, there was little chance, in the time available, that the crew could have secured the door in the closed position. The open door therefore significantly hampered the crew's efforts to contain the fire, and the fire's migration into the engine room was inevitable.

2.4.5 Fixed fire-fighting systems

Neither *Yeoman Bontrup* nor her sister vessel *Yeoman Bridge* was required, under SOLAS, to have a fixed fire-fighting system fitted in the cargo handling spaces. Research indicates that very few self-unloading vessels are fitted with such systems, although spaces of similar size on other types of vessel are protected by fixed equipment.

The fire was not detected until it was well-developed, and this prevented any realistic attack by first-aid or portable appliances.

The absence of a fixed fire-fighting system significantly compromised the crew's ability to fight the fire. Had a fixed system been fitted, the fire-fighting effort would probably have been far more effective.

2.5 FIRE-FIGHTING

2.5.1 Crew

The crew made determined efforts to control the fire. The quick deployment of boundary cooling around the tower and accommodation area, and the use of fire hoses and the foam generator into the tower's main deck starboard door, were well-considered. Unfortunately, by that time, the fire was too well-established for these measures to be successful.

The chief engineer and his team were particularly brave in fighting the fire from within the tunnels. Unfortunately, their efforts were hampered because the fire was being fed with air, drawn in by the "chimney" effect, through the tunnel access and ventilator terminals which were left open. There were also a number of windows and doors left open in the superstructure, which eased the fire's migration through the ship.

Once the master ordered the second and third engineers to leave the engine room, it would have been prudent to have immediately closed all engine room openings and operated the engine room CO_2 system. This might have controlled the fire in the engine room and prevented its spread into the steering gear compartment. As it was, this action was considered too late, by which time the heat and smoke prevented the chief engineer from operating the system.

While the chief engineer was still attacking the fire from within the tunnels and was optimistic about the outcome, he was unaware of how far the fire had spread through the rest of the ship. It was clear to the master that the situation was overwhelming the firefighters, and his decision to evacuate the ship while his full crew was accounted for, some 45 minutes after the fire was discovered, was a prudent and safe course of action.

2.5.2 Drills

The effective conduct and critical assessment of drills is an essential management tool in ensuring that crews act instinctively and safely to an emergency situation.

It was recognised by the crew, ship's manager and owner that the conveyor belts, and thus the tunnels and SUS tower, constituted a significant fire risk. Fire drills were listed in the VMS Schedule of Drills. However, dealing with a fire in the SUS cargo handling area was not specified, and had not been practised.

Masters should have the latitude to determine the type and scope of drills. However, where a particularly high risk is identified, then it is sensible that an associated drill should be specified in the Schedule of Drills.

2.5.3 Glensanda Quarry and HIFRS fire-fighting support

Although the Glensanda Quarry fire team arrived on the scene very quickly, the extent of support it could provide was limited. The team was not trained in the use of BA or in ship fire-fighting techniques. Nevertheless, it provided valuable boundary cooling assistance and pastoral care to the ship's staff on their evacuation.

The HIFRS's arrival on-scene was unavoidably delayed because of the remoteness of the quarry site. The harbourmaster deployed his vessel transport facilities as quickly as possible, but by the time the HIFRS arrived there was no realistic prospect of carrying out internal fire-fighting with the limited assets available. The firefighters could only concentrate on boundary cooling from the land side of the shiploader berth until the arrival of the ETV when cooling of the port side of the ship became possible.

2.6 USE OF PASSENGER ELEVATOR

Both the TSSR and the chief engineer used the passenger elevator after the fire alarm had been sounded. Neither knew the location or extent of the fire or of the risk of interruptions to the elevator's electrical supplies. Had power been lost then either the TSSR or chief engineer could easily have been trapped in the elevator cab with little prospect of rescue. The use of the elevator was contrary to best safety practice. While the visitor's "welcome onboard" leaflet identified that elevators were not to be used in an emergency, the VMS did not.

2.7 RISK ASSESSMENTS

Thorough and complete risk assessments are an integral part of a company's procedures in ensuring it fulfils its health and safety obligations. Only by identifying the risks, can appropriate control measures be put in place to minimise risks to personnel and equipment.

The crew were required to carry out paper risk assessments if the computer-based "ShipSure" system was unavailable. However, unlike the database, the paper system did not require an assessment of the residual risk after the initial control measures had been applied. This process shortcoming could have led to the belief that the risks were acceptable even though a re-assessment might well have identified that further control measures were required to reduce risks to an acceptable level.

The risk assessments in support of hotwork requests were reviewed by the ship's manager. The assessment for the hopper hotwork was a generic risk assessment drawn from the "ShipSure" database, and had been used many times before without proper review by either the crew or the ship's manager. Had a review been undertaken, the silometer radiation hazard, as well as additional risks associated with working at height and lighting, might have been identified.

2.8 CONVEYOR BELT SPECIFICATIONS

2.8.1 Fire risk

It was well known among owners and operators of SUL bulk carriers that the conveyor belts were a high fire risk. The belts were vulnerable to the effects of hotwork and friction heat build-up from belt supporting rollers, pulleys and idler wheels. Various sections of the VMS emphasised the high fire risk.

In the conveyor configuration on board *Yeoman Bontrup,* the vertical conveyor belt was the most vulnerable to fire. The fire tests proved that the side curtains were the most easily ignitable component. They also identified that the curtains had a very high Heat Release Rate (HRR) of 521.2 kW/m^2. Once a self-sustaining flame had been established, the fire progressed quickly because of the high heat energy, and the smoke levels were correspondingly dense.

In the absence of IMO or classification society guidance, it is the responsibility of the vessel's owner/manager to ensure the specification of the conveyor belt is appropriate. The system fitted on board *Yeoman Bontrup* was of the standard type that had no fire-resistant properties and consequently represented an increased risk compared to fire-resistant belts. There is anecdotal evidence that the inclusion of fire retardant chemicals in belts may make them brittle and reduce their life expectancy. As fire-resistant belts can be in the order of 25-50% more expensive than the standard belt, it is currently a matter of commercial choice whether or not to opt for the higher specification belt.

2.8.2 Regulation

The extracts from the fire test report at **Annex K** identified that the Maximum Average Heat Release Emission (MAHRE)[14] values for the base belt, cleat and side curtain were 157.2, 241.0 and 271.5 kW/m^2 respectively. It is significant that, as a comparison, the railway industry maximum MAHRE value for any materials application is 90 kW/m^2; one-third of the side curtain MAHRE value.

Cargo handling systems fall outside classification society rules, and there are no regulations under SOLAS relating to the standards for conveyor belts or their components. Had *Yeoman Bontrup*'s vertical conveyor belt been either fire-resistant or of a self-extinguishing type, there was a possibility that the fire could have been either prevented or the crew could have extinguished it before it had a chance to develop.

2.9 SHIP'S-USE CHEMICALS

The importance of proper consideration for the stowage of ship's-use chemicals should not be underestimated. A wide range of the chemicals commonly in use in the marine industry can violently interact with one another should they become damaged or involved in a fire. This is particularly so where oxidising agents are included.

[14] MAHRE is a means of assessing and clarifying performance from the data derived from cone tests

2.9.1 Stowage

The use of the steering gear compartment for stowing chemicals is commonplace. It is dry and well-ventilated, and generally has sufficient space for racking, as was the case on *Yeoman Bontrup*. While there were separate acid and alkali stowages adjacent to oil stowages, it is unclear where the oxidising chemicals were located.

The scale of the fire would have involved the chemicals wherever they were stowed in the steering gear compartment. However, the initial explosion serves to highlight the need to consider the high risk that chemicals can pose in the event of a fire, and this should be considered during drills.

2.9.2 Guidance and regulation

There is a lot of guidance and regulation regarding the carriage of dangerous goods as cargo. Despite similar risks, there is virtually no formal guidance concerning the stowage of ship's-use chemicals, except for passing reference in COSWP of the need to refer to the specific MSDSs for advice on separation and segregation.

2.10 RADIATION ISSUES

2.10.1 Risk of exposure to radiation

The ship's manager and owner were aware that *Yeoman Bontrup* was fitted with the silometer radioactive sources, but these were not recorded on VMS Form TEC 22- Inventory of Potentially Hazardous Materials in the Ship's Structure and Equipment. There was a complete absence of any safety instructions for the silometers in the VMS, so none of the manufacturer's safety instructions had been complied with. This was despite the safety recommendations regarding access restrictions made by the contractor after the *Yeoman Bridge* survey of 18 March 2002. The oversight was possibly because the units had not been used in the previous 10 years and were considered redundant.

The condition of the units on board *Yeoman Bontrup* was especially poor, with the port source container suffering from severe corrosion that had resulted in perforation of the outer steel casing. The investigation found that the port source container had lain on the platform grating since at least 28 April 2010. Despite this being known by a number of the crew, no action was taken. It is unclear why the source container had been removed from its mounting bracket. It might have been because of the need for maintenance in the area, and it was not replaced because the system was not used.

None of the source containers was fitted with a security padlock. The operating mechanisms, although found in the "off" position following the fire, could, at any time, have been set to the "on" position, with the risk of exposing the crew to gamma radiation.

During the fire investigation, a number of people entered the area where the source containers were located. They were not briefed on the presence of the silometers or the possible radiation hazards and, as a result, some were exposed to low levels of radiation when they examined the port source container. Expert examination after the accident established that the Cobalt 60 radiation sources had remained intact. However, had the sources been compromised, there would have been a high risk of radioactive particles becoming airborne, being washed into the sea with the fire-fighting water, or ingested by the personnel who handled the sources.

While the implications of this exposure and contamination are outside the scope of this report, the case amply demonstrates the real dangers isotopes can pose if the correct management guidance and controls are not in place.

2.10.2 Regulations

The UK's Statutory Instrument 1999 No.3232, Health and Safety, The Ionising Radiation Regulations 1999 provides detailed requirements regarding the management of radioactive sources. However, the regulations only apply to sources which are shore-based.

While there are regulations controlling the transport of radioactive cargoes, neither the Bahamas Maritime Authority, Department for Transport, MCA nor the IMO has regulations specifically covering the shipboard use of radioactive sources.

As automation on board ships has increased, so has the use of radiation sources in control devices. Some ship owners and managers have adapted the existing shore-based regulations, including external authority certification and auditing procedures, for incorporation into their SMS. Others have no safety procedures to deal adequately with the dangers associated with the use of radioactive sources. The introduction of formal guidance would ensure a greater degree of security and safety to those directly or indirectly involved with shipborne radioactive sources.

Despite there being no specific regulations relating to the management of shipborne radioactive sources, *Yeoman Bontrup*'s managers had a responsibility under Section 1.2.2.2 of the ISM Code to assess and establish safeguards for all identified risks.

In this case the radiation risks were not considered at all.

2.11 HOUSEKEEPING

Good housekeeping is an important aspect of effective on board management of risks and ensuring the crew's wellbeing and safety.

During the investigation, there were numerous examples, both onboard *Yeoman Bontrup* and *Yeoman Bridge,* of chemicals and oils being stowed in passageways, workshops and in machinery spaces. While it may be a matter of convenience, the random stowage of corrosive and flammable chemicals presents both fire and health hazards.

Measures should be taken to ensure that all such chemicals and oils are kept in a safe, approved stowage. While not always obvious, housekeeping malpractices should be easily captured by the onboard senior management team and those conducting audits.

2.12 FATIGUE

Yeoman Bontrup's manning level was over twice that required by her Safe Manning Certificate. The crew were well-rested at the time of the fire, and fatigue is not considered to have been a contributory factor in this accident.

SECTION 3 CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT WHICH HAVE RESULTED IN RECOMMENDATIONS

1. Despite the ship's manager reinforcing the need to fully comply with the VMS hotwork instructions, the crew had become complacent in their implementation as a consequence of the high frequency of hotwork repairs. [2.3.2, 2.3.3]

2. There were no classification society rules or SOLAS regulations governing the cargo-handling areas and equipment on self-unloading bulk carriers. Consequently, while *Yeoman Bontrup* complied with the extant standards, attempts to contain and fight the fire were hampered by the following factors:
   - The conveyor belt systems posed a high fire risk.
   - The lack of suitable smoke detectors meant that the fire was already well established by the time it was detected.
   - The fire spread quickly through the compartment, making manual fire-fighting difficult due to the absence of fire curtains or other methods of containing the fire.
   - The compartment was not equipped with a fixed fire-fighting system. [2.4, 2.5.1, 2.8]

3. The design of the engine room workshop/hydraulic pump space door prevented it from being easily closed and secured from both sides, hampering the crew's efforts in containing the fire. [2.4.4]

4. There was a wide range of chemicals stowed in the steering gear compartment, which escalated the fire and contributed to the initial explosion. While there were instructions in the VMS there is virtually no formal guidance on the stowage of ship's-use chemicals. [2.9.1, 2.9.2]

5. Poor housekeeping resulted in chemicals and oils being stowed in passageways and workshops, which increased the risk of the spread of fire. These were also evident in *Yeoman Bridge.* [2.11]

3.2 OTHER SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION ALSO LEADING TO RECOMMENDATIONS

1. Despite wide use of radioactive sources in the marine industry, there are no regulations controlling their use or management. [2.10.2]

3.3 SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION WHICH HAVE NOT RESULTED IN RECOMMENDATIONS BUT HAVE BEEN ADDRESSED

1. The crew were not practised in fighting a fire in the cargo handling spaces and the drill schedule did not specify the requirement despite the recognised high risk. [2.5.1, 2.5.2]

2. The passenger elevator was used after the fire alarm was sounded. The visitor's leaflet identified that the elevators should not be used during an emergency, but the VMS did not. [2.6]

3. When using the paper risk assessment process, the residual risks were not assessed to determine whether additional control measures were required to reduce risks to an acceptable level. [2.7]

4. A regular review of the hopper generic risk assessment had not been undertaken. The risk of exposing personnel to radiation from the silometers was not recognised, and there were no measures to deal with this in the VMS. [2.7, 2.10.1, 2.10.2]

5. The VMS did not provide any guidance or safety instructions relating to the radioactive sources. Neither were they recorded on the ship's VMS Form TEC 22- Inventory of Potentially Hazardous Materials in the Ship's Structure and Equipment, so personnel involved in the fire and subsequent investigation were not briefed on the presence of the silometers or the possible radiation hazards. [2.10.1]

SECTION 4 - ACTION TAKEN

4.1 THE MARINE ACCIDENT INVESTIGATION BRANCH

The Chief Inspector of Marine Accidents has produced a Safety Flyer highlighting the circumstances and lessons to learn from this accident **(Annex N)**.

4.2 V.SHIPS UK LIMITED

The ship's manager has:

- Reviewed the hotwork approvals procedure and strengthened the safety action plan and risk assessment requirements.
- Revised the chemical stowage arrangements to provide the appropriate level of separation on the advice of the prime supplier.
- Contracted SeaTec UK to carry out a full safety inspection of *Yeoman Bridge* and to conduct fire training, involving the SUS, in addition to SeaTec's standard safety training programme.
- Revised VMS Form SAF03 – Risk Assessment, to include a requirement to assess residual risks.
- Conducted an audit of its managed vessels to determine which vessels carry radioactive sources.
- Amended the VMS **(Annex O)** and the "Inventory of Potentially Hazardous Materials in the Ship's Structure and Equipment" to include radiation sources.
- Revised the risk assessment relating to work in the cargo hopper area to include the risk of exposure to radiation **(Annex P)**.
- Amended the drill schedule to include fire drills in the cargo handling areas **(Annex Q)**.
- Amended the VMS (Section 4.10.2 Passenger Elevators) to reflect that elevators must not be used during an emergency.

4.3 WESTERN BRIDGE (SHIPPING) LIMITED AND AGGREGATE INDUSTRIES UK LIMITED

The registered and group owners have:

- Instructed the ship's manager to operate a "permit-to-work" system for opening the hinged, bolted door between the engine room workshop and the SUS hydraulic pump space.

- Completed inspection and measurement of the radioactive source holders on board *Yeoman Bridge*.

- Reviewed the “Hardox” sacrificial tile provision to improve the supply timeliness.

- Arranged for a trial using rubber segments in the cargo hopper on *Yeoman Bridge* to reduce the need for hotwork repair.

- Established the SUL Owners and Operators Forum with other major self-unloading shipping companies to discuss mutual SUL safety issues, including the need for fire protection, detection and extinguishing systems in the cargo handling spaces.

SECTION 5 - RECOMMENDATIONS

The Bahamas Maritime Authority, supported by the Maritime and Coastguard Agency, is recommended to submit proposals to the International Maritime Organization to:

2011/109 For self-unloading vessels:

- Review and improve fire detection, containment and extinguishing standards for cargo handling areas.
- Develop standards for conveyor belt fire resistance properties.

2011/110 Establish standards for the use and control of radioactive isotopes on ships.

The Maritime and Coastguard Agency is recommended to:

2011/111 Improve its existing guidance on the stowage of ship's-use chemicals.

V.Ships UK Ltd is recommended to:

2011/112 In recognition of the high workload and routine nature of tasks on board self-unloading bulk carriers, establish a more robust regime of supervision and audit with particular reference to:

- Hotwork procedures.
- Housekeeping discipline with regard to stowage of chemicals and oils.

2011/113 With respect to *Yeoman Bontrup* and *Yeoman Bridge*, review the suitability of the engine room workshop/hydraulic pump space hinged, bolted door securing arrangement with regards to watertight integrity and operational fire containment requirements.

Marine Accident Investigation Branch
May 2011

Safety recommendations shall in no case create a presumption of blame or liability