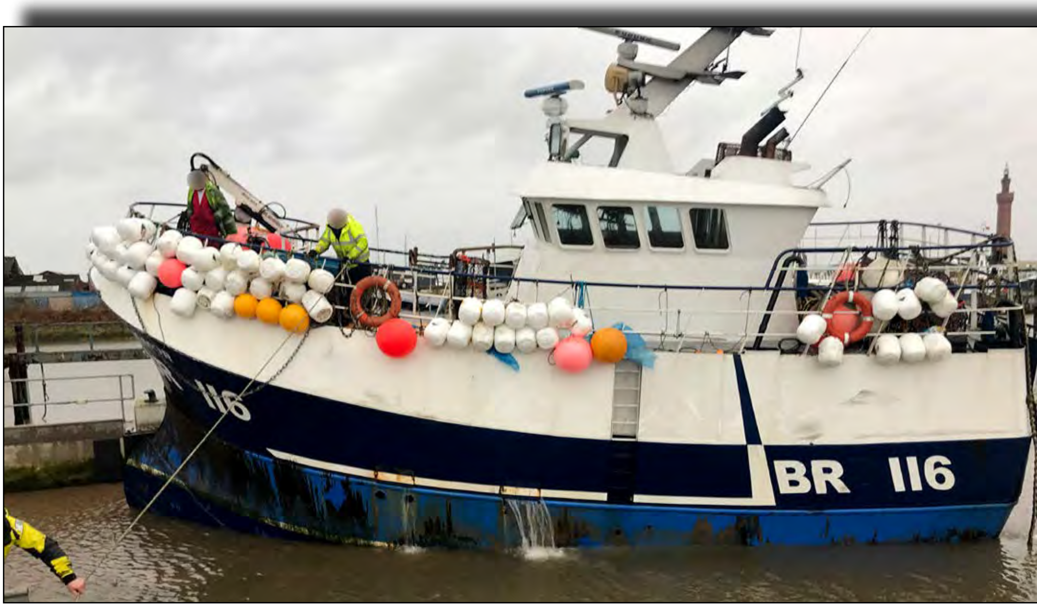
ACCIDENT REPORT

MAIB
MARINE ACCIDENT INVESTIGATION BRANCH

Report on the investigation of a subsea explosion resulting in crew injuries and vessel damage to the crab potting vessel *Galwad-Y-Mor* (BRD 116)

22 nautical miles north of Cromer, England

on 15 December 2020



SERIOUS MARINE CASUALTY REPORT NO 1/2022 JANUARY 2022

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2012 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012 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 14(14) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

Front Cover image courtesy of Andrew Oliver

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

ALB	-	all-weather lifeboat
DNT	-	dinitrotoluene
EH	-	exploratory hunting
EOD	-	explosive ordnance disposal
FRB	-	fast rescue boat
FTB	-	fast transfer boat
GP	-	general purpose
HE	-	high explosive
kg	-	kilogram
kW	-	kilowatt
m	-	metre
mm	-	millimetre
MGN	-	Marine Guidance Note
MOD	-	Ministry of Defence
MSN	-	Merchant Shipping Notice
MVC	-	microvoid coalescence
ng	-	nanogram
nm^2	-	square nautical mile
OREI	-	Offshore Renewable Energy Installations
PFD	-	personal flotation device
RDX	-	Research Department eXplosive
RN	-	Royal Navy
RNLI	-	Royal National Lifeboat Institution
RoW	-	Receiver of Wreck
t	-	tonne

TNT - trinitrotoluene

UKAS - United Kingdom Accreditation Service

UKHO - UK Hydrographic Office

UTC - universal time coordinated

UXO - unexploded ordnance

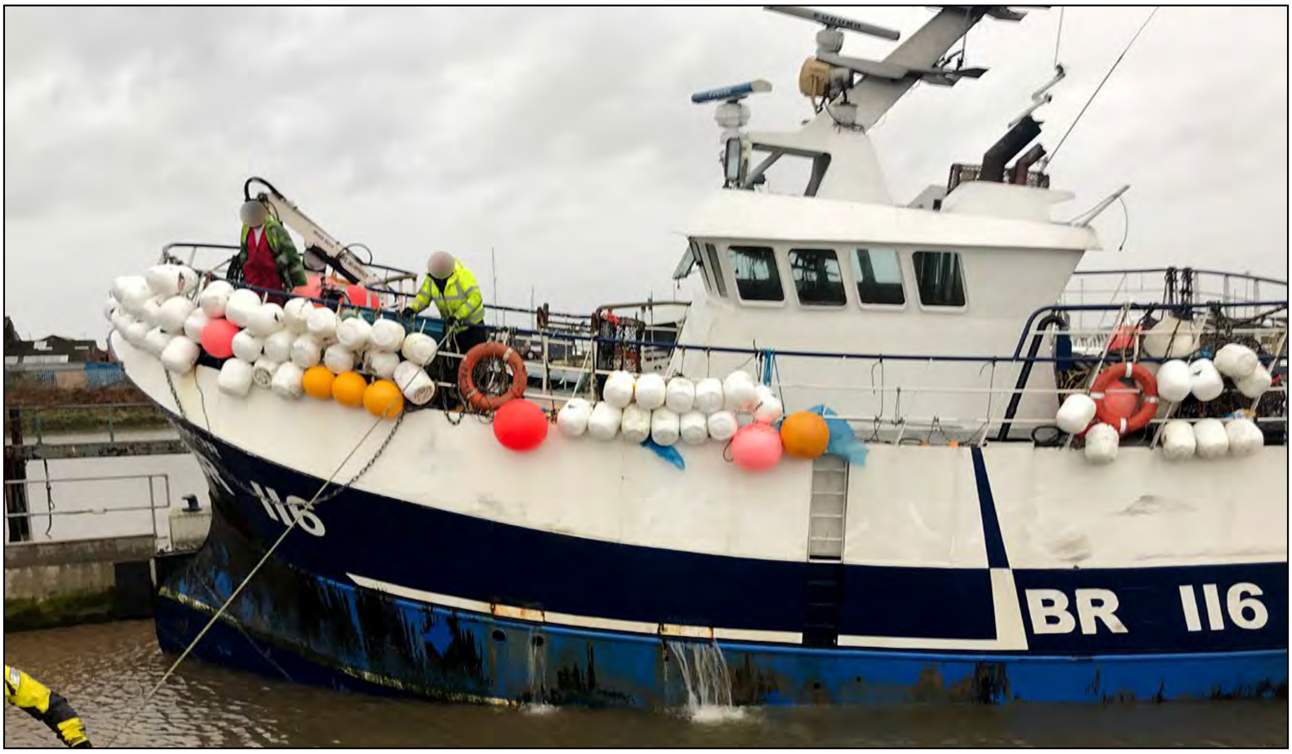
VHF - very high frequency

WWI - The First World War

WWII - The Second World War

TIMES: all times used in this report are UTC unless otherwise stated.

Image courtesy of Andrew Oliver



Galwad-Y-Mor

SYNOPSIS

On 15 December 2020, the 14.95m crab potting vessel, *Galwad-Y-Mor*, disturbed a piece of unexploded ordnance on the seabed while recovering crab pots in the North Sea, approximately 22 nautical miles off Cromer, England. The ordnance detonated and the ensuing explosion threw *Galwad-Y-Mor* up from the surface of the sea, causing significant crew injuries and damage to the vessel. The crew were rescued and evacuated to local hospitals and *Galwad-Y-Mor* was later towed to Grimsby.

The MAIB investigation found that:

- The ordnance was an air-dropped bomb that had remained intact on the seabed since The Second World War.
- The bomb detonated on the seabed and the shock wave and gas bubble from the explosion hit *Galwad-Y-Mor*.
- The position of most seabed unexploded ordnance is unknown and *Galwad-Y-Mor*'s crew could not have anticipated the fouling of a bomb in the crab potting string.
- *Galwad-Y-Mor*'s crew training, experience, length of service together and emergency preparedness improved their survival chances.
- *Galwad-Y-Mor*'s hull was well constructed and able to withstand the force of the nearby seabed explosion.

Based on this accident's circumstances, no action has been taken by external stakeholders and no recommendations made.

The aim of this report is to highlight the dangers that still exist with unexploded ordnance in the seas around the UK, and the actions to take should fisherman encounter any. In this case, the skipper and crew could not have foreseen the explosion and their level of preparedness to deal with such an emergency saved lives.

SECTION 1 – FACTUAL INFORMATION

1.1 PARTICULARS OF *GALWAD-Y-MOR* AND ACCIDENT

SHIP PARTICULARS	
Vessel's name	*Galwad-Y-Mor*
Flag	United Kingdom
IMO number/fishing numbers	BRD 116
Type	Crab potting vessel
Registered owner	The *Galwad-Y-Mor* Shellfish Company
Manager(s)	Not applicable
Construction	2007
Year of build	Steel
Length overall	14.95m
Registered length	12.90m
Gross tonnage	63.23

VOYAGE PARTICULARS	
Port of departure	Grimsby
Port of arrival	Grimsby
Type of voyage	Commercial
Cargo information	Shellfish
Manning	7

MARINE CASUALTY INFORMATION	
Date and time	15 December 2020 at 1122
Type of marine casualty or accident	Serious Marine Casualty
Location of accident	53°18.59'N 001°15.46'E
Place on board	Hull and all compartments
Injuries/fatalities	Significant injuries to crew members
Damage/environmental impact	Extensive deformation to hull plating, engine room flooded and severe shock damage in all internal compartments
Ship operation	Fishing, recovering pots
External & internal environment	Wind, south-westerly force 3-4, sea state slight/moderate, visibility good
Persons on board	7

1.2 NARRATIVE

At about 2000 on 13 December 2020, the crab potting vessel, *Galwad-Y-Mor* left Grimsby with seven crew on board and spent the following day shooting and recovering strings of crab pots in the North Sea. *Galwad-Y-Mor* made passage overnight to the next crabbing ground; the skipper and five of the crew took rest while the night watchman navigated the vessel.

On the morning of 15 December, *Galwad-Y-Mor* was operating in fishing grounds east of The Wash **(Figure 1)**. The vessel was loaded with approximately 3 tonnes (t) of catch in the seawater-filled vivier tank[1], 7t of bait, and approximately 7000 litres of fuel.

At about 1110, the crew started to haul in a string of 100 crab pots from 30m water depth; the string's main line was about 1.2 miles long. The skipper was seated in the wheelhouse pilot chair, five crew were on the main deck, and the night watchman was in bed in the crew cabin. After approximately 15 crab pots had been hauled on board, the crew signalled to the skipper that there was a lot of tension to the main line. The skipper increased the vessel's engine speed in an attempt to free the potting string from the seabed.

At 1122, there was an explosion external to *Galwad-Y-Mor* and three loud bangs were heard by the crew on the main deck. The vessel was thrown about. Propulsion and electrical power immediately failed. The main deck was deluged with seawater and one crew member's personal flotation device (PFD) automatically inflated. The skipper had hit his head and was dazed; four of the crew were severely injured but all remained conscious. The wheelhouse equipment was seriously damaged, water flooded onto the main deck, and into the engine room, and the vessel settled low in the water **(Figure 2)**. The skipper roused the night watchman and made a distress call with a handheld very high frequency (VHF) radio on channel 16. Unsure that the distress call had been received, he contacted fishing vessel *Ingenuity*'s skipper via mobile phone messaging service and requested that a distress message be relayed to the coastguard. *Galwad-Y-Mor*'s skipper launched the liferaft with the help of a crew member and ordered the crew to prepare to abandon ship.

At 1148, the coastguard tasked a search and rescue helicopter to fly to the accident site. At 1158, a Royal National Lifeboat Institution (RNLI) all-weather lifeboat (ALB), based at Cromer, was also tasked to *Galwad-Y-Mor* by the coastguard.

The captain of wind farm offshore support vessel *Esvagt Njord*, positioned approximately four miles to the south of the accident site, heard the VHF distress call and dispatched his vessel's fast rescue boat (FRB) to help *Galwad-Y-Mor*'s crew. *Galwad-Y-Mor*'s skipper assisted three crew members to board the FRB once it had arrived, and then cut away the potting string from *Galwad-Y-Mor*'s hauler. After hearing reports of the severity of crew injuries, *Esvagt Njord*'s captain then dispatched his vessel's fast transfer boat (FTB) to the accident site. Once it had arrived alongside, *Galwad-Y-Mor*'s skipper and the remaining crew members boarded the FTB and both boats returned to *Esvagt Njord*. By 1159, they were hoisted on board. *Esvagt Njord*'s crew and the team of wind farm contractors on board, which included a paramedic, administered first aid to the injured fishermen.

[1] A vivier tank is used for storing live shellfish.

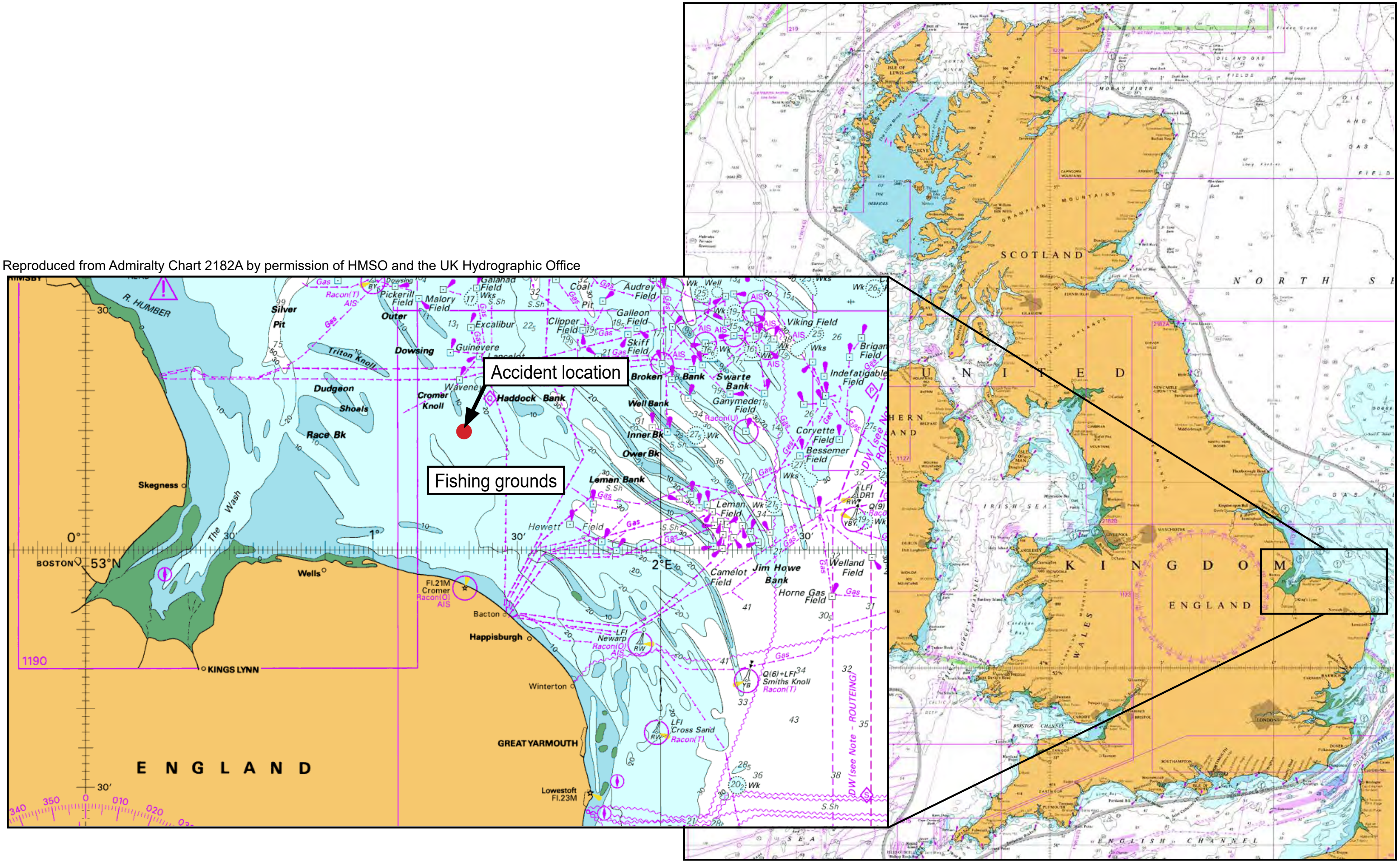


Figure 1: Location of the accident

Image courtesy of Andrew Oliver

Figure 2: *Galwad-Y-Mor* settled low in the water

At 1350, two of *Galwad-Y-Mor*'s crew were airlifted from *Esvagt Njord* by the coastguard helicopter and taken to hospital. At 1430, four crew were taken ashore to Cromer in the ALB and then to hospital by ambulance. At 1550, the last injured crew member was taken to hospital by the coastguard helicopter.

Galwad-Y-Mor's owner arranged for the tug *GPS Avenger* to salvage *Galwad-Y-Mor*. At about 2130, *Galwad-Y-Mor* was taken under tow to Grimsby, and was lifted out of the water into a local ship repair facility the following morning.

On 27 December 2020, *Galwad-Y-Mor*'s owner boarded *Ingenuity* and, on arrival at the accident location, recovered the remainder of the potting string. A distorted metal fragment was found in one of the crab pots; the MAIB sent the fragment and a section of rope from the crab pot string to explosive analysis specialists and metallurgists for forensic examination.

1.3 ENVIRONMENTAL CONDITIONS

At the time of the accident, the wind was southerly force 3 to 4, visibility was good and the sea state was slight to moderate.

1.4 *GALWAD-Y-MOR*

1.4.1 Vessel description

Galwad-Y-Mor **(Figure 3)** was designed by Macduff Ship Design Ltd and built in 2007 by MMS shipyard in Hull. The vessel had a 6mm steel-plated hull, set on frames 450mm apart, and a box keel **(Figure 4)**.

Galwad-Y-Mor had a shelter deck with a wheelhouse and deck crane. The main deck had aft accommodation, including a galley, crew mess and shower. At its forward end was a working area with a hydraulic hauling winch and catch handling table and a store that was also used as a working mess room. There was a ‘tween deck clearance of approximately 2.3m between the main deck and shelter deck. The lower deck consisted of a six berth cabin, separate skipper’s cabin, four fuel tanks and a steering compartment to aft. The engine room was positioned at midships and there was a vivier tank, bait hold and freshwater tank to forward.

The engine room had a 265kW main engine that provided power for propulsion. There was also a 100kW main generator, harbour generator and main electrical switchboard fitted in the engine room.

The wheelhouse was equipped with three VHF radios, one with Digital Selective Calling[2] functionality for sending distress messages and two handheld radios. The navigation equipment consisted of two radars, a chart plotter, an echo sounder and two fishing computers. The wheelhouse floor to deckhead clearance was approximately 2.5m.

Interior linings and wheelhouse equipment were fixed to wood battens bonded to the steel structure.

1.4.2 Crew

Galwad-Y-Mor was crewed by a skipper, night watchman and five deckhands. The crew had worked together for several years and held the mandatory qualifications to work on a fishing vessel of this size.

The crew had undergone safety familiarisation and periodic training on board *Galwad-Y-Mor*. Safety routines, such as man overboard, abandon ship and fire drills were carried out each month in accordance with the requirements of Merchant Shipping Notice (MSN) 1871 Amendment 1 (F) Code of Practice for the Safety of Small Fishing Vessels of less than 15m Length Overall.

At the time of the accident, all crew on the main deck were wearing automatic inflation PFDs and the two crew working around the hauling table were wearing hard hats. The main deck watertight doors to the accommodation and engine room and fish hold hatch cover were all closed. This was standard practice when *Galwad-Y-Mor* was at sea.

[2] Digital Selective Calling (DSC) is a method of quickly sending designated pre-programmed digital messages that automatically include a vessel’s identification and location.

Image courtesy of [Macduff Ship Design]

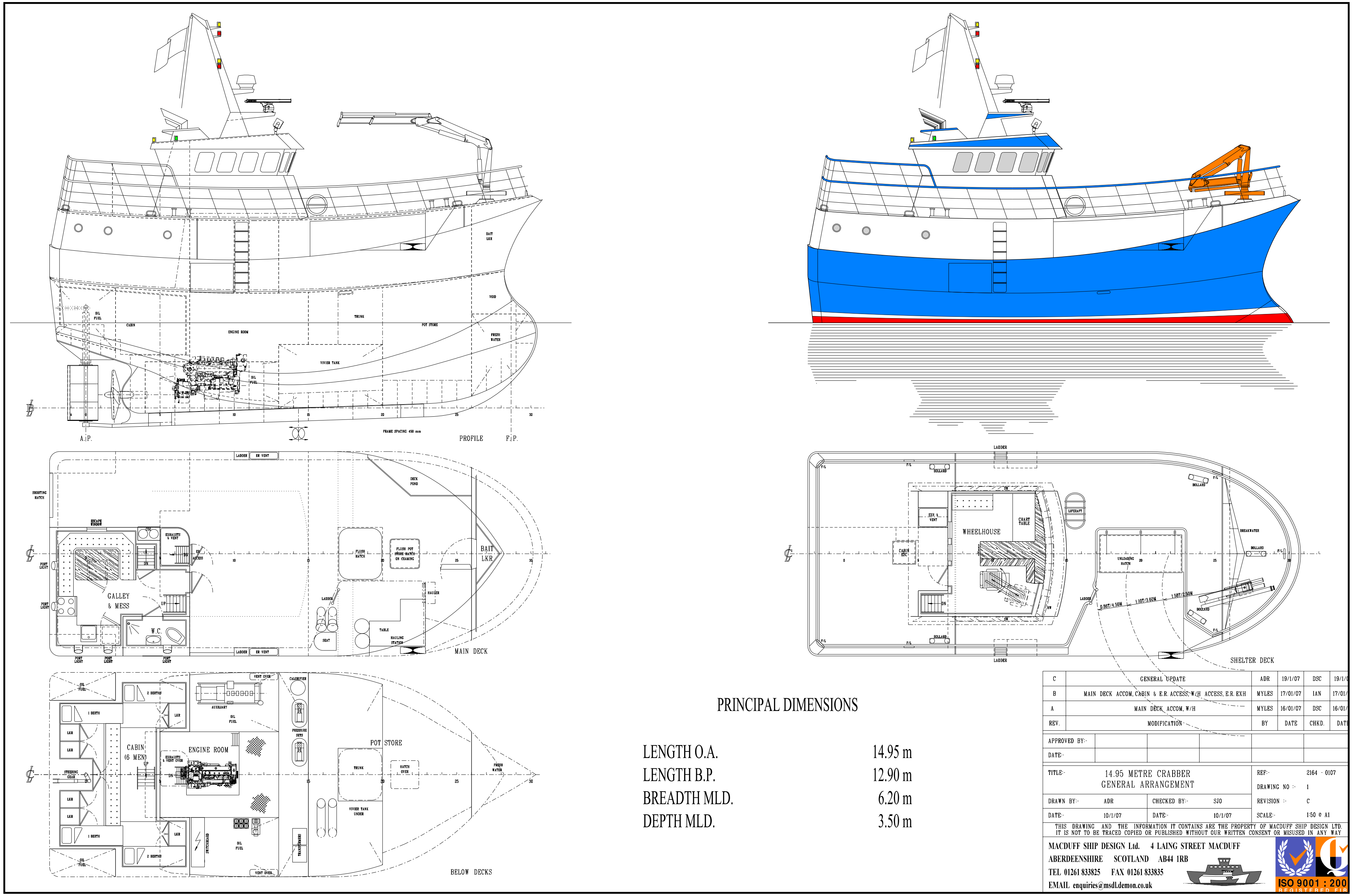


Figure 3: *Galwad-Y-Mor* general arrangement plan

Figure 4: *Galwad-Y-Mor* hull and keel detail

1.4.3 Vessel operation

Galwad-Y-Mor was owned and operated by the *Galwad-Y-Mor* Shellfish Company that also owned *Ingenuity*, a second potting vessel. *Galwad-Y-Mor* typically caught crab and lobster in the North Sea. Both vessels had regularly caught crab in the accident's vicinity and it was common for their pots and lines to catch on objects such as boulders on the seabed.

The skipper navigated *Galwad-Y-Mor* during daytime passages and potting operations. The night watchman usually navigated the vessel to the next crabbing ground overnight.

At the start of potting operations, the skipper manoeuvred the vessel towards a pot string marker buoy while steering by hand. The crew retrieved the marker buoy and used the hydraulic hauling winch, which had a 2t lifting capacity, to heave the string of pots onto the catch handling table. The skipper switched the steering to autopilot and used the throttle to manually control the vessel's speed. Two deckhands worked either side of the catch handling table, emptying each pot in turn and dropping the crabs into the vivier tank. The other three deckhands rebaited the pots and stacked them on the main deck in preparation for the next shoot **(Figure 5)**.

Each string consisted of 60 to 100 crab pots. Each pot weighed approximately 30kg when full; the recovery, rebaiting and shooting of a string of pots took about an hour. *Galwad-Y-Mor*'s skipper recorded the track of each crab pot string in the fishing computer. It was typical to spend 7 days at sea, catch around 14t of crab and use about 1t of bait per day.

1.4.4 Vessel stability

Galwad-Y-Mor's owner was supplied with a stability booklet on the vessel's delivery and *Galwad-Y-Mor* had not been significantly altered since its build. To minimise free surface effect[3] the vessel's load conditions were based on a full vivier tank, which both the owner and skipper were aware of. The vessel's intact stability passed the various MSN 1871 Amendment 1 (F) load condition requirements. Section 3.37 of the MSN required damage stability to be calculated for multihulled fishing vessels, which was not applicable to *Galwad-Y-Mor*.

1.5 CREW INJURIES AND VESSEL DAMAGE

1.5.1 Crew injuries

Five of the seven crew experienced significant injuries in the accident, some of which were life-changing **(Figure 6)**. Most of the injured crew required operations and extended stays in hospital, during which one crew member contracted COVID-19.

1.5.2 Vessel damage

There was significant structural damage to *Galwad-Y-Mor*. Hull plating was pushed in by up to 40mm between frames and the starboard side hull plating was holed. The transverse bulkheads were buckled, and the port side bilge keel was twisted **(Figure 7)**.

[3] Free surface effect occurs when a ship's tank or compartment is partially filled and any rolling motion causes the liquid to move and reduce ship stability.

Image courtesy of [Macduff Ship Design]

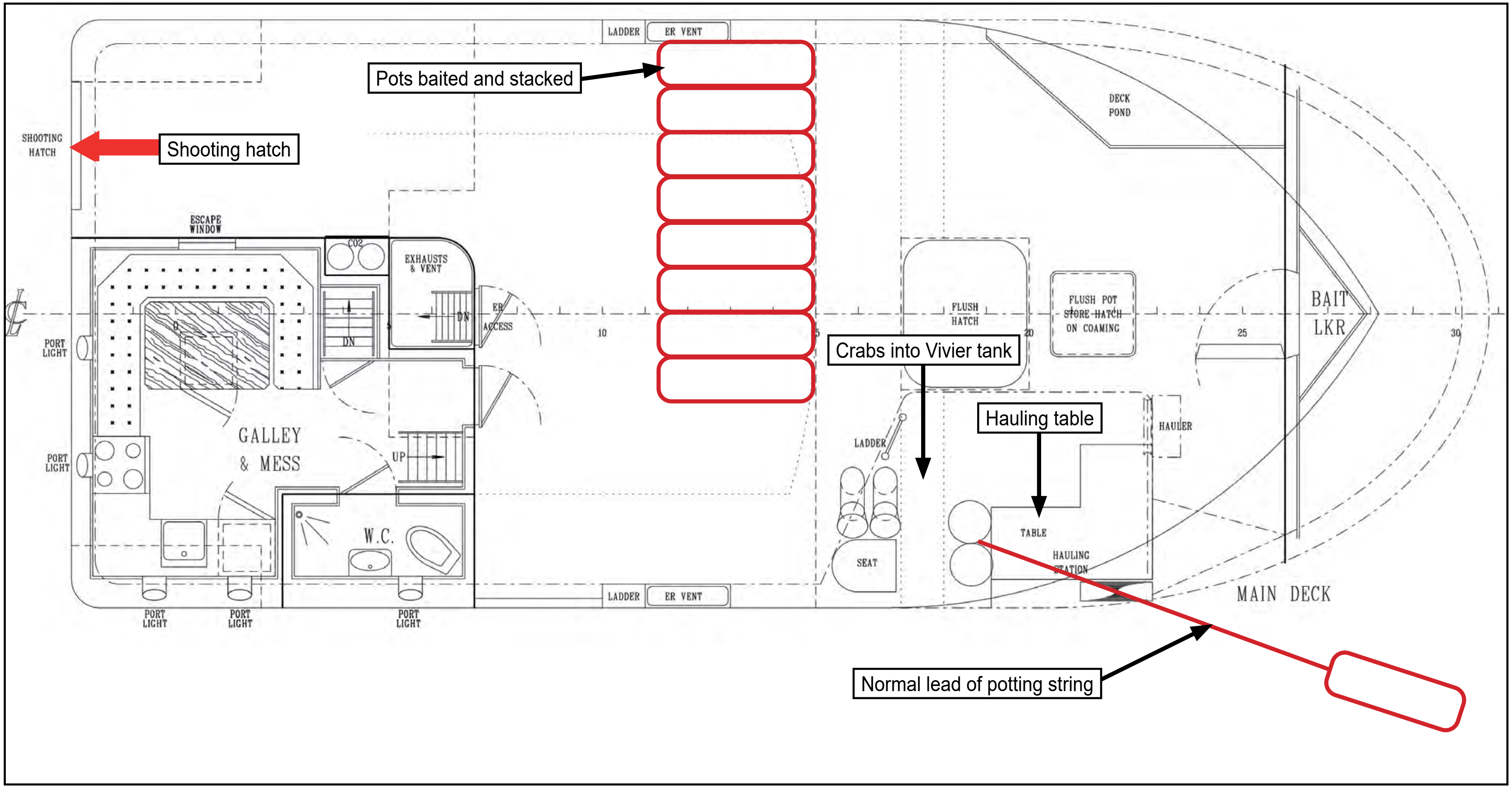


Figure 5: *Galwad-Y-Mor* crab potting arrangement

Image courtesy of Macduff Ship Design

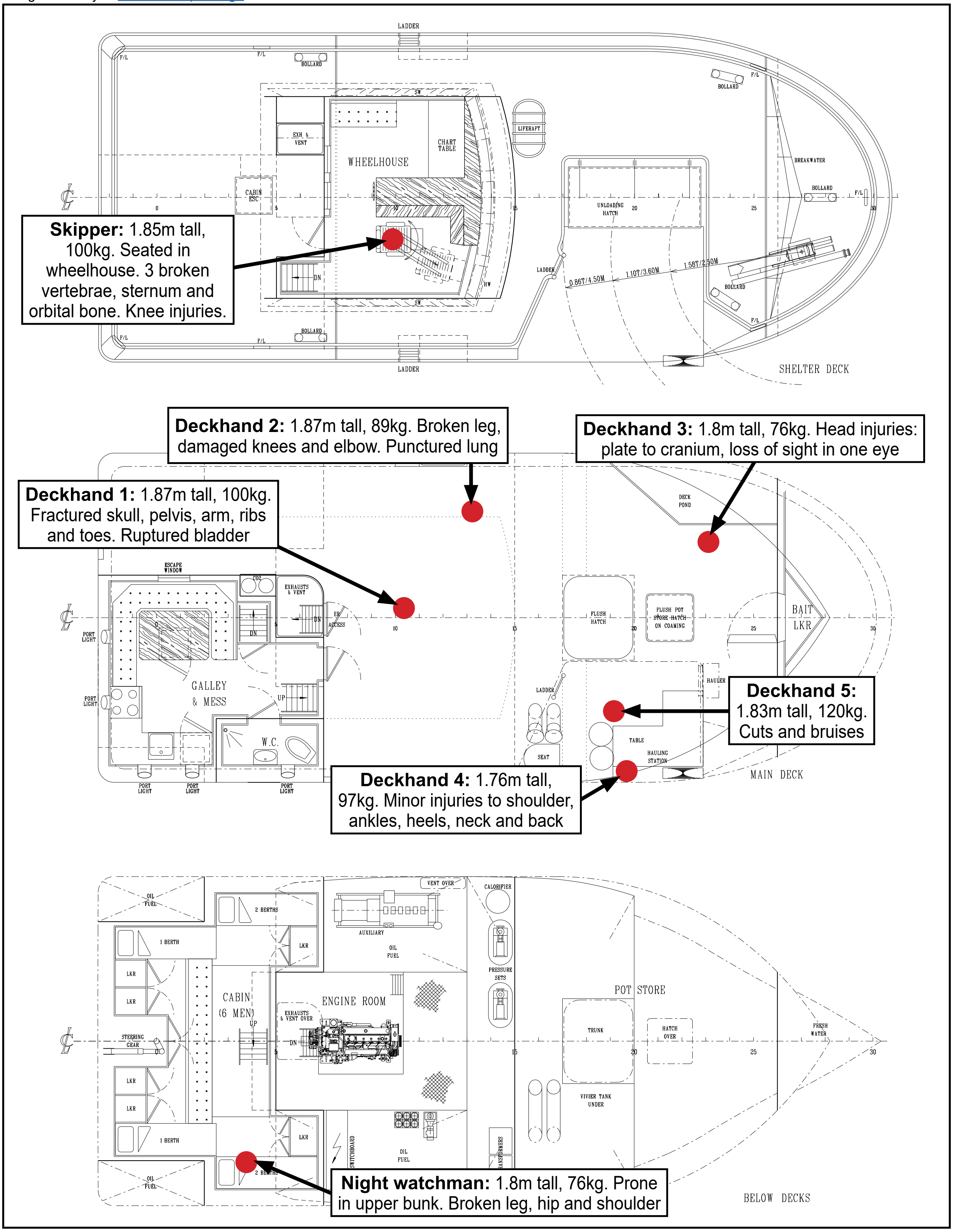


Figure 6: Position of crew and injuries sustained at time of the accident

Figure 7: *Galwad-Y-Mor* structural damage

The main engine, gearbox, generator, switchboard, hydraulic power pack and miscellaneous small pumps sheared from their rigid mountings. The main seawater inlet valve was sheared at its inlet flange and the engine room was flooded to the top of the compartment. The rudder actuator was displaced from the rudder stock **(Figure 8)**.

The wheelhouse equipment and linings were displaced from their mountings. The outfitting of the galley, crew mess, toilet and cabin was significantly damaged **(Figure 9)**. There was a great deal of disruption to external deck areas with numerous instances of scattered equipment, damage to mast-mounted antennae, displaced light fittings, and broken pipe clamps.

1.6 EXAMINATION OF ROPE AND METAL FRAGMENT

1.6.1 Explosive trace examination

The recovered metal fragment and crab pot rope were tested for traces of a range of explosives in line with United Kingdom Accreditation Service (UKAS)[4] standard operating procedures and methods. **Table 1** shows the test results:

Explosive	Quantity of explosive recovered from sample/ ng[5]	
	Metal Fragment	**Rope**
Dinitrotoluene (DNT)	Indicated	0
Picrate	Indicated	0
Research Department Explosive (RDX)	0.2	0
R-salt[6]	<0.05	0
Trinitrotoluene (TNT)	1600	9

Table 1: Results of explosive trace examination

Trinitrotoluene (TNT) was identified on both the metal fragment and the rope. TNT is used widely across the world in many explosive applications and was commonly used in First World War (WWI) and Second World War (WWII) ordnance.

The quantity of TNT detected on the metal fragment was consistent with the item having been in direct contact with the explosive or an item heavily contaminated with it. The quantity of TNT detected on the rope was also consistent with it being in contact with the explosive. The small amounts of some of the other explosives found on the metal fragment were too low to provide the basis for conclusive analysis.

1.6.2 Metallurgical examination of metal fragment

The metal fragment **(Figure 10)** was magnetic and measured 94mm in length, 129mm in width and had a 7.41mm average thickness. Visual inspection showed that the metal fragment had deformed into a curved shape. Rust was visible on

[4] UKAS is the national accreditation body appointed by UK government to assess organisations that provide certification, testing and calibration services.

[5] Nanogram one thousand millionth of a gram.

[6] R-salt is a derivative of Research Department eXplosive.

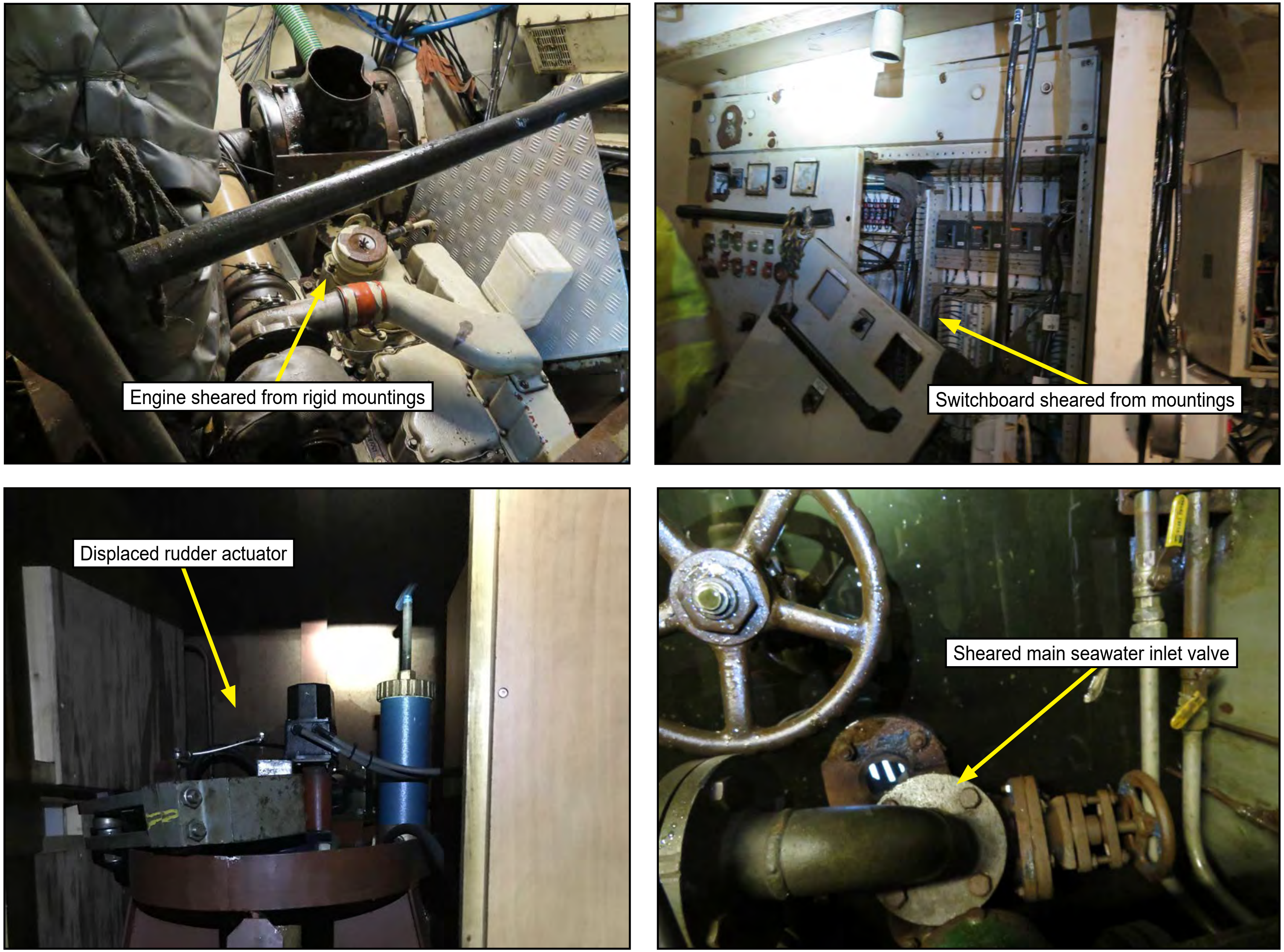


Figure 8: *Galwad-Y-Mor* machinery damage

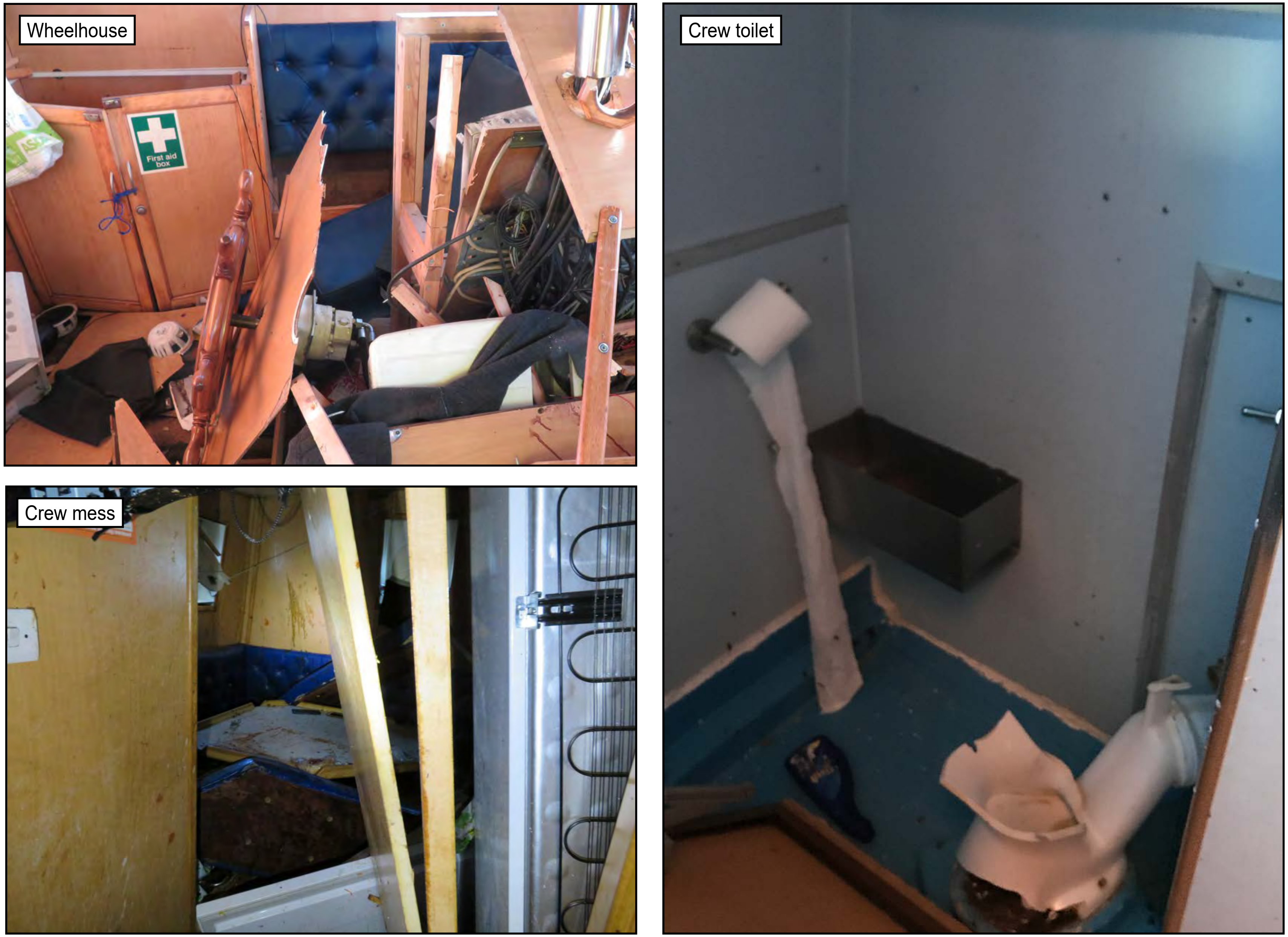


Figure 9: *Galwad-Y-Mor* interior damage

Image courtesy of the 1710 Naval Air Squadron

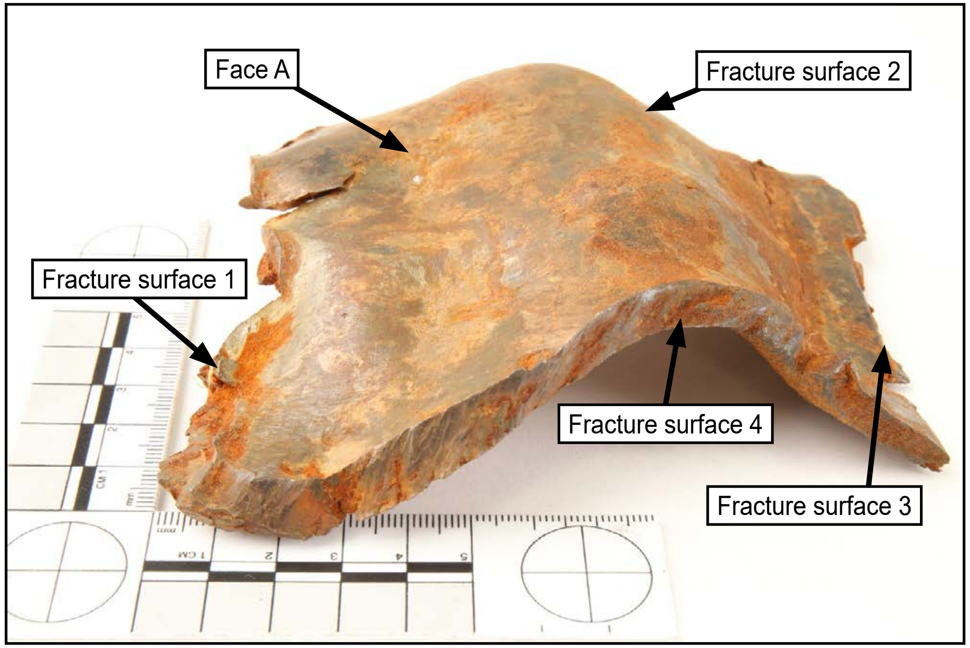
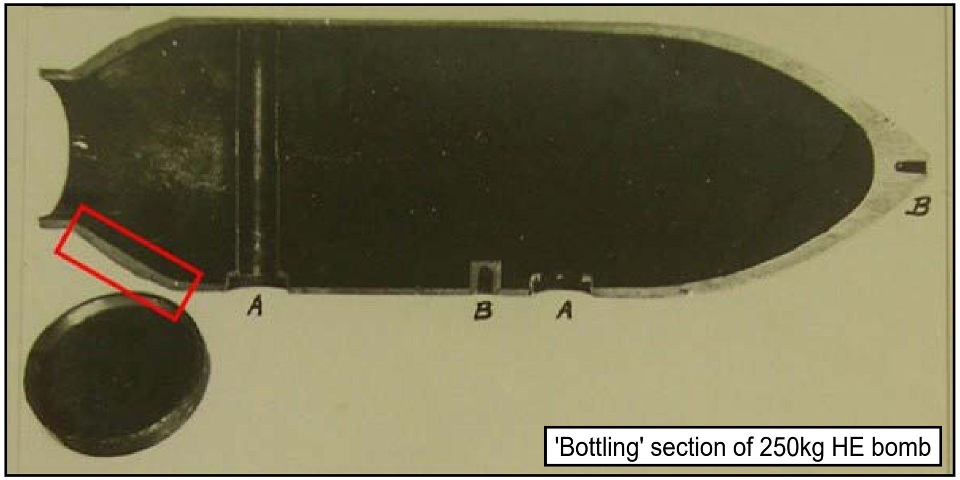


Figure 10: Steel fragment detail

Images courtesy of the Defence Science and Technology Laboratory



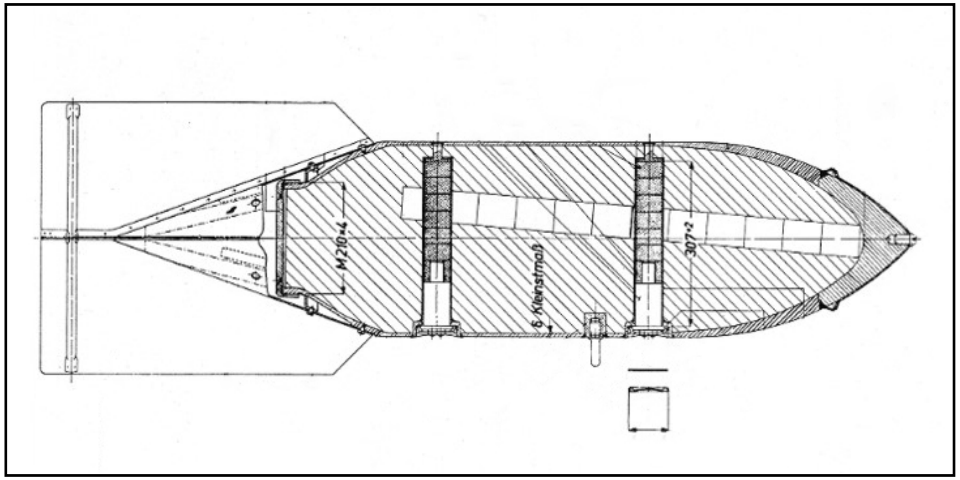


Figure 11: SC250 high explosive bomb

both sides and observed as more progressed along the concave face (Face B), indicative of longer exposure to a corrosive environment or an accelerated reaction to corrosion.

The metal fragment's four fracture surfaces **(Figure 10)** were examined with scanning electron microscopy and showed features consistent with ductile microvoid coalescence (MVC)[7]. These features are indicative of ductile overload, which is the failure mode that occurs when a material is loaded to beyond its ultimate tensile strength. Optical profilometry showed machine tool marks on the metal fragment's convex face (Face A) **(Figure 10)** consistent with a turning tool[8] machining process.

The metal fragment was examined by scanning electron semi-quantitative Energy Dispersive X-ray Analysis[9], which established the metal's elemental composition **(Table 2)**.

Elements found	Weight as a % of the fragment
Silicon	0.5-0.6
Vanadium	0.4-0.5
Phosphorus	Not applicable
Chromium	1.4-1.9
Manganese	0.6-0.8
Carbon	0.42
Sulphur	0.02
Nickel	Not applicable
Iron	96.597.8
Other elements	<0.05

Table 2: Elemental composition of the metal fragment

The metal fragment's composition was consistent with a medium carbon steel that is obsolete and historic in nature.

The metal fragment's properties were compared with that of historic ordnance and it was found that:

1. The material thickness was greater than that commonly used in torpedoes and depth charges.

2. The material thickness was greater than that used in WWI and WWII British and German sea mines. Also, the elemental composition of the fragment was remarkably different from a WWII German mine casing, which tests found was made from iron with 0.5% manganese and no other alloying elements.

3. The material thickness and machining method was comparable with that used on the 'bottling section' of a general purpose (GP) high explosive (HE) air-dropped bomb **(Figure 11)**. The fragment's elemental composition was

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7 MVC is a process where voids form and join in a material resulting in a failure.

8 Machining process used to manufacture round components.

9 This is a widely applied elemental microanalysis method capable of identifying and quantifying all elements in the periodic table except Hydrogen, Helium, and Lithium.

comparable with materials used in German SC[10] 250 GP air-dropped HE bombs, manufactured between 1940 and 1942. SC bombs were the most deployed air-dropped WWII German bomb and weighed 1800kg, 1000kg, 250kg or 50kg respectively. The SC250 bomb was 1173mm long, 385mm in diameter, and contained approximately 123kg of explosive that consisted of TNT and ammonium nitrate.

Historic bombing records indicated that approximately 10% of HE bombs dropped during WWII did not detonate[11].

1.7 ORDNANCE

1.7.1 Unexploded ordnance found at sea

In a paper titled *Low order deflagration for UXO disposal for the commercial sphere*, submitted to a UK parliamentary sub-committee in September 2020, it was estimated that there are approximately 500,000 (100,000t) pieces of unexploded ordnance (UXO) in the seas around the UK. This UXO may originate from German or allied air-dropped bombs jettisoned to sea after aborted bombing missions, German air-dropped bombs used to target allied shipping, depth charges, torpedoes, sea mines. Since WWII, the Royal Navy (RN) also disposed of expired ordnance at sea in approved designated areas.

UXO contains an explosive charge that can produce unstable degradation products over time. If an immersed UXO casing remains intact, the explosive and any degradation products are not washed away by seawater. When UXO is disturbed, the degradation products can detonate and cause a secondary detonation of the main explosive charge. An unstable fuse can also cause intact UXO to detonate if disturbed. At sea, WWI and WWII UXO is highly volatile and explosive ordnance disposal (EOD) specialists tend to dispose of it by controlled explosion rather than attempt to defuse.

1.7.2 Injuries to people on vessels subjected to subsurface exploding ordnance

Injuries sustained due to a subsurface ordnance explosion are categorised as follows:

- **Primary injuries** are blast type injuries caused by proximity to an explosion and include shock wave damage to internal organs such as lungs and intestines.
- **Secondary injuries** are penetrative injuries caused by interaction of the body with fragments from the explosion, such as shrapnel.
- **Tertiary injuries** are blunt force trauma injuries caused by the body being rapidly thrown about by the blast.
- **Quaternary blast injuries** are thermal burn injuries due to exposure to the explosive blast.

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[10] Sprengbombe cylindrish German to English translation: high explosive cylindrical bomb.

[11] The Imperial War Museum: https://www.bbc.com/future/article/20150922-these-nazi-bombs-are-more-dangerous-now-than-ever-before.

1.7.3 Effect to vessels subjected to subsurface exploding ordnance

The damage experienced by a vessel from an underwater explosion is dependent on its proximity to the ordnance at the time of the explosion. In the case of a vessel striking a piece of ordnance such as a contact mine, the ensuing explosion causes direct damage to the hull in the form of a hole, and secondary damage to equipment from fragmentation of the mine casing and the vessel's structure. Damage caused by contact with ordnance usually includes flooding and the sinking of the vessel.

A more distant underwater explosion of a piece of ordnance creates a gas bubble that rises to the surface, collapses, and is filled with seawater moving at high velocity, which creates a water plume jettisoned into the air. If the collapsing gas bubble interacts with a vessel's hull, the energy from the in-rush of seawater can hole the hull or even break it apart.

Ordnance detonated on the seabed creates a shock wave that tends to exert hydraulic pressure to any nearby vessels on the surface, causing them to be thrown about. Damage may include pushing in of hull plating and displacement of equipment. In large explosions, nearby vessels can be thrown upwards out of the water, causing the unsupported hull to hog and then abruptly sag, which can result in a broken keel.

It is common for people to hear more than one bang when a vessel encounters a single underwater explosion. This is due to reverberation of sound caused by the pulse bubble and shock wave.

Blast effect modelling of a seabed ordnance explosion at a 30m water depth showed that the onset of surface vessel damage would require a minimum explosive charge of 121.5kg TNT equivalent[12] and would result in a surface gas bubble of 2.5 to 3.0m in diameter. The Ministry of Defence (MOD) recommend that, to safely avoid damage when clearing UXO, non-military vessels should keep a distance of at least 530m during a controlled underwater explosion of ordnance this size.

1.7.4 Records of at sea unexploded ordnance

The Receiver of Wreck (RoW) is a government body that deals with cases of voluntary salvage wreck material across the UK. The RoW keeps records of reported UXO findings and activities such as EOD clearance in UK waters. In the five years prior to this accident, the RoW listed 49 instances of ordnance found at sea, of which 31 related to UXO found in fishing nets. The rest occurred during dredging, diving, subsea surveying and mine hunting.

The UK Hydrographic Office (UKHO) is the MOD agency responsible for providing hydrographic and marine geospatial data to mariners and maritime organisations across the world. The UKHO held some records of British and German WWII minefields, collated from RN reference books, historic admiralty charts and copies of original German records stored in the RN Historic Branch archive. The UKHO considered the currency of this information to be questionable due to inaccuracy of positional data at the time of mine laying, the effect of the passage of time on submerged mines and the lack of detail of the effectiveness of mine clearance activities. Known seabed ordnance dumps are marked on published admiralty

[12] This is the method of quantifying the energy released in explosions.

charts. Because the location of other seabed UXO such as air-dropped bombs, depth charges and torpedoes are unknown, they are not marked on UKHO charts or other charting systems used by the fishing industry.

Developers of Offshore Renewable Energy Installations (OREI) often consult with commercial organisations that hold digitalised records of WWII minefields when developing plans for new OREI. It is commonplace to carry out extensive seabed UXO surveys prior to installation of windfarms, subsea turbines and subsea power or telecom cables. If UXO is detected, then further surveys may be carried out to determine if they can be left in position, moved, or detonated. A UXO survey report is then submitted to the marine licensing authority responsible for the geographical OREI area, such as The Crown Estate. UXO survey information can be downloaded free of charge from The Crown Estate's Marine Data Exchange website[13].

A pre-installation seabed survey of the Dudgeon Offshore Wind Farm site, which was 1.5nm to the east of the *Galwad-Y-Mor* accident, covered a 90 square nautical mile survey area **(Figure 12)**. It identified numerous potential UXO targets, of which 244 were classed as high risk to the wind farm's installation and operation. EOD specialists cleared several UXO, including German SC bombs, using controlled explosion methods and post detonation fragment collection **(Figure 13)**.

1.7.5 Potential unexploded ordnance near the *Galwad-Y-Mor* accident location

The *Galwad-Y-Mor* accident occurred beneath WWII flight paths used by both allied and German air forces, which jettisoned numerous bombs into the sea.

The location was also close to coastal shipping routes and known British and German historic WWII minefields. Although the minefields were swept by the RN during WWII and in post-war years, whether this activity was completely effective is unknown.

None of the RoW recorded UXO findings were within a 10nm radius of the *Galwad-Y-Mor* accident, and the nearest charted ordnance dump lay more than 100nm to the east.

In February 2021, the RN carried out an exploratory hunting (EH) survey of a 1nm² area centred on a datum at the first reported position of the *Galwad-Y-Mor* accident, which was approximately 3.5nm north-west of the explosion. As a result of the EH survey, the RN concluded that this location was not historically used to dump munitions.

1.7.6 Unexploded ordnance guidance available to mariners

The Maritime and Coastguard Agency's Marine Guidance Note (MGN) 323 (M+F) *Explosives Picked Up At Sea*, provided guidance to owners, masters, skippers and crew of trawlers, fishing vessels, dredgers and other vessels involved in seabed operations. The MGN advised that explosives found at sea can be volatile and should not be landed on deck or tampered with; suspected ordnance should be reported to the coastguard. It also stated that fishing vessels suspecting they have an item of ordnance in their trawls should reduce vessel speed, transit to a safe area, and lower their trawl to the seabed in a depth of less than 30m if possible, while notifying the coastguard of their position.

[13] www.marinedataexchange.co.uk.

Image courtesy of Equinor UK Ltd

Reproduced from Admiralty Chart 2182A by permission of HMSO and the UK Hydrographic Office

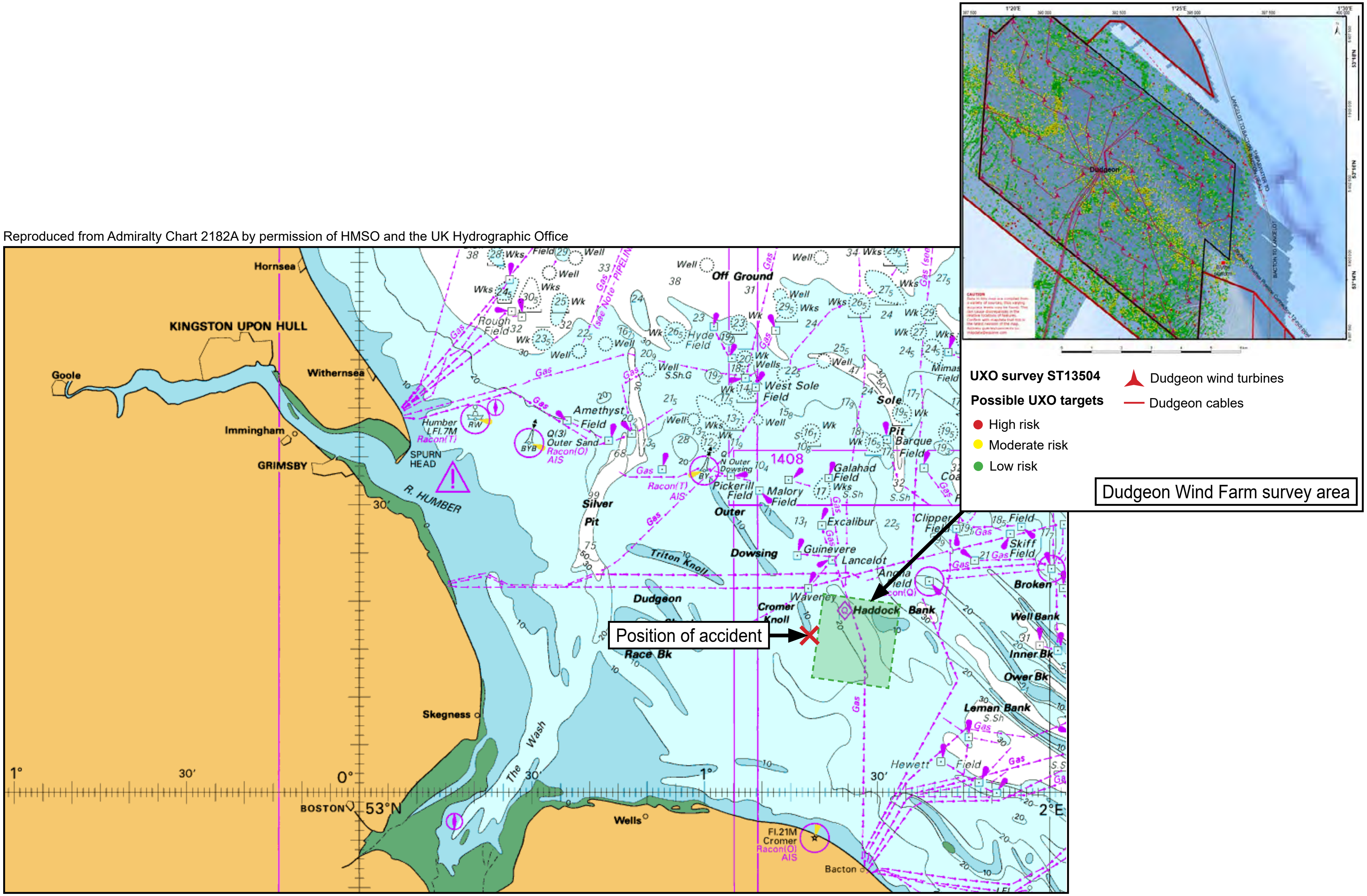

Figure 12: Possible UXO in Dudgeon Wind Farm survey area

Image courtesy of [Equinor UK Ltd]

Figure 13: SC250 high explosive bomb found and detonated in Dudgeon Wind Farm survey area

The Crown Estate's Guidance Note *Dealing with munitions in marine sediments*, provided guidance for dealing with potential UXO recovered from the seabed by vessels dredging for aggregates, undertaking navigational dredging, and discharging cargos. This document detailed procedures for identifying potential UXO and the notification of retained EOD specialists, police or coastguard dependent on the vessel's location.

1.8 PREVIOUS/SIMILAR ACCIDENTS

In December 2020, a Marine Scotland research vessel operating in the Firth of Clyde landed a 350kg explosive charge German WWII mine on board. The crew alerted the coastguard and were evacuated from the vessel by the RNLI. An RN EOD team lowered the mine to the seabed and carried out a controlled explosion.

In February 2017, a dredger recovered what was believed to be a German SC250 bomb in Portsmouth Harbour, England. The bomb was towed out to sea and blown up by an RN EOD team.

In November 2016, fishing vessel *Star of Annan* (OB50) picked up what was thought to be a chemical bomb while dredging for scallops in the Irish Sea. The bomb exploded and caused a small fire on the deck of the fishing vessel and chemical injuries to crew members.

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 THE ACCIDENT

2.2.1 The ordnance

Although the external explosion to *Galwad-Y-Mor* occurred in the vicinity of historic WWII offensive and defensive minefields, the material thickness and elemental composition of the recovered metal fragment shows that it was unlikely it originated from a German or British sea mine.

The elemental composition, thickness, machine tool marks and the exposure to TNT of the recovered metal fragment suggest with a high degree of certainty that it originated from an unexploded WWII German HE SC250 air-dropped bomb. The metal fragment's deformation and ductile overload indicates that it was exposed to an explosive event.

The lack of overall corrosion to the recovered fragment suggests that the bomb was buried below the seabed for several years. The light corrosion to one surface of the metal fragment indicates that the bomb was intact and not flooded, therefore the explosive charge had not been washed away by seawater.

The lack of a major hole to *Galwad-Y-Mor*'s hull indicates that the vessel did not directly contact the bomb. It is likely that direct exposure to the full detonation of ordnance, containing 123kg explosive charge, would have blown the vessel apart. *Galwad-Y-Mor*'s damage was commensurate with the explosive charge detonating below the vessel at a water depth of 30m, therefore it is likely that the bomb fully detonated on the seabed.

2.2.2 The explosion

The string of pots the crew were attempting to recover at the time of the explosion most likely became fouled on an SC250 bomb. It is possible that the bomb was dragged along the seabed and caught on an obstacle, such as a boulder, causing the potting string to tighten on the hauler. As *Galwad-Y-Mor*'s skipper increased vessel power, the disturbance of the bomb caused either an unstable fuse to activate or explosive charge degradation products to detonate and this resulted in the bomb exploding on the seabed.

2.2.3 Crew injuries

Most of the injuries experienced by the crew were of a blunt force trauma nature and did not include penetrating wounds, burns or major internal damage **(Figure 6)**. These were consistent with tertiary injuries most likely caused by the acceleration forces the crew experienced when *Galwad-Y-Mor* was thrown about. The head injuries to deckhands 1 and 3, who were not wearing safety helmets, suggests they struck the deckhead at the time of the accident. The skipper was seated when the bomb exploded and struck his head on the wheelhouse deckhead, which caused injuries to his eye socket and face. His back and knee injuries were probably incurred when he landed back down on the deck.

Although the physical injuries were significant to five of the seven crew, they were fortunate not to be killed. The crew member working on the starboard side of the main deck could have been ejected overboard. Although wearing a working PFD, his survivability might have been threatened by the impeded ability of the injured crew to retrieve him.

2.2.4 Vessel damage

The potting string quickly tightening at the hauler suggested that the bomb was directly below the vessel on the seabed prior to the explosion. The hull plating deformation, buckled bulkheads, and machinery and equipment displacement were commensurate with *Galwad-Y-Mor* interacting with the shock wave created by the explosion. It is likely that the single hole to the hull plating was caused by the plating bending in way of the adjacent structure and fracturing as a result.

It is therefore concluded that *Galwad-Y-Mor* was close to the explosion and well below the MOD's recommended 530m safe stand-off distance for non-military vessels to be unaffected by a seabed explosion of this size. Nevertheless, *Galwad-Y-Mor*'s thick shell plating presented good resistance to the shock wave generated by the explosion, and the heavy section box keel was able to resist bending forces set up by the pulse bubble underneath the vessel.

The main seawater inlet valve was sheared either by the effect of the seawater system being pressured by the shock wave, or by the displacement of the machinery it was connected to. The sheared seawater inlet valve allowed water to enter and flood the engine room. Although the transverse bulkheads had buckled, they remained intact and prevented the seawater transferring to other compartments.

Galwad-Y-Mor's machinery mountings and internal fit out were damaged because they were not designed to withstand the forces created by the action of the vessel being thrown about.

2.2.5 Anticipation of the danger from unexploded ordnance

Both *Galwad-Y-Mor* and *Ingenuity* had fished for crabs in the vicinity of the accident for many years and had not experienced any previous UXO interactions. The seabed positions of air-dropped UXO are unmarked on UKHO charts and are largely unknown, apart from sporadic at-sea findings recorded by the RoW and offshore installation licensing authorities. Consequently, the crew could not have known of the impending danger from the fouling of a bomb and its ensuing explosion.

If the bomb had not exploded and been hauled on board, the information contained within MGN 323 (M+F) would have helped the crew deal with the bomb and notify the appropriate authority.

2.2.6 UXO location information available to fishermen

Apart from known ammunition dumping grounds that are marked on navigation charts, there is little information readily available to fishermen concerning the presence of UXO on the seabed.

No single authority holds data concerning the location of UXO found on the seabed. Information is held by the RoW, the UKHO, The Crown Estate, and commercial owners or installers of offshore infrastructure such as wind farms, pipelines and cables.

It is known that some areas around the UK were subjected to more wartime activity than others. For example, the Strait of Dover, the River Thames and estuary, and the areas around naval ports. While it may be possible to infer from this that there is a greater potential risk of encountering wartime UXO, many of these areas have been fished since 1945 without apparent incident.

Although the requirement to report UXO encounters to the RoW and Coastguard exists within MGN 323, anecdotal evidence suggests that there is significant under-reporting.

2.3 POST-ACCIDENT

2.3.1 Emergency response

The crew's actions after the explosion were both prompt and effective; five of the seven crew were significantly injured and yet they were able to send a distress message, launch a liferaft, and evacuate to *Esvagt Njord*'s rescue boats. It is likely that *Galwad-Y-Mor* crew's formal training, emergency drills, and combined length of onboard service prepared them to deal with this unforeseen emergency scenario and enabled them to take swift action that, undoubtedly, saved lives.

The emergency response and rescue that *Esvagt Njord* provided was also prompt and effective. The onboard triage of the casualties was aided by the presence of a trained paramedic and increased the survivability of *Galwad-Y-Mor*'s injured crew members.

2.3.2 Vessel survivability

Galwad-Y-Mor remained afloat despite having one flooded compartment that caused the vessel to settle low in the water close to its maximum draught of 3.6m at the stern. The flooding of the engine room increased the vessel's draught and reduced the freeboard to such an extent that the main deck was at sea level, which allowed seawater onto the deck. As all main deck watertight doors and hatches were closed, and the transverse main deck bulkheads remained watertight, the seawater was prevented from entering other compartments, and the stability of the vessel was not compromised further.

Despite severe damage and flooding, *Galwad-Y-Mor* had good reserve buoyancy. However, it was fortunate that the weather conditions were favourable, which reduced the risk of the vessel capsizing while under tow to a place of safety.

SECTION 3 – CONCLUSIONS

3.1 OTHER SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT

1. *Galwad-Y-Mor* was severely damaged and its crew injured because a German high explosive bomb, dropped during WWII, exploded on the seabed beneath it. It is highly likely that the bomb was a WWII German HE SC250 air-dropped bomb. [2.2.1]

2. Even after many years of submersion, UXO can be highly volatile, become unstable, and explode unexpectedly. [2.2.1]

3. Galwad-Y Mor's potting gear disturbed the bomb and it subsequently exploded. [2.2.2]

4. The bomb's explosion released a gas bubble and pressure wave that threw *Galwad-Y-Mor* about on the surface, causing significant injuries to crew and damage to the vessel. The effect of the explosion could have resulted in multiple fatalities. [2.2.1, 2.2.3]

5. *Galwad-Y-Mor*'s machinery, on board equipment and internal outfitting were considerably damaged, but its hull was strong enough to withstand the forces generated by a nearby seabed explosion, which went far beyond the hull's design requirement. [2.2.4]

6. There were no records or information available to fishermen that could have alerted *Galwad-Y-Mor*'s skipper to the risk of snagging unexploded ordnance in the area where he had laid his pots. [2.2.6]

7. Although *Galwad-Y-Mor*'s crew could not have anticipated the fouling of a bomb in the potting string, their training, experience, length of service together and emergency preparedness improved their chances of survival. [2.3.1]

8. Although *Galwad-Y-Mor* flooded during the accident, the vessel's reserve buoyancy and calm weather conditions meant the vessel did not capsize. [2.3.2]

SECTION 4 – ACTION TAKEN

4.1 MAIB ACTIONS

The **MAIB** has:

- On 21 December 2020, published a preliminary assessment[14] into the *Galwad-Y-Mor* accident.

SECTION 5 – RECOMMENDATIONS

In view of the actions already taken, no recommendations have been made.

[14] https://www.gov.uk/government/publications/preliminary-assessment-galwad-y-mor/explosion-resulting-in-damage-to-fishing-vessel-galwad-y-mor.

Marine Accident Report

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