Investigation report

Re	Report												
Rep	port title	Activity number											
Re	Report of the investigation into the engine-room fire on <i>Scarabeo</i> 5 401001006												
Se	curity grading												
\checkmark	Public		Restricted		Strictly confidential								
	Not publicly available		Confidential										

PETROLEUMSTILSYNET

Summary

The fire alarm sounded in the port engine room on *Scarabeo 5* at 17.16 on 22 November 2016. This fire occurred as the result of a leak in a diesel oil pipe associated with diesel generator number seven (DG7). The oil ignited on the hot surface of the DG7 exhaust manifold. Fire damage was caused to areas of the engine room and to part of the equipment associated with DG7.

The emergency response organisation on *Scarabeo 5* was activated and personnel mustered. Both Saipem and Statoil established a second-line response on land. It took 14 minutes to obtain a full overview of personnel on board.

Confirmation that the fire had been extinguished came after the Novec extinguishing system was activated at 17.33.

Involved	
Main group	Approved by/date
T-mobile	
	26 April 2017
Members of the investigation team	Investigation leader
Irja Viste-Ollestad, Kristi Wiger,	Irja Viste-Ollestad
Gustav W Dunsæd and Svein Harald Glette	

Contents

1	Sum		3				
2	Introduction						
	2.1	Scarabeo 5					
	2.2	Regula	ations	5			
	2.3	The PS	SA's investigation	6			
3	Cour	urse of events					
4	Potential of the incident						
	4.1	Actual	9				
	4.2	4.2 Potential consequences					
5	Causes						
	5.1	Techn	10				
	5.2	Maintenance system 11					
	5.3 Modifications recommended by the supplier						
6	Syste	em for h	andling emergency preparedness	1	13		
7	Observations			1	16		
		7.1.1	Measures to prevent engine-room fires	16			
		7.1.2	Maintenance management	16			
		7.1.3	System for handling emergency preparedness	17			
		7.1.4	System for training and drills	17			
		7.1.5	Management and system	18			
		7.1.6	System for following up recommendations from suppliers	18			
8	Barriers which have functioned						
	8.1	19					
	8.2 Emergency response barriers						
9	Asse	ssessment of Saipem's investigation report					
10) Uncertainties related to the incident						
11	References						

1 Summary

On 22 November 2016, *Scarabeo 5* was moored on the Njord field but not connected to a well.

The fire alarm sounded in the port engine room on *Scarabeo 5* at 17.16. A leak had occurred in a low-pressure diesel oil pipe associated with diesel generator number seven (DG7). This leak arose in a flange held by two bolts and sealed with an O-ring. As a result, diesel oil came into contact with hot surfaces and a fire started. The assumed ignition point was about 30cm up from the leak point where oil contacted hot surfaces. After the incident, a temperature of more than 300°C was measured at the same location on a similar generator on board.

The emergency response organisation on *Scarabeo 5* was activated and personnel mustered. Immediate action by the engine-room operator limited the consequences of the fire. He quickly shut off the diesel oil supply to DG7 (quick-closing valve). This meant the fire ceased to get further supplies of oil, whereby DG7 also stopped one minute and 13 seconds after the fire was detected. The Novec extinguishing system was activated at 17.33 and the fire put out.

Both Saipem and Statoil established a second-line response onshore. It took 14 minutes to obtain a full overview of personnel on board. Thirty-three non-essential personnel were eventually evacuated by helicopter.

The fire caused damage to the engine, the instrument panel, cables on and over the engine, and ventilation channels and structures in the vicinity of DG7. One person was sent to hospital suffering from smoke inhalation, but could be released the following day.

As a result of the investigation, the following observations have been made.

• Leak in flange on diesel oil piping.

Saipem has not implemented recommended modifications or conducted sufficient preventive maintenance to avoid leaks and vibrations.

- Vibrations and leaks have been registered in the diesel oil system to the generators on *Scarabeo 5*. Similarly, the supplier has warned of incidents which have led to fires with similar machinery elsewhere and recommended modifications to and improvements of the diesel oil system. The investigation has found that Saipem lacks a system for registering and following up these recommendations. Furthermore, few of the recommendations have been implemented.
- Hot surfaces not isolated.
 - Recommendations on isolating hot surfaces have not been implemented.
 - The maintenance system does not incorporate adequate measures to stop fuel-oil leaks and protect hot surfaces in order to prevent fires and explosions.
 Modifications recommended by the supplier, for example, to prevent leaks and isolate hot surfaces were not implemented.
- The investigation found deficiencies in managing the response on the unit.
 - Deficiencies have been identified in company documents governing emergency preparedness, training and exercises.
 - An audit on *Scarabeo 5* in 2013 identified nonconformities related to governing documents and training/drills. Saipem's measures in 2013 have not been fully

implemented as required by sections 17 of the management regulations and 23 of the activities regulations.

- Lack of expertise on the regulations
 - The above-mentioned findings, as well as information and responses in interviews conducted in connection with the investigation, reveal a lack of expertise related to leadership and enterprise management among senior Saipem personnel.

2 Introduction

2.1 Scarabeo 5

Scarabeo 5 is operated by Saipem Norge AS, a wholly owned subsidiary of Saipem Italia ENI. The Bahamas-registered unit received an acknowledgement of compliance (AoC) in 2003 and had its most recent class survey in 2013 at Keppel Verholme in the Netherlands.

A fourth-generation semi-submersible drilling rig, *Scarabeo 5* is built to the Moss Maritime ME 4500DP design. The unit is classed by the ABS with the DP 3 class notation and the ABS ICE CLASS IC notation. It has an eight-point mooring system which can be assisted by thrusters (the rig's own propulsion). As required for DP 3, the unit has two separate engine rooms with a total of eight diesel generators each able to deliver 4800 KVA, 6000 V at 60 Hz.

The unit has largely operated on the Norwegian continental shelf (NCS) since it arrived as a newbuilding from Italy in 1990. Charterers have been Saga Petroleum A/S, Norsk Hydro and later Statoil AS. Its assignments have included drilling in deep water (1 720 metres) on Solsikke and under high pressure and temperature on the Kristin field.

Diesel system

The Wärtsilä Vasa 32 engine is designed to run on both diesel and heavy oil. The V12 engines on *Scarabeo 5* use marine diesel oil (MDO). *Scarabeo 5* has eight identical Vasa 32 engines. These are divided between two engine rooms with their control room between them. The engines are supplied with diesel oil from a 25 000-litre tank. Diesel oil circulates in a ring main and is pumped up to a pressure of 9.5 bar before being distributed to each side of the V engine and on to the fuel pumps for each cylinder. The fracture and leak occurred on the low-pressure (9.5 bar) side of the diesel system.

The diesel oil line where the leak occurred is a pipe with an external diameter of 35mm and 3mm of wall thickness. The leak occurred at the transition between this line to the bridge pipe (see figure 1).



Figure 1. Diesel oil supply on the Vasa 32 engine. Source: Wärtsilä/Saipem. Text in red: Leak point/fracture site.

Quick-closing valves are installed in the space between the two engine rooms to shut off diesel oil supply to the engines. These halt the flow of fuel to all four engines in the port engine room, but it takes some time before the pressure drops and a possible leak stops.

Novec fire extinguishing system

Novec is an environment-friendly solution which replaces halon in gas extinguishing systems. The method is most suitable in spaces where air circulation can be kept at a low level. Novec has been developed to act swiftly, with the heat absorbed fast to extinguish the fire. It contains no carbon dioxide, bromide or chlorine and has no ozone-depletion effects. The system can be used with people present. The Novec system on *Scarabeo 5* was designed to be activated just once.

2.2 Regulations

Saipem has opted to utilise section 3 of the framework regulations with the specifications and limitations which follow from section 1 of the facilities regulations. Section 3 of the framework regulations specifies that mobile facilities registered in a national ships' register, and which follow a maritime operational concept, can use relevant technical requirements in the regulations from the Norwegian Maritime Authority [NMA] for mobile facilities and with supplementary classification rules provided by Det Norske Veritas or international flag state rules with supplementary classification rules providing the same level of safety.

The relevant authority is thereby section 6b of the NMA's regulation no 856 of 4 September 1987 on the construction of mobile offshore units, which specifies the following:

"Machinery, appurtenant systems and components shall be in accordance with the rules of the MOU classification society pertaining to mobile offshore units. This includes:

- machinery, appurtenant systems and single components in general
- main and auxiliary machinery ...
- pumps and piping related to the machinery systems and the hull ..."

In addition, section 4 of NMA regulation no 227 of 31 January 1984 on precautionary measures against fire and explosion on mobile offshore units specifies which risk assessments are to be carried out for spaces and areas with fire and explosion hazards. Engine rooms are regarded as spaces where a risk assessment for fire safety precautions must be conducted. This can be a failure mode and effect analysis (FMEA).

Chapter II-2, regulation 4 of the International Convention for the Safety of Life at Sea (Solas) requires that hot surfaces with a temperature above 220°C and which could be exposed because of leaks in the fuel oil system must be adequately isolated to prevent fire and explosion. Similarly, requirements specify that the necessary precautions must be taken to prevent leaked oil from coming into contact with hot surfaces.

The Solas requirements in chapter II-2 on fire precautions, detection and extinguishing have not been made applicable to mobile drilling units through NMA regulations. However, Wärtsilä – the supplier of the main engines to *Scarabeo 5* – bases its recommendations for fire-prevention measures on Solas.

Through section 3 of the framework regulations, Saipem applies the classification society's requirements for engine systems and measures to prevent engine-room fires.

The classification society's requirements build primarily on Solas. These requirements are specified in the ABS *Rules for building and classing mobile offshore drilling units* – part 5, chapter 3, section 1.15, fire precautions for machinery spaces, and part 4, chapter 2, section 5, fuel oil systems and tanks.

2.3 The PSA's investigation

The Petroleum Safety Authority Norway (PSA) decided on 22 November 2016 to investigate the incident, and appointed an investigation team with the following composition:

- Irja Viste-Ollestad, logistics and emergency preparedness discipline area (investigation leader)
- Kristi Wiger, process integrity discipline area
- Svein Harald Glette, process integrity discipline area (did not participate on board)
- Gustav W Dunsæd, drilling and well discipline area

The investigation team conducted verifications and interviews on *Scarabeo 5* on 24-25 November 2016. It has also subsequently conducted further interviews and meetings with Wärtsilä and Saipem to obtain information.

As part of its verification, the PSA has asked DNV GL to verify the quality of four bolts associated with the leak point because markings on them indicated that some of these bolts differed in terms of quality.

3 Course of events

Diesel generator number seven (DG7) was repaired on 21 November 2016 because of a leak in a lube oil pipe. The generator was restarted after the repair. On 22 November 2016, DG7 was in normal operation at low load together with diesel generator number six (DG6). The other diesel generators in the port engine room were not in operation.

The chief electrician, technical supervisor and motorman were in the port engine room between 16.00-17.16 on 22 November 2016 without noticing anything unusual about DG7.

At 17.16.17,¹ the fire alarm was activated in the port engine room. The engine-room operator was in the engine control room located between the engine rooms. He opened the door to the port engine room, saw flames in front of DG7, shut the door, called the bridge and confirmed the fire. He later explained that the fire appeared as a column of flame in front of DG7.

The control room sounded the general alarm, followed by the order to muster. The engineroom operator and the motorman mustered in the engine control room.

In the control room, the engine-room operator checked available load on the power grid and decided that he needed to start generator number four (DG4), located in the starboard engine room, before he could stop DG7. DG4 was started at 17.17.03.¹

At 17.17.24,¹ DG7 was shut down by the engine-room operator. DG6 shut down when the oil mist detector was activated. The engine-room operator halted the supply of diesel with the aid of a quick-closing valve. This valve was placed in the stairwell up from the engine control room. At 17.17.30,¹ DG7 was stopped. The technical supervisor, located in the emergency control room, was uncertain whether the diesel oil supply was shut off since he knew from experience that this handle was stiff. He therefore contacted the engine-room operator, who confirmed that the quick-closing valve was shut. All air supply to the engine room was also closed. There was smoke in the engine room, and the engine-room operator accordingly fetched a smoke mask.

At 17.21,² the cabinet for the Novec fire extinguishing system was opened. But the system was not activated since the emergency response command was uncertain whether all doors and dampers in the engine room were closed. Personnel were asked to check this manually.

The bridge phoned to ask whether all fans were stopped and all doors closed. That was confirmed by the engine-room operator. The fire team and the on-scene commander were mustered and established by the port pipe deck.

At 17.30,² the emergency control room had a full overview of all personnel on board.

The emergency response command was still uncertain whether all air supply was closed – and therefore had this confirmed one more time before Novec was activated.

At 17.33,² the Novec system was activated and the fire extinguished.

¹ Exact times in the course of events are taken from the automatic log in the engine room.

² Times in the course of events are taken from the emergency response log on *Scarabeo 5* – these are approximate.

At 17.35,² the fire team checked the surrounding area with an infrared camera to determine its temperature.

At 18.12,² the smoke diving team entered the engine room to cool it down and check valves which were meant to have been closed via quick closing. The technical supervisor was uncertain whether the smoke divers had the necessary expertise to check equipment/valves in the engine room, and therefore asked the engine-room operator to put on smoke diving gear and enter the engine room together with the smoke diving team.

From 17.49 to 19.27, the standby ship conducted external cooling of the unit. At 18.49,² the fire team ceased cooling down the engine room.

4 Potential of the incident

4.1 Actual consequences

One person was sent to hospital suffering from smoke inhalation He was released the following day. This person was in the engine control room, where smoke intruded. He carried out consequence-reducing and verification duties.

Scarabeo 5 suffered damage to DG7, ventilation channels, fire insulation, high-voltage cabling and other equipment in the engine room. In the investigation team's view, the consequences of the incident could have been reduced if the Novec extinguishing system was activated earlier.



Figure 2 Photograph of DG7 after the fire. Taken by the police.

4.2 *Potential consequences*

The investigation team takes the view that the incident, under different circumstances, could have led to loss of human life and substantial material damage. Personnel are free to enter the engine room (no access control), and three people had been inside it during the final hour before the incident. The incident's timing is considered a matter of chance, and it could equally have occurred with people nearby. One person was in the engine room shortly before the incident happened. Vaporisation or atomisation of a diesel oil leak can cause an explosive fire, posing great danger to people in the vicinity. The threat of an explosion could also have been increased had the incident occurred when the unit was connected to a well and in contact with hydrocarbons.

If diesel oil supply had not been shut down, the fire would very probably have had greater consequences. The diesel generator stopped running one minute and 13 seconds after the fire alarm was activated.

5 Causes

The direct cause of the accident was that diesel oil came into contact with a hot surface after a bolt had fractured in a flange

The investigation has identified the following underlying causes.

- Weaknesses existed in the original design of the diesel oil pipes with regard both to pipe configuration and to the fact that the flanges only have two bolts.
- Saipem has failed to implement key modifications to avoid leaks and reduce vibration. Vibration and leaks have been recorded over time with the generators on board. Similarly, the supplier has registered incidents on other units/ships, leading to recommendations for modifications to and improvements of the existing system. Few of these recommendations have been implemented on *Scarabeo 5*.
- Failure to isolate hot surfaces. The maintenance system does not include sufficient measures to protect hot surfaces in order to prevent fires. Recommended modifications from the suppliers as well as Solas and class requirements aimed at isolating hot surfaces have not been implemented.

Underlying causes of the incident are described below.

5.1 Technical conditions

The leak occurred in a low-pressure diesel oil pipe supplying DG7. It arose in a flange held with two bolts and sealed with an O-ring. The investigation revealed that the fracturing of one of these bolts caused the leak. According to DNV GL, the most likely cause of the fracture was fatigue. Bolts fracturing after a certain time in use is not unusual.



Figure 3 Diesel oil pipeline with flange and O-ring. Taken by the police.

The original design of the diesel oil piping contains weaknesses with regard to both pipe configuration and the fact that the flanges only have two bolts. Wärtsilä amended the design in the early 1990s by converting to a flange with four bolts. Several thousand Vasa 32 engines have been sold since these came on the market about 40 years ago. Experience with vibration and leaks over time has led to improvements and design changes, in this case on the low-pressure side of the diesel oil system (see Bulletin 3217T044GB from Wärtsilä, dated 17

August 1999). Wärtsilä has improved the design in part through the use of clamping to reduce vibration, and has come up with solutions to protect hot surfaces.

Preventive maintenance is important for avoiding engine-room fires. Regular inspection of piping and flanges, combined with monitoring wear and hot surfaces, is essential to prevent leaks and to avoid them coming in contact with a hot surface.

5.2 Maintenance system

It emerged from interviews on board that leaked oil was often found under the diesel generators. Incidents related to diesel oil leaks were also registered. Printouts from the maintenance system showed a history of repairs to a number of leaks on all the generators over the past two-three years. Information entered after repairs was often insufficiently specific to evaluate these measures with regard to preventing new incidents.

Diesel-generator leaks were not registered in Saipem's system for following up incidents and nonconformities, only in the maintenance system. Saipem's own investigation report shows that this type of equipment had 35 faults between 2004 and 2015.

Before the incident, no routines were established in the maintenance system for inspection or measurements – with thermography, for instance – to identify surfaces with temperatures above 220° C.

Bolts with different properties were used for attaching the pipe where the leak occurred. A possible replacement of the original bolts is not documented in the maintenance system. The design specification states that bolts must be in the 8.8 property class. After the incident, bolts were found to be in property classes 8.8 and 12.9.

5.3 Modifications recommended by the supplier

The diesel generators date from 1989-90, when *Scarabeo 5* was built. Wärtsilä issued a number of bulletins between 1999 to 2015 to inform users of measures and modifications which would make diesel oil supply more robust, both in terms of preventing leaks and of protecting hot surfaces in the event of a leak.

These bulletins, called service letters, spare parts notices or technical bulletins, covered measures related to design changes for diesel oil piping, installation of dampers to reduce vibration, measures to screen hot surfaces and so forth. Wärtsilä sent the recommendations to the shipping companies and operators which owned or operated the Vasa 32 engine type. In *Scarabeo 5*'s case, the bulletins were sent before 2010 by registered post to Saipem's office in Sola. Since then, they have been sent by e-mail to various addresses in Saipem.

The earliest bulletin the PSA has had access to, technical bulletin 3217T044GB dated 17 August 1999, deals with safety and maintenance of the system for diesel oil supply. This 21page document provides a detailed description of recommended modifications to reduce the pressure stroke and vibrations, and to enhance the strength of diesel oil piping (new design) and bolted connections. The diesel oil piping on the Vasa 32 were originally designed with an oval flange connection which had just two bolts (see figure 3). In the early 1990s, this was changed to a flange with four bolts. A recommendation to change to new flanges was also issued in 1990.

A number of the recommendations from the supplier concern protection of hot surfaces. Technical bulletin 3220T067GB dated 17 June 2004 recommends replacing or upgrading the isolation protection (cowling) around the exhaust manifold. Wärtsilä writes in its survey report that some of the engines had the new cowling, but this was not replaced on DG7. Openings in the exhaust manifold cowling were the reason that the diesel oil leak ignited.

In a service letter from 2002, the supplier emphasises the importance of preventive maintenance for avoiding fires. That involved regular inspection of the diesel and lube oil piping, flanges and bolts. As late as January 2015, a bulletin was issued to sum up earlier recommendations aimed at preventing fires in the Vasa 32 engines.

Saipem Norge established a system in 2010 to deal with recommendations from suppliers. This system has now been centralised in the company. After recommendations have been received from suppliers, they are sent to each individual entity without being sorted in terms of their relevance to the mobile unit or entity concerned. This means that individuals receive many irrelevant recommendations, and the possibility that some are thereby overlooked cannot be excluded.

Where the recommendations from Wärtsilä are concerned, Saipem has informed the investigation team that it has not registered either before or after 2010 whether recommendations from the diesel-generator supplier have been received. It is difficult to see that modifications have been made on *Scarabeo 5* as a result of the supplier recommendations.

6 System for handling emergency preparedness

The PSA has identified several weaknesses in Saipem's system for emergency preparedness, including emergency preparedness assessments (EPA), the emergency preparedness manual (EPM), drills and training. Deficiencies in governing documents and training/drills were also identified as a nonconformity by an audit conducted on *Scarabeo 5* in 2013 (PSA ref: 2013/277). Several of these weaknesses, both individually and collectively, indicate an ignorance of regulatory requirements for emergency preparedness, expertise and the health, safety and environmental (HSE) system.

EPA and EPM

The EPA sets no performance requirements which accord with regulatory requirements and are tailored to the technical solutions on board.

Saipem's EPA specifies that doors and hatches designed to prevent the spread of fire must be closed within five minutes and confirmed as closed within 10. This does not accord with the regulatory requirement that fire doors must normally be closed and that the extinguishing system must be activated automatically with a confirmed fire. The investigation team has been informed that dampers in the engine room shut automatically when the ventilation system is closed. There were three doors into the engine room. The team has been informed that these are always closed (hydraulically) and that a work permit is required for the doors to be kept open. The requirements in the EPA therefore do not accord with the actual conditions on board.

Knowledge of the Novec system was not good in Saipem. The advantages and disadvantages of this fire extinguishing solution are not described in the EPA. Saipem has not established performance requirements for activating the system, but specified instead that this will be done on the instructions of the offshore installation manager. In many cases, that could delay action and thereby cause unnecessary escalation.

Measures in the EPA and EPM for dealing with defined situation of hazard and accident (DSHA) number 4 *Fire in engine room and auxiliary machinery room* are not adequately described. That includes no requirements set for, training in or drilling with the regulatory requirement that doors must normally be shut and that the extinguishing system must be activated automatically with a confirmed fire. Nor have requirements been set for, trained on or drilled with activating Novec on the basis of the system's role in preventing escalation.

The team has been informed that ventilation decreases automatically and the alarm sounds when the Novec cabinet is opened. A manual delay of 30 seconds occurs because a valve must be turned to activate the system. The team was told that the philosophy underlying this manual delay is that personnel who may be in the engine room have these 30 seconds to escape after the alarm sounds (Novec cabinet opened) to get out. On 22 November, the Novec cabinet was opened about four-five minutes after the incident. But the emergency response command was uncertain that the engine room was air-tight, and the Novec system was therefore not activated until 10 minutes later. In the team's view, these 10 minutes could have been crucial in other circumstances for preventing escalation of the fire.

Shutting off the diesel oil supply is not described in the preparedness plan for DSHA 4. Knowledge of this barrier is thereby not specified. During the incident, the technical supervisor and engine-room operator took actions which probably reduced the consequences

of the fire. Among other moves, the engine-room operator quickly closed the diesel oil supply to DG7, causing it to shut down and removing the supply of flammable material (diesel oil).

Drills

Saipem's plan for drills in 2016 was not complied with. No documentation could be produced to explain why the plan was not followed. The 2016 plan showed four drills related to the DSHA on *Fire in engine room and auxiliary machinery room*. Only two took place. Lessons from the drills performed are documented to a very limited extent.

From a review of drills conducted from 2014-17, it might appear that a key point has been to stop ventilation within two minutes. Although diesel oil supply is shut off in certain drills, this is not defined as a consequence-reducing measure in the EPA or plan. The other defined measures are sporadically noted in the drill log. Saipem could not demonstrate any follow-up of these performance requirements.

The investigation team has been unable to find a systematic approach to training and drills based on descriptions in the EPA and EPM. One conclusion is that quick closing of diesel oil supply to DG7 had its background in the expertise of individuals on board. The team cannot see that Saipem has a system which ensures that personnel on the unit train and drill systematically to handle DSHAs in an effective manner. It emerged from interviews with people offshore and senior personnel onshore that Saipem regards its drills as training.

A review of drills conducted during 2014-17 in relation to engine-room fires reveals that the aspects verified (performance requirements) in a drill vary, and that results related to performance requirements are registered in a sporadic manner.

The review of drills carried out shows that ventilation is closed between one and three minutes after an alarm, with Novec activated about 15 minutes after an alarm. This fails to meet the regulatory requirements that doors should normally be closed and that the extinguishing system must be activated automatically with a confirmed fire. Drills should aim to comply with the requirement.

Systematic training of response personnel is intended to assure the emergency response command that individuals are able to perform their duties in an emergency. Saipem has no system for training or drills which meet this requirement. Goals for emergency response drills include verifying and confirming for the emergency response command that response personnel can do their jobs. In this incident, the emergency response command on board took time to double-check that all doors to the engine room were closed before activating Novec. Drills carried out have not assured the emergency response command on board that this routine function.

<u>No plan for and follow-up of individual training for emergency response team members</u> The investigation has revealed that no systematic training is provided for emergency response team members on *Scarabeo 5*. Saipem could not point to a system where it plans, describes the content of, or logs training at an individual level. Furthermore, no system exists for possible follow-up of actions or lessons from training which can be communicated between teams/shifts. No plan could be presented on request for training emergency response teams (first-aid, fire, technical, MOB and other teams), either offshore or onshore. An annual plan/matrix entitled *Scarabeo 5 – Emergency Preparedness Training 2017* has subsequently been submitted. This shows a total of 10 planned training activities. The matrix reveals a mix of sling courses, cherry-picker training, sea fastening, lifeboats, MOB boat and so forth, and does not cover the requirement to follow-up individual training for emergency response team members. It appears to be a general training matrix for everyone on board.

Lack of systematic training for emergency response team members could have been a cause of the following during the incident.

- Personnel assigned to smoke diving were not trained to carry out assignments in the engine room (nor were they familiar with the engine room from their daily work). During the incident, the technical supervisor was unsure whether the smoke diving team had the expertise required to check equipment/valves in the engine room. The engine-room operator, who is not a member of the smoke diving team, therefore put on smoke diving gear and entered the engine room to check equipment/valves. This expertise could have been provided by training personnel in the smoke diving team, and verified with drills.
- Routines for closing doors and valves were not incorporated or verified. It took 15 minutes to ensure (check and double-check) that the engine room was airtight before Novec was activated.
- Novec was not activated at an earlier stage. Saipem has not trained on or drilled with activating Novec on the basis of the system's role in preventing escalation.

The investigation team was presented with two different emergency response training plans for the first-aid team. It was not possible to identify which year these plans applied to. Nor did they contain an overview at individual level. It was not possible to verify that these training programmes had been implemented, and who had participated in the training. Documentation for completed emergency response training and for the content of these programmes could not be provided.

7 Observations

The PSA's observations fall generally into two categories.

- Nonconformities: this category embraces observations which the PSA believes to be a breach of the regulations.
- Improvement points: these relate to observations where deficiencies are seen, but insufficient information is available to establish a breach of the regulations.

7.1.1 Measures to prevent engine-room fires

Nonconformity

Adequate technical measures had not been taken to prevent diesel oil leaks and protect hot surfaces in order to hinder engine-room fires. The machinery therefore failed to meet the technical requirements.

Grounds

Reference is made to the following observed conditions. See sections 5.2 and 5.3.

- a) Saipem has failed to meet the requirements related to protection against leaks and ignition on hot surfaces. It could not present a risk assessment of the technical fire conditions in the engine rooms in the form of a FMEA, for example. No nonconformities from the specified requirements were registered internally or by the classification society.
- b) Inadequate identification of barrier elements and associated performance requirements for barriers which are significant for preventing fire and explosion in the engine room. A bow-tie analysis was conducted for the main engines and potential diesel oil leaks. This was not specific on which concrete technical, organisational and operational barriers were included or what performance requirements were set for these.
- c) The supplier has recommended modifications to the pipeline where the leak occurred because of previously reported incidents. These are not implemented on *Scarabeo 5*.

Requirements

Section 4, paragraphs one and two of the management regulations on risk reduction Section 5 of the management regulations on barriers

Section 3 of the framework regulations on the application of maritime regulations in the offshore petroleum activities, see section 6b on machinery systems of the NMA regulations no 856 of 4 September 1987 on the construction of mobile offshore units, see part 5, chapter 3, section 1.15 on fire precautions for machinery spaces and part 4, chapter 2, section 5 on fuel oil systems and tanks of the ABS rules for building and classing mobile offshore drilling units, 2017.

7.1.2 Maintenance management

Nonconformity

Insufficient maintenance and inadequate routines in the maintenance system for preventing leaks of diesel oil and prevent ignition.

Grounds

Reference is made to the following observed conditions. See sections 5.2 and 5.3.

- a) It emerged from interviews on board that leaked oil was often found under the machinery. A number of incidents related to diesel oil leaks were also registered.
 Printouts from the maintenance system showed a history of repairs to many leaks on all the machinery over the past two-three years. Information entered after repairs was often insufficiently specific to evaluate these measures with regard to preventing new incidents.
- b) Inadequate routines for following up hot surfaces. No routines were established in the maintenance system before the incident for inspection or for using thermography, for example, to identify possible hot surfaces (temperatures over 220°C).
- c) Bolts with different properties were used to attach piping. This is not documented in the maintenance system. The design specification referred to bolts in the 8.8 property class. After the incident, bolts were found to be in property classes 8.8 and 12.9.
- d) Saipem's modifications to the diesel generators are characterised by corrective rather than preventive maintenance. They have thereby failed to ensure that leaks, vibrations and hot surfaces are avoided. In some cases, Saipem has waited for damage/faults to occur before making modifications.

Requirements

Section 45 of the activities regulations on maintenance Section 47 of the activities regulations on maintenance programme

7.1.3 System for handling emergency preparedness

Nonconformity

Saipem has not ensured that operational barriers which limit the consequences of fire in the engine room are taken care of. The EPA and emergency preparedness plan have deficiencies which mean they fail to provide the necessary decision basis.

Grounds

Reference is made to the following observed conditions, which are amplified in chapter 6.

- a) Relevant consequence-reducing barriers are not described in the EPA or emergency preparedness plan. Relevant performance requirements for DSHA 4 are not defined.
- b) Action plans contain conflicting performance requirements.
- c) Relevant senior personnel in Saipem had little knowledge of managing emergency response and relevant regulatory requirements.

Requirements

Section 5 of the management regulations on barriers Section 17 of the management regulations on risk analyses and emergency preparedness assessments

Section 76 of the activity regulations on emergency preparedness plans

7.1.4 System for training and drills

Nonconformity

Saipem has not ensured that personnel are capable at all times of handling hazards and accidents in an effective manner.

Grounds

Reference is made to the following observed conditions, which are amplified in chapter 6.

- a) No action has been taken on nonconformities related to training and drills identified by the PSA's audit of emergency preparedness in 2013, PSA ref: 2013/227.
- b) No system for training has been established.
- c) The system for drills has deficiencies related to execution, follow-up and learning.

Requirements

Section 21, paragraph one of the activities regulations on competence Section 23, paragraph one of the activities regulations on training and drills

7.1.5 Management and system

Improvement point

Parts of the Saipem management were ignorant of the relevant regulatory requirements and deficiencies in the company's own system.

Grounds

It emerged from several interviews that Saipem's management was unaware of deficiencies in the system for maintenance, emergency preparedness and follow-up, as described in chapters 5 and 6. Nor was management familiar with relevant regulatory requirements related to these systems. A number of these weaknesses, individually and collectively, reveal an ignorance of regulatory requirements related to maintenance, follow-up, emergency preparedness, competence and the HSE system.

Requirements

Section 21 of the activities regulations on competence

7.1.6 System for following up recommendations from suppliers

Improvement point

Saipem has an inadequate system for dealing with recommendations from suppliers.

Grounds

Saipem Norge established a system in 2010 for following up supplier recommendations. This system is now centralised in the company. It receives recommendations from suppliers, among others, which are sent to each entity without being sorted for relevance. Individuals thereby receive many irrelevant recommendations. This could mean that important information disappears in the crowd and is not followed up. See also chapter 6.1.1

Requirements

Sections 21 and 23 of the management regulations on follow-up and continuous improvement respectively.

8 Barriers which have functioned

Barriers which have functioned are described by the investigation team below.

8.1 Technical safety barriers

Halting DG7 within one minute and 13 seconds by the engine-room operator and swift operation of the quick-closing valve for diesel oil supply were most important consequence-reducing barriers.

Alarms and Novec (when activated) functioned as intended.

8.2 *Emergency response barriers*

Barriers which functioned

Scarabeo 5's emergency preparedness plan describes how the response to an incident should be on the unit in order to limit its consequences. The general alarm with subsequent announcement was sounded soon after the fire broke out. Personnel consequently mustered in safe areas. Furthermore, cooling of the affected area was carried out and the medic dealt with the injured personnel.

The fire team conducted damage limitation in the form of identifying damage and isolating it. This gave the emergency response command on board an overview of and control over actual damage and an overview of possible escalation.

Since the position was unclarified and uncertain, the emergency response command opted to evacuate non-essential personnel by helicopter. Had the incident developed, several resources were available in the area. A FiFi vessel provided the necessary cooling.

9 Assessment of Saipem's investigation report

Saipem and Statoil established a joint team under Saipem's leadership to investigate the incident. Its report was presented on 12 January 2017. This investigation has largely identified the same overall causes as the PSA, but fails to a great extent to identify the underlying factors. The investigation report notes that detailed technical and analytic work has been done by Wärtsilä to understand elements of significance for the incident, but fails to discuss this to any extent. The report thereby provides a limited basis for learning from the incident.

The report from Saipem and Statoil goes into little detail about what happened immediately before and during the incident. The emergency response is described in detail.

The investigation report does not discuss the possible significance of ambiguities related to information exchange (technical and service bulletins from Wärtsilä) or lack of maintenance.

10 Uncertainties related to the incident

The investigation has concentrated on how a leak in DG7 could arise. This means the work has centred on design, specifications and maintenance in relation to DG7. Documentation has been requested as far as possible on these conditions, but not everything has been available or possible to check.

Uncertainties exist over whether and how Saipem has received technical bulletin 3217T044GB dated 17 August 1999 from Wärtsilä. This document provides a detailed description of recommended modifications to reduce the pressure stroke and vibrations, and to enhance the strength of the diesel oil pipes (new design) and bolted connections.

11 References

- Technical bulletin 3217T044GB dated 17 August 1999 from Wärtsilä
- Service bulletin 3200S269 dated 1 January 2015 from Wärtsilä
- *Site survey* Scarabeo 5, *Solas inspection of 8x Vasa 12V32*, Wärtsilä, DocID: DBAE237085, dated 16 December 2016
- *Root Cause Analysis Report* Scarabeo 5, *Fire on DG7*, Wärtsilä, DocID: DBAE246129, dated 12 January 2017
- Scarabeo 5 *Brann i DG7, Skadeanalyse av bolter*, DNV GL, report no 2017-3001, rev 0, document no 113CAC53-4, dated 1 January 2017
- *Event investigation report fire in port side engine room*, report no ER-SCA5-046-16-1, dated 12 January 2017
- Scarabeo 5 *emergency preparedness manual*, Doc no SCA5-MAN-ENG-001E, dated 6 January 2016
- *Emergency preparedness analysis* Scarabeo 5, Doc no SCA5/EPA, dated 11 November 2015
- Registered drills in 2014-17 related to fire in the engine room