PETROLEUMSTILSYNET

Investigation report

Report	
Report title Investigation report following the fatal accident on *Maersk Interceptor*	Activity number 400010004

Security grading		
☑ Public	☐ Restricted	☐ Strictly confidential
☐ Not publicly available	☐ Confidential	

Involved	
Group T-F	Approved by/date
Members of the investigation team Jan Erik Jensen, Roar Høydal, Bjørn Andreas Hanson	Investigation leader Sigmund Andreassen

Maersk Interceptor (source: AoC application)

Contents

1 Summary

A fatal accident occurred at 11.59 on 7 December 2017 during a lifting operation on *Maersk Interceptor*. The facility was working for Aker BP on the Tambar field.

The PSA has investigated the incident, and assisted the South-West Norway police district in conducting its own investigation.

The incident caused one person to fall into the sea and perish. Another was thrown to the deck and suffered serious injuries. Material and financial consequences were also suffered.

In slightly different circumstances, more human lives could have been lost.

The incident occurred during work on replacing a raw water (seawater) pump on the facility. Four people participated in this job.

Failure of the lifting sling was the direct cause of the accident. The reasons why the consequences proved so substantial are more complex.

Work on installing the raw water pump did not go as planned. It was interrupted several times by weather conditions as well as technical and operational factors. This meant that the job extended over several shifts and lasted more days than planned.

When the sling broke, two members of the work team were holding the pump clear of the deck. The two others were in the immediate vicinity.

The power cable attached to the pump lay in a small coil on the deck before continuing up above the work area and into an installation reel on the roof of a ventilation housing.

When the pump fell into the sea, the cable followed it down and hit the two people standing closest. One fell into the sea, the other ended up on the deck with his head over the edge.

The underlying causes of the accident were multiple and complex. They can be related to design weaknesses and inadequacies in following these up, maintenance of lifting equipment, training, failure to identify risk at several levels, and planning and work practice.

2 Background information

Maersk Drilling AS (MD) operates three identical jack-up facilities on the NCS, all built at the Keppel Fels yard in Singapore. It also operates a jack-up facility with a large living quarters, built in Korea. These facilities are based on the same design concept and have the same type of equipment on board. They are:

Maersk Intrepid (MINT) delivered in 2013 - Singapore
Maersk Interceptor (MINC) delivered in 2013 - Singapore
Maersk Integrator (MING) delivered in 2015 - Singapore
Maersk Invincible (MINV) delivered in 2016 - Korea

The first three have identical systems for seawater intake. MINV has a different lifting system for handling the seawater installation.

2.1 Description of facility and organisation

Somewhat simplified, MD's organisation for operations on the NCS comprises two teams – location team Stavanger (MDN) for Norway and the harsh environment asset team (Heat) in Copenhagen and Stavanger for activities with harsh-environment facilities. The latter is responsible for day-to-day operation of facilities on the NCS, while MDN supports these operations in such areas as preparing acknowledgements of compliance (AoCs). The heads of MDN and Heat report to the chief operating officer (COO) in Copenhagen.

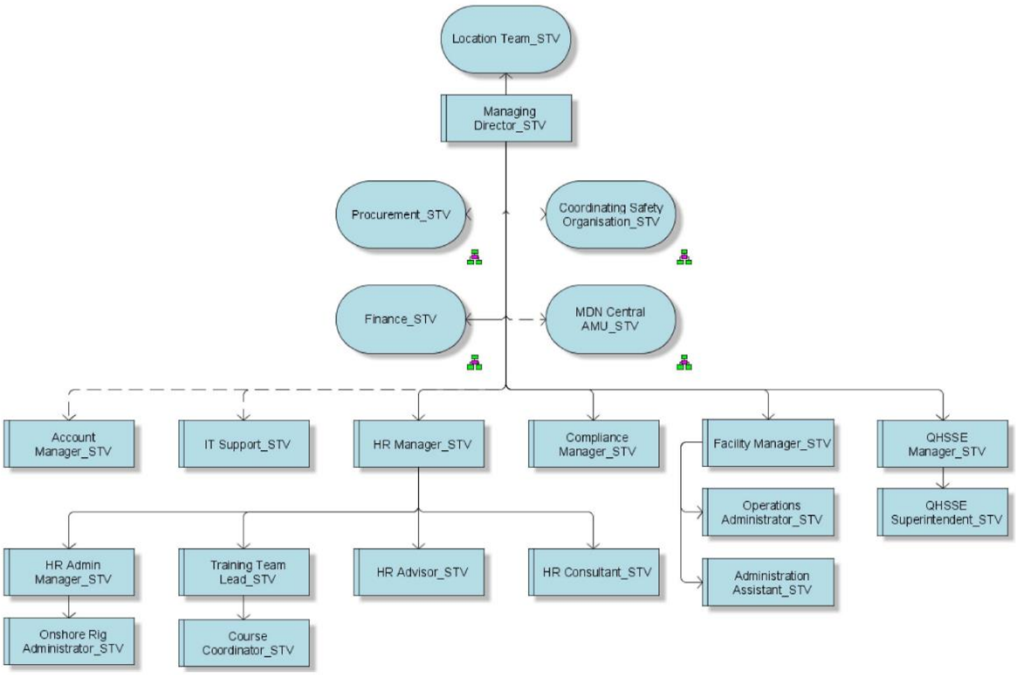

Illustration 1: MDN's organisation structure in Norway.

Each facility has a rig team on land headed by a rig manager who reports to the head of Heat. Teams for the facilities operating on the NCS are located in Norway.

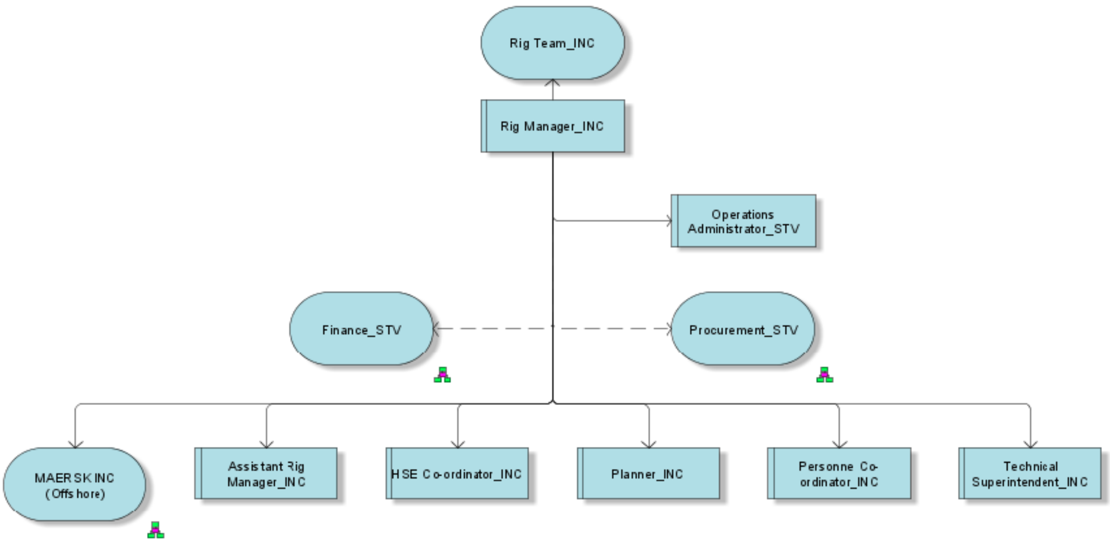

Illustration 2: Organisation structure for MINC's rig team.

The offshore installation manager (OIM) has overall operational and personnel responsibility their facility. The drilling section leader (DSL) is responsible for all activities related to drilling activities, and for deck personnel. The latter also include employees who conduct lifting operations on deck. The technical section leader (TSL) is responsible for technical equipment and maintenance, and for maintenance personnel. The marine section leader (MSL) is responsible for maritime operations and has operational responsibility for crane/lifting operations on deck, but not direct personnel responsibility.

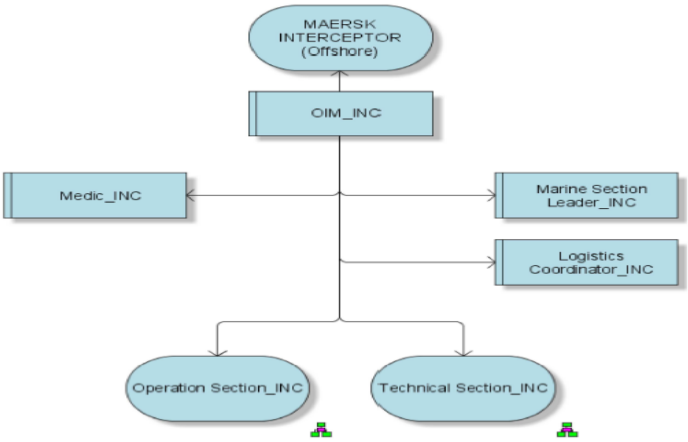

Illustration 3: MINC's offshore organisation structure.

The report will use Maersk as the designation throughout, because Maersk as a company is responsible for HSE.

2.2 Abbreviations and definitions

2.2.1 Abbreviations

AAR	After action review (experience transfer)
AoC	Acknowledgement of compliance
DNV	Det Norske Veritas, now DNV GL
DSL	Drilling section leader
FAT	Factory acceptance test
GA	General alarm
Heat	Harsh environment asset team
HSE	Health, safety and the environment
MD	Maersk Drilling AS
MDN	Maersk Drilling Norge
MINC	*Maersk Interceptor*
MING	*Maersk Integrator*
MINT	*Maersk Intrepid*
MINV	*Maersk Invincible*
MOB	Man overboard
MSL	Marine section leader
NCS	Norwegian continental shelf
NMA	Norwegian Maritime Authority
OJT	On-the-job training
PSA	Petroleum Safety Authority Norway
RR	Revision request
SAR	Search and rescue

SJA	Safe job analysis
TBT	Toolbox talk
TSL	Technical section leader
WLL/SWL	Working load limit/safe working load
WP	Work permit

Definitions and terms

Raw water pump system

The system comprises the raw water pump, pump housing, riser sections, cable reel, power cable and guide cylinders with associated operating panel.

Crane

Machine or equipment which can move loads horizontally in more than one direction, and which also moves the load vertically (from Norsok R-002, section 3.1.8).

Overhead crane

Crane which can move on rails or tracks, has at least one horizontal main beam and is equipped with at least one hoisting mechanism (from NS-EN 15011 – 2011 Cranes. Bridge/overhead and portal cranes, part 3.1 Bridge/overhead crane).

Electrical chain hoist

Electrically powered chain hoist for lifting loads. The hoist must be installed together with a suspension system or in a crane which forms part of the crane (NS-EN 14492-2 – 2006 Cranes. Motor-driven winches and hoists part 2: Motor-driven hoists).

SJA[1]

A systematic and step-by-step review of hazards in a work operation or assignment.

The purpose of an SJA is to identify and reduce risk. It ensures broad participation by everyone with a role in the work – the person responsible for its conduct, executing personnel, the person responsible for measures, the area/operations supervisor and the area technician. If area and operations responsibility is split between two posts, both are responsible.

TBT

A start-up conversation where personnel involved review the work operation or assignment to identify and reduce risk. The function is the same as an SJA, but it is less extensive. The TBT usually takes place at the work site.

WP[2]

A permit intended to ensure that all risks associated with a work activity are taken into account. Prepared before work begins, it will describe the operation and the risk assessments carried out as well as identifying measures required before the operation can begin.

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[1] Norwegian Oil and Gas Association no 090 Recommended guidelines for common model for safe job analysis (SJA).

[2] Norwegian Oil and Gas Association no 088 Recommended guidelines for common model for work permits.

3 The investigation

3.1 Mandate

- Clarify the incident's scope and course of events
- Assess actual and potential consequences
    a. Harm caused to people, material assets and the environment
    b. The incident's potential for harming people, material assets and the environment
- Assess direct and underlying causes, including possible correlations with measures related to reducing costs and enhancing efficiency as well as the level of activity in the company concerned
- Identify nonconformities and improvement points related to the regulations (and internal requirements)
- Discuss and describe possible uncertainties/unclear aspects
- Discuss barriers which have functioned
- Assess the player's own investigation report
- Prepare a report and accompanying letter (possibly with proposals for use of enforcement measures) in accordance with the template
- Recommend – and normally contribute to – further follow-up

3.2 Composition of the investigation team

Sigmund Andreassen	Logistics and emergency preparedness (investigation leader)
Jan Erik Jensen	Logistics and emergency preparedness
Roar Høydal	Working environment
Bjørn Andreas Hanson	HSE management (did not accompany offshore)

3.3 Procedure

- Kick-off meeting at Maersk on 8 December 2017 with a briefing on the incident.
- Interview with personnel involved before going offshore.
- Inspection and interviews offshore. The planned departure was 9 December 2017, but difficult weather conditions made travel out to the facility impossible until 10 December. The team was on the facility until 13 December.
- Interviews on land with personnel involved, operative management and support personnel.
- Document and system review.
- Inspection of the raw water pump in Dusavik together with the police and the investigation team from Maersk and Aker BP.
- Observer status during destructive testing of wire rope slings at DNV GL in Høvik. Testing of slings similar to those used for lifting the raw water pump lift on MINC. Representatives for Maersk and Aker BP were present.

The team also provided technical support for the police during site inspection and witness interviews.

4 Course of events

4.1 Background

MINC is equipped with six raw water pumps, two of which were in use at the time of the incident. The pump to be installed was a replacement for one removed in September 2016. Plans also called for the two remaining pumps in use to be taken ashore for maintenance.

At the time of the incident, the facility was passing through a hectic period with several parallel activities, drilling and well service operations as well as a modification project on the Tambar facility. A maintenance turnaround was also planned, so it was important to complete outstanding work.

Activities in addition to daily operation called for extra personnel. When the raw water pump was to be installed, a scaffolding team from Norsk StillasEntreprenør (NSE) was mobilised along with an additional mechanic (from Maersk) to assemble and install the pump.

The area where the incident occurred was on the main deck at the forward end of the facility, to the rear of leg number 1. See the illustrations below.

Illustration 4: The arrow points to where the raw water pump was to be installed.

4.2 Activities and events before the day of the incident

A summary of work operations conducted before the incident day is provided below.

Monday 4 December 2017
Extra personnel (scaffolders and mechanic) arrive on the facility to prepare for and execute installation of the raw water pump.

A WP to erect scaffolding over the sea and assemble the raw water pump in the pump housing was approved.

Tuesday 5 December 2017
The raw water pump to be installed came from MINV. It had a different type of housing than the one used on MINC, so this was replaced with one suited to the raw water pump system on MINC. The work was to be done by the night shift on deck and be completed by 6 December.

A suspended scaffolding was constructed at the rear edge of the site where the raw water pump would be installed (see illustration 5). This was to ensure access for the mechanic to assemble riser sections for the pump. It emerged from interviews that the job would have been regarded as work over the sea if no scaffolding had been provided. This was the first time MINC used scaffolding (see illustration 5) during installation of a raw water pump system, but the solution had been used on other Maersk facilities.

Illustration 5: The raw water pump was to be lowered between two guide pipes (red arrow) and readied for installing riser sections (yellow arrow).

The overhead crane to be used during the installation was checked by the mechanic to test the end switches for the crane. It was known that this did not always function.

Wednesday 6 December 2017
The scaffolding over the sea was completed, together with a temporary stand for the cable reel on top of the ventilation housing. Similar operations had shown that the reeling apparatus for the cable was weak. It was explained in interviews that this was why the reel was installed in a dedicated reeling stand made from scaffolding material.

The raw water pump and cable reel were lifted from the deck to the roof of the ventilation housing with the offshore crane. Two flat-braided wire rope slings were choked around the pump together with slings for the reel. Three offshore crane pennants were attached to the crane's main hook to manage the actual lift to the ventilation housing roof, where the reel with cable was lifted into a temporary stand for reeling.

Further work consisted of preparations and various lifting operations.

Two flat-braided slings were installed at the upper end of the raw water pump to turn it into a vertical position and transfer the load to the overhead crane. One sling was used for lifting by the offshore crane and the other when the load was transferred to and lifted by the overhead crane. Measuring two metres in length, the slings had a WLL of 4.8 tonnes.

Four lifting pad eyes were welded to the top of the flange for handling the pump. Two were used to attach slings with the aid of shackles positioned diagonally to each other. The crane pennant hook was attached to the centre of the sling loop to form a two-part sling.

The raw water pump was lifted down alongside leg number 1 by using one of the two flat-braided slings. Since the pump was lifted into place close to the leg, the safety system for zone operations had to be disconnected. This was also a blind lift for the crane operator.

When the pump had been lowered to and offloaded on the deck, the second of the two flat-braided slings was hooked onto the overhead crane and the offshore crane could be freed up. Since the capacity of one sling should have been adequate, the mechanic thought two were unnecessary. The sling used to lower the pump to the deck was therefore left hanging loose. The mechanic had to fetch anti-fall equipment to do this job.

Just as the pump was to be lifted into place, the mechanic discovered that insufficient space was available to lower it. Work therefore had to be discontinued while the scaffolding was modified. The pump was accordingly lowered onto a wooden pallet to ensure its stability, while it was secured in the overhead crane. Scaffolding modification was postponed to the following day because light and weather conditions were inadequate.

A crew change would normally have taken place on this day, but weather conditions meant the helicopter was four hours late. Since both the TSL and the MSL were to be replaced, the OIM did not release the WP until the following day.

4.3 Thursday 7 December 2017 – day of the incident

The scaffolding was modified in the morning.

Preparations

At 10.30, the mechanic asked the crane operator to recruit two roustabouts to help install the pump. The operator appealed over the walkie-talkie for volunteers. One roustabout (the fatality) came forward immediately and got another to go with him.

A TBT was held at 10.35 with those involved (in a break room – coffee bar) while they waited for the WP and the work procedures. The assistant crane operator was also present. The mechanic would then fetch the approved WP and get it signed by the area technician before the actual work could begin.

During the TBT, it was decided that the two mechanics would handle the pump. The two roustabouts would manage the power cable from the ventilation housing. Both mechanics had experience from and familiarity with this type of job.

The team was familiar with the (general) risk of dropped objects, and included this in the TBT. The risk of crushing during handling was also included, but the team did not regard this as a lifting operation and therefore did not assess the various hazards of such work.

10.45 – the OIM released the WP.
11.30 – the crane operator signed the WP as area technician.
11.45 – the WP was activated and work could begin.
11.59 – the incident occurred.

The actual work operation
Work began with the two mechanics (hereafter called the mechanic and the supervisor) down by the pump, while the two roustabouts (hereafter roustabout A and B) were atop the ventilation housing. After the roustabouts had paid out enough power cable and secured this, they were asked to descend to where the pump was to be installed. The power cable now lay in a small coil at the rear edge of the installation area and then ran up to the reel on the roof of the ventilation housing, about 15 metres above the installation area.

Since lifting the pump into place was designed in a way which led to offset traction, the mechanic had to push the unit off the side of the deck and conduct it between the guide pipes while the supervisor operated the overhead crane.

The power cable can be damaged by movement, so it was fastened with strips to the pump. When the latter was lowered, one or more of these strips were pulled off. It was then decided to lift the pump up again and attach new strips to keep the cable in place.

The pump was too heavy for the mechanic to keep clear of the deck on his own, so he was assisted by roustabout A. The pump was still too heavy, and the supervisor handed the remote control for the overhead crane to roustabout A so he could help keep the pump off the deck.

When the pump had been raised and was considered to be high enough to attach new strips, the mechanic went to fetch more of them. At the same moment, the supervisor saw that the pump had become snagged along the deck side and shouted “stop!” several times. The pump was then about 1.2 metres above deck level, and is assumed to have snagged on a plate butt sticking out a couple of centimetres. Roustabout B halted the lift, and at the same moment the sling attaching the pump to the crane broke. The pump and 150 metres of cable plunged into the sea.

The consequence was that roustabout A fell into the sea, while the supervisor remained lying badly injured on the deck.

It is not clear why roustabout A went overboard. The most likely explanation is that he was hit by the cable. The supervisor *was* hit by the cable and ended up lying on the deck with his head over its edge. He says he could hear the cable running out and tried to reach a safe place.

The mechanic, who was standing to the left of the pump, had moved a little on his way to fetch new strips. The overhead crane operator (roustabout B) stood to the right behind the water riser to pump 2 and did not directly observe the pump falling, but saw the person lying on the deck and ran to help. Roustabout B and the injured person took cover under a stairway at the rear of the accident site.

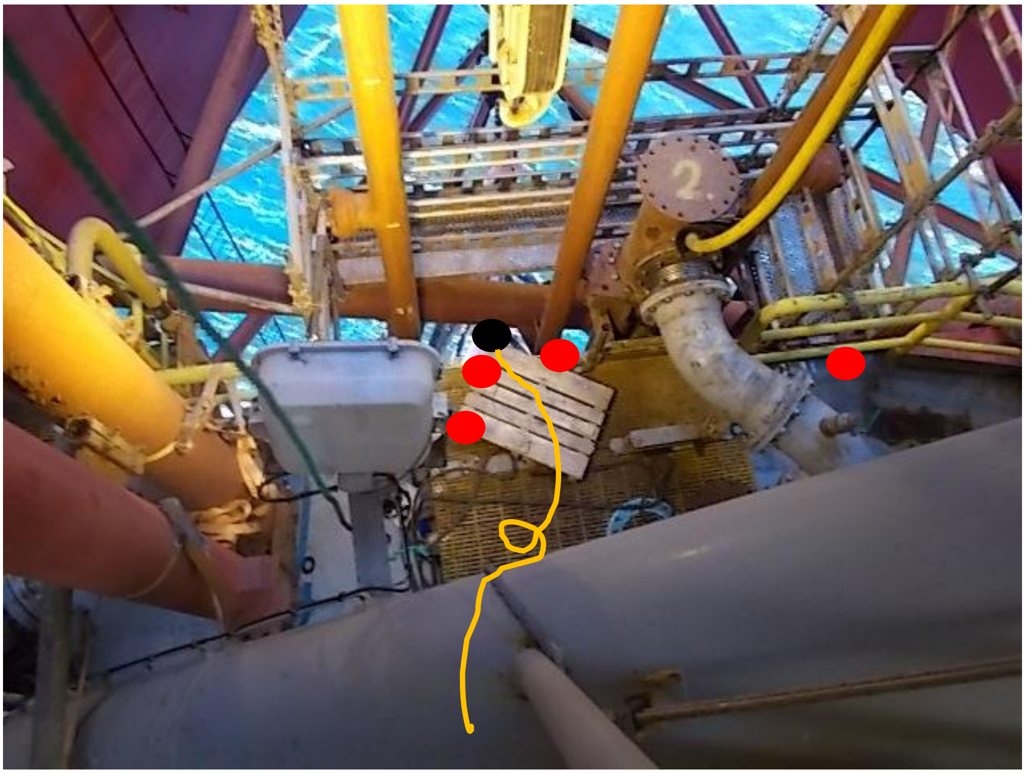

Illustration 6: Where the team believes personnel involved in the operation were standing (red dots) when the sling broke and the raw water pump (black dot) with cable (yellow line) plunged into the sea.

The temporary cable stand was not fastened, but stood atop the ventilation housing and was held in place by the weight of reel and cable. The stand fell over during the incident and was turned through 180 degrees. Scaffolding components fell to the main deck.

Illustration 7: The photograph on the left shows where the cable reel was positioned for reeling out while the raw water pump was being positioned. The photograph on the right shows the overturned scaffolding.

Personnel in the living quarters heard that something had happened and went to the windows facing the accident site. A GA was immediately activated.

4.4 Emergency response

The emergency preparedness organisation for MINC's activities on Tambar is specified in the bridging document /2/.

First-line response
Noise and unusual shaking of the facility when the raw water pump and its associated cable plunged into the sea meant that a number of people in the office modules of the living quarters witnessed the event. It was immediately realised that an undesirable incident had occurred, and the control room was informed. The latter activated a GA over the PA system and reported an MOB. Everyone mustered in accordance with the alarm instructions.

At the incident site, one of the uninjured in the work team kept an eye on the person who had fallen overboard, and had visual contract with him until he drifted out of sight inside the leg framework. An observation post was then established by the railings on the main deck and maintained until the person in the sea was recovered by the MOB boat from standby ship *Esvagt Cornelia*, which was close to MINC when the incident occurred.

The MOB boat was launched three minutes after the GA. The first officer on *Esvagt Cornelia* asked the MINC crane operator to keep an eye on the person in the sea. The rough conditions, with significant wave heights around five metres and a fresh gale blowing, meant the MOB boat depended on directions from the observation post.

The MOB boat picked up the person six minutes after the alarm was given. The victim was taken to the ship's sick bay, where cardiopulmonary resuscitation was given until he was flown by SAR helicopter to Haukeland Hospital in Bergen.

After getting to the living quarters under his own steam, the injured person on MINC was taken to the sick bay for treatment by the nurse and first-aid team before being flown by SAR helicopter to Stavanger University Hospital for further treatment.

Notification was given in accordance with applicable action plans. The injury site was cordoned off and secured in the usual way.

Second- and third-line response
Aker BP and Maersk established second-line response organisations after the incident. A crisis reception for those most closely affected by the incident was established on land.

The team has not assessed work by and organisation of operator and rig-owner follow-up in the second- and third-line response on land, because that falls outside its mandate.

5 Description of equipment in use

5.1 Flat-braided wire rope slings

Flat-braided slings are braided from several individual steel wire ropes – in this case, 10 ropes laid together in pairs and braided to a broad strap which gives a good grip against steel. The flat-braided sling used for this operation had a WLL of 4.8 tonnes and was two metres long.

Wire rope specification
Part no 01.G10133060G Type 7x19 six mm diameter, rupture strength 2 381 kg.

Flat Braided Slings

Material: Manufactured of preformed aircraft cable in construction 7x7 or 7x19. Lengths as requested.
Finish: Galvanized.
200 kg/mm^2.
Standard: Taluritspliced. Soft eyes.
Safety factor: 5:1.

Illustration 8: Flat- braided wire rope sling.

Table 1 below shows how the manufacturer rates the lifting capacity for the flat-braided wire rope sling in different lift configurations

Load diagram

	1-Part	U-lift	Laced	Basket	
Angle of inclination				0° - 45°	45° - 60°
Load factor	1	2	0,8	1,4	
10.74FWS0950X	0,95 t	1,9 t	0,76 t	1,33 t	0,95 t
10.74FWS1600X	1,6 t	3,2 t	1,28 t	2,24t	1,6 t
10.74FWS2500X	2,8 t	5,6 t	2,24 t	3,92 t	2,8 t
10.74FWS3500X	3,8 t	7,6 t	3,04 t	5,32 t	3,8 t
10.74FWS4800X	4,8 t	9,6 t	3,84 t	6,72 t	4,8 t
10.74FWS5800X	5,8 t	11,6 t	4,64 t	8,12 t	5,80 t
10.74FWS8000X	8,0 t	16 t	6,4 t	11,2 t	8 t
10.74FWS11000X	11 t	22 t	8,8 t	15,4 t	11 t

Table 1: Manufacturer’s lifting diagram for flat-braided wire rope slings, showing safety factors in different lift configurations.

5.2 Overhead crane

The overhead crane used on MINC for installing and removing raw water pumps with riser sections was assembled at the yard in Singapore from components delivered by several suppliers. These are described below.

The electrically powered chain hoist with trolley and control system was manufactured by ASME A/S in Denmark. The hoist had an SWL of 18 tonnes.

Illustration 9: Assembly of electrical chain hoist and trolley without crane rail.

Crane rail
The crane rail comprised a beam attached to two cylinders for sideways adjustment. It[3] had a design SWL of 18 tonnes.

Illustration 10: Attachment of the crane rail with adjustment cylinders.

5.3 Lifting yoke

The yoke to lift riser sections for raw water pumps was manufactured by MAK Engineering Pte Ltd in Singapore.

[3] H340-01.

Illustration 11: Lifting yoke to lift riser sections for raw water pumps.

5.4 Crane pennant

The crane pennant was manufactured in a 22-mm rotation-resistant steel rope. Its WLL is eight tonnes in a vertical lift. It was manufactured by Henrik Veder Group in accordance with Norsok R-002 in March 2017. Certificate number: 63155.1.

5.5 Raw water pump system

5.5.1 Description of the raw water pump

The raw water pump was manufactured by Flowserve Hamburg GmbH.

MINC is designed with six raw water pumps, two in each leg. They supply the facility with seawater for such purposes as fire-fighting and cooling engines.

5.5.2 Suspension system for raw water pumps

To assist installation/removal of riser and pumps, two beams could be moved back and forth hydraulically. The pump with riser could be set down on these to relieve the load.

Illustration 12: Operation panel and control valves to operate the relieving system for the raw water pump.

5.5.3 Power cable for the raw water pump

The power cable accompanying the pump came from Prysmian Kabel und Systeme GmbH.

Diameter 58 mm, weight 6.25 kilograms per metre, length 150 metres.

6 Consequences and potential of the incident

Actual consequences
The actual consequences include loss of human life, injury, and loss of material and financial assets.

The work team responsible for the operation comprised four people. One died and another was badly injured. The three survivors were strongly affected. Personnel on board were affected to varying degrees.

Maersk decided to replace the whole crew as quickly as possible. Everyone had been replaced by the Wednesday after the accident.

Other consequences were:

- Maersk halted all activities with MINC for six days in consultation with Aker BP
- minor material damage on MINC (structure)
- production from Tambar was halted for six days
- costs were incurred for retrieval, transport and loss of the raw water pump.

Potential consequences
Four people were in the immediate vicinity when the pump plunged into the sea and the cable paid out. In slightly different circumstances, more lives could have been lost.

7 Direct and underlying causes

Events immediately before, during and immediately after the incident have been clarified with little uncertainty. But complexity – and thereby uncertainty about cause and effect – rise when moving back along the causal chain. However, the investigation has shown that the accident resulted from a number of causes which occurred at different times and in various parts of the Maersk system.

Identified causes show in part that:

- installation and removal of the raw water pump system was a risky and demanding operation, and this was knowable
- decisions and actions, or lack of actions, at several levels meant that the risk was not identified, communicated and managed.

7.1 Direct cause

Several strips came off when lowering the pump into place. The team decided it had to lift the pump back up to re-attach the cable. As the pump was lifted, it snagged on a point, the wire rope sling broke, and pump and cable plunged into the sea.

The direct cause of the accident was that the wire rope sling became overloaded.

The flat-braided sling used has a WLL of 4.8 tonnes. A safety factor of five is specified when lifting. Doubling the sling over the hook and down both sides, as in the operation here, can increase the lifting capacity. The overhead crane's SWL is rated as 18 tonnes. In other words, the sling should have coped with the crane's maximum lifting capacity.

Flat-braided wire rope slings must be deployed so that the load is evenly distributed on all the steel cables making up the sling. This type of sling is known for having a good grip on the object to be lifted, and will not normally move over the hook and balance the load on both legs. Users must also ensure that the sling is undamaged and in good condition, and that the individual steel cables lie with their flat side against the hook used.

Investigations of the overhead-crane hook revealed differences between the wear points on its sides. This suggests that the sling used did not engage as intended with the hook so that the load became unbalanced. The slings attached to the pump showed signs of damage and incorrect use. That was revealed by the inspection in Dusavik.

The lifting operation on MINC was simulated and tested by DNV GL under conditions which corresponded to those on board: a V configuration, lifting at an angle to the vertical plane, a limited radius on the hook combined with uneven loading on the sling. These tests shown that the sling could break under a load as low as about 18.8 tonnes – a safety factor of two.

Furthermore, the tests showed that the safety factor for this type of flat-braided sling is lower than that specified by the manufacturer, even under optimum conditions.

7.2 Underlying causes

These causes were multiple and complex, and can be related to maintenance of lifting equipment, training, design weaknesses and follow-up of these, and failure to identify risk at several levels, as well as planning and work practice.

7.2.1 Technical equipment - design

The design of the crane system used to lift the raw water pump into place had weaknesses. It had offset traction. This meant that manual force had to be used to push the pump clear of the deck and into the start position for assembling the water riser. Personnel thereby had to be in the lifting zone, exposed to a high level of risk were the lift to fail.

To compensate for the offset traction, a special lifting yoke had been made for the water riser. Executing personnel maintained that this was unsuitable for lifting/lowering the actual pump since its bottom section would be pressed in towards the deck because of the low centre of gravity. That also increased the threat of the pump becoming snagged.

The pump was delivered with a power cable solution which meant that this heavy cable had to be attached to the pump during installation. This complicated the lifting operation and increased the risk. When the pump was lifted to the start position for installing the water riser, the cable ran between two people. When the lift failed, the pump plunged into the sea. The heavy cable was dragged with it, and struck these people.

To simplify cable handling during actual installation, Maersk has raw water pumps fitted with a quick connection. That means the cable does not have to be connected until the pump is in its initial position for installing the water riser. This simplifies the lifting operation and lowers its risk. In the present case, a pump with quick connection had been ordered but one without this was sent to MINC. A change of priorities meant the pump ordered went to MINV.

The power cable was attached to a specially designed reel to regulate its length, but weaknesses in the brakes on the reel had earlier led to uncontrolled unreeling of the cable on Maersk facilities. Building a temporary scaffolding to hold the reel (which the cable was delivered on) reduced opportunities for such uncontrolled unreeling. In order to simplify pump handling and installation, part of the cable was then laid on the deck behind the personnel. But that represented a big risk for the personnel handling the lift if it failed.

The design fault which resulted in offset traction was known to Maersk from when the facility was built, and the company tried out a solution at the yard to prevent it. Involving a piston to reduce manual involvement in the (offset) lift, this proved cumbersome and was thereby rejected.

It emerged from interviews that communication of the design weakness from the project organisation to the operations organisation was poor. MINC therefore began operating on the field with a known design fault which posed a big risk for personnel doing this kind of job.

The challenges posed by installing raw water pumps were also noted in Maersk's various follow-up systems (such as AAR and Synergi), but the offset traction was not dealt with. Manual force was therefore required during installation, and personnel have been in an exposed area during all change-outs on three of the facilities (MINC, MINT and MING). Such change-outs normally take place twice a year on each of these units.

7.2.2 Technical equipment – observations

7.2.2.1 Wire rope sling

Maersk had the flat-braided wire rope sling tested by DNV GL after the accident.

The first tests were conducted on slings from MINC with a WLL of 4.8 tonnes and lengths of two, four and six metres, all produced in 2014-17.

These tests demonstrated that the wire rope slings have a lower safety factor than specified in the user manual, and that the conversion factor used for a U lift is inaccurate. All the values are significantly lower than those provided by the supplier (see table 1 in section 5.1).

The second set of tests used corresponding slings from other manufacturers under the same test conditions. Although rupture strength varied, these slings also failed at a lower safety factor than the one specified.

This suggests that figures from the manufacturers do not take account of locking or twisting when calculating WLL, because these factors reduce the sling's rupture strength and have a significant effect on capacity – it becomes substantially lower.

The receiving inspection function at Maersk has failed to pick up the following.

- The conformity declaration for the flat-braided wire rope sling used on MINC refers to an older version of the machinery directive– 98/37/EF. The applicable one is 2006/42/EF.
- The manufacturer has prepared a user manual for the flat-braided wire rope slings used. This manual is inadequate in relation to the requirements in the machinery directive annex 1, sub-section 1.7.4.2 Content of the user manual and section 4.4, User manual, sub-section 4.4.1 Lifting appliances.

7.2.2.2 Overhead crane

The overhead crane was assembled at the Singapore yard from components delivered by several suppliers. Because it was defined as these individual components rather than as a crane, it was not risk-assessed, maintained and checked as a overhead crane. Maintenance and use were based on the user manual for the electrical chain hoist with trolley.

The electrical chain hoist with trolley and control system was manufactured by ASME A/S in Denmark. The crane rail was not part of the delivery. Chain hoist capacity with trolley is 180 kN with a speed of three metres per second. The trolley has a speed of 15 metres per minute. The hoist with trolley weighs about 1 400 kilograms, the chain weighs roughly 250 kilograms and the total weight on the crane rail is roughly 1 650 kilograms.

The FAT for the hoist with trolley, capacity 180 kN, was witnessed by DNV with a test load of 22.6 tonnes.[4] The DNV certificate contains five restrictions on use, including one which specifies that the hoist is not designed to lift while the trolley or the facility are moving. This information was not known by or communicated to personnel using the overhead crane.

Westcon has issued a certificate for the lifting equipment[5] based on documentation from the manufacturer and in accordance with directive 2006/42/EC. The certificate has been issued with a WLL of 18 tonnes, but Westcon has not tested the hoist.

Westcon has conducted tests and investigations which comply with the specified guidelines and requirements in the NMA’s regulations on cargo-handling appliances in ships (FOR 1978-01-17-4). This does not accord with Maersk’s AoC application, which specifies that the technical specification of lifting equipment will be based Norsok R-002.

7.2.2.3 Crane rail

The crane rail comprises a beam attached to two cylinders to adjust its sideways movement. The rail[6] has an SWL of 20 tonnes and was tested to 25 tonnes by the yard on 2 May 2014. This test was witnessed by DNV and Maersk.[7]

No certificate has been issued for the assembled overhead crane, but one is issued for the actual crane rail.[8] This sets the WLL to 20 tonnes in a vertical lift, based on test memo TM-M025. Westcon has issued a certificate in accordance with the NMA’s regulations on cargo-handling appliances on ships. It was issued on 14 November 2014 on ILO form 2.

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[4] CoC No TEBOK-201309654 DNV dated 3 June 2013.

[5] ILO form 2 Certificate no WCL-2014-90128 rev 2 dated 1 November 2014.

[6] H340-01.

[7] TM-M025, page 39.

[8] Certificate WCL-2015-01460 rev 2.

Maersk used Westcon as its enterprise of competence. The latter has certified the crane as individual components on the basis of the NMA's regulations for cargo-handling appliances on ships, even though it should be certified as a complete crane under the regulations mentioned (the certificate refers to section 15 of the regulations on initial examination and testing of cargo-handling appliances).

Maersk, for its part, refers to Norsok R-002 as the norm to be used for all lifting equipment on board, but that has not been done in this case. Section 5.7.1 in part 5 of Norsok R-002 specifies general requirements for the strength and stability of lifting equipment. It says that recognised international standards and design codes shall be used. Appendix G contains more detailed information on and descriptions of crane categories and the division into crane types. Item G10 on overhead cranes refers in turn to NS-EN 15011 as the standard to be used.

It does not appear from the documents reviewed that Maersk or Westcon have based certification of the overhead crane on NS-EN 15011. This has meant that:

- components were not assessed collectively as an overhead crane
- the overhead crane was not risk-assessed after completion
- the overhead crane was not tested after installation on the facility
- no user manual for operation, maintenance or training was prepared.

7.2.2.4 Pennant for the offshore crane

The offshore review identified faults and deficiencies in the crane pennant used when lifting the raw water pump and cable reel into place. Maersk was unable to provide user manuals for the pennant. These should include information on use, checking and maintenance as well as how the pennant should *not* be used.

Nor was the pennant checked as described in the specified part C14 of Norsok R-002. Damage to all three pennants used for lifting was incompatible with continued use.

Illustration 13:Damage to the crane pennant used when moving the pump and cable from the deck to the roof of the ventilation housing.

7.2.2.5 Lifting yoke

The yoke for lifting raw water pump components was manufactured by MAK Engineering Pte Ltd in Singapore, which has issued a conformity declaration on the basis of a test report from DNV.[9] Two Type B.RW lifting devices (yokes) were tested with a load of 22 500 kilograms.

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[9] DNV report 1G7XDY7-2.

Based on these documents, Westcon issued an ILO form no 3 certificate, WCL-2015-00300 revision 1. It also conducted an annual inspection on 14 January 2017 without comments.

Portable lifting equipment must comply with section 92 of the activities regulations on lifting operations. The guidelines to this section recommend the use of Norsok R-003. Appendix E to that standard covers documentation and marking of lifting equipment, including the need for such equipment to have CE marking and a conformity declaration which accords with the machinery directive. The lifting yokes in use had neither conformity declaration nor user manual.

Appendix H to Norsok R-003 specifies that the enterprise of competence must satisfy itself during initial examination that the necessary documentation is present. See parts H2 and H3.

The certificate and control card for this equipment refer to the NMA's regulations on cargo-handling appliances on ships. This does not accord with Maersk's statement that Norsok R-002 will be used for the technical specifications of lifting equipment.

7.2.2.6 Raw water pump

The raw water pump was manufactured by Flowserve Hamburg GmbH. MINC has six such pumps, two in each leg. They supply the facility with seawater for such applications as fire-fighting and cooling engines.

The user manual for the pump only has a general chapter on handling and lifting, and another on installation. These chapters do not explain directly how handling, lifting and installation should be done on the facility, but Maersk has developed a separate procedure for the work. This was inadequate for the operation carried out during installation of the pump.

7.2.2.7 Suspension beams and suspension system for the raw water pump

To assist installation/removal of riser components and the pump, two beams were installed which could be pushed out hydraulically to relieve the load from the pump and the individual riser. This system was combined with sideways movement of the overhead crane. Simultaneous operation of crane and beams was prevented through a hydraulic interlock system. A description and marking were missing on the control panels for the suspension beams. Nor were they included in the OJT description for this type of operation. Erroneous settings for these valves could have led to movement in the suspension beams.

Illustration 14: Operation panel and control valves to operate the relieving system for the raw water pump.

7.2.2.8 Materials handling of the raw water pump

Mechanics in Maersk regarded materials handling and maintenance of the pump as demanding, with several heavy-duty jobs. That applied particularly to installation/removal of the pump. The overhead crane to be used for these operations was not centred over the pump, which resulted in offset traction.

The procedure for handling the pump system[10] explained that the offset angle of five degrees on the crane reduced its SWL to 17.5 tonnes. But it lacked a description of the equipment to be included in the lifting operation, how the pump itself was to be lifted in and out of position, and how it should be handled with the aid of the overhead crane.

The materials handling plan is intended to be the basis for all such operations on MINC, but only applied to equipment with a maintenance programme. Since the raw water pump was classified as "run to failure" equipment, this lifting operation was not covered by the plan.

7.2.3 Maintenance of lifting equipment

The on-board inspection revealed that a number of flat-braided wire rope slings were damaged and used incorrectly. The team also found damaged wire rope slings in the lifting equipment container which were checked and ready for use. On deck, it found three offshore crane pennants which were damaged and no longer in use.

User manuals for the lifting equipment were not available. These are intended to give users information on use, restrictions, pre-use checks, scrapping criteria and maintenance.

7.2.4 Planning and execution of the work operation

Installing seawater pumps was known in the Maersk system to be a difficult and physically demanding job. It was characterised as a complex and non-standard operation. The company

[10] MSC C170-150 MD 004 /AUG 2016 and INC-0001-17977/WCL-R-2075 rev 0.

has various tools for dealing with risk in such jobs, partly in the form of organisational, operational and technical barrier elements.

In its review of organisational barrier elements, Maersk identifies SJAs, WPs and TBTs as important for identifying and reducing risk in work operations.

7.2.4.1 Use of WPs when installing the raw water pump

The WP tool in Maersk has two levels. Level 1 is required for work which has enhanced risk and requires coordination and clearance at facility level. Level 2 is used for other work where the risk calls for coordination and clearance within an area/system. The need for a WP must be assessed at both levels.

Two WPs at level 1 were issued for installing the pump, for 6 and 7 December 2017 respectively.

The following procedures were checked off in the WPs

- 31217 Handling procedure for raw water (RW) riser.
- 31350 Raw water pump/casing operation.

The following risks were identified: dropped objects, working with tools, securing tools, securing against cable reeling out from the reel and the need for a TBT.

Neither WP identified the job as a critical lifting operation and work over the sea. Important barriers such as the use of an SJA and involvement of lifting expertise might thereby have been overlooked.

7.2.4.2 TBT

The work team conducted the TBT in the coffee bar, not in the work area for the installation. It emerged from the interviews that the WP and the procedure were not reviewed, but the intention was to review them after the raw water pump was lifted into place and secured.

The TBT identified the following risks:

- crush injuries because of heavy equipment
- uncontrolled reeling out of cable
- dropped tools.

It emerged from the interviews that the operation was once again not regarded as work over the sea (because scaffolding had been built) or a critical lifting operation. No safety harness was accordingly used during the work, and the lifting risk was not assessed. The TBT did not identify the need for an SJA.

7.2.4.3 Procedure for handling the raw water pump system

The procedure for handling the raw water pump system was deficient and did not describe the actual installation and removal of the pump. This was a lifting operation, and could be regarded as the most critical part of the job since the hanging load had to be managed manually. A checklist had been prepared for the procedure, but this was not tailored to lifting the pump in/out.

The workers accordingly lacked procedures which could have contributed to a safe operation.

7.2.4.4 SJA

A number of processes in Maersk's management system specify when an SJA must be conducted. Process Instruction 007/Jan2017 lists the evaluation criteria which will identify the possible requirement. If the work is regarded as risky or complex, an SJA must be carried out. Furthermore, an SJA is required if the work operation is unfamiliar, or the procedures and WP are inadequate for the operation.

Identifying the need for an SJA comprises several phases, from planning the job until the work is to be done. This means that everyone involved in planning, approval, WPs and work execution must assess the need for an SJA.

Maersk was unable to comply with the team's request that it document the conduct of an SJA for this job on MINC. The need for an SJA was not identified during planning of the work, in the WP or by the team responsible for its execution.

The PSA's review showed that an SJA was not normally conducted for this type of operation. That was also confirmed in interviews. Mention was made in several interviews that SJAs were regarded as time- and resource-intensive, and that an TBT could be just as good.

Both rank-and-file and supervisory personnel generally expressed the view after the accident that an SJA should have been used for this work operation.

That would have ensured a more systematic and step-by-step review of hazards than a TBT.

7.2.4.5 Roles and responsibilities

Responsible parties for areas and operations were defined on MINC to ensure involvement of the right expertise. The TSL is responsible for maintenance operations, while the MSL covers lifting operations.

Since this job was regarded as a maintenance assignment, the MSL was not involved in its planning.

The TSL planned how the work was to be done, using AAR as part of the basis. Particular attention was paid to dealing with the cable and the use of scaffolding. Connecting the water risers would have easier with improved access from scaffolding.

Connecting the risers was not regarded as work over the sea. It emerged from interviews that this could have been a reason why "work over the sea" and "critical lifting operation" were not included in the WP.

7.2.5 Training and expertise

Interviews and reviews of governing documents show that the facility's OJT does not fully cover materials handling of the raw water pump. It also emerged from interviews that this type of training was not always given when the level of activity was high or (too) little time was available to do it adequately. The same applied to the evaluation of OJT.

OJT for handling the raw water pump does not cover lifting in/out. Nor is this covered by procedures, materials handling plans or user manuals from the manufacturer of the raw water system or the overhead crane.

The person operating the raw water pump on the day of the incident had not received OJT. He was given only a very brief introduction to the up and down functions on the control panel.

Neither executing nor supervisory personnel were familiar with the special attention which had to be paid when using flat-braided wire rope slings, even though Maersk has conducted two investigations after such slings have failed.

Maersk has no system on the facility which provides adequate access to user manuals from the manufacturer, and which ensures they are read and reviewed before use. The user manuals provide the latest guidelines on hazards from the manufacturer.

The review of Maersk's emergency preparedness (also) exposed the lack of a system to ensure that all first-aiders on board have adequate first-aid competence. It emerged from interviews that pressure of time during working hours means that training sessions for first-aiders were reduced to about half the level recommended by Norwegian Oil and Gas in modules for such training. Interviews also revealed that most of the MOB boat crew had only been on the water once or twice. This is not considered adequate for safe MOB operations. The same observation was made on MINT during a PSA audit in May-June 2017.

7.2.6 Continuous improvement

Maersk was aware that the crane design produced an offset angle, and that manual force was needed when lifting the raw water pump in/out. This meant personnel had to be in an exposed area.

The company could not document that a risk assessment of the manual operation had been conducted in either the design or the operation phases.

Maersk had a procedure with a checklist for handling the raw water pump system, but this contained significant deficiencies since it did not describe lifting the pump in/out. Lifting in/out is a critical operation, since personnel have to handle the load manually. The procedure had not been revised since 2016, even though several in/out pump lifts have been carried out after that and a number of proposals have been made for improving the procedure.

The team has not assessed whether other procedures are deficient, since that falls outside its mandate. A number of interviewees believed a number of procedures were too general and failed to describe the actual conditions adequately.

The materials handling plan is additional to the procedure for lifting the pump in/out. Interviews revealed that the plan was general and little known or used by employees.

Where emergency preparedness on MINC is concerned, the facility had not followed up the nonconformities concerning training of MOB crew on MINT (see section 7.2.5). See the PSA's audit of the latter facility in May-June 2017.

On the basis of its observations, the team requested a review of those parts of the management system[11] intended to ensure continuous improvement to and compliance with[12] handling of the raw water pump system.

Tools and systems given special mention were:

- the AAR – a tool for ensuring experience transfer with regard to job execution
- Synergi – a tool for registering and following up incidents
- the RR – a tool for individuals to propose improvements to procedures, which is designed so that the proposer can submit specific improvement suggestions.

The review of relevant Maersk-registered AARs[13] related to handling of raw water pumps in recent years shows that the operation is difficult and risky, in part because of snagging points and cable handling. A number of the AARs included recommendations for a *dedicated* work team to handle this operation, with no other duties when lifting these pumps in/out.

A review of the RRs showed that two proposed improvements to the procedures for pump handling were submitted after 2016. A change to the procedure was proposed in April 2017, but consideration of this had not been completed when the accident occurred. Interviews suggested that personnel did not make active use of the RR tool.

At the team's request, Maersk searched Synergi for cases involving the raw water pump system. A total of 69 were registered for the four facilities mentioned in this report.

Nine incidents were registered from 2014 to the day of the incident. Most related to equipment shortcomings. One of these, which involved uncontrolled reeling out of the cable,[14] can be related to the present incident.

The team also reviewed other incidents Maersk has reported to the PSA. See the appendix. These have several features in common with the incident which led to the accident, such as factors related to procedures, risk assessments, training and planning

It emerged from interviews that learning lessons across the company can be challenging because ownership for taking improvement points further is perceived to be lacking and the tools intended to deal with improvement points are difficult to use.

Maersk does not appear to have made full use of improvement proposals received and lessons learnt from incidents and audits.

7.3 Cost reductions, efficiency enhancements and high level of activity

The mandate also called for an assessment of whether a correlation existed between causes and measures related to cost reductions, efficiency enhancements and level of activity. The team has not established any absolute correlations, but the following have emerged.

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[11] Maersk uses the Sirius management system.

[12] Continuous improvement includes improvement proposals, communicating and implementing such proposals, learning from incidents, training and the company's own follow-up.

[13] AARs reviewed: GLB: 119346, 102562, 121370, 10100000648, 10600000166, 10600000708, 10600000144.

[14] Synergi case no 1179961.

- Indications were obtained in interviews that employees are experiencing increased work pressure, but do not feel they are under pressure from management. The time pressure is described as self-imposed.

- In interviews with both supervisory personnel and rank-and-file, it was emphasised that efficiency improvements and cost cuts should not be at the expense of safety. The primary aim was to work more intelligently and eliminate wasted time.

- Interviews and observations indicate that MINC devotes less time than before to
    - OJT
    - follow-up of lifting operations by the person responsible for operations
    - pre-use checks of portable lifting equipment
    - planning of jobs – with less use of SJAs, for instance, because they are seen as resource-intensive
    - training sessions for first-aiders.

- Everyone interviewed at various levels commented that work should cease if unforeseen circumstances arose or procedures were inadequate. The investigation shows that, from the start to construction of MINC until the incident occurred, a number of unforeseen circumstances arose which should have caused work to halt. One of these was an attempt when the raw water system was first installed to find a solution to prevent manual handling with offset traction. This approach was rejected because it was too cumbersome. Several conditions during the actual job should have led to a halt and risk assessment, but this did not occur.

8 Other incidents

To secure a more complete picture of Maersk's system for learning and improvements after incidents, the team has also reviewed other incidents reported by the company to the PSA and relevant internal investigations available to personnel in the form of one-pagers, and asked Maersk to search its own Synergi register for incidents related to slings, lifting equipment and shackles. The Synergi reports fell between 1 January 2014 and 9 January 2018 and covered 424 incidents.

These incidents were drawn from all Maersk-operated facilities on the NCS. Summaries of a selected few are presented below.

MINC
MINC had two one-pagers available for personnel, relating to the following Synergi cases.

- Synergi reference 1758763
    - Experience transfer related to dropped objects, 17 August 2017.
    - Crane pennant fell from the hook after contact with staircase.

- Synergi reference 1698778
    - Experience transfer related to use of a lever hoist, 13 April 2017.
    - Personnel failed to get the hoist to work because it was a different make from the one they normally used. The learning point was personnel training.

Incidents reported to the PSA
The team has reviewed these reports and summarised the observations. Some of the incidents are listed below. Causal evaluations are from Maersk's own investigation reports.

MINC
Synergi reference 1819790, dated 16 December 2017, dropped object while changing steel cable on crane.

Old and new steel cable were connected with the aid of a cable sock. While reeling in, the cable sock snagged and the cable slipped out of the sock and fell to the deck.

The following deficiencies were among those identified in the report:

- work errors when installing the sock
- no conformity between specifications from crane supplier and manufacturer
- lack of self-checking/pre-use checks
- planning deficiencies
- failure to learn from earlier incidents
- deficiencies in competence
- unclear procedures.

MINC
Synergi reference 121546, dated 22 October 2017, dropped objects from drill floor to well while handling conductor tubing with slips.

The following deficiencies were among those identified in the report:

- nonconformity with work instructions
- wrong equipment used
- planning deficiencies
- inadequate risk understanding
- inadequate training
- deficiencies in using procedures.

Maersk Guardian
The following report from Det Norske (now Aker BP) has been reviewed: MG-DENOR-S-1369 reference, investigation of dropped sub on *Maersk Guardian*, incident date 13 August 2012.

While lifting a 9 7/8-inch sub from main deck to pipe deck, the sling failed when the sub became snagged. The sub weighed 205 kilograms. The sling used was a flat-braided type with a WLL of 1.6 tonnes. The recorded load on the hook was six tonnes when the sling failed.

The following deficiencies were among those identified in the report:

- planning deficiencies
- inadequate follow-up of procedures
- inadequate risk understanding
- inadequate management.

Maersk Inspirer
Synergi reference 925927, report dated 28 October 2013, cement hose fell to the deck during lifting operation.

Flat-braided 2.5-tonne slings, hose weight about one tonne, sling wound around hose. Hose snagged during lifting and the sling failed.

The following deficiencies were among those identified in the report:
- risk assessment/TBT
- communication
- procedures
- pre- and post-use checks
- maintenance
- roles and responsibilities
- training.

In addition, the report described a number of other underlying causes – such as planning.

MINT
Synergi reference 1797233, investigation into loss of blowout preventer control functions on 1 November 2017.

The following deficiencies were among those identified in the report:
- communication
- WP
- expertise
- training and barrier understanding
- procedures.

Summation
These incidents share several common features with the accident. Causes relate to procedures, risk assessment, training, planning and so forth.

9 Discussion and summation of underlying causes

Investigation of this incident has shown that it has no single cause, but results from interaction between a number of causes.

The review of these causes shows that Maersk, at various levels and at different times, could have identified, communicated and managed the risk of the work operation concerned.

This operation was pursued on three identical jack-ups, and Maersk knew it was demanding and risky. This emerges in part through several AARs. The information has not been used to initiate risk-reducing measures.

The procedures for handling raw water pumps were inadequate for this lifting operation. They had not been revised since 2016, even through a number of corresponding jobs had been conducted since then.

Although handling raw water pumps was known to be a demanding job, involving several disciplines and risky manual intervention, practice has not been to use SJAs. One claim made in interviews was that a good TBT was on a par with an SJA, and that the latter was time- and resource-intensive. That could indicate an unfortunate practice had developed.

The review of Maersk's AAR system shows that a number of people believe a dedicated work team should be used for this job because it is complex and demands the full concentration of those involved. Looking at the *whole* job investigated up to the moment of the incident, work was spread over several shifts and with varying team composition.

Although all management levels and rank-and-file say that work must halt if the procedures are inadequate or if unplanned circumstances occur, nobody took advantage of this opportunity on the days when the pump operation was conducted. This could be synonymous with a culture which places the greatest emphasis on efficiency and progress.

Significant underlying operational and organisational causes of the incident can be summarised as follows.

- Maersk had not followed up and managed the hazards posed by the job through technical or organisational measures.
- Working practice was not robust in terms of risk identification, planning and preparation of the job.
- Workers were not given adequate operating parameters for doing the job they were assigned to carry out in a good and safe manner. In this context, operating parameters mean appropriate procedures, sufficient time and necessary expertise.

10 Discussion of uncertainties

Although considerable certainty prevails about the main features of the incident, the team has identified some uncertainties. These are not decisive for its conclusions.

It has been assumed that the person who fell into the sea and perished was hit by the unreeling cable. Since he was using manual force to keep the pump clear of the deck, he could have lost his balance when the wire rope sling failed and the pump plunged to the sea.

Where technical aspects are concerned, some uncertainty prevails about why the sling failed – in other words, the force it was subject to when it broke. It emerged from discussions that the crane's overload system was set to 10 per cent above its WLL of 18 tonnes. Tests carried out by DNV GL show that the sling's WLL was reduced because of the offset traction, uneven loading on the sling and a possible twisting when it was attached to the crane hook.

Where the underlying causes are concerned, the team cannot say how decisive the identified individual causes have been.

11 Assessment of Maersk's investigation report

The report is detailed and extensive, and points to the same causal relationships identified by the PSA team.

Maersk has commissioned a number of tests at DNV GL with the equipment used. Wire rope slings from several manufacturers were tested. One finding is that the slings have a lower WLL and conversion factor for lifts than those provided by the manufacturers.

Maersk has also produced an animated video of the course of events and obtained calculations from IKM Test Team Solution AS.

Recommendations in the investigation report relate to design, processes and procedures, lifting operations, control of work, and culture.

The team interprets the report to also point to more generic conditions than those which apply to this job or this facility. The PSA will follow up Maersk's work on recommendations in the report and the way is uses the lessons learnt from this process.

12 Regulations

Maersk based the construction of MINC on section 3 of the framework regulations on the application of maritime regulations in the offshore petroleum activities. This section provides the opportunity to apply relevant maritime requirements for *maritime areas* (in this case, the technical requirements in the NMA's regulations for mobile units (the Red Book) following the amendments in 2007) instead of the requirements in the facilities regulations.

Where lifting and materials handling are concerned, Maersk opted to apply Norsok R-002 on lifting equipment for design and R-003 on safe use of lifting equipment for operation, as prescribed in the provisions of both the facilities and the activities regulations.

13 Other comments

The team has had meetings with other owners of comparable jack-ups to identify their handling of raw water pumps. This was done to assure the team that the industry has a satisfactory system for handling such equipment and for sharing experience immediately after the incident.

Suppliers and manufacturers of flat-braided slings have also been informed of the investigation's findings. This information was sent to Norwegian and Danish players.

In addition, the Norwegian Labour Inspection Authority, the NMA and the Danish Working Environment Authority have been informed.

14 Observations

The PSA's observations fall generally into two categories.

- Nonconformities: observations where a breach of the regulations has been identified.
- Improvement points: observations where deficiencies are seen, but insufficient information is available to establish a breach of the regulations.

Observations here are additional to the order of 5 January 2018.

14.1 Nonconformities

14.1.1 Planning of the work operation

Nonconformity

Planning of the work operation failed to ensure that important contributors to risk were kept under control.

Grounds
Planning of the work operation was inadequate for doing a safe job.

The work operation related to lifting the raw water pump into place was not planned and executed in accordance with Maersk's internal procedures and routines. This includes:

- the lifting equipment and crane were not checked before use
- the work operation was not halted when the procedure was inadequate
- no SJA was carried out even though the procedure was inadequate
- experience from similar jobs, other shifts and facilities, and the construction phase was not adequately used in the planning
- those involved lacked sufficient OJT for the job they were doing
- the job was not regarded as a lifting operation
- the job was not regarded as work over the sea/beyond the rig edge.

Requirements
Section 29 of the activities regulations on planning of activities on the individual facility
Section 92 of the activities regulations on lifting operations. See the guidelines, which refer to Norsok R-003N

14.1.2 Configuration of lifting equipment

Nonconformity
Equipment for materials handling of raw water pumps was inadequately configured.

Grounds
The equipment is not configured in a robust manner and the simplest possible way, ensuring that opportunities for human error are restricted and it can be operated without threat to personnel.

Maersk has chosen lifting equipment for materials handling of raw water pumps which makes it possible for the pump to snag, so that the lifting equipment can be subject to greater forces than it is designed for.

The lifting equipment lacked an indicator which showed the load imposed during use.

The equipment also required manual handling which exposed personnel to risk.

Requirements
Section 10 of the facilities regulations on installations, systems and equipment. See the guidelines, which refer to Norsok R-002
Section 13 of the facilities regulations on materials handling. See the guidelines, which refer to Norsok R-002

14.1.3 Use of information and continuous improvement

Nonconformity
Failure to use available information to implement improvement measures.

Grounds
Maersk has a number of AARs which show that the operation (handling of the raw water pump system) is demanding and risky – in part because of snagging points and cable handling. Several of the AARs include a recommendation that a *dedicated* work team be used for the operation, which then had no other duties when lifting the pump in/out. Maersk has not used the available information to identify the need for improvement and to initiate necessary improvement measures related to installing the raw water pump system.

Maersk has not used the findings of its own investigations to make necessary improvements. Six investigation reports and two safety announcements from Maersk in 2012-18 show a number of concurrent conclusions and improvement proposals. The conclusions concur with observations in the present investigation. Recurrent issues in the reports include training, planning, communication, procedures and understanding of risk.

In its audit of MINT of May-June 2017, the PSA identified nonconformities with regard to training of the MOB crew. Maersk amended procedures to ensure that the MOB crew received the necessary training (this emerged from the letter responding to the audit report), but these corrective measures were not implement on MINC.

Requirements
Section 23 of the management regulations on continuous improvement
Section 19 of the management regulations on collection, processing and use of data

14.1.4 Education and training

Nonconformity
Inadequate education and training of personnel.

Grounds
Maersk had not ensured that personnel received the training and expertise required to carry out the activities in a safe manner.

No equipment-specific training had been given on MINC for installing raw water pumps. The OJT developed for this job was inadequate for the actual lifting of the pump in/out. Nor had OJT been given to the person operating the overhead crane when the accident occurred.

It emerged from interviews that less time than before is generally allocated for necessary training when the level of activity on the individual facility is high.

Requirements
Section 21 of the activities regulations on competence
Section 23, paragraph 1 of the activities regulations on training and drills

14.1.5 Use of lifting appliances and equipment

Nonconformity
Lack of accessibility to and use of user manuals for lifting appliances and equipment.

Grounds
Maersk had failed to ensure that the necessary governing documents, including technical operating documents, were available and known to operations personnel.

No user manuals or other governing documents describing safe use of the equipment were provided to the investigation. Random sampling showed that manuals were lacking for flat-braided wire rope slings, the overhead crane, the lifting yoke and crane pennants.

Available user manuals were not utilised to ensure that equipment was used, checked and maintained in accordance with the manufacturer's recommendations.

Requirement
Section 20, paragraph 2, litera b of the activities regulations on start-up and operation of facilities

14.1.6 Enterprise of competence

Nonconformity
Lack of follow-up of the enterprise of competence.

Grounds
The overhead crane for lifting the raw water pump was not regarded as an assembled lifting appliance pursuant to Norsok R-002, the standard applied by Maersk.

In its certification, the enterprise of competence has approved the system as individual components, where the beam is one component and the hoist another. When assembling several components to produce a fixed lifting appliance, the whole appliance/crane must be assessed on the basis of its area of application and type of assembly. Only then can a risk assessment be conducted for the complete lifting appliance as the basis for preparing a user manual and certifying the appliance.

The approach adopted has resulted, for example, in an excessive SWL for the electrical hoist in terms of the crane rail's capacity. The overhead crane also lacked a load indicator.

Requirements
Section 18 of the framework regulations on qualification and follow-up of other participants
Section 21 of the management regulations on follow-up
Section 92 of the activities regulations on lifting operations. See the guidelines, which refer to Norsok R-003N

14.2 Other nonconformities

14.2.1 Barriers and obstacles

Nonconformity
Barriers and obstacles in escape routes on deck.

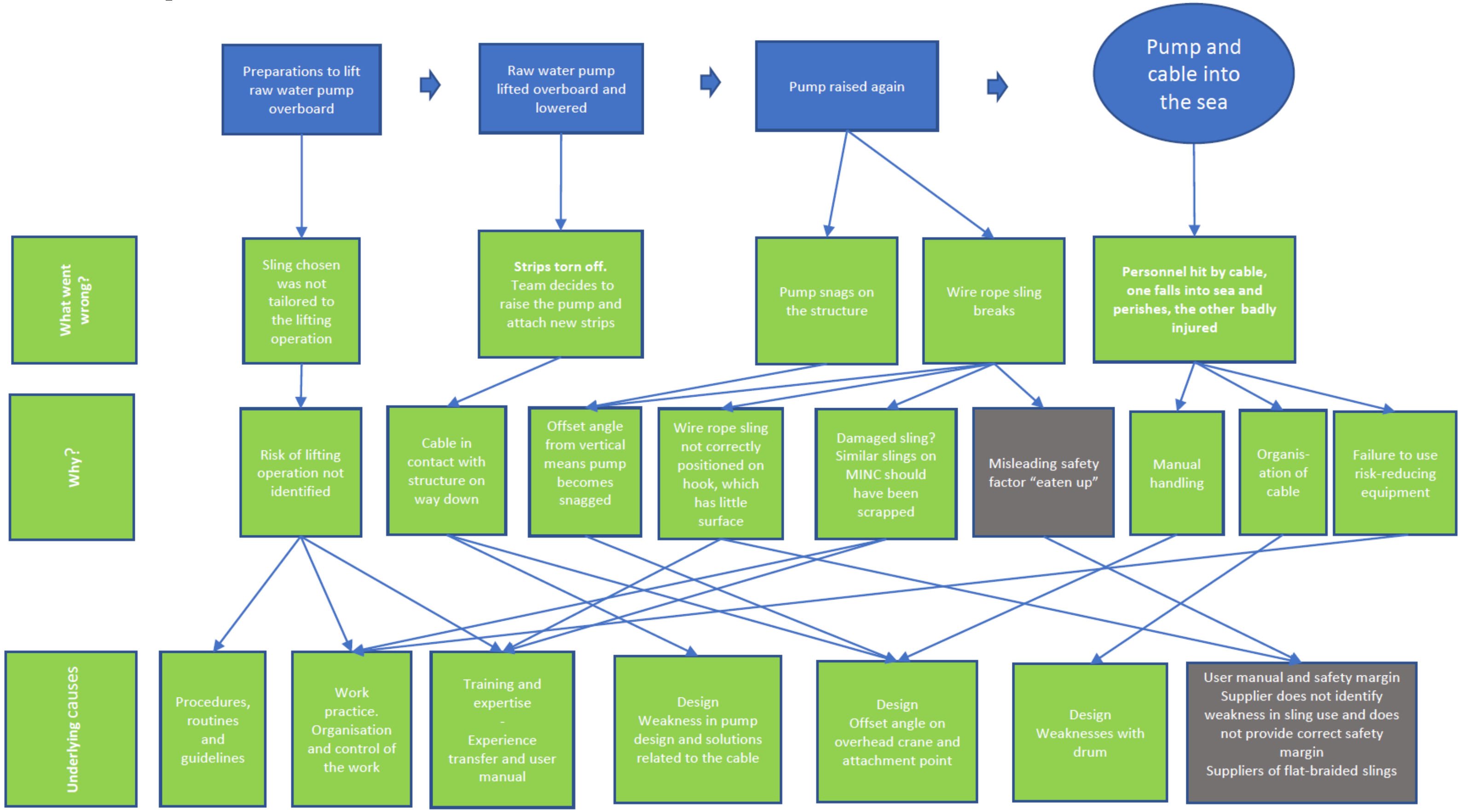
Grounds
During the team's tour of inspection, it observed several containers and anchor chains which were placed in escape routes without an alternative route being marked.

This was observed in the stern part of the facility, by the starboard raft station and on the port side. Alternative escape routes were only marked on the port side.

Grounds
Section 3 of the framework regulations on application of maritime regulations in the offshore petroleum activities. See section 15, number 4 of the NMA's regulations on construction of mobile offshore units

15 Appendices

A: Timeline, simplified course of events



Investigation report

B: The following documents have been utilised in the investigation

MINC Operation_Section
Raw water pump_ casing - operation M-CPH-1171-31350_EN
Effect guidewords M-CPH-1171-00285_EN
Flowchart Perform Safe Job Analysis
Form for SJA M-CPH-1171-00283_EN
Hazard guidewords M-CPH-1171-00284_EN
Process Instruction Safe Job Analysis Instruction M-CPH-1171-00876_EN
Service company responsibilities M-CPH-1171-00713_EN
SJA Checklist M-CPH-1171-00501_EN
SJA responsibilities M-CPH-1171-00715_EN
Stored Energy Guidelines M-CPH-1171-35942_EN
Trolley hoist INC-0001-04049_02_001
Position for ST BY Boat
20171211222135090
20171211221941677
load test 20171211222020348
Westcon sert. 20171211222038457
Årlig kontroll 20171211222048593
20171211222118186
Sert. 20171211222126039
Trolley hoist INC-0001-04049_02_001
INC-0001-03519_01_001
INC-0001-03579_02_001
INC-0001-03583_02_002
INC-0001-03888_02_001
Work over the side M-CPH-1171-00700_EN
Lifting Yoke for RWT ControlCard_231955
Certificate for Lifting Yoke for RWT WCL-2015-00292_-_Rev-1
Certificate for Lifting Yoke for RWT WCL-2015-00300_-_Rev-1
Certificate for Lifting Yoke for RWT WCL-2015-00302_-_Rev-1
Lifting Yoke for RWT ControlCard_231947
Lifting Yoke for RWT ControlCard_231952
Dokument oversikt løfteprosess - Lokale løfteprosedyrer
M-CPH-1171-00389_EN Lifting operation plan
M-CPH-1171-00477_EN Overhead crane
M-CPH-1171-20493_EN Best practice lifting operations
M-CPH-1171-21242_EN Use of flat braided sling
M-CPH-1171-26072_EN Roles and responsibilities
M-CPH-1171-30810_EN Daily lifts
M-CPH-1171-31217_EN Handling procedure for raw water riser
M-CPH-1171-31350_EN Raw water pump casing operation
M-CPH-1171-33059_EN Map of blind zones
M-CPH-1171-34052_EN OJT55 Raw water crane
M-CPH-1171-39475_EN Internal lifts
Beredskapsmanual MINC M-CPH-1171-31665_EN

Bridging Document MINC_Tambar_Rev02
Certificate of conformity DNV for EL. Hoist
Certificate_33615
Certificate_231952 for Lifting Yoke
Control Card (ID 50397) Lifting Yoke from January 2017
Control Card (ID 50397) Monorail beam TB201-01 in January 2017
Control Card (ID 50397) Trolley with hoist in January 2017
Extract from MHP MD ref 4.4.11
Initial documents and test of 6 x Lifting Yokes
QC104
QC420
TM-M025 - INC-14-011-001-363
WCL-2014-90128_-_Rev-2 (1)
WCL-2015-01460_-_Rev-2
WCP-10.17 Prosedyre for kontroll av travers kran
Overall methodology plan_Ptil 2017_1321_SA
Reply - Notice of Order - PSA
Final PSA presentation_Ptil 2017_1321_SA
Granskingsrapport etter hendelse personskade dødsulykke på Tambar Maersk Interceptor 07122017

C: Overview of personnel interviewed