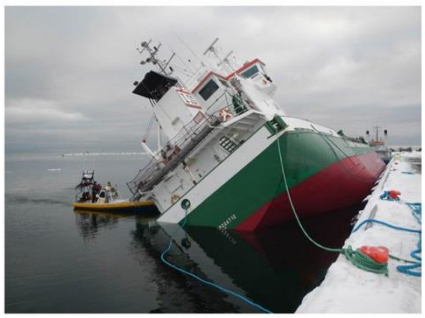
Statens haverikommission
Swedish Accident Investigation Authority



Final report RS 2016:04e

OSLO WAVE – collapsed loading crane in Bollstabruk, Sweden, 9 of June 2015

File no. S-86/15

03/06/2016

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available, both in English and Swedish, on SHK´s web site: www.havkom.se

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Content

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

The investigation

SHK was informed on June 9, 2015 that a marine causality involving a ship with the registration 9190092 / V7AG6 had occurred in Bollstabruk, Västernorrland county, same day at 14:30 hrs.

The accident has been investigated by SHK represented by Mr Mikael Karanikas, Chairperson, Capt. Jörgen Zachau, Investigator in Charge, Capt. Dennis Dahlberg, Operations Investigator, Capt. Mikael Sjölund, Technical Investigator, Mr Alexander Hurtig, Investigator Behavioural Science.

The investigation was followed by Capt. Patrik Jönsson of the Swedish Transport Agency and Mr. Anders Åsén of Swedish Work Environment Authority.

The following organisations have been notified: European Maritime Safety Authority (EMSA), EU-commission and the Swedish Transport Agency.

The investigation has been led by SHK but has been conducted jointly with the Republic of the Marshall Islands, which is the flag state represented, by Capt. Dale Ferriere.

Investigation material
Interviews have been conducted with the ship's crew, stevedores from Ådalens Farmartjänst, the management of Ådalens Farmartjänst, crane operators from Marine Crane, technicians from MacGregor, the management of Marine Crane and the concerned managers in SCA Bollstabruk.

A meeting with the interested parties was held on March 8 2016. At the meeting SHK presented the facts discovered during the investigation, available at the time.

Final report RS 2016:04e

Ship particulars	
Flag/register	Marshall Islands
Identification	OSLO WAVE
IMO identification/call sign	9190092/V7AG6
Vessel data	
Type of ship	General cargo/multipurpose
New building shipyard/year	Jing Jiang Jiao Tong Shipyard/2000
Gross tonnage	12,993
Length, over all	143.15 metres
Beam	22.80 metres
Draft, max	9.72 metres
Deadweight at max draft	17,451 tons
Main engine, output	6,965 kW
Propulsion arrangement	Fixed blade propeller
Lateral thruster	Bow thruster
Rudder arrangement	Conventional
Service speed	14 knots
Ownership and operation	LCI Ship holdings Inc./Bulkship Management AS
Classification society	ABS
Minimum safe manning	18

Voyage particulars	
Ports of call	Bollstabruk (Kramfors) Sweden
Type of voyage	Moored
Cargo information/passengers	Sawn timber in packaged bundles
Manning	18

Marine casualty or incident information	
Type of marine casualty	Accident/Near-miss which could have resulted in a very serious marine casualty
Date and time	09/06/2015 14:30
Position of the marine casualty	N 62°59.7′ E 017°41.5′
Other factors	Collapse of the vessel's loading crane
Consequences	Halted cargo handling
Personal injuries	No physical injuries
Environment	NIL
Vessels	Crane no. 1 damaged

Figure 1. OSLO WAVE. Image: Marshall Islands (flag state)

SUMMARY

The vessel OSLO WAVE was in Bollstabruk loading wood products in form of packaged timber. The ship was moored to a large barge equipped with a knuckle boom crane used to load the ship together with one of the ship's own cranes. Two stevedores worked together in the ship's cargo hold, directing the loading and uncoupling of the sling. No other member of the stevedoring team was on board to act as signalman or hatch boss to supervise and control the loading operation from the ship's deck. The ship's crane had difficulties reaching certain zones of the cargo hold, resulting in that the crane arm operated close to its lower limit. During the cargo handling, the perception of the crane operator operating the ship's crane was that the crane arm could be operated in an unusually low position. When cargo handling had been ongoing for around a day and a half the cable that lowers the crane arm released from the winch drum, and the crane arm fell into the cargo hold and landed about half a meter from the stevedores. No physical injuries were sustained by individuals.

The collapse of the crane arm was caused by the fact that it was possible to lower the arm to a point which was too low for cargo handling; such that there was insufficient cable remaining on the winch drum to hold the combined weight of the crane arm and cargo load. The reason it was possible for the crane arm to be lowered to this low point was that the low limit switches had been bypassed by means

of an extra switch installed in the crane's control cabinet. A contributory factor was that the self-inspections on board the ship were not carried out in such a way that the extra switch was discovered. The crew were thereby not aware of the inadequate functioning of the crane's safety features. Another contributory factor was that the operator of the ship's crane did not perform a full operational check of the crane before operation.

SHK also notes that there were inadequate procedures at the port relating to cargo handling and that certain work procedures were not documented. It has also been noted that there was a lack of coordination in the harbour between the actors involved in the loading of the ship.

Safety recommendations

The safety issues which SHK has identified in this investigation are primarily the lack of documented and implemented procedures for loading and unloading of ships. It has also been established that a safety-critical function in the crane has been bypassed, which was not discovered prior to use.

SHK deems the measures taken (see section 3) to be appropriate.

When it comes to the shipping company, has it during the investigation emerged indications that the self-inspection system does not work in such a manner that deviations are sure to be detected. Even if the measures taken by the shipping company today should lead to a malfunction identified before a crane is used, it also need to be taken measures to ensure that all checks performed in accordance with the ship's SMS are done complete and in correctly manner.

Bulkship Management AS is therefore recommended:

- Take action to ensure that the checks to be carried out in accordance with the ship's SMS are sufficiently thorough to enable the identification of deviations before safety-critical work activities begin. (*RS 2016:04 R1*)

1. FACTUAL INFORMATION

1.1 Sequence of events

The vessel OSLO WAVE arrived in Bollstabruk, Kramfors, Sweden, on Sunday 7 June 2015, with instructions to load wood products in the form of packaged timber. Loading was planned to commence the following day, Monday 8 June, at 06:45, and was estimated to be completed on Friday 12 June. The ship was moored to a large barge with the ship's starboard side (see figure 2). The barge was connected to shore and was equipped with a knuckle boom crane used to loading ships.

Figure 2. OSLO WAVE moored to the barge. Image: MacGregor.

On Monday 8 June at 06:15, the stevedore team leader arrived at the port to plan the loading. The team leader made contact with the ship's chief officer to discuss the loading plan and loading strategy, as well as cordons on the deck of the ship prior to commencing work. Safety information related to cargo handling was provided verbally. The team leader also checked with both crane operators before loading commenced. No written documentation of checklist for loading and procedures was provided.

OSLO WAVE had not previously loaded in Bollsta and she is larger than the ships that normally dock at the port. OSLO WAVE can load 17 timber packages in breadth, compared to the normal 14–15. This meant that the loading could not be completed with the barge's knuckle boom crane alone; instead, the ship's own cranes had to be used due to limited reach from the barge. The team leader was to work

together with a colleague in the ship's cargo hold, directing the loading and uncoupling of the sling (lifting belt or cable used to lift the timber packages). An additional 5–6 people worked on the barge, assisting with loading and securing timber packages with the sling. The team leader, crane operators and personnel on the barge were able to communicate via radio.

The crane operator who was due to operate the ship's crane no. 1, the forward crane, boarded the ship and made contact with the deck crew. It was the operator's first time on board this ship, and it was also a long time since he had operated a similar crane, as the barge's knuckle boom crane is normally sufficient for loading. He noted that the crane was in parked position and that the crew had not prepared the crane for the loading operation in the usual manner. The ship's crew confirmed that the ship's auxiliary engines had been started and that sufficient power was available to drive the crane. The crane operator climbed up the crane and performed a general ocular inspection of the cabin and machinery, and got the impression that everything looked good. He did not make a detailed inspection of the crane's winch drums and cable.

The crane was started up and the crew released the crane arm from its lashing. The crane operator activated a spring loaded key switch (see figure 10) to enable manoeuvring of the crane arm from its parked position to operational position. The crane arm was manoeuvred upwards and the function of the limit switch for the upper limit position was tested. However, testing of the lower limit switch via maximal lowering of the crane arm was not performed. Shortly thereafter, the cargo handling commenced by lifting the sling equipment ashore, from the ship to the barge, where the timber packages were linked.

The ship had three cargo holds in total; two larger and one smaller. Loading began in cargo hold no. 2, the central and the largest of the cargo holds. The barge's knuckle boom crane operated in the aft of the cargo hold, along the landward side. The ship's crane operated in the fore of the cargo hold and along the seaward-side. It is common practice to avoid operating the knuckle boom crane and the ship's crane simultaneously in the same cargo hold on the ship where possible, as it is difficult for personnel in the cargo hold to maintain focus on the movements of two cranes at the same time. The work routine also dictates that personnel may not be present in the cargo hold when the knuckle boom crane is being operated.

The knuckle boom crane had a function with open hooks which allowed the cargo (the timber packages) to be lifted and unhooked without the assistance of personnel in the cargo hold. However, the ship's crane lifted the cargo with a sling, requiring two people to be present in the cargo hold to unhook the timber packages once they had been positioned correctly. These timber packages are normally lifted in twos, weighing approx. 3–3.5 tons each.

During loading, the team leader was together with a colleague in the cargo hold. The team leader maintained radio contact with the crane operators. No other members of the stevedoring team were on board to act as signalman or hatch boss to supervise and control the loading operation from the ship's deck.

During the cargo handling, the perception of the crane operator operating the ship's crane was that the crane arm was not stopping at its lower limit, which tends to be normal for this type of crane. He was therefore reluctant to lower the crane arm into its lowest position, as he felt doubtful of its functionality. As it is difficult to see the angle of the crane arm from the control cabin of the ship's crane, the crane operator made radio contact with the operator of the knuckle boom crane in order to enquire how the angle of the crane arm looked from his position. The operator of the knuckle boom crane confirmed that the crane arm looked to be above its horizontal position – i.e., the angle was less than 90 degrees, which tends to be the lowest position a crane arm can be lowered to (see figure 8 – the normal lowest position for the crane arm when handling cargo). Cargo handling continued. It was deemed to be going according to plan and proceeding well.

On Tuesday 9 June, loading of OSLO WAVE continued. The team leader working in the ship's cargo hold during the first day of loading was replaced by a deputy with the same function and task. The replacement team leader that day also started his shift, 30 minutes before loading, with a verbal run-through with his colleagues and a check of cordons on the deck of the ship. Once again, no written documentation regarding loading and procedures was handed out or run through. According to the team leader, the checklists are the responsibility of SCA.

During loading, the ship's crew were required to go down to the cargo hold to mark off partial loads. There were also other instances in which the crew entered the cargo hold, at which time it was the team leader's task to stop the loading until the crew had left.

The ship was now loaded with approx. four layers of timber packages in cargo hold no. 2, and the seaward corner was being loaded astern. In order to reach all the way out, the ship's crane operated in its lowest position. The ship's crane had difficulties reaching certain zones of the cargo hold, meaning that the knuckle boom crane on the barge had to help to drag or push some timber packages into the correct position. The crane operator attempted to keep the crane arm at no more than 90 degree angle, i.e. above horizontal level.

At 14:30, after the knuckle boom crane had assisted with the positioning of two timber packages, the crane operator gave the team leader radio confirmation that it was clear to remove the sling from these packages. The team leader was located somewhat to the side of the timber packages and his colleague was below the crane arm. Just after the sling had been unhooked, the team leader saw one end of the

timber packages moving in the corner of his eye, and the large crane block swung towards him, causing him to run to the side. At the same time, his colleague saw the timber package coming towards him and ran to the side of cargo hold. When the team leader turned back, he saw that the crane arm had fallen into the cargo hold and landed right on top of the timber package, about half a meter behind him. Neither the team leader, his colleague in the cargo hold nor the crane operator felt there was any prior warning of what happened; they only heard a whining sound from the crane's cable. This gave the initial impression that there had been a cable break. It later emerged that the cable that lowers the crane arm had been torn away from the winch drum (see section 1.5).

After the incident, many of the ship's crew descended into the cargo hold to see what had happened. It was established that the crane arm had collapsed and fallen very close to the persons working in the cargo hold, but no-one in the cargo hold or on the ship's deck sustained any physical injuries. After some time, the crew wanted to continue with the loading in cargo hold no. 3, the aftermost, using ship crane no. 2 instead, but the crane operator objected to this and called a contact at the Swedish Work Environment Authority to inform them of the incident.

The ship's master, chief officer and chief engineer were located in the ship's cargo office at the time of the incident. After the incident, the master reported to the shipping company and to the Swedish Transport Agency, the latter also being the Swedish inspectorate authority.

Figure 3. The ship's crane after the collapse.

Figure 4. The crane arm after the collapse.

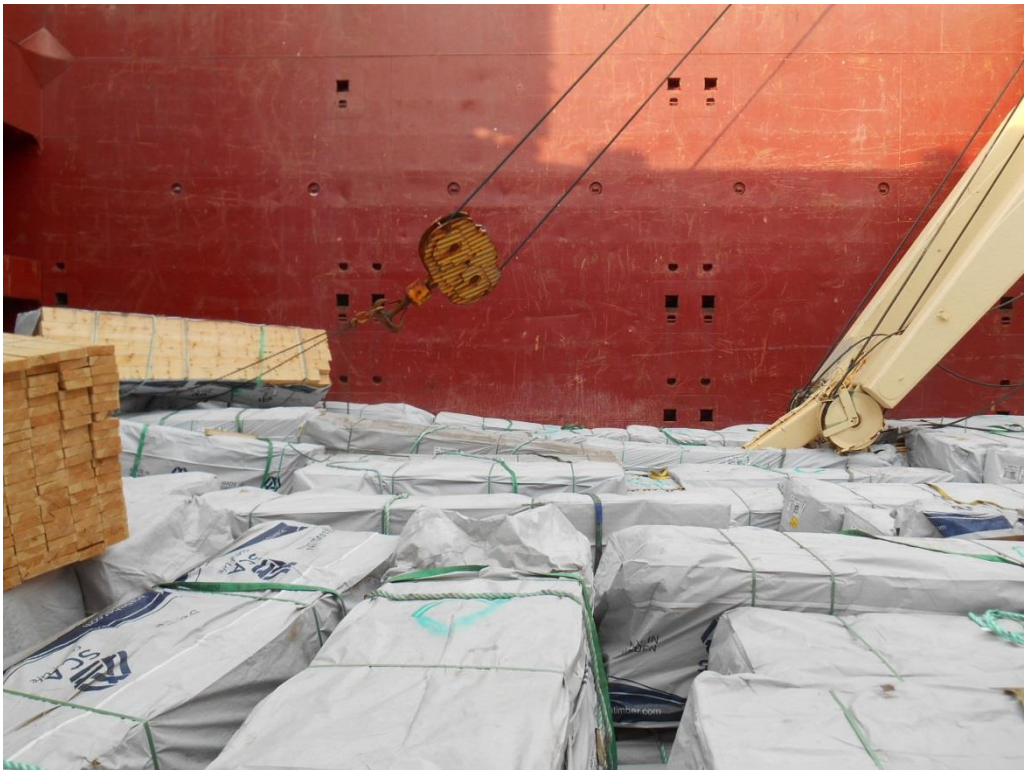


Figure 5. Top and block of the crane arm. Image: Bulkship Management

1.2 Damages

The arm of ship crane no. 1 sustained damage to the mounting and external edge and to the drum's cable lock. The cable also developed a number of defects. Damage costs amounted to about 460 000€.

The top timber package was damaged by the falling crane arm.

No physical injuries were sustained by individuals.

Figure 6. Mounting, crane arm.

1.3 Accident site/loading port

The port where OSLO WAVE was loading is situated by Bollsta sawmill in Bollstabruk, Kramfors municipality, Västernorrland county, Sweden. The sawmill and the port are owned by SCA Timbers. To facilitate the loading of ships, a large barge anchored to land is used. Ships are moored with the long side towards the barge.

The sawmill's (SCA) forklifts transport the timber load from the sawmill out onto the barge via ramps, after which the timber packages are left in a designated place known as the loading point. There is a knuckle boom crane on the barge which lifts the load from the loading point on board into the ship's cargo hold and moves the timber packages to their correct position in the cargo hold.

When using the ship's crane, there are personnel on the barge who, when the load has been left at the loading point, place a sling around the timber packages. The ship's crane then lifts the timber packages on board and sets them down in the allocated space in the ship's cargo

hold with the help of instructions from stevedores located in the cargo hold.

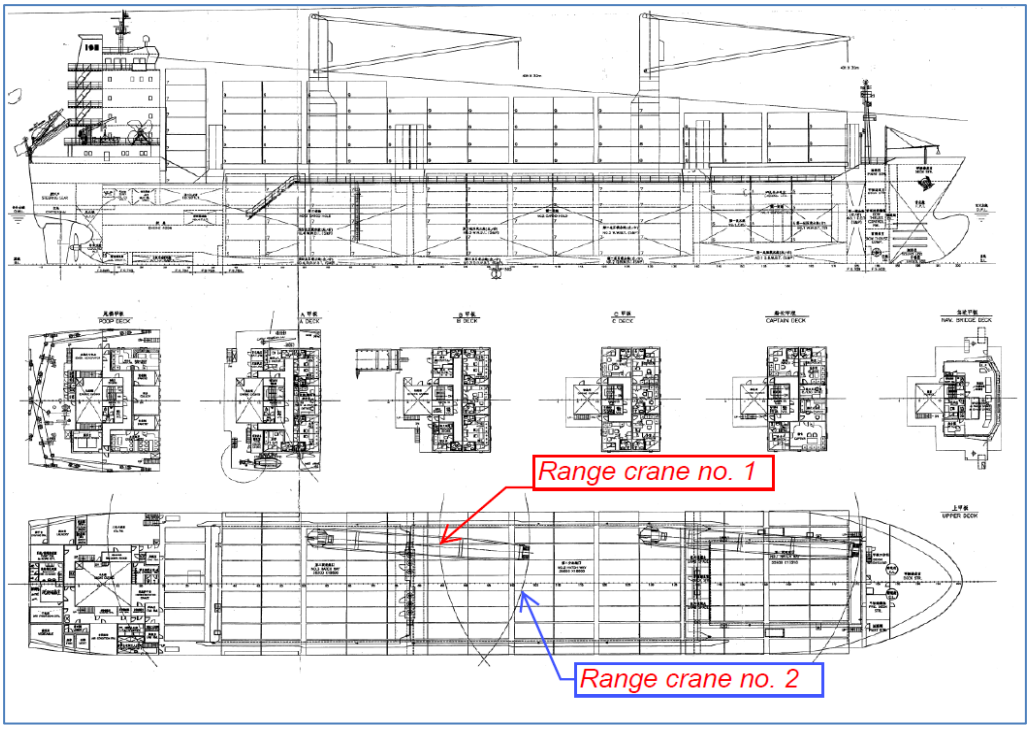
1.4 The vessel

1.4.1 General

OSLO WAVE is a general cargo/multipurpose vessel built in 2000 and equipped with two cranes numbered 1 and 2, starting from the bow, which have a lifting capacity of 40 tons SWL[1] and a maximum reach of 32 m for the crane arm. The ship has three cargo holds, numbered 1, 2 and 3, starting from the bow, of which cargo hold no. 2 is the largest. The ship can load break bulk cargo, dry bulk cargo and containers.

The ship had new management from 19 December 2014 and thereby an entirely new crew, which had been relieved during the spring/early summer of 2015. During the period 18 December 2014 to 25 January 2015, the ship was at the shipyard in Gdynia, Poland. The last port of call before Bollstabruk was Varberg, Sweden, where the ship remained between 31 May and 4 June and where a large proportion of the crew came aboard but no cargo handling was carried out. Before Varberg, the ship had been to the ports of Gibraltar, Porto Empedocle, Italy and Alexandria, Egypt.

The current crew had only used ship crane no. 1 (the one that collapsed) once previously, in Alexandra, where the ship remained between 29 April and 16 May. The crane was operated by stevedoring personnel at this time. Ship crane no. 2 had been used 5–6 times, and mostly to lift supplies and necessities to the ship from land.



[1] SWL – Safe Working Load

Figure 7. Reach of the cranes. Image: Marshall Islands

The maximum reach for each crane are shown in figure 7. The forward crane has range throughout the forward cargo hold, but has not full range throughout the second cargo hold. The aft crane has full range throughout the third cargo hold and some range in the aft part of the second cargo hold. This causes that the aft part of the second cargo hold must be loaded with the aft crane, or a crane from shoreside. When the cargo hatch covers are open, they are folded in a vertical position and limit to some extent the visibility from the crane´s control cabin down into the cargo hold. The largest limitation of visibility is from the aft crane if used in the second cargo hold (see figure 8).

Figure 8. Ship crane no. 2 in the 32 m position. Lowest position for cargo handling. Cargo hatch covers in vertical position – means limited visibility into the second cargo hold. Image: MacGregor.

1.4.2 Description of the ship's crane

The ship's cranes are of the make Hägglunds/MacGregor. The maximum capacity of the cranes is 57 tons SWL with a 10–22 m extension on the crane arm, and 40 tons SWL with a maximum extension of 32 m. The crane arm can be set in three different limit positions using a keyswitch in the control cabin (see figure 9), depending on the type of load to be lifted or the necessary reach of the crane arm.

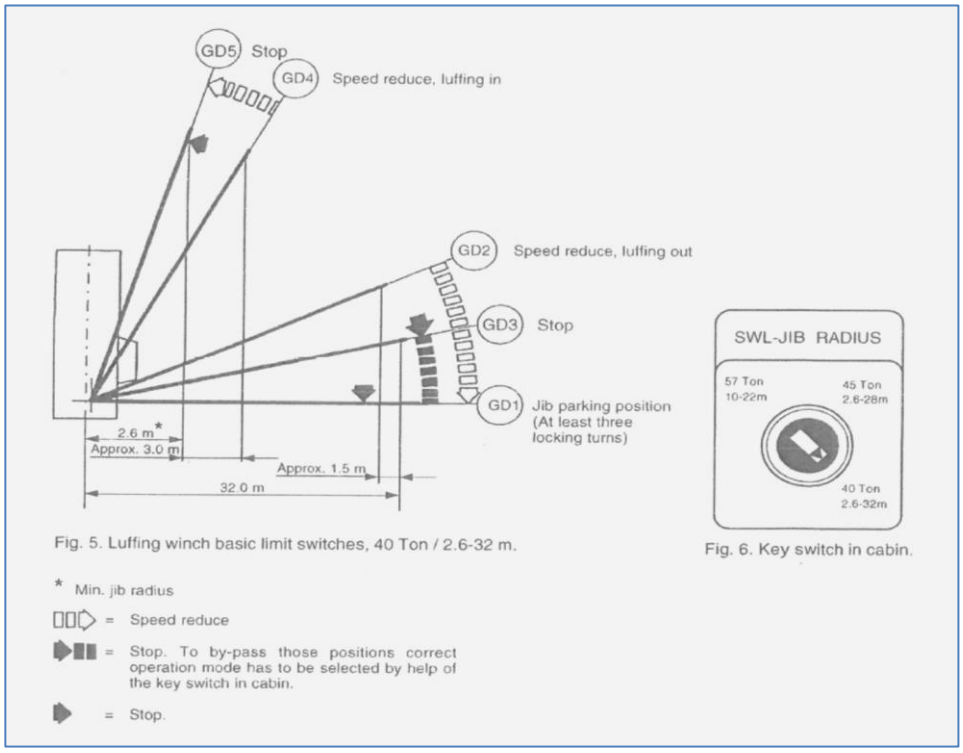


Figure 9. The crane's lower limit switch for 32 m extension position and keyswitch for various lengths/ load on the crane arm. Image: MacGregor Service Manual.

The three different positions provide a maximum reach of 22 m, 28 m or 32 m with the crane arm, and a lifting capacity of 57, 45 and 40 tons respectively. Figure 9 shows ship's crane no. 2 set in the 32 m position, which is the lowest position and angle at which the crane arm can be operated during cargo handling.

The crane arm's movement and operative angles are limited by a number of limit switches with the function of limiting the crane arm so that it is not operated at too high or low level. This is in order to ensure that the crane is not loaded with excessive forces and that the cables which control the crane arm and the pulley block are functioning optimally and have sufficient length remaining on the winch drum.

When lowering the crane arm, lower limit switch GD2 is activated, which reduces the crane arm's downward movement speed. If the arm is lowered further, switch GD3 will be activated, stopping the crane arm in its lowest permissible position for cargo handling. In this position, the crane arm can have an extension limit of 32 metres and a lifting capacity of 40 tones SWL, if the keyswitch is set to this mode. If the setting is at 22 m or 28 m, other limit switches will be activated earlier in order to stop the crane arm at the correct angle.

When parking the crane arm in its support base on the ship's deck, the crane operator activates a “parking” switch (see figure 10) which allows the crane arm to be lowered past the GD3 all the way down to the parking position at “horizontal” level. When it is within this angle, the crane arm must not be loaded.

Figure 10. Keyswitch for activation of parking position.

As a last safety switch for the downward movement of the crane arm into parking position, there is the GD1 limit switch, which is the absolute lowest position the crane arm can be manoeuvred to. In this position, there are at least three loops of cable left on the winch drum. In the parking position, the crane arm has a length/extension of 32.9 m.

At the event in question, neither of the limit switches GD3 or GD1 had been activated. These limit switches were bypassed with an extra 2-way switch (see section 1.5) located in the crane's control cabinet. Switches GD3 and GD1 thus had no functionality whatsoever. The crane arm could both be lowered past the lowest level for cargo handling and parking position. The crane arm could also be loaded within this range of motion.

As stated by the shipping company the latest cable change on the crane was performed in November 2011.

1.4.3 Regular checks and inspection of the crane

Classification society

The ship is under the class for the classification society ABS, the American Bureau of Shipping. ABS conducts annual inspections of the ship and its cargo handling equipment before signing the obligatory certificates for operational approval of the ship. The last annual inspection carried out on the ship's cranes was on 14 October 2014. The results were approved and no remarks were recorded. According to ABS, an extra connection in the crane's electrical cabinet disconnecting the function of the limit switches would have been noted in the annual inspection, during which tests are also carried out on the ship's cranes and their safety functions.

ABS also conducts loading tests on the cranes and their lifting cables. The most recent test was conducted in November 2011.

Self-inspections

The ship has a self-inspection system for the cranes and their equipment. It is the ship's operational crew that carries out these inspections at intervals of 200 and 500 hours of operation on the crane. The self-inspection system also includes monthly inspections of certain equipment on the cranes.

The last 200-hour check was conducted on 21 May 2015 and no remarks were recorded. This check largely covers the control of mechanical components for the crane's driving unit.

The last 500-hour check was conducted on 2 February 2015, and again, no remarks were recorded. This check is more extensive than a 200-hour check and entails a more comprehensive overhaul of the crane's driving unit, cables and certain electrical equipment. According to the procedural instructions for these checks, electrical equipment shall be inspected in accordance with sections in the manufacturer's manual. These checks include inspection of all electrical cabinets and their components, including contacts, switches, cables and the sealing around the cabinet door. The ship's crew has documented that this check has been carried out, but they have not observed any extra switches connected to the control cabinet.

The last monthly inspection was conducted on 1 June 2015. No remarks were recorded. This inspection includes inspection of all electrical cabinets and terminal boxes. The ship's crew has documented that this check has also been carried out, but they have not observed any extra switches connected to the control cabinet. This check was carried out by the chief officer on board the ship.

Work instructions for the various self-inspections as the ship’s crew performed, does not include any operational control of the crane’s limit switches.

1.4.4 Crew

The crew consisted of 18 persons. The majority of the crew had only been on board since the ship was in Varberg on 2 June. The master, the chief officer, chief engineer and the boatswain signed on in April/May. All crew members were relatively new in their positions on board OSLO WAVE, as she had previously had another owner and crew.

1.5 Special tests and research

On the morning of Wednesday 10 June, the day after the incident, a technician from MacGregor, who normally carries out service and reparation on cranes of the type OSLO WAVE was equipped with, came aboard the ship. MacGregor had been contacted by shipping company Oslo Bulk and had been commissioned to carry out checks and inspection of the collapsed crane. The technician commenced by checking ship crane number 2, the crane that had not yet been used for cargo handling. He performed a check of the crane's functions with limit switches for the crane's operating angles. Everything was in order and the crane functioned as it should.

The technician then proceeded to perform checks and inspections on the collapsed crane, whose crane arm was still laying wrecked in the cargo hold. Witnesses to the incident, both on board and ashore, had explained that the crane arm had been operated at a more or less horizontal level, which the technician remarked on as the crane should never be able to reach horizontal level during cargo handling as this corresponds to the parking position. The position of the keyswitch (see figure 9) in the cabin was set to the middle position of 28 m for the crane arm's length/extension. He also saw that the cable that lowers the crane arm had been torn away from the cable lock of the winch drum (see figure 11).

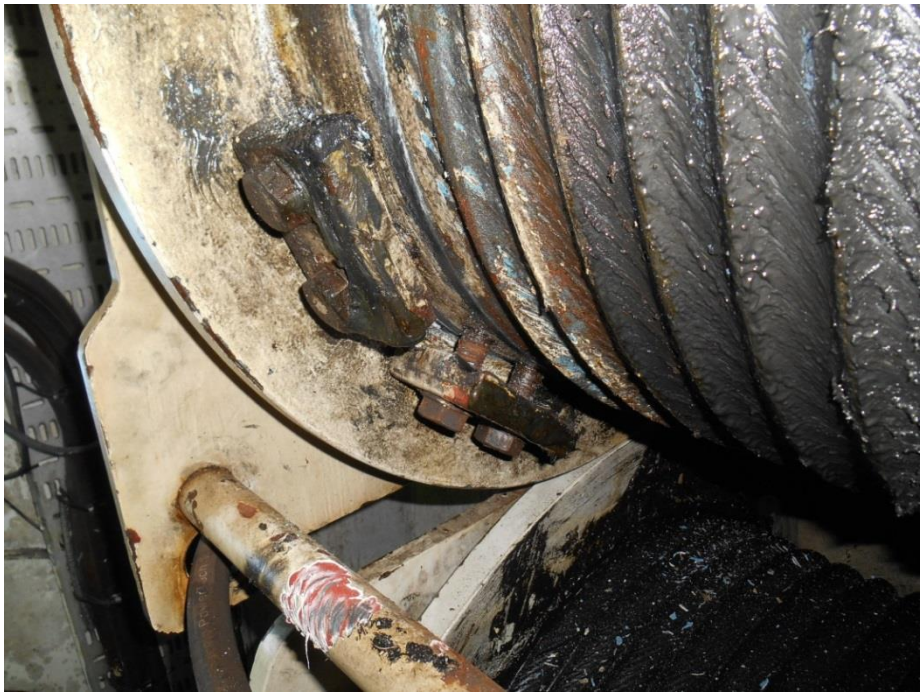


Figure 11. Cable locks on the winch drums. Image: Bulkship Management

The technician then opened the control cabinet, where technical equipment such as the crane's limit switches and contacts are located. He saw almost immediately that the mechanical cams that activate limit switches GD3 (max. extension of 32 m) and GD1 (parking position) had been passed and thereby activated. This means that the crane arm must have been under horizontal level when it collapsed

(the cable came loose from the drum). The mechanical connections were otherwise in good condition. When performing a test run of the winch drum, it was established that both limit switches in question were activated in the correct position, but that they had not given a stop signal to stop the crane arm's downward movement, i.e. making it possible to lower the crane arm to a level which was too low for safe operation.

The technician then opened the control cabinet to check the control indicator lights and established that there were no indicators lit for limit switches GD3 and GD1, which should have been active at this point. In close proximity to this, there was also an extra 2-way switch (see figure 12), mounted on connected cables. The switch was placed about 5-6 cm inside the cabinet edge and in proximity to other cables in the cabinet.

When this switch was flipped over to the alternative position, the light indicators for the limit switches were activated correctly. After having tested the winch again, it was established that both limit switches for the crane arm were now correctly activated and would thereby have stopped the crane arm in the right position for both normal operation and parking position.

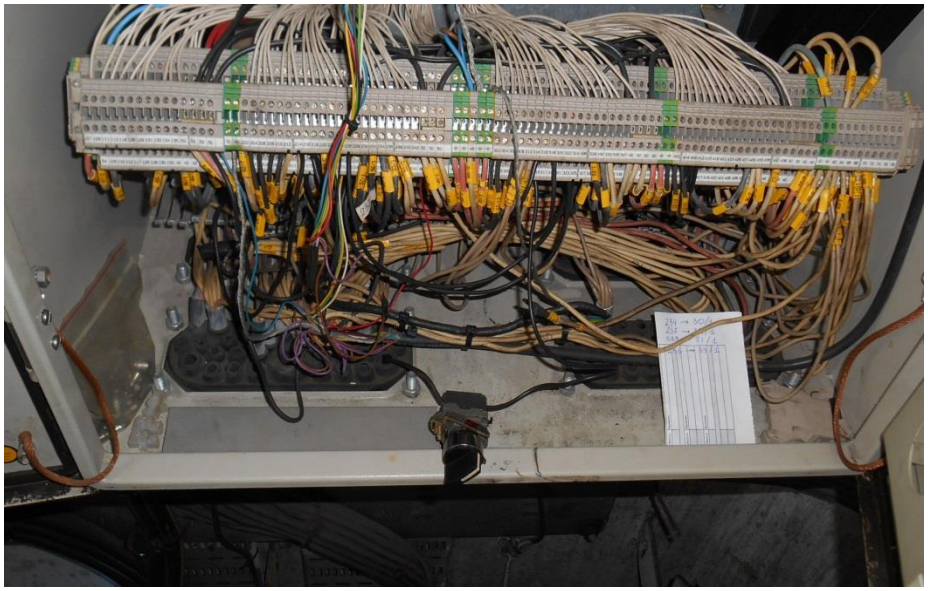


Figure 12. Extra 2-way switch connected. Image: MacGregor.

The activation of this extra 2-way switch functioned in such a way that all safety switches relating to the lower limit for the position of the crane arm were switched off. According to the technician, this switch has had a bypass function and enabled the limit switches for both the crane arm's lowest position and parking position to be by-passed. This means that the crane had been used for cargo handling within a range that entailed insufficient cable length on the winch drum. The weight of the crane arm itself, together with the load in question, was greater than what the cable lock alone has the capacity to hold. The cable was therefore torn away from the winch drum and

the crane arm fell. When the crane arm is in the lowest position for cargo handling (32 m extension), there are normally at least 7–8 turns of cable left on the drum. In the parking position, there are at least 3 turns of cable left on the winch drum.

According to the technician, this extra switch is not part of the crane's standard equipment and was not mounted originally. Another experienced technician has carried out the installation at a later date.

1.6 Legislation and other regulations

1.6.1 Work Environment Act

In accordance with Chapter 1, Section 2 a of the Swedish Work Environment Act (1977:1160), AML, and Section 1 of the Work Environment Ordinance (1977:1166), AMF, certain provisions in the law also apply to foreign vessels in Swedish territorial waters. The following requirements are included:

- The work environment must be satisfactory in terms of the nature of the work and the social and technological development in society, and with regard to the requirements of maritime safety (Chapter 2, Section 1, first paragraph of AML).
- Work shall be planned and arranged so that it can be carried out in a safe and sound environment (Chapter 2, Section 2, AML).
- The workspace shall be designed and equipped in a way that makes it appropriate from a work environment perspective (Chapter 2, Section 3 of AML).
- Machines, equipment and other technical facilities must be constructed, located and used in such a way as to provide a satisfactory level of protection against ill health and accidents (Chapter 2, Section 5, AML).

In accordance with Chapter 3, Section 7 d and e of AML, which also applies to foreign vessels within Swedish territorial waters, responsibility for the coordination of warranted protection measures for a ship loading or unloading in a Swedish port lies with the employer responsible for this work. Responsibility for coordination can be transferred to the port or ship owner. The party responsible for coordination of work environment-related matters must ensure that:

- the work to prevent risks of ill health and accidents is coordinated in the shared workplace,
- a schedule is drawn up for the work, in order to prevent risks of accidents as a result of other operations being conducted simultaneously,

- general safety devices are introduced and safety regulations issued, and that the required responsibility for special safety devices is clarified.

1.6.2 Systematic work environment management

According to the Work Environment Authority's regulations (AFS 2001:1) on systematic work environment management, the employer must investigate, carry out and follow up activities in such a way that ill health and accidents related to the work are prevented and that a satisfactory working environment is achieved. The employer must regularly investigate the working conditions and assess the risks of someone being subjected to ill health or accident at work. The risk assessment must be documented in writing.

1.6.3 Regulations on dock work in Sweden

The Work Environment Authority's regulations and general advice (AFS 2001:9) on port work state that a signalman shall be provided for every lifting device where a person is present within the working area of the lifting device, unless the working area can be kept under surveillance nevertheless. There shall, if necessary, be two or more signalmen for one lifting device. Signalmen shall supervise safety within their work areas and verify that their instructions are complied with. They may not have larger work areas than they are able to keep under surveillance. They shall be provided with and shall use the special equipment needed in order for the work to be done safely. During hoist movements for which signalmen are needed, these persons shall command such a view that the movements can take place without risk. Contact between drivers and between signalmen and traffic guards shall be sustainable throughout the movement. If the driver loses this contact, the movement shall be stopped immediately. The signalman's duties include:

- keeping a close watch on the cargo handling in progress and giving warning well in advance of a suspended load,
- taking up a position where he can be clearly seen by the operator of a lifting device, where he will be safe in the event of a load falling and where he is able to observe as much as possible of the full work cycle,
- directing the operator of a lifting device in a safe, agreed-upon manner,
- exercising special attention with regard to the slinging of goods and to load conditions affecting equipment,
- making sure that everyone employed in the stevedoring operation has left the ship after work is concluded.

The regulations also state that in connection with work on board ship, an on-shore employer shall co-operate with a representative of the ship in order to achieve co-ordination of the work of shipboard and

on-shore employees. The party conducting port work shall transmit written instructions to the ship's representative. The instructions shall describe the rules of safety applying to the port call.

Another stipulation is that prior to the commencement of loading or unloading work on board a ship, the workplace and the technical devices shall be in such condition that the work can be done safely. The technical devices on board which are to be used during the work shall be checked to ensure that they are in working order. Before technical devices (cranes) on a ship are used, steps shall be taken to ensure that they can be operated safely. It is recommended that a lifting test is carried out and that the person who is to use the device should test its manoeuver properties before loading or unloading begins.

1.6.4 Regulations on the use of lifting devices and equipment

The Work Environment Authority's regulations and general advice (AFS 2006:6) on the use of lifting devices and equipment are applicable to the port's equipment, i.e. the barge's knuckle boom crane.

In accordance with Section 9, work with lifting devices and equipment is planned, organised and implemented in such a way that dangerous situations are prevented. In connection with lift operations where representatives from several different activities are involved, one person shall be appointed responsible for planning and implementation of the lift operations. In accordance with Section 11, a load may not normally be transported above unprotected workplaces where people are present.

The regulations also state that if the operator of a lifting device does not have an unobstructed view over the entire lifting area, a signalman shall be used. The latter shall maintain direct contact with the operator and guide them.

1.6.5 The ship's regulation – ISM code

The ship and the shipping company are covered by a regulation known as the ISM[2] code. This is a safety organisation system with the overall purpose of achieving safe navigation and protection for people, environment and property via systematic safety work. A safety organisation is a structured and documented system that allows for a ship's personnel to effectively implement the company's safety and environmental protection policy.

The ISM code stipulates that there must be procedures in place to identify equipment and technical systems that can entail danger if they

[2]International standard for the safe management and operation of ships and for pollution prevention. (ISM: International Safety Management)

are not functioning. The code also states that checks must be performed in accordance with documented procedures and errors are to be rectified by senior staff.

1.7 Companies involved and procedures for cargo handling

A total of four different parties were involved in the ship cargo handling at Bollstabruk. The ship and its crew, Ådalens Farmartjänst (the stevedoring company), SCA (Bollsta sawmill) and Marine Crane (manning of the cranes). In interviews and contacts with these, the following emerged.

1.7.1 The ship and its crew

When loading in Bollstabruk, the ship's cranes were used, but the ship's crew was not involved in the operation of the cranes. The crew normally only prepare the ship's cranes for operation. The officer in charge oversees the loading together with the deck crew and carries out some marking of partial loads in the cargo hold. The crew do not otherwise participate in the actual cargo handling. The ship had drawn up a stowage list for how the cargo would be loaded in to the ship's various cargo holds. The stowage list was handed over before loading commenced.

In interviews, it has emerged that the crew did not consider it necessary for the crane arm to be operated close to its limit positions. They had however observed differences between the cranes in terms of how the cranes' limit positions were activated. It seemed to them that crane no. 2 reached its limit positions at an earlier point than crane no. 1, but they nevertheless believed that the limit switches for the crane arm's lowest position were functioning as they always used a keyswitch (see figure 10) to activate the crane's parking function which would allow them to lower the crane arm to the horizontal parking position. None of the crew had seen or been aware of the additional 2-way switch existence.

The former management of the vessel

The management company that handled OSLO WAVE before 19 December 2015, Wallen Ship Management, Hong Kong, claiming that they have not mounted any extra bypass switch, and that is not something that is encouraged by the company. They make the assessment that the switch has been installed after the takeover in December.

1.7.2 Farmartjänst Ådalen (the stevedoring company)

General

The company has been loading ships in Bollstabruk on commission from SCA since 2005. The personnel working for Farmartjänst are members of an association which in turn owns Farmartjänst Ådalen. They are contractors hired as necessary. Many of the staff have served with Farmartjänst for many years and have previous experience as agricultural workers and entrepreneurs, or combine their activities with work for Farmartjänst. The company's management consists of a CEO and two operations managers, who do not work from Bollstabruk. Farmartjänst has an agreement with the client SCA for stevedoring operations and the loading of ships. In accordance with this agreement, SCA is responsible for coordination at the port. Farmartjänst trains its own personnel. The team leaders receive special training for their role. The CEO is responsible for safety and training-related matters.

Procedures for loading

SCA notifies Farmartjänst Ådalen about the loading of ships and recruitment of personnel. The team leader is available on-site 30 minutes before loading commences and starts by retrieving documents from the port office. These documents are a "Ship/Shore Safety Checklist" and stowage list (where applicable) relating to the load that the ship may have sent in advance. The team leader then continues his inspection of the ship and a run-through with the crane operators. Before loading commences on the first day, the check list shall be reviewed together with the officer in charge on the ship and signed by both parties thereafter. The checklist must then be taken to the port office and archived. According to Farmartjänst Ådalen, SCA is responsible for this document.

According to applicable procedures, it is not permitted for the knuckle boom crane and the ship's cranes to operate in the same cargo hold at the same time. If both cranes are used, they must be operating in different cargo holds. When the knuckle boom crane sets down the load in the cargo hold, no personnel may be present in the hold. The crane operator and team leader have a joint responsibility for monitoring this. During the loading of OSLO WAVE, both crane operators were stand-ins and not regular crane operators at Bollstabruk.

According to Farmartjänst Ådalen, SCA is responsible for coordination between all parties involved in the loading of ships in Bollstabruk. The parties in turn have their own responsibilities as employer. SCA does not exercise daily control of the activities and is not present during loading. Together with Bollsta sawmill (SCA), Farmartjänst Ådalen has conducted risk analyses for the loading of ships. The safety work with risk analyses had commenced in 2006–

2007 and was said to be an ongoing process involving improvement measures for safety and procedures.

In connection with a risk assessment in 2009, the stevedoring company made the assessment that the signalman's position at the top of the framework of the cargo hold on the ship's deck entailed a major risk. The measure taken was to remove the function of the signalman on the ship's deck and instate a new position on the barge instead. At this time, they also more clearly defined the team leader's duty to run through the Ship/Shore Safety Checklist and clarify for all those involved that it was forbidden to enter the cargo hold within the crane's operating area.

1.7.3 SCA (Bollstabruk)

General

Bollsta sawmill in Bollstabruk is part of SCA Timbers. The sawmill supplies pine products for industrial timber, processed wood and standard wood. SCA has an agreement with Farmartjänst Ådalen regarding stevedoring operations in the port. SCA also has an agreement with Marine Crane and hires their personnel and equipment for the loading of ships. Bollsta sawmill has a port director/unloading manager on-site. Bollsta sawmill also has a sawmill manager who has overall responsibility and who is also the appointed coordinator for cargo handling in the port. SCA employs forklift drivers who transport the wood products from the sawmill out to the barge, where they are positioned for loading onto the ship.

Procedures for loading

The company SCA (Bollstabruk) has a documented procedure for the loading of ships: "Running and Operating Instructions, loading – Ship". This set of instructions for personnel, forklifts and cranes defines how work is to be carried out on the barge. It does not include instructions on how work is to be carried out on board the ship. These work instructions do not regulate how and where a signalman is to be used.

SCA is responsible for keeping a documented Ship/Shore Safety Checklist, which is to be run through, filled in and signed together with the ship's appointed representative before loading commences. The checklist covers important points related to the safety of the ship, the crew and other personnel during the port call and loading operations. It is the responsibility of the stevedoring company to carry out procedures using the checklist and thereafter hand it over to the port director (port office, SCA) for registration.

When enquiring with the port (SCA) regarding older checklists for other ships that had previously visited the port, there were none registered for the past six months or the last 8 ships loaded before OSLO WAVE.

The port (SCA) is responsible for coordination regarding the loading of ships in Bollstabruk.

Coordination

Responsibility for personnel and the working environment is partially delegated to subordinates in the company, including the port director, but responsibility for coordination was not delegated. SCA has a cooperation agreement with Farmartjänst Ådalen and Marine Crane and uses these companies and their personnel as subcontractors tasked with loading ships.

The coordinator has stated that the applicable procedures for the loading of ships in the port have not followed the written procedures and checklists to the letter. SCA itself has identified a number of points regarding loading operations that have not been followed. The company has had two internal meetings following the incident with the intention of structuring the operations.

Following the incident, SCA has worked together with Farmartjänst to produce complementary procedures for the loading of ships. These include risk analyses and checks that must be carried out before loading commences. When using the ship's cranes, it is stated that there is now a separate procedure which also covers instructions on how a signalman should be used. When asked how stand-in crane operators were introduced to the applicable procedures and what checks SCA uses for this, the response was that they do not perform full checks and that this was an area for improvement.

1.7.4 Marine Crane AB

General

The company is part of Marine Group and specialises in the servicing of mobile cranes in port operations and other applications. The company provides both a floating barge and a knuckle boom crane for the operations in Bollstabruk. SCA then hires this equipment. Personnel operating the cranes are employed by Marine Crane AB. In this case, personnel from Marine Crane AB also operated the ship's crane.

Procedures for loading

There are no fixed procedures for operators of the ship's cranes. The crane operator conducts their own procedural checks prior to operation. These normally consist of testing various controls and performing a lifting test in order to check the operating angles of the crane. The majority of ship cranes are fairly similar in construction and manoeuvrability. The company's personnel manning the knuckle boom crane undergo internal training for this type of crane.

When the knuckle boom crane is used, no personnel are required to be in the cargo hold to unhook the timber package. The procedure is that the knuckle boom crane may not be operated if there are personnel in the cargo hold. If personnel enter the cargo hold, cargo handling is halted. If it is necessary for personnel to be in the cargo hold due to use of the ship's crane, a signalman/hatch boss must be positioned on the ship's deck towards the seaward side. The signalman, who may not be positioned in the cargo hold, monitors the cargo handling and helps the crane operator get the correct dimensions of the timber packages that are to be loaded. The signalman also has the task of ensuring people do not enter the cargo hold during loading. The only situation in which a signalman is not required is when only the knuckle boom crane is being used, as this does not require personnel to unhook the timber packages. The signalman or hatch boss must be provided by the stevedoring company.

There are special procedures for when both cranes need to be used simultaneously in the same cargo hold. The knuckle boom crane may not be operated in areas where personnel may be present. The cranes must operate in different parts of the cargo hold. A signalman must be positioned on the ship's deck. The joint instructions have been produced in collaboration with Farmartjänst Ådalen. They clarify the procedure involving the signalman/hatch boss and how the loading work is to be carried out.

What has emerged during interviews is that both crane operators have assumed that the crane arm's lowest operating level for load handling was the horizontal level. This is not in line with the crane arm's lowest operating position as the crane arm stops correctly at its lower limit position (see figure 9).

1.7.5 Procedural drift

In all types of regulation or norm-based operations, there is a certain amount of unpredictability in how the work is carried out. This unpredictability can be said to emerge due to the presence of a natural and gradual negative development in terms of how the duties should be carried out compared with how they are actually carried out. If this process continues without any attempts to understand and counteract it, a clear “gap” will emerge between the desired and actual outcome. In the long term, this can lead to accidents. This process has been given the name “procedural drift”.

A system with various duties and tasks has at some point been designed in order to obtain a certain result. This design is normally based on the assumption that people will uphold the original intended working methods, and therefore does not take into account the fact that there can be a procedural drift if the working methods are not continuously monitored.

There can be a number of causes for a procedural drift. Some regulations or procedures can be "over or under-designed" so that they are difficult or even impossible to follow. There may also be different tasks and goals in a work process which are incompatible. Deviations from procedures which do not lead to negative effects can over time reinforce the belief that the deviations are safe, and such deviations from procedures run the risk of becoming normative for the work being carried out.

A change away from the original, intended situation takes place gradually and with small, often unobservable steps. When a procedural drift is allowed to continue without being dealt with, meaning that the gap between the intended and the actual situation increases and the actual situation gets worse, the risk of damage to property or persons increases.

2. ANALYSIS

2.1 Initial observations

The loading and unloading of ships is an operation which involves many different parties. When loading break bulk cargo, assistance from personnel with the lifting equipment is often required, both at the quay and in the cargo hold. The work is carried out with the use of cranes from land or with the ship's own cranes where available. It is important to have solid safety procedures in place where there are crane movements and suspended loads in the immediate vicinity of certain personnel and crew working on the ship.

In conjunction with a loading operation, it is often different companies, together with the ship's crew, that are responsible for the various duties such as crane operation, stevedoring and other port operations. Good planning and coordination is required throughout the process in order to achieve a good level of safety and a sound working environment for all personnel. It is of great importance that an individual with the right conditions and competence is placed in charge; an individual who can ensure good planning and implement the correct preventive measures in order to achieve optimal safety throughout the workplace, including the ship. There may be different conditions for a loading operation in a port, depending on the type and size of the ship to be loaded. Resources and planning are therefore necessary in order to ensure proper staffing. This can for example mean a signalman or equivalent, with the task of monitoring and guiding the loading operation in the best and safest way as possible. It is also very important that procedures and checks regarding safety and the use of equipment are followed in accordance with applicable regulations and that there is uniformity between all personnel involved

in terms of how the procedures are to be applied and who is responsible for what.

In the same way, it is important that the equipment used is fully functional and checked before the loading and unloading operation commences.

2.2 Course of Events

It has been established via the technical investigations that the crane collapsed due to the fact that the crane arm was manoeuvred below its lower limits, which resulted in insufficient cable on the winch drum to bear the weight of the crane arm together with the load in question. The cable locks on the drum thereby came loose and the crane arm collapsed.

At the time of the incident, cargo handling had been under way for around a day and a half, during which time the crane arm had been partially operated in too low a position. The crane may also have been used prior to the incident in Bollstabruk for cargo handling with bypassed lower limits. It is not unlikely that the cable for the crane arm gradually worked its way free of the cable locks and thus slipped out of them. Ultimately, the number of loops of cable remaining on the drum was too few to gain sufficient frictional force on the locks, and the cable has therefore come loose from the drum entirely. In the crane arm's parked position at horizontal level, there are normally at least 3 loops of cable remaining on the drum.

The reason the crane arm could be operated at the lower limit was that an extra 2-way switch had been connected with the function of disabling the lower limit switches for the crane arm.

The central questions in this investigation are when and why the extra switch was connected, why the switch was not noted upon inspection, or when the crane was used, and why the faulty functionality was not noticed before work commenced. Questions have also been raised regarding risk management in respect of the personnel working in the ship's cargo hold during loading.

2.3 The ship and its cranes

2.3.1 When and why was the extra switch installed?

During the course of the investigation, SHK has attempted to establish when and why the extra switch was installed but has not managed to gain any information on this via questions put to and interviews with the crew, classification society and the ship's two most recent management companies.

The reason for installing an extra switch with the function of disabling the crane arm's lower limits, thereby enabling the crane arm to achieve a lower position than normal, is likely to be one of the following:

- To gain extra reach on the crane arm in conjunction with loading and unloading, despite the fact that this is prohibited.
- Specific task for the crane with the intention of being able to lower the crane arm further than normal in connection with service, repairs, maintenance or special jobs during shipyard visits.
- In conjunction with replacing the cable on the winch drum, where it is desirable to lower the crane arm as much as possible in order to facilitate the task.

The ship's crew have declared that they were not aware of the extra switch had been installed. It has not emerged in the investigation that contradicts this. The findings of the investigation tend to indicate that the ship's crane had been manipulated prior to the ship left the shipyard in January 2015. It is also difficult to see a clear reason for disabling the crane arm's lower limit switches during normal operation of the ship, especially seeing as the crew does not operate the cranes themselves during loading and unloading operations. Nor has it been revealed that there should have been a need for extra reach of the crane arm in the crew's very limited use of the crane. SHK therefore assume in the following that is most likely that the switch was not installed after the ship left the shipyard in January 2015.

It has not been possible to shed light on what happened with the crane prior, or during the ship's stay in the shipyard. The previous management company has affirmed that the extra switch not had been installed under their management. It cannot, however, according to SHK's opinion, be ruled out that so actually happened without the management company was aware of it.

The ship's cranes were checked and inspected by ABS in October 2014 and no remarks were made. According to ABS, faulty functionality of the lower limits of the crane arm would have been discovered during this inspection as these functions are always checked. It can, however, according to SHK's opinion, not be ruled out that the extra switch was installed at the time, but it was not discovered at an operational check of the crane, if the switch was in the off-position. In such case, the switch would not have prevented the crane arm's lower limit switches functioning normally.

This would mean that an operational check of the crane would not expose the existence of the switch, but also that the inspection of the crane's control cabinet had been carried out in such a manner that the switch had not been found.

In summary, SHK nevertheless finds it likely that the extra switch was installed at some point during the shipyard visit from December 2014 – January 2015, and that those with knowledge of the alteration of the crane arm's limit positions, had forgotten to reactivate the connection after use, or flip the switch to the position for normal operation.

2.3.2 Why was the bypass switch not detected during use of the crane?

The current crew had only used ship crane no. 1 (the one which collapsed) for loading once prior to the incident in question, and on that occasion the crane was operated by stevedoring personnel. The boatswain had been driving the crane on some five occasions since 15 May, but not in connection with cargo handling. The rest of the crew had only tested the crane without manoeuvring the crane arm to its limit positions. The crew was however of the belief that the crane arm's limit positions were functioning correctly as they always used the crane arm's parking switch to park the crane arm in its support base. The ship's electrical engineer had been on board for five days, and had not been in contact with the crane and its equipment during this time. However, the crew had noted differences between the cranes in terms of the angles at which they could be operated.

The ship's crew was not active in the operation of the crane during cargo handling; they merely supervised the loading process. The crew had not prepared the crane as usual to the stevedoring company to operate it from the parking position to the operation position. This can be explained that most of the crew had been on board a short time and that all procedures had not yet been established.

In summary, according to SHK's opinion, the crew's limited use of the crane and the fact it then seems to have handled only under such conditions that the malfunction does not appear, explain why the crew did not notice the bypass function when using the crane.

2.3.3 Why was the bypass switch not detected during the self-inspections?

The ship had a self-inspection system for cranes and their equipment. All checks were completed with no remarks. These checks are carried out by the crew at intervals of 200 and 500 hours of operation of the crane, as well as monthly checks. The latest 500-hour check was carried out on 2 February 2015 and included, according to the description, checking the cranes' electrical control cabinets. According to the description, the cranes' electrical control cabinets would be opened for a visual inspection of switches, components and sealing around the cabinet door. The ship's crew had documented that this check had been carried out and with no deviations.

The latest monthly check was carried out on 1 June 2015, also without remarks. This inspection was a more general inspection of amongst other things, all electrical cabinets and junction boxes.

If the 500-hour check had been performed entirely in accordance with the description, there would likely have been an opportunity to discover the extra connected switch if it had been in place at the time. The switch was positioned in the bottom of the cabinet, approx. 5-6 cm from the opening in the cabinet frame, and close to other cables; i.e., somewhat further in the cabinet than what it shown in figure 12. The switch's unusual position compared to other equipment could

have given the crew cause for further investigation. This check was carried out by the ship's first crew when the ship was put in service for the new management following the shipyard visit, and before the current crew signed on in the spring/early summer.

The deficiencies in the checks can possibly be explained by that in short time the management and the whole crew was changed, and that the ship was new to the crew and that they had served on board for a relatively short time. The ship's existing documentation regarding equipment and maintenance also indicated that everything was in good order. At times – such as with OSLO WAVE – when there is a change of both crew and management within a short period of time, and everyone is relatively new to their positions on board, the crew must prioritise the most important responsibilities on board. This thereby entails a risk that self-checks of certain equipment will not be given the highest priority. It is thus reasonable to assume that the latest 500-hour check, which was conducted in February 2015, was not as thorough as intended, which may explain why the switch was not discovered despite the check.

2.4 Crane operation at the time

The crane operators in Bollstabruk were provided by Marine Crane. At the time in question, when loading OSLO WAVE, both crane operators were filling temporary roles for operation. The operator of the ship's crane had many years' experience in the profession and was a qualified crane operator. His experience of ship cranes was limited, however, and it had been a long time since he last operated such a crane.

There was no special checklist used by the crane operator before operating the ship's crane. Each crane operator normally carries out their own checks. In this case only a limited operational check of the function of the ship's crane had been performed before operation; once which did not include checking the crane's lower limit.

The Work Environment Authority's regulations and general advice (AFS 2001:9) on port work prescribe a functional check of all technical equipment on board that is to be used during the course of work. It must also be ensured that manoeuvring can be performed safely and it is recommended that a lifting test is carried out and that the person who is to use the device should test its manoeuver properties before loading or unloading begins.

The regulations and the general advice are however, for natural reasons, generally observed, and the matters of how the functional check will be carried out and what the crane operator should react to vary from one crane to the next. In this case, there was no crane-specific support material in the form of a manual or similar, to allow the crane driver to determine whether or not the limit position had been exceeded. This means that a practical functional check in

accordance with the Work Environment Authority's regulations, in order to ensure the lower limit position was activated, instead could lead to the crane collapsing as early as this stage as the crane operator had no knowledge of what was the “right angle” for the lower position.

If the crane operator had known the lower limit’s position and specifically performed a test of the lower limit position, however, it is reasonable to assume that the latter would have reacted to the crane's poor functionality. The crane operator may then have had an opportunity to inform the work management or the ship of the crane's defective safety functions before cargo handling commenced. It would thereby have been more probable that the manipulated crane arm's limit positions would have been discovered at this point, or that the crane would not have been used for cargo handling.

A specific check of the lower limit was not performed before the loading work commenced. It was however clear to the crane operator from an early stage of the cargo handling that it was possible to lower the crane arm to a very low position, and the crane operator even asked his colleague in the knuckle boom crane about the crane arm's position. It is difficult for the crane operator sitting in the control cabin to determine exactly what level the crane arm is at, but for people standing at a distance from it, the angle is considerably easier to perceive.

The crane operator has stated that during operation, he focused on keeping the crane arm at an angle of less than 90 degrees; i.e., above horizontal level. This gives the impression that the crane operator believed the crane arm could normally be operated as low as a horizontal level. Neither the operator of the ship's crane nor the operator of the knuckle boom crane appear to be aware that when the crane arm was at horizontal level, this corresponded to the crane arm's parking position and not the normal operating position.

That the crane operator did not understand that it was fault with the crane based on the fact that the crane arm could be lowered to horizontal position without any of the limit switches activating, can be explained by lack of crane-specific information or checklists, combined with the crane operator's limited experience of ship cranes. The questions to the colleague in the knuckle boom crane about the crane arm’s position may indicate that the crane operator not was sure that everything was working properly. In addition to this is the fact that a decision to interrupt a loading operation can be perceived by the individual crane operator as a major decision which has significant implications for both the port and the ship. This may thus act as a deterrent and may explain why a person does not take such a decision without be completely sure that something is wrong.

2.5 Cargo handling in general

2.5.1 Procedures

The only documented routines that exist regarding cargo handling have been produced by SCA: "*Kör och Arbetsinstruktion Utlastning - Båt*" [Operation and Work Instruction loading - Boat] and "*Skyddsinstruktion Utlastning*" [Safety Instruction, loading]. None of these instructions look at how the work is to be carried out on board the ship; only on the barge.

In addition, the Work Environment Authority's regulations and general advice (AFS 2001:9) on port work prescribes that a signalman be used for conditions such as those prevailing in the loading operation.

According to information from Farmartjänst Ådalen and Marine Crane, there were "verbal procedures", i.e. some form of established practice, regarding how the knuckle boom crane and ship crane respectively were to be operated and when the personnel were allowed to be in the cargo hold. These procedures were somewhat contradictory. It was for example stated that the knuckle boom crane and the ship's crane could not be operated at the same time in the same cargo hold, whilst it was also stated that if this was to take place, there were special procedures for this. It has also arisen that there is different information in the procedures regarding how a signalman is to be used.

During the investigation it has also emerged that neither the stevedores nor the crane operators fully understood how these verbal procedures and the Work Environment Authority's rules was to be applied. Nor was there an established means of communicating these verbal routines to new personnel, such as a substitute.

There was thus no uniformly documented and implemented system for ensuring that all personnel involved had knowledge of how the work is intended to be carried out, what special risks were involved and how these risks should be managed. Instead, the "system" actually used was seen to be based on the individual's professional knowledge and awareness of how the work was generally carried out. A system of this nature is fraught with risks and may explain why two people were located in the cargo hold beneath the crane without the supervision of a signalman in conjunction with the crane's operation; this despite the fact that this was prohibited in accordance with the "verbal procedures" and the Work Environment Authority's provisions.

If a signalman had been positioned on the ship, this would have facilitated the use of the ship's aft crane, also in cargo hold no. 2, in the area where the forward crane experienced difficulties with the reach, and which at the time of the event required the assistance of the knuckle boom crane when positioning cargo. Without a signalman,

however, the aft crane cannot be used in this area as the visibility down in this part of the cargo hold is restricted by the open cargo hatches (see figure 9). It can be noted in this context that it is dubious as to whether it would be at all possible to load in the farthest corner, as seen from the forward crane, if the limit switch was functioning normally. This is something which does not appear to have been taken into closer consideration when planning the loading operation.

In summary, there are several uncertainties in terms of the management intended the work to be carried out, how this was communicated to those carrying out the work and how it was ensured that the work was actually carried out in the manner intended. According to Accident Investigation Authority, there is significant room for improvement in this area.

2.5.2 Checklist

The loading was also covered by requirement of a documented checklist of safety procedures, "Ship/Shore Safety Checklist" which the port (SCA) was responsible (see section 1.7.3). The checklist was however not used for the loading of OSLO WAVE.

During the investigation it has emerged that there is uncertainty over how the procedure with the checklist is to be applied and who is responsible for ensuring it is used and documented. The port (SCA) has assumed that the stevedoring team takes care of this, without performing checks to ensure this is the case. The stevedoring team's understanding was that the team leader runs through the checklist prior to loading the ship, but believed that ultimate responsibility lay with the port.

If personnel, such as team leaders are switched from one day to the next, there are no procedures in place to ensure that the information regarding the checklist has been performed. OSLO WAVE was the 9th ship that had loaded in Bollstabruk since December 2014, and it has been revealed that this checklist had not been used for the previous 8 ships that had been loaded in the port either. Neither of the parties had reacted to the fact that the pre-loading checklist had not been used for a long time. There was no clear procedure agreed between the port manager (SCA) and stevedoring team leader which could ensure this procedure is followed.

These shortcomings have not affected the incident in this case, but indicates weaknesses in the system which have not received attention and been rectified.

2.5.3 Coordination between various actors

Responsibility for coordination between all actors in the port regarding the loading of ships lies with the port (SCA). The port's appointed coordinator was stationed at the port, Bollstabruk. During the investigation, it has been revealed that the role of the coordinator has not been entirely clear. A diffuse image has been given of who has responsibility and how this job was secured in the workplace. According to the Work Environment Act, the person responsible for coordination of work environment issues shall make sure to prevent risks of ill health and accident and to ensure safety devices and regulations in the workplace as correctly employed. Responsibility for coordination largely entails responsibility for good planning of the workplace between all parties involved.

According to SHK, there seems to be shortcomings in the coordination between the parties involved in the loading of ships in Bollstabruk, primarily in terms of which procedures apply and are to be applied when loading and unloading ships (see section 2.5.1).

SHK consider it to be of major significance that all procedures are coordinated and that everything is clearly documented, and that clear responsibility is allocated for the different parts. It is also of great importance that the procedures are established among all concerned personnel and that there is a focus on a safe work environment.

2.6 Procedural drift

SHK states that rules and several of the written and verbal procedures were not applied in the business. This applies particular “Ship/Shore Safety Checklist”, personnel in the cargo hold when the knuckle boom crane is used and Work Environment Authority's provisions regarding use of the signalman. In some cases, as was the case with regard to the use of a signalman, there has been an active decision to not follow the provision in its wording. In other cases, it appears more gradually have developed an approach that did not follow the procedures in order to more effectively solve the work tasks. These conditions indicate that there are procedural drift in the business and lack of or inadequate controls performed to anticipate them.

2.7 CONCLUSIONS

2.7.1 Findings of the investigation

a) The ship had a new management and crew with only a short period of service on board.
b) The safety checklist prior to loading was not used.
c) There was uncertainty regarding who was in charge and had responsibility for the checklist, and how this was to be documented.

d) The role of coordinator for loading in the harbour was not entirely clear.
e) The ship's crane was manipulated, having an extra 2-way switch installed which had the function of bypassing important limit switches.
f) The crew had not discovered the extra 2-way switch during the course of their own self-inspections.
g) The operator of the ship's crane conducted only a limited operational check of the crane before operation.
h) Cargo handling had been under way for around a day and a half and the crane operator felt unsure of the crane's functionality.
i) The cargo handling was carried out using the shore crane and the ship's crane at the same time in the same cargo hold.
j) The cargo handling took place without the assistance of a signalman and there was uncertainty as to if and when a signalman should be used.
k) Handover from one work day to the next between all personnel was inadequate.
l) Inadequate procedures were in place for the cargo handling in terms of work on board the ship.
m) Certain work procedures were not documented.
n) There were personnel from the stevedoring company in the cargo hold during the loading with the ship crane and knuckle boom crane in violation of applicable procedures.

2.8 Causes

The collapse of the crane arm was caused by the fact that it was set up in such a way that it was possible to lower the arm to a point which was too low for cargo handling; such that there was insufficient cable remaining on the winch drum to hold the combined weight of the crane arm and cargo load. The reason it was possible for the crane arm to be lowered to this low point was that the low limit switches had been bypassed by means of an extra switch installed in the crane's control cabinet.

A contributory factor was that the self-inspections on board the ship were not carried out in such a way that the extra power switch was discovered. The crew were thereby not aware of the inadequate functioning of the crane's safety features.

Another contributory factor was that the operator of the ship's crane did not perform a full operational check of the crane before operation.

3. MEASURES TAKEN

3.1 SCA and Farmartjänst Ådalen

Following the incident, SCA (the port) worked together with Farmartjänst Ådalen (the stevedoring company) to produce supplementary procedures for loading ships in Bollstabruk. These new procedures encompass a new checklist which clarifies matters of safety in connection with various tasks on board the ship and the barge. The checklist includes, among other things directions regarding when a signalman shall be used and what their task is.

The stevedoring has produced a checklist for functional checks of the ship's crane before operation, in which the crane operator must provide confirmation to the team leader that a full functional check has been performed before loading can commence.

SCA (port) has in the company's reporting system for deviations, also implemented port operations in order to quickly dispose deviations with corrective measures.
All appropriate personnel regarding the work at the port has received information about the revised documents and procedures.

3.2 Bulkship Management AS

Following the incident, Bulkship Management (the shipping company) has produced a specific checklist which the ship's crew shall apply before the cranes are to be used. This checklist covers checks of the crane's various functions and important safety devices before operation. The checklist must then be signed by both the ship's chief mate and the operator of the ship's crane.

3.3 Marshall Islands

Ship's flag state, the Marshall Islands, plans to take the following actions related to the event:

- Make the ship's classification society aware of the finding of the installed bypass switch that enabled the crane could be operated outside the safety zone.
- Make the ship's classification society aware of the deficiencies in the company's Safety Management System (ISM Code) concerning the crew's unfamiliarity with some equipment on board.
- Make the company's classification society aware of the deficiencies in the company's Safety Management System (ISM Code) related to the event.

4. SAFETY RECOMMENDATIONS

The safety issues which SHK has identified in this investigation are primarily the lack of documented and implemented procedures for loading and unloading of ships. It has also been established that a safety-critical function in the crane has been bypassed, which was not discovered prior to use.

SHK deems the measures taken (see section 3) to be appropriate.

When it comes to the shipping company, it has during the investigation emerged indications that the self-inspection system does not work in such a manner that deviations are sure to be detected. Even if the measures taken by the shipping company today should lead to a malfunction identified before a crane is used, it also need to be taken measures to ensure that all checks performed in accordance with the ship's SMS are done complete and in correctly manner.

Bulkship Management AS is therefore recommended:

- Take action to ensure that the checks to be carried out in accordance with the ship's SMS are sufficiently thorough to enable the identification of deviations before safety-critical work activities begin (*RS 2016:04 R1*)

The Swedish Accident Investigation Authority respectfully requests to receive, by **1 September 2016** at the latest, information regarding measures taken in response to the recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas Jörgen Zachau