MA2015-4

MARINE ACCIDENT
INVESTIGATION REPORT

March 26, 2015

JTSB Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board is to determine the causes of an accident and damage incidental to such an accident, thereby preventing future accidents and reducing damage. It is not the purpose of the investigation to apportion blame or liability.

Norihiro Goto
Chairman,
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

MARINE ACCIDENT INVESTIGATION REPORT

March 12, 2015

Adopted by the Japan Transport Safety Board

Chairman Norihiro Goto

Member Kuniaki Shoji

Member Satoshi Kosuda

Member Toshiyuki Ishikawa

Member Mina Nemoto

Accident type	Injury of worker
Date and time	September 11, 2013, at about 17:00 (local time, UTC +9 hours)
Location	Nakashima Quay No. 3, Port of Himeji, Himeji City, Hyogo Prefecture 160° true, 540 m from Shikama Higashi East No.2 Breakwater Lighthouse, located in Himeji City (approximately 34°46.2' N, 134°39.6'E)
Summary of the Accident	The cargo ship GREEN HOPE, carrying the master and 20 crew members, was discharging a cargo of timber at Nakashima Quay No. 3, Port of Himeji. At about 17:00 on September 11, 2013, deck crane No. 1 collapsed and caused injury to the crane operator.
Process and Progress of the Investigation	(1) Setup of the investigation The Japan Transport Safety Board appointed an investigator-in-charge and one other investigator to investigate the accident on September 12, 2013. (2) Collection of evidence On-site investigation and interview on September 13 and 14, 2013, interview on September 19 and 20, and November 5, 6 and 20, 2013, interview on April 22, May 26, and July 25, 2014, collection of questionnaire on October 2 and 8, 2013, January 20, April 25, May 9 and 27, June 4, July 2 and 28, August 6, 7 and 22, 2014, and interview and collection of questionnaire on May 30, 2014. (3) The National Maritime Research Institute has been tasked with the analysis and investigation of a bolt fracture in connection with this accident. (4) Comments on the draft report were invited from parties relevant to the cause of the accident. (5) Comments on the draft report were invited from the GREEN HOPE's flag state.
Factual Information Vessel information Vessel type and name	 Cargo ship GREEN HOPE (hereinafter referred to as "the Ship")

IMO number	9261750
Gross tonnage	21,185 gt
Port of registry	Panama, Republic of Panama
Owner	TUI MARITIME S.A. (Republic of Panama)
Management company	Sojitz Marine & Engineering Corporation
Class	NK
L×B×D, hull material	178.03 m × 28.00 m × 15.00 m, steel
Engine, output, date of launch	Diesel engine, 7,080 kW, May 2002
Deck crane information	(1) The Ship was equipped with four deck cranes. Deck crane No. 1 (hereinafter referred to “the crane”) was installed between cargo hold No. 1 nearest to the bow and cargo hold No. 2 behind that. Deck cranes No. 2 to 4 were installed similarly between the respective cargo holds No. 2 to 5. (Refer to photograph 1.)  Photograph 1: External view of the deck cranes on the Ship (2) The following is a description of the use of the deck cranes on the Ship. ① The Ship was loaded with approximately 36,000 pieces of timber from a port in New Zealand, which was then unloaded at a Japanese port. She made this journey on the average of eight to nine times a year. ② The maximum load that could be taken by the hooks on the deck crane during the cargo handling was about 26 t in New Zealand, where wire hooks were used, and about 22 t in Japan, where grab buckets were used. ③ The cargo handling was generally carried out on the starboard side. (3) The performance, structure, and other aspects of the crane were as follows. ① Performance The crane had a maximum slewing radius of 22 m, and a limit load of 30.5 t. Operation stopped when the limit load was exceeded. ② Structure The crane was made up of a crane house, jib, wire rope, hook, and other parts. It was attached to the top of the cylindrical post on the deck. A hoisting and luffing winch, and other parts were set up inside the crane house, while a slewing bearing was attached to the bottom part of the crane house.

The outer circumference of the slewing bearing was fastened to the crane house by 60 bolts (hereinafter referred to "crane-side bolts"), while the inner circumference was fastened to the post by 60 bolts (hereinafter referred to as "hold-down bolts"). (See Figures 1 and 2.)

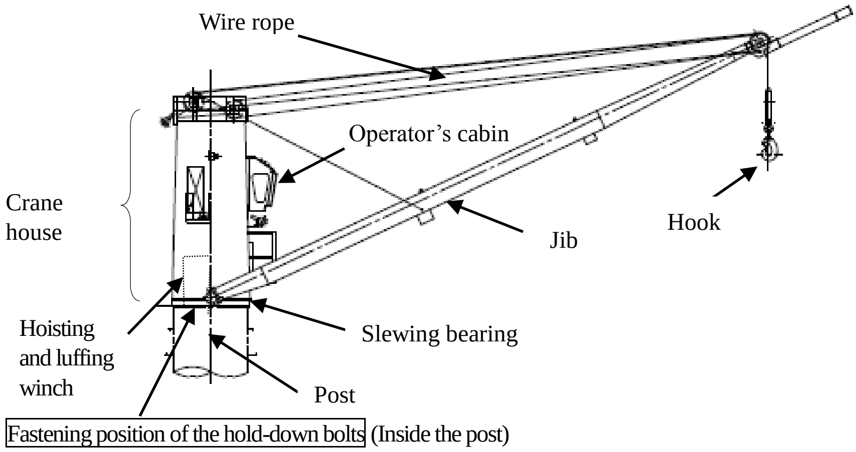


Figure 1: Side view of the crane

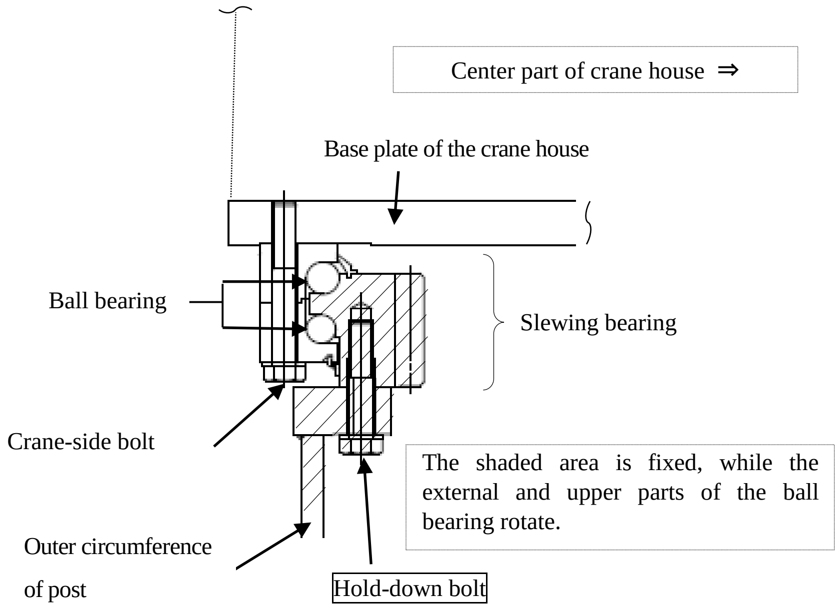


Figure 2: Magnified view of the areas around the hold-down bolts (cross-sectional view)

③ Overview of the hold-down bolts

The following are the standards, material, and other information about the hold-down bolts according to the product inspection certificate (issued on September 4, 2001).

- Standards: JIS B1180 Annex
- Material: SCM435H
- Tensile strength：1,059 N/mm²
- Main dimensions: Outer diameter 33 mm, length 165 mm, pitch 1.5

	mm ▪ The chemical composition and strength met the standards. ▪ The shape, dimensions, thread precision, and external appearance were all satisfactory. (See photograph 2.)  Photograph 2: Same type of bolt as the hold-down bolt The crane-side bolt was of the same material and shape as the hold-down bolt, except that its length was 230 mm and its pitch was 2.0 mm. (4) The crane was designed by the heavy machinery manufacturer that sold the crane (hereinafter referred to as “Company A”), manufactured by a marine equipment manufacturer (hereinafter referred to as “Company B”), and installed on the Ship by the shipyard (hereinafter referred to as “Company C”). Company B also began to sell the deck crane designed by Company A in 2004. Company B became the exclusive seller in 2007. (5) As of September 2013, 280 deck cranes of the same model as the crane had been manufactured (including the crane). If other models of a similar structure with the deck crane designed by Company A were included, 1,591 cranes had been manufactured. However, there had been no cases of bolts that fasten the crane house to the post fracturing. There had also been no reports of loosened bolts. (6) At the time of this accident, the crane operator had not experienced any abnormalities in the operation of the crane.
Crew Information	(1) Master (Nationality: People’s Republic of China), male, 51 years old Endorsement attesting the recognition of certification under STCW regulation: Master (Issued by the Republic of Panama) Date of issue: January 10, 2012 (Valid until June 24, 2016) (2) Chief Officer (Nationality: People’s Republic of China), male, 39 years old Endorsement attesting the recognition of certification under STCW regulation: Chief Officer (Issued by the Republic of Panama) Date of issue: March 13, 2012 (Valid until December 31, 2016) (3) Crane operator, male, 38 years old

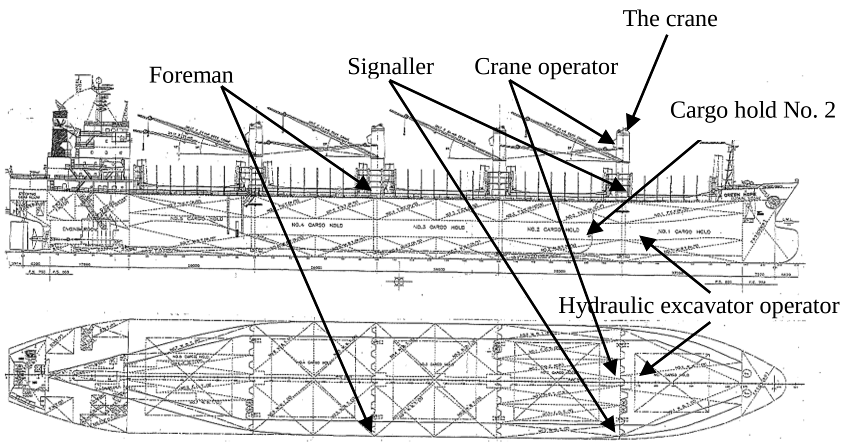
<table>
<tr><td></td><td>Acquired crane operation qualifications about three years ago. When the Ship entered the Port of Himeji, he was mostly engaged in the operation of the crane, and was accustomed to operating the crane. He was in good health at the time of the accident.</td></tr>
<tr><td>Injuries to persons</td><td>Serious injury to one person (crane operator)</td></tr>
<tr><td>Damage to Vessel (or Other Facilities)</td><td>Complete loss of the crane. Additional damage includes the bending of the hatch cover for cargo hold No. 2.</td></tr>
<tr><td>Events Leading to the Accident</td><td>(1) Movements of the Ship
The Ship was loaded with 35,945 pieces of timber, and there had been approximately 10.85 m of draught for both the bow and stern. At about 06:50 on September 5, 2013, after it berthed at starboard side at Nakashima Quay No. 3, Port of Himeji, the grab bucket used to hold the timber was attached to the deck crane with a hook.
The Ship was engaged in discharging cargo from about 08:00 to about 18:00 on September 5, and from about 07:30 to about 18:00 every day from September 6 to 10 with the exception of Sunday.
(2) Conditions when the accident occurred
① The Ship began discharging cargo at about 07:30 on September 11, 2013.
The crane lifted 10 pieces of timber in cargo hold No. 2 using a grab bucket at about 17:00, handled by the stevedores, as shown in Figure 3. The grab bucket was lowered while slewing to the left, and the crane collapsed toward the starboard stern when the grab bucket came to a position of about 2 m above the quay. The operator’s cabin hit the end of the hatch cover (hereinafter referred to as “the hatch cover”) at the front side of cargo hold No. 2, in an open and erect position, and was damaged. (Refer to photographs 3 and 4.)


Figure 3: Positions of the stevedores at the time of this accident (related to the crane)</td></tr>
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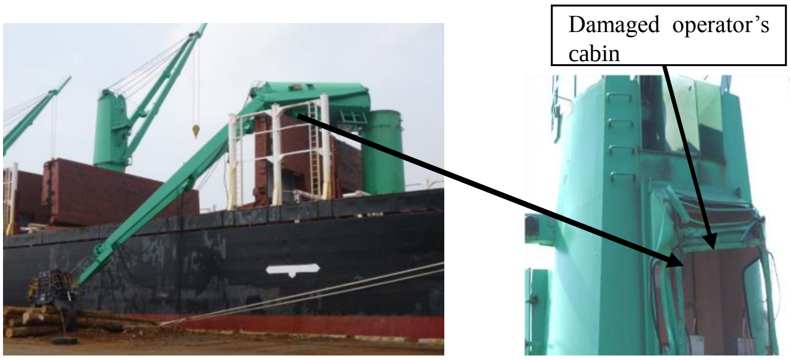


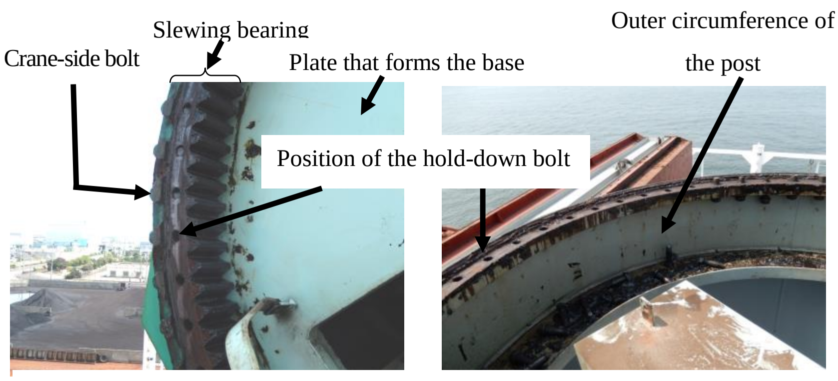
Photograph 3: The collapse of the crane

Photograph 4: Damage to the operator's cabin

The draught at the time of this accident was about 6.5 m at the bow and about 7.7 m at the stern.

② When the crane collapsed, all the hold-down bolts were fractured, and the upper end of the post tore open. (Refer to photographs 5 and 6).

Among the hold-down bolts, two bolts had rusted completely over the entire surface of the fracture.



Photograph 5 (left): Collapsed state of the crane (lower part of the crane)
Photograph 6 (right): Upper end of the post at the lower part of the crane

(3) Rescue operations after this accident

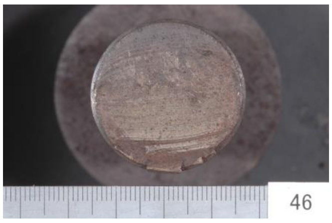
After the crane collapsed, the crane operator used the ladder hanging on the operator's cabin and lowered himself to the roof of the deck hold that was below the crane. He was transferred to the hospital in an ambulance that arrived at about 17:20, and was diagnosed with multiple traumas (hip contusion, lower right leg contusion, pelvic fracture) requiring about three months of hospitalization.

Weather and Sea Conditions	Weather: Weather - Fine, Wind - South, Wind force – About 3 m/s Sea conditions: Calm

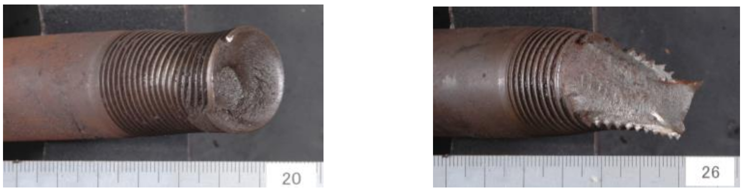
Analysis of the fracture to the hold-down bolts conducted by the National Maritime Research Institute

The results of the analysis were as follows.

(1) There were fatigue fractures (fractures caused by repeatedly applied loads) on 36 hold-down bolts, mostly located on the port side of the post. There were also only ductile fractures (fractures caused by loads above the tensile strength) on the 24 remaining hold-down bolts, mostly located on the starboard side of the post. (Refer to photographs 7 and 8, and Figure 4.)

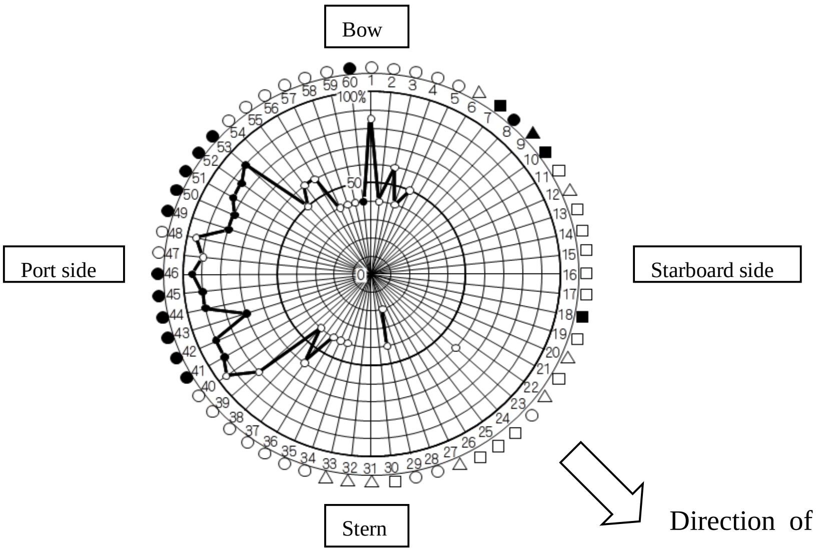


Photograph 7: Fatigue fractures on the hold-down bolts



(Cup and cone type) (Not cup and cone type)

Photograph 8: Ductile fractures arising on the hold-down bolts



●○ : Bolts with fatigue fractures

■□ : Bolts with ductile fractures only

▲△ : Bolts with ductile fractures only (cup and cone type)

(The line graph in the figure above shows the proportion of the fatigue fracture surface.)

(The black marks above show bolts remaining in the bolt holes, while the white marks show bolts that had escaped and fallen from the bolt holes.)

Bolt in position 8: Did not become detached. (Unable to compute the surface area of the fatigue fracture)

Position of the white-mark bolts: Estimated from the position that they had dropped to in the tray 400 mm below.

Figure 4: Distribution of damage for all the hold-down bolts

	(2) The following are the verified and highly probably causes leading to the fatigue fractures in the 36 bolts described in (1) above (hereinafter referred to as “the bolts”). ① The fatigue fractures occurred near the first screw thread (the lower part of the screw thread that is interlocking with the locking screw in the way the hold-down bolt is fastened in Figure 2). ② The hardness of the screw part adhered to values set out in the standards. (There were no abnormalities in the heat processing.) ③ Processing flaws and signs of processing flaws were not found on the underside of the screws. ④ Although there was light rusting on the fracture surfaces of the two bolts, rust was mostly not found on the screw parts, and it is highly improbable that rust had been the factor causing the fatigue fractures.
Other Matters	(1) According to the inspection table for the deck crane in the safety management manual, the items that required monthly inspection through visual checks and other means included sound and oil leakage from the hydraulic motor and hydraulic pump, quantity of lubricating oil, grease on moving parts, paint, steel plate parts, and wire ropes. (2) According to the instruction manual for the deck crane on the Ship, the requirement was to check if the hold-down bolts had come loose in the maintenance and inspection carried out every three months (hereinafter referred to as “the inspection for loose bolts”), to check their conditions before operations, and to tighten them where necessary. (3) The management company of the Ship (hereinafter referred to as “Company D”) considered that it would be acceptable to inspect the looseness of hold-down bolts by checking if any bolts had come off, and had not given the Ship instructions to inspect the bolts for looseness. (4) The work of installing the hold-down bolts during the new construction of the Ship by Company C had been undertaken based on procedures for torque tightening as stipulated in the outfitting manual drawn up by Company A. The foreman had verified each process during the outfitting period. (5) The crane had not been damaged up to the point of the maintenance carried out most recently before this accident (in July and August 2012). From the point of the maintenance to the point of this accident, there had also been no reports of damage from the Ship to Company D. (6) There had been no cracks observed on the crane-side bolts. (7) Through magnetic particle inspection and torque wrench, it was verified that there were no cracks or looseness on the 60 bolts on the post side of deck cranes No. 2 to 4 of the Ship.

	(8) According to the first volume of *Zairyō Rikigaku* (Ichiro Nakahara, published by Yokendo Co., Ltd. in 2010), material fatigue is explained as follows. *13.11 Material fatigue* （Omitted） *Repeatedly applied loads make the material fatigued and weakening. This is known as material fatigue.* （Omitted） *When stress is repeatedly generated without causing plastic deformation, the weakest part of the material, for example the part where stress is concentrated on, first produces fine cracks. Once a crack occurs, the stress on both ends of the crack becomes extremely large, and the cracks increase progressively with load thereafter. The cross-sectional area that bears the load gradually becomes smaller, and a fracture arises in the instant when an amount of stress equal to the fracture stress is applied.*
Analysis Involvement of crew members Involvement of vessel, engine, etc. Involvement of weather and sea conditions Analysis of the findings	Yes Yes No (1) The crane operator sustained multiple traumas (hip contusion, lower right leg contusion, pelvic fracture). (2) While the Ship was discharging timber at Nakashima Quay No. 3, Port of Himeji, all the hold-down bolts were fractured and the crane collapsed. It is highly probable that the operator’s cabin had hit the hatch cover, and became damaged. (3) It is probable that all the hold-down bolts became fractured in the following process. ① The handling of cargo for the Ship had usually been carried out on the starboard side. As such, fatigue fractures had developed and grew near the first screw thread on the bolts, mostly for the hold-down bolts on the port side of the post where the load had been relatively large. ② Among the bolts as described in ① above, the fracture surfaces for two bolts had rusted completely (bolts on positions 40 and 47 in Figure 4). Based on this, at least two of the bolts had been fractured before this accident, while the remaining became fractured during this accident. ③ As a result of the fracture to the bolts as described in ② above (hereinafter referred to as “the fatigue fracture”), the load of cargo

	handling was placed on the 24 bolts, mostly the hold-down bolts on the starboard side of the post that had not suffered from any fatigue fractures. Hence, these bolts became fractured. (4) Based on the following reasoning, it is somewhat likely that the fatigue fracture on the bolts had resulted from repeated cargo handling with some of the bolts in a loosened condition (including the two bolts in (3)② above). Typically, fatigue fractures arise in a bolt in one of the following cases: ① when excessive external force is applied repeatedly to the bolt, or ② when external force is applied repeatedly to the bolt in a state of stress concentration arising from fine cracks. Hence, the cause leading to the fatigue fracture on the screw part of the bolts, as shown in the following table, are hypothesized to be a ~ c. However, cases a and c did not arise during the actual handling of cargo on the Ship, and it is probable that b had occurred. On the other hand, the situation leading to the loosening of some of the bolts could not be elucidated, and it could not be verified that the bolts had become loosened.

	① Excessive external force applied repeatedly to the bolts		②External force applied repeatedly to the bolt in a state of stress concentration arising from fine cracks
Hypothesis	a. Repeated cargo handling exceeding the limit load.	b. Repeated cargo handling with some of the bolts in a loosened state.	c. Repeated cargo handling with fine cracks in the screw parts that had arisen from impact or other factors.
Actual cargo handling	The actual weight of the load during the cargo handling had been less than the limit load. Even if the limit load had been exceeded, the crane would have stopped operating.	As inspection had not been carried out for the loosening of the bolts, the bolts had not been tightened. There was room for the probability of case b occurring.	The crane and the crane-side bolts did not incur any damage through impact or other factors. As such, cracks did not develop in the bolts as a result of impact or other factors.

	(5) As Company D had not given the Ship instructions to inspect the bolts for looseness as stipulated in the instruction manual, it is somewhat likely that repeated cargo handling was carried out with some of the bolts in a loosened state.
Probable Causes	It is probable that this accident, which occurred on the Ship at Nakashima Quay No. 3, Port of Himeji, had occurred due to fatigue fractures in the bolts during the discharging of timber from the Ship, which caused all the remaining hold-down bolts that took on the full weight of the load to become fractured, the crane to collapse, and the operator’s cabin to hit the hatch cover.

	It is somewhat likely that the fatigue fracture to the bolts had resulted from repeated cargo handling with some of the bolts in a loosened state. It is somewhat likely that the repeated cargo handling with some of the bolts in a loosened state had occurred because Company D had not given the Ship instructions to inspect the bolts for looseness as stipulated in the instruction manual.
Safety Actions	After this accident, Company A issued a document dated October 23, 2013, requesting ship management companies and owners of ships equipped with deck cranes designed and sold by the company to promptly check all bolts following the breakage of hold-down bolts, to take measures such as tightening of bolts when loosened bolts are found, and to disseminate the information to all parties concerned in case that ownership changes. Since December 2013, Company B has explained to crew members the need to carry out inspections for loosened bolts when delivering ships equipped with the deck cranes that it sells. In addition, from November to December 2014 Company B also made the same request regarding the contents in the document described above to the ship management companies and owners of ships equipped with deck cranes designed by Company A except those Company A had already informed. Starting January 20, 2014, Company C has recorded torque-tightening work during the installation of hold-down bolts, and carried out this work using checklists that are checked by several people. The following measures would help to prevent recurrence of similar accidents: ・With regard to inspections for loosened bolts in order to prevent the collapse of deck cranes, give instruction from Company D to the master and crewmembers in charge of inspections, developing a reliable implementation method through the use of an inspection table or other means, based on accurate technical information from the manufacturer and instruction manuals.