

# Rudder and Rudder Horn Repair on the Bulk Freighter Sophia D

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The Island of Curacao is part of the Netherlands Antillean, located in the Caribbean Sea, just off the coast of Venezuela. For many people this Island is associated with vacation, a getaway from the everyday stress at work. Not so for a group of dedicated, commercial divers, welders, inspectors and engineers, working for Miami Diver, Inc. For 130 days it was their place of work. 130 of days hard work, 7 days a week, 12 -14 hours per day, with one day off during the entire job.



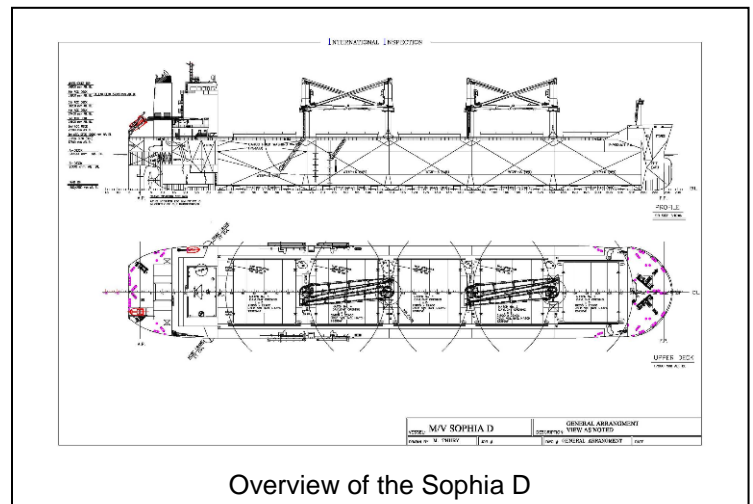
Miami Diver Inc., is a member of the Subsea Solutions Alliance, specializing in underwater ship husbandry offering repair and maintenance solutions, worldwide.

## INTRODUCTION

On January 21, 2009 the 56,000 t Bulk Carrier Sophia D was in route to China, loaded with thousands of tons of iron ore. Off the coast of Brazil, the ship run on ground, damaging the rudder so severely that the vessel was dead in the water, unable to steer.

The crew of 22 members was stranded for several weeks.

Kevin Peters, President of Miami Diver, Inc. was asked to develop a repair procedure for the damaged components.



Overview of the Sophia D

The owner of the vessel and the insurer accepted Miami Diver's proposal to perform the repair of the rudder, the rudder horn, and other affected components afloat. Part of the proposal was to perform the repair in Curacao, where Miami Diver has a fully equipped facility.

Due to the location, several miles off shore and bad weather, the extent of the damage done to the vessel when it hit ground could not be determined.

The proposed repairs could not be performed at the location where the vessel was stranded. The vessel was towed to Curacao, to a lay by berth, close to Miami Diver's facility on the island. It took 28 days to tow the vessel the 1,000 miles from Brazil to Curacao.



Sophia D in the Caracas Bay

At the time of the accident, the 623 feet long freighter was less than a year old.

### **THE PLAN (The Proposed Repair)**

The proposal included a rigging plan to transfer the weight of the rudder from air chain hoists to lift bags and use 2 of the ship's 35 tons cranes to load the rudder blade with a two cane pick onto the barge.

To remove the rudder blade under water a plan was formed on how to repair the damage to the vessel. After the rudder blade had to be removed underwater, a cofferdam had to be built and installed around the rudder horn to be able to perform the repairs in the dry. The cargo needed to be moved from aft holes to the fwd holes, allowing the ship to trim the cofferdam one meter above the water line. The cofferdam had to be dewatered to enable the evaluation of the damage to the rudder horn and the aft peak tank. At the same time, the Rudder was planned to be transported for an evaluation of the damage to the ship yard in Curacao by barge.

While all this work was performed, the welding procedures and the welders had to be qualified and certified to weld on 45 mm thick high tensile steel.

The repairs to the rudder horn and other damaged components in the aft peak tank could not be performed until the aforementioned was completed.

The rudder horn had to be cut free from the hull and a 200 mm insert plate needed to be installed to remove the “dog leg” so that the pintle bushing could be realigned with the upper neck bushing.

The damaged shell plating on the ship hull needed to be cropped out and replaced, as well as damaged frames and the longitudinal in the aft peak tank.

The external rudder plating needed to be cropped out and renewed; internal frames were bent and needed to be replaced. After the repair to internal frames and the skin plate had to be finalized, the upper and lower casting for the rudder stock and pintle had to be line bored.

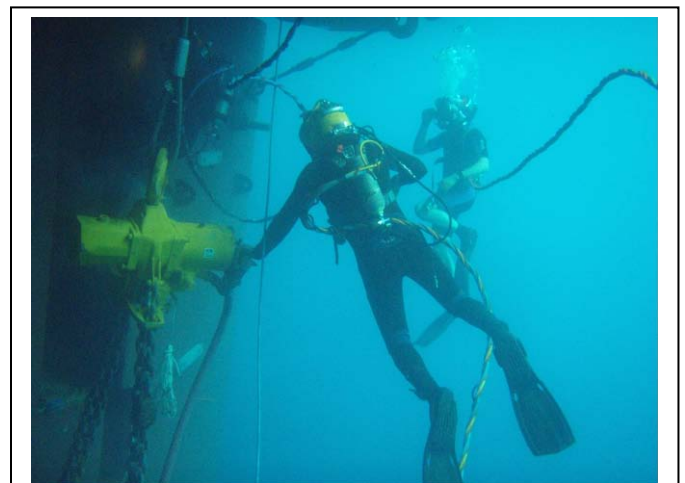
After the repairs to the rudder horn and the shell plating were complete, the rudder needed to be installed and the rudder stock put in place. For that, the cofferdam has to be removed.

Renew steering motor foundation, remounting steering gear to rudder stock, Sea Trials.

## REMOVAL OF THE RUDDER BLADE

The first step was to remove the 50 Ton, 30 feet tall Rudder underwater.

Divers from Miami Diver, Parker Diving, All Sea Enterprises, and Trident Diving welded 1 inch thick rigging pad eyes with 3/4” fillet welds, to connect the air hoists, underwater onto the rudder and above the water line to the ship’s hull. All welding in the wet was performed employing the wet SMAW welding process, with the Hydroweld FS electrodes, by diver welders certified to the AWS D3.6 Underwater Water Welding Code. A total of four 25 ton air hoists had to be installed.



Diver operating a 25 ton air chain hoist during the removal of the rudder

The divers furthermore had to remove the access plates to the rudder stock hydraulic nut. The underwater cutting was performed utilizing the hydro carbon arc gouging process, allowing the diver a precise removal of the 1¼” sized weld

on the access plate. The 500 pound rudder stock hydraulic nut had to be removed to allow the rudder stock to be pulled out through the main deck.

Due to the misalignment between the lower and upper bore, the rudder stock could not be moved and had to be cut apart underwater using a hydraulic diamond rope saw.

The freed rudder blade was lowered on the four air hoists and transferred aft to 70 tons Lift bags. The rudder blade was towed to the backboard side of the ship and a preset rigging was attached to perform a two crane pick using two of the ship's 35 ton cargo cranes. The rudder blade was loaded onto the barge and brought to the ship yard.



The underwater removal of the rudder was featured on the National Geographic Channel in a show called "The Worlds Toughest Fixes"

## FIRST EVALUATION

The first evaluation of the extent of the damage revealed the following:

- Pintel shaft and rudder stock were unusable
- Upper and lower castings on rudder blade were misaligned
- Steering gear foundation was severely damaged
- Rudder horn was bent 7" starboard, 2" aft
- Ship's hull was fractured in fwd of the gusset plate
- Fwd gusset plate was damaged
- Internal frames in the aft peak tank were damaged and fractured in way of the rudder horn connections

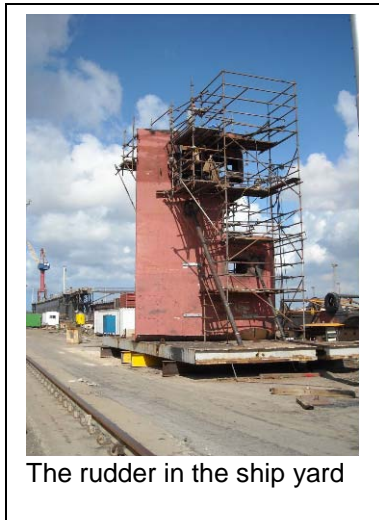
The damaged shell plating on the ship hull needed be cropped out and replaced, as well as damaged frames and the longitudinal in the aft peak tank.

The external rudder plating needed to be cropped out and renewed. Internal frames were bent and needed to be replaced.

After the repairs to the rudder horn and the shell plating were complete, the rudder needed to be installed and the rudder stock to put in place. For that, the cofferdam has to be removed.

Furthermore; the steering motor foundation needed to be renewed, the steering gear had to be remounted to the rudder stock, Sea Trails

## RUDDER BLADE REPAIR



The repair of the rudder was performed in the Shipyard in Curacao. After the rudder was stood up, an inspection and evaluation of the damage to the rudder was performed.

The inspection revealed severe damage to the rudder, which included the following:

- The upper and lower castings on rudder blade were misaligned
- The 1.75 inches thick rudder bottom plate was bent upwards up to an angle of 45°.
- The skin plates on the port and starboard side as well as the top plate were buckled.
- After the skin plates on the port and starboard side were cropped out to be renewed, internal plates were found to be buckled to a point that they needed to be cropped out and replaced.

The plate mounted to the bottom of the rudder (1 ¾ ") was bent so badly, it had to be trimmed approx. 1" overlapping the edge of the rudder skin, before the rudder could be re-installed onto the vessel. This plate will be replaced later in the ship yard. The purpose of this plate is to help with the steering of the vessel at slow speeds.



After all welding was complete on the new installed insert plates on the port and starboard side, internal plates and the top plate, 100% visual inspection was performed on all welds. All complete joint penetration welds were ultra sonically

inspected. All inspections were performed by Mr. Mark Thury with International Inspections. After the welds passed inspection, the DNV surveyor had to be in agreement with the inspector.

The welding in the shipyard was performed by shipyard welders, certified to DNV standards. Welding procedures qualified by DNV had to be followed.

After the repairs to the internal frames and the skin plate, the upper and lower hydraulic taper for the rudder stock and pintle had to be line bored.

## **BUILDING AND INSTALLING THE COFFERDAM**

A Cofferdam displacing 130 cubic yards of water was engineered by a marine engineer specifically for this job, to be installed around the rudder horn, once the rudder was removed. The 23,000 pound cofferdam was built in facilities of Miami Diver in Curacao. The approximately 15 feet long, 13 feet wide, and 14 feet tall cofferdam was built out of ¼” (6.35 mm) thick ASTM A36, reinforced with 4X4X3/8 angles at the bottom and the side walls.



The cofferdam was built while the vessel was being towed from Brazil to Curacao.



After the cofferdam was finished, it was transported with Miami Diver's crane barge to the vessel, lowered into the water, lifted up and welded to the ship's hull. Once installed, 30 tons of cargo had to be moved to the forward compartments allowing the ship to trim the cofferdam three feet above the water line. The cofferdam was dewatered to enable evaluation of the damage to the rudder horn

and the aft peak tank.

## **QUALIFYING THE PROCEDURES AND THE WELDERS**

Before any welding could be performed on the vessel, the welders had to be certified and the welding procedure approved by DNV (Det Norske Veritas).

The tests were performed at Miami Diver's facility in Miami, Florida. Welders were flown in from Curacao office. The necessary PQR's were written by the

welding engineer. After the PQR was qualified, five more welders were tested in Curacao, witnessed by the local DNV surveyor

In Miami, two welders welded identical procedure qualification plates, 1" thick, and 350 mm long per DNV specifications. One welder welded welder qualification plates according to AWS D1.1, on 1" thick material, in the 3G and 4G positions.

Time and passing the tests were crucial, since the welding procedure was the foundation for the weld repair. Preparations and test runs were performed Sundays.

The welding procedure qualification plates were welded in the 2G (horizontal) position. The root, filler passes and cover passes were welded, and then the root was back gouged and re-welded from the back side. The welding process was SMAW with DNV approved Atom Arc ESAB 7018 Electrodes, Ø1/8".

The material of the rudder horn was AH 36 DNV High Strength Steel; the procedure qualification was performed on High Strength Low Alloy material, comparable to ASTM A572 Gr. 50, High Strength Low Alloy

Preheat and interpass Temperatures were calculated from the chemical composition provided by mil certificates and based on the Code ISO 17844 – Standard Method for the Avoidance of Cold Cracking – CE Method.

The preheat temperature was calculated to 225°F, with a max. Intepass Temperature of 400°F. Temperatures during the tests were controlled with heat indicating crayons.

The welding of the qualification tests was witnessed by the DNV surveyor. The welds passed the visual inspection and were brought to a local metallurgical lab, accredited by the class societies.

The following laboratory tests were performed:

- Radiography
- Round Tensile Test (weld metal)
- Tensile Test (flat specimen transverse to the weld)
- Charpy V-Notch Tests at -20°C with the notch location in weld metal, fusion line, HAZ + 2 mm, and HAZ + 5 mm
- Transverse Side Bend Tests
- Hardness Measurements (Rockwell A)
- Macro Section Test

Test results were available one week after the plates were delivered to the lab, and the results were positive.

## MATERIAL

All materials, including the electrodes and the steel had to be certified material. The steel had to meet certain criteria, was purchased in the US and had to be flown to Curacao. The steel had to be approved and stamped by DNV. DNV approved and stamped plate proofed to be difficult to find on a very short notice in the US. DNV agreed to use material approved and stamped by ABS (American Bureau of Shipping) another classification society. Riverfront Steel in Cincinnati, Ohio was able to locate the material needed in Houston, Texas.

These plates were loaded on a truck, transported to Miami and shipped to Curacao.

## RUDDER HORN



Since the rudder horn was bent 8 inch starboard, 2 inch aft, the horn was cut from the vessel at approximately 12 inch below the hull penetration, and an approximately 8 inch tall section was removed. During the cutting operation the lower, 25 ton portion of the horn was supported vertically by six 15 ton load rated turn buckles. For side alignment, four 10 ton chain hoists were placed fwd and aft at the port and star board side between the hull plating and the lower casting at an approximately 30° angle.

The rough cut was ground smooth, and a 45 bevel was prepared at the upper part of the rudder horn plating. For the lower part of the joint, the 200 mm tall plate insert needed to be prepared with a 45 bevel.

An 8 inch tall plate insert was installed to remove the "dog leg" so that the pintle bushing could be realigned with the upper neck bushing.

The rudder horn nose plate was found to be cracked and had to be copped out and replaced. The steel thickness for the rudder horn plating and the nose plate was 1 3/4".



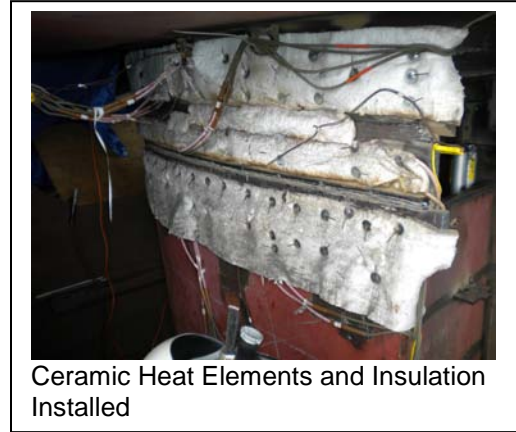


The 8 inch tall plate insert on the port and starboard side, as well as the nose insert plate were tacked in place and strong backs were welded onto the back side of the joint. Run off plates were welded at the ends of the welding joints.

Joint preparation was a single bevel groove weld with a 45° opening angle on top, to use the lower part of the joint as a shelf. The root opening was held at approximately 4 mm.

After the alignment of the inserts was confirmed, ceramic heating elements and insulation pads were installed, to maintain the pre-heat temperature and to reduce the cooling rate of the finished welds.

After approximately two hours the preheat temperature of 225°F was achieved and the root could be welded. Preheat and minimum interpass temperatures were maintained during the welding operation for a distance not less than 3 in. [75 mm]) in all directions from the point of welding.



Ceramic Heat Elements and Insulation Installed



Two Welders Welding Simultaneously on the Portside Side

The two upper joints on the port and starboard side were welded first. The root passes on the upper weld seams were welded simultaneously by one welder on each side, welding in a predetermined welding sequence, starting from the center to the outside. Fill and cover passes were then welded by four welders at the same time, 2 on each side. Welding in two 12 hour shifts.

The welders started in the center of the joint, moving outwards. The challenge was to convince welders it was not a race and each welder had to weld at the same speed. It took 35 passes and approximately 24 hours to fill each of the 12 foot long joints.

After welding the outsides of the insert plates and the front section, the rudder horn nose, the root sides of the welds needed to be gouged out and re-welded from the inside. This posed a burden on the welders, since they had to sit inside the rudder horn, with pre-heat temperatures still applied. After welding the root from the inside of the rudder horn, the internal girder and the plates needed to be installed.

After welding was performed, the temperature was increased to 350, held for two hours and decreased in 50F per every two hours until a mbient temperature was achieved.

Other welding repairs performed in way of the rudder horn connections were internal frames in the aft peak tank, the hull plate and the gusset plate forward of the rudder horn. The steering gear foundation was reconstructed and main deck plate which had to be cut out to remove and re-install the rudder stock and steering gear foundation needed to be re-installed.

## **WELD INSPECTION**

Insepctions, including weld inspections were performed by a 3rd party inspection agency – International Inspections, Inc. out of California.

DNV required 100% visual inspection of all welds, Magnetic particle on root passes of all welds on insert plates, and ultra sound inspection of all complete joint penetration welds.

In addition Leak testing had to be performed on all water tight compartments.

After Mark Thury passed the inspected items, the DNV surveyor had to perform a verification inspection.

## **REMOVAL OF THE COFFERDAM**

With the completion of all repairs, the cofferdam was removed by divers and the rudder had to be re-installed, as well as the rudder stock and the steering gear foundation.

After a total of 130 days in Curacao, the Sophia D passed the sea trails and was on her way to China.