

WELDING *Journal*

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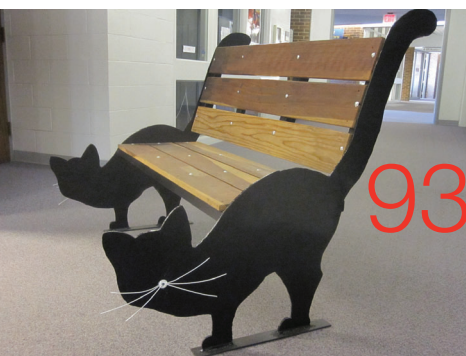
Marine Construction and Repair

- FABTECH Canada Preview
- New Filler Metal Spec
- Do-It Yourself Project
- Bonus: The American Welder

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On the cover: A Hydrex senior diver/welder/technician welds a longitudinal stiffener on the side of the Eleftheria K in October 2011 as part of a major repair after the ship had grounded off the Suez Canal. (Photo copyright 2011, Hydrex.)

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Fig. 1 —
The Eleftheria K
at sea.



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UNDERTAKING A COMPLEX UNDERWATER REPAIR

A damaged freighter needed repairs to stop a leak, prevent buckling, and keep cracks from spreading so the ship could sail to where she could unload

The *Eleftheria K* (Fig. 1), a Capesize-class bulk carrier, ran aground at the mouth of the Suez Canal in July 2011. European Navigation, Inc., Piraeus, Greece, operates the ship, which was built in Japan in 1985. The *Eleftheria K* is 297 m long overall, 50 m in the beam, 214,263 metric tons DWT (dry weight), with a 26.7-m depth, 19.8-m draught, and a displacement of 240,311 tons.

The Damage

When she ran aground, the *Eleftheria K* had on board a full cargo of iron ore concentrate, totaling 212,297.75 metric tons, which had been loaded at the ports of Odessa and Yushny in the Ukraine for discharging at Rizhao and Qingdao, China. The starboard bilge strake was grounded at the level of double-bottom

ballast tanks (DBBTs) 1, 2, and 3. The damage was extensive, covering about 85 m along the hull. The grounding caused severe indentation of the bilge strake, opening seven holes and cracks along the damaged area resulting in the flooding of ballast tanks 1, 2, and 3 — Fig. 2.

A local diving company in Egypt carried out temporary repairs using doubler plates and putty from the outside and cement boxes on the inside — Fig. 3. The ship then resumed its voyage to China. However, one week after sailing from Suez, the ballast tanks flooded again and a vertical crack developed on the starboard vertical side shell plating, on the aft part of the area damaged by the grounding and just forward of the bulkhead between DBBTs 2 and 3, and cargo holds 3 and 4 — Fig. 4.

The approximately 1300-mm-long

crack had an average uneven gap of 100–200 mm. Had it propagated upward, the crack would have caused cargo holds 3 and 4 to flood, which could have been catastrophic for the vessel and her cargo.

The most difficult part of the underwater repairs was covering this crack/fracture for it to become watertight while at the same time maintaining local and longitudinal strength to a level higher than the minimum required by the rules.

Underwater repairs and reinforcements had to be carried out at a depth of approximately 19 m with the ballast tank flooded, meaning equal pressure from inside and outside. Repair procedures and welding quality had to be at maximum in order to hold firm while deballasting the ballast tank so the shell plate could cope with the resulting hydrostatic pressure from the outside. To effect these repairs,

the ship had to be diverted to an anchorage at Fujairah, United Arab Emirates.

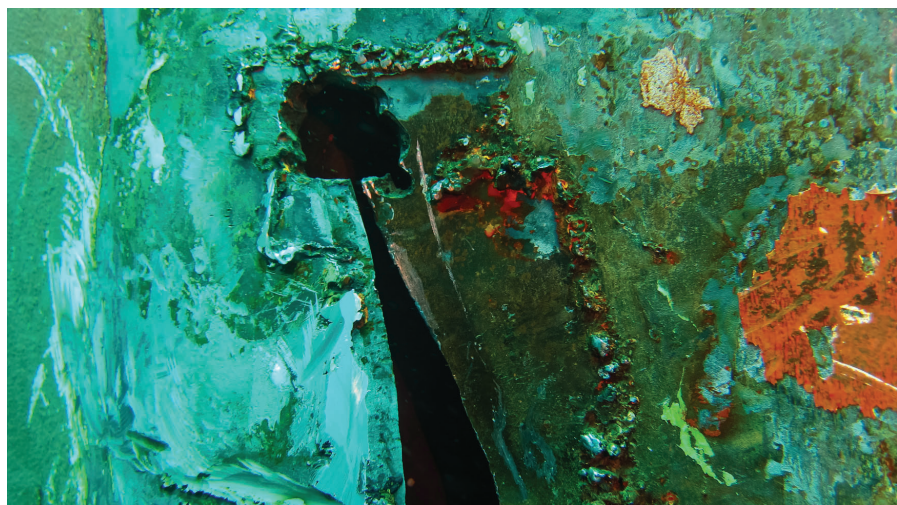
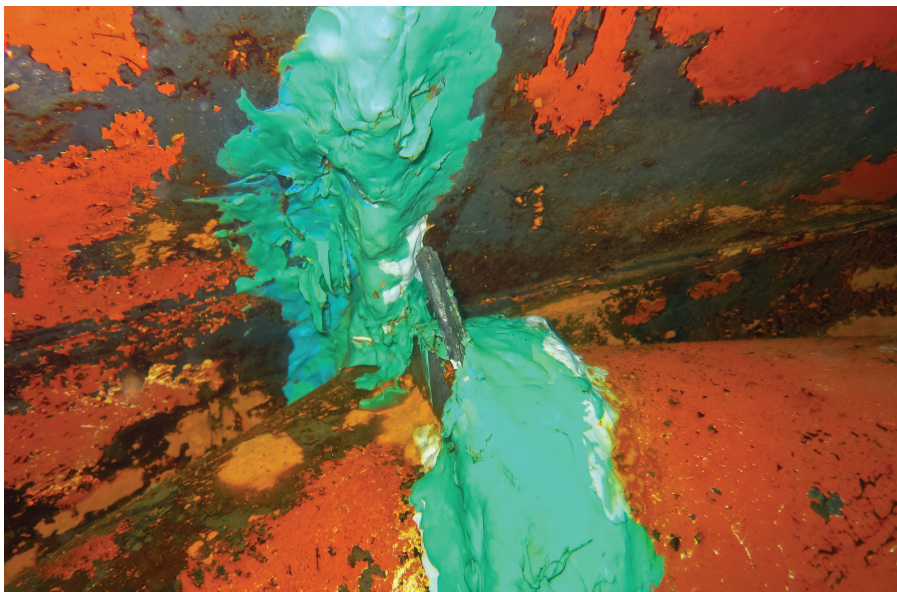
Inspection

S. Georgiou, technical manager of European Navigation, Inc., called in Hydrex, an international underwater repair and maintenance company based in Antwerp, Belgium. The Hydrex inspection revealed a new vertical crack directly on the bulkhead between ballast tanks 2 and 3.

Georgiou said he decided to call in Hydrex for the repairs because “due to the extent and the severity of the damage, the job was considered very difficult; therefore, we decided a specialized company such as Hydrex, with a successful record, well organized, safety oriented, and experienced in underwater welding jobs, should be arranged. Furthermore, any other option to discharge her cargo ashore and/or transfer the cargo to another ship was impossible due to the ship’s size, her deep draft, quantity of cargo on board, no availability of suitable port/berth facilities for a vessel of that size in the area, and no availability of shore floating cranes.”

Toon Joos, an experienced senior diver/welder/technician with Hydrex, flew to Dubai to conduct a detailed inspection at Fujairah 20 miles off the coast. His report and some of the photos from that inspection follow.

“The damage starts approximately on frame number 315 and runs all the way to frame number 227, a total length of approximately 100 m with a height on the vertical side of approximately 6 m and a width under the flat bottom of approximately 3 m. All the plating is pushed inside heavily with several cracks that have been repaired by other diving companies by means of doublers and epoxy putty. Unfortunately, there are still leaks. We can’t determine the locations due to the previ-



*Fig. 3 — (Top) The buckled hull and the previous attempt at repairs.
Fig. 4 — (Bottom) Close-up showing the severity of the long, vertical crack discovered in the hull.*



Fig. 2 — The ship at anchor near Fujairah, UAE. The ship has a severe list to starboard due to the leaks and flooding of the ballast tanks.

Fig. 5 — Sketches of the damage and repair proposal: A — Transverse view of the side shell vertical fracture; B — repair proposal for the vertical fracture.

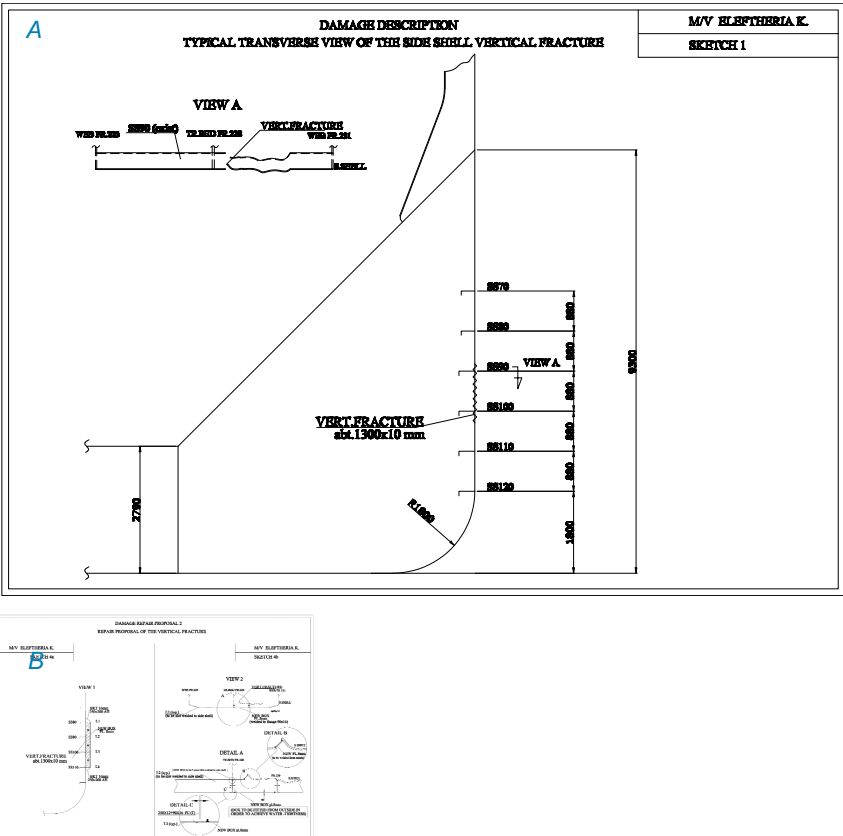
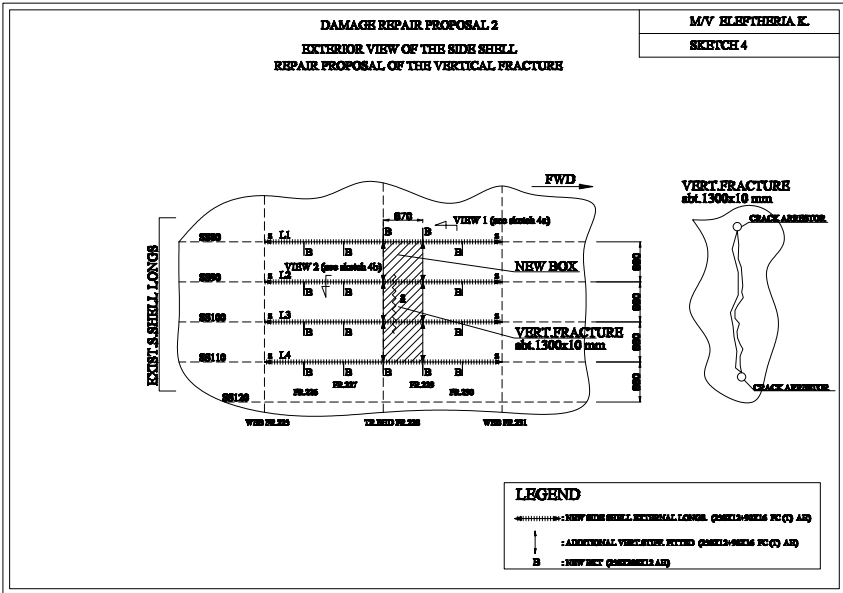


Fig. 6 — Exterior view of the side shell repair proposal for the vertical fracture.



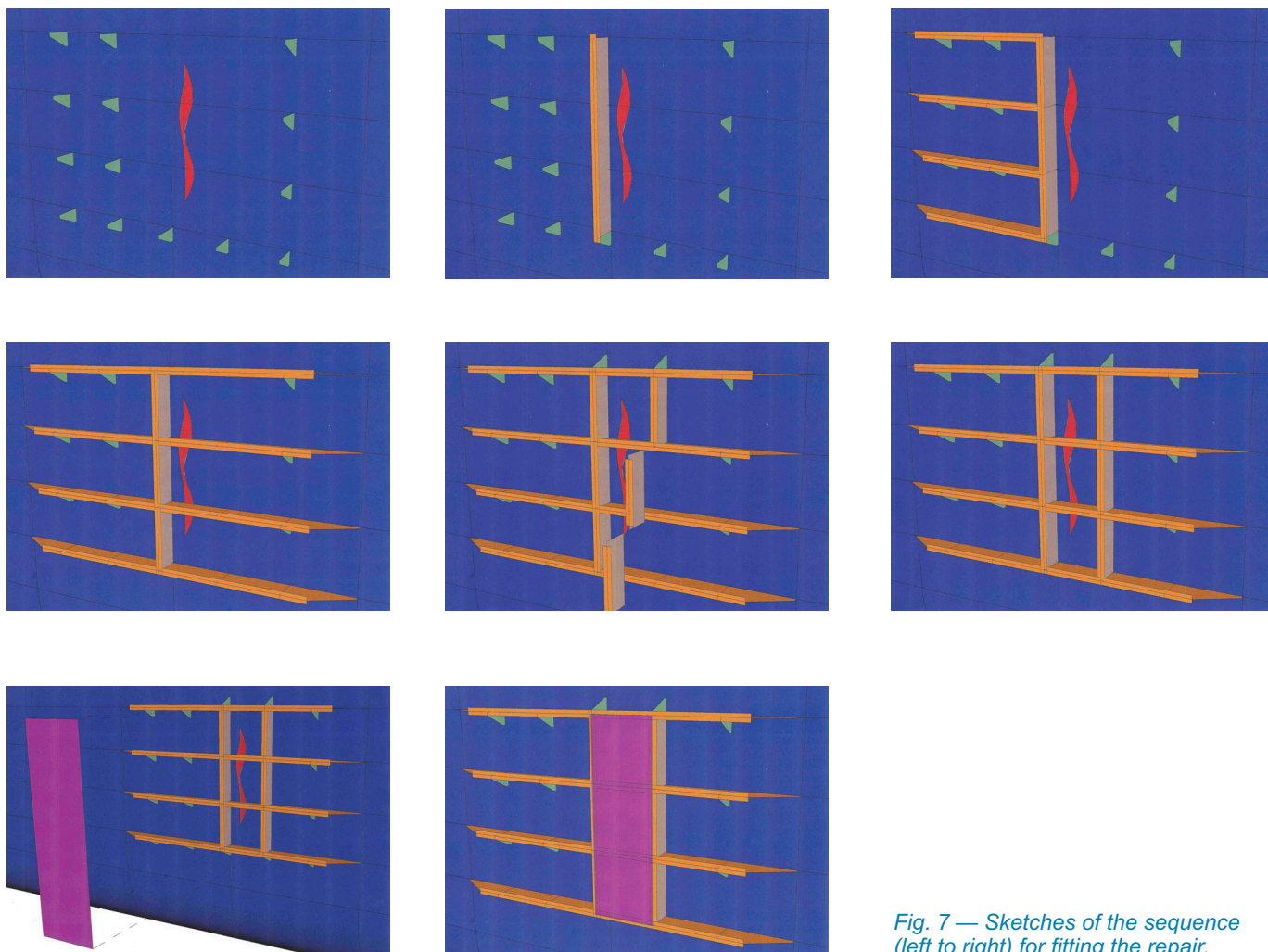


Fig. 7 — Sketches of the sequence (left to right) for fitting the repair.

ous repairs and because the tanks (numbers 1, 2, and 3) are flooded. Between tanks 2 and 3, I can see there is a crack 1300 × 10 mm just in front of the bulkhead. There is a repair done by (local company), but the shell plating is pushed inside due to the water pressure when the tank was pumped out.”

Planning the Repair

Part of Joos’s report was a proposal for repair of the damage. The idea was to make sufficient repairs for the vessel to sail to China to unload her freight. Then she could be drydocked and permanent repairs made. The main problem was to sufficiently reinforce the 1.3-m vertical crack to prevent the torsion of the ship while under way from expanding it and breaking the ship, and to make the hull watertight so that the ballast tanks could be pumped out. The first step of the proposal was to involve a naval architect so that the various drawings and calculations could be done and approved.

The Naval Architect

Hydrex had recently worked successfully with Michalis Chourdakis of C. N. Zachopolous & Associates Ltd., marine surveyors and consultant engineers, Piraeus, Greece. The company recommended his services to Georgiou, who was in charge of the repair operation for European Navigation. Chourdakis is also a technical consultant with Tsavlis Salvage Co., one of the world’s leading salvors. In this case, no salvage operation was required so Tsavlis was not involved, but Chourdakis explained that his work with Tsavlis has given him a great deal of experience with major repairs of this nature.

Chourdakis and his colleague, P. Koutsourakis, a surveyor and specialist in 3D drawings and presentations, studied the results of the Hydrex inspection and the proposed repairs and worked out the engineering details. They came up with a new description of the damage, a

plan for repairs, calculated the various strengths and thicknesses required, and produced a set of drawings.

Grounding Damage

Following is the new damage description and temporary repairs proposal.

The damage description is based on information received from the Hydrex diver on board at Fujairah on May 9, 2011.

The report stated in part: “On the side shell plate starboard side and in the area of the double-bottom ballast tank No. 2 starboard found a vertical crack of approximate dimensions 1300 × 10 mm located between frames No. 228 and 229 and on the first plate after the bilge plate. Double-bottom ballast tank No. 2 starboard is flooded — Fig. 5.

Repairs Proposal

The purpose of the repairs was to accomplish the following:

Fig. 8 — (Top) Construction of the initial frame on the deck of the freighter.

Fig. 9 — (Bottom left) The distorted shape of the hull was carefully measured in relation to the frame, with measurements taken every 5 cm, so the plates that would become the structure of the box could be accurately cut to fit.

Fig. 10 — (Bottom right) The plates were lowered down the side of the ship so they could be fitted accurately to the damaged hull before being welded into a watertight box on deck.



- Stop the crack (avoid propagation).
- Reinforce the damaged area.
- Reinstall water tightness of double-bottom ballast tank No. 2.
- Reinstall the continuity of the double-bottom side longitudinals.
- Reinforce the cracked side shell plate to avoid movement.

Following is the repair plan:

- To stop the crack and avoid propagation, drill adequate crack-arrest holes on the shell plate at both ends of the crack — Fig. 6.
- To reinforce the damaged area, fit four angle bars and weld them externally on the shell plate in line with the existing double-bottom tank's side longitudinals covering two web frame spaces.
- Extend the stiffening longitudinally from frame 225 to frame 231.
- Fit same-size angle bars and weld them vertically and in line with frames 228

and 229. These would be extended one side longitudinal up and down from the crack's ends — Fig. 6.

- Form the web of the angle bars to exactly fit the hull's actual shape.

Three-dimensional fitting sketches show how the repair was planned to go forward — Fig. 7.

Hydrex confirmed that the plan could be executed, and European Navigation accepted the proposals.

All calculations for the local and longitudinal strength of the vessel were submitted and approved by the vessel's classification society, Nippon Kaiji Kyokai (Class NK), and H&M Underwriters' surveyors. While the work was being conducted, a Class NK surveyor was on site to verify the repairs were carried out according to the approved drawings.

Chourdakis noted that for the job to be successful, high-quality welding

and precise premeasurements were required.

Making the Repairs

Hydrex flew two experienced divers/technicians, Cedric Wyckmans and Philip Martens, from Antwerp to Dubai to make preparations for the job, including securing a suitable workboat and other necessary equipment. A week later, Joos flew in with a team of four additional divers/welders/technicians. Work began and continued intensively, day and night, for the next 5½ weeks.

The first step was to take measurements for the frame that would be fabricated and then welded in place over the large vertical crack. The frame would form the structure of the cofferdam that would be used to make the crack watertight and would also be used as a frame of reference



Fig. 11 — (Left) The 300 × 60 cm box fabricated on deck prior to being lowered into the water and welded to the hull.

Fig. 12 — (Right) Close-up showing the box in position over the crack.

so that accurate measurements could then be made and plates cut and welded in place. Hydrex welders working with subcontractors on the deck of the *Eleftheria K* constructed the frame — Fig. 8.

With the frame in place, measurements could then be taken so that the sides of the cofferdam could be cut to the shape of the badly buckled hull and then fitted — Fig. 9. Joos explained, “A good fitting makes it much easier to weld. Under the water, a gap of 1 cm is a lot harder to weld than a gap of 3 mm. If you go over 1 or 1.2 cm, then you have to build up. So about 1 cm is the limit. Some welders can handle a 1 cm gap. A good fit makes it much easier. If you have a zero gap, it saves hours and hours of welding time.” With the ship out of service until the repairs could be completed, the old adage, “time is money,” took on a whole new meaning.

The plates were cut on deck, then lowered and tacked to the hull so they could be adjusted to ensure a close fit before being welded to the box — Fig. 10.

After the plates were fitted, the 300 × 60 cm box was constructed on deck — Fig. 11. This was done because surface welding is somewhat faster than underwater welding.

The finished box was then lowered into the water and welded to the frame and the hull, inside and out, three passes through-

out — Fig. 12.

Once the box was in place, the stiffeners were ready to be welded onto the hull extending fore and aft from the cracked hull area. The stiffeners were fabricated on deck, then lowered into position and tack welded in place. They were then strip welded with a 15-cm strip every 15 cm, top and bottom of the stiffeners — Fig. 13.

The next step was to close the cofferdam by welding a plate on top of the box that had already been welded to the hull and the frame. When the cofferdam was sealed, the crack was no longer open to the sea — Fig. 14.

Joos recalled the problems encountered when ballast tanks 1, 2, and 3 were deballasted — Fig. 15. “When we started pumping, unfortunately some cracks

broke. Nobody knew what was inside — how many longitudinals were still attached on the inside — so we put additional stiffeners and then tried to pump again. Again, we had a few minor cracks. Because the depth of the vessel was 24 meters on the bottom, there was a huge amount of pressure forcing inward. The full structure needed to resist the pressure. We had a few cracks again so we decided to stop and put in some additional stiffeners in more layers to get more strength on the welds. The third time we started deballasting everything went okay. There was no further leak.”

Georgiou added, “Furthermore, during the course of repairs — due to failure of the reinforcements — the original repair plan had to be reviewed twice and



Fig. 13 — Strip welding the longitudinal stiffeners in place on the shell plate.

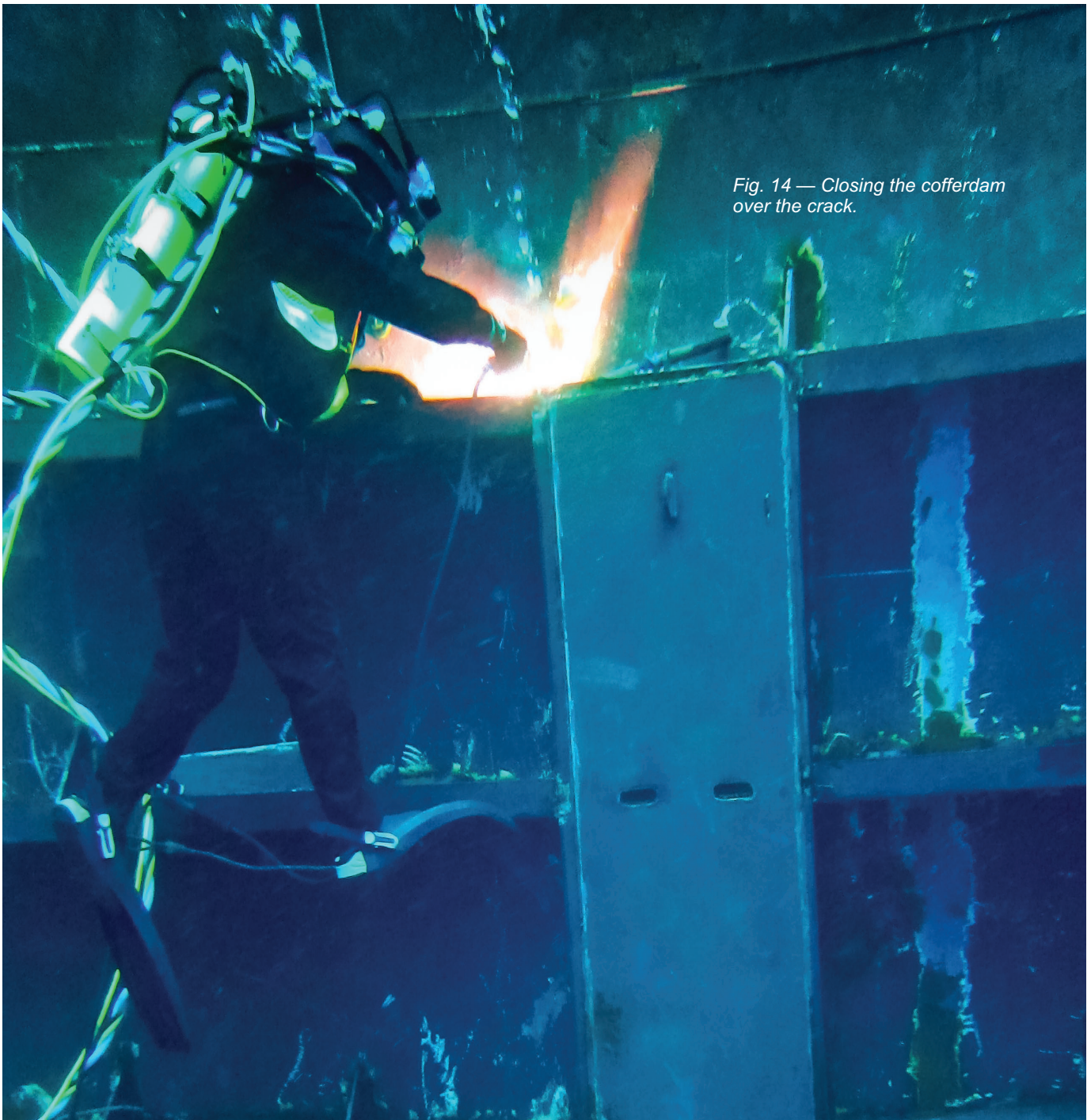


Fig. 14 — Closing the cofferdam over the crack.

extra stiffeners had to be fitted.” This proved the degree of difficulty of the job, according to Georgiou.

Finally, just 27 days after work began, the repair was finished with all stiffeners and brackets in place and welded. Epoxy was applied to prevent the welds from rusting — Fig. 16.

Another team worked on the inside after the crack was made watertight and the ballast tanks could be pumped out. It was with this repair fully completed with classification society approval that the ship was able to sail.

External welding totaled approximately 500 m, an incredible amount of welding for the given timeframe, particularly when one considers that most of it was underwater and at considerable depth. Shielded metal arc welding was used throughout. Two welding machines worked constantly, and there was a third on standby as a backup. The equipment is basically the same as is used above water except that a different electrode, suitable for underwater use, is employed.

The underwater external repair was

carried out by seven Hydrex welders working in shifts. The diving routine consisted of two hours under the water followed by a 21-min decompression stop at 3 m and then a 4-h interval before diving again in the afternoon, following the same routine. The divers dove once or twice daily following the same routine, with two divers in the water at the same time. All the divers used nitrox, a 40% oxygen/60% nitrogen mixture.

At the beginning, the divers worked at a depth of 20 to 21 m. When the ballast tanks were emptied and the ship came up

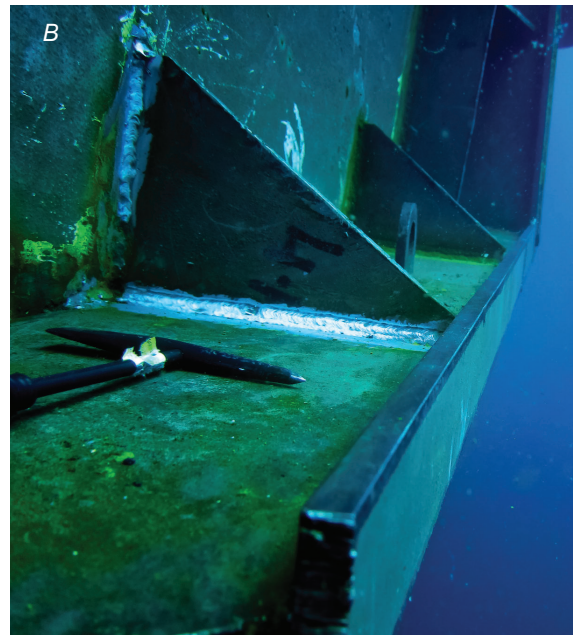
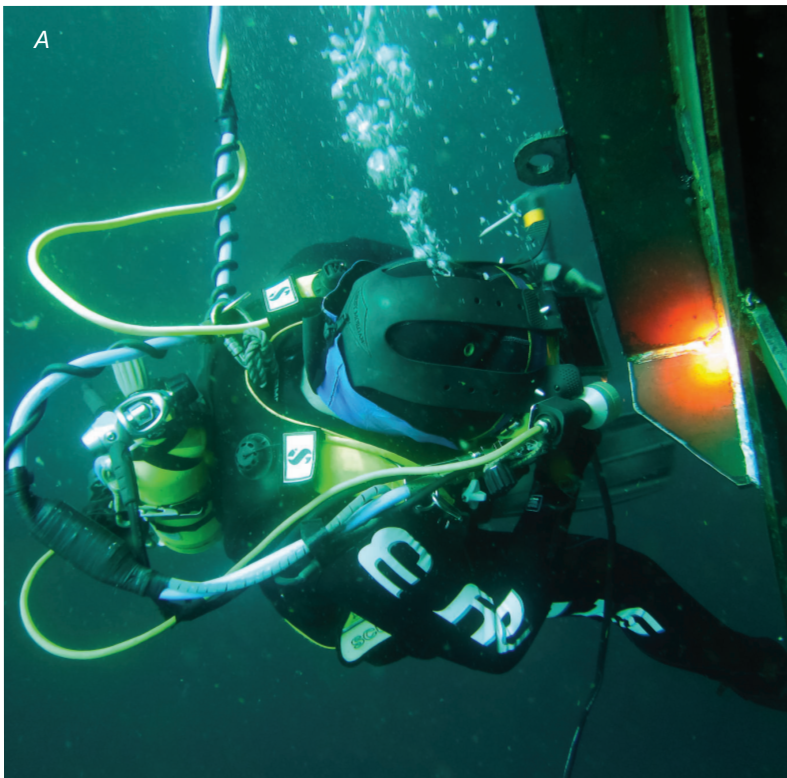


Fig. 15 — A — Additional reinforcement was added to the repairs to ensure the welds would hold up when the ballast tanks were emptied; B — a close-up of the reinforcement.

straight, recovering from its list, they were working at 17 m.

Georgiou, who chose the repair company and the naval architects, was very satisfied with the work and the results. “We had very good cooperation during the entire period of repairs,” he said of the teamwork between European Navigation, the naval architect, and Hydrex. “The repair was successful, allowing the vessel to sail to China; therefore, the quality of the job was good. The job completed in about 27 days, which was very close to quoted time (24 days), but it should be considered that additional reinforcement had to be carried out, therefore the speed was also satisfactory.”

Conclusion

The purpose of this repair to the *Eleftheria K* was to stop the leak, prevent buckling, and stop the cracks from spreading so the ship could sail to where she could discharge her full load and then go to dry-dock for permanent hull repair. The repair was warranted because although the

ship is 27 years old, she has several years of service life ahead.

“The vessel arrived at its port of destination for discharging doing good speed despite encountering heavy weather and without any damage to the repairs carried out or any other damage,” Chourdakis said.

Georgiou said, “Upon completion of underwater repairs, some additional repairs/reinforcements carried out inside the ballast tanks (according to the request of naval architect) and the vessel was inspected by Class. Everything was found okay and she resumed her voyage to China to discharge her cargo. The ship arrived

in China after about 30 days voyage, without any problem or water ingress in the ballast tanks during the voyage, and discharged/delivered all her cargo safely, at the ports of Rizhao and Qingdao. The provisional repairs carried out by Hydrex at Khorfakkan anchorage enabled the vessel to perform the voyage to her destination safely.”

The repairs to the *Eleftheria K* can be considered a major accomplishment in the field of underwater ship repair and a testimony to the skill and teamwork of the ship operator, the naval architect, and the divers/technicians who carried it off successfully. ♦



Fig. 16 — The finished repair. The welds were protected with epoxy to prevent corrosion.