How PX-15 Hull Was Constructed

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IN FEBRUARY 1966, following the signing of an exclusive consultation agreement between Grumman Aircraft Engineering Corp. and Swiss ocean engineer, Dr. Jacques Piccard, an extensive design study was undertaken by both parties for an underwater research and commercial/work vehicle, based on a preliminary design drawn up by Dr. Piccard.

Later that spring, additional studies were completed at Grumman's Bethpage facility concerning the usage of the new vehicle, and in April a meeting in Switzerland, where Piccard operates his laboratory and test base, covered the steps in the production of the pressure hull for the vehicle, which bears the designation *PX-15.*

Initial considerations pointed to a vehicle suitable for an extended underwater drift mission in the Gulf Stream but following use in research, scientific exploration and underwater situations dictated a more flexible primary design.

(See OCEAN INDUSTRY, February 1967 for a description of the Gulf Stream Drift Mission.)

Piccard's initial hull design consisted of a cylindrical vessel capped with hemispherical ends. It would be 48 ft. long, 10 ft. in diameter and weigh about 130 tons. Again, considering the utility of the vehicle for future missions, it was decided that the hull would be constructed to permit ease of modifications while retaining the costly and complicated system components, such as the electrical system, and the major components of all other subsystems.

Flange Joints. The design ultimately decided upon included a flange joint allowing changes in the configuration of the submarine, while keeping the pneumatic, electrical, hydraulic and life support systems relatively intact. This design has an asymmetrical separation aft of the cabin area. The larger forward section houses the principal systems of the power supplies and the controls. In this manner, the aft section can be easily changed to permit alternate configurations in future models of the vehicle.

Materials

The steels selected for the hull were chosen for strength properties as well as weldability. After an extensive analysis it was decided to employ two European steels which exhibited properties ideally suited to our needs.

Aldur steel 35 mm thick, with a yield-strength of 77,000 psi, was selected for the cylindrical portion of the submarine. This steel has properties not unlike HY steels used in most U.S. military submarines, and it possesses good weldability and resistance to cracking.

The Welmonil steel of the same thickness, with a

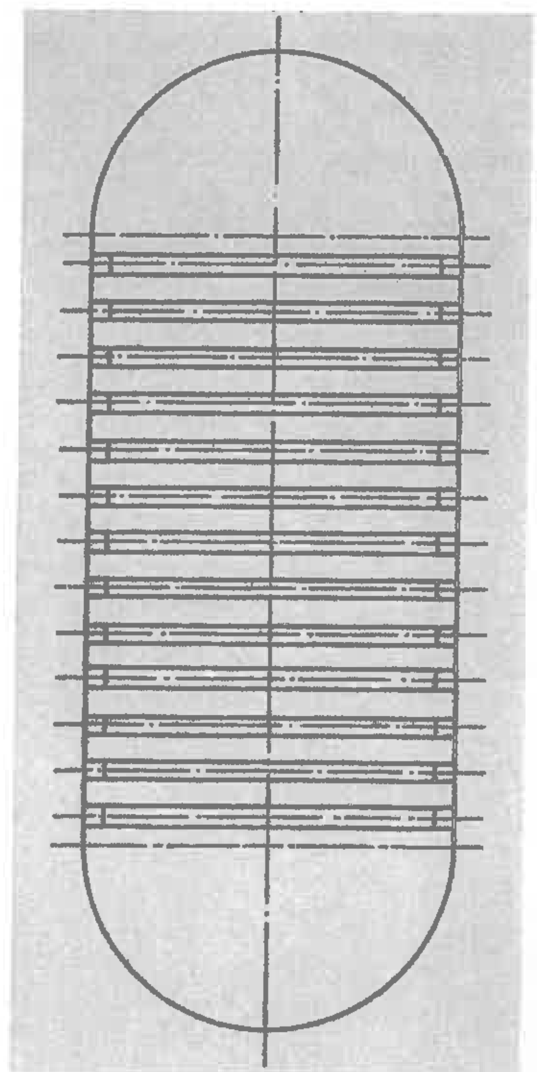

Fig. 1—Sketch plans for PX-15 hull.

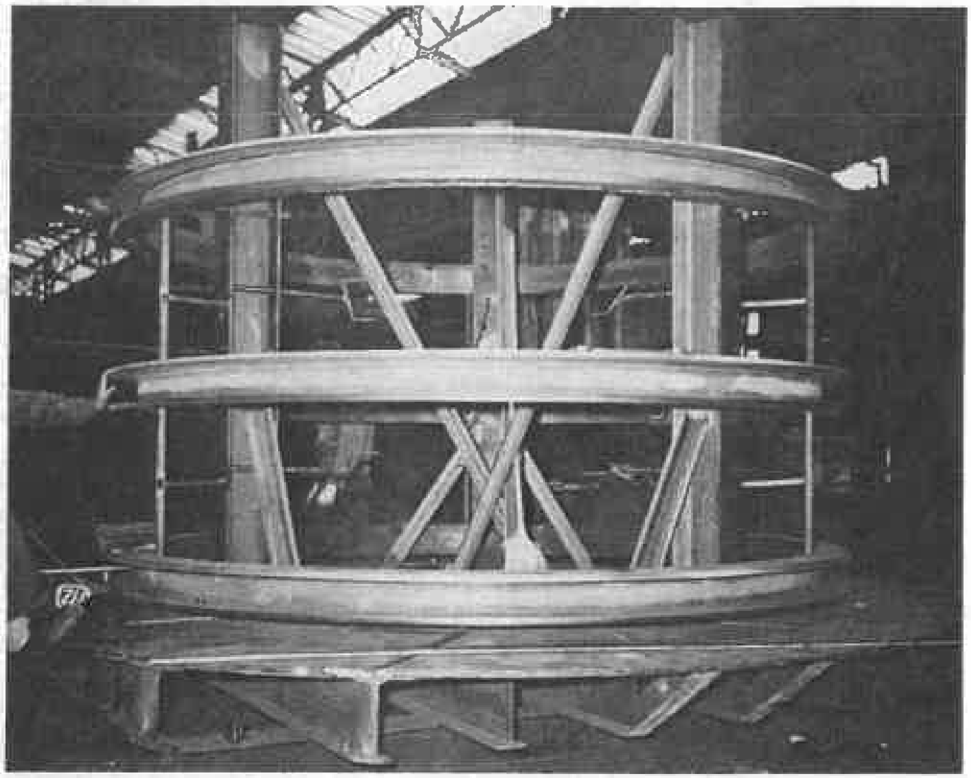

Fig. 2—View of assembly fixture with three rings in place prior to arrival of shell section.

yield strength of 71,500 psi, used for the hemispherical ends has somewhat greater impact strength and better forgeability.

The Aldur was supplied by Vöest, in Austria, while the Welmonil came from HOAG, in Germany.

Fabrication

The cylindrical portion of the hull was fashioned by assembling six sections of rolled Aldur steel, each containing reinforcing rings. The six plates were ordered approximately to size and trimmed as necessary so that each piece had only one longitudinal seam. The plates were then cold formed to cylindrical shape in a plane-rolling machine and the longitudinal joint was hand welded. All welds were ground, both inside and out, and following the grinding, the cylinder was rerolled to maintain the exact circularity required for hull strength.

Internal Stiffeners. As the cylinders were being formed, internal stiffeners were also being fabricated. These rings were made from Aldur steel, too, and when their assembly was completed, the internal weld bevels were machined to assure perfect circularity and straightness of the outside plating.

Shrink Fitting. When fabrication of the stiffener rings and the cylinders was completed, the stiffeners were assembled on a special jig. The cylindrical shells were then heated to about 200° C and were lowered over the jig. As they cooled, they contracted, tightening around the reinforcing rings and assuring close dimensional tolerance on the hull.

To reduce deflection between the reinforcements in the area of circumferential welds, additional temporary stiffeners were installed at the same time the cylindrical sections were assembled using the jig.

Fig. 3—Grinding one of the 16 stiffener rings used to reinforce the 33-mm-thick hull shell.

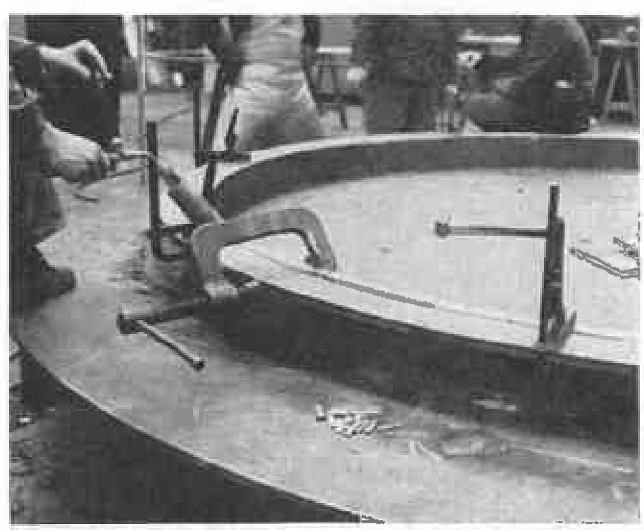

Fig. 4—Pre-heat is being applied before welding flange to cap during fabrication of radial stiffener rings.

Heat Treating. These stiffeners prevented distortions in diameter in the vicinity of the welds which normally reduce in diameter as a result of shrinkage of the weld. The rings were welded to the cylinders which were maintained at a temperature of 150° C until the operation was completed. As soon as the welding was completed and before the cylindrical sections were allowed to cool, each section was placed in a heat treat furnace and stress relieved for 70 minutes at 525° C.

Ultrasonic testing followed cooling of the sections and showed high quality welding.

Forging the Hemispherical Ends. Each hemispherical end for the pressure hull was formed by welding seven pieces of Welmonil steel. The various segments were cut out of the steel and then forged to the shape of the hemisphere. For forging, the segments were heated to 960° C and promptly brought to the press and forged before the temperature dropped below 900° C. Each segment was cut to size and beveled following forging and then assembled to form the hemisphere.

Assembly of the Cylinder and Hemispheres

The seven cylindrical sections and hemispheres were tack welded together, two pieces at a time and then the main circumferential welds were made. This was done automatically on the outside of the hull, and by hand on the inside.

Brackets and Clips. All of the subsystems: electrical, pneumatic, hydraulic, mechanical, life support and so on are held to the hull by a series of brackets and clips and other fastener systems, welded to the inside or outside of the vehicle.

All of these clips, brackets and so on were welded to the hull before the final stress relief was performed. The brackets, and other appendages welded into the hull totaled over 1,000 items and took about six weeks to properly affix. Each weld was checked with a dye penetrant system for cracks.

Hull Penetrations

There are a total of 42 cast steel reinforcement plates welded into the hull to allow for portholes, and pipes or lines to be brought through the pressure vessel. These plates are cast from steel with a yield strength of 78,000 psi. All hull penetrations plate welds were X-rayed and ultrasonically tested both before and after stress relief.

Stress Relief

When all welds were completed and each was checked either ultrasonically or by X-ray in the case of major joints, and with dye penetrant for every other one, the hull sections were stress relieved in a large electric oven at the fabrication site, Giovanola, S. A. in Monthey, Switzerland. The hull was heated to 525° C and held there for approximately three and one-half hours (2 minutes per mm of thickness). The hull was then slowly cooled in still air. Following this heat treatment, all main welds were *again* ultrasonically checked to be sure that each was free of cracks that may have occured during and after stress relief. All were found to be satisfactory.

Tolerances. While this check was being made, the hull was also measured for straightness and roundness, since these determine the pressure resisting ability of the hull. The radius tolerance is plus or minus 5 mm of the theoretical radius at any point. The straightness tolerance calls for plus or minus 2½ mm from a straight line between any two adjacent stiffeners.

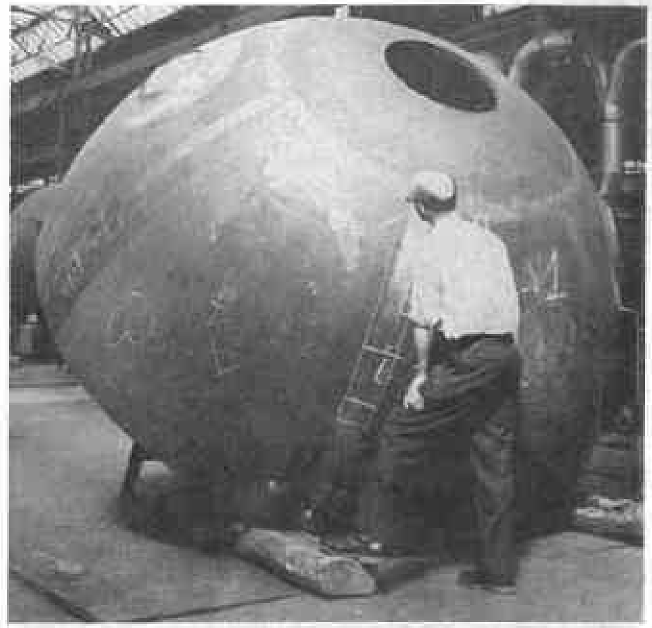

Fig. 5—Technician checks completed hemispherical section. Chalk marks identify X-ray film locations.

Fig. 6—Capt. Louis DeCamp of the U.S.N. Hydrological Office (left) and Dr. Jacques Piccard examine a prefabricated porthole before its installation. PX-15 will have 30 portholes, including those in hatches.

ABS certification. The hull met or exceeded all of these severe requirements for straightness and roundness. This, and every other major operation in the fabrication of the hull was closely monitored by a representative of the American Bureau of Shipping, which will certify the vehicle upon completion. The *PX-15* thus becomes the first submarine to earn ABS certification.

Coating. When the weld check and measurements were completed, the hull sections which until now had a

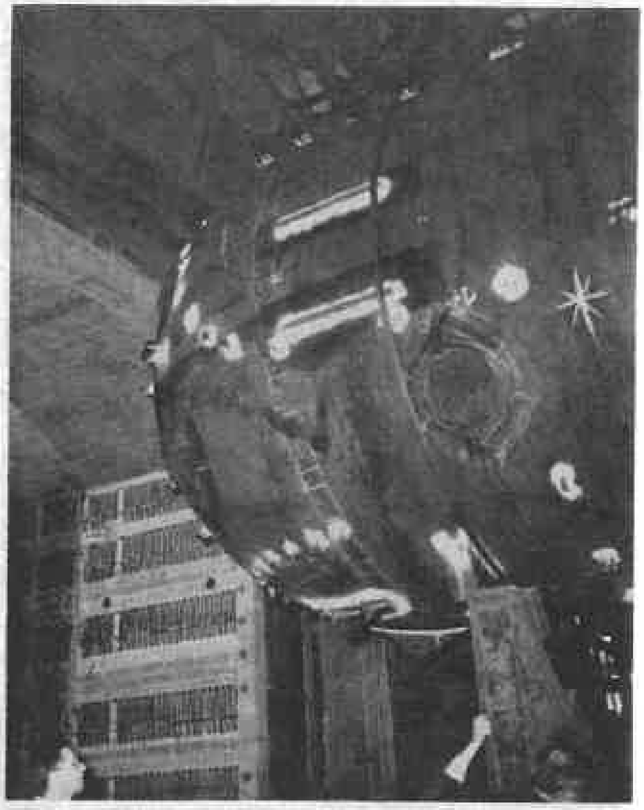

Fig. 7—Forward section of PX-15 enters oven for stress relief.

Fig. 8—Project engineer Donald Terrana turns technician to make one of the 2,000 hull measurements made for straightness.

Fig. 9—Piccard employe Gerard Baechler reads indicator while working in forward hull section.

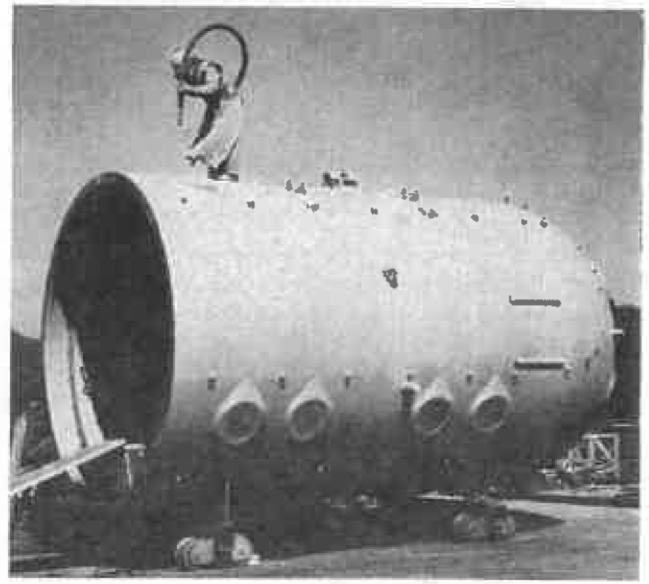

Fig. 10—Spaceman-like worker sandblasts exterior of hull's aft section.

rather nondescript appearance, were sandblasted and painted with two coats of zinc-based epoxy and one coat of white paint.

Machining of the Flange

Machining of the 10-ft. diameter flange required a larger capability machine than was available at the Giovanola foundry. Therefore, arrangements were made to have this operation performed at the factory of Ateliers de Constructions Mecaniques de Vevey, at Vevey, some 25 miles from Monthey. The hull sections, weighing about 20 and 35 tons respectively for the aft and forward sections, were easily transported by truck to the distant machining site. The flange was machined with a tool rotating on a horizontal axis as the hull is held stationary.

Conclusion

This is the status of the *PX-15* construction today. All internal and external equipment will be installed following the return of the hull section to Monthey. The Swiss portion of the fabrication is slated for completion by the end of the year, when the vehicle will be transported to Palm Beach, Fla., and final outfitting done for the Gulf Stream Drift Mission. ■