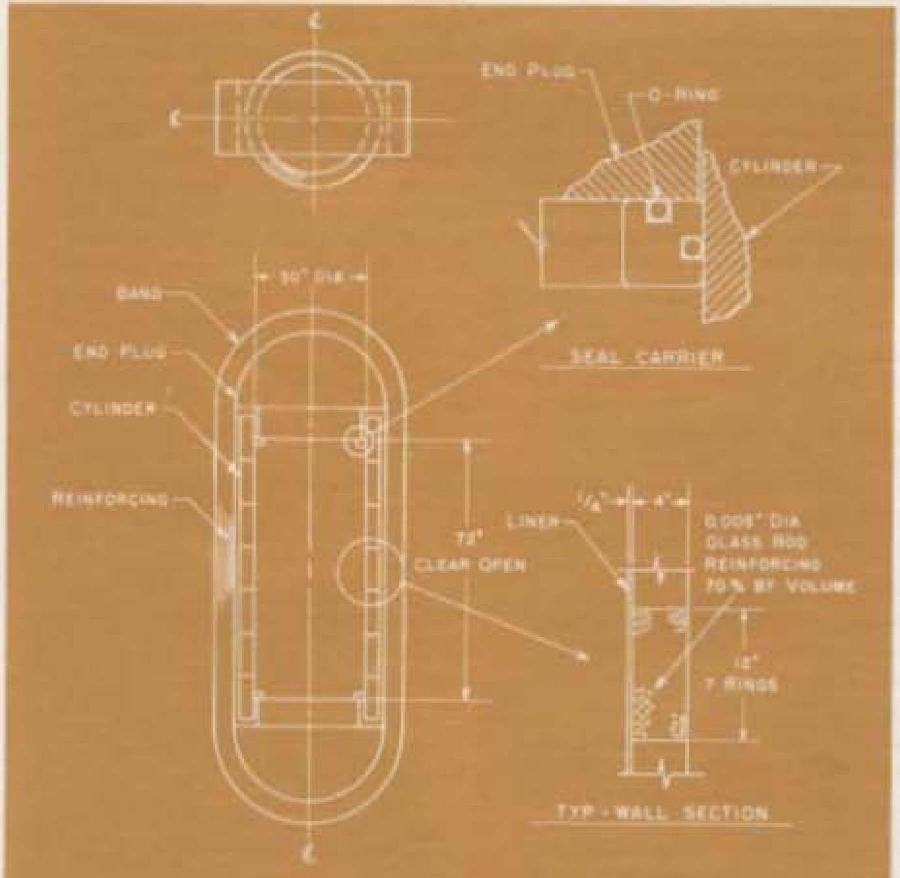
CHESDIV Guides Production

Deep-Ocean Simulator Built for NOAA

Fully assembled cylinder. Note several strain gauges spaced along length of outer surface.

Cross section of glass pressure vessel with details of seal carrier and typical wall section.



• Washington, D. C.

The National Oceanographic and Atmospheric Administration (NOAA), Department of Commerce, recently acquired a deep-ocean simulator that had the unusual requirement of being totally non-magnetic. The simulator is to be used by NOAA to calibrate deep ocean instruments. The pressure vessel was designed and fabricated from a monofilament glass "advanced composite" by the Illinois Institute of Technology Research Institute. The Chesapeake Division of NAVFAC was selected by NOAA to provide the technical expertise to monitor the design, manufacture and testing of the vessel.

The pressure vessel is 30" inside diameter by 72" clear inside length; the maximum operating pressure is 10,000 psi. The temperature variation of the salt water testing medium is controlled to within 0.01°F.

The vessel consists of a series of rings that resist hoop load, two end plugs that provide end pressure seal, and bands that resist longitudinal load.

The three structural elements; rings, end plugs and bands, are fabricated in the form of "advanced composites." The term "advanced composites" includes all forms of materials that are reinforced to improve strength, stiff-

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Long loop bands aid in resisting longitudinal load in the cylinder.

ness, or some other mechanical property. In this case, 0.005" diameter glass rod is used to reinforce epoxy resin. The composite is 70% glass by volume and has an ultimate tensile strength of 200,000 psi.

The material is similar to reinforced concrete in that it's strength and elasticity are different in all directions (anisotropic). The O-rings are in a seal carrier that is molded from talcum bearing epoxy. The epoxy liner is specially formulated to act as a fluid barrier.

The manufacturing procedures of the elements are proprietary; however, the procedure for a ring might be to build a mandrel of a diameter equal to the inside diameter of the ring. The mandrel is mounted on a lathe type device so that it may be slowly rotated.

The reinforcing is purchased in "tape" form on a spool with approximately 120 reinforcing rods in the tape. The rods are held together by epoxy resin in a partially cured condition.

The end of the tape is fixed to the mandrel and the mandrel is rotated. The tape is fed under slight tension to the ring as it forms on the mandrel. The epoxy on the first or inner windings must be cured so that it can support the radial load produced by the tension in the outer windings. Other steps are required to produce the finished ring.

A cylinder wall ring (front) and a seal carrier.

Several technical problems called for special attention in the fabrication of this vessel. They were:

Unusually large deflections take place that must be accounted for in the design. The modulus of elasticity of the material is $6.5x10^6$ # in.^{2} The increase in vessel diameter under operating pressure is 3/16 inch.

The seal carrier is particularly affected and must be sufficiently elastic to expand radially, with the rings, in order to maintain the seal. As the rings expand the carrier scrubs against the end plug. In addition, it has to be free to scrub longitudinally against the cylinder wall as the distance between the end plugs increases. The carrier must remain stable during pressurization and depressurization cycles; that is, it must not rotate and break the seal.

Complex stress distributions exist in the cylinder walls in the vicinity of the seals outboard of which there is no internal pressure and no tendency to expand. Finite element stress analysis was conducted to evaluate the local discontinuity stress in the thick wall vessel.

The analysis provides hoop, longitudinal, radial, and shear stresses, as well as radial displacements. The stresses must be carefully analyzed and evaluated because the composite is "brittle" (has a straight stress-strain curve from zero strain to rupture).

While the material does not possess the "forgiving" qualities of a ductile steel, it does not fail catastrophically as does a brittle steel. When rupturing, these vessels go "a string at a time." Of particular concern are the shear stresses, because the composite may have an ultimate shear of as little as 3,000 psi, depending on fabrication quality.

The end plugs displace longitudinally; the distance between them increases ½ inch. This is a result of the elongation of the bands. Shear stresses must be screened in two cases: first, at the junction of the straight and curved section the classical stress pattern changes from straight line to hyperbolic.

In the second case, the increase in length of the curved section results in those portions of the band, at the point of tangency, attempting to become straight.

In order to accomplish the design and manufacturing task for which little precedent exists, each step along the way was checked with laboratory data:

Finite element stress analyses were conducted in order to get as accurate a statement of stresses as possible. Laboratory data was researched and developed ot determine all ultimate stresses including fatigue data. The work was monitored closely by Chesapeake Division personnel.

Each component, ring, band, etc., was individually tested to assure its structural adequacy. The development testing indicated a need to saturate the seal carrier molding with talcum. This reduced the coefficient of friction so that the necessary scrubbing and elongating could take place without breaking the seal.

The completed pressure vessel will be hydrostatically tested to 11,500 psi at the factory. After installation at San Diego, a final hydrostatic and leak test will be performed.