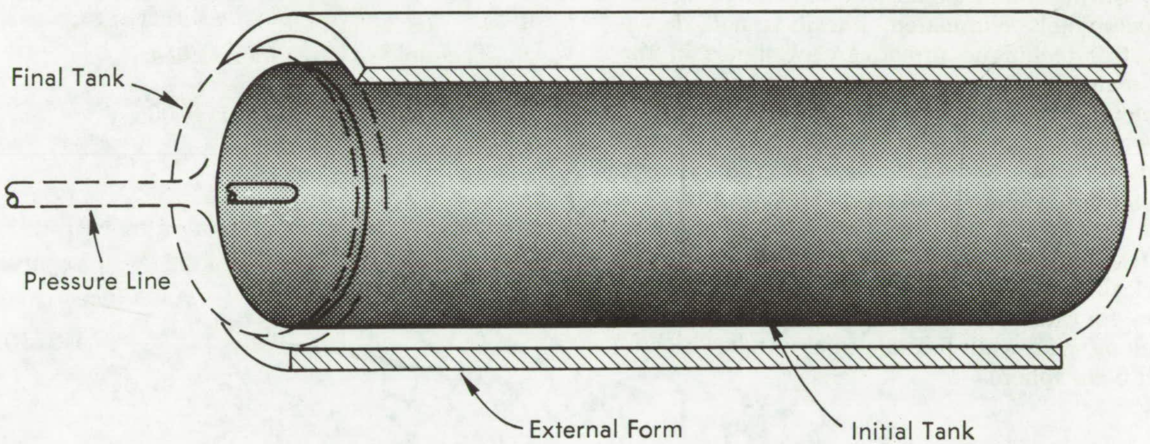
NASA TECH BRIEF
Ames Research Center

Simple Method for Forming Thin-Wall Pressure Vessels

A novel method that has been developed for forming thin-wall pressure vessels for spacecraft also appears to be applicable to the commercial fabrication of a wide variety of tanks.



The need for reducing tank construction costs for the Space Shuttle was clearly evident from the beginning of the program, for it was realized that nearly one third of the direct cost per flight could be represented by the expendable hydrogen tanks unless their manufacture could be accomplished more cheaply. The results of a series of feasibility studies revealed that current manufacturing techniques or contemplated developments would not reduce costs significantly.

However, a novel concept was prompted by conclusions derived from results of an experimental study on buckling of hydrostatically formed cylinders. In the course of this study, cylinders were formed by hydrostatic expansion of type 304 stainless steel, seam-welded tubing (0.04-cm wall) from an initial diameter of 15.2 cm to a final diameter of 21.6 cm. The resulting cylinders were highly uniform in wall thickness, remarkably free of geometric imperfections, and uniformly work hardened to a yield strength of about 62 meganewtons/m² (90,000 psi). Accordingly, it appeared that this combination of effects of plastic expansion would be uniquely favorable to the concept of hydrostatic formation of large thin-walled high quality tanks.

The new method for forming thin-wall pressure vessels merely requires application of internal hydrostatic pressure to a seam-welded circular cylindrical tank that has corner-welded, flat, circular ends. As shown in the diagram, a form is used to limit expansion of the cylindrical portion of the final tank while the hemispherical ends develop freely. No external form or restraint of any kind is required to fabricate spherical tanks. Some research has been conducted

(continued overleaf)

on the possibility of free-forming tanks with cylindrical sections; however, these techniques are not perfected at this time.

Two types of weld joints for attachment of the cylindrical section to the flat circular ends of the original tanks have been used with metal thickness of the order of 0.03 cm or less (0.012 inch). The ends were formed with a shallow flange to facilitate welding the thin material; a simple corner butt weld was used with thicker material. In experiments performed thus far, the 15.2-cm tubes were the standard, seam-welded, bead-rolled type 304 S.S. tubing; larger diameters have been formed from sheet stock, and have butt-welded longitudinal seams.

When pressure is applied to the original cylindrical tanks, expansion occurs relatively uniformly over the cylindrical surfaces, but wrinkles develop at the corner butt welds; however, these wrinkles are completely smoothed out in the final pressurization stages. In tests conducted with confining end plates attached to the cylindrical outer form to prevent bulging of the ends during initial expansion, the wrinkling was nearly completely eliminated, but it is not known whether this technique provides advantages in the weld or material integrity of a finished tank.

In general, cylindrical and spherical tanks formed in this way are expanded to a final diameter corresponding to about a 40% plastic elongation in the hoop direction at maximum diameter. This results in a work-hardened yield stress of 85% to 95% of the ultimate stress for the materials used.

Spherical tanks are formed by the free expansion of cylinders; for example, a cylinder 15.2 cm in diameter, 14.7-cm long, with walls 0.05-cm thick can be "blown" into a 21.6-cm sphere.

Notes:

1. Rupture pressures for cylinders and spheres are close to theoretical values: cylindrical vessels can withstand nearly one-half the pressure of spherical vessels owing to the fact that cylindrical hoop stress should be exactly twice the maximum tensile stress in the hemispherical end.
2. Spherical tanks as large as 129 cm in diameter have been fabricated by this method.
3. The outside surfaces of the tanks are remarkably smooth and can be finished to a high polish.
4. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)
   Reference: NASA TMX 62 043,

   A Simplified Method of Forming Thin-Walled Pressure Vessels.
5. No additional documentation is available. Specific questions, however, may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: B72-10025

Patent status:

No patent action is contemplated by NASA.

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