Mechanics

Code Assesses Risks Posed by Meteoroids and Orbital Debris

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BUMPER II version 1.92e is a computer code for assessing the risk of damage from impacts of micrometeoroids and orbital debris on the International Space Station (ISS), including those parts of the ISS covered by shielding that affords partial protection against such impacts. (Other versions of BUMPER II have been written for other spacecraft.) Bumper II quantifies the probability of penetration of shielding and the damage to spacecraft equipment as functions of the size, shape, and orientation of the spacecraft; the parameters of its orbit; failure criteria that quantify impact damage at the threshold of failure for each spacecraft surface; and the impact-damage resistance of each spacecraft surface as defined by "ballistic limit equations" that return the size of a failure-causing particle as a function of target parameters (including materials, configurations, thicknesses, and gap distances) and impact conditions (impact velocity and the density and shape of the impactor). BUMPER II version 1.92e contains several dozen ballistic limit equations that are based on results from thousands of hypervelocity impact tests conducted by NASA on ISS shielding and other hardware, and on results from numerical simulations of impacts.

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Asymmetric Bulkheads for Cylindrical Pressure Vessels

These bulkheads would offer advantages over prior concave, convex, and flat bulkheads.

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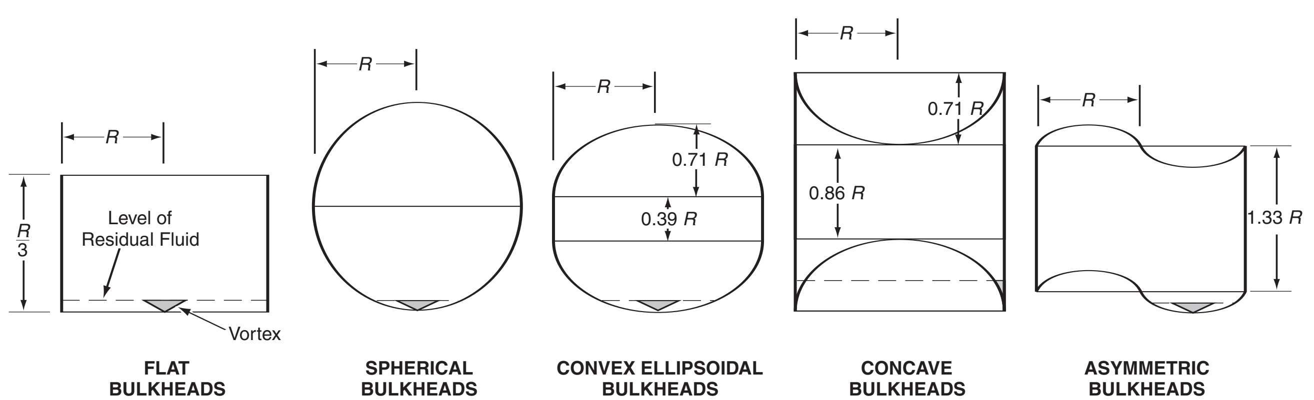
Asymmetric bulkheads are proposed for the ends of vertically oriented cylindrical pressure vessels. These bulkheads, which would feature both convex and concave contours, would offer advantages over purely convex, purely concave, and flat bulkheads (see figure). Intended originally to be applied to large tanks that hold propellant liquids for launching spacecraft, the asymmetric-bulkhead concept may also be attractive for terrestrial pressure vessels for which there are requirements to maximize volumetric and mass efficiencies.

A description of the relative advantages and disadvantages of prior symmetric bulkhead configurations is prerequisite to understanding the advantages of the proposed asymmetric configuration:

- In order to obtain adequate strength, flat bulkheads must be made thicker, relative to concave and convex bulkheads; the difference in thickness is such that, other things being equal, pressure vessels with flat bulkheads must be made heavier than ones with concave or convex bulkheads.
- Convex bulkhead designs increase overall tank lengths, thereby necessitating additional supporting structure for keeping tanks vertical.
- Concave bulkhead configurations increase tank lengths and detract from



These **Pressure-Vessel Configurations** have the same radius (*R*) and volume ($4\pi R^3/3$). The different shapes are shown here to illustrate the advantages and disadvantages of each. This is a representative but not exhaustive set of configurations, and is limited to single, non-nested pressure vessels for the sake of simplicity.

volumetric efficiency, even though they do not necessitate additional supporting structure.

- The shape of a bulkhead affects the proportion of residual fluid in a tank — that is, the portion of fluid that unavoidably remains in the tank during outflow and hence cannot be used. In this regard, a flat bulkhead is disadvantageous in two respects: (1) It lacks a single low point for optimum placement of an outlet and (2) a vortex that forms at the outlet during outflow prevents a relatively large amount of fluid from leaving the tank.
- A concave bulkhead also lacks a single low point for optimum placement of an outlet.

Like purely concave and purely convex bulkhead configurations, the proposed asymmetric bulkhead configurations would be more mass-efficient than is the flat bulkhead configuration. In comparison with both purely convex and purely concave configurations, the proposed asymmetric configurations would offer greater volumetric efficiency. Relative to a purely convex bulkhead configuration, the corresponding asymmetric configuration would result in a shorter tank, thus demanding less supporting structure. An asymmetric configuration provides a low point for optimum location of a drain, and the convex shape at the drain location minimizes the amount of residual fluid.

This work was done by Donald B. Ford of **Marshall Space Flight Center**.

This is the invention of a NASA employee, and a patent application has been filed. Inquiries concerning license for its commercial development may be addressed to the inventor:

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