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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MSC-23774

Asymmetric Bulkheads for Cylindrical Pressure Vessels

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

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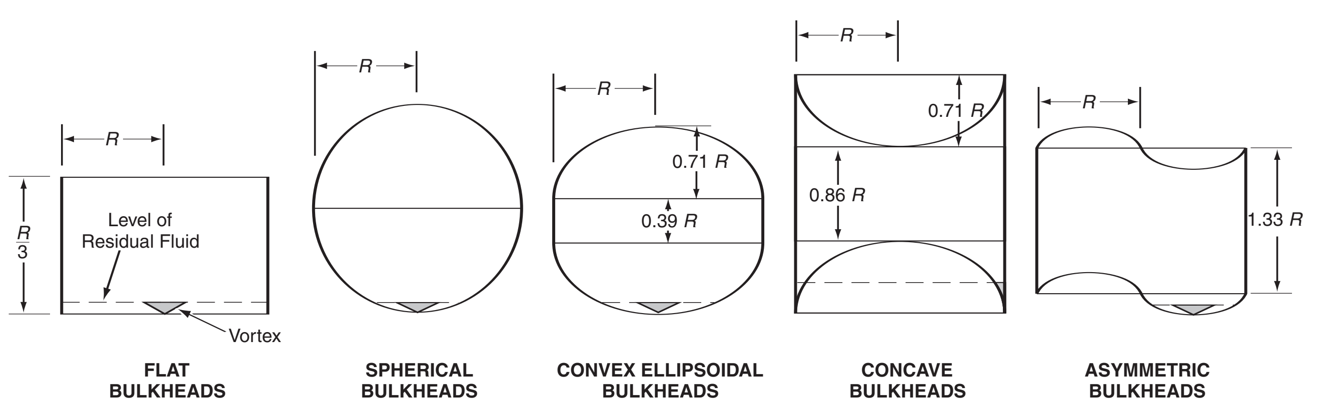
Asymmetric bulkheads are proposed for the ends of vertically oriented cylindrical pressure vessels. These bulkheads, which would feature both convex and concave contours, would offer advantages over purely convex, purely concave, and flat bulkheads (see figure). Intended originally to be applied to large 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.