ical and empirical results when cognizance is taken of the afterflow or springback of target material, e.g, the compressive properties.

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Ultra-Lightweight, Highly Efficient, High-Temperature, Thermal-Insulation System

Bertram Klein*

Hughes Aircraft Company, El Segundo, Calif.

Many years ago, a system of glass vacuum spheres was patented for insulation for room temperature. Today such a system can be modified for high-temperature usage. The modifications consist of replacing ordinary glass by some other ceramic and adding radiation barriers. These barriers consist of many ultra-thin, electrically charged, ceramic flakes housed in the vacuum spheres. The number of rows of spheres is such that over-all heat transfer is at a minimum for a given weight. Minimum gage of the sphere wall is determined by manufacturing limitations. Also, this gage must be large enough to prevent leaks. The density of the ceramic flakes must be kept low in order to minimize conduction and keep radiation blockage.

A typical $(R/t)_{max}$ of a ceramic sphere is calculated by writing

$$15R/2t = 0.1\,E\,t/R$$

$$(R/t)_{max} = (0.2\,E/15)^{1/2} \approx 400$$

Thus, for

$R = 0.25$ in., $t \approx 0.0006$ in.

E = Young's modulus $\approx 10^7$

R = sphere radius

t = sphere thickness

More thickness is needed to prevent leakage and allow manufacturing feasibility. Assume the minimum gage to be 0.0015 in. Further, assume four rows of spheres and an average density of ceramic flakes of about 1 lb/ft^3. Then the weight per cubic foot of the total system, using ρ of ceramic of 0.08 lb/in.^{3}, is about 2.5.

If we assume thermal conductivity of sphere material of 0.5 Btu/hr per ft per °F at elevated temperature, the effective k of the total system is estimated to be about 0.05. This value compares with about 0.12 for 4.5 lb/ft^3 dyna-quartz at 2000°F.[1] Various tests are needed to confirm the theoretical efficiency of the vacuum sphere-charged flake insulation system.

One way to manufacture a vacuum sphere filled with electrically charged flakes is to immerse the flakes in a plastic sphere. The ceramic material is cast onto this sphere. Since the casting is porous, the plastic can be sublimed out at a low temperature. Finally, the ceramic is fired to become gas-tight.

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* Staff Engineer, Engineering Mechanics and Preliminary Design Department, Space Systems Division.

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