

Improved Thermal-Insulation Systems for Low Temperatures

Efficient, robust insulation for soft vacuum.

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Improved thermal-insulation materials and structures and the techniques for manufacturing them are undergoing development for use in low-temperature applications. Examples of low-temperature equipment for which these thermal insulation systems could provide improved energy efficiency include storage tanks for cryogenics, superconducting electric-power-transmission equipment, containers for transport of food and other perishable commodities, and cold boxes for low-temperature industrial processes. These systems could also be used to insulate piping used to transfer cryogenics and other fluids, such as liquefied natural gas, refrigerants, chilled water, crude oil, or low-pressure steam.

The present thermal-insulation systems are layer composites based partly on the older class of thermal-insulation systems denoted generally as "multilayer insulation" (MLI). A typical MLI structure includes an evacuated jacket, within which many layers of radiation shields are stacked or wrapped close together. Low-thermal-conductivity spacers are typically placed between the reflection layers to keep them from touching. MLI can work very well when a high vacuum level ($<10^{-4}$ torr) is maintained and utmost care is taken during installation, but its thermal performance deteriorates sharply as the pressure in the evacuated space rises into the "soft vacuum" range [pressures >0.1 torr (>13 Pa)]. In addition, the thermal performance of MLI is extremely sensitive to mechanical compression and edge effects and can easily decrease from one to two orders of

magnitude from its ideal value even when the MLI is kept under high vacuum condition.

The present thermal-insulation systems are designed to perform well under soft vacuum level, in particular the range of 1 to 10 torr. They are also designed with larger interlayer spacings to reduce vulnerability to compression (and consequent heat leak) caused by installation and use. The superiority of these systems is the synergistic effect of improvements in materials, design, and manufacture.

The materials used in these systems include combinations of the following:

- Radiation-shielding layers.
- Spacers made of microglass papers or fabrics.
- Granules of either silica or aerogel.
- Outer wrappers that can be made of paper, fabric, or plastic films as required for a given application.

The developmental layered composite insulation systems are divided into the following three categories according to the design structure of the spacer layer:

- Paper, powder deposited on surface of paper, radiation-shielding layer.
- Fabric, powder mechanically deposited inside fabric, radiation-shielding layer.
- Fabric, powder formed chemically within fabric, radiation-shielding layer.

Within each category, thermal-insulation materials may be produced in several different forms of continuous single- or multiple-layer rolls, multiple-layer cylindrical sleeves, and multiple-layer blankets.

The overall effectiveness of the system of insulation depends on thermal performance, versatility and durability, ease of use in manufacturing and installation, and costs of operations and maintenance. Tests of the layered composite insulation systems have thus far confirmed the expectations of high efficiency. Soft-vacuum (1 to 10 torr) systems have much less "vacuum burden" cost compared to high-vacuum (0.00001 torr) systems — the key to lowering manufacturing and life-cycle costs of equipment. Although new systems are targeted for low-cost, soft-vacuum solutions, they also offer advantages for high-vacuum superinsulation applications because of their robust nature. The apparent thermal conductivity for a typical layered composite under evaluation is as follows: 2.4 mW/m-K (milliwatt per meter-kelvin) at 1 torr vacuum level (versus about 12 mW/m-K for MLI) and 0.09 mW/m-K at 10^{-4} torr (comparable to about 0.08 mW/m-K for MLI). These values are for boundary temperatures of approximately 80 and 290 K and residual gas of nitrogen.

This work was done by James E. Fesmire of Kennedy Space Center and Stanislaw D. Augustynowicz of Dynacs Engineering Co. Further information is contained in a TSP (see page 1).

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-8130. Refer to KSC-12092.