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Insulation Systems in Spacecraft

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Nowadays, it is impossible to imagine a spacecraft without thermal protection and control system. Spaceship equipment is not capable to work in outer space without this system. Multi-layer protection system is widely used in practice. Also aerogel is a promising insulating material for spacecraft. These two materials will be discussed in the article.

Multi-layer insulation(MLI) is thermal insulation composed of multiple layers of thin sheets and is often used on spacecraft. It is one of the main items of the spacecraft thermal design, primarily intended to reduce heat loss by thermal radiation. In its basic form, it does not appreciably insulate against other thermal losses such as heat conduction or convection. It is therefore commonly used on satellitesand other applications in vacuum where conduction and convection are much less significant and radiation dominates. Typical structure of MLI is shown on figure 1.

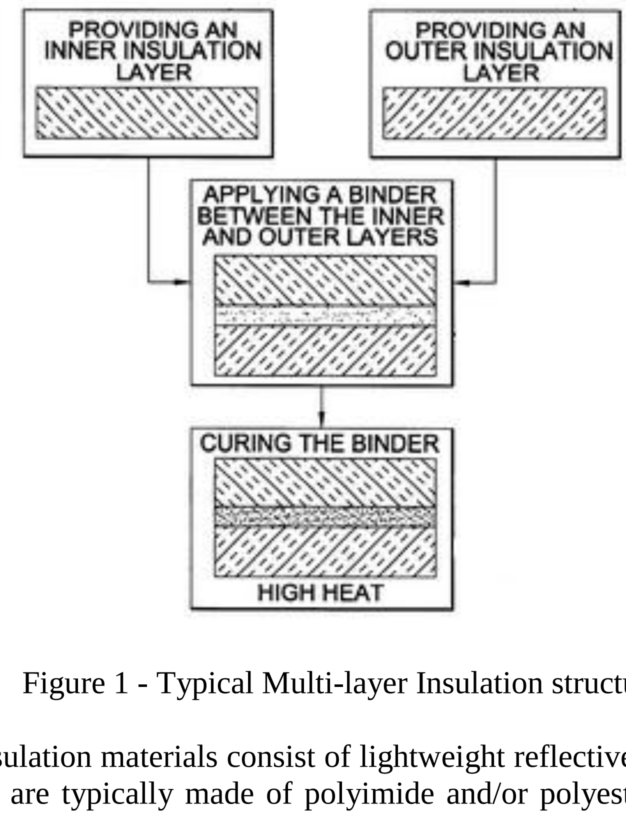

Figure 1 - Typical Multi-layer Insulation structure

Multi layer insulation materials consist of lightweight reflective films assembled in many thin layers. These layers are typically made of polyimide and/or polyester films (according to design, could be from 5 to 30 layers) that are vapor deposited with 99.99% aluminum, on one or both sides. The multilayer films assist in the material's heat management by reducing emittance with each layer [2].

As it is very difficult to design an MLI insulation blanket that reflects 100% of incident radiation, a multilayer film design can range from a few simple layers to a complex array of blankets that completely surround the spacecraft and many of its external components. The designs of these layers typically reflect 95% of radiation back away from the Spacecraft. The total effect by the time the radiation energy makes its way to the innermost layers is, effectively, a 100% reflective barrier [5].

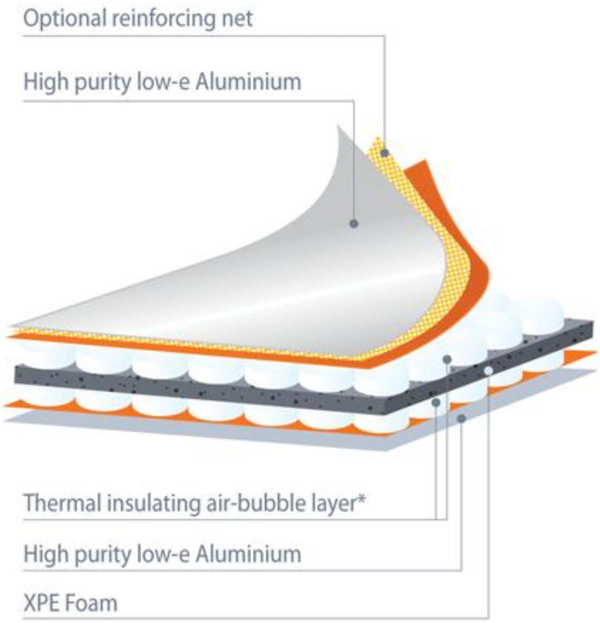

Figure 2 - Polynum Multi. MLI material used in industry

Ideally, temperatures which are most desired for a spacecraft to operate at maximum capacity is between -23°C to +40°C (-70°F to +107°F). This is accomplished by using MLI insulation materials that will work for both active as well as passive systems. Active systems can be best described as energy sources such as battery powered heaters, which work to keep the spacecraft at nominal temperatures (+70°F) during cold cycles. Passive systems are best described as using engineered materials, as are found in MLI blankets and offer radiation heat barriers to retard and control the flow of energy [1].

The terms absorption and emittance are two critical factors in the design and effectiveness of a multi layer insulation system. Absorptance is a material's ability to reflect solar energy. Typically, a material that has low solar absorptance will have high reflective properties, such as a mirror that deflects heat (solar energy) away from the spacecraft. Vacuum Deposited Aluminum (VDA) is the most commonly used coating as it offers low absorptance and emittance properties at an affordable cost. Emittance is a material's ability to radiate energy in the form of heat. Similar to a hot coal, once the energy source (in this instance - fire) is removed, the coal continues to emit heat. MLI insulation materials with high emittance will radiate heat long after the Spacecraft is out of the sun's exposure. By design, both Absorptance and Emittance properties can be configured to control the temperature of the spacecraft surfaces.

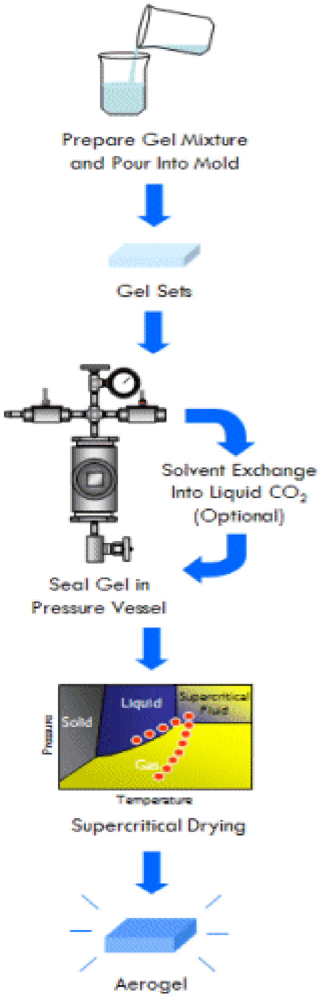

Figure 3 - Aerogel crafting process

Aerogel is a synthetic porous ultralight material derived from a gel, in which the liquid component of the gel has been replaced with a gas. The result is a solid with extremely low density and low thermal conductivity. Nicknames include *frozen smoke*, *solid smoke*, *solid air*, or *blue smoke* owing to its translucent nature and the way light scatters in the material. It feels like fragile expanded polystyrene (Styrofoam) to the touch. Aerogels can be made from a variety of chemical compounds.

Aerogels are produced by extracting the liquid component of a gel through supercritical drying. This allows the liquid to be slowly dried off without causing the solid matrix in the gel to collapse from capillary action, as would happen with conventional evaporation. The first aerogels were produced from silica gels. Kistler's later work involved aerogels based on alumina, chromia and tin dioxide. Carbonaerogels were first developed in the late 1980s [3].

Aerogel is a material that is 98.2% air. The lack of solid material allows aerogel to be almost weightless. The reason for the difference in the composition is the structure of the aerogel. Aerogel has a porous solid network tcontains air pockets, with the air pockets taking up majority of space within the material.

Despite their name, aerogels are solid, rigid, and dry materials that do not resemble a gel in their physical properties: The name comes from the fact that they are made from gels. Pressing softly on an aerogel typically does not leave even a minor mark; pressing more firmly will leave a permanent depression. Pressing extremely firmly will cause a catastrophic breakdown in the sparse structure, causing it to shatter like glass – a property known as *friability*; although more modern variations do not suffer from this. Despite the fact that it is prone to shattering, it is very strong structurally. Its impressive load bearing abilities are due to the dendritic microstructure, in which spherical particles of average size (2–5 nm) are fused together into clusters. These clusters form a three-dimensional highly porous structure of almost fractal chains, with pores just under 100 nm. The average size and density of the pores can be controlled during the manufacturing process [4].

Aerogels are good thermal insulators because they almost nullify two of the three methods of heat transfer (convection, conduction, and radiation). Silica aerogel is especially good because silica is also a poor conductor of heat (a metallic aerogel, on the other hand, would be less effective). Aerogels are poor radiative insulators because infrared radiation (which transfers heat) passes through silica aerogel.

MLI systems are obsolete. A lot of layers make construction heavy and increases the size. Aerogel is able to take any form and to protect the smallest objects. Aerogel - is the future of spacecraft.

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