November 1967 Brief 67-10465

NASA TECH BRIEF

Study Made of Transfer of Heat Energy Through Metal Joints in Vacuum Environment

A study was made to seek additional information about the transfer of heat across bolted joints and flat metal surfaces in a partial vacuum of less than 10^{-4} torr. Electronic components and other pieces of equipment used on space vehicles develop heat energy as a byproduct of their respective functions. The dissipation of this energy becomes a problem in space because of vacuum conditions and the resulting loss of convection in and around each article. To overcome this problem, conduction into a heat sink is extensively used. However, if the components are clamped or bolted to a heat sink in a high vacuum environment, a problem in heat transfer does remain.

The joining of articles in an environment containing gas at pressures well above 10^{-4} mm Hg will result in good heat transfer from the component to the heat sink or cold plate, since gas molecules between the adjoining surfaces help transfer heat. If the number of molecules per unit volume is reduced below that contained at a pressure of 10^{-4} mm Hg, the heat transfer is effected mainly by direct contact of the two surfaces. The actual contact area of ordinary machined surfaces, either flat or form fitting, is very low at low surface contact pressures because of the roughness caused by tool marks, scratches, etc., and because of a wave variant from absolute flatness. The net result is that temperature differences between the two surfaces tend to be greater than is normally experienced. This study presents information associated with this phenomenon. The conclusions drawn from this study are presented below:

Temperature Drop across a Bolted Joint. In a vacuum environment, such as that found in outer space, heat energy transfer across joints bolted together displays several useful and interesting thermal conductivity characteristics.

(a) If two thin sheets of a metal alloy, for example aluminum alloy 6061-T6, are bolted together, heat energy transfer from one sheet of metal to the other sheet of metal is closely concentrated around the bolt.

(b) At a given heat energy load, the temperature drop across a bolted joint decreases rapidly as the bolt and nut are tightened to a minimum torque level. Increasing the torque load above this level does not decrease the temperature drop significantly.

(c) A flange with a large or a small footing area, made of thin metal, transfers heat energy to a heat sink with equal effect.

(d) A thick flange, with a large footing area, transfers heat energy more efficiently to a heat sink having a rigid surface than a thin flange with the same-sized footing area.

(e) The insertion, between a flange and mounting base, of a soft shim material possessing a low thermal resistance is of very little practical value in increasing heat energy transfer efficiency.

(f) The temperature distribution around a bolt holding a flange to a heat sink is symmetrical. The temperature drop from a thin flange to a heat sink increases abruptly at a short distance from the perimeters of the bolt head and the nut.

Temperature Difference of Rigidly-Backed Heat Transfer Surfaces. Rigidly-backed flat metal surfaces pressed together in a vacuum environment display a cyclical improvement in heat energy transfer as the interface pressure is increased. This suggests changing rapidity with which actual contact area increases, through a settling together of the surfaces.

A small rise irregularity on one of the flat surfaces lowers the heat energy transfer efficiency. In the tests described in the report, a small rise irregularity caused

(continued overleaf)

the temperature difference of two surfaces to double. Below 30 psi, temperature differences increase rapidly and the ratio of two no longer applies.

Note:

Additional details are contained in *A Study of Thermal Resistance across Aluminum Joints in a High Vacuum*, by D. H. Elliot, Douglas Aircraft Company, Report No. SM-46759, December 1964. Copies of this report are available from:

Technology Utilization Officer
Marshall Space Flight Center
Huntsville, Alabama 35812
Reference: B67-10465

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

Source: D. H. Elliot
of Douglas Aircraft Company
under contract to
Marshall Space Flight Center
(MFS-12534)