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THERMAL CONTACT CONDUCTANCE OF MULTIPLE FOIL LAYERS

This note reports the results of tests to determine the improvement in thermal contact conductance between two uneven surfaces by means of multiple layers of crumpled aluminum foil. In the thermal design of certain types of equipment, it is frequently necessary to insure reasonably good thermal conductance between two adjoining parts. If the mating surfaces are not precisely machined and held in contact by considerable pressure, the conductance will be limited by the degree of actual contact between parts and the thermal conductivity of the fluid or gas in the intervening void. Conductance is frequently improved by the application of some sort of conductive cement which has a higher conductivity than the fluid or gas. However, the use of such a cement might be unacceptable if it is not easily removable, if it promotes corrosion or if the parts are in an unsatisfactory environment such as exposure to high radioactivity.

In the past several years there have been numerous investigations of thermal contact conductance as a function of surface finish, contact pressure and vacuum environment (see References). Some of the conclusions indicate the following:

(1) The average gap between machined surfaces may be as much as 100 times the rms value of the surface finish. The maximum peak to valley height is a more significant parameter than the rms value.

(2) At low contact pressures (below 10 psi) the conductance in a vacuum atmosphere may be an order of magnitude less than the conductance at atmospheric pressure.

(3) At higher contact pressures (between 40 and 140 psi) the conductance is less sensitive to the pressure of the environment. Between contact pressures of 40 psi and 140 psi the conductance in vacuum varies between 80% and 90% of the conductance in air.

(4) As is to be expected, materials with lower yield points and surface hardness have higher conductances for the same contact pressure than harder materials.

(5) Creep of the mating faces increases the conductivity.

The application studied in this note is the use of commercial strip heaters to be attached to the outside of the wall of an extruded aluminum vacuum chamber for the purpose of bakeout. It is anticipated that there will be a considerable gap between the chamber wall and the heater. The use of a common copper bearing thermal cement is not advisable because of the danger of corrosion of the aluminum wall. It was therefore proposed that several layers of crumpled aluminum foil be sandwiched between the parts.

The test arrangement is shown in Fig. 1. A one-foot long by 1-1/2 inch, 250-watt strip heater was bolted to a strip of 3/16-inch thick aluminum plate. For reasons related to another test, the heat sink was furnished by a 6 × 12-inch aluminum plate welded at right angles to the 1-1/2 inch strip. Chomel-alumel thermocouples were located between the strip heater and the aluminum foil (TC1), and on the "cool" side of the aluminum strip (TC2). The heater and strip were insulated with three 1/2-inch layers of insulating material with a conductivity of 0.03 Btu/hr. ft. ^{o}F (0.52 mW/cm ^{o}C). Air was blown across the bare cooling fin. Power to the heater was furnished by a Variac and measured with a wattmeter. Readings were taken at several values of power input. The aluminum foil was 0.001 inch thick.

The results of the tests are shown in Table 1 and Fig. 2. Four layers of crumpled aluminum foil has an effective conductivity 15 times greater than the air gap and resulted in an effective coefficient of heat transfer 6 times greater than the air gap. The increase in conductivity and coefficient of heat transfer is apparently limited by the unit pressure exerted by the heater and bolts. For this particular set-up, the conductivity and coefficient of heat transfer decreases with more than four layers of aluminum.

REFERENCES

1. W. R. Studstad, "Thermal Contact Resistance Between Thin Plates in Vacuum," ASME Publication 65-HT-16, April 13, 1965.
2. F. J. Petri, "An Experimental Investigation of Thermal Contact Resistance in a Vacuum," ASME Publication 63-WA-156, November 17, 1963.
3. A. M. Clausing and B. T. Chao, "Thermal Contact Resistance in a Vacuum Environment," ASME Journal of Heat Transfer, May 1965.

TABLE 1

Average Gap Inches	Conductivity		Coefficient of Heat Transfer		Layers of Foil
	Btu/hr. ft. °F	mW/cm °C	Btu/hr. ft.^{2} °F	watts/cm^2 °C	
0.020	0.015	0.26	9.4	5.3	0
0.025	0.053	0.92	27.7	15.7	2
0.053	0.232	4.01	57.5	32.6	4
0.049	0.223	3.86	54.6	31.0	6
0.050	0.178	3.08	42.7	24.2	8

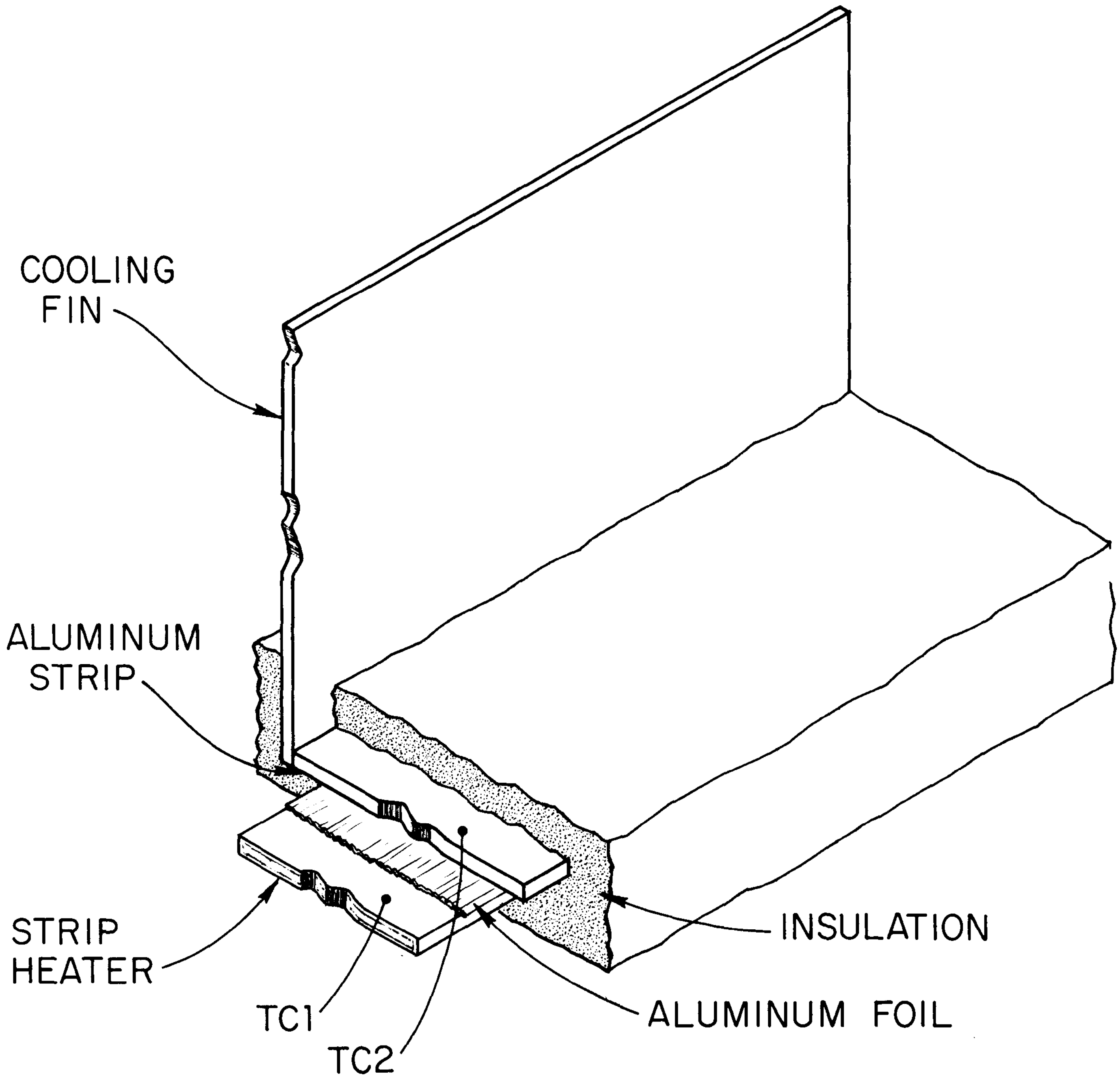
COOLING
FIN
ALUMINUM
STRIP
STRIP
HEATER
TC1
TC2
INSULATION
ALUMINUM FOIL

Fig. 1

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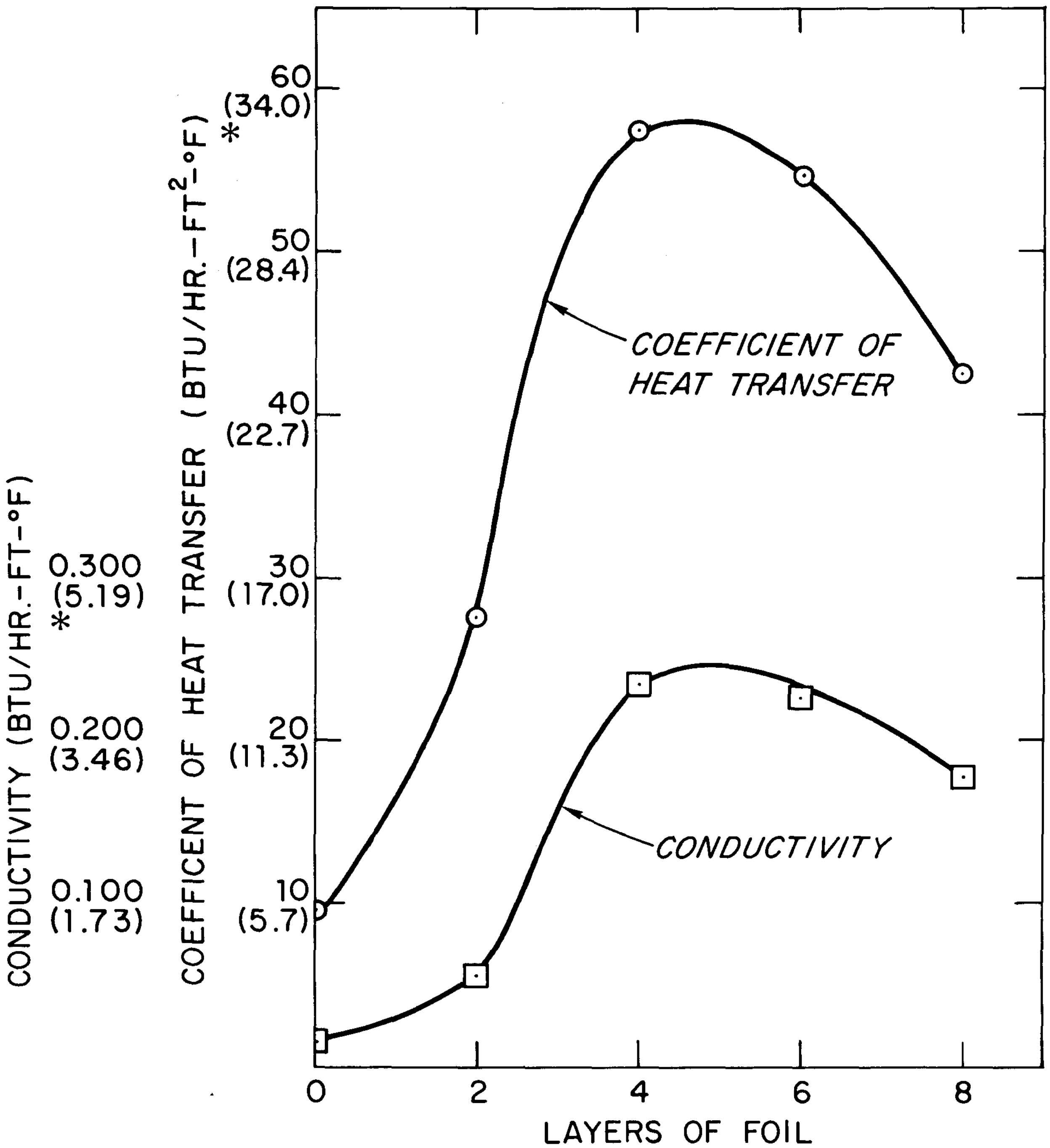

*Conductivity units in parenthesis are MW/CM °C
Coefficient units are MW/CM^2 °C

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Fig. 2