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Date: February 5, 1962

From: D. A. Pugliese

Subject: Shield Capsule Thermal Analysis
WANL-TME-010

TO: F. D. Retallick

REFERENCE

A detailed thermal analysis was made on the lithium hydride shield geometry which is being developed for the flight engine of the NERVA project. The geometry consists of one-half inch outside tube diameter capsules arranged in a triangular array. The capsules are spaced apart from 0 to 18 mils. For this analysis, it was assumed that at worst, the capsules would be touching therefore giving us a pitch ($\frac{s}{d}$) of 1.

At operating conditions it is assumed that the capsule consists of a 0.458 in. diameter Li H pellet encased in a stainless steel tube of 0.020 in. wall thickness. Between the pellet and the tube, there is assumed to exist a clearance gap of 0.001 in. The Li H pellets are 0.766 in. long and are stacked to form the capsule. Intermittently between the pellets beginning with the third from the bottom will be placed stainless steel discs. The bottom two pellets with an assumed interface gap of 1 mil were used for this analysis. The assumption of a 1 mil gap resulted from the difficulty in manufacturing parallel faces on the Li H.

The hydrogen coolant at inlet is at 117°R and 642 psia. The hydraulic diameter of the flow channel is 0.0513 in. The resulting Reynold's number at the film temperature (assuming a 100 R° film drop) is 5350. The convective coefficient correlation used is

$$(h)_{ave.} = 0.036 \frac{k_f}{D_h} (Re)_f^{0.8} (Pr)_f^{0.4} (L/D)^{-0.1}$$

where L/D was used as 1.0. The average convective coefficient was found to be $683. \times 10^{-6} \text{ BTU/sec} - \text{in}^2 - \text{R}^\circ$. The local coefficient is a function of the angle from the contact point to the point in consideration. This is shown in Figure 1.

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The heat generation is shown in Figure 2. as a function of axial distance; it is different in the steel and in the Li H. The value used in this analysis is twice that given by the figure.

The two pellets which comprise this analysis were divided into five elements in the axial direction as shown in Figure 3. Since the temperature field of the capsule has symmetry, only a 30° sector was considered. It was then subdivided into six radial elements and three angular elements. The analysis then consisted in writing the finite difference heat balance equations for the 80 elements resulting in a set of 80 simultaneous equations. At our East Pittsburgh division there is a Fortran computer code for the solution of a system of a maximum of 75 simultaneous equations. In order to apply this program, the original grid of 80 elements had to be modified and it was done so by assuming some symmetry in the angular direction in the last plane, that farthest away from the core. Another analysis was done on the first plane, that facing the core, by assuming heat flow in the radial and angular directions only thereby neglecting axial heat conduction.

The results of these analyses are shown by the attached computer output sheets. A temperature distribution was originally assumed so that the thermal conductivity of Li H, steel and helium could be used as variables of temperature. These functions are shown on Figure 4.

The original assumed distribution when compared with the results were found to be slightly high in the Li H and too low in the helium. These both tend toward low thermal conductivities. If these conductivities are changed to fit the new temperature distribution, the whole temperature field would be lowered.

REF. REACTOR HEAT TRANSFER CONFERENCE OF 1956, BOOK 2
 "ANALYSIS OF AXIAL TURBULENT FLOW AND HEAT TRANSFER THROUGH
 BANKS OF RODS AND TUBES". PGS. 416-461 BY: DEISSLER & TAYLOR

FIG. 2

EUGENE DIETZEN CO.
PRINTED IN U.S.A.

LOG-PROBABILITY GRAPH PAPER
11-LOGARITHMIC 3 CYCLES X 10 DIVISIONS

10¹

100

10⁻¹

Heating Rate (Watts/cubic centimeter)

RADIATION * HEATING IN SHIELD

Transverse Radius = 0 centimeters

63 % LiH
27 % Steel

10% Aluminum
40% Steel

VOID

10% Aluminum, 40% Steel

Aluminum

0 10 20 30 40 50

Axial Distance From Top Of Core (centimeters)

THERMAL CONDUCTIVITY OF PROPERTIES AS A
FUNCTION OF TEMPERATURE

FIGURE 4