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Temperature Distribution in the SPF Reactor Shield Plug
During Operation

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ABSTRACT

Steady state temperature distributions in the reactor support ring, shield plug, and actuator portions of the SPF reactor have been determined. The reactor was assumed to be operating at 300 Kwt with a coolant inlet temperature of 1125°F. Heat generation rates within the reactor support plate, shield material, and actuator motors were included.

The results of this analysis indicate that a cold plate will not be necessary between the shield plug and the actuator and gear set support ring.

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Objective

A thermal analysis was performed to determine the steady state temperature distribution in the SPF reactor shield plug during operation at 300 Kwt. The purpose of this analysis was to see if a cold plate is necessary between the shield plug and the actuator and gear set support ring.

The reactor system was assumed to be surrounded by a 120°F cold wall in a 10^{-5} torr vacuum. A MINI-TAP thermal network was constructed to represent the reactor support ring, reactor support ring, reactor support plate, and shield plug portions of the SPF reactor. Approximated geometric forms of the actuator and gear set support ring, actuator motors and the nose cap were included in the thermal model to serve as boundary conditions for the shield plug. The control drum drive shafts were also included in the thermal network as a resistance between the reflector support ring and the actuator motors.

A total of five cases were studied with nuclear heating in the shield components, insulation, and radiant heat transfer between the shield plug and the LiH shield as the variables. In all cases considered the reactor inlet plenum was assumed to be at a uniform constant temperature of 1125°F. Appropriate nuclear heating was input to the reactor support plate, LiH shield material, and the actuator motors. The first case

neglected radial heat transfer between the shield plug and the adjacent LiH shield. In this case the mode of heat loss from the shield plug was in the axial direction via various conduction and radiant heat paths to the nose cap. The only mode of heat transfer from the nose cap was assumed to be radiation to the surrounding 120° F cold wall.

The second case was essentially the same as the first with a 0.125 inch layer of thermal insulation added between the reactor support plate and the shield plug stainless steel containment vessel. This case was analyzed to determine the extent of heat transfer between the reactor and the shield plug.

The third and fourth cases both include radiant heat transfer between the shield plug and the adjacent LiH shield in the radial direction. To be conservative, the material adjacent to the shield plug was assumed to be at a uniform constant temperature of 800° F . An insulation layer was not included in these cases. The third case provided the correct amount of nuclear heating to shield components. The fourth case had twice the correct amount of nuclear heating input to the reactor support plate, LiH and actuator motors.

The fifth case inputs the correct amount of nuclear heating to the shield components. It includes radiant heat transfer between the shield plug and the adjacent LiH shield and has a layer of insulation between the reactor support plate and the shield plug containment vessel.

Figure 2 shows the results of the five cases analyzed. This figure presents the steady state thermal profile existing in the shield and support ring components located between the reactor support flange and nose cap for each case investigated.

The LiH material temperatures at nodes 5 and 9 and the approximate average LiH temperature for each case are given below. Node 5 is located at the edge of the shield material closest to the reactor. Node 9 is located at the edge of the shield material away from the reactor.

Case	Trace	Temperatures, °F		
		Node 5	Node 9	Average
1	A	1131	1015	1073
2	B	1153	1024	1088
3	C	1086	872	979
4	D	1102	898	1000
5	E	995	847	921

By comparing Traces C and D in Figure 2, it can be seen that a wide variation in the values of nuclear heating input to the model does not produce a significant difference in the shield plug thermal profile. However, by incorporating the radial radiant heat transfer between the shield plug and the adjacent shield the average shield plug temperature is lowered approximately 100°F. The cases with radial radiant heat transfer are more realistic than those cases without

side radiation. It is also felt that the temperature of the adjacent shield may be lower than the 800°F assumed in this analysis. Therefore the thermal profiles given in traces C, D and E may actually be somewhat lower than those given in Figure 2.

From Trace E in Figure 2 it can be seen that a layer of insulation placed between the reactor support plate and the LiH containment vessel lowers the maximum temperature in the shield plug LiH by approximately 100°F.

In all cases analyzed the cylindrical actuator support plate serves as a large thermal resistance in the axial direction. Due to this thermal resistance a large temperature gradient exists between the actuator support flange and the actuator motors. In all cases the average actuator motor temperature remains at approximately 500-575°F. With a cold wall temperature of 120°F the nose cap temperature is approximately 300°F in all cases.

The nose cap and actuator motor temperatures obtained in this analysis represent approximate values. This portion of the reactor system was not modeled in detail and served as a boundary condition for the rest of the analytical model.

From the results of this analysis it may be concluded that a cold plate is not necessary between the shield plug and the actuator and gear set support ring. It is further recommended that a layer of insulation be placed between the reactor support plate and the shield plug containment vessel. This configuration was simulated by Case 5. The results of this case are given by Trace E in Figure 2.

The maximum shield plug LiH temperature is 995°F and the average LiH temperature is 921°F for Case 5. The maximum temperature is well below the maximum allowable temperature for LiH. The average temperature is an optimum operating temperature from the standpoint of radiation induced expansion in LiH. As shown in Figure 5 of Reference 1, the percent volume expansion produced by radiation in LiH approaches a minimum value at temperatures of 800 + °F.

A layer of insulation between the shield plug and the reactor support plate will limit the heat transfer between these components and lower the maximum shield plug LiH temperature by 100°F. The heat transferred to the shield plug from the reactor without insulation is approximately equal to the amount of heat generated in the shield components due to nuclear heating.

A 0.125 inch layer of thermal insulation with a thermal conductivity value of 0.03 btu/hr-ft-°F was used in this analysis. The reactor support flange was assumed to be 1.5 inches high. Variations in the design of the reactor support flange may alter the heat transfer between the reactor and reactor support plate. A thicker layer of insulation may be required to compensate for any reduced reactor support flange height.

Models

The MINI-TAP computer model developed for this study is shown in Figure 1. The model represents a 360° radial portion of the SPF reactor shield plug components between the reactor and the actuator motors.

A thermal resistance representing the aggregate effect of all eight actuator drive shafts was included between the reactor support plate actuator motors. Other conduction and radiant heat transfer paths are shown as zig-zag or dashed lines in Figure 1.

Nuclear heat generation was input to the nodes representing the reactor support plate, LiH shield material, and the actuator motors. The amount of nuclear heat generation input to each node was determined as a function of reactor operating power, component material properties and component geometry. Figure B5 of Reference 2 was used to determine the rate of heat generation per unit volume of the materials used in this study. The heating rates given in Reference 2 were initially reduced by a factor of 2 to compensate for the 300 Kwt operating power level. Allowance was then made for the gamma shield material differences. The heat generation rate in the stainless steel reactor support plate was assumed to be 50% of that given for the Ta-10W gamma shield in Reference 2.

The nuclear heat generation rates input to the various analytical nodes are listed below:

Node 2	Reactor Support Plate	1.4×10^{-2}	$\frac{\text{Watts}}{\text{cc}}$
Node 6	First LiH Node	1.3×10^{-2}	$\frac{\text{Watts}}{\text{cc}}$
Node 7	Second LiH Node	1.35×10^{-3}	$\frac{\text{Watts}}{\text{cc}}$
Node 8	Third LiH Node	2.5×10^{-4}	$\frac{\text{Watts}}{\text{cc}}$
Node 14	Actuator Motors	7.5×10^{-4}	$\frac{\text{Watts}}{\text{cc}}$

All exterior surfaces of the reactor system are stainless steel with an assumed thermal emissivity value of 0.3. The 120°F cold wall was assumed to be stainless steel lined. This surface was also given an emissivity value of 0.3.

References

1. Welch, F. H., SNAP Reactor Component Performance Capabilities-
High Temperature Shield Materials; NAA-SR-MEMO-12168,
September 22, 1966.
2. Thomson, R. J., Reference Ta-10W Shield Nuclear Analysis,
TI-696-23-064, June 22, 1970.

Figure 1
MINI-TAP MODEL THERMAL NETWORK

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