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QUARTERLY PROGRESS REPORT OF RESEARCH AND DEVELOPMENT
OF VACUUM FOIL-TYPE INSULATION FOR RADIOISOTOPE
POWER SYSTEMS

November 30, 1966

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AEC RESEARCH AND
DEVELOPMENT REPORT

THERMO ELECTRON ENGINEERING CORPORATION

QUARTERLY PROGRESS REPORT OF RESEARCH AND DEVELOPMENT
OF VACUUM FOIL-TYPE INSULATION FOR RADIOISOTOPE
POWER SYSTEMS

RELEASED FOR ANNOUNCEMENT
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August - October 1966

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THERMO ELECTRON ENGINEERING CORPORATION

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POWER SYSTEMS

August - October 1966

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Contract No. AT(30-1)-3634

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Progress Report

VACUUM FOIL-TYPE INSULATION FOR
RADIOISOTOPE POWER SYSTEMS

by

J. B. Dunlay, M. L. Paquin, V. L. Poirier, and L. van Someren

ABSTRACT

This report is the third quarterly progress report on the development of high temperature thermal insulation under Contract No. AT(30-1) 3634 with the U. S. Atomic Energy Commission and covers the work period August through October 1966.

The results of planar heat transfer tests are presented for Ta - ThO₂ insulation samples. Temperature profiles and effective heat transfer coefficients are established from the experimental heat transfer data.

Results of the compatibility screening tests are summarized for exposures up to 2000 hours at 1700°C and 1900°C.

Final Designs are presented for a support insulation heat loss test assembly and an extended soak test assembly.

I. INTRODUCTION AND SUMMARY

This report is the third quarterly progress report on the development of high temperature thermal insulation under Contract No. AT(30-1)-3634 and covers the work period August - October 1966. Heat transfer coefficients were obtained for Ta - ThO₂ insulation under zero loading conditions. Analysis of edge heat losses was continued. A computer program neared completion for investigating the heat transfer paths through the edge.

The 2000 hour compatibility screening tests were completed. W - ThO₂ shows the most promise for operating temperatures of 1700°C and higher. Ta - ThO₂ appears satisfactory for operation at temperatures less than 1700°C. A series combination insulation consisting of W - ThO₂ on the hot side and Ta - ThO₂ on the cold side appears to offer satisfactory high temperature capability while retaining the simplicity of fabrication exhibited by Ta - ThO₂.

Insulation consisting of alternate layers of Ta - W separated with ThO₂ is unsatisfactory for 1700°C operating temperatures due to excessive diffusion of Ta into W.

Additional measurements were completed on the planar thermal conductivity test assemblies. Heat fluxes through Ta - ThO₂ insulation varies inversely with the number of insulation layers. A factor of two increase in the number of layers results approximately in a factor of two decrease in heat flux.

Final designs were completed for the support insulation heat loss test assembly and the extended soak test assembly. Fabrication of both test assemblies is underway.

II. COMPLETED THIRD QUARTER WORK

2.1 Task 2. Analysis

Heat Transfer Coefficients

Measurement of the heat flux through several different layers of foil insulation versus the hot-side temperature of the foils is described in section 2.3 and the results are shown in Figure 24. The cold-side temperature is held constant and the parameter from curve to curve is the number of layers in the insulation sample. Figure 25 replots the data presented in Figure 24 in a slightly different format. The hot-side temperature is plotted versus the number of layers, the heat flux becoming the parameter. Figure 25 not only plots the hot-side temperature versus the number of layers, but, in fact, presents the temperature profile across all the foils in the sample insulation. That this is true follows from the realization that only two of the three parameters, hot-side temperature, cold-side temperature, and heat flux, are independent. Consider the following example. Suppose that for a cold-side temperature of 800°K and a hot-side temperature of 1380°K , we measure a heat flux of $.2 \text{ watts/cm}^2$ across 20 layers of insulation. Further suppose that we now insert a 30 layer sample of insulation, maintain the cold-side temperature at 800°K , and adjust the hot-side temperature to that value which produces a heat flux of $.2 \text{ watts/cm}^2$. Then the temperature of the twentieth layer is still 1380°K . Since the cold-side temperature is constant in Figure 25, complete temperature profiles across the insulation can be inferred from a plot of the hot-side temperature versus the number of layers.

Having established the fact that Figure 25 does, in fact, plot the temperature profile across an insulation sample we can read the temperatures of any two adjacent layers of foil and use this information to define ϵ_{eff} and h_{eff} in the equation

$$q/A = \epsilon_{\text{eff}} \sigma \left(T_{\text{hot}}^4 - T_{\text{hot-1}}^4 \right) + h_{\text{eff}} \left(T_{\text{hot}} - T_{\text{hot-1}} \right)$$

(T_{hot} is the temperature of the hotter foil and $T_{\text{hot-1}}$ is the temperature of the cooler adjacent layer.) By choosing a value of T_{hot} and obtaining from Figure 25 the values of $T_{\text{hot-1}}$ for each heat flux, we obtain enough data to write six equations (one for each heat flux) in two unknowns (ϵ_{eff} and h_{eff}). ϵ_{eff} and h_{eff} are then chosen to be those values which best satisfy all equations. These values are attributed to the temperature $\bar{T}$, where

$$\bar{T} = \frac{\sum_{i=1}^6 \frac{T_{\text{hot}i} + T_{\text{hot-1}i}}{2}}{6}$$

i. e. the average of the average temperature of T_{hot} and $T_{\text{hot-1}}$.

Table 1 presents the values of $T_{\text{hot-1}}$ read from Figure 25 for various values of T_{hot} and the heat flux. At the 1000°K temperature level, the slopes of the temperature plots in Figure 25 are too great to read an accurate value of $T_{\text{hot-1}}$. Thus the values of $T_{\text{hot-1}}$ which appear in Table 1 at 1000°K were added only after values of ϵ_{eff} and h_{eff} were obtained at higher temperatures. These values were used to define ϵ_{eff} and h_{eff} at 1000°K by extrapolation from higher temperatures. $T_{\text{hot-1}}$ at 1000°K was then calculated and included in Table 1 for the sake of completeness. Table 2 presents the values calculated for ϵ_{eff} and h_{eff} at temperatures of 1200°K, 1400°K, 1600°K, and 1800°K. This data is presented in graphical form in Figure 1 (ϵ_{eff} vs. T) and Figure 2 (h_{eff} vs. T). The magnitudes of ϵ_{eff} and h_{eff} are such that at higher temperatures (~1800°K) radiation is the dominant heat transfer mechanism while at lower temperatures (~1000°K) conduction and radiation are roughly comparable effects.

7498

Figure 1. ϵ_{eff} versus Temperature.
 (Ta-ThO₂ Insulation with Zero Loading)

7499

Figure 2. h_{eff} versus Temperature.
 (Ta-ThO₂ Insulation with Zero Loading)

TABLE 1

TEMP. °K		HEAT FLUX WATTS/CM ²					
		. 1	. 2	. 3	. 4	. 5	. 6
1000	T _{HOT}	1000	1000	1000	1000	1000	1000
	T _{HOT-1}	975*	948*	920*	892*	865*	837*
1200	T _{HOT}	1200	1200	1200	1200	1200	1200
	T _{HOT-1}	1183	1166	1149	1132	1115	1098
1400	T _{HOT}	1400	1400	1400	1400	1400	1400
	T _{HOT-1}	1389	1378	1367	1356	1345	1334
1600	T _{HOT}	1600	1600	1600	1600	1600	1600
	T _{HOT-1}	1594	1587	1580	1573	1566	1560
1800	T _{HOT}	1800	1800	1800	1800	1800	1800
	T _{HOT-1}	—	1791	1787	1783	1779	1775

* Inferred from Figure 23 and Figure 24

TABLE 2

TEMPERATURE °K	ϵ_{eff}	h_{eff} WATTS/CM ² °K
1000	. 110 [*]	. 00154 [*]
1200	. 117	. 00165
1400	. 127	. 00175
1600	. 143	. 00188
1800	. 167	. 00196

*Inferred from the values at higher temperatures

Edge Losses

The heat losses directly through multi-layered foil thermal insulation has proven to be so small that a significant fraction of the total heat lost from an insulated hot body can occur at the joints between cylindrical side-wall insulation and planar end insulation. The foils provide such an effective heat transfer barrier that the edges can become a prime area of heat loss. The problem of designing effective edge joints therefore becomes very important to the overall performance of foil insulation. For this reason an analytic study of foil edge configurations was undertaken.

The design of effective edges for the insulation must be consistent with realistic fabrication techniques. Overlapping joints of the type shown in Figure 3 are believed to be the most practical configuration and were selected for analytic investigation. This study seeks to determine optimum values for foil thickness, layer spacing, number of foil groups, number of foils per group, etc., etc.

The presence of both conductive and radiative heat transfer plus the geometric complexity of the joint dictate that an iterative numerical solution be sought for the temperature distribution at nodes throughout the insulation. A computer program has been developed to perform the necessary iterations. That design which allows the least heat to leak through the joint will be deemed the best. The remainder of this section describes the various features of the model chosen to represent the corner depicted in Figure 3.

It is sufficient to isolate one group (Figure 4) from the corner assembly for study because the total heat loss will be minimized for several groups when the heat loss through each individual group is minimized. Furthermore, one will note two different grid sizes in the nodal network depicted in Figure 4. The larger grid size is used when radiation from non-opposing nodes can be neglected. The view

7500

Figure 3. Overlapping Edge Configuration.

7502

Figure 4. One Group Edge Heat Transfer Network.

factor between two infinite parallel planes is 1.0 and whenever the foil spacing is small compared to the spacing between nodes, radiation from non-opposing nodes is negligible. Smaller grid spacing, however, is required in that portion of the horizontal foils which is under the vertical foils. Those areas on the top horizontal foil facing an oxide gap in the vertical foils effectively see a black body hole, whereas immediately adjacent regions face the flanking vertical foils. The larger grid couldn't accurately describe the heat fluxes into the top horizontal foil layer; hence the necessity of two grid sizes.

The equation which describes the heat transfer between adjacent foils across an oxide gap is

$$q/A = \epsilon_{\text{eff}} \sigma \left(T_{\text{hot}}^4 - T_{\text{cold}}^4 \right) + h_{\text{eff}} \left(T_{\text{hot}} - T_{\text{cold}} \right) \quad (1)$$

T_{hot} is the hotter foil temperature and T_{cold} is the colder foil temperature. The first term represents the radiative heat flux between foils and the second term describes the conduction through the intervening oxide. ϵ_{eff} and h_{eff} are an empirically-determined effective emissivity and effective conduction heat transfer coefficient respectively. Equation 1 is used repeatedly wherever adjacent foils are separated by oxide.

In the larger grid regions no allowance is made for radiation arriving at a node from another, non-opposing node. The view factor is such that the total amount of such radiation is small compared with that arriving from a node directly opposed to the node in question. In the smaller grid region the view factors don't approach 1.0 and additional terms are necessary to account for radiation from non-opposing nodes. Consider the situation depicted in Figure 5. Crossing plane B is a mixture of radiation, principally from temperatures T_3 and T_6 . Furthermore, it is reasonable to consider it to be black body radiation since if a stream of radiation were

7503

Figure 5. Local Heat Transfer Considerations.

to be directed into the gap, across plane B, it most probably would be totally adsorbed. The expression for the heat flux striking node 5 after crossing plane B is taken to be

$$1/2 \left[\frac{\sigma}{2} \left(\frac{T_3^4 + T_6^4}{2} \right) \right] \quad (2)$$

The first 1/2 is present because only half the radiation crossing plane B strikes node 5. The second 1/2 accounts for the fact that only half the radiation originating from nodes 3 and 6 travels leftward. The final factor of 2 says that the radiation crossing plane B is an equal mixture of T_3 and T_6 radiation. Similar expressions are written for planes A, C, and D.

Next, consider the heat flux out of the bottom of the vertical foils into the top horizontal foil. When wrapping foils into a cylinder it is unreasonable to expect the bottom (or top) edges to line up within a few mils of one another. Thus when a small gap separates the vertical and horizontal foils, radiation and not conduction is the heat transfer mechanism. The model specifies radiative heat transfer from the bottom of the vertical foils. Admittedly, some of the vertical foils must make physical contact with the top horizontal foil, but in reality very few actually will (and those that do must overcome a sizeable contact resistance to conductive heat transfer).

A final feature specifies zero heat transfer along the direction of the foils at the right edge of the horizontal foils and the top end of the vertical foils. This means simply that the horizontal width and vertical height of the foils must be sufficiently large to make this boundary condition valid.

The computer program which analyzes the geometry depicted in Figure 4 in a manner consistent with the model described above has been written and, to a large extent, debugged. No less than thirty separate heat balances were required for various nodes to account for geometry changes and the various model features.

2.2 Task 3. Compatibility Screening

The 2000 hour compatibility screening tests were completed on insulation samples consisting of the refractory metals Ta, W, W(25)Re, and Mo and the oxides ThO_2 and Y_2O_3 . Each sample consisted of a combination of one refractory metal and one oxide. Test temperatures were 1700°C and 1900°C . Additional testing was completed for 1000 hours at 1700°C and 1900°C on samples consisting of alternate layers of Ta and W separated with ThO_2 . The results of all of these compatibility tests are summarized below.

Ta - Y_2O_3 - Figures 6 and 7

No gross chemical reactions were observed during the 2000 hour test. This material combination is the most susceptible, of the combinations tested, to bonding between foil layers. At 1700°C , moderate bonding was detected after 500 hours and became excessive after 2000 hours. The excessive bonding prohibits separation of the layers without tearing or destruction of the foils. At an exposure temperature of 1900°C , strong bonds were developed at the end of 100 hours and became excessive after 500 hours.

W - Y_2O_3 - Figures 8 and 9

No gross chemical reactions were observed during the 2000 hour test period. No bonding occurred after 2000 hours at 1700°C . At 1900°C , however, weak bonds were beginning to form after 500 hours and strong bonds had developed after 2000 hours. The photomicrographs shown in Figures 8 and 9 illustrate the growth of the Y_2O_3 grains at high temperature. This coarsening of the oxide grain size is typical of the insulation samples containing Y_2O_3 . Some increase in ThO_2 grain size was observed but to a much lesser degree than the Y_2O_3 .

7488

Figure 6. Ta - Y_2O_3 Surface, 310X. (2000 Hour Exposure at 1700°C)

Figure 7. Ta - Y_2O_3 Surface, 310X. (2000 Hour Exposure at 1900°C)

7489

Figure 8. W - Y_2O_3 Surface, 310X. (2000 Hour Exposure at 1700°C)

Figure 9. W - Y_2O_3 Surface, 310X. (2000 Hour Exposure at 1900°C)

W(25)Re - Y_2O_3 - Figures 10 and 11

No gross chemical reactions were observed. Weak bonding was observed after 100 hours at 1700°C. The extent of this bonding remained relatively constant throughout the entire test period of 2000 hours. Similarly, moderate bonding had occurred following 100 hours at 1900°C and remained essentially unchanged after 2000 hours.

Mo - Y_2O_3 - Figures 12 and 13

At 1700°C, strong bonds had developed by 500 hours. Moderate bonds formed at 1900°C after 100 hours and became stronger after 2000 hours. No chemical reactions were detected. The bonding between the Mo foils separated with Y_2O_3 is less than the bonds formed with ThO_2 . These results are in contrast to the general results experienced with the other refractory metals. ThO_2 is superior to Y_2O_3 for use with Ta, W, and W(25)Re foils.

Ta - ThO_2 - Figures 14 and 15

The Ta - ThO_2 samples showed very weak bonding after 500 hours at 1700°C. Moderate bonding developed after 2000 hours. At 1900°C, weak bonds formed after 100 hours and became excessive after 2000 hours. The 1900°C, 2000 hours samples could not be separated without tearing. No chemical reactions were observed.

W - ThO_2 - Figures 16 and 17

The combination of W - ThO_2 showed the least bonding of any of the materials tested. No bonding was detected at 1700°C and only moderate bonding was observed after 2000 hours at 1900°C. The W foils exhibit increased brittleness after exposure to high temperatures. Samples of bare W foils (no ThO_2 layer) exposed at both 1700°C and 1900°C for 1000 hours exhibit similar brittleness and indicate that the brittleness is characteristic of the W foils and is not significantly affected

7490

Figure 10. W(25)Re - Y_2O_3 Surface, 310X. (2000 Hour Exposure at 1700°C)

Figure 11. W(25)Re - Y_2O_3 Surface, 310X. (2000 Hour Exposure at 1900°C)

7491

Figure 12. Mo - Y_2O_3 Surface, 310X. (2000 Hour Exposure at 1700°C)

Figure 13. Mo - Y_2O_3 Surface, 310X. (2000 Hour Exposure at 1900°C)

7487

Figure 14. Ta - ThO₂ Surface, 310X. (2000 Hour Exposure at 1700°C)

Figure 15. Ta - ThO₂ Surface, 310X. (2000 Hour Exposure at 1900°C)

7492

Figure 16. W - ThO₂ Surface, 310X. (2000 Hour Exposure at 1700°C)

Figure 17. W - ThO₂ Surface, 310X. (2000 Hour Exposure at 1900°C)

by the presence of the ThO_2 . Very strong bonds formed between these bare W foils, which demonstrates the worth of the ThO_2 layer in preventing bonding.

W(25)Re - ThO_2 - Figures 18 and 19

The material combination of W(25)Re - ThO_2 exhibits similar bonding characteristics to the combination of W - ThO_2 . No chemical reactions are observed, no bonding occurs at 1700°C , and only moderate bonding results after 2000 hours at 1900°C . The W(25)Re foils remain ductile after 2000 hours at 1900°C and do not exhibit the brittleness shown by the W foils.

Mo - ThO_2 - Figures 20 and 21

Mo - ThO_2 samples exhibit strong bonding after 2000 hours at 1700°C and excessive bonding after 2000 hours at 1900°C . The 1900°C - 2000 hour sample could not be separated without destruction of the sample. The Mo foils become moderately embrittled after exposure. No gross chemical reactions were observed.

Ta - W - ThO_2 - Figures 22 and 23

Composite samples of alternate Ta and W foils separated with ThO_2 were tested for 1000 hours at 1700°C and 1900°C . After 100 hours, the 1700°C sample showed no bonding and was in good condition. The 1900°C sample, however, showed considerable porosity in the Ta foils and weak bonding between the Ta and W foils. Emission-spectroscopic analysis revealed that the W foils contained .03% to .3% of Ta. Control W foils exposed to the same test conditions without Ta showed no detectable Ta (the detectability limit of the analysis is about 1/10 of the level of Ta observed).

After 500 hours of exposure at 1900°C , the sample showed gross corrugation of the foils. Strong bonding had occurred. The Ta foils were very porous and had negligible mechanical strength. Emission spectroscopic analysis indicated that

7493

Figure 18. W(25)Re - ThO₂ Surface, 310X. (2000 Hour Exposure at 1700°C)

Figure 19. W(25)Re - ThO₂ Surface, 310X. (2000 Hour Exposure at 1900°C)

7494

Figure 20. Mo-ThO₂ Surface, 310X. (2000 Hour Exposure at 1700°C)

Figure 21. Mo-ThO₂ Surface, 310X. (2000 Hour Exposure at 1900°C)

7495

Figure 22. W Surface of W-Ta-ThO₂ Sample, 310X.
(1000 Hour Exposure at 1700°C)

Figure 23. W Surface of W-Ta-ThO₂ Sample, 310X.
(1000 Hour Exposure at 1900°C)

the W foils contained .3% to 3% of Ta, ten times the level found in the 100 hour - 1900°C sample. The 1700°C sample showed very little bonding but some porosity.

After 1000 hours, the 1700°C sample still showed very little bonding but the Ta foils had disintegrated almost completely and warping of the sample had occurred. In the 1900°C sample, the Ta foils were no longer distinguishable. The W foil surfaces were clean (in the sense of not showing signs of corrosive attack or chemical reaction), but did not have the same appearance as surfaces in single-metal samples. Figures 22 and 23 illustrate these W surfaces after 1000 hour exposure.

The most plausible explanation for these observations is that the Ta is diffusing into the adjacent W foils. Ta forms a continuous solid solution in W and any point of contact between the Ta and W constitutes a diffusion couple. The time and temperature dependence of the effect lend qualitative support to this explanation.

The extent of the Ta transfer is so large that it seems likely that transport to the W foils occurs by surface diffusion across the intervening oxide particles. The corrugation found in the 1900°C samples may have been a consequence of the increase in mass and volume of the W foils which could only be relieved by wrinkling of the foils.

Test Conclusions

In general, the use of ThO_2 is superior to Y_2O_3 in preventing bonding between the insulation layers. The combination of W - ThO_2 is the most resistant to bonding for continuous usage at 1700°C and for limited periods up to 1900°C. Ta - ThO_2 can be used at lower temperatures (lower than 1700°C) but exhibits some bonding after 500 hours at 1700°C.

A series-type insulation combination employing W - ThO₂ on the high temperature side and Ta - ThO₂ on the cold side of the insulation appears as a satisfactory insulation for operation up to 1700°C. The W side provides the high temperature capability for continuous operation and the Ta side offers simplicity of fabrication.

The use of alternate layers of Ta - W - ThO₂ is unsatisfactory due to excessive diffusion of the Ta into the W. Excessive diffusion occurs both at 1700°C and 1900°C. Diffusion and its resultant porosity are not observed in either Ta or W foils when they are used separately.

W(25)Re - ThO₂ can be substituted for W - ThO₂ in applications requiring room temperature ductility. The W(25)Re foils remain ductile at room temperature while the W foils become brittle.

The use of Mo as a foil material is limited to temperatures less than 1700°C. Since Mo exhibits room temperature brittleness and is less easily fabricated than Ta, the use of Mo is probably limited to special applications which prohibit the use of Ta.

2.3 Task 4. Planar Thermal Conductivity Tests

Heat Flux Measurements

Additional heat transfer measurements were completed on Ta - ThO₂ insulation samples. These tests were conducted with zero loading applied across the samples. Since this zero loading condition should minimize the effect of conduction heat transfer through the insulation, the measured heat fluxes are considered to be the minimum values which can be expected with this insulation combination.

While measurement of the variation of heat flux with pressure has not yet been completed, preliminary evidence indicates that heat transfer through the

insulation is relatively sensitive to the loading applied across the insulation. During checkout and initial operation of the planar thermal conductivity test assemblies, a factor of 3 to 5 increase in heat flux was observed for loadings of approximately 5 psi. The magnitude of this increase in heat transfer suggests that only very small loadings can be tolerated if low heat losses through the insulation are to be realized.

The results of the zero loading $T_a - ThO_2$ measurements are shown in Figure 24. The variation of heat flux is approximately inversely proportional to the number of foil layers. This dependence on the number of foil layers is in close agreement with the analytical solution to the heat transfer assuming uniform radiation and conduction coefficients through the insulation. With uniform coefficients, the heat flux is

$$q/A = \frac{1}{n-1} \left[\epsilon_{eff} \sigma \left(T_{hot}^4 - T_{cold}^4 \right) + h_{eff} \left(T_{hot} - T_{cold} \right) \right]$$

where n is the number of foil layers. The experimental results show that the $1/n$ dependence is closely followed up to the maximum number of foil layers tested (80 layers).

Temperature Profiles

The temperature profiles through the insulation are shown in Figure 25. These curves were obtained from the experimental data by plotting temperature versus number of foil layers for the condition of uniform heat flux. The temperature difference between layers is greatest at the cold side of the insulation and smallest at the hot side. This change in temperature gradient is consistent with the assumption that radiation is the dominant means of heat transfer. The fourth power dependence of radiant heat transfer with temperature allows a specified heat flux to be established with a smaller temperature difference between foils at the hot side of the insulation.

7505

Figure 24 . Planar Heat Flux Test Results. (Ta-ThO₂ Insulation with Zero Loading)

7501

Figure 25 . Insulation Temperature Profiles. (Ta-ThO₂ Insulation with Zero Loading)

2.4 Task 5. Cylindrical Thermal Conductivity Tests

No work was scheduled for the cylindrical thermal conductivity tests during this quarter.

2.5 Task 6. Edge Heat Loss Tests

No work was scheduled for the edge heat loss tests during this quarter.

2.6 Task 7. Support Insulation Heat Loss Tests

The final design of the support insulation heat loss test assembly was completed and fabrication was initiated. Figure 26 shows the test assembly configuration. The high-temperature source is heated by sheath heater elements brazed directly to the heater block. The support insulation test sample provides mechanical support for the heater block and connects the block to the collector section of the calorimeter. One and three member support samples are illustrated in the Figure.

The first high-temperature sheath heater samples were distorted during pressure bonding. Further study of the bonding conditions indicates that collapse of the thin wall sheath tube occurs prior to uniform yielding. Since collapse leads to distortion, we are investigating the use of thick wall tubes to prevent collapse. Additional thick wall heater samples have been fabricated and are ready for bonding.

2.7 Task 8. Extended Soak Tests

The final design of the extended soak test assembly is shown in Figure 27. Fabrication of the assembly is underway and the initial tests are scheduled early in December. The test assembly contains four high-temperature chambers. Each chamber provides test space for one thermal conductivity sample and one outgassing sample. Two of the chambers will operate at a hot-side temperature of

7504

Figure 26. Final Design of the Support Insulation Heat Loss Test Assembly.

7507

Figure 27 . Final Design of the Soak Test Assembly.

1700°C and the remaining two at a temperature of 1900°C. The outgassing samples are sealed from the bell jar environment. An evacuation tube leading from each outgassing sample is connected to a vac-ion pump located exterior to the bell jar. The base plate and chamber configurations are shown in Figures 28 and 29.

The thermal conductivity samples will consist of two combinations of Ta - ThO₂ and W - ThO₂ with the W - ThO₂ located at the hot side of the insulation sample. Samples containing 10 W layers and 30 Ta layers will be tested at 1700°C and 1900°C hot side temperatures. The remaining two chambers will test samples containing 20 Ta layers and 20 W layers at 1700°C and 1900°C hot side temperatures. The outgassing tests will investigate the individual outgassing rates of Ta - ThO₂ and W - ThO₂ at both test temperatures.

2.8 Task 9. Static Structure Tests

No work was scheduled in this quarter.

2.9 Task 10. Dynamic Structure Tests

No work was scheduled in this quarter.

2.10 Task 11. Insulation Demonstration Systems

No work was scheduled in this quarter.

7497

Figure 28 . Soak Test Assembly Baseplate Configuration.

7496

Figure 29. Soak Test Assembly High-Temperature Chamber Configuration.

III. PLANNED FOURTH QUARTER WORK

Task 2. Analysis

Work will continue as required to analyze the results of the planar thermal conductivity measurements. The extended soak test samples will be studied to determine any changes in performance which may occur as a function of operating life.

The computer program for investigating edge heat losses will be debugged and edge heat loss paths studied.

Task 3. Compatibility Screening

New samples of insulation will be installed in the test assemblies for further evaluation. These samples will be cylindrically shaped and consist of a series combination of Ta - ThO₂ and W - ThO₂.

Task 4. Planar Thermal Conductivity Tests

Testing will continue on the planar thermal conductivity test assemblies. Work will concentrate on the insulation combination W - ThO₂. Heat loss tests will be run on the extended soak test samples as required.

Task 5. Cylindrical Thermal Conductivity Tests

The final design of the cylindrical thermal conductivity test assembly will be completed and fabrication initiated.

Task 6. Edge Heat Loss Tests

The final design of the edge heat loss test assembly will be completed and fabrication initiated.

Task 7. Support Insulation Heat Loss Tests

Fabrication and checkout of the support insulation heat loss test assembly will be completed. Testing will begin with one and three member Re support structures.

Task 8. Extended Soak Tests

Fabrication and checkout of the extended soak test assembly will be completed. Life testing of the thermal conductivity and outgassing samples will begin.

Task 9. Static Structure Tests

No work is planned.

Task 10. Dynamic Structure Tests

No work is planned.

Task 11. Insulation Demonstration Systems

No work is planned.