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SUBJECT: EXAMINATION OF SODIUM, BERYLLIUM, INCONEL PUMP LOOPS NUMBERS 1 AND 2

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For The Atomic Energy Commission

H. F. Canale

Chief, Declassification Branch *ml*

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EXAMINATION OF SODIUM, BERYLLIUM, INCONEL PUMP LOOPS 1 AND 2

G. M. Adamson - E. Long

INTRODUCTION

As a portion of the sodium, beryllium, Inconel compatibility studies two large pump loops were operated by the Experimental Engineering Section of the Aircraft Reactor Engineering Division.

The loops were of an all Inconel construction with small venturi shaped inserts of beryllium metal in the hot portions. Sodium was circulated at high velocities by means of electromagnetic pumps. The first loop operated for its scheduled 1000 hours but the second was terminated after 270 hours by a power failure. The general configurations of the loops along with the temperatures, Reynold's numbers and location of the metallographic samples are given in Figures 1 and 2. It should be noted that in loop 1 the beryllium temperature was 1200°F with a Reynold's number of 95,000 and a throat velocity of >11 ft. per second. In loop 2 the beryllium temperature was 1300°F with a Reynold's number of 395,000 and a throat velocity of >45 fps. In both loops a temperature drop of 300°F was achieved. The higher velocity in loop 2 was accomplished by using both a larger insert, Figures 3 and 9, and larger pipes. High purity sodium, which before filling had an oxygen content of 0.02%, was used in both loops; the purity was maintained by means of cold traps.

After termination the sodium was frozen in place. The loop was sectioned by using pipe cutters and the sodium was dissolved from the samples using alcohol. No measurments of any changes in size or weight of the beryllium inserts were made. After the sodium had been dissolved the small sections were turned over to metallurgy for examination.

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CONCLUSIONS:

From the data obtained from these two loops, it appears that it will be feasible to use beryllium in Inconel systems containing molten sodium if the temperature is held below 1200°F. At this temperature some attack and mass transfer will be found but they do not appear to be severe enough to cause difficulty.

Layers of nickel-beryllium alloy will be found on Inconel surfaces that contact or lie close to the beryllium and are separated from it by essentially stagnant sodium. In most cases the beryllium metal is transported through the sodium and alloys with the nickel in the Inconel. Where sodium velocities on the beryllium are high only very thin beryllium deposits, of undetermined nature, are found in the rest of the loop. A thin black deposit is found on some portion of the beryllium that has been exposed to high velocity sodium, but it has not been completely identified. The rate of dissimilar metal mass transfer increases rapidly with temperature since thicker layers were found after 170 hours at 1300°F than in 1000 hours at 1200°F.

The mechanism of attack on the beryllium sections is not understood. As would be expected some surface roughening takes place; however, below the surface apparent voids are also found. No definite mechanism for formation of voids in a single metal have been developed. These voids seem to be real since they have also been found in other sodium, beryllium, Inconel studies. Additional work is being done in an effort to understand their formation. The attack on the beryllium surface also seems to vary with the machining since the machine marks become more pronounced and the surface rougher during the corrosion.

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Even with high velocities and 300°F temperature drops only a maximum attack of 0.5 mils was found in the hot Inconel sections. In loop 1 the maximum temperature in this area was 1250°F with a Reynold's number of 53,000; while in loop 2 they were 1300°F and 113,000 respectively.

DISCUSSION:

A. Loop #1

Section 17 - Beryllium Insert

After the sodium had been removed from the insert from the first loop, a thin black adherent scale was apparent on the exposed portions. Diffraction could not identify this scale. The insert was sectioned longitudinally with one half being submitted to metallography and the other used for the X-ray studies. Figure 3 is a photograph showing the shape and size of this insert.

The beryllium insert had been held in an Inconel can which was removed for the X-ray studies. It was necessary to use a chisel to separate the can but visually it appeared as if a void which was completely filled with sodium existed between the two. When the sodium was removed by water a very rough surface with a black scale was found on both the Inconel and the beryllium. A diffraction study of these rough surfaces by R. E. Thoma revealed the presence of two compounds BeNi and $\text{Be}_{21}\text{Ni}_5$.

Metallographically the inner surface of this first insert was quite rough. Both pits and cracks extending to a depth of 4 mils were found. The intensity of the roughness was greater on the sloping section, as shown in Figure 4, than in the flat throat. The depth in the throat varied from a smooth surface to the 3 mils shown in Figure 5. In addition to the roughness,

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voids measuring up to 1 mil in diameter were found as deep as 3 mils below the surface of both areas. Visually it was noted that the roughness occurred in rings or steps such as would be expected from machining marks but the steps were larger than normal machining marks.

To determine if the roughness described above was caused by machining, another beryllium sample was sectioned. This sample was the same shape and size as the one used in the second loop except, by mistake, it had been machined without a throat. The as-machined surface of this piece was not consistent. The majority of the surface was slightly rough with pits and cracks to 1 to 1 1/2 mils; however, in a few areas they extended to 3 1/2 mils. While these are not as bad as was found after operation in the first insert, there is no assurance that they compared originally.

The heaviest attack on the beryllium was on the outside surface adjacent to the Inconel can. As shown in Figure 6 this surface was quite rough with considerable pitting and with voids up to 2 mils in diameter found to a maximum depth of 5 mils. A fine black precipitate was found in the area of the voids. No layer or deposit could be found on the surface or in the grain boundaries by using polarized light or by etching as shown by Figure 7, which is a micro-photograph taken with polarized light, the anisotropic nature of beryllium is maintained to the edge. If a layer was present, this would not be the case.

An intermittent metallic layer averaging 1 mil in thickness was found on the Inconel opposite the insert, Figure 6. The deposit was heaviest in areas directly opposite to where the heaviest attack on the beryllium was found. No areas were found in which a contact existed between the beryllium and the layer. At operating temperature this space would be smaller than shown but would still be present. The beryllium in the alloy

layer must have been transported through a thin layer of sodium.

Inconel Heated Section

The attack found in the all Inconel portion of the heated loop was very light. A few scattered pits to a maximum depth of 0.5 mils was the extent of it, Figure 8. No subsurface voids or intergranular type of attack was found in any section.

Although no layers could be seen metallographically, M. Murray of the Chemistry Department by using a micro drill and spectrographic determination, was able to show that traces of beryllium were present on the loop surfaces. The value was 34 micrograms per cm^2 in the hot leg just after the insert and it decreases to 18 $\mu\text{gm}/\text{cm}^2$ just before the entrance to the heat exchanger; it continued to decrease to a value of 6.6 $\mu\text{gm}/\text{cm}^2$ at the end of the cold loop. Murray is not able to determine the form of the beryllium.

Inconel Cooled Sections

Several areas from the cold loop, the surge pot and the cold trap were examined. No attack or deposit was found metallographically in any of them. As explained in the previous sections, traces of beryllium were found spectrographically.

Heat Exchanger

Metallographically no attack or deposit was found in any of the three heat exchanger sections that were examined. The examination included both the inner and the outer tubes.

B. Loop #2

Beryllium Insert

After the sodium in the second insert, Figure 9, had been removed by alcohol, a fairly heavy and adherent black scale was found on the inlet side of the venturi. On the outlet side only thin scattered patches were

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found. There was not enough of this scale for a good diffraction study. Although the lines were open to question $\text{Be}_{21}\text{Ni}_5$ and BeO seem to be present with other unidentified lines. The outer surface of the beryllium was covered with what appeared to be machining marks; however, the machinist says they are much more pronounced than any marks left on the as-machined piece. The available-standard is also much smoother. The inner surface of the Inconel can was quite rough.

Metallographically the deepest attack was again found on the outside of the beryllium adjacent to the Inconel. The surface in this area was very rough with pits and subsurface voids being found to a maximum depth of 7 mils, Figure 10. Subsurface voids to a depth of 4 mils with some surface roughening were found on the inner surfaces of the insert.

A thick dense layer with a maximum thickness of 8 mils was present on the Inconel which surrounded the beryllium. This layer, Figure 11, completely jacketed the inner surface of the Inconel. It was shown by Thoma to consist of the same two compounds found in loop 1.

Inconel Loop

Metallographically no attack or deposit was found in any of the hot or cold loop portions examined. M. Murray was again able to find traces of beryllium on the loop walls.

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SPEC. POS.	Re NO.
1	42 600
9	41 800
11	13 400 (ANNULUS)
15	14 900 (ANNULUS)
16	51 900
17	95 500 (THROAT)
21	53 600

Na-Be-INCONEL HIGH Δ TV LOOP No.1 TEST UNIT ASSEMBLY

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SPEC. POS.	Re No.	TEMP.(°F)
1	182600	1000
2	52000	1000
3	395000	1300
4	113 000	1300

Na-Be-INCONEL HIGH Δ TV LOOP No.2 TEST UNIT ASSEMBLY

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Fig. 3 T 6149 1.5 X
Beryllium insert from high Δ TV Loop No. 1
encased in two Inconel cans.

Fig. 4 T 5985 250 X
Inner Surface of Beryllium insert from
high Δ TV Loop No. 1

Fig. 5 T6133 250 X
Throat of beryllium insert from high Δ TV
Loop No. 1

Fig. 6 T 6056 250 X
Interface of Beryllium-Inconel (Inconel
at top - Beryllium at bottom) Showing
metallic deposit on Inconel.

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Fig. 7 T 6151 250 X
Inner surface of beryllium insert from high ΔTV Loop No. 2 under polarized light.

Fig. 8 T 6346 250 X
Heated section of Inconel pipe of high ΔTV Loop No. 1 Etch: Mod. Ag. Regia

Fig. 9 T 6113 3/4 X
Beryllium insert from high ΔTV Loop No. 2 encased in an Inconel can.

Fig. 10 T 6347 250 X
Subsurface void formations in Beryllium insert from high ΔTV Loop No. 2

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Fig. 11

T 6079

250X

Metallic deposit found on the Inconel can at the Beryllium-Inconel interface.

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