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SUMMARY

A 1585 hr. run was completed on the 400A-1 pump with a 0.4 m UO_2SO_4 fuel solution as the pumped fluid, during which it was attempted to operate with gas bubbles in the solution. The gas content ranged from 0.56 ml/gm of solution to 1.189 ml/gm of solution and the gas other than CO_2 , which was assumed to be nitrogen, varied from 0.39 ml/gm of solution to 0.966 ml/gm of solution. Because of uncertainties in the CO_2 solubility it cannot be stated conclusively that the liquid was or was not saturated. However, the loss of metal at a number of places due to corrosion and/or gas bubble erosion makes it advisable not to operate a pump of this exact design at or near gas saturation.

The 1585 hr. above are the last of 13185 hrs. maintenance free operation. A general examination of the pump disclosed severe corrosion and softening of the Stellite 12 overlay on the 347 stainless steel thrust bearing shoes, Fig. 3. The thermal barrier seal weld had cracked and there was noticeable corrosion in the region between the thermal barrier gasket and metallic "O" ring seal.

INTRODUCTION

The present design of the HRE-3 does not call for a continuous letdown of the blanket and core fuel solution. Therefore, should the solution become gas saturated, a knowledge of what occurs in the pump would be of considerable value. For this reason, a test was conducted on the 400A-1 pump to determine whether or not gas would collect in the back of the pump and what if any damage would be done to the pump while pumping a gas saturated uranyl sulphate fuel solution.

PROCEDURE

A bomb with a sight glass was installed above the pump motor. This was to serve as a reservoir for any gas which entered the back of the pump and to provide a visual indication of this condition. The loop was filled to the desired level with fuel solution and pressurized to 200 psi by partial pressures of 100 psi each of O_2 and N_2 . The pump was started and the loop temperature raised to $250^\circ C$ resulting in a loop pressure of 1050 psig.

Except for approximately 48 hr. at the beginning of the test and during two other occasions in which the loop was thermal cycled, the experiment was conducted with the solution in the pressurizer at a temperature of $3^\circ C$ to $5^\circ C$ less than that of the main circulating stream. This condition would give a higher gas saturation concentration in the pressurizer than in the main loop.

During the run the pressure tended to decrease and after approximately 190 hr. and 1030 hr. of operation O_2 additions were made to raise the loop pressure from 980 to 1120 psig, and from 950 to 1100 psig, respectively. Prior to the second addition, approximately 3 liters of the fuel solution had leaked out through a sample station.

Samples were taken during the run for gas analysis and at the beginning and at the end of the run for U, SO_4 , Cu, Ni, Fe, Mn, Co, Cl, Cr, and PH analysis. The fuel solution contained approximately 10 gm of U per liter of solution.

At the end of the test run, the pump was disassembled for a complete inspection.

RESULTS

Assuming the residual gas to be N_2 and neglecting the relatively small amounts of CO_2 , the gas pressure as determined from sample analyses was less than that necessary for saturation in 89.5% of the samples. The CO_2 concentration was less than 0.05 ml/gm of solution in 68.5% of the samples; and there seemed to be no correlation between the higher CO_2 concentrations and the difference between the $O_2 + N_2$ pressure and $O_2 + N_2$ saturation pressure (Table I).

After approximately 145 hr. of operation the pump was stopped and heaters turned off. When the temperature decreased to $160^\circ C$ the pump was restarted and heaters turned on. It did not become gas bound as was expected. After approximately 170 hr. of operation the heaters were turned off and the temperature decreased to $215^\circ C$. Gas did not appear in the back of the pump during either of the above operations. In a previous test on a pump of this type gas was slowly injected through a sample station and a part of it did collect in the back of the pump.

Physical damage to the hydraulic end of the pump due to corrosion and/or gas bubble erosion did occur at the following places (see photographs), but no gas was visible in the sight glass at any time during the test:

1. On the downstream side of the heads of the screws which fasten the lower wear ring, Fig. 1.
2. On the inside surface of the diffuser which mates with the outside surface of the lower wear ring, Fig. 2.
3. Near the inside ends of three diffuser vanes, Fig. 2.

The above parts which were damaged are type 347 stainless steel. The titanium impeller was undamaged and lost no weight.

A general examination of the pump disclosed severe corrosion and softening of the Stellite 12 on the 347 stainless steel thrust bearing shoes. The thermal barrier seal weld had cracked and there was noticeable corrosion in the region between the thermal barrier gasket and metallic "O" ring seal.

Upon examination of the thrust bearing shoes, E. S. Bomar¹ reported that carbon had apparently diffused from the Stellite and deposited in the stainless steel grain boundaries at the interface during application of the Stellite. As a result of the corrosion the Stellite appears to be composed of a loosely knit structure of fine particles. In the area bounding the heavily attacked overlay there is evidence of selective attack of the cobalt rich matrix. Selective attack also occurred on the grain boundaries of the stainless steel suspected to have been effected by carbon diffusion. The dark area of Fig. 3 is the heavily attacked stellite. That part of the overlay to the right of the dark area and the stellite around the pin hole were virtually unattacked. Photomicrographs of these regions indicate a greater amount of dilution with the base metal which apparently improved the corrosion resistance.

The thermal barrier seal weld had cracked and the crevice was corroded. The cracks appeared to have started on that part of the weld adjacent to the stagnant region between the thermal barrier gasket and the metallic "O" ring seal which had also corroded. $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$ and FeSO_4 were present in the corrosion products.

CONCLUSIONS AND RECOMMENDATIONS

It cannot be stated conclusively that the pumped solution was or was not gas saturated; however, the physical damage to the hydraulic end of the pump makes it advisable not to operate a pump of this exact design with a solution at or near gas saturation.

The lower wear ring and diffuser are type 347 stainless steel and the impeller is titanium. Since the impeller was not damaged and lost no weight a titanium lower wear ring and diffuser might prevent the corrosion and/or erosion which occurred during this test. It is also recommended that modifi-

cations be made in the design of the lower wear ring to reduce the turbulence at the heads of the fastening screws.

In rebuilding the pump, an arrangement was made by J. M. Baker to provide flow in the region between the thermal barrier gasket and metallic "O" seal. Should this prevent corrosion and seal weld cracking, it is recommended that a similar arrangement be made on the other pumps of this type whenever they are disassembled in the future.

REFERENCES

1. Bomar, E. S., HRP Metallography (Y-12) Report No. 66, 1-22-58, Examination of Stellite Overlayed Thrust Shoes from 400A-1 Pump.

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TABLE I

Operating Time Hrs.	Loop Temp. °C	ml O ₂ / gm. of Sol.	ml CO ₂ / gm. of Sol.	ml N ₂ / gm. of Sol.	Required O ₂ Partial Pressure for Saturation psia	Required N ₂ Partial Pressure for Saturation psia	O ₂ + N ₂ Partial Pressure	Total Pressure Minus H ₂ O Vapor Pressure	Saturated H ₂ O Vapor Pressure psia	Total Pressure psia
5	248	0.696	0.0607	0.644	206	230	436	507	558	1065
29	252	0.570	0.0197	0.636	169	227	396	469	596	1065
48	252	0.860	0.0638	0.917	255	327	582	469	596	1065
48	252	0.635	0.0739	0.720	188	257	445	469	596	1065
53	250	0.702	0.00506	0.906	208	324	532	467	578	1045
53	250	0.665	0.0081	0.617	197	220	417	467	578	1045
71	250	0.568	0.223	0.586	168	209	377	437	578	1015
71	250	0.573	0.146	0.622	170	222	392	437	578	1015
143	250	0.542	0.0465	0.534	161	191	352	437	578	1015
143	250	0.533	0.0165	0.527	158	188	346	437	578	1015
194	215	0.662	0.00506	0.390	273	225	498	530	305	835
744	251	0.840	0.0131	0.453	249	162	411	577	588	1165
819	250	0.895	0.00506	0.424	265	151	416	467	578	1045
1031	251	0.724	0.0116	0.374	214	133	347	387	588	975
1059	251	1.129	0.00506	0.374	334	133	467	527	588	1115
1155	250	0.990	0.0972	0.373	293	133	426	487	578	1065
1347	250	1.092	0.0228	0.390	324	139	463	507	578	1085
1419	251	1.018	0.0263	0.378	301	135	436	477	588	1065
1536	251	0.967	0.0410	0.429	287	153	440	477	588	1065

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FIGURE 1

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FIGURE 2

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FIGURE 3