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TECHNICAL MEMORANDUM

MASTER

A 1000 HOUR TEST OF A CORROSION PRODUCT SEPARATOR
UNIT IN A HAYNES ALLOY NO. 25 LOOP CONTAINING MERCURY
TEST G-16

TM 3388-67

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A 1000 Hour Test of a Corrosion Product Separator
Unit in a Haynes Alloy No. 25 Loop Containing Mercury

Test G-16

Project No. 512-169052-08

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March 9, 1962

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ABSTRACT

One of the major unsolved problems affecting the life of the SNAP II Power Conversion System is the mass transfer of corrosion products by mercury and subsequent deposition. It is feared that the corrosion products might tend to accumulate in critical areas such as orifices, bearings and so forth. Therefore, this test was conducted to evaluate a corrosion product separator and to determine the influence of corrosion product removal on corrosion rate. This test is part of the materials evaluation program conducted under subcontract to Atomics International (Atomic Energy Commission Contract AT(11-1)-GEN 8). The corrosion product separator was successful in removing 85 percent of the elements corroded from the container walls. The loop and separator, both fabricated from Haynes alloy No. 25, operated for 1000 hours. The mercury was boiled and condensed at 1100°F, superheated to 1190°F and subcooled to 325°F. The flow rate in this loop was much higher than in previous loops, being approximately 37 pounds of mercury per hour as contrasted with approximately 12 pounds of mercury per hour. No increase in corrosion rate was noticed as a result of the higher flow rates and velocity or by the removal of corrosion products. If this type of separator or an improved type works equally as well in the final application, the danger of failure from corrosion products should be greatly reduced.

INTRODUCTION

All commercially-available, common alloys of construction are corroded by liquid mercury. Only some refractory metals such as tantalum, tungsten, etc. are resistant enough not to yield any corrosion products (1)*. However, these materials are difficult to fabricate at present.

The mass transport of corrosion products resulting from material corrosion in the SNAP II Power Conversion System can result in serious fouling of critical control areas. This can result in premature system failure; and in fact, deposits have been observed in bearing lubricant flow passages, in nozzles, and in orifices of SNAP test systems. In addition, the presence of dispersed solids in the liquid metal may lead to erosion and wear problems (2). Therefore, if the corrosion products can be either totally or at least substantially removed, it is obvious that the chances of increased system longevity become more probable.

This loop test containing a corrosion product separator unit was the first of a series conducted as part of the SNAP II Power Conversion System materials effort under subcontract to Atomics International (Atomic Energy Commission Contract AT(11-1)-GEN-8).

The methods which have been tried in the past to remove corrosion products were (1) sintered metal filters in the SNAP II test system capable of removing 2 micron size particles, and (2) a trap in the coldest portion of a Type 316 steel loop (1). Both of these methods failed to prevent corrosion product circulation. Therefore, other methods had to be devised. These were based on the observation that more noble metals tended to act as getters for corrosion products (3), and that magnetic susceptibility could possibly be used to advantage to remove at least iron, nickel and cobalt (4) (5).

The magnetic separator design was based on the fact that with a shaped pole piece a convergent flux field would result, and the corrosion products which are paramagnetic would tend to migrate to the converging pole. The diamagnetic mercury would tend to migrate to the flat pole face (or into the diverging flux field) and thus some purification of the mercury would result. The ferromagnetic materials, of course, would be attracted to and held by the magnets.

*Figures appearing in parentheses pertain to the references appended to this report.

DESCRIPTION OF LOOP AND TEST PROCEDURE

The loop was fabricated from 1/2 in. O.D. by 0.065 in. thick wall and 1 in. by 0.049 in. thick wall Haynes alloy No. 25 annealed tubing, which was cut to length, formed and welded to form the completed assembly shown schematically in Fig. 1.

The separator unit, 2-1/8 in. in diameter by 20 in. long, was fabricated from 0.034 in. thick Haynes alloy No. 25 sheet formed and welded as shown schematically in Fig. 2.

The end caps were made of 0.085 in. thick Haynes alloy No. 25 sheet. The vertical strip separating the magnet poles from the magnet cavity was also made of this material. Low carbon steel plates, 1/2 in. thick, were welded to the outside of these caps for strength. The inside compartments were made of 0.034 in. Haynes stock. The first compartment of the separator was 5 in. long and contained about 60 grams of pure-columbium, fine, machine-turnings. In the next compartment (10 in. long) were placed the three "C" path magnets cast from Alnico V (2 pounds each), each 2-1/8 in. O.D. (1-1/2 in. I.D.) by 3 in. long with a 0.66 in. air gap and a 0.25 in. wide pole face. The magnets had a free air gap flux density of approximately 2,500 gauss. The shaped pole piece, 9 in. long, was machined from low carbon steel bar stock tapered from 1/2 in. on the entry end to 3/16 in. on the exit end. In the width direction, the pole piece was tapered to a 1/16 in. wide pole face. The magnets were suspended 1/2 in. from the bottom section to allow circulation of mercury into the center cavity of the magnets. The flow tubes, one on the flat face of the magnets and the other in the center cavity of the magnets, were made of 3/16 in. O.D. by 0.035 in. wall Haynes alloy No. 25 tubing. The final compartment was 5 in. long, and contained about 16 grams of iron wool.

The loop was cleaned with hot (185°F) Oakite solution (10 oz. No. 90 Oakite per gallon of water), thoroughly rinsed with hot water, rinsed with acetone and dried. The loop was leak tested at 700 psi, then was placed into its enclosure, and thermocouples, heaters, subcooler and condenser manifolds were installed as shown in Fig. 3 (prior to filling of the enclosure with vermiculite insulation).

The entire system was leak tested by its ability to hold a vacuum of 1000 microns for 12 hours. The loop was charged with 19,200 grams of mercury under a nitrogen cover, evacuated to about 1000 microns and testing was initiated.

Chromel-alumel thermocouples were used to measure wall temperatures, and these were automatically recorded by a multipoint recorder. Heaters were controlled with millivoltmeter controllers operating on separate thermocouples. A pressure recorder-controller recorded system pressure and acted as a safety device in case of overpressure.

Average daily temperatures measured over the loop are presented in Table 1. The average boiling and condensing temperature of the mercury was 1100°F. The mercury vapor was superheated to 1190°F and subcooled to a minimum temperature of 325°F. The mercury flow rate was calculated to be 36.9 pounds of mercury per hour.

The corrosion product separator unit was cooled with water circulating through copper coils.

The loop sprang a leak caused by formation of a crack in the lineheat section after 437 hours. This section was replaced. Weld leaks, which subsequently appeared after start-up at the boiler 1 in. O.D. to 1/2 in. O.D. coupling and at the entrance to the separator were repaired. The mercury drained from the system during each repair was placed under an argon cover. This mercury was recharged into the loop, the system was evacuated and testing was resumed.

At test completion (1000 hours), the mercury was drained from the system, placed under an argon cover, and chemically analyzed. The separator unit was removed and sectioned. Deposits in each compartment were removed and kept separate, including the columbium turnings and iron wool. The loop was sectioned into convenient lengths, and deposits were removed. All deposits were analyzed.

Sections were removed from the loop for metallurgical evaluation of corrosion as indicated in Fig. 1.

RESULTS

The loop was examined after test termination both for mercury attack and corrosion product deposition in the loop per se and corrosion product separator.

Mercury Corrosion

Results of metallographic inspection of sections removed from the loop as shown in Fig. 1 are summarized in Table 2. Representative photomicrographs are shown in Figs. 4 through 9.

The subcooler and boiler inlet showed crevice type attack to a depth of 0.6 and 0.7 mils, respectively, in 320 to 410°F liquid mercury, Fig. 4. The boiler area was attacked to a maximum depth of 3 mils. The lower quarter of the boiler showed a combination of crevice and depleted layer type corrosion, Fig. 5, whereas the rest of the boiler showed only a leached or depleted corrosion layer, Fig. 6. The mercury entered the boiler at 320°F and was heated to 1100°F.

The lineheat area contacted by vapor (wet) showed layer and crevice attack up to 1.9 mils. Some intergranular, leached crevices up to 2.8 mils penetration were observed, Fig. 7. Some deposition was observed in this area. The superheater showed deposits, columnar in appearance, of the nucleation and growth type, Fig. 8. No attack was visible in this area.

The condenser entry was attacked to a depth of 3.3 mils, Fig. 9. The attack was manifested as a leached zone, typical for this material at higher temperatures. The attack in the condenser varied from 3.0 mils to 1.7 mils at the lower quarter of the condenser. The condenser was exposed to liquid-vapor mercury at 1090 to 1070°F.

The condenser exit contacted by liquid mercury at 730°F showed a leached zone 0.4 mils thick. The separator shell was attacked to a maximum depth of 0.6 mils in 615°F liquid mercury, and the post condenser area suffered 0.8 mils of penetration in 540°F liquid mercury.

Deposition of Mass-Transported, Corroded Metal

Deposition results are summarized in Table 3 and in bar graph form in Fig. 16. These results indicate that the separator unit removed 85.1 percent of the corroded metal, the loop per se contained 14.3 percent and the mercury contained 0.62 percent of the corroded metal.

Corrosion Products in Mercury

The mercury drained from the system after 1000 hours of operation and placed under an argon cover was clean but developed a surface scum on standing. This scum (1.95 grams) was removed by filtering the mercury, and contained only 0.046 grams of elements leached from the container walls. The composition is given in Table 3. The mercury filtrate contained trace amounts of Fe, Cu, Ca and Ag, Table 3.

Corrosion Products in the Loop

Loosely adherent deposits consisting of mercury and corroded metals were removed from the condenser (10.63 grams), subcooler and boiler (1.9 grams). These deposits consisted mainly of chromium and cobalt with lesser amounts of nickel and iron, Table 3. The superheater deposit was tightly adherent and had to be scrapped off (0.356 grams). Cobalt was the principle constituent with minor amounts of nickel, chromium and iron, Table 3.

Corrosion Products in the Separator

The first compartment containing the columbium turnings trapped an amalgam or pasty-like mass (18.4 grams). The amalgam was entrained in the upper portion of the wool and also clung to the compartment top, Figs. 10 and 11. The amalgam contained 0.23 grams of corroded metal which consisted principally of chromium, cobalt and nickel, Table 3. The columbium turnings were wetted by the mercury over about one-half the packing distance from the entry side and contained 0.657 grams of adsorbed corroded metal. This metal consisted of chromium, cobalt and nickel. The liquid mercury entered this compartment at 730°F and left at 615°F.

The magnets contained a pasty mass of amalgam (23.63 grams) which filled the cavity between the pole faces to a length of about 2 in., Fig. 12. The amalgam contained 0.69 grams of corroded metal which consisted of chromium, cobalt, iron and nickel, Table 3. The mercury temperature was reduced from 615 to 560°F through the magnets.

The iron wool was wetted by the mercury, Fig. 13, and contained 5.03 grams of amalgam. This amalgam contained 0.27 grams of corroded metal which consisted of chromium, cobalt and nickel, Table 3. The corroded metal adsorbed on the wool surface amounted to 0.885 grams. Chromium was the principal constituent, Table 3.

Lineheat Failure

The lineheat failure after 437 hours of operation manifested itself as a crack shaped as a "U" in the circumferential direction. The fracture surface was intergranular, Fig. 14. The failure appeared to be caused by preferential mercury attack on the inclusions which appeared to be unusually numerous in this section of the Haynes alloy No. 25 tubing. The inclusions were largely intergranular and this material also appeared as membranes surrounding some of the grains, Fig. 14.

DISCUSSION

One of the questions raised by utilization of a separator was what effect would removal of corrosion products have on corrosion. In this case, the separator unit did not appear to have any significant influence on the corrosion of the Haynes alloy No. 25, since the penetration experienced agreed with the previous loop corrosion data (3), Fig. 15. The higher mercury flow rate in this loop of 36.9 pounds of mercury per hour (0.02 ft. per sec.) as contrasted to the lower previous flow rates of 10 pounds of mercury per hour (3) also suggested that corrosion was independent of flow rate in this range. For materials which develop a protective corrosion layer where erosion effects are not experienced, one would expect penetration to be only slightly dependent on flow rate (2). In fact, erosion effects have not been observed in mercury at flow rates below 10 ft. per sec. (2). However, where a material is corroded and the mercury contains corrosion products, erosion effects may be anticipated at higher flow rates with an attendant increase in corrosion rate.

The total amount of mass transported and deposited corroded metal was 3.21 grams, Table 3. This figure was within the range of 1.9 (average) to 3.7 grams (maximum) calculated from bent reflux tube capsule data (3). The deposits contained combined mercury and the total deposit weight including this mercury was 63.49 grams. Where the deposit appeared as a silvery amalgam, cobalt and chromium were always present in amounts greater than 20 percent by weight of the total corroded metal weight in the amalgam. The corroded metal (3.21 grams) consisted of 59 percent Cr, 6 percent Ni, 31 percent Co and 4 percent Fe.

The separator removed a total of 85.1 percent of the corroded metal weight or 76.7 percent of the total deposit weight including combined mercury, Fig. 16 and Table 3. The loop deposits amounted to 14.3 percent (20.4 percent including combined mercury) and the mercury contained 0.62 percent of corroded metal. Of interest is the fact that the coolest portion of the system--the subcooler--contained the least amount of corroded metal. The columbium separator trapped 27.7 percent, the magnetic separator--21.5 percent and the iron separator 35.9 percent of the corroded metal.

Both the columbium and iron served as preponderant getters for chromium, since this element was adsorbed preferentially. The iron trapped the largest amount of chromium. This could be the result of either lower temperatures in this area or magnetic coagulation effects.

The condenser deposit contained 70 percent Co, 21 percent Cr, 6 percent Ni and 3 percent Fe. The subcooler deposit contained 45 percent Cr, 37 percent Co, 17 percent Ni and 6 percent Fe. The superheater deposit consisted of 90 percent Co, 5 percent Ni, 3 percent Fe and 2 percent Cr. This deposit resulted from the drying out of corrosion products carried in the wet vapor from the boiler. On the other hand, the mercury contained in solution 11 percent Co, 36 percent Cr, 23 percent Ni and 3 percent Fe of the corroded metal. Based on the weight of mercury in the system, these elements were apparently soluble in mercury in concentrations of ppm as follows:

0.38 Cr, 0.24 Ni, 0.26 Fe, and 0.12 Co.

CONCLUSIONS

1. The corrosion product separator removed 85 percent of the corroded metal, demonstrating adequately the feasibility of removal of harmful corrosion products in a system.
2. The columbium and iron served as getters for the corrosion products Cr, Co and Ni (in order of preferred removal).
3. The magnet removed Co, Cr, Fe and Ni (in order of preferred removal).
4. The corrosion of Haynes alloy No. 25 was not affected by corrosion product removal.
5. A flow rate up to 37 pounds of mercury per hour did not affect the corrosion of Haynes alloy No. 25.
6. Certain inclusions when found intergranularly in Haynes alloy No. 25 appear to be excessively susceptible to mercury attack.

RECOMMENDATIONS

1. Test another loop with a corrosion product separator incorporating the following recommendations in the design:
 - a. Remove the corrosion products carried to the superheater from the boiler. This may be accomplished with a columbium separator in the lineheat section.
 - b. Separate effects of filtering, thermal gradient and magnetic action on trapping of corroded metal.
 - c. Revise path of initial mercury entry into magnetic separator, preferably into magnet cavity first, to prevent amalgam build-up on pole faces and possible flow obstruction.
2. Install a separator unit into the SNAP II prototype system to get essential operating information.

REFERENCES

1. J. J. Owens, J. F. Nejedlik and J. W. Vogt, "The SNAP II Power Conversion System Topical Report No. 7; Mercury Materials Evaluation and Selection," Report No. ER-4103, NASA 21096 (June 1, 1960).
2. A. Dvorak, "Problémy korose konstrukčních materiálů tekutými kovy," Jaderna Energie, Vol. 6, No. 5 (1960), p. 155.
3. J. F. Nejedlik, "The SNAP II Power Conversion System Report No. 2, Topical Report No. 14; Mercury Materials Evaluation and Selection," Report No. ER-4461 (April 10, 1961).
4. L. F. Bates and P. F. Illsley, "Magnetic Properties of Iron Amalgams," Proceedings Physical Society of London, Vol. 49 (1937).
5. L. F. Bates and J. H. Prentice, "The Electrical Resistance of Nickel Amalgams," Proceedings Physical Society of London, Vol. 51 (1939).

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TABLES

TABLE 1
AVERAGE CORROSION LOOP TEMPERATURES

<u>Thermocouple Location</u>	<u>Temperature, °F</u>
Boiler Inlet	320
Boiler Outlet	1100
Superheater Inlet	950
Superheater Midpoint	1190
Superheater Outlet	1100
Condenser Inlet	1090
Condenser Midpoint	1070
Condenser Outlet	730
Columbium Wool Outlet	615
Magnetic Separator Outlet	560
Steel Wool Outlet	540
Subcooler Inlet	500
Subcooler Midpoint	410
Subcooler Outlet	325

NOTE: Boiling temperature based on system pressure of 312 psia
is 1094°F.

TABLE 2
METALLOGRAPHIC RESULTS OF TEST G-16

<u>Micro No.</u>	<u>Location</u>	<u>Corrosion, Mils</u>	<u>Deposition, Mils</u>	<u>Remarks</u>
1	Subcooler Midpoint	0.6 Crevice	Some crystal.	
2	Boiler Inlet; Weld	0.8 Crevice	Slight crystal.	Moderate crystal deposition on weld.
3	Boiler lower quarter	3.0 Layer and Crevice	-	
4	Boiler Midpoint	3.0 Layer	-	
5	Boiler Upper Quarter	3.0 Layer	-	
6	Boiler Exit	2.8 Layer	-	
7	Lineheat Entry	1.9 Layer and Crevice	-	
7A	Lineheat; Weld	0.4 Crevice	Moderate crystal.	
8	Lineheat Exit	0.6 Layer and Crevice	-	2.8 mil inter- granular layer.
9	Superheater Entry	-	1.9 Nucleation and growth type.	
10	Superheater Midpoint	-	2.8 Nucleation and growth type.	
11	Superheater Exit	-	1.2 Nucleation and growth type.	
12	Condenser Entry.	3.3 Layer	-	
13	Condenser Upper Quarter	2.8 Layer	-	
14	Condenser Midpoint	3.0 Layer	-	
15	Condenser Lower Quarter	1.7 Layer	Some entrapped crystals.	
16	Condenser Exit	0.4 Layer	Moderate crystal.	
17	Separator, Magnet Entry	0.6 Crevice and Layer	-	
18	Separator, Magnet Exit	0.28 Crevice	Light crystal.	
19	Post Condenser Exit	0.8 Layer	Very slight crystal.	

TABLE 3

WET ANALYSIS OF DEPOSITS FROM LOOP TEST G-16

Location	Total Deposit Weight ¹	Acid Leached Metal Weight ²	Composition, Percent								Corroded Metal Weight ⁶	% of Corrosion Products	
			Cr	Ni	Fe	Co	W ³	Mn ⁴	Si	Hg		Corroded Metal ⁶	Total Deposit ¹
Columbia Separator:													
From Amalgam	18.44g	0.410g	27.6	7.4	3.3	16.3	0.02	0.25	0.16	bal	0.23g	7.17	30.1
From Turnings	0.657	0.657	85.8	7.5	0	6.7					0.657	20.5	
Magnetic Separator	23.63	0.883	22.7	5.7	9.04	40.3	1.03	0.35	0.18	bal	0.69	21.5	37.2
Iron Separator:													
From Amalgam	5.03	0.270	45.3	6.2	4.9	44.7	0.21	0.15	0.14	bal	0.27	8.4	9.33
From Wool	0.885	0.885	95	1		4					0.885	27.5	
Condenser	10.63	0.19	15.5	4.1	2.3	51.5	0.25	0.05	Nil	bal	0.14	4.38	16.8
Subcooler and Boiler	1.90	0.105	21.2	7.9	3.0	17.5	1.6	0.75	0.89	bal	0.05	1.56	3.0
Superheater	0.356	0.356	1.7	4.0	2.2	67.9	Minor ⁵	Trace ⁵	Minor ⁵	bal	0.27	8.4	0.56
Mercury Crud ⁷	1.96 ⁸	0.046	15.8	9.8	1.1	4.8	Trace ⁵	1.0	0.6	bal	0.02 ⁹	0.62	3.09
Total Weight:	63.49g ⁸										3.21g ⁹		

1 - Contains amalgam and some liquid mercury.

2 - 50 percent HCl extraction of metals from amalgam and from columbium and iron wool.

3 - Residue identified by spectrographic analysis.

4 - Estimated.

5 - Spectrographic analysis.

6 - Metal leached from container walls.

7 - Filtered mercury spectrographic analysis: Trace - Ag, Ca, Cu, Fe.

8 - 63.49g equivalent to about 0.29 cubic inches.

9 - 3.21g equivalent to about 0.025 cubic inches.

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FIGURES

FIG. 1
CORROSION LOOP SCHEMATIC

FIG. 2
CORROSION
PRODUCT
SEPARATOR

Fig. 3. Corrosion Loop Installed in Insulation Container.

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RDM 4651

250X

Fig. 4. Crevice Corrosion on Boiler Inlet (Micro. 2, Fig. 1).

RDM 4652

250X

Fig. 5. Crevice and Layer Corrosion on Lower Quarter of Boiler (Micro. 3, Fig. 1).

RDM 4653

250X

Fig. 6. Depleted Corrosion Layer on Upper Quarter of Boiler (Micro. 5, Fig. 1).

RDM 4648

250X

Fig. 7. Intergranular Depleted Layer Penetration in Lineheat Exit (Micro. 8, Fig. 1).

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RDM 4650

250X

Fig. 8. Columnar Deposition on Superheat Midpoint (Micro. 10, Fig. 1).

RDM 4649

250X

Fig. 9. Depleted Corrosion Layer on Condenser Entry (Micro. 12, Fig. 1).

Fig. 10. Top of First Compartment of Separator Containing Columbium Turnings.

06095-6

Fig. 11. Columbium Turnings Showing Heavy Amalgam Trapping on Entry Side.

Fig. 12. Entry of Magnetic Separator Showing Heavy Amalgam Build-up.

06095-4

Fig. 13. Iron Wool Showing Some Contaminant Trapping.

06095-1

RDM 4325

(a)

500X

RDM 4307

(b)

1000X

RDM 4310

(c)

2000X

Fig. 14. Haynes Alloy No. 25 Tube Failure: (a) Intergranular Nature of Fracture Surface and Mercury Attack on Inclusions; (b) Inclusions Predominantly in Grain Boundaries; (c) Inclusion Detail.

Figure 15. Haynes Alloy No. 25 Corrosion Loop Penetration as a Function of Inverse Temperature.

Fig. 16. Corroded Metal Deposit Location and Composition