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SUBJECT: HRT Corrosion Samples -- Additional Data on Specimens
Removed Prior to Run No. 20.

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SUMMARY

Results of the examinations of corrosion specimens exposed in the HRT are presented. Specimens examined include (1) core screen samples, (2) core specimen array No. 1, (3) blanket specimen array No. 2, (4) core solution line specimen arrays No. 103 and 103A, (5) blanket solution line specimen array No. 203. Complete information is still not available on all the specimens removed from the reactor, however, those data which have been accumulated are presented. These include corrosion rates, computed from specimen weight-changes, and results of chemical analyses of scales removed from the specimens or specimen holders. Also included in this report is a summary of the HRT operating schedule during exposure of the specimens and of the status of examinations for those specimens removed from the reactor prior to run 20.

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Introduction:

Numerous corrosion specimen arrays have been exposed at various times in the HRT. Most of these arrays are still in the reactor system and many cannot be removed until the reactor is dismantled. Reports of the examination of several arrays removed from the system have been issued. Other arrays have been removed and examined but not reported. Complete information is still not available on all the specimens removed; however, those data which have been accumulated, and not previously reported, will be presented in this report. Exposure information and the status of examinations for specimen arrays that have been removed from the reactor are summarized in Table 1. A summary of the HRT operating schedule during exposure of the specimen arrays is given in Table 2. Locations of the specimens in the pressure vessel core and blanket regions are shown in Fig. 1.

1. Core Region - Pressure Vessel

a. Core Screen Samples.--Following run 17, samples were cut from the centers of four of the core screens which had been in the core since the beginning of the HRT experiment. The samples from screens No. 5, 6, 7, and 9 were submitted for measurements of induced activity and for chemical analyses. As previously reported,¹ flux values, calculated for an average core power level of 2 Mw, varied from 5.3×10^{13} neutrons/cm² sec for screen sample No. 9 located 11-in. below the core center, to 3.8×10^{13} neutrons/cm² sec for screen sample No. 5 located 17-in. below the core center. Calculations showed that about 70% of the activity in these specimens at the time of counting was induced during run 17 and

about 25% during run 16. The average power level in the core during these runs was 1.5 and 1.3 Mw, respectively.

The results of ionic and spectrographic analyses of solutions obtained by dissolution of portions of the samples indicate that very little scale was present on these samples. The largest amount of uranium found was 75 μg in a 0.5 g sample from the top screen, No. 9, which had an estimated external area of 1 cm^2 . Because of the exfoliation the actual surface area of the specimen may have been somewhat greater than 1 cm^2 . About 10 to 35 μg uranium per cm^2 of estimated external area were found on the other three screens. These amounts are somewhat greater than those found on in-pile loop specimens² in a comparable solution and the exfoliation may account for this.

b. Core Region Loading No. 1.--Core region loading No. 1 was exposed in the core of the reactor during run 17 only. The HRT logged 2426 Mwhr during this run, which began on Aug. 1 and ended on Sept. 12, 1958. Approximately 40% of the reactor energy was generated in the blanket region, and the total time at temperatures greater than 250°C was 890 hr. The reactor was at temperatures between 100 and 250°C for an additional 185 hr. Corrosion rates quoted below are based on the 890 hr of high temperature operation during which the average total power level was 2.7 Mw and the average core power 1.7 Mw.

Considerable scale was found on the portion of the titanium specimen holder exposed in the core neck, Fig. 1, increasing in amount from station D to station A. Some scale was found on that portion of the holder in the

core itself, stations E through H, but the amount was very much less. Analyses of material scraped from the holder indicate that the scale at the lower end contained sizeable amounts (4-10%) of iron, titanium, zirconium, and uranium. However analyses of scale taken from the upper portion of the holder (stations A through D) indicate that zirconium was the major constituent (50%), with uranium being present to the extent of about 1.5%. These data are shown in Table 3.

Seven corrosion specimens from the high flux stations (stations E through H) were recovered from the core holder and top screen. The weight data obtained for these are given in Table 4. Since most of the weight losses or damage occurred at the ends where the specimens were held, and were probably associated with damage to the specimen holder,³ corrosion rates are not meaningful and are not given.

All of the specimens from the low-flux stations (stations A through D) were weighed as removed, and most of them were then subjected to cathodic defilming operations. The tee-heads were cut from most of the specimens before the defilming operations and submitted for chemical analyses of the surface materials. With four of the specimens, a sample for this type analysis was also taken from a section of the specimen which was adjacent to the tee-head but which was entirely accessible to solution in the reactor test. The tee-head surfaces were partially covered by the titanium holder during the in-pile test. Typical specimens contained in the core and blanket vessel arrays are shown in Fig. 2. The method employed for mounting these impact and tensile specimens is shown in Fig. 3. The manner in which

portions of the specimen tee-heads are covered by the holders can also be seen in this photograph.

Most of the specimens showed weight gains as removed from the holder, and most of the zirconium alloy and titanium alloy specimens showed weight gains after repeated cathodic defilming operations. In Table 5 are listed the specimen loading number, the station and position, estimated amount of scale, and corrosion rate values where weight losses were observed. The amount of scale was estimated from the difference between the as-removed and installed weights where no weight loss was observed after defilming, and from the difference between the as-removed and defilmed weights where defilmed weight losses were found. Values for the fission power density in solution adjacent to a specimen are also given where thermal neutron flux values are available.¹ The values were calculated on the basis of the flux, a uranium concentration of 5 g per liter in the core, and an operating temperature of 265°C.

As shown in the table, an appreciable Zircaloy-2 corrosion rate was observed for only one specimen (W-2-d). Weld specimens of this type were severely corroded in out-of-pile tests so that the severity of this corrosion cannot be ascribed to the in-pile operation alone. The corrosion apparently resulted from weld contamination by titanium.⁴

No appreciable rates were observed with the titanium alloy specimens.

The corrosion rates for the stainless steel specimens, especially the 304 ELC specimen, are probably greater than expected in out-of-pile exposure. For example, stainless steel specimens pretreated with high temperature water exhibited weight losses of 1 mg/cm² or less when subsequently exposed

to UO_2SO_4 solutions in out-of-pile loops or in low-flux regions of in-pile loops.^{5,6} It appears that the high weight losses of 3 to 10 mg/cm² observed for the HRT core specimens (also pretreated with high temperature water) were a result of reactor power operation. The weight losses are greater than expected from the results of in-pile loop and autoclave experiments which indicate no effect of irradiation at these very low power densities. No explanation for the increased corrosion is apparent.

For the Zr-15Nb specimen (H-2-a, unpretreated) which showed a rate of 2.7 mpy (-4.5 mg/cm²), no out-of-pile corrosion data are available for comparison. It may be noted however, that specimens of this material exposed at in-line positions of in-pile loops^{6,7} showed significant weight gains, presumably because of adherent, deposited scales. Also, a pre-treated specimen located in the blanket region during run 17 corroded at the same rate as H-2-a although the fission power density near the blanket specimen was at least a factor of ten greater. It is probable that the relatively high corrosion of H-2-a was associated with the absence of pre-treatment, and that the low intensity irradiation had little effect on the corrosion.

The scale on the low-flux specimens increased in amount with increasing distance from the core until about the midpoint of the holder. Above this position the amounts of scale on all the specimens were about the same, 20 to 25 mg/cm². In general, the results for the amounts of scale on different specimens indicate scale behavior under irradiation in the HRT similar to that observed in in-pile loop experiments.⁸ In this behavior

pattern, scale is apparently put into solution (ionic or colloidal) within the core and is deposited as strongly adherent material on surfaces outside the core.

The results of the analyses on these specimens, submitted in the as-removed or defilmed condition, are shown in Table 6. In each case, the analytical sample was comprised largely of metal dissolved along with the surface material. As shown, the uranium content of these samples varied from 0 to 0.4% which corresponds to 0 to 187 $\mu\text{g}/\text{cm}^2$ of specimen area. Assuming the weights of scale on the specimens to be those average values shown in Table 5, the weight per cent uranium found in the scale samples from the as-removed specimens varies, with one exception as shown in Table 7, from 0.04 to 0.51%. These amounts are considerably less than the amount present in the scale on the titanium holder, reported above as 1.5%. Scale from the exception, type 347 stainless steel specimen in station C-6, contained 1.8% uranium. Also shown in Table 7 are the corrected amounts of the other constituents found in the analytical samples from the as-removed specimens. (Corrected for amounts of sample constituents originating from metal specimens).

2. Blanket Region - Pressure Vessel

a. Blanket Region Loading No. 2.--Blanket region loading No. 2 was exposed in the blanket of the reactor during run 17 only. As reported above the HRE-2 logged 2426 Mwhr during the run, approximately 40% of which was generated in the blanket region, and operated at temperatures greater than 250°C for 890 hr. Corrosion rates quoted below are based on the 890 hr of high temperature operation during which the average total power

cores.

As for the core specimen array no appreciable rates were observed with the titanium alloy specimens. One Ti-6Al-4V specimen, M-3-a, exhibited a corrosion rate of only 0.3 mpy following defilming, while the second specimen of this material, M-3-b, which was not defilmed, exhibited a slight (0.5 mg/cm^2) weight increase in the as-removed condition. The single specimen of Ti-A40, located at J-5, exhibited a weight increase of 0.2 mg/cm^2 following defilming.

The 347 stainless steel annealed specimens exhibited corrosion rates of about 2.5 mpy, but the rates on the welded specimens were approximately 4.7 mpy. These values are higher than most of the rates observed in in-pile loops at comparable power densities but are within the range of values found in one experiment, L-2-10.¹⁰ Considerable amounts of uranium were found in the scale removed from both of the 347 SS specimens that were analyzed (Table 9) and it is possible that the power densities at the surfaces of these specimens were appreciably higher than estimated from the neutron flux and uranium concentration in solution¹¹ and that these higher effective power densities contributed appreciably to the increased corrosion.

Single specimens of 304 ELC and 309 SCb corroded at rates of 1.5 and 7.1 mpy, respectively. Similar differences between the radiation effects on these materials and those on 347 stainless steel are indicated by results of some in-pile loop experiments but the differences are not clear-cut nor are explanations for the differences available.^{6,12,13}

The single Incoloy specimen corroded at 4.3 mpy.

Corrosion rates observed for the Zircaloy-2 specimens ranged from 3.2 to 3.9 mpy for those specimens in stations J, K and L, but were about 20%

lower for those specimens from station M where the thermal neutron flux is also approximately 20% lower. The single Zr-15Nb β -quenched alloy specimen in station M corroded at about the same rate as the Zircaloy-2 specimens while the single α -annealed Zr-15Nb specimen in station L exhibited a corrosion rate of 7.5 mpy, roughly twice that of the Zircaloy-2 specimens. For comparison of these Zircaloy-2 corrosion rates with those observed in in-pile loops, an α value of about 1¹⁴ can be calculated from these rate and power density values and an assumed temperature of 260°C. This value is about the same as that estimated for the blanket solution composition and velocity (1 fps and 2 gpl solutions) from in-pile loop results together with laboratory sorption data for the variation in amounts of uranium sorbed with variation in solution composition.¹⁴

As was the case for specimens from core region loading No. 1, reported above, the analytical samples for the specimens from this array, submitted in the as-removed condition, were comprised largely of metal dissolved along with the surface material. Shown in Table 9 are the direct results of analyses and shown in Table 10 are the corrected amounts of the constituents found in the analytical samples. (Corrected for amounts of constituent in the sample originating from the metal specimens). The results show many inconsistencies. For example, the fractional amounts of zirconium in several of the Zircaloy-2 scales are much less than the amounts which were probably present in the samples which were mainly dissolved Zircaloy-2. Also, in several cases the totals of the calculated amounts of the several scale constituents are greater than the probable amounts of

retained scale. Thus, these analytical results should be regarded as only roughly quantitative.

3. Solution Circulating Lines

a. Core Solution Line Array No. 103.--Core solution circulating line array No. 103, installed in the reactor system prior to the shakedown run, was removed and replaced with a substitute array (103A) following run 13. Array 103 had been temporarily removed from the system, examined and reinserted in the reactor following run 7. Results of the examination have been reported.¹⁵ During run 13, the first power run, the reactor produced 49 Mwhr, all in the core, and the total time at temperatures greater than 250°C was 191 hr. The reactor was at temperatures between 100 and 250°C for an additional 187 hr. Corrosion rates quoted below are based on the 191 hr of high temperature operation during which the average power level was 0.3 Mw.

The eight coupons from array No. 103 were removed, examined and weighed. Half of the coupons, one each of the specimen materials employed, were then defilmed once and reweighed. The defilming solutions were transferred to the Analytical Chemistry Division for analyses. Results of the examinations and analyses have been reported.¹⁶ The uranium content of the scale varied from 2 $\mu\text{g}/\text{cm}^2$ of specimen area for the Zr-2 coupon to 45 $\mu\text{g}/\text{cm}^2$ for the type 347 stainless steel coupon and corresponded to 0.5% and 1.5% of the scale by weight. The average amount of iron in the four scale samples was 76%.

At the same time that array No. 103 was removed from the reactor, scale samples were scraped from various locations in the reactor and submitted for

chemical analyses. The results of these analyses¹⁶ indicate that these scale samples were also largely composed of iron and that the uranium content was approximately that found on the specimens from array No. 103.

All eight coupons from the array were later subjected to repeated cathodic defilming and were reweighed and examined. Results of these later examinations are presented here.

The Ti-75A, Zr-2 and type 347 SS coupons showed weight gains as removed from the holder while both type 309 SCb coupons showed weight losses. Following the several defilming operations, all coupons excepting the two Zr-2 specimens exhibited weight losses; weight gains were observed for the Zr-2 coupons. In Table 11 are listed the specimen number, specimen material, estimated amount of scale, weight changes and corrosion rate values where weight losses were observed. The amount of scale was estimated from the difference between the as-removed and installed weights where no weight loss was observed after defilming, and from the difference between the as-removed and defilmed weights where defilmed weight losses were found.

The 191 hr time basis yields deceptively high corrosion rates for the stainless steel specimens since much or all of the corrosion may have occurred during pre-power operation of the reactor - about 900 hr with UO_2SO_4 solution at temperatures between 250 and 300°C. Indeed, since the type 347 stainless steel specimens exhibited weight losses of about 1 mg/cm² it appears that they were attacked only to the extent expected for 347 stainless steel that had been pretreated with high temperature water and subsequently exposed to UO_2SO_4 solution in the absence of radiation. The

same or slightly higher attack can be expected for similarly treated 309 SCb stainless steel. As shown in Table 11, specimens of this material exhibited losses of 2.5 and 4.7 mg/cm² and reactor operations may have had some small effect on the corrosion of this material. These low rates for the steel specimens during run 13, show that the high initial rate of steel corrosion during that run (about 20 mpy over-all rate in the core system based on 191 hr and the amount of nickel in solution)¹⁷ was not uniform over the surfaces of the high pressure system and that some surfaces corroded at greater rates than the average.

Core Solution Line Array No. 103A.--Core solution line array No. 103A, installed in the reactor system following run No. 13, was removed following run 19 and replaced by array No. 103B. During runs 14 through 19, the reactor produced 4802 Mwhr, 2997 Mwhr of which was in the core. During this period the total time at temperatures greater than 250°C was 2898 hr. The reactor was at temperatures between 100 and 250°C for an additional 1008 hr. Corrosion rates quoted below are based on the 2898 hr of high temperature operations during which the average core power level was 1.0 Mw.

The eight coupons from array 103A were removed, examined, weighed and cathodically defilmed. All of the coupons showed weight gains as removed from the holder. Following four defilming operations all coupons, excepting one of the Ti-75A and both Zr-2 coupons, exhibited weight losses; weight gains were observed for the exceptions. In Table 12 are listed the specimen numbers, specimen materials, estimated amounts of scale, weight

changes and corrosion rate values where weight losses were observed. The amount of scale was estimated from the difference between the as-removed and defilmed weights where defilmed weight losses were found. As shown in the table, only very low corrosion rates (maximum 0.2 mpy on steel) were observed and again most of this corrosion would have occurred in the absence of reactor operation.

Chemical analyses were not made of the scale on these coupons, however a sample of scale scraped from the titanium holder from this array was submitted for analyses of constituents. Values for the various constituents were U, 0.25%; Cu, 0.3%; Cr, 0.5%; Ni, 0%; Fe, 22.6%; Zr, 1.7%.

c. Blanket Solution Line Array 203.--Blanket solution line array 203, installed in the reactor system prior to operation of the reactor, was removed and replaced with a substitute array (203A) following run 19. During the power runs through 19 the reactor produced 4851 Mwhr, 1812 Mwhr of which was released in the blanket commencing with run 16. During this period (runs 16 through 19) the total time at temperatures greater than 250°C was 2650 hr and the reactor was at temperatures between 100 and 250°C for an additional 937 hr. The total circulation time in the reactor prior to run 16, at all temperatures, was 3500 hr. Corrosion rates quoted below are based on the 2650 hr of high temperature operations during which the average blanket power level was 0.7 Mw.

As removed from the holder, the 8 coupons exhibited weight gains. Following three defilming operations the type 347 and 309 SCS stainless steel

coupons exhibited slight weight losses but weight increases were still observed for the Zircaloy-2 and Ti-75A coupons. In Table 13 are listed the specimen numbers, specimen materials, estimated amounts of scale, weight changes and corrosion rate values where weight losses were observed. The amount of scale was estimated from the difference between the as-removed and defilmed weights where defilmed weight losses were found. As shown in the table, only negligible corrosion rates were observed. The low weight losses would probably have occurred also in the absence of reactor operation.

Chemical analyses were not made of the scale on these coupons but analyses of a sample of scale scraped from the titanium holder showed the following amounts of constituents to be present: U, 0.81%; Cu, 0.5%; Cr, 0.2%; Ni, 0.4%; Fe, 18.6%; Zr, 4.5%.

SPECIMEN LOCATIONS

FIG. 1. DISTANCE FROM CORE CENTER (INCHES)

PLATE 2094

FIG. 2. TYPICAL IMPACT AND TENSILE SPECIMENS

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FIG. 3

Table 1. Specimens Removed from HRT

Specimens	Remarks	Fabrication Report	Data Report
<u>Blanket Region-Pressure Vessel</u>			
Loading No. 1	Removed following run 14. Contained 24 tensile and impact specimens of type 347 SS and of zirconium and titanium alloys.	CF 58-4-38	CF 58-10-83
Loading No. 2	Exposed only during run 17. Contained 24 tensile and impact specimens of types 309SCb and of zirconium and titanium alloys.	CF 58-7-69	This Report
Loading No. 3	Exposed in reactor following loading No. 2. Removed following run 21. Stored in burial ground. Specimens similar to loading No. 1.	CF 59-5-58	----
<u>Core Region-Pressure Vessel</u>			
Loading No. 1	Exposed only during run 17. Contained 48 tensile and impact specimens of various stainless steels and of zirconium and titanium alloys.	CF 58-7-68	This Report
<u>Code Access Flange Specimens and Scales</u>			
1. Blind Flange Scales	Exposed during run 13.	CF 58-9-37	CF 58-9-37
2. Flange & SS specimens & Scales	Exposed during run 14.	CF 58-9-37	CF 58-9-37
3. Stainless steel specimens & Scales	Exposed during runs 15 and 16.	HRP-58-197	CF 58-10-84
<u>Circulating Pump Surge</u>			
Fuel System			
Array No. 125	Removed during Run 19. Contained 4 coupons of Stellite #12, Stellite #19, Graphitar #14, and Al 203 and 1 beam-type stress specimen of type 347 SS.	CF 56-6-82	Appendix I, This Report
Array No. 325	Removed following run 21. Stored in pool in 7500. Specimens identical to array No. 125	CF 58-5-42	----
Blanket System			
Array No. 225	Removed during run 19. Specimens identical to array No. 125.	CF 56-6-82	Appendix I, This Report
<u>Circulating Lines</u>			
Fuel System			
Array No. 101	Removed after run 7, scrubbed, weighed, photographed and reinstalled. Contained 8 coupons, 2 each of Ti-75A, Zr-2, types 347 SS and 309 SCb.	CF 56-6-62	CF 56-6-62 Addendum I
Blanket System			
Array No. 201	Removed after run 7, scrubbed, weighed, photographed and reinstalled. Contained 8 coupons, 2 each of Ti-75A, Zr-2, types 347 SS and 309 SCb.	CF 56-6-62	CF 56-6-62 Addendum I
<u>Circulating Pump Outlet</u>			
Fuel Side			
Array No. 103	Removed after run 7, scrubbed, weighed, photographed and reinstalled. Specimens similar to array No. 101. Removed after run 13.	CF 56-6-62 CF 56-6-62	CF 56-6-62 Addendum I CF 58-9-37 and this report
Array No. 103 A	Replaced array No. 103. Exposed from after run 13 through run 19. Specimens similar to array No. 103.	CF 58-5-41	This report
Blanket Side			
Array No. 203	Removed after run 7, scrubbed, weighed, photographed, and reinstalled. Specimens similar to array No. 103. Removed after run 13.	CF 56-6-62 CF 56-6-62	CF 56-6-62 Addendum I This Report
<u>Core Screen Samples</u>	Removed following run 17.	----	This Report
<u>Scale</u>	Removed from various places in HRT following runs 13 and 14.	----	CF 58-9-37

Table 2. Summary of HRT Operations

Run No. Purpose	Thermal Cycles	Power Start Ups	Energy (Mwhr)	Core Power ^a Total Power	Circulation Time								At All Temperatures (hr)	With U ²³⁵ (hr)
					At 100°C (hr)	With U ²³⁵ (hr)	At 100-200°C (hr)	With U ²³⁵ (hr)	At 200-250 (hr)	With U ²³⁵ (hr)	At 250-300 (hr)	With U ²³⁵ (hr)		
Unnumbered Run Shakedown					129								129	
D-1 Dump Test					2		7						9	
D-1A Dump Test					6		13						19	
1. Oxygenated Water Pretreatment					21		24		76		147		268	
2. Criticality Temperature Tests					30								30	
3. Operations Training					1		5		33		189		223	
4. Oxygenated Water and Operations Training					1		16		9		107		133	
5. Preparation for Depleted U					12		17		16		75		120	
6. Preparation for Depleted U					7		13		14		164		198	
7. Depleted U Run					9		29		17		651	(520) ^b	706	(520) ^b
8. TSP-H ₂ O-HNO ₃ -H ₂ O Rinse					69								69	
9. H ₂ O Run					24		32		9		155		220	
10. Depleted U Run					4		20	(12) ^b	15	(7) ^b	295	(238) ^b	334	(257) ^b
11. D ₂ O Run Prior to 1st Critical Run	26				28		19		12		82		141	
12. Critical Run			0.0001		100	52	72	46	18	18	14	14	204	130
13. 1st Power Run	3	3	49	1.0	11		155	2	21	9	191	145	378	156
14. 2nd Power Run	1	1	351	1.0	8	1	23	7	8	2	227	189	266	199
15. Determine Location of Leak in Core Run	1				5		21		6		21		53	
16. One Region Mixing Experiment	4	2	1655	0.55	23		219	103	106	104	643	642	991	849
17.	2	5	2426	0.62	10		42		143	129	890	803	1085	932
18.	4	2	363	0.62	0		61		231	194	989	641	1281	835
19.	1	2	7		0		94		8		128	18	230	18

^a Private communications from P. N. Haubenreich.^b With depleted uranium.

Table 3. Chemical Analysis of Scale Removed from HRT Core Specimen Holder
(Loading No. 1)

Identification	Sample Weight (mg)	Analytical Procedure	Analysis (Wt. %)										
			SO ₄ ²⁻	U	Cu	Cr	Ni	Fe	Zr	Mn	Ti	Sn	Zr/Fe
Station A	232.6	Chemical Spectrographic		1.63	0.5	0	0.13	2.92	33.1	--	---	---	11.3
					0.4	0.6	<0.22	4.4	72.2	--	1.3	0.6	16.4
Station B	204.6	Chemical* Spectrographic		1.85	1.3	---	0.04	1.5	---	--	---	---	---
					0.3	0.6	<0.24	4.7	53.8	--	1.2	0.3	11.4
Station C	235.2	Chemical Spectrographic		1.25	0.14	0	0.04	2.0	44.7	--	---	---	20.3
					0.6	1.2	<0.21	7.2	63.2	--	1.7	0.9	8.8
Station D	186.8	Chemical Spectrographic		1.59	0.17	0	0.06	2.4	69.6	--	---	---	29.0
					0.3	1.3	<0.27	9.9	53.5	--	1.5	0.8	5.4
Station E	16.2	Chemical Spectrographic	0.05	11.7	0.95	0.9	0.5	3.9	31.6	--	---	---	10.7
					0.4	1.2	ND	7.4	8.0	ND	9.73	---	1.1
Station F	16.3	Chemical Spectrographic	ND	3.98	0.7	0.15	0.3	11.5	4.99	--	---	---	0.4
					0.5	1.1	ND	8.8	4.1	ND	10.1	---	0.5
Station G		Chemical Spectrographic	Lost in Analytical Processing										
Station H	4.9	Chemical Spectrographic	ND	3.1	1.6	0.3	ND	12.7	7.6	--	---	---	0.6
					0.7	VFT	ND	10.2	5.4	ND	7.9	---	0.5

* Sample lost before chemical analyses were completed.

ND. - Not detected.

Table 4. HRT Core Specimens (Loading No. 1)^b
High Flux Stations

Specimen	Station and Position	Material	Original Weight (g)	As-Removed Weight (g)	Weight Difference (g)
Y-1-a	E-2	Zr-2*	18.9380	18.4853	- 0.4527
E-1-a	E-5	Zr-15% Nb ^a	20.2570	19.1317	- 1.1253
J-1-a	F-1	Ti-A40	13.0876	12.9367	- 0.1509
Y-1-b	F-2	Zr-2*	19.1040	18.4478	- 0.6562
B-1-a	F-3	Zr-2**	19.0387	18.2164	- 0.8223
W-1-b	H-1	Zr-2***	18.7868	15.5636	- 3.2232
Y-1-c	H-2	Zr-2*	19.2065	17.2613	- 1.9452

* Allegheny-Ludlum - welded

** Allegheny-Ludlum

*** Core-tank material - welded. This material was severely attacked in out-of-pile tests, presumably because of weld contamination with titanium

a α -annealed

b Six additional specimens have been recovered since Run 20.

Table 5. HRT Core Specimens (Loading No. 1)
Low Flux Stations

Specimen	Station and Position	Material	Average Weight of Scale (mg/cm ²)	Corrosion Rate (based on 890 hr exposure at 1.7 Mw) (mpy)	Power Density* at 1.7 Mw Av. Core Power Level (w/cc)
A-2-a	A-1	Zr-2	20	+	0.007
B-2-a	2	Zr-2	10	x	
Y-2-a	3	Zr-2	11	+	
H-2-a	4	Zr-15 Nb	21	2.7	
M-2-a	5	Ti-6Al-4V	23	+	
O-2-a	6	347 SS	22	1.7	
A-2-b	B-1	Zr-2	18	+	
B-2-a (I)	2	Zr-2	27	x	
X-2-a	3	X-Bar	25	+	
J-2-a	4	Ti-A-40	22	+	
U-2-a	5	347 SS		x	
O-2-b	6	347 SS	11	x	
A-2-c	C-1	Zr-2	23	x	0.07
B-2-b (I)	2	Zr-2	22	+	
E-2-a	3	Zr-15 Nb	6	+	
J-2-a (I)	4	Ti-A-40	19	0.3	
R-2-a	5	304 ELC-SS	13	4.8	
O-2-c	6	347 SS	4	x	
A-2-a (I)	D-1	Zr-2	6	+	0.09
B-2-c (I)	2	Zr-2	7	x	
W-2-d	3	Zr-2	5	9.5	
J-2-b	4	Ti-A-40	3	x	
M-2-b	5	Ti-6Al-4V	3	+	
U-2-b	6	347 SS	3	2.6	

+ Showed gain in weight following third defilming
x Tee-heads cut off, corrosion rates unavailable
(I) Impact specimens; others are tensile specimens

Materials description - refer to first letter under specimen designation

A - Core tank material

B - Allegheny-Ludlum stock

U - Welded

E - Zr-Nb-15% Sponge, α annealed

H - Zr-Nb-15% Sponge, β quenched

W and Y - As welded

All others - Annealed

* Flux value is reasonably representative for entire station and for holder.

Table 6. Chemical Analysis of Retained Scale on HRT Core Loading No. 1 - Low-Flux Specimens

Specimen	Station and Position	Material	Surface ¹	U	Sample	Surface ²	Analytical	Analysis (Wt. %)								SO ₄ ⁼
			Area	(μg/cm ²)	Weight			Condition	Procedure	U	Cu	Cr	Ni	Fe	Zr	
A-2-a	A-1	Zr-2	3	6	447.7	D	Chemical	0.004	0.04	0	0.02	1.8	49.8			0
B-2-a	A-2	Zr-2	3	0	446.6	D	Spectrographic	0	0.01	0	0.04	0.7	70.0			0
H-2-a	A-4	Zr-15% Nb	3	24.2	169.4	D	Chemical	0.043	0.01	0	0.02	1.3	60.2			0
							Spectrographic									
A-2-b	B-1	Zr-2	3	16	561.2	D	Chemical	0.009	0.01	0	0.03	0.7	69.1			0
							Spectrographic									
B-2-a(I)	B-2	Zr-2	3	12	613.7	AR	Chemical	0.006	0	0	0.14	0.3	21.8	--	--	0
							Spectrographic			0.05		4.0	39.2		Trace	
B-2-a-2(I)	B-2	Zr-2	1.2	187	936.0	AR	Chemical	0.024	0.02	0	0.10	0.4	67.3	--	--	0
							Spectrographic			0.14	--	8.3	63.2	--	Trace	
U-2-a	B-5	347 SS	3	56	502.2	AR	Chemical	0.03	0	11.6	8.8	27.9	1.6			0.24
							Spectrographic		--	15.3	8.6	55.4	1.0	1.5		
O-2-b	B-6	347 SS	3	56	499.3	AR	Chemical	0.034	1.6	10.0	11.0	28.0	1.9			1.1
							Spectrographic		--	15.2	8.4	57.8	1.6	1.1		
O-2-b-2	B-6	347 SS	1.2		207.5 ⁴	AR	Chemical	101γ	0	10.9 mg	7.2 mg	47 mg	4.8 mg			6.9 mg
							Spectrographic			4.9	2.6	19.3	1.5	0.3		
A-2-c	C-1	Zr-2	3	38	275.0	AR	Chemical	0.042	0.06	0	0.2	0.1	48.2			0.8
							Spectrographic						21.2			
B-2-b*(I)	C-2	Zr-2	3	3.9	580.3	D	Chemical	0.002	0.01	0	0.07	0.7	76.7			0
							Spectrographic									
E-2-a	C-3	Zr-15% Nb	3	83	253.7	D	Chemical	0.098	0.01	0	0.02	0.4	63.2			0
							Spectrographic									
J-2-a-(I)	C-4	Ti-A 40	3	100	77.5	D	Chemical	0.40	0.01	0	0.15	3.3	19.5			0
							Spectrographic									
O-2-c	C-6	347 SS	3	70	303.8	AR	Chemical	0.069	0	3.5	12.2	78.6	3.7			2.66
							Spectrographic			12.4	8.6	54.4	4.0	0.11	--	
A-2-a(I)	D-1	Zr-2	3	12	264.5	D	Chemical	0.014	0.01	0	0.08	0.5	67.7			0
							Spectrographic									
B-2-c(I)	D-2	Zr-2	3	4	401.1	AR	Chemical	0.003	0.05	0	0.08	0.4	74.8			0.1
							Spectrographic		--	--	--	--	74	--		
B-2-c-2(I)	D-2	Zr-2	1.2	3.3	390.9	AR	Chemical	0.001	0.04	0	0.5	0.4	81.9			1.5
							Spectrographic						96			
J-2-b	D-4	Ti-A40	3	3.7	159.5	AR	Chemical	0.007	0.5	--(3)	0.3	1.3	13.2			--(3)
							Spectrographic		--	--	--	--	1.6	--		
J-2-b-2	D-4	Ti-A40	1.2		180.7 ⁴	AR	Chemical	9γ	387γ	--(3)	454γ	2.1 mg	3.0 mg		62	--(3)
							Spectrographic		--	--	--	--	0.8	--	30.1	

1) The surface areas also indicate specimen location: a) 3 cm² - Tee-head removed and pickled for scale analysis. Part of this area in contact with Ti holder.

b) 1.2 cm² - 1/4" long section adjacent to the Tee-head removed for analysis. Area entirely accessible to solution.

2) Surface condition: D - defilmed cathodically before removing scale for analysis. AR - surface in the as-received condition.

3) Sample preparation precluded the SO₄⁼⁼ and Cr analyses.

4) Sample handling difficulties - results at best qualitative.

Table 7. Chemical Analyses of Retained Scale on HRT Core Loading No. 1 Low Flux Specimens

Specimen	Station and Position	Material	Surface Area (cm ²)	Sample Weight (mg)	% U in** Scale	Constituents of film and weights from chemical analyses of "as-removed" specimens						
						U	Cu	Cr	(μg/cm ²)		Fe	Zr
B-2-a (I)	B-2	Zr-2	3	614	0.04	12	0	0	180	*	--	0
B-2-a-2 (I)	B-2	Zr-2	1.2	936	--	187	160	0	390	*	--	0
A-2-c	C-1	Zr-2	3	275	0.17	38	55	0	140	*	--	700
B-2-c (I)	D-2	Zr-2	3	401	0.06	4	67	0	40	*	--	130
B-2-c-2 (I)	D-2	Zr-2	1.2	391	--	3	13	0	146	*	--	5000
U-2-a	B-5	347 SS	3	502	--	56	0	--	--	--	2680	40
O-2-b	B-6	347 SS	3	499	0.51	56	2460	--	--	--	3160	1830
O-2-c	C-6	347 SS	3	304	1.8	70	0	--	--	--	3740	2690
J-2-b	D-4	Ti-A-40	3	160	0.12	4	203	--	160	691	7020	--

* Weight per cent reported in sample less than weight per cent in metal specimen

** Based on average scale weight given in Table 5

Table 8. HRT Blanket Specimens (Loading No. 2)

Specimen	Station and Position	Material	Average Weight of Scale (mg/cm ²)	Corrosion Rate (based on 890 hr exposure at 1.0 Mw) (mpy)	Power Density*** at 1 Mw Average Core Level (w/cc)
A-1-d(I)	J-1	Zr-2		3.9*	0.5
B-1-e	2	Zr-2	.01	3.4 ^d	0.4
D-3-a	3	Zr-2	.02	3.2 ^d	
J-3-e	4	Ti-A-40	.8	+ ^d	
O-3-c	5	347 SS		2.7*	
O-3-b	6	347 SS		2.4**	
A-3-e	K-1	Zr-2		3.7**	
B-3-b(I)	2	Zr-2		3.5**	
Y-3-c	3	Zr-2	.06	3.7 ^d	
M-3-a	4	Ti-6Al-4V	.6	0.3 ^d	
U-3-c	5	347 SS		4.6**	
R-3-a	6	304 ELC		1.3*	
A-3-f	L-1	Zr-2	.06	3.6 ^d	0.5
B-3-d(I)	2	Zr-2		3.5*	0.4
E-3-c	3	Zr-15Nb	.15	7.5 ^d	
M-3-b	4	Ti-6Al-4V	.5	+**	
S-3-a	5	309 SCb		7.1*	
T-3-a	6	Incoloy	.7	4.3 ^d	
A-1-g	M-1	Zr-2		2.9**	
B-1-i(I)	2	Zr-2		2.9**	
H-3-b	3	Zr-15Nb	.01	2.8 ^d	
O-3-a	4	347 SS		2.6**	
U-3-a	5	347 SS	.9	4.7 ^d	
U-3-b	6	347 SS		4.6**	

* Rates based on as-removed weights. Tee-heads cut off

** Rates based on as-removed weights. Specimens reinserted in Loading No. 3 without defilming

+ Exhibited weight increase

d Rates based on defilmed weights

(I) Impact specimens; others are tensile specimens

Materials description - refer to first letter under specimen designation

A - Core tank material

B - Allegheny-Ludlum stock

D - β quenched

Y - Allegheny-Ludlum stock, welded

E - Zr-Nb 15% Sponge, α annealed

H - Zr-Nb 15% Sponge, β quenched

U - Type 347 SS, welded

All others, with exception of Incoloy annealed

*** Flux value is reasonably representative for entire station and for holder.

Table 9. Chemical Analysis of Retained Scale and Film on Specimens from Blanket Loading No. 2

Specimen	Station and Position	Material	Surface Area (cm ²)	U (μg/cm ²)	Sample Weight (mg)	Surface Condition	Analytical Procedure	Analysis (wt. %)									
								U	Cu	Cr	Ni	Fe	Zr	Mn	Ti	SO ₄ [*]	Al
A-1-d	J-1	Zr-2	3	33	286.6	As-removed	Chemical Spectrographic	0.034 --	0.06 --	0 0.05	0.07 0.05	0.2 7.0	63.0 40.6	-- 0.05	-- 0.08	8.5 --	-- --
B-1-e	J-2	Zr-2	3	17	160.5	Defilmed	Chemical Spectrographic*	0.032 --	0.14 --	0 --	0.19 --	0.4 --	99.8 --	-- --	-- --	0 --	-- --
J-3-e	J-4	Ti-A40	3	30	89.7	Defilmed	Chemical Spectrographic	0.10 --	0 --	0 0.1	0.68 1.0	0.6 1.1	0.5 1.2	-- 0.1	-- 83	4.6 --	-- 7.6
O-3-c	J-5	347 SS	3	481	800.9	As-removed	Chemical Spectrographic*	0.18 --	0.85 --	0.04 --	7.38 --	78.1 --	1.4 --	-- --	-- --	0.2 --	-- --
M-3-a	K-4	Ti-6Al-4V	3	28	104.0	Defilmed	Chemical Spectrographic	0.082 --	0.18 --	0 0.1	0.18 1.0	0.6 1.0	4.7 2.2	-- 0.1	-- 64	0 --	-- 10.9
R-3-a	K-6	304L SS	3	40	523.9	As-removed	Chemical Spectrographic*	0.023 --	0.64 --	0.1 --	7.28 --	8.7 --	0 --	-- --	-- --	0.5 --	-- --
A-3-f	L-1	Zr-2	3	46	467.0	Defilmed	Chemical Spectrographic	0.030 --	0.03 --	0 0.08	0.22 0.02	0.3 8.8	18.7 47.6	-- 0.02	-- 0.09	0 --	-- --
B-3-d	L-2	Zr-2	3	19	301.3	As-removed	Chemical Spectrographic	0.019 --	0.05 --	0.1 0.17	0.22 0.2	0.8 7.7	94.1 39	-- 0.03	-- 0.08	0 --	-- --
B-3-d-2	L-2	Zr-2	1.2	43	427.7	As-removed	Chemical* Spectrographic*	0.012 --	0.04 --	0.1 --	-- --	0.14 --	-- --	-- --	-- --	-- --	-- --
S-3-a	L-5	309 SCh	3	266	113.9	As-removed	Chemical Spectrographic	0.07 --	1.76 --	0.9 19.3	16.7 12.6	9.3 50.5	0.9 1.9	-- 1.2	-- 0.14	0 --	-- 8.5
U-3-a	M-5	347 SS	3	194	1139.9	Defilmed	Chemical Spectrographic	0.051 --	4.54 --	7.21 13.5	7.4 9.0	3.5 55.0	0.6 0.4	-- 0.1	-- 0.04	0 --	-- --

* Sample lost before analyses could be completed.

Table 10. Chemical Analyses of Retained Scale on HRT Specimens--Blanket Loading No. 2

Specimen	Station and Position	Material	Surface Area (cm ²)	Sample Weight (mg)	Constituents of film and weights from chemical analyses of "as-removed" specimens						
					U	Cu	Cr	(μg/cm ²) Ni	Fe	Zr	SO ₄ ⁻
A-1-d	J-1	Zr-2	3	287	33	57	0	19	76	--	8120
B-3-d	L-2	Zr-2	3	301	19	50	0	171	682	--	--
B-3-d-2	L-2	Zr-2	1.2	428	43	143	0	Sample lost	71	--	Sample lost
O-3-c	J-5	347 SS	3	801	481	1949	*	*	--	3730	533
R-3-a	K-6	304 ELC	3	524	40	908	*	*	--	0	871
S-3-a	L-5	309 SCb	3	114	27	667	*	--	--	342	--

* Weight per cent reported in sample less than weight per cent in metal specimen

Table 11. Core Solution Line Specimens (No. 103)

Specimen	Material	Weight Change (mg/cm ²)	Corrosion Rate (based on 191 hr exposure) (mpy)	Average Weight of Scale (mg/cm ²)
H-87 (T-5)	Ti-75A	- 0.09	0.4 ^b	2.0 ^c
H-88 (T-6)	Ti-75A	- 0.09	0.4 ^b	2.2 ^c
H-95 (Z-5)	Zr-2	+ 0.33	+ ^a	0.8 ^d
H-96 (Z-6)	Zr-2	+ 0.42	+ ^b	0.7 ^d
H-70 (7-6)	347 SS	- 1.08	2.5 ^a	3.0 ^c
H-71 (7-7)	347 SS	- 0.66	1.5 ^b	2.5 ^c
H-77 (9-5)	309 SCb	- 2.47	5.7 ^b	2.2 ^c
H-78 (9-6)	309 SCb	- 4.71	10.8 ^a	2.0 ^c

^a Specimen defilmed twice

^b Specimen defilmed three times

^c Based on difference between as-removed and defilmed weights

^d Based on difference between initial and as-removed weights

+ Exhibited weight increase

Table 12. Core Solution Line Specimens (No. 103-A)

Specimen	Material	Weight ^a Change (mg/cm ²)	Corrosion Rate (based on 2898 hr exposure) (mpy)	Average Weight of Scale (mg/cm ²)
H-238 (Z-21)	Zr-2	+ 4.32	+	5.9
H-239 (Z-22)	Zr-2	+ 1.97	+	5.7
H-208 (9-21)	309 SCb	- 0.99	0.2	6.8
H-209 (9-22)	309 SCb	- 1.00	0.2	5.9
H-179 (T-24)	Ti-75A	+ 0.40	+	10.1
H-180 (T-25)	Ti-75A	- 0.01	<0.01	4.7
H-150 (7-26)	347 SS	- 0.81	0.1	5.9
H-151 (7-27)	347 SS	- 1.04	0.2	5.3

^a Defilmed four times

Table 13. Blanket Solution Line Specimens (No. 203)

Specimen	Material	Weight ^a Change (mg/cm ²)	Corrosion Rate (based on 2650 hr exposure) (mpy)	Average Weight of Scale (mg/cm ²)
H-85	Ti-75A	+ 0.06	+	2.6
H-86	Ti-75A	+ 0.24	+	2.8
H-93	Zr-2	+ 1.48	+	2.0
H-94	Zr-2	+ 1.86	+	2.2
H-67	347 SS	- 0.09	< 0.01	1.6
H-69	347 SS	- 0.02	< 0.01	1.5
H-75	309 SCb	- 0.02	< 0.01	3.3
H-76	309 SCb	- 0.04	< 0.01	3.6

^a Defilmed three times

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Appendix I

Polaroid photographs of specimen arrays Nos. 125 and 225 from the fuel and blanket pump purge-surge sections, of individual specimens and some components from the arrays, and visual descriptions of the specimens and of some of the components were supplied by R. E. McDonald of the Post-Irradiation Examination Group. This information was transmitted to S. E. Beall on July 25, 1960 in a letter from J. E. Baker, Examination of Corrosion Sample Arrays from Pump Purge Lines 125 and 225. Listed on the following page are the plate numbers of the photographs and the visual descriptions.

Figure	Post-Irradiation Examination Group Plate No.	Magnification	Specimen or Component	Description
<u>HRT Pump Purge Line 125</u>				
1	290P	1/8x	Surge line after cut	
2	291P	1/8x	Interior or surge line	
3	292P	1/8x	Side view of specimen array	
4	293P	1/8x	Oblique view of specimen array	
8	132-A1C	10x	Alumina specimen	Clean, white. Free of localized attack.
9	133-A1C	3.3x	Alumina specimen	Clean, free of scale. Hole edge good, area about hole result of bolting.
10	134-A1C	3.3x	Graphitar specimen	No localized attack. No scale. Edge of hole is good.
11	135-A1C	10x	Graphitar specimen (same as Fig. 10)	No localized attack. No scale. Edge of hole is good.
12	136-A1C	3.3x	Stellite #19 specimen (1 notch)	Bright, clean with no localized attack.
13	137-A1C	3.3x	Stellite #12 specimen (2 notches)	Bright, clean with no localized attack.
14	138-A1C	3.3x	Stress at weld	Clean, no evidence of attack on surface.
15	139-A1C	3.3x	Base plate and fulcrum (weld at stenciled end)	Clean, no evidence of localized attack on surface or weld.
16	140-A1C	3.3x	Base plate and fulcrum (weld at opposite end)	Clean, no evidence of localized attack on surface or weld.
17	141-A1C	3.3x	Base plate and fulcrum (opposite side from 16)	Clean, no evidence of localized attack on surface or weld.

(Cont'd.)

Figure	Post-Irradiation Examination Group Plate No.	Magnification	Specimen or Component	Description
<u>HRT Pump Purge Line 225</u>				
5	294P	1/8x	Side view of specimen array	
6	295P	1/8x	Side view of specimen array rotated 180 degrees	
7	296P	1/8x	Side view of specimen array rotated 90 degrees	
18	155-A1C	3.3x	Stellite H-114 (1 notch)	Mostly covered with light brown film, scattered rust like particles. Shows metallic gray underlay. Machine marks in evidence. Opposite side: Less brown film and rust particles.
19	156-A1C	3.3x	Stellite H-117 (2 notches)	Mostly covered with brown film. Small amount of rust like particles. Shows deep metallic gray underlay. Faint machine marks in evidence. Opposite side: No rust particles. Gray to brown film.
20	157-A1C	3.3x	Graphitar H-119 (2 notches)	Light tan to brown mottled brown. Roughened area about notches. Opposite side: Clean and free of discoloration and roughened areas.

References

1. J. E. Baker, G. H. Jenks, and A. R. Olsen, Thermal Neutron Fluxes in HRE-2 Determined from Zircaloy-2 Induced Activity Measurements, Runs 16 and 17, December 18, 1959, ORNL CF 59-12-54.
2. G. H. Jenks, A Model for the Effects of Irradiation on Zircaloy-2 Corrosion and a Review and Correlation of In-Pile Zircaloy-2 Corrosion Data, ORNL-3039 (in press).
3. G. M. Adamson et al., HRP Quar. Prog. Rep. for Period Ending Jan. 31, 1959, ORNL-2696, p 155.
4. M. L. Picklesimer, Oral presentation at Materials Section Meeting.
5. J. C. Griess, Personal communication to G. H. Jenks.
6. G. H. Jenks and J. E. Baker, HRP Radiation Corrosion Studies: Summary Report of 250°C HRP In-Pile Loop Experiments DD, FF, GG, EE, L-4-12, L-4-13, and 235°C Experiment L-4-18. (In preparation).
7. G. H. Jenks and J. E. Baker, HRP Radiation Corrosion Studies: In-Pile Loop Experiment L-2-22. (In preparation).
8. G. H. Jenks et al, HRP Quar. Prog. Rep. for Period Ending July 31, 1957, ORNL-2379, p 113.
9. D. T. Jones and T. H. Mauney, HRT Corrosion Specimens and Holder - Blanket Region of Pressure Vessel (Loading No. 3), May 12, 1959, ORNL CF 59-5-58.
10. G. H. Jenks and J. E. Baker, HRP Radiation Corrosion Studies: In-Pile Loop L-2-10, ORNL-2962 (in press).
11. G. H. Jenks et al, HRP Quar. Prog. Rep. for Period Ending Oct. 31, 1960, ORNL-2920, p 78.

12. G. H. Jenks and J. E. Baker, HRP Radiation Corrosion Studies: In-Pile Loops L-2-15 and L-4-16, ORNL-3099 (in preparation).
13. G. H. Jenks and J. E. Baker, HRP Radiation Corrosion Studies: In-Pile Loop L-2-19, ORNL-2953, (in preparation).
14. G. H. Jenks et al, HRP Quar. Prog. Rep. for Period Ending Jan. 31, 1960, ORNL-2920, p 78.
15. R. M. Warner, HRT Corrosion Sample Data and Fabrication - Circulating Lines - Addendum No. 1, ORNL CF 56-6-62.
16. G. H. Jenks, A. R. Olsen and W. C. Yee, Examinations of Specimens and Scales Taken from the HRT Following Runs 13 and 14, ORNL CF 58-9-37.
17. J. R. Engel et al, Summary of HRE-2 Run No. 13, ORNL CF 58-10-115.

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