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Operation of In-Pile Loop L-2-10.

TO: Distribution

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REFERENCES

HRP In-Pile Solution CorrosionLoop L-2-10 Operation

INTRODUCTION

Loop L-2-10 was the eighth completed in-pile loop experiment and the first in the HB-2 beam hole at the LITR. The loop was inserted on July 2, 1956 and removed on September 3, 1956.

Total circulation time with enriched fuel	1672 hr
Total accumulated LITR energy	.3765 Mwhr
Oxygen pressure in pressurizer	230 to 60 psi
Main stream temperature	280°C
Pressurizer temperature	305°C
Approximate concentration of original fuel solution:	

UO ₂ SO ₄ (enriched)	0.04 <u>m</u>
CuSO ₄	0.0075 <u>m</u>
H ₂ SO ₄ (excess acid)	0.02 <u>m</u>

1. Radiation Effects

1.1 Fission and Gamma Heat. The average total fission and gamma heat at 3 Mw reactor power as determined by electrical power differences was 1256 ± 18 watts¹ throughout the run. There was no significant drift or shift of the fission and gamma heat during the run. The loop core was made of type 347 stainless steel and contained a calculated fuel solution volume of 298 cc at room temperature.

1.2 Radiolytic Gas. The average radiolytic gas pressure in the pressurizer at 3 Mw reactor operation was 6.1 ± 0.5 psi as determined by special pressure-temperature measurements before and after reactor shutdowns,

and 6.8 ± 0.4 as determined from the partial pressure plot. There was no statistically significant drift or change in radiolytic gas pressure during the run.

1.3 Radiation Intensities. Since the average power density in this loop was approximately the same as the power density in HB-4 loops, the radiation intensities encountered during sampling were essentially the same as those previously encountered in sampling at the HB-4 facility². A summary of radiation measurements is presented in Table I.

During the drain procedure, the concentration of radioactive gas in the East Experimental Room reached sufficient concentration to necessitate evacuation of the room. It was determined, by use of a specially equipped constant air monitor, that the active gas was coming from an open process drain. The additional fact that the high gas activity was coincident with use of the water aspirator (used for evacuating loop between rinses) leads to the conclusion that the gas separator on the aspirator discharge was not performing properly.

2. Mechanical and Instrument Performance

2.1 Pump Performance. Operation of loop L-2-10 was terminated by the failure of the 5-gpm circulating pump. Prior to the pump failure there was no indication, such as consistently erratic pump power or abnormal pump temperature, of impending failure.

After the active fuel solution was drained from the loop, an electrical check of the pump windings showed normal phase to phase resistance and normal resistance to ground within the accuracy of the measurements. Subsequent checks of the electrical components on the panel board showed that the pump failure was not caused by the electrical supply part of the system.

2.2 Response of Safety Interlock System and Sequence of Events During Pump Failure.

A) Pump Power: At the time of pump failure, the pump power

suddenly increased from a normal of 1060 watts to 1580 watts, causing a reactor scram. The pump continued to run, but the circulation rate was inadequate for maintaining proper temperature distribution in the loop. Within approximately five minutes, the temperature distribution in the loop was so far from normal that the pump and heaters were shut off manually. Subsequent attempts to restore adequate circulation were unsuccessful.

B) Loop Temperature Recorder: Immediately after the reactor was shut down by high pump power, the loop temperature, as indicated by the loop temperature recorder, dropped from 278°C to 274°C due to the sudden loss of fission and gamma heat in the core. After approximately 3 minutes, the temperature began to increase rapidly to a maximum of 284°C at which time the pump and heaters were shut off manually. This large increase in temperature was due to the proximity of the thermocouple to the loop heater which was operating at full power in response to the loop temperature controller (see D).

C) Pressurizer Heater: After the reactor was scrammed by high pump power, the pressurizer heater temperature increased from 301°C to 306.5°C at which time the pump and heaters were shut off manually. This increase in temperature was due to the proximity of the thermocouple to the pressurizer heater.

D) Loop Temperature Controller: The loop temperature, as indicated by the loop temperature controller decreased steadily from the moment of pump failure on. By the time the pump and heaters were shut off manually, the temperature had dropped from 277°C to 252°C .

E) Core Temperature: Within 7 minutes after the reactor was scrammed, the core temperature had dropped from 277°C to less than 230°C .

F) Pressurizer Pressure: After circulation failed, the total pressure in the pressurizer dropped from 1400 psia to 1390 psia and then increased to a maximum of 1442 psia from which point it decreased rapidly until the loop was drained. The pressure increase was probably due to boiling in the pressurizer heater.

G) Pressurizer Temperature: After circulation failed, the temperature in the pressurizer dropped from 307.5°C to 283°C within approximately 3 minutes.

2.3 Circulation Rates. The circulation rate in the main stream was 5 gpm as determined by room temperature pressure drop measurements at Y-12.

The pressurizer flow rate, as measured by electrical power differences, was 9 cc (293°C)/sec at the beginning of the run and dropped steadily to 8 cc (293°C)/sec at the end of the run (See Fig. 1). Another indication of decreased flow through the pressurizer was an increase in the temperature drop across the pressurizer.

2.4 Thermocouple Performance. During the original steam calibration, temperature as measured by the C.A. and I.C. thermocouples in the pressurizer agreed with the actual temperature (as determined by steam pressure) within 0.5°C and 2.9°C, respectively. With the exception of a short period early in the run when instrument trouble was encountered, the bias (based on 8 hr averages) between these two thermocouples was never more or less than $1.25 \pm 0.25^\circ\text{C}$.

During the course of the run the pressurizer inlet and pressurizer outlet thermocouple readings decreased approximately 6°C and 8°C, respectively. This decrease may have been caused by deterioration of the thermal insulation around the thermocouples.

2.5 Pressure Cell. A Baldwin pressure transducer made of 410 stainless steel was used to measure the pressure in the pressurizer. The pressure cell was calibrated with a dead weight tester from atmospheric pressure to 2000 psig within ± 2 psi. A comparison was made with pressure cell number five during each fuel expansion. These checks demonstrated that there was no large change or drift in the calibration of the pressurizer pressure cell. However, the zero on pressure cell number five drifted badly.

2.6 Pressurizer Jacket-Temperature Controller. The miniature automatic temperature control system installed at HB-2 to control the pressurizer jacket temperature performed so poorly that manual control was used during a large portion of the run.

2.7 Radiation Instruments. During run L-2-10, a large number of unscheduled reactor shutdowns were caused by spurious false signals from various radiation instruments in the loop leak detection system. Similar erratic radiation instrument behavior has been observed previously at the HB-4 loop installation.

3. Oxygen and Solution Balances

3.1 Loop Volume. The loop volume (at room temperature) as measured at HB-2 by oxygen additions was 1526 cc including pressure lines and the pressure cell.

3.2 Fuel Loading. The loop was originally filled with 1041.3 g of enriched fuel solution and 5.5 ml of water in lines 1, 4, and 5. A summary of volumes of the system is given in Table II.

3.3 Oxygen Pressure Factor. Only one oxygen addition (the original fill) was made during run L-2-10. The quantity of oxygen in the loop, at a

given oxygen partial pressure, was 12.8 cc(STP)/psi.

4. Auxiliary Components

The solution samples obtained during run L-2-10 were smaller in volume than those obtained when sampling HB-4 loops. The reason for these small samples was traced to excessive volume in the line between valve 20 and the sample tank connection tube. This situation has been corrected by moving valve 20 closer to the sample tank connection tube.

5. Procedure Changes.

5.1 Fuel Expansion Procedure. During the first few fuel expansions to loop L-2-10, difficulty was experienced with accumulation of gas bubbles in the fuel expansion tank. This situation was corrected by altering the procedure slightly to omit a step where valve 16 was opened during the preliminary portion of the procedure.

6. Preparation, Installation, and Removal from HB-2

6.1 Preparation. Preparation of the loop consisted of the following steps:

- a. Measuring the volumes of the capillary lines.
- b. Measuring the loop and oxygen metering tank volumes by oxygen additions.
- c. Steam calibration of the pressurizer thermocouples against the pressurizer pressure cell.
- d. Filling the loop with fuel solution and filling the pressure cell and line #4 with water.
- e. Adding oxygen to the pressurizer.
- f. Operating the loop out-of-pile for 204 hours.
- g. Pressurizer jacket heater test.
- h. Pressurizer flow check.
- i. Operation for a short time on the emergency power supply.

6.2 Installation. Insertion of the loop package into HB-2 beam hole was

accomplished without difficulty.

6.3 Removal from HB-2. No significant difficulties were encountered in removing the loop package from HB-2 beam hole. Approximately 30 hours were required for draining and rinsing the system, disconnection in the small equipment chamber, removal of the loop package, separation of the loop and shielding plug, and insertion of shielding plugs into HB-2. The inner shielding plug would not fit into the beam hole and it was necessary to leave it out until a new plug could be constructed.

As with HB-4 loops, the maximum radiation dosage received by the operators was less than laboratory tolerance (60 mr/day).

Table IRadiation Intensities

RD-5 (Discriminator 15, gain 7)

Reactor at zero power

 1.0×10^4 cpm

Reactor at 3 Mw

 4.4×10^4 cpm

24 hours after sample

RD-1 98 mr/hr

RD-2 163 mr/hr

RD-3 181 mr/hr

RD-4 172 mr/hr

RD-6 $20 N_t/cm^2/sec$ Radiation through front of small Equipment Chamber During
Sample Purges

Fast Neutrons

75 mrep per hr maximum

Thermal Neutrons

1800 neutrons per square cm per
secondRadiation Intensity in Small Equipment Chamber During
Loop Removal

At front of chamber with cover plates removed:

375 mr/hr

Inside Chamber:

1.5 R/hr

Table IISummary of Loop Volumes

	Volume at 25°C,	Operating Conditions,		
	cc	cc		
Line No. 1	0.9	25°C	0.9	H ₂ O
Line No. 2	4.4	"	4.4	Fuel
Line No. 3	5.9	"	5.9	Fuel
Line No. 4	4.1	"	4.1	H ₂ O
Line No. 5	0.5	"	0.5	H ₂ O
Pressure Cell P-1	7.5	"	7.5	H ₂ O
Pump	160	90°C	160.8	Fuel
Main Stream	809.1	280°C	819.9	Fuel
Pressurizer				
Inlet line (66")	19.6	293°C	19.8	Fuel
Outlet line (7")	2.1	305°C	2.1	Fuel
Liquid phase		305°C	318.9	Fuel
(Vapor)		305°C	201.0	Vapor
(Total)	<u>534.0</u>	305°C	<u>541.8</u>	
TOTAL	1526.4		1545.8	

Table III

Typical Operating Data

Hours Circulation on Enriched Fuel	°C Average with Reactor at Zero Power			°C Average with Reactor at 3.0 Mw	
	40-80 [†]	376-384	1552-1560	392-400	1568-1576
Pressurizer Temp. (CA)	304.5	305.5	305.1	305.7	305.5
Pressurizer Temp. (IC)	309.1*	306.8	306.6	307.0	306.9
Pressurizer Htr. Temp. (7)					
Pressurizer Htr. Temp. Controller	305.2	303.7	300.2	303.6	300.1
Pressurizer Outlet Temp. (4)	297.8	294.4	292.2	294.7	292.5
Pressurizer Jacket Temp. (6)	301.0	304.8	303.4	303.4	303.9
Loop Temperature Controller	277.8	277.6	277.0	276.0	276.0
Loop " Recorder	281.3	281.8	281.0	279.0	278.9
Loop " before loop cooler (2)	279.9	280.3	280.0	280.2	280.0
Core Temperature Recorder	267.2	265.4	264.9	280.0	278.0
Core Temperature (1)	277.7	278.5		286.8	286.3
Graphite Temperature (5)	120	124.5		199.5	200
Pump Temperature	52	52		50	51

Pump Power (from 240 to 880 hr circulation) = 1045 watts at 105 volts, amps = 15.3
 (from 960 to 1600 hr ") = 1063 watts at 106 volts, amps = 15.4

Pump and liner coolant flow = 2.2 gpm demineralized water
 Plug coolant flow = 1.6 gpm process water
 Loop " " = 1.4 gpm demineralized water
 Equipment Chamber flow = 0.5 scfm
 Equipment " vacuum = 2.5 inches of H₂
 Loop container flow = 0.87 scfm
 Loop " pressure = 50 psig

[†] Out-of-pile operator

* Instrument not operating properly

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