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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
HOT SODIUM CIRCULATION TEST

AI-P-1167

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
HOT SODIUM CIRCULATION TEST

AI-P-1167

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SUMMARY

The purpose of this test was to verify the adequacy of the design, construction, and components of the main heat transfer system of the Hallam Nuclear Power Facility (HNPF) for elevated temperature and low power operation. To this end, certain tests were performed to:

- 1) Chart pipe displacements.
- 2) Determine system hydraulics.
- 3) Obtain an interrelationship between the main heat transfer system and plant control system.
- 4) Verify core alignment at elevated temperatures.
- 5) Determine the effect, if any, of elevated temperature on control rod operation.
- 6) Determine, by careful observation and inspection, that no adverse conditions of interference, motion, binding, or stress of system components occurred or could be expected to occur during power operation.

Item 1) was performed between 340 F and 540 F. Items 2), 3), and 6), above, were carefully investigated at system temperatures of 340 F, 440 F and 540 F. Items 4) and 5), above, were investigated only at 540 F, that being the highest temperature reached in the overall test.

Certain piping interferences existed, some hangers were found inoperable, some valve difficulties developed, and some of the recorded piping displacement measurements deviated from the predicted displacements. The interferences were cleared and the hangers were repaired. Valve difficulties were resolved as necessary to complete this test. Testing was extended to accomplish the following:

- 1) Investigation of the displacement discrepancies and recheck of data during cooling from 540 F to 350 F.
- 2) Re-determination and extension of system hydraulic characteristics.
- 3) Verification that corrective actions taken had indeed corrected the items listed and had not created any undesirable characteristics.

Testing results are exhaustively presented in an objective manner in Section III of this report.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
HOT SODIUM CIRCULATION TEST, AI-P-1167

I. TEST PURPOSE

The purpose of Hot Sodium Circulation Test, AI-P-1167, was to achieve the following:

- a) Verify that the piping displacements in the sodium heat transfer system, under simulated operating conditions and with circulating sodium at an elevated temperature, would not impair the integrity of the system. Verification of the integrity of the system at test conditions, and of the performance to be expected with power generation under actual operating conditions.
- b) Mechanically operate the main sodium pumps, flow control valves, and blocking valves in the sodium heat transfer system, and demonstrate their operability under the conditions of the test, which will simulate the plant operating conditions of an elevated temperature and a sodium environment.
- c) Operate control and safety rod drive mechanisms, in the reactor structure, with sodium at an elevated temperature flowing through the core. Simulate scram conditions to verify satisfactory operability of the control and safety rods under the conditions of the test.
- d) Verify core - loading face alignment at an elevated temperature, by demonstrating the capability of changing fuel with 540 F isothermal sodium in the reactor, through the removal and insertion of a dummy element and an actual fuel element assembly (without fuel cluster) in three peripheral core positions.

II. DISCUSSION OF TEST PERFORMANCE

A. PIPING DISPLACEMENT MEASUREMENTS

Sodium heat transfer system piping movement was monitored at 57 strategic points during the performance of AI-P-1167, "Hot Sodium Circulation Test". Measurement points No. 1 to 15 inclusive are in the vicinity of the reactor cavity diaphragm seal and are expected to give information on the movement of the primary pump suction lines inside the reactor cavity. Measurement points No. 24, 25, 26, 30, 31, 32, 36, 37, 38, and 54 are located near the sodium pumps and their displacements would be indicative of any deformation of the pump cases. The balance of the points were selected to provide indication of any obstructions at intermediate points which could prevent the free movement of the systems. Measurements cover all three primary loops and one of the three identical secondary loops.

The pipe movements at the selected strategic points are transmitted to plumb bobs or other pointers by means of pipe attachments and piano wire. The pointers are conveniently located for measuring the amount of movement with respect to a reference plate secured to the floor or other structure.

Piping displacement measurements were made with each of the following conditions existing:

- 1) Piping at ambient temperature and empty of sodium.
- 2) Piping at approximately 340 F and empty of sodium.

- 3) Piping at approximately 340 F and filled with sodium.
- 4) Piping at approximately 440 F and filled with sodium.
- 5) Piping at approximately 540 F and filled with sodium.

Additional measurements were taken at 440 F and 350 F (during and after the cooldown) in order to recheck and correct readings, and to demonstrate proper piping movement during cooldown.

B. PIPING INSPECTION

Concurrent with making piping displacement measurements at each of the conditions described above, a general inspection of system piping was performed. The inspection included investigation of the following items:

- 1) Adjustment of pipe hangers. All variable load spring hangers were checked and adjusted to assure that hanger loads at operating temperature will agree with the design loads.
- 2) Observation of movement of the constant load hanger supports.
- 3) Piping vibration with sodium flowing in the system (visual examination only). This investigation was performed by competent piping engineers.
- 4) Potential interference at operating temperatures between piping and adjacent structures or equipment. This investigation includes all material applied or attached to the piping, such as insulation, lagging, measuring devices, heaters and accessories.
- 5) Leakage of sodium at valve stems, freeze traps, or any other point.

C. RAISING SODIUM TEMPERATURE TO 440 F

Filling of the steam generators with water, blow-down and sampling activities, and the maintaining of evaporator level, were performed according to Standard Operating Procedures.

The electrical preheat system and the six main sodium pumps were utilized to increase sodium temperature. Temperatures were determined from the plant control system temperature recorder controllers and checked by obtaining superheater pressures and referring to a table of saturated steam properties for the corresponding temperatures.

Those items of equipment and piping that will be subjected to elevated temperatures during power operation were raised in temperature with the main heat transfer system. The equipment maintained at 350 F during this test is listed in Appendix A.

The test temperature of the system was maintained by controlling pump speed, thereby controlling the heat input capacity of the six main pumps.

A slight decreasing temperature trend occurred when the primary pump speeds were reduced below 20% for system testing. Testing was interrupted as necessary to maintain system temperatures within approximately 5 F of the desired test temperature.

D. TRANSFER OF LOOP HAND CONTROL STATIONS AT 440 F

Pump speeds were decreased from power input speeds to 20% when 440 F was reached.

Division of Load Computer hand control stations (steam demand) HCS-501, -502, and -503 were manually set at 20% steam (demand). Pump speed controllers

HCS-102, -202, -302, -104, -204, and -304 were then switched to automatic control to determine smoothness of transfer from manual control to automatic. A significant step change would result in an undesirable thermal transient at operating temperature conditions.

Loop flow (millivolt signal), pump speed, and pump differential pressure data were recorded for all six pumps at 20% speed in manual control and immediately after transferring to automatic control.

E. ESTABLISHING PRESSURE DROP

Primary throttle valves were positioned to simulate the calculated reactor pressure drop of 38.4 psi at rated flow.

F. PUMP SPEED INCREASES

The speed of circuit No. 1 pumps was increased to 30% steam demand by hand control station HCS-501. Both the primary and secondary pumps were observed to come up to 30% steam demand speed. Circuit No. 2, and then circuit No. 3, pumps were increased to 30% steam demand, employing HCS-502 and -503, respectively.

Circuit No. 3, pumps were increased to 50% steam demand speed. Flow in the remaining two circuits was similarly increased.

All pump speeds were then increased to 100% steam demand; circuit No. 1 first, followed by No. 2 and then No. 3.

Flow, speed, pressure in, pressure out, and pressure rise data were recorded for each of the six main sodium pumps with pump speed at 100% steam demand.

G. FLOW TRIMMING

With 60% scale settings on HCS-501, HCS-502, and HCS-503, load computer signals FCCp-501, -502, -503, -504, -505, and -506 were trimmed to equalize flows in all loops. Pump control was then transferred to HCS-504, total steam demand hand control station, by transferring HCS-501, -502, and -503 to automatic control. Flow control was thus established by the plant base load hand control station, HCS-504. The division of load computer ratio relays were adjusted as required to trim all flows to 60%.

H. DETERMINATION OF SYSTEM HYDRAULIC CHARACTERISTICS

The sodium heat transfer system was subjected to the following hydraulic manipulations to obtain data with which to appropriately evaluate system performance:

- 1) All three circuits set at approximately 600 rpm pump speed from HCS-504.
- 2) All three circuits set at approximately 550 rpm pump speed from HCS-504.
- 3) All three circuits set at approximately 440 rpm pump speed from HCS-504.
- 4) All three circuits set at approximately 330 rpm pump speed from HCS-504.
- 5) All three circuits set at approximately 220 rpm pump speed from HCS-504.
- 6) All three circuits set at approximately 110 rpm pump speed from HCS-504.
- 7) All three circuits set at 50% from HCS-504.
- 8) All three circuits set at 70% from HCS-504.
- 9) HCS-501 transferred to "Manual" and Circuit No. 1 adjusted to 70% flow.

- 10) Circuit 1 reduced to 60% flow from HCS-501; 2 and 3 compensating.
- 11) Circuit 1 increased to 75% flow from HCS-501; 2 and 3 compensating.
- 12) Control of Circuit No. 1 transferred to HCS-504 at 70% flow.
- 13) Items 9, 10, 11, and 12 repeated for Circuit No. 2; 1 and 3 compensating.
- 14) Items 9, 10, 11, and 12 repeated for Circuit No. 3; 1 and 2 compensating.
- 15) All three circuits at 50% flow, controlled from HCS-504.

Periodic inspections of the areas were conducted for possible noises, pipe motion, interferences or potential interferences, and any other indication of unsatisfactory performance.

I. RAISING SODIUM TEMPERATURE TO 540 F

Sodium heat transfer system temperature was increased to 540 F in the manner described in Section II. C of this report. Warm-up to 540 F was accomplished at a rate of 1.5 to 2.0 F per hour. Temperature was controlled by pump speed after 540 F had been attained.

J. TESTING AT MAXIMUM SODIUM TEMPERATURE

1. Sodium Pumps

The six main sodium pumps were operated at 20%, 50%, and 100% of design speed, at 540 F system temperature, to determine that proper operating characteristics exist at elevated temperatures. All pump instrumentation was observed closely during each of the three runs. The performance test was sufficiently long to allow stable temperature and flow conditions to be verified.

Each pump was stopped and started three times at 540 F. Each time a pump was stopped, it was shut down for 20 to 30 min. While the pump was in the shut-down condition, other 540 F testing was accomplished, such as main loops blocking valve manipulation and core alignment tests.

In addition to recording pump information as displayed by pump instrumentation for each of the six pumps, the following items were investigated:

- a) Internal noise or rumble.
- b) Vibration of pump assembly.
- c) Unstable speed or pulsation.
- d) Seal oil system operation.

2. Throttle and Block Valves

The primary throttle valves were operated to full open, to full closed (98%), and back to the simulated core pressure-drop position, with a system temperature of 540 F. Pump speeds were then increased to 100% and proper valve operation tested by simultaneously driving the throttle valves to full closed and de-energizing the pump coupling. During testing, the valves and adjacent piping were observed for stem leakage and movement, respectively. Other items investigated regarding valve operation:

- a) Operation of air motors.
- b) Operation of line shafts.
- c) Rigidity of bearing supports.

- d) Vibration.
- e) Adequate lubrication of components.
- f) Leaks on stem seals.
- g) Piping movement during quick-closure.
- h) Clearance of mechanisms.

During one of the three pump shutdowns, as discussed previously, the primary blocking valves were operated from the full open position to full closed (blocking) position and back to full open. The secondary throttling valves were subjected to the same quick-closure test described for the primary throttling valves. The valves were observed for the same eight items listed above for the primary throttling valves.

K. CONTROL ROD DRIVE TESTING

Control rods were operated at a system temperature of 540 F to verify proper operation at elevated temperatures. Each rod was individually withdrawn and then scrambled. Withdrawal time and drop time were measured and recorded. The control rod test cart was used to manipulate the rods.

Each control rod was operated as necessary to verify proper operation of the indicating lights and snubbers. The drive was then operated up and down sufficiently to obtain voltage and current measurements for each phase in each direction. Each rod was withdrawn until the drive-up limit switch stopped the drive. Proper position was verified and withdrawal time recorded. The rod was then scrambled and latch release time, drop time to the four ft. position (70% insertion), and time to the full insertion position were determined by the use of a Sanborn recording oscillograph.

L. TESTING CORE ALIGNMENT

Three dummy elements and one mock fuel element (a fuel element with the fuel cluster removed) were utilized to demonstrate proper core alignment at 540 F. The fuel handling machine was employed to accomplish the operation in order to maintain the helium atmosphere over the sodium pool in the reactor. The fuel handling machine was initially loaded with the mock fuel element. This element was then exchanged for each of the three dummy elements in the reactor; reinsertion of each dummy completed the testing. System primary pump speeds were at 20% during the operations.

The core positions utilized for this portion of the test are in the outer periphery of the core at approximately 120 degree intervals; specifically, core positions C-185, C-209, and C-233.

Fuel handling machine grapple load cells were used to determine if any misalignment of the elements was occurring during element moving operations. Load cell readings were observed and recorded at the following four points for both the dummy elements and the actual element at the three core locations:

- 1) First six inches of upward travel (breakaway).
- 2) Remainder of upward travel.
- 3) During downward travel.
- 4) During last six inches of downward travel (re-seating).

M. SYSTEM TESTING AT 540 F

All portions of main heat transfer system hydraulic and control testing performed at 440 F were repeated at 540 F, to verify proper operation at that temperature and

to detect any changes created by the 100 F rise. The portions of the test repeated at 540 F are listed below, with references to portions of this report which have already described the mode of test performance.

- 1) Transfer of Loop Hand Control Station at 540 F - Reference II. D.
- 2) Establishing Pressure Drop - Reference II. E.
- 3) Pump Speed Increases - Reference II. F.
- 4) Flow Trimming - Reference II. G.
- 5) Determination of System Hydraulic Characteristics - Reference II. H.

N. ADDITIONAL TESTING

Analysis and review of the overall test led to the addition of the following sections to the test:

- 1) Piping displacements measurements at 440 F, and 350 F (during cooldown).
- 2) Correcting assumptions made in originally establishing the primary pump 100% speeds and re-running the hydraulic tests on each of the six loops at each temperature during cooldown.

The first addition was for the purpose of determining the effect of repairing the reactor cavity pipe hangers, and to recheck readings where measured pipe displacement did not agree with predicted displacements.

The second addition was made to recheck and extend loop hydraulic characteristics.

O. COOLDOWN TO PREHEAT TEMPERATURE

Sodium system cooldown from 540 F to 350 F was accomplished at a rate of less than 50 F per hour.

Pump speeds on all six pumps were reduced to 20% speed and all preheat controller setpoints were estab-

lished at 350 F to initiate the cooldown. The equipment being maintained manually at 350 F was put on automatic control after the reduction of preheat controller setpoints to 350 F.

The cooldown rate was controlled by bleeding steam through the superheater stop check valve drain valves, the superheater vent valves, and the eliminator vent valves. The second drain valve on each of these blow-down lines was employed as a throttle valve.

III. ANALYSIS AND PRESENTATION OF RESULTS

A. PIPING DISPLACEMENT MEASUREMENTS

Piping displacement measurements were made at the 57 locations in the sodium heat transfer system indicated in Figures 1167-1 through 1167-8.

The agreements between the calculated and measured displacements indicates the validity of the stress analysis performed in connection with the system design. This stress analysis was performed according to the following procedures and design objectives:

- a) Forces and movements due to the thermal expansion of each line were obtained by using the Kellogg General Analytical Method as programmed for the IBM 709. (Design of Piping Systems - The M. W. Kellogg Co. publication)
- b) Maximum stresses were computed from the movement and force data calculated by the IBM 709.
- c) According to the design objectives, the calculated pipe stresses in the sodium heat transfer system do not exceed 75% of the allowable values which are stipulated in the American Standard Code for Pressure Piping ASA B31.1 - 1955, except for secondary lines No. 264, 265, and 266 between the gas seal and the intermediate heat exchangers where the analysis showed a maximum stress of 100% of the Code allowable range.
- d) Forces and movements transmitted to equipment did not exceed the maximum values allowed by the equipment manufacturer.

Expected pipe movements were calculated prior to the performance of the test. These calculations were reviewed during the test performance and were modified according to more accurate computations required in the evaluation process.

Figure 1167-1 Plumb Bob Locations For Pipe Movement Test

Figure 1167-2 Plumb Bob Locations For Pipe Movement Test

Figure 1167-3 Plumb Bob Locations For Pipe Movement Test

Figure 1167-4 Plumb Bob Locations For Pipe Movement Test

Figure 1167-6 Plumb Bob Locations For Pipe Movement Test

INDICATOR ARM
PRIMARY SODIUM PUMPS

(3 REQ,D)

SEC SODIUM PUMP NO. 2

(1 REQ,D)

Figure 1167-7 Plumb Bob Locations For Pipe Movement Test

- 6) Line No. 271 (Figure 1167-6)
Horizontal movements are calculated by the same procedures as used for lines No. 231, 232, and 233. Vertical movements are based on the downward displacement of the secondary pump discharge and the rise of the superheater inlet nozzle and adjacent radial pipe suction, assuming uniform slope between these points and point No. 56 (rigid hanger).
- 7) Line No. 274 (Figure 1167-5)
Measurement points No. 48 and 49 are between the evaporator outlet and seal plate. Horizontal movements are based on the free expansion of the straight pipe runs. Uniform slope and vertical movement, as caused by the expansion of the run adjacent to the evaporator, are assumed between this leg and the anchor seal. Measurement points No. 46 and 47 are in the IHX cell between the anchor seal and IHX inlet. Configuration and calculation method is similar to line No. 265 but without a vertical leg, and consequently no movement in that direction.

The results of the displacement measurements performed preceding and during the temperature rise are incorporated in Table I. This table includes the identification of all measurement points, the calculated movements at 350 F and 540 F and the actually measured displacements at or in the vicinity of 340, 440 and 540 F temperatures. The measurements were taken with the utmost care, but certain readings proved to be inconsistent with adjacent readings and not reliable for analysis purposes. These discrepancies are mainly due to the fact that a long time period elapsed between two readings at the same point and the measurement equipment had been disturbed by operations and maintenance activities. The behavior of the piping at these points was rechecked during the cooldown of the system; the resulting data are presented in the course of the analysis. However, some other inconsistent measurements which had negligible significance in this analysis have

LEGEND: X + South, - North; Z + West, - East;
Y + Up, - Down
O No movement or less than 1/8" observed or theoretically expected
X Reading is not valid and useless for analysis
— Measurement is not practical or does not represent pipe movement
NOTE: Movement is from ambient to temperature shown, except as noted.

TABLE I
PIPING DISPLACEMENT MEASUREMENTS

Measure- ment Point No.	Pipe Line No.	Area	Identi- fication or Hanger No.	Ambient				310°				Expected @ 350°				440°				Max°				Expected @ 540°				Movement 540° - 350° (Cool Down)								
				Pipe Temp (F)	Base Reading (inches)			Pipe Temp (F)	Movement				Pipe Temp (F)	Movement (inches)				Pipe Temp (F)	Movement (inches)				Pipe Temp (F)	Movement (inches)				Actual Expected								
					X	Z	Y		W/O	With	W/O	With		W/O	With	W/O	With		W/O	With	W/O	With		W/O	With	W/O	With	W/O	With	X	Z	Y	X	Z	Y	X
1			Bellows Assy.	78°	0	-1/8		330°	342°			-1/2	-5/8		350°	-	-3/4	-	433°		-3/4		530°		-1/4		540°	-	-13/8	-		+3/8		-	+5/8	-
2		Primary	504				64 7/8							+3/8	+3/8			+1/4				+3/8				+3/8		-	-	+1/2			-5/16	-	-	-1/4
3	231	Pipe	Leak Det. BD-104		0	0						-1/2	-7/8			-	-7/8	-			x			x			-	-15/8	-		+3/8	-	-	+3/4	-	
4		Tunnel	505				98 1/8							+1/4	+3/8			+1/8				+3/8			+3/8			-	-	+1/4		+5/16	-	-	+1/8	
5		East	907	78°	-1/8	0		330°	342°			-1	-1		350°	-	-1/8	0	433°		-13/4		530°		-2 1/4		540°	-	-2 1/8	0		+5/8	-	-	+1	-
6			Bellows Assy.	78°	0	+1/8		345°	338°			+5/8	+5/8		350°	-	+3/4	-	433°		+1		530°		+13/8		540°	-	+13/8	-		-1/2	-	-5/8	-	
7			648				64 1/4							+1/8	+1/8			+1/4				+3/8			+3/8			-	-	+1/2		0	-	-	-1/4	
8	232		Leak Det. BD-105		-1/4	0						+3/4	+3/4			-	+7/8	-			x			x			-	+15/8	-		-1/16	-	-	-3/4	-	
9		Primary	649				105 5/8							0	0		-	-	+1/8				+1/8		0		-	-	+1/4			-1/16	-	-	-1/8	
10		Pipe	673		0	0		345°	338°			+1	+1/8			-	+1	0			+1 1/2			+2 1/8			-	+2	0		-13/16	-	-	-1	-	
11		Tunnel	Bellows Assy.		0	0		330°	340°			+1/2	+3/4			-	+3/4	-			+7/8			+13/8			-	+13/8	-		-5/8	-	-	-5/8	-	
12		West	654				62 5/8							0	-1/4		-	-	+1/4				-3/8		-3/8		-	-	+1/2			-1/8	-	-	-1/4	
13	233		Leak Det. BD-106		0	0						+13/8	+1/4			-	+7/8	-			x			x		-	+15/8	-		-1/2	-	-	-3/4	-		
14			655				100							0	0		-	-	+1/8				-3/8		-1/4			-	-	+1/4		0	-	-	-1/8	
15			679	78°	0	0		330°	340°			+7/8	+1/8		350°	-	+1/8	-	433°		+1 1/2		530°		+2 1/8		540°	-	+2 1/8	-		-13/16	-	-	-1	-
16	231		910	78°	0	0		330°	342°	-1/4	-1/8			0	0	350°	-1/4	-	0	433°	-1/4		0	530°	-1/4		0	540°	-1/2	-	0	+1/8		+1/4	-	-
17		Primary	911		-3 1/8	-2 1/8		330°	342°			+1/2	+3/8		0	0		+3/8	0			+1/2	0		+5/8	0		-	+5/8	0		-1/4	-	-	-1/4	-
18	232	Pipe	401														-3/8	0									-	-5/8	0		+3/8	-	-	+1/4	-	
19		Tunnel	911A		+1/8	0		345°	338°	0	+1/4			0	0		+3/8	-	0		+1/2		0		+5/8		0	+5/8	-	0	-1/8		-1/4	-	-	
20	233	North	683	78°	-4 1/4	+2 7/8		330°	340°			-1/2	-3/8		0	0		-3/8	0			-3/8	0		-5/8	0		-	-5/8	0		+1/4	-	-	+1/4	-
21			682	76°	0	+1/8		330°	340°	-1/4	-1/8			0	0	350°	-1/4	-	0	433°	-1/8		0	530°	-1/4		0	540°	-1/2	-	0	+1/8		+1/4	-	-
22			864A	74°	-1/8	+1/4		330°	342°	-1/2	-1/2					350°	-1/2	-	-1/8	433°	-1/2		530°	-5/8		540°	-7/8	-	-1/4	+1/4		+3/8	-	-		
23	231	IHX	865		0	+1/8						+3/8	0			-	+1/4	-1/4			+3/8			+1/2		-	+1/2	-1/2		-3/16	-	-	-1/4	-		
24		Cell	PI-100T		-1/8	0				+1/8	+1/8	+1/8	+1/4			0	+1/8	-			0	+1/8		+1/8	+1/8		0	+1/4	-	0	-1/8	0	-1/8	-		
25		No. 1	Pump Suct. Ell		0	0				0	0	0	0			0	0	-3/8	433°	0	0	x		0	0	x		0	0	-5/8	0	0	0	0	-	
26	234		PI-101T		0	0				-1/8	-1/8	+1/8	+1/4			0	+1/8	-	435°	-1/8	+3/8			-1/8	+1/4		0	+1/4	-	0	-3/16	0	-1/8	-		
27			866	74°	0	0		330°	342°			+1/4	+1/2		350°	-	+1/4	-1/4	435°		+1/2		530°		+3/4		540°	-	+1/2	-1/2		-1/8	-	-	-1/4	-
28			437A	72°	0	0		345°	338°	-3/8	-1/2				350°	-1/2	-	-1/8	433°	-3/4		530°	-7/8		540°	-7/8	-	-1/4	+3/8		+3/8	-	-	-		
29	232	IHX	436		0	0						+1/8	+1/4			-	-1/4	-1/4			-3/8			-3/8		-	-1/2	-1/2		+1/8	-	-	+1/4	-		
30		Cell	PI-200T		0	0				0	-1/4	0	-1/4			0	-1/8	-			-1/4	-1/4		-1/8	0		0	-1/4	-	0	+1/16	0	+1/8	-		
31		No. 2	Pump Suct. Ell	72°	+1/8	0		345°	338°	0	0	-1/8	0		350°	0	0	-3/8	433°	0	0	x	530°	0	0	x	540°	0	0	-5/8	0	0	0	0	-	

LEGEND: X + South, - North; Z + West, - East;
Y + Up, - Down
O No movement or less than 1/8" observed or theoretically expected
X Reading is not valid and useless for analysis
— Measurement is not practical or does not represent pipe movement
NOTE: Movement is from ambient to temperature shown, except as noted.

TABLE I
PIPING DISPLACEMENT MEASUREMENTS

Measure- ment Point No.	Pipe Line No.	Area	Identifi- cation or Hanger No.	Ambient			340°								Expected @ 350°				440°				Max.°				Expected @ 540°				Movement 540° - 350°																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
				Pipe Temp (F)	Base Reading (inches)			Pipe Temp (F)	Movement (inches)								Pipe Temp (F)	Movement (inches)				Pipe Temp (F)	Movement (inches)				Pipe Temp (F)	Movement (inches)				(Cool Down)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
					X	Z	Y		W/O	With	W/O	With	W/O	With	W/O	With		X	Z	Y	W/O		With	W/O	With	X		Z	Y	W/O	With	X	Z	Y	X	Z	Y	X	Z	Y																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		

been eliminated from the tabulation and marked X. In these cases, data which were obtained from the movements of adjacent points provided sufficient information.

The comparison of the computed and measured displacements took place at the values obtained at 540 F temperature. The figures for lower temperatures were too small as compared with the accuracy of the readings (approximately $\pm 1/8$ inch), and therefore these values were used for control purposes only, to ascertain the continuity of the movements. The analysis of the displacements is performed in three groups according to the areas covered and the information obtained from the readings.

- 1) Primary sodium pump suction lines in the vicinity of the reactor cavity diaphragm seals outside the cavity. These measurements were mainly taken to check the axial movement of the junction points between the sodium pipe and the guard pipe provided for the piping section between the reactor and the blocking valve. These readings should prove that the restraint on the stainless steel sodium pipe imposed by the carbon steel guard pipe is consistent with values used for the purpose of the original stress calculations, and thereby the validity of the stress analysis and the integrity of the system is verified.

All the east-west displacement measurements performed at these pipe sections are within one-eighth inch of the computed values. This amount of deviation is by all means acceptable, owing to the accuracy of this kind of measurement. The vertical movement of this piping was also within one-eighth inch of the expected displacement, with the exception of points No. 9, 12, and 14. These points were inspected after the test and the reference points on the insulation cladding had been obviously displaced by crushing of the sheet metal enclosure by maintenance or operation activities. Subsequent checking

of the movements during cooldown showed that the amount and direction of movement is in agreement with the expected movement at each of these points.

The axial movements of the junction points were also observed during the cooldown. These movements were slightly below the expected values. Although, due to the comparatively small temperature range, this difference is not significant, the observation of these movements by the already installed remote reading devices will give valuable information during future high temperature operation.

- 2) Piping adjacent to the primary and secondary sodium pumps. All pointers attached to the elbows below the pump suction at the center line of the pump indicated no horizontal movement with the rise of temperature. Consequently, no deformation of the pump casing resulted at any of the pumps observed. Some readings on the suction and discharge lines of the primary pumps in the immediate vicinity of the pump nozzle showed movements contradictory to the adjacent measuring points at the pump suction elbow and points located farther away from the pump along the same lines. A subsequent inspection of the measuring devices, which were attached to pressure transducers, indicated that the provisions were not sufficiently solid to offer acceptable readings. However, readings on adjacent points on the line confirmed the conclusion concerning the integrity of the pumps. Furthermore, the remote reading devices, which have already been installed, will record any possible movements of the pump casing at higher temperatures.
- 3) Intermediate measurement points. Observation of these points was mainly stipulated in order to obtain evidence that no obstructions exist which may restrain the anticipated free movement of piping and which could impose undue stress and strain to equipment and piping. All measurements taken at these points are within one-fourth inch of the expected values. These deviations are within the limits of accuracy of computation and measurement. Furthermore, any movement of this order of magnitude at

these points is at a considerable distance from any equipment, and does not have appreciable affect on the stresses.

Readings at point No. 53 were eliminated, since the inspection at the time of this analysis showed that the measuring devices were installed on an adjacent pipe line.

Readings of vertical movements of these points are not shown in the tabulation because these movements were affected by the adjustment of the variable load spring hangers and are discussed in the corresponding section of this report.

A remote pipe displacement transmitter-recorder system was completed and installed during the period the system was being maintained at 540 F. Six locations were instrumented for remote determination of displacement, as follows:

- 1) At each of the primary pumps to determine east-west and north-south displacement.
- 2) At each of the primary reactor outlet lines on the pump side of the outer bellows on the guard pipe to determine east-west and vertical displacement.

During cooldown, data were taken from the displacement recorder and compared with the measurements taken at the corresponding points. Displacements obtained from the remote transmitters related to the measured displacements within the accuracy of the measurement methods.

B. PIPING INSPECTION

The general inspection of sodium heat transfer system piping, performed concurrently with the taking of piping displacement measurements, determined the following:

- 1) Some of the variable load spring hangers require adjustments.
- 2) Some of the constant hanger supports for piping inside the reactor cavity did not appear to follow the expected pipe movement.
- 3) There was piping vibration in the secondary loops with high sodium flow rates.
- 4) There were piping interferences.

All defects mentioned above were corrected as required for continued performance of the hot circulation test. The discussions below describe the details of the problem areas and remedial action taken in each case.

1. Variable Load Spring Hangers

Figures 1167-B-1 through 1167-B-13 in Appendix B display the locations of sodium heat transfer system variable spring hangers.

The final adjustment of the spring hangers will be made at 350 F to show a hanger loading which will result in the design load when the anticipated pipe movement (obtained from an extrapolation of measured movement) is achieved at operating temperature. Appendix B shows the design data and the conditions of adjustment for each hanger in the primary and secondary heat transfer systems. These adjustments will be accomplished prior to initiation of the wet critical test.

2. Constant Load Spring Hangers

Movement of the constant support hangers for piping inside the reactor cavity was of special significance during warm-up to 540 F sodium temperature, because the piping could not be visually observed to determine proper movement due to thermal expansion. Eleven of the seventeen hangers for the cavity piping

could not be definitely verified as having moved upward during the increase to 540 F. Since only the spring assembly is accessible when the reactor cavity is sealed the reason of malfunction could not be established. The cavity access opening covers were removed and the cavity was entered in order to inspect the piping, the hanger structures, and the hanger rod penetrations through the concrete shielding. The inspection revealed that two hangers were obviously not carrying any piping load, while others appeared to be operating inadequately due to the lack of free movement of the hanger rods in the shielding penetration sleeves. Disassembly of the malfunctioning hangers indicated that the binding in the sleeves was due to one or both of the following reasons:

- a) The key which was provided to prevent rotation of the rod and thereby damage to the bellows seals, was made of square stock material and the sharp corners dug into the key-way in the sleeve.
- b) Rust accumulation in the sleeves caused by water penetration during construction.

In order to assure proper operation of the constant load hanger supports, all 17 assemblies were disassembled, repaired, cleaned and reinstalled. A detailed list of work performed on subject hangers is contained in Appendix D.

Operation of the hangers was observed during the cooldown period; the results obtained are presented in Appendix B. Comparison of data indicates that all hangers moved in the direction anticipated, but varied somewhat from the listed "expected" values. Measured movements are taken from hangers on the guard pipe, and are developed by the combined effects of the sodium line and guard pipe. Results may be expected to vary from line to line, depending on initial conditions established during installation.

3. Piping Vibration

Some piping vibration was observed in the secondary sodium loop piping at elevated flows (above 500 rpm pump speed). The vibration was investigated and determined to be the result of helium gas entrainment in the sodium. The loop expansion tank served as the source of the helium. As pump speed was increased past 500 rpm, the expansion tank level was observed to increase and tank pressure decrease, indicating the entraining of gas. The piping will be modified following completion of hot circulation testing. Namely, an expansion tank bypass line will be installed which will bypass approximately 96% of the flow around the tank, thus decreasing the turbulence therein and eliminating the gas entraining process.

The secondary pumps were limited to a speed of 500 rpm except when testing operations were being performed, or unless hourly inspection tours of IHX cells and steam generator rooms were performed.

Gas entrainment and the resulting pipe vibrations will be verified and examined in detail as a part of preoperational test AI-P-1103, "Main Heat Transfer System". This test will be completed following the planned modifications.

During the period when rework of the reactor cavity pipe hangers was being performed, motion of the reactor return lines was observed. Analysis of the condition was delayed until after completion of the hanger rework. In primary loops No. 1 and 2, with 70% flow and the throttle valves approximately 52% closed (to simulate core drop), an erratic motion of the reactor return line occurred. Peak-to-peak displacements of less than one-sixteenth inch were measured in the east-west runs of the pipes. This was accompanied by

a high level hydraulic noise. Upon opening the throttle valve in loop No. 1 and re-establishing 70% flow, the hydraulic noise level and line motion decreased to an insignificant level. In loop No. 2, approximately 30% flow was established with the throttle valve open with the same observed decrease in hydraulic noise and pipe motion (it was not possible to operate the loop at higher flow without obtaining a low pump case sodium level alarm due to lack of back pressure in the loop).

It was concluded from the observations noted above that the motion originally observed was due to turbulence in the reactor return lines, caused by use of the throttling valves to simulate a loaded core pressure drop.

4. Piping Interferences

Certain piping interferences were determined to exist by the investigation of the system piping as a part of preoperational test AI-P-1103, "Main Heat Transfer System". The interferences observed are listed in Appendix C. The problem areas were corrected, or are being corrected as required. No additional interferences developed during the performance of the test, nor are further interferences expected to occur at operating temperatures.

C. RAISING SODIUM TEMPERATURE TO 440 F

Increase in sodium temperature from 350 F to 440 F was accomplished in a total of 31 hours, for an average rate of 2.9 F per hour. A combination of the electrical preheaters and the heating capacity of the six main heat transfer system sodium pumps was utilized for the operation. Heat input from the primary pumps was approximately 90 kw each, from the secondary pumps

approximately 55 kw each, and approximately 300 kw from the preheat system electrical heaters. Figure 1167-9 depicts the sodium temperature with respect to time for the duration of the heatup to 440 F.

Upon attaining 440 F, pump speeds were decreased to 20% to start hand control station auto-to-manual transfer testing. It was determined that system temperature decreased rapidly (~ 2 F per hr) when the pumps were not operating at higher speeds. Thus, it was not necessary to employ the Electromatic relief valves to maintain temperature. This was desirable, as the relief valves temperature control deadband was expected to be such that close temperature control would be difficult.

Evaporator and superheater shell temperatures were monitored during heat-up to avoid temperature differences greater than 50 F between sodium and evaporator or superheater. Nearly isothermal temperatures existed throughout the test. Evaporator feedwater make-up was required for sampling losses only.

D. TRANSFER OF LOOP HAND CONTROL STATIONS AT 440 F

The six main sodium pumps were switched from manual control to automatic control at 15% speed, with a system temperature of 440 F. The switchover was accomplished smoothly. Table II presents the operating conditions immediately prior to transfer from manual to automatic control and also the conditions immediately following the transfer. The values listed indicate that a minor "bump" occurred during the transfer. Subsequent review of the recorded data and the control system revealed that the bump was due to the combined effect of the primary sodium flow control system temperature trim and mismatch between primary and secondary flow control systems.

Figure 1167-9 Raising Sodium Temperature to 440F

TABLE II

HCS TRANSFER TEST DATA AT 440 F

Pump No.	Variable	Units	Before Transfer	After Transfer
1 Primary	Flow	millivolts	5	4
	Speed	rpm	125	107
	Delta P	psig	0.5	0.2
2 Primary	Flow	millivolts	5	4
	Speed	rpm	127	113
	Delta P	psig	1.5	1.5
3 Primary	Flow	millivolts	5	4
	Speed	rpm	133	127
	Delta P	psig	2	2
1 Secondary	Flow	millivolts	5	5
	Speed	rpm	147	130
	Delta P	psig	2	1
2 Secondary	Flow	millivolts	5	5
	Speed	rpm	150	135
	Delta P	psig	2.5	2.3
3 Secondary	Flow	millivolts	4	5
	Speed	rpm	145	150
	Delta P	psig	1	1.3

Minor tuning of the flow controllers plus elimination of the temperature trim effect (by placing TRC-101, -201, and -301 on "Manual") eliminated the bump (see Table XIV).

E. ESTABLISHING PRESSURE DROP AT 440 F

A pressure drop of 38.4 psig was established across each primary pump to simulate expected core pressure drop in preparation for system hydraulic testing. In all three loops, the throttle valve position required to develop the necessary pressure drop was 60% - closed. Primary pump speeds were as follows when the throttle valve positions were established (these speeds were calculated to be the speeds necessary for 100% plant design flow conditions. Corrected assumptions based on a better understanding of the system are discussed in Section III. R of this report):

- 1) Primary Pump No. 1 - 675 rpm
- 2) Primary Pump No. 2 - 641 rpm
- 3) Primary Pump No. 3 - 641 rpm

Data shown in Table III were obtained with the six main sodium pumps at 100% speed. This information established the base data for system testing at 440 F.

TABLE III
440 F BASE DATA

Pump	Flow (mv)	Speed (rpm)	Inlet Press (psig)	Outlet Press (psig)	ΔP (psi)
Primary No. 1	28	678	-2.0	36.5	38.5
	2	641	-2.0	36.5	38.5
	3	641	-2.8	35.8	38.6
Secondary No. 1	29	675	16.5	61.0	45.0
	2	675	16.0	59.0	43.0
	3	675	17.0	61.0	44.0

F. PUMP SPEED INCREASES AT 440 F

The following facts concerning interaction of the pumps during speed increases were verified by observation of the main control board instruments:

- 1) With all primary pumps operating at the speed corresponding to 15% steam demand, any one pump can be increased to the speed corresponding to 30% of steam demand without affecting the flow through the other two loops.
- 2) The same results were obtained when increasing each loop to the speed corresponding to 50% steam demand with the other two loops at 30% steam demand.
- 3) The same results were obtained when increasing each loop to that speed corresponding to 100% steam demand (from 50%) with the remaining loops at the speed corresponding to 50% steam demand.

G. FLOW TRIMMING AT 440 F

The output signals from load computers FCCp-501, -502, -503, -504, -505, and -506 were trimmed to equalize all six flows when the loop steam demand hand control stations (HCS-501, -502, and -503) were set at 60% scale. Flow control was then transferred to base load controller HCS-504, and it was visually verified that the six loop flows equalized at the same value for various settings of HCS-504 (steam demand hand control station).

H. DETERMINATION OF SYSTEM HYDRAULIC CHARACTERISTICS AT 440 F

The system hydraulic characteristics determination portion of the hot sodium circulation test consisted of two areas of testing:

- 1) Operating all six loops as a unit (from plant steam demand controller, HCS-504) from 100% of plant design flow down to approximately 15% flow.

- 2) Operating each circuit on manual control, individually, with the remaining two circuits on automatic control, to verify proper automatic flow compensation when flow in the circuit on manual control was varied.

The results of these tests verify that circuit flows and pump speeds are stable over the entire operating range and that circuits on automatic control compensate for variations imposed on the system by operation of one loop on manual control.

Typical plots of pump speeds and developed sodium pressures as a function of loop flow at 440 F for one primary and one secondary loop are presented in figures 1167-10 and -11. Flow ramps were imposed to verify that all circuits changed flows smoothly.

The compensating ability of circuits on automatic control from 60% steam demand to 75% steam demand (HCS -501, -502, and -503), was demonstrated by establishing two circuits at 70% steam demand on automatic control and varying the third circuit from 70% to 60% to 75% and back to 70%. The two circuits on automatic control came to the position required for compensation. Table IV shows the manner in which the manipulations were accomplished and the results obtained. Errors in control system tuning are reflected in the table. These were corrected prior to performance of the corresponding section at 540 F (see Table XVI).

I. RAISING SODIUM TEMPERATURE TO 540 F

Increase in sodium temperature from 440 F to 540 F was accomplished in a manner similar to that discussed in section III. C of this report. The temperature increase required a total of 58 hours, corresponding to an average rate of 1.7 F per hour. Figure 1167-12

TABLE IV
AUTOMATIC FLOW COMPENSATION
AT 440 F

Circuit De- viating (on Manual)	Manual HCS Setting	PRIMARY FLOWS			Total Pri Flow (mv)	SECONDARY FLOWS			Total Sec Flow (mv)
		Ckt 1 Flow (mv)	Ckt 2 Flow (mv)	Ckt 3 Flow (mv)		Ckt 1 Flow (mv)	Ckt 2 Flow (mv)	Ckt 3 Flow (mv)	
No. 1, HCS-501	60%	20.2	26.2	26.0	72.4	21.6	27.2	28.5	77.3
No. 1, HCS-501	75%	25.8	27.4	23.6	76.8	27.8	24.4	25.8	78.0
No. 2, HCS-502	60%	25.5	20.8	26.9	72.2	27.4	21.6	28.5	77.5
No. 2, HCS-502	75%	23.4	26.3	24.3	74.0	24.5	27.3	25.6	77.4
No. 3, HCS-503	60%	26.8	27	19.8	73.6	28.0	28.0	21.4	77.4
No. 3, HCS-503	75%	23.6	24.2	25.3	73.1	25.3	25.4	26.8	77.5

Figure 1167-10 Hydraulic Characteristics at 440 F
Primary Loop No. 2

Figure 1167-11 Hydraulic Characteristics at 440 F
Secondary Loop No. 2

depicts the sodium temperature with respect to time for the duration of the heat-up.

Upon attaining 540 F, pump speeds were decreased to 20% to start hand control station auto-to-manual transfer testing. System temperature decreased rapidly (~ 2 F/hr) when the pumps were not operating at the higher speeds. Thus, as at 440 F, it was not necessary to employ the Electromatic relief valves to maintain temperature. It was necessary to interrupt the test occasionally, to operate the main pumps at higher speeds in order to maintain the system at 540 F.

Evaporator and superheater shell temperatures were monitored during heat-up to avoid excessive temperature differences. Essentially isothermal conditions were maintained throughout the test. Evaporator feedwater make-up was required for sampling losses only.

J. TESTING AT MAXIMUM SODIUM TEMPERATURE

Piping displacement measurements were made at 540 F sodium temperature and 20% flow. Results were previously discussed in III. A and B of this report.

Performance runs were made at 20%, 50% and 100% design speeds on each of the six main sodium pumps. Secondary pump No. 3 could not be operated at 100% design speed (675 rpm) because of a pump sodium high level alarm which actuated above 660 rpm until the sodium level was lowered. (Note: This is attributed to the expansion tank arrangement problem discussed earlier and will be corrected by the planned modification.) The following items were observed during the performance runs:

- 1) No adverse internal noise or rumble in the pumps. A high pitched squeal was observed in the vicinity of all pumps under certain condi-

Figure 1167-12. Raising Sodium Temperature to 540F

tions of flow and speed. The sound appears to be speed and flow dependent; that is, it exists only at certain combinations of speed and flow. The sound does not translate to the single pump thrust bearing and it is concluded, therefore, that it does not originate in the fluid bearing. In one instance, the sound was due to motion of the pump preheat furnace. Careful consideration was given to this area by site personnel and specialists from Atomics International headquarters in Canoga Park, California, and it is concluded that no deleterious condition exists.

- 2) No vibration of pump assemblies.
- 3) A 10 rpm speed oscillation was observed in the pumps. This is covered in Section II. O of this report.
- 4) Satisfactory stopping and starting of pumps.
- 5) The thrust bearing oil circuit lower seal in primary pump No. 2 and secondary pump No. 1 developed oil leaks which permitted oil to be discharged into the first (of two) oil sump below the seal housing. The condition in the secondary pump was erratic and has since ceased. The primary pump seal will be disassembled for inspection and maintenance.

No further malfunctions were observed in the oil system operation. Periodic observations were made of each system including the oil pump, cooling fan, seals and piping.

Each pump was started and stopped three times at 540 F. There was no difficulty encountered in the stopping or starting operations, indicating proper functioning. Pump and drive data recorded at 540 F had also been recorded, under the same flow conditions, at 340 F. Tables V through X show the comparison of the values at the two temperatures.

The primary throttle valves (three main loop and one moderator loop valve) were operated from the full-open to the 95% closed position with sodium temperature at

TABLE V
PRI Na PUMP NO. 1 PERFORMANCE TESTS AT 340F AND 540F

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
<u>PUMP DATA:</u>						
Na Temp (°F) TR-2-4	340	535	340	530	341	528
Suction Pressure (psig)	+0.7	+.8	0	+.2	-2.5	-2
Disch Pressure (psig)	1.5	2.2	8.5	+9	36	+36
TI-116						
(Internal Pump -1.	225	390	230	385	239	390
Thermal Barrier -2.	63	75	65	70	65	75
Temperature- °F) -3.	63	79	65	72	66	75
-4.	215	355	215	355	215	355
-5.	210	352	215	350	213	355
-6.	65	76	67	72	69	75
-7.	65	75	67	76	67	75
-8.	225	379	230	375	233	380
High Level Alarms	NONE	NONE	NONE	NONE	NONE	NONE
FIN Temps (°F) 1.	135	170	137	172	135	172
2.	118	146	118	147	118	147
3.	130	167	130	168	130	168
4.	102	116	102	116	101	116
5.	217	327	217	333	216	329
6.	158	269	158	221	159	221
7.	187	278	188	278	188	278
8.	137	205	137	206	137	206

TABLE V - Continued

Item	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
Seal Oil Temp (° F)	103	107	105	116	109	119
Throttle Valve Pos % Closed	50	60	50	60	50	60
Loop Flow * (lb/hr)	$16 \times 3 \times 10^4$	$17 \times 3 \times 10^4$	$43 \times 3 \times 10^4$	$40 \times 3 \times 10^4$	$81 \times 3 \times 10^4$	$78 \times 3 \times 10^4$
DRIVE DATA:						
Pump Speed (rpm)	135	160	335	340	675	675
Coupling Coil Temp (° F)	58	80	58	72	65	77
Motor Input Volts Amps	4040 18.7	4220 21	4080 20.6	4200 16	4080 36.5	4200 35.5
TI-108 (Motor Coil -1. Temperature-°F) -2. -3. -4. -5. -6.	85 26 82 103 79 78	108 20 100 116 100 99	89 30 86 108 84 84	91 21 87 100 86 83	96 43 93 114 91 93	113 21 110 123 107 106
Coupling Current (amps)	0.4	0.5	1.15	1.2	2.65	2.6

* As obtained from FRC-101, Primary Loop No. 1 Sodium Flow Recorder-Controller.

TABLE VI
PRI Na PUMP NO. 2 PERFORMANCE TESTS AT 340F AND 540F

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
<u>PUMP DATA:</u>						
Na Temp (°F) TR-2-4	340	536	340	530	341	528
Suction Pressure (psig)	+0.3	+.4	-0.2	-.2	-2.3	-2
Disch Pressure (psig)	2.0	3.8	10	10.6	36	+37
TI-116						
(Internal Pump -1.	235	400	237	390	238	395
Thermal Barrier -2.	60	73	63	65	63	70
Temperature- °F) -3.	60	75	63	70	63	70
-4.	200	340	207	335	201	335
-5.	195	323	196	315	199	320
-6.	60	75	63	70	64	75
-7.	60	73	60	65	62	70
-8.	233	400	235	395	237	400
High Level Alarms	NONE	NONE	NONE	NONE	NONE	NONE
FIN Temps (°F) 1.	133	181	134	181	133	182
2.	117	149	117	148	117	148
3.	135	176	135	177	136	177
4.	114	141	114	140	114	140
5.	205	331	204	329	204	328
6.	159	232	160	232	160	230
7.	210	321	209	319	208	318
8.	156	259	156	218	155	218

TABLE VI - Continued

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
Seal Oil Temp (° F)	95	102	95	107	94	104
Throttle Valve Pos % Closed	54	60	54	60	54	60
Loop Flow* (lb/hr)	$15 \times 3 \times 10^4$	$19 \times 3 \times 10^4$	$43.5 \times 3 \times 10^4$	$42 \times 3 \times 10^4$	$80 \times 3 \times 10^4$	$78 \times 3 \times 10^4$
DRIVE DATA:						
Pump Speed (rpm)	135	168	335	340	640	640
Coupling Coil Temp (° F)	60	85	65	77	68	82
Motor Input Volts Amps	4040 18.6	4220 21	4080 21	4200 21.5	4080 36.5	4200 36
TI-108 (Motor Coil Temperature- ° F)	-1. 80 -2. 75 -3. 83 -4. 76 -5. 80 -6. 75	99 91 102 95 99 94	84 80 90 83 85 83	85 80 90 82 87 83	94 88 100 92 96 93	113 100 116 104 110 107
Coupling Current (amps)	0.55	0.6	1.45	1.4	2.9	2.8

* As obtained from FRC-201, Primary Loop No. 2 Sodium Flow Recorder-Controller.

TABLE VII
PRI Na PUMP NO. 3 PERFORMANCE TESTS AT 340F AND 540F

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
<u>PUMP DATA:</u>						
Na Temp (°F) TR-2-4	340	536	340	530	341	528
Suction Pressure (psig)	-0.2	0	-0.9	-.8	-3.8	-2.5
Disch Pressure (psig)	2.0	3	9	8.5	37.8	+35.5
TI-116						
(Internal Pump -1.	235	401	240	372	240	385
Thermal Barrier -2.	70	70	70	65	70	70
Temperature- °F)-3.	70	70	70	65	70	70
-4.	100	168	101	155	113	150
-5.	105	139	105	135	110	135
-6.	95	112	95	105	93	110
-7.	75	77	75	75	75	75
-8.	113	137	114	135	114	135
High Level Alarms	NONE	NONE	NONE	NONE	NONE	NONE
FIN Temps (°F) 1.	117	188	117	188	116	188
2.	100	127	100	127	100	126
3.	115	161	114	162	115	162
4.	113	140	113	140	112	141
5.	213	330	213	329	213	329
6.	132	214	135	215	134	212
7.	213	330	213	329	215	329
8.	155	226	154	226	154	227

TABLE VII - Continued

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
Seal Oil Temp (°F)	100	106	103	114	107	117
Throttle Valve Pos % Closed	52	65	52	65	52	65
~ Loop Flow * (lb/hr)	$14 \times 3 \times 10^4$	$20 \times 3 \times 10^4$	44	$40 \times 3 \times 10^4$	$83 \times 3 \times 10^4$	$78 \times 3 \times 10^4$
DRIVE DATA:						
Pump Speed (rpm)	135	190	338	340	673	640
Coupling Coil Temp (°F)	67	98	75	83	77	90
Motor Input Volts	4040	4220	4080	4200	4080	4200
Amps	18.9	23	22.5	23	43	39
TI-108						
(Motor Coil -1.	112	126	117	118	131	134
Temperature- °F)-2.	110	126	117	117	133	135
-3.	107	123	113	113	128	132
-4.	122	138	128	128	146	147
-5.	110	127	117	117	133	137
-6.	115	129	121	121	136	138
Coupling Current (amps)	0.25	0.5	1.05	1.0	2.70	2.4

* As obtained from FRC-301, Primary Loop No. 3 Sodium Flow Recorder-Controller.

TABLE VIII
SEC Na PUMP NO. 1 PERFORMANCE TESTS AT 340F AND 540F

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
<u>PUMP DATA:</u>						
Na Temp (°F) TR-2-4	340	535	340	530	340	528
Suction Pressure (psig)	20.5	22	19.7	19.5	16.5	16.5
Disch Pressure (psig)	22	24.5	30.2	31	61	60
TI-116						
(Internal Pump -1.	145	235	151	215	157	220
Thermal Barrier -2.	175	290	187	275	192	285
Temperature- °F)-3.	260	445	265	420	271	420
-4.	270	465	280	440	282	440
-5.	270	455	275	430	278	430
-6.	245	412	250	380	250	380
-7.	155	210	160	208	160	208
-8.	130	175	140	175	140	173
High Level Alarms	NONE	NONE	NONE	NONE	NONE	NONE
FIN Temps (°F)1.	141	161	140	165	135	163
2.	140	186	138	185	136	187
3.	111	121	110	127	107	127
4.	127	138	123	146	121	143
5.	199	241	193	257	190	240
6.	191	298	192	295	193	298
7.	124	156	122	148	121	146
8.	143	171	138	165	139	163

TABLE VIII - Continued

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
Seal Oil Temp ($^{\circ}$ F)	107	113	110	124	114	127
Throttle Valve Pos % Closed	0	0	0	0	0	0
Loop Flow * (lb/hr)	$15 \times 3 \times 10^4$	$21 \times 3 \times 10^4$	$46 \times 3 \times 10^4$	$43 \times 3 \times 10^4$	$88 \times 3 \times 10^4$	$86 \times 3 \times 10^4$
DRIVE DATA:						
Pump Speed (rpm)	130	175	335	340	675	675
Coupling Coil Temp ($^{\circ}$ F)	93	138	105	126	108	132
Motor Input Volts Amps	4040 18.5	4200 20.5	4080 21	4200 22	4020 40.5	4200 40.5
TI-108						
(Motor Coil -1.	122	163	134	155	148	183
Temperature- $^{\circ}$ F)-2.	135	177	148	170	160	200
-3.	125	170	138	160	150	188
-4.	130	173	142	163	155	192
-5.	132	176	146	167	157	193
-6.	127	172	139	160	150	188
Coupling Current (amps)	0.5	0.7	1.45	1.4	3.35	3

* As obtained from FRC-102, Secondary Loop No. 1 Sodium Flow Recorder-Controller.

TABLE IX
SEC Na PUMP NO. 2 PERFORMANCE TESTS AT 340F AND 540F

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
<u>PUMP DATA:</u>						
Na Temp (°F) TR-2-4	330	527	330	530	330	528
Suction Pressure (psig)	20	20.8	19	19	16	15.8
Disch Pressure (psig)	22	24.5	30.2	30	60	59
TI-116						
(Internal Pump -1.	130	215	135	215	140	217
Thermal Barrier -2.	150	270	160	273	165	275
Temperature- °F)-3.	275	485	280	470	285	470
-4.	275	485	280	465	239	465
-5.	278	480	285	460	240	460
-6.	275	412	280	400	235	400
-7.	215	240	220	240	222	240
-8.	170	210	175	190	183	190
High Level Alarms	NONE	NONE	NONE	NONE	NONE	NONE
FIN Temps (°F) 1.	119	147	118	148	117	148
2.	131	185	130	192	130	191
3.	122	132	120	134	119	132
4.	156	167	155	167	153	164
5.	185	293	185	303	186	300
6.	132	217	129	220	127	214
7.	132	202	128	186	127	129
8.	207	233	206	245	205	241

TABLE IX - Continued

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
Seal Oil Temp ($^{\circ}$ F)	105	114	110	124	115	127
Throttle Valve Pos % Closed	0	0	0	0	0	0
Loop Flow * (lb/hr)	$15 \times 3 \times 10^4$	$18 \times 3 \times 10^4$	$46.2 \times 3 \times 10^4$	$43 \times 3 \times 10^4$	$91 \times 3 \times 10^4$	$87 \times 3 \times 10^4$
DRIVE DATA:						
Pump Speed (rpm)	130	175	335	340	678	675
Coupling Coil Temp ($^{\circ}$ F)	82	140	93	125	100	132
Motor Input Volts Amps	4040 18	4220 20.7	4080 20.7	4200 21.5	4020 41	4200 40.5
TI-108						
(Motor Coil -1.	120	165	130	156	147	180
Temperature- $^{\circ}$ F)-2.	124	172	135	159	150	197
-3.	117	165	127	150	144	177
-4.	122	169	131	156	152	183
-5.	117	164	127	150	143	175
-6.	124	171	135	160	155	184
Coupling Current (amps)	0.45	0.6	1.4	1.4	3.2	2.6

* As obtained from FRC-202, Secondary Loop No. 3 Sodium Flow Recorder-Controller.

TABLE X
SEC Na PUMP NO. 3 PERFORMANCE TESTS AT 340F AND 540F

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
<u>PUMP DATA:</u>						
Na Temp (°F) TR-2-4	340	530	340	530	340	528
Suction Pressure (psig)	19.8	20.1	19.2	19.2	16.5	16.5
Disch Pressure (psig)	20	22.5	28	29	60.2	57.5
TI-116						
(Internal Pump -1.	120	245	128	250	132	250
Thermal Barrier -2.	150	290	165	290	170	290
Temperature- °F)-3.	250	450	261	435	267	440
-4.	270	450	278	430	280	430
-5.	275	440	278	420	280	425
-6.	280	440	282	420	280	425
-7.	195	230	200	230	195	230
-8.	150	215	185	220	155	215
High Level Alarms	NONE	NONE	NONE	NONE	NONE	NONE
FIN Temps (°F) 1.	123	148	120	149	120	148
2.	129	212	129	219	131	218
3.	128	148	122	151	120	151
4.	151	192	150	192	149	192
5.	130	152	127	156	126	154
6.	163	300	170	306	180	298
7.	169	152	160	151	153	151
8.	205	290	202	239	202	234

TABLE X - Continued

Items	20% Speed		50% Speed		100% Speed	
	340F	540F	340F	540F	340F	540F
Seal Oil Temp (°F)	108	114	113	124	117	127
Throttle Valve Pos % Closed	0	0	0	0	0	0
Loop Flow * (lb/hr)	13.3×10^4	21×10^4	42×10^4	43×10^4	85×10^4	86×10^4
DRIVE DATA:						
Pump Speed (rpm)	130	190	335	340	675	660
Coupling Coil Temp (°F)	65		68		70	
Motor Input Volts Amps	4040 18	4200 20.3	4080 20.2	4200 21	4020 40.5	4200 39.5
TI-108						
(Motor Coil -1.	98	132	106	119	118	135
Temperature- °F)-2.	103	142	112	126	127	142
-3.	103	142	111	129	125	140
-4.	105	140	113	127	125	143
-5.	102	138	113	125	126	142
-6.	100	136	108	123	120	137
Coupling Current (amps)	0.6	0.7	1.55	1.50	3.55	2.2

* As obtained from FRC-302, Secondary Loop No. 3 Sodium Flow Recorder-Controller.

540 F and loop flows at 20%. The following operational discrepancies were observed:

- 1) No. 1 primary throttle valve became inoperable due to a sheared key on the jackshaft on one side of the operating yoke.
- 2) No. 3 primary throttle valve stroked only three-quarters of its travel and it was subsequently determined that binding within the valve was occurring.
- 3) The moderator throttle valve operator was observed to discharge oil from the air motor exhaust.

It was determined that the discrepancy noted in 1) above was caused by a maladjustment in the valve positioner. A faulty oil seal in the operator air motor was determined to be the cause of the oil discharge described in 3). Maintenance procedures are being developed for the purpose of investigating and repairing primary throttle valve No. 3.

With the exception of primary throttle valve No. 3, the above conditions were remedied by rechecking and (where necessary) re-aligning all valve positioners and by replacing the sheared key and oil seal after which one quick-closure cycle was performed on each valve, as described in part II., "Discussion of Test Performance". There was no excessive movement of valves or adjacent piping during the cycle. The following items were observed to be satisfactory during operation of the valves:

- 1) Air motor operation.
- 2) Line shaft operation.
- 3) Bearing support rigidity.
- 4) Component vibration.
- 5) Component lubrication.
- 6) Stem seals leakage.

7) Movement during quick-closure.

8) Mechanism clearances.

Each primary blocking valve was closed and re-opened one time at 540 F sodium temperature, with the pumps shutdown. Proper operation was determined by observing the same items as listed previously for the primary throttling valves.

Similarly, by observation of the same items, it was determined that the secondary throttling valves function satisfactorily.

K. CONTROL ROD DRIVE TESTING

Individual operation of control rods from the test cart revealed no significant effect on rod operability. Each rod was operated from the fully inserted position to 15 inches out, through various short up and down cycles (to obtain current and voltage data for each phase in each direction), back to the fully inserted position, and then to the fully withdrawn position. From this position, each rod was scrambled and drop times were measured.

Data obtained during control rod testing are presented in Table XI. Data obtained at ambient temperature during performance of preoperational test AI-P-1148 "Control Rod Operability" are included in the table under the heading "AMB" for comparison purposes. Of particular significance is the close correlation between the ambient and 540 F full insertion times, since these are timed free falls and reflect all changes in friction or binding.

There were no apparent differences in motor currents or voltages at 540 F, as compared to those obtained at ambient temperatures.

TABLE XI

CONTROL ROD OPERATION AT AMBIENT
AND AT 540 F SYSTEM TEMPERATURE

Rod No.	Withdrawal (min)		Average Speed (in./min)		Latch Release Time (msec)		Scram Time (msec) to:			
	AMB	540F	AMB	540F	AMB	540F	4 ft. Pos.	Full Insert.	AMB	540F
1.	12.4	12.2	12.52	12.79	51	50	768	765	960	960
2.	12.6	12.7	12.35	12.28	52	55	781	778	963	966
3.	12.5	12.35	12.52	12.63	51	50	770	779	960	955
4.	12.6	12.5	12.35	12.48	51	53	760	771	950	961
5.	12.8	12.6	12.20	12.38	50	55	783	783	971	975
6.	12.4	12.25	12.58	12.73	53	54	770.2	774	962	962
7.	12.3	12.75	12.70	12.24	52	53	769	772	967	969
8.	12.2	12.1	12.80	12.89	51	57	767	778	956	955
9.	12.5	12.55	12.44	12.43	52	56	771	794	978	969
10.	12.7	12.14	12.28	12.14	51	54	770	775	952	948
11.	12.4	12.55	12.57	12.43	50	52	768	768	956	960
12.	13.4	12.58	12.62	12.58	55	54	784	791	991	993
13.	12.7	12.4	12.24	12.58	51	58	772	772	955	964
14.	12.2	12.6	12.88	12.38	51	53	783	793	970	975
15.	12.7	12.65	12.24	12.33	51	54	773	775	946	953
16.	12.4	12.34	12.58	12.63	53	53	778.2	786	960	960
17.	12.7	12.45	12.30	12.53	53	53	774	778	947	943
18.	12.8	12.97	12.19	12.03	53	56	769	773	968	966
19.	12.4	12.65	12.60	12.33	52	52	767	768	957	961

L. TESTING CORE ALIGNMENT

A review of the test method concerning the testing of core alignment at 540 F sodium temperature, determined that the removal and re-insertion of a dummy element in the reactor was not a stringent enough test. This conclusion was based on the fact that a dummy element is 0.4 inch less in diameter than an actual fuel element. To supplement the check of core alignment, a process tube, hanger rod, and shield plug assembly (an actual fuel element with the fuel cluster removed) were inserted and removed from each of the three core positions which contained a dummy element. The test thus included:

- 1) Removal of a dummy element (previously installed)
- 2) Insertion of a mock fuel element
- 3) Removal of the mock fuel element
- 4) Insertion of the dummy element.

Observation of the fuel handling machine grapple load cells during element removal and insertion operations, determined that there was no binding nor hang-up of the dummy element, over the entire range of travel, from the fully inserted position to the travel position in the fuel handling machine.

The mock fuel element hung up during withdrawal from core positions C-185 and C-233, at a reading of about 353 on the fuel handling machine grapple position indicator. In each case, the element was lowered slightly and was withdrawn without further difficulty.

The position of "hang up" corresponds to the point previously experienced following the dry excess loading. At that time the "hang up" was due to a "flat" on the slip ring used to assemble the fuel cluster to the hanger rod. The slip rings were modified and further tests indicated the problem had been alleviated. The mock fuel

element used in the present test was equipped with a modified slip ring. Since this element did not contain a fuel cluster it was substantially lighter than a standard fuel element. Prior to its use, some consideration was given to the fact that the light process tube might not have sufficient weight to hang straight and hence would provide a more stringent test than a normal fuel element. The element used will be washed and inspected to determine the cause of the hang up.

When re-inserting the mock fuel element in core position C-233, the load cell momentarily indicated a minimum load of -1600 lbs during the last inch of travel. This is attributed to quad-ring drag; this is substantiated by the fact that the breakaway load upon removal of the element is comparable to that obtained in the other positions. Otherwise, all element breakaway forces were as anticipated and travel loads represented element weights plus fuel handling machine friction losses. Table XII presents load cell readings obtained over a storage cell for comparison purposes.

It is concluded from the observations made and the data obtained that core alignment was maintained at the elevated temperature. Table XIII presents load cell readings and the actual element weights.

A helium leak check verified that the helium gas integrity of the reactor was maintained following the insertion of each element.

M. TRANSFER OF LOOP HAND CONTROL STATIONS AT 540 F

The six main sodium pumps were switched from manual control to automatic control at 15% speed without difficulty. The switchover was accomplished smoothly and without creating a step-change ("bump") in system operating conditions.

TABLE XII

BASE DATA
CORE ALIGNMENT TEST, FHM LOAD CELL DATA

Grapple No. 1, Storage Cell S-30 Dummy Element No. DE-31		Grapple No. 2, Storage Cell S-49 Mock Fuel Element RP-207	
Weight of Element	495 lbs	Weight of Element	430 lbs
Max. load first 6 inches travel up (breakaway)	800 lbs	Max. load first 6 inches travel up (breakaway)	700 lbs
Load during up -travel	600 lbs	Load during up -travel	510 lbs
Load during down -travel	500 lbs	Load during down -travel	400 lbs
Min. load last 6 inches travel down (reseat)	-350 lbs	Min. load last 6 inches travel down (reseat)	-500 lbs

TABLE XIII
CORE ALIGNMENT TEST, FHM LOAD CELL DATA

GRAPPLE NO. 1		GRAPPLE NO. 2	
CORE POSITION C-185			
<u>Dummy Element</u>		<u>Mock Fuel Element</u>	
Weight of Element	495 lbs	Weight of Element	430 lbs
Max. load first 6 inches travel up (breakaway)	600 lbs	Max. load first 6 inches travel up (breakaway)	850 lbs
Load during up -travel	550 lbs	Load during up -travel	550 lbs
Load during down -travel	400 lbs	Load during down -travel	400 lbs
Min. load last 6 inches travel down (reseat)	-200 lbs	Min. load last 6 inches travel down (reseat)	-200 lbs
CORE POSITION C-209			
<u>Dummy Element</u>		<u>Mock Fuel Element</u>	
Weight of Element	495 lbs	Weight of Element	430 lbs
Max. load first 6 inches travel up (breakaway)	800 lbs	Max. load first 6 inches travel up (breakaway)	600 lbs
Load during up -travel	550 lbs	Load during up -travel	500 lbs
Load during down -travel	400 lbs	Load during down -travel	400 lbs
Min. load last 6 inches travel down (reseat)	-200 lbs	Min. load last 6 inches travel down (reseat)	-400 lbs
CORE POSITION C-233			
<u>Dummy Element</u>		<u>Mock Fuel Element</u>	
Weight of Element	495 lbs	Weight of Element	430 lbs
Max. load first 6 inches travel up (breakaway)	900 lbs	Max. load first 6 inches travel up (breakaway)	650 lbs
Load during up -travel	600 lbs	Load during up -travel	500 lbs
Load during down -travel	400 lbs	Load during down -travel	400 lbs
Min. load last 6 inches travel down (reseat)	-300 lbs	Min. load last 6 inches travel down (reseat)	-1600 lbs

After transferring to automatic control on all six pumps, it was determined that:

- 1) the three primary pumps were operating at approximately the same speed and flow;
- 2) the three secondary pumps were operating at approximately the same speed and flow; and
- 3) no evidence of pump malfunction existed.

Table XIV presents the operating conditions immediately prior to transfer from manual to automatic control and also the conditions immediately following the transfer. The values listed substantiate that no significant bump occurred due to the transfer.

N. ESTABLISHING PRESSURE DROP AT 540 F

A simulated core pressure drop of 38.4 psig was established across each primary loop by proper positioning of the primary throttle valves. The throttle valve HCS setting required to develop the necessary pressure drop was 60% closed for each loop. Primary pump speeds were established at 100% of design speed, when the throttle valve positions were established. 100% design pump speed was calculated to be as follows:

- 1) Primary Pump No. 1 - 675 rpm
- 2) Primary Pump No. 2 - 641 rpm
- 3) Primary Pump No. 3 - 641 rpm

Data shown in Table XV were obtained for each of the six main sodium pumps at the assumed 100% design speed. This information establishes the base data for system testing at 540 F.

TABLE XIV

HCS TRANSFER TEST DATA AT 540 F

Pump No.	Variable	Units	Before Transfer	After Transfer
1 Primary	Flow	millivolts	3.4	3.5
	Speed	rpm	105	100
	Delta P	psig	1.0	1.0
2 Primary	Flow	millivolts	4.3	4.3
	Speed	rpm	125	125
	Delta P	psig	1.5	1.0
3 Primary	Flow	millivolts	4.5	4.5
	Speed	rpm	140	137
	Delta P	psig	2.0	2.0
1 Secondary	Flow	millivolts	4.4	4.3
	Speed	rpm	120	120
	Delta P	psig	0.5	0.5
2 Secondary	Flow	millivolts	4.8	4.8
	Speed	rpm	130	130
	Delta P	psig	1.5	2.0
3 Secondary	Flow	millivolts	5.4	5.5
	Speed	rpm	145	145
	Delta P	psig	0.5	0.5

TABLE XV

540 F BASE DATA

Pump	Flow (mv)	Speed (rpm)	Inlet Press (psig)	Outlet Press (psig)	ΔP (psig)
Primary No. 1	27.0	675	-1.8	36.6	38.4
2	26.9	640	-1.9	37.5	39.4
3	25.9	640	-2.4	36	38.4
Secondary No. 1	30.1	675	16.5	59	42.5
2	30.8	675	16	57	41.0
3	30.9	675	17	59	42.0

O. PUMP SPEED INCREASES AT 540 F

The following facts concerning interaction of the pumps during speed increases were verified by observation of the main control board instruments:

- 1) With all primary pumps operating at the speed corresponding to 15% steam demand, any one pump can be increased to the speed corresponding to 30% of steam demand without affecting the flow through the other two loops.
- 2) The same results were obtained when increasing each loop to the speed corresponding to 50% steam demand with the other two loops at 30% steam demand.
- 3) Increasing each loop to that speed corresponding to 100% steam demand (from 50%) with the remaining loops at the speed corresponding to 50% steam demand, yielded the same results.

P. FLOW TRIMMING AT 540 F

The output signals from load computers FCCp-501, -502, -503, -504, -505, and -506 were trimmed to equalize all six flows when the loop steam demand hand control stations (HCS-501, -502, and -503) were set at 60% scale. Flow control was then transferred to base load controller HCS-504 and it was visually verified that the six loop flows equalized at the same value for various settings of

HCS-504 (steam demand hand control station).

Q. DETERMINATION OF SYSTEM HYDRAULIC CHARACTERISTICS

The six main sodium pumps were operated simultaneously from steam demand hand control station HCS-504, over a range of approximately 110 rpm to 600 rpm, to determine significant system hydraulic characteristics. Results of the testing demonstrated the similarity between the three primary loops and between the three secondary loops.

Pump motor winding temperatures and coupling temperatures were closely observed during circulating operations, to detect any off normal conditions. At 100% speed on secondary pump No. 3, a high winding temperature alarm was actuated with an indicated 200 F. This occurred simultaneously with a pump high sodium level alarm (Refer to Part III. J) and the pump was shutdown. It was determined that the temperature alarm setpoint was excessively stringent according to pump manufacturer's information. Hence, the temperature was not considered an alarm condition. There had been no alarm prior to this time, nor was this winding temperature reached again during subsequent hot circulation testing. All coupling temperatures remained within alarm limits during all phases of testing.

During all pump operation, surveillance was maintained over the pumps for indications of malfunctioning, as indicated by unusual noise, vibration, over-heating, or similar off-normal conditions.

The main pumps were particularly scrutinized during operation at low flows, to detect signs of pump and flow instability. No drifting was observed. A speed oscillation occurred, which was subsequently analyzed and reported

in the Test Completion Report for Preoperational Test
AI-P-1120* - Plant Control System - as follows:

"When on manual speed control from HCS-102, -202, -302, -104, -204 and -304, a 10 rpm oscillation in pump rpm was observed. This oscillation was not present when operating from manual speed control at the coupling control cabinet. It was noted that the coupling is powered from critical control power, while the last amplifier in HCS-102, -202, -302, -104, -204 and -304 is powered by noise-sensitive power. By changing the frequency of the noise-sensitive M-G sets, it was possible to change the period of the pump oscillation. This problem will be corrected by changing the power feed to the last amplifier in HCS-102, -202, -302, -104, -204 and -304 to critical power."

Pump speed indicators were re-checked (employing a Stobotac) prior to 540 F, to firmly establish that the pump speed values recorded would be accurate; no adjustments were required.

As at 440 F, the system hydraulic characteristics determination portion of the hot sodium circulation test at 540 F consisted of two areas of testing:

- 1) Operating all six loops as a unit (from base load controller, HCS-504) from 100% of plant design flow down to approximately 15% flow.
- 2) Operating each circuit on manual control, individually, with the remaining two circuits on automatic control, to verify proper automatic flow compensation when flow in the circuit on manual control was varied.

The results of these tests verified that circuit flows and pump speeds are stable over the operating range and that circuits on automatic control compensate for

* To be published.

variations imposed on the system by operation of one loop on manual control.

Loop flow and pressure changes as a function of pump speed were as anticipated at 540 F. Figures 1167-13 through -15 display the information obtained at 540 F for these variations. Figure 1167-13 shows the close relationship of the three primary pumps and the three secondary pumps, with respect to pump speed as a function of flow. This information verifies the similarity of the loops under operating conditions. Figures 1167-14 and 1167-15 display a similar relationship with respect to loop pressure drop and power demand hand control station HCS-504, respectively.

Flow ramps were imposed to verify that all circuits changed flows smoothly at the correct rate-limited value of 20% per minute.

The compensating ability of circuits on automatic control from 60% steam demand to 75% steam demand (HCS -501, -502, and -503) was demonstrated by establishing two circuits at 70% steam demand on automatic control, and varying the third circuit from 70% to 60% to 75% and back to 70%. The two circuits on automatic control came to that position required for compensation. Table XVI shows both the manner in which the manipulations were accomplished and the results obtained.

The instrumentation balancing and tune-up accomplished following 440 F testing corrected the undesirable traits that were demonstrated at 440 F. The loop hand control stations were also transferred from automatic to manual as a re-check of the manual-to-auto operation to confirm that the transfer could be accomplished smoothly.

TABLE XVI
AUTOMATIC FLOW COMPENSATION
AT 540 F

Circuit De- viating (on Manual)	Manual HCS Setting	PRIMARY FLOWS			Total Pri Flow (mv)	SECONDARY FLOWS			Total Sec Flow (mv)
		Ckt 1 Flow (mv)	Ckt 2 Flow (mv)	Ckt 3 Flow (mv)		Ckt 1 Flow (mv)	Ckt 2 Flow (mv)	Ckt 3 Flow (mv)	
No. 1, HCS-501	60%	20	26	26	72	22	28	27.9	77.9
No. 1, HCS-501	75%	24.9	22.8	23.9	71.7	26.9	26.0	24.9	77.8
No. 2, HCS-502	60%	25.9	20	25.9	71.8	27.9	21.9	27.9	77.7
No. 2, HCS-502	75%	23.9	24.9	22.9	71.7	24.9	27.9	24.9	77.7
No. 3, HCS-503	60%	25.9	25.9	20	71.8	27.9	27.9	21.9	77.7
No. 3, HCS-503	75%	22.9	24	24.8	71.7	25.9	25.9	27	77.5

Figure 1167-1 Loop Flow (mv) vs Pump Speed (RPM)

Figure 1167-14 Loop Flow (mv) vs Pump Delta Pressure (psig)

Figure 1167-15 Loop Flow (mv) vs HCS-504 (Percent Scale)

R. EXTENDED HYDRAULIC TESTING

Analysis of the hydraulic data obtained led to the correction of basic assumptions made in establishing the 100% primary pump speeds. The 100% primary pump speeds were corrected to 675 rpm for pumps No. 2 and 3 and to 685 rpm for pump No. 1. Based on better understanding of the main heat transfer system gained in the test, it is believed that these values more adequately simulate the system performance with a loaded core.

The simulated core drop of 38.4 psig was established in each of the primary loops at the corrected 100% speed values at 540 F. Hydraulic data were obtained for 540, 440, and 350 F. for each of the six loops, without changing the primary throttling valve positions.

Expected values for the primary and secondary pumps are depicted in Figure 1167-16. Developed differential pressures and pump speeds for each loop at each temperature are presented in Figures 1167-17 through 1167-22.

S. COOLDOWN TO 350 F SODIUM TEMPERATURE

Cooldown of the main heat transfer system from 540 to 440 F and from 440 to 350 F was accomplished at a rate of approximately 25 F per hour. A limitation of 25 F steam-to-sodium temperature was established and was at no time exceeded during the cooldown.

Careful control was maintained during cooldown to ensure that the operation was accomplished safely and that sodium temperatures were accurately controlled.

Hydraulic tests were performed at 540, 440 and 350 F as part of the extended testing. Piping displacement data and hanger settings were repeated, as previously reported, at each of the three temperatures.

Figure 1167-16. Expected Hydraulic Characteristics

Figure 1167-17. Hydraulic Characteristics
Primary Loop No. 1

Figure 1167-18. Hydraulic Characteristics
Primary Loop No. 2

Figure 1167-19. Hydraulic Characteristics
Primary Loop No. 3

Figure 1167-20. Hydraulic Characteristics
Secondary Loop No. 1

Figure 1167-21. Hydraulic Characteristics
Secondary Loop No. 2

Figure 1167-22. Hydraulic Characteristics
Secondary Loop No. 3

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the Test Completion Criteria associated with preoperational test AI-P-1167, "Hot Sodium Circulation Test", as listed in NAA-SR-5700, Supplement 4, Page XI(a)-101, with remarks regarding the test to explain compliance with the criteria.

- 1) Criterion: Primary and secondary sodium heat transfer systems have been filled and sodium circulation has been accomplished at the temperatures specified in the test.
Remarks: Circulation of sodium was accomplished in the primary and secondary sodium systems from 340 F to 540 F, which was the maximum sodium temperature specified in the test procedure. The systems were filled prior to the test, in accordance with sodium filling preoperational test procedures AI-P-1156 and AI-P-1157.
- 2) Criterion: Operability of the system mechanical components has been demonstrated at the various temperatures specified.
Remarks: Two main pump oil seals developed leaks. One of the seals subsequently stopped leaking. The remaining one will be repaired by disassembly of the seal housing and replacing the faulty components.

Primary throttle valve No. 3 became inoperable due to internal binding. Maintenance procedures are being developed for investigation and repair of the valve.

All other system mechanical components were determined to be operable as described in detail in this report. No relationship between the above two discrepancies and system temperature are believed to exist.

- 3) Criterion: Piping movements have been charted at the temperature levels called for in the detailed test procedure. Piping movements have not caused failure, damage, or distress and consequent leakage in the systems.

Remarks: Piping movements were observed and recorded at the specified temperatures of ambient, 340 F, 440 F, and 540 F according to the test procedure. The information obtained is presented within the body of this report.

It was demonstrated that piping movements due to thermal expansion caused by sodium heat-up to 540 F created no failures, damage, or distress and consequent leakage in the systems, as described in detail within this report.

- 4) Criterion: Control rods function properly and without binding over the range of temperatures tested.

Remarks: Proper control rod operation, specifically without binding, was verified at 540 F system temperature. Data obtained regarding control rod operation at 540 F established that no change occurred in rod functioning at 540 F as compared to functioning at ambient temperature.

- 5) Criterion: Alignment of the core and loading face shield has been preserved within design limits.

Remarks: Proper alignment of the core and loading face shield was demonstrated at the hot sodium circulation test temperature of 540 F.

V. EVALUATION

The hot circulation test proved to be a very extensive and rigorous test of the sodium heat transfer system at temperatures up to 540 F.

Except for primary throttle valve malfunctions and minor sodium pump seal problems the test completion criteria as stated in the HNPF Safeguards Report, NAA-SR-5700 (Supplement 4), were met.

Although problems were encountered, (as presented in Part III, "Analysis and Presentation", of this report), the majority were not directly related to the elevated temperature achieved during the test. The required action to correct these problems has been or will be completed before wet critical testing. Such corrective action will insure the satisfactory operation of the system at design operating conditions.

A. PIPING

The test demonstrated that the heat transfer piping and associated components will not be subjected to detrimental stress and strain resulting from thermal expansion over the full operating temperature range of the system. The actual measured piping movements compared well with the calculated predicted movements, thus confirming the validity of the piping stress analysis performed during the system design. In addition, the free movement of the system will be assured by the elimination of all interferences which could conceivably restrict movement during the operation of the system at design conditions.

During the cooldown from 540 F to 350 F there was evidence of some restraint on pump suction line 231 by the pipe guide located just outside the core cavity. The

measured axial movement of the pipe lagged behind the expected axial movement associated with the temperature change. Shortly after the system reached 350 F the total measured displacement from 540 F was only 1/8 in. as opposed to a calculated movement of 5/8 in. Approximately two days later the displacement had increased to 5/16 in. This condition was observed during heat-up to 540 F, but at that time it was attributed to erroneous measurements. It is theorized that this is a result of excessive friction in the guide, necessitating a build-up of sufficient force to overcome the friction before movement results. When the piping reaches a temperature equilibrium, there is still residual restraining force equal to the friction of the guide. The normal vibration due to the high fluid velocity in the system caused the line to gradually move, and after a period of time it reached an unrestrained condition. The restraint observed during the test did not endanger the integrity of the system since the calculated pipe stresses in this line amount to only approximately 50 percent of the code allowable stress at design temperature. However, to prevent any problems which may occur at elevated temperatures the restraint will be eliminated by modification of the guide contact surfaces.

B. CORE CAVITY HANGERS

The complete restoration of all core cavity hanger rod shield penetrations should insure continued freedom of movement and satisfactory operation of the support assemblies. During the cooldown of the system from 540 F to 350 F the piping moved as expected and the hangers moved accordingly. However, the position indicators on the cavity constant load hangers did not provide an accurate indication of movement and it was necessary to

enter the cavity to measure the movement of the hanger rods. A simple, direct reading position indicator will be installed on each constant load spring hanger assembly prior to the approach to operating temperatures. This will provide an accessible and accurate means of determining proper operation of the hangers and cavity piping after the cavity is sealed.

C. VALVES

During the hot circulation test the heat transfer system block and throttle valves were operated extensively for the first time. In this period three valve malfunctions occurred of which two were in the operating mechanism and cannot be attributed to the elevated temperature achieved during the test. Primary throttle valve No. 3 did however become inoperable as a result of internal binding at 540 F. The cause of this malfunction has not been determined at this time. However, during construction a shield block was inadvertently set on the valve actuator. The actuator was damaged but there did not appear to be any damage to the stem or the valve internals. It is conceivable that damage did result but did not appear until the valve was operated at elevated temperature. The difficulties encountered to date have been or will be corrected. Due to the limited operating experience, there is no assurance that additional valve or valve actuator malfunction will not occur, and it was therefore recommended that all valves be subjected to a thorough functional checkout consisting of cycling the valve over its full travel 25 to 50 times. This will be accomplished before power operation.

D. PUMPS

The operability of the six sodium pumps was demonstrated in the temperature range attained during the test. The hydraulic performance of all the pumps is comparable and is essentially unaffected at the higher test temperatures. With the exception of a few probably minor problems (discussed below), the operation of the pumps during the test indicates that dependable, satisfactory performance can be expected at design operating conditions.

Shaft seal oil leaks developed in two of the sodium pumps during the test. In one case, secondary pump No. 1, the leak ceased after a period of time; but the leak in primary pump No. 2 still exists.

The cause of this leakage cannot be determined until the seal is disassembled and inspected. Prior to this test an upper seal on primary pump No. 3 developed a leak. The seal was disassembled and it was found that the sealing surfaces were rough due to improper machining during the seal fabrication. New O-rings were installed and the seal returned to service. Since that time no leakage has resulted from this seal.

Based on this experience, it is speculated that this is also the problem with the other two pumps and that secondary pump No. 1 sealed as a result of extensive run-in. Primary pump No. 2 will undoubtedly require disassembly to correct the problem, but it is expected that a permanent repair will be accomplished.

Excessively low sodium levels in the primary pump cases have resulted when the pumps have been operated at the higher flow rates (60 to 100 percent of full flow) with less than design pressure differential across the pump. Under normal operating conditions, the sodium leakage across the wear rings to the upper side of the impeller is greater than the flow back through the impeller pressure balancing

holes. This provides an upward flow through the hydrodynamic bearing into the pump case and a constant operating level is maintained by means of the case overflow. Apparently, under certain conditions this flow relationship across the impeller is upset and sodium is drawn from the case, resulting in a low level condition. This condition was considered to be outside the normal operating range and was not checked out to determine the system conditions where the anomaly occurs. It is conceivable that the actual pressure drop across the loaded core will be less than the calculated value. (In the case of two-loop operation, the pressure drop will certainly be less.) In either or both of these cases, it is possible that the primary throttle valve will have to be throttled during normal operation to provide the required head conditions. It is therefore recommended that after the core is loaded, a hydraulic test be performed which will define this condition and provide a basis for a change in system operation if required.

An independent investigation of the high pitched squeal detected in the pumps indicates that this squeal is speed dependent and is not affected by flow or pressure differential. At speeds of 400 rpm in the secondary pumps and 500 rpm in the primary pumps, the noise reached a maximum level. At speeds higher and lower than those noted above, the noise becomes intermittent and finally ceases approximately 50 rpm above and below this point.

There are several theories as to the cause of the squeal, such as:

- 1) Hydraulic whistle
- 2) Bearing or seal face rubbing
- 3) Preheat furnace vibrating and rubbing on the outside of the pump case.

This condition has been investigated extensively, but at this time there is nothing to substantiate any of these

theories. The noise has existed since the pumps were first placed in operation and has not worsened with time or increased temperature. Since no obvious detrimental effects have resulted after extended operation, it must be assumed that this condition is not serious, unless further developments prove otherwise.

E. CORE ALIGNMENT

The successful insertion and removal of a mock fuel element in three peripheral core channels is considered a satisfactory test of core alignment. An investigation of the hang up of the mock fuel element in two of the three channels indicates that this condition is apparently not a result of core misalignment. A check of the test data indicates the point of hang up occurred at 169-1/2 inches out of the reactor. At this point, the top of the element process tube disconnect sleeve is at the same elevation as the bottom of the top shield. This corresponds to the point of hang up experienced during the removal of the fuel elements following the dry critical experiment.

Upon completion of the core alignment test, the mock fuel element was visually inspected and it was found that the sleeve had been modified (by chamfering the top edge of the sleeve). The top of the sleeve was well chamfered, but there was sufficient diametric clearance to allow the sleeve to slip to one side and project beyond the hanger tube. A drawing check of the sleeve and associated components indicates that under the most adverse combination of tolerances, the sleeve could project 0.047 inches. During future removal of these elements some hang up will undoubtedly be experienced, regardless of the reactor temperature conditions. It

does not appear that any element damage could result from such a hang up. To relieve this condition simply requires cycling the grapple up and down once or twice. At worst, this condition is only a minor inconvenience. Nevertheless, for future core loadings it is recommended that the disconnect mechanism be redesigned to eliminate this inconvenience.

F. CONTROL RODS

All 19 control rods were subjected to the same mechanical check out as was performed during the control rod preoperational test AI-P-1145. Rod drop times, latch release time, etc. compare well with the preoperational test data and are well within the limits set forth in HNPF Technical Specifications.

APPENDIX A
EQUIPMENT MAINTAINED AT 350F DURING
HOT CIRCULATION TESTING

Preheat System	Switch	Equipment or Line	Circuit Breaker
"B"	120	H-401, Carbon Trap Heater	C-304-A
"F"	1,2, and 3	Line 211, fill & drain line, secondary loop No. 3	C-307-A
"F"	4,5,6, and 7	Drain line, secondary loop No. 3	C-307-A
"F"	8 thru 24	Line 183 & V-499 - Secondary sodium line drain header	C-307-A
"F"	25,26, and 27	Line 108 & V-490 and Secondary Na fill tank No. 1 inlet line from sodium supply header	C-507-A
"F"	28,29, and 30	Line 109 & V-492 and Secondary Na fill tank No. 2 inlet line from sodium supply header	C-507-A
"F"	31 thru 34	Line 110 & V-494 - Secondary Na fill tank No. 3 inlet line from Na supply header	C-507-A
"F"	35	T-410 - Secondary Na fill tank No. 1	42-A-205
"F"	36	T-411 - Secondary Na fill tank No. 2	42-A-210
"F"	37	T-412 - Secondary Na fill tank No. 3	42-A-215
"F"	38,39, and 40	Line 178 & V-491 - Secondary Na fill tank No. 1 drain line	C-507-A

APPENDIX A - Continued

Preheat System	Switch	Equipment or Line	Circuit Breaker
"F"	41,42, and 43	Line 179 & V-493 - Secondary Na fill tank No. 2 drain line	C-507-A
"F"	44,45, and 46	Line 180 & V-495 - Secondary Na fill tank No. 3 drain line	C-507-A
"F"	47,48,49, and 50	Line 181 - Drain header. Secondary Na fill tank to secondary Na service pump	C-507-A
"F"	51	P-403-Secondary Na service pump header	C-507-A
"F"	52 thru 57	Secondary Na fill & drain header (cold trap supply)	C-507-A C-507-B
"F"	58 thru 61	Line 192 & V-4104 - Fill & drain line - secondary loop No. 1	C-307-B
"F"	62 thru 65	Line 198 & V-4105 - Fill & drain line - secondary loop No. 2	C-307-B
"F"	66 thru 72	Line 204 & V-4106 - Fill & drain line - secondary loop No. 3	C-307-B
"F"	73	Line 184 & V-498 - Cross connect between Na fill & drain header	C-307-B
"F"	74,75, and 76	Line 185 & V-498 - Cross connect between secondary Na fill tank inlet & outlet headers	C-307-B

APPENDIX A - Continued

Preheat System	Switch	Equipment or Line	Circuit Breaker
"F"	77, 78, and 79	Line 187 & V-496 & V-497 - Drain to secondary Na service drain tank from Na fill tank outlet header	C-307-B
"F"	80	Secondary Na service drain tank	42-A-211
"F"	81 thru 84	Secondary Na line to plugging meter	C-307-B
"F"	85	X-406 - Secondary Na plugging meter economizer	C-307-B
"F"	86	X-403 - Secondary Na plugging meter cooler	C-307-B
"F"	87	P.M. 403 - Secondary sodium plugging meter	C-307-B
"F"	88, 89, and 90	Secondary sodium return line from plugging meter	C-307-B
"F"	91 thru 95	Secondary sodium line to cold trap	C-307-B
"F"	96	CT-403 - Secondary sodium cold trap	52-A-201-A
"F"	97 thru 100	Line 214 & V-452 - Secondary sodium line from cold trap	C-507-B
"J"	1 thru 6	Line 177 & V-107 - Primary Na pump No. 1 vent	C-502-A
"J"	8	Spare	Spare
"J"	13	Spare	Spare

APPENDIX A - Continued

Preheat System	Switch	Equipment or Line	Circuit Breaker
"J"	14 thru 22	Line 186 & V-207 - vent line from pri. pump No. 2	C-502-A
"J"	24	Spare	Spare
"J"	29	Spare	Spare
"J"	30 thru 40	Vent line from primary pump No. 3 to reactor, line 188 & V-307	C-302-B
"J"	42	Spare	Spare
"J"	47	Spare	Spare
"J"	48 thru 52	Line 217 - Vent line, secondary pump No. 1 to expansion tank	C-502-B
"J"	56 thru 60	Line 303 - Vent line, secondary pump No. 2 to expansion tank	C-502-B
"J"	64 thru 68	Line 304 - Vent line, secondary pump No. 3 to expansion tank	C-303-A C-502-B
"J"	72	T-404 - Primary sodium fill tank No. 4	42-B-209
"J"	73	P-401 - Primary Na service pump No. 1 - headers	C-303-A
"J"	74	P-402 - Primary Na service pump No. 2 - headers	C-303-A

PREPARED BY:	ATOMICS INTERNATIONAL A DIVISION OF NORTH AMERICAN AVIATION, INC. Appendix B	PAGE NO. 1 OF 8
CHECKED BY:		REPORT NO.
DATE 6-26-62		MODEL NO.
SPRING HANGER ADJUSTMENT DATA		

Hanger Number (Test)	Pipe Line Number	Area	Hanger Number (Constr)	Nature of Pipe	Operating Temp. (F)	Load @ 340° F With Na	Load @ 540° F With Na	Displacement From 340° To 540° F	Linearly Extrapa- lated Load @ Oper. Temperature	Desired Calcu- lated Load @ Oper. Temperature	Load	Corrected Load@ 340°F (Final Setting)	LEGEND:				
						ins lbs	ins lbs	ins lbs	lbs	lbs	lbs	lbs		+ Down	- Up		
1000	270		157A	HS	900°	2 2900	1 7/8 2800	-1/8 -100	2620	2900	-280	3180		0	No Movement Or		
1001	270		157	HS	900°	3 2600	2 5/8 2500	-3/8 -100	2320	2600	-280	2880		Less Than 1/8"			
1003	312		20"Line#1	20"Line#1	830°	1 3/4 2700	1 1/2 2600	-1/4 -100	2455	2700	-245	2945		Observed Or			
1004	209		155B	SS	340°	1 7/8 690	1 7/8 690	0 0	—	690	—	—		Theoretically			
1005	312		20"Line#1	20"Line#1	830°	2 3/8 3150	2 1/4 3000	-1/8 -150	2783	3150	-367	3517		Expected.			
1006	209		155A	SS	340°	2 1/2 210	2 1/2 210	0 0	—	210	—	—		-- Measurement Is Not			
1007	209		155C	SS	340°	2 180	2 1/4 190	+1/4 +10	—	180	—	—		Practical Or Does			
1008	267		156B	HS	900°	2 3/4 800	2 3/4 800	0 0	800	800	0	800		Not Represent			
1009	267		156B	HS	900°	2 3/4 800	2 3/4 800	0 0	800	800	0	800		Pipe Movement			
1010	270		158A	HS	900°	1 3/4 2070	1 3/4 2070	0 0	2070	2070	0	2070					
1011	267		156A	HS	900°	2 3/4 800	2 7/8 820	+1/8 +20	856	800	+56	744	NOTES:				
1012	267	Steam	156A	HS	900°	2 3/4 800	2 7/8 825	+1/8 +25	870	800	+70	730	1. Load Correction =				
1013	264	Generator	156	HS	900°	2 3/8 1630	2 3/8 1630	0 0	1630	1630	0	1630	Extrapolated Load At				
1014	264	Room #1	155	HS	900°	5 1/4 3250	4 7/8 3150	-3/8 -100	2970	3250	-280	3530	Operating Temperature				
1015	264		154B	HS	900°	1 1/4 850	1 800	-1/4 -50	710	850	-140	990	Minus (-) Desired				
1016	276		159	AS	340°	2 140	2 140	0 0	—	140	—	—	Calculated Load At				
1017	217		188	AS	340°	1 1/2 90	1 1/4 85	-1/4 -5	—	90	—	—	Operating Temperature				
1018	217		188	AS	340°	1 1/2 90	1 1/4 85	-1/4 -5	—	90	—	—					
1019	217		187	AS	340°	2 170	1 7/8 160	-1/8 -10	—	170	—	—	2. Corrected Load At 340° =				
1020	306		160C	AS	340°	2 375	2 375	0 0	—	375	—	—	Load At 340° - Load				
1021	306		160C	AS	340°	2 375	2 375	0 0	—	375	—	—	Correction.				
1022	306		160C	AS	340°	2 3/8 205	2 1/2 210	+1/8 +5	—	205	—	—					
1023	306		160B	AS	340°	2 3/8 205	2 1/2 210	+1/8 +5	—	205	—	—	3. Nature:				
1024	293		160	AS	340°	2 1/4 60	2 1/4 60	0 0	—	60	—	—	AP Auxiliary Primary				
1025	293		160	AS	340°	2 1/4 60	2 1/2 65	+1/4 +5	—	60	—	—	AS Auxiliary Secondary				
1026	290		159B	AS	340°	5/8 50	3/8 47	-1/4 -3	—	50	—	—	HP Hot Primary				
1027	290		159B	AS	340°	5/8 50	1/8 45	-1/2 -5	—	50	—	—	HS Hot Secondary				
													CP Cold Primary				
1028	192		174	SS	340°	3 230	3 3/8 240	+3/8 +10	—	230	—	—	CS Cold Secondary				
1029	273		182	CS	557°	1 7/8 4100	2 4200	+1/8 +100	4208	4100	+108	3992	SP Service Primary				
1030	273		181	CS	557°	1 510	1 1/8 535	+1/8 +25	537	510	+27	483	SS Service Secondary				
1031	194	Nitrogen	175	SS	340°	1 1/2 240	1 1/2 240	0 0	—	240	—	—					
1032	264	Cooling	180D	HS	900°	2 1/4 1600	2 3/8 1620	+1/8 +20	1656	1600	+56	1544					
1033	264	Area #1	180D	HS	900°	2 3/4 1760	2 7/8 1800	+1/8 +40	1872	1760	+112	1648					
1034	264		180C	HS	900°	1 1/2 1210	1 1/2 1210	0 0	1210	1210	0	1210					
1035	209		176	SS	340°	1 1/2 330	1 5/8 340	+1/8 +10	—	330	—	—					
1036	192		174A	SS	340°	3 230	3 1/4 235	+1/4 +5	—	230	—	—					

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Hanger Number (Test)	Pipe Line Number	Area	Hanger Number (Constr)	Nature of Pipe	Operating Temp. (F)	Load @ 340° F With Na	Load @ 540° F With Na	Displacement From 340° To 540°	Linearly Extrapolated Load @ Oper. Temperature	Desired Calculated Load @ Oper. Temperature	Load Correction	Corrected Load @ 340° F (Final Setting)	LEGEND:	
						ins lbs	ins lbs	ins lbs	lbs	lbs	lbs	lbs		+ Down - Up
1037	318		878	SP	340°	2 1/8 195	2 1/8 195	0 0	—	195	—	—		0 No Movement Or
1038	234		866	HP	945°	2 1/4 1540	2 1/4 1575	0 +35	1643	1540	+103	1437		Less Than 1/8"
1039	231		865	HP	945°	2 3/4 1710	2 7/8 1775	+1/8 +65	1904	1710	+196	1514		Observed Or
1040	196		881	AP	340°	1 1/2 300	1 5/8 325	+1/8 +25	—	300	—	—		Theoretically
1041	207		883	AP	340°	3 1/4 460	3 3/8 470	+1/8 +10	—	460	—	—		Expected.
1042	177		880	AP	340°	2 1/4 60	2 1/4 60	0 0	—	60	—	—		-- Measurement Is Not
1043	177		880	AP	340°	2 1/4 60	2 1/4 60	0 0	—	60	—	—		Practical Or Does
1044	196		882	AP	340°	1 5/8 330	1 5/8 330	0 0	—	330	—	—		Not Represent
1045	237		868A	CP	602°	2 3/8 850	2 3/8 850	0 0	850	850	0	850		Pipe Movement
1046	237		384A	CP	602°	1 1000	1 1000	0 0	1000	1000	0	1000		
1047	231		379	HP	945°	1 1000	1 1000	0 0	1000	1000	0	1000	NOTES:	
1048	207		884	AP	340°	3 1/4 460	3 1/4 460	0 0	—	460	—	—	1. Load Correction =	
1049	231		864	HP	945°	2 1470	2 1470	0 0	1470	1470	0	1470	Extrapolated Load At	
1050	231		864A	HP	945°	2 2800	2 2800	0 0	2800	2800	0	2800	Operating Temperature	
1051	234		866A	HP	945°	3 1200	3 1200	0 0	1200	1200	0	1200	Minus (-) Desired	
1052	243	IHX	863	CP	602°	7/8 1400	7/8 1425	0 +25	1433	1400	+33	1367	Calculated Load At	
1053	237	Cell	868	CP	602°	2 1/2 2900	2 1/8 2900	0 0	2900	2900	0	2900	Operating Temperature	
1054	255	#1	862	CS	557°	7/8 960	3/4 900	-1/8 -60	895	960	-65	1025		
1055	254		873	CS	557°	1 7/8 960	1 3/4 950	-1/8 -10	949	960	-11	971	2. Corrected Load At 340° =	
1056	242		871	CP	602°	7/8 1400	7/8 1400	0 0	1400	1400	0	1400	Load at 340° - Load	
1057	273		869	CS	557°	2 2300	2 2200	0 -100	2192	2300	-108	2408	Correction	
1058	254		872	CS	557°	2 1/8 1840	2 1800	-1/8 -40	1793	1840	-43	1883		
1059	255		861	CS	557°	2 1/8 1840	2 1/8 1840	0 0	1840	1840	0	1840	3. Nature:	
1060	264		869	HS	900°	2 1/4 2300	2 2200	-1/4 -100	2020	2300	-280	2580	AP Auxiliary Primary	
1061	253		861	HS	900°	1 1/4 1840	1 1725	-1/4 -115	1518	1840	-322	2162	AS Auxiliary Secondary	
1062	253		862	HS	900°	1 7/8 960	1 1/2 900	-3/8 -60	792	960	-168	1128	HP Hot Primary	
1063	264		875	HS	900°	1 1/4 1810	1 1775	-1/4 -35	1714	1810	-96	1906	HS Hot Secondary	
1064	252		873	HS	900°	1 7/8 960	1 1/2 900	-3/8 -60	792	960	-168	1128	CP Cold Primary	
1065	252		872	HS	900°	1 1/4 1840	1 1700	-1/4 -140	1449	1840	-391	2231	CS Cold Secondary	
1066	240		874	HP	945°	5 1/2 1700	5 1640	-1/2 -60	1518	1700	-182	1882	SP Service Primary	
1067	234		867A	HP	945°	3 7/8 2830	3 1/2 2750	-3/8 -80	2588	2830	-242	3072	SS Service Secondary	
1068	241		860	HP	945°	1 3/4 1700	1 1/4 1575	-1/2 -125	1323	1700	-377	2077		
1069	234		867	HP	945°	2 1/4 2400	1 3/4 2250	-1/2 -150	1946	2400	-454	2854		
1070	297		877	AS	340°	2 1/4 200	1 7/8 185	-3/8 -15	—	200	—	—		
1071	293		877A	AS	340°	2 140	1 3/4 135	-1/4 -5	—	140	—	—		
1072	264		180B	HS	900°	2 3/8 1625	2 1/4 1600	-1/8 -25	1555	1625	-70	1695		
1073	264		180A	HS	900°	2 1/2 780	2 3/8 750	-1/8 -30	696	780	-84	864		

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Hanger Number	Pipe Line	Area	Hanger Number	Nature of Pipe	Operating Temp. (F)	Lead @ 340° F With Na	Lead @ 540° F With Na	Displacement From 340° to 540°	Linearly Extrapolated Lead @ Oper. Temperature	Desired Calculated Lead @ Oper. Temperature	Load Correction	Corrected Load @ 340° F (Final Setting)	LEGEND:	
(Test)	Number		(Constr)			ins lbs	ins lbs	ins lbs	lbs	lbs	lbs	lbs		+ Down - Up
1074	273	Microfilm Cooling	182A	CS	557°	2 1/8 1550	2 1/2 1625	+3/8 +75	1631	1550	+81	1469	0	No Movement Or Less Than 1/8"
1075	273	Area #1	182A	CS	557°	2 1/8 1550	2 3/8 1625	+1/4 +75	1631	1550	+81	1469		Observed Or Theoretically Expected
1076	224		506	SP	340°	2 1/4 180	2 1/4 180	0 0	180	180	0	180	--	Measurement Is NOT Practical Or Does Not Represent Pipe Movement
1077	231		505	HP	945°	2 3/8 2330	2 3/8 2330	0 0	—	2330	—	—		
1078	231	Primary	504	HP	945°	3 1/8 2660	3 1/8 2660	-1/4 0	2660	2660	0	2660		
1079	136	Pipeway	501A	SP	340°	3 1/4 330	3 1/4 330	0 0	330	330	0	330		
1080	136		501B	SP	340°	1 3/4 310	1 7/8 350	+1/8 +40	—	310	—	—		
1081	136		500C	SP	340°	2 1/4 185	2 1/4 185	0 0	—	185	—	—		
2000	201		470	AP	340°	1 1/2 300	1 1/2 300	0 0	—	300	—	—	NOTES:	
2001	319		479	SP	340°	2 1/4 200	2 1/4 200	0 0	—	200	—	—	1. Load Correction =	
2002	201		471	AP	340°	1 5/8 330	1 5/8 330	0 0	—	330	—	—	Extrapolated Load At	
2003	238		465A	CP	602°	2 3/8 850	2 3/8 850	0 0	850	850	0	850	Operating Temperature	
2004	238		416B	CP	602°	1 1000	7/8 975	-1/8 -25	967	1000	-33	1033	Minus (-) Desired	
2005	232		403	HP	945°	1 1000	1 1000	0 0	—	1000	—	—	Calculated Load At	
2006	208		474	AP	340°	3 1/8 460	3 1/4 465	+1/8 +5	—	460	—	—	Operating Temperature	
2007	208		475	AP	340°	3 1/8 460	3 1/4 465	+1/8 +5	—	460	—	—		
2008	232		437A	HP	945°	2 1/4 2990	2 1/4 2990	0 0	2990	2990	0	2990	2. Corrected Load At 340° =	
2009	232		437	HP	945°	1 7/8 1470	2 1490	+1/8 +20	1530	1470	+60	1410	Load at 340° - Load	
2010	232		436	HP	945°	2 3/4 1710	2 3/4 1710	0 0	1710	1710	0	1710	Correction	
2011	235		438	HP	945°	2 1/4 1540	2 1/4 1540	0 0	1540	1540	0	1540		
2012	235	THX	438A	HP	945°	3 1200	3 1/8 1220	+1/8 +20	1260	1200	+60	1140	3. Nature:	
2013	186	Cell	468	AP	340°	2 1/4 60	2 1/4 60	0 0	—	60	—	—	AP Auxiliary Primary	
2014	186	#2	468	AP	340°	2 1/4 60	2 1/4 60	0 0	—	60	—	—	AS Auxiliary Secondary	
2015	247		444	CP	602°	3/4 1400	3/4 1400	0 0	1400	1400	0	1400	HP Hot Primary	
2016	238		449	CP	602°	2 1/2 2900	2 1/2 2900	0 0	2900	2900	0	2900	HS Hot Secondary	
2017	246		443	CP	602°	3/4 1400	3/4 1400	0 0	—	1400	—	—	CP Cold Primary	
2018	258		445	CS	557°	2 1/8 1840	2 1/8 1840	0 0	1840	1840	0	1840	CS Cold Secondary	
2019	274		449	CS	557°	2 2300	2 2300	0 0	2300	2300	0	2300	SP Service Primary	
2020	258		445A	CS	557°	2 1/4 960	2 1/8 950	-1/8 -10	949	960	-11	971	SS Service Secondary	
2021	259		446A	CS	557°	2 1/4 960	2 1/8 950	-1/8 -10	949	960	-11	971		
2022	259		446	CS	557°	2 1/8 1840	2 1800	-1/8 -40	1797	1840	-43	1883		
2023	257		446	HS	900°	6 1/4 1840	6 1800	-1/4 -40	1728	1840	-112	1952		
2024	257		446A	HS	900°	1 3/4 960	1 5/8 900	-1/8 -60	792	960	-168	1128		
2025	245		442	HP	945°	5 3/8 1700	4 7/8 1625	-1/2 -75	1473	1700	-227	1927		
2026	265		449	HS	900°	2 1/4 2300	2 2200	-1/4 -100	2020	2300	-280	2580		

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Appendix B

SPRING HANGER ADJUSTMENT DATA

Hanger Number	Pipe Line	Area	Hanger Number	Nature of Pipe	Operating Temp. (F)	Load @ 340° F With Na	Load @ 540° F With Na	Displacement From 340° to 540°	Linearly Extrapolated Load @ Operating Temperature	Desired Calculated Load @ Operating Temperature	Load Correction	Corrected Load @ 340° F (Final Setting)	LEGEND:	
(Test)	Number		(Constr)			ins lbs	ins lbs	ins lbs	lbs	lbs	lbs	lbs		+ Down - Up
2027	265		450	HS	900°	3 1810	2 7/8 1780	-1/8 -30	1726	1810	-84	1894	0	No Movement Or
2028	256		445A	HS	900°	1 7/8 960	1 1/2 900	-3/8 -60	792	960	-168	1128		Less Than 1/8"
2029	244		441	HP	945°	5 3/8 1700	4 7/8 1625	-1/2 -75	1473	1700	-227	1927		Observed Or
2030	256		445	HS	900°	6 1/4 1840	6 1800	-1/4 -40	1728	1840	-112	1952		Theoretically
2031	235		439	HP	945°	5 1/8 2400	4 5/8 2310	-1/2 -90	2128	2400	-272	2672		Expected.
2032	235		440	HP	945°	3 7/8 2830	3 1/2 2750	-3/8 -80	2588	2830	-242	3072	--	Measurement Is Not
2033	299	IHX	478	AS	340°	2 1/4 200	2 190	-1/4 -10	—	200	—	—		Practical Or Does
2034	294	Cell	466	AS	340°	2 140	1 7/8 135	-1/8 -5	—	140	—	—		Not Represent
2035	264	#2	277A	HS	900°	2 1/4 780	2 1/4 780	0 0	780	780	0	780		Pipe Movement
2036	265		277B	HS	900°	2 1/2 1625	2 1/2 1625	0 0	1625	1625	0	1625		
														NOTES:
2037	198		272	SS	340°	1 7/8 260	2 1/8 270	+1/4 +10	—	260	—	—	1.	Load Correction =
2038	274		279A	CS	557°	2 1/4 1550	2 1/2 1650	+1/4 +100	1658	1550	+108	1442		Extrapolated Load At
2039	274		279A	CS	557°	2 1/4 1550	2 1/2 1650	+1/4 +100	1658	1550	+108	1442		Operating Temperature
2040	274		279	CS	557°	1 7/8 4100	2 4200	+1/8 +100	4210	4100	+110	3990		Minus (-) Desired
2041	198	Nitrogen	271	SS	340°	2 1/2 220	2 1/2 220	0 0	—	220	—	—		Calculated Load At
2042	274	Cooling	278	CS	557°	1 510	1 1/8 525	+1/8 +15	526	510	+16	494		Operating Temperature
2043	265	Area #2	277C	HS	900°	2 1/2 1670	2 3/4 1700	+1/4 +30	1754	1670	+84	1754		
2044	265		277C	HS	900°	2 5/8 1690	2 5/8 1690	0 0	1690	1690	0	1690	2.	Corrected Load At 340° =
2045	200		274	SS	340°	1 3/4 250	1 3/4 250	0 0	—	250	—	—		Load at 340° - Load
2046	265		277H	HS	900°	1 1/2 1210	1 1/2 1210	0 0	—	1210	—	—		Correction
2047	210		276C	SS	340°	3 1/2 350	3 1/2 350	0 0	—	350	—	—		
														3. Nature:
2048	271		263A	HS	900°	2 2900	1 3/4 2800	-1/4 -100	2620	2900	-280	3180		AP Auxiliary Primary
2049	271		263	HS	900°	3 2600	2 5/8 2500	-3/8 -100	2320	2600	-280	2880		AS Auxiliary Secondary
2050	313	Steam	20"Line#2	20"Line#2	830°	1 5/8 2700	1 5/8 2700	0 0	2700	2700	0	2700		HP Hot Primary
2051	313	Generator	20"Line#2	20"Line#2	830°	2 3/8 3150	2 1/4 2900	-1/8 -250	2540	3150	-610	3760		HS Hot Secondary
2052	210	Room #2	268A	SS	340°	1 7/8 690	1 3/4 650	-1/8 -40	—	690	—	—		CP Cold Primary
2053	210		268B	SS	340°	2 1/8 190	2 1/8 190	0 0	—	190	—	—		CS Cold Secondary
2054	210		268C	SS	340°	1 7/8 160	2 170	+1/8 +10	—	160	—	—		SP Service Primary
2055	294		269	AS	340°	2 1/4 60	2 1/4 60	0 0	—	60	—	—		SS Service Secondary
2056	294		269	AS	340°	2 1/4 60	2 1/4 60	0 0	—	60	—	—		
2057	307		273H	AS	340°	2 375	2 375	0 0	—	375	—	—		
2058	307		273H	AS	340°	2 325	2 1/8 390	+1/8 +15	—	375	—	—		
2059	268		262B	HS	900°	2 7/8 840	3 850	+1/8 +10	868	800	+28	772		
2060	268		262B	HS	900°	2 1/2 770	2 5/8 780	+1/8 +10	798	800	+28	772		
2061	265		260A	HS	900°	2 1/2 1650	2 7/8 1600	-1/8 -50	1510	1650	-140	1790		

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Hanger Number (Test)	Pipe Line Number	Area	Hanger Number (Constr)	Nature of Pipe	Operating Temp. (F)	Load @ 340° F With Na	Load @ 540° F With Na	Displacement From 340° to 540°	Linearly Extrapolated Load @ Operating Temperature	Desired Calculated Load @ Operating Temperature	Load Correction	Corrected Load @ 340° F (Final Setting)	LEGEND:
						ins lbs	ins lbs	ins lbs	lbs	lbs	lbs	lbs	+ Down - Up 0 No Movement Or Less Than 1/8" Observed Or Theoretically Expected. -- Measurement Is Not Practical Or Does Not Represent Pipe Movement
2062	265		260	HS	900°	5 1/4 3250	4 3/4 3150	-1/2 -100	2970	3250	-280	3530	
2063	265		260B	HS	900°	2 1000	1 5/8 930	-3/8 -70	808	1000	-192	1192	
2064	271		264A	HS	900°	1 3/4 2070	1 3/4 2070	0 0	2070	2070	0	2070	
2065	268		262A	HS	900°	2 5/8 800	2 3/4 810	+1/8 +10	814	800	+14	786	
2066	268		262A	HS	900°	2 5/8 800	2 3/4 810	+1/8 +10	814	800	+14	786	
2067	277	Steam	267	AS	340°	2 140	1 7/8 138	-1/8 -2	—	140	—	—	
2068	303	Generator	282	AS	340°	1 1/2 90	1 1/4 86	-1/4 -4	—	90	—	—	
2069	303	Room #2	282	AS	340°	1 1/2 90	1 1/4 86	-1/4 -4	—	90	—	—	
2070	303		283	AS	340°	2 170	1 7/8 160	-1/8 -10	—	170	—	—	
2071	291		268H	AS	340°	2 70	2 70	0 0	—	76	—	—	
2072	291		268H	AS	340°	2 70	2 70	0 0	—	70	—	—	NOTES:
													1. Load Correction = Extrapolated Load At Operating Temperature Minus (-) Desired Calculated Load At Operating Temperature
2073	232		640	HP	945°	1 5/8 2730	1 5/8 2730	0 0	2730	2730	0	2730	
2074	232	Primary	648	HP	945°	1 3/8 2570	1 1/4 2500	-1/8 -70	2358	2570	-212	2782	
2075	225	Pipeway	509	SP	340°	2 1/4 190	2 1/4 190	0 0	—	190	—	—	
2076	186		500D	AP	340°	2 3/8 200	2 3/8 200	0 0	—	200	—	—	
													2. Corrected Load At 340° = Load at 340° - Load Correction
3000	272		265A	HS	900°	2 2900	1 3/4 2800	-1/4 -100	2620	2900	-280	3180	
3001	272		265	HS	900°	3 2600	2 3/4 2550	-1/4 -50	2460	2600	-140	2740	3.
3002	211	Steam	268E	SS	340°	1 1/2 240	1 1/2 240	0 0	—	240	—	—	Nature:
3003	211	Generator	268D	SS	340°	2 3/4 310	2 3/4 310	0 0	—	310	—	—	AP Auxiliary Primary
3004	314	Room #3	20"Line#3	20"Line#3	830°	1 1/2 2700	1 1/2 2600	0 -100	2455	2700	-245	2945	AS Auxiliary Secondary
3005	211		268F	SS	340°	2 3/8 210	2 1/4 200	-1/8 -10	—	210	—	—	HP Hot Primary
3006	211		268G	SS	340°	2 3/4 250	2 7/8 250	0 0	—	250	—	—	HS Hot Secondary
3007	295		270	AS	340°	2 1/4 60	2 1/4 60	0 0	—	60	—	—	CP Cold Primary
3008	295		270	AS	340°	2 1/4 60	2 1/4 60	0 0	—	60	—	—	CS Cold Secondary
3009	314		20"Line#3	20"Line#3	830°	2 3/8 3150	2 1/4 3050	-1/8 -100	2905	3150	-245	3395	SP Service Primary
3010	269		262D	HS	900°	2 3/4 800	2 7/8 810	+1/8 +10	828	800	+28	772	SS Service Secondary
3011	269		262D	HS	900°	2 1/2 780	2 3/4 800	+1/4 +20	836	800	+36	744	
3012	266		262	HS	900°	2 1/2 1650	2 3/8 1600	-1/8 -50	1510	1650	-140	1790	
3013	266		261	HS	900°	5 1/4 3250	4 3/4 3125	-1/2 -125	—	3250	—	—	
3014	266		261A	HS	900°	2 1000	1 3/4 950	-1/4 -50	860	1000	-140	1140	
3015	272		266A	HS	900°	1 3/4 2070	1 3/4 2100	0 +30	2154	2070	+84	1986	
3016	269		262C	HS	900°	2 3/4 800	2 7/8 830	+1/8 +30	884	800	+84	716	

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DATE 6-26-68		MODEL NO

Hanger Number	Pipe Line	Area	Hanger Number	Nature of Pipe	Operating Temp. (F)	Load @ 340° F With Na	Load @ 540° F With Na	Displacement From 340° to 540°	Linearly Extrapolated Load @ Operating Temperature	Desired Calculated Load @ Operating Temperature	Load Correction	Corrected Load @ 340° F (Final Setting)	LEGEND:
(Test)	Number		(Constr)			ins lbs	ins lbs	ins lbs	lbs	lbs	lbs	lbs	+ Down
3017	269		262C	HS	900°	2 3/4 800	2 7/8 825	+1/8 +25	870	800	+70	730	0 No Movement Or
3018	278		268	AS	340°	2 140	1 3/4 130	-1/4 -7	—	140	—	—	Less Than 1/8"
3019	304	Steam	284	AS	340°	1 1/2 90	1 1/4 85	-1/4 -5	—	90	—	—	Observed Or
3020	304	Generator	284	AS	340°	1 1/2 90	1 1/4 85	-1/4 -5	—	90	—	—	Theoretically
3021	304	Room #3	285	AS	340°	2 170	1 3/4 160	-1/4 -10	—	170	—	—	Expected
3022	292		268K	AS	340°	1/2 50	1/2 48	0 -2	—	50	—	—	-- Measurement Is Not
3023	292		268K	AS	340°	1/2 50	3/8 47	-1/8 -3	—	50	—	—	Practical Or Does
													Not Represent
3024	204		276	SS	340°	1 3/4 250	1 7/8 260	+1/8 +10	—	250	—	—	Pipe Movement
3025	275		281A	CS	557°	2 1/4 1550	2 1/2 1650	+1/4 +100	1658	1550	+108	1442	
3026	275		281A	CS	557°	2 1/4 1550	2 1/2 1650	+1/4 +100	1658	1550	+108	1442	NOTES:
3027	211		276D	SS	340°	3 3/4 500	3 7/8 510	+1/8 +10	—	500	—	—	1. Load Correction =
3028	266		277F	HS	900°	1 1/2 1210	1 1/2 1200	0 -10	1182	1210	-28	1238	Extrapolated Load At
3029	206	Nitrogen	277	SS	340°	1 3/4 260	1 7/8 260	+1/8 +10	—	250	—	—	Operating Temperature
3030	275	Cooling	280	CS	557°	1 510	1 1/4 530	+1/4 +20	531	510	+21	489	Minus (-) Desired
3031	266	Area #3	277G	HS	900°	2 3/8 1625	2 1/2 1650	+1/8 +25	1691	1680	+66	1614	Calculated Load At
3032	266		277G	HS	900°	2 3/8 1625	2 3/4 1725	+3/8 +100	1900	1680	+220	1405	Operating Temperature
3033	275		281	CS	557°	1 7/8 4100	2 4200	+1/8 +100	4208	4100	+108	3992	
3034	204		275	SS	340°	3 250	3 260	0 +10	—	250	—	—	2. Corrected Load At 340° =
													Load at 340° -- Load
													Correction
3035	202		472	AP	340°	1 5/8 330	1 5/8 330	0 0	—	330	—	—	
3036	320		480	SP	340°	2 1/8 195	2 1/8 195	0 0	—	195	—	—	
3037	202		473	AP	340°	1 5/8 330	1 5/8 330	0 0	—	330	—	—	3. Nature:
3038	239		465B	CP	602°	2 3/8 875	2 3/8 900	0 +25	905	850	+30	820	AP Auxiliary Primary
3039	239	IHX	421B	CP	602°	1 1000	1 1000	0 0	1000	1000	0	1000	AS Auxiliary Secondary
3040	233	Cell	408	HP	945°	1 1000	1 1000	0 0	1000	1000	0	1000	HP Hot Primary
3041	233	#3	452A	HP	945°	2 1/4 2990	2 1/4 2990	0 0	2990	2990	0	2990	HS Hot Secondary
3042	233		452	HP	945°	1 3/4 1420	1 7/8 1475	+1/8 +55	1552	1470	+132	1338	CP Cold Primary
3043	233		451	HP	945°	2 5/8 1700	2 7/8 1750	+1/4 +50	1850	1710	+150	1560	CS Cold Secondary
3044	212		476	AP	340°	3 1/4 460	3 1/2 475	+1/4 +15	—	460	—	—	SP Service Primary
3045	212		477	AP	340°	3 1/4 460	3 1/4 460	0 0	—	460	—	—	SS Service Secondary
3046	188		469	AP	340°	2 5/8 70	2 5/8 70	0 0	—	70	—	—	
3047	188		469	AP	340°	2 5/8 70	2 5/8 70	0 0	—	70	—	—	
3048	236		455	HP	945°	2 1/8 1540	2 1/4 1560	+1/8 +20	1600	1540	+60	1480	
3049	236		455A	HP	945°	3 1200	3 1/8 1225	+1/8 +25	1275	1200	+75	1125	
3050	251		459	CP	602°	3/4 1400	7/8 1425	+1/8 +25	1433	1400	+33	1367	
3051	239		464	CP	602°	2 2300	2 2300	0 0	2300	2300	0	2300	

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DATE: 6-26-62		MODEL NO.

Hanger Number (Test)	Pipe Line Number	Area	Hanger Number (Constr)	Nature of Pipe	Operating Temp. (F)	Load @ 340°F With Na	Load @ 540°F With Na	Displacement From 340° to 540°	Linearly Extrapolated Load @ Oper. Temperature	Desired Calculated Load @ Oper. Temperature	Load Correction	Corrected Load @ 340°F (Final Setting)	LEGEND:
						ins lbs	ins lbs	ins lbs	lbs	lbs	lbs	lbs	+ Down - Up 0 No Movement Or Less Than 1/8" Observed Or Theoretically Expected -- Measurement Is Not Practical Or Does Not Represent Pipe Movement
3052	250		458	CP	602°	3/4 1400	3/4 1400	0 0	1400	1400	0	1400	
3053	262		460	CS	557°	2 1/8 1840	2 1/8 1800	-1/8 -40	1797	1840	-43	1883	
3054	262		460A	CS	557°	2 1/4 960	2 1/8 950	-1/8 -10	949	960	-11	971	
3055	275		464	CS	557°	2 2300	2 2300	0 0	2300	2300	0	2300	
3056	263		461	CS	557°	2 1/8 1840	2 1/8 1840	0 0	1840	1840	0	1840	
3057	263		461A	CS	557°	2 1/4 960	2 1/8 920	-1/8 -40	917	960	-43	1003	
3058	261		461	HS	900°	6 1/4 1840	6 1800	-1/4 -40	1728	1840	-112	1952	
3059	249	IHX	457	HP	945°	5 3/8 1700	5 1650	-3/8 -50	1549	1700	-151	1851	
3060	261	Cell	461A	HS	900°	1 7/8 960	1 1/2 900	-3/8 -60	792	960	-168	1128	
3061	236	#3	453	HP	945°	3 3/4 2830	3 3/8 2750	-3/8 -80	2588	2830	-242	3072	
3062	223		431	AS	340°	2 1/4 200	1 3/4 180	-1/2 -20	—	200	—	—	NOTES:
3063	295		467	AS	340°	2 140	1 5/8 135	-3/8 -5	—	140	—	—	1. Load Correction =
3064	266		464	HS	900°	2 1/4 2300	2 2200	-1/4 -100	2020	2300	-280	2580	Extrapolated Load At
3065	266		465	HS	900°	3 1810	2 7/8 1790	-1/8 -20	1754	1810	-56	1866	Operating Temperature
3066	260		460A	HS	900°	1 3/4 960	1 3/8 900	-3/8 -60	792	960	-168	1128	Minus (-) Desired
3067	260		460	HS	900°	6 1/4 1840	6 1800	-1/4 -40	1728	1840	-112	1952	Calculated Load At
3068	236		454	HP	945°	5 2400	4 1/2 2300	-1/2 -100	2095	2400	-305	2705	Operating Temperature
3069	248		456	HP	945°	5 3/8 1700	5 1650	-3/8 -50	1549	1700	-151	1851	
3070	266		277E	HS	900°	2 3/4 1625	2 1/4 1610	-1/4 -15	1583	1625	-42	1667	2. Corrected Load At 340° =
3071	266		277D	HS	900°	3 3/4 810	3 5/8 800	-1/8 -10	782	800	-28	828	Load at 340° - Load
													Correction
3072	233		654	HP	945°	1 5/8 2650	1 5/8 2650	-1/8 0	2650	2650	0	2650	
3073	233	Primary	655	HP	945°	2 1/4 2300	2 1/4 2300	0 0	2300	2300	0	2300	3. Nature:
3074	145	Pipeway	641	SP	340°	1 1/4 100	1 3/8 110	+1/8 +10	—	100	—	—	AP Auxiliary Primary
													AS Auxiliary Secondary
3075	308	Steam	273N	AS	340°	2 375	2 375	0 0	—	375	—	—	HP Hot Primary
3076	308	Generator	273N	AS	340°	2 375	2 375	0 0	—	375	—	—	HS Hot Secondary
3077	308	Room #3	273K	AS	340°	2 1/4 205	2 1/2 210	+1/8 +5	—	205	—	—	CP Cold Primary
3078	308		273K	AS	340°	2 1/4 205	2 1/2 210	+1/8 +5	—	205	—	—	CS Cold Secondary
													SP Service Primary
													SS Service Secondary
5000	159		645A	SP	340°	4 110	4 110	0 0	—	110	—	—	
5001	284	Primary	512	SP	602°	1 5/8 300	1 5/8 300	0 0	300	300	0	300	
5002	305	Pipeway	519	SP	602°	2 3/8 200	2 5/8 230	+1/4 +30	239	200	+39	161	
5003	189		500B	SP	340°	7/8 80	3/4 70	-1/8 -10	—	80	—	—

Figure 1167-B-1. Reactor Cavity - Hanger Locations

SPRING HANGER LOCATION

- SPRING HANGER
- TEST
CONSTR.

 HANGER NUMBERS

Figure 1167-B-2. Primary Pipe Tunnel West - Hanger Locations

Figure 1167-B-3. Primary Pipe Tunnel East - Hanger Locations

Figure 1167-B-4. Primary Pipe Tunnel North - Hanger Locations

Figure 1167-B-5. IHX Cells No. 1 South and No. 1 Center - Hanger Locations

Figure 1167-B-6. IHX Cell No. 1 Center and N₂ Cooling Area No. 1 - Hanger Locations

Figure 1167-B-7. Steam Generator Cell No. 1 - Hanger Locations

Figure 1167-B-8. IHX Cells No. 2 South and No. 2 Center - Hanger Locations

Figure 1167-B-9. IHX Cell No. 2 Center and N₂ Cooling Area No. 2
 - Hanger Locations

Figure 1167-B-10. Steam Generator Cell No. 2 - Hanger Locations

Figure 1167-B-11. IHX Cells No. 3 South and No. 3 Center - Hanger Locations

Figure 1167-B-12. IHX Cell No. 3 Center and N₂ Cooling Area No. 3 - Hanger Locations

Figure 1167-B-13. Steam Generator Cell No. 3 - Hanger Locations

APPENDIX C
PIPING INTERFERENCES

The following piping interferences were determined by the investigation of the system piping and were corrected:

- 1) IHX Cell No. 1 - Hanger No. 148 on line No. 273 bearing against steel brace.
- 2) IHX Cell No. 2 - Two insulation boxes on line No. 186 bearing against west wall.
- 3) IHX Cell No. 3 - Hanger No. 421 on line No. 239 bearing against line 223.
- 4) Nitrogen Cooling Area No. 1
 - a) Line No. 192 bearing against nitrogen cooling housing.
 - b) Air duct tearing insulation box from line No. 273 at hanger No. 182.
 - c) Line No. 273 bearing against cable tray.
- 5) Nitrogen Cooling Area No. 2 - Line No. 198 bearing against nitrogen cooling housing.
- 6) Nitrogen Cooling Area No. 3
 - a) Line No. 204 bearing against nitrogen cooling housing.
 - b) Air duct bearing against secondary throttle valve No. 3.
- 7) Steam Generator Room No. 1
 - a) Line 209 bearing against service lines.
 - b) Line 267 one-quarter in. from kick plate.
 - c) Vertical support on personnel platform penetrates insulation on line No. 303.
 - d) Shield on insulation off at hanger No. 154B on line No. 264.

- e) Hanger No. 156B bearing against line No. 270.
- f) Thermocouple tubing on line No. 270 bearing against room divider.
- g) Building wall penetrates insulation on line 217.

8) Steam Generator Room No. 2

- a) Hanger No. 260B on line No. 265 bearing against air duct.
- b) Line No. 325 bearing against building joist.
- c) Line No. 268 1/4 in. from kick plate.
- d) Line No. 210 bearing against service lines.
- e) Vertical support on personnel platform penetrates insulation of line No. 307.

9) Steam Generator Room No. 3

- a) Line No. 211 bearing against service lines and west wall.
- b) Line No. 326 bearing against building joist.
- c) Line No. 269 bearing against kick plate.
- d) Vertical support on personnel platform penetrates insulation on line No. 269.
- e) Insulation on line No. 266, at expansion tank, sagging.
- f) Hanger 262D bearing against line No. 272.
- g) Hanger 261A bearing against air duct.
- h) Thermocouple terminal box and tubing on line No. 272 bearing against room divider.
- i) Loose thermocouple tubing on line No. 272.
- j) Line No. 278 bearing against west wall.
- k) Line No. 295 bearing against west wall.

10) Primary Pipe Tunnel (West)

- a) Hanger No. 671A on line No. 168 bearing against thermocouple terminal on line No. 239.
- b) Hanger No. 608A on line No. 141 bent loose and bearing against line No. 232.
- c) Line No. 145 bearing against south wall.

11) Primary Pipe Tunnel (North)

- a) Two insulation boxes on line No. 159 bearing against south wall. One torn from pipe.
- b) Hanger No. 506 on line No. 224 bearing against line 123.

12) Primary Pipe Tunnel (East)

- a) Valve No. V-463 bearing against line No. 237.
- b) Valve No. V-461 bearing against building column. Insulation is cut away.
- c) Line No. 413 bearing against steel beam.

APPENDIX D

REWORK OF THE PIPE HANGERS IN THE CAVITY LINER

I. SUMMARY OF REWORK PERFORMED

- a. Spring Hanger No. 503 was checked for proper travel. It was found to be free to move full travel, up and down. When moved downward, approximately half a cup of clear water dripped out of the opening through the ceiling of the cavity liner.
- b. Hanger No. 514 was disconnected and jacked up and down the full length of travel. The hanger rod would not move freely and had to be jacked in both directions. The bellows assembly was cut free of the shaft and unscrewed from the threaded sleeve. While unscrewing the bellows, three convolutions at the bottom of the bellows were dented. It is felt that this bellows would still be useable; but since a spare was available, it has not been reused. When the hanger rod was pulled out of the sleeve, the key which prevented rotation of the rod was observed to dig into the shaft. It required up to 5000 lbs. force to remove this shaft. A close examination of the key revealed that it had been made from rectangular stock. No effort had been made to break the sharp corners. This key could readily prevent free motion of the hanger rod within the sleeve. The key will be replaced with a standard radius Woodruff-type key. Some rust was found on the shaft. Only a small portion of the shaft had any evidence of lubrication. The shaft was cleaned with trichlorethylene, wire brush, emery cloth and grinder. The sleeve penetrating through the floor was cleaned with trichlorethylene and the bearing surfaces were honed with an automobile cylinder hone. The shaft was lubricated with a film of radiation resistant grease. It was placed in the sleeve and found to be free to travel up and down and to rotate 360 degrees. The new key was then installed and the bellows was set at the proper position, welded in place, and leak tested.

- c. Hanger No. 511 was checked for proper up and down travel. It was found to be free to move as required. The hanger rod at the bottom of the penetration through the shielding was found to be free to rotate. This indicated that no tack welds had been made inside the penetration sleeve. The bellows was cut from this hanger and the rod removed. The key was again found to interfere with proper removal of the shaft. This rod was reworked, re-installed, and helium leak tested.
- d. Hanger No. 645 was found to be not supporting the pipe. That is, the pipe had moved up off the hanger support. Jacks were used to move this hanger rod through the up and down travel range. Considerable force was required to move the rod in either direction. The rod was then removed and observed to contain a coating of rust. The key again interfered with removal of the rod. This rod has been cleaned and re-installed. The lower flange of the bellows assembly came loose from the bellows when the solder joint between these two pieces failed. Since no permanent damage was done to the bellows, the joint was resoldered.
- e. Hanger No. 501 was also observed to be not supporting the pipe, and the hanger rod also required jacking force to travel either up or down. This rod was removed and found to contain a rust film. The key again interfered with proper removal of the shaft. The hanger was reworked and reinstalled.

It is felt that the proper travel of the hanger rods was being prevented by either or both of the problems noted above (that is: rust film on the shaft and improper key). All spring hangers in the cavity liner (17) were removed and reworked.

II. PROCEDURE EMPLOYED FOR HANGER REPAIR

A. To Remove Rods

- 1. Work Required Inside Cavity Liner.
 - a. Shore Piping.

- b. Remove tack weld or welds, and disconnect rod at upper stop and remove nut and washers. When the stop is at the down stop position.

2. Work Required At Spring Hanger

- a. Jack down spring hanger until position indicator reads midscale. Lock in position by welding keeper on both sides of hanger.
- b. Remove nut at top of rod.
- c. Remove spring hanger. Caution: Check to see that rod does not move up as hanger is being removed.
- d. Remove two lead shields.
- e. Cut out seal weld between rod and top of bellows.
- f. Unscrew and remove bellows. Apply torque at bottom nipple. Make sure no torque is applied to the bellows convolutions.
- g. Remove rod. Watch for key as rod is removed.

B. Clean Hangers

- 1. Inspect for rust.
- 2. Remove all moisture from bellows, rod and hole.
- 3. Clean up rod with emery paper and wire brush or automobile cylinder hone.
- 4. Clean rust from hole using wire brush or automobile cylinder hone.
- 5. Lubricate rod with radiation resistant grease.
- 6. Grind off remaining weld at washer at top.

7. Check to see that all segments of rod are tack welded together per drawing requirements.
8. Grind bevel on top washer of bellows as required for welding.
9. Reinstall rod and check to see that it is free to move up and down.

C. Rework Hanger Rods At Pipes

1. Trapeze Hangers
 - a. Cut off 3/4" up 12" from bottom of rod.
 - b. Cut nuts off rod and throw away nuts and segments of rod.
 - c. Install new rod segment and sleeve in position. Do not weld at this time.
2. Clevis Hangers
 - a. Cut off bolt through clevis and eye on pipe and replace with new bolt and nut.
 - b. Cut tack weld off of nut at clevis.

D. Reinstall Hangers

1. Reinstall rod and check to see that it is free to move up and down. Check to see that key is in place and rod will not rotate.
2. Screw bellows in place. Make sure no torque is applied to convolutions of the bellows.
3. Weld bellows to rod.
Caution: Protect bellows convolutions from weld splatter. Weld per A.W.S. Code. Weld to be leak tight and will be helium leak checked at a later date by AI. Dye penetrant inspect completed weld.
4. Reinstall two lead shields.
5. Replace spring hanger.

6. Reinstall nuts and washers at top and bottom of rod.
7. Connect rod at upper stop.
8. Adjust nuts at bottom of rod to approximately mid range of adjustment threads.
9. Wedge bellows cover cylinder to proper dimension.
10. Shim spring hanger until spring arm is just resting freely on top of bellows cover cylinder.
11. Screw top nut down to top of spring hanger arm.
12. Adjust stop at ceiling to proper clearance dimension.
13. Weld new rod segment in place for a trapeze hanger. Tighten adjustment bolts in lower hanger rods so that rod is supporting a portion of the weight of the pipe.
14. Remove wedges from bellows cover cylinder.
15. Set jack on top of spring hanger and take the load. Then cut keepers off the spring hanger.
16. Slowly remove jack load and check for motion of hanger rod.
17. Check clearances at top and bottom of rod for proper dimension.
18. If clearances off more than 1/8", readjust nuts at top and bottom as required.
19. Align the spring hanger so that the level hinge pins are centered in the slotted holes.
20. Disconnect rod at pipe and check to see that spring hanger is free to travel from full up to full down positions.

21. Reconnect rod and tighten to take a portion of the weight of the pipe.
22. Tack weld the spring hanger to the floor.
23. Replace tack welds on stop at ceiling in the cavity liner.