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FINAL EVALUATION REPORT
HALLAM NUCLEAR POWER FACILITY
VOLUME III

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
PLANT PROTECTIVE SYSTEM

AI-P-1121

Test and Analysis
by
W. H. SPALDING

Evaluation
by
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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
PLANT PROTECTIVE SYSTEM, AI-P-1121

I. PURPOSE OF TEST

The purpose of this test was to check out and align the plant protective panel for operation and to system test all associated input signal circuitry, alarm, setback and scram circuits, and startup interlock circuits.

II. DISCUSSION OF TEST PERFORMANCE

The protective panel, which is the major component of the protective system was given a comprehensive quality control test at the manufacturer's plant prior to installation.

After installation, power was applied to the protective panel and the voltages of all power supplies within the protective panel were measured and verified to be correct. Reference junction oven temperatures were measured to be nominally 150 F. All computer chassis, including spares, were aligned and setpoints were set as shown in Table I (32 mv as the 100 % primary flow signal, and 34 mv as the 100 % secondary flow signal, were used in place of 50 mv as called out in 7518-S72015, the plant protective panel acceptance test and checkout specification).

The protective system was checked out and tested. All wiring between protective panel and sensing elements was tested for continuity, absence of wiring shorts, noise, correct wire type and polarity. Loop resistances of the sodium flowmeter and thermocouple leads were measured and recorded. Simulated signals were then fed into the protective panel to prove out the trip points previously setup, and to verify the

TABLE I
COMPUTER TRIP POINTS

Trips	Trip Points		
	Alarm	Setback	Scram
<p>dT/dt Computer</p> <p>High fuel channel outlet temperature</p> <p>High fuel channel outlet temperature rate (meter set at zero and full scale for ± 25 F step and ± 75 F/hr ramp).</p>	<p>975 F</p> <p>± 60 % of half scale</p>	<p>out</p> <p>None</p>	<p>1025 F</p> <p>± 95 % of half scale</p>
<p>T_o Computer</p> <p>High neutron flux (for low Na flow)</p> <p>High computed fuel channel outlet temperature</p> <p>High neutron flux</p>	<p>12 % for Na flow less than 10 % full flow</p> <p>975 F</p> <p>107 %</p>	<p>16 % for Na flow less than 12 % full flow</p> <p>1000 F</p> <p>115 %</p>	<p>20 % for Na flow less than 14 % full flow</p> <p>1025 F</p> <p>125 %</p>
<p>Flow Ratio Computer</p> <p>High primary to secondary Na flow ratio</p> <p>Low primary to secondary Na flow ratio</p>	<p>1.25 for primary flow above 15 %</p> <p>0.87 for secondary flow above 15 %</p>	<p>None</p> <p>None</p>	<p>1.35 for primary flow above 20 %</p> <p>0.80 for secondary flow above 20 %</p>

correct readout on all associated meters. Proper alarm, setback and scram trip and annunciator action was verified at this time. Verification of correct coincidence circuitry was included. Finally, the load characteristics of the scram latch power supplies, "A" and "B", were tested using the latching magnets of 19 control rods as the load. For the last section of this test procedure, check-out of the startup interlock system was performed. It was verified that in order to satisfy the startup interlock system the following conditions must be met:

- 1) Key-1, startup interlock switch closed.
- 2) No setback action exists.
- 3) Control Rods No. 1 through No. 19 full down.
- 4) No scram action exists.
- 5) Moderator coolant block valve full open.
- 6) Moderator coolant throttling valve at least 2% open.
- 7) At least two of the following conditions:
 - a) Circuit No. 1 cutout switch in non-cutout position, No. 1 block valve full open and No. 1 throttle valves at least 2% open.
 - b) Circuit No. 2 cutout switch in non-cutout position, No. 2 block valve full open and No. 2 throttle valves at least 2% open.
 - c) Circuit No. 3 cutout switch in non-cutout position, No. 3 block valve full open and No. 3 throttle valves at least 2% open.
- 8) Count rate on source range channels I and II at least 600 cpm.

It was also verified that the neutron source startup interlock contacts are bypassed only when nuclear channel III or IV indicates at least 10^{-9} amperes.

With the startup interlock system satisfied, it was verified that the control rod down position startup interlock was bypassed and would remain bypassed 10 minutes after the interlock circuit was broken.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

Loop resistances of the flowmeter and thermocouple circuits looking into the sensing element from the protective panel were measured and recorded. All resistances were of proper value as shown in Table II. In addition, the circuits were tested for continuity, shorts, polarity and noise, and were found correct and acceptable.

Table III presents the results of problems run on the T_o computers. Simulated neutron flux, sodium flow and sodium temperature signals were applied to each computer. The indicated fuel channel temperature (T_o) calculated by the computer was then recorded. In addition, the associated trip was verified for each case. This was done by establishing all input values listed in the table except the value having the arrow, then setting up the value with the arrow by increasing or decreasing the variable in the direction indicated by the arrow. Trips in all instances were found to occur close to the predicted conditions.

Table IV presents problems run on the flow ratio computers. Simulated sodium flow signals were applied to each computer and the indicated ratio, as calculated by the computer, was then recorded. In addition, the associated trip was verified for each case. This was done by first setting up the value without the arrow, then setting up the value with the arrow by increasing or decreasing the variable in the direction indicated by the arrow. Trips in all cases were found to occur close to the predicted conditions.

Table V presents data obtained from the dT/dt computers. Simulated fuel channel outlet temperatures were applied to each computer and the indicated output and rate of change temperatures were recorded. In addition, associated trips were verified. These trips in all cases were found to occur close to the set values.

TABLE II
FLOWMETER AND THERMOCOUPLE LOOP RESISTANCES

Sensing Element	Resistance (ohms)
TX-4E	72
TX-5E	64
TX-6E	78
TX-7E	62
TX-8E	85
TX-9E	62
TX-10E	58
TX-11E	60
TX-12E	58
Reactor T/C (C-2-2)	89 (dT/dt Computer A)
Reactor T/C (C-7-2)	84 (dT/dt Computer B)
Reactor T/C (C-10-2)	92 (dT/dt Computer C)
FRC-101E	3.7 (T_o Computer A)
FRC-101E	3.7 (T_o Computer B)
FRC-101E	3.7 (T_o Computer C)
FRC-101E	3.8 (Ratio Computer A)
FRC-101E	3.9 (Ratio Computer B)
FRC-101E	3.8 (Ratio Computer C)
FRC-201E	4.3 (T_o Computer A)

TABLE II Continued

Sensing Element	Resistance (ohms)
FRC-201E	4.3 (T_o Computer B)
FRC-201E	4.3 (T_o Computer C)
FRC-201E	4.4 (Ratio Computer A)
FRC-201E	4.4 (Ratio Computer B)
FRC-201E	4.3 (Ratio Computer C)
FRC-301E	4.6 (T_o Computer A)
FRC-301E	4.5 (T_o Computer B)
FRC-301E	4.5 (T_o Computer C)
FRC-301E	4.6 (Ratio Computer A)
FRC-301E	4.6 (Ratio Computer B)
FRC-301E	4.5 (Ratio Computer C)
FRC-102E	3.5 (Ratio Computer A)
FRC-102E	3.5 (Ratio Computer B)
FRC-102E	3.4 (Ratio Computer C)
FRC-202E	2.0 (Ratio Computer A)
FRC-202E	2.0 (Ratio Computer B)
FRC-202E	2.0 (Ratio Computer C)
FRC-302E	1.6 (Ratio Computer A)
FRC-302E	1.6 (Ratio Computer B)
FRC-302E	1.6 (Ratio Computer C)

TABLE III
T_o COMPUTER TEST PROBLEMS

PROBLEM	VOLTS (N)	PERCENT OF RATED FLOW			TEMP (F) OF SENSING T/C			TRIP	COMPUTED T _o (F)	INDICATED T _o (F)			
		W _{p1}	W _{p2}	W _{p3}	T ₁	T ₂	T ₃			No. 1	No. 2	No. 3	No. 4
a	10.0	100	100	100	610	610	610	NONE	945	968	942	950	935
b	1.2 ↑	10	10	10	610	610	610	ALARM	1012	1050	1013	1011	1030
c	1.6 ↑	10	10	10	610	610	610	SETBACK	1146	1190	1149	1155	1180
d	2.0 ↑	10	10	10	610	610	610	SCRAM	1280	1200	1200	1200	1200
e	10.7 ↑	100	100	100	350	350	350	ALARM	708	740	705	715	720
f	11.5 ↑	100	100	100	350	350	350	SETBACK	736	770	735	745	750
g	12.5 ↑	100	100	100	350	350	350	SCRAM	768	805	767	780	780
h	10.0	75.3 ↓	100	100	610	610	610	ALARM	975	1000	970	975	965
i	10.0	57.7 ↓	100	100	610	610	610	SETBACK	1000	1025	995	1000	990
j	10.0	42.2 ↓	100	100	610	610	610	SCRAM	1025	1050	1023	1025	1020
k	10.0	100	42.2 ↓	100	610	610	610	SCRAM	1025	1055	1020	1020	1020
l	10.0	100	100	42.2 ↓	610	610	610	SCRAM	1025	1050	1020	1030	1030
m	10.0	100	100	100	700 ↑	610	610	ALARM	975	1000	975	980	965
n	10.0	100	100	100	775 ↑	610	610	SETBACK	1000	1020	1000	1005	990
o	10.0	100	100	100	850 ↑	610	610	SCRAM	1025	1045	1030	1035	1015
p	10.0	100	100	100	610	850 ↑	610	SCRAM	1025	1045	1030	1035	1010
q	10.0	100	100	100	610	610	850 ↑	SCRAM	1025	1050	1030	1040	1000
r	9.7 ↑	100	100	100	650	650	650	ALARM	975	1000	975	980	965
s	10.5 ↑	100	100	100	650	650	650	SETBACK	1000	1025	1000	1010	995
t	11.2 ↑	100	100	100	650	650	650	SCRAM	1025	1050	1030	1045	1020

TABLE IV
FLOW RATIO COMPUTER TEST PROBLEMS

PROBLEM	PERCENT OF RATED FLOW		TRIP	COMPUTED FLOW RATIO (W_p/W_s)	INDICATED FLOW RATIO (W_p/W_s)									
	W_p	W_s			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
a	100	100	NONE	1.00	0.99	0.99	0.99	0.98	0.98	0.98	0.99	0.99	0.97	1.00
b	10	15 ↑	ALARM	0.67	0.67	0.68	0.68	0.69	0.67	0.67	0.69	0.67	0.67	0.72
c	10	20 ↑	SCRAM	0.50	0.50	0.50	0.51	0.51	0.50	0.50	0.51	0.49	0.50	0.57
d	15 ↑	20	ALARM	1.50	1.41	1.55	1.52	1.55	1.50	1.49	1.51	1.55	1.51	1.64
e	20 ↑	10	SCRAM	2.00	2.02	2.08	2.07	2.07	2.01	1.99	2.03	2.08	2.02	2.04
f	43.5 ↓	50	ALARM	0.87	0.86	0.88	0.87	0.89	0.84	0.86	0.88	0.87	0.86	0.88
g	40 ↓	50	SCRAM	0.80	0.79	0.81	0.80	0.82	0.80	0.80	0.81	0.80	0.80	0.82
h	50	40 ↓	ALARM	1.25	1.23	1.27	1.26	1.29	1.25	1.24	1.26	1.27	1.23	1.26
i	50	37 ↓	SCRAM	1.35	1.37	1.38	1.36	1.39	1.36	1.34	1.37	1.38	1.34	1.36
j	87 ↓	100	ALARM	0.87	0.85	0.86	0.86	0.87	0.85	0.85	0.86	0.86	0.86	0.86
k	80 ↓	100	SCRAM	0.80	0.80	0.79	0.79	0.80	0.79	0.79	0.79	0.79	0.81	0.78
l	100	80 ↓	ALARM	1.25	1.24	1.25	1.26	1.26	1.23	1.24	1.24	1.26	1.23	1.22
m	100	74 ↑	SCRAM	1.35	1.34	1.35	1.36	1.37	1.34	1.33	1.34	1.37	1.33	1.34

TABLE V
HIGH TEMP FUEL OUTLET dT/dt COMPUTER TEST DATA

Temperature Applied	Trip	Indicated Temperature			
		No. 1	No. 2	No. 3	No. 4
975 F	ALARM	980 F	972 F	976 F	973 F
1025 F	SCRAM	1030 F	1022 F	1030 F	1030 F

Temperature Step Applied	Trip	Indicated Temperature Rate			
		No. 1	No. 2	No. 3	No. 4
+ 15 F	ALARM	+16.0 F/hr	+15.0 F/hr	+15.0 F/hr	+15.0 F/hr
- 15 F	ALARM	-14.5	-15.5	-14.5	-14.5
+ 24 F	SCRAM	+25.0	+25.0	+24.5	+24.0
- 24 F	SCRAM	-23.5	-24.0	-24.0	-23.5

In testing the scram-latch power supplies, the following data were taken:

- 1) With both power supplies connected:

a)	CONDITION	POWER SUPPLY A	POWER SUPPLY B
	All control rod latch magnets energized	30.0 VDC 1.8 Amp	30 VDC 1.8 Amp
b)	All control rod latch magnets de-energized	31.0 VDC 0 Amp	31.0 VDC 0 Amp

- 2) With only one power supply connected:

	CONDITION	POWER SUPPLY A	POWER SUPPLY B
	All control rod latch magnets energized	29.3 VDC 3.3 Amp	29.0 VDC 3.5 Amp

With all control rod latch magnets energized by both power supplies, power supply "A" was pulled out and the total load was automatically

transferred to power supply "B" without dropping a rod. The same procedure was then repeated, except that power supply "B" was pulled out. Again no rods dropped.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with preoperational test AI-P-1121, Plant Protective System, as listed in NAA-SR-5700, Supplement 4, page XI (a)-45, with remarks regarding the test to explain compliance with the criteria:

- a) Criterion: Protective panel alignment, and trip point settings for alarms, setbacks and scrams have been accomplished.
Remarks: All protective panel alignments and settings of trip points were accomplished.
- b) Criterion: Correct wiring of protective system sensing elements has been demonstrated.
Remarks: All wiring between protective system sodium flowmeters, thermocouples, neutron flux instruments and protective panel was checked for continuity, wiring shorts, noise, correct wire type and polarity. Other wiring between reactor sodium level instruments, evaporator level instruments, pump contactors, manual switches and protective panel was verified to be correct when the field contacts were actuated and the alarm, setback and scram circuits were tested.
- c) Criterion: Correct operation of the protective system has been demonstrated by using actual or simulated signals from the sensing elements.
Remarks: Correct operation of the protective system was demonstrated. Simulated signals were used in place of actual signals from the sodium flowmeters, thermocouples and the nuclear chambers. In testing the remaining alarm, setback and scram circuits the associated field contacts were operated.
- d) Criterion: Each sodium circuit bypass switch is operable.
Remarks: This was accomplished and the required effect on the startup interlock system was demonstrated.

- e) Criterion: Correct wiring and operation of startup interlocks has been demonstrated.

Remarks: It was demonstrated that each and every startup interlock had to be satisfied before the startup could be satisfied.

V. EVALUATION

The HNPF Plant Protective System was designed to prevent high temperature damage to the components of the reactor core. Preoperational test AI-P-1121 was performed to verify correct operation of the protective panel and its associated inputs and outputs. All checks and calibrations required by the master test procedure have been completed. The test completion report confirms proper connection of all circuitry and presents results of test problems calculated with the temperature rate, primary to secondary flow ratio, and power to flow ratio computers using simulated input signals.

Analyses of the data presented in the report, and independent checks of the calculated and indicated trip points, have yielded the following results:

- a) Temperature Rate (dT/dt) Computers.

All four computers have been calibrated and trip points set to specified accuracy (See Appendix); they are ready for on-line service. However, an apparent inconsistency in relation to these computers, is that the 50 F/hr programmed temperature rate of the control system will put them in an alarm state after 45 minutes. That is, an acceptable rate of temperature rise will cause an alarm trip. This clearly is an undesirable condition, since it destroys the operators' cognizance of the seriousness of the alarm signal.

It is, therefore, recommended that the present alarm rate be increased to 60 F/hr. With the new rate, at a hypothetical rise of 200 F/hr there would be a delay of 4 minutes from the time of alarm to initiation of scram action; sufficient time for operator action to prevent

scram, if such action is possible. The possibility of an earlier alarm from the measured outlet temperature portion of the system would allow still more time between the alarm and scram trips. At rates of temperature rise greater than 200 F/hr, the time between alarm and scram is correspondingly less. Operator action, however, in those situations is questionable, and a scram action would unquestionably be preferred.

Operational experience with the HNPF will probably show that the controlled rate of 50 F/hr can be safely increased to 60 F/hr as has been the case at the Sodium Reactor Experiment.

b) Primary to Secondary Flow Ratio Computers.

All computers have been calibrated to calculate and initiate trip action within specified accuracy (See Appendix); they are prepared for on-line service.

c) Power-to-Flow Ratio Computers.

Computers calibrated with the accepted procedure did not perform within allowed limits throughout the range of 15% to 100% flow. (See Appendix).

A change of calibrating procedure was suggested to take advantage of the accuracy of the digital indicator in the test fixture, and to use calculated neutron flux as the basic set parameter (instead of indicated temperature). Computers calibrated with this suggested procedure calculate temperatures and initiate trip signals within allowed limits throughout the entire flow range.

Modifications have been completed to the reactor sodium level alarm and scram system, to comply with HNPF operating technical specification requirements. The trip coils were repositioned to alarm when the sodium level is lower than 1428 ft or higher than 1429 ft 8 inches, and to scram when the level is lower than 1427 ft 6 inches (elevations based on sea level). This system, and the evaporator water level and loss of pump power trip circuits are prepared for protective system service.

The scram magnet power supply was changed from the non-noise sensitive supply to the noise sensitive supply, after several instances of control rods dropping without the scram relay actuating. Subsequent tests revealed that the voltage at which the rods were released was higher than that to drop out the relays; consequently, a fluctuation in supply voltage

due to rapid load changes or atmospheric disturbances could release the rods without actuating the scram relays. Steps have been taken to ascertain the nature of the transients causing these spurious rod drops. The release of any one control rod does actuate the "Rod-Mag Separated" alarm.

Components of the protective system were designed to be at least 90% fail safe. Every off normal situation is protected against by two independent channels; each channel requiring two out of three coincidence signals to initiate trip action (except the loss of pump power and short period circuitry). These design features provide redundancy, reliability and protection consistent with "state of the art" protective system theory. However, a number of failures which do not cause the computer output to initiate a trip signal may occur, e. g. loss of neutron flux signal or reactor inlet temperature signal to the power-to-flow ratio computers.

Presently, the protective panel is constantly observed by Atomic International personnel and by the Consumers Public Power District technicians being trained to maintain it; this assures rapid detection of any malfunction not automatically annunciated. But computer outputs are not regularly monitored as a part of daily operating data. It is suggested that as soon as the testing program is complete, protective panel data which can be easily obtained from indicators in the front of each computer be included as a part of regular operating data. This is in addition to, and not instead of, less frequent on-line inspection and alignment checks.

The preoperational test completion criteria have been met as indicated by the test completion report. The computers were calibrated, using simulated sensing element signals. Readjustment of some of the computers may be necessary if, as a result of post critical testing, sensing element characteristics are discovered to be different from those presently available.

APPENDIX

Following are portions of the Atomics International acceptance specification for the plant protective panel, as regards required calibration accuracies discussed in the evaluation.

3.1.4 Accuracy of Ratio Computation - (W_p/W_s)

3.1.4.1 When primary and secondary flow signals are above the scram cutout point, the indicated ratio shall be within ± 0.05 of the calculated ratio determined by division of the millivolt signals. For this latter computation, a calculation error of ± 0.05 mv shall be allowed in each of the flow signals. That is, when full scale flow is 30 mv, primary flow is set at 6 mv (with scram cutout at 20 percent) and secondary flow is at 12 mv, the exact calculated ratio should be 0.5. The calculated ratio can be between $\frac{5.95}{12.05} = 0.494$ and $0.506 = \frac{6.05}{11.95}$. The allowable indicated ratio is any value between 0.444 and 0.556.

3.1.4.2 When above the alarm cutout point, but below scram cutout point, the indicated ratio shall be as in 3.1.4.1 above, except the ± 0.05 error in ratio is allowed to be ± 0.07 .

3.1.4.3 Below the alarm cutout point, no accuracy is required. However, the circuits must be limited from overload damage for any value of primary or secondary flow (including zero) input.

3.2.4 Accuracy of T_o Computation

3.2.4.1 Provided flow is above the low alarm point, and flux is below the high alarm point, indicated value of T_o , calculated according to the formula of 3.2.1, as determined by measured inputs, shall be within 30 F of the calculated value.

3.2.4.2 Provided flow is below the low alarm point, no accuracy of T_o computation is required. However, the circuits must be limited from overload damage for inputs within their operating range (including zero).

3.3.4 Accuracy of Computation (dT/dt)

3.3.4.1 Indicated value of temperature shall be within ± 20 F of the value determined by millivolt input.

3.3.4.2 Full scale relative rate of change shall be indicated within ± 3 F/hr of the actual value set for full scale. For example: when full scale is set for 100 F/hr and the input is put on a sustained ramp of 100 F/hr, meter deflection (after four time constants) shall be between 97 and 103. The upper value shall be estimated (on zero centered ± 100 scale).

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
RADIATION DETECTION AND MONITORING SYSTEM

AI-P-1122

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
RADIATION DETECTION AND MONITORING SYSTEM, AI-P-1122

I. PURPOSE OF TEST

The purpose of preoperational test AI-P-1122, Radiation Detection and Monitoring System, was to verify that:

- a) The components which make up the complete radiation detection and monitoring system will function properly when installed as a system.
- b) The presence of radioactivity will be detected in the reactor building operating areas and in systems in which detectors have been installed.
- c) Adequate control action and/or radiation level indication is provided.

II. DISCUSSION OF TEST PERFORMANCE

The radiation detection and monitoring system consists of nine subsystems as follows:

- a) Radioactive vent monitoring and control system.
- b) Primary cell and pipe tunnel atmosphere contamination monitoring and control system.
- c) Secondary sodium monitoring system.
- d) Radioactive liquid waste monitoring and control system.
- e) Reactor atmosphere monitor.
- f) Area radiation monitors.
- g) Airborne particle radiation monitors.
- h) Fuel handling cask radiation monitor.
- i) Fuel storage cell atmosphere monitor.

Prior to the start of the test, the following items were made available for use with the radiation detection and monitoring system:

- a) Instrument air system
- b) 120 V noise-free power
- c) 120 V critical power
- d) 125 V dc annunciator power

Each subsystem was treated as a separate system for preoperational testing purposes. However, due to the similarity of tests performed on each subsystem, this report will discuss testing of the composite system rather than the individual subsystems.

The mechanical and electrical installations of all the radiation monitoring and detection system equipment were checked before the equipment was placed in operation.

Each subsystem was set up and checked for operation according to the manufacturer's instructions. The background radiation level at each of the detectors was measured with a portable GM survey meter prior to the start of the test. Each detector was then operated using a radioactive source and the detector internal calibration source. The radioactive source was placed near a detector and the associated indicator was observed for correct reading. Each detector channel calibration was checked by using the internal calibration source and associated indicators. Measurement of the radioactive source strength was accomplished by use of both a Juno survey meter and a portable GM survey meter.

The control and alarm action of each measuring channel was initiated by a simulated signal and the system was checked to determine that all of the correct control action and alarm functions were accomplished.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

A. EQUIPMENT INSTALLATION

As a result of checking the mechanical and electrical installation of the equipment, the following items required attention before the test could be completed:

- 1) Due to excessive line loss, the filament voltage to the reactor atmosphere monitor and the stack monitor preamplifiers had to be increased. This was accomplished by adding an additional transformer winding to the reactor atmosphere monitor filament circuit, and by adding a separate filament transformer to the stack monitor circuit.
- 2) Several of the solenoid valves in the oxygen analyzer system had been wired to the wrong switches on the main console panel, and required rewiring.
- 3) Several of the position switches on the control valves operated by this system required adjustment so as to operate at the end of valve travel.
- 4) The wire used on the "in-cell" area monitors collected moisture while in the unheated cells, because of the porous nature of the radiation resistant insulation on the wiring. This wiring required drying out before the detectors could be placed in operation.
- 5) Due to the voltage losses caused by the high current loads and long lines, it was necessary to install powerstats on each of the mobile particulate air monitors, the sample pump motors on the stack, and reactor atmosphere monitors to increase the voltage to an acceptable level for operation.

B. DETECTOR OPERATION AND CALIBRATION

The components of each subsystem were checked and calibrated as recommended by the manufacturer. The B+ voltage for each of the detectors was measured; all were within tolerance.

Each detector was placed in operation per the manufacturer's instructions. The radiation background level at each of the detectors was measured with a portable survey meter and the values recorded. These values, together with the detector readout indication, are found in Table I.

Each of the detectors was exposed to the respective internal calibration source. The resulting indicator and recorder readings are found in Table II.

The individual detectors were exposed to an external radiation source to establish a check point for each of the detectors. The strength of the radiation field produced by the radiation source was measured with portable survey meters. The readings taken with the survey meters, and response of the detectors, are given in Table III and plotted on Figures 1122-1 through 1122-4.

TABLE I
BACKGROUND RADIATION LEVELS AND INDICATOR RESPONSE

Detector	Location	Measured Background Radiation mr/hr	Indicator Reading
RD-1	Reactor Atmosphere Monitor	0.01	350 cpm
RD-100	Secondary Sodium Loop No. 1	0.02	<10 cpm
RD-200	Secondary Sodium Loop No. 2	0.02	<10 cpm
RD-300	Secondary Sodium Loop No. 3	0.02	<10 cpm
RD-900	Nitrogen Vents	0.02	2.2×10^{-5} μ c/cc
RD-1000	Non R/A Vents	0.02	5×10^{-5} μ c/cc
RD-1001	Reactor Building Stack	0.02	400 cpm
RD-1002	Pre Stack Line	0.02	2.1×10^{-5} μ c/cc
RD-1004	Wash Cell Vents	0.02	3.5×10^{-5} μ c/cc
RD-1100	R/A Liquid Waste	0.01	90 cpm
RD-1102	R/A Waste Facility Stack	0.02	400 cpm
RD-1400-1	Control Room	0.02	0.03 mr/hr
RD-1400-2	Carbon Trap Cell	0.02	<.001 r/hr
RD-1400-3	Primary Cold Trap Cell No. 1	0.025	<.001 r/hr
RD-1400-4	Primary Cold Trap Cell No. 2	0.025	<.001 r/hr
RD-1400-5	Maintenance Cell Operating Area	0.03	<.001 r/hr
RD-1400-6	Equipment Decontamination Room	0.02	0.04 mr/hr
RD-1400-7	Control Rod Carriage	0.01	0.04 mr/hr
RD-1400-8	Local Board 29 and 30	0.01	0.05 mr/hr
RD-1401-1	IHX Cell No. 1 Atmosphere	0.02	<10 cpm
RD-1401-2	IHX Cell No. 2 Atmosphere	0.02	<10 cpm
RD-1401-3	IHX Cell No. 3 Atmosphere	0.015	<10 cpm
RD-1401-4	Cold and Carbon Trap Cells Atmos	0.01	<10 cpm
RD-1401-5	Primary Fill Tank Cell Atmosphere	0.01	<10 cpm
RD-1401-6	Moderator Pump Cells and Primary Pipe Tunnel Atmosphere	0.02	<10 cpm
RD-1401-7	Primary Pipe Tunnel Atmosphere	0.02	<10 cpm
RD-1402	Air Particulate Reactor Area	0.01	600 cpm
RD-1403	Air Particulate Over IHX Cells	0.02	200 cpm
RD-1404	Air Particulate Auxiliary Bay	0.02	450 cpm
RD-1405	Air Particulate Maintenance Cell Operating Area	0.02	200 cpm
RD-1406	Air Particulate Decon. Room	0.02	500 cpm
	Fuel Handling Machine	0.02	0.001 r/hr

TABLE II
RESPONSE TO INTERNAL CALIBRATION CHECK SOURCE

Radiation Detector	Expected Reading	Indicator Reading	Recorder Reading
RD-100	900 to 1020 cpm	900 cpm	not recorded
RD-200	1100 to 1400 cpm	1100 cpm	not recorded
RD-300	350 to 500 cpm	370 cpm	not recorded
RD-900	10^{-3} $\mu\text{c/cc}$	10^{-3} $\mu\text{c/cc}$	1.05×10^{-3} $\mu\text{c/cc}$
RD-1000	10^{-3} $\mu\text{c/cc}$	10^{-3} $\mu\text{c/cc}$	1.2×10^{-3} $\mu\text{c/cc}$
RD-1001	8×10^4 cpm	8×10^4 cpm	8×10^4 cpm
RD-1002	10^{-3} $\mu\text{c/cc}$	10^{-3} $\mu\text{c/cc}$	10^{-3} $\mu\text{c/cc}$
RD-1004	10^{-3} $\mu\text{c/cc}$	10^{-3} $\mu\text{c/cc}$	10^{-3} $\mu\text{c/cc}$
RD-1100	β γ : 1200 to 1300 cpm γ : 1750 to 1850 cpm	β γ : 1250 cpm γ : 1700 cpm	0
RD-1102	750 to 850 cpm	800 cpm	800 cpm
RD-1400-1	1 mr/hr	1 mr/hr	1 mr/hr
RD-1400-2	100 mr/hr	100 mr/hr	95 mr/hr
RD-1400-3	100 mr/hr	100 mr/hr	95 mr/hr
RD-1400-4	100 mr/hr	100 mr/hr	95 mr/hr
RD-1400-5	100 mr/hr	100 mr/hr	
RD-1400-6	1 mr/hr	1 mr/hr	1 mr/hr
RD-1400-7	1 mr/hr	1 mr/hr	0.96 mr/hr
RD-1400-8	1 mr/hr	1 mr/hr	1 mr/hr
RD-1401-1	800 to 1020 cpm	1000 cpm	950 cpm
RD-1401-2	320 to 420 cpm	410 cpm	400 cpm
RD-1401-3	590 to 810 cpm	700 cpm	640 cpm
RD-1401-4	480 to 680 cpm	600 cpm	520 cpm
RD-1401-5	490 to 670 cpm	420 cpm	410 cpm
RD-1401-6	510 to 710 cpm	600 cpm	520 cpm
RD-1401-7	900 to 1020 cpm	1010 cpm	900 cpm
RD-1402	5400 cpm	5500 cpm	5500 cpm
RD-1403	4300 cpm	4500 cpm	4500 cpm
RD-1404	5300 cpm	5500 cpm	5500 cpm
RD-1405	4800 cpm	5000 cpm	5000 cpm
RD-1406	5000 cpm	5100 cpm	5100 cpm
Fuel Handling Machine	No internal check source		
RD-1 Portable Purge Unit Radiation Monitor	These units are gamma spectrometers; the internal check source is used to give only an upscale reading.		

TABLE III
RESPONSE TO KNOWN EXTERNAL RADIATION SOURCE

Radiation Detector	Expected Reading	Indicator Reading	Recorder Reading
RD-100	18.0 mr/hr	2500 cpm	not recorded
RD-200	16.5 mr/hr	2800 cpm	not recorded
RD-300	14.5 mr/hr	1500 cpm	not recorded
RD-900	90 mr/hr	$2.2 \times 10^{-3} \mu\text{c/cc}$	$2.2 \times 10^{-3} \mu\text{c/cc}$
RD-1000	90 mr/hr	$3.3 \times 10^{-3} \mu\text{c/cc}$	$3.3 \times 10^{-3} \mu\text{c/cc}$
RD-1001	90 mr/hr	2300 cpm	2300 cpm
RD-1002	90 mr/hr	$5.0 \times 10^{-3} \mu\text{c/cc}$	$5.0 \times 10^{-3} \mu\text{c/cc}$
RD-1004	90 mr/hr	$2.8 \times 10^{-3} \mu\text{c/cc}$	$2.8 \times 10^{-3} \mu\text{c/cc}$
RD-1100	5 mr/hr	$\beta \gamma = 1600 \text{ cpm}$ $\gamma = 600 \text{ cpm}$	600 cpm
RD-1102	90 mr/hr	1500 cpm	1500 cpm
RD-1400-1	3 mr/hr	3 mr/hr	3 mr/hr
RD-1400-2	1.5 r/hr	1.5 r/hr	1.9 r/hr
RD-1400-3	1.5 r/hr	1.5 r/hr	1.6 r/hr
RD-1400-4	1.5 r/hr	1.5 r/hr	1.5 r/hr
RD-1400-5	0.003 r/hr	0.003 r/hr	0.0025 r/hr
RD-1400-6	420 mr/hr	450 mr/hr	300 mr/hr
RD-1400-7	2.0 mr/hr	2.5 mr/hr	2.5 mr/hr
RD-1400-8	20.0 mr/hr	20.0 mr/hr	19 mr/hr
RD-1401-1	16.5 mr/hr	1500 cpm	1500 cpm
RD-1401-2	17.5 mr/hr	600 cpm	580 cpm
RD-1401-3	15.5 mr/hr	950 cpm	900 cpm
RD-1401-4	14.0 mr/hr	1500 cpm	1500 cpm
RD-1401-5	14.0 mr/hr	500 cpm	450 cpm
RD-1401-6	19.5 mr/hr	620 cpm	550 cpm
RD-1401-7	18.5 mr/hr	1020 cpm	900 cpm
RD-1402	16.5 mr/hr	10,500 cpm	10,500 cpm
RD-1403	16.5 mr/hr	20,000 cpm	20,000 cpm
RD-1404	16.5 mr/hr	20,000 cpm	20,000 cpm
RD-1405	16.5 mr/hr	9,500 cpm	9,500 cpm
RD-1406	16.5 mr/hr	11,000 cpm	11,000 cpm
Fuel Handling Machine	42 mr/hr	40 mr/hr	not recorded

Figure 1122-1. RD-1 Reactor Atmosphere Monitor Gamma Spectrometer Response to a Cesium - 137 Source.

Figure 1122-2. RD-1 Reactor Atmosphere Monitor Gamma Spectrometer Response to a Simulated Iodine - 131 Source.

Figure 1122-3. Fuel Cell Purge Unit Gamma Spectrometer Response to a Cesium - 137 Source.

Figure 1122-4. Fuel Cell Purge Unit Gamma Spectrometer. Response to a Barium - 133 Source.

The sample gas flow through the flow-through gas monitors was adjusted to 10 cfm and the low flow alarm adjusted to operate at 9 cfm, using data supplied by the manufacturer.

C. ALARM AND CONTROL ACTION

All setpoints for the alarm and control action test were set above the normal background readings, and the monitors were adjusted to exceed the setpoints. The alarm and control circuits thus actuated, operated correctly and caused correct operation of the associated control valves.

D. ALARM AND CONTROL SETPOINTS

The calibration data supplied by the manufacturers, as well as the data taken during this test, were analyzed by the Health and Safety group. Based on the analysis, setpoints were selected for each of the radiation indicators. These values are listed in Table IV. The setpoint on each indicator was then adjusted to the selected value.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with preoperational test AI-P-1122, Radiation Detection and Monitoring System, as listed in NAA-SR-5700, Supplement 2, Page XI (a)-18 with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: All components are properly calibrated and operating correctly. B+ voltages have been adjusted and compared with power supply voltage. Measurements with the external isotopic source result in the same readings on connected indicators and recorders. Measurements with internal sources are consistent between indicators and recorders. Gas flow through monitors reads 10 scfm on attached flowmeters and causes low flow annunciation at 9 scfm.

Remarks: The above criterion has been met, as described in III. B. of this report.

TABLE IV
ALARM AND CONTROL SETPOINTS

Detector	Location	Read Out (Units)	Setpoint Limits (Tech Specs)	Setpoint
RD-900	Nitrogen Vents	$\mu\text{c/cc}$	$<10^{-3} \mu\text{c/cc}$	$1.0 \times 10^{-3} \mu\text{c/cc}$
RD-1000	Non R/A Vents	$\mu\text{c/cc}$	$<10^{-2} \mu\text{c/cc}$	$1.0 \times 10^{-3} \mu\text{c/cc}$
RD-1004	Wash Cell Vents	$\mu\text{c/cc}$	$<10^{-2} \mu\text{c/cc}$	$1.0 \times 10^{-3} \mu\text{c/cc}$
RD-1002	Pre Stack Line	$\mu\text{c/cc}$	$<10^{-2} \mu\text{c/cc}$	$1.0 \times 10^{-3} \mu\text{c/cc}$
RD-1001	Reactor Building Stack	cpm	$<10^{-4} \mu\text{c/cc}$	$4.5 \times 10^3 \text{ cpm}$
RD-1400-1	Control Room	mr/hr	2.5 mr/hr	2.5 mr/hr
RD-1400-2	Carbon Trap Cell	r/hr	none	none
RD-1400-3	Primary Cold Trap Cell No. 1	r/hr	none	none
RD-1400-4	Primary Cold Trap Cell No. 2	r/hr	none	none
RD-1400-5	Maintenance Cell Operating Area	r/hr	2.5 mr/hr	2.5 mr/hr
RD-1400-6	Equipment Decontamination Room	mr/hr	none	2.5 mr/hr
RD-1400-7	Control Rod Carriage	mr/hr	7.5 mr/hr	7.5 mr/hr
RD-1400-8	Local Boards 29 and 30	mr/hr	7.5 mr/hr	7.5 mr/hr
RD-1400-9	Fuel Handling Machine	r/hr	none	7.5 mr/hr
RD-1401-1	IHX Cell No. 1 Atmosphere	cpm	twice background	20 cpm
RD-1401-2	IHX Cell No. 2 Atmosphere	cpm	twice background	20 cpm
RD-1401-3	IHX Cell No. 3 Atmosphere	cpm	twice background	20 cpm
RD-1401-4	Cold and Carbon Trap Cells Atmos.	cpm	twice background	20 cpm
RD-1401-5	Primary Fill Tank Cell Atmosphere	cpm	twice background	20 cpm
RD-1401-6	Moderator Pump Cells and Primary Pipe Tunnel Atmosphere	cpm	twice background	20 cpm
RD-1401-7	Primary Pipe Tunnel Atmosphere	cpm	twice background	20 cpm
RD-100	Secondary Sodium Loop No. 1	cpm	twice background	20 cpm
RD-200	Secondary Sodium Loop No. 2	cpm	twice background	20 cpm
RD-300	Secondary Sodium Loop No. 3	cpm	twice background	20 cpm

TABLE IV (Continued)

Detector	Location	Read Out (Units)	Setpoint Limits (Tech Specs)	Setpoint
RD-1	Reactor Atmosphere	cpm	Between twice background and 10.0 $\mu\text{c/cc}$	2 decades greater than equilibrium activity at a fixed power level
RD-2	Fuel Storage Cell Atmosphere	cpm	none	none
RD-1100	R/A Liquid Waste	cpm	2.0 to 4.0 $\times 10^{-6}$ $\mu\text{c/cc}$	35 cpm Beta
RD-1102	R/A Waste Facility Stack	cpm	10^{-5} $\mu\text{c/cc}$	4.5×10^3 cpm
RD-1402	Air Particulate Reactor Area	cpm	none	9.0×10^3 cpm
RD-1403	Air Particulate Over IHX Cells	cpm	none	9.0×10^3 cpm
RD-1404	Air Particulate Auxiliary Bay	cpm	none	9.0×10^3 cpm
RD-1405	Air Particulate Maintenance Cell Operating Area	cpm	none	9.0×10^3 cpm
RD-1406	Air Particulate Decontamination Room	cpm	none	9.0×10^3 cpm

- b) Criterion: Correct control and/or annunciation occurs on (simulated) high radiation. Setpoints are established for these tests above the operating level. The monitor is then adjusted to exceed the setpoint and the control action to close specific valves and/or annunciation confirmed.

Remarks: The above criterion has been met, as described in III. C. of this report.

- c) Criterion: All alarm and/or control setpoints are properly set at valves established for reactor operation.

Remarks: The above criterion has been met, as described in III. D. of this report. The setpoints were chosen for convenience as well as for compliance with the technical specification associated with the reactor operation. Note: Criterion c) states that setpoints are properly set at valves; this is in error and should read ". . . setpoints are properly set at values. . ."

V. EVALUATION

The radiation detection and monitoring system was designed to monitor areas within the plant for personnel protection, to indicate off-normal conditions, and to prevent the release of excessively radioactive material to the surrounding areas. It has been evaluated based on radiation monitoring requirements, design specifications and preoperational test completion criteria.

It is felt that based on the above, the thirty-five strategically located individual detectors (in 9 separate subsystems) can satisfy plant monitoring requirements within practical limitations. All routinely occupied areas, and most limited access areas, are monitored. Portable instruments are available for unusual operating situations. However, numerous component failures have necessitated subsystem modifications which altered operating conditions such that design specifications are no longer met.

1) Constant Air Monitors

Modifications have restricted air flow to 6 scfm instead of the 10 scfm as specified; sensitivity has thereby been reduced. Maintenance records show low component reliability. Monitors will operate, but excessive maintenance effort is expected.

2) Secondary Sodium Monitors

Background radiation level is not indicated as required by specifications. It is therefore difficult to tell whether or not the monitor is operating. It is recommended that these units be checked for operation frequently by using the built-in calibration source.

3) Reactor Atmosphere Monitor

Leaks in the piping which connects the filter, detector and pump have been found. This piping was not built to the same specifications as the rest of the piping to which it is connected. This condition has been rectified by replacement of flanged, threaded and soldered fittings where required.

The proximity of the filter to the detector may generate spurious signals in case the filter becomes contaminated with radioactive sodium vapor. Relocation of the filter to provide some additional shielding between the filter and the detector may be desirable; this modification, however, should be delayed until a history of operation is available for the equipment.

4) Flow-Through Monitors

Data to calibrate the wash cell, non-radioactive vent, nitrogen vent, liquid waste, pre-stack and stack monitors over the working range of the instruments has been supplied by the vendor. Two calibration points are available. One point (obtained using radioactive gas) is about a decade above the normal operating point. The other, a calibration check, is less than the normal setpoint. A linear extrapolation had been made between these points, and the alarm and control setpoints set on the basis of this straight line. Since the required alarm and control setpoints are between the calibration point, the resulting calibration is adequate for the purpose.

5) Liquid Waste Monitor

A very strong possibility exists that this monitor will require decontamination after every release of liquid waste, due to the collection of radioactive deposits on the detector tubes. Removal of the unit for decontamination will be quite difficult because of the inaccessible location. Should such removal be required, it is recommended that this monitor be permanently removed from the system, and that the discharge of liquid waste be put under complete administrative control.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
LIGHTING, POWER, AND COMMUNICATION SYSTEM

AI-P-1130

Test and Analysis

by

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Evaluation

by

O. G. JENKINS

A T O M I C S I N T E R N A T I O N A L

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
LIGHTING, POWER, AND COMMUNICATION SYSTEMS, AI-P-1130

I. PURPOSE OF TEST

This test was separated into five sections, each dealing with a specific portion of the lighting, power and communication systems. The purpose of each of the five sections was to ensure that the following subsystems operate satisfactorily:

- a) 4160V system (Section 1)
- b) 480V auxiliary power system (Section 2)
- c) Communication system (Section 3)
- d) Emergency lighting system (Section 4)
- e) Automatic bus transfer, normal-to-reserve station transformer (Section 5)

II. DISCUSSION OF TEST PERFORMANCE

A. 4160V SYSTEM (Section 1)

All of the 4160V air circuit breakers (ACB) were racked-out to the TEST position. The eleven ACB's which comprise the 4160V switchgear are (see Figure 1130-1 for a single-line diagram of the 4160V system):

- 1) 152-1 Normal Station Transformer
- 2) 152-2 4160V Switchgear "C" Feeder
- 3) 152-3 Secondary Sodium Pump No. 3
- 4) 152-4 Primary Sodium Pump No. 3
- 5) 152-5 Secondary Sodium Pump No. 2
- 6) 152-6 Primary Sodium Pump No. 2

Figure 1130-1. Simplified Single-Line Diagram of 4160V System

- 7) 152-7 Secondary Sodium Pump No. 1
- 8) 152-8 Primary Sodium Pump No. 1
- 9) 152-9 4160V Switchgear "B" Feeder
- 10) 152-10 4160V Switchgear "A" Feeder
- 11) 152-11 Reserve Station Transformer

The automatic bus transfer from the normal to reserve station transformers was defeated by removing the contact blocks from undervoltage relays 127 B/A and 127 B/C. This was required, since the 4160V bus was dead during this test.

Using the local control switch (located on the breaker cubicle) each of the eleven 4160V ACB's was closed and tripped. Proper operation of each ACB, and associated indicating lights (red for closed ACB, green for open ACB), was observed.

Each individual phase overload relay contact on ACB's 152-1, 152-2, 152-9, 152-10, and 152-11 was operated manually with the ACB closed. In all cases, the ACB tripped as soon as the phase overload contact closed. Also, the overload relay sealing contacts picked up, and it was necessary to turn the local ACB control switch to TRIP to release the sealing contacts before re-closing the ACB and moving on to the next phase overload contact. With the same ACB's previously closed, the ground overcurrent relay contacts were manually operated, and the ACB tripped. Since the ground overcurrent relay does not have sealing contacts, the ACB could be re-closed after allowing the relay to drop out. In this manner, the overload trips for the normal, reserve, and switchgear "A", "B", and "C" feeder ACB's were checked for correct operation.

The 4160V breakers were tripped and were left racked-out in the TEST position. Attempts were made to close both the normal and reserve station ACB's from the main board control switches, without turning on the synchronizing equipment. In neither case did the breaker close.

Synchronizing equipment for the normal station ACB was turned on, and the main board control switch was used to close and trip the breaker. With the synchronizing equipment on, the normal station ACB responded

properly. The same test was performed for the reserve station ACB, using the reserve station synchronizing equipment, with the same results.

Next, the normal station ACB was closed. The synchronizing equipment for the reserve station ACB was turned on, and the reserve ACB closed. As expected, the normal station ACB tripped as soon as the reserve ACB closed, and the annunciator "Normal Station ACB Trip" actuated. This annunciator could be reset by turning the main board control switch for the normal station ACB to TRIP. The same test was repeated for the normal station ACB, with the same results, except that the annunciator "Reserve Station ACB Trip" actuated.

The normal station ACB was left closed, and the contact blocks for undervoltage relays 127 B/A and 127 B/C, which set up the automatic bus transfer from normal to reserve station transformers, were simultaneously inserted. Since the 4160V bus was dead, the automatic transfer occurred, i. e., the normal station ACB tripped and the reserve station ACB closed.

The contact block for undervoltage relay 127 B/C, which sets up automatic closing of the reserve station ACB, was removed. The reserve ACB was tripped, and the normal station ACB was closed.

Since the 4160V bus was still dead, the normal station ACB tripped, and, because the contact block for undervoltage relay 127 B/A was still in place, the automatic transfer sequencing started. This included trip of the normal station ACB and the start of timing relay 162, which allows automatic closing of the reserve ACB to occur only within 0.3 sec of normal station ACB trip. (This is the anti-hunt relay, which prevents continual automatic cycling of the reserve ACB should it trip after an automatic closure). The contact block for relay 127 B/C was inserted, and, since relay 162 had already timed out, the reserve station ACB could not, and did not, close.

The contact blocks for relays 127 B/A and 127 B/C were removed. The normal station ACB was closed. The reserve station overcurrent

relay 151-11, was manually picked up, and proper operation of the annunciator "Overcurrent Reserve Station Transformer" was observed. The contact blocks for relays 127 B/A and 127 B/C were simultaneously inserted, thus starting the automatic bus transfer. The normal station ACB tripped, and proper non-closure of the reserve station ACB, because of the simulated fault, was observed.

The 4160V switchgear "A", "B", and "C" feeder ACB's were closed and tripped from the main board control switches. Proper operation of the ACB's and associated main board indicating lights was observed.

The 4160V switchgear "A" feeder ACB was closed. The overcurrent relay for this ACB was manually actuated, the breaker tripped, and the annunciator "Load Center Overcurrent" actuated. Resetting the annunciator was possible by moving the main board control switch to TRIP. The same test was repeated for the "B" and "C" feeder ACB's with identical results.

The six sodium pump ACB's were closed and tripped from main board control switches. Proper operation of the ACB's and associated indicating lights was observed. It was also verified that in order to close a pump ACB, the following interlocks had to be satisfied:

- 1) Coupling control de-energized
- 2) Seal oil pump running
- 3) Pump speed demand below zero

It was further verified that tripping any primary or secondary pump ACB resulted in automatic tripping of the corresponding primary or secondary pump ACB.

Prior to racking the ACB's into the operating position, the switchgear manufacturer's representative arrived at the Hallam Nuclear Power Facility (HNPF) to set the various overcurrent, undervoltage, and protective relays for the 4160V and 480V systems. All protective relays were set in accordance with Bechtel Drawing D-794515. The setting of these relays was witnessed by an Atomics International representative.

Also before racking-in the 4160V ACB's, a phase sequence and phase voltage check was made at the incoming feeder circuit breaker stabs in the normal and reserve breaker cubicles, to insure correct phasing between the two sources of 4160V power.

Once the protective relays were set and source phasing checked, each of the 4160V ACB's was racked into the OPERATE position. Under-voltage relay 127 B/A and 127 B/C contact blocks were left out to defeat the automatic bus transfer.

Attempts were made to close the eleven 4160V ACB's by using the local control switches. In all cases, the breaker did not close, per design.

Testing of the 4160V breakers from the main board control switches was then continued per the procedure followed when the ACB's were in the TEST position. The automatic transfer from normal to reserve source is discussed in the Section 5 portions of this report. Since the ACB's were in the operating position, it was possible to verify proper operation of synchronizing equipment and the associated voltage, frequency, and current meters. The sodium pump motors were checked for proper rotation. In all cases, the ACB's and associated synchronizing and/or metering equipment operated properly.

B. 480V AUXILIARY POWER SYSTEM (Section 2)

All 480V ACB's were racked-out to the TEST position. The 4160V bus was energized through the reserve station ACB. The "A", "B" and "C" 4160V feeders were closed, so power was available to the 480V buses when required.

The 480V ACB's for the "A", "B", and "C" switchgear (see Figure 1130-2 for a single-line diagram of the 480V system), 52-A1, 52-B1 and 52-C1 were closed and tripped from the local control switches. Proper breaker and indicating light response was observed.

Figure 1130-2. Simplified Single-Line Diagram of 480V System

These ACB's were then racked into the OPERATE position, and attempts were made to close the breakers from the local control switch. Proper non-response was observed.

The 480V ACB's for the "A", "B", and "C" switchgear were then closed and tripped from the main board control switches. Proper breaker and indicating light response was observed.

The diesel breaker, 52-A2, was racked into the OPERATE position. The 480V ACB's for the "A" and "B" switchgear were closed and tripped from the main board control switch, and proper breaker response was verified.*

ACB 52-A1 was closed. Proper operation of the main board and local voltmeters was observed. Also, pick-up of undervoltage relays 27A and 27-A1 was noted. Relay 27A was manually actuated, and proper tripping of ACB 52-A1, along with actuation of the annunciator "Trip 480V Switchgear A", was observed. Resetting the annunciator was possible by moving the main board control switch for ACB 52-A1 to TRIP. The same test was then repeated for 480V switchgear "B" with similar results.

A Variac was connected to undervoltage relays 27A, 27-A1, 27B, and 27-B1 and the pick-up and drop-out voltage values were obtained and recorded.

Next, 480V ACB 52-A1 was closed. All the 480V feeder circuit breakers feeding off of the 480V "A" bus were closed. Proper operation of main board and local ammeters was observed. The 4160V "A" switchgear feeder was tripped. The time interval between tripping of both the 4160V "A" switchgear feeder and ACB 52-A1 (through relay 27A), and the tripping of the 480V feeder circuit breakers (through 27-A1) was

* When the diesel breaker, 52-A2, is in the operating position, and is closed, it is not possible to close the 480V "A" or "B" ACB's without using the 480V synchronizing equipment. This was verified in AI-P-1118, Emergency Power System.

recorded. It was also noted that all the 480V "A" bus ACB's tripped on undervoltage, except breaker 52-A7 (Emergency Feed to Instrument Air) and 52-A9 (Control Center A-3) which did not trip, per design. The same test was then repeated for the "B" switchgear, with similar results, except that all "B" bus breakers tripped.

ACB 52-C1, for 480V switchgear "C", was closed. All the 480V feeder circuit breakers feeding off of the 480V "C" bus were closed. Proper response of the main board and local ammeters was observed. (The "C" bus does not have any undervoltage trips.)

The tie breaker, 52-A11, between the "A" and "B" buses was removed from its cubicle. Proper voltage between phases and proper phase sequencing between "A" and "B" buses was verified at the bus stabs in the tie breaker cubicle. The tie breaker was replaced in its cubicle and was racked into the operating position.

Additional data on the 4160V and 480V switchgear are found in Appendix B of this report. Automatic tie breaker control actuation was verified by setting the main board main and auxiliary control switches in the following positions:

- 1) With the main control switch in TRIP, the tie breaker did not close upon loss of "A" and/or "B" bus, regardless of the position of the auxiliary switch.
- 2) With the main control switch in the AUTOMATIC position, and the auxiliary control switch also in the AUTOMATIC position, the tie breaker would automatically close only on loss of "A" bus. Upon restoration of "A" bus, from either the normal source or the diesel generator source, the tie breaker would automatically trip.
- 3) With the main control switch in the AUTOMATIC position and the auxiliary switch in the closed position, the tie breaker would close automatically upon loss of "A" or "B" bus, or both. Upon restoration of power from the diesel generator, the tie breaker remained closed. Upon restoration of power from both the "A" and "B" buses, the tie breaker would automatically trip.

C. COMMUNICATION SYSTEM (Section 3)

The building evacuation siren switch was switched to the REACTOR position. The building evacuation siren operated and was audible throughout the nuclear portion of the plant. The switch was moved to the ALL position and the siren was audible throughout both the nuclear and conventional plant.

The area evacuation siren pushbutton was depressed, actuating the area evacuation siren, which was clearly audible over the entire Sheldon Station site. After 2 min 15 sec, the siren automatically shut off.

The public address system and the two plug-in telephone systems were observed to operate satisfactorily.

D. EMERGENCY LIGHTING (Section 4)

The 480V ac feed to lighting transformer No. 1 was tripped by opening circuit breaker 52-A301A. Sensing a loss of normal input voltage, the automatic transfer relay immediately transferred to the emergency 125V dc feed. The reactor plant was toured, and it was observed that the emergency lighting fixtures were operating satisfactorily.

Breaker 52-A301A was re-closed, and the transfer relay returned to its normal position.

E. AUTOMATIC BUS TRANSFER, NORMAL-TO-RESERVE STATION TRANSFORMER (Section 5)

Prior to making a live automatic transfer from the normal to reserve sources of power, the plant was set up as follows:

- 1) Normal station transformer ACB 152-1 was closed.
Reserve station transformer ACB 152-11 was open and in the operating position.

- 2) All 480V buses were energized, and all available equipment was operating.
- 3) The main sodium pumps were operating, and were pumping sodium at about 90% rating.

A Sanborn high speed oscillograph was connected to record the following:

- 1) Time of trip, ACB 152-1
- 2) Time of close, ACB 152-11
- 3) 4160V bus voltage
- 4) Reserve source current
- 5) Reserve source voltage
- 6) Primary sodium pump No. 1 current

Initial values of 4160V voltage and current were recorded, the Sanborn recorder started, and the normal station ACB manually tripped. The reserve station ACB automatically closed, and the Sanborn recorder was stopped after the transient had ceased. It was observed that none of the sodium pumps or 480V main ACB's had tripped, but a critical panel transfer to the M-G sets and back to normal power had occurred. Quantitative results of this test are given in Part III, E. Additional data on the critical panel transfer are found in Appendix A of this report.

By proper use of the synchronizing equipment, the normal station ACB was re-closed, and the reserve station ACB automatically tripped and was also locked out. The Sanborn recorder was started, and the normal station ACB was tripped, thus de-energizing the electrical feed to the plant. After the "loss of power" transient ceased, the Sanborn recorder was stopped.

The critical panels transferred to the M-G sets, and the M-G set drive was picked up by the 250V dc batteries. Proper tripping of the six sodium pump ACB's (one for each pump) was noted. Likewise, proper tripping of 52-A1, 52-B1, and all "A" and "B" control centers, except A3 was observed.

- 2) All 480V buses were energized, and all available equipment was operating.
- 3) The main sodium pumps were operating, and were pumping sodium at about 90% rating.

A Sanborn high speed oscillograph was connected to record the following:

- 1) Time of trip, ACB 152-1
- 2) Time of close, ACB 152-11
- 3) 4160V bus voltage
- 4) Reserve source current
- 5) Reserve source voltage
- 6) Primary sodium pump No. 1 current

Initial values of 4160V voltage and current were recorded, the Sanborn recorder started, and the normal station ACB manually tripped. The reserve station ACB automatically closed, and the Sanborn recorder was stopped after the transient had ceased. It was observed that none of the sodium pumps or 480V main ACB's had tripped, but a critical panel transfer to the M-G sets and back to normal power had occurred. Quantitative results of this test are given in Part III, E. Additional data on the critical panel transfer are found in Appendix A of this report.

By proper use of the synchronizing equipment, the normal station ACB was re-closed, and the reserve station ACB automatically tripped and was also locked out. The Sanborn recorder was started, and the normal station ACB was tripped, thus de-energizing the electrical feed to the plant. After the "loss of power" transient ceased, the Sanborn recorder was stopped.

The critical panels transferred to the M-G sets, and the M-G set drive was picked up by the 250V dc batteries. Proper tripping of the six sodium pump ACB's (one for each pump) was noted. Likewise, proper tripping of 52-A1, 52-B1, and all "A" and "B" control centers, except A3 was observed.

Normal power was resumed by closing the reserve station ACB and re-closing all tripped breakers.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

A. 4160V SYSTEM (Section 1)

The 4160V ACB's were checked for proper operation in both the TEST and OPERATE positions. The following items were verified:

- 1) When the 4160V ACB's are in the TEST position, the ACB can be closed or tripped from its local control switch. When the 4160V breakers are in the OPERATE position, the ACB can only be tripped from its local control switch.
- 2) When the 4160V ACB's are in the TEST or OPERATE position, operation of any overload device will trip the ACB and actuate the proper annunciator.
- 3) In either the TEST or OPERATE position, the normal station and reserve station ACB's can be closed only when the associated synchronizing equipment is energized. Synchronizing the normal station ACB feed with the reserve station ACB closed, and then closing the normal station ACB, results in tripping the reserve station ACB and vice versa.
- 4) The automatic bus transfer from normal station to reserve station ACB's, while in the TEST position, functions correctly. (See Section 5 for results of the live transfer.)
- 5) The 4160V "A", "B", and "C" switchgear feeder ACB's can be tripped or closed from the main board control switches, with the ACB's in the TEST or OPERATE position.
- 6) With the sodium pump ACB's in either the TEST or OPERATE position, the ACB's can be closed from the main control board switches only when the "coupling energized", "seal oil pump running", and "zero speed demand" interlocks are satisfied. When a primary or secondary sodium pump ACB is tripped, the corresponding primary or secondary pump ACB will trip. Proper rotation of pump motors was observed.

- 7) With the 4160V ACB's in the OPERATE position, proper response of the synchronizing bus meters, and all other voltmeters and ammeters, was observed.
- 8) All protective relays were set in accordance with Bechtel Drawing D-794515.

B. 480V AUXILIARY POWER SYSTEM (Section 2)

Circuit breakers associated with the 480V switchgear were checked for proper operation. The following was verified:

- 1) The 480V ACB's for the "A", "B", and "C" switchgear (52-A1, 52-B1, and 52-C1) would be closed and tripped from the local control switches when the ACB's were in the TEST position. When in the OPERATE position, these ACB's can only be tripped from the local control switches. As long as the diesel breaker (52-A2) is not closed, these ACB's can be closed or tripped from the main board control switches if the ACB is in either the TEST or OPERATE position.
- 2) The 480V feeder circuit breakers feeding from the "A", "B", or "C" buses operate properly.
- 3) Undervoltage on the 480V "A" bus results in undervoltage relay 27A tripping 480V switchgear "A" ACB 52-A1; and undervoltage relay 27-A1 tripping all the circuit breakers feeding off of the "A" bus, except for breaker 52-A9 and breaker 52-A7. Breaker 52-A9 feeds control center A3, and breaker 52-A7 supplies emergency power to the Consumers Public Power District instrument air compressors. Undervoltage on the 480V "B" bus results in undervoltage relay 27B tripping 480V switchgear "B" ACB 52-B1; and undervoltage relay 27-B1 tripping all the circuit breakers feeding off of the "B" bus. Pick-up and drop-out voltages and operating times of undervoltage relays 27A, 27-A1, 27B, and 27-B1 are shown in Table I.
- 4) Proper automatic operation of the tie breaker through the main board main and auxiliary control switches, was verified.
- 5) Proper operation of the voltmeters and ammeters associated with the 480V switchgear was observed.

TABLE I

OPERATING CHARACTERISTICS OF 480V
"A" AND "B" BUS UNDERVOLTAGE RELAYS

Relay	Pick-up* (volts)	Drop-out* (volts)	Operating time** (seconds)
27A	95	90	0.5
27-A1	90	85	0.5
27B	95	90	0.1
27-B1	90	85	0.1
<p>* Multiply by 4 to obtain corresponding 480V system settings.</p> <p>** Time between drop-out of relay and actuation of trip circuit The time delay is deliberate, and avoids tripping of "A" and "B" equipment during short transients such as occur during the normal-to-reserve station transfer.</p>			

C. COMMUNICATION SYSTEM (Section 3)

The building evacuation siren, the area evacuation siren, the public address system, and the two plug-in telephone systems operate satisfactorily.

D. EMERGENCY LIGHTING (Section 4)

Upon loss of 480V ac power to lighting transformer No. 1, the transfer relay switches to 125V dc emergency power and the emergency lighting fixtures operate satisfactorily.

E. AUTOMATIC BUS TRANSFER, NORMAL-TO-RESERVE
STATION TRANSFORMER (Section 5)

Data from the live automatic normal-to-reserve station transformer transfer are shown in Table II.

TABLE II
LIVE AUTOMATIC NORMAL-TO-RESERVE
STATION TRANSFORMER TRANSFER

Parameter	Value
4160V bus voltage	4120 V
Reserve station transformer voltage	4160 V
4160V load	350 Amp
Primary sodium pump No. 1 load	36 Amp
Primary sodium pump No. 2 load	37 Amp
Primary sodium pump No. 3 load	34 Amp
Secondary sodium pump No. 1 load	39 Amp
Secondary sodium pump No. 2 load	37 Amp
Secondary sodium pump No. 3 load	38 Amp
480V load center "A" load	465 Amp
480V load center "B" load	470 Amp
480V load center "C" load	475 Amp
4160V system total transfer time from manual trip of normal station ACB to close of reserve station ACB	17.5 Cycles
Time for residual bus voltage to decay to 80% from trip of normal station ACB	6.0 Cycles

Curves of 4160V bus voltage decay and primary sodium pump No. 1 inrush current are shown in Figure 1130-3.

Curves of 4160V bus voltage decay and pump current decay for a complete power outage are shown in Figure 1130-4.

Based upon the above results, the following conclusions were made.

- 1) Automatic transfer from the normal to reserve station transformer can be successfully made without tripping the sodium pumps.
- 2) Transfer from the normal to reserve source of power may be made without a reactor scram, if the critical panel transfer can be delayed. (A time delay relay was later installed in the critical panel, but was not entirely successful. Refer to Appendix A for a detailed discussion of this item.)
- 3) Tripping of the normal station transformer results in a total transfer time of 280 milliseconds. If the transfer is automatically initiated by undervoltage, transfer time will be 190 milliseconds. (Actual automatic transfer is initiated by 4160V bus undervoltage relay set at 80% actuation.)
- 4) Inrush currents, following an automatic bus transfer, are not excessive.
- 5) During the time between normal station ACB tripping and reserve station ACB closing, 4160V bus voltage is held up by the back EMF produced by the rotating inertia of the sodium pump motors.

Figure 1130-3. 4160V Bus Voltage Decay and Pump Current During Normal to Reserve Transformer Transfer.

Figure 1130-4. 4160V Bus Voltage Decay and Pump Current Decay Upon De-energizing the 4160V System

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with pre-operational test AI-P-1130, Lighting, Power, and Communication System, as listed in NAA-SR-5700, Supplement 2, pages XI (a)-19 through XI (a)-22 with remarks regarding the test to explain compliance with the criteria.

A. 4160V SYSTEM (Section 1)

- 1) Criterion: 4160V local breaker controls operate with the breakers in racked-out position.

Remarks: The 4160V local breaker controls operate properly with the breakers racked-out to the TEST position.

- 2) Criterion: 4160V main board controls operate with breakers in racked-out position.

Remarks: The 4160V main board controls operate properly with the breakers racked-out to the TEST position.

- 3) Criterion: 4160V breakers operate in racked-in position.

Remarks: The 4160V breakers operate properly when the breakers are racked into the OPERATE position.

- 4) Criterion: Protective relays have been set in accordance with Drawing D-794515.*

Remarks: Protective relays were set in accordance with Bechtel Drawing D-794515, as witnessed by an Atomics International representative.

B. 480V AUXILIARY POWER SYSTEM (Section 2)

Switchgear A and B

- 1) Criterion: 52 A1 and 52 B1 operate.

Remarks: ACB's 52-A1 and 52-B1 operate properly with the breakers racked-out to the TEST position, and with the breakers racked-in to the OPERATE position.

* Bechtel Drawing

- a) Criterion: Interlocks on 52 A1 or 52 B1 prevent closing, or trip diesel generator breaker 52 A2 if 52 A1 or B1 is closed.

Remarks: ACB's 52-A1 and 52-B1 are interlocked to the diesel breaker 52-A2. The diesel breaker can close only if 52-A1 and 52-B1 are open, or will be tripped if either 52-A1 or 52-B1 is closed. This was verified in AI-P-1118, "Emergency Power System".

- b) and c) Criterion: Interlocks trip 52 A11, bus tie breaker, when both 52 A1 and B1 are closed. Interlocks close 52 A11, bus tie breaker, when either 52 A1 or 52 B1 are open.

Remarks: The tie breaker, 52-A2, was modified after these criteria were written. This modification consisted of adding an auxiliary control switch at the main board so that feed to 480V "B" bus from 480V "A" bus through 52-A11 is not automatic unless the plant operators have set the auxiliary control switch on CLOSED. Automatic closing of the tie breaker upon opening of 52-A1, and subsequent feeding of the 480V "A" bus by the 480V bus, was not changed. Proper operation of the modified tie breaker circuit was verified. (See Part III, Presentation of Test Results.)

- d) Criterion: Undervoltage 27A trips 52 A1 and 27B trips 52 B1.

Remarks: Undervoltage on 480V "A" bus results in drop-out of undervoltage relay 27A. Drop-out of relay 27A results in tripping ACB 52-A1. The same is true of 480V "B" bus, with drop-out of undervoltage relay 27B and subsequent tripping of ACB 52-B1.

- 2) Criterion: 52 A2 (See Emergency System AI-P-1118.)

- a) Criterion: 52 A8 and 52 B6 are locked out when 52 A2 closes.

Remarks: Proper operation of the diesel generator ACB 52-A2, and lock-out of 52-A8 and 52-B6 (preheat control centers A2 and B2), when 52-A2 is closed, was verified in AI-P-1118, Emergency Power System.

- 3) Criterion: 52 A3, A4, A5, A6, A7, A8, A10, and 52 B2, B3, B4, B5, B6 and B7 all operate.

Remarks: Proper operation verified.

- a) Criterion: Undervoltage 27A-1 trips all A Breakers.
Remarks: Undervoltage 27 A-1 trips all "A" Breakers except 52A9. (See criterion 4 below for remarks on operation of 52A9.)
- b) Criterion: Undervoltage 27B-1 trips all B Breakers.
Remarks: Proper operation verified.
- c) Criterion: 52 A8 and 52 B6 - See 2A above.
Remarks: See criterion 2 a) above.
- 4) Criterion: 52 A9 operates.
Remarks: Proper operation verified.
Criterion: Undervoltage does not trip 52A9.
Remarks: Proper operation verified.

Switchgear C

- 1) Criterion: 52C1, 52C2, 52C3, 52C5, 52C6 operate.
Remarks: Proper operation verified.

C. COMMUNICATION SYSTEM (Section 3)

- 1) Criterion: The building evacuation siren and the public address system operate so as to be audible and intelligible within the reactor building, the administration building and conventional plant.
Remarks: These devices have been demonstrated to be audible in the areas required.
- 2) Criterion: The area evacuation siren and the public address system operate so as to be audible and intelligible in the area surrounding the reactor building.
Remarks: These devices have been demonstrated to be audible in the areas required.

D. EMERGENCY LIGHTING (Section 4)

- 1) Criterion: Emergency lighting fixtures operate upon loss of 480-volt lighting power.
Remarks: Emergency lighting fixtures have been demonstrated to operate properly upon loss of 480V lighting power.

E. AUTOMATIC BUS TRANSFER, NORMAL-TO-RESERVE
STATION TRANSFORMER (Section 5)

No completion criteria are noted for this portion of the test. However, it was determined that the automatic bus transfer from the normal to reserve station transformer operates satisfactorily.

V. EVALUATION

In keeping with the completion report of this test, the evaluation is presented in five sections, one for each of the separate parts of the electrical system as covered by the test.

A. 4160V SYSTEM (Section 1)

In the process of testing this system it was proven that:

- 1) With the breakers racked-out to the TEST position, the local breaker controls and the main board breaker controls operate properly.
- 2) With the breakers racked-in, the local breaker controls and the main board breaker controls operate properly.

Although all the 4160V system protective relays were set according to specifications by a representative from the switchgear vendor (under observation by a representative from Atomics International), many cases of switchgear malfunction have arisen since completion of the test. Such failures indicate that the electrical switchgear was not in first class condition. These failures by type are:

- 1) Auxiliary contacts improperly adjusted.
- 2) Control wires loose and catching on operating mechanism linkage.
- 3) Broken indicating flag linkages.
- 4) Operating handle positioning spring off of spring retaining pin, disabling operating handle.

- 5) Small ring terminals placed under large ring terminals which bridge terminal insulators, preventing tightening of the large terminals onto the small terminals.
- 6) Broken "racking" operating mechanism. It was almost impossible to rack-in the large DMB-50 breakers, by means of the racking mechanism alone.
- 7) Misaligned and bent ground studs.
- 8) Non-operation or intermittent operation corrected by removing and re-racking breakers. Trouble has been attributed to weak control contact finger springs or dust on the contact fingers, though neither could be proven.

The existence of these discrepancies has been checked and verified by the vendor, and a vendor representative sent to the site to perform a thorough checkout of the 4160V switchgear. Necessary repairs and modifications were instituted while the representative was at the HNPF. Appendix C discusses the switchgear repairs performed.

B. 480V AUXILIARY POWER SYSTEM (Section 2)

All interlocks, relays and air circuit breakers operated as prescribed in the technical specifications.

One modification to this system, effected while the preoperational test was being conducted, was the addition of an auxiliary tie breaker switch on the main board in the control room. Unless this auxiliary switch is in the closed position, breaker 52-A11, which ties "A" and "B" buses together, will not automatically close when power is lost to "B" bus. This gives Operations more protection for critical power which is fed from "A" bus: if "B" bus is feeding a fault, the tie breaker can thus be kept open to keep from overloading "A" bus. However, if power is lost to "A" bus, the tie breaker between "A" and "B" bus will automatically close to maintain power to "A" bus, thus assuring a more constant supply for critical loads.

Since completion of the preoperational test, 480V load center "C" has been running "hot". This is attributed to excessive preheat loads. Forced air cooling fans have been ordered for this cabinet.

C. COMMUNICATION SYSTEM (Section 3)

The public address system, building and area evacuation siren, and the plug-in telephone system were all tested and noted to operate satisfactorily. With proper maintenance, these components should remain ready for service at all times.

A longer extension cord was put on the head sets, to enable the operator to communicate via the head sets when required to move about the control panel to read pertinent gages and read out instruments.

D. EMERGENCY LIGHTING (Section 4)

Power to 480V lighting transformer No. 1 was interrupted by opening the circuit breaker feeding this transformer. The automatic transfer relay immediately transferred over to the 125V dc feed and the emergency lights remained on. When the 480V ac transformer feed circuit breaker was reclosed, the transfer relay returned to its normal position.

It was noted during the course of this test that the emergency lighting load was excessive. This excessive load resulted from the same wattage bulbs being used for emergency lights as for the normal lighting fixtures. This discrepancy was corrected by replacing the offending lights with bulbs of the specified lower wattage.

E. AUTOMATIC BUS TRANSFER, NORMAL-TO-RESERVE
 STATION TRANSFORMER (Section 5)

During the 280 msec interim after the "Normal" station tripped, before the "Reserve" station picked up the load, the 4160V bus did not drop lower than 2200V. The main sodium pump motors, the biggest load on the 4160V bus, did not trip out. However, the inrush current to these motors came to about 108 amperes, which is about what is taken to start the motors.

One modification affected as a result of this test was the incorporation of a one-second time delay in the critical panel transfer circuit. The purpose of this time delay is to prevent a transfer of the critical bus from critical to noise-free power in the 300 msec interim between "Normal" station trip and "Reserve" station pickup. This will prevent scrams during the momentary loss of power to the relays in the protective panel. After the one-second delay was installed, a transfer from "Normal" station to "Reserve" station was initiated, and the critical panel transfer did not take place. However, the reactor did scram during the transfer interim. The cause for the scram was difficult to determine, since no indication was given other than the scram plaque being lighted. The postulated reason for the scram was the loss of scram relays K-48 and K-64 due to voltage decay on the critical bus.

From experience gained during and after execution of this pre-operational test, the following suggestions are tendered toward enhancement of future design and installation of electrical systems:

- 1) Stipulate in the contract that after the entire system is installed, prior to acceptance of the system, a vendor's representative set the switchgear and check it out, under the surveillance of an observer from Atomics International.
- 2) Design the cabinets for adequate cooling under maximum load conditions.

- 3) Consider fire danger in the design. Strive for horizontal rather than vertical arrangement of the switchgear. Incorporate fire walls to minimize spread of fire.
- 4) Arrange the new system so that automatic tie-in can only occur in a single direction from buses supplying non-vital loads to buses supplying vital loads. This will prevent vital power from being lost due to feeding a fault in the non-vital portion of the system.

APPENDIX A

AVOIDING REACTOR SCRAM DURING AUTOMATIC NORMAL-TO-RESERVE TRANSFORMER TRANSFER

During testing of the live automatic bus transfer from normal to reserve transformer, it was noted that a reactor scram would have occurred due to the initiation of a critical panel transfer. The most probable causes of a transfer occurring are a generator fault, a normal station transformer fault, a switchyard fault, or generator underfrequency, all of which result in a turbine trip. Under these conditions, it would be desirable to avoid the scram, as the plant control system will normally program reactor power down, and, with the reactor operating, steam would be available to immediately roll the turbine and get the generator back on the line in as short a time as 10 min following turbine trip.

There is another possible cause of a transfer — a fault in the HNPF 4160V electrical system. Under this condition the transfer would take place, but the reserve transformer ACB would immediately trip out on the fault, leading to a necessary scram.

The ultimate cause of the "electrical scram" is loss of critical control power to relays within the protective panel. During the normal-to-reserve transformer transfer, the 4160V bus voltage decays to a minimum value of 2100V, or 51%. This 51% voltage dip is reflected in the 480V and 208/120V systems. When the critical panel transfer relays sense a voltage dip of 75%, the critical panel transfer is initiated. Since the critical panel transfer relays are "break-before-make" and the critical panel transfer to the M-G sets takes 28 milliseconds, there is a complete loss of critical power for 1-3/4 cycles, resulting in drop-out of the protective panel relays and a subsequent reactor scram.

Tests on the protective panel relays showed that these relays will hold in until voltage dips 32%, and drop-out time is 20 milliseconds. Consequently, it was felt that if the critical panel transfer relays could be reset to actuate at 30% voltage dip, or if they could be delayed in transferring for longer than 280 milliseconds (time required for the normal-to-reserve transformer transfer), a scram might be avoided.

To test this hypothesis, a separate normal-to-reserve transformer transfer was made, but with the critical panel transfer relays blocked, i.e., the critical panel transfer relays were prevented from transferring. During this test, no protective panel relays dropped out, and the reactor would not have scrambled.

Since the installed critical panel transfer relays cannot be set to actuate at lower than 75% voltage dip, a time delay had to be installed.

Addition of a time delay relay on the critical panel transfer relays did not result in any safety compromise, since loss of electrical power or any other normal scram condition still results in a reactor scram.

Subsequent to addition of the time delay relay, the initial critical panel transfer was performed without scrambling the reactor. Later normal to reserve station transfers, however, have provided only limited success in avoiding scrams. The time delay has proven successful in avoiding scrams caused by transient voltage dips which do not cause a normal to reserve transfer. Further investigation of this condition is currently underway.

APPENDIX B

SWITCHGEAR MALFUNCTIONS

During construction tests and preoperational testing, there were numerous malfunctions traceable to the 4160V and 480V switchgear. These difficulties are presented in an Atomics International I O L from W. W. Johnson to C. C. Conners, dated 4-25-62, and quoted below:

"During the construction phase of the checkout of plant equipment, many unrecorded instances of equipment malfunction or non-function were traced to malfunctioning switchgear, i.e., loose terminals, broken wires, open N/C contacts, closed N/O contacts, bent contact operating linkages, loose bolts and nuts, broken arc chutes and other plastic components. These malfunctioning switchgear caused control circuit malfunction, particularly in circuits to the Nitrogen Coolers, Building Exhaust Fans, Cooling Water Pumps, and various control centers.

"In the early stages of preoperational testing, many items of equipment (mostly the same as those listed in the paragraph above) were found to be malfunctioning or non-functioning. With the electrical construction contractor still at the site, these were referred to him, in most cases directly by the test engineer, and in many instances, malfunctioning of the switchgear as indicated in the paragraph above were found.

"Some failures which have been noted but have not been logged as to specific breaker or particular time of malfunction are:

- a) Auxiliary contacts improperly adjusted.
- b) Control wires loose and catching on operating mechanism linkage.
- c) Broken indicating flag linkage.
- d) Operating handle positioning spring off of spring retaining pin, disabling operating handle.
- e) Small ring terminal placed under large ring terminals which bridge terminal insulators, preventing tightening of the large terminals onto the small terminals.
- f) Broken 'racking' operating mechanism. It is almost impossible to rack in the large DMB-50 breakers by means of the racking mechanism alone.

- g) Misaligned and bent ground stud.
- h) Non-operation or intermittent operation corrected by removing and re-racking breaker. Trouble has been attributed to weak control finger springs or dust on the contact fingers, though neither can be proven.

"Some specific switchgear failures are:

- a) October 21, 1961 — The several apparent malfunctions which resulted finally in a major switchgear fire.*
- b) January 5, 1962 — Exhaust fan breaker 52-B3 would not close on 'auto'. Found auxiliary contacts out of adjustment, and arc chute broken, a control wire catching on an operating mechanism arm, and the indicating flag linkage was broken.
- c) February 23, 1962 — Control center B1 breaker 52-B2. C phase in the control center was dead. The feeder breaker was withdrawn and checked and no specific cause for malfunction found. The breaker was reinstalled and the control center power was found to be normal 3 phase again.
- d) March 15, 1962 — Tie breaker 52-A11. Breaker would not close either on 'auto' or 'close' position of tie breaker switches. Trouble in 'auto' circuit finally traced to faulty interlock contact in main breaker 52-A1. These interlock contacts are actuated by a complex linkage connected to the main contact arms. There is enough friction and 'slack' in the linkage to cause the interlocks to stop in partially operated position. The trouble in the 'close' circuit has been traced to improper operation of the tie breaker cell switch. The breaker, as is true in most of the others in the switchgear, has some variation of its 'racked-in' position, and is apparently barely making contact with the cell switch.

In checking out the malfunction of the tie breaker, several loose wiring connections were found, but correcting these did not correct the non-operating conditions described above."

* As a result of this fire, the reduced voltage starting circuits on the building exhaust fans were deleted, the tie breaker control circuit was modified, and a firewall was installed between the "A" and "B" buses in the A-B switchgear cubicle.

- e) April 13, 1961 — Control center C1 breaker 52-C3 would not close electrically. The trouble was determined to be in the breaker close circuit, but upon withdrawal and check out of the circuit breaker no specific cause for malfunction could be found. The breaker was re-installed in the switchgear and operated satisfactorily.
- f) Instrument Air Breaker 52-A7. The linkage arm to the close coil interlock contact was missing. This contact de-energized to close coil after the breaker had closed. Thus, when the breaker was first closed, the closing coil remained energized and burned out.

"Though it does not particularly fit the category of switchgear failures, it is pertinent to note that equipment and control fuse identification were lacking as the switchgear was received from the manufacturer, making trouble shooting difficult. The problem has been further complicated by the many errors which have been found in the vendors schematic and wiring diagrams."

APPENDIX C

SWITCHGEAR REPAIR

Following is the text of an I O L from R. H. Baulig to G. A. Carlson, regarding adjustment and repair of the HNPF switchgear:

"Mr. J. R. Burnett of Federal Pacific Electric Company arrived at the site November 12, 1962, to service and adjust the FPE switchgear. It was decided that the most benefit would be gained from his presence if the CPPD electricians, as well as myself, did most of the adjustments and repairs, under Mr. Burnett's guidance. Following this plan throughout adjustments and servicing of the switchgear, we now have capabilities of handling most of the problems that could come up with the switchgear. Although training was not the prime reason for Mr. Burnett's presence, it may well prove to be worth the expense involved.

"The condition of the switchgear, except for a few breakers, was fair and would probably continue to operate with a few minor adjustments for a long period of time.

"In other I O L's to you from Mr. W. W. Johnson, of Atomics International, there were many instances sighted of X relays burning out and of switchgear tripping out for no apparent reason, the latter has happened several times since I have assumed Mr. Johnson's duties. I believe we can now explain why these problems have happened and have eliminated the possibility of a majority of these failures in the future.

"It is believed that the X relays burned out because the mechanical linkage that opens the X relay coil was at a critical point where it could slip off its operating collar and not open the X relay contacts on closing of the breaker. This allowed continuous current through the contacts and the small intermittent duty coils and hence burn out. A simple adjustment to the linkage corrected this.

"Regarding the tripping of the breaker for no apparent reason, it was found that many of the breakers had very low contact pressure; this would or could cause excessive heating (evidence of this excessive heat was found on several breakers on removal from service). Although heating itself should not trip the breaker it can expand trip linkages, which, when adjusted properly, are

set to trip with little movement, and trip the breaker. Almost without exception the 480 volt breakers had low contact pressure, sometimes as low as 40% of proper value.

"Another problem which has been a continual source of complaint is that of hard racking in and out. The solution to this was to grease, with proper lubricant, the contacts on the breakers. One man can now rack in and out any breaker with very little effort.

"The following 480 volt breakers had troubles of a serious nature which could have effected the overall operation of the plant:

Breaker No.	Use	Trouble	Fix
52B3	Reactor Bldg. Exhaust Fan	X relay burned out	Replaced
52A4	N ₂ Cooler No. 5	Broken trip bar end bracket.	Repaired
52A6	Control Center A1	3 broken Arc chutes	Replaced
52A1	Main breaker Bus A	Faulty Mark "Q" Assy	Replaced
52A16	Control Center A4	Unable to adjust center main contacts	Replaced shaft center contacts.
52C6	Control Center C4A & B	Broken X relay and rack in Mech.	Replaced both.
52C2	Control Center C5	Broken ground connector & sticky closing coil	Replaced ground connector. Clean closing coil.
52C4	Control Center C2	X relay coils burned	Replaced
52A11	Tie Breaker	Bad square shaft bearing	Replaced

"The following breakers were cleaned, lubricated, and contact pressure and spacing adjusted.

Breaker No.	Use	Type No.
52A3	Reactor Bldg. Exhaust Fan No. 1	DBM-15
52A5	Cooling Tower Pump No. 1	DBM-25
52B5	Cooling Tower Pump No. 2	DBM-25
52B4	Nitrogen Cooler No. 6	DBM-25
52B3	Reactor Bldg. Exhaust Fan No. 2	DBM-15
52A12	Dry Scrubber	DBM-25
52A11	Tie Breaker	DBM-25
52A4	Nitrogen Cooler No. 5	DBM-25
52A7	Emergency Instrument Air	DBM-25
52A2	Diesel Generator	DBM-50
52A6	Control Center A1	DBM-25
52A8	Control Center A2	DBM-25
52B2	Control Center B1	DBM-25
52B6	Control Center B2	DBM-25
52A9	Control Center A3	DBM-25
52A1	Main Breaker Bus A	DBM-50
52B1	Main Breaker Bus B	DBM-50
52A10	Control Center A4	DBM-25
52C1	Main Breaker Bus C	DBM-50
52C6	Control Center C4A & B	DBM-25
52C5	Control Center C3	DBM-25
52C2	Control Center C5	DBM-25
52C4	Control Center C4	DBM-25
52C3	Control Center C1	DBM-25

"The 4160 volt breakers were also checked and nothing of major importance was found wrong. On breaker 152-1, normal station transformer, a roll pin was found missing in the safety lock; this was replaced. Breaker 152-2, 480 volt load center C, required the tension on C phase contacts to be adjusted. Breaker 152-6 Primary Na pump No. 2 had a counter which jumped 2 or 3 numbers when tripped, this counter was replaced. All breakers were inspected, cleaned and lubricated.

"Following is a list of the 4160 breakers and their number of operations as indicated by the counter.

Breaker No.	Use	Counter No.
152-1	Normal Station Transformer	364
152-2	480 volt Load Center C	209
152-3	Secondary Na Pump No. 3	509
152-4	Primary Na Pump No. 3	1036
152-5	Secondary Na Pump No. 2	---
152-6	Primary Na Pump No. 2	483 old 63 new
152-7	Secondary Na Pump No. 1	482
152-8	Primary Na Pump No. 1	548
152-9	480 volt Load Center B	196
152-10	480 volt Load Center A	95
152-11	Reserve Station Transformer	---

"During the servicing of the switchgear two items were noticed. First, that regular preventative maintenance of the switchgear would increase its reliability by catching small troubles before they caused failures. The maintenance schedule would depend on the type of load and its function in the system. Second, that some difficulty was encountered in getting breakers for maintenance when the reactor is running because of a possibility of a scram. I believe that part of this latter problem can be overcome by transferring some of the loads from one breaker to another and the addition of a simple sync. circuit.

"At this time I have not had time to make the necessary study required to set up a maintenance schedule, or which loads should be transferred to facilitate maintenance. I hope to gather the required information and make a concrete proposal within a month.

"Our switchgear was found fairly clean and the Federal Pacific Electric representative agreed that our equipment should have little trouble.

"Another point of importance is the excellent cooperation of Operations Manager, Mr. T. W. Withers, and his people who provided technical assistance on how to get critical breakers out of service and also the speed in which they released the breakers for maintenance upon request. Thanks to them we were able to complete the job ahead of schedule."

Signed

R. H. Baulig

Operation Services Engineer

AI-P-1133

January 20, 1964

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
WASH CELLS, AI-P-1133

I. PURPOSE OF TEST

The purposes of the wash cell test were to determine that:

- a) The services, (steam, demineralized hot water, helium, nitrogen, and vacuum) to the three fuel wash cells and the pump wash cell are operable and meet specified flows, temperatures, and pressures. The cells can be evacuated and purged with helium or nitrogen.
- b) All cell high level alarms function properly.
- c) A fuel element can be installed in, properly washed, dried, and removed from the fuel wash cell without difficulty, and the wash cell vent system will disperse hydrogen released during a washing cycle without hazard to personnel or equipment.

II. DISCUSSION OF TEST PERFORMANCE

A. SYSTEM DESCRIPTION

Basically, the system is comprised of four 40-ft-deep, steel-lined cavities designed for the cleaning of sodium-contaminated components. Three of the cavities contain removable cells for washing fuel elements and small core components. The fourth contains a larger cell for washing sodium pumps. A fuel wash cell with larger diameter adapter rings and guide vanes could be installed in the pump wash cavity to provide another fuel wash facility if necessary.

Each cavity is provided with pipe connections for all the services. However, cooling water connections to the pump wash cell are capped at the cavity wall, as no cooling water is used nor are connections provided on the pump wash cell basket liner.

The three fuel wash cells have cooling water jackets to remove decay heat from irradiated fuel elements. These cells also have an inner thimble of perforated stainless steel to permit retrieving of damaged or broken fuel elements.

The fuel handling machine provides a shielded, helium-cooled atmosphere for the transfer of irradiated fuel elements to and from the wash cells. Actual washing of a fuel element is comprised of cleaning with plant service steam reduced to 5-10 psig line pressure (100-150 lb/hr flow rate) for 15-20 min (normal). Drying is by means of purging, evacuating, and repurging the cell. Gases evolved in the cleaning operation are handled by the R/A vent system, with liquid drainage going to the R/A liquid waste system.

B. TEST METHOD

Test performance consisted of operating all services to the cells to verify leak-tightness and proper operation of all valves, controls, and related instruments. Leakage was the main problem disclosed by this portion of the test.

Testing of the cell high level alarms was accomplished by injecting water into the piping at a point just below each level sensing element in lieu of raising cell water level (Figure 1133-1). Temperature setpoints, steam pressure control valve (PCV-1300), and the demineralized water and steam mixing valve were adjusted at this point. Operation of the steam jet ejector in the vacuum vent line was satisfactory; a vacuum (25 in. Hg) was drawn in the vent header line in less than one minute. A test was conducted to demonstrate the compatibility of the wash cells and fuel handling machine. Each cell was evacuated and a helium atmosphere was established. The fuel handling machine was positioned over a cell and a mock fuel element exchanged for the wash cell plug. The fuel handling machine was repositioned over the cell and the mock fuel element removed and the cell plug reinstalled.

The final phase for wash cell testing was the actual washing of a sodium exposed core component. An empty process tube, a dummy fuel element, and two in-core instrument thimbles, which had been in the core during hot circulation tests were successfully washed. All three cells were used in the washing operation. The fuel handling machine was used to transfer all components.

Prior to installation of the sodium-covered components, the cell was preheated by admitting steam, evacuated and purged with helium. No cooling water to the cell was used. A typical wash cycle consisted of admitting steam to the preheated cell (7 psi line pressure, 100 to 150 lb/hr flow rate) for 15 min. Nitrogen was then admitted to the cell for purging of water vapor, the cell evacuated and repurged with nitrogen.

Figure 1133-1. Wash Cell Level Instrumentation,
Typical Piping Installation

The building crane was employed to remove the components from the wash cell for visual examination. The hanger rod retaining ring, locking tabs, and process tube grid seal rings were examined in particular. Photographs were taken and the component reinstalled in the wash cell. The cell was evacuated and a helium atmosphere established for fuel handling machine operation.

C. DIFFICULTIES AND CORRECTIVE ACTION

During the initial test, PCV-1300 (steam pressure control) could not be adjusted to maintain a continuous flow rate in the low pressure range (5 to 15 psi). The valve was replaced and successful operation in the low pressure range was achieved over a varied flow rate.

Preliminary attempts to evacuate the fuel wash cells were unsuccessful and disclosed that there were major leaks in the cells. All areas of leakage were traced down and repaired or modifications to the cells and/or equipment were made. This leakage problem was crucial in that an inert atmosphere is essential in order to prevent "spoiling" of the fuel handling machine atmosphere when the machine is placed over and connected to a wash cell. Likewise, the oxygen content in the cells must be kept at a minimum during the wash cycle.

Investigation of the leakage problem disclosed three major areas of leakage; i. e., the cell service connections and two O-ring seals at the lower end of the wash cells. A typical wash cell is shown in Figure 1133-2.

The service connections were short-coupled rigid pipe unions. Modification was required in order to eliminate this leak source. These rigid unions were also unsatisfactory since the working space in the wash cell cavities is limited, making it difficult to align six short-coupled rigid pipe unions simultaneously. The unions were replaced with a more flexible type (commercial steam hose) which could also be easily removed for extraction of a wash cell.

Inspection of the O-ring area at the bottom of the wash cell cavity showed that the cavity-to-wash cell socket seal flange had deep grooves in the wash cell socket O-ring sealing surface. When the seal flange was removed for rework it was found that the flange to cavity O-ring seal had never been installed. A special test fixture was designed and fabricated to allow independent checking of the two O-ring seals. Tests conducted with the fixture established that,

Figure 1133-2. HNPF Wash Cell

independently, the O-rings were now leak tight. Insertion of the wash cell into the cavity socket and subsequent testing showed a leak still existed at the bottom of the cell.

From the results of previous wash cell testing and from the above mentioned test fixture test, it was concluded that handling difficulties on insertion of a wash cell, coupled with the out-of-plumb condition due to the length of the wash cell (40 ft), and the inaccessible location of the cavity socket flange, created lower end misalignment and resultant leakage. Correction of this misalignment was accomplished by the installation of special spacers under the socket flange around the bolts, thus providing self-alignment by enabling the flange to "float" into proper position.

Tests were repeated on all three fuel wash cells and satisfactory evacuation of the cells was demonstrated (25 in. Hg in 1.5 min). Pressure decay tests were conducted over a 24 hr period with the wash cells isolated from the vacuum vent header; no appreciable loss of cell vacuum was detected.

During preliminary testing of the steam and demineralized water systems (prior to modifications of the service connections) erratic flows and pressures were noted. It was suspected that the wash cell steam nozzles were partially clogged, causing a pressure drop which, in turn, resulted in the higher than expected line pressures and low steam flow rates. To verify this condition, demineralized water was admitted to the cells and spray patterns were observed. Three of the six nozzles on the No. 1 wash cell appeared to be plugged and the nozzles of the No. 2 and 3 cells partially plugged, as evidenced by very poor spray patterns. The strainers ahead of the steam traps in the condensate lines were found to be clogged, supplying further evidence of foreign material in the steam lines. During the modification work, the 18 nozzles from the three fuel wash cells were removed and cleaned. Line strainers were installed in the steam lines at each fuel wash cell and an additional strainer was installed in the demineralized water line header.

D. PUMP WASH CELL

Pretest examination of the pump wash cell design disclosed that the diameter of the O-ring used to seal the cell liner to a sodium pump would conflict with the pump flange bolt circle. Under this condition a gas tight seal could not be obtained. An adapter ring was designed and fabricated to correct this situation.

Further examination of the primary and secondary pumps disclosed that the flange bolt circles were of different diameters. A second adapter ring was fabricated to accommodate the difference in diameters.

Testing of the pump wash cell high level alarm was accomplished in the same manner as the fuel wash cells. Testing of the pump wash cell services was conducted upon installation of an adapter ring. A pump cavity blind flange cover was placed over the adapter ring. The cell was evacuated and a nitrogen atmosphere established. Steam was admitted to the cell and the cell drain valve opened. With a flow rate of 250 lb/hr at 7 psig line pressure, the cell pressure increased to 1 psig and remained constant at this pressure throughout the 15 min steaming operation. Demineralized water was admitted to the cell to verify flow, but no further testing was done as there are no mixing nozzles or spray nozzles in the pump wash cell lines. The cell was purged with nitrogen, evacuated, back-filled with nitrogen, and the cell services secured.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

Upon completion of all wash cell modification and rework, the wash cells performed per design specifications. A core component was successfully washed and dried in each wash cell. Satisfactory operation of the pump wash cell was demonstrated by the successful cleaning of a primary and secondary pump

Presented in this report are photographs depicting the successful operation of the fuel wash cells. Photographs No. 1 and No. 2 show the prewash condition of empty process tube (Figure 1133-3). The heavy concentration of sodium and sodium oxide is attributed to the low temperature of the sodium during removal of the process tube assembly from the core, combined with the length of storage time and in-leakage of air to the cell helium atmosphere. Photographs No. 3 and No. 4 show the results of wash cell cleaning (Figure 1133-4). The hanger rod retaining ring and locking tab were clean and free moving. Visual examination of the process tube grid seal rings showed these to be clean; no difficulty was encountered in compressing the rings, indicating that all sodium had been flushed from within the ring grooves. The tube was hot (approximately 180°F) and showed no evidence of moisture. The results show that a core component can be washed and dried satisfactorily and safely in the fuel wash cells.

Photo 1

Photo 2

Figure 1133-3. Sodium-coated Process Tube Before
Insertion in Wash Cell

Photo 3

Photo 4

Figure 1133-4. Process Tube After Removal
from Wash Cell

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with preoperational test AI-P-1133, Wash Cells, as listed in NAA-SR-5700 (Supplement 4) pages XI(a)-46 and XI(a)-47, with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: The wash cell was satisfactorily evacuated to approximately 1 in. Hg absolute pressure and filled with helium to approximately 3 psig.

Remarks: The wash cells were evacuated to 25 in. Hg, the maximum the steam jet ejector would allow with available steam pressures. The cell was filled with helium to 1 psig rather than the 3 psig specified in the criterion, because system design is for the lower pressure. This pressure conforms with the internal pressure of the fuel handling machine.

- b) Criterion: Using the fuel handling machine, the wash cell plug was removed and the mock fuel element inserted in the cell. Helium atmosphere in the cell was maintained during this operation.

Remarks: Verification of the above was accomplished by removing a wash cell plug and installing the mock fuel element in all three fuel wash cells. The helium atmosphere was maintained at 1 psig during these operations.

- c) Criterion: Superheated steam was satisfactorily injected into the wash cell through the steam cleaning nozzles for a period of 10 min. It was determined that steam flow was continuous and smooth and that the drain valve did not allow the water level to reach the set point on the high alarm.

Remarks: Tests conducted verified that steam was satisfactorily injected into the wash cell through the steam nozzles for 10 min. Visual observation of steam flow and high alarm instrumentation verified that the flow was continuous and smooth and that the high alarm was not energized.

- d) Criterion: Demineralized water was satisfactorily added to the steam in the mixing nozzles to rinse the fuel element for a period of 3 min. The condensate drain valve was manually blocked and the condensate allowed to reach the high alarm set point where it was verified that the alarm annunciated.

Remarks: It was verified that demineralized water could be added to the steam in the mixing nozzles to rinse a fuel element. However, it was demonstrated through testing that rinse water was not necessary to satisfactorily clean an element.

It was verified that the high alarm set point would energize and the alarm annunciate by the method described in this report under Section II-B, Test Method. This procedure was preferable as no test water had to be drained to the R/A liquid waste system. Actual raising of the water level in each cell would have accumulated unnecessary water in the waste transfer tank (approximately 35 gal per fuel wash cell and several hundred gallons in the pump wash cell) that would eventually have to be handled by the liquid waste system.

- e) Criterion: Condensate was satisfactorily drained from the wash cell to the R/A waste transfer tank and nitrogen was admitted into the wash cell until N_2 pressure reached approximately 3 psig.

Remarks: Condensate from all wash cells was satisfactorily drained to the R/A waste transfer tank. As the wash cell system was designed for 1 psig operation and the pressure control station set at this pressure, nitrogen was admitted into the wash cell until the pressure reached 1 psig.

- f) Criterion: The cell was evacuated of N_2 to approximately 1 in. Hg and filled with helium to approximately 3 psig.

Remarks: The wash cells were evacuated to 25 in. Hg, the maximum the steam jet ejector would allow with available steam pressures. The cell was filled with helium to 1 psig rather than the 3 psig specified in the criterion, because system design is for the lower pressure. This pressure conforms with the internal pressure of the fuel handling machine.

g) Criterion: The mock fuel element was satisfactorily removed from the wash cell and the wash cell plug inserted in the cell by the fuel handling machine while a helium atmosphere was maintained in the cell.

Remarks: The above was verified by removing the mock fuel element and installing a wash cell plug in all three fuel wash cells using the fuel handling machine. The helium atmosphere was maintained at 1 psig during the operation.

h) Criterion: Satisfactory cleaning of the mock fuel element was verified by visual inspection at the pickup cell.

Remarks: Satisfactory cleaning of the sodium covered hanger rod and process tube was verified by visual inspection.

V. EVALUATION

Preoperational test criteria for the wash cells require that the steam, helium, nitrogen, and vacuum services to the cells be adequate for washing fuel elements, core components, and pumps which have become contaminated with sodium. The criteria also require that a component can be installed, properly washed, and removed from the wash cell without difficulty.

Wash cell leakage was the most prominent difficulty encountered during initial testing. One of the major leaks was due to the omission of an "O" ring seal during initial assembly of the wash cell. The O-ring is intended to seal an intermediate sleeve and flange to the bottom of the wash cell cavity. Additional leakage in this area was caused by damage to the O-ring sealing surface (of the sleeve) during initial insertion of the wash cell thimble.

To effect a seal, the sleeve was remachined and spacers were installed under the flange to provide a floating seal, thus allowing the sleeve to be self-aligning with the thimble. Modification of the sleeve and installation of the O-ring proved to be a satisfactory solution to the problem.

The service connections to the thimble were a second major source of leakage. Original connection lines were rigid steel piping which made leak-proof fitting almost impossible. After replacing the steel piping, with flexible steam hoses, the leakage problem in this area was solved. No further major leakage was encountered; all other small leaks (level gages, check valves) were repaired without difficulty. Most of the problems associated with cell leakage

and various service line leakage resulted from poor construction practices. Such things as loose fittings and poor connections caused much of the delay associated with this test.

Plugging of the inlet steam nozzles with pipe scale and other corrosion products was encountered during the test. Installation of Y-strainers in the steam line directly ahead of the nozzles proved to be an effective solution to the problem. To eliminate the need for extra maintenance, the Y strainers should be cleaned at the same time the O-rings and rubber steam hoses are replaced (as may be required because of radiation hardening).

The various service systems to the wash cells performed satisfactorily during the test, delivering the required services according to design. Vacuum to the cells (25 in. Hg) was not as low as specified (28 in. Hg) in the design, but was, nevertheless, adequate for the required task. Steam flow and steam conditions were excellent after installation of a new pressure control valve. Helium, nitrogen, and demineralized water services to the cells were as specified. Actual washing of various sodium-covered components gave an indication of the capability of the wash cells as noted in the following sections.

A. FUEL WASH CELLS

All components washed in the fuel wash cells were installed without difficulty. From the top of the wash cell, no noises could be heard to indicate a rapid sodium-steam reaction that could cause damage due to localized heating of the component. After the prescribed washing cycle of 15 to 20 min, the components were pulled from the cell with the high bay crane and inspected. To date, all components checked after the wash period have been found to be clean and dry, demonstrating effectiveness of the cells.

B. PUMP WASH CELL

Approximately 2 to 3 hr was required to clean sodium from sodium pumps installed in the pump wash cell. To date, all six pumps have been washed successfully with very little residual sodium (other than small amounts left in the annulus between the pump case and impeller shaft and on the threads of various bolts) and only a small amount of water remaining on the flat surfaces of the pumps. The temperature was such that the water quickly evaporated.

In conclusion, the wash cells have proven adequate for the required task and perform properly as designed.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
PORTABLE PURGE UNIT

AI-P-1137

Test and Analysis
by
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Evaluation
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A T O M I C S I N T E R N A T I O N A L
A DIVISION OF NORTH AMERICAN AVIATION, INC.
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HALLAM NUCLEAR POWER FACILITY

PREOPERATIONAL TEST COMPLETION REPORT

PORTABLE PURGE UNIT, AI-P-1137

I. PURPOSE OF TEST

The purpose of this test was to determine that the HNPF portable purge unit can be satisfactorily employed to purge storage cells, to change reactor shield plug quad rings, and to obtain storage cell gas samples.

II. DISCUSSION OF TEST PERFORMANCE

The portable purge unit was transported on its dolly to a storage cell, and positioned over the cell on an index ring. The purge unit grapple was lowered into the plug pick-up cup, engaged, and raised sufficiently to put the plug weight on the purge unit, thus effecting a better seal between the storage cell and index ring and between the index ring and the purge unit.

A vacuum was established within the purge unit and leak-tightness was verified with the unit positioned over a storage cell. The shield plug was raised, the storage cell evacuated, and a helium atmosphere established in the cell and purge unit.

New quad rings were installed on the shield plug using the rubber gloves and port holes provided on the purge unit. The shield plug was lowered into the storage cell and the grapple withdrawn from the plug. The portable purge unit was then replaced on the dolly.

Test performance included the same operations that will be performed during normal usage of the portable purge unit. The fuel handling cells' vacuum pump was required to accomplish proper evacuation of the storage cell and purge unit (as opposed to the radioactive vent system fan, as was improperly specified in the test procedure). No trouble shooting nor repair effort was required to satisfactorily complete proper performance of the test.

A radiation detector and a moisture transducer are provided as a part of the HNPF handling equipment and are used in conjunction with the portable purge unit. These items are mounted together on a rack which is independent of the purge unit and thus will be preoperationally tested independent of the purge unit. The moisture transducer will undergo an operational test and proper performance of the detector will be verified as a part of AI-P-1122, Radiation Detection and Monitoring System.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

A. PURGE UNIT TEST

The portable purge unit test was performed employing storage cell No. 26 and the shield plug therein. In placing the unit over the storage cell, it was determined that the outer ring on the index ring must be removed to obtain an adequate seal between the unit and the index ring. The grapple lowering operation established that it was quite easy to lower the grapple too far into the pick-up adapter, thus releasing the grapple fingers with the subsequent requirement of re-cocking the grapple. Initial engaging and lifting of the shield plug creates an excellent seal and firmly establishes the portable purge unit in position. Connecting of the helium and vent lines to the portable purge unit can

be accomplished quickly and efficiently. The vacuum line was attached to the fuel handling cells vacuum pump suction header line containing valve V-1048.

B. STORAGE CELL PURGE TEST

The valves on the helium and vent lines operated properly and are tight fitting when closed. Leak-tightness of the unit was verified by establishing 11 in. of Hg vacuum in the unit and allowing the unit to hold the vacuum for approximately 5 min. The necessity for removing the index ring outer ring, used in conjunction with the fuel handling machine television indexing system, was discovered at this time, since the initial vacuum decayed from 11 in. to 6 in. of Hg in approximately 5 min. Removal of the outer ring allowed a proper seal. (Refer to Figure 1137-1 for details.) Following the verification of leak-tightness the unit was evacuated to a vacuum of 26 in. of Hg. A vacuum of 30 in. of Hg could not be attained due to the vacuum pump limitations. The shield plug was then raised and the storage cell was also evacuated to a vacuum of 26 in. of Hg, common with the purge unit. Evacuating the cell in this manner established that the gas could be analyzed for both radiation and moisture by passing it through the devices which would be installed between the unit and the vacuum pump.

The shield plug raising operation was accomplished easily and without incident. The fuel handling cells' vacuum pump and pump motor overheated while holding the 26 in. of Hg vacuum. The pump motor breaker tripped out, was reset, and the test continued. Helium admission to the storage cell, following isolation of the vacuum pump, pressurized the cell to zero psig in approximately

Figure 1137-1. Fuel Handling Machine Index Ring

one min. The helium needle valve was found to be a slow acting valve and pressurization to zero psig was difficult without overpressurizing. In the future, close-down of the helium supply valve will have to be started sooner to stop the helium pressurization at the desired point of zero psig.

C. QUAD-RING CHANGE TEST

The shield plug quad rings were changed quickly and efficiently, using the purge unit gloves, and the new quad rings were placed on the top of the pick-up adapter at the start of the operation. The shield plug was lowered properly by opening the hydraulic pump valve, and the grapple released automatically when the shield plug DOWN position was reached. The grapple was re-cocked and the purge unit placed back on the dolly.

The total time required for the quad ring change operation, as accomplished in this test, was 4 hrs 10 min. However, the elapsed time included the removal of the index ring outer ring and the re-routing of the vacuum supply to the fuel handling cells vacuum pump, both of which are not a part of a normal change operation. The operators who performed the test procedure firmly expressed the opinion that a re-do of the quad ring change operation would require approximately one hour and would better represent a normal operation.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with the portable purge unit as listed in NAA-SR-5700, pages XI(a)-49 and -50, Supplement 4, with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: The portable purge unit fits on the index ring properly.

Remarks: It was verified that the purge unit fits on the index ring properly if the outer ring on the index ring is removed. Removing the outer ring on the index ring is acceptable as the outer ring is employed for indexing by the fuel handling machine only.

- b) Criterion: The hydraulic hand pump operates satisfactorily and the hydraulic grapple engages the storage plug pick-up adapter properly.

Remarks: Satisfactory pump and grapple operation were demonstrated as described in the body of this test completion report.

- c) Criterion: A satisfactory seal is created between the purge unit and the index ring when the load of the plug is placed in the purge unit.

Remarks: The purge unit was pulled down to a vacuum of 26 in. of Hg. The vacuum held for a minimum of 5 min. which verified the seal was leak-tight with the load of the plug on the purge unit.

- d) Criterion: The hydraulic pump is capable of lifting the plug to the UP position.

Remarks: The lifting capability of the pump was verified as described in the body of this report.

- e) Criterion: A full vacuum can be established in the purge unit and storage cell.

Remarks: The fuel handling cells vacuum pump

is capable of establishing a vacuum of 26 in. of Hg in the purge unit and storage cell, which is adequate for the operations to be performed therein.

- f) Criterion: Old quad rings can be removed from the plug and new quad rings satisfactorily installed on the plug.

Remarks: The quad-ring change operation can be accomplished satisfactorily as described in the body of this report.

- g) Criterion: The hydraulic pump satisfactorily lowers the plug into the cell and the grapple automatically disconnects from the pick-up adapter when the plug seats in the storage cell.

Remarks: Plug lowering operations and automatic grapple disconnecting were verified as described in the body of this report.

V. EVALUATION

This test has demonstrated that the portable purge unit can be utilized, in conjunction with the radioactive vent and helium systems, to perform the following function:

- a) Purge storage cells, including the lifting of the plug, evacuation of cell, and back-filling with helium.
- b) Replace quadrings.

Since the cell can be evacuated, it has been assumed that a storage cell gas sample can be obtained.

Normally the fuel storage cell atmosphere analyzer will be used in conjunction with the portable purge unit to detect a radioactive gas or moisture in the cell atmosphere. As indicated, it is planned to test this analyzer as a part of the preoperational test, AI-P-1122, Radiation Detection and Monitoring System.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
DECONTAMINATION ROOM

AI-P-1138

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FIGURE

1138-1. Water Loss <u>vs</u> Temperature Curve (depicting water loss to <u>hold-up</u> tanks as required to attain 140 F tap water temperature.)	5
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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
DECONTAMINATION ROOM, AI-P-1138

I. PURPOSE OF TEST

The purpose of this test was to determine that the equipment provided for the decontamination of items contaminated with radiation material functions properly.

II. DISCUSSION OF TEST PERFORMANCE

A. INSPECTION

The equipment decontamination room facilities consist primarily of laboratory equipment and facility services. Initially, the facilities were inspected for utility design and accountability. Laboratory equipment such as sinks, hoods, cabinets, shelves, and storage cabinets were inspected for completion and operability. Several miscellaneous pertinent items such as the vacuum cleaner, gloves, chemicals and tools were added at a later date.

Facility services included 480 V, 240 V, and 120 V electrical outlets which were checked for design ratings. Hot and cold potable water and demineralized water lines were checked for proper source. The steam line was traced to the auxiliary steam source. During the test, the decontamination room atmosphere was at a normal nominal pressure of $-1/8$ inch of water.

B. TESTING

1. Fume Hood

The gas and vacuum piping system of the fume hood were traced and pressurized for leak checks. As all plumbing is located behind the fume hood, it was necessary to remove the cover paneling to gain access to the lines and piping. Inlet air velocity at the fume hood was measured, using a velometer, and found to be 70 ft/min.

2. Monorail Hoist

A monorail mounted hoist is used to move items from the maintenance cell tunnel or from the high bay area to the decontamination area. The hoist is also used to lift and relocate items in the decontamination room.

The monorail and trolley system were inspected and checked for clearances, protective stops, and switch operation. The switches did not operate freely, and required lubrication before proper operation could be obtained. Forward and reverse trolley speeds were measured. Operation of the trolley disclosed intermittent "dead spots" in the motor contact-rail system. Subsequent inspection and cleaning of the contact rail alleviated, but did not eliminate, intermittent operation. Hoist operation was checked and lifting and lowering velocities of the hoist hook were measured. Length of the hoist cable was verified and the safety stop system was operated.

3. Steam Cabinet

A steam cabinet, equipped with a stainless steel open-mesh tool tray, is used to decontaminate small items, such as tools, by spraying steam on the items. The cabinet contains two pair of fixed lower nozzles which aim the steam downwards. The steam nozzles, as received, were replaced due to slot damage detected on the original nozzles. Room atmosphere enters the cabinet through front louvers and is passed through an annulus that surrounds the cabinet. The outer cabinet surface is thereby kept cool to the touch. Air

entering the cabinet mixes with the spent steam at the rear of the cabinet and is exhausted to the building ventilation system at a point above the room ceiling.

The cabinet effluent lines were checked for out-leakage, and pipe temperatures were monitored. Cabinet steam effluent is piped to the room exhaust lines located above the room ceiling. The cabinet drain removes the condensate. The cabinet steam lines were energized and operation of the movable nozzles, nozzle spray, and the flow patterns of steam and air exhaust were noted.

4. Steam Cleaner

The steam cleaner is a device which pumps detergent water into a live steam line. A steam hose line equipped with a lance and nozzle is used to spray-wash contaminated items placed under a washpan hood. The hood is designed to cover and contain the contamination, splashing, and steam spray. The hood is equipped with eight nozzle ports, eight pairs of glove ports, and window viewing area. Effluent steam is piped to the room exhaust located above the room ceiling. Condensate drains-off through a floor drain to holdup tanks.

Detergent tank fill-and-drain operations and pump effluent and pressures were noted. Nozzle valve pressure conditions were seen to control the detergent mixing and pump feed cycles.

5. Wash Pan Hood

The steam lance and nozzle were used in the wash pan hood to check the hood under actual working conditions. Room and hood pressures, and hood misting conditions, were observed. Exhaust clearing time was noted after the steam lance valve was turned off. Cleaning effectiveness of the steam cleaner was also tested.

Variable inlet port opening conditions were compared for misting, visibility, and exhaust effect by opening and closing a one inch valve. Glove handling and passport feasibility were studied. Glove ports were noted to leak when the nozzle stream impinged on the inside of the port.

6. Ultrasonic Cleaner

The ultrasonic cleaner consists of an ultrasonic generator which is rated to deliver 3000 watts at 40 kilocycles to a transducer tank. The transducer tank, when filled with water or a water mixture with detergent or solvent, can be used to clean contaminated tools or small equipment items. Demineralized water is used in the transducer tank which is equipped with a recirculating unit that circulates tank fluid through a filter. The tank drains to the decontamination room holdup and monitoring tanks.

The ultrasonic generator was started and tuned. The transducer tank was energized and the tank basket was inserted. Changes in the fluid pattern effects were noted, before and after the recirculation unit was put in service. Several small items were cleaned to test the effectiveness of the unit.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

A. DECONTAMINATION ROOM FACILITIES

The cabinet and sink equipment were determined to be in good condition. It was observed that approximately 15 gallons of water were wasted to the holdup tanks before the hot water tap reached a temperature of 140 F from an ambient of 80 F (see Figure 1138-1). Insulation of the hot water pipe would reduce the amount of water wasted.

Fume hood air influent velocity was measured at several locations and found to be more than 70 ft/min. The fume hood receptacle voltages were measured and found to be correct at 120 V/240 V. All hand control valves and lines located on the fume hood were leak-checked. A few minor leaks were noted and subsequently repaired.

Figure 1138-1. Water Loss vs Temperature Curve (depicting water loss to hold-up tanks as required to attain 140 F tap water temperature.)

The decontamination room monorail trolley and hoist systems were tested. Electrical connections to the hoist were modified to improve conductor clearances. Operation of the monorail contacting feelers was adjusted to eliminate dead spots in the monorail system. However, it was not possible to eliminate all dead spots. On occasion, the trolley must be "tugged" (manually) a slight amount in order to establish contact. The forward and reverse velocity of the trolley was found to be approximately 36 ft/min; vertical velocity of the hoist was measured at 18 ft/min. Both velocities satisfy design specifications.

Trolley overtravel after release of the motion switch, is one foot. The trolley can be satisfactorily inched along as required. When the trolley is stopped at a dead end, the drive wheels will continue turning and slipping on the rails as long as the drive is energized. This condition is deemed desirable because it prevents a locked rotor condition. The hoist stop satisfactorily de-energized the hoist motor.

B. STEAM CABINET

Operation of the steam cabinet was checked. The steam line to the cabinet was first blown down by removing the cabinet nozzles and opening the inlet steam valve. After the steam appeared to be clean, the nozzles were replaced and steam was again admitted. After 20 min of operation, the nozzles clogged. Successive periods of blowdown and steaming followed. It became apparent that in order to keep the steam nozzles operating, a strainer would have to be installed in the steam line. It is recommended that the four end nozzles be removed before steam cleaning is initiated and the line blown out with live steam, even though the strainer has been installed.

While operating the steam cabinet, it was also noted that steam condensing in the vent pipe formed a water pool in the low portion of a bent horizontal vent line. The vent line slope was subsequently modified to allow condensate to run back into the steam cabinet drain. Leaks in the vent line were also sealed at this time. The asbestos seal around the steam cabinet door was replaced with a neoprene seal, to prevent the door crack from leaking, and to provide

easier cleaning and decontamination, when required. A standard operating procedure was prepared for steam cabinet operation.

C. STEAM CLEANER

The Kelite steam cleaner tanks were filled and proper operation of the float valves verified. The steam input agitator to the concentrate tank provided strong localized agitation in the tank. Whereas, the electrical system was originally wired for 120/240 volts, the pressure switch was designed for 120 volt application and would not turn the makeup tank inlet valve off. Consequently, electrical connections to the steam cleaner had to be modified to 120 V condition to allow the test to proceed. Using water only, the steam cleaner was operated (with hose and nozzle connected) to check pump flow. Under this condition the pump delivered the 5 gpm design flow. A combination of steam and water was then used to check the pump operating range; the pump cycled ON at ~160 psig and OFF at 220 psig. A pressure of ~175 psig was maintained during continuous operation with the steam lance attached. Results obtained from the preoperational test satisfied the pressure design requirements. A standard operating procedure was prepared for operation of the steam cleaner.

It was observed that the steam lance nozzle provided a straight stream of water, with steam rolling out freely. However, during the test the nozzle handle became hot, requiring the use of gloves for operation of the valve.

D. WASH PAN HOOD

After three minutes of steam lance operation in the wash pan hood, it was impossible to see into the hood. Admitting air through the inlet valve had little or no effect upon visibility in the hood. The vapor cleared within about two minutes, after the steam was shut-off. Pressure of the atmosphere under the wash pan hood, which held more or less constant at -1.6 inches of water for the duration of the test, seemed more negative than necessary. Although the position of the air vent valve had little or no effect upon the pressure under

the wash pan hood, this pressure appeared to vary slightly with the decontamination room pressure. The rubber cone seal through which the steam lance passes into the hood failed after a few minutes of lance usage. It was felt that the original seal was faulty; spares were ordered. The hole size for accommodation of the lance seemed to be the proper diameter and the high temperature of the lance should not have affected the seal.

Installation of the gloves in the glove ports was accomplished only after much difficulty. The standard gloves supplied for the hood were too small for normal installation in the ports. It was also noted that the long sides of the wash pan hood pulled in at the bottom center due to the negative pressure maintained within the hood.

Insertion and removal of items under the wash pan hood is accomplished by lifting the hood with the hoist. During the test, the maximum clearance obtainable was determined. It was found that by using a pair of 74 inch slings to lift the hood, a clearance of 41 inches is available if only one end of the hood is raised. When the entire hood is raised, the (level) clearance above the ledge is approximately 20 inches.

E. ULTRASONIC CLEANER

The ultrasonic generator was energized and tuned for maximum agitation. During the startup process, the overload system was checked because of fuse blowing. The fuses were replaced with time-lag type fuses and the transformer taps were set at 5, eliminating the fuse problems. Plate power was ready to be energized in 17 seconds.

Water agitation in the transducer tank was noted. The pattern varied in intensity with the optimum tuning. A swirling pattern at the surface seemed to present a better cleaning location. Placing an object in the water severely affected the pattern above the object. Inserting the basket noticeably decreased the pattern. Operation of the filter-recirculation unit affected the pattern at influent and effluent locations. Excellent cleaning results were noted during

the test. The drain, overflow, and recirculation systems functioned properly. A standard operating procedure was supplied to the operating department.

It is recommended that a rack and plastic container be provided for use in the tank so as to lessen contamination of the cleaner and consequently to reduce the volume of liquid waste from the cleaner. Small contaminated articles could be submerged in a liquid in the container; the container tops would remain above tank water level. When the tank is energized, the high frequency wave effect will be transmitted into the container with very little attenuation. As only the inside of the container will be contaminated, very little waste water would result. A cover is also needed for the transducer tank.

Following is a list of remediable deficiencies noted during the performance of this preoperational test. Suggestions for possible corrective measures are included.

- 1) The standard gloves supplied for use with the wash pan hood were of less diameter at the sleeve opening than that of the glove ports, making glove installation difficult.
Suggested solution: Modify glove attachment rings or install standard glove ports, to provide for easier installation of standard gloves.
- 2) Negative pressure within the wash pan hood causes the sides to pull in at the bottom.
Suggested solution: Installation of a pair of metal guide pegs in the concrete base would prevent malforming of the hood wall under the negative pressure condition.
- 3) Inconvenience of lifting the wash pan hood to permit insertion of tools and other decontamination appurtenances.
Suggested solution: Installation of a pair of pass-through ports to facilitate insertion of items, to supplant raising the hood for this purpose.
- 4) Whereas satisfactory operation of the wash pan drain was verified, difficulty was experienced in removing the lead drain plug.
Suggested solution: Fabrication of a portable fixture to "lever" the plug out of the drain.

- 5) The flex tubing connecting the wash pan hood to the vent system is susceptible to burning in the event unconsumed bits of free sodium (remaining after wash cell operation) are carried into tubing by the exhaust flow.

Suggested solution: Installation of a mechanical filter, or utilization of a standard operating procedure which would require close inspection of items (for sodium contamination) prior to insertion in the wash pan.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with preoperational test AI-P-1138, Decontamination Room, as listed in NAA-SR-5700 (Supplement 4), Page XI (a)-51, and -52, with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: The ultrasonic cleaner operates satisfactorily per manufacturer's instructions.
Remarks: The ultrasonic cleaner operates satisfactorily with optimum tuning and good tank fluid pattern.
- b) Criterion: The steam cabinet operates satisfactorily per manufacturer's instructions.
Remarks: The steam cabinet provides satisfactory steam flow and steam operation in the steam cleaning function for which it was designed.
- c) Criterion: The steam cleaner operates satisfactorily for five minutes and does not leak.
Remarks: The steam cleaner supplies rated flow of detergent additive to a steam source under satisfactory pressure ranges. The unit does not leak.
- d) Criterion: All decontamination room equipment is properly installed and available for service.
Remarks: All decontamination room equipment is properly installed and available for service.

V. EVALUATION

A. SCOPE OF TEST

The decontamination facility was designed as a means of reducing minor radioactive contamination to a level which will allow contact maintenance and re-use of various components such as pumps, valves, tools, and maintenance cell equipment. The objective of this test was to determine whether the equipment provided for decontamination of items contaminated with radioactive material functions properly.

Equipment supplied for the decontamination room is as follows:

- a) Monorail crane
- b) Ultrasonic cleaner
- c) Steam cabinet
- d) Wash pan hood
- e) Steam cleaner
- f) Vacuum cleaner
- g) Laboratory equipment

B. ANALYSIS OF TEST RESULTS

The preceding equipment has been observed under actual operating conditions and the following conclusions drawn as to the performance.

1. Monorail Crane

The monorail crane performed satisfactorily under actual operating conditions. The only trouble that might be encountered with this equipment is in the motor-to-rail electrical contact. At times, the crane has been stopped on "dead spots" in the electrical contact. Restarting requires manually pulling the crane a short distance along the rail until the unit re-energizes. This

mode of operation would be unfeasible if a heavy component were suspended from the monorail crane at the time. Other than the above stated problem, the crane should perform adequately, as per design.

2. Ultrasonic Cleaner

Efficiency of the ultrasonic cleaner was demonstrated when the unit was used to decontaminate the maintenance cell light fixtures. Radiation readings from the fixtures dropped from an initial level of 2500 dpm to less than 30 dpm after cleaning, thus illustrating the cleaner's effectiveness. During the cleaning operation, all aspects of the cleaner functioned properly except for a check valve on the transducer tank high level overflow line. This check valve has been replaced with a lighter unit and now operates properly. From this and other cleaning operations, it appears that operation should be satisfactory and adequate.

3. Steam Cabinet

This particular piece of equipment consists of eight small nozzles in an enclosure. These nozzles were determined to be subject to plugging from small bits of rust and other corrosion products from the steam line. Installation of a Y-strainer in the steam line leading to the nozzles has helped, but the nozzles must still be removed periodically for cleaning. It was found that the nozzles could be easily damaged during removal and reinstallation after cleaning. For this reason it is recommended that the nozzles be fitted only finger tight, thus eliminating the use of a wrench which could damage the small nozzle openings.

4. Wash Pan Hood

The wash pan hood has several areas in which improvements could be made. One of these is the glove ports. Better designed glove rings are available and could be installed.

The other defect in the hood is the steam lance ports. The one rubber lance seal that was supplied with the hood tore after limited use. This failure was traced to the jagged lance opening which enabled the rubber to tear easily. It is recommended that lance seals be obtained for all eight ports and that an adequate supply of spares be kept on hand.

5. Steam Cleaner

The ability of the steam cleaner to supply an ample mixture of water and detergent to the incoming steam has been adequately demonstrated. One difficulty that has been observed during past operation is the forming of large quantities of rust on the sides of the concentrate tank when not used for long periods of time. It is recommended that the condensate tank be drained after use; in this way any unwarranted rusting of the tank will be eliminated.

6. Vacuum Cleaner

The vacuum cleaner and support equipment are standard rather than heavy-duty type equipment. It was decided that, because of the possibility of a high internal contamination which would necessitate disposal of the cleaner, the standard model would be both cheaper and less of a loss on disposal. The standard model should amply satisfy requirements.

7. Laboratory Equipment

The laboratory equipment consists of a fume hood, sink unit, laboratory table, open shelving case, storage cabinet, and a pegboard.

The fume hood has been proven adequate under actual operating conditions. One point that should be noted is the variation in air velocities across the sash opening. This velocity should be in the order of 70 ft/min, which can only be obtained if the damper in the sink unit hood is closed. Both the sink hood and the fume hood are ducted into the same low pressure piping. With the sink hood damper open, most of the air that is normally drawn through

the fume hood will then pass through this new opening, thus lowering fume hood air velocity. At this time there is no way of closing the sink hood damper except by using a long stick. It is recommended that a pull chain be attached to the damper and that this damper be closed whenever work is being conducted with the fume hood sash open; this should assure an adequate air velocity through the sash opening.

Another point of interest is that of mineral deposits which have collected in the sink of the fume hood. These deposits are from water that has not properly drained from the sink. With these deposits, it will be difficult to decontaminate the sink. A possible solution to this problem would be to dry the sink after use, thus reducing the occurrence of deposit formation.

The sink unit, laboratory table, open shelving case, and storage cabinet all appear to meet specifications and should efficiently perform the design task.

The pegboard supplied for the decontamination room is of poor construction and design. Most of the peg holes are not drilled to a sufficient depth to support the pegs; some of the pegs are already out of the board. There are also two large splits (which will probably increase in size with time) down the middle of the board. This particular piece of equipment should be replaced, as it does not meet specifications.

C. CONCLUSIONS

In conclusion, except for the particular instances mentioned in the evaluation, most of the decontamination equipment will perform in accordance with design criteria, and is in good operating condition.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
MAINTENANCE CELL

AI-P-1139

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
MAINTENANCE CELL, AI-P-1139

I. PURPOSE OF TEST

The purpose of this test was to verify that the normal maintenance cell operations can be performed efficiently and safely, and that the planned operating procedures, and the tools and equipment are adequate.

II. DISCUSSION OF TEST PERFORMANCE

A. SYSTEM DESCRIPTION

The maintenance cell (Figure 1139-1) consists of two areas, a shielded in-cell work area and a separate three-level equipment operating area. In-cell dimensions measure 7 ft wide by 9 ft long, by 54 ft deep from the reactor room floor. An offset, 18 ft down from the reactor room floor, provides a shelf 3 ft by 7 ft on the north wall (Figure 1139-2).

Access to the cell is through a tunnel leading to a 4 ft by 5 ft stepped aperture in the west wall of the cell. The tunnel extends to an area directly below a hatchway in the floor of the plant decontamination room. A remotely operated dense concrete door provides radiation shielding. The door is equipped with a tool shelf for the conveyance of special tools and equipment to and from the cell. A particulate seal on the door prevents radioactive particulate from accumulating on the body of the door and in the door aperture. An inflatable seal on the tunnel side of the door opening maintains a gas-tight seal with a flange on the door.

All interior surfaces of the maintenance cell are lined with 3/8-in. steel plate. The joints are welded and ground smooth to provide a smooth decontaminable surface. All ports are stepped and lined with steel sleeves which are welded to the liner for gas-tight integrity. A viewing window is provided on the south wall at each operating level. The windows are 42 in. thick and are of the radiation shielding type, made of high density, nonbrowning glass. Space between the window panes are filled with oil to eliminate distortion. The window

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Figure 1139-1. Maintenance Cell and Operating Area

Figure 1139-2. Maintenance Cell Interior as Seen From Reactor Building Floor

aperture is sealed on the cell (hot) side by a 1-in. thick glass pane mounted on the maintenance cell liner to prevent in-leakage of air to the cell (Figure 1139-3).

Figure 1139-3. Radiation Shield Window

Illumination of the cell interior is furnished by mercury vapor lamps located above each window. The lamps are rated at 1500 watts each and provide a minimum of 300 ft candles illumination at a level with the window. In addition, there is a spare lamp above each window, completely wired and ready for operation. Each lamp is controlled from the operating area by a separate breaker.

A removable, 42-in.-thick rectangular plug of steel-encased high density concrete comprises the cell roof. Stepped shielding plugs of different diameters are provided in the roof plug for installation of reactor components with the aid of the fuel handling machine (FHM). The roof provides necessary shielding to maintain the radiation dose rate at the reactor high bay floor level at less than 7.5 mr/hr with a source of 10^5 r/hr at any point 18 in. beneath the plug.

NOTE: The HNPF fuel handling machine is a 175-ton shielded cask mounted on a trolley and gantry which rides on rails along the length of the reactor room floor. The cask is provided with internal hoists and is equipped to index to, and maintain a shielded gas-tight atmosphere with, any reactor core fuel channel, fuel storage or process cell, shipping cask and the maintenance cell.

The floor of the cell has two 30 in. diameter, 10 ft deep storage wells. Each well is equipped with a stepped shield plug and a drain to the radioactive liquid waste system. One well has a 50-mesh screen basket and the other well a waste container.

The in-cell area is equipped with the following major pieces of equipment:

- 1) One bridge crane of 3 ton capacity, capable of giving full cell coverage.
- 2) One pair of heavy duty master slave manipulators mountable through the south wall operating face at any one of the three levels. The manipulators are provided with side canting and extension electrical drives. Maximum recommended capacity of a manipulator is 40 lb with the slave positioned vertically.
- 3) One tool positioner (Figure 1139-4) equipped with a vise and mounted on vertical tracks on the west wall of the cell (Figure 1139-5), capable of being located at any cell depth by a ball screw and drive assembly (Figure 1139-6).
- 4) One remotely operated servo manipulator mounted on a boom and slide assembly (Figure 1139-7) which rides on vertical tracks on the east wall in the same manner as the tool positioner. The servo manipulator is rated to handle 40 lb at a 36 in. reach in all attitudes.
- 5) One radiation monitor consisting of an ion chamber type beta and gamma detector, with readout equipment in the operating area. Both detector and control unit are portable and have a range of 1 mr/hr to 10^6 mr/hr.
- 6) A total of 18 filters (9 prefilters and 9 absolute filters) located on the north wall, at the third level (see Figure 1139-1). Six of these filters (three prefilter, three absolute) are for the low volume systems; the remaining 12 are in the high volume system.

Control of the in-cell atmosphere is effected by a high and low volume ventilation and exhaust system, with the low volume system being combined with an inert gas system. Whenever the cell access door or ports are opened the high volume system will provide the cell with an air atmosphere at a negative pressure, as referenced to outdoor atmospheric pressure.

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Figure 1139-4. Maintenance Cell Tool Positioner Assembly

Figure 1139-5. Track Mounted Tool Positioner Equipped With Tool Vise

The maintenance cell operating area is normally maintained at a pressure of minus 1/8 in. water gage (in. wg). The high volume system exhausts through roughing filters and prefilters located in the lower sections of the maintenance cell. Gases removed from the cell in this manner also pass through a set of separate "absolute" final filters which are not a part of any other plant system.

When operations are to be performed in the cell with all ports closed, and which involve no hazards (fire or radiation), the low volume system will maintain the cell at a negative pressure of 3/8 in. wg. Differential pressure controls prevent lowering cell atmospheric pressure below minus 3/4 in. wg under any circumstances. When irradiated fuel elements are handled in the cell or when cell operations involve a fire hazard, the low volume system, combined with the

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Figure 1139-6. Vertical Track and Drive Assembly

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Figure 1139-7. Manipulator Positioner Assembly

inert gas system, will maintain an inert (nitrogen) atmosphere at a negative pressure of 3/8 in. wg with oxygen limited to 2% by volume.

An oxygen analyzer, with the sampling line installed in the nitrogen cooler ductwork, is provided to sample the cell atmosphere. Two circulating fans (one on standby) are located in the nitrogen cooler ductwork and are combined with a cooling system to limit the ambient operating temperature in the cell to 150°F. Hand control stations are provided at each cell operating level to allow the operator to control the amount of nitrogen being admitted to the cell.

The three-level equipment operating area is south of the cell proper, with the levels at 18 ft, 34-1/2 ft, and 51 ft, respectively. Equipment access to each operating level is provided through hatches in the floor above. Personnel access to the operating levels is by stairway from the reactor room floor.

Each operating level is equipped with a control console which is mobile and may be positioned as convenient to the operator. All in-cell equipment is controlled from these consoles with the exception of the lights and door drive. Typical layout of console controls is shown in Figure 1139-8. The door drive is operable only from controls in the plant decontamination area. All in-cell equipment controls are safety interlocked so as to be operable from only one console at a time.

An audio system is provided for transmitting highly amplified sounds from the cell to the operating area.

Three sensitive microphones, remotely removable, are located in the cell at each window. Speakers are mounted in the operating area, above each window. The amplifier and preamplifier, equipped with individual and master microphone gain controls, and speaker selector switch are located at the first operating level. Speaker volume control is available at each operating level. By manipulating the microphone gain controls, the operator can determine approximate location of sounds within the cell.

B. GENERAL DISCUSSION

During the performance of the maintenance cell test, but not as a part of the planned test activity, it became necessary to handle radioactive and contaminated material in the cell. Reactor dry critical tests required a neutron source; a second source was required for wet critical tests and a third "hotter" source (increased neutron activity) was required for reactor startup. Subsequently, several control rod assemblies selected from the core were placed in the cell for visual examination and measurement of poison can diameters.

Special handling fixtures and measuring devices had to be designed, fabricated and installed in the cell. Trial runs were conducted using a mockup source in order to establish procedures and check the adequacy of the equipment used to safely handle a radioactive source.

Figure 1139-8. Control Console No. 1 — Layout of Controls

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During preoperational testing, entry to the cell was almost constant for modification and/or repair to cell components. Thus installation of radioactive and contaminated material necessitated the early initiation of safeguard practices regarding radiation and contamination hazards to personnel.

Radiation surveys of the maintenance cell face were conducted each time the antimony tetroxide source was handled in the maintenance cell. Although not a part of the preoperational test, a general description of the results of the survey is presented herein as radiation shielding is of necessity associated with maintenance cell operation.

Results of the survey indicated that the shielding in the cell face and plug ports on all three levels was adequate with the exception of the window area on levels No. 1 and 3. It was determined that radiation streaming was occurring in the upper corner of the window unit at level No. 1 and at the lower corner of the window aperture frame at level No. 3. Upon determination of where radiation streaming was occurring, both windows were removed from the wall. As the windows weigh approximately 10,000 lb each, suitable shoring was erected in front of each window to facilitate handling and insure proper support for the windows.

Voids in the concrete shielding were found in the upper corner of the window unit at the first level. Examination of the window opening frame at the third level disclosed a gap (approximately .005 to .010 in.) between the vertical wall plate and a base support angle. As the vertical wall plate and base angle were not a part of the radiation stop in the base plate, the gap extended through the window opening to the cell. Upon removal of an 8 in. section of angle, a small piece of shim stock was found wedged between the wall plate and the base support angle. Repairs to both windows were accomplished by removal of concrete and filling the void with sufficient lead shot to insure adequate shielding.

It was generally acknowledged by site personnel that the viewing height of the shielding windows (5-1/2 ft to 6 ft) was too high. This, combined with the height of the master slave manipulators in a fully retracted position, placed the tongs just above the center line of the window. Thus, with the work positioned just below eye level, it was difficult to hold objects steady with the tongs when viewed in the upper section of the window. The average person is accustomed

to viewing their work looking down, whether it is at a work bench or desk. To provide better viewing and less operator fatigue in future design of hot cells, this observation should be given due consideration.

C. TEST METHOD

Test performance consisted of operating all equipment and services in and to the cell to verify satisfactory operation and proper response of all valves, controls, and related instruments. Planned maintenance cell operations were subsequently conducted in the cell to establish operating procedures and to verify the adequacy of tools and equipment to perform these cell operations.

The planned preoperational tests covered the following four basic tests:

- 1) Functional test of all equipment: All operations on in-cell equipment were performed to assure proper response and satisfactory operation. The high and low volume exhaust and ventilation systems were tested to assure specified atmospheric conditions and pressure in the cell, and specified line pressures to the nitrogen operated machinery in the cell and to the access tunnel door inflatable seal.
- 2) In-cell fuel handling procedure test: A mock fuel element was disassembled, the fuel rod cluster installed in and removed from a spent fuel canister, and the fuel element reassembled.
- 3) In-cell poison column handling procedure test: A control rod poison column was disassembled and reassembled to the control rod and plug assembly in the cell.
- 4) In-cell filter exchange procedure test: All of the in-cell filters were removed from and replaced in the filter banks.

1. In-cell Equipment

a. Audio System

The cell audio system microphone gains were balanced by using a portable sound system capable of putting out metered sounds at frequency ranges from 50 cps to 1500 cps. To check audio system operation, a speaker was lowered through the 7-in. plug in the cell roof. The test consisted of positioning the speaker at the center line of each window and at the midpoint between windows

No. 1 and No. 2 as shown in Figure 1139-9. These positions were repeated with the transmission sound system set at 50, 250, 500, and 1000 cps, respectively, and the db level recorded.

Figure 1139-9. Illustration of Audio System Test Method

b. Exhaust and Ventilation System

This test involved changing atmospheric conditions in the cell to verify that the exhaust and ventilation system (Figure 1139-10) would respond to pressure changes and maintain a programmed atmosphere in the cell.

System testing was started with the hatch cover in the decontamination room removed and the cell door open. With the key switch (located in the control room radiation monitor panel) in the high volume position, it was verified that the high volume exhaust valve (CV-1540) opened and the low volume valves (CV-923, CV-924) and nitrogen valve (CV-922) closed automatically. Air velocity

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Figure 1139-10. Maintenance Cell Exhaust and Ventilation Control System

through the cell door was measured; the cell pressure and exhaust flow through the in-cell filters and pressure drop across the final (absolute) filters was recorded. If the pressure in the cell exceeds $-3/4$ in. wg, a low pressure over-ride transfers control of the high volume valve from flow to differential pressure.

The high and low pressure alarms (PAH-900 and PAL-904) were set at $-1/2$ in. wg and $-1/4$ in. wg, respectively, and the key switch positioned to low volume. The cell door was closed and cell pressure controller PIC-910 was set to control cell atmosphere at $-3/8$ in. wg. The high volume valve to the stack fans closed and the low volume exhaust valves to the R/A vent system opened; control of the cell atmosphere was established at $-3/8$ in. wg. Should the exhaust valves fail to function properly, allowing the negative pressure in the cell to exceed $-3/4$ in. wg, PS-900 will automatically admit nitrogen to the cell at a rate not to exceed 50 scfm.

The setpoint on PIC-910 was lowered to actuate PAL-904; it was verified that the alarm circuit energized the main board and local board No. 42 annunciators, and that the exhaust valve opened. PIC-910 was then raised to bring in PAH-900; the alarm circuit again energized and the exhaust valve closed. PIC-910 was reset to control at minus $3/8$ in. wg.

R/A vent block valve V-1061 and nitrogen block valve V-946 were then closed. HCS-900 was transferred to manual and the loading pressures increased to verify proper function of the low volume valves and indicating panel lights. HCS-900 was returned to automatic and the block valves opened. The setpoint on PIC-910 was raised in a negative direction to bring in PS-900 which opened nitrogen control valve CV-922. The cell pressure and nitrogen flow rate (FI-913) were recorded.

PIC-910 was reset and the loading pressures of HCS-901, -902, and -903 were adjusted for nitrogen flows of 10, 25, and 50 scfm as indicated on FI-913. With all hand control stations reset to zero and the cell controlling at minus $3/8$ in. wg, the oxygen analyzer (O_2 AN-901) was placed in operation. Nitrogen bypass valve V-948 was opened and the cell purged until the O_2 recorder indicated a cell atmosphere of 2% by volume per oxygen analyzer.

c. Access Tunnel Door

Pendant controls in the access tunnel were used to retract the tunnel door to the west end and then return it to the east end of the tunnel. Door travel

speed was recorded. The door shelf was raised and lowered from the control console on the first operating level, and the operating speed recorded.

Nitrogen pressure regulator PCV-921 was adjusted to 28 psig and the door seal inflated from the console on the first operating level.

d. In-cell Crane

The hoist, bridge, and trolley were satisfactorily operated from each control console at all three levels. Speeds were recorded for all crane movements and maximum hook height was noted.

e. Vertical Drive and Nitrogen Operated Carriage Equipment

The vertical drives for the manipulator and tool positioner carriages were operated from all three consoles. Four travel speeds were recorded for each carriage. Tests were conducted to determine the emergency stop over-travel distance at high speeds, and the results were recorded.

Nitrogen pressure requirements were determined and recorded for satisfactory operation of the gripping tool, tool slide and jib manipulator slide movements. Each operation was performed from all three consoles and speed of travel was recorded.

f. In-cell Manipulator

This test consisted of checking manipulator performance in accordance with the manufacturer's operating instructions. The real test of manipulator performance was accomplished during in-cell fuel handling and control rod disassembly.

2. In-cell Fuel Handling

This test was conducted to establish methods, procedures, and adequacy of tooling for disassembly of a spent fuel element and installation in a spent fuel canister. Subsequent reassembly of new fuel to the reused hanger rod and process tube was also included. A mock fuel element consisting of a standard shield plug and hanger rod, but with a stainless steel process tube and solid stainless rods in the fuel bundle assembly, was used for the test.

Prior to inserting the mock fuel element in the cell, a radiation survey was conducted and contamination levels reduced to insure no contamination of the mock fuel element. Preparation of the cell included placement of the small

accessory tools on the tool shelf and fabrication of a tool tray for installation on the tool vise. The need for a catch-all tray in the immediate working area had been demonstrated during earlier operations. The tool tray was bolted to the gripping tool vise in two pieces to allow the vise jaws to open and close.

As additional operating experience was acquired with each test performed, it was evident that changes would have to be made in the planned preoperational test procedure for in-cell fuel handling and control rod disassembly. Accordingly, Section M (in-cell fuel handling) and Section N (in-cell control rod handling) of preoperational test AI-P-1139 was rewritten to show these changes in method and addition or deletion of handling tools.

As there were no spent fuel canisters available at the HNPF when the fuel handling tests were being conducted, a mock canister was designed and built for test use. The canister was fabricated to prototype configuration but using available mild steel tubing and pipe fittings as no contamination containment or seal for fission gases was required. The canister was installed in the maintenance cell and hung on the wall storage rack.

With the cell thus prepared, the mock fuel element, equipped with a rotating ball bearing pickup cup, was transferred from a storage cell to the maintenance cell via the fuel handling machine. The machine was indexed to the 7-in. plug in the cell roof and the gas-lock seal lowered in position. Communication was established between the maintenance cell operator and the fuel handling machine operator. The fuel element was then lowered into the cell until the top of the process tube was approximately in the center of window No. 1.

The vise positioned at the 2nd level window and equipped with the 3.875-in. inserts was visually centered under the process tube and raised into position to grip the bottom section of the tube. The three process tube retainer pins were rotated clockwise 90° to the unlock position with a 1/4-in. square drive wrench held by the servo manipulator.

The fuel cluster was extracted from the process tube via the FHM hoist and raised until the bundle was within the cell roof plug. With the process tube thus free of the fuel bundle, the bundle was extracted from the process tube via the FHM. The FHM hoist load-cells were constantly monitored while the fuel cluster was removed from the process tube (Figure 1139-11). The hanger rod and attached fuel bundle were raised up into the cell roof plug in order to clear the

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Photo A

7518-1512A

Photo B

Figure 1139-11. Installing Mock Canister Top (Photo A) and Removing Fuel Cluster From Process Tube (Photo B)

in-cell crane movement. The process tube was equipped with a pickup adapter bail and installed in the cell storage rack.

After replacing the 3.875-in. vise inserts with the 5.00-in. inserts, the spent fuel canister was installed in the vise and the cap removed with the aid of a special wrench and the master slaves. The fuel bundle was then lowered into the canister and the bundle disconnected from the hanger rod. After again raising the hanger rod into the roof plug, the cap was replaced on the canister and the loaded canister installed in the storage rack (Figure 1139-11).

The 5.00-in. inserts were replaced with 4.400-in. inserts and the process tube transferred from the storage rack to the tool vise. After exchanging the process tube pickup adapter for a hanger rod adapter, the process tube was reassembled to the hanger rod. This assembly was then raised into the FHM and transferred to a storage cell.

Again the vise inserts were exchanged and the loaded canister installed in the vise.

After depositing the empty process tube, the FHM operator picked up the shuttle rod from the pickup cell and returned to the maintenance cell. The shuttle rod was lowered into the cell, the canister was attached, and the assembly then removed from the cell and transferred to the pickup cell. At this time the canister was removed from the pickup cell with the building crane. New locking pins were installed on the fuel bundle upper casting in the manner of new fuel and the canister replaced in the pickup cell.

At this point the mock fuel bundle was now handled as new fuel. The FHM was reindexed over the pickup cell, the canister retrieved, and the assembly transferred to the maintenance cell and stored on the north wall.

The previously used hanger rod and process tube were returned to the cell and installed in the vise. The process tube was disconnected and placed in the storage rack on the north wall. The canister containing the fuel bundle was returned to the vise and the capsule cap removed. Reassembly of the hanger rod to the fuel bundle was accomplished and the assembly raised into the cell roof.

The empty canister was installed in the storage rack and the 5.00-in. vise inserts were exchanged to accommodate the process tube. A special process tube guide was placed on top of the tube to act as a funnel when the fuel bundle

was inserted in the process tube. Rotation of the three tube retainer pins to the lock position completed reassembly of the fuel rod.

3. In-cell Poison Column Handling

Planned procedure is to use a spent fuel canister or similar containment vessel for handling, and eventual disposal of, a poison column assembly. As the overall length of a fuel cluster assembly is greater than a poison column assembly, a false bottom was fabricated and inserted in the mock canister previously used in the fuel rod handling test. Communication was established with the FHM operator and the FHM was employed to transfer a control rod from the storage cell to the maintenance cell.

The modified canister was installed in the maintenance cell gripping tool and the control rod poison column assembly inserted in the canister. The three Allen head 5/32-in. lock screws were loosened approximately 1/4 in. with the aid of the master slaves. The hex nut on the control rod pull tube assembly was engaged with a wrench mounted on the manipulator boom. An electric impact hammer supported by the in-cell crane was positioned to strike a wrench secured to flats on the poison column (Figure 1139-12).

Using the master slaves to guide the impact hammer, the hammer was actuated for the initial unthreading operation. At this point the tool slide containing the canister was lowered 2-3/4 in. to receive the poison column assembly. Completion of the unthreading operation was easily accomplished with the master slaves. The capsule cap was screwed on and the canister placed in the storage rack.

The poison column was successfully reassembled to the hanger rod and shield plug by reversing the procedure. The FHM operator raised the control rod into the machine and returned it to the storage cell.

4. In-cell Filter Exchange

This test involved the removal and remote handling of the prefilters and absolute filters located in racks on the north wall of the cell. This was accomplished with a special filter bail fixture capable of lifting and supporting a filter in a horizontal position.

The bail was hung from the in-cell crane hook and positioned in a horizontal attitude by adjustment of a counter balance weight. The fixture is designed

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Photo A

7518-1509

Photo B

Figure 1139-12. Unlocking the Lock Screws (Photo A) Preparatory to Disconnecting the Poison Column Assembly (Photo B)

to engage an existing flange on the exposed face of the filter. When engaged with the flange, the counter weight was again adjusted to maintain the filter in a horizontal position upon removal.

Test procedure was to remove a prefilter and install it in an adjacent filter rack. Access to an absolute filter thus was accomplished and the filter removed and installed in an adjacent rack. Procedure was then reversed and the filters replaced in their original rack. The test thus demonstrated that the filters could successfully be removed and handled remotely. It was also verified that a filter could be removed from the cell via the access tunnel and that a filter could be reinstalled in the cell using remote equipment.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

Performance of the maintenance cell tests disclosed several problem areas. Maintenance cell window radiation streaming presented the greatest potential hazard. Problems concerning maintenance cell equipment and planned operations were of lesser, although important, significance. Minor operational problems can be expected to appear during the initial operation of a newly constructed facility. Test results, in addition to a discussion of the individual problems encountered, and remedial measures taken, are discussed in the sections that follow.

A. IN-CELL EQUIPMENT

1. Audio System

Metered sounds of various frequencies which were fed into the cell by means of the audio oscillator demonstrated that the decibel level was within the acceptable range. The audio system proved capable of picking up these metered sounds at four test signals of different frequencies. Noises produced by motors, clutches, solenoids, and similar equipment during in-cell operations were clearly audible at all three operating levels. The sound source was easily identifiable by manipulation of the microphone selector switch. Operation of the volume controls was satisfactory; the system was capable of amplifying low-level sounds so as to be clearly discernible at all three operating levels.

2. Exhaust and Ventilation System

During testing of the low volume system, difficulties were experienced with the high-low alarm pressure switches. Corrective action required replacing both pressure switches with a unit capable of responding quickly over a narrow pressure range of minus 1/4 in. wg to minus 1/2 in. wg.

In addition, the solenoid valves used in the low volume and nitrogen systems failed to operate in proper sequence. Successful operation of the valves was accomplished by correctly rerouting instrument control air lines, in the proper sequence, to the solenoid valves.

The low volume system test was further hampered by an excessive in-leak of air to the cell. Before performing the test it was necessary to reduce the cell leak-rate. The in-leakage, in most cases, was due to small details left unfinished or overlooked during the cell construction phase. Missing gas-kets were installed on cell ports. Window seal frame bolts were torqued, pipe entrances into the cell were plugged, water traps in drain lines were filled, and similar minor discrepancies corrected to reduce the leak rate.

While testing performance of the maintenance cell ventilation control, it was found that cell pressures were influenced by pressure conditions elsewhere in the reactor building.

As the maintenance cell ventilation control is referenced to the outdoor leg of the heating and ventilating system, the opening of a door in the high or auxiliary bay would cause a change in cell pressure and volume flow rate. Desired pressure could be maintained in the cell only when reactor building pressures were within limits specified for the controlled areas.

Data obtained during the test are presented in Table I.

The high volume valve to the exhaust stack closed automatically when the key switch was turned to low volume position and the cell door was closed. The low volume valves to the R/A vent system opened and the cell atmosphere was established at minus 3/8 in. wg. As cell pressure was varied for test purposes, the high and low pressure alarm actuated at the prescribed setpoints of 1/2 and 1/4 in. wg, respectively.

Operation of the nitrogen system and related components was satisfactory. By means of a nitrogen purge, oxygen content of the cell atmosphere was reduced

TABLE I
EXHAUST AND VENTILATION SYSTEM TEST RESULTS

High Volume Test			
	Readout Point	Reading	
Air velocity through cell doorway	Cell doorway	100 fm	
Exhaust flow*			
Circulating Fan† OFF	FIC-1500	2500 cfm	
Circulating Fan† ON	FIC-1500	1900 cfm	
Cell pressure	PIC-910	~ 0 psi	
Pressure drop§	DPI-1506	0.59 in.wg	
	DPI-1507	0.70 in.wg	
Low Volume Test - N ₂ Cell Atmosphere			
Nitrogen Flow (scfm) FI-913	Loading Pressures (psig)		
	HCS-901	HCS-902	HCS-903
10	4	4	4
25	5	5	5
47	20	19.5	19.5

*Exhaust flow through in-cell filters

†Nitrogen cooler circulating blower

§Measured across separate final (absolute) filters

to 2% (as indicated by O₂AN-901) in about 8 hr. Cell atmosphere was successfully maintained at this value for an additional 2 hr, to satisfy the test completion criteria.

3. Access Tunnel Door

Depressing the REVERSE button on the pendant control caused the tunnel door to retract to the open position (west end of the tunnel). Operation was satisfactory although it was necessary to release the control button when the door reached the full open position. The control circuit does not contain an automatic cutoff to limit door travel in this direction.

The door moved to the east end of the cell, entering the door aperture, when the FORWARD button on the pendant control was depressed. However, the automatic cutoff feature intended to stop the door in the seal position failed to work. Inspection disclosed a door-mounted microswitch was not being engaged

by a fixed stop located on the floor. An adjustable stop was welded to the rail in the tunnel floor, to trip the microswitch, and adjusted to cause the door to stop automatically in the seal position.

With the cell door in the closed position, attempts to fold the lower seal face in position to contact the inflatable seal were unsuccessful. Rework of the faceplate was necessary for smooth operation. Basic configuration of the door assembly is shown in Figure 1139-13.

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Figure 1139-13. Access Tunnel Door

An initial attempt to inflate the door seal was unsatisfactory due to a leaking weld in the nitrogen supply line to the seal. After repairing the leak, the seal was satisfactorily inflated to 28 psig upon actuating the door seal switch on the first operating level console.

4. In-cell Crane

During in-cell crane tests it was noted that only one speed was available for all crane movements. Specification criteria called for infinitely variable speeds over a specific range for hoist, bridge and trolley movements. Investigation of this condition disclosed shorted diodes in the control circuit bias.

Tests were resumed upon replacement of the diodes; the hoist, bridge, and trolley controls were operated satisfactorily from all three consoles. Speeds recorded for all crane movements, and maximum hook height, are given in Table II. During subsequent use of the crane in performance of other in-cell equipment tests, failure of control power to the crane was experienced. Investigation disclosed that the mineral insulated power cable which penetrates the cell wall had shorted across the tube seal fittings on the in-cell end of the cable. Repair was difficult as the cable had short leads. These terminated in a box mounted on the cell wall at a point approximately 44 ft above floor level.

TABLE II
OPERATING SPECIFICATIONS* – IN-CELL EQUIPMENT

Equipment Item	Measured Value
Cell door (open and close)	16.5 ft/min
Door shelf operating time (full travel)	20 sec
Crane trolley speed	11 ft/min
Crane bridge speed	11 ft/min
Crane hoist speed (maximum)	20 ft/min
Crane hoist speed (minimum)	2 ft/min
Crane hook height (maximum):	
a) measured from floor	46 ft 6 in.
b) measured from tool shelf	10 ft 7 in.

*As measured during maintenance cell preoperational testing.

Examination of the spare cable disclosed a low resistance to ground, apparently due to high moisture content of the insulation. With the cables as a conductor, and resistance heaters as a load, voltage was applied in increasing

increments to bake out the moisture. New seal fittings were installed on both cables, and the crane returned to service.

During crane operation, it had also been observed that the pulleys on the in-cell slide wire did not properly carry the weight of the conductor cable thus preventing the cable from coiling and uncoiling correctly during bridge travel. A different type of pulley was installed and satisfactory operation was obtained.

5. Vertical Drive and N₂ Operated Equipment

Satisfactory operation of the vertical drives, for the manipulator and tool positioner carriages, was achieved from each of the three control consoles. Response to controls for positioning the carriages was excellent; movement of the carriages within an 1/8 of an in. at any level was possible. The average operating speeds are tabulated in Table III.

TABLE III
VERTICAL DRIVE SPEEDS*

Control Setting (Console)	Vertical Drive - Manipulator		Vertical Drive - Tool Slide	
	Raise (sec/ft)	Lower (sec/ft)	Raise (sec/ft)	Lower (sec/ft)
1	None	9.85	None	10.65
2	21.76	9.09	13.46	8.73
3	16.07	8.31	10.33	8.21
4	16.15	8.1	8.39	8.05

*Obtained by averaging speeds recorded for operation from each of the three consoles.

A loss of power was experienced during subsequent use of the vertical drive units. The trouble was found to be in the in-cell electrical connector plugs. Due to an interference fit in the housing, poor electrical contact was made and successive vibration resulted in the loss of electrical contact power. A new insert was fabricated for one unit; the other was reworked.

Upon inspecting the nitrogen operated equipment prior to beginning the test, it was noted that the solenoid operated valves and air motors lacked provision for remote lubrication. Thus, oil lubricators were subsequently installed

in the cell nitrogen supply lines at the second level operating area. Subsequent operation of the nitrogen operated equipment, from all three consoles, was satisfactory. Distance of travel and operating time are shown in Table IV.

TABLE IV
OPERATING TIME FOR NITROGEN OPERATED EQUIPMENT

N ₂ Operated Component	Normal N ₂ Pressure (psig)	Distance of Travel	Operating Time
	Tool Slide Unit		
Cross Slide	30	29-1/2 in.	1.74 sec/in.
Tool Slide	30	9-1/2 in.	3.28 sec/in.
Gripping Tool	30	6-3/4 in.	9.11 sec/in.
	Manipulator Slide		
Rotating Boom	15	180°	1.22 sec/ft
Boom Slide	15	12 in.	4.71 sec/in.

6. In-cell Manipulator

A visual inspection of the master slaves showed that cleaning and adjustment were required. Thus, prior to testing this equipment, the two master slaves were removed from the cell for cleaning and adjustment. At this time, heat imprints of the manipulator boot fabric were found on the outer support surface of the upper manipulator arm. This condition was attributed to the close proximity of the in-cell lights to the manipulator boots. New boots were installed and the manipulators were replaced. Routine adjustments were made on the manipulator, and satisfactory operation was achieved.

Due to the manipulator boot damage, the lights were relocated. Heat shields were also installed on the lights, to reflect the heat away from the boots.

B. IN-CELL FUEL HANDLING

During initial attempts to rotate the process tube retainer pins, the 1/4-in. square drive wrench held by the servo manipulator broke off the manipulator adaptor at the weld junction. A new wrench, which was fabricated from a 1/4-in. high speed tool bit, proved to be satisfactory.

As the fuel cluster was removed from the process tube, the load-cell indicators showed an intermittent increase of 5 to 10 lb over the initial load. This was attributed to the fuel rod spacers catching on the process tube lock pin holes.

When equipped with the pick-up adaptor, the process tube could not be safely transferred to the storage rack because the single lift pin could not adequately support the process tube. Two additional lift pins were added to the adaptor and satisfactory support was obtained. Figure 1139-14 shows the assembly in the transport position.

Removal of the split ring that locks the fuel bundle to the hanger rod was easily accomplished. Reassembly was more difficult due to the close tolerances in aligning the two sections. A crimping tool that had been designed to depress the locking tabs on the split ring retainer sleeve was found to be difficult to use. A special tool was fabricated to fit the master slave manipulator tongs and the slot in the locking tab. A slight pressure with the slave easily depressed the tab to the desired lock position (Figure 1139-15).

C. IN-CELL POISON COLUMN HANDLING

It had been originally planned to use special inserts in the gripping tool which formed a 3-in. hex opening when the vise jaws were closed. This hex opening would grip the hex nut on the upper hanger rod, thus preventing rotation when unscrewing the poison column. A lifting device installed in a fixture on the manipulator carriage boom would support the canister for installation of the poison column assembly. This arrangement limited the use of the servo-manipulator which is attached to the boom and obscured viewing of the work area.

Experience gained in equipment testing and fuel rod disassembly demonstrated that the gripping tool and servo-manipulator could be used more advantageously. The ability of the gripping tool to position and support reactor components for greater visibility and remote handling contributed to the decision to change the planned procedure. Accordingly, a wrench was designed and fabricated to fit the fixture on the manipulator carriage boom. The wrench supersedes the special inserts, thus freeing the gripping tool to support the canister.

D. IN-CELL FILTER EXCHANGE

During the exhaust and ventilation systems test, the in-cell filters were visually examined for signs of damage or clogging of the filter medium. None was found. At this time it was observed that the prefilters did not have a

7518-1510

Figure 1139-14. Process Tube With
Bail Attached Preparatory to
Transfer to Storage Rack

7518-1512B

Figure 1139-15. Using Manipulator
Tongs to Depress Locking Tabs
on Fuel Bundle

recessed flange on the exposed ends, as did the absolute filters. As this flange was incorporated in the design of the filter removal bail it was necessary to fabricate and install flanges to all nine prefilters. The filters were removed from the racks and placed in the access tunnel where the rework was performed.

Initial attempts to remove a filter disclosed that modification of the filter removal bail was necessary. The counter balance weight (approximately 40 lb) was too heavy for the in-cell manipulator to handle. The counter weight was cut into three sections, each weighing approximately 13 lb. A lifting handle was attached to each section for easier handling by the manipulator.

The removal of a filter in a horizontal position is desirable in order to prevent the spread of contamination in the cell.

Subsequent removal and replacement of the filters, as called for by the test procedure, was accomplished.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with preoperational test AI-P-1139, Maintenance Cell, as listed in NAA-SR-5700, Supplement 4, pages XI (a)-54 through XI (a)-57, with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: The maintenance cell in-cell area lamps operate properly and provide adequate lighting.

Remarks: In-cell area lamps operated properly and provided adequate illumination for in-cell operations. However, as originally installed, the lights were too close to the manipulator slaves. Intensity of the heat had melted the plastic in a large area, leaving an imprint of the fabric boot on the manipulator arm. To rectify the condition, the lamps were relocated and heat reflecting shields were installed to reflect heat away from the manipulator boots. Relocation of the lamps did not reduce the effectiveness of in-cell illumination. Photos presented in this report were obtained by means of in-cell lights.

b) Criterion: Audio System

- 1) Microphone gains have been balanced.
- 2) Volume controls operate properly.
- 3) It was verified that sounds can be generally located in the cell by selective "on" and "off" manipulation of the microphone switches.

Remarks:

- 1) Microphone gains were balanced over a range of 50 to 1500 cps.
- 2) Volume controls operated satisfactorily and demonstrated an adequate range of sensitivity.
- 3) Location of sounds in the cell was successfully accomplished by manipulation of microphone switches.

c) Criterion: High Volume Exhaust

- 1) Exhaust valve opens when key switch is turned to high volume.
- 2) Minimum velocity of intake through maintenance cell access tunnel door is 100 fpm.
- 3) Exhaust valve closes when key switch is turned to low volume.

Remarks:

- 1) By both visual inspection and measurement of the exhaust flow rates, it was verified that the exhaust valve opened when the key switch was turned to high volume position.
- 2) Minimum air velocity was verified to be 100 fpm as measured with an air velocity meter positioned at the open tunnel door. A prerequisite for this criteria was that the decontamination room hatchway be open and the high volume system operating.
- 3) By visual inspection, it was verified that the exhaust valve closes when the key switch is turned to low volume.

d) Criterion: Cell Low Volume System

- 1) Pressure in cell is about $-3/8''$ H₂O when the low volume system is operating under normal conditions.

- 2) The high pressure alarm annunciates when pressure reaches about $-1/4''$ H₂O and the position switch, which actuates low volume exhaust valve, operates properly, i.e., actuates the valve thus permitting the R/A vent system to pull pressure in the cell back down to about $-3/8''$ H₂O. Proper lights on gage board light when annunciator alarms.
- 3) The low pressure alarm annunciates when pressure in the cell reaches $-1/2''$ H₂O and the N₂ supply valve opens allowing pressure to return to about $-3/8''$ H₂O.
- 4) The cell has been purged and oxygen content held to approximately 2 percent by volume (as per O₂ analysis) for a period of not less than 2 hours.

Remarks:

- 1) Test results substantiate that the low volume system will more than adequately maintain the cell at $-3/8$ in. H₂O even under abnormal operating conditions, e.g., excessive in-leakage of air.
- 2) and 3) These criteria were met after installation of a new pressure switch as discussed in Section III-A-2.
- 4) The cell was successfully purged and the oxygen content held within the limits specified.

e) Criterion: Cell Door

- 1) The maintenance cell access tunnel door seal was inflated and deflated satisfactorily from the maintenance cell operating area console.
- 2) The door was successfully retracted to the west end of the tunnel and returned to the east end by the pendant controls located in the tunnel.
- 3) The door shelf was raised and lowered successfully by controls on the console on the first operating level. The proper lights on the console lighted when the shelf was "up" or "down."

Remarks: Satisfactory performance of the items listed in the criterion was demonstrated through the repeated operation of cell door and door components while the maintenance cell was being used for activities outside the scope of the test.

- f) Criterion: The maintenance cell in-cell hoist, crane and trolley were operated satisfactorily from all three consoles.

Remarks: The in-cell hoist, crane and trolley were satisfactorily operated from all three consoles during the testing and subsequent operations activities.

- g) Criterion: The vertical drive for the manipulator carriage was operated satisfactorily from all three consoles.

Remarks: This criterion was verified as in criterion f).

- h) Criterion: The vertical drive for the tool positioner carriage was operated satisfactorily from all three consoles.

Remarks: This criterion was verified as in criterion f).

- i) Criterion:

1) The tool slide was satisfactorily moved from side to side and "in" and "out" from all three consoles.

2) The gripping tool was opened and closed satisfactorily from all three consoles.

Remarks: Operations listed in this criterion were satisfactorily performed during test performance and while carrying out work activities performed in the maintenance cell.

- j) Criterion: The manipulator slide was satisfactorily rotated "CW" and "CCW" and "in" and "out" from all three consoles.

Remarks: This criterion was verified as in criterion i).

- k) Criterion: The Lee Manipulator has been satisfactorily operated according to the manufacturer's instructions.

Remarks: Satisfactory operation was demonstrated when the manipulator was operated in accordance with the manufacturer's operating instructions and during subsequent activities carried out in performance of maintenance cell tests.

- l) Criterion: The AMF Master Slave Manipulators have been satisfactorily operated according to the manufacturer's instructions.

Remarks: This criterion was verified in the same manner as criterion k).

m) Criterion: In-cell Fuel Handling

- 1) Communications were satisfactorily maintained between the maintenance cell operator and the fuel handling machine operator.
- 2) A gastight seal was established and maintained between the fuel handling machine cask and the maintenance cell and the mock fuel element positioned satisfactorily during the in-cell operations.
- 3) The fuel element process tube was successfully removed from the fuel bundle and stored in the fuel rack.
- 4) The fuel bundle was removed from the fuel element shield plug and hanger rod assembly, placed in a fuel shipping capsule and the capsule stored in the fuel rack.
- 5) The fuel bundle was reassembled to the fuel element shield plug and hanger rod assembly and the process tube reinstalled on the fuel bundle thus verifying the adequacy of the tools and equipment for all anticipated maintenance cell fuel handling operations.

Remarks: In-cell fuel handling operations, including the items listed in this criterion, can be performed safely and in a satisfactory manner. The adequacy of in-cell tools and equipment used in fuel cell handling was verified by disassembly and reassembly of a mock fuel element. To eliminate the need for long extension cords used to establish communication between the FHM operator and maintenance cell operator, a phone jack was installed in the FHM.

n) Criterion: In-cell Poison Column Handling

- 1) The control rod poison column was successfully disassembled from the pull rod and shield plug assembly, placed in a shipping capsule and stored in the fuel rack.
- 2) The control rod poison column was removed from the capsule and reassembled to the pull rod and shield plug assembly thus verifying that the tools and equipment for control rod poison handling were adequate.

Remarks: Operations listed in the criterion were successfully carried out in performance of the in-cell poison column handling test.

Originally, planned operation of the electric impact hammer was with the on-off trigger switch bypassed. The tool cord had to be plugged into a wall receptacle for operation of the impact hammer. This operation was questionable as the operator had no direct control over the tool. Thus, to provide control of the tool, a switch was wired into the receptacle circuit. This entailed installing a three-position switch (on, off, or spring return), in pendant form, at the operating face, at all three operating levels.

o) Criterion: In-cell Filter Change

- 1) Filters were removed from the filter bank and removed from the cell by way of the maintenance cell access tunnel door.
- 2) Filters were returned to the maintenance cell by the door and reinstalled in the filter bank thus verifying that the tools and equipment are adequate for filter change in the maintenance cell.

Remarks: All operations called for in the criterion were satisfactorily carried out during performance of the maintenance cell test. Further evidence of compliance with this criterion was demonstrated by the successful removal and replacement of a damaged filter. A filter was accidentally damaged during performance of AI-P-1139 and was removed to the access tunnel using in-cell equipment.

V. EVALUATION

This test verified that the normal maintenance cell operations can be performed efficiently and safely, and that the operating procedures and the tools and equipment are adequate. All test completion criteria listed in NAA-SR-5700, Supplement 4, were adequately met. Some minor operational difficulties were encountered during the course of the test program. These problems were all adequately resolved.

AI-P-1145

Evaluation
by
S. L. PFAHLER

October 8, 1962

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
CONTROL ROD DRIVE AND ACTUATOR ASSEMBLIES, AI-P-1145

I. PURPOSE OF TEST

The purpose of this test was to insure satisfactory performance of the Mark B Control Rod Drive and Actuator Assemblies and to verify operability of mechanical and electrical components and position indicating signal devices contained in the drive and actuator assemblies after installation of the control rod support structure on the reactor loading face shield.

II. DISCUSSION OF TEST PERFORMANCE

The control rod simulator test was performed concurrently with this test. A few errors were found in the control rod circuitry with the control rod simulator and were easily corrected.

The Control Rod Drive and Actuator Assembly test was performed without major incident for each drive and actuator assembly. The Control Rod Test Cart and Heiland Visicorder (timing instrument) were connected to the Control Rod Drive and Actuator Assembly. The motor brake housing cover was removed and the drive operated from the test cart. The motor brake and blower were checked for proper operation.

The digital position indicator (on the test cart) was set so that it would read 999.9 when the down-limit switch stopped the drive. The rod latch magnet was energized, the drive gear removed and the drive shaft

rotated clockwise by hand until the weight of the poison column could be felt. The digital position indicator reading was recorded and compared with like data in the Site Assembly Log. * The drive shaft was then rotated counter clockwise until the mechanical stop was hit and the digital position indicator reading was recorded and compared with like data in the Site Assembly Log. The shaft was again rotated clockwise until the digital position indicator reading was 999.9 and the drive gear was re-assembled on the drive shaft.

The control rod drive switch was actuated up and the control rod drive started raising the rod. The "Drive Out" light was energized when the motor was energized. The "Rod In" light was de-energized at approximately position 001.0 and the "Snubber Up" light was energized at approximately position 003.0. The rod was raised until the digital position indicator reading was 015.0. The magnet voltage was reduced until the weight of the poison column separated the latch and the rod was released. The release voltage and current were recorded and compared with the average voltages and currents of all previous tests recorded in the Control Rod Acceptance Test Log. **

The control rod drive was operated up and down sufficiently to determine the drive motor voltage and current in each direction and to measure the motor speed in each direction. The data taken was recorded

* Log of Assembly of Control Rod Actuator at HNPF

** Log of Control Rod Acceptance Test performed at AI Laboratory

and compared with average motor voltages, currents and speeds of all previously recorded tests of proper functioning drive assemblies.

The latch magnet voltage was increased to normal and the control rod drive operated down until the down-limit switch stopped the drive (digital position indicator reading 999.9) and it was noted that the "Drive In" indicator light was energized when the control rod drive was operated Down. It was also noted that the "Rod Mag Latched" light was energized when the digital position indication was 999.9. The control rod drive was operated up until the up-limit switch stopped the drive. It was noted that the digital position indicator reading was 156.0 when the up-limit switch stopped the drive. The control rod was manually scrambled and the time required for the first nine feet of rod fall and for full rod insertion was measured by the Visicorder (timing instrument) and recorded. Time for the first nine feet of fall (T_{a1}) was compared with the average time ($\bar{T}_{a1}$) from all previous tests. Time for full insertion (T_{s1}) was compared with the 95% confidence levels calculated from T_{s1} recorded on all previous tests.

The control rod drive was operated down, the control rod was engaged and the control rod drive operated up until the digital position indicator reading was 078.0. The control rod was manually scrambled and the time required for the first 2-1/2 feet of rod fall and for full rod insertion was measured by the Visicorder and recorded. Time for the first 2-1/2 feet of fall (T_{a2}) was compared with the average time ($\bar{T}_{a2}$)

from all previous tests. Time for full insertion (T_{s2}) was compared with the 95% confidence levels calculated from T_{s2} recorded on all previous tests.

The control rod was raised by the control rod drive until the digital position indicator reading was approximately 015.0. The control rod was manually scrambled and the rod magnet latch release time was measured and recorded.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

A. CONTROL ROD DRIVE MOTOR BRAKE AND BLOWER

The motor brakes operate smoothly when properly adjusted but require periodic cleaning of the solenoids to insure failure free operation. The drive motor blowers start after the motors have started and stop after the motors stop, thus providing air cooling to the drive motor when cooling is required.

B. LOCATION OF DOWN-LIMIT SWITCH

With the digital position indicator set at 999.9 (where the down-limit switch stopped the drive) and the control rod drive shaft manually rotated clockwise until the latch engaged the control rod pickup cup, the position indicator read 000.0 when checked on all control rod actuator and control rod assemblies. The drive shaft was rotated counter clockwise until the mechanical stop prevented further rotation and the position indicator reading was 999.8 ± 0.3 in all cases. These readings compare with like readings in the Site Assembly Log. This test verified that the latches

engage the control rods at position 000.0 (000.1 inches above the position where the down-limit switch stops the drive on all rods) and that the down-limit switch was properly positioned.

C. OPERATION OF INDICATING LIGHTS AND CHECKING ROD
 LATCH RELEASE VOLTAGE AND CURRENT

When the control rod switch was actuated to the up position, the control rod drive started raising the rod and the "Drive Out" indicating light was energized thus verifying proper operation of the drive out controls and indicating light. The permanent magnet on top of the control rod was raised above the glass-switch and the "Rod In" light was de-energized, thus verifying proper operation of the glass-switch. When the control rod was raised, the return springs on the snubber returned the snubber to the full up position and the "Snubber Up" light (on the test cart) was energized thus verifying that the snubber cocking equipment and the brush switch operated properly. These tests were successfully performed on all control rods without exception. Voltage to the latch magnet was slowly reduced (with the rod positioned at 015.0) until the latch released the rod. The latch release voltage and current (Table I) compared satisfactorily with the average of all the release voltages and currents measured for each latch during the Control Rod Acceptance Test thus verifying proper operation of the latch and magnet.

TABLE I
LATCH RELEASE VOLTAGES AND CURRENT

	Test AI-P-1145		Previous Tests*	
Rod No.	Volts	Amps	$\bar{v}_L$ (Volts)	$\bar{a}_L$ (Amps)
1	17.2	0.105	16.5	0.0964
2	13.5	0.086	14.3	0.0864
3	15.4	0.095	15.1	0.0860
4	15.4	0.095	16.2	0.0962
5	15.9	0.098	17.2	0.1028
6	14.7	0.090	15.7	0.0932
7	15.0	0.091	16.0	0.0972
8	14.1	0.087	15.2	0.0934
9	16.3	0.104	15.6	0.0950
10	14.1	0.089	16.3	0.0970
11	14.8	0.094	14.2	0.0890
12	13.5	0.085	16.7	0.1016
13	14.8	0.096	12.3	0.0760
14	12.5	0.078	13.7	0.0804
15	14.2	0.090	15.0	0.0936
16	14.0	0.086	14.1	0.0860
17	15.4	0.097	15.5	0.0966
18	14.3	0.092	14.8	0.0894
19	12.4	0.079	14.6	0.0900

* Mean from previous laboratory tests:

$$\bar{v} \text{ or } \bar{a} = \bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

where:

n = number of all previously recorded test results

D. DRIVE MOTOR SPEED, VOLTAGE AND CURRENT

The control rod drive motor speed, voltage and current were measured while operating the control rod drive up and down without the control rod attached to the drive. The motor speed, voltage (v_m) and current (a_m) (Table II and Table III) compared satisfactorily with the motor speeds, and average voltage ($\bar{v}_m$) and current ($\bar{a}_m$) measured during the Control Rod Acceptance Test. The motor is a Specially Wound Diehl Low Inertia Servo Motor. It is 2 phase with 208 V and 117 V windings (Figure 1145-1). Voltage measurements were made of each phase and include the drive motor brake across the 208 V winding and the blower motor across the 117 V winding.

E. OPERATION OF INDICATING LIGHTS AND MEASURING SCRAM TIME FROM 156.0 INCHES.

When the digital position indicator reading was 999.9 after driving the latch down to the fully inserted rod, the "Rod Mag Latched" light was energized thus verifying proper operation of the indicator switch in the latch. When the control rod control switch was actuated down, the drive was energized and the "Drive Down" indicating light was energized thus verifying proper operation of the light. The control rod was operated up until the up-limit switch stopped the drive at position indicator reading 156.0 thus verifying proper operation of the up-limit switch. All indicating lights and up-limit switches on all control rod actuators operated properly. The control rod was scrambled from 156.0 and the time for the first nine feet of fall and for full insertion of the rod was measured and recorded. Time for the first nine feet of fall (T_{a1}) on all rods was less than 803 milli-

TABLE II
MOTOR SPEEDS, VOLTAGE AND CURRENT DRIVING DOWN

Rod No.	Voltage (volts)				Current (amps)				Motor Speed	
	Phase A - B		Phase C - N		Phase A - B		Phase C - N		(rpm)	
	$v_m(1)$	$\bar{v}_m(2)$	$v_m(1)$	$\bar{v}_m(2)$	$a_m(1)$	$\bar{a}_m(2)$	$a_m(1)$	$\bar{a}_m(2)$	(1)	(2)
1	200	209.0	115.0	122.0	1.45	1.440	0.90	0.830	3260	3262
2	208	206.0	118.0	122.0	1.61	1.375	0.98	0.835	3230	3210
3	202	205.3	115.0	116.6	1.58	1.416	0.90	0.883	3180	3202
4	210	210.6	120.0	123.0	1.19	1.416	0.82	0.843	3200	3265
5	202	210.0	116.0	121.5	1.43	1.440	0.88	0.835	3204	3190
6	218*	202.5	117.5	115.0	1.22	1.425	0.93	0.870	3300	3230
7	218	204.0	119.0	117.0	1.60	1.465	0.95	0.900	3238	3300
8	208	208.5	117.0	120.0	1.55	1.450	0.95	0.900	3280	3290
9	201	208.5	115.0	118.0	1.62	1.590	0.98	0.980	3070	3160
10	201	207.0	116.0	119.5	1.70	1.710	0.95	0.950	3170	3265
11	208	207.0	119.0	118.0	1.73	1.510	1.02	0.940	3185	3275
12	208	204.5	119.0	115.5	1.61	1.435	0.96	0.910	3240	3260
13	207	201.0	118.0	115.0	1.65	1.450	0.98	0.890	3140	3220
14	208	203.5	119.0	116.5	1.40	1.390	0.93	0.880	3260	3320
15	210	206.0	120.0	118.5	1.71	1.425	1.00	0.900	3210	3300
16	204	206.0	117.0	118.0	1.50	1.435	0.90	0.890	3242	3280
17	208	204.5	119.0	116.5	1.43	1.540	0.87	0.820	3185	3210
18	208	204.0	118.0	115.5	1.66	1.440	1.00	0.850	3135	3210
19	208	205.5	118.0	116.5	1.58	1.485	0.97	0.910	3250	3300

(1) Preoperational Test AI-P-1145

(2) Mean from previous laboratory tests:

$$\bar{v} \text{ or } \bar{a} = \bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

where:

n = number of all previously recorded test results

TABLE III
MOTOR SPEEDS, VOLTAGE AND CURRENT DRIVING UP

Rod No.	Voltage (volts)				Current (amps)				Motor Speed	
	Phase A - B		Phase C - N		Phase A - B		Phase C - N		(rpm)	
	$v_m(1)$	$\bar{v}_m(2)$	$v_m(1)$	$\bar{v}_m(2)$	$a_m(1)$	$\bar{a}_m(2)$	$a_m(1)$	$\bar{a}_m(2)$	(1)	(2)
1	200	209.0	113.0	121.0	0.90	0.820	1.45	1.436	3250	3210
2	208	208.5	117.0	120.0	0.99	0.850	1.68	1.385	3170	3185
3	203	205.0	113.0	116.0	0.90	0.830	1.58	1.466	3145	3187
4	210	210.3	118.0	122.6	0.82	0.853	1.22	1.470	3120	3240
5	203	210.0	114.0	120.5	0.85	0.850	1.42	1.435	3165	3195
6	219	202.5	117.5	113.0	0.92	0.880	1.45	1.450	3260	3210
7	210	204.0	116.0	115.0	0.92	0.875	1.55	1.525	3230	3270
8	208	208.5	117.0	119.0	0.90	0.875	1.55	1.490	3262	3305
9	201	208.0	112.0	117.5	0.97	0.965	1.62	1.625	3070	3150
10	202	207.5	112.0	117.5	0.90	0.910	1.72	1.750	3180	3250
11	208	207.0	117.0	117.0	0.99	0.900	1.64	1.575	3170	3250
12	207	204.0	116.0	114.5	0.95	0.875	1.64	1.550	3220	3260
13	207	201.5	117.0	115.0	0.97	0.880	1.64	1.500	3102	3200
14	208	203.0	116.0	115.5	0.91	0.850	1.50	1.400	3215	3300
15	210	206.5	118.0	117.5	1.00	0.885	1.75	1.500	3180	3300
16	204	207.0	115.0	118.0	0.90	0.890	1.48	1.475	3235	3275
17	208	204.0	117.0	115.0	0.84	0.800	1.44	1.560	3170	3190
18	208	209.5	117.0	115.0	0.99	0.865	1.68	1.475	3108	3170
19	208	205.5	117.0	115.5	0.95	0.900	1.62	1.525	3240	3270

(1) Preoperational Test AI-P-1145

(2) Mean from previous laboratory tests:

$$\bar{v} \text{ or } \bar{a} = \bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

where:

n = number of all previously recorded test results

Figure 1145-1. Control Rod Drive Motor Circuit

secs (as required in the tech specs) and compared satisfactorily with ($\bar{T}_{a1}$) from previous tests. Scram time (T_{s1}) on all rods was less than 1015 milliseconds. All scram times fell within 95% confidence levels (Table IV).

F. MEASURING SCRAM TIME FROM 78.0 INCHES

The control rods were scrambled from 78.0 and the time for the first 2-1/2 feet of fall and for full insertion of each rod was measured and recorded. Times for the first 2-1/2 feet of fall (T_{a2}) compared satisfactorily with ($\bar{T}_{a2}$) on all previous tests. Scram times (T_{s2}) on all rods except five were within 95% confidence levels and the greatest difference exceeded the 95% confidence level by five milliseconds which is less than instrument error of one percent (Table V).

G. MEASURING ROD LATCH RELEASE TIMES

The control rods were scrambled from 15.0 inches and the rod latch release times were measured and recorded (Table VI). Rod latch release time in this test was determined by measuring the period from the time the latch magnet voltage was interrupted and the time when the "Rod Mag Latched" light current was interrupted. The latch magnet voltage was, of course, interrupted by actuating the scram button on the test cart. The "Rod Mag Latched" indicating light current is interrupted when the switch (located in the latch) is opened by the control rod pickup cup falling off the latch.

TABLE IV
SCRAM TIME FROM FULL HEIGHT (156.0)

Rod No.	Drop Time First Nine ft (msec)		Drop Time Full Insertion (msec)	
	T_{al}^*	T_{al}	T_{sl}^*	$L_{T_{sl}}^{**}$
1	768.0	768.1	960	971.0/953.0
2	781.0	772.8	963	971.3/952.7
3	770.0	769.5	960	961.1/950.9
4	760.0	771.4	950	967.4/948.6
5	783.0	781.6	971	977.8/962.2
6	770.2	773.6	962	966.4/951.6
7	769.0	770.9	967	971.7/964.3
8	767.0	769.1	956	961.2/948.8
9	771.0	776.2	969	976.3/955.7
10	770.0	773.3	956	961.3/952.7
11	768.0	769.0	952	952.8/949.3
12	784.0	787.9	991	1001.4/980.7
13	772.0	770.4	955	968.8/945.2
14	783.0	787.3	970	978.4/965.7
15	773.0	769.5	951	958.2/947.8
16	778.2	774.5	960	961.4/954.7
17	774.0	769.5	947	953.8/944.3
18	769.0	767.1	968	971.0/949.0
19	767.0	762.3	957	962.2/949.8
<p>* Preoperational Test AI-P-1145 drop times recorded during this test.</p> <p>** $L_{T_{sl}}$ = 95% confidence levels computed from all previous tests.</p> <p>† Test average (955.8) of 5 rod scram times taken in July 1962 to verify 95% confidence levels (Ref IOL P. F. Shaw to R. E. Durand dated 7/28/62).</p>				

TABLE V
SCRAM TIME FROM HALF HEIGHT (78.00)

Rod No.	Drop Time First 2-1/2 ft (msec)		Drop Time Full Insertion (msec)	
	T_{a2}^*	T_{a2}	T_{s2}^*	$L_{T_{s2}}^{**}$
1	404	406.4	702	716.9/691.1
2	404	405.5	702	703.9/682.9
3	405	407.4	698	700.4/690.2
4	402	410.4	691	715.0/693.1
5	407	407.0	698	705.6/692.4
6	410	411.2	705	701.6/694.5
7	407	409.4	702	717.7/704.3
8	403	404.9	693	699.1/692.1
9	410	411.7	716	720.4/707.6
10	405	406.3	691	698.1/689.9
11	408	407.2	702	696.7/687.3
12	411	415.6	737	775.0/731.0
13	412	407.5	700	701.5/688.5
14	420	410.3	710	711.4/694.0
15	410	405.3	692	692.0/684.0
16	415	409.1	702	700.0/688.1
17	410	408.5	686	690.9/685.1
18	405	403.7	709	710.3/695.7
19	402	404.6	700	707.1/694.9
<p>* Preoperational Test AI-P-1145 drop times recorded during this test.</p> <p>** $L_{T_{s2}} = 95\%$ confidence levels computed from all previous tests.</p>				

TABLE VI
ROD LATCH RELEASE TIME

Rod No.	Time (Millisec)	Rod No.	Time (Millisec)
1	51	11	50
2	52	12	55
3	51	13	51
4	51	14	51
5	50	15	51
6	53	16	53
7	52	17	53
8	51	18	53
9	52	19	52
10	51		

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the Test Completion Criteria associated with pre-operational test AI-P-1145, Control Rod Drive and Actuator Assemblies as listed in NAA-SR-5700, Supplement 2, pages XI (a)-23 and XI (a)-24 with remarks regarding the test to explain compliance with the criteria.

In the tests where the requirement is that "No significant difference exists", the word significant is herein qualified as based upon a significance at the 95% confidence level. However, the number of tests run prior to this test on all but control rod scrams was too small to provide enough data to be of any real value in evaluating 95% confidence level limits. The 95% confidence level limits have been calculated for scram times using the

following method taken from the "ASTM" Manual and Quality Control, publications 15-6, dated January 1951; where:

- a) L_{ts} = maximum and minimum limits of the 95% confidence level.
- b) T_s = scram time for full insertion.
- c) n = number of recorded scram times (for each rod) from previous tests.

$$d) \quad \bar{T}_s = \frac{1}{n} \sum_{i=1}^n T_{si} \quad T_{si} = \text{mean scram time}$$

$$e) \quad \sigma^2 = \frac{1}{n-1} \sum_{i=1}^n (T_{si} - \bar{T}_s)^2 \quad = \text{standard deviation squared.}$$

then

$$L_{ts} = \bar{T}_s \pm 1.96 \frac{\sigma}{\sqrt{2}}$$

Where 95% confidence level limits could not be realistically calculated to qualify certain test data according to the completion criteria in NAA-SR-5700, the mean ($\bar{X}$), was derived from all previous tests and used for comparison with data from this test. Hence, the determination that no significant difference exists between data from this test and mean data from manufacturing proof tests was made by the Test Engineer and AI Management based on sound engineering judgement and the particular extenuating circumstance related to a particular test.

- a) Criterion: Oil level has been checked.
Remarks: Oil levels were checked during site assembly and there were no indications of oil leaks. Hence, this check was not repeated in this test.
- b) Criterion: The motor, brake, blower and slip clutch are operable. Motor speed, current, and voltage readings have been taken and compared with the data from the manufacturing proof test. No significant differences exist.*
Remarks: Drive motor, brake and blower were checked. Although checking the slip clutch was not part of the test, this checkout was made on each drive. Motor speed, voltage and current were measured and compared with averages from previous tests. In no case was there evidence or firm indication of improperly functioning drive motors, brakes or blowers.
Sufficient data for calculating 95% confidence level limits was not available. Measurements of motor voltage (v_m), current (a_m) and speed were compared with $\bar{a}_m$, $\bar{v}_m$ and motor speeds from manufacturing proof test data.
- c) Criterion: The latch release voltage and current readings have been taken and compared with the data from the manu-

* Based upon a test of significance at the 95% confidence level.

facturing proof test. No significant differences exist.*

Remarks: The latch release voltages and currents were compared with averages from previous tests. There were no indications of improper performing latches.

A 95% confidence level could theoretically be calculated but is not very realistic where a total of 6% error must be assumed in the measuring instrument readout and instrument itself.

As in motor voltage and currents, the latch release voltages (v_L), and currents (a_L) were compared with $\bar{v}_L$ and $\bar{a}_L$ from manufacturing proof test data.

- d) Criterion: The down-limit switch is positioned at the point where the actuator starts to pick up the weight of the poison column.

Remarks: The down-limit switch is actually positioned 1/10 of an inch below the point where the actuator starts to pick up the weight of the poison column in order to insure that the latch has sufficient room to lock inside the pickup cup. Consequently the digital position indicator is set at 999.9 (i. e., minus 1/10) where the down-limit switch stops the drive in order that the position indicated will be 000.0 when the actuator actually begins to pickup the weight of the poison column.

* Based upon a test of significance at the 95% confidence level.

- e) Criterion: The up-limit switch is positioned at 156 ± 0.2 inches above the point at which the actuator starts to pick up the weight of the poison column.
- Remarks: The up-limit switches were positioned to stop the drive at 156.0 ± 0.2 .
- f) Criterion: The analog position transmitters are zeroed (then backed off two turns) at the point where the down-limit switch stops rod travel.
- Remarks: The analog position indicator on the test cart was zeroed and the correct span adjusted during the Site Assembly Tests. However, analog position indicator readings compare satisfactorily with digital position indicator readings thus verifying proper operation of the potentiometer which initiates the signal from the actuator assembly. Main board analog position indicators were adjusted during the Control Rod Operability Test, AI-P-1148.
- g) Criterion: The rod has been scrambled from full and half height. The rod insertion time data has been compared with the data from the manufacturing proof test. No significant differences exist.* The time from interruption of magnet current until the rod has fallen nine feet does not exceed 803 milliseconds.

* Based upon a test of significance at the 95% confidence level.

Remarks: Scram time data taken in this test compares with data previously taken. No significant differences exist. Time for the first nine feet of fall from 156.0 inches does not exceed 803 milliseconds.

- h) Criterion: The control rod snubbers are observed to return to the up position when the rod is raised following a scram.

Remarks: Proper snubber action was verified on all control rods.

V. EVALUATION

The purpose of preoperational test AI-P-1145, Control Rod Drive and Actuator Assemblies, was to insure satisfactory performance of the control rod drive and actuator assemblies after installation at HNPF.

Proper operation of the motor brake and blower, the drive motor, the ball screw and nut, and the latch assembly was verified for each control rod. Position indicators, and the "Drive Out", "Rod In", "Snubber Up", and "Rod Mag Latched" lights were adjusted and gave correct annunciation on the test cart. Up and down limit switches stopped the drive in the desired position. All control rod components and circuitry not tested and discussed in this report were covered in preoperational test AI-P-1148, Control Rod Operability.

Control rod drive speeds have been verified to be within specified limits (withdrawal 12.4 ± 0.6 in. /minute, insertion 12.6 ± 0.6 in. /minute).

The replacements of single lip worm shaft seals with double lip seals in the control drives did not significantly change the drive speeds. Measured scram time from full up to nine feet and "fully in" positions, as well as time from magnet de-energization to actuation of the latch switch was within specified limits (Technical Specifications for Operation at Power for HNPF: magnet de-energized to nine feet free fall $\leq$ 803 msec, magnet de-energized to fully snubbed position 900 to 1015 msec, magnet de-energization to actuation of the latch switch 45 to 60 msec).

Results of the preoperational test show compliance with the test completion criteria of NAA-SR-5700, Supplement 2, except that some operating data were not within the 95% confidence level. It is felt that the 95% confidence level requirement is unnecessarily severe at the present time, since in some instances it could result in close to zero allowable variation of operating parameters. Rod drop times within the limits of the technical specifications outlined above appear to be adequate. Control rod operating data should be recorded semi-annually or annually and any recognizable trends analyzed and investigated for possible signs of malfunction. As additional statistics are gathered on each assembly, it may be possible and appropriate to compute 95% confidence limits as an aid in determining whether or not a trend is in fact in existence. However, caution should be used when applying statistical analysis as a tool in detecting control rod malfunctions. For example, the detailed mechanical reason for a single drop time in excess of specifications may be far more significant than the fact that the mean of a series of drop times is within the 95% confidence limits.

The conclusion of this evaluation is that, so far as can be verified prior to actual power operation of the reactor, the control rods will perform in accordance with design criteria, and are in good operating condition.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
CONTROL ROD ACTUATOR SUPPORT STRUCTURE
AI-P-1146

Test and Analysis
by
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Evaluation
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HALLAM NUCLEAR POWER FACILITY
PRE OPERATIONAL TEST COMPLETION REPORT
CONTROL ROD ACTUATOR SUPPORT STRUCTURE, AI-P-1146

I. PURPOSE OF TEST

The purpose of this test was to accomplish final alignment of the control rod actuator support structure and the individual actuator assemblies on the reactor loading face shield, and verify repeatability of alignment of the support structures and actuators. In addition, it was required that a time study be made (for future reference) of removal and reinstallation of the structure on the loading face shield.

II. DISCUSSION OF TEST PERFORMANCE

The test started with the control rod actuator support structure located in the reactor building auxiliary bay and all 19 actuator assemblies temporarily clamped in their proper locations.

The structure tow-bar was bolted to the west side of the structure, a towing cable was attached to the tow-bar, passed through a "come-along" on the east gantry track, and then fastened to the building crane 15-ton auxiliary hook. As the crane hook was raised, the control rod support structure was towed from the auxiliary bay to the reactor high bay on the embedded rails provided in the floor. The structure was raised with the building crane and set on the reactor loading face shield in its approximate proper position.

The support structure was properly oriented and leveled, and the structure base plates were welded to the bottom of the unit.

(Figure 1146-1)

Each actuator was lowered into a control rod thimble (previously installed in the correct core position) and aligned (within one-quarter in.) vertically over the full height of the actuator housing.

Hold-down-bolt holes were match-drilled through the actuator housing support plates and the support structure beams on which the actuator assemblies are supported. The hold-down bolts were installed, thus securing each actuator assembly in the support structure in the vertical position. (Figure 1146-2)

The actuator assemblies were individually raised with the crane to allow the jack springs (one on each of two opposite sides of the actuator) to be installed and bolted in place. The actuators were individually lowered back into the top of the thimble and necessary adjustments were made to the spring installation in order to eliminate any binding of the actuator assembly lower section and the thimble.

The jacks were assembled to the actuator lifting lugs, and the helium hose and electrical cables were connected to each actuator assembly.

Each actuator assembly was raised to its UP position, to verify that the helium hose and the control and power cables were of sufficient length, and that the jack would raise the actuator.

Figure 1146-1. Control Rod Structure Support

Figure 1146-2. Control Rod Actuator Support

The actuator assemblies were individually lowered with the jack until the lower end of each assembly was properly inserted in a control rod thimble. Necessary adjustments were made to the hose, cables, and jacks, to improve action.

The control rod test cart was connected to each actuator assembly. The control rods were individually engaged by the latch, raised about 10 in., lowered back to the ROD IN position, and disconnected to verify proper relationship between the actuator assembly and control rod thimble.

All actuator assemblies were raised by the jacks and pinned in the UP position. The control rod support structure was unbolted from the reactor loading face shield, picked up with the building crane, and set down on the embedded rails on the east side of the high bay. Using the towing cable, a "come-a-long", and the crane in the auxiliary bay, the control rod actuator support structure was towed into the auxiliary bay.

The control rod actuator support structure was towed back into the reactor high bay, picked up with the building crane, set down on the reactor loading face shield, and doweled into its exact proper position.

All actuator assemblies were lowered (with the jacks) into the control rod thimbles and bolted to the loading face shield. The control rod test cart was reconnected to each actuator and the control rods were again individually raised and lowered to verify repeatability of proper installation of the actuator assemblies.

The time consumed while removing the control rod support structure from the reactor loading face to the auxiliary bay and reinstalling it on the reactor loading face shield was recorded for future reference.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

A. MOVING THE SUPPORT STRUCTURE

Towing the support structure from the auxiliary bay to the reactor high bay was performed very satisfactorily. The structure rollers rolled straight and did not vary from the embedded rails. However, it was necessary to tow the structure west, until the west side rollers traveled approximately a foot beyond the end of the embedded rails, in order that the main building crane hook cables would not rub against a cable tray mounted on the east wall of the reactor high bay when the structure was picked up by the crane. Continued handling of the control rod structure resulted in damage to the concrete. Consequently, the embedded rails were extended to eliminate this difficulty. When the support structure was picked up by the crane, it tilted slightly eastward, due to the added weight of the helium and control connector box mounted on the east side. This condition presented no problems in positioning the structure on the loading face shield.

B. INSTALLING THE SUPPORT STRUCTURE

Prior to placing the support structure on the loading face shield, the structure base plates were bolted in place on the loading face, with the locating dowel pins inserted. The structure was oriented so that its

support plates were centered on the base plates. Next, the structure rollers were unpinned and the structure was lowered to rest on the base plates. The structure was then jacked to a level position and shimmed and the support plates were welded to the base plates. Leveling was determined with a transit, using the east and west ends of the extreme north and south structure support beams. (Figure 1146-3)

C. INSTALLING THE ACTUATOR ASSEMBLIES

Each of the 19 actuator and drive assemblies was installed in its proper control rod thimble and vertically aligned. The individual rod housing supporting structures were drilled and permanently installed in the control rod structure.

The actuator and drive assembly was supported by the main building crane 15-ton auxiliary hoist; the actuator housing and temporary hold-down clamps were released; and the actuator assembly was guided and lowered into the control rod thimble until the actuator assembly seated. The actuator assembly was vertically aligned by plumbing to within one-quarter in. over the full height of the actuator assembly (approximately 15 ft-5 in.).

The housing was centered around the actuator, the support plates match-drilled with the support beams and the housing assembly bolted in place. Plunger clamps and centering bolts on the housing were adjusted so that the actuator assembly would be forced into its proper vertical position any time that the plunger clamps were in the closed position.

Figure 1146-3, Structure Leveling Diagram

D. INSTALLATION OF JACK SPRINGS AND JACKS

Jack springs were installed on each actuator assembly, and all jacks were assembled to their respective actuator assemblies. The actuators were raised and lowered to test the ease of jacking and satisfactory re-alignment of the actuator in the control rod thimble. In some cases, the jack springs had a tendency to "walk-off" the base, thus causing binding in the jack. The springs were centered at the base and fixed so that they would not "walk" out of position and set up binding. Adjustment on the jacks did not, in some cases, reduce the force on the jack handle (required to actuate the jack) to within 10 lb as required by the installation specification 7518-S70000. The jacks worked well in the first few inches of travel from the full down position. However, the force required to actuate the jack handle increased considerably as the actuators were raised. Jacks were lubricated and gears and jack nuts were re-adjusted to reduce, as much as possible, the forces required to turn the jack handles. Due to irregularities in the control rod actuator casing surfaces, the plunger clamps had to be relaxed when raising or lowering the actuator assemblies by jacks, to prevent binding between the plunger clamps and the irregular surfaces. The actuator centering bolt, located in the housing at the lower end of the jack, also had to be backed out of position to prevent damage to the induction coil* when the actuator assembly was jacked to the

* The induction coil which is wound around the actuator casing four feet from the bottom is used for measuring control rod acceleration during rod drop tests.

full up position.

With the centering bolt out of position below the jack and with the actuator assembly supported by the jack on the same side, the actuator assembly lower end would swing in the direction of the jack. Consequently, the actuator assembly had to be guided into the control rod thimble by hand when the actuator was jacked down. Since readjusting the centering bolt takes much more time than guiding the assembly in by hand, the centering bolts were left in the housing, but were backed out of position. When actuators were guided in by hand, they could be driven down and seated firmly on the step provided in the thimble and plug assembly. Hold-down bolts were installed easily, but were found to be unnecessarily long and were exchanged for shorter bolts which would not require such long installation time.

E. PROPER ACTUATOR-DRIVE-CONTROL ROD RELATIONSHIP

Proper relationship between each drive and actuator assembly and the corresponding control rod assembly, after actuator installation, was tested. The control rod test cart was connected to the drive assembly and the actuator driven down until the limit switch stopped the drive. Scram magnet voltage was set at 28V and the actuator driven up until it was verified that the latch had properly engaged the control rod and that the snubbers raised properly. The rod was driven down until the limit switch stopped the drive; the scram magnet voltage was reduced to zero and the latch driven up far enough to verify that the rod had been properly disengaged.

F. REPEATABILITY OF PROPER INSTALLATION

The actuator assemblies were unbolted from the reactor loading face shield, jacked up, and pinned in the UP position. The control rod support structure was unbolted from the loading face shield, the control box plug-ins disconnected, and the structure picked up with the high bay crane and positioned over the embedded rails running from the high bay to the auxiliary bay. The structure rollers were lowered onto the rails. The tow-bar was assembled to the east side of the structure, the "come-a-long" arrangement installed between the tow-bar and the auxiliary bay crane, and the structure was towed out of the reactor high bay into the auxiliary bay. Moving the structure from the reactor loading face to the auxiliary bay was performed very satisfactorily with no hold ups.

The structure was towed back into the reactor high bay in the same manner as described in III A. preceeding, and positioned over the reactor loading face. The structure rollers were unpinned, the structure lowered and positioned (with the dowels) with relative ease, and lowered the rest of the way to rest properly in place on the reactor loading face shield. The actuator assemblies were jacked down and bolted in place. The control rod support structure was then bolted in place.

Each control rod drive and actuator assembly was again tested for proper relationship with its corresponding control rod assembly, in the same manner as described in III. E. preceeding. All assemblies performed satisfactorily.

G. REMOVAL AND INSTALLATION TIME STUDY

The time required for performing that part of the test described previously in III F. was measured for future reference. Total time was nine hours. However, six hours of this time was for testing all actuator and control rod relationships, one at a time. Under normal conditions, this test will be performed from the main control board (rather than the test cart), which will only take about 10 minutes.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with pre-operational test AI-P-1146, Control Rod Actuator Support Structure, as listed in NAA-SR-5700, Supplement 2, Page XI (a)-25 with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: The support structure, with 19 drive and actuator assemblies, was installed on the loading face shield. The actuators were aligned within 1/32 inch in 3 feet. Each control rod was operated up and down a few feet to verify (visually) latch engagement.

Remarks: The above criterion has been met, as described in III A. through E. of this report.

- b) Criterion: The support structure was removed to the service area in the low bay, then returned to the loading face. The structure re-aligned with the bolting pads. Each actuator

was lowered into place without binding or interference between the actuator guide and thimble. The alignment and latch engagement checks (see preceding paragraph) were repeated.

Remarks: The above criterion has been met as described in Section III F. of this report, with one qualification. That is, when lowering the actuator guide into the control rod thimble, manual guidance must be used to prevent binding and to align the hold-down bolt holes in the actuator flange with those in the loading face, as described in Section III D. of this report.

- c) Criterion: The time required to perform the above operations was recorded for future reference.

Remarks: The above criterion has been met, as described in Section G. of this report.

V. EVALUATION

The preoperational test of the control rod actuator support structure was performed in order to accomplish final alignment of the structure and individual actuator assemblies on the reactor loading face shield, and to confirm repeatability of the alignment operation.

During the test the support structure was positioned and aligned on the loading face shield, removed to the auxiliary bay and repositioned on the loading face. Each actuator assembly was custom fitted over its correct core position to within one-quarter inch along the full height of

the actuator housing. The control rods were individually latched, partially raised, and lowered back to the ROD IN position to ascertain correct component alignment.

In some instances the force required to turn the jack handle which raises and lowers the actuator was excessive because of binding between jack nuts, gears and actuator.

No serious difficulties have been experienced in moving the structure on and off the loading face shield. Recent examination, however, revealed some damage to the concrete on the north side of each embedded rail.

It is recommended that operating personnel be fully acquainted with the need for proper positioning of the support structure on the embedded rails when moving it on or off the reactor, to prevent further damage to the concrete floor. Since the actuator jacks are expected to be used a relatively few times after the plant is operational, the inconvenience experienced due to binding of the screw and nut does not justify additional corrective measures.

The test completion report shows compliance with the test completion criteria. The control rod actuator structure will perform in accordance with design requirements; the design requirements are adequate for plant operation. Six additional control rods (presently 19) could be supported by the structure without major modifications, if required.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
CONTROL ROD OPERABILITY

AI-P-1148

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
CONTROL ROD OPERABILITY, AI-P-1148

I. PURPOSE OF TEST

The purpose of this test was to verify that all components of the control rods and the control rod circuitry perform satisfactorily and give reliable indication of control rod status.

II. DISCUSSION OF TEST PERFORMANCE

Prior to operation of any rod from the main board, each control circuit was connected to the control rod simulator and it was verified that all indicator lights on the main board operated properly and that the magnet current to each control rod was correct.

The control rod thimbles and actuator housings were pressurized with helium to verify that this part of the helium system operates properly.

The main board digital position indicators for each drive were set to read 999.9 when the drive-in limit switch stops the drive. This setting provides for a reading of 000.0 when the rod latch engages the control rod as the drive is actuated to raise the control rod from a full "in" position.

The main board analog position indicators for each rod were set at zero when the rod drive was in full "in" position.

All rods were driven out until the drive-out limit switches stopped the drives and it was verified that all digital position indicators read 156.0 ± 0.5 . The analog position indicator span was adjusted as required on each rod so that the indicator would read 156.0 when the rod drive was fully out.

Each control rod was operated manually from the main board to verify proper operability of the rod and correct indication of main board indicator lights and snubber up lights on the control rod support structure.

Each gang of control rods was operated from the gang switch with each control rod switch in the bank position. Each gang of rods was scrambled to verify that all the rod drives will drive "in" (after the scram) regardless of the position of the gang switch or the rod switch.

Each control rod was timed as it was driven from the full "in" to the full "out" position and vice versa to verify that all rod drive speeds were within specifications.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

A. CONTROL ROD SIMULATOR

The control rod simulator test revealed a few errors in rod circuitry such as improper installation of analog position indicators, low voltage to some scram magnets and one wiring error. Although the rod simulator test was not included as an official part of this test procedure, it was useful for checking the circuitry and thus expedited the test. When the required trouble shooting (revealed by the simulator test) was completed, the rod operability test was performed according to the procedure without incident.

B. PRESSURIZING THE CONTROL ROD ASSEMBLY

Helium was supplied to each control rod thimble and actuator housing from the control rod structure manifold which in turn was supplied through a flex line which ties into the helium system valve located in the control rod control pit. It was determined that the three-way helium valve and pressure indicator mounted at the lower end of each actuator housing function properly when the actuators

and thimbles are pressurized to 15 psig with Helium. This part of the test verified that the control rod thimble can be successfully purged with helium when required.

C. MAIN BOARD CONTROL ROD POSITION INDICATOR ORIENTATION

The digital position indicators on the main board were set at 999.9, where the drive "in" limit switches stop the rod drives, so that the indicators read 000.0 when the rod latches engage the rods as the drives are driven "out" from the full "in" position. It should be noted that each drive-in limit switch is positioned so that the latch is driven down 0.100 in. below actual engagement position in order that sufficient clearance is assured for full closing of the latch. It should be further noted that anytime a rod drive is operated from the test cart the digital position indicator will have to be reset as above. All position indicators were set as specified with exception of a few which read within 20 to 30 mils of the specified reading.

The analog position indicators were set. The readings compared satisfactorily with those of the corresponding digital position indicators.

D. MANUAL CONTROL ROD CIRCUITRY OPERABILITY VERIFICATION

As each rod was driven up, it was observed that the proper "snubber up" light on the control rod structure energized and that the snubber actually raised to the full up position. The "snubber down" annunciator window on the main board remained energized so long as one or more snubbers were down and deenergized when all snubbers were up.

The "rod mag latched" light on each rod energized so long as the rod was engaged by the latch and deenergized when the rod and latch separated. Further, the "rod mag latch" annunciator on the main board energized anytime one or more rods and latches were separated.

The "drive out" and "drive in" limit lights energized when the rod drives reached the upper and lower limit of travel, respectively.

All "rod in" limit lights energized when the rods were fully inserted.

All "drive up" and "drive down" indicator lights energized when the rod drives were actuated up and down, respectively.

E. MANUAL GANG CONTROL TEST

With the individual switches for a preselected gang of control rods set on "Bank", the rods in the gang drove up and down when the gang switch was actuated up and down. When a manual scram was actuated, all rod drives moved down regardless of any other attempted operation with the individual switches.

During rod gang operations, the relative positions of the individual rods in each gang were recorded. Considering that there is some variation in individual rod motor speeds, the relative positions of the rods driven from the gang switch will vary. Table I shows the maximum rate of change

TABLE I

MAXIMUM RATE OF CHANGE IN ROD POSITION DIFFERENCE

Gang No.	(1)	(2)	Control Rod Nos.
1	0.0448 in/in	7 inches	14, 15, 16, 17, 18, 19
2	0.0391 in/in	6.1 "	5, 7, 8, 10, 11, 13
3	0.0154 in/in	2.4 "	2, 3, 4
4	0.0247 in/in	3.85 "	6, 9, 12
(1) Max rate of change in rod position difference			
(2) Max rod position difference over 156.0 travel			

in rod position difference for each gang, and the maximum rod position difference in each gang after 156.0 in. of travel of the fastest rod in each gang.

F. ROD SPEED TEST

Each rod was withdrawn all the way and inserted all the way and the time required for each operation was measured. Each operation was repeated at least once to determine an average. The Dry, Zero Power Experiments Technical Specifications specify that the rod withdrawal speed for each rod must be 12.4 in./min $\pm$ 5% (max 13.02; min. 11.78) and the insertion speed 12.6 in./min $\pm$ 5% (max 13.23; min. 11.98). Table II shows the average rod withdrawal and insertion times and speeds recorded during this test.

TABLE II

ROD SPEED

Rod No.	Withdraw		Insert	
	Avg. Time (min)	Avg. Speed (in/min)	Avg. Time (min)	Avg. Speed (in/min)
1	12.434	12.52	12.200	12.80
2	12.618	12.35	12.267	12.71
3	12.450	12.52	12.250	12.72
4	12.618	12.35	12.217	12.75
5	12.783	12.20	12.467	12.50
6	12.400	12.58	12.217	12.75
7	12.292	12.70	12.167	12.82
8	12.184	12.80	11.985	13.02
9	12.535	12.44	12.342	12.62
10	12.710	12.28	12.500	12.47
11	12.417	12.57	12.167	12.82
12	13.362	12.62	12.167	12.82
13	12.735	12.24	12.300	12.68
14	12.117	12.88	11.892	13.10
15	12.735	12.24	12.517	12.45
16	12.400	12.58	12.133	12.85
17	12.684	12.30	12.467	12.51
18	12.800	12.19	12.492	12.48
19	12.384	12.60	12.116	12.81

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

The following is a list of the Test Completion Criteria taken from NAA-SR-5700 pages XI (a)-26 and XI (a)-27 of Supplement 2 with remarks about the test to show compliance with the criteria.

- 1) Criterion: The control rod thimbles and actuators have been purged with helium.
Remarks: It was verified that the system and all necessary components for purging the actuators and thimbles function properly and that 15 psig helium pressure can be maintained in each thimble and actuator housing. The actual purging of the system will be done prior to wet critical fuel loading.
- 2) Criterion: The leakage rate of helium from the actuator assemblies does not exceed 1 CFH per actuator.
Remarks: A leakage test was made on each actuator assembly after final assembly at the HNPF. In no case did the leakage rate exceed 0.2 CFH.
- 3) Criterion: Each control rod position indicator on the main board has been zeroed at the point where the down-limit switch stops rod travel.
Remarks: The control rod digital position indicators were zeroed where the rod drive latch first engages the rod. Each indicator reading was set at 999.9 where the down-limit switch stops the drive; i.e., .10 in. below zero position.

- 4) Criterion: For each rod, the span of the analog position indicator has been adjusted to agree with the digital indicator at the point where the up-limit switch stops rod travel. The reading of the digital indicator has been taken and compared with the same information from the manufacturing proof test; no significant difference exists.

Remarks: The analog position indicators were set and the span adjusted to read zero when the down-limit switch stopped the drive and to read 156.0 in. when the up-limit switch stopped the drive. Although the analog indicators do not always compare exactly with the digital indicators in the mid range of travel, the difference is not significant. The digital position indicators compared with the manufacturing proof test data.

- 5) Each rod has been operated from the control board, and the following actions verified:

- a) Criterion: Manual operation, up and down. Actual motion of the rod agrees with the input command.

Remarks: Proper operation was verified.

- b) Criterion: The control switch returns to neutral by spring action from the "up" position.

Remarks: Action was verified.

- c) Criterion: Indicating lights and position indicators operate and agree with the corresponding rod positions or action.

Remarks: Proper operation of indicating instrumentation was verified.

- d) Criterion: Rod control can be switched to "Bank" and each rod can then be operated with the gang control switch.

Remarks: Each rod switch was positioned to "Bank" and operated from the gang switch.

- e) Criterion: When the scram button is pressed, the rod falls in, and the drive is automatically energized in the down direction. The drive continues down with the individual and gang control switches in any position until the scram reset button is pressed.

Remarks: This operation was verified.

- f) Criterion: Rod speed is measured, and does not exceed 12.6 in. per minute.

Remarks: Four drives exceed slightly the test completion criterion in the withdrawal direction. Fourteen have insertion speeds slightly faster than the 12.6 in. per minute criterion. The technical specifications section D, 1C specifies that rod speed shall be: driving up - 12.4 in./min $\pm$ 5%, driving down - 12.6 in./min $\pm$ 5%. It was verified that all rod speeds are within technical specification limits.

- g) Criterion: Snubbers are observed to return to the up position when the rod is raised following a scram. The

"snubber down" annunciator operates following a real (or simulated) failure of a snubber to return.

Remarks: The snubber always returned to the full up position when a rod was raised above the snubber. The "snubber down" annunciator window light (on the main board) is energized at any time there is at least one control rod fully inserted.

V. EVALUATION

The review of the test results and analysis indicates that all components of the control rods and the control rod circuitry performed satisfactorily and gave reliable indication of control rod status.

The results of the control rod speed tests (see Section III f) indicate that all rod speeds are within the rod speed limitations specified in "Technical Specifications for Dry, Zero Power Experiments for Hallam Nuclear Power Facility", but several of the rod speeds exceed the test completion criterion of a maximum of 12.6 in. per minute. Utilizing the limited information on control rod worths obtained during AI-P-1163, Dry Excess Loading Test, an evaluation of control rod speeds indicates the maximum reactivity insertion rate may exceed 0.03% ($\Delta k/k$)/second. Further tests following the wet critical loading will be necessary to determine maximum reactivity insertion rates.

This test was conducted on November 11, 1961. Subsequent to this date control rod drive maintenance has required substitution of spare control rod drives for several of the drives tested. Control rod speed should be determined following any control rod drive maintenance. In addition, control rod speeds for all rods should be

measured periodically throughout the life of the plant. Data from these tests should be utilized in an evaluation to assure continued conformance with technical specifications.

Experience since the completion of this test has indicated that the analog position indicators can be adjusted to operate properly but they require considerable maintenance and readjustment. As a result, the indicators are frequently out of adjustment and are used by the operators as only a rough indication of control rod position. Increased reliance is therefore placed on the digital position indicators. The digital position indicators have been operating satisfactorily.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
NEUTRON CHAMBER CART, DRIVES, AND CABLES

AI-P-1149

Test and Analysis
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Evaluation
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A T O M I C S I N T E R N A T I O N A L
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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
NEUTRON CHAMBER CART, DRIVES, AND CABLES, AI-P-1149

I. PURPOSE OF TEST

The purpose of this test was to verify the integrity and high quality of the nuclear instrumentation coaxial cables, and to determine operability of the neutron chamber carts after installation of all neutron chambers in the respective carts. Also included in the test purpose were calibration of the BF_3 chamber position indicators, testing of chamber thermocouple circuits, and setting of the BF_3 chamber temperature alarm points.

II. DISCUSSION OF TEST PERFORMANCE

This test was performed in conjunction with the Nuclear Instrumentation Test, AI-P-1119. All chamber carts were removed from the associated thimbles; the coaxial cables and connectors were inspected for good workmanship, and the connectors were cleaned. The resistance between the center and the outer conductor and between the outer conductor and ground of each cable was measured with a megohmmeter, to verify that the insulation was without defects.

The neutron chambers were installed in the carts and all cables were connected. Chamber temperatures were verified as readout on the temperature indicators, TI-18, TI-19 and TI-20, located on the back of the main board. Heat was applied to each chamber thermocouple and a rise in temperature was observed for each corresponding readout point. The BF_3 high temperature alarm points were manually set at 150 F within the indicators, and alarm annunciation was verified.

The carts were installed at the bottom of the thimbles. For source range channels I and II, the remotely operated positioning mechanisms were verified to be operable as designed. By measuring the drive cable diameter

and the drive gear circumference and observing the drive gear rotation with respect to the position indicator, the indicated chamber position accuracy was determined. This accuracy was found to be within 1/10 inch for each 10 inches travel of the chamber.

III. ANALYSIS AND PRESENTATION OF RESULTS

Resistance between the center and the outer conductor of each coaxial cable was measured and found to compare favorably with the calculated and recommended values. The results of this measurement are presented in Table I along with the calculated values. The calculated value is based on a realistic figure calculated for the cable supplies.

TABLE I
RESISTANCE BETWEEN CONDUCTORS

Channel	Resistance in ohms		
	Calculated	Actual	Recommended **
Source Range I	1×10^9	2×10^{11}	1×10^9
Source Range II	1×10^9	2×10^{11}	1×10^9
Intermediate III	1×10^9	1×10^{13} *	2×10^{13}
Intermediate IV	1×10^9	1×10^{13} *	2×10^{13}
Power Range V	1×10^9	2×10^{11}	1×10^{11}
Power Range VI	1×10^9	5×10^{11}	1×10^{11}
Power Range VII	1×10^9	1×10^{11}	1×10^{11}
Power Range VIII	1×10^9	2×10^{10}	1×10^{11}
Power Range IX	1×10^9	2×10^{11}	1×10^{11}

* 1×10^{13} is the highest reading on available instruments; instrument went off scale when taking reading.

** Recommended by C. L. Dunsmore, Specialist, AI.

The dc resistance between conductors of a coaxial cable is given by the formula, $R = \rho / \pi L$

where:

ρ = resistivity of the dielectric

L = length of cable

Thus, for 150 ft of cable, a polyethelyne dielectric with a resistivity of 5.25×10^{11} ohm/ft has a resistance of 1×10^9 ohms. A possible explanation for the consistently low calculated values is that the values of resistivity used were low. Measured values of resistivity are found to vary with sample size. In general, resistivity decreases with increasing sample thickness. Thickness of the dielectrics used in the cable are less than that of the standard sample.

Resistance between the outer conductor and ground of each cable was measured; resultant values compare favorably with calculated values as shown in Table II. Experience gained subsequent to the measurement indicates satisfactory performance for all channels concerned.

TABLE II
SHIELD TO GROUND RESISTANCE

Channel	Resistance in ohms	
	Calculated	Actual
Source Range I	5×10^7	5×10^8
Source Range II	5×10^7	1×10^8
Intermediate III	5×10^7	1×10^8
Intermediate IV	5×10^7	1×10^8
Power Range V	5×10^7	2×10^8
Power Range VI	5×10^7	2×10^8
Power Range VII	5×10^7	9×10^7
Power Range VIII	5×10^7	2×10^8
Power Range IX	5×10^7	2×10^8

The resistance was determined using the following relationship and assuming the outer insulation is in contact with conduit around the entire circumference of the cable. The coaxial cable used has an outside insulation of vinyl $\sim 3/64$ inches thick with a resistivity of 0.5×10^{10} ohm/cm. Length of cable is 150 ft. The calculation was made as follows:

$$R = \rho L/A$$

Where:

R = Resistance

ρ = Resistivity

L = Thickness of the resistive medium

A = Cross sectional area perpendicular to current

Choosing a 6 inch length of cable as an example:

$$R = 5 \times 10^{10} \times \frac{3/64}{3.14 (3.46)^2} \times \frac{1}{2.54}$$

$$R = 1.4 \times 10^8 \text{ ohms}$$

Applying this to a 150 ft length of cable and assuming resistances are in parallel, the 6 inch resistance multiplied by 300 is used.

$$\text{Then: } R = \frac{R_{6''}}{300}$$

$$R = 4.7 \times 10^5$$

If one now assumes that in fact only 1/100 of the outer surface is in contact with the insulation; the value for R becomes 4.7×10^7 .

The neutron chambers were installed in the various thimbles, as shown in Table III following.

Difficulty was encountered in the initial attempts at operating the BF_3 chamber positioning mechanisms. The BF_3 cable assemblies became kinked and hung up as they moved over the pulley, because of insufficient clearance between the wires and the coaxial cable of the cable assembly. As a result, new cable assemblies were made and the problem was eliminated.

TABLE III
NEUTRON CHAMBER LOCATION

Thimble and Channel	Chamber Type	Serial Number
I	WL 6938	601702
II	WL 6938	601701
III	WL 6377	601718
IV	WL 6377	01307
V	5467870G13	4131119
VI	5467870G13	4131111
VII	5467870G13	4131117
VIII	5467870G13	4131120
IX	5467870G13	4131113

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with preoperational test AI-P-1149, Neutron Chamber Cart, Drives, and Cables, as listed in NAA-SR-5700 Supplement 2, Page XI (a)-29, with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: Integrity of the nuclear instrumentation coaxial cables is demonstrated by measuring at least 10^{15} ohms (10^{13} ohms for BF_3 cables) between the center conductor and outer conductor and at least 10^{11} ohms between the outer conductor and ground. Noise between inner and outer conductors is not measurable with oscilloscope sensitivity of 0.005 V/cm.

Remarks: It was found that the cable supplied could not be expected to meet the values specified. The resistance between the center conductor and the outer conductor of all coaxial cables was measured and found to be at least 10^{10} ohms. These measured values were found to agree favorably with calculated

and recommended values. In addition, operation of the channels subsequent to this test yielded satisfactory performance. Measurement of the unamplified cable noise was found to be less than one millivolt when the cables were properly terminated.

- b) Criterion: Nuclear chambers have been installed.
Remarks: All nuclear chambers were installed.
- c) Criterion: BF_3 chamber carts are operable.
Remarks: BF_3 chamber carts are operable as designed.
- d) Criterion: BF_3 chamber position indicators have been calibrated to 1 in. with readings at 1 ft. increments.
Remarks: The chamber position indicators were found to be within 1/10 inch for positions read every 10 inches throughout full travel of the chambers.
- e) Criterion: Chamber temperature measuring circuits are operable, and the high BF_3 temperature alarm points have been set at 150 F.
Remarks: Proper operation of chamber temperature instrumentation was verified and the BF_3 chamber temperature setpoints were set at 150 F.

V. EVALUATION

Preoperational test AI-P-1149 was performed to ascertain proper operation and satisfactory performance of the neutron chamber cart, drives, cables and associated equipment. The carts and drives provide in-thimble movement of the nuclear instrumentation channels. The source range channels (I and II) have remotely operated positioning systems.

During preoperational testing, it was discovered that the source range channel cables were binding in the tip positioning pulleys, which prevented detector positioning. Installation of new cables eliminated this difficulty.

Instrument thimble atmosphere samples showed that the humidity in each thimble was below the 50 percent maximum allowable value.

The master test procedure showed completion of all required steps. Objectives of the test, such as assurance of operability of the neutron chamber carts, calibration of chamber position indicators, integrity of thermocouple

circuits and source range detector temperature alarm points were satisfied. All test completion criteria in NAA-SR-5700, except criterion a) "Resistance requirements for the coaxial cables" were fulfilled.

With regard to resistance requirements for the coaxial cables, it is important to match the cable resistance between conductors, and to ground with the detector impedance, to minimize signal leakage and readout noise. Criteria for establishing the values recommended in Table I were:

- 1) 6 db loss of ground and 1 mv leakage between conductors for the BF_3 channels.
- 2) 50 percent error on the 10^{-10} scale of the intermediate channels.
- 3) Less than 1 percent leakage above 1 percent power for the power range channels.

A factor of 5 is also included for insulation resistance decay from 80 F to 150 F; about 50 ft of the total 200 ft. length of cable per channel may be exposed to temperatures above 100 F.

The resistance to ground is lower than recommended on the intermediate and power range channels. This resistance, however, mainly indicates whether the detector is grounded in the thimble; each channel is a single-point ground system with the ground at the control room end. The resistance from shield-to-ground is therefore not a measure of cable characteristics.

Since it has been demonstrated that the performance of the nuclear instruments is adequate, the question of proper inter-conductor and shield-to-ground resistances is somewhat academic. However, determination of these resistances, as they now exist, has been a useful exercise. Resistances should be measured periodically in the future and compared with the preoperational values.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
PURGE OF THE SECONDARY SODIUM SYSTEM

AI-P-1150

Test and Analysis

by

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Evaluation

by

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
PURGE OF THE SECONDARY SODIUM SYSTEM, AI-P-1150

I. PURPOSE OF TEST

The purpose of test procedure AI-P-1150, "Purge of the Secondary Sodium System," was to verify that a helium atmosphere which contains less than 0.5% oxygen can be established in the secondary sodium loops.

II. DISCUSSION OF TEST PERFORMANCE

Each of the three secondary sodium loops was purged separately with helium gas. In each loop, the helium was admitted through the normal helium supply manifold into the secondary sodium expansion tank and exhausted through the helium connection on the throttle valve. Throughout the purge, the throttle valve remained open, thereby allowing the helium to flow through the steam generator and also through the intermediate heat exchanger in two parallel paths.

Since the CPPD vacuum system was not available at the time, the helium was exhausted to atmosphere at the throttle valves. No adverse effects were observed as a result of this deviation from the preoperational test procedure.

Although the test purpose did not require a minimum moisture content, it was desired that the amount of moisture in the loops be reduced to a low value. The moisture test which was used is capable of detecting a minimum of 10% relative humidity.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

A. PURGE OF SECONDARY SODIUM LOOP NO. 3

Helium flow was established first in loop No. 3. The pressure in the loop, as indicated by PI-306, increased steadily to approximately 20 psig in one and one-half hours (Figure 1150-1a). The helium flow rate was maintained at 35 scfm (all helium flowmeters are calibrated at 60 F and 20 psig) for the first hour and one-half. Later, as shown in Figure 1150-1b, the helium flow rate decreased to approximately 13 scfm. The oxygen and moisture content of the effluent gases decreased rapidly at first and then more slowly (Figure 1150-1c). Purging of loop No. 3 was discontinued when the oxygen content reached $<0.5\%$. At that time the humidity of the purge gas was less than 10% R.H.

The evidence of a non-uniform purge rate, as outlined above, is most likely explained by the position of the secondary sodium throttle valve. During the purge of secondary sodium loop No. 2 (Section B, below) it was found that the sodium throttle valve stem would block the flow of helium if the valve were in the full open position. During the purge of loop No. 3, the secondary sodium throttle valve was probably too close to the full open position, thereby restricting the helium flow and extending the time required to reduce the oxygen to an acceptable level.

B. PURGE OF SECONDARY SODIUM LOOP NO. 2

Helium flow was established next in loop No. 2. The pressure in the loop as indicated by PI-206, increased gradually to approximately 12 psig in one and one-half hours (Figure 1150-2a). The helium flow rate remained

constant at 35 scfm (Figure 1150-2b) and the oxygen content of the effluent gases had decreased to 0.5% (Figure 1150-2c). Since the apparent time required to purge loop No. 2 was considerably less than that required to purge loop No. 3, all valve positions were checked and the sodium throttle valve was found to be closed. With this valve closed, that portion of the loop from the expansion tank through the steam generator and up to the throttle valve would not be purged. The sodium throttle valve was then opened and the purge was continued. At this time, it was discovered that helium flow could not be maintained even though the pressure in the loop was at 20 psig, and all valves were in the proper position. The sodium throttle valve was then backed away from the full open position and helium flow was established once again. The loop pressure and the helium flow rate remained nearly constant at 18 psig and 35 scfm respectively for the next 30 min. The oxygen and moisture content of the effluent gases rose sharply and then decreased rapidly to acceptable values. The purge of loop No. 2 was discontinued when the oxygen content reached $< 0.5\%$. At that time, the humidity of the purge gas was less than 10% R.H.

C. PURGE OF SECONDARY SODIUM LOOP NO. 1

Helium flow was established in loop No. 1. The pressure in the loop, as indicated by PI-106, rose steadily to approximately 12 psig at the end of the first hour and one-half and then rose more slowly to 15 psig (Figure 1150-3a). The helium flow rate remained near 35 scfm throughout the purge of loop No. 1 (Figure 1150-3b). Both the oxygen and moisture content of the effluent gases decreased slowly at first and then more rapidly (Figure 1150-3c). The purge of loop No. 1 was discontinued when

Fig. 1150-1 Purge of Secondary Loop No. 3

Fig. 1150-2 Purge of Secondary Loop No.2

Fig. 1150-3 Purge of Secondary Loop No. 1

the oxygen content reached $<0.5\%$. At that time, the humidity of the purge gas was less than 10% R.H.

D. SUMMARY

All three of the secondary sodium loops were successfully purged with helium until the oxygen content of the effluent gases was less than 0.5% and the moisture content was extremely low. Under optimum conditions, the minimum purging time required for one loop was less than two hours. The maximum purging time required for one loop was three hours. The amount of helium used in these purging operations was not measured accurately; however, the total volume of helium used appears to be between 11,000 and 14,000 scf. All instruments and controls performed satisfactorily throughout the purging test.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the Test Completion Criteria, as taken from pages XI (a)-59 and XI (a)-60 of NAA-SR-5700, Supplement 4. The remarks are to verify compliance with these criteria.

Criteria:

Section 1 - A helium atmosphere of less than 3 percent oxygen content is established in the Sodium Heat Transfer System secondary loops.

Section 2 - A helium atmosphere of less than one half percent oxygen content is established in the Sodium Heat Transfer System secondary loops.

Remarks: Each of the secondary sodium heat transfer loops was purged once. It was verified that an atmosphere

containing less than 0.5% oxygen was established and maintained in each of the sodium heat transfer system secondary loops. Immediately prior to the first introduction of sodium into each of the secondary loops, the oxygen content of the loop atmosphere was measured and found to be less than 0.5%.

V. EVALUATION

Purging of the secondary sodium system with helium, according to procedures outlined in AI-P-1150, established the required atmosphere (about 1/2% oxygen) for sodium filling of the system.

The drop in flow through loop No. 3 after about 2 hours of purging is thought to have been caused by disconnecting the conventional plant vacuum system from the exhaust line. This incident had no adverse effect upon successful completion of the purging operation.

AI-P-1150 procedures guarantee purging of all parts of the system. Successful purging, as indicated in the test completion report, constitutes proof of the adequacy of the procedures and equipment.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
PURGE OF THE PRIMARY SODIUM SYSTEM
AND REACTOR VESSEL WITH HELIUM

AI-P-1151

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A T O M I C S I N T E R N A T I O N A L
A DIVISION OF NORTH AMERICAN AVIATION, INC.
P. O. Box 309 Canoga Park, California

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
PURGE OF THE PRIMARY SODIUM SYSTEM AND
REACTOR VESSEL WITH HELIUM, AI-P-1151

I. PURPOSE OF TEST

The purpose of Section 1 of Preoperational Test AI-P-1151, "Purge of the Primary Sodium System and Reactor Vessel with Helium", was to establish a helium atmosphere of less than 3% oxygen content (approximate) in the primary sodium loops and the reactor vessel prior to preheat of the loops and vessel, following completion of the ambient portion of AI-P-1163, "Dry Excess Loading".

Section 2 was to establish a helium atmosphere with less than 1/2% oxygen content (approximate) in the primary sodium loops and the reactor vessel with the loops and vessel at preheat temperature.

II. DISCUSSION OF TEST PERFORMANCE

A purge pipe was temporarily installed in the reactor to facilitate the performance of the purge operation. The pipe was four inches in diameter and approximately 40 ft in length. A flange, which rested on the loading face shield and affected a partial seal with the top of the shield, was connected near the top. Helium entering the reactor vessel displaced the air atmosphere therein downward, and back up and out through the purge pipe.

The sensing line of an oxygen analyzer was inserted approximately six ft into the top of the purge pipe to obtain a representative sample at various times during the purge.

Helium was admitted to the sodium heat transfer system at the three intermediate heat exchanger freeze trap (piping high point) helium supply stations. The purge was conducted for 50 min with the block valves open and the throttle valves closed. The throttle valves were then opened, the block valves closed, and the purge continued for an additional 60 min. The block valves were then re-opened, the throttle valves closed, and the purge of the reactor maintained for 230 min. At the end of this time, the gas being discharged through the purge pipe was determined to have less than three percent oxygen content and the test was considered to be complete.

Following the completion of Section 1 of the test procedure, the purge was continued as an operational function. Oxygen content was reduced to less than 1/2% in the atmosphere of the primary sodium heat transfer system. The reactor atmosphere control system was then placed in service and the helium atmosphere maintained. Immediately prior to fill of the primary system with sodium, the atmosphere was sampled and oxygen content again verified to be less than 1/2%. Performance of Section 2 of AI-P-1151 was thus not required.

III. PRESENTATION AND ANALYSIS OF TEST RESULTS

A one-volume purge of the reactor vessel had been completed prior to the performance of this test, to satisfy requirements associated with dry critical testing.

The one-volume purge was performed with the loop block and throttle valves closed, employing the helium supply station and the radioactive vent station which service the reactor vessel during normal operation.

Approximately 5 hrs and 30 min were required to complete the purge per AI-P-1151, Section 1, in addition to one hour needed to manually manipulate the throttle valves. 96 bottles of helium were discharged into the system during the purge. These values compare favorably with the anticipated 5 hrs and 40 min time requirement and 100 bottles of helium expected to be used. The helium bottles were exchanged (full for empty) on a continual basis once the purge had started.

Figure 1151-1 depicts the decrease of oxygen in the sodium heat transfer system atmosphere as a function of time and of helium discharged into the system. The helium bottles used each contained 225 scfm of helium.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Test Completion Criteria associated with Preoperational Test AI-P-1151, "Purge of the Primary Sodium System and Reactor Vessel with Helium", are listed on pages XI (a)-62 and XI (a)-64 of NAA-SR-5700, Supplement 4, and are as follows:

- a) Criterion: A helium atmosphere of less than 3% oxygen content is established in the sodium heat transfer system loops and reactor vessel.
Remarks: The above test completion criterion has been complied with as described within this report.

Figure 1151-1. Purge of Primary Sodium System and Reactor Vessel

- b) Criterion: A helium atmosphere of less than 1/2% oxygen content is established in the sodium heat transfer system primary loops and reactor vessel.

Remarks: The above test completion criterion has been complied with; the oxygen content of the atmosphere was verified to be less than 1/2% in the sodium heat transfer system primary loops and reactor vessel.

- c) Criterion: Reactor system pressure is being maintained in a normal manner at 1 in. to 6 in. water by the helium and vent control valves.

Remarks: The above test completion criterion has been complied with as described within this report.

V. EVALUATION

Purging of the primary sodium system and reactor vessel with helium, according to procedures outlined in AI-P-1151, established the required atmosphere (about 1/2% oxygen) for sodium filling of the system.

AI-P-1151 procedures guarantee purging of all parts of the system. Successful purging, as indicated in the test completion report, constitutes proof of the adequacy of the procedures and equipment.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
SODIUM LEAK DETECTION SYSTEM

AI-P-1152

Test and Analysis
by
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Evaluation
by
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O. G. JENKINS

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
SODIUM LEAK DETECTION SYSTEM, AI-P-1152

I. PURPOSE OF TEST

The purpose of this test was to verify that the sodium leak detection system is capable of detecting a sodium leak which occurs in the vicinity of the detector.

II. DISCUSSION OF TEST PERFORMANCE

Each of the leak detectors and associated test circuits was tested for correct operation. The 25,000 ohm field resistor for each detector was shorted with a 400 ohm resistor in order to assure that a 0-400 ohm short across the detector will cause a sodium leak detection alarm in the control room. The loop resistances of the sheath thermocouple type reactor leak detectors were measured to verify the continuity of the detectors. The "Out-Normal-Test" switch for each detector circuit was also actuated to determine that in the "Out" position the detector would not annunciate and in the "Test" position the circuit resistance would indicate correctly. The test circuit was modified so that the test meter would indicate mid-scale deflection when the detector was not shorted and full-scale deflection when the detector has a zero ohm short. The schematic of the modified test circuit is shown in Figure 1152-1. The test meter is common to all "Out-Normal-Test" switches.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
SODIUM LEAK DETECTION SYSTEM, AI-P-1152

I. PURPOSE OF TEST

The purpose of this test was to verify that the sodium leak detection system is capable of detecting a sodium leak which occurs in the vicinity of the detector.

II. DISCUSSION OF TEST PERFORMANCE

Each of the leak detectors and associated test circuits was tested for correct operation. The 25,000 ohm field resistor for each detector was shorted with a 400 ohm resistor in order to assure that a 0-400 ohm short across the detector will cause a sodium leak detection alarm in the control room. The loop resistances of the sheath thermocouple type reactor leak detectors were measured to verify the continuity of the detectors. The "Out-Normal-Test" switch for each detector circuit was also actuated to determine that in the "Out" position the detector would not annunciate and in the "Test" position the circuit resistance would indicate correctly. The test circuit was modified so that the test meter would indicate mid-scale deflection when the detector was not shorted and full-scale deflection when the detector has a zero ohm short. The schematic of the modified test circuit is shown in Figure 1152-1. The test meter is common to all "Out-Normal-Test" switches.

Figure 1152-1. Schematic of Modified Test Circuit

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

Upon the first testing of the 96 detector circuits, 48 were found defective in one way or another. These defects consisted of such things as broken detector connectors, shorted detectors, open and incorrect field resistors, and inoperative relays. Many defects were found with the detectors that were mounted in the stems of the bellows seal valves. These detectors were damaged by personnel working in the area and apparently stepping on the pigtails and connectors. In a few cases where detectors were used in damp cells, such as the primary fill tank cell the presence of moisture caused low resistance readings between electrodes. All defects were corrected and all leak detectors were placed in proper operation.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with pre-operational test AI-P-1152, Sodium Leak Detection System, as listed in NAA-SR-5700, Supplement 4 with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: Each leak detector will cause a "Sodium Leak" annunciation when shorted by 400 ohms or less.

Remarks: The above was verified by momentarily shorting the field resistor for each leak detector with a 400 ohm resistor.

b) Criterion: The leak detector circuit is correctly wired.

Remarks: Correct wiring was verified when the field resistor for each leak detector was shorted with a 400 ohm resistor and the proper alarm actuated in the main control room. Additional proof of circuit correctness was obtained when each "Out-Normal-Test" switch was placed in the "Test" position and mid-scale indication on the test meter was observed.

V. EVALUATION

The purpose of this test was to verify that the sodium leak detection system is capable of detecting any sodium leak which occurs in the vicinity of the detectors. This verification was accomplished by momentarily shorting the field resistor for each individual leak detector with a 400 ohm resistor and observing that the sodium leak annunciator was activated. This action also gave verification that the circuits were correctly wired.

A modification, conceived and executed during performance of this test, changed the test metering circuit so that the test-meter will indicate mid-scale deflection when the detector is not shorted and full-scale deflection when the detector has a zero ohm short. This modification will give the operator a much more precise indication of when there really is a sodium leak.

This test did not include a continuity check of all the leak detector circuits nor a measure of the sheath-to-ground resistance for all the

individual circuits. These checks were made as a part of the post installation field inspection prior to acceptance of the system. Some of the circuits indicated much too low a resistance due to moisture collected in the magnesium oxide insulation. A decision was made by field operations management to accept these circuits as is. It was assumed that, as the environment around the detector elements was heated the insulation would dry out and resistances would increase to acceptable levels. This assumption has proven to be valid. After inert atmospheres were established and the surroundings were heated, the switches were moved to the "Test" position and the meter indicated mid-scale deflection; thus denoting the lack of a short of any kind in the circuit.

Another item which was not covered in the test was a check of the under voltage relay on the 24V dc power supply. An independent test was performed later by interrupting the 24V dc power and noting that the sodium leak annunciator was activated.

Test completion criteria for this system, as called out in NAA-SR-5700, HNPF Safeguards Report, have been complied with. Certain points not included in the preoperational test procedure were later checked by the evaluator. The combined results of the prescribed and independent testing have proven that the sodium leak detection system is capable of performing its intended function.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
TEMPERATURE INSTRUMENTATION USING THERMOCOUPLE ELEMENTS

AI-P-1154

Test and Analysis

by

D. J. SOBO

Evaluation

by

C. W. GRIFFIN

A T O M I C S I N T E R N A T I O N A L

A DIVISION OF NORTH AMERICAN AVIATION, INC.

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
TEMPERATURE INSTRUMENTATION USING THERMOCOUPLE ELEMENTS
AI-P-1154

I. PURPOSE OF TEST

The purpose of this test was to verify proper functioning and calibration of all temperature instrumentation with thermocouple inputs which are not part of the plant control, pre-heat, or protective systems.

II. DISCUSSION OF TEST PERFORMANCE

A. PYROMETER CALIBRATION

All millivolt type pyrometer instruments were calibrated per manufacturer's instructions using a Pyrotest model 9B potentiometer as a source of simulated temperatures. Per manufacturer's directions, the input thermocouple was disconnected and its loop resistance measured with a Wheatstone bridge. (On instruments having more than one thermocouple input through a selector switch, all thermocouples were disconnected, loop resistances measured, and an average of the highest and lowest loop resistances was determined.) This value of loop resistance was set on a decade resistance box and was inserted in series with the thermocouple input to the pyrometer type instrument. Utilization of the direct reading iron-constantan thermocouple scale on the Pyrotest was made possible by using iron-constantan wire to connect the Pyrotest, the decade resistance box, and the pyrometer type instrument. The Pyrotest scale zero was then

made to read the same as the temperature at its output terminals. A mercury thermometer, supplied with the Pyrotest, was used to measure the temperature at the Pyrotest's terminals. Once this setup was made, the Pyrotest was dialed to temperatures in the lower quarter, middle, and upper quarter of the pyrometer type instrument's scale, and the pyrometer's calibration was checked. If required, the pyrometer instrument was re-calibrated so its maximum error at any point was no more than $\pm 1.0\%$ of full scale.*

B. NULL-BALANCE TEMPERATURE INSTRUMENTS CALIBRATION

All null-balance type temperature instruments were calibrated per manufacturer's instructions. The calibration technique was the same as noted above. However, it was not necessary to account for thermocouple loop resistance on this type of instrument due to its high impedance when it is in balance. When necessary, the instrument was re-calibrated so its maximum error was no more than $\pm 0.5\%$ of full scale.

On null-balance indicators, proper operation of selector switches was verified. On null-balance multi-point recorders, proper synchronization of the print wheel with the thermocouple input was verified.

The reactor temperature scanner-logger (TR-3a and TR-3b) is a null-balance type unit, with its thermocouple inputs terminated at a multiple bank and point switching cabinet located in the cable spreading room. All thermocouple inputs are terminated at this switching cabinet,

* Three-point calibration data are shown in the Appendix.

and a single pair of copper wires are brought up to the multiple point recorder. Verification of wiring and switching is discussed below, under checkout of reactor thermocouple extension wiring. Because the thermocouples terminate at the switching cabinet, the cold junction reference for the instrument is at the switching cabinet rather than within the instrument. Therefore, the Pyrotest was connected at the switching cabinet, instead of at the instrument, and calibration of the recorders was checked.

C. THERMOCOUPLE-TO-PRESSURE OR -CURRENT TEMPERATURE INSTRUMENT CALIBRATION

Temperature instruments which consist of a thermocouple-to-pressure or -current converter and a pressure or current recorder were calibrated per manufacturer's instructions. The thermocouple converters were calibrated by using the Pyrotest as a temperature source. It was not necessary to account for thermocouple loop resistance due to the high input impedance of these converters.

To verify the output of the converters, a Wallace and Tiernan precision pneumatic calibrator and a Weston precision milliammeter were used for the pressure and current converters, respectively. The recorders were calibrated to insure their inputs were identical to the converters' outputs. The Wallace and Tiernan pneumatic calibrator was used for the pressure recorders; a Foxboro Model 8131 current source was used for the current recorders. Finally, the thermocouple converters were connected to their recorders, and overall system accuracy was verified.

D. OTHER EQUIPMENT VERIFICATIONS

The thermocouple extension wiring between the reactor loading face shield and the reactor temperature scanner -logger was checked. This was done by connecting the Pyrotest, individually, to each thermocouple connector at the loading face shield. Each thermocouple pair being tested was patched into the scanner-logger multi-point recorder at the main patch panel, and a scanner-logger continuous recorder was patched in at the monitoring patch panel. In this manner, the continuous recorder showed the simulated temperature continuously, and the multi-point recorders printed full upscale (due to upscale burnout protection) until they reached the point being monitored, and they then printed the simulated temperature. A simulated temperature of 945 F was used, as this will be the normal operating temperature. A simplified diagram of this test set up is shown in Figure 1154-1. At the same time this thermocouple check was performed, the reactor core light matrix was monitored to verify that the proper light was synchronized with the core position being tested.

Some reactor thermocouples do not connect to the reactor scanner-logger. These thermocouples are associated with the three reactor temperature elements, the two specially instrumented fuel elements, the specially instrumented moderator can, and the source element. These thermocouples are connected directly to several multi-point null-balance indicators and/or multi-point recorders. These instruments were monitored as each pair of thermocoupled extension wires was subjected to a simulated temperature, as described above, and proper wiring was verified.

When this test of reactor thermocouple extension wiring was completed, it was noted that of the 518

Figure 1154-1: Test Set-up for Checking Thermocouple Extension Wiring Between Reactor Loading Face Shield and Reactor Temperature Scanner-Logger

thermocouple pairs originating at the reactor, 177 (~ 34%) of the pairs were defective. Subsequent investigation revealed that virtually all of the problems were in the wiring beneath the top plate of the loading face shield. Thermocouple wiring in this area was crossed, open, and shorted, and there were numerous poor solder connections at the various disconnect plugs. A repair effort, involving 10 man weeks, was initiated. After repair, this portion of the test was repeated, and only three defective pairs were found. Since spare thermocouples were available at the locations of the defective pairs, further repair work was not initiated.

Proper operation of the alarms associated with temperature instruments having an alarm function was verified. The alarms were set, and proper operation of the annunciator drop associated with the alarm was verified.

The thermocouples associated with the two thermocoupled fuel elements are connected to TR-12 and TR-13. TI-18 is paralleled with all the thermocouples associated with TR-12 and TR-13. Normally, simultaneous operation of the indicator and recorder does not result in any problems, since the impedance of these instruments is infinite when they are balanced. However, operator actuation of an indicator point, at the same time the recorder is scanning that point, results in a false temperature transient, as the two instruments are not balanced. This false transient does cause false annunciation. The annunciator clears as the two instruments balance. This problem of false annunciation can be overcome by merely informing the control room operator that TI-18 is to be operated.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

Calibration data for millivolt type pyrometers are shown in Table I of the Appendix. Maximum calibration errors are within $\pm 1.0\%$ of full scale range.

Calibration data for null-balance potentiometer type temperature instruments are shown in Table II of the Appendix. Maximum calibration errors are within $\pm 0.5\%$ of full scale.

Calibration data of thermocouple-to-pressure (or -current) converters and for pressure (or current) recorders are shown in Table III of the Appendix. Maximum calibration errors are within $\pm 0.5\%$ of full scale.

The results of the check of reactor thermocouple extension wiring are shown in Table IV of the Appendix. Using an input signal of a simulated 945 F, it can be seen that the readout device reads 945 ± 5 F, thus indicating there are no inhomogeneous* thermocouple extension wires. Three pairs of thermocouple wires were open; C108-1, C130-2, and C236-6. Since spares are available in these channels (C108-2, C130-1, C236-5), no further repair action has been undertaken.

Table V of the Appendix shows the setting of each alarm associated with temperature instruments.

* Inhomogeneities in the iron wire as result of bending result in spurious iron-to-iron thermal junctions resulting in false EMFs, with subsequent erroneous temperatures being sensed.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following is a list of Test Completion Criteria taken from page XI(a)-30, NAA-SR-5700, Supplement 2, with remarks about the test to show compliance with the criteria.

- a) Criterion: All null-balance type temperature instruments calibrated to $\pm 0.5\%$ of full scale accuracy.
Remarks: Verified.
- b) Criterion: Proper annunciator actuation occurs on (simulated) high or low temperature alarms.
Remarks: Verified.
- c) Criterion: All millivolt type pyrometers calibrated to $\pm 1.0\%$ of full scale accuracy.
Remarks: Verified.
- d) Criterion: All reactor thermocouples are wired correctly, with the right polarity.
Remarks: Three thermocouple pairs, C108-1, C130-2, and C236-6, are open. Originally, there were 177 open or otherwise defective pairs. After an extensive repair effort, this number has been reduced to three. Since spares are available (C108-2, C130-1, and C236-5), and since further repair effort may damage other wires, no further action will be taken.

V. EVALUATION

In the review of the test performance and results, the following observations are noted.

- a) Each test of temperature recording instrumentation was performed in accordance with the manufacturer's specification.
- b) Sound experimental procedure was maintained with respect to wiring material and circuitry.
- c) Coordination with respect to position, readout, alarm, and light matrix was confirmed.
- d) The three unrepaired defective thermocouples have adequate spare back-up.
- e) Numerous points in addition to those shown in Tables I, II, and III were monitored for each readout and all meet the specified criteria on page XI(a)-30, NAA-SR-5700, Supplement 2.
- f) The resistance of the one thermocouple which appeared to be excessively large (Table I, thermocouple 108-6) was still small compared to the recorder input resistance. Direct comparison with temperature measurements of the other thermocouples at this location showed no discrepancy.

In view of these observations, this test is evaluated as having adequately accomplished its specified objective of determining readout reliability with respect to calibration and position. However, this does not assure accuracy of the thermocouples themselves. A test should be considered wherein all reactor and piping thermocouples would be monitored for at least one hour when the reactor is as near isothermal as possible, with no nuclear heating. Comparison of readout during such a test would indicate the degree of reliability of any specified thermocouple. Similar tests should be conducted for thermocouples not in the sodium piping or core.

TABLE I
CALIBRATION DATA
FOR PYROMETER TEMPERATURE INSTRUMENTS

Tag No.	Thermo- couple Locations	Element No. and Loop Resist. (ohms)	Range of Inst. (F)	Calibration (F)						Max Error Per cent of Full Scale
				Lower		Middle		Upper		
				Simul	Indic	Simul	Indic	Simul	Indic	
TI-108	Pri Na Pump No. 1 Motor Windings	-1 9.2	0-400	100	99	200	200	350	351	0.3
		-2 10.0								
		-3 9.0								
		-4 8.9								
		-5 9.7								
		-6 *24.5								
TI-208	Pri Na Pump No. 2 Motor Windings	-1 8.2	0-400	100	100	200	200	350	349	0.3
		-2 8.2								
		-3 7.7								
		-4 7.7								
		-5 8.0								
		-6 7.4								
TI-308	Pri Na Pump No. 3 Motor Windings	-1 8.2	0-400	80	81	300	300	390	390	0.3
		-2 7.6								
		-3 7.3								
		-4 7.8								
		-5 7.3								
		-6 8.2								
TI-109	Sec Na Pump No. 1 Motor Windings	-1 7.2	0-400	100	100	200	200	350	352	0.5
		-2 8.0								
		-3 7.5								
		-4 7.9								
		-5 8.1								
		-6 7.1								
TI-209	Sec Na Pump No. 2 Motor Windings	-1 8.8	0-400	100	100	250	250	350	350	0
		-2 8.2								
		-3 7.9								
		-4 8.7								
		-5 8.4								
		-6 7.6								

* Although this loop resistance appears excessive, this point is operating satisfactorily.

TABLE I CONTINUED

Tag No.	Thermo-couple Locations	Element No. and Loop Resist. (ohms)		Range of Inst. (F)	Calibration, (F)						Max Error Per cent of Full Scale
					Lower		Middle		Upper		
					Simul	Indic	Simul	Indic	Simul	Indic	
TI-309	Sec Na Pump No. 3 Motor Windings	-1 -2 -3 -4 -5 -6	8.1 8.8 9.3 10.2 9.3 8.6	0-400	100	100	200	196	350	350	1.0
TI-113	Pri Na Pump No. 1 Coupling	-1	8.1	0-400	72	73	200	200	390	392	0.5
TI-213	Pri Na Pump No. 2 Coupling	-1	7.5	0-400	70	70	200	199	390	393	0.8
TI-313	Pri Na Pump No. 3 Coupling	-1	7.8	0-400	72	72	200	198	390	387	0.8
TI-114	Sec Na Pump No. 1 Coupling	-1	6.7	0-400	100	100	200	200	350	351	0.3
TI-214	Sec Na Pump No. 2 Coupling	-1	7.5	0-400	100	100	200	200	350	352	0.5
TI-314	Sec Na Pump No. 3 Coupling	-1	open	0-400	This pump, was shipped at an early date to Santa Susana for testing, and has no thermocouple in its coupling.						
TI-402	Sec Na Service Pump	-1	13.2	0-1200	200	200	600	600	1190	1188	0.2
TI-403	Pri Na Service Pump No. 1	-1	16.0	0-1200	80	80	600	600	1100	1094	0.5
TI-404	Pri Na Service Pump No. 2	-1	15.0	0-1200	80	80	600	600	1100	1090	0.9
TI-414	Na Transfer Pump	-1	8.0	0-400	88	90	200	200	375	378	0.8

TABLE I CONTINUED

Tag No.	Thermo-couple Locations	Element No. and Loop Resist. (ohms)	Range of Inst. (F)	Calibration, (F)						Max Error Per cent of Full Scale
				Lower		Middle		Upper		
				Simul	Indic	Simul	Indic	Simul	Indic	
TI-66	Steam Generator Feedwater Header	-1 4.5	0-1000	200	199	800	800	950	948	0.2
TI-115	Pri Na Pump No. 1 Vent Valve	-1 11.6	0-1200	200	202	500	501	1100	1098	0.2
TI-215	Pri Na Pump No. 2 Vent Valve	-1 11.6	0-1200	200	202	500	501	1100	1098	0.2
TI-315	Pri Na Pump No. 3 Vent Valve	-1 10.0	0-1200	200	201	500	502	1100	1090	0.9
TI-116	Pri Na Pump No. 1	-1 10.0	0-1200	200	200	800	800	1100	1100	0
		-2 9.5								
		-3 9.5								
		-4 9.7								
		-5 9.8								
		-6 9.3								
		-7 9.6								
		-8 10.0								
		-9 10.4								
TI-216	Pri Na Pump No. 2	-1 8.4	0-1200	200	200	800	800	1100	1095	0.4
		-2 7.7								
		-3 7.6								
		-4 8.0								
		-5 8.2								
		-6 7.6								
		-7 7.8								
		-8 8.4								
		-9 7.6								

TABLE I CONTINUED

Tag No.	Thermo-couple Locations	Element No. and Loop Resist. (ohms)		Range of Inst. (F)	Calibration, (F)						Max Error Per cent of Full Scale
					Lower		Middle		Upper		
					Simul	Indic	Simul	Indic	Simul	Indic	
TI-316	Pri Na Pump No. 3	-1	8.4	0-1200	200	205	800	800	1100	1095	0.4
		-2	7.8								
		-3	7.8								
		-4	8.2								
		-5	8.3								
		-6	7.8								
		-7	7.9								
		-8	8.5								
		-9	9.0								
TI-117	Sec Na Pump No. 1	-1	9.0	0-1200	200	200	800	800	1100	1090	0.9
		-2	9.0								
		-3	9.1								
		-4	9.0								
		-5	9.0								
		-6	9.1								
		-7	9.2								
		-8	9.0								
		-9	10.5								
TI-217	Sec Na Pump No. 2	-1	8.8	0-1200	200	200	500	500	1100	1097	0.3
		-2	9.0								
		-3	9.0								
		-4	8.8								
		-5	8.9								
		-6	8.8								
		-7	8.8								
		-8	8.6								
		-9	10.2								
TI-317	Sec Na Pump No. 3	-1	8.7	0-1200	200	200	500	501	1100	1100	0.1
		-2	8.9								
		-3	8.9								
		-4	8.8								
		-5	8.8								
		-6	8.8								
		-7	8.8								
		-8	8.6								
		-9	10.3								

TABLE I CONTINUED

Tag No.	Thermo-couple Location	Element No. and Loop Resist. (ohms)		Range of Inst. (F)	Calibration, (F)						Max Error Per cent of Full Scale
					Lower		Middle		Upper		
					Simul	Indic	Simul	Indic	Simul	Indic	
TI-155	Steam Generator No. 1	-1	4.2	0-1000	200	198	500	500	990	990	0.2
		-2	3.4								
		-3	6.4								
		-4	7.1								
		-5	7.6								
		-6	3.9								
		-7	4.6								
		-8	7.8								
TI-255	Steam Generator No. 2	-1	4.2	0-1000	200	199	500	500	950	948	0.2
		-2	3.1								
		-3	6.4								
		-4	6.7								
		-5	7.1								
		-6	3.8								
		-7	4.4								
		-8	7.2								
TI-355	Steam Generator No. 3	-1	4.6	0-1000	200	199	500	500	990	989	0.1
		-2	3.4								
		-3	6.0								
		-4	7.1								
		-5	6.8								
		-6	3.8								
		-7	4.6								
		-8	6.6								
TI-19	BF3 Chamber Nuclear Channel I	-1	80.0	0-600	100	100	300	294	500	494	1.0
TI-20	BF3 Chamber Nuclear Channel I	-1	76.0	0-600	100	105	300	300	500	496	1.0

TABLE II
CALIBRATION DATA FOR NULL BALANCE
POTENTIOMETER TYPE TEMPERATURE INSTRUMENTS

Tag No.	Thermocouple Locations	Range of Instr. (F)	Calibration (F)						Max Error Per cent of Full Scale
			Lower		Middle		Upper		
			Simul	Indic	Simul	Indic	Simul	Indic	
TI-8	Special Fuel Elements	0-1500	78	78	650	650	1490	1488	0.2
TI-9	Special Moderator Can	0-1500	150	147	750	750	1480	1479	0.2
TI-14	Source & Temp Elements	200-1200	220	220	750	751	1190	1190	0.1
TI-18	Reactor LFS & Biol. Shield	0-600	100	100	300	301	580	582	0.3
TI-21	Reactor Vessel and Structure	0-1200	300	298	600	599	1190	1192	0.2
TI-118	Na Pumps Fin Section	0-400	300	300	600	600	1180	1182	0.2
TI-400	Misc. Na Temps	0-1200	100	100	600	599	1100	1101	0.1
TI-412	Freeze Seal Valves	200-1200	100	100	200	200	390	391	0.3
TI-413	Sec Na Bellows Seal Valves	0-400	100	100	250	250	380	381	0.3
TI-415	Pri Na Bellows Seal Valves	0-400	100	99	200	199	390	390	0.3
TI-416	Pri Na Bellows Seal Valves	0-400	100	99	200	200	390	390	0.3
TI-22	Intermediate Heat Exchangers	0-1200	300	301	600	601	1170	1172	0.2
TI-112	Sec Loop 1 Vents and Valves	0-1200	100	100	600	588	1190	1191	0.2
TI-212	Sec Loop 2 Vents and Valves	0-1200	100	100	600	600	1190	1190	0
TI-312	Sec Loop 3 Vents and Valves	0-1200	100	98	600	600	1180	1181	0.2
TI-408	Primary Cold Traps	0-800	200	200	400	400	790	790	0
TI-409	Secondary Cold Traps	0-800	100	99	500	500	650	652	0.3
TI-417	Pri Na Bellows Seal Valves	0-400	100	98	200	199	400	400	0.5
TI-418	Na Transfer Tank	0-400	150	149	250	249	350	351	0.3

TABLE II CONTINUED

Tag No.	Thermocouple Locations	Range of Instr. (F)	Calibration (F)						Max Error Per cent of Full Scale
			Lower		Middle		Upper		
			Simul	Indic	Simul	Indic	Simul	Indic	
TI-419	Carbon Trap	0-1200	300	300	600	599	1150	1150	0.1
TI-800	Vapor Traps	0-400	100	100	250	249	380	381	0.1
TR-1	Freeze Seal Valves	0-400	100	99	250	249	390	389	0.3
TR-2	Sodium Temps	200-1200	300	300	700	700	1100	1100	0
TR-4	Na Pumps Seal Oil	0-400	100	99	200	199	390	390	0.3
TR-12	Special Fuel Element	0-1500	78	80	800	799	1480	1480	0.1
TR-13	Special Fuel Element	0-1500	400	399	800	800	1480	1480	0.1
TR-402	Freeze Seal Valves	0-400	100	99	250	248	380	380	0.5
TR-3A	Reactor Scanner-Logger	200-1200	250	251	700	701	1190	1191	0.1
TR-3B	Reactor Scanner-Logger	200-1200	250	252	700	700	1190	1189	0.2

TABLE III
CALIBRATION DATA
FOR
THERMOCOUPLE-TO-PRESSURE OR -TO-CURRENT CONVERTERS
AND
ASSOCIATED INDICATORS OR RECORDERS

Tag No.	Thermocouple Locations	Type Converter	Range (F)	Calibration (F)						Max Error Per cent of Full Scale
				Lower		Middle		Upper		
				Simul	Indic	Simul	Indic	Simul	Indic	
TI-15	Reactor Lower Plenum	Current	0-1000	100	102	550	550	1000	1000	0.2
TI-16	Reactor Lower Plenum	Current	0-1000	100	100	550	550	1000	1000	0
TI-17	Reactor Lower Plenum	Current	0-1000	100	100	550	550	1000	1000	0
TR-6	Fuel Element	Current	700-1200	700	700	950	950	1190	1189	0.2
TR-7	Fuel Element	Current	700-1200	700	700	950	950	1190	1188	0.4
TR-8	Fuel Element	Current	700-1200	700	700	950	950	1190	1189	0.2
TR-9	Fuel Element	Current	300-800	300	302	550	550	790	790	0.4
TR-9	Fuel Element	Current	700-1200	700	701	950	950	1190	1188	0.4
TR-10	Fuel Element	Current	300-800	300	301	550	552	790	788	0.4
TR-10	Fuel Element	Current	700-1200	700	700	950	948	1200	1198	0.4
TR-11	Fuel Element	Current	300-800	300	300	550	552	790	792	0.4
TR-11	Fuel Element	Current	700-1200	700	699	950	950	1200	1200	0.1
TR-100	IHX No. 1 Pri Na Inlet	Current	200-1200	200	205	700	702	1200	1200	0.5
TR-101	IHX No. 1 Sec Na Outlet	Current	200-1200	200	201	700	700	1200	1200	0.1
TR-200	IHX No. 2 Pri Na Inlet	Current	200-1200	200	205	700	700	1200	1200	0.5
TR-201	IHX No. 2 Sec Na Outlet	Current	200-1200	200	202	700	700	1200	1200	0.2
TR-300	IHX No. 3 Pri Na Inlet	Current	200-1200	200	201	700	703	950	952	0.3
TR-301	IHX No. 3 Sec Na Outlet	Current	200-1200	200	205	700	705	950	950	0.5
TR-102	IHX No. 1 Pri Na Outlet	Current	200-1200	400	405	800	800	1000	1002	0.5

TABLE III CONTINUED

Tag No.	Thermocouple Location	Type Converter	Range (F)	Calibration (F)						Max Error Per cent of Full Scale
				Lower		Middle		Upper		
				Simul	Indic	Simul	Indic	Simul	Indic	
TR-103	IHX No. 1 Sec Na Inlet	Current	200-1200	200	205	700	705	1200	1195	0.5
TR-202	IHX No. 2 Pri Na Outlet	Current	200-1200	200	200	700	700	1200	1200	0
TR-203	IHX No. 2 Sec Na Inlet	Current	200-1200	200	200	700	700	1200	1200	0
TR-302	IHX No. 3 Pri Na Outlet	Current	200-1200	200	198	700	700	1200	1200	0.2
TR-303	IHX No. 3 Sec Na Inlet	Current	200-1200	200	205	700	700	1200	1200	0.5
TR-104	Superheater No. 1 Na In	Current	200-1200	200	204	700	699	1200	1200	0.4
TR-204	Superheater No. 2 Na In	Current	200-1200	200	199	700	700	1200	1199	0.1
TR-304	Superheater No. 3 Na In	Current	200-1200	200	205	700	700	1200	1200	0.5
TR-105	Evaporator No. 1 Na In	Current	200-1200	200	199	700	696	1200	1200	0.4
TR-205	Evaporator No. 2 Na In	Current	200-1200	200	203	700	699	1200	1199	0.3
TR-305	Evaporator No. 3 Na In	Current	200-1200	200	200	700	702	1200	1200	0.2
TR-106	Evaporator No. 1 Na Out	Current	200-1200	200	200	700	700	1200	1200	0
TR-206	Evaporator No. 2 Na Out	Current	200-1200	200	201	700	699	1200	1196	0.4
TR-306	Evaporator No. 3 Na Out	Current	200-1200	200	201	700	702	1200	1201	0.2

APPENDIX

TABLE IV
CHECK OF REACTOR
THERMOCOUPLE EXTENSION WIRING

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C1-1	Fuel Exit	945	948	948	Scanner
C1-2	Fuel Exit	945	948	948	Scanner
C2-1	Fuel Exit	945	947	947	Scanner
C2-2	Fuel Exit	945	947	948	Scanner
C3-1A	Fuel Exit	945	945	950	Scanner
C3-2A	Fuel Exit	945	944	949	Scanner
C3-1B	In Fuel	945	940	940	TI-18 & TR-12
C3-2B	In Fuel	945	940	940	TI-18 & TR-12
C3-3B	In Fuel	945	940	940	TI-18 & TR-12
C3-4B	In Fuel	945	940	940	TI-18 & TR-12
C3-5B	In Fuel	945	940	941	TI-18 & TR-12
C3-6B	In Fuel	945	940	942	TI-18 & TR-12
C3-7B	In Fuel	945	940	942	TI-18 & TR-12
C3-8B	In Fuel	945	940	941	TI-18 & TR-12
C3-9B	In Fuel	945	940	941	TI-18 & TR-12
C3-10B	In Fuel	945	940	941	TI-18 & TR-12
C3-11B	In Fuel	945	940	941	TI-18 & TR-12
C3-12B	In Fuel	945	940	941	TI-18 & TR-12
C3-13B	In Fuel	945	940	941	TI-18 & TR-12
C3-14B	In Fuel	945	941	941	TI-18 & TR-12
C3-15B	In Fuel	945	940	941	TI-18 & TR-12
C3-16B	In Fuel	945	940	940	TI-18 & TR-12
C3-17B	In Fuel	945	940	941	TI-18 & TR-12
C3-18B	In Fuel	945	940	941	TI-18 & TR-12
C4-1	Source	945	---	947	TI-14
C4-2	Source	945	---	947	TI-14
C4-3	Source	945	---	947	TI-14
C4-5	Source	945	---	946	TI-14
C4-6	Source	945	---	946	TI-14
C4-7	Source	945	---	944	TI-14
C4-8	Source	945	---	949	TI-14
C4-9	Source	945	---	949	TI-14
C4-10	Source	945	---	949	TI-14
C4-11	Source	945	---	948	TI-14
C4-12	Source	945	---	948	TI-14
C4-13	Source	945	---	949	TI-14
C4-14	Source	945	---	948	TI-14
C4-15	Source	945	---	948	TI-14
C4-16	Source	945	---	948	TI-14
C5-1	Fuel Exit	945	948	947	Scanner
C5-2	Fuel Exit	945	941	943	Scanner

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C6-1A	Fuel Exit	945	944	943	Scanner
C6-2A	Fuel Exit	945	943	943	Scanner
C6-1B	In Fuel	945	944	943	TI-18 & TR-13
C6-2B	In Fuel	945	944	942	TI-18 & TR-13
C6-3B	In Fuel	945	943	942	TI-18 & TR-13
C6-4B	In Fuel	945	944	943	TI-18 & TR-13
C6-5B	In Fuel	945	944	943	TI-18 & TR-13
C6-6B	In Fuel	945	944	943	TI-18 & TR-13
C6-7B	In Fuel	945	943	943	TI-18 & TR-13
C6-8B	In Fuel	945	943	942	TI-18 & TR-13
C6-9B	In Fuel	945	942	941	TI-18 & TR-13
C6-10B	In Fuel	945	942	941	TI-18 & TR-13
C6-11B	In Fuel	945	941	941	TI-18 & TR-13
C6-12B	In Fuel	945	942	941	TI-18 & TR-13
C6-13B	In Fuel	945	942	941	TI-18 & TR-13
C6-14B	In Fuel	945	942	941	TI-18 & TR-13
C6-15B	In Fuel	945	941	940	TI-18 & TR-13
C6-16B	In Fuel	945	942	941	TI-18 & TR-13
C6-17B	In Fuel	945	942	941	TI-18 & TR-13
C6-18B	In Fuel	945	942	941	TI-18 & TR-13
C7-1	Fuel Exit	945	943	949	Scanner
C7-2	Fuel Exit	945	949	945	Scanner
C8-1	Fuel Exit	945	945	950	Scanner
C8-2	Fuel Exit	945	944	949	Scanner
C9-1	Fuel Exit	945	946	950	Scanner
C9-2	Fuel Exit	945	944	949	Scanner
C10-1	Fuel Exit	945	946	950	Scanner
C10-2	Fuel Exit	945	944	949	Scanner
C11-1	Fuel Exit	945	940	943	Scanner
C11-2	Fuel Exit	945	940	944	Scanner
C12-1	Fuel Exit	945	941	943	Scanner
C12-2	Fuel Exit	945	941	942	Scanner
C13-1	Fuel Exit	945	941	944	Scanner
C13-2	Fuel Exit	945	940	944	Scanner
C14-1	Fuel Exit	945	941	944	Scanner
C14-2	Fuel Exit	945	941	943	Scanner
C15-1	Fuel Exit	945	940	943	Scanner
C15-2	Fuel Exit	945	941	944	Scanner
C16-1	Fuel Exit	945	945	950	Scanner
C16-2	Fuel Exit	945	945	950	Scanner
C17-1	Fuel Exit	945	943	943	Scanner
C17-2	Fuel Exit	945	943	944	Scanner
C18-1	Fuel Exit	945	943	943	Scanner

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C18-2	Fuel Exit	945	942	942	Scanner
C19-1	Fuel Exit	945	943	943	Scanner
C19-2	Fuel Exit	945	943	943	Scanner
C20-1	Fuel Exit	945	945	949	Scanner
C20-2	Fuel Exit	945	945	948	Scanner
C21-1	Fuel Exit	945	944	948	Scanner
C21-2	Fuel Exit	945	944	947	Scanner
C22-1	Fuel Exit	945	941	948	Scanner
C22-2	Fuel Exit	945	943	948	Scanner
C23-1	Fuel Exit	945	946	949	Scanner
C23-2	Fuel Exit	945	945	949	Scanner
C24-1	Fuel Exit	945	945	948	Scanner
C24-2	Fuel Exit	945	949	945	Scanner
C25-1	Fuel Exit	945	941	948	Scanner
C25-2	Fuel Exit	945	948	942	Scanner
C26-1	Fuel Exit	945	940	948	Scanner
C26-2	Fuel Exit	945	940	948	Scanner
C27-1	Fuel Exit	945	940	950	Scanner
C27-2	Fuel Exit	945	940	948	Scanner
C28-1	Fuel Exit	945	945	949	Scanner
C28-2	Fuel Exit	945	945	948	Scanner
C29-1	Fuel Exit	945	940	949	Scanner
C29-2	Fuel Exit	945	940	949	Scanner
C30-1	Fuel Exit	945	946	940	Scanner
C30-2	Fuel Exit	945	941	947	Scanner
C31-1	Fuel Exit	945	941	942	Scanner
C31-2	Fuel Exit	945	941	944	Scanner
C32-1	Fuel Exit	945	942	945	Scanner
C32-2	Fuel Exit	945	942	946	Scanner
C33-1	Fuel Exit	945	941	942	Scanner
C33-2	Fuel Exit	945	942	944	Scanner
C33-1	Fuel Exit	945	941	942	Scanner
C33-2	Fuel Exit	945	942	944	Scanner
C34-1	Fuel Exit	945	940	943	Scanner
C34-2	Fuel Exit	945	944	941	Scanner
C35-1	Fuel Exit	945	941	944	Scanner
C35-2	Fuel Exit	945	949	945	Scanner
C36-1	Fuel Exit	945	941	946	Scanner
C36-2	Fuel Exit	945	941	943	Scanner
C37-1	Fuel Exit	945	941	945	Scanner
C37-2	Fuel Exit	945	941	943	Scanner
C38-1	Fuel Exit	945	945	950	Scanner
C38-2	Fuel Exit	945	945	950	Scanner

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C39-1	Fuel Exit	945	940	946	Scanner
C39-2	Fuel Exit	945	940	946	Scanner
C40-1	Fuel Exit	945	942	944	Scanner
C40-2	Fuel Exit	945	942	942	Scanner
C41-1	Fuel Exit	945	942	942	Scanner
C41-2	Fuel Exit	945	942	943	Scanner
C42-1	Fuel Exit	945	941	943	Scanner
C42-2	Fuel Exit	945	942	944	Scanner
C43-1	Fuel Exit	945	940	943	Scanner
C43-2	Fuel Exit	945	941	944	Scanner
C44-1	Fuel Exit	945	941	945	Scanner
C44-2	Fuel Exit	945	940	942	Scanner
C45-1	Fuel Exit	945	941	946	Scanner
C45-2	Fuel Exit	945	940	946	Scanner
C46-1	Fuel Exit	945	942	946	Scanner
C46-2	Fuel Exit	945	942	947	Scanner
C47-1	Fuel Exit	945	947	944	Scanner
C47-2	Fuel Exit	945	947	945	Scanner
C48-1	Fuel Exit	945	941	948	Scanner
C48-2	Fuel Exit	945	941	949	Scanner
C49-1	Fuel Exit	945	942	943	Scanner
C49-2	Fuel Exit	945	942	942	Scanner
C50-1	Fuel Exit	945	947	946	Scanner
C50-2	Fuel Exit	945	948	946	Scanner
C51-1	Fuel Exit	945	943	946	Scanner
C51-2	Fuel Exit	945	942	946	Scanner
C52-1	Fuel Exit	945	948	947	Scanner
C52-2	Fuel Exit	945	948	942	Scanner
C53-1	Fuel Exit	945	946	942	Scanner
C53-2	Fuel Exit	945	949	944	Scanner
C54-1	Fuel Exit	945	949	942	Scanner
C54-2	Fuel Exit	945	949	943	Scanner
C55-1	Fuel Exit	945	949	943	Scanner
C55-2	Fuel Exit	945	940	946	Scanner
C56-1	Fuel Exit	945	943	943	Scanner
C56-2	Fuel Exit	945	943	947	Scanner
C57-1	Fuel Exit	945	940	946	Scanner
C57-2	Fuel Exit	945	941	946	Scanner
C58-1	Fuel Exit	945	942	946	Scanner
C58-2	Fuel Exit	945	940	946	Scanner
C59-1	Fuel Exit	945	943	945	Scanner
C59-2	Fuel Exit	945	946	945	Scanner
C60-1	Fuel Exit	945	947	945	Scanner

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C60-2	Fuel Exit	945	948	947	Scanner
C61-1	Fuel Exit	945	943	943	Scanner
C61-2	Fuel Exit	945	945	944	Scanner
C62-1	Fuel Exit	945	945	950	Scanner
C62-2	Fuel Exit	945	945	950	Scanner
C63-1	Fuel Exit	945	949	949	Scanner
C63-2	Fuel Exit	945	947	950	Scanner
C64-1	Fuel Exit	945	948	950	Scanner
C64-2	Fuel Exit	945	940	945	Scanner
C65-1	Fuel Exit	945	940	944	Scanner
C65-2	Fuel Exit	945	940	942	Scanner
C66-1	Fuel Exit	945	950	949	Scanner
C66-2	Fuel Exit	945	949	948	Scanner
C67-1	Fuel Exit	945	940	942	Scanner
C67-2	Fuel Exit	945	943	948	Scanner
C68-1	Fuel Exit	945	947	947	Scanner
C68-2	Fuel Exit	945	947	947	Scanner
C69-1	Fuel Exit	945	944	942	Scanner
C69-2	Fuel Exit	945	948	945	Scanner
C70-1	Fuel Exit	945	940	943	Scanner
C70-2	Fuel Exit	945	940	943	Scanner
C71-1	Fuel Exit	945	943	943	Scanner
C71-2	Fuel Exit	945	942	945	Scanner
C72-1	Fuel Exit	945	941	945	Scanner
C72-2	Fuel Exit	945	948	944	Scanner
C73-1	Fuel Exit	945	941	944	Scanner
C73-2	Fuel Exit	945	944	943	Scanner
C74-1	Fuel Exit	945	945	945	Scanner
C74-2	Fuel Exit	945	940	942	Scanner
C75-1	Fuel Exit	945	941	942	Scanner
C75-2	Fuel Exit	945	940	945	Scanner
C76-1	Fuel Exit	945	942	944	Scanner
C76-2	Fuel Exit	945	945	949	Scanner
C77-1	Fuel Exit	945	945	949	Scanner
C77-2	Fuel Exit	945	947	949	Scanner
C78-1	Fuel Exit	945	945	949	Scanner
C78-2	Fuel Exit	945	946	947	Scanner
C79-1	Fuel Exit	945	945	949	Scanner
C79-2	Fuel Exit	945	949	949	Scanner
C80-1	Fuel Exit	945	942	945	Scanner
C80-2	Fuel Exit	945	944	944	Scanner
C81-1	Fuel Exit	945	941	945	Scanner
C81-2	Fuel Exit	945	945	950	Scanner

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C82-1	Fuel Exit	945	942	947	Scanner
C82-2	Fuel Exit	945	944	946	Scanner
C83-1	Fuel Exit	945	945	945	Scanner
C83-2	Fuel Exit	945	942	945	Scanner
C84-1	Fuel Exit	945	945	950	Scanner
C84-2	Fuel Exit	945	949	941	Scanner
C85-1	Fuel Exit	945	942	945	Scanner
C85-2	Fuel Exit	945	945	945	Scanner
C86-1	Fuel Exit	945	941	945	Scanner
C86-2	Fuel Exit	945	942	945	Scanner
C87-1	Fuel Exit	945	940	943	Scanner
C87-2	Fuel Exit	945	940	944	Scanner
C88-1	Fuel Exit	945	945	945	Scanner
C88-2	Fuel Exit	945	940	945	Scanner
C89-1	Fuel Exit	945	947	947	Scanner
C89-2	Fuel Exit	945	940	944	Scanner
C90-1	Fuel Exit	945	945	943	Scanner
C90-2	Fuel Exit	945	940	944	Scanner
C91-1	Fuel Exit	945	943	945	Scanner
C91-2	Fuel Exit	945	941	943	Scanner
C92-1	Fuel Exit	945	950	948	Scanner
C92-2	Fuel Exit	945	949	948	Scanner
C93-1	Fuel Exit	945	950	947	Scanner
C93-2	Fuel Exit	945	950	948	Scanner
C94-1	Fuel Exit	945	944	944	Scanner
C94-2	Fuel Exit	945	941	944	Scanner
C95-1	Fuel Exit	945	948	943	Scanner
C95-2	Fuel Exit	945	949	942	Scanner
C96-1	Fuel Exit	945	943	943	Scanner
C96-2	Fuel Exit	945	940	946	Scanner
C97-1	Fuel Exit	945	948	943	Scanner
C97-2	Fuel Exit	945	943	943	Scanner
C98-1	Fuel Exit	945	944	943	Scanner
C98-2	Fuel Exit	945	950	942	Scanner
C99-1	Fuel Exit	945	948	950	Scanner
C99-2	Fuel Exit	945	948	948	Scanner
C100-1	Fuel Exit	945	945	949	Scanner
C100-2	Fuel Exit	945	945	949	Scanner
C101-1	Fuel Exit	945	949	949	Scanner
C101-2	Fuel Exit	945	941	942	Scanner
C102-1	Fuel Exit	945	945	946	Scanner
C102-2	Fuel Exit	945	950	946	Scanner
C103-1	Fuel Exit	945	948	950	Scanner

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C103-2	Fuel Exit	945	948	950	Scanner
C104-1	Fuel Exit	945	948	950	Scanner
C104-2	Fuel Exit	945	948	950	Scanner
C105-1	Fuel Exit	945	945	948	Scanner
C105-2	Fuel Exit	945	945	949	Scanner
C106-1	Fuel Exit	945	947	949	Scanner
C106-2	Fuel Exit	945	945	949	Scanner
C107-1	Fuel Exit	945	945	949	Scanner
C107-2	Fuel Exit	945	945	948	Scanner
C108-1	Fuel Exit	945	Open Thermocouple		Scanner
C108-2	Fuel Exit	945	948	948	Scanner
C109-1	Fuel Exit	945	948	945	Scanner
C109-2	Fuel Exit	945	948	945	Scanner
C110-1	Fuel Exit	945	945	945	Scanner
C110-2	Fuel Exit	945	942	944	Scanner
C111-1	Fuel Exit	945	944	943	Scanner
C111-2	Fuel Exit	945	945	943	Scanner
C112-1	Fuel Exit	945	946	946	Scanner
C112-2	Fuel Exit	945	942	946	Scanner
C113-1	Fuel Exit	945	944	945	Scanner
C113-2	Fuel Exit	945	945	946	Scanner
C114-1	Fuel Exit	945	945	946	Scanner
C114-2	Fuel Exit	945	946	945	Scanner
C115-1	Fuel Exit	945	944	943	Scanner
C115-2	Fuel Exit	945	945	944	Scanner
C116-1	Fuel Exit	945	945	946	Scanner
C116-2	Fuel Exit	945	943	945	Scanner
C117-1	Fuel Exit	945	943	944	Scanner
C117-2	Fuel Exit	945	943	946	Scanner
C118-1	Fuel Exit	945	949	949	Scanner
C118-2	Fuel Exit	945	945	945	Scanner
C119-1	Fuel Exit	945	944	947	Scanner
C119-2	Fuel Exit	945	943	946	Scanner
C120-1	Fuel Exit	945	945	947	Scanner
C120-2	Fuel Exit	945	943	946	Scanner
C121-1	Fuel Exit	945	944	947	Scanner
C121-2	Fuel Exit	945	942	945	Scanner
C122-1	Fuel Exit	945	944	944	Scanner
C122-2	Fuel Exit	945	945	946	Scanner
C123-1	Fuel Exit	945	945	945	Scanner
C123-2	Fuel Exit	945	948	945	Scanner
C124-1	Fuel Exit	945	945	945	Scanner
C124-2	Fuel Exit	945	947	947	Scanner

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C125-1	Fuel Exit	945	945	945	Scanner
C125-2	Fuel Exit	945	946	945	Scanner
C126-1	Fuel Exit	945	946	945	Scanner
C126-2	Fuel Exit	945	946	945	Scanner
C127-1	Fuel Exit	945	944	945	Scanner
C127-2	Fuel Exit	945	945	945	Scanner
C128-1	Fuel Exit	945	944	942	Scanner
C128-2	Fuel Exit	945	941	946	Scanner
C129-1	Fuel Exit	945	944	945	Scanner
C129-2	Fuel Exit	945	942	945	Scanner
C130-1	Fuel Exit	945	945	946	Scanner
C130-2	Fuel Exit	945	Open Thermocouple		Scanner
C131-1	Fuel Exit	945	946	948	Scanner
C131-2	Fuel Exit	945	945	946	Scanner
C132-1	Fuel Exit	945	944	945	Scanner
C132-2	Fuel Exit	945	945	946	Scanner
C133-1	Fuel Exit	945	945	945	Scanner
C133-2	Fuel Exit	945	945	945	Scanner
C134-1	Fuel Exit	945	945	945	Scanner
C134-2	Fuel Exit	945	945	945	Scanner
C135-1	Fuel Exit	945	945	947	Scanner
C135-2	Fuel Exit	945	945	945	Scanner
C136-1	Fuel Exit	945	948	948	Scanner
C136-2	Fuel Exit	945	949	948	Scanner
C137-1	Fuel Exit	945	944	948	Scanner
C137-2	Fuel Exit	945	948	949	Scanner
C138-1	Fuel Exit	945	945	948	Scanner
C138-2	Fuel Exit	945	945	945	Scanner
C139-1	Fuel Exit	945	945	945	Scanner
C139-2	Fuel Exit	945	945	945	Scanner
C140-1	Fuel Exit	945	945	945	Scanner
C140-2	Fuel Exit	945	945	945	Scanner
C141-1	Fuel Exit	945	945	945	Scanner
C141-2	Fuel Exit	945	945	945	Scanner
C142-1	Fuel Exit	945	945	945	Scanner
C142-2	Fuel Exit	945	945	942	Scanner
C143-1	Fuel Exit	945	945	945	Scanner
C143-2	Fuel Exit	945	945	943	Scanner
C144-1	Fuel Exit	945	945	942	Scanner
C144-2	Fuel Exit	945	941	945	Scanner
C145-1	Fuel Exit	945	950	948	Scanner
C145-2	Fuel Exit	945	950	949	Scanner
C146-1	Fuel Exit	945	950	948	Scanner

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C146-2	Fuel Exit	945	950	948	Scanner
C147-1	Fuel Exit	945	949	948	Scanner
C147-2	Fuel Exit	945	950	948	Scanner
C148-1	Fuel Exit	945	948	945	Scanner
C148-2	Fuel Exit	945	942	944	Scanner
C149-1	Fuel Exit	945	949	946	Scanner
C149-2	Fuel Exit	945	949	944	Scanner
C150-1	Fuel Exit	945	942	943	Scanner
C150-2	Fuel Exit	945	942	945	Scanner
C151-1	Fuel Exit	945	942	945	Scanner
C151-2	Fuel Exit	945	942	944	Scanner
C152-1	Fuel Exit	945	942	946	Scanner
C152-2	Fuel Exit	945	942	944	Scanner
C153-1	Fuel Exit	945	942	944	Scanner
C153-2	Fuel Exit	945	940	945	Scanner
C154-1	Fuel Exit	945	942	943	Scanner
C154-2	Fuel Exit	945	942	944	Scanner
C155-1	Fuel Exit	945	949	949	Scanner
C155-2	Fuel Exit	945	946	943	Scanner
C156-1	Fuel Exit	945	945	944	Scanner
C156-2	Fuel Exit	945	941	944	Scanner
C157-1	Fuel Exit	945	942	945	Scanner
C157-2	Fuel Exit	945	945	948	Scanner
C158-1	Fuel Exit	945	945	945	Scanner
C158-2	Fuel Exit	945	945	947	Scanner
C159-1	Fuel Exit	945	945	948	Scanner
C159-2	Fuel Exit	945	946	948	Scanner
C160-1	Fuel Exit	945	942	948	Scanner
C160-2	Fuel Exit	945	945	945	Scanner
C161-1	Fuel Exit	945	945	948	Scanner
C161-2	Fuel Exit	945	947	946	Scanner
C162-1	Fuel Exit	945	941	945	Scanner
C162-2	Fuel Exit	945	945	945	Scanner
C163-1	Fuel Exit	945	947	943	Scanner
C163-2	Fuel Exit	945	941	944	Scanner
C164-1	Fuel Exit	945	942	944	Scanner
C164-2	Fuel Exit	945	948	944	Scanner
C165-1	Fuel Exit	945	947	944	Scanner
C165-2	Fuel Exit	945	941	944	Scanner
C166-1	Fuel Exit	945	945	943	Scanner
C166-2	Fuel Exit	945	945	943	Scanner
C167-1	Fuel Exit	945	941	941	Scanner
C167-2	Fuel Exit	945	942	945	Scanner

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C168-1	Fuel Exit	945	945	944	Scanner
C168-2	Fuel Exit	945	943	941	Scanner
C169-1	Fuel Exit	945	946	943	Scanner
C169-2	Fuel Exit	945	942	946	Scanner
C170-1	Fuel Exit	945	943	947	Scanner
C170-2	Fuel Exit	945	941	946	Scanner
C171-1	Fuel Exit	945	942	948	Scanner
C171-2	Fuel Exit	945	941	946	Scanner
C172-1	Fuel Exit	945	943	947	Scanner
C172-2	Fuel Exit	945	946	948	Scanner
C173-1	Fuel Exit	945	945	948	Scanner
C173-2	Fuel Exit	945	942	947	Scanner
C174-1	Fuel Exit	945	945	948	Scanner
C174-2	Fuel Exit	945	942	947	Scanner
C175-1	Fuel Exit	945	943	942	Scanner
C175-2	Fuel Exit	945	945	948	Scanner
C176-1	Fuel Exit	945	946	946	Scanner
C176-2	Fuel Exit	945	942	947	Scanner
C177-1	Fuel Exit	945	945	948	Scanner
C177-2	Fuel Exit	945	941	947	Scanner
C178-1	Fuel Exit	945	945	946	Scanner
C178-2	Fuel Exit	945	942	944	Scanner
C179-1	Fuel Exit	945	945	944	Scanner
C179-2	Fuel Exit	945	942	943	Scanner
C180-1	Fuel Exit	945	942	942	Scanner
C180-2	Fuel Exit	945	942	948	Scanner
C181-1	Fuel Exit	945	942	948	Scanner
C181-2	Fuel Exit	945	941	949	Scanner
C185-1	Fuel Exit	945	945	949	Scanner
C185-2	Fuel Exit	945	942	948	Scanner
C187-1	Fuel Exit	945	942	948	Scanner
C187-2	Fuel Exit	945	941	949	Scanner
C188-1	Temp Element	945	948	948	TI-14
C188-2	Temp Element	945	948	948	TI-14
C188-3	Temp Element	945	948	948	TI-14
C188-4	Temp Element	945	949	949	TI-14
C188-5	Temp Element	945	943	943	TI-14
C188-6	Temp Element	945	944	944	TI-14
C188-7	Temp Element	945	943	943	TI-14
C188-8	Temp Element	945	943	943	TI-14
C188-9	Temp Element	945	943	943	TI-14
C188-10	Temp Element	945	945	945	TI-14
C188-11	Temp Element	945	941	941	TI-14

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C188-12	Temp Element	945	---	945	TI-14
C188-13	Temp Element	945	---	942	TI-14
C188-14	Temp Element	945	---	942	TI-14
C188-15	Temp Element	945	---	946	TI-14
C188-16	Temp Element	945	---	945	TI-14
C189-1	Fuel Exit	945	945	947	Scanner
C189-2	Fuel Exit	945	942	945	Scanner
C191-1	Fuel Exit	945	941	944	Scanner
C191-2	Fuel Exit	945	943	942	Scanner
C198-1	Fuel Exit	945	945	947	Scanner
C198-2	Fuel Exit	945	947	947	Scanner
C200-1	Fuel Exit	945	945	946	Scanner
C200-2	Fuel Exit	945	945	946	Scanner
C202-1	Fuel Exit	945	944	946	Scanner
C202-2	Fuel Exit	945	945	945	Scanner
C209-1	Fuel Exit	945	948	948	Scanner
C209-2	Fuel Exit	945	943	946	Scanner
C211-1	Fuel Exit	945	945	945	Scanner
C211-2	Fuel Exit	945	948	948	Scanner
C212-1	Temp Element	945	---	949	TI-14
C212-2	Temp Element	945	---	947	TI-14
C212-3	Temp Element	945	---	948	TI-14
C212-4	Temp Element	945	---	947	TI-14
C212-5	Temp Element	945	---	944	TI-14
C212-6	Temp Element	945	---	943	TI-14
C212-7	Temp Element	945	---	948	TI-14
C212-8	Temp Element	945	---	948	TI-14
C212-9	Temp Element	945	---	948	TI-14
C212-10	Temp Element	945	---	946	TI-14
C212-11	Temp Element	945	---	948	TI-14
C212-12	Temp Element	945	---	947	TI-14
C212-13	Temp Element	945	---	946	TI-14
C212-14	Temp Element	945	---	948	TI-14
C212-15	Temp Element	945	---	948	TI-14
C212-16	Temp Element	945	---	948	TI-14
C213-1	Fuel Exit	945	948	945	Scanner
C213-2	Fuel Exit	945	948	948	Scanner
C215-1	Fuel Exit	945	947	945	Scanner
C215-2	Fuel Exit	945	948	948	Scanner
C222-1	Fuel Exit	945	945	948	Scanner
C222-2	Fuel Exit	945	942	949	Scanner
C224-1	Fuel Exit	945	---	945	Scanner Cont. Rec. only

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Reading (F)	Continuous Recorder Reading (F)	Remarks
C224-2	Fuel Exit	945	---	945	Scanner Cont. Rec. only
C226-1	Fuel Exit	945	---	948	Scanner Cont. Rec. only
C226-2	Fuel Exit	945	---	948	Scanner Cont. Rec. only
C233-1	Fuel Exit	945	---	949	Scanner Cont. Rec. only
C233-2	Fuel Exit	945	---	950	Scanner Cont. Rec. only
C235-1	Fuel Exit	945	---	945	Scanner Cont. Rec. only
C235-2	Fuel Exit	945	---	948	Scanner Cont. Rec. only
C236-1	Temp Element	945	---	944	TI-14
C236-2	Temp Element	945	---	944	TI-14
C236-3	Temp Element	945	---	945	TI-14
C236-4	Temp Element	945	---	945	TI-14
C236-5	Temp Element	945	---	945	TI-14
C236-6	Temp Element	945	Open Thermocouple	945	TI-14
C236-7	Temp Element	945	---	945	TI-14
C236-8	Temp Element	945	---	945	TI-14
C236-9	Temp Element	945	---	945	TI-14
C236-10	Temp Element	945	---	945	TI-14
C236-11	Temp Element	945	---	945	TI-14
C236-12	Temp Element	945	---	944	TI-14
C236-13	Temp Element	945	---	943	TI-14
C236-14	Temp Element	945	---	943	TI-14
C236-15	Temp Element	945	---	949	TI-14
C236-16	Temp Element	945	---	949	TI-14
C237-1	Fuel Exit	945	---	950	Scanner Cont. Rec. only
C237-2	Fuel Exit	945	---	949	Scanner Cont. Rec. only
C239-1	Fuel Exit	945	---	948	Scanner Cont. Rec. only
C239-2	Fuel Exit	945	---	947	Scanner Cont. Rec. only
C246-1	Fuel Exit	945	---	947	Scanner Cont. Rec. only
C246-2	Fuel Exit	945	---	948	Scanner Cont. Rec. only
C248-1	Fuel Exit	945	---	945	Scanner Cont. Rec. only

TABLE IV CONTINUED

Channel	Function	Simulated Input (F)	Multipoint Recorder Readings (F)	Continuous Recorder Readings (F)	Remarks
C248-2	Fuel Exit	945	---	943	Scanner Cont. Rec. only
C250-1	Fuel Exit	945	---	946	Scanner Cont. Rec. only
C250-2	Fuel Exit	945	---	946	Scanner Cont. Rec. only
M3-1	Moderator Can	945	---	943	TI-9
M3-2	Moderator Can	945	---	943	TI-9
M3-3	Moderator Can	945	---	942	TI-9
M3-4	Moderator Can	945	---	943	TI-9
M3-5	Moderator Can	945	---	943	TI-9
M3-6	Moderator Can	945	---	943	TI-9
M3-7	Moderator Can	945	---	943	TI-9
M3-8	Moderator Can	945	---	943	TI-9
M3-9	Moderator Can	945	---	943	TI-9
M3-10	Moderator Can	945	---	942	TI-9
M3-11	Moderator Can	945	---	944	TI-9
M3-12	Moderator Can	945	---	942	TI-9
M3-13	Moderator Can	945	---	944	TI-9
M3-14	Moderator Can	945	---	942	TI-9
M3-15	Moderator Can	945	---	943	TI-9
M3-16	Moderator Can	945	---	943	TI-9

TABLE V

TEMPERATURE INSTRUMENT ALARM SETTINGS

Instr. Tag No.	Alarm Tag No.	Alarm Description	Alarm Setting (F)
TI-108	TAH-105	High Temp Motor Pri Pump No. 1	230
TI-208	TAH-205	High Temp Motor Pri Pump No. 2	230
TI-308	TAH-305	High Temp Motor Pri Pump No. 3	230
TI-109	TAH-106	High Temp Motor Sec Pump No. 1	230
TI-209	TAH-206	High Temp Motor Sec Pump No. 2	230
TI-309	TAH-306	High Temp Motor Sec Pump No. 3	230
TI-113	TAH-107	High Temp Coupling Pri Pump No. 1	230
TI-213	TAH-207	High Temp Coupling Pri Pump No. 2	230
TI-313	TAH-307	High Temp Coupling Pri Pump No. 3	230
TI-114	TAH-108	High Temp Coupling Sec Pump No. 1	230
TI-214	TAH-208	High Temp Coupling Sec Pump No. 2	230
TI-314	TAH-308	High Temp Coupling Sec Pump No. 3	230
TI-402	TAH-402	High Temp Sec Na Service Pump	800
TI-403	TAH-403	High Temp Pri Na Service Pump No. 1	800
TI-404	TAH-404	High Temp Pri Na Service Pump No. 2	800
TI-414	TAH-414	High Temp Na Transfer Pump	400
TI-19	TAH-19	High Temp BF ₃ Chamber	150
TI-20	TAH-20	High Temp BF ₃ Chamber	150
TR-1	TAH-12	High Temp Throttle & Block Valves	180
TR-2	TAH-11	High Temp Reactor Outlet	1000
TR-4	TAH-103	High Temp Main Pumps Seal Oil	150
TR-12	TAHL-5	High-Low Temp Fuel Elements	550,1200
TR-13	TAHL-6	High-Low Temp Fuel Elements	550,1200
TR-402	TAH-413	High Temp Service Valves	180
TR-3A	TAHL-3A	Fuel Outlet Scanner	920,970
TR-3B	TAHL-3B	Fuel Outlet Scanner	920,970
TR-102	TAH-102	High Temp IHX No. 1 Outlet	690
TR-202	TAH-202	High Temp IHX No. 2 Outlet	690
TR-302	TAH-302	High Temp IHX No. 3 Outlet	690
TR-6	TAH-26	Fuel Outlet Scanner	970
TR-7	TAH-27	Fuel Outlet Scanner	970
TR-8	TAH-28	Fuel Outlet Scanner	970
TR-9	TAH-29	Fuel Outlet Scanner	970
TR-10	TAH-30	Fuel Outlet Scanner	970
TR-11	TAH-31	Fuel Outlet Scanner	970

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
DRY CRITICALITY

AI-P-1155

Test and Analysis
by
H. C. KEMPT

Evaluation
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CONTRACT: AT(11-1)-GEN-8

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PREOPERATIONAL TEST COMPLETION REPORT

DRY CRITICALITY, AI-P-1155

I. PURPOSE OF TEST

The purpose of this test was to determine the minimum critical mass of the HNPF core without sodium. The data obtained will subsequently be used to determine the reactivity worth of sodium which is normally present in the core. It is important to know the worth of the sodium so that adequate shutdown margin can be assured for the unlikely event of complete loss of sodium. A subcritical calibration of the central control rod was performed and the relative reactivity worths of the inner ring of six control rods were determined. In addition, the data obtained will be used to adjust pre-critical physics calculations.

II. DISCUSSION OF TEST PERFORMANCE

There was no sodium in the reactor during this test and the core was at ambient temperature. Three fission chambers were placed in the core in positions C-191, C-215 and C-239. These chambers had three important functions; first, control; second, protection; and third, to obtain required data. These instruments were required because the normal nuclear instrumentation is insensitive to low neutron flux levels. Before criticality was obtained, however, the source range instruments (BF_3 chambers) were on scale. Figure 1155-1 shows how the three scalers, two automatic digital printers and the dual preset counter were arranged. Two of the startup channels recorded automatically, while the third was recorded manually, as required. On each of the incore channels a high level scram was set at 90% and an alarm was

set at 75% of full scale. In addition, each range switch had a physical stop on the 10^6 range. This was done so that saturation of the incore instruments could not occur and to maintain the count rate below the point where resolution time errors would be appreciable. The resolution time (τ) for these instruments was determined to be 3.67×10^{-8} min. Thus, saturation would occur at approximately 2.7×10^7 com. to correct for resolution time errors the following relationship was utilized:

$$c_a = \frac{c_m}{1 - \tau c_m}$$

where,

c_m is the measured count rate

c_a is the adjusted count rate

τ is the resolution time of the circuitry

Resolution corrections were applied for count rates greater than 1.36×10^5 cpm where c_a is approximately 0.5% greater than c_m .

Period alarm set points on the source range instruments were set at a 30 sec period. Period scram set points were set at 5 sec and setback setpoints were set at 20 seconds on the intermediate range channels.

In addition, a final backup high flux scram was set at approximately 2% of full power flux on three of the normal power range protective system instruments. This was a coincidence scram requiring two of the three instruments to be at the scram setpoint in order to cause a scram. The in-fuel thermocouples of the fuel element in core position C-3 were connected to temperature recorder TR-12. A high temperature alarm was set at 25 F above ambient. Upon the annunciation of this alarm, "High Temp Fuel Elements", the operator was required to manually scram the reactor.

The control rods must be disconnected from their respective drive mechanisms and the control rod support carriage removed from the loading face in order to load fuel into the reactor. Accordingly, the poison section of the control rods is in the fully inserted position during any fuel loading operation.

Fuel elements were loaded into the active core with the fuel handling machine (FHM). A licensed HNPF operator was stationed on the FHM. During the insertion of each fuel element, the control room operator watched the nuclear instruments and maintained continuous, direct communication with the fuel handling machine. The licensed operator wore a telephone head set which provided an audible indication of the neutron count rate so that he could make an independent determination of reactor conditions and if necessary stop or reverse the fuel handling machine.

After each incremental fuel loading the corresponding shield plugs in the loading face shield were helium leak checked to detect any reactor cover gas leakage. Then the control rod support carriage was placed on the loading face and bolted down. A standard operating procedure was performed (SOP 5003, Testing of the Control Rod Drive Operation) each time the control rod support carriage was reinstalled to verify the operability of the control rods.

A temporary SOP was written for the dry, zero power experiments to be used each time prior to startup in checking out the instruments required for reactor operation. A total of seven nuclear instruments was required throughout the tests. These were three incore fission chambers, two source range instruments (BF_3 's), and two intermediate range instruments (compensated ion chambers).

The Technical Specifications for the dry, zero power experiments specified the maximum operating conditions to be allowed during the tests. In general, the Technical Specifications defined the instrumentation required, the

operating equipment required, and the administrative controls required throughout the test. The loading of fuel was specified by the Technical Specifications as follows:

- a) The first two fuel loading increments will be 9 and no more than 6 fuel elements respectively.
- b) Each subsequent loading increment will not be greater than four fuel elements.
- c) Multiplication measurements will be made with control rods down after each element is inserted. When the multiplication as indicated by any of the three incore channels reaches a value of 10 during or following the insertion of any fuel element, this will be deemed a fuel loading increment. The increments, after reaching a multiplication of 10, will be limited to one element.
- d) After each incremental loading, curves of inverse multiplication will be plotted as functions of the number of fuel elements in the core. Extrapolation of the various curves to zero, or $k_{\text{eff}} = 1$, will be made prior to loading the next increment of fuel.
- e) The next increment will be no more than 1/2 the number of additional elements needed to reach the extrapolated critical loading. However, if the extrapolation indicates that less than two elements are required, one element will be loaded.
- e) Following the second incremental loading, the rods in and rods out inverse multiplication curves will be extrapolated to predict the worth of the control rods in terms of number of fuel elements and no loading increment thereafter will exceed 1/2 of this estimated worth.

In addition to the aforementioned specifications, the minimum allowable count rate was 300 on the incore instruments and the maximum scram level was no higher than 3,000 times source critical. Since the minimum count rate was 300 and the maximum scram level 9×10^5 counts per minute because of the physical stop on the range switches, the 3,000 times source critical scram requirement was inherent in the system.

Prior to loading any fuel, source count rate data was obtained in order to determine multiplication (M). Multiplication on any incore channel was defined as follows:

$$M = C_f / C_o$$

where,

C_o = count rate with no fuel

C_f = count rate with fuel

After each incremental loading, a point was plotted appropriately in each of the following inverse multiplication graphs:

Inverse of the average multiplication vs.

- 1) Number of fuel elements (N)
- 2) Square root of number of elements ($\sqrt{N}$)
- 3) Log of number of elements (Log N)
- 4) A factor proportional to radial buckling (B_r^2)

where,

$$B_r^2 \text{ is proportional to } \frac{10^5}{(R + S)^2}$$

and,

$$R = \sqrt{\frac{NA}{\pi}}$$

N = number of fuel elements

A = fuel cell area (870 cm^2)

S = reflector savings (approximately 22 cm)

These plots were maintained for the following control rod configurations:

- 1) all rods in
- 2) gangs 1, 2, 3, out; 4 and 5 in

- 3) gangs 1, 2, 3, in; 4 and 5 at 50%
- 4) all rods out

The number of control rods in each gang and the core position of each is given in Table I. Figure 1155-2 shows the location of the rods in the reactor.

TABLE I
CONTROL ROD POSITIONS

Gang No.	No. of Rods	Core Position
1	6	C-78, C-118, C-110, C-102, C-94, C-86
2	6	C-38, C-68, C-62, C-56, C-50, C-44
3	3	C-20, c-28, c-36
4	3	C-16, C-24, C-32
5	1	C-1 (central rod)

Control rod gangs 1, 2, and 3 were withdrawn as one bank, and the inverse of the average multiplication was determined and plotted. After determining that the core was sub-critical, control rod gangs 4 and 5 were withdrawn 50%, observing that the core remained sub-critical. Inverse of the average multiplication was again determined and plotted. Control rod gang 5 was then fully withdrawn. Observing that the core remained sub-critical, gang 4 was withdrawn the remaining 50% and the inverse of the average multiplication determined and plotted (all rods out). When it was thought that criticality would be reached on withdrawal of control rod gang 4, individual rods of this gang were withdrawn in 6-inch increments, until criticality was reached. The reactor was made critical on gang 4. This was desirable since it was expected that gang 4 would be worth less than gang 5 and thus criticality would be approached more slowly.

After criticality was reached with gangs 1, 2, 3 and 5 fully withdrawn and gang 4 in the critical position, gang 5 was inserted in 6-inch increments until fully inserted. Sub-critical multiplications were determined for each incremental insertion.

In turn, the relative reactivity worths of each of the six control rods in gangs 3 and 4 were determined. This was done by first bringing the reactor critical with the rod to be evaluated fully withdrawn and then fully inserting this rod and determining the multiplication. From this multiplication data, the relative reactivity worths of the central seven control rods were obtained.

The 31 fuel elements required for criticality were loaded in increments of 9, 2, and 3 elements, and seventeen one element loadings.

Table II shows the actual fuel loading sequence. The sequence for loading the twelfth through the nineteenth elements was rearranged from the original loading scheme.

TABLE II
FUEL LOADING SEQUENCE

1. C-11	9. C-5	17. C-15	25. C-34
2. C-12	10. C-9	18. C-17	26. C-18
3. C-3	11. C-6	19. C-27	27. C-22
4. C-2	12. C-25	20. C-19	28. C-30
5. C-10	13. C-35	21. C-21	29. C-14
6. C-31	14. C-8	22. C-29	30. C-53
7. C-33	15. C-7	23. C-37	31. C-65
8. C-13	16. C-23	24. C-26	

After 26 fuel elements were loaded, the fission chambers had to be moved to de-sensitize them in order to prevent reaching the scram point before all of the rods could be withdrawn. This was accomplished by withdrawing two of the chambers to the top of the moderator cans and inserting one to the bottom of the moderator cans.

At the critical loading of 31 fuel elements, it was necessary to move the chambers again in order to establish a period and achieve criticality. To indicate the relative positions of the incore chambers, the loading face shield (LFS) was taken as 0 inches. Then the top of the moderator cans is 258 in. below the LFS, the center line of the core 362 in. below the LFS, and the bottom of the moderator cans 465 in. below the LFS. Through the loading of 26 fuel elements the chamber positions of incore channels 11, 12, and 13 were 415, 410, and 410 in. respectively; from 27 to 31 fuel elements, the chamber positions were 263, 452, and 452 in. respectively. At criticality (31 fuel elements) the positions were 191, 452, and 268 in. respectively.

Some difficulties were encountered on the approach to criticality with 31 fuel elements, before criticality was attained. First, a high flux scram occurred on the incore channels because there was not enough counting range to reach criticality. Two fission chambers, channels 11 and 13, were then moved above the core. This was performed with control rod gangs 1, 2, 3, and 5 fully withdrawn and gang 4 withdrawn 50%. After the two were moved, channel 12 was deactivated since it was not working properly. The approach to criticality was attempted again and criticality was successfully attained with control rod gangs 1, 2, 3, and 5 fully withdrawn and gang 4 at 132.0 inches. This produced approximately a 370 sec period. Next the flux was reduced by inserting gang 4 and then withdrawing gang

4 to approximately 132.8 inches. This time a 260 sec period was attained. The flux rise was stopped by inserting gang 4 until a steady state flux level was achieved. This occurred with gang 4 at approximately 131 inches. From the data obtained in the dry excess loading, it was determined that the minimum critical mass was 30.6 fuel elements.

When the reactor was put on a period, nuclear heating occurred as evidenced by a two to three degree fahrenheit temperature rise of the in-fuel thermocouples in the fuel element in core position C-3. During the test which followed (Dry Excess Loading AI-P-1163), it was necessary to perform period measurements between point B and point A. Point B (true criticality) is the lowest flux level where the effect of the source is negligible. Point A is the flux level where nuclear heating occurs and was defined as a 2 F rise in fuel temperature. It was apparent from the approach to criticality that the range between point B and point A was limited. In order to minimize nuclear heating and to reduce the critical flux level, the strength of the source was reduced. This was accomplished by separating the antimony capsule from the beryllium sleeve. The antimony and beryllium sections are both approximately 10 in. long. However, it was found that the antimony capsule had to be withdrawn 29 in. in order to obtain about a decade and a half of counting range on the incore instruments. A procedure was written and approved for accomplishing the source separation operation.

Subcritical multiplication data was obtained in order to find the relative integral reactivity worth of the central control rod in the dry critical loading (Figure 1155-7).

The loading was performed around the clock on a 24-hour basis and criticality was achieved at 0322 on January 19, 1962 (on schedule). All operations were performed in accordance with master test procedure, Dry Criticality, AI-P-1155.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

Table III shows the extrapolated critical loading for the various plots after each incremental fuel loading with all rods out. Figures 1155-3, -3a, -3b, -3c, -4, -4a, -4b, -5, -5a, and -6 are plots of inverse average multiplication vs functions of fuel loading. Table IV is a tabulation of the multiplication data taken throughout the dry critical test.

After the first nine elements were loaded, a linear extrapolation of the "rods-out" points indicated that criticality would occur at 10 1/2 elements, (See Figure 1155-3a). However, from a plot of inverse average multiplication with "rods-in", (Figure 1155-3), determined from data taken after each of the first nine elements was loaded, it can be seen that the curve is taking the characteristic bend. Therefore, the "rods out" curve should also assume this shape. For the second step, two fuel elements were loaded. The third loading was three elements after which a multiplication of 10 was reached on two incore instruments. Thus, from this loading until criticality was attained, only one element per increment was loaded. The inverse average multiplication plots and data compiled in Table IV have been corrected for source decay and normalized for changes in fission chamber location. It can be seen from the plots that there was a definite break in the extrapolated critical mass curves upon loading the 21st fuel

TABLE III

EXTRAPOLATED CRITICAL LOADING

No. of Elements Loaded	Linear Plot (N)	Square Root Plot (N)	Log Plot (Log N)	Radial Buckling (B_r^2)
9	10.5	12.3	----	----
11	16.8	19.0	20.0	25.5
14	19.5	20.3	21.5	25.5
17	22.0	22.0	23.5	25.0
18	22.2	22.0	23.2	23.5
19	24.5	25.0	25.3	27.0
20	22.8	23.0	23.7	24.0
21	26.8	27.0	27.5	28.5
22	26.5	27.0	27.5	29.0
23	26.8	27.0	27.5	27.5
24	27.4	27.5	27.5	28.0
25	28.0	28.5	29.0	29.0
26	30.0	30.5	31.0	31.0
27	30.0	30.2	30.5	30.7
28	31.0	31.2	31.0	31.5
29	31.3	31.4	31.5	31.4
30	30.5	30.5	30.5	30.5

element. It was concluded that the source neutrons, at approximately 50 Kev, have a much less probability of reaching the fission chambers than the high energy fission neutrons. Therefore, the count rates obtained without fuel were low relative to count rates obtained with fuel. Thus, the apparent multiplication (determined from the incore channels) was higher than the "true" multiplication.

It should be noted that the linear plot is extremely conservative. The buckling plot appears to have merit because even after two loadings of fuel (9 and 11) a critical loading of 25.5 elements was extrapolated. In addition, the log plot and square root plot indicated the critical loading more closely than the linear plots. When near criticality, (within five or six elements) all four plots were of equal value.

It was concluded that a shaping factor (square root, log, radial buckling) should be used to extrapolate criticality, especially during the first few fuel loading increments.

As the loading approached 30 elements, it was obvious that the analytical calculation of 23 fuel elements for criticality, was in error. After criticality was attained, further analysis indicated that the effect of the source had been neglected in the original calculations. The importance of the source core position, C-4, was overlooked. Recalculation, accounting for the source and not a fuel element in C-4, indicated that criticality would be achieved with 32 ± 2 fuel elements. It was concluded that the difference in worth between the source and a fuel element in this location was approximately 4% Δk_k .

In order to find the relative integral reactivity worth of the central control rod in the dry critical loading, subcritical multiplication data were obtained. A plot of these data is shown in Figure 1155-7. It should

TABLE

		0	26	27	28	29	30	31
Total Number of Fuel Elements Loaded (N)		0	26	27	28	29	30	31
Number of Fuel Elements Loaded This Step		0	1	1	1	1	1	1
Channel of Last Fuel Element Loaded		0	C18	C22	C30	C14	C53	C65
Square Root of N		0	5.099	5.196	5.291	5.385	5.477	5.568
Factor Proportional to B_{∞}^2		---	8.76	8.50	8.26	8.028	7.813	7.608
All Control Rods Out								
	Multiplication FC in C-191 (11)	1.0	38.23	41.412	42.581	46.16	48.30	48.808
	Multiplication FC in C-215 (12)	1.0	27.89	28.048	29.886	30.65	38.08	40.176
	Multiplication FC in C-239 (13)	1.0	13.14	14.658	15.994	17.72	17.33	23.989
	Average Multiplication	1.0	26.42	28.039	29.487	31.51	34.57	37.653
	Inverse of Average Multiplication	1.0	0.0379	0.03566	0.03391	0.0317	0.0289	0.066
Gages 1, 2, 3 Out: 4 and 5 50%								
	Multiplication FC in C-191 (11)	1.0	121.43	143.01	156.01	183.20	214.55	261.95
	Multiplication FC in C-215 (12)	1.0	90.11	103.11	120.61	130.50	216.86	275.39
	Multiplication FC in C-239 (13)	1.0	31.68	35.926	44.72	51.12	61.50	107.58
	Average Multiplication	1.0	81.07	94.02	107.11	121.61	164.30	214.97
	Inverse of Average Multiplication	1.0	0.0123	0.0106	0.009336	0.0082	0.00609	0.00465
All Control Rods In								
	Multiplication FC in C-191 (11)	1.0	32.40	312.14	401.76	595.24	7643.47	
	Multiplication FC in C-215 (12)	1.0	178.50	231.45	310.70	421.00	641.41	
	Multiplication FC in C-239 (13)	1.0	63.84	81.38	116.83	166.84	473.69	
	Average Multiplication	1.0	158.25	208.32	276.43	394.36	1252.86	
	Inverse of Average Multiplication	1.0	0.00632	0.00480	0.003618	0.0025	0.000798	

be noted that the integral reactivity worth curve is asymmetrical. The first 50% of rod withdrawal is worth more than the last 50%. In addition, the relative worths of the control rods of gangs 3 and 4 were found from subcritical multiplication data and compared to the central control rod. These relative worths are tabulated in Table V. From these relative worths it was concluded that gangs 3 and 4 were worth approximately one and one-half times the central control rod in the dry critical loading. The delta k's tabulated in Table V were derived from the relationship $k_{\text{eff}} = 1 - 1/M$. It has already been pointed out that the measured or apparent multiplication was higher than the true multiplication. Therefore, there was no concern about the indicated low worths of the control rods.

TABLE V

RELATIVE REACTIVITY WORTHS OF THE 7 CENTRAL CONTROL RODS

Core Position	Gang Number	Relative Worth	Delta K
C-1	5	1.000	.00944
C-16	4	.289	.00273
C-24	4	.265	.00260
C-32	4	.239	.00226
C-20	3	.248	.00234
C-28	3	.259	.00245
C-36	3	.219	<u>.00207</u>
			Σ .02389

With the source strength reduced, point B was determined. Figure 1155-8 is a plot of critical control rod position vs neutron flux level. The count rate at which the control rod position became constant as new steady flux

levels were attained was defined as point B. Point B was marked on the source range count rate meters on the main board at approximately 300 cpm.

Figure 1155-9 is a plot of k_{eff} vs the number of fuel elements derived from subcritical multiplication data as in the case of the control rod worths. Figure 1155-10 shows the apparent inverse multiplication plot for the individual chambers.

The experience gained from this test indicates that restrictions on loading of fuel could be minimized. A restriction, such as: "No more than one half the number of additional fuel elements needed to reach extrapolated critical loading, plus one, may be loaded per fuel increment," may suffice. Also, it appears that it would be more advantageous to derive the extrapolated critical loading from plots of inverse average multiplication vs several functions of fuel loaded (N , $\sqrt{N}$, $\log N$, B_r^2). Further, it was found that the most meaningful plots of inverse multiplication were based on the average rather than the individual multiplications of the three incore instruments.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

In Supplement 4 of NAA-SR-5700, Safeguards Report for the HNPF, the test completion criteria for the Dry Criticality Test, AI-P-1155, are: (a) the reactor is made critical with a minimum number of fuel elements in the dry core, and (b) a subcritical calibration of the central control rod has been made. These criteria were satisfactorily met.

V. EVALUATION

The dry critical experiment was conducted in a very safe, conservative manner. The loading procedure followed was slow but yielded additional data for analysis and evaluation.

The test completion criteria as stated in the test procedure have been met. The reactor was made critical, data was taken which will be used in determination of sodium worth, the pre-critical physics calculations have been adjusted and the sub-critical calibration of the central seven control rods has been made.

The performance of the test and evaluation of the results have indicated two areas which will require further investigation:

- a) Predicted Critical Mass
- b) Control Rod Worth

A. PREDICTED CRITICAL MASS

The difference between predicted and actual critical loading required re-evaluation of calculations made to predict "dry" and "wet" critical mass. Prior to the dry critical experiment, the predicted dry critical loading was 23 ± 2 fuel elements, and the predicted wet critical loading was approximately 37 elements (Safequards Report on Dry, Zero-Power Experiments in HNPF, Supplement 1, NAA-SR-5700). When it became apparent that criticality would not be achieved with a 23 fuel element loading the calculations were reviewed to evaluate discrepancies between actual and assumed core conditions. The neutron source, which replaces a fuel element in a position of maximum worth has an appreciable negative reactivity effect, particularly in the small core. Calculations were made accounting for the presence of the source. The results are presented in Figure 1155-11. The calculated critical loading, with the source, is close in agreement with actual critical loading. The new prediction for wet critical loading, with the source, is 50 ± 5 fuel elements. Although calculated

and actual critical mass are now in close agreement, further evaluation of calculated and actual fuel element worths will be made during Dry Excess Loading.

B. CONTROL ROD WORTH

A preliminary evaluation of "rods-down" apparent multiplication in the subcritical loading indicates the calculated control rod worths may be in error. The test data, thus far, are inconclusive. Further evaluation will be made when data are available from the Dry Excess Loading, AI-P-1163

Figure 1155-1. Arrangement of Nuclear Counting Instruments

NOTE:

Core positions prefixed by "C" have removable plugs in loading face shield.

Position C-3 contained a thermocoupled fuel element.

M-3 is the instrumented moderator can.

LEGEND	
	CONTROL RODS
	SOURCE
	SODIUM LEVEL MEASURING ELEMENT
	SODIUM TEMPERATURE MEASURING ELEMENT
	REGULAR FUEL ELEMENT
	REFLECTOR FILLER
	IN-CORE FISSION CHAMBERS

Figure 1155-2. HNP Dry Critical Loading

Figure 1155-3. Inverse Average Multiplication vs Number of Fuel Elements With All Rods In

Figure 1155-3a. Inverse Average Multiplication vs Number of Fuel Elements

Figure 1155-3b. Inverse Average Multiplication vs Number of Fuel Elements

Figure 1155-4. Inverse Average Multiplication vs Square Root of Number of Fuel Elements

Figure 1155-4a. Inverse Average Multiplication vs Square Root of Number of Fuel Elements

Figure 1155-4b. Inverse Average Multiplication vs Square Root of Number of Fuel Elements

Figure 1155-5. Inverse Average Multiplication vs Factor Proportional to Radial Buckling

Figure 1155-5a. Inverse Average Multiplication vs Factor Proportional to Radial Buckling with all Rods Out.

Figure 1155-6. Inverse Average Multiplication vs Logarithm of Number of Fuel Elements

Figure 1155-7. Sub-Critical Calibration of the Central Control Rod at the Dry Critical Loading 31 Fuel Elements

Figure 1155-8. Critical Rod Position vs Flux Level

Figure 1155-9. Plot of K_{eff} vs Number of Fuel Elements

Figure 1155-10. Inverse Average Multiplication vs Number of Fuel Elements for the Individual Fission Chambers - All Rods Out

Figure 1155-11. Plot of Predicted K_{eff} vs No. of Fuel Elements

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
INITIAL FILL OF THE SECONDARY SYSTEM WITH SODIUM

AI-P-1156

Test and Analysis
by
L. E. KELLER
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Evaluation
by
O. G. JENKINS

A T O M I C S I N T E R N A T I O N A L
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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
INITIAL FILL OF THE SECONDARY SYSTEM WITH SODIUM, AI-P-1156

I. PURPOSE OF TEST

The purpose of this test was to verify that the three secondary heat transfer loops can be safely and efficiently filled with sodium.

II. DISCUSSION OF TEST PERFORMANCE

Each of the three secondary sodium loops was filled separately to a predetermined expansion tank level. Prior to each filling operation, the helium atmosphere within the loop was checked for impurities, and temperatures throughout the loop were brought within prescribed limits. Sodium temperature in the secondary fill tanks was also adjusted to an optimum value, immediately prior to each filling operation. The considerations which dictated the temperature limits were twofold:

- 1) The sodium must be maintained at a sufficiently high temperature to prevent solidification.
- 2) The temperature of each component in the loop must be at or near the temperature of the entering sodium to prevent thermal shock.

Consideration 2) above is especially important for the superheater and the evaporator. The tube sheet welds in these components could be severely over-stressed by an excessive temperature differential.

The secondary sodium service EM pump was used to fill each loop. Sodium was introduced into each loop at the throttle valve, which is the low point in the loop, and the helium was allowed to exhaust to atmosphere at the expansion tank.

Each of the secondary sodium pumps was started immediately after the loop was filled. The initial 48 hours of operation for each secondary sodium pump was included in this test procedure.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

Conditions enumerated below were satisfied prior to the introduction of sodium in each of the secondary loop filling operations:

- 1) Oxygen content of the atmosphere within the sodium loop was less than 0.5%.
- 2) The steam generator third fluid helium system was in operation and pressurized to 45 psig.
- 3) The helium relief valve on the expansion tank was set at approximately 5 psig and the corresponding pressure control valve was set slightly lower than the relief valve setting.
- 4) Helium supply to the secondary fill tank(s) being used was in operation and the pressure control valve set at 20 psig.
- 5) The secondary sodium heat transfer loop including the intermediate heat exchangers (IHX), expansion tank, pump, and 14 in. and 20 in. sodium pipes, but excluding the steam generator was preheated; each component was retained at an average temperature of $300\text{ F} \pm 25\text{ F}$ with no thermocouple reading more than 350 F nor less than 275 F.
- 6) The steam generator was preheated and retained at an average temperature of $300\text{ F}, +25\text{ F} - 0\text{ F}$, with a maximum of 350 F and a minimum of 300 F, using surface thermocouples only.
- 7) Sodium used in the filling operation was retained at a temperature equal to the average steam generator temperature $+ 25\text{ F}, - 0\text{ F}$.
- 8) The plugging temperature of the sodium in the secondary fill tanks was less than 280 F.

In each of the three filling operations, the sodium flow path was from a secondary sodium fill tank, through the secondary sodium service EM pump, and into the secondary sodium throttle valve; from the throttle valve, sodium flow was divided into two paths:

- 1) One flow path was through the two IHX's to the expansion tank.
- 2) The other was through the evaporator, superheater, secondary sodium pump and into the expansion tank.

Helium was automatically exhausted to atmosphere through the relief valve on the expansion tank.

The flow of sodium was followed upward through the loop by observing the process and surface thermocouples which are a part of the system components and piping.

As soon as sodium was detected in the expansion tank, the level in the tank was monitored by the portable "search coil" sodium level indicator which had been placed in the expansion tank level-alarm thimble. As the sodium level approached the desired elevation, the voltage to the secondary sodium service EM pump was decreased. It was then possible to control the sodium flow rate accurately and to establish the final sodium level exactly at the desired elevation ($\sim 1468' - 6''$).

Immediately after filling each loop, the associated secondary sodium pump was rotated by hand to insure that it was not binding. The pump was started and the speed increased slowly to 125 rpm. The pump was placed on manual speed control and allowed to run at 125 rpm for the first 48 hours. During this time, the entire secondary sodium loop was observed closely for any indication of abnormal operation.

Items of interest concerning the fill of each of the three secondary sodium loops are described in the following pages:

A. FILL OF SECONDARY SODIUM LOOP NO. 2

Secondary sodium loop No. 2 was filled first. The filling operation proceeded as described above.

The oxygen content in the loop before filling was less than 0.5% and the moisture content provided less than 10% relative humidity. Sodium flow was initiated from secondary fill tank No. 2. As the level was rising in the expansion tank, secondary fill tank No. 2 was emptied and the suction lost on secondary EM pump. The loop was then isolated from the service system; several hours were required to prepare for sodium flow from another fill tank. Sodium flow was established from secondary sodium fill tank No. 3 and the filling operation completed. Total time required to fill loop No. 2 was 6 hours 45 minutes. The initial 48 hour operation of secondary sodium

pump No. 2 proceeded satisfactorily; all temperature, pressure, level, and flow instrumentation in this system appeared to function properly.

B. FILL OF SECONDARY SODIUM LOOP NO. 3

Secondary sodium loop No. 3 was filled next. The filling operation proceeded without incident.

The oxygen content in the loop before filling was less than 0.5% and the moisture content provided less than 10% relative humidity. Sodium was used from both secondary sodium fill tanks No. 2 and No. 3. Total time required to fill loop No. 3 was 1 hour 35 minutes. The initial 48 hour operation of secondary sodium pump No. 3 proceeded satisfactorily. All temperature, pressure, level and flow instrumentation in this system appeared to function properly.

C. FILL OF SECONDARY SODIUM LOOP NO. 1

Secondary sodium loop No. 1 was filled last and the filling operation proceeded without incident.

The oxygen content in the loop before filling was less than 0.5%; however, the relative humidity was ~26%. Sodium was used from both secondary sodium fill tanks No. 1 and No. 2. Total time required to fill loop No. 1 was 2 hours 45 minutes. Prior to starting secondary sodium pump No. 1, it was found that the pump could not be rotated by hand. The pump was started successfully by energizing the magnetic coupling slowly; no detrimental effects were observed during the initial 48 hour performance run. All temperature, pressure, level, and flow instrumentation in the system appeared to function properly.

Through accurate measurements of secondary fill tank levels and expansion tank levels, it was determined that the volume of secondary loop No. 1, when filled to elevation 1468' -9", was 1300 cubic feet.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the test completion criteria associated with preoperational test AI-P-1156, Initial Fill of the Secondary System With Sodium, as listed in NAA-SR-5700, Supplement 4, Page XI (a)-72 with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: The secondary sodium loops are filled with sodium to 75 ± 2 inches in the loop expansion tank at preheat temperature. (Equivalent to normal sodium charge in the system.)

Remarks: It was determined that 75 ± 2 inches in the loop expansion tank corresponded to 12 inches above the sodium pump low level alarm. The elevation of the pump low level alarm was, therefore, used as a reference in filling the loops.

- b) Criterion: The sodium level, pressure, temperature, and flow instruments associated with the secondary loops fill operations function properly as evidenced by actual use.

Remarks: The sodium pressure, temperature, and flow instrumentation associated with the fill of the secondary sodium loops functioned properly during this preoperational test. Some sodium level process instrumentation required adjustment; therefore, the "search coil" portable level indicator was used to measure sodium levels accurately.

V. EVALUATION

A test of this type is designed primarily for the purpose of determining that the standard operating procedure does work as expected. The initial fill of the HNPF secondary heat transfer system was accomplished using essentially the same method outlined in the HNPF Operating Manual (SOP No. 1102). However, additional steps were introduced during the filling operation.

The gas in the loops was sampled for oxygen content and relative humidity prior to filling, and the approximate volume of sodium required for filling was determined. In addition, extra precautionary steps were

taken during the initial filling operation; none of these steps being specified as part of the standard operating procedure.

The fact that only minor difficulties were encountered while filling all three loops to operating level verifies that the standard operating procedure is adequate. This evaluation will discuss the propriety of the additional steps taken, as applicable to future filling operations.

A. ESTABLISHMENT OF $<0.5\%$ OXYGEN CONCENTRATION IN THE PIPING

If the systems were filled without checking the oxygen content of the piping, sodium oxide could be formed as the result. The maximum amount that could be formed would be dependent upon the piping being full of air. In such case, assuming that all the air in the piping reacts with the sodium, approximately 70 pounds of sodium oxide would be formed for each loop filled under this condition, or a total of 210 pounds of oxide for all three loops. This is not catastrophic, since one cold trap can remove about 200 pounds of oxide, but should be avoided. Restriction of oxygen content to less than 0.5% prevents formation of more than 5 pounds of sodium oxide.

B. ESTABLISHMENT OF $<10\%$ RELATIVE HUMIDITY

If the humidity of the gas in the piping were not checked prior to filling, it is possible, although extremely unlikely, that the piping could contain considerable water vapor. At 300 F and 5 psig, a maximum of 63 pounds of water (in the form of superheated steam) could conceivably be present in each loop. If all this water reacted with the sodium, 215 pounds of sodium oxide per loop would be formed, or a total of 645 pounds of oxide for all three systems.

The relative humidity of the purge gas was measured at room temperature. Under these conditions an indicated relative humidity of 100%

is equivalent to the presence of 1.4 pounds of water per loop, which could result in the formation of 5 pounds of sodium oxide per loop, or 15 pounds of oxide for all three loops. However, the highest measured relative humidity during the test was 26%, resulting in a maximum of 1.2 pounds of sodium oxide per loop, a negligible quantity.

C. CONCLUSIONS AND RECOMMENDATIONS

Although it is unlikely that conditions existing at the time of the initial fill of the secondary sodium system will be duplicated, similar procedures should be used when refilling should the loops be drained for any reason. An oxygen sample should be taken prior to filling, and purging initiated, if oxygen content is above 0.5%.

While the loop is drained, every effort should be made to limit the entrance of air into the system as the air will react with the residual sodium immediately. Subsequent purging is ineffective in removing oxides formed in this way.

Relative humidity should also be determined prior to filling. A measured relative humidity which is definitely less than 100%, is adequate. Purging to a lower relative humidity, 80% for example, is expensive and unnecessary.

HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
INITIAL FILL OF THE PRIMARY SYSTEM WITH SODIUM

AI-P-1157

Test and Analysis

by

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Evaluation

by

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A T O M I C S I N T E R N A T I O N A L

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HALLAM NUCLEAR POWER FACILITY
PREOPERATIONAL TEST COMPLETION REPORT
INITIAL FILL OF THE PRIMARY SYSTEM WITH SODIUM, AI-P-1157

I. PURPOSE OF TEST

The purpose of this test was to verify that the Primary Heat Transfer System can be filled with sodium safely and efficiently and to determine the volume of sodium required.

II. DISCUSSION OF TEST PERFORMANCE

Prior to starting the fill operation, the primary system was purged with helium and preheated to approximately 325 F. Sodium in the fill tanks had been cold - trapped to the degree required to reduce the oxide content below the point corresponding to a plugging temperature of 260 F. The sodium in the fill tanks was held at a temperature of approximately 330 F. Transferred sodium volumes were determined from measurements of fill tank sodium-helium interface levels referenced to floor levels.

The system was filled from the primary fill tanks by a combination of gravity flow and use of the electromagnetic sodium service pumps. The procedure followed was as described in the following pages (Figure 1157-1):

A. FILL OF THE REACTOR VESSEL

The reactor vessel was filled to the low operating level with three block and three throttle valves open;

Figure 1157-1. Primary System Fill Sequence (One Heat Transfer Loop Shown)

the vent lines between the reactor, pump cases, and fill tanks common; and with the intermediate heat exchanger (IHX) freeze traps venting to the radioactive (R/A) vent system. This operation filled the reactor vessel, pump suction lines, horizontal runs of the pump discharge lines, pump impeller housings, and the return lines from the IHX's. Sodium was pumped into the three reactor return lines upstream of the throttle valves by gravity and use of the electromagnetic sodium service pump. The portable sodium level indicating device ("dipstick") was utilized to determine accurately the sodium levels in the fill tanks and the reactor vessel.

B. FILL OF LOOP NO. 1 IHX'S

The two IHX's in loop No. 1 were filled by pumping sodium into the reactor return line upstream of the throttling valve, with the throttling valve closed and the block valve in the loop open. During this operation, the "dipstick" was used to constantly monitor reactor sodium level to determine when the IHX's were full and overflowing through the pump discharge line, hence increasing the core level.

C. FILL OF PUMP DISCHARGE LINE IN LOOP NO. 1

To fill the pump discharge line the loop No. 1 high point freeze trap helium supply valve (V-856), loops No. 2 and No. 3 R/A vent block valves (V-1012 and V-1013, respectively), and the R/A vent header block valves (V-1024 and V-1025) were closed and a vacuum was pulled through an auxiliary tap on the vent header (Figure 1157-2). Sodium for this operation was drawn through the pump suction line from the reactor. Make-up sodium was provided to the reactor vessel from the primary fill tanks by use of the electro-

Figure 1157-2. Auxiliary Equipment for Vacuum Fill of the Primary Pump Discharge Line

magnetic service pump. Progress of the operation was determined by observing the vacuum gage reading and referring to Figure 1157-3.

When it became evident that the inverted bucket float in the freeze trap had closed off, the vacuum in the vent line was increased to 20 in. Hg and maintained there by opening valve XYZ (Figure 1157-2) as required. The freeze seal was assumed to be made when the sodium-side freeze trap temperature decreased to equilibrium. At this time, the freeze trap vent block valve was closed and the vacuum pump was removed from service.

As soon as the line was determined to be filled (by observation of the vacuum gage), the main sodium pump in the loop was turned over by hand and started. The pump was operated for 48 hours at speeds from 135 rpm at the beginning of the run-in period to 190 rpm near the end.

The high-point vent line freeze traps on loops No. 1 and No. 2 leaked air through the cam operating shaft packing at a vacuum of 15.5 in. Hg. The air in each case was drawn into the vent lines, through the vacuum pump and exhausted into the R/A vent header. This necessitated packing a sealing compound around the shaft packing follower to complete the operation. The condition allowing this is being corrected. No hazardous condition exists in the interim, because the freeze seal was designed and made to be retained even if cooling to the cell is lost.

D. FILL OF LOOPS NO. 2 AND NO. 3

Loops No. 2 and No. 3 were filled individually in the same manner as loop No. 1 (B and C, above).

At the beginning of the fill operation on loop No. 3, the valve operator on primary throttle valve No. 3 was

Note: This plot is for
 350 F Sodium.
 Specific Gravity of Na
 at 350 F = .923

Figure 1157-3. Fill of Primary Pump Discharge Line

found to be inoperable. The valve was positioned by hand throughout the procedure. The failure was subsequently determined to be due to excessive wear on a "clutch dog" within the drive. This part had been repaired once in the field as a matter of expediency. New parts ordered at the time of first failure have since been installed.

III. ANALYSIS AND PRESENTATION OF TEST RESULTS

A. FILL OF THE REACTOR VESSEL

A total of 6,690 ft³ of sodium, at an average temperature of about 335 F was required for filling the reactor vessel to elevation 1428 ft 2-1/2 in., the pump suction lines, pump impeller housing, horizontal runs of the pump discharge lines, and the reactor return lines between the IHX's and the reactor vessel. During this operation, primary fill tanks No. 1, 2, 3, and 5 were emptied and No. 4 was used to complete the fill. Total transfer of sodium to the reactor and the above listed lines to fill to the final elevation of 1428 ft 6 in. was 6,780 ft³ as shown in Table I.

TABLE I
SODIUM TRANSFER

Date	Elevation	Core Vessel Na Volume (Ft ³)	Na Volume Transferred To			Na Volume Transferred (Ft ³)	System Na Temp (F)
			Loop 1	Loop 2	Loop 3		
4- 8-62	1428'2-1/2"	6,690	-	-	-	6,690	338
4- 8-62	1428'3"	12	310	-	-	322	338
4-10-62	1428'4"	26	-	246	-	272	338
4-12-62	1428'6"	52	-	-	326	378	340
TOTALS		6,780	310	246	326	7,662	

Fill of the reactor vessel was accomplished smoothly and easily. No difficulties were encountered, and all equipment performed satisfactorily.

B. FILL OF LOOP NO. 1

With loop No. 1 throttle valve closed and the blocking valve open, sodium was pumped into the return line between the throttling valve and the IHX by use of the electromagnetic service pump. As soon as it could be determined that the core sodium level was increasing, the vacuum pump was started and the rate of pumpdown of the vertical line between the IHX and the main sodium pump discharge was controlled by cracking valve XYZ, (Figure 1157-2) to maintain a nearly constant level of sodium in the reactor vessel. A vacuum between 17 and 17.5 in. Hg was required to fill the vertical run of the pump discharge line. A total of 323 cu ft of sodium, at approximately 338 F, was required to complete the filling of loop No. 1 and to raise the core level 1/2 in., leaving a net of 310 cu ft to fill loop No. 1. When it became apparent (by a rapid change of vacuum from 17.5 to 20 in. Hg) that the high-point vent freeze trap inverted bucket had floated-off, the throttle valve was opened completely and the main sodium pump in the loop was started. The pump controls were tuned and control of the pump was transferred to the main board controls. The pump was operated continuously at speeds from 115 to 190 rpm for 48 hours and the following data was recorded:

- 1) Sodium temperature (from TR-4).
- 2) Pump discharge and suction pressures.
- 3) Pump thermal barrier temperatures.
- 4) Pump case sodium high and low alarm meter relay readings.

- 5) Motor winding temperatures.
- 6) Coupling voltage and current.
- 7) Pump speed.
- 8) Reactor sodium level (from "dipstick" readings).
- 9) Room temperature.

The pump performed as expected, with no abnormal noise or motion in the pump, IHX's, valves, or associated equipment. The reactor level remained constant within the limits of measurement accuracy.

A vacuum of 20 in. Hg was maintained on the vent line for over 24 hours, during which time the sodium-side freeze trap temperature stabilized, thus indicating that the sodium seal had frozen-off (the He-side temperature remained below the sodium freezing temperature throughout). At this time, the loop high-point vent block valve was closed and tagged - out.

C. FILL OF LOOP NO. 2

The fill of loop No. 2 was performed in the same manner as that detailed in B, above, for loop No. 1. A total of 272 cu ft of sodium was transferred to fill loop No. 2 and to increase the level in the reactor vessel one inch, leaving a net volume of 246 ft³ of sodium required to fill loop No. 2.

After the high-point vent freeze trap inverted bucket was floated-off, the No. 2 primary pump was operated for 48 hours at speeds from 100 to 180 rpm; the 180 rpm speed was applied after approximately 40 hours of operation at the lower speeds. The same data as listed in B, above, was taken hourly. The same indications of satisfactory pump and loop operation were observed.

A vacuum of 20 in. Hg was maintained on the vent line until the freeze trap temperature stabilized, indicating that the freeze seal was well established. At this time, the vent line block valve was closed and tagged-out.

D. FILL OF LOOP NO. 3

The fill of loop No. 3 was performed in the same manner as that detailed in B, above, for loop No. 1. Sodium was pumped into the IHX from the sodium service system, using the electromagnetic service pump, with the throttling valve closed and the blocking valve open.

When the operation had proceeded for about one-half hour, the electromagnetic pump throat temperature indicator showed decreasing sodium temperature. The service pump was stopped and valve XYZ (Figure 1157-1) was closed to permit adequate time to evaluate the condition. Subsequent to the stop, it was noted that thermocouples on various sodium service valves along the service line being used and on the service pump throat gave average temperature indications of approximately 280 F.

The situation was analyzed as follows:

- 1) At the start of the operation, sodium in the service lines was approximately 310 F, as determined by deenergizing the service pump and observing the pump throat temperature. The 30 F temperature decrease took place over a period of about five minutes, thus, only a minor amount of sodium under 300 F could have reached the loop.
- 2) It was agreed by the test engineer, the AI Shift Leader, and the Operations Manager, that the test requirement of 300 F minimum sodium had essentially been adhered to and no temperature shock damage could have resulted, for the following reasons:
 - a) A very small amount of sodium colder than 300 F passed through the service pump, probably not reaching the main loop.

- b) The loop fill-and-drain line pre-heat controllers were in operation for 350 F and added heat to the flowing sodium in the service line.
- c) If any sodium under 300 F reached the loop, it was a very minor amount compared to the volume of the sodium already present in the loop.
- d) The secondary loop in this circuit was filled and in operation, which tended to equalize temperatures further, particularly in the IHX. Temperatures in the loop remained at 340 F throughout the operation.

The helium cover gas pressure on secondary loop No. 3 was reduced from 20 to approximately 5 psig to limit the differential pressure across the IHX, and the remainder of the loop was filled from the reactor vessel by the vacuum fill method. Make-up sodium to the reactor vessel was provided from the cold fill tank by operating the electromagnetic service pump at as high a voltage as possible and throttling flow with a valve downstream, thus using pump power to increase sodium temperature. The pre-heat controllers in the service line were maintained "ON" to further add heat to the flowing sodium. The sodium was bled into the return lines on the other two loops, which were operating, in order to obtain good mixing. Indications from valve thermocouples in the service line, upstream of the point of injection of sodium into the loops, indicated a temperature of 295 F.

Bulk sodium temperature in the remainder of the system was at 340 F, as indicated by the reactor temperature elements.

A total of 378 ft³ of sodium at an average temperature of approximately 300 F was transferred from the fill tanks to the system in order to fill primary loop No. 3 and to raise the reactor vessel two inches to elevation 1428 ft

6 in., leaving a net of 326 ft³ required to fill loop No. 3. The primary sodium temperature at the completion of the operation was unchanged at 340 F.

When the freeze trap closed (indicated by a rapid change of vacuum from 17.5 to 20 in. Hg) the main pump in the loop was started and, after tuning the controls, control was transferred to the main board. The pump was operated under this test for a 48-hour run-in period at speeds from 135 to 190 rpm, with a short run at 440 rpm after 35 hours. The data listed in section B were recorded. The pump operated properly with no conditions of noise, vibration, or over-temperature being observed during the 48-hour run-in period.

When it became apparent that the freeze seal had been made, as indicated by the stabilization of the freeze trap sodium-side temperature, the vent line block valve was closed and tagged-out.

IV. COMPLIANCE WITH TEST COMPLETION CRITERIA

Following are the Test Completion Criteria associated with preoperational test AI-P-1157, "Initial Fill of Primary System" as listed in NAA-SR-5700, Supplement 4, page XI(a)-75 with remarks regarding the test to explain compliance with the criteria.

- a) Criterion: The reactor vessel and primary loops of the Sodium Heat Transfer System are filled to approximately 1427 ft 9 in. elevation as indicated on two reactor core level indicators with the pump discharge piping and IHX's also filled for normal operation.

Comments: The reactor was filled to the 1428 ft 6 in. elevation, to ensure adequate sodium in the pump cases for lubrication of the fluid

bearing during initial operation. The portable sodium-level probe was used for the determination of sodium level. This was considered preferable to relying on the installed level instruments, since they require balancing and check-out with a filled system. The entire primary system (three loops and reactor vessel) was filled without undue difficulty.

- b) Criterion: Those level, pressure, temperature and flow instruments which could be proven operable during the fill procedure function properly.

Comments: The three primary flowmeters were proven to be operable after interchanging leads to take care of polarity reversal. The process pressure instruments were operable. Temperature instrumentation was proven operable; some minor attention was required to correct such conditions as loose connections and reversed leads. Testing and checkout of sodium process instrumentation will be (or has been) performed under the following preoperational test procedures:

- 1) AI-P-1159 - Sodium Level Instrumentation
- 2) AI-P-1160 - Sodium Flow Instrumentation
- 3) AI-P-1161 - Sodium Pressure Instrumentation

V. EVALUATION

This test demonstrated that the main primary heat transfer system, which includes the reactor vessel and three loops, can be safely and efficiently filled with

sodium. The volume of sodium required to fill the system at a temperature of about 350 F was determined (Table I).

The test in itself is considered to have adequately covered its original intent. However, there were three areas requiring further attention:

- 1) Resolution of the loop high point freeze trap shaft packing leakage problem. This problem has been resolved by replacing the loose spring type packing follower in the freeze trap with a solid follower.
- 2) A simpler method of determining the bulk or stream sodium temperature in the fill tanks and/or sodium fill and drain lines. It is recommended that a thermocouple well be placed in primary fill and drain line 150.
- 3) Completion of checkout and calibration of all sodium level instrumentation. This item is being consummated per AI-P-1159 Sodium Level Instrumentation.

The vacuum method of filling the pump discharge lines is believed preferable to that originally planned. It is recommended that the present semi-permanent installation be retained for future use. Also, the method of draining the pump discharge line can be simplified by the admission of helium into the vacuum connection (Figure 1157-2) at a controlled rate to lower the head.