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DOCUMENT NO.

HW-83367

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N-REACTOR SHUTDOWN FOR FUEL RUPTURE INDICATIONS - TUBE 3361

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N-REACTOR SHUTDOWN FOR FUEL
RUPTURE INDICATIONS - TUBE 3361

By

D. L. Renberger
Process Engineer
Process Evaluation and Control

July 31, 1964

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N-REACTOR SHUTDOWN FOR FUEL RUPTURE

INDICATIONS - TUBE 3361

ABSTRACT

The N-Reactor was shutdown on July 7, 1964, due to fuel rupture indications on tube 3361. The rupture has been confirmed as a failure in the downstream inner fuel element in tube 3361 caused by a pin hole in the weld and braze metal.

This document presents a historical record of the rupture indications observed prior to and following the shutdown. The operating history of tube 3361 is compared with an adjacent tube, with no abnormal conditions observed at any time. Reactor temperature and power history since initial primary loop heatup are presented to show the total operating history experienced by N-Reactor.

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N-REACTOR SHUTDOWN FOR FUEL
RUPTURE INDICATIONS - TUBE 3361

The N-Reactor was shutdown at 0744 on July 7, 1964, due to fuel rupture indications on tube 3361. The following record of events and background data are provided as a historical record:

1.0 FUEL RUPTURE INDICATION

The gamma energy, gross gamma, and multichannel analyzer results are presented in HW-83195. (1) Briefly, the following trends were observed:

1.1 Gamma Energy Monitor

The activity level from tube 3361 first showed an increase above other tube readings at about 2200, 7-6-64. The chart reading remained at 10% chart scale units or less above the reference readings until about 0100, 7-7-64. At that time, the reading increased to 30% chart scale units above the reference. At about 0215, 7-7-64, the reading increased to the instrument trip setting of 40% scale units above the reference channel for the first time. At that time, the turret was stopped and the activity level from 3361 continuously recorded until about 0300, 7-7-64. The chart reading slowly decreased from about 40% scale units (trip point) above the reference to 30% units. Several blips above trip point were received during this period. At 0300, the turret was restarted and then was stopped with the second counting chamber positioned at 3361. This chamber showed readings of about 25% units above reference channel until 0400. Readings then became erratic during backflushing of sensing lines. At 0415, the turret was restarted and at 0430 the first chamber repositioned at 3361. Activity levels went to 80% scale units above reference, then dropped off in about seven minutes to 50% units above reference. The level remained in this region until about 0700 when it again increased to 80% scale units above reference. From shortly after 0700 to 0730, the instrument was out of service during scanning with a multichannel gamma energy analyzer. At 0730, the system was back in service and 3361 read 65% units above reference. The reactor was started down, and readings slowly reduced.

At 1315 on 7-9-64, (53.6 hours after shutdown), tube 3361 still read 30% scale units above reference.

1.2 Gross Gamma Monitor

The gross gamma meter was first plugged into the output from 3361 at 0330, 7-7-64, with an initial reading of 140 millivolts (105 millivolts above the reference channel). At about 0345 sample flow was increased and the reading went to 170 mv and

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(1) HW-83195, "Data For Suspect Fuel Element Rupture 100-N Area, July 7, 1964," G. L. Erickson and G. R. Klingler, July 8, 1964.

held until 0415. From 0415 to 0445, readings were erratic during backflush of sensing lines. At 0445, the sample lines were back in service and the reading showed a blip to 400 mv, then was somewhat erratic between 200 and 375 mv between 0445 and 0500. Between 0500 and 0645, readings held fairly steady at 230 to 240 mv. At 0645, the reading showed a rapid increase to a new level of 330 mv, then on up to 375 mv. The reading was at about 300 mv when the reactor was started down at 0735. Monitoring was then switched to the diversion systems. The reactor was shutdown at about the same time and the diversion header reading slowly decreased from 250 mv to 50 mv.

1.3 Gamma Energy Spectrum

A gamma energy spectrum was obtained by G. L. Erickson and G. R. Klingler⁽²⁾ that showed count rates from tube 3361 to be up to ten times above count rates from a reference tube 3365 at certain gamma energy levels.

1.4 G.M. Tube Readings on Gamma Monitor Sample Lines

Direct readings taken by radiation monitoring showed the following readings:

<u>Time</u>	<u>Tube</u>	<u>Mr/hr</u>	<u>Counts/min</u>
0340	3361	4	25,000
	3360	2	17,000
0445	3361	9	48,000
	3360	4	25,000
0600	3361	9	48,000
	3360	4	25,000
0700	3361	10	55,000

2.0 REACTOR SHUTDOWN

From the gross gamma and gamma energy charts, both systems showed signal levels above Process Standards limits at about 0445 following backflush of sensing lines. The readings decreased to within Standard in about five minutes, then both did not go above Standards limits for a sustained period until about 0700. Based on all indications of a rupture, the tube 3361 flow was diverted at 0732 and the reactor started down from 800 MW at 0735. At 0744, a scram occurred from low flow on tube 1743 due to the primary pump speed reduction necessitated by the reduction in reactor generated steam.

3.0 EFFECTS OF TUBE 3361 DIVERSION

About 60 seconds prior to diversion of flow from tube 3361, a fast-speed recorder was started to record selected primary and secondary loop variables being monitored following scrams during N-3 testing. A summary of results is as follows:

(2) See Figure 5, HW-81395.

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3.1 Injection Flow

The peak injection flow during diversion was 1500 gpm compared to a later peak of 4000 gpm due to primary loop water contraction resulting from the shutdown.

3.2 Other Primary Loop and Secondary Loop Variables

No effects of the tube diversion were observed on other monitored variables except for pressurizer level showing a slight decrease (0.2 ft) and pressurizer pressure showing a slight increase (+30 psi) after injection flow increased.

4.0 LOOP ACTIVITY ANALYSES FOLLOWING THE SHUTDOWN

Various analyses of loop activity were made following the shutdown, and gave the following results:

4.1 Primary Loop Water Analysis for Neptunium 239 (3)

At 0800, 7-7-64, (16 minutes after shutdown), a primary loop water sample was obtained and analyzed at 200-W for gamma energy levels. The Neptunium 239 level was found to be 4.5 microcuries/liter. This level is compared to less than 3×10^{-5} microcuries/liter from a sample obtained on June 28, 1964, at the same reactor power level.

A second analysis at 0100 on 7-8-64, showed 2.8 microcuries/liter.

4.2 Primary Loop Uranium Samples

Routine primary loop sample analyses have been performed for the past several months as backup for the gamma monitor systems during low power operation. The recent results are presented as Table II in the Appendix. Analysis results from these samples did not indicate a rupture was present.

4.3 Primary Loop Piping Surveys

Primary loop piping surveys showed readings of 25 R/hr at 1" from diversion riser #10 (from 3361) three hours after shutdown. Diversion header #11 read 15 mr/hr at 2". Five hours after shutdown, the rear connector of 3361 read 40 mr, compared to 23 and 20 mr on adjacent tubes. At the same time, the right inlet flush line from the V-10's read 40 to 100 mr/hr compared to 2 to 5 mr/hr on the left inlet V-10's. The front cap to 3361 read 1 mr/hr, 18 hours after shutdown. Other readings are available from J. G. Myers.

5.0 TUBE 3361 FLOW, TEMPERATURE AND POWER HISTORY

Tube flow, temperature and power are compared with tube 3360 and a maximum powered tube in Table I of the Appendix. Tube 3361 showed no abnormal flow or temperature readings prior to and during the

(3) Personal Communication with A. Case, July 7, 1964.

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rupture indication. The tube flow and temperature were continuously monitored on the trend recorder during the period when a rupture was suspected and no changes were observed.

Maximum tube power reached on tube 3361 was about 710 KW on 7-6-64, and 7-7-64. The maximum tube power previously attained on any N-Reactor tube was 1415 KW on July 1, 1964. Tube 3361 operates at a normal power of 27 to 64% of the maximum powered tube and 45 to 83% of the average powered tube depending on the amount of pile flattening at the time. (See Appendix, Figures 1 - 5 for reactor operating history.)

The calculated uranium temperature is 392 F at the inside surface of the cladding.* Fuel exposure has been estimated at approximately 10 MWD/ton.**

5.1 Fuel History and Loading

The fuel in tube 3361 was loaded into the reactor on February 15, 1964; in a charge pattern of 18 pieces of 24" metal. Component identification for the metal is presented in Table III of the Appendix.

5.2 Rupture Verification

Inspection of the fuel pieces from tube 3361 verified that a rupture had occurred near the end cap of the center fuel piece #304816.***

5.3 Acknowledgments

The above information was obtained through discussion with several parties involved in analyzing the circumstances surrounding the rupture. The author wishes to acknowledge the cooperation of G. R. Klingler and G. R. Erickson for the analysis of the gamma monitor charts; A. H. Case for the primary loop water sample analysis results; A. E. Guay and C. D. Shadinger for the fuel information.

* EM-CISA-64-14, "Preliminary Interpretation of Suspect Fuel Element Indication in Process Tube 3361 on July 7, 1964," D. W. Leiby and D. O. Allred, July 8, 1964.

** Personal Communication with W. S. Nechodom.

*** See HW-83343 by A. Guay for a detailed discussion of the fuel rupture investigation.

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Appendix - TABLE I
COMPARATIVE OPERATING HISTORY

Tube 3361										Tube 3360										Central High Powered Tube										Tube 3361 Power	
Date	Time	Reactor Level MW	% AP Flow	GPM	Outlet Temp.	Inlet Temp.	ΔT	Tube Power		Flow % AP	GPM	Outlet Temp.	Inlet Temp.	ΔT	Tube Power KW	Tube No.	Flow % AP	GPM	Outlet Temp.	Inlet Temp.	ΔT	Tube Power KW	% of max. powered tube	% of ave. powered tube							
6-10-64	0259	200	19.9	98	339	329	10	129		19.2	98	340	329	11	141	1662	19.9	98	359	328	31	400	32.3	64							
6-11-64	0722	400	29.9	120	348	333	15	237		30.2	120	349	333	16	252	1662	29.6	120	379	335	44	695	34.1	83							
6-17-64	1810	400	32.4	126	352	341	11	182		32.9	126	353	341	12	198	1559	32.0	126	381	340	41	678	27.0	45							
6-23-64	0723	400	46.1	150	353	337	16	315		46.9	150	354	337	17	335	2067	45.9	150	365	340	25	493	64	78							
6-27-64	2227	800	52.8	163	370	339	31	665		52.9	163	369	339	30	643	1457	54.3	164	392	344	48	1035	64	83							
7-1-64	1027	NE*	52.9	163	345	333	12	257		52.9	163	347	333	14	300	2054	48.1	153	374	337	37	745	34								
7-1-64	1516	800 UR**	52.8	163	359	340	19	407		53.2	163	359	340	19	408	1658	49.6	156	409	340	69	1415	28	51							
7-3-64	0250	800	52.6	162	369	340	29	618		52.9	163	369	340	29	622	1457	53.9	162	397	344	53	1130	55	77							
7-5-64	1605	800	53.1	163	369	341	28	600		53.3	163	370	341	29	618	1458	47.3	153	397	340	57	1147	52	75							
7-6-64	1526	NE*	27.9	117	309					28.4	118	310																			
7-6-64	1800	800	53.4	163	374					54.1	164	373																			
7-6-64	2113	800	53.4	163	374					53.7	164	375																			
7-7-64	0005	800	53.4	163	374					53.9	164	375																			
7-7-64	0348	800	53.1	163	373					53.9	164	374																			
7-7-64	0516	800	53.0	163	374					53.9	164	375																			
7-7-64	0627	800	53.1	163	374	341	33	710		53.9	164	375	341	34	733	1457	54.6	164	393	344	49	1060	58	89							
7-7-64	0739	800	52.9	163	374					54.3	164	375																			
* Non-equilibrium																								58							
** Uniform Rods																								89							
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** Uniform Rods

* Non-equilibrium

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Appendix - TABLE I
PERFORMANCE OPERATING HISTORY

Tube 3360					Central High Powered Tube							Tube 3361 Power	
GPM	Outlet Temp.	Inlet Temp.	ΔT	Tube Power KW	Tube No.	Flow % ΔP	GPM	Outlet Temp.	Inlet Temp.	ΔT	Tube Power KW	% of max. powered tube	% of ave. powered tube
98	340	329	11	141	1662	19.9	98	359	328	31	400	32.3	64
120	349	333	16	252	1662	29.6	120	379	335	44	695	34.1	83
126	353	341	12	198	1559	32.0	126	381	340	41	678	27.0	45
150	354	337	17	335	2067	45.9	150	365	340	25	493	64	78
163	369	339	30	643	1457	54.3	164	392	344	48	1035	64	83
163	347	333	14	300	2054	48.1	153	374	337	37	745	34	
163	359	340	19	408	1658	49.6	156	409	340	69	1415	28	51
163	369	340	29	622	1457	53.9	162	397	344	53	1130	55	77
163	370	341	29	618	1458	47.3	153	397	340	57	1147	52	75
118	310												
164	373												
164	375												
164	375												
164	374												
164	375												
164	375	341	34	733	1457	54.6	164	393	344	49	1060	58	89
164	375												

TABLE II

<u>Date</u>	<u>Time</u>	<u>Sample Point Number*</u>	<u>UO₂</u> <u>grams/ml</u>
7-4-64	0030	71	$<5.0 \times 10^{-11}$
	1200	71	$<2.8 \times 10^{-11}$
	1700	71	$<2.8 \times 10^{-11}$
7-5-64	0100	71	2.8×10^{-11}
	0430	71	2.8×10^{-11}
	1000	71	2.8×10^{-11}
	2100	71	7.29×10^{-11}
	1430	71	1.18×10^{-10}
	1700	71	$<2.8 \times 10^{-11}$
	2100	71	$<2.8 \times 10^{-11}$
7-6-64	0100	71	$<2.8 \times 10^{-11}$
	0500	71	$<2.8 \times 10^{-11}$
	0900	70	6.53×10^{-11}
	1700	71	$<2.8 \times 10^{-11}$
	2100	71	$<2.8 \times 10^{-11}$
7-7-64	0030	71	$<2.8 \times 10^{-11}$
	0300	70	$<2.8 \times 10^{-11}$
	0900	71	$<2.8 \times 10^{-11}$
7-8-64	0430	70	4.48×10^{-9}

Rupture indications are readings above 10^{-7} gms/ml.

*Points 70 and 71 are primary loop water samples from Cells 2 and 3 pump discharge lines, respectively.

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TABLE III

TUBE 3361 PIECE IDENTIFICATION

<u>Tube No.</u>	<u>Position</u>	<u>Inner</u>	<u>Outer</u>	<u>Mag #</u>	<u>Mag. Charge Date</u>	<u>Charge Date (HAPO)</u>
3361	01	300913	402910	136	2-15-64	082 (2-15-64)
	02	312105	294403			
	03	141612	455511			
	04	300506	498108			
	05	139301	297602			
	06	305506	269807			
	07	197913	284212			
	08	199413	254405			
	09	317112	453204			
	10	143214	455703			
	11	141716	456112			
	12	143215	457308			
	13	141815	441308			
	14	141606	454905			
	15	130704	418511			
	16	318214	277703			
	17	303811	400810			
	18	304816*	257907			

Position #1 is downstream.

* Rupture

Note: From the position of the ruptured fuel piece, as found in the discharge basket, it is believed that the ruptured piece was actually loaded at the downstream position in the tube, i.e., piece 18 downstream.

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Figure 1

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HOT PHYSICS TESTS
Pump Energy Heating

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Figure 2

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SEQUENCE OF TEST

- A. STARTUP TO 100 & DATA Step 9 & 10
- B. INCREASE TO 200 & DATA Step 11 & 12
- C. SETBACK TO 50 Step 13
- D. INCREASE TO 400 & DATA Step 14 & 15
- E. SCRAM FROM B BUS TRIP Step 20
- F. STEAM PRESSURE INCREASE Step 22
- G. SETBACK TO 200 AND CELL ISOLATION Step 18 & 24
- H. CONSTANT STEAM PRESS. CONTROL - 3 CELLS Step 25
FULL LOAD DUMP CONDENSER Step 31
- J. DIVERSION SYSTEM Step 32
- K. SKEWING & POWER VARIATION Step 35
- L. DATA AT 400 Step 37
- M. BALL SAFETY SCRAM Step 38

CONTINUITY OF TEST

- 1 SCRAM HI AVG. FLUX CALIBRATION ERROR.
- 2 SCRAM LO STM. GEN. LEVEL OPER. ERROR
- 3 SCRAM LO FLOW TRIP CLOSE SETTING
- 4 SCRAM FAULTY FLOW MONITOR SELF TEST (manual)
- 5 BALL DROP FAULTY WIRING TO FLUX MONITORS
- 6 SCRAM HI FLOW TRIP. CLOSE SETTING. Step 14 DATA
- 7 SCRAM LO FLOW TRIP CLOSE SETTING. Step 19 DATA
- 8 BALL DROP FROM DC POWER SWITCHING ERROR
- 9 SCRAM B BUS TRIP OFF Step 20
- 10 SCRAM SURGE TANK LOW LEVEL - VALVE FAILURE
- 11 SCRAM LOSS OF TG VACUUM (manual)
- 12 SCRAM (manual) PRE-STEP 38 MODIFICATIONS
- 13 SCRAM BOILER FLAMEOUT (manual)
- 14 SCRAM LO FLOW FROM TG STM PRESS. LIMITER
- 15 BALL DROP Step 38

STARTUP TEST N-2 - LOW POWER TESTING PROGRAM

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Figure 3

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5/11/64
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N-3 TEST SEQUENCE

KE 10 X 10 TO THE CM. 358-14
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Figure 5

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N-3 TEST SEQUENCE

10 X 10 TO THE CM. 358-14
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