MASTER

PATHFINDER ATOMIC POWER PLANT

SHIELDING AND RADIATION SURVEY MEASUREMENTS (332)

Submitted to
U. S. ATOMIC ENERGY COMMISSION
NORTHERN STATES POWER COMPANY
and
CENTRAL UTILITIES ATOMIC POWER ASSOCIATES

by

ALLIS-CHALMERS MANUFACTURING COMPANY
ATOMIC ENERGY DIVISION
Bethesda, Maryland

Ref: AEC Contract No. AT(11-1)-589

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PATHFINDER ATOMIC POWER PLANT

BEST PRICE

SHIELDING AND RADIATION
SURVEY MEASUREMENTS (332)

H.C. \$ 3.00, M. 65

by J. W. Lewellen, P. S. Lacy, and T. M. Raby

Submitted to

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NORTHERN STATES POWER COMPANY

and

CENTRAL UTILITIES ATOMIC POWER ASSOCIATES

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ALLIS-CHALMERS MANUFACTURING COMPANY

under

Agreement dated 2nd Day of May 1957, as Amended
betweenAllis-Chalmers Manufacturing Company and Northern States Power Company
under

AEC Contract No. AT(11-1)-589

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PATHFINDER ATOMIC POWER PLANT
SHIELDING AND RADIATION SURVEY MEASUREMENTS

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FOREWORD

One of a series of reports on research and development in connection with the design of the Pathfinder Atomic Power Plant, this particular report deals with Shielding and Radiation Survey Measurements (Test 332) performed during various phases of the plant power escalation program. The Pathfinder Plant is located at a site near Sioux Falls, South Dakota and reached initial criticality early in 1964. Northern States Power Company is the owner and operator of the plant. Allis-Chalmers is responsible for the design and construction of the plant and also for the performance of specific research and development efforts associated with the plant.

The U.S. Atomic Energy Commission, through Contract No. AT(11-1)-589 with the Northern States Power Company and Central Utilities Atomic Power Associates (CUAPA) are sponsors of the research and development program. The plant's reactor is of the controlled recirculation boiling water type with nuclear superheater.

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1. INTRODUCTION

This report contains the results of the shielding measurements and radiation surveys performed at the Pathfinder Power Plant during reactor plant startup and reactor power escalation programs. The objective of the tests is to verify initial shielding calculations,⁽¹⁾ to establish the adequacy of the biological shielding around the reactor, to determine radiation dose levels throughout the plant, and to identify (and isolate, if necessary) suspected or high-radiation areas. These measurements and surveys were conducted as part of Test Procedure 332.⁽²⁾

The measurements and surveys were carried out using calibrated portable radiation survey meters including both neutron and gamma monitors as well as installed nuclear and temperature instrumentation in the reactor biological shield. If necessary, they were to be supplemented by X-ray film or by personnel film badges placed in pre-selected locations in the plant. The readings from the Radiation Monitoring System were monitored throughout the test.

Neutron surveys throughout the plant take place from time to time, but no neutrons outside the reactor building (except the MSL entry in the turbine building) have been observed; these observations, therefore, are unreported.

Radiation surveys were initially performed at a reactor power level of 6.5 Mw thermal, and the surveys were repeated at intermediate and higher power levels up to and including 90 percent of full design power.

The latest survey data, conducted on May 1, 1967, at 85 percent of power (162 Mwt) is presented in its entirety as an appendix to this report.

2. GENERAL TEST METHOD

The procedures for radiation surveys are presented in detail in Test 332, Shielding and Radiation Survey Measurements.⁽²⁾ That procedure sets forth a planned program of radiation and dose level measurements to be taken throughout the plant at various power levels. Portable and installed instrumentation were used to obtain the measurements. Film badge exposures were to be utilized when necessary to supplement the measurements. Determination of both gamma and neutron levels are included. The procedure also outlines certain prerequisites, plant conditions, and administrative controls to be followed during the measurements. In general two types of portable instruments were used for the surveys; these are described below.

2.1 β - γ DETECTOR

The Teletector survey instrument was used. This instrument is a "Total 6112." It employs two g.m. tubes on a probe. One is a "Valvo 18529" for 1 R/hr to 1000 R/hr levels; the other is a "Valvo 18504" for the 1 mr/hr to 2 R/hr range. The instrument has a telescopic probe which extends from 20 in. to 160 in.

A window for β detection is on the sensing unit but is rarely used for plant surveys; practically all dose measurements apply to cases where the field is measured at a point separated from the pertinent source region by a pipe wall or similar structure. Therefore, measured dose rates are γ only unless β is specifically indicated.

The energy dependence of the response, relative to a uniform ("flat") response is as follows:

80 kev - 200 kev	+15% to -25%
0.2 Mev - 2 Mev	$\pm 10\%$
2 Mev and higher	essentially flat

2.2 NEUTRON DETECTOR

Nuclear-Chicago "DN-3" proportional counters, employing a standard BF_3 tube, are used.

The BF_3 tubes are inside a 1-in. thick wax cover, which in turn is shielded by a 20-mil thickness of cadmium.

The total response range is 0.02 ev - 10 Mev with a peak at 5 kev. The sensitivity between 1 Mev and 10 Mev varies between 10 and 25 percent of the 5 kev value.

3. DOSE POINT DESCRIPTION

Dose points at which radiation measurements were taken (except those taken initially at 6.5 Mwt) are shown in Fig. 3.1 through Fig. 3.9. Dose points for initial surveys at 6.5 Mwt are described in Sec. 4. Dose points for which calculated values were obtained are presented in reference (1). In relating measured dose rates to those previously calculated, the appropriate dose point identification will be clearly shown for both cases. The change in dose point locations for survey measurements from those locations originally proposed in the shielding analyses of reference (1) was necessitated by the results of initial site surveys. The test procedure was therefore revised to establish survey points that exhibit sufficient and meaningful data to verify and evaluate shielding design and adequacy.

DOSE POINTS: REACTOR BUILDING - OPERATING FLOOR

FIG. 3.1

DOSE POINTS: REACTOR BUILDING - MEZZANINE FLOOR

FIG. 3.2

DOSE POINTS: REACTOR BUILDING - PLUG FLOOR

FIG. 3.3

DOSE POINTS: FUEL BUILDING - OPERATING FLOOR

FIG. 3.4

DOSE POINTS: FUEL BUILDING - MEZZANINE FLOOR

FIG. 3.5

DOSE POINTS: FUEL BUILDING - BASEMENT FLOOR

FIG. 3.6

DOSE POINTS: TURBINE BUILDING - OPERATING FLOOR

FIG. 3.7

DOSE POINTS: TURBINE BUILDING - MEZZANINE FLOOR

FIG. 3.8

DOSE POINTS: TURBINE BUILDING - BASEMENT FLOOR

FIG. 3.9

4. INITIAL RADIATION TEST SURVEYS AT 6.5 MW THERMAL

4.1 INTRODUCTION

The initial phase of the radiation survey program consisted of measurements of radiation levels around the Pathfinder plant at low power. Reactor conditions during the test are presented in Table 4-1.

The majority of the readings were taken in the reactor building. Since steam was being dumped to the condenser, only a few readings were taken in the turbine building along the main steam line and the off-gas line. Because there was no purification flow, meaningful readings around the off-gas monitors 860 K and 1383 could not be obtained.

4.2 SURVEY RESULTS

4.2.1 Reactor Building

Measured activity levels at selected points in the reactor building at reactor power of 6.5 Mwt are presented in Fig. 4.1 along with dose point locations. The dose levels shown include both γ and neutron dose contributions. A comparison between full power dose rates extrapolated from measurements at 6.5 Mwt and dose rates calculated in reference (1) is presented in Table 4-2. The results indicate good agreement between extrapolated measured values and calculated values.

The activity levels at the ends of the nuclear instrument tubes located in the biological shield on the plug floor are as shown in Table 4-3. These measurements were taken with the instrument tube concrete shield plugs removed. The results indicated that calculated doses are very conservative.

4.2.2 Turbine Building

The measured activity levels along the off-gas line are presented in Fig. 4.2. The measured dose rates at 6.5 Mwt along the main steam line were 5.0 - 7.0 mr/hr at contact. The calculated dose at contact on the main steam line (MSL) is 4 mr/hr at 6.5 Mwt. Extrapolation to full power of measurements obtained at 6.5 Mwt would not yield accurate prediction of dose levels at full power in this case. This is because of significant differences in reactor conditions at the two power levels. At 6.5 Mwt, the flow of steam is low; N-16 (which is the primary source of radiation along the MSL) is produced in the superheater. The boiler contribution at this time is small due to the long transit time between the boiler and superheater (55 sec at 25,000 lb/hr steam flow). However, at full power because of the much shorter transit time (4.8 sec) between the boiler and the shorter residence time in the superheater, the boiler section becomes the dominant source of N-16. For this reason there is no direct relationship for N-16 levels between 6.5 Mwt and full power.

4.3 CONCLUSIONS

The extrapolated full power activity levels for few selected points in the reactor building were found to be equal to or less than the predicted values in reference (1). Based only on the limited information obtained at 6.5 Mwt, no significant radiation problems are expected in the reactor building at full power. Additionally, if the neutron streaming through the instrument tube (which is to be subsequently measured) is lower than that calculated, fewer concrete shielding plugs will be needed at the ends of the instrumented tubes to maintain a 10-30 mr/hr level on the plug floor of the reactor building.

No useful full power information could be generated from radiation measurements performed in the turbine building at the initial power level of 6.5 Mwt.

TABLE 4-1

REACTOR CONDITIONS

Power	6.5 Mwt
Recirculation Flow	64,000 gpm
Steam Flow	25,000 lb/hr
Purification Flow	0
Water Temperature	420 F
Steam Temperature	480 F

TABLE 4-2

FULL POWER DOSE RATES (r/hr)

<u>Dose Point</u>	<u>Full Power (Extrapolated)</u>	<u>Full Power (Calculated, Ref. 1)</u>
2	54.0	39.0
3	5.9	7.5
4	0.54	0.60
5	0.027 - 0.040	0.01 - 0.03
6	0.013 - 0.022	0.01 - 0.03
7	0.188	0.195
8	0.008	0.01
9	0.0027	0.001 - 0.003

TABLE 4-3

NUCLEAR INSTRUMENT TUBE DOSE RATES (mr/hr)

<u>Channel No.</u>	<u>Measured (6.5 Mwt)</u>	<u>Full Power (Extrapolated)</u>	<u>Full Power (Calculated, Ref. 1)</u>
1	0.7 - 0.8	18.8 - 21.5	50.0 - 250.0*
2	0.4 - 0.6	10.8 - 16.1	
3	0.4 - 0.5	10.8 - 13.5	
4	0.6 - 0.8	16.1 - 21.5	
5	1.5 - 2.0	40.4 - 54.0	
6	1.0 - 1.5	27.0 - 40.4	
7	0.7 - 0.8	18.8 - 21.5	
8	0.8 - 1.0	21.5 - 27.0	

*Gamma contribution only, neutron dose rate is calculated to be 2 - 10 rem/hr.

All dose rates are mR/hr unless noted otherwise

Dose point Measured (6.5 mut)

1	50 r/hr
2	2 r/hr
3	220.
4	20.
5	1.0-1.5
6	0.5-0.8
7(a)	7
8	0.3
9	0.1
10	0.02
11(b)	300.
12	0.1

(a) Entrance to pump room, trap door

(b) 12' below water surface

Dose Rates North Wall

Dose Rates West Wall

5. RADIATION SURVEYS AT 40 MWT

This section deals with radiation survey measurements performed at a reactor power level of 40 Mwt. It also includes measurements made during initial turbine startup to 20 percent power, or approximately 6 Mwe. The results are summarized and presented in Tables 5-1, 5-2, and 5-3. Also included in the tables are full-power calculated dose rates for dose points common to both measurement and calculations. The plant conditions are specified for each run.

Examination of the survey results indicate that in some cases, observed dose rates exceed reported results when extrapolated from 20 percent power to full power. Specific instances are dose points 23 and 25 in the reactor building and point 6 in the fuel building. Some discrepancy between measured and predicted values is expected, mainly because of the complex geometry involved and the fact that, in many instances, only approximate correspondence between measured and calculated points is possible. Based upon the survey results at 40 Mwt, no operational or radiation problems were identified which would preclude increasing reactor power to the next level in the gradual power escalation program.

TABLE 5-1

OBSERVED DOSE RATES AT SELECTED POINTS

Reactor Building (Incl. Instrument Ports)

(mr/hr γ unless otherwise indicated)

Dose Point		Dose Rate 100% Power	Notes	Run of			
a	b			6/21/66	6/24/66	8/5/66	8/6/66
			Power Level	40 Mwt	40	40	40
			Recirc. Flow	60,000 gpm	62,000		63,000
			Steam Flow	151,000 lb/hr	120,000	139,000	140,000
			Purif. Flow	0 lb/hr	0	1000	100
			Reactor H ₂ O	427 F	477	475	474
			Steam Temp.	510 F	590	510-520	550
			Off-Gas Flow	-- cfm		5-5.8	
			Turbine	--	--	--	6 Mwe
3	3	<5		--	0.1	0.05	0.05 $\beta\gamma$, 0n
4	13	0.4		--	--	0.05	<0.02
5	--			1.0	0.7	0.7	0.50
8	--			2.0	4.0	2.0	3.0
9	19	--		0.2	0.2	0.15	0.20
11				0.3	--	0.10	0.15
20				7.0	7.0	3.0	4.0
22			Closed Hatch	16.0	14.0	14 $\beta\gamma$, 200n	14, -170
23	26, 28, 16	<10		7.0	6.0	6.0	6.0
24	--			4.0	3.0	3.0	4.0
25	22, 25, 28	65	Closed Hatch	16.0	16.0	14 $\beta\gamma$, 120n	13, -110
26				3.0	1.5	2.0	1.0
28			Closed Hatch	15.0	14.0	12 $\beta\gamma$, 45n	25, -100
Inst. Ports							
3	3	<13.5	(Plug	3.0	3.0	3.0	2.5
		<10n	Out)	2.5	1.0	1.3	0.6
8	8	<27	(Plug	5.0	5.0	5.0	5.0
		<10n	In)	<0.2	<0.2	<0.2	<0.2

a - as shown in Sec. 3

b - as in ACNP-62016 (Ref. 1)

TABLE 5-2
OBSERVED DOSE RATES AT SELECTED POINTS
Fuel Handling Building
(mr/hr γ)

Dose Point		ACNP-62016 (Ref. 1) Dose Rate 100% Power	Run of			
a	b		6/21/66	6/24/66	8/5/66	8/6/66
			40 Mwt	40 Mwt	40 Mwt	40 Mwt
1	5	0.6	--	--	0.02	0.05
2			--	--	0.05	0.05
4	3	0.75	--	--	0.02	0.05
5	~4	0.3	--	--	0.02	0.05
6	6	1.1	0.3	0.15	0.15	0.6
7	-		0	0	6.0	2.5
10	9	0.6	--	--	0.05	0.3
12-11	-		0.8	0.7	1.2	0.7
13	11	0.1	--	--	0.02	0.05
15	~13	0.1	--	--	0.02	0.02
17	18	0.1	--	--	0.02	0.02
18	17	5.0	--	--	0.02	0.02
21	26	3.4	--	--	0.5	3.0
23	-		(1.5)	(3.0)	18	80
25-11	29	0.5	--	--	0.10	0.8
27	31	1.0	--	--	0.05	0.05
29	34	0.5	--	0.03	<0.10	<0.15
30	-		0	--	0.02	0.05

a - as shown in Sec. 3

b - as in ACNP-62016 (Ref. 1)

TABLE 5-3

OBSERVED DOSE RATES AT SELECTED POINTS

Turbine Building

(mr/hr γ unless otherwise indicated)

ACNP-62016 (Ref. 1)

Dose Point		Dose Rate 100% Power	Run of			
a	b		6/21/66	6/24/66	8/5/66	8/6/66
			40 Mwt	40 Mwt	40 Mwt	40 Mwt
2	59	11.6	--	--	1.2	2.0
5	40	1.80	--	--	0.02	0.05
7	52	11.0	--	--	0.02	0.7
9	~54	32	--	--	0.8	2.5
15	-		--	(0.15)	0.05	0.06
21	-		--	--	0.02	0.15
23	71	0.6	--	--	0.05	0.02
25	-		--	--	0.05	0.02
26	64	0.6	(0.7)	--	1.3	0.50
32	-		--	--	<150	<75
34	~87	12.8 R	<8	4.0	2.0	1.5
39	~84	2.8 R	<100	50	200	160
40	~83	1.3 R	45	30	13	22
43	82	140	--	--	0.5	2.0
45	109	190	--	--	4.0	5.0
46	-		--	--	10	25
48	~111	1.31 R	(30)	(20)	50	35
49	-		≤ 400	<150	90	100
52	-		<7.0	--	2.0	2.0
53	110	1.33 R	--	5.0	12.0	4.0
54			--	10.0	20	2.0
59			--	8.0	3.0	1.2
60			--	2.0	2.0	1.4
61	-		--	--	0.05	0.05

a - as shown in Sec. 3

b - as in ACNP-62016 (Ref. 1)

6. RADIATION SURVEYS DURING 20 PERCENT - 40 PERCENT POWER ESCALATION PHASE

Radiation surveys were continued during the third phase of the power escalation program. Measurements were made during runs at power levels of 65, 70, and 80 Mwt. Pertinent results are tabulated in Tables 6-1, 6-2, and 6-3, along with corresponding calculated values which are provided for comparison. Selection of data points was made on the basis of providing significant and more meaningful results that would represent all measurement areas, reflect occurrence of relatively high radiation, and allow a direct comparison between measured and calculated values.

In general, the results observed consistently and proportionately reflected the increased power levels. Certain areas showed relatively higher dose rates than were anticipated. These include points 23 and 25 in the reactor building and points 2, 7, and 9 in the turbine building. The levels at these points were not such as to preclude proceeding to the next higher power of 60 percent of full power.

TABLE 6-1

OBSERVED DOSE RATES AT SELECTED POINTS

Reactor Building (Incl. Instrument Ports)

(mr/hr γ unless otherwise indicated)

ACNP-62016 (Ref. 1)

Dose Point		Dose Rate 100% Power	Notes	Run of		
a	b			8/9/66	8/9/66	8/22/66
			Power Level	65 Mwt	80	70
			Recirc. Flow	66,000 gpm	60,000	60,000
			Steam Flow	210,000 lb/hr	265,000	255,000
			Purif. Flow	50,000 lb/hr	25,000	35,000
			Reactor H ₂ O	479 F	478	478
			Steam Temp.	560 F	610	645
			Off-Gas Flow	4.3 cfm	4.4	3.5
			Turbine	--	--	17 Mwe
			CRG 1		48 in.	73 in.
			2		0	0
			3		73 in.	73 in.
			4		73 in.	73 in.
			5		73 in.	73 in.
3	3	5		0.1 $\beta\gamma$, 0n	0.15 $\beta\gamma$, 0n	0.15 $\beta\gamma$, 0.2n
4	13	0.4		0.02	0.05	0.05
5	-			1.0	1.2	1.4
8	-			7.0	7.0	5.0
9	19	-		0.3	0.4	0.6
11				0.25	0.6	0.25
20				5.0	6.0	5.0
22			Closed Hatch	17 $\beta\gamma$, 250n	25-250	5-70
23 26, 28, 16		<10		9.0	4.0	10.0
24	-			5.0	5.0	7.0
25 22, 25, 28		65	Closed Hatch	17-200	27-320	54-75
26				4.0	5.0	6.0
28			Closed Hatch	14-70	17-94	2-40
Inst. Ports						
3	3	<13.5	(Plug	6.0	7.0	6.0
		<10n	Out)	3.0	3.0	1.5
8	8	<27	(Plug	8.0	11.0	10
		<10n	In)	<0.2	<0.2	<0.2

a - as shown in Sec. 3

b - as in ACNP-62016 (Ref. 1)

TABLE 6-2
OBSERVED DOSE RATES AT SELECTED POINTS
Fuel Handling Building
(mr/hr.y)

Dose Point		ACNP-62016 (Ref. 1) Dose Rate 100% Power	Run of		
a	b		8/9/66	8/9/66	8/22/66
			65 Mwt	80	70 Mwt
1	5	0.6	0.08	0.15	0.05
2			0.09	0.15	0.1
4	3	0.75	0.05	0.05	0.05
5	4	0.3	0.02	0.05	0.05
6	6	1.1	0.8	1.5	0.7
7	-		12	18	11
10	9	0.6	0.5	0.6	0.3
12-11	-		2.5	8.0	0.9
13	11	0.1	0.02	0.07	0.05
15	13	0.1	0.02	0.40	0.05
17	18	0.1	0.02	0.02	0.05
18	17	5.0	0.02	0.05	0.05
21	26	3.4	4.0	5.0	2.5
23	-		130	220	75
25-11	29	0.5	0.8	1.0	3
27	31	1.0	0.05	0.02	0.3
29	34	0.5	0.15	0.05	0.1
30	1		0.05	0.02	0.05

a - as shown in Sec. 3

b - as in ACNP-62016 (Ref. 1)

TABLE 6-3
OBSERVED DOSE RATES AT SELECTED POINTS
Turbine Building
(mr/hr γ unless otherwise indicated)

Dose Point		Dose Rate 100% Power	Run of		
a	b		8/9/66	8/9/66	8/22/66
			65 Mwt	80 Mwt	70 Mwt
2	59	11.6	2.0	6.0	17
5	40	1.80	0.05	0.05	0.2
7	52	11.0	0.05	0.02	6
9	~ 54	32	1.5	2.0	22
15	-		0.09	0.2	0.2
21	-		0.35	0.15	0.8
23	71	0.6	0.08	0.15	0.1
25	-		0.12	0.25	0.2
26	64	0.6	3.2	7.0	3.0
32	-		<350	<1.2 R	<450
34	~ 87	12.8 R	5.0	8	75
39	~ 84	2.8 R	350	500	600
40	~ 83	1.3 R	50	75	80
43	82	140	2.0	10	15
45	109	190	7.0	0.6	1.5
46	-		50	100	70
48	111	131 R	130	200	150
49	-		600	1.4 R	800
52	-		10	17	35
53	110	1.33 R	45	18	28
54			100	35	20
59			18	35	6
60	-		7.0	15	8
61			0.1	0.3	0.15

a - as shown in Sec. 3

b - as in ACNP-62016 (Ref. 1)

7. RADIATION SURVEY AT 40 PERCENT - 60 PERCENT OF FULL POWER

The radiation surveys conducted during lower power levels were continued during increase of reactor power from 40 to 60 percent of full power. Pertinent results at previously selected dose points are presented in Table 7-1. The dose rates observed in the reactor and fuel handling buildings, with reactor power at 109 Mwt, are reasonably consistent with values obtained at lower power levels. For the majority of points, these rates do not appear to deviate a great deal from expected values, nor would they present radiation or operational problems during further power increases.

Radiation levels in the turbine building, particularly near the low pressure section of the turbine (pts 2, 9), the high pressure section (pt 7), the aftercooler (pt 32), and the hot wells (pt 53) have increased sufficiently to require control of the area. The radiation near the turbine low pressure section appeared high enough to possibly cause a serious operational problem at full power if a further anticipated radiation increase occurs with power increase to 100 percent; corrective action in the form of additional shielding was indicated. The observed high levels represent a significant increase over corresponding readings taken at lower reactor power levels.

Possible causes of the higher-than-expected turbine building dose rates were investigated. There did not seem to be any fission product release involved, because (a) there had been no significant rise in stack monitor readings, (b) there was no evidence of radioactive accumulation in the hot well areas, and (c) analysis of the radioactive species entrained in the main steam line showed only the isotopes which were anticipated: i.e., N-13, A-41, Zn-65, and Mn, Fe, and Cr isotopes. (N-16 does not appear in this analysis because of its 7-sec half life.) The nature of the high level radiation indicated that it was most likely caused by a short half life isotope in the steam. Nitrogen-16 was, therefore, the object of attention at present. Other considered effects which could contribute to the high dose rates were:

- (1) Direct shine from the dump valve to the turbine area may be present. (60,000-80,000 lb/hr of steam are being dumped during the interim operation mode being used.)
- (2) There may be more N-16 formation in the reflector sections than was included in the original analysis.
- (3) Incomplete mixing of the steam exiting the separators with that in the vessel dome may exist, lessening the effective time delay between the core and turbine.
- (4) There may be sufficient moisture accumulation in the turbine low pressure section to significantly increase the N-16 density.
- (5) Part of the nitrogen may enter the gaseous phase shortly after it was formed, rather than remaining in solution until boiled off with the water. This would shorten the average time between formation and passage through the turbine. Operation of other reactors does not indicate a nitrogen affinity for the gaseous phase; however, the effect is included here because of the differing steam separators being used.

Rough estimates indicated that the activity in the steam line outside the reactor building was approximately proportional to the square of the power in a power range near 100 percent.

The maximum low pressure turbine contact dose rate (pt 9) is expected nominally to be about 200 and 340 mr/hr at 80 percent and 100 percent of power respectively; on the high pressure section (pt 7), dose rates in the ranges of 32 and 50 mr/hr are indicated. Based on these results, testing at higher power levels could continue with appropriate administrative controls applied in the turbine area.

TABLE 7-1

OBSERVED DOSE RATES AT SELECTED POINTS(mr/hr γ unless otherwise indicated)PLANT CONDITIONS

Thermal power level	109 Mw
Recirculation flow	58,000 gpm
Steam flow	380,000 lb/hr
Purification flow	30,000 lb/hr
Moderator temperature	480 F
Steam temperature	643 F
Off-gas flow	5 cfm
Electric output	23 Mwe

Reactor Building		Fuel Handling Building		Turbine Building	
point	dose rate	point	dose rate	point	dose rate
3	0.1 $\beta\gamma$ 0 n	1	0.6	2	70
4	0.1	2	0.1	5	7
5	2.0	4	0.05	7	18
8	0.40	5	0.05	9	120
9	0.8	6	1.5	15	0.7
11	1.5	7	35.0	21	0.6
20	18	10	1.2	23	0.3
22	2.5 $\beta\gamma$ - 1.8 n	12-11	12.0	25	0.3
23	18	13	0.15	26	8.0
24	12	15	0.05	32	< 2500
25	180	17	0.05	34	200
26	10	18	0.30	39	1200
28	2.5 $\beta\gamma$ - 4.0 n	21	2.0	40	250
		23	3.0	43	3.5
Inst. Ports		25-11	3.0	45	3.0
		27	0.10	46	45.0
3	9.0 $\beta\gamma$ - 60 n	29	< 7.0	48	300
8	15 $\beta\gamma$ - 4.0 n	30	0.10	49	100
				52	75
				53	80
				54	70
				59	17
				60	17
				61	0.4

8. RADIATION SURVEYS AT 60 PERCENT - 80 PERCENT OF FULL POWER

The plant radiation level surveys were continued during power escalation to 80 percent. Specific attention was given to the high dose rates adjacent to the turbine. The results for the selected dose points are presented in Table 8-1. The measurements were made at reactor power level of 153 Mwt.

Results of the surveys made in the reactor and fuel handling buildings again revealed normally expected moderate increases in dose levels due to increased power. These levels will offer no problems at full power. Dose levels in the turbine room are higher than those measured at 60 percent, especially at contact with the turbine casing. However, the increase over the 60 percent levels was significantly less than predicted based upon extrapolation of the 40-60 percent power data. A neutron dose rate of 5 mrem was observed at point 47 in the turbine room. This was attributed mainly to the decay of N-17 plus a slight contribution from neutron streaming and scattering in the main steam line. Turbine area surveys were made with the dump valve at 13 percent and 6 percent open positions in order to determine the effect of valve position on dose level. Reactor power was held at a fixed level near 80 percent of full power. Moderately higher dose rates were observed with the dump valve at the 6 percent open position, but the increases over prior measurement were not significant. This indicated that direct shine from the dump valve was not an important contributing factor to the high turbine area dose rates.

The cause of the high turbine area dose rates could not be clearly defined. Fission product activity did not appear to be present. This was confirmed by the behavior of the stack gas monitor, which did not indicate any significant change in count level at power levels of 40 percent of full power and above. Concurrently, a significant increase in the dose rate was observed for turbine room dose point 9. Table 8-2 shows the gas monitor level with comparable point 9 dose levels at various power levels.

Upon a power increase to 100 percent, the turbine dose rates will increase. The data for the 80 percent power step indicates, however, that this increase should be quite modest relative to the projection based upon data observed. The level of point 9 will probably increase to 170 - 200 mr/hr at full power with the dump valve closed. Corrective action in the turbine room was indicated as necessary to reduce radiation doses to acceptable levels.

TABLE 8-1

OBSERVED DOSE RATES AT SELECTED POINTS
(mr/hr γ unless otherwise indicated)

PLANT CONDITIONS

Thermal power level	153 Mw
Recirculation flow	56,000 gpm
Steam flow	53,000 lb/hr
Purification flow	32,000 lb/hr
Moderator temperature	484 F
Off-gas flow	5 cfm
Dump valve position	10%

Reactor Building		Fuel Handling Building		Turbine Building	
point	dose rate	point	dose rate	point	dose rate
3	0.40 $\beta\gamma$, <0.20 n	1	1.5	2	90
4	0.10	2	0.30	5	1.2
5	2.0	4	0.05	7	19.0
8	0.80	5	0.05	9	140.0
9	1.50	6	3.0	15	0.70
11	2.50	7	42.0	21	0.5
20	10.0	10	0.60	23	0.6
22	3.0 $\beta\gamma$, 16 n	12-11	1.3	25	0.6
23	16.0	13	0.30	26	18.0
24	12.0	15	0.30	32	<4800
25	200.0	17	0.10	34	275
26	15.0	18	0.05	39	1500
28	2.5 $\beta\gamma$, 5.0 n	21	2.5	40	300
		23	8.0	43	3.0
Inst. Ports		25	3.0	45	10.0
		27	2.0	46	100.0
3	9.0 $\beta\gamma$, 70 n	29	<7.0	48	155.0
8	13.0 $\beta\gamma$, 9 n	30	0.10	49	45.0
				52	150.0
				53	200.0
				54	300.0
				59	30.0
				60	30.0
				61	0.40

TABLE 8-2

STACK GAS MONITOR RESULTS

<u>Date of Run</u>	<u>Thermal Power (Mw)</u>	<u>Gas Monitor Level</u>	<u>Dose at Point 9 (mr/hr)</u>
8/5	40	65	0.80
8/6	40	100	2.5
8/9	80	450	2.0
8/22	70	500	22.0
12/3	109	300	120
12/20	153	400	140

9. RADIATION SURVEYS AT 80 PERCENT - 90 PERCENT OF FULL POWER

This section gives the results of the radiation surveys performed at a power level of approximately 167 Mwt. The dose rates near the turbine remain high, but they do not appear to have increased appreciably over readings obtained at lower reactor power levels. Noticeable increases in observed dose rates just prior to the 167 Mwt survey occurred at points 32, 49, and 52 in the turbine building, and at points 22, 25, and 26 in the reactor building.

While it is not expected that the turbine area dose rates will become significantly higher when the plant is operated at the full design power level of 190 Mwt, there is a need to limit and control personnel access to the area. Based on survey results at power levels up to 167 Mwt, supplementary shielding in certain areas of the operating floor of the turbine room was indicated in order to reduce dose rates to levels compatible with operational requirements and personnel access.

Table 9-1 gives selected measured dose rates for the 167 Mwt run.

TABLE 9-1

OBSERVED DOSE RATES AT SELECTED POINTS(mr/hr γ unless otherwise indicated)PLANT CONDITIONS

Thermal power level	167 Mwt
Recirculation flow	55,500 gpm
Steam flow	575,000 lb/hr
Purification flow	36,000 lb/hr
Reactor water temperature	486 F
Reactor steam temperature	663 F
Off-gas flow	4.2 cfm
Dump valve	6% open
Electric output	45 Mwe

<u>Reactor Building</u>		<u>Fuel Handling Building</u>		<u>Turbine Building</u>	
<u>point</u>	<u>dose rate</u>	<u>point</u>	<u>dose rate</u>	<u>point</u>	<u>dose rate</u>
3	0.4 $\beta\gamma$, 0 n	1	0.6	2	150
4	0.1	2	0.30	5	2.0
5	3.0	4	0.05	7	35
8	2.0	5	0.05	9	150
9	0.40	6	5.0	15	1.3
11	--	7	15.0	21	1.0
20	30.0	10	2.5	23	0.5
22	250 $\beta\gamma$ - 1300 n	12-11	8.0	25	1.0
23	30.0	13	0.2	26	17.0
24	15.0	15	0.15	32	< 8000
25	205 $\beta\gamma$ - 1300 n	17	0.05	34	600
26	13.0	18	0.20	39	630
28	150 $\beta\gamma$ - 1300 n	21	3.0	40	400
		23	12.0	43	3.0
Inst. Ports		25-11	5.0	45	5.0
		27	1.5	46	175
3	13 $\beta\gamma$ - 150 n	29	< 8.0	48	550
8	17.5 $\beta\gamma$ - 50 n	30	0.10	49	4500
				52	900
				53	400
				54	300
				59	20
				60	50
				61	0.4

10. SUMMARY

Dose levels at full power of 190 Mwt are predicted to generally increase at no more than a power-proportional rate relative to measurements taken at 167 Mwt. The basis for this conclusion is the observation that, while sharp increases were observed in escalating to approximately 120 Mwt, the recorded differences between individual runs were larger than increases occurring at many of the observation points and due to power advancement above that level. Not all measurements will fit this trend; a probable example of an exception is the aftercooler at point 32 in the turbine building, where large dose increases over previous results were recorded in the last survey.

Initial attempts to extrapolate dose rates at low power to higher power were in many cases unsuccessful because of the rapid increases that occurred upon power escalation up to 120 Mwt levels.

An inspection of the tabulated results and reported analytical predictions shows that wide deviations between observations and computed results are common. Specific instances include information pertaining to points in contact with the turbine casing on the operating floor, point 6 in the fuel handling building, and point 23 in the reactor building.

To some extent, the discrepancy can be attributed to the only partial correlation of point locations as selected for calculation, and as later determined to be operationally convenient for measurement surveys. The most serious problem, that which arises from high radiation levels in the turbine area, may be a result of the contributions of steam-entrained activated corrosion products. On the other hand, the discrepancy could follow from erroneous assumptions, preliminary to analysis, concerning N-16 formation and its release from the reactor water; but there is no direct evidence that this is the case. The shielding analysis included only consideration of water activation processes, primarily N-16 formation. In general, the instances of analytical underprediction arise from omission of, or underestimates of ill-defined secondary radiation sources such as the corrosion products just cited, or from attempts at dose prediction in locations characterized by complex geometry where, at best, only estimates can be made. Examples of the trend of dose levels as a function of increasing reactor power are presented in Figs. 10.1 through 10.4 for selected representative dose points within the plant.

None of the underestimates of dose levels relate to problems involving sources as intense as the reactor core or heavily irradiated fuel elements. Consequently, the only interference with normal operating procedures which has developed from radiation control considerations, is the high level near the turbine during operation. Supplementary shielding has been supplied to reduce the radiation levels in this area to acceptable operational values.

The auxiliary shielding consists of a movable concrete wall made up of precast concrete beams for easy assembly and disassembly. The wall is 8 ft high, 31 ft wide, and 18 in. thick; and it extends from the generator hydrogen panel to the high pressure turbine panel. In addition, a fence has been installed within the turbine building. Access within the fenced boundary is controlled through locked gates, and the radiation level is monitored by an annunciating horn located in the turbine building. A sketch of the auxiliary shielding wall and the additional fencing is shown in Fig. 10.5.

Radiation survey measurements conducted subsequent to the installation of the shield wall showed an overall reduction in dose levels by a factor of approximately four. These measurements were made at reactor power level of 162 Mwt, and the results are presented in Fig. 10.6. The data indicate that the corrective steps taken through installation of the shield wall and fencing are adequate to meet reactor operational requirements at full design power.

RADIATION SURVEY MEASUREMENTS
REACTOR BUILDING AND INSTRUMENT PORT NO. 8

FIG. 10.1

RADIATION SURVEY MEASUREMENTS
FUEL HANDLING BUILDING

FIG. 10.2

RADIATION SURVEY MEASUREMENTS
TURBINE BUILDING - OPERATING FLOOR

FIG. 10.3

RADIATION SURVEY MEASUREMENTS
TURBINE BUILDING, MEZZANINE FLOOR

Not to Scale

Turbine Building - Operating Floor

- Fence
- ▨ Concrete wall addition

SHIELD WALL AND FENCE ADDITIONS

FIG. 10.5

<u>Point</u>	<u>Turbine Side mr/hr</u>	<u>Admin. Bldg. Side mr/hr</u>	<u>Attenuation Factor</u>
A	18	5	3.6
B	8-1/2	3-1/2	2.4
C	22	4-1/2	4.9

Readings taken close to face of shield at points indicated.
 Points A and B approx. center of slabs as shown.
 Point C is believed to be best indicator of shield effectiveness.
 Mean attenuation through shield $\approx$ factor of 4.

11. REFERENCES

1. R. J. Holl and D. W. Stephen, "Pathfinder Atomic Power Plant Shielding Analysis," ACNP-62016, July 15, 1962, Allis-Chalmers Atomic Energy Division.
2. "Pathfinder Atomic Power Plant, Procedure for Test 332 Radiation Testing," ACNP-66567, Rev. 2, October 25, 1966, Allis-Chalmers Atomic Energy Division.

APPENDIX

COMPLETE RADIATION SURVEY DATA AT 162 MWT

This appendix consists of data sheets which present the most recent comprehensive radiation survey results conducted at the Pathfinder plant. This survey was conducted on May 1, 1967, with the reactor at 85 percent of full design power, or approximately 162 Mwt. These data are presented in this form to provide a means for comparison with future survey measurements results.

Test 332

Date: 5/1/67

Data Sheet 1

Power level	162.8 Mwt
Recirculation flow	61,000
Steam flow	560,000
Purification flow	32,000
Reactor water temperature	486
Steam temperature	645
Off-gas flow	4.5
Dump valve position	6%

Test 332

Data Sheet 2

Reactor Building

<u>Survey Pt</u>	<u>Reading</u>	<u>Survey Pt</u>	<u>Reading</u>
1	0.1	22 (2 ft down $\beta\gamma$)	--
2 (calorimeter)	0.7	(2 ft down neut)	--
3 $\gamma\beta$	5.0	22 (at grating $\beta\gamma$)	--
3 neutron	0	23	27
4	0.15	24	17
5	2.5	25 (closed hatch $\beta\gamma$)	4.0
6	0.1	(closed hatch neut)	30
7 (directly above 3)	0.1	25 (2 ft down $\beta\gamma$)	--
8 (open chase)	2.5	(2 ft down neut)	--
9	2.0	25 (at grating $\beta\gamma$)	--
10	1.2	26	16
11	2.5	27	10
12	6.0	28 (closed hatch $\beta\gamma$)	6.0
13	2.0	(closed hatch neut)	20
14	2.5	28 (rtr. head drain line)	40
15 (water column)	5.0	(elec. penetration to vault)	20
16 (No. 11 filter)	2.0	28 (rtr. sump chase - #3 grating)	50
16 (No. 12 filter)	75		
17	--	General:	
18	--	neutron = 1.6 mrem/hr	
19	--	$\beta - \gamma = 10 \text{ mr/hr}$	
20	30		
21	15		
22 (closed hatch $\beta\gamma$)	4.0		
(closed hatch neut)	30		

Test 332

Data Sheet 3

Reactor Building Inst. Ports

<u>Port</u>	<u>$\beta\gamma$ Reading</u>	<u>Neutron Reading</u>
1	12	0.3
2	10	0.2
3	9	0.3
4	14	0.6
5	18	0.3
6	18	0.3
7	1	0.3
8	30	12
Spare	15	12

Readings taken at entrance to ports

Shield plugs in or out of tubes (cross out one)

Test 332

Data Sheet 4

Fuel Handling Building

<u>Survey Point</u>	<u>Reading</u>	<u>Survey Point</u>	<u>Reading</u>
1	0.6	27	14
2	1.5	28	0.3
3	0.5	29 pool filters No. 11	110
4	0.1	12	17
5	0.1	13	7.0
6	6.0	30 (general)	2.5
7 (off-gas filter)	5.0		
8 (at opening)	13	Purif precoat drain. to conc waste	150
9	17		
10	3.0		
11	2.0		
12 No. 11	4.0		
No. 12	7.0		
13	5.0		
14	1.8		
15	2		
16	1.3		
17	0.4		
18	0.3		
19	1.5		
20 (behind board)	0.7		
21	5.0		
22 (off-gas filter)	15		
23 (purif line)	12		
24 (general)	9.0		
25	8.0		
26	4.0		

Test 332

Data Sheet 5

Turbine Building

<u>Survey Point</u>	<u>Reading</u>	<u>Survey Point</u>	<u>Reading</u>	<u>Survey Point</u>	<u>Reading</u>	<u>Survey Point</u>	<u>Reading</u>
1	2.0	20	0.6	37	400	56	0.8
2	140	21	0.4	38	620	57	0.2
3	150	22 (count. room)	0.2	39	2000	58 No. 11	50
4	28	23	1.0	40	480	No. 12	90
5	2.0	24	0.8	41 (inside hairpin)	1200	59 (hot well)	50
6	4.0	25	1.3	42 (off-gas line)	80	60 (hot well)	80
7	60	26	10	43	50	61	0.4
8	30	27	0.6	44 (filter)	220	62	1.0
9	190	28	1.2	45	50		
10	150	29	30	46	250	Inst. spare parts shop - 0.15 mr/hr	
11	150	30 (at wall)	550	47 (inside elbow)	1200	Turbine oper area	
12	4.0	31 (off-gas cl)	175	48	500	monitor - 12 mr/hr	
13	3.0	32 (inner cooler)	5000	49	3000	Center of shield wall directly	
14	3.0	(aftercooler)	8000	50	2000	above wall - 12 mr/hr	
15	2.5	(off-gas cooler)	1500	51	700	East side of turbine shield wall	
16	2.5	33	200	52	1200	opposite #2 - 10 mr/hr	
17	1.0	34	520	53 (hot well)	220	East side of turbine shield wall	
18	0.8	35 (off-gas line)	100	54 (hot well)	170	opposite #3 - 12 mr/hr	
19	6.0	36	280	55	125	Turbine entrance door (at hand	
						and foot monitor) - 0.3 mr/hr	
						Hallway between turbine bldg	
						and control room - 0.2 mr/hr	
						Neutron reading (top of	
						turbine) - 7 mrem/hr	

Test 332

Data Sheet 6

Radiation Monitor Readings

Date: 5/1/67

Reactor Power: 162.8 Mwth

Recorder: _____

<u>Instrument No.</u>	<u>Reading</u>	<u>Instrument No.</u>	<u>Reading</u>
Shield Pool Area Mon	0.5	407 A	9,000
R B Oper Floor	1.4	407 B	200,000
R B Equip Floor	1.5	407 C	180,000
R B Plug Floor	3.0	407 D	350,000
Control Room	<0.05	407 E	750,000
F H B Storage Pool	3.0	407 F	2,000
F H B Basement North	8.0	407 G	700,000
F H B Basement South	0.2	295 A	55,000
F H B Mezzanine	3.0	295 B	9,000
Hot Chem Lab	8.0	R B Gaseous CAM	250
Stack Gas	200	F B Gaseous CAM	400
R B Vent Exh	6000	Flash Tank	700
T B Vent Exh	4500	T B Oper FI Area Monitor	14.0
F H B Vent Exh	800		
Stack Part	200		
1383	2.4		
T B Basement	1.3		