DOCKET NO. 50-336

MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2

EVALUATION OF NEUTRON SHIELD EFFECTIVENESS

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NOVEMBER, 1979

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I. INTRODUCTION

During the start-up test program at Calvert Cliffs Unit No. 1, higher than anticipated neutron levels resulting from neutron streaming in the reactor cavity were observed within and adjacent to the containment building (Reference 1). Millstone Unit No. 2 has a reactor design almost identical to that of the Calvert Cliffs units, and tests conducted during the Millstone Unit No. 2 start-up test program confirmed that a similar condition existed (Reference 2). This condition resulted in limitations being placed on containment and penetration room access during reactor operation in order to minimize personnel radiation exposure. It is believed that these high radiation levels may also lead to the accelerated degration of certain equipment necessitating permature replacement. Therefore, it became necessary to perform design modifications to reduce the dose rates to more acceptable levels.

II. SUMMARY

The optimum solution to the radiation streaming phenonema was determined to be a water tank placed over reactor shield annulus (Reference 3). The results of this shielding modifications are:

(1) neutron dose rate reductions ranging from factors of 25-150 for the 38' 6" level (operating floor), 50-90 for the 14' 6" level, and 7-30 for the -3' 6" level; and (2) gamma dose rate reductions ranging from factors of 5-30 for the 38' 6" level, 2-15 for the 14' 6" level, and 1-8 for the -3' 6" level.

These reduction factors are based on results obtained after shield installation, which assumed a 100% power level of 2700 Mw(th) as opposed to the measurements obtained before installation, which assumed a 100% power level of 2560 Mw(th). This fact, in addition to the change in core leakage, based on the new core loading arrangement, make the measured reduction approximately 30-40% less than that actually experienced.

The measured reduction factors are slightly in excess of the factor of 40 designed reduction for the operating floor. The total dose rate for areas of the containment which are occupied as required by operating personnel are now in general less than 100 mrem per hour.

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III. DISCUSSION

A. Causes of the High Radiation Levels

A review of the Millstone Unit No. 2 shield arrangement indicated that the high radiation levels inside the containment could be caused by streaming from: (1) the annulus between the reactor vessel flange and the primary shield wall, (2) the annulus between the reactor coolant piping and penetrations in the primary shield wall, and (3) the access opening through the lower segment of the primary shield wall. Based on the tests conducted during the start-up phase of the units, it was determined that the most significant contribution was the cavity streaming region since the highest dose rates were measured in the areas surrounding the reactor cavity.

B. Shield Design & Effectiveness

Since initial plant start-up in 1975, various alternate shield designs have been investigated and ultimately rejected for various reasons. The shielding concept that was finally selected consists of two water filled stainless steel semi-circular tanks. When the two halves are joined in place by the four hinge pins, they form a collar around the reactor vessel head at the flange elevation and span the gap between the reactor vessel and the refueling cavity floor.

The neutron shield was designed to minimize stay time in the reactor cavity area during installation. The work inside the cavity was the major contribution to the total man-rem required for the initial installation of the shield. It was originally estimated that three man-rem would be required for this task. After the work was completed, the exposures recorded on the radiation work permits were totaled. The entire task required 1.5 man-rem, half of the estimate.

The shield was also designed to minimize the time required for the removal and installation during each refueling outage. This is calculated to be two man-rem per outage, half of this due to activation of the shield and the remaining due to activation of other structures within the containment building and other sources. The minimum total annual dose savings was calculated to be 12 man-rem per year. This is for the case of containment entries only for the purpose of obtaining safety injection tank (SIT) samples as required by the technical specifications. With the increased operational flexibility resulting from the shield, it is estimated that there could be a savings of 100 man-rem per year.

Figures 1-4 show the results of neutron measurements and Figures 5-8 the results of the gamma measurements taken at 10%, 50% and 100% power. All results are extrapolated to 100% power. All neutron measurements were performed with a PNR-4 neutron rem-meter and all gamma measurements were performed with ionization chambers. In some cases, the PNR-4 readings were verified with the use of an Anderson-Braun meter.

As can be seen in Figure 1, the neutron dose rate reduction factors varies from a factor of 25 for areas overlooking the cavity to 100-150 for areas near the containment building wall.

Figure 2 shows reduction factors of 50-90 for neutrons on the 14' 6" level. Neutron dose reduction factors of 7-30 are shown on Figure 3 (elevation -3' 6"). Inside the personnel air lock, Figure 4, there is a neutron dose rate reduction factor of 50.

The gamma dose rates are reduced in much a similar manner as the neutron. The highest reduction occurring on the 38' 6" level (Figure

5), lower on the 14' 6" level (Figure 6), and even lower on the -3' 6" level (Figure 7). Points N7 and N2 actually show an increase in gamma dose rates. This is because the major source at these points was not streaming but nearby piping and the fact that the reactor power level has now been increased by approximately 5% over the Cycle 1 power level.

C. Actual Man-rem Savings to Date

Several weeks after the installation of the neutron shield and the start of Cycle 3 operation, a primary coolant system leak developed inside the containment. This leak was repaired at full power with an expenditure of 0.4 man-rem. It is estimated that an additional 10 man-rem would have been expended to repair the leak at power without the neutron shield.

A second repair was recently made at full power. This repair was on one of the safety injection tanks with a resulting exposure of 0.5 man-rem. For this repair, the shield saved 20 man-rem.

Additional man-rem savings are routinely gained every month for the purpose of obtaining SIT tank samples. Before this shield, each entry resulted in an expenditure of 1 man-rem. With the shield, this has decreased to 0.15 man-rem.

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IV. CONCLUSION

The water tank shield design has proven itself to be an effective design for the reduction of neutron streaming near the vessel flange. This design has superior qualities in that it takes a minimal expenditure of man-rem for initial and subsequent removal and installations and provides the necessary reduction in total dose rate. This goal was accomplished without unduly compromising other design considerations.

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V. REFERENCES

1. MPR Associates, Inc., Calvert Cliffs Nuclear Plant Unit No. 1, Report of Temporary Shield Modifications, MPR-457, Baltimore Gas and Electric Company, February 1975.

2. Millstone Nuclear Power Station, Unit II, Radiation Survey Results in and Around Millstone Unit II Containment Building, Northeast Nuclear Energy Company, April 1976.

3. W. G. Counsil letter to R. Reid, dated February 23, 1979.

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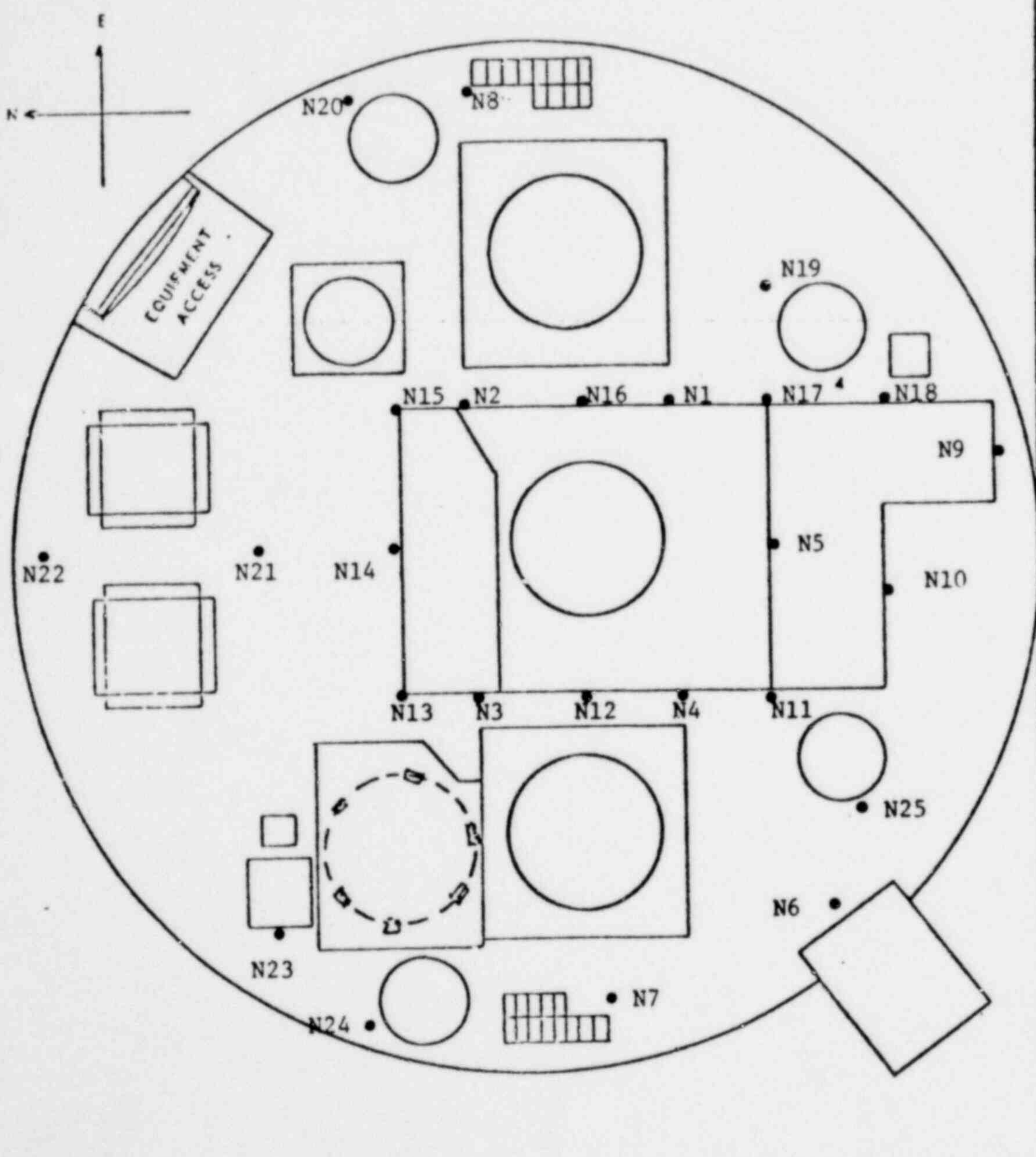
MILLSTONE NUCLEAR POWER STATION
UNIT NO. 2

Neutron Survey

B = Before Shield
A = After Shield
RF = Factor of Reduction
R = Thousands (R/hr)

+1 LEVEL CONTAINMENT (38' 6")



mrem/hr

RESULTS			
POINT	B	A	RF
N1	60R	1R	60
N2	60R	1R	60
N3	60R	-	-
N4	60R	1R	60
N5	65R	1R	65
N6	4R	40	100
N7	1.5R	10	150
N8	1.5R	10	150
N9	5R	150	33
N10	20R	600	33
N11	10R	400	25
N12	6R	-	-
N13	10R	-	-
N14	10R	400	25
N15	10R	-	-
N16	6R	-	-
N17	10R	400	25
N18	6R	-	-
N19	5R	60	83
N20	1.4R	15	93
N21	7R	80	88
N22	2R	30	67
N23	2R	30	67
N24	2R	30	67
N25	3R	40	75

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100% Power (2700 Mwth) Radiation Levels
Based on 13%, 50% and 100% Surveys

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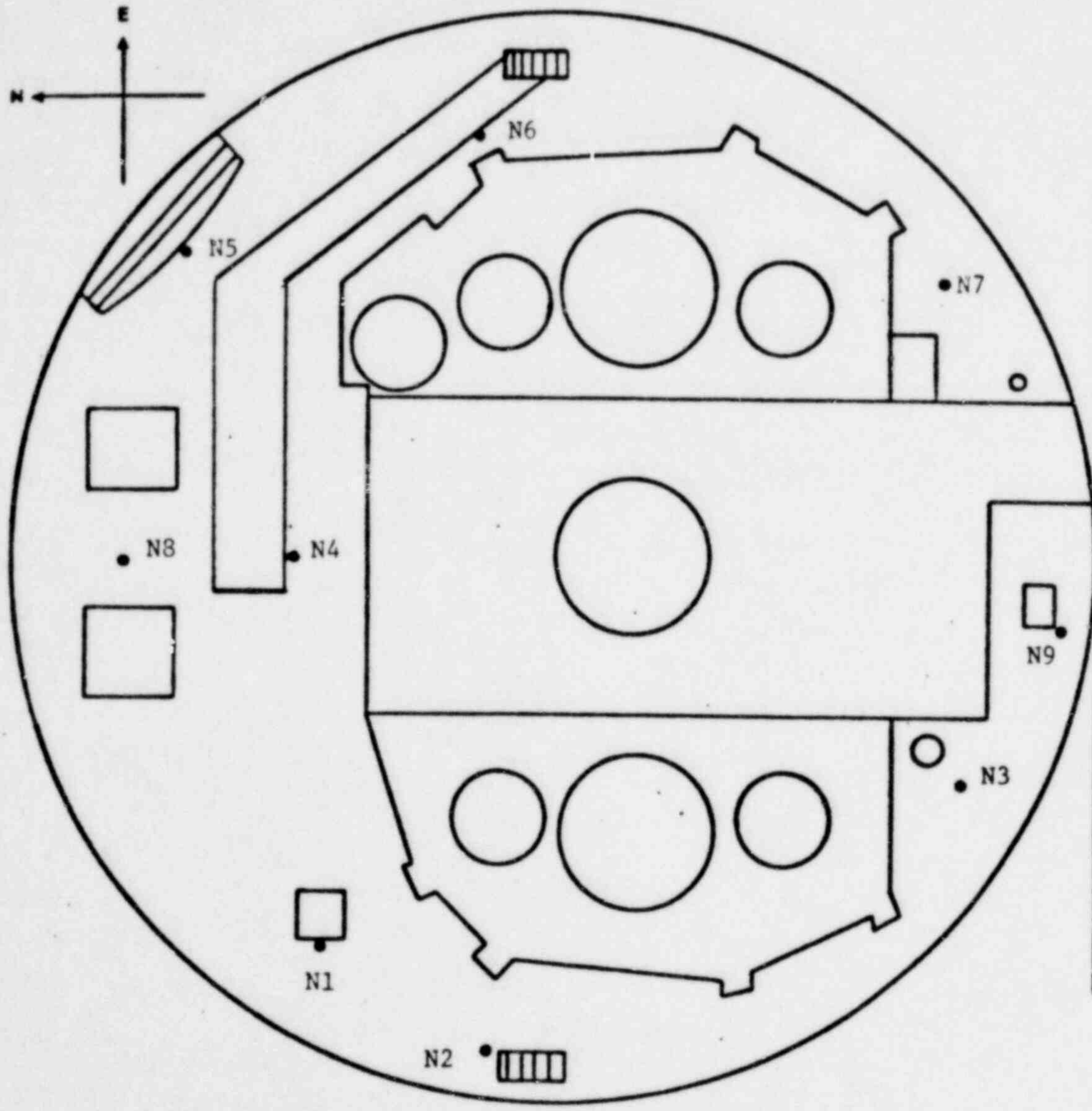
MILLSTONE NUCLEAR POWER STATION
UNIT NO. 2

NEUTRON SURVEY

B = Before Shield
A = After Shield
RF = Factor of Reduction
R = Thousands (R/hr)

GROUND LEVEL CONTAINMENT (14' 6")



mrem/hr

	RESULTS		
POINT	B	A	RF
N1	400		
N2	300	6	50
N3	300	6	50
N4	800		
N5	900	10	90
N6	300		
N7	300		
N8	-	10	-
N9	-		

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100% Power (2700 Mwth) Radiation Levels
Based on 13%, 50% and 100% Surveys

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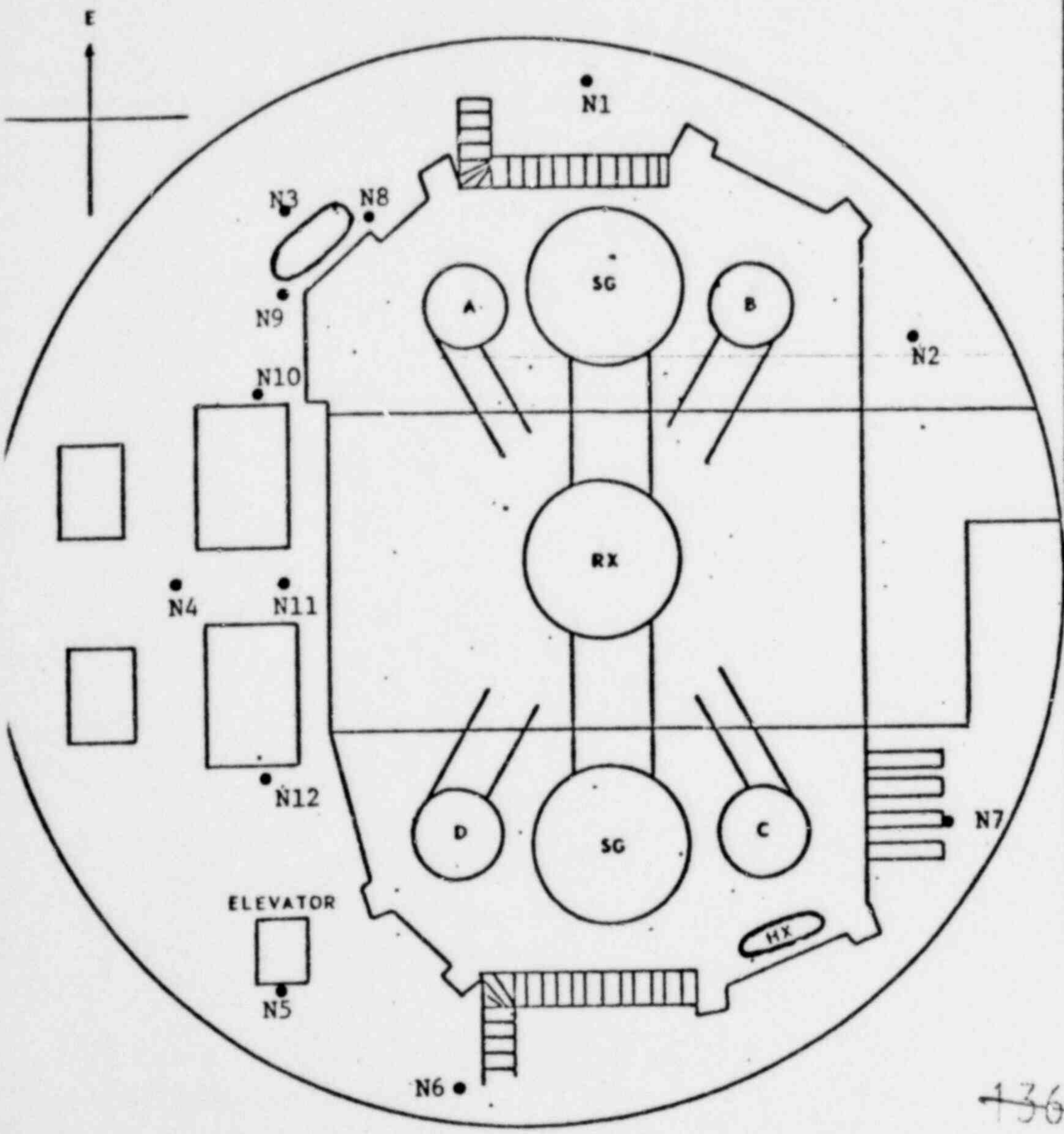
MILLSTONE NUCLEAR POWER STATION

UNIT NO. 2

NEUTRON SURVEY

B = Before Shield
A = After Shield
RF = Factor of Reduction
R = Thousands (R/hr)

-1 LEVEL CONTAINMENT (-3' 6")



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RESULTS			
POINT	B	A	RF
N1	200		
N2	175	25	7
N3	250	8	25
N4	250	10	31
N5	250		
N6	200	8	25
N7	200	8	25
N8	-		
N9	-		
N10	-		
N11	-		
N12	-		

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100% Power (2700 Mwth) Radiation Levels
Based on 13%, 50% and 100% Surveys

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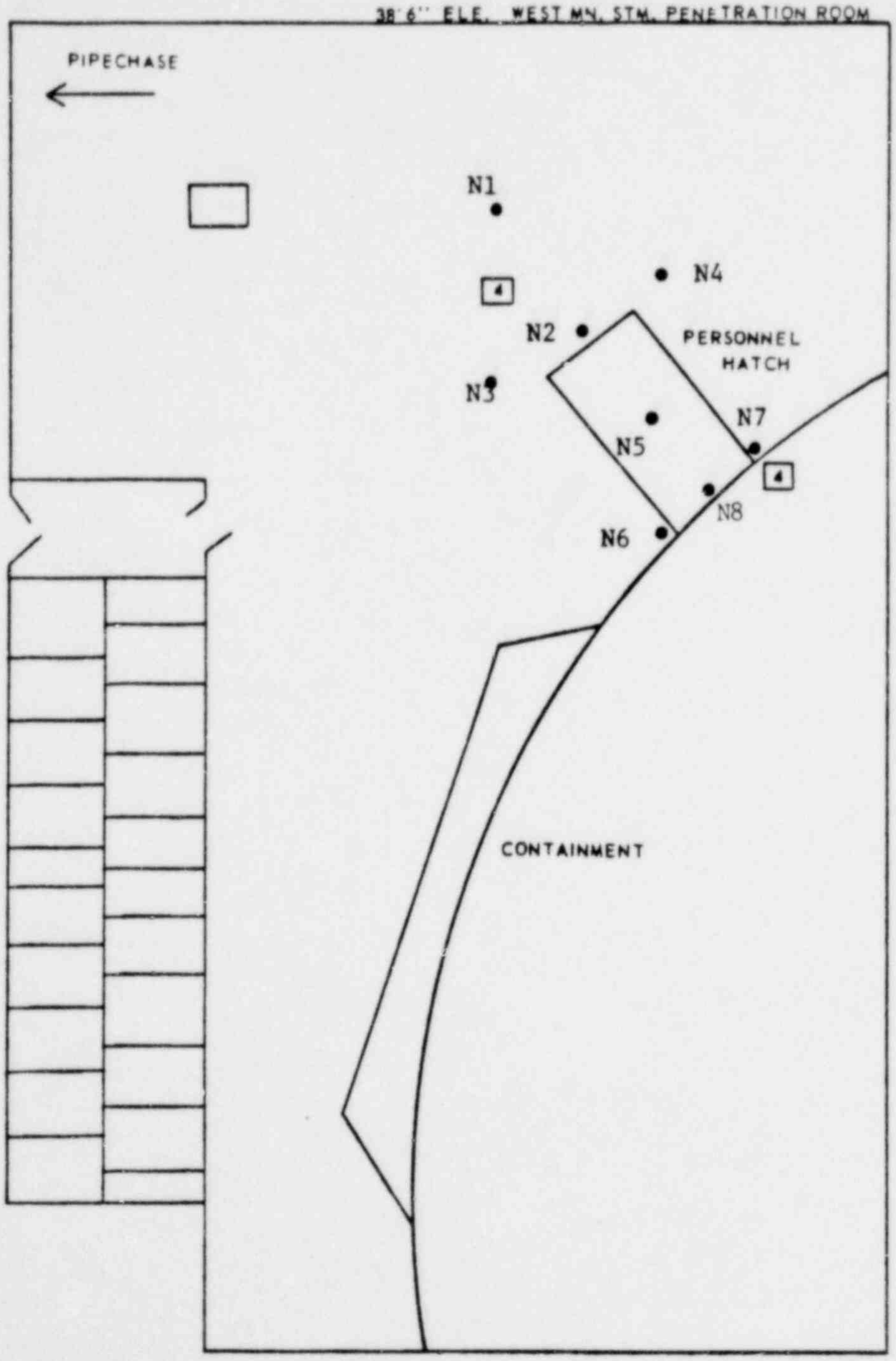
MILLSTONE NUCLEAR POWER STATION
UNIT NO. 2

NEUTRON SURVEY

B = Before Shield
A = After Shield
RF = Factor of Reduction
R = Thousands (R/hr)

38'6" ELE. WEST MN. STM. PENETRATION ROOM



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RESULTS			
POINT	B	A	RF
N1	20		
N2	100		
N3	30		
N4	30		
N5	300	6	50
N6			
N7			
N8	-	8	

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100% Power (2700 Mwth) Radiation Levels
Based on 13%, 50% and 100% Surveys

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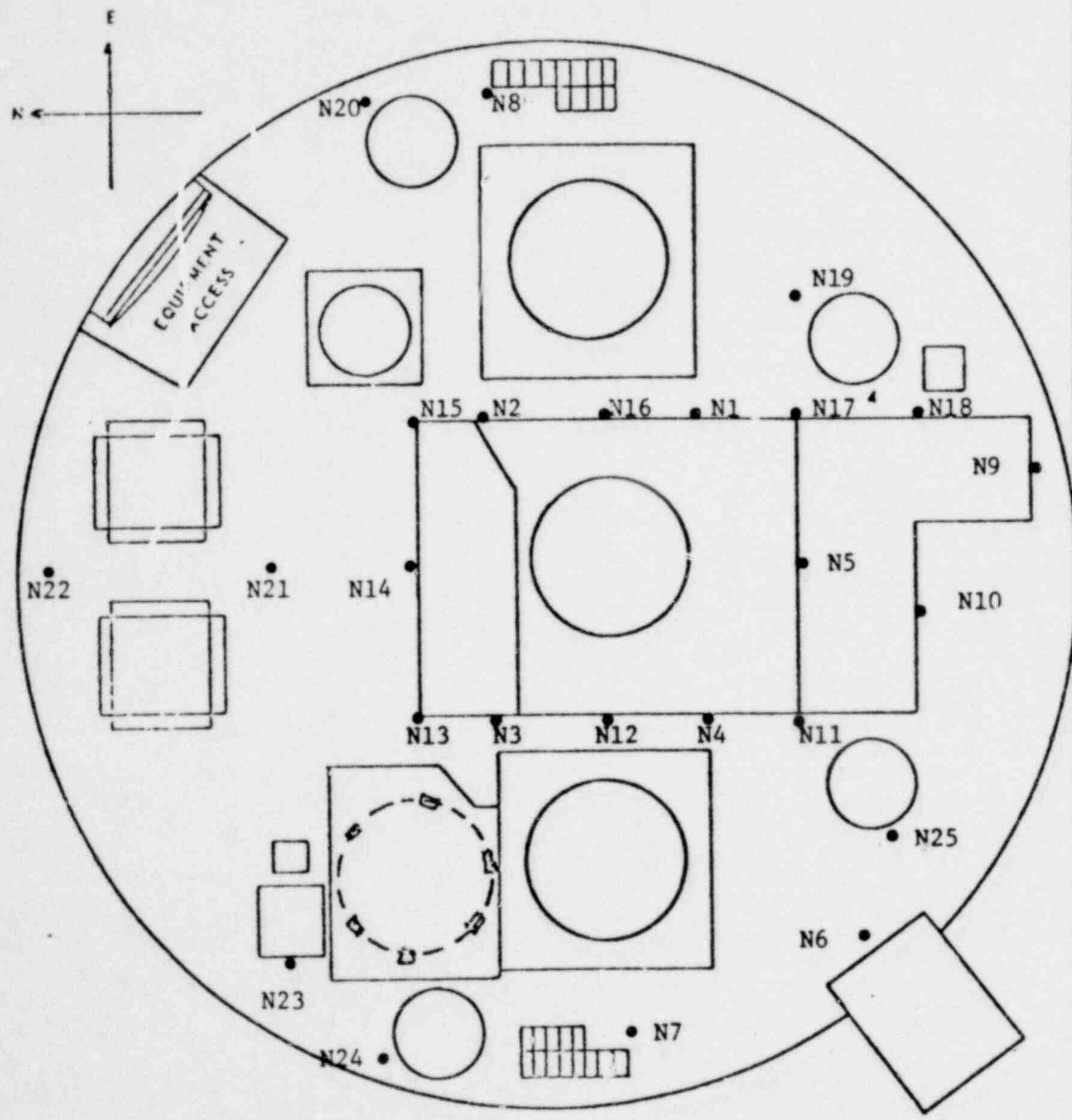
MILLSTONE NUCLEAR POWER STATION
UNIT NO. 2

GAMMA SURVEY

B = Before Shield
A = After Shield
RF = Factor of Reduction
R = Thousands (R/hr)

+1 LEVEL CONTAINMENT (38' 6")



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RESULTS			
POINT	B	A	RF
N1	8R	1.7R	5
N2	8R	1.7R	5
N3	8R	-	-
N4	8R	1.7R	5
N5	10R	1.7R	6
N6	450	20	22
N7	225	10	22
N8	225	10	
N9	1R	200	5
N10	4R	600	7
N11	2.5R	400	6
N12	1.5R	-	-
N13	2.5R	-	-
N14	3.2R	250	13
N15	2.5R	-	-
N16	1.5R	-	-
N17	2.5R	400	6
N18	1.5R	-	-
N19	1R	50	20
N20	180	20	9
N21	1.1R	40	27
N22	400	20	20
N23	350	15	23
N24	450	17	26
N25	450	25	18

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100% Power (2700 Mwth) Radiation Levels
Based on 13%, 50%, and 100% Surveys

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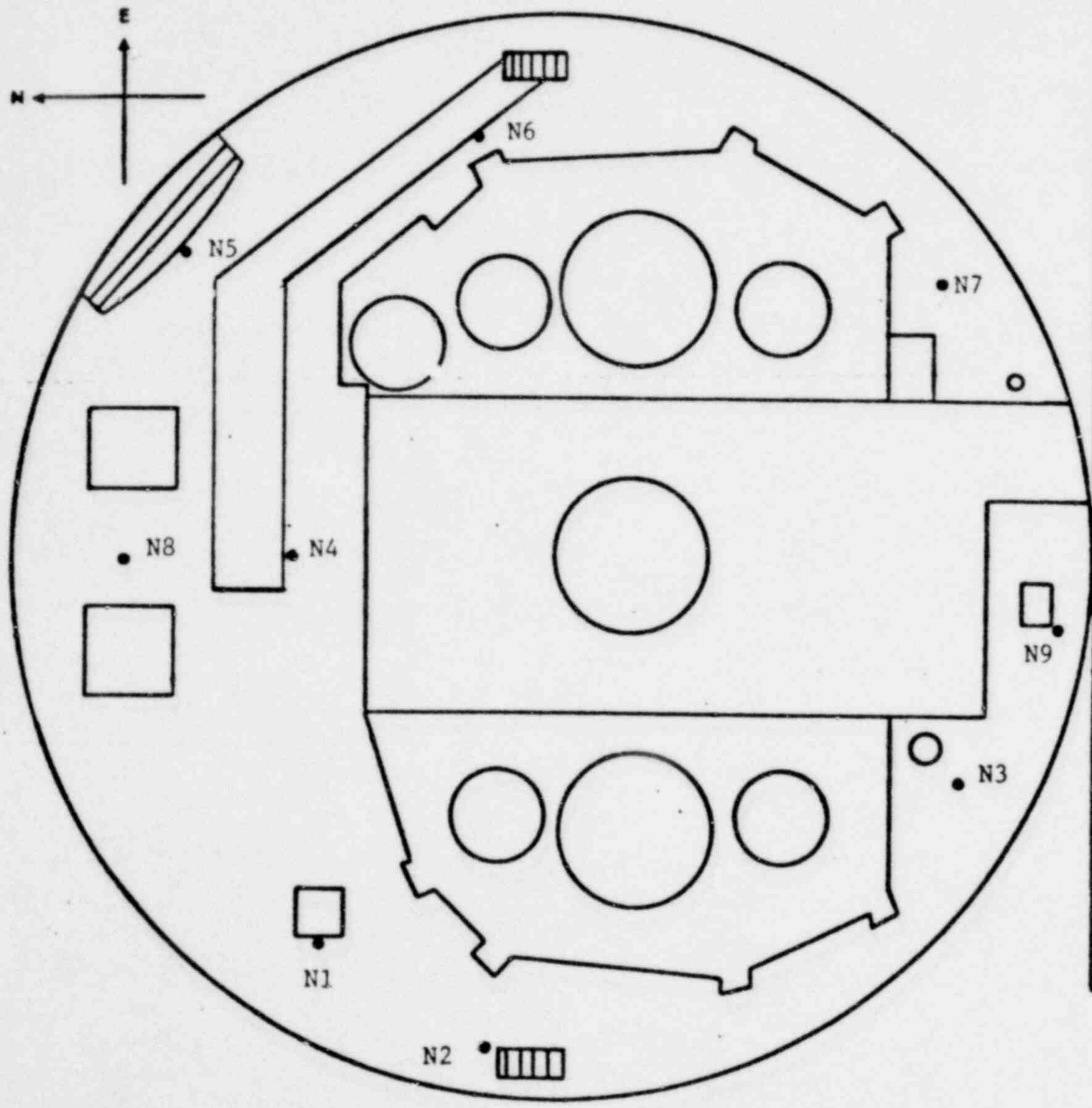
MILLSTONE NUCLEAR POWER STATION
UNIT NO. 2

GAMMA SURVEY

B = Before Shield
A = After Shield
RF = Factor of Reduction
R = Thousands (R/hr)

GROUND LEVEL CONTAINMENT (14' 6")



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RESULTS			
POINT	B	A	RF
N1	60		
N2	50	6	8
N3	60	25	2
N4	130	8	16
N5	130	8	16
N6	50	25	2
N7	50	8	6
N8	–	8	–
N9	–		

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100% Power (2700 Mwth) Radiation Levels
Based on 13%, 50%, and 100% Surveys

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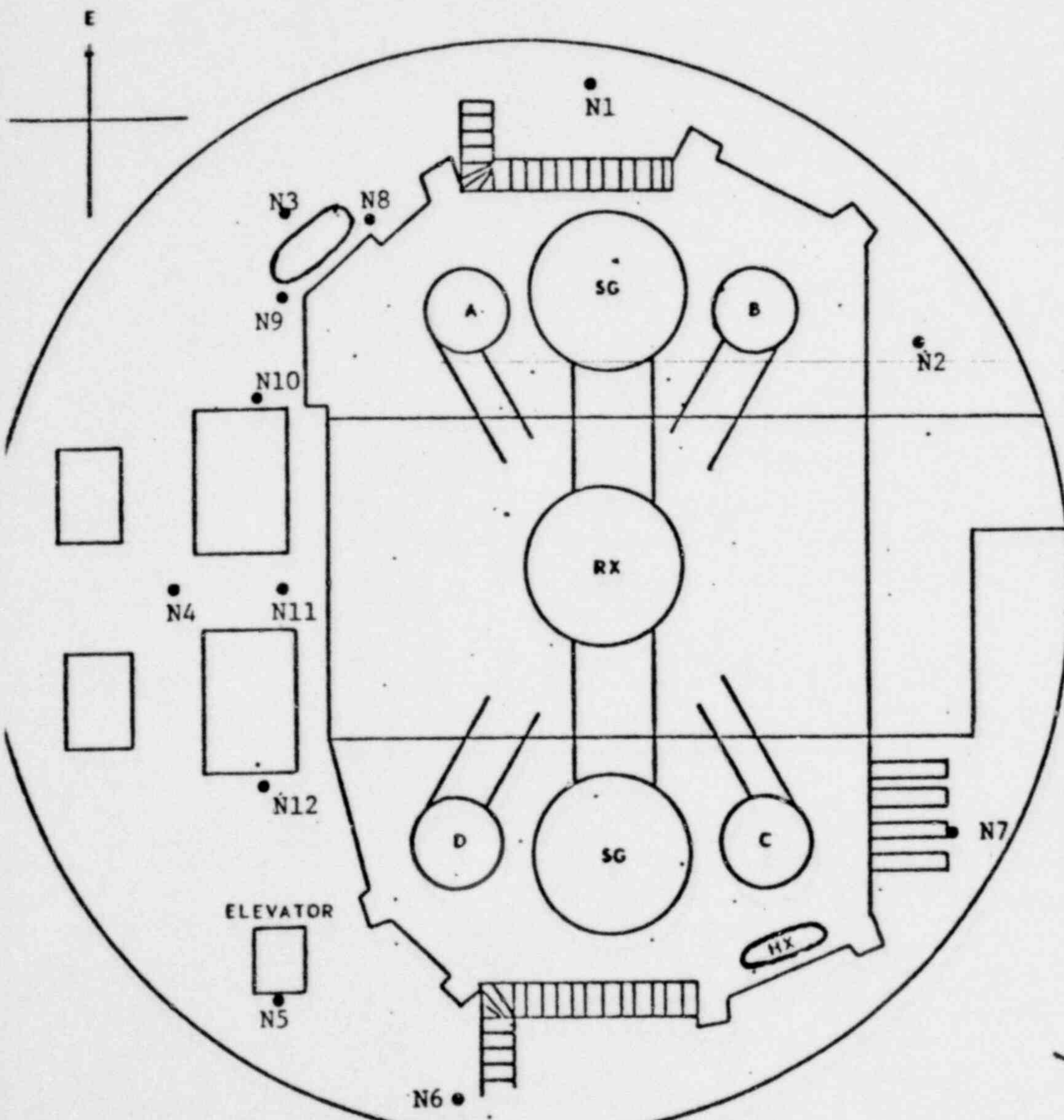
MILLSTONE NUCLEAR POWER STATION
UNIT NO. 2

GAMMA SURVEY

B = Before Shield
A = After Shield
RF = Factor of Recution
R = Thousands (R/hr)

-1 LEVEL CONTAINMENT (-3' 6")



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RESULTS			
POINT	B	A	RF
N1	15		
N2	20	24	1
N3	40	20	2
N4	40	6	7
N5	40		
N6	30	10	3
N7	250	280	1
N8	–	20	
N9	–		
N10	–		
N11	–		
N12	–		

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100% Power (2700 Mwth) Radiation Levels
Based on 13%, 50% and 100% Surveys

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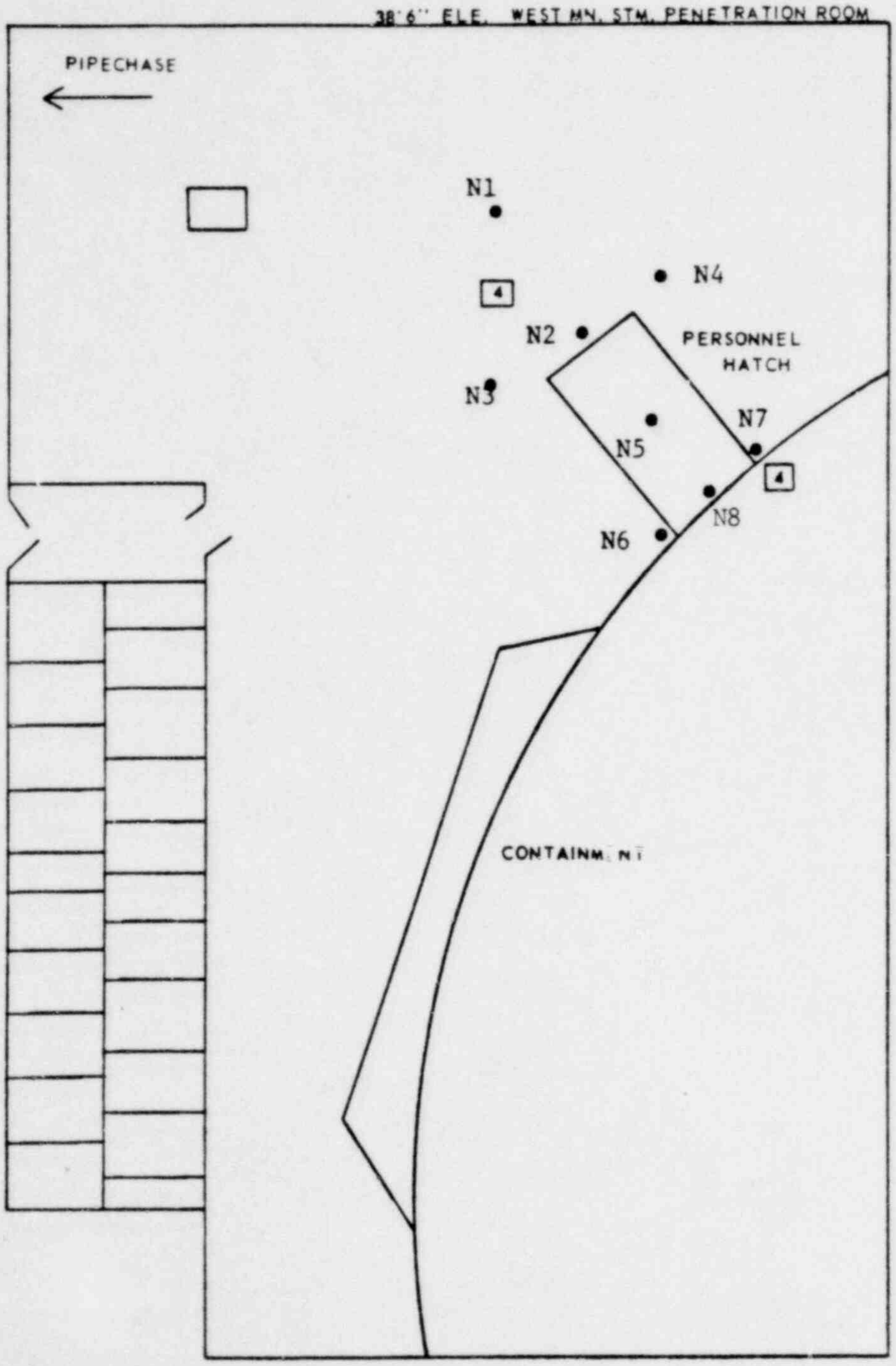
MILLSTONE NUCLEAR POWER STATION
UNIT NO. 2

GAMMA SURVEY

B = Before Shield
A = After Shield
RF = Factor of Reduction
R = Thousands (R/hr)



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RESULTS			
POINT	B	A	RF
N1	2.5		
N2	15		
N3	4		
N4	4		
N5	35	3	12
N6			
N7			
N8	-	6	

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100% Power (2700 Mwth) Radiation Levels
Based on 13%, 50%, and 100% Surveys