VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

June 30, 1980

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
ATTN: Mr. Robert A. Clark, Chief
Operating Reactors Branch No. 3
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Serial No. 352
NO/DWL/WAT:ms
Docket No. 50-338
License No. NPF-4

Dear Mr. Denton:

NORTH ANNA POWER STATION UNIT NO. 1
ADDITIONAL INFORMATION REGARDING STEAM
GENERATOR CHEMISTRY AND CORROSION

Attached you will find additional information regarding the corrective actions which were implemented as a result of the observed North Anna Unit No. 1 steam generator support plate corrosion. This information is provided in response to your letter dated April 8, 1980.

Very truly yours,

B. R. Sylvia
Manager - Nuclear
Operations and Maintenance

Attachment

cc: Mr. James P. O'Reilly, Director
Office of Inspection and Enforcement - Region II

8007020456

Attachment

REQUEST FOR ADDITIONAL INFORMATION REGARDING
STEAM GENERATOR CHEMISTRY AND CORROSION
NORTH ANNA POWER STATION
UNIT NO. 1

NRC REQUEST

1. The results of the flushing program to reduce the sulfate contaminates, in particular, data on hideout return after 50% load reduction and prior to returning to full power.

RESPONSE

To date, steam generator blowdown samples have been obtained at low power (~27%); zero power following a unit trip; during a power ramp and also at stable low power operation (~30%). A comprehensive chemical return study was set up for the next scheduled shutdown (the last week in May). This study was agreed upon between VEPCO and Westinghouse. The recommended procedure was:

A. Reduce blowdown to approximately 10 gpm/SG and establish equilibrium chemistry conditions.

B. Sample steam generators during power reduction. Blowdown samples are to be collected at intervals corresponding to each 20% reduction in power level.

C. Hold unit at 20 - 30% reactor power for 24 hours. Sample steam generator blowdown every 4 - 6 hours and analyze samples for boric acid concentration and selected hideout species.

D. If boric acid concentration is around 1.0 ppm and decay curve for cation conductivity is asymptotic and <2 μmhos/cm, proceed to hot shutdown. If cation conductivity is >2 μmhos/cm, use maximum blowdown flowrate to bring the steam generator bulk water chemistry within the normal range. When proper chemistry conditions have been established, proceed to hot shutdown.

However, the unit tripped at 2240 hours on May 22, 1980 and the unit proceeded to cold shutdown. Steam generator samples were taken and are in the process of being analyzed. Preliminary data on a sample taken at 0900 hours on May 23 are shown in Table 1.1.

TABLE 1.1
SAMPLE TAKEN AT 0900 HOURS ON MAY 23, 1980 FOLLOWING UNIT TRIP

	Steam Generator		
	A	B	C
pH	7.79	7.72	7.63
Conductivity μmhos/cm	5.80	5.80	5.58
Cation conductivity μmhos/cm	10.5	11.6	10.8
Cl ppm	0.38	0.35	0.36
Na ppm	0.66	0.70	0.66
SiO_2 ppm	0.95	0.89	0.95
O_2 ppb	0.0	0.0	0.0
NH_3 ppm	0.16	0.16	0.20
N_2H_4 ppm	<0.002	<0.002	<0.002
Blowdown gpm	20	20	20
Power %	0.0	0.0	0.0

Table 1.1 indicates that hideout return is occurring. The cation conductivity cannot be accounted for by the anions analyzed for. As in previous samples, it is expected that sulfate will be present and contribute towards the unaccounted for cation conductivity. Other samples are in the process of being analyzed. The data available to date would indicate that material is still returning.

NRC REQUEST

2. The effects of boric acid treatment on the non-stainless steel ferrous components in the feedwater train of the secondary system.

RESPONSE

In order to identify the potential corrosiveness of the feedwater to non-stainless ferrous materials at North Anna Unit No. 1, calculations have been carried out to determine the pH of solutions containing typical boric acid and ammonia concentrations experienced at North Anna Unit No. 1 and at temperatures consistent with the feedwater train. Table 2.1 shows the temperature profile of the feedwater train.

TABLE 2.1

NORTH ANNA UNIT NO. 1 FEEDWATER TRAIN TEMPERATURES

Location	Temperature °F
Condensate	100
#6 heater	110 (inlet) 176 (outlet)
#5 heater	176 (inlet) 228 (outlet)
#4 heater	228 (inlet) 284 (outlet)
#3 heater	284 (inlet) 315 (outlet)
#2 heater	315 (inlet) 386 (outlet)
#1 Heater	389 (inlet) 437 (outlet)

Boric acid concentrations in the feedwater are expected to range from 0.5 to 1.0 ppm B (for a steam generator bulk concentration of 5 - 10 ppm B). The calculations cover 0, 0.2, 0.4, 0.6, 0.8 and 1.0 ppm B. Ammonia concentrations at North Anna Unit No. 1 normally have been 0.1 and 0.2 ppm, with occasional excursions to 0.4 ppm. Separate Tables 2.2 through 2.6 are provided for 0.1, 0.2, 0.25, 0.3 and 0.4 ppm NH_3.

Correlations of equilibrium ionization data at saturation pressure and zero ionic strength were used in these calculations. Corrections for the effect of ionic strength are negligible at the concentrations of boric acid and ammonia considered. Similarly, corrections for the differences between feedwater pressures and saturation pressures are also negligible. The ionization data employed were those of Sweeton, Mesmer and Baes for water (1), Hitch and Mesmer for ammonia (2), and Mesmer, Baes and Sweeton for boric acid (3). All borate ion species indicated by reference 3 were included in the calculations.

Figure 2.1 shows the typical effect of boric acid on alkalinity at feed-train temperatures in North Anna Unit No. 1, for 0.25 ppm NH_3 with and without 1.0 ppm B. The pH depression effect of boric acid is significant only in the No. 6 heater (110° - 176°F). This is the lowest temperature heater. The solutions are still above neutral, therefore, significant corrosion due to the presence of boric acid is not expected. At the higher temperatures the boric acid depression is negligible, the added ammonia being the chemically dominate species, thereby providing the desired alkalinity.

References

1. F. H. Sweeton, R. E. Mesmer and C. F. Baes, Jr., J. Solution Chemistry, 3, page 191, 1974.

2. B. Kitch and R. E. Mesmer, J. Solution Chemistry, 5, page 667, 1976.

3. R. E. Mesmer, C. F. Baes, Jr., and F. H. Sweeton, Proceedings from the 32nd International Water Conference, Pittsburgh, PA page 55, 1971.

FIGURE 2.1 TYPICAL EFFECT OF BORIC ACID ON ALKALINITY AT FEEDTRAIN TEMPERATURES IN NORTH ANNA I

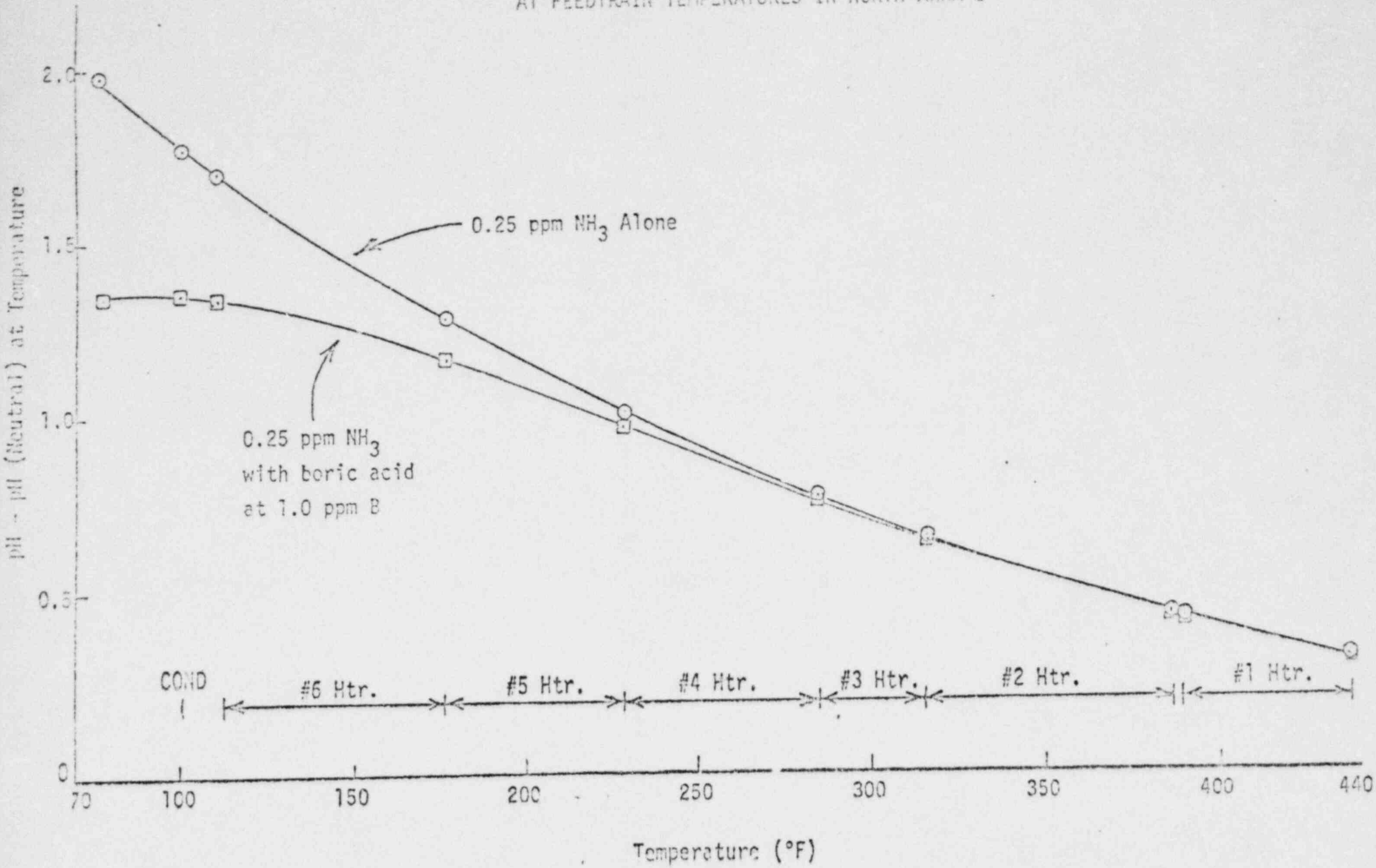


TABLE 2.2

pH OF AMMONIA, BORIC ACID MIXTURES FOR .1 PPM NH_3.

TEMP. (DEG. F)	PPM B 0.00	.20	.40	.60	.80	1.00
77.0	8.66	8.41	8.24	8.12	8.02	7.95
100.0	8.27	8.12	8.01	7.92	7.84	7.78
110.0	8.12	8.00	7.90	7.83	7.76	7.70
176.0	7.28	7.25	7.22	7.20	7.18	7.15
228.0	6.78	6.77	6.76	6.75	6.74	6.74
284.0	6.38	6.37	6.37	6.37	6.36	6.36
315.0	6.20	6.20	6.20	6.19	6.19	6.19
386.0	5.91	5.90	5.90	5.90	5.90	5.90
389.0	5.90	5.90	5.[illegible]	5.89	5.89	5.89
437.0	5.77	5.77	5.77	5.77	5.77	5.77

pH-pH(NEUT) OF AMMONIA, BORIC ACID MIXTURES FOR .1 PPM NH_3

TEMP. (DEG. F)	PPM B 0.00	.20	.40	.60	.80	1.00
77.0	1.66	1.41	1.25	1.13	1.03	.95
100.0	1.47	1.32	1.21	1.12	1.04	.98
110.0	1.39	1.28	1.18	1.10	1.04	.98
176.0	.97	.94	.92	.89	.87	.85
228.0	.72	.71	.70	.69	.68	.67
284.0	.51	.50	.50	.50	.49	.49
315.0	.41	.41	.41	.41	.40	.40
386.0	.25	.25	.25	.24	.24	.24
389.0	.24	.24	.24	.24	.24	.24
437.0	.16	.16	.16	.16	.16	.16

TABLE 2.3

pH OF AMMONIA, BORIC ACID MIXTURES FOR .2 PPM NH_3

TEMP. (DEG. F)	PPM B 0.00	.20	.40	.60	.80	1.00
77.0	8.90	8.69	8.53	8.41	8.32	8.24
100.0	8.51	8.38	8.28	8.19	8.12	8.06
110.0	8.36	8.25	8.17	8.09	8.03	7.98
176.0	7.51	7.48	7.46	7.44	7.42	7.40
228.0	7.00	6.99	6.98	6.98	6.97	6.96
284.0	6.57	6.57	6.57	6.56	6.56	6.56
315.0	6.38	6.38	6.38	6.37	6.37	6.37
386.0	6.04	6.04	6.04	6.04	6.04	6.04
389.0	6.03	6.03	6.03	6.03	6.03	6.03
437.0	5.88	5.88	5.88	5.87	5.87	5.87

pH-pH(NEUT) OF AMMONIA, BORIC ACID MIXTURES FOR .2 PPM NH_3

TEMP. (DEG. F)	PPM B 0.00	.20	.40	.60	.80	1.00
77.0	1.90	1.69	1.54	1.42	1.32	1.25
100.0	1.71	1.58	1.48	1.39	1.32	1.26
110.0	1.63	1.53	1.44	1.37	1.31	1.26
176.0	1.20	1.18	1.16	1.13	1.11	1.09
228.0	.94	.93	.92	.91	.90	.90
284.0	.70	.70	.70	.69	.69	.69
315.0	.59	.59	.59	.59	.58	.58
386.0	.38	.38	.38	.38	.38	.38
389.0	.38	.37	.37	.37	.37	.37
437.0	.27	.27	.26	.26	.26	.26

TABLE 2.4

pH OF AMMONIA, BORIC ACID MIXTURES FOR .25 PPM NH_3

TEMP. (DEG. F)	PPM B					
	0.00	.20	.40	.60	.80	1.00
77.0	8.97	8.77	8.62	8.51	8.42	8.34
100.0	8.58	8.46	8.36	8.28	8.21	8.15
110.0	8.43	8.33	8.25	8.18	8.12	8.06
176.0	7.58	7.56	7.53	7.51	7.49	7.47
228.0	7.07	7.06	7.05	7.05	7.04	7.03
284.0	6.64	6.63	6.63	6.63	6.62	6.62
315.0	6.44	6.44	6.44	6.43	6.43	6.43
386.0	6.09	6.09	6.09	6.09	6.09	6.09
389.0	6.08	6.08	6.08	6.07	6.07	6.07
437.0	5.92	5.91	5.91	5.91	5.91	5.91

pH-pH(NEUT) OF AMMONIA, BORIC ACID MIXTURES FOR .25 PPM NH_3

TEMP. (DEG. F)	PPM B					
	0.00	.20	.40	.60	.80	1.00
77.0	1.98	1.78	1.63	1.51	1.42	1.34
100.0	1.78	1.66	1.56	1.48	1.41	1.35
110.0	1.71	1.61	1.53	1.46	1.39	1.34
176.0	1.28	1.25	1.23	1.21	1.19	1.17
228.0	1.01	1.00	.99	.98	.97	.97
284.0	.77	.76	.76	.76	.75	.75
315.0	.65	.65	.65	.65	.64	.64
386.0	.43	.43	.43	.43	.43	.43
389.0	.42	.42	.42	.42	.42	.42
437.0	.31	.30	.30	.30	.30	.30

TABLE 2.5

pH OF AMMONIA, BORIC ACID MIXTURES FOR .3 PPM NH_3

TEMP. (DEG. F)	PPM B 0.00	.20	.40	.60	.80	1.00
77.0	9.03	8.84	8.70	8.58	8.49	8.42
100.0	8.64	8.52	8.43	8.35	8.28	8.22
110.0	8.49	8.39	8.31	8.25	8.19	8.13
176.0	7.64	7.62	7.59	7.57	7.55	7.53
228.0	7.13	7.12	7.11	7.10	7.09	7.09
284.0	6.69	6.69	6.68	6.68	6.68	6.67
315.0	6.49	6.49	6.49	6.48	6.48	6.48
386.0	6.13	6.13	6.13	6.13	6.13	6.13
389.0	6.12	6.12	6.12	6.12	6.11	6.11
437.0	5.95	5.95	5.95	5.95	5.95	5.95

pH-pH(NEUT) OF AMMONIA, BORIC ACID MIXTURES FOR .3 PPM NH_3

TEMP. (DEG. F)	PPM B 0.00	.20	.40	.60	.80	1.00
77.0	2.03	1.85	1.70	1.59	1.50	1.42
100.0	1.84	1.72	1.63	1.55	1.48	1.42
110.0	1.77	1.67	1.59	1.52	1.46	1.41
176.0	1.33	1.31	1.29	1.27	1.25	1.23
228.0	1.06	1.05	1.05	1.04	1.03	1.02
284.0	.82	.82	.81	.81	.81	.80
315.0	.70	.70	.70	.70	.69	.69
386.0	.47	.47	.47	.47	.47	.47
389.0	.46	.46	.46	.46	.46	.46
437.0	.34	.34	.34	.34	.34	.34

TABLE 2.6

pH OF AMMONIA, BORIC ACID MIXTURES FOR .4 PPM NH_3

TEMP. (DEG. F)	PPM B 0.00	.20	.40	.60	.80	1.00
77.0	9.12	8.95	8.81	8.70	8.61	8.54
100.0	8.73	8.62	8.53	8.46	8.39	8.33
110.0	8.58	8.49	8.41	8.35	8.29	8.24
176.0	7.73	7.70	7.68	7.66	7.64	7.63
228.0	7.21	7.20	7.19	7.19	7.18	7.17
284.0	6.77	6.77	6.76	6.76	6.76	6.75
315.0	6.57	6.56	6.56	6.56	6.56	6.56
386.0	6.20	6.20	6.19	6.19	6.19	6.19
389.0	6.18	6.18	6.18	6.18	6.18	6.18
437.0	6.01	6.00	6.00	6.00	6.00	6.00

pH-pH(NEUT) OF AMMONIA, BORIC ACID MIXTURES FOR .4 PPM NH_3

TEMP. (DEG. F)	PPM B 0.00	.20	.40	.60	.80	1.00
77.0	2.12	1.95	1.82	1.71	1.62	1.54
100.0	1.93	1.82	1.73	1.66	1.59	1.53
110.0	1.86	1.77	1.69	1.63	1.57	1.52
176.0	1.42	1.40	1.38	1.36	1.34	1.32
228.0	1.15	1.14	1.13	1.12	1.11	1.11
284.0	.90	.90	.89	.89	.89	.88
315.0	.78	.78	.77	.77	.77	.77
386.0	.54	.54	.54	.54	.53	.53
389.0	.53	.53	.53	.53	.53	.52
437.0	.40	.39	.39	.39	.39	.39

NRC REQUEST

3. Preliminary data on the effectiveness of the boric acid treatment to stop tube support plate corrosion; i.e., (a) results of the low power soak treatment, (b) boron analysis on condensate, feedwater, blowdown, main steam and heater drains, and (c) hydrogen, oxygen, ammonia, pH, and cation conductivity analysis.

RESPONSE

The following is a summary of the low power (25 - 35%) soak with boric acid at North Anna Unit No. 1. The objective of the boric acid soak is to reduce the rate of denting by minimizing further corrosion of the carbon steel TSP tube hole. The steam generator boric acid conditioning commenced January 9, at 2400 hours, however, due to operational delays, the low power boric acid soak was not completed until January 27, at 2400 hours. In accordance with the subject boric acid conditioning procedure, a boron accountability program was also performed to determine secondary system boron demand. From the data collected (see Figure 3.1 and 3.2 for graphical presentation of data), it appears that the steam generator boron demand was satisfied (according to the 90% accountability criteria) within the 96 hour soak period. The cumulative (between January 9-27) boron accountability for the three steam generators was 91%.

3.1 Conditions and Sequence of Test

The injection of boric acid into the steam generators (via the auxiliary feed system) was initiated January 9 at approximately 1500 hours. At this time, the unit was at 350°F. Later that day the temperature was reduced to approximately 200°F. This mode of operation (fluctuation in system temperature) continued through January 15. On January 10, the boron concentration reached 45 ± 5 ppm for each of the steam generators and remained at approximately that level for the duration of the soak.

On January 15, at approximately 1000 hours, operations established feed from the hotwell to the steam generators. At about 1625 hours the unit reached hot standby conditions and remained in this mode until January 19. 1980, at which time physics testing was performed (~3% RX Power). After returning to hot standby (~550°F) for a day, the unit was taken to power (a maximum of 27% Rx Power was obtained) to perform the turbine overspeed test which was completed on January 22.

The boric acid soak commenced on January 23 at 2400 hours and was completed on January 27 at 2400 hours. The range of reactor power, during the 96 hour soak, was between 27% and 35% as shown in Figure 3.2.

3.2 Results

3.2.1 Steady-state accountability tests were conducted on January 26 (between 0030-0745) and January 27 (between 1215-2030). The boron concentrations for these periods were:

January 26	0030	46	43	39 ppm B
	0745	40	39	36 ppm B
January 27	1215	53	52	47 ppm B
	2030	48	48	47 ppm B

As per the recommended procedure, boron demand is satisfied when:

$$\frac{[B]_{t=x}}{[B]_{t=o}} = 90\% \pm 5$$

With no blowdown

Where x is > 6 hours

Calculations for January 26 and January 27 give ratios of 89 and 94% respectively, i.e., the results indicate that boron demand was satisfied under steady-state conditions.

3.2.2 As of January 27, 245 kg of boron (1379 kg of boric acid) were added to the secondary system. 222 kg of boron were accounted for based on the total mass leaving the steam generator plus the the steam generator bulk water inventory. Therefore, the accumulative hideout of boron in the North Anna Unit 1 steam generators is estimted at 23 kg or 9% of the total boron addition.

3.2.3 During transient power conditions, control chemistry parameters (specifically cation conductivity and chlorides) were not within the guidelines identified in the procedure. Therefore, action was taken to bring the unit down to hot standby conditions to remove impurities from the steam generator water. The unit remained at hot standby conditions for approximately 24 hours.

The high cation conductivity was thought to be due to sulfate (SO_4) return in the steam generators. The data in Tabel 3.1 reveal some SO_4 return; however, the sulfate could not be analyzed on a daily basis due to laboratory limitations. The data also reveal that the chloride species could not account for the total increase in cation conductivity. In some cases the cation conductivity can be accounted for by the measured chloride and sulfate. In other cases the data indicate the presence of other anions. These were not identified and, therefore, a complete assessment of the steam generator environment during the soak is not possible.

3.3 Hydrogen Monitoring

A hydrogen monitoring program at North Anna Unit 1 has been underway since the boron soak. Figure 3.3 shows the average corrosion hydrogen (g.moles/hr) for the time period of March, 1980 - May, 1980. the data indicates a stable corrosion hydrogen value of approximately 0.5 g.moles/hr. When North Anna Unit 1 starts up, a further boric acid soak will be carried out at 50 ppm B to ascertain that the boron demand in the steam generators has been satisfied. On line addition of 5 to 10 ppm B as boric acid is being maintained and hydrogen monitoring continued.

TABLE 3.1

AVERAGE DAILY STEAM GENERATOR DATA

DATE	STEAM GENERATOR A CAT COND µmhos/cm	STEAM GENERATOR A Cl** ppm	STEAM GENERATOR A SO_4 ppm	W ANALYSES Cl ppm / SO_4 ppm	STEAM GENERATOR B CAT COND µmhos/cm	STEAM GENERATOR B Cl** ppm	STEAM GENERATOR B SO_4 ppm	W ANALYSES Cl ppm / SO_4 ppm	STEAM GENERATOR C CAT COND µmhos/cm	STEAM GENERATOR C Cl** ppm	STEAM GENERATOR C SO_4 ppm	W ANALYSES Cl ppm / SO_4 ppm
1/09/80	7.00*	0.08			6.58*	0.12			16.00*	0.20		
1/10/80	5.02*	0.09			3.54*	0.09			4.42*	0.10		
1/11/80	2.99*	0.05			2.34*	≤0.05			2.81*	≤0.05		
1/12/80	3.00*	0.06			2.57*	0.06			2.94*	0.06		
1/13/80	3.32*	≤0.05			2.90*	≤0.05			3.60*	≤0.05		
1/14/80	3.99*	0.12			3.24*	0.07			2.75*	0.06		
1/15/80	3.86*	0.13			3.10*	0.09			3.34*	0.08		
1/16/80	3.75*	0.06			2.73*	0.06			3.10*	0.07		
1/17/80	3.16	≤0.05			2.40*	≤0.05			3.13*	0.06		
1/18/80	2.30*	≤0.05			1.95	≤0.05			2.06*	0.05		
1/19/80	2.08*	0.05			1.77	0.11			1.85	0.08		
1/20/80	2.33*	≤0.05			1.99	≤0.05			2.2*	≤0.05		
1/21/80	1.85	≤0.05			1.66	≤0.05			1.77	≤0.05		
1/22/80	5.57*	≤0.05		0.1 / 0.19	5.73*	≤0.05			6.06*	≤0.05		
1/23/80	12.49*	0.10		0.06 / 0.13	10.75*	0.21	≤0.5	0.05 / 0.11	10.72*	0.07	0.385	0.06 / 0.12
1/24/80	3.01*	0.12	≤0.5	<0.01 / 0.04	3.07*	0.11	≤0.5		3.34*	0.10	≤0.5	
1/25/80	2.13*	≤0.05		<0.01 / 0.09	2.18*	≤0.05			2.38*	≤0.05		
1/26/80	2.11*	≤0.05			2.14*	≤0.05			2.15*	≤0.05		
1/27/80	2.28*	≤0.05		<0.01 / 0.10	2.20*	≤0.05			2.31*	≤0.05		
1/28/80	1.72	-			1.83	-			1.82	-		

*AVT Guideline upper limit is 2.00 µmhos/cm
**Conc. of ≤.05 incl. as 0.05 in avg.

FIGURE 3.1 PRE-LOW POWER SOAK

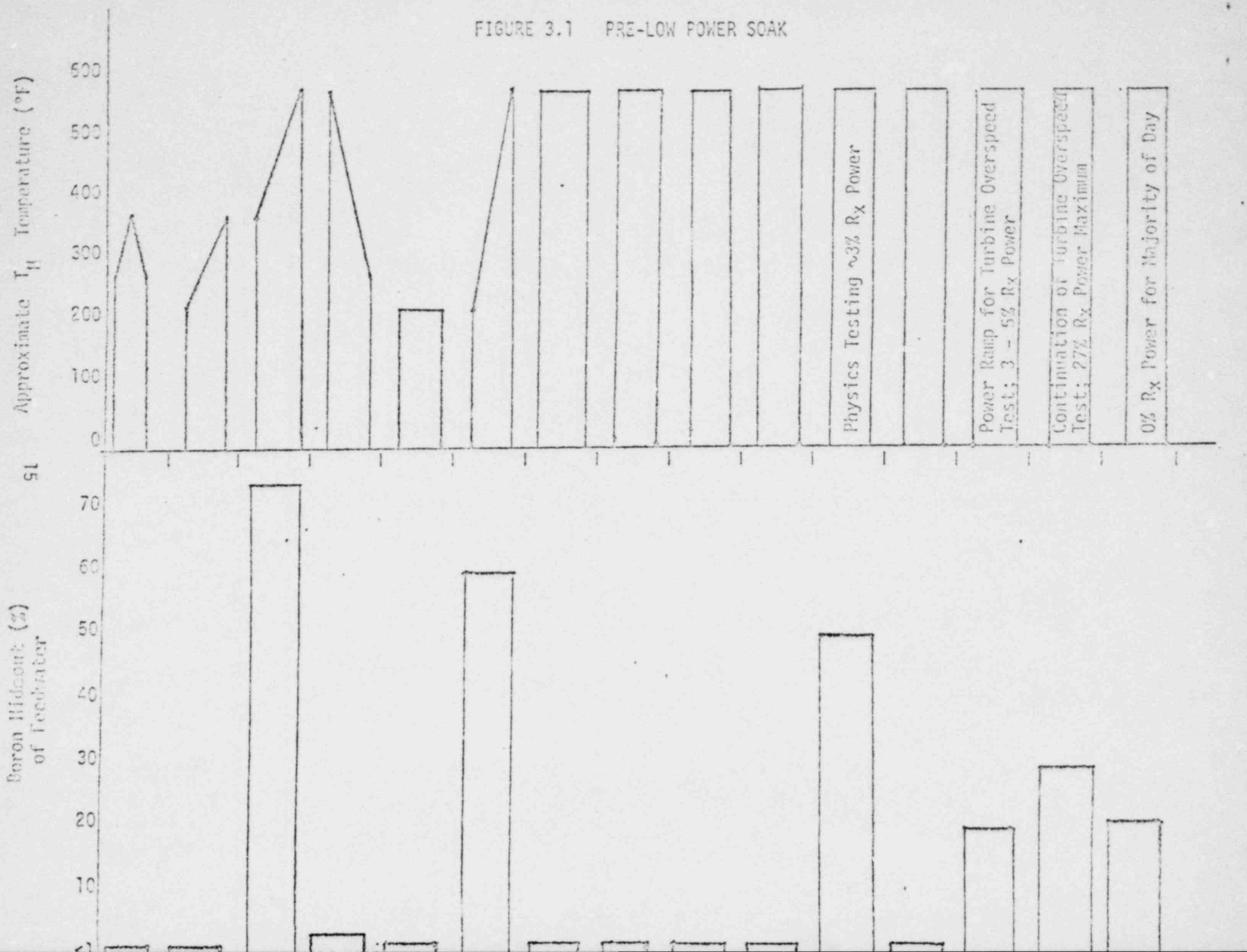


FIGURE 3.2 LOW POWER SOAK

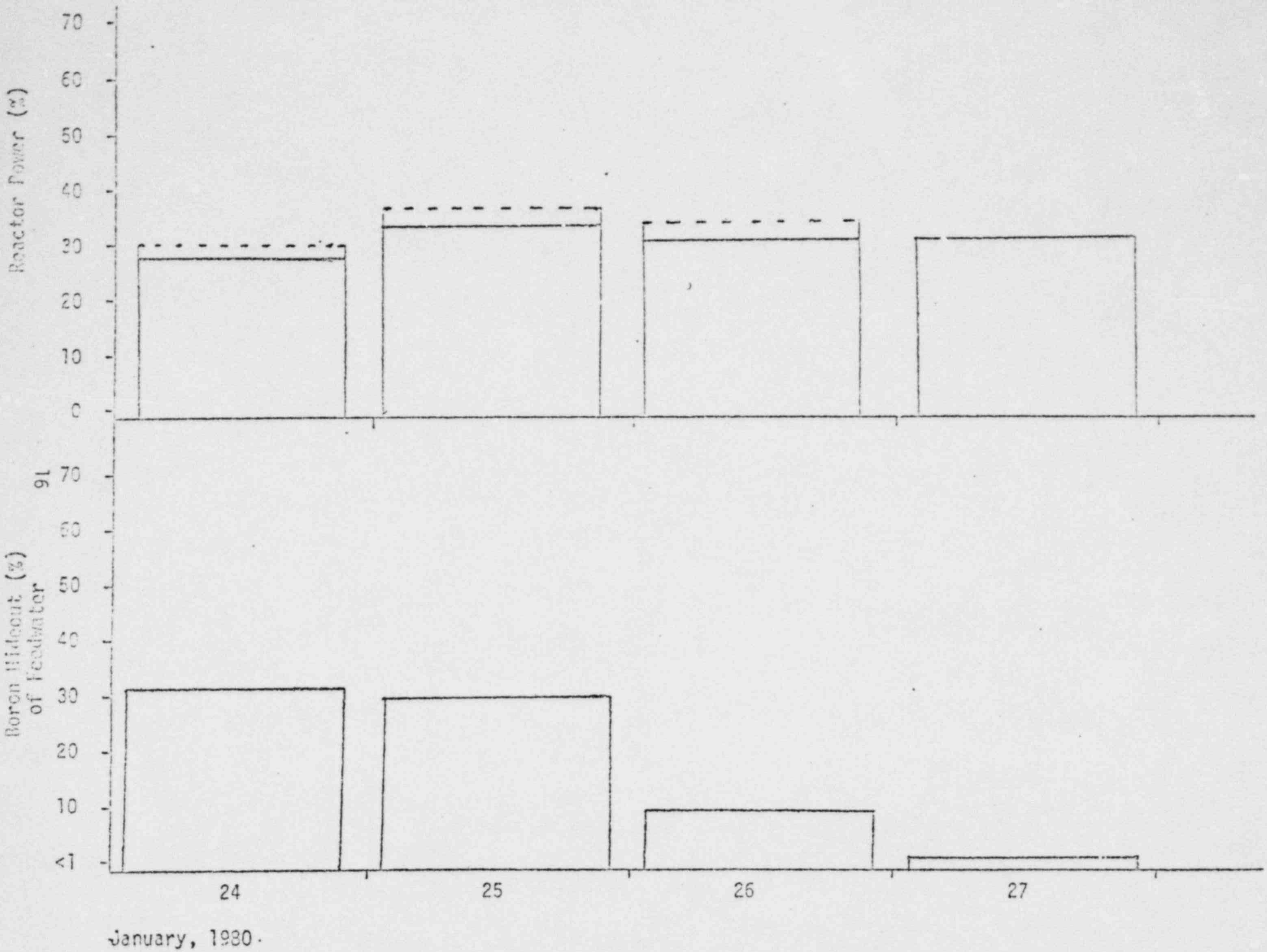
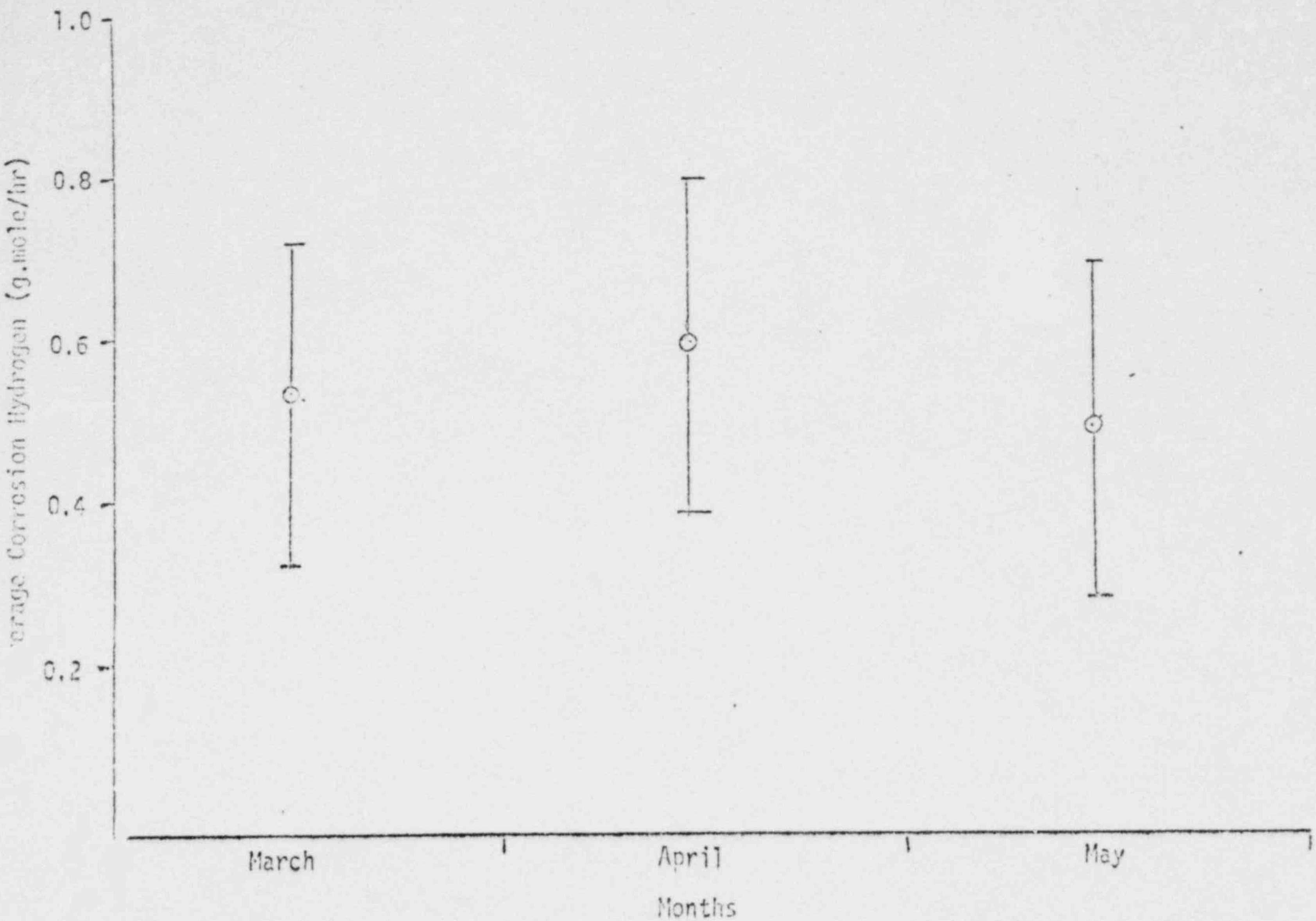


FIGURE 3.3 NORTH ANNA UNIT I HYDROGEN MONITORING RESULTS



3.4 Boron Analysis

Boron analysis is not typically run on the condensate, feedwater, main steam or heater drains during normal operation of the unit. Data was collected during the January low power soak which typically showed boron levels of 2.0 to 4.0 ppm in the main steam, condensate and feed trains. During this same time frame, January 23 through 27, 1980, the steam generators were being maintained at approximately 50 ppm as per our boron soak procedure requirements. Since this soak, boron has been maintained at 5 - 10 ppm in the generators at power operating conditions, with the values being reduced to 1 ppm in corrolation with the unit shutting down.

3.5 Oxygen, Ammonia, pH and Cation Conductivity

The dissolved oxygen levels in the steam generators have been maintained at the non-detectable level, i.e., <0.005 ppm; the pH values have been maintained at a value in excess of 7.0 with an accompanying ammonia value of 0.15 to 0.40 ppm. The cation conductivity has remained below the 2.0 μmhos limit except during load reductions, when hideout return has been experienced, and during a condenser leak on March 12, 1980. In both cases proper action was taken to bring the units back into operating specs.