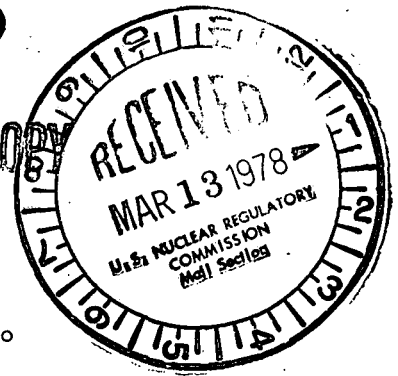




**Consumers  
Power  
Company**

REGULATORY DOCKET FILE COPY



General Offices: 212 West Michigan Avenue, Jackson, Michigan 49201 • Area Code 517 788-0550

March 9, 1978

Director, Nuclear Reactor Regulation  
Att: Mr Dennis L Ziemann, Chief  
Operating Reactors Branch No 2  
US Nuclear Regulatory Commission  
Washington, DC 20555

DOCKET 50-255 - LICENSE DPR-20 -  
PALISADES PLANT - IODINE REMOVAL SYSTEM -  
PROPOSED TECHNICAL SPECIFICATION CHANGES

Consumers Power Company has completed a reevaluation of the Palisades Plant iodine removal system as required by Amendment 31 to Provisional Operating License DPR-20. The attached proposed Technical Specification changes when implemented will enhance system performance.

If possible, the review and approval of this request should be completed prior to plant start-up from our current refueling outage.

*David P. Hoffman*

David P Hoffman  
Assistant Nuclear Licensing Administrator

CC: JGKeppler, USNRC

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CONSUMERS POWER COMPANY  
Docket 50-255  
Request for Change to the Technical Specifications  
License DPR-20

For the reasons hereinafter set forth, it is requested that the Technical Specifications contained in Provisional Operating License DPR-20, Docket 50-255, issued to Consumers Power Company on October 16, 1972 for the Palisades Plant be changed as described in Section I below:

I. Changes

Change Technical Specifications 3.19.1.a and 3.19.1.b to read as follows:

3.19.1 During power operation, the Iodine Removal System shall be operable with:

- a. The Iodine Removal Hydrazine Tank (T-102) containing  $270 \pm 17$  gallons of  $15.5 \pm 0.5\%$  w/o of hydrazine solution with a cover gas pressure of  $11.2 \pm 2$  psig.
- b. The Iodine Removal Make-Up Sodium Hydroxide Tank (T-103) containing a minimum 3,900 gallons of  $30.0 \pm 0.5\%$  w/o sodium hydroxide solution.

II. Discussion

The attached reports entitled:

1. Palisades Plant Iodine Removal System Evaluation dated December 1977,
2. Palisades Plant - Special Test Procedure - T-102 Hydrazine Injection System Flow Rate Test dated March 2, 1978,
3. A Hydraulic Evaluation of the Proposed Modification to the Hydrazine Injection System at the Palisades Plant dated March 6, 1978

provide the basis for the proposed change to Technical Specification

3.19.1.a. The preliminary modifications proposed in our December 1, 1977 letter have been reviewed and finalized. As proposed, the volume, hydrazine concentration and nitrogen cover gas pressure of T-102 will be changed from the current conditions. The one-minute time delay has been left in the control circuitry of the T-102 tank discharge valves. It is important to note that system testing and modeling have demonstrated that the gravity feed system will perform as required under all potential plant conditions during an MHA. The effect of the time delay was very conservatively evaluated (5- and 20-minute delays in hydrazine injection) when performing dose calculations.

The changes to Technical Specification 3.19.1.b are proposed to improve system control. The current required tank volume (approximately 93% full) makes it extremely difficult to maintain proper tolerances on liquid level and cover gas volume for a horizontal tank.

The change will maintain the same quantity of sodium hydroxide and, therefore, identical pH control capability.

The proposed changes will allow for improved system performance over the current required Technical Specifications conditions.

III. Conclusion

Based on the foregoing, both the Palisades Plant Review Committee and the Safety and Audit Review Board have reviewed this proposed change and recommend its approval.

CONSUMERS POWER COMPANY

By C R Bilby  
C R Bilby, Vice President  
Production & Transmission

Sworn and subscribed to before me this 9th day of March 1978.

Linda R. Thayer  
Linda R Thayer, Notary Public  
Jackson County, Michigan  
My commission expires July 9, 1979.

IODINE REMOVAL SYSTEMApplicability

Applies to the operational status of the Iodine Removal System.

Objective

To define those conditions when it is necessary to have the Iodine Removal System operable.

Specification

- 3.19.1 During power operation the Iodine Removal System shall be operable with:
- The Iodine Removal Hydrazine Tank (T-102) containing  $270 \pm 17$  gallons of  $15.5 \pm 0.5\%$  w/o of hydrazine solution with a cover gas pressure of  $11.2 \pm 2$  psig.
  - The Iodine Removal Make-Up Sodium Hydroxide Tank (T-103) containing a minimum 3,900 gallons of  $30.0 \pm 0.5\%$  w/o sodium hydroxide solution.
  - T-102 capable of supplying hydrazine solution to the water from the SIRW tank (T-58) and T-103 capable of supplying sodium hydroxide solution to the suction header between the containment sump and the spray and injection pumps.
  - With the Iodine Removal System inoperable, restore the system to operable status within 72 hours or be in hot shutdown condition within the next 48 hours until operable status is achieved.

Bases

The Iodine Removal System acts in conjunction with the containment spray system to reduce the post-accident level of fission products in the containment atmosphere. Hydrazine is added to the water from the SIRW tank after a LOCA to provide for iodine retention. Sodium Hydroxide is added to the recirculated water after a LOCA to establish a neutral pH.

References

FSAR, Section 6.4.

FSAR, Section 14.22.

Consumers Power Company Report, "Palisades Plant Iodine Removal System Evaluation," December 1977.

Consumers Power Company Report, "A Hydraulic Evaluation of the Proposed Modification to the Hydrazine Injection System at the Palisades Plant," March 6, 1978.

PALISADES PLANT  
IODINE REMOVAL SYSTEM EVALUATION

Consumers Power Company  
212 W. Michigan Ave.  
Jackson, Michigan 49201

December, 1977

# PERFORMANCE OF HYDRAZINE ADDITION SYSTEM

Our evaluation of the hydrazine addition system as it presently exists indicates that the present system is adequate. Under all modes of operation the hydrazine system was found to supply greater than 50 ppm hydrazine in the containment spray water assuming a tank concentration of 50,000 ppm. The evaluation considered both minimum and maximum safeguards flow rates and operation of one or both hydrazine injection lines.

<u>Case</u>	<u>Safeguards Flow</u>	<u>Injection Lines In Operation</u>	<u>Time of Hydrazine Initiation</u>	<u>Time of Switchover to Recirculation</u>
1	Maximum	Both	585 sec	1228 sec
2	Minimum	Both	1232 sec	2454 sec
3	Maximum	One	294 sec	1228 sec
4	Minimum	One	1067 sec	2453 sec

Based on the above information, we calculate that 10CFR100 dose limits are not exceeded during the MHA. Dose calculations were performed as described in Appendix A.

Our evaluation also considered potential hydrazine addition system modification for improved performance. The modification which we propose to test and potentially implement is as follows:

1. pressurize the hydrazine tank to 10 psig
2. eliminate the one-minute timer delay
3. increase the hydrazine concentration in the tank to 15%

Pressurization of the tank and elimination of the delay will provide for a nearly immediate injection of hydrazine into the containment spray water. The only delay would be the inherent time required to purge the injection lines - about 30 seconds. Tank pressurization will require that the regulated nitrogen supply be isolated during the injection period so that the tank will not empty too rapidly. The tank hydrazine concentration will be increased to compensate for the longer injection period and consequently lower allowed flow rates. A summary of important results of our evaluation of the modified system are presented below:

<u>Case</u>	<u>Safeguards Flow</u>	<u>Injection Lines In Operation</u>	<u>Time of Hydrazine Initiation</u>	<u>Time of Switchover to Recirculation</u>
1	Maximum	Both	35 sec	1227 sec
2	Minimum	Both	38 sec	2452 sec
3	Maximum	One	24 sec	1227 sec
4	Minimum	One	29 sec	2451 sec

The proposed test would be conducted during the upcoming refueling outage. The hydrazine tank would be filled to normal level with demineralized water and pressurized to 10 psig. Using one low-pressure safety injection pump, water would be pumped from the Safety Injection Refueling Water and hydrazine tanks to the fuel pool. Tank levels as a function of time would be recorded for comparison with and verification of the computer simulations.

### LONG-TERM pH CONTROL ALTERNATIVES

#### Present NaOH System

Our analyses indicate that the present hydroxide system is fully capable of supplying sufficient NaOH to provide post-LOCA recirculating water pH in the range of pH 7 to 8 over the full range of possible boron concentrations. Table 1 presents pH values for various quantities of hydroxide. Volumes of 23% NaOH in the region between 75 ft<sup>3</sup> and 150 ft<sup>3</sup> will maintain pH no lower than 7, nor higher than 8 under all possible sets of conditions. Water sources with maximum and minimum boron concentrations are given in Table 2.

Initiation of hydroxide addition shortly following recirculation start (within one hour post-LOCA) will reduce chloride stress corrosion and increase iodine partition factor (2) at a time when such action is most beneficial in mitigating offsite consequences of the accident. The increased partition coefficient reduces iodine loss (3) from out-of-containment coolant leakage to significantly less than the 10% value utilized in the SER. The increased partition coefficient also enhances the recirculation spray affinity for iodine removal within containment and speeds conversion to iodate.(2)

#### Tri-Sodium Phosphate

The possibilities for conversion to a passive buffer (dodecahydrated tri-sodium phosphate) have been investigated. The advantages of early-LOCA pH adjustment would be achieved equally well by either NaOH or TSP. Trisodium phosphate offers the advantages of being a passive in-containment system, and of not being as corrosive as NaOH. Disadvantages of TSP include system bulk (approximately 150 ft<sup>3</sup> of TSP must be available on the 590 level), and the engineering effort involved in container design.

### EFFECT OF TIME DELAY ON HYDRAZINE VALVES

The dynamic flow simulations described in Part (1) "Performance of Hydrazine Addition System", indicate that a time delay of at least  $\frac{1}{2}$  minute can be expected due to flow dynamics, whether or not the hydrazine valves are open. Thus, the maximum gain in spray time would be  $\frac{1}{2}$  minute, were the timer removed. This interval represents an approximate 1% dose contribution (1.8 rem) of the 180 rem (two-hour site boundary thyroid dose) from containment leakage as analyzed in the SER. Although this effect is small, there appears to be no safety problems involved in removing the timer. In keeping with ALARA policy, the timer should be removed.

### MINIMIZING CONSEQUENCES OF PASSIVE FAILURES

Partition coefficient values will range from 1,100 at pH 7 to 10,000 at pH 8 with 50% of the 103 moles iodine inventory (radioactive and stable isotopes) for a 2650 Mwt core dissolved in 56,000 ft<sup>3</sup> of water at 125°C. Since the safeguards room sumps are covered and room ventilation is isolated upon high radiation signal in the ventilation ducting from both rooms, air exchange between the sump airspace and the room will be extremely slow. Assuming low liquid leak rates, air to liquid volume ratios in the sumps could be as high as 100-to-1. At low leak rates then, gas/liquid equilibrium could bring eventual iodine escape as high as 100/5,000 or 2%, given a partition coefficient of 5,000 at pH 7.5. In comparison, a partition coefficient of approximately 10 (applicable to unbuffered boric acid) eventually could release essentially all the iodine into the air space of the sump.

At high leak rates, the sumps will fill to air/liquid ratios less than 10. This reduces iodine escape to  $<10/5,000 = <0.2\%$ . Again, nearly all the iodine eventually could escape to the air space if only unbuffered boric acid were involved.

It is concluded that early pH adjustment to pH 7-8, and limitation of air-space volume above the liquid are the most feasible methods of limitation iodine escape and thereby mitigating the consequences of passive failures.



APPENDIX A - DOSE CALCULATIONSAssumptions

1. Power level - 2650 MWt
2. Core history - 1/3 core: 1 cycle  
1/3 core: 2 cycles  
1/3 core: 3 cycles
3. Exclusion Area Boundary - 677 meters, LPZ boundary distance - 4827 meters
4. X/Q's from Figures 2(A) and 2(B) of Regulatory Guide 1.4, with building wake factor of 2.35 (0.5A = 1105 m per FSAR 14.22.2.1)

<u>TIME PERIOD (HRS)</u>	<u>X/Q (sec/m<sup>3</sup>)</u>	<u>LOCATION</u>
0-2	$5.2 \times 10^{-4}$	EAB
0-8	$6.1 \times 10^{-5}$	LPZ
8-24	$1.3 \times 10^{-5}$	LPZ
24-96	$4.2 \times 10^{-6}$	LPZ
96-720	$9.1 \times 10^{-7}$	LPZ
24-720(mean)	$1.33 \times 10^{-6}$	LPZ

## 5. Containment Spray

<u>CASE</u>	<u>TIME PERIOD (min)</u>	<u>SOLUTION</u>	<u>IODINE REMOVAL RATE (min<sup>-1</sup>)</u>				<u>ORGANIC</u>
			<u>INORG *</u>	<u>INORG **</u>	<u>PART *</u>	<u>PART **</u>	
1	0-5	BoratedWater	.0255	.0145	.0167	.0111	-
2	0-20	BoratedWater	.0255	.0145	.0167	.0111	-
1	5-20	50 ppm N <sub>2</sub> H <sub>2</sub>	.167	.0278	.0167	.0111	-
2	20-40	50 ppm N <sub>2</sub> H <sub>2</sub>	.167	.0278	.0167	.0111	-
1	20-150	Unbuffered	.0127	.0087	.0167	.0111	-
2	40-150	Recirculation	.0127	.0087	.0167	.0111	-
1&2	150 & beyond***	pH 7.5	.127	.0262	.0167	.0111	-

6. Containment free volume -  $1.64 \times 10^6$  ft<sup>3</sup>
7. Sprayed volume - 90%
8. Unsprayed volume - 10%
9. Air exchange between unsprayed and sprayed volumes - 2 unsprayed volumes per hour = 0.033 min<sup>-1</sup>

\* Sprayed Volume

\*\* Unsprayed Volume

\*\*\* NaOH from T-103, or TSP dissolution, assumed to occur by t=150 min

10. Iodine lost from engineered safeguards room - 4.4% of iodine in leaked liquid volume,  $t = 20$  to  $t = 50$  minutes, 1.35% of leaked liquid volume beyond 50 min (Ref 5)
11. Iodine plateout factor - 2.0
12. Recirculation volume (see Table 2 in body of report) - 56,000 ft<sup>3</sup>
13. Core inventory I-131 -  $2.51 \times 10^4$  Ci/Mwt (FSAR 14.22.2.1)
14. Dose-per-Curie factors (FSAR 14.22.2.1) - I-131 =  $1.48 \times 10^6$  rad/Curie and other dosimetry assumptions:

<u>TIME</u>	<u>DOSE EQUIVALENCE FACTOR</u>	<u>BREATHING RATE (m<sup>3</sup>/hour)</u>	<u>CONTAINMENT LEAKAGE RATE (% PER DAY)</u>
Average, 0-120 min	1.82	1.25	0.1
Average, 120-1440 min	1.43	0.795*	0.1
1440 min-30 days	0.346	0.833	0.05

15. Fission product release from core:

	<u>IODINES</u>	<u>NOBLE GASES</u>
Release to containment atmosphere	25%	100%
Release to containment liquid	25%	-
Adsorbed on surfaces	50%	-

16. Iodine forms in atmosphere: iodine vapor - 22.75% of core  
iodine particulate - 1.25% of core  
organic iodine - 1% of core

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\* 120-480 @ 1.25, 480-1440 @ 0.630

Procedure

Iodine removal rates for unbuffered borated water in the sprayed volume were determined by the formula: (3)

$$\lambda = \frac{F}{V} HE \quad \text{EQUATION I}$$

where:  $F$  = spray flow rate (251 ft<sup>3</sup>/min, FSAR 14.22.2.3)  
 $V$  = sprayed volume (90% of 1.64 x 10<sup>6</sup> ft<sup>3</sup> = 1.48 x 10<sup>6</sup> ft<sup>3</sup>)  
 $HE$  = 150 for injection phase, 75 for recirculation phase

Removal rate for boric acid buffered to pH 7 was determined from stagnant film model data provided in Reference 3, based upon a partition coefficient of 1,100 at pH 7 (3.6 x 10<sup>-5</sup> mole iodine/liter of recirculation fluid) per Reference 2. The value of 0.165 min<sup>-1</sup> thus obtained was adjusted for a slight difference between the referenced volume flow rate of 1.5 x 10<sup>-3</sup> gpm/ft<sup>3</sup> sprayed volume as compared with the minimum for Palisades of 1.27 x 10<sup>-3</sup> gpm/ft<sup>3</sup>. Test data from Reference 3 shows that the slope of  $\lambda$  as a function of volume flow rate has a slope of 163  $\lambda$ /gpm/ft<sup>3</sup>. Thus, (163) ( $\Delta 0.23 \times 10^{-3}$ ) =  $\Delta 3.75 \times 10^{-2} \lambda$ , and 0.165 - 0.0375 = 0.127.

Removal rates for iodine by hydrazine at 50 ppm ( $\lambda = 0.167 \text{ min}^{-1}$ ) and for particulates from all sprays ( $\lambda = 0.0167 \text{ min}^{-1}$ ), as used in the SER for Amendment No 31 (Reference 4) were found to be consistent with the literature, and were applied to this analysis.

Iodine removal rates ( $\lambda_e$ ) for inorganic and particulate iodine within the unsprayed regions were calculated according to the formula:

$$\lambda_e = \frac{1}{\frac{1}{\lambda_1} + \frac{1}{\lambda_2}} \quad \text{EQUATION II}$$

where:  $\lambda_e$  = effective removal rate (min<sup>-1</sup>)  
 $\lambda_1$  = sprayed region removal rate (min<sup>-1</sup>)  
 $\lambda_2$  = volume exchange rate between sprayed and unsprayed regions (min<sup>-1</sup>)

Iodine removal rate constants described above, and as tabulated in Item 5 of the assumptions, were used to determine iodine remaining in the containment atmosphere as a function of time post-LOCA:

$$C_T = C_0 e^{-\lambda t} \quad \text{EQUATION III}$$

where  $C_T$  = iodine as percent of core inventory present in containment atmosphere at time =  $t$

$C_0$  = iodine as percent of core at  $t=0$

$\lambda$  = removal rate ( $\lambda_s$ ) in case of sprayed volume, or effective removal rate ( $\lambda_e$ ) for unsprayed volume

$t$  = time post-LOCA (min)

Results of calculations for five-minute delay prior to hydrazine addition (case 1) and for 20-minute delay prior to hydrazine addition (case 2) are given in Tables 3 and 4. The amounts of iodine leaked to the environment, as percent of core iodine inventory, also are shown for each calculated time interval and for the cumulative interval.

$$\begin{array}{l} \text{\% of total iodine} \\ \text{leaked from containment} \\ \text{during the time interval } t \\ \text{(Tables 3 and 4)} \end{array} = \frac{x}{100\%} (6.944 \times 10^{-5}) (t) \quad \text{EQUATION IV}$$

where:  $6.944 \times 10^{-5}$  = leakage rate (%/min)

$t$  = time interval of leakage (min)

$x$  = % of total iodine in containment air (Tables 3 and 4)

$$\begin{array}{l} \text{\% of total iodine} \\ \text{leaked from safeguards} \\ \text{room during the time} \\ \text{interval } t \\ \text{(Table 5)} \end{array} = \frac{0.0272}{56,000} (50\%-A) (0.044) (.5) (t) \quad \text{EQUATION V}$$

where:  $0.0272$  = leak rate ( $\text{ft}^3/\text{min}$ )

$56,000$  = recirculation water ( $\text{ft}^3$ )

$0.044$  = see assumption 10

$A$  = % of total iodine in containment air (Tables 3 and 4)

$0.5$  = iodine plateout factor

$t$  = time interval of leakage (min)

It is interesting to note that at a leak rate of 0.1% per day, volume leaked equals only 1.14 cubic foot per minute ( $6.94 \times 10^{-7}$  volume per minute). Iodine release for each interval was considered to be at the highest rate determined for that interval (ie, the rate present at the end of the prior interval). Total inorganic iodine reduction was limited to a factor of 100 so that containment atmosphere at no time reduces below 1.23% of core inventory (1% organic plus  $1/100 \times 22.75\%$  inorganic).

Containment leakage of iodine is converted to Curies of I-131 on the basis that core content equals  $6.65 \times 10^7$  Ci at 2650 MWt (FSAR 14.22.2.1). The cumulative leakage at the time of interest divided by seconds in that interval, gives Q for input to the dose equation as follows:

$$\text{Thyroid Dose} = (Q)(X/Q)(B)(DCF)(DEF)(t)$$

EQUATION VI

where:

- Q = I-131 release rate (Ci/sec)
- X/Q = diffusion coefficient (sec/m<sup>3</sup>) (see assumption 4)
- B = breathing rate (m<sup>3</sup>/hr) (see assumption 14)
- DCF = dose conversion factor for I-131 ( $1.48 \times 10^6$  rad/Ci)
- DEF = dose equivalency factor to account for iodine isotopes in addition to I-131 (see assumption 14)
- t = time of release (hr)

Out-of-containment leakage begins with initiation of recirculation. Half the core inventory of iodine is assumed present in the 56,000 ft<sup>3</sup> of recirculation water at this time. Release of iodine from a maximum leak rate of 0.20 gpm (0.0272 ft<sup>3</sup>/min) occurs as described in assumption 10. Amounts of I-131 which escape to the environment from the safeguards room are given in Table V.

Conclusions

Dose to thyroid from both containment and out-of-containment leakage is determined according to Equation VI. Thyroid doses are as follows:

<u>CASE</u>	<u>TIME PERIOD</u>	<u>LOCATION</u>	<u>CONT LEAK (Rem)</u>	<u>EX-CONT LEAK (Rem)</u>	<u>TOTAL DOSE (Rem)</u>
1	0-2 hrs	EAB	149	8.1	157
2	0-2 hrs	EAB	174	5.0	179
1	0-8 hrs *	LPZ	30.5	3.19	33.7
2	0-8 hrs *	LPZ	33.0	2.83	35.8
1	8-24 hrs	LPZ	2.63	.493	3.12
2	8-24 hrs	LPZ	2.63	.493	3.12
1	24 hr-30 d	LPZ	1.85	0.71	2.56
2	24 hr-30 d	LPZ	1.85	0.71	2.56
1	0-30 d	LPZ	35.0	4.39	39.4
2	0-30 d	LPZ	37.5	4.03	41.5

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\* 0-2 hr values for Breathing Rate and DEF applied for 0-8 hr dose computation.

It is determined that dose to thyroid for both the exclusion area boundary (EAB) and low population zone (LPZ) residents are below 10CFR100 criteria. Total body dose criteria of 10CFR100 are met per original calculations of the FSAR. Total body dose has not been re-evaluated because iodine removal spray does not enter into the calculation.

APPENDIX B

Tables

TABLE 1

100°C			25°C			
NaOH Added 23wt%	Min Boron (1584 ppm)	Max Boron (2400 ppm)	Calculated		Observed	
			Min Boron	Max Boron	Min Boron	Max Boron
0	4.756	4.573	4.666	4.026	4.6	4.
100 ft <sup>3</sup>	7.654	7.283	7.598	7.478	7.8	7.3
200 ft <sup>3</sup>	8.033	7.661	8.478	7.502	8.25	7.8
300 ft <sup>3</sup>	8.291	7.918	8.623	7.833	8.55	7.1
400 ft <sup>3</sup>	8.500	8.123	8.70	8.168	8.80	8.35
500 ft <sup>3</sup>	8.683	8.296	8.958	8.415	9.02	8.6
600 ft <sup>3</sup>	8.854	8.450	9.165	8.635	----	---
700 ft <sup>3</sup>	9.023	8.588	9.400	8.836	----	---



TABLE 2

<u>TIME</u>	<u>VOLUME</u>	<u>MAX PPM</u>	<u>MIN PPM</u>	
t=0	7,800 ft <sup>3</sup>	1,070	0	PCS
t=0	8,130 ft <sup>3</sup>	2,000	0	CWRT
t=0	1,740 ft <sup>3</sup>	17,500	11,000	CBAT
t=0	4,000 ft <sup>3</sup>	2,000	1,720	SI Bottles (4)
t=0 → 20 min to 45 min	34,000 ft <sup>3</sup>	2,000	1,720	SIRW 10,900 gpm @ 5,476 gpm
t=20-45 & on by 4 hr	recirculation at nominal rate of <u>≤100 ft<sup>3</sup></u> 23.0 ± 0.5% NaOH to give pH 7.0			4,900 gpm

TABLE 3

Case 1  
Hydrazine Flow from t=5 min to t=20 min

TIME (MIN)	$\lambda$ (hr <sup>-1</sup> )	INORGANIC (0.9 x %)	UNSPRAYED (0.1 x %)	PART		ORGANIC (%)	TOTAL (%)	LEAKED $\Delta(\% \times 10^{-5})$	$\Sigma(\% \times 10^{-4})$
				(0.9%)	(0.1%)				
0	-	20.475	2.275	1.125	0.125	1.0	25.0	-	
0-5	1.53/1.0	18.02	2.27	1.035	0.118	1.0	22.44	8.68	0.868
5-7.5	10/1.0	11.88	2.12	0.993	0.115	1.0	16.11	3.90	1.258
7.5-10	10/1.0	7.83	1.98	0.952	0.112	1.0	11.87	2.80	1.538
10-12.5	10/1.0	5.16	1.84	0.913	0.108	1.0	9.02	2.06	1.744
12.5-15	10/1.0	3.40	1.72	0.876	0.106	1.0	7.10	1.57	1.901
15-20	10/1.0	1.48	1.50	0.806	0.100	1.0	4.89	2.47	2.148
20-30	0.763/1.0	1.30	1.37	0.682	0.090	1.0	4.44	3.39	2.487
30-60	0.763/1.0	0.890	1.038	0.414	0.0642	1.0	3.406	9.24	3.411
90	0.763/1.0	0.608	0.788	0.251	0.046	1.0	2.69	7.10	4.121
120	0.763/1.0	0.415	0.598	0.152	0.033	1.0	2.197	5.610	4.682
150	7.6/1.0	0.009	0.271	0.092	0.024	1.0	1.396	4.577	5.140
180	-	-	0.123	0.056	0.017	1.0	1.196	2.908	5.431
beyond 180							1.23		
180-8 hr							1.23	25.6	7.994
8-24 hr							1.23	82.0	16.19
1-30 d							0.612	1,770	194

TABLE 4

Case 2  
Hydrazine Flow from t=20 min to t=40 min

TIME (MIN)	$\lambda$ (hr <sup>-1</sup> )	INORGANIC (0.9%)	UNSPRAYED (0.1%)	PART (%)		ORGANIC (%)	TOTAL (%)	LEAKED	
				0.9	0.1			(Δ%)x10 <sup>-5</sup>	(Σ%)x10 <sup>-5</sup>
0	-	20.475	2.275	1.125	0.125	1.0	25.00	-	-
0-2.5	1.53/1.0	19.210	2.194	1.079	0.122	1.0	23.605	4.340	4.340
2.5-5	1.53/1.0	18.024	2.116	1.035	0.118	1.0	22.293	4.098	8.438
5-7.5	1.53/1.0	16.910	2.041	0.993	0.115	1.0	21.059	3.870	12.308
7.5-10	1.53/1.0	15.867	1.969	0.952	0.112	1.0	19.900	3.656	15.964
10-12.5	1.53/1.0	14.886	1.899	0.913	0.108	1.0	18.806	3.455	19.419
12.5-15	1.53/1.0	13.970	1.832	0.876	0.106	1.0	17.784	3.265	22.684
15-17.5	1.53/1.0	13.104	1.767	0.840	0.102	1.0	16.813	3.087	25.771
17.5-20	1.53/1.0	12.295	1.704	0.806	0.100	1.0	15.905	2.919	28.690
20-22.5	10/1.0	8.105	1.590	0.773	0.097	1.0	11.565	2.761	31.451
22.5-25	10/1.0	5.343	1.483	0.742	0.094	1.0	8.662	2.008	33.459
25-30	10/1.0	2.322	1.291	0.682	0.090	1.0	5.383	3.008	36.467
30-35	10/1.0	1.009	1.123	0.628	0.085	1.0	3.845	1.870	38.337
35-40	10/1.0	0.439	0.978	0.578	0.080	1.0	3.075	1.335	39.672
40-60	0.763/1.0	0.340	0.814	0.414	0.064	1.0	2.632	4.271	43.943
60-90	0.763/1.0	0.232	0.617	0.251	0.046	1.0	2.146	5.483	49.426
90-120	0.763/1.0	0.159	0.468	0.152	0.033	1.0	1.812	4.471	53.897

TABLE 4  
(Continued)

Case 2  
Hydrazine Flow from t=20 to t=40 min

TIME (MIN)	$\lambda$ (hr <sup>-1</sup> )	INORGANIC (0.9%)	UNSPRAYED (0.1%)	PART (%)		ORGANIC (%)	TOTAL (%)	LEAKED	
				0.9	0.1			$(\Delta\%) \times 10^{-5}$	$(\Sigma\%) \times 10^{-5}$
120-150	0.763/1.0	0.108	0.355	0.092	0.024	1.0	1.579	3.775	57.672
150-180	7.6/1.0	0.002	0.161	0.056	0.017	1.0	1.236	3.290	60.962
180-210	7.6/1.0	-	0.073	0.034	0.012	1.0	1.228	2.575	63.537
beyond 210							1.228	2.558	66.095
0-8 hr								86.54	86.54
8-24 hr								81.86	168.4
1-30 d								1780	1948

TABLE 5

Out-of-Containment Leakage (Safeguards Room)

<u>CASE</u>	<u>TIME (MIN)</u>	<u><math>\Delta\%</math> OF CORE</u>	<u><math>\pm\%</math> OF CORE</u>
1	20-50	$1.46 \times 10^{-5}$	$1.46 \times 10^{-5}$
2	40-50	$5.01 \times 10^{-6}$	$5.01 \times 10^{-6}$
1	50-120	$1.06 \times 10^{-5}$	$2.52 \times 10^{-5}$
2	50-120	$1.06 \times 10^{-5}$	$1.55 \times 10^{-5}$
1	beyond 120	$1.64 \times 10^{-7}/\text{min}$	$2.52 \times 10^{-5} + 1.64 \times 10^{-7} \Delta t$
2	beyond 120	$1.64 \times 10^{-7}/\text{min}$	$1.55 \times 10^{-5} + 1.64 \times 10^{-7} \Delta t$
1	0-8 hr	$8.42 \times 10^{-5}$	$8.42 \times 10^{-5}$
2	0-8 hr	$7.45 \times 10^{-5}$	$7.45 \times 10^{-5}$
1	8-24 hr	$1.54 \times 10^{-4}$	$2.38 \times 10^{-4}$
2	8-24 hr	$1.54 \times 10^{-4}$	$2.29 \times 10^{-4}$
1	1-30 d	$6.76 \times 10^{-3}$	$7.00 \times 10^{-3}$
2	1-30 d	$6.76 \times 10^{-3}$	$6.99 \times 10^{-3}$

## APPENDIX C

### References

1. USNRC "Calculational Error Affecting the Design Performance of a System for Controlling pH of Containment Sump Water Following a LOCA". IE Bulletin No 77-04. (November 4, 1977).
2. L. F. Parsly "Design Considerations of Reactor Containment Spray Systems - Part IV". ORNL-TM-2412, Part IV. (January, 1970).
3. A. K. Postma and W. F. Paseday, "A Review of Mathematical Models for Predicting Spray Removal of Fission Products in Reactor Containment Vessels". WASH-1329. (June 15, 1973).
4. USNRC "Safety Evaluation by the Office of Nuclear Reactor Regulation Supporting Amendment No 31 to Provisional Operating License No DPR-20". (November 1, 1977).
5. R. A. English "Palisades Plant - Radiation Release to Atmosphere from SIRW Tank Vent" RAE 46-77, AIR SP-77-11. (August 18, 1977).



#### APPENDIX D

### Neutralization of Boric Acid Solutions With Sodium Hydroxide and Trisodium Phosphate

December 14, 1977

Ability to maintain pH at or slightly above neutral in the event of a loss of coolant accident in a PWR is of concern relative to corrosion of system materials and the attendant generation of hydrogen. On this basis, NWT was requested by Consumers Power Company to evaluate the pH variation associated with addition of 23% sodium hydroxide and granular trisodium phosphate to various solutions of boric acid which could be released in the event of an incident. The five major sources of boric acid with maximum and minimum concentrations are given in Table 1. Consideration was given to the primary coolant system, two 50% full clean waste receiver tanks, the concentrated boric acid tank, four safety injection bottles, and the SIRW tank. Neutralization of the total mixture of approximately  $3.3(10^6)$  pounds of water at maximum and minimum boron concentrations of 2406 ppm and 1584 ppm, respectively, was evaluated.

Table 1: Boric Acid Solution Sources

<u>Source</u>	<u>Volume</u>	<u>Boric Acid as ppm B</u>	
		<u>Maximum</u>	<u>Minimum</u>
Primary Coolant System	7,800	1,070	0
Clean Waste Receiver Tanks	8,130	2,000	0
Concentrated Boric Acid Tank	1,740	17,500	11,000
Safety Injection Bottles (4)	4,000	2,000	1,720
SIRW Tank	34,000	2,000	1,720

Boric acid equilibrium relations were obtained from reference 1 and phosphoric acid relations from reference 2. Association of sodium with any ion was assumed negligible. The specific gravity of the 23 wt % sodium hydroxide solution in T103 was taken as 1.25 from reference 3. The apparent bulk density of granular trisodium phosphate 12-hydrate was measured and found to be approximately 0.89. The effect of small lithium concentrations on the pH of the solutions subsequent to addition of the initial amounts of sodium hydroxide or trisodium phosphate was neglected.



To support the analytical solutions on the neutralization reactions, laboratory tests were also performed. In these tests, approximately 800 ml of boric acid solution was titrated while continuously stirring and purging with nitrogen (99.998% pure). The titration was performed with granular trisodium phosphate dodecahydrate and 23 wt % sodium hydroxide.

The pH meter was an Orion 601A digital ion analyzer. An Orion combination pH electrode was employed. After each titrant addition, the solution was allowed to stabilize to 0.01 pH units. With sodium hydroxide addition, the readings stabilized within 2 to 5 minutes. With granular trisodium phosphate, readings stabilized within approximately 15 minutes. The phosphate titration was checked by back titrating with boric acid over the high range of the curve. Results were verified to 0.035 pH units.

Results of the analytical laboratory test program at room temperature are summarized in Figures 1 and 2. In Figure 1, the variation of solution pH with additions of 23 wt % sodium hydroxide is presented. As shown, the experimental and analytical results are in reasonable agreement at both the minimum and maximum boron concentrations. In general, the analytical predictions seem to underestimate the actual pH of the system several tenths of a pH unit at higher amounts of titrant.

Results of the neutralization with granular trisodium phosphate are presented in Figure 2. As for the case of sodium hydroxide neutralization, the analytical results appear to underestimate the achieved solution pH at a given addition of trisodium phosphate.

Corresponding analytical results at 100°C are presented for consideration in Figures 3 and 4. These are of interest since the solutions remain near boiling in the hypothesized incident. Neutral pH values are presented for reference. As shown, smaller amounts of titrant are required to achieve neutral pH at the higher temperature. This results from the temperature variation of the equilibrium relations predominantly for boric acid. A specific reason for



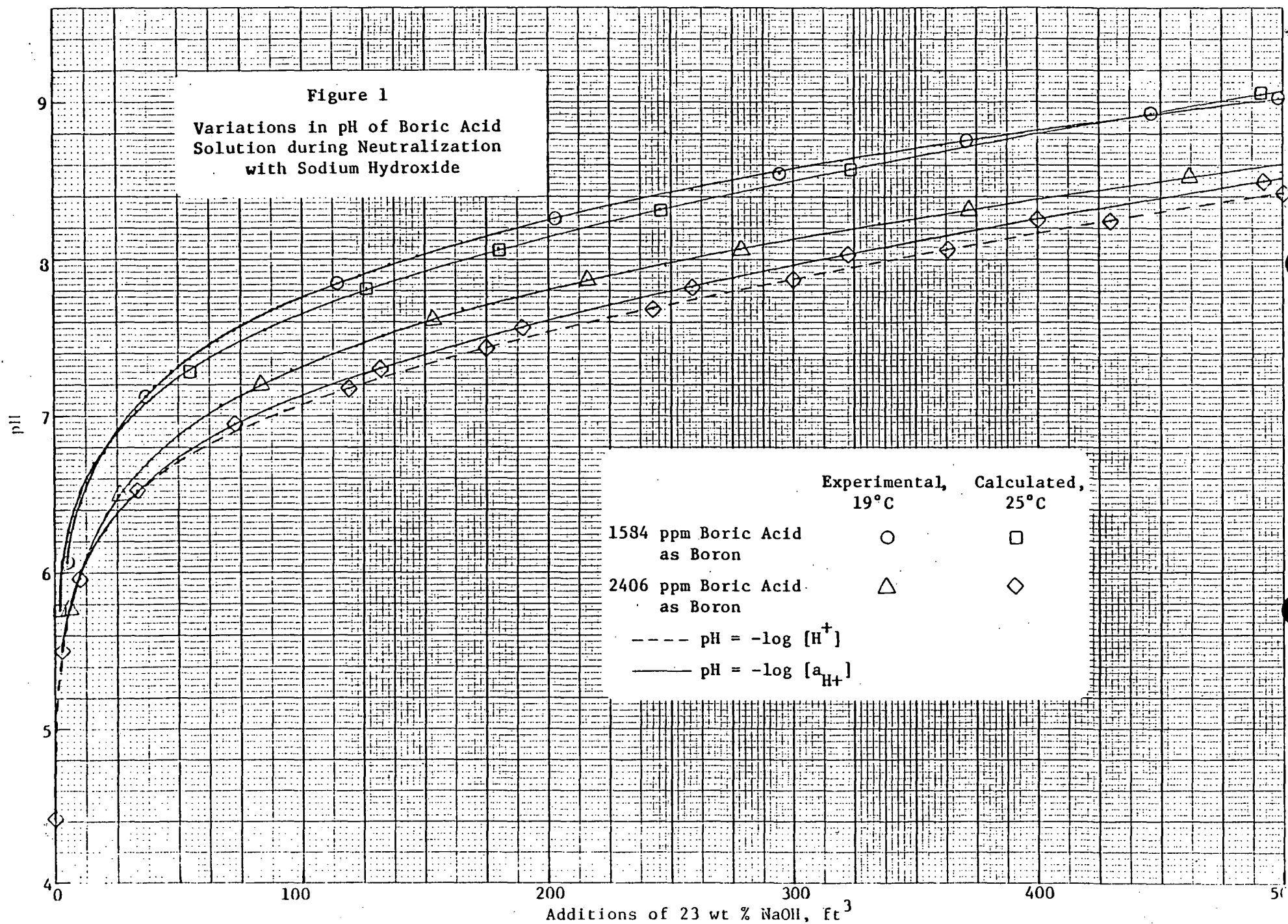


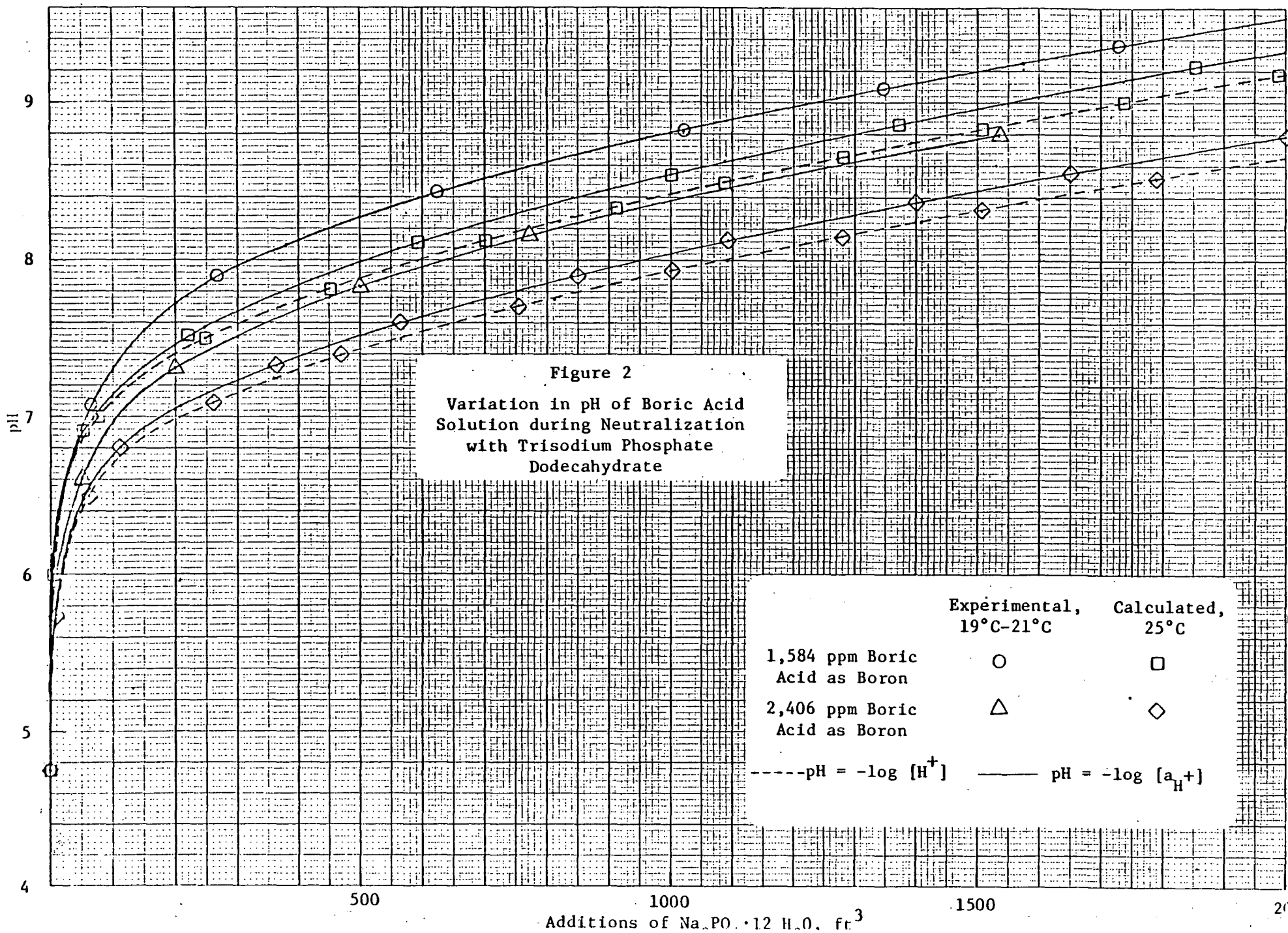
the differences observed between the experimental and analytical results relative to the pH variation during neutralization is not known. However, it seems likely that variations in the equilibrium relations with ionic strength for water, borate, and phosphate solutions which were obtained in media different from those considered in the course of developing the analytical results probably are the prime source of error.

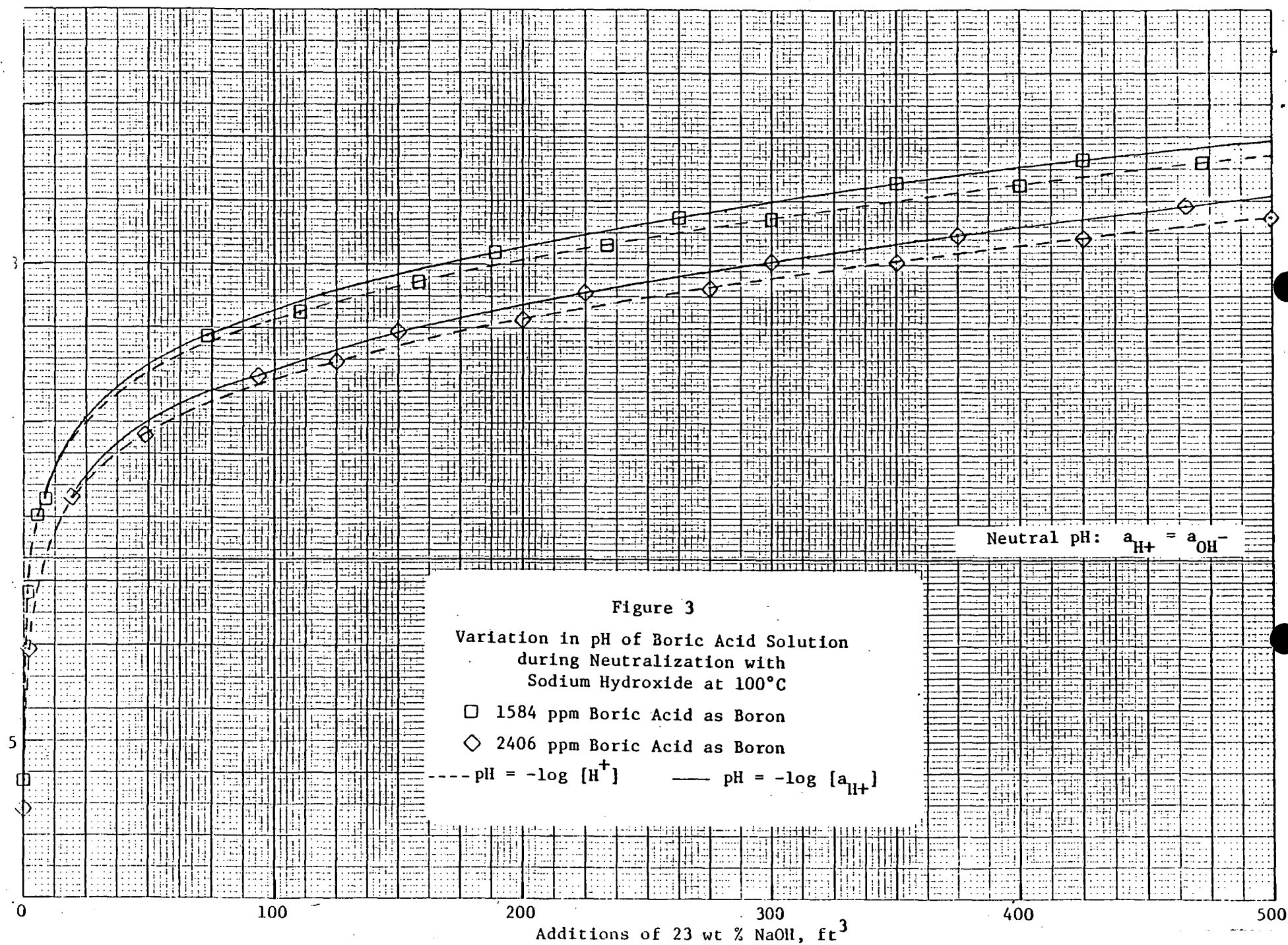
#### References

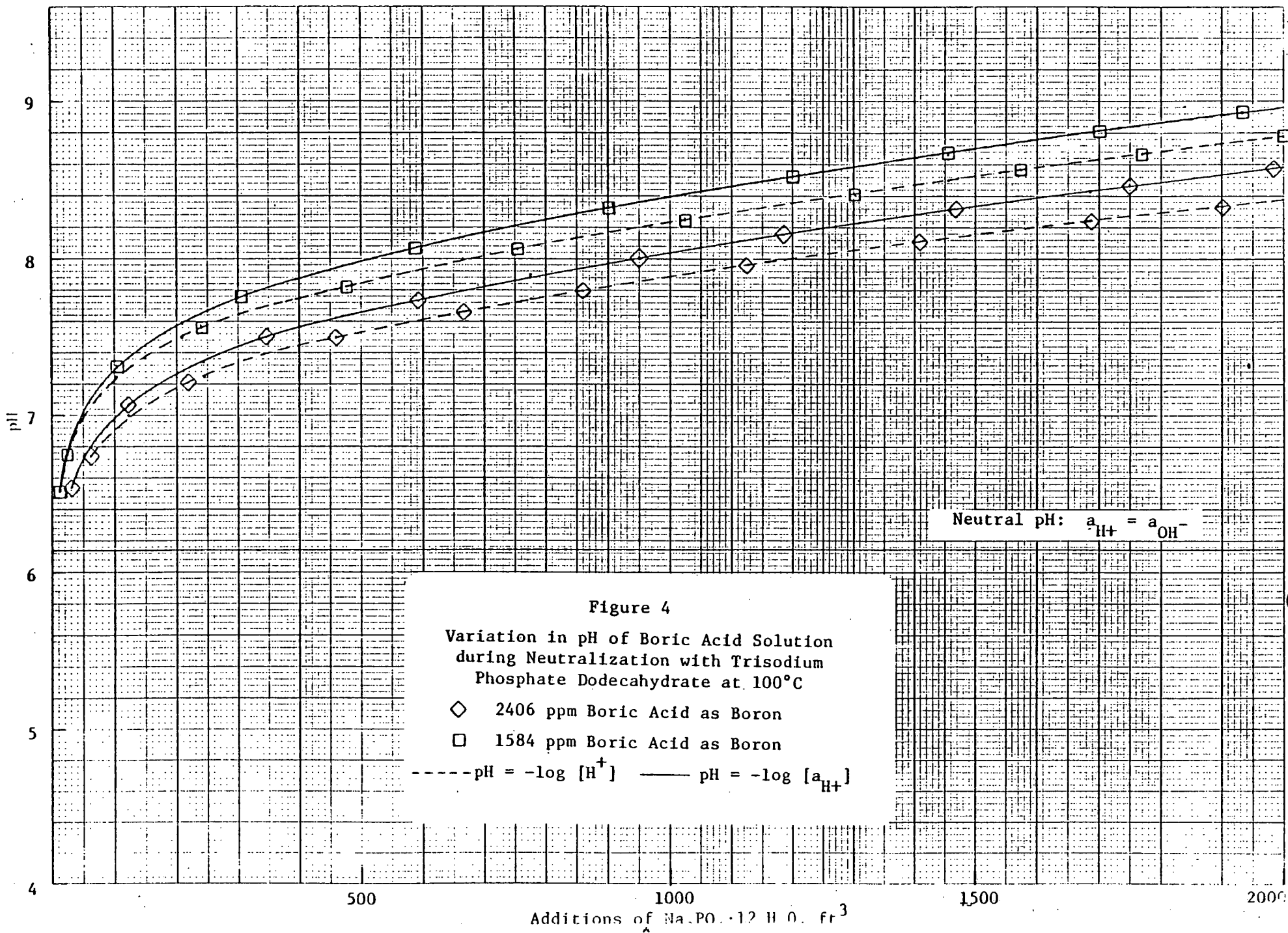
1. Mesmer, R. E., Baes, C. F., Jr. and Sweeton, F. H., "Boric Acid Equilibria and pH in PWR Coolants", Proceedings, 32nd International Water Conference, November 1971, pp. 55-65.
2. Mesmer, R. E. and Baes, C. F., Jr., "Phosphoric Acid Dissociation Equilibria in Aqueous Solutions to 300°C", Journal of Solution Chemistry, Vol. 3, No. 4, 1974, pp. 307-322.
3. Chemical Engineers' Handbook, John H. Perry, Editor in Chief, Textbook Edition, McGraw-Hill Book Company, Inc. 1950, Table III, p. 182.

Figure 1  
Variations in pH of Boric Acid  
Solution during Neutralization  
with Sodium Hydroxide









PALISADES PLANT

Special Test Procedure

T-102 Hydrazine Injection System Flow Rate Test

CONSUMERS POWER COMPANY

212 W Michigan Avenue  
Jackson, MI 49201

March 2, 1978

## SPECIAL TEST PROCEDURE

### T-102 Hydrazine Injection System Flow Rate Test

#### Purpose:

The test of the Iodine Removal System was performed to demonstrate that the following modifications will improve system performance. The modifications are:

1. Pressurize the hydrazine tank (T-102) to 10.7 psig.
2. Increase the hydrazine concentration to 15 weight percent.
3. Reduce the hydrazine volume to approximately 270 gallons.

The test results will be used for comparison with, and verification of, computer simulations of the Palisades Plant Iodine Removal System incorporating the above proposed modifications.

The scope of the test, therefore, included the collection of data generated from operation of the Iodine Removal System incorporating the four modifications described above. The data were then supplied to the Nuclear Activities Department for analysis.

#### Precautions to Insure Reactor Safety:

A Safety Evaluation for the test was completed.

Two concerns for reactor safety were discussed and evaluated in the Safety Evaluation. The first was the addition of a quantity of unborated water into the core region. This condition could occur if there was no flow from the SIRW tank when CV-3031 or CV-3057 was opened. If this occurred coincidentally with the opening of CV-0437A or CV-0437B and the starting of one of the low-pressure safety injection pumps, the contents of T-102 (plant PMW) could be injected into the core. The problem was addressed in the Special Test Procedure. Prior to starting the opening of the T-102 discharge valve, two conditions had to be met:

1. The SIRW tank discharge valve (CV-3031 or CV-3057) had to open and,
2. The low-pressure safety injection pump was started and flow through FIC-0306 must have had to be greater than 2500 gpm.

Mixing of flow from T-102 and the 2500 gpm minimum flow from the SIRW tank in the LPSI pump insured no unborated water entered the core region.

The second concern was the reduction in boron concentration in the SIRW due to the addition of 275 gallons of primary make-up water. The calculations from the Safety Evaluations indicated a reduction in boron concentration in the SIRW of less than 2 ppm.

#### Results:

The test results are included in this report and attached as Appendix A. The test was completed on February 28, 1978. Figure 1 is the graph of the percent level of the SIRW tank versus time. The graph indicates the constant rate of discharge of the tank as expected.

Figure 2 indicates the change in tank level of T-102 as a function of time. The portion of the curve labeled "A" indicates a slope of 3.6%/min which corresponds to a flow rate of approximately 13.8 gallons/min. After this initial surge of water the flow rate from the tank decreased until 5 minutes after beginning the test. The slope of the line after 5 minutes appears to be constant and be equal to 0.273%/min which corresponds to a flow rate from T-102 of 1.05 gallons/min. (Review of vendor's drawings indicates a total tank volume of 456 gallons and volume between the level transmitters located at 11'6" and 0'6" to be 384 gallons. This corresponds to 3.84 gallons/% on level indicator. Therefore, the flow is 0.237%/min  $\cdot$  3.84 gallons/% = 1.05 gallons/min).

Assuming 15 weight percent hydrazine in T-102, one can calculate the concentration of hydrazine available to the spray heads with the following equation:

$$[N_2H_4]_i \cdot f_i = [N_2H_4]_T$$

$f_i$  = Flow Rate From T-102 (Gpm)

Solve for  $[N_2H_4]_T$

$$[N_2H_4]_T = \frac{[N_2H_4]_i \cdot f_i}{f_T}$$

$[N_2H_4]_i$  = Hydrazine Concentration From T-102 =  $0.15 \times 10^6$  Ppm

$f_T$  = Total Flow to Spray Header (From FIC-0306 = 3000 Gpm)

$[N_2H_4]_T$  = Hydrazine Concentration to Spray Header (Unknown)

$$[N_2H_4]_T = \frac{0.15 \times 10^6 \text{ Ppm} \cdot 1.05 \text{ Gpm}}{3000 \text{ Gpm}} = 52.5 \text{ Ppm}$$

The required concentration of hydrazine is 50 ppm.



The calculations performed by the writer indicate satisfactory performance of the iodine removal system as tested with the modifications proposed by the Nuclear Activities Department

Recommendations for Further Action:

The writer recommends that the data from Special Test Procedure T-102 be submitted to the Nuclear Activities Department for comparison to and verification of computer simulations of the Palisades Plant Iodine Removal System.



Consumers Power

## PALM DES NUCLEAR PLANT

SPECIAL TEST

PROC NO T-103

PAGE 6 OF 6

REVISION 0

DATE

TITLE; HYDRAZINE INJECTION SYSTEM FLOW RATE  
TEST (T-102)

Form T-103-B

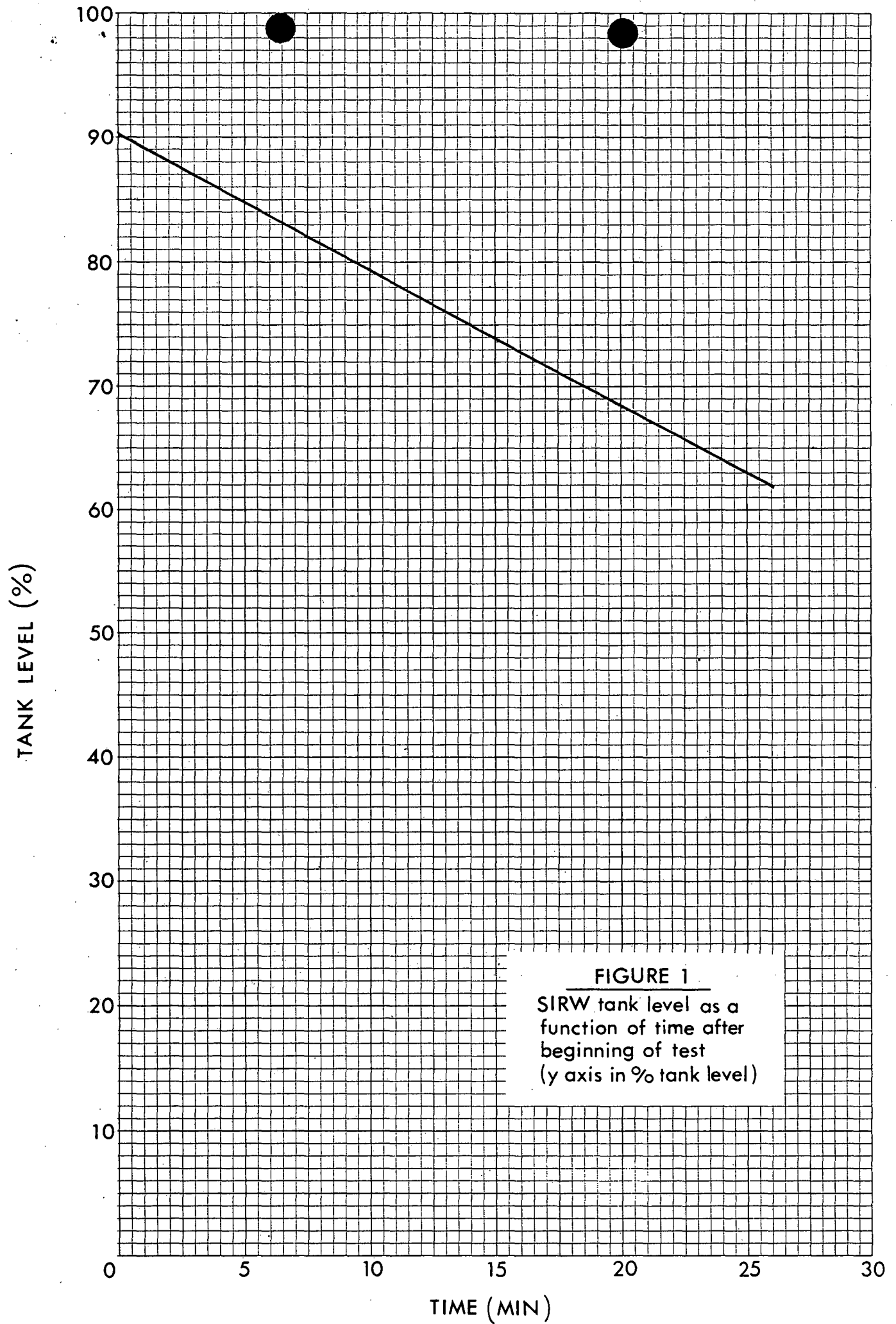
Data Sheet

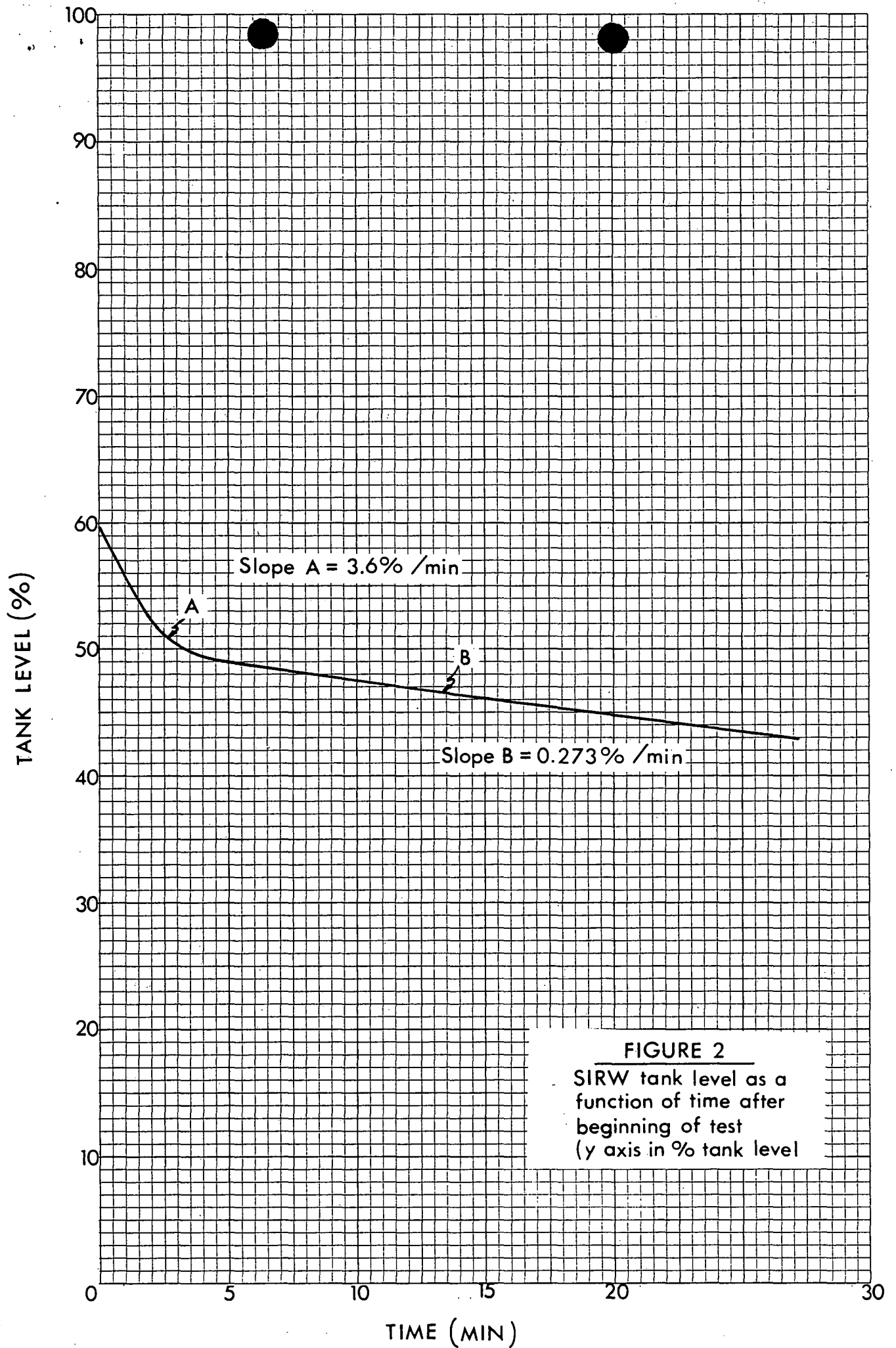
<u>T-102</u>			<u>SIRW Tank</u>	
<u>Date/Time</u>	<u>Level</u>	<u>Pressure</u>	<u>Date/Time</u>	<u>Level</u>
Initial Conditions	% Tank Level	(psi)		
2/28/78				
2240	60%	10.7	2241	90%
Start 2243				
2244	56%	Missed reading	2243	90%
2246	50%	6	2245	88%
2248	49%	5.5	2247	85.5%
2250	48%	5.3	2249	84%
2252	48%	5.1	2251	82%
2254	47%	4.9	2253	79.9%
2256	46.5%	4.7	2255	77%
2258	46%	4.5	2257	75%
2300	45.8%	4.3	2259	72.5%
2302	45%	4.2	2301	71%
2304	44.1%	4.0	2303	68%
2306	44.0%	4.0	2305	66.2%
2308	43.8%	3.8	2307	64.1%
2310	43%	3.6	2309	62%

Stop Test 2310

No indication of pressure loss from T-102  
prior to test. Held at 10.7 for 45 min and  
at 12 psi for 15 min.

3000 gpm flow (total)  
through flow controller valve  
FCV-0306





A HYDRAULIC  
EVALUATION OF THE PROPOSED  
MODIFICATION TO THE HYDRAZINE  
INJECTION SYSTEM AT THE  
PALISADES PLANT

Consumers Power Company  
212 W. Michigan Ave.  
Jackson, Michigan 49201

March 6, 1978

## I. Introduction

The present hydrozine injection system consists of a tank (T-102) filled with 390 gallons of a 5 w/o hydrazine solution and pressurized to about 0.1 psig with a regulated nitrogen supply. The tank is connected to the suction of the containment spray pumps just below the SIRW tank via two 2" lines as shown on piping and instrument diagram M-204 (figure 1). Several problems associated with the present design, but which do not exist for the modified design, are listed below:

1. Due to the elevation difference between the initial water level in the SIRWT and that in T-102, injection of hydrazine would be delayed by at least 6 minutes and possibly by as much as 20 minutes.
2. A single failure of a pressure control valve in the nitrogen supply system could incapacitate the system.

In the modified system T-102 is filled with 270 gallons of a 15 w/o hydrazine solution and pressurized to approximately 11 psig. However in the modified system the tank is not on a regulated nitrogen supply and therefore the single failure problem discussed above does not apply. Pressurizing the tank to 11 psig results in an almost immediate injection of hydrazine once containment spray is actuated. The only delays inherent in the system are: (1) A one-minute intentional delay on the opening of hydrazine injection system valves CV-0437A and CV-0473B; and, (2) the time required to purge the injection lines of hydrazine - free water (normally less than 50 seconds).

This evaluation utilized a computer model which is described in Section II. The computer model was verified against an actual plant test. The test and model verification are discussed in Section III. The sensitivity studies that were conducted to determine the adequacy of the modified system are discussed in Section IV. The results and the recommended operating limits are discussed in Section V.

## II. Computer Model

The RETRAN computer code<sup>(1)</sup> was used to simulate the transient response of the hydrazine injection system. The model that was employed is shown on Figure 2. The model consists of six volumes and six junctions. Tank and piping dimensions were taken from actual plant drawings.

## III. Model Verification

A test of the hydrazine system was run on 2/28/78 during the refueling outage. The test consisted of pumping down the SIRWT into the refueling cavity with a single low pressure injection pump. The pump was started and the valves in the associated discharge lines from the SIRWT and T-102 were opened at 2243. The valves in the discharge lines running to the header associated with the alternate low pressure safety injection pump were left closed. Readings of T-102 level and pressure and of SIRWT level were taken every two minutes during the test. The test was terminated at 23:10. The test results are tabulated on Table 1.

The test was simulated in RETRAN using the basic model shown on Figure 2. The model was initialized at conditions identical to that of the test.

T-102 level = 60% = 7.25 ft. above bottom weld

T-102 pressure = 10.7 psig at pressure tap which is 3.5 ft. above bottom weld

SIRWT level = 90% = 21.75 ft. above bottom weld

A flow rate of 3015 gpm was assumed. Inspection of the test results indicate that the average flow out of the SIRWT was 3015 gpm. The measured flow past FCV-0306 was 3000 gpm during the test.

(1) "RETRAN - A Program for One-Dimensional Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volume 1: Equations and Numerics", Electric Power Research Institute, NP-408, January 1977.

Results of the computer simulation are shown on figures 3 through 5. The actual test results are shown on these figures as well. Referring to figures 3 and 4, it is seen that the model accurately predicts the levels in the T-102 and in the SIRWT as a function of time. As shown on figure 5, the model slightly overpredicts the pressure in T-102 as a function of time. The worst error is less than 0.7 psig. Based on this comparison it was concluded that the model accurately predicts the actual situation in the plant, and therefore can be used to determine the adequacy of the modified system.

#### IV. Sensitivity Studies

A number of sensitivity studies were conducted to evaluate the performance of the modified hydrazine injection system. The effects of the following variables on system performance were evaluated.

1. Engineered safeguards flow rate.
2. Single failure of a T-102 discharge valve.
3. T-102 pressure.
4. T-102 level.

The cases evaluated are listed on Table 2.

#### V. Results and Recommended Operating Limits

The results of each of the seven cases are summarized on figures 6 through 12. Each figure shows containment spray water hydrazine concentration as a function of time after the opening of the hydrazine injection valve(s). Also shown on each figure is the time required to purge the hydrazine injection lines of hydrazine-free water, the time at which switch over to recirculation would occur, and the level in T-102 at switchover.



Cases 1 through 4 indicate the sensitivity of the system performance to engineered safeguards flow rate and to a possible failure of a hydrazine injection valve to open. The system performs adequately (i.e. hydrazine concentration is greater than 50 ppm) over the required range of engineered safeguards flow rate, even when a failure of an injection valve is considered. The hydrazine concentration does fall below 50 ppm very briefly in the early part of the transient for cases 2 and 4. This would have little impact on the MHA dose.

Cases 5 through 7 were conducted to determine the sensitivity of system performance to the initial pressure and level in T-102. Case 5 shows that even assuming the highest engineered safeguards flow rate, the highest allowed T-102 nitrogen pressure (13.2 psig), and the lowest allowed T-102 level, T-102 does not empty prior to switchover. Cases 6 and 7 illustrate that even assuming the lowest engineered safeguards flow, the highest allowed T-102 level, and the lowest allowed T-102 nitrogen pressure (9.2 psig), the system's performance is adequate (i.e. it provides 50 ppm hydrazine in the containment spray water for all but a very brief period during the transient).

The recommended hydrazine injection system operating limits are as follows:

T-102 level:  $7.09 \pm 0.5$  ft. above bottom weld ( $270.5 \pm 17.5$  gallons)

T-102 N<sub>2</sub> pressure:  $11.2 \pm 2.0$  psig

T-102 hydrazine concentration:  $15.5 \pm 0.5$  w/o

TABLE 1 - TEST RESULTS

<u>T-102</u>			<u>SIRWT</u>	
<u>Time</u>	<u>Level</u>	<u>Pressure</u>	<u>Time</u>	<u>Level</u>
2243	60%	10.7 psig	2243	90%
2244	56	missed reading	2245	88
2246	50	6	2247	85.5
2248	49	5.5	2249	84
2250	48	5.3	2251	82
2252	48	5.1	2253	79.9
2254	47	4.9	2255	77
2256	46.5	4.7	2257	75
2258	46	4.5	2259	72.5
2300	45.8	4.3	2301	71
2302	45	4.2	2303	68
2304	44.1	4.0	2305	66.2
2306	44	4.0	2307	64.1
2308	43.8	3.8	2309	62
2310	43	3.6		

TABLE 2 - CASES EVALUATED

<u>Case No.</u>	<u>Safeguards Flow</u>	<u>T-102 Nitrogen Pressure</u>	<u>T-102*** Level</u>	<u>SIRWT*** Level</u>	<u>Single Failure</u>
1	maximum*	10.2 psig	6.59 ft.	22.33 ft.	none
2	minimum**	10.2	6.59	22.33	none
3	maximum	10.2	6.59	22.33	T-102 discharge valve
4	minimum	10.2	6.59	22.33	T-102 discharge valve
5	maximum	13.2	6.59	22.33	none
6	minimum	9.2	7.59	22.33	none
7	minimum	9.2	7.59	22.33	T-102 discharge valve

\* Assumes 3 containment spray pumps, 3 high pressure injection pumps, and 2 low pressure safety injection pumps at runout flow.

\*\* Assumed to be 50% of maximum safeguards flow.

\*\*\* Above bottom weld.

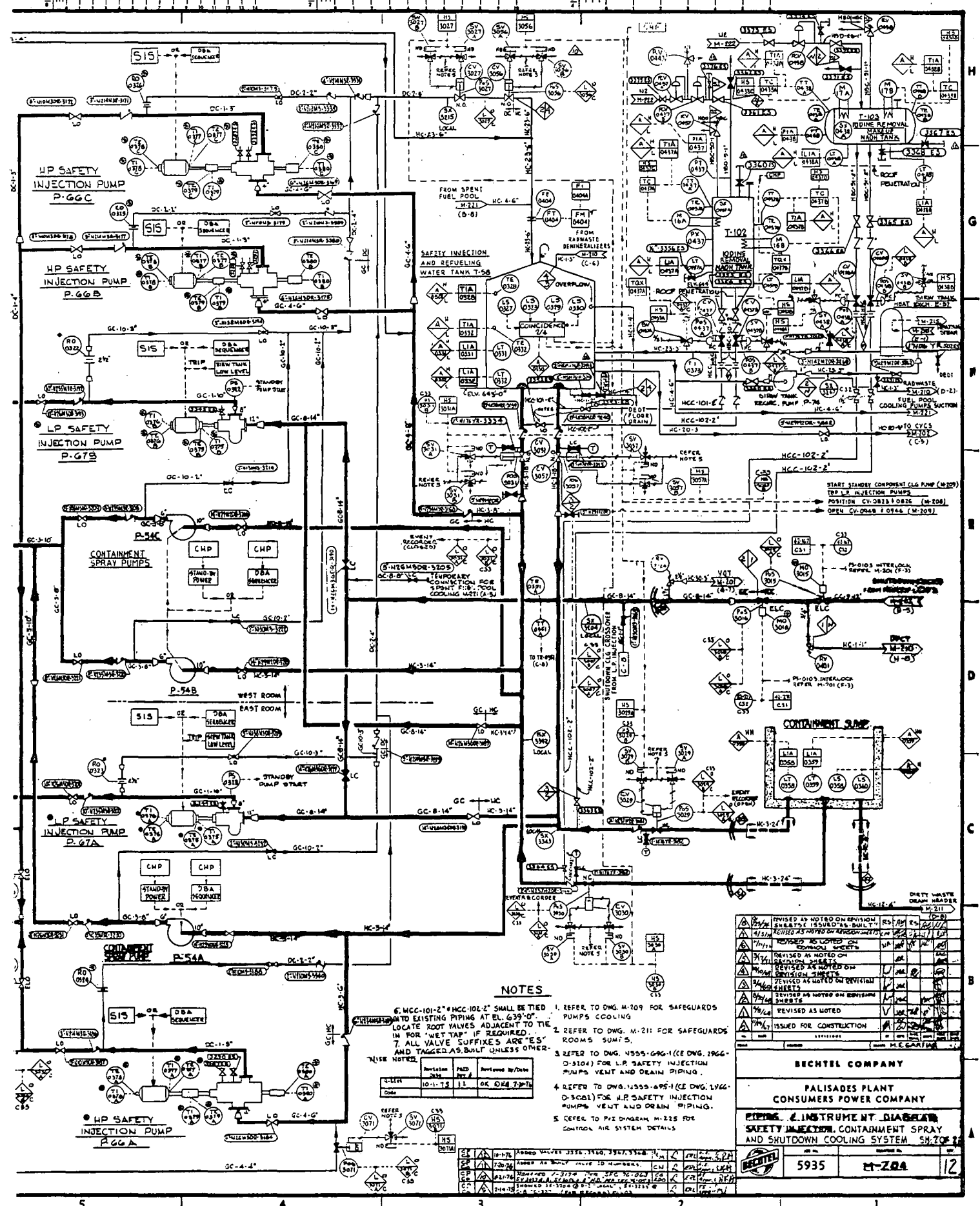


FIGURE 1

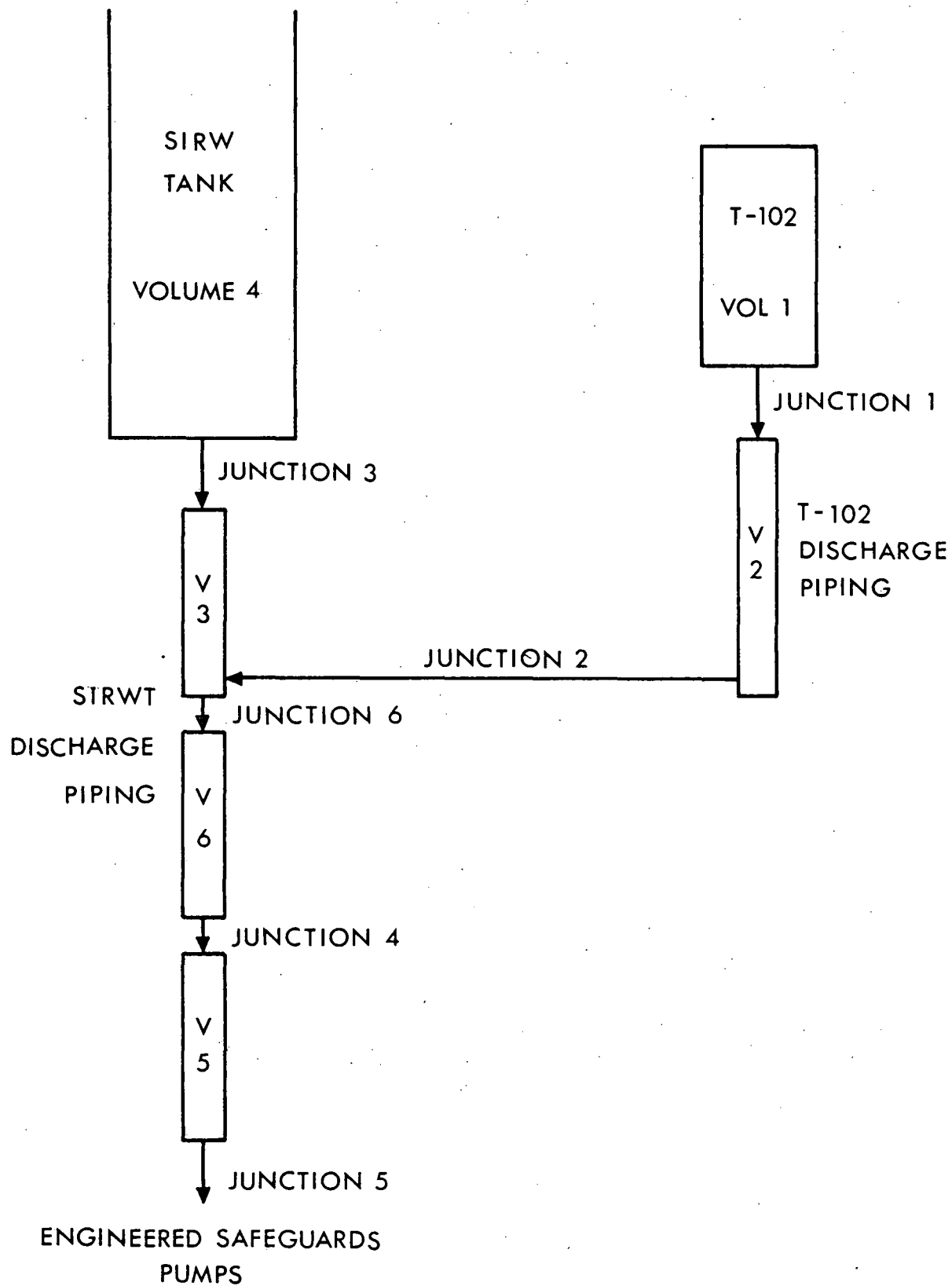


FIGURE 2. COMPUTER MODEL

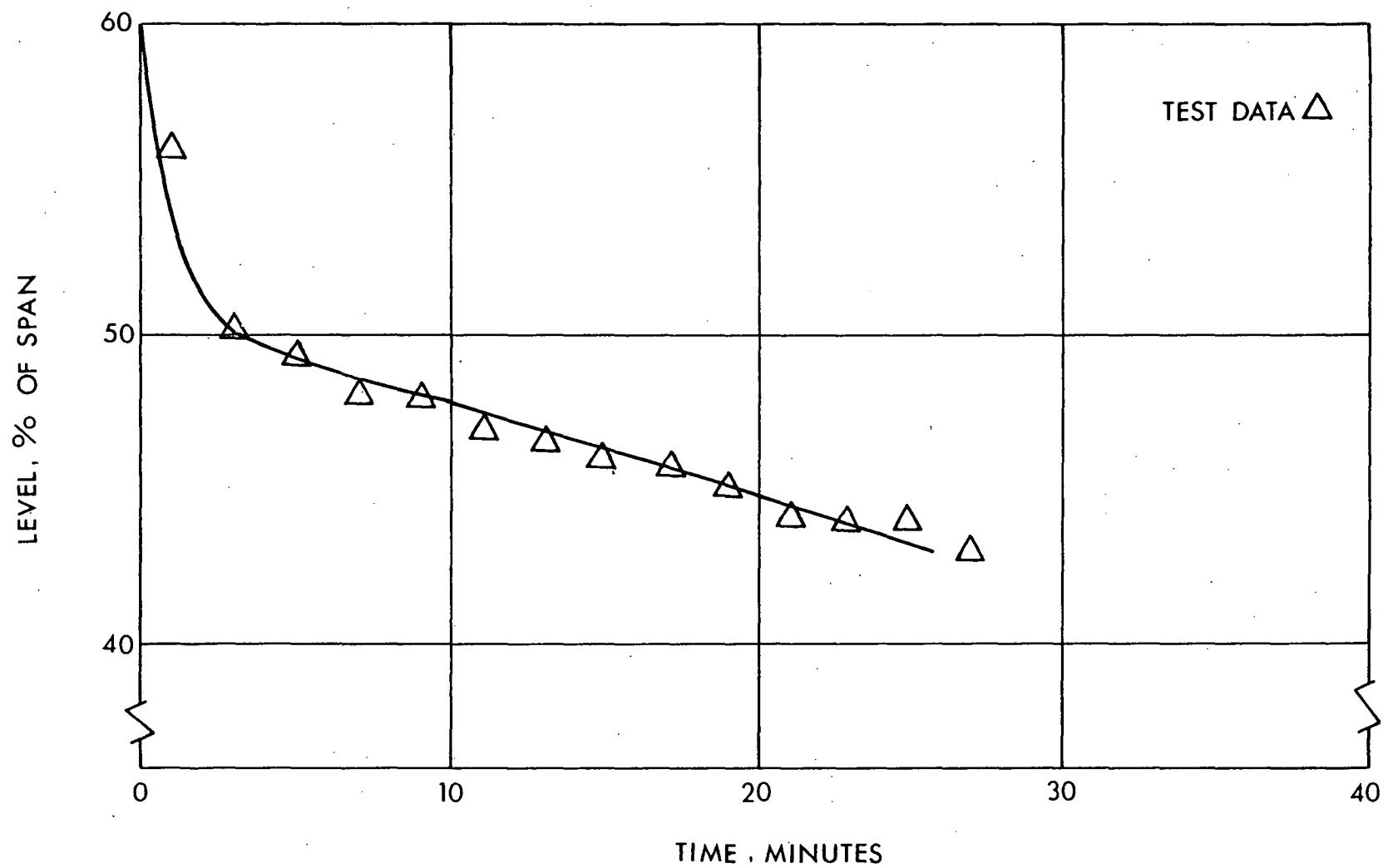


FIGURE 3 MODEL VERIFICATION - T-102 LEVEL VS TIME

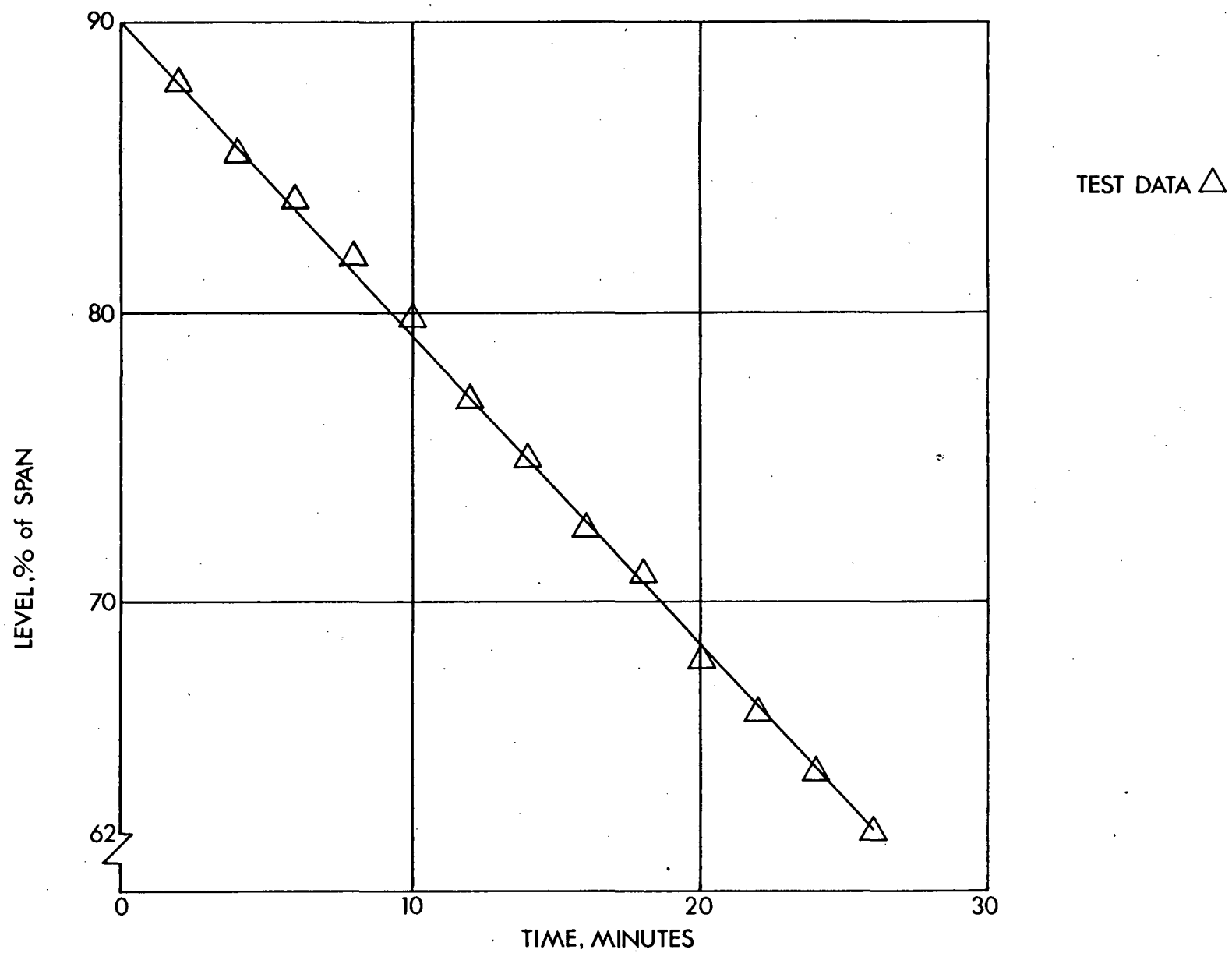
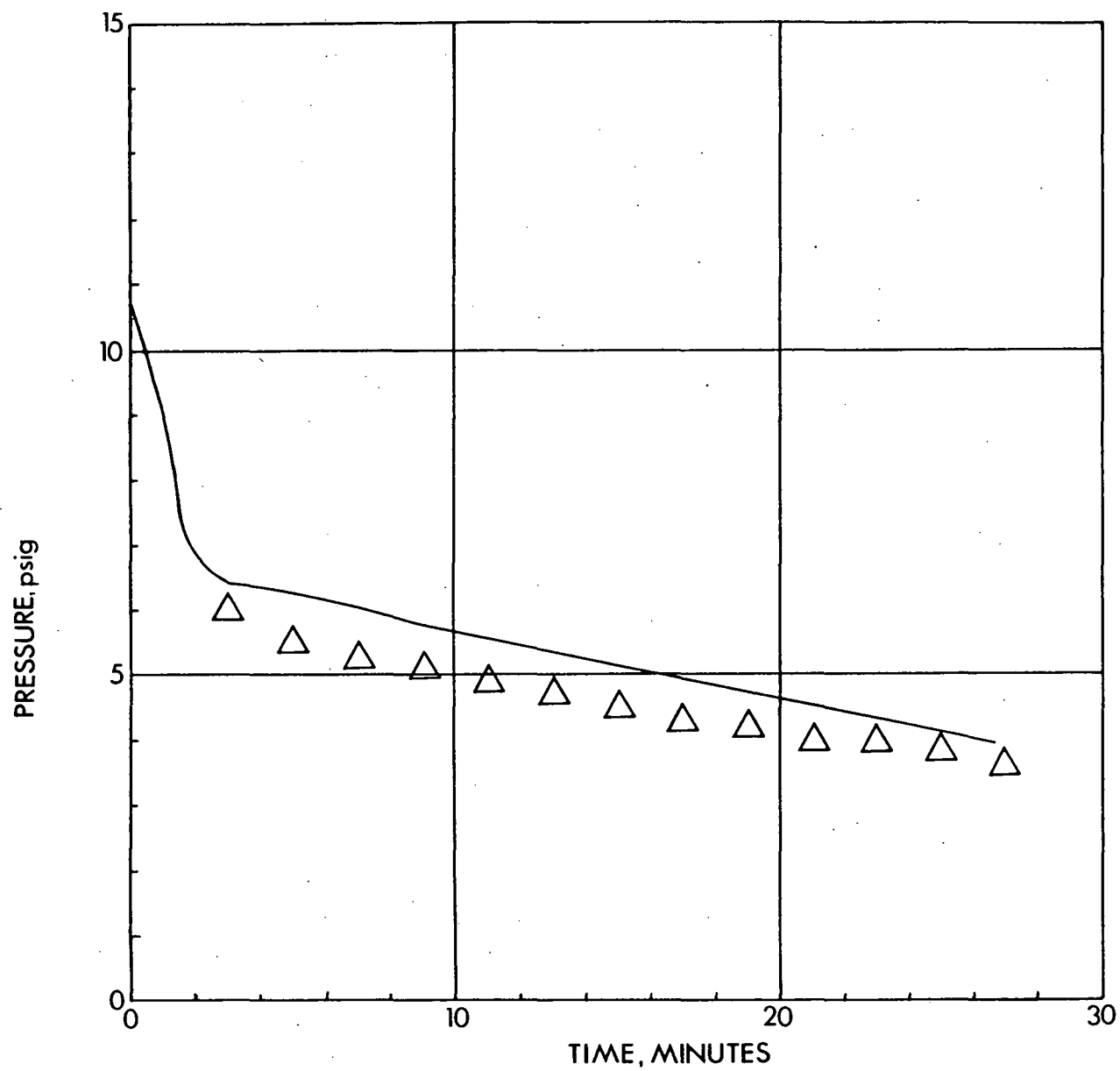


FIGURE 4. MODEL VERIFICATION - SIRWT LEVEL VS TIME



TEST DATA  $\triangle$

FIGURE 5 ; MODEL VERIFICATION - T-102 PRESSURE



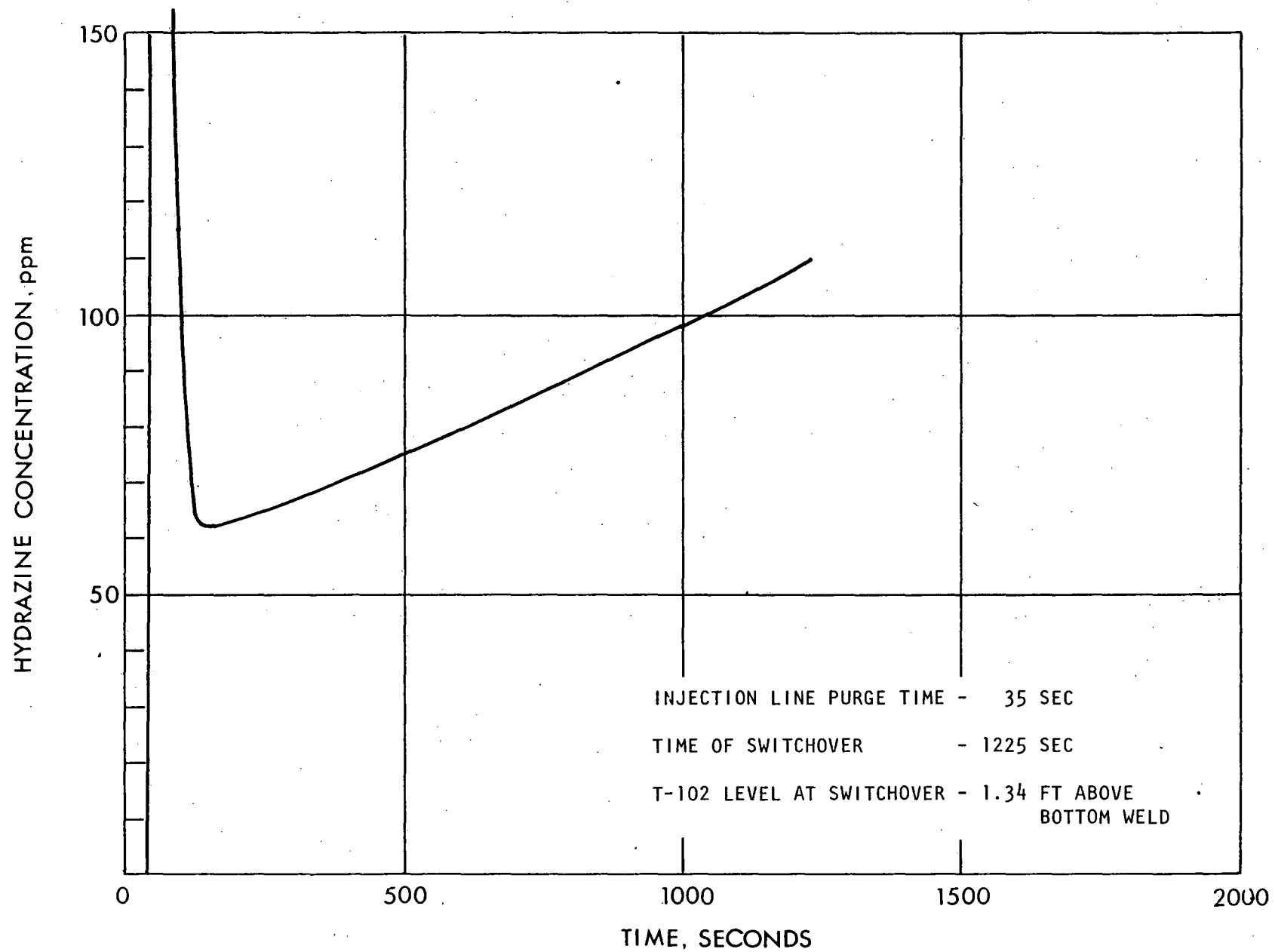


FIGURE 6 HYDRAZINE CONCENTRATION VS TIME - CASE 1

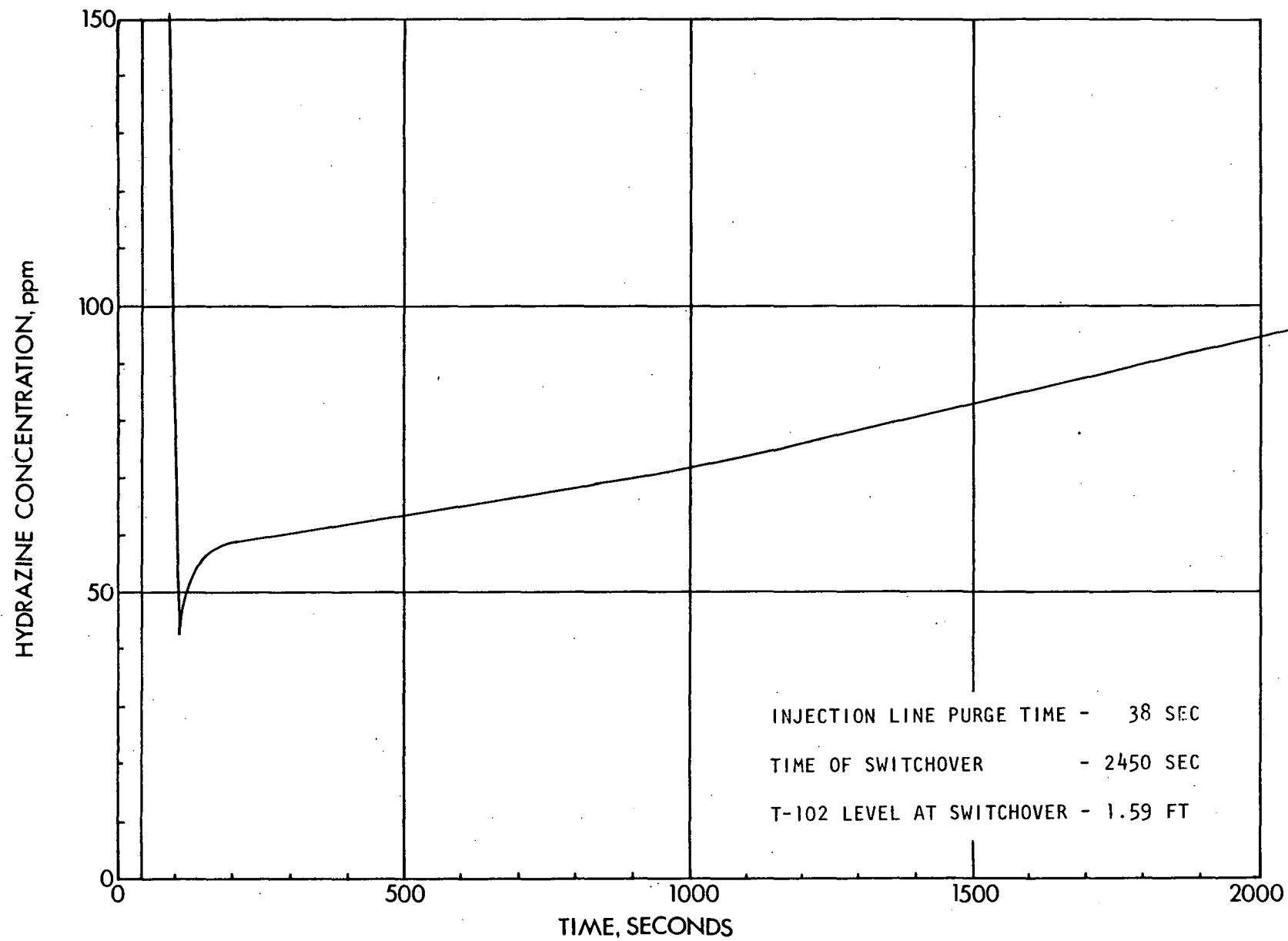


FIGURE 7; HYDRAZINE CONCENTRATION VS TIME - CASE 2

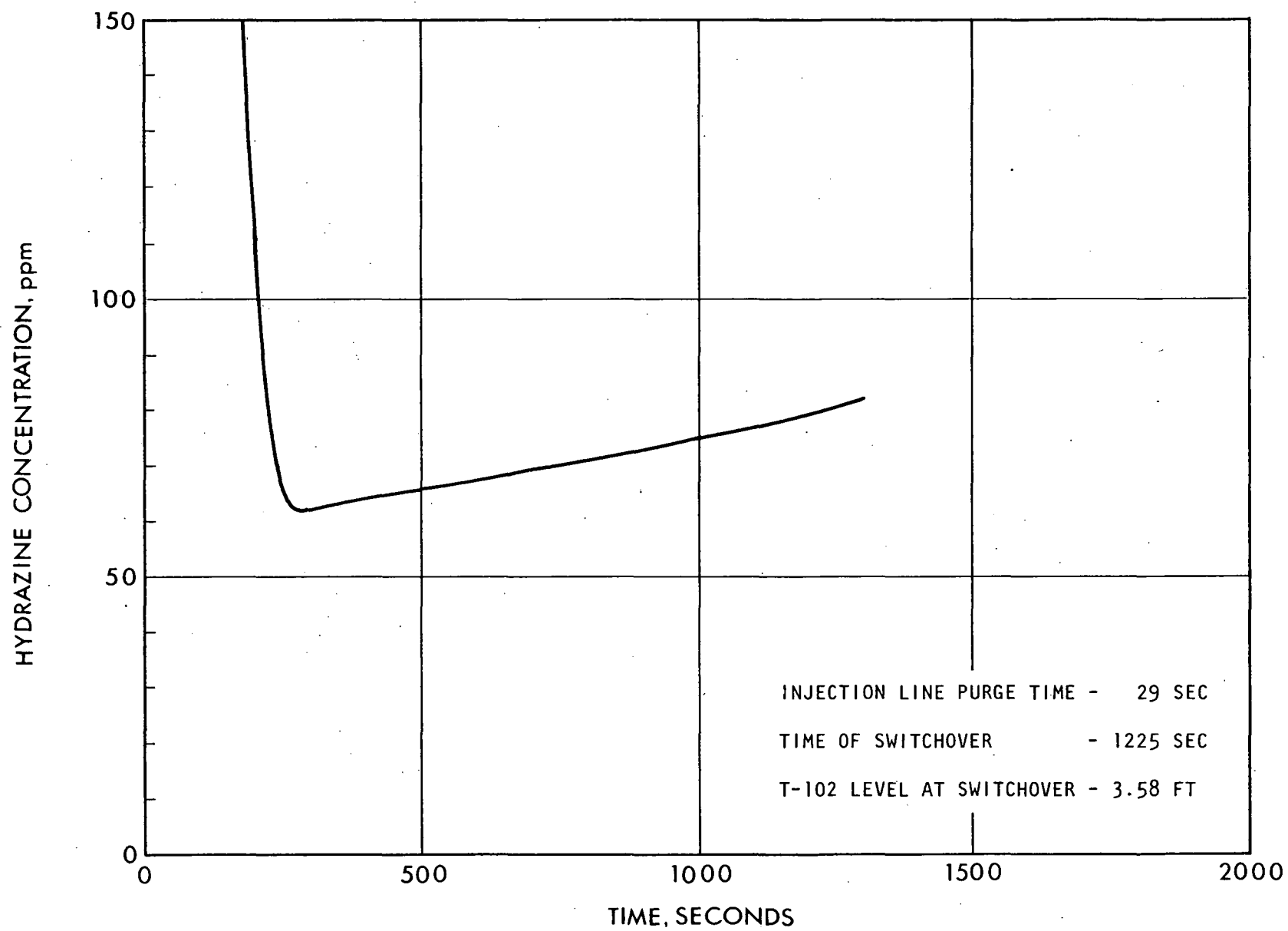


FIGURE 8 HYDRAZINE CONCENTRATION VS TIME - CASE 3

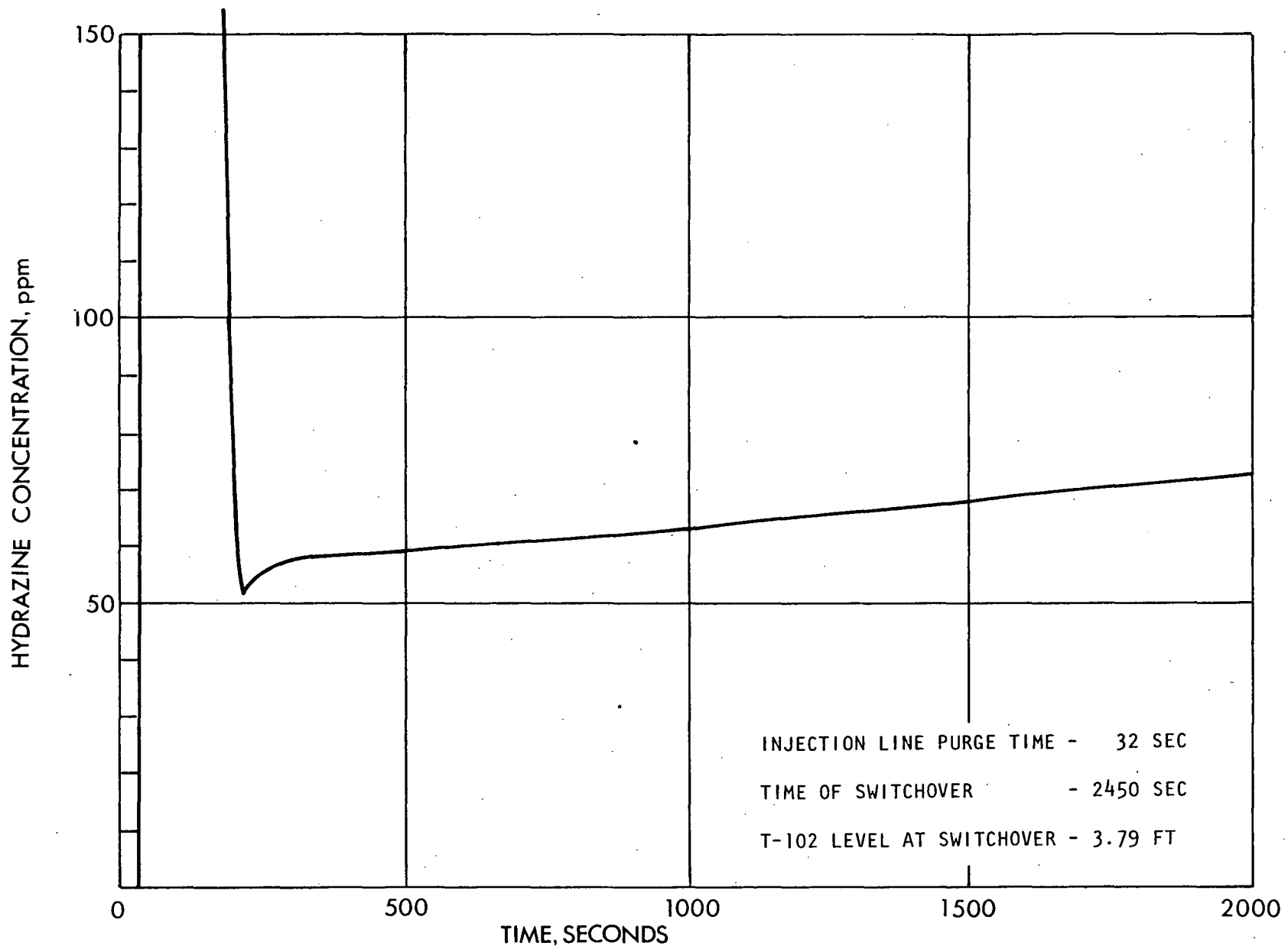


FIGURE 9 HYDRAZINE CONCENTRATION VS TIME - CASE 4

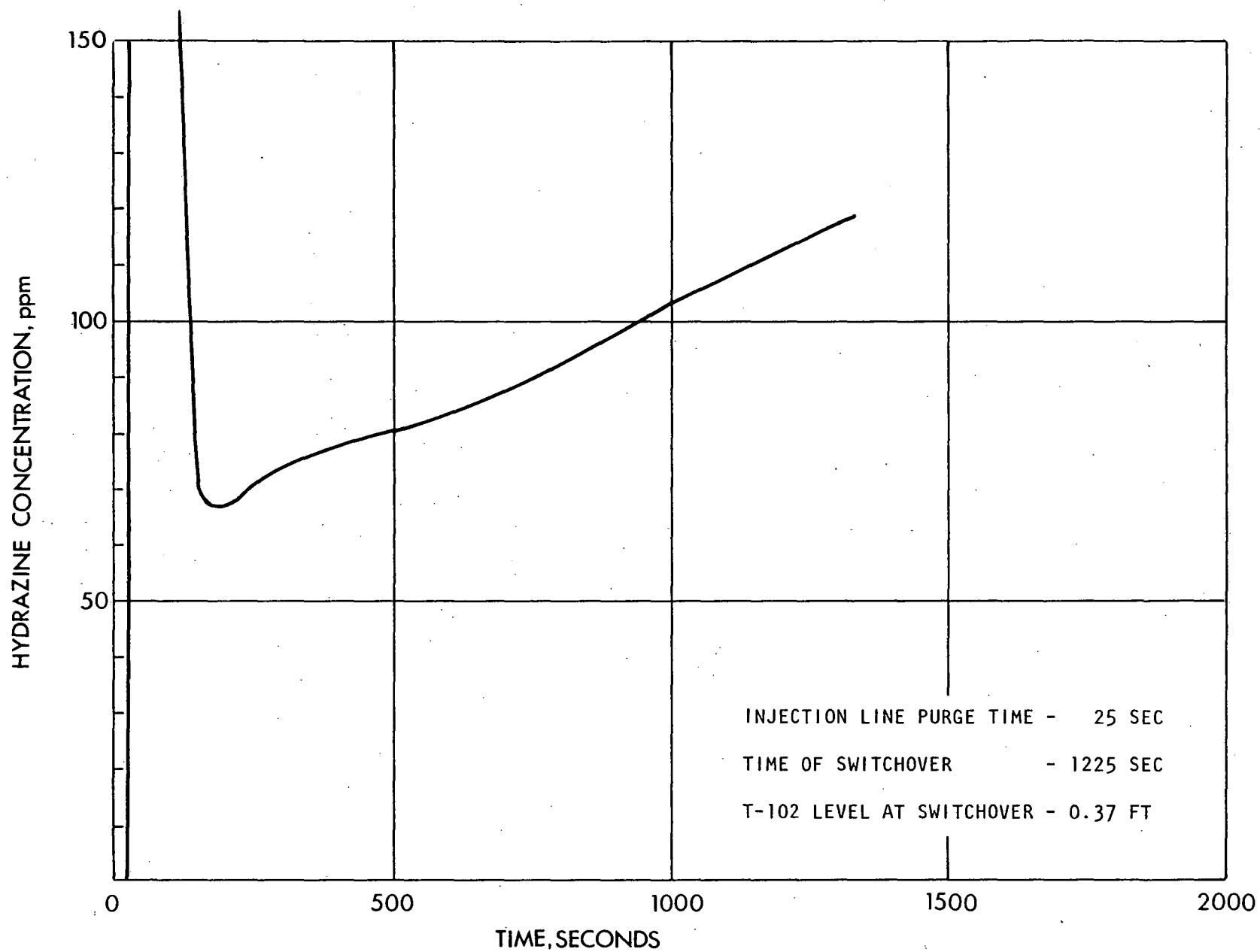


FIGURE 10 HYDRAZINE CONCENTRATION VS TIME - CASE 5

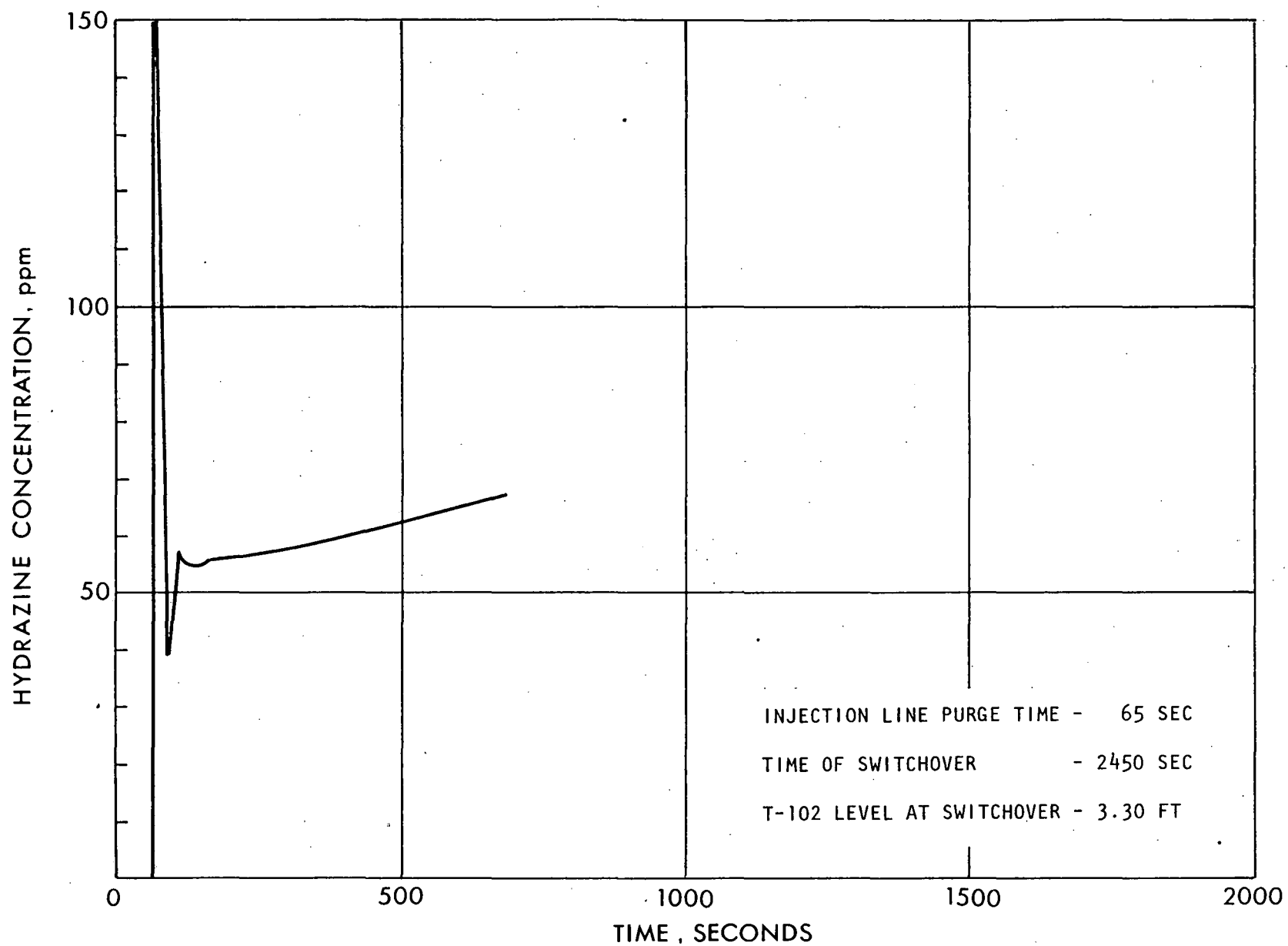


FIGURE 11 HYDRAZINE CONCENTRATION VS TIME - CASE 6

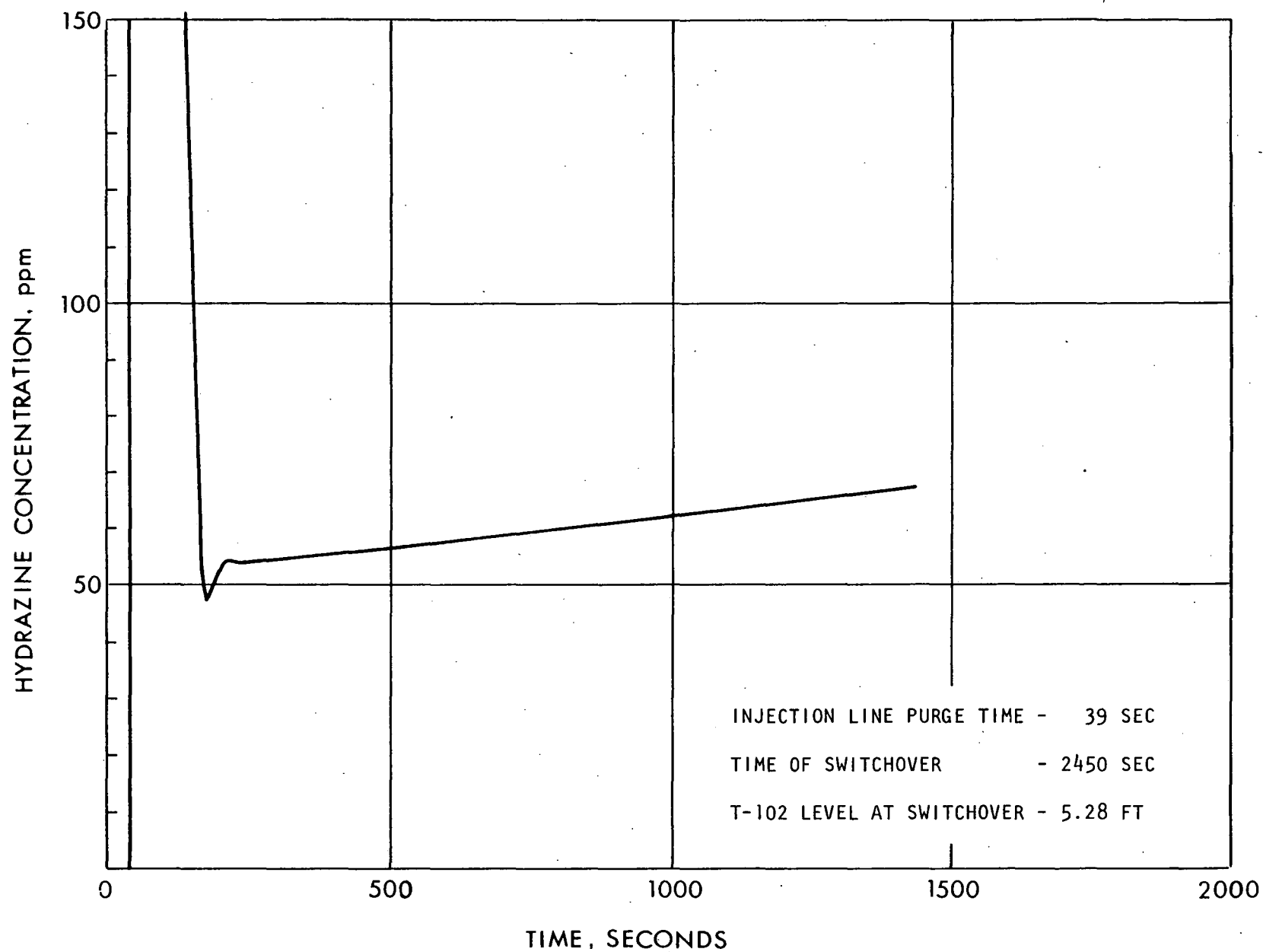


FIGURE 12 HYDRAZINE CONCENTRATION VS TIME - CASE 7