NRC FORM 195 (2-76)

U.S. NUCLEAR REGULATORY COMMISSION

NRC DISTRIBUTION FOR PART 50 DOCKET MATERIAL

DOCKET NUMBER: 50-289

FILE NUMBER:

TO: MR R W REID

FROM: METROPOLITAN EDISON CO, READING, PENN, R C ARNOLD

DATE OF DOCUMENT: 2-21-76*****

DATE RECEIVED: 6-1-76

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PROP

INPUT FORM

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DESCRIPTION

LTR REF OUR 1-20-76 LTR......TRANS THE FOLLOWING........

ENCLOSURE

ADDITIONAL INFO WITH RESPONSE TO QUESTIONS CONCERNING THEIR ANALYSIS OF THE TMI-1 REACTOR BUILDING SPRAY SYSTEM.......

2 PG
18 ENCL

ACKNOWLEDGED
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NOTE::::::: ****

FOR LA...ATTACHED IS FIRST COPY REC WITH DATE OF 2-21-76...SUGGEST YOU CONTACT APPL FOR CONFIRMATION OF 2-21-76 DATE.........

PLANT NAME: Three Mile Island #1

6-2-76 RR

FOR ACTION/INFORMATION

ASSIGNED AD:		ASSIGNED AD:	
✓ BRANCH CHIEF: (6)	REID	BRANCH CHIEF:	
PROJECT MANAGER:		PROJECT MANAGER:	
✓ LIC. ASST.: (17)	R. Ingram	LIC. ASST.:	

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NRC FORM 195 (2-76)

7910290627

Regulatory Docket File

METROPOLITAN EDISON COMPANY

POST OFFICE BOX 542 READING, PENNSYLVANIA 19603 TELEPHONE 215 - 929-3601

February 21, 1976
GQL 0249

Director of Nuclear Reactor Regulations
Attn: R. W. Reid, Chief
Operating Reactors Branch #4
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

Three Mile Island Nuclear Station Unit 1 (TMI-1)
Operating License No. DPR-50
Docket No. 50-289

By letters dated October 13 and November 12, 1975, Metropolitan Edison Company transmitted the results of our analysis of the TMI-1 Reactor Building Spray System. Your letter dated January 20, 1976 requested additional information be provided to permit completion of your review on this subject. The specific information requested and our response are contained below. *

1. Discuss how the minimum static pressure at the points where the chemical tank discharge lines join the lines leading from the BWST to the spray pumps was determined.

   Response: Refer to Attachment #1, Mathematical Method.

2. Describe and justify the methods used for determining the static pressure head due to the liquid in the BWST, the aspiration force in the spray lines at the chemical tank discharge points, and the friction forces involved.

   Response: Refer to Attachment #1

3. Provide system drawings showing the elevation of the chemical tanks, BWST and connecting piping.

   Response: Figures 1, 2 and 3 of Attachment #1 provide the schematic arrangement of the TMI-1 tanks and connecting piping. Table A-I of Attachment 1 provides the elevation information requested as well as other pertinent information for each node or section of pipe identified on the above figures.

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*Note: 3 signed originals provided herewith; 37 additionally requested copies to follow under separate cover.

4. Since free vortex formation in the BWST could affect the static pressure head, provide the following information:

   a. Provide the liquid heights in the BWST at the end of the injection phase.

   b. Provide the maximum liquid velocity in the suction lines and the suction line diameters.

   c. Describe any anti-vortex formation devices that are provided in the BWST. Provide an analysis of the effectiveness of these devices and include available emperical data which demonstrates that they will be effective in preventing vortex formation.

<u>Response</u>: The end of the injection phase occurs when the liquid height in the BWST reaches the tank lo-lo level alarm. This alarm is set for a level of 3 feet above the tank level tap or 1.25 ft. above the center of the outlet nozzle. Attachment 2 is a figure showing the maximum flow rate in the suction lines of the system. These flow rates are based on the four pumps, DH-P 1A/B and LS-P 1A/B, operating at design flow. In addition, it was assumed that no flow exists from the chemical tanks since this represents the worst conditions which could exist at the end of the injection phase. The BWST contains no anti-vortex formation devices. As part of the startup and test program of TMI-1, a test was conducted to check sodium hydroxide-sodium thiosulfate-Borated Water Storage Tank draw down performance. During this test, the BWST was drawn down to the tank lo-lo level set point with each of the above four pumps operating at design flow conditions. Test personnel stationed by the pumps heard no indications of cavitation or vortexing during this test nor did flow indication reveal any cavitation or vortexing effects. The above test results, therefore, confirm that anti-vortex formation devices are not required in the TMI-1 BWST.

Sincerely,

Signed: R. C. ARNOLD

R. C. Arnold
Vice President

RCA:CWS:ilm

bcc: R. H. Hawk*
J. J. Colitz
T. M. Crimmins
D. N. Grace
J. G. Herbein
R. W. Heward
R. M. Klingaman
L. L. Lawyer
J. F. Peters
J. R. Thorpe-Chairman, GORB, TMI-1
J. P. O'Hanlon-Chairman, PORC, TMI-1
B. M. McCutcheon*
C. W. Smyth
R. S. Brown

Mr. R. A. Govers
Babcock & Wilcox
P. O. Box 1260
Lynchburg, VA 24505

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ATTACHMENT 1

50-289
DTD 2-21-76
CONTROL 5429

MATHEMATICAL METHOD

The drawdown transient is modeled by determining the steady state flow from the tanks at their initial level. The volume of fluid drawn from the tank during a five minute interval is calculated from the above flow. In some cases a smaller interval was used because of rapidly changing steady state flow rates. The tank levels are adjusted and another steady state balance is performed. This procedure is repeated until the transient is over.

The computer program performs a steady state pressure balance on an arbitrary piping network. A relaxation iterative method of network analysis, a modified Bernoulli equation, and the Colebrook equation (the basis of the Moody diagram) are the bases of analysis for the program.

The two fluid properties required to calculate the flow in a pipe are the specific volume and the viscosity of the fluid. These properties may be inputted into the computer program as a function of temperature for any fluids desired, e.g. sodium hydroxide or sodium thiosulfate. If the fluid in a pipe is water, these properties may be inputted as above or calculated by the program.

Assuming saturated water conditions exist in the pipe at a specified temperature, the program calculates the specific volume as follows:[1]

$$V_s = \frac{V_c + a\,T^{1/3} + bT + CT^4}{1 + d\,T^{1/3} + eT} \quad k$$

where V_s = specific volume at saturated water conditions (ft^3/lb)
V_c = 3.1975 cm^3/g
$T = t_c - t$
t_c = critical temperature = 374.11°C.
t = temperature in degrees C

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a = - 0.3151548

b = - 1.203374×10^{-3}

c = + 7.48908×10^{-13}

d = + 0.1342489

e = - 3.946263×10^{-3}

k = conversion constant

= 0.0160185 $(ft^3/lb)/(cm^3/g)$

Again assuming saturated conditions, the viscosity of liquid water is calculated as follows:[2]

$$\mu = k241.4 \times 10^{247.8(T-140)^{-1}}$$

where μ = viscosity (lb/ft-sec)

T = temperature ($^{\circ}$ K)

k = conversion constant

= 6.7197×10^{-8} (lb/ft-sec)/(micropoise)

The Moody friction factor is then computed by iterating the Colebrook equation[3]

$$f^{-0.5} = - 0.86 \ln \left(\frac{\varepsilon}{3.7d} + \frac{2.51}{R_e^{0.5}}\right)$$

where f = Moody friction factor

ε = pipe roughness (feet); the standard roughness of commercial pipe, 0.0018 inches, is assumed.

d = inner diameter of the pipe (feet)

R_e = Reynolds Number

$$= \frac{dV_e}{V_s \mu}$$

V_e = fluid velocity in the pipe (ft/sec)

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To compute the flow rate in a branch, the line resistance of each pipe must be known. The line resistance is calculated as:

$$R_{ij} = 0.03115\ f\ L_e/d^5$$

where

R_{ij} = line resistance from function j to junction i (ft/gpm^2)

f = Moody friction factor

L_e = equivalent length of pipe (ft)

$= L + (\frac{L}{d})\ d$

L = length of straight pipe (ft)

$(\frac{L}{d})$ = total representative equivalent length in pipe diameters of various valves and fittings

d = inner diameter of the pipe (ft)

In addition to the data required to calculate the above properties for each pipe branch in the system, data must be supplied to the program in which the branches are combined to form closed loops. To compute the flow rate in each branch, it is assumed that each closed loop obeys Kirchoff's second law, i.e. the sum of pressure drops due to pipe losses and elevation changes around any closed loop is zero. Therefore:

$$H - \Sigma\ \Delta\ P_{EL} - \Sigma\ \Delta\ P_p = R$$

where

H = pump head (psi)

ΔP_{EL} = pressure loss due to elevation gain (psi)

ΔP_p = pressure loss due to friction (psi)

R = residual pressure if loop is not balanced ($R = 0$ in a balanced loop)

and

$$H - \Sigma\ \Delta\ P_{EL} - \Sigma\ \frac{R_{ij}}{\nu_{ij}}\ (Q_{ij} + \Delta Q_k)^2 = 0$$

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where Q_{ij} = previously calculated flow between junctions i and j
ΔQ_k = flow added to each line in the k^{th} loop to balance Kirchoff's equation (make residual R equal 0)

Let
$$a = \Sigma \frac{R_{ij}}{\nu_{ij}}$$

$$b = 2\Sigma \frac{R_{ij}\ Q_{ij}}{\nu_{ij}}$$

$$c = H - \Sigma\ \Delta\ P_{EL} - \Sigma \frac{R_{ij}\ Q_{ij}^{\ 2}}{\nu_{ij}}$$

Then, using a modified form of the quadratic formula so the difference between large numbers is not caluclated,

$$\Delta Q = \frac{2c}{-b- (b^2-4ac)^{1/2}}$$

To balance the network, the loop with the greatest error is selected, ΔQ_k calculated and the residual made zero. This process is repeated until the residual in every loop is less than 0.01 psi or the largest velocity change in all loops since the previous iteration is less than 0.05 feet/second.

The system being modeled is an open system (Figure I). In order to mathematically close the system and insure the same pressure on the top of the fluid in each tank, i.e. 14.7 psi, a control valve (which does exist in the system and is set for the proper flow) was added to the discharge line of each pump, preset to the designated flow through the pump. The necessary pressure drop across this valve is calculated to insure the proper flow. The pump discharge lines then converge to a common junction (Junction 1, Figures II and III). A "dummy" fluid of low density and viscosity, is used to close the loop from Junction 1 to the top of the fluid in each tank. A large pipe (ID = 100 inches) is assumed so no pressure loss occurs and the low density insures no pressure loss due to the elevation change. Thus, the same pressure exists on the fluid surface in each tank.

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Other parameters calculated by the program are:

1. Junction Pressure

$$P_i = P_j - \frac{R_{ij} \, Q_{ij}^{\,2} + \Delta E_{ij}}{V_s^{ij}}$$

ΔE_{ij} = elevation change between junctions i and j

V_s^{ij} = specific volume in the branch between junctions i and j

2. Fluid velocity (ft/sec)

$$V_e = \frac{kQ}{\pi(\frac{d}{2})^2}$$

k = conversion constant

$$= \frac{0.13368 \text{ ft}^3}{\text{gal}} \times \frac{1 \text{ min.}}{60 \text{ sec}}$$

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VERIFICATION OF ANALYTICAL MODEL

As part of the start up and test program of TMI #1, a test was conducted in 1973 to check the sodium hydroxide-sodium thiosulfate - BWST drawdown by pumping water to the fuel transfer canal. The test and results of both the full flow and half flow tests are recorded in Test Procedure 204/3 of TMI Unit 1.

A comparison of the observed and calculated results of the full flow test is presented in Table I and Figures IV a, b, c. The computer model is shown in Figure II. The calculated level drop per five minutes was comparable to that observed for the three tanks. It should be noted that since a steady state analysis is being done, there exists a larger discrepancy between the observed and calculated results during the startup of the test. The discrepancy at the end of the test is due to the manner in which the liquid levels were recorded; the automatic print-out device used was set to record the levels every five minutes. When the LO-LO level alarm in the BWST was tripped, the pumps were throttled to terminate the test. The liquid levels and time were not recorded; the levels were recorded at the end of the five minute interval, thereby causing the tail-off shown in Figures IV a, b, and c. Test personnel stationed by the pumps heard no indication of cavitation or vortexing during the tests. 1

Further verification of the program is provided by comparison to the half flow water test in which pumps DH-P1B and BS-P1B did not operate. (Figure III). In contrast to the full flow test, the flow rates through the pumps were not constant. This effect was included in the analysis. Good agreement between the observed and calculated results is shown in Table II and Figures V a, b, c.

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FIGURE 1

METROPOLITAN EDISON COMPANY

THREE MILE ISLAND NUCLEAR STATION - UNIT 1

SCHEMATIC OF DECAY HEAT AND REACTOR BUILDING SPRAY SYSTEMS

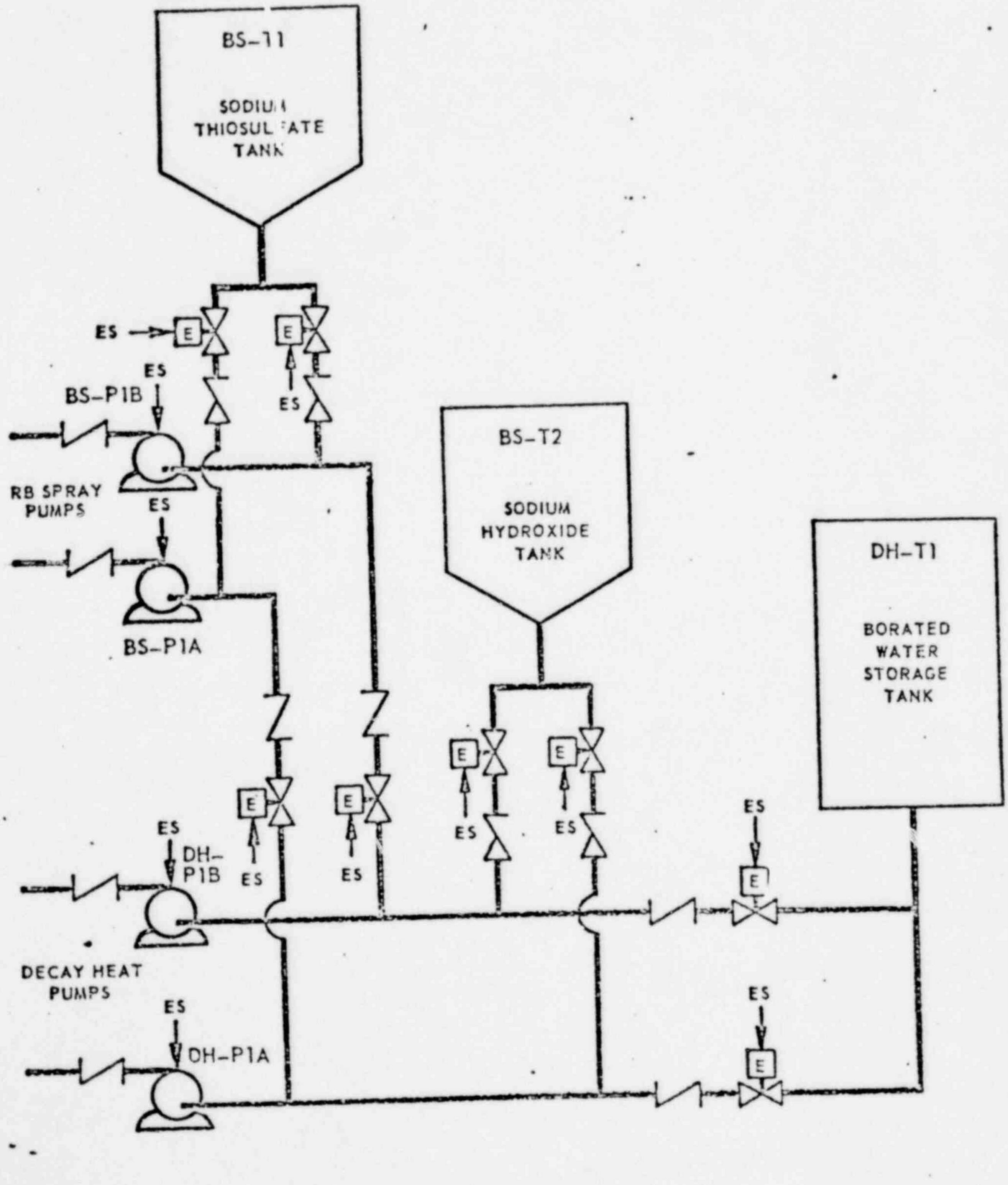

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FIGURE II

METROPOLITAN EDISON COMPANY

THREE MILE ISLAND NUCLEAR STATION - UNIT 1

MODEL OF DECAY HEAT AND REACTOR BUILDING SPRAY SYSTEMS FOR FULL FLOW DRAWDOWN ANALYSIS

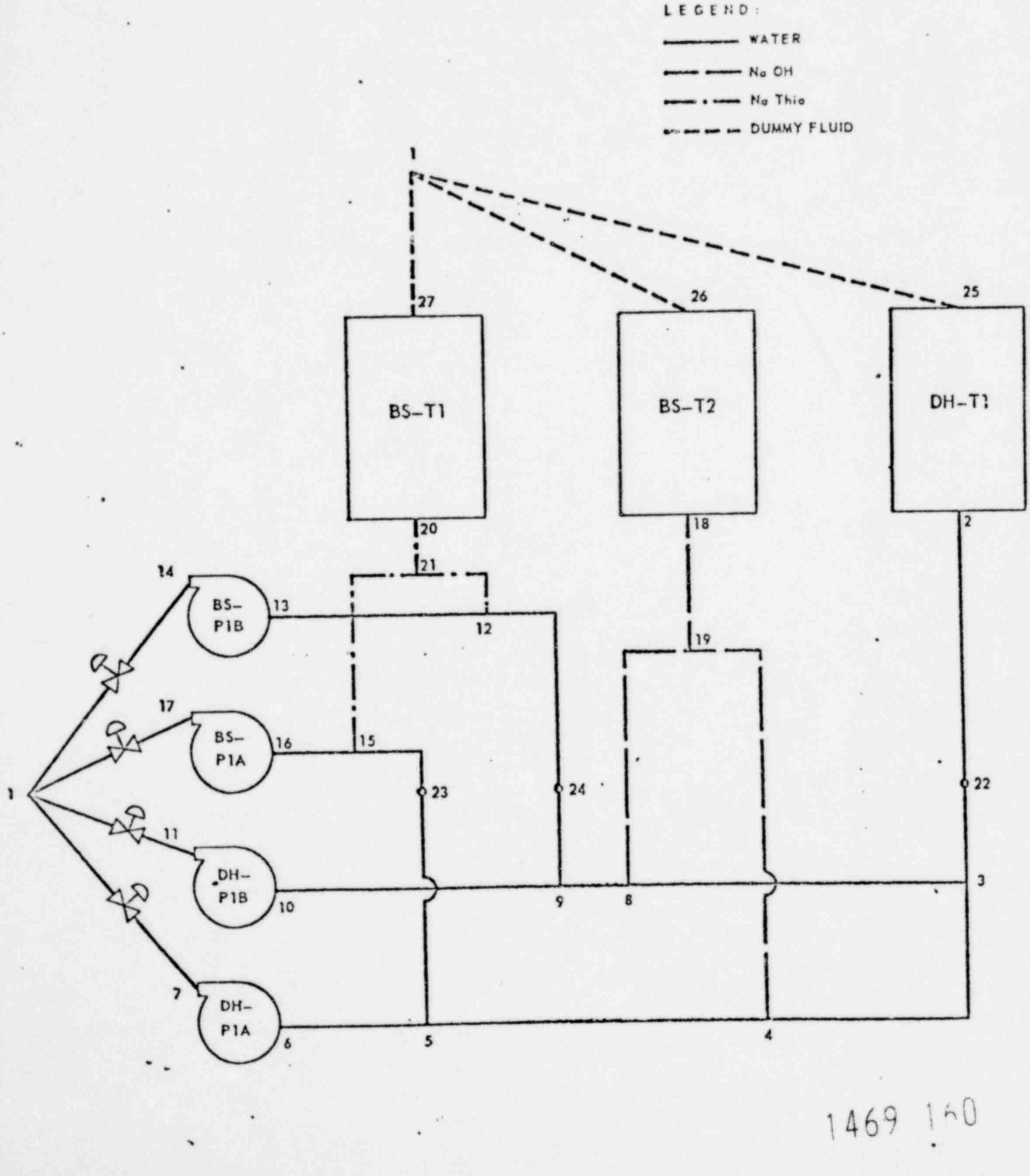

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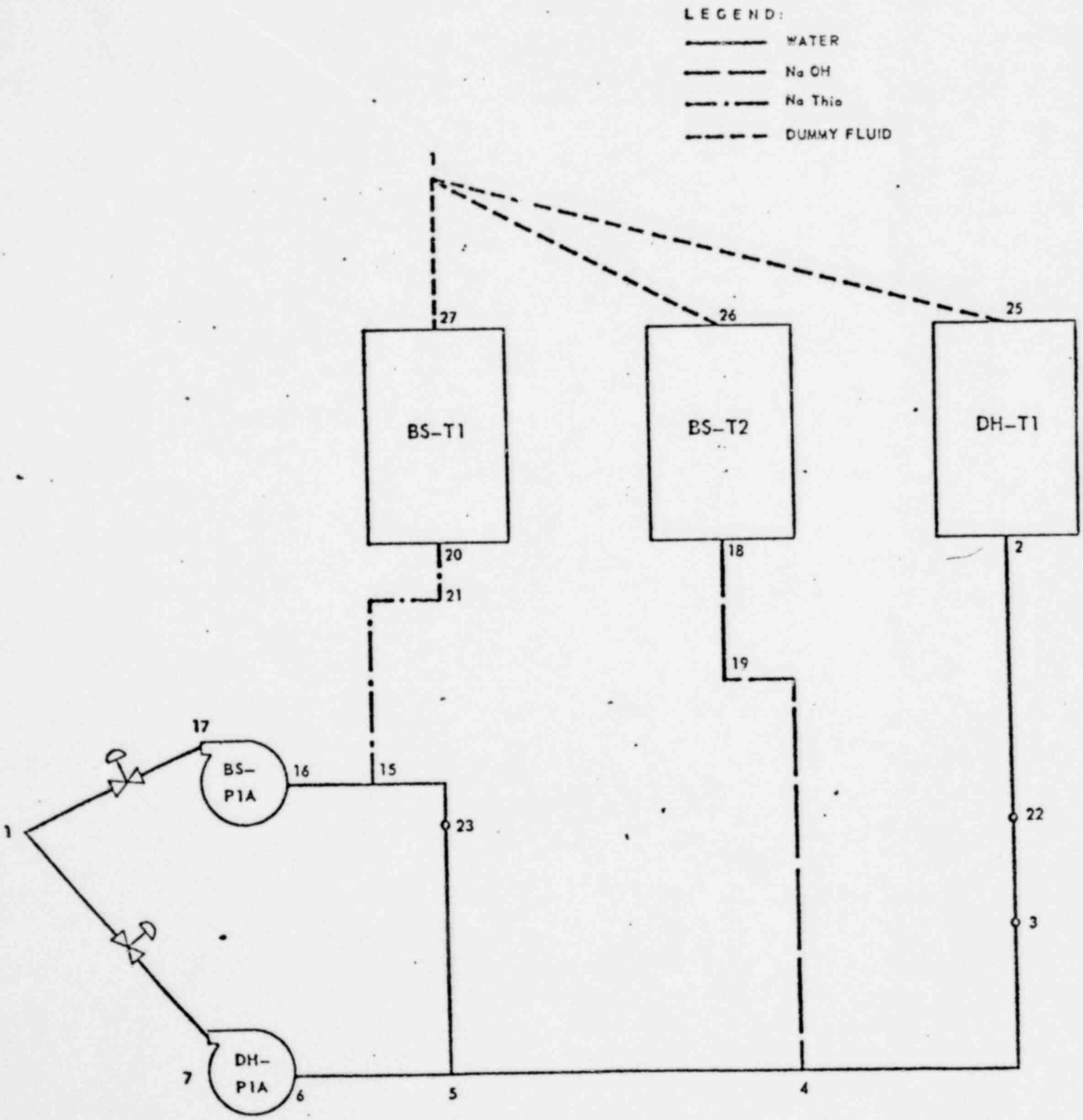
FIGURE III

METROPOLITAN EDISON COMPANY

THREE MILE ISLAND NUCLEAR STATION - UNIT 1

MODEL OF DECAY HEAT AND REACTOR BUILDING SPRAY SYSTEMS FOR HALF FLOW DRAWDOWN ANALYSIS



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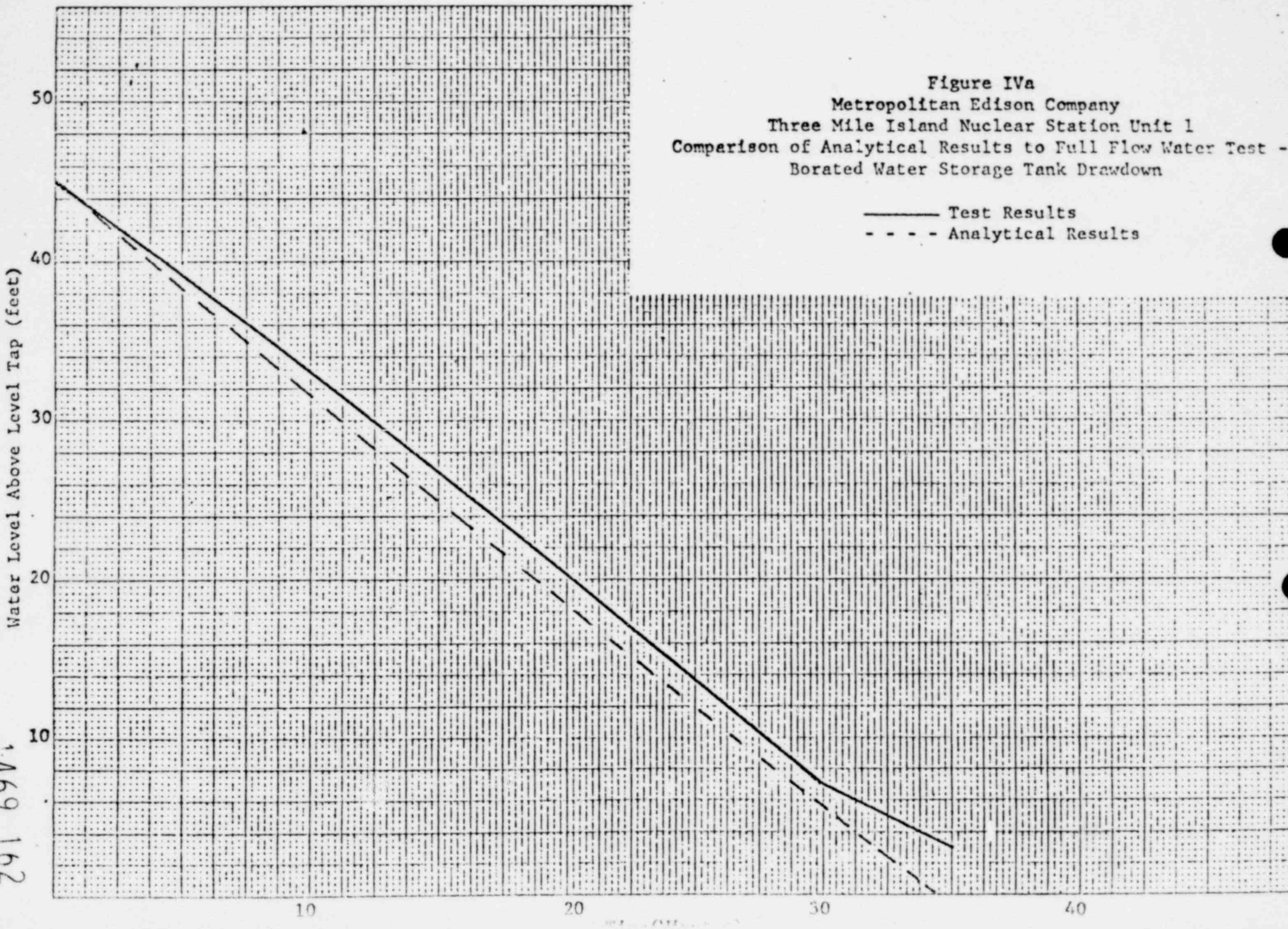

Figure IVa
Metropolitan Edison Company
Three Mile Island Nuclear Station Unit 1
Comparison of Analytical Results to Full Flow Water Test -
Borated Water Storage Tank Drawdown

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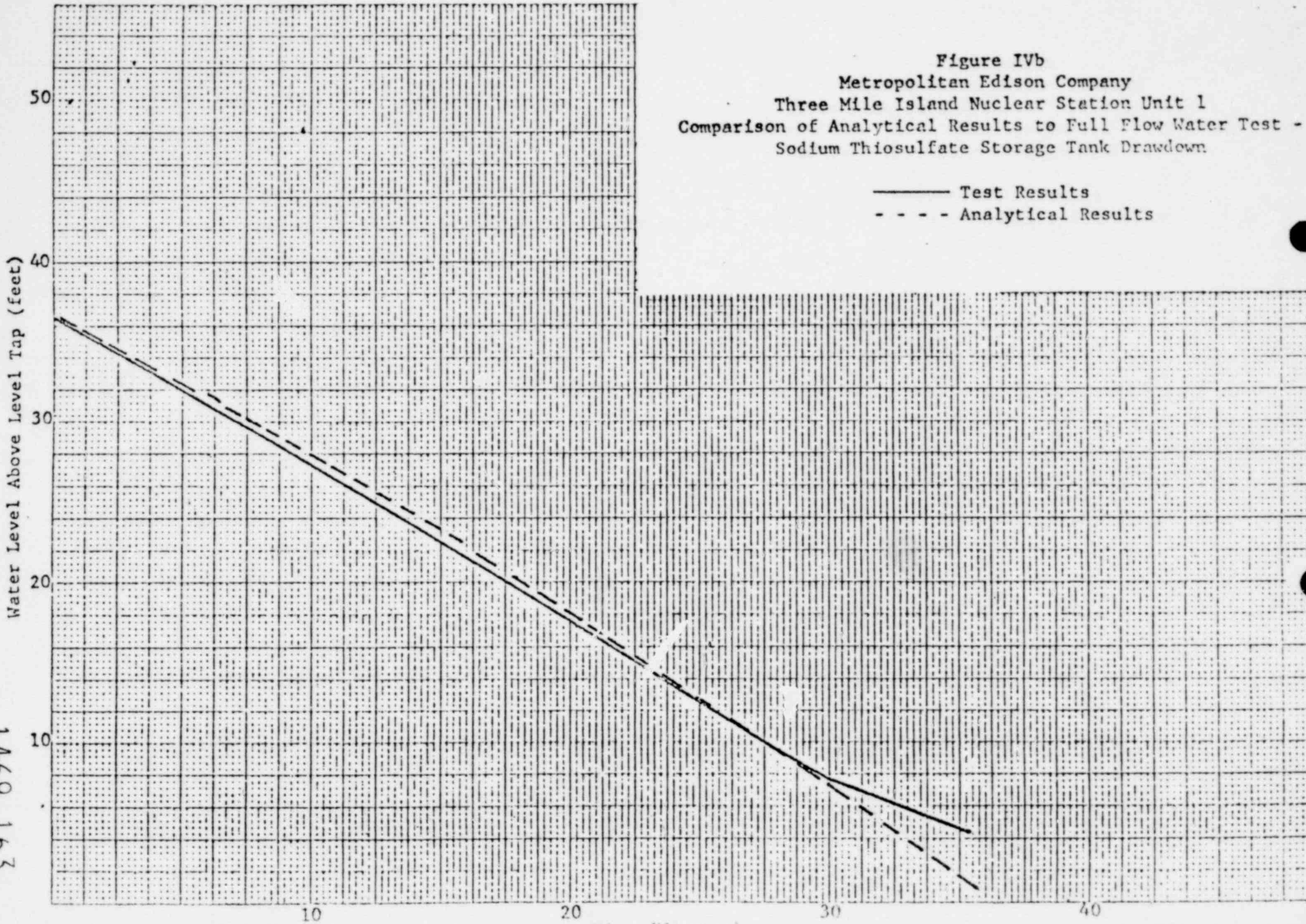
Figure IVb
Metropolitan Edison Company
Three Mile Island Nuclear Station Unit 1
Comparison of Analytical Results to Full Flow Water Test -
Sodium Thiosulfate Storage Tank Drawdown
——— Test Results
- - - - Analytical Results
Water Level Above Level Tap (feet)
50
40
30
20
10
10
20
30
40

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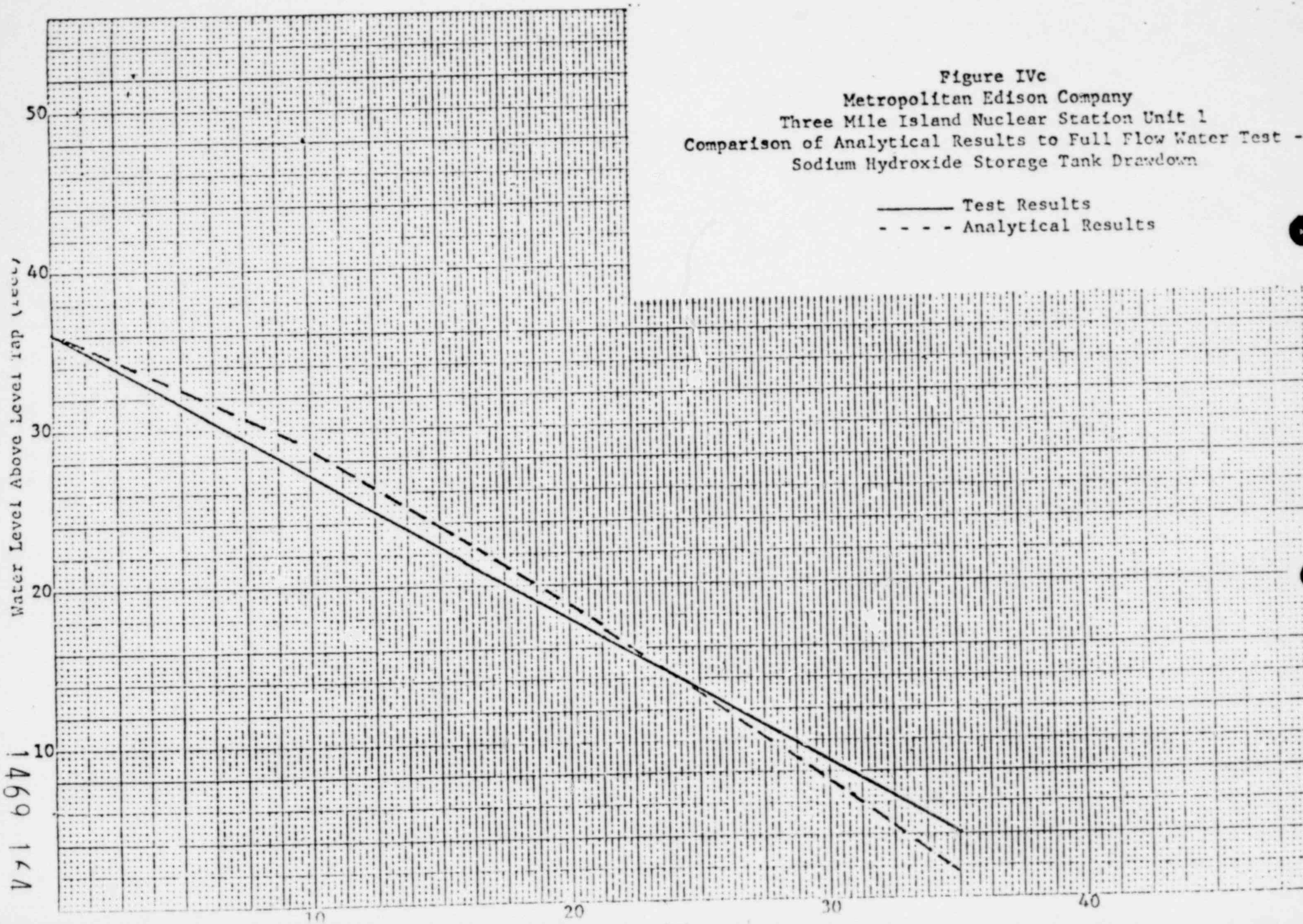

Figure IVc
Metropolitan Edison Company
Three Mile Island Nuclear Station Unit 1
Comparison of Analytical Results to Full Flow Water Test - Sodium Hydroxide Storage Tank Drawdown

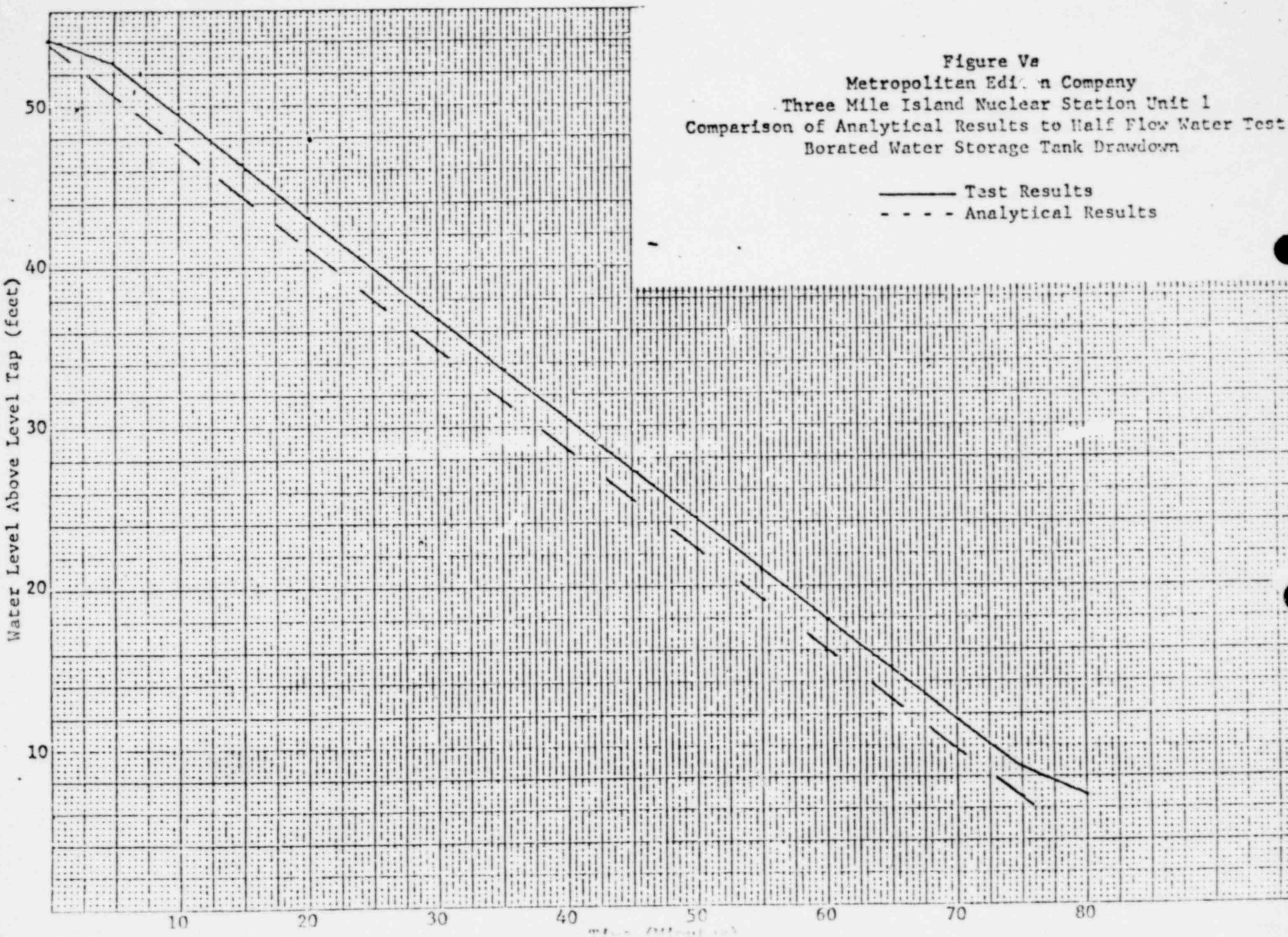
Figure Va
Metropolitan Edi. n Company
Three Mile Island Nuclear Station Unit 1
Comparison of Analytical Results to Half Flow Water Test
Borated Water Storage Tank Drawdown
Test Results
Analytical Results
Water Level Above Level Tap (feet)
50
40
30
20
10
10
20
30
40
50
60
70
80

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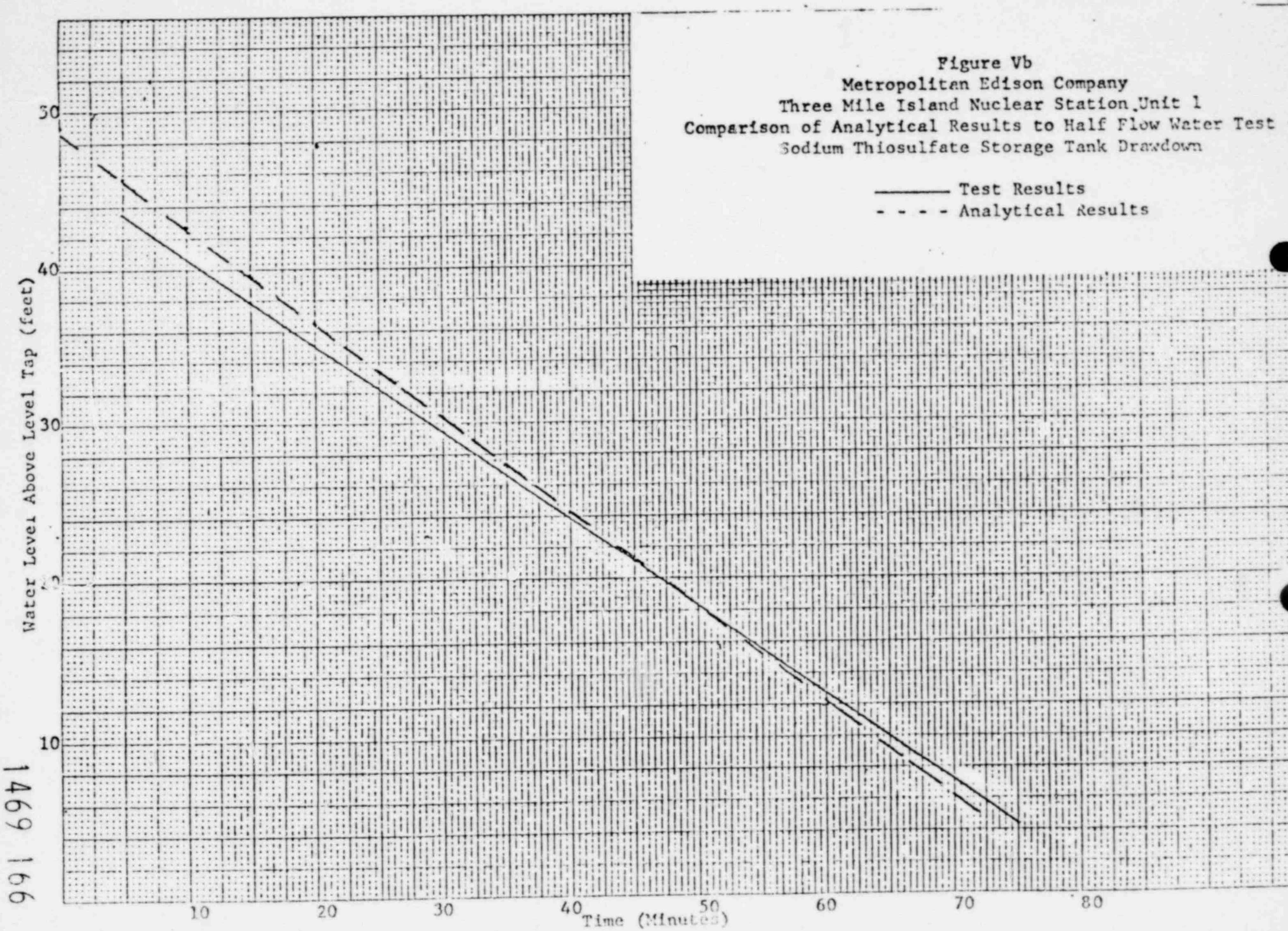
Figure Vb
Metropolitan Edison Company
Three Mile Island Nuclear Station, Unit 1
Comparison of Analytical Results to Half Flow Water Test -
Sodium Thiosulfate Storage Tank Drawdown



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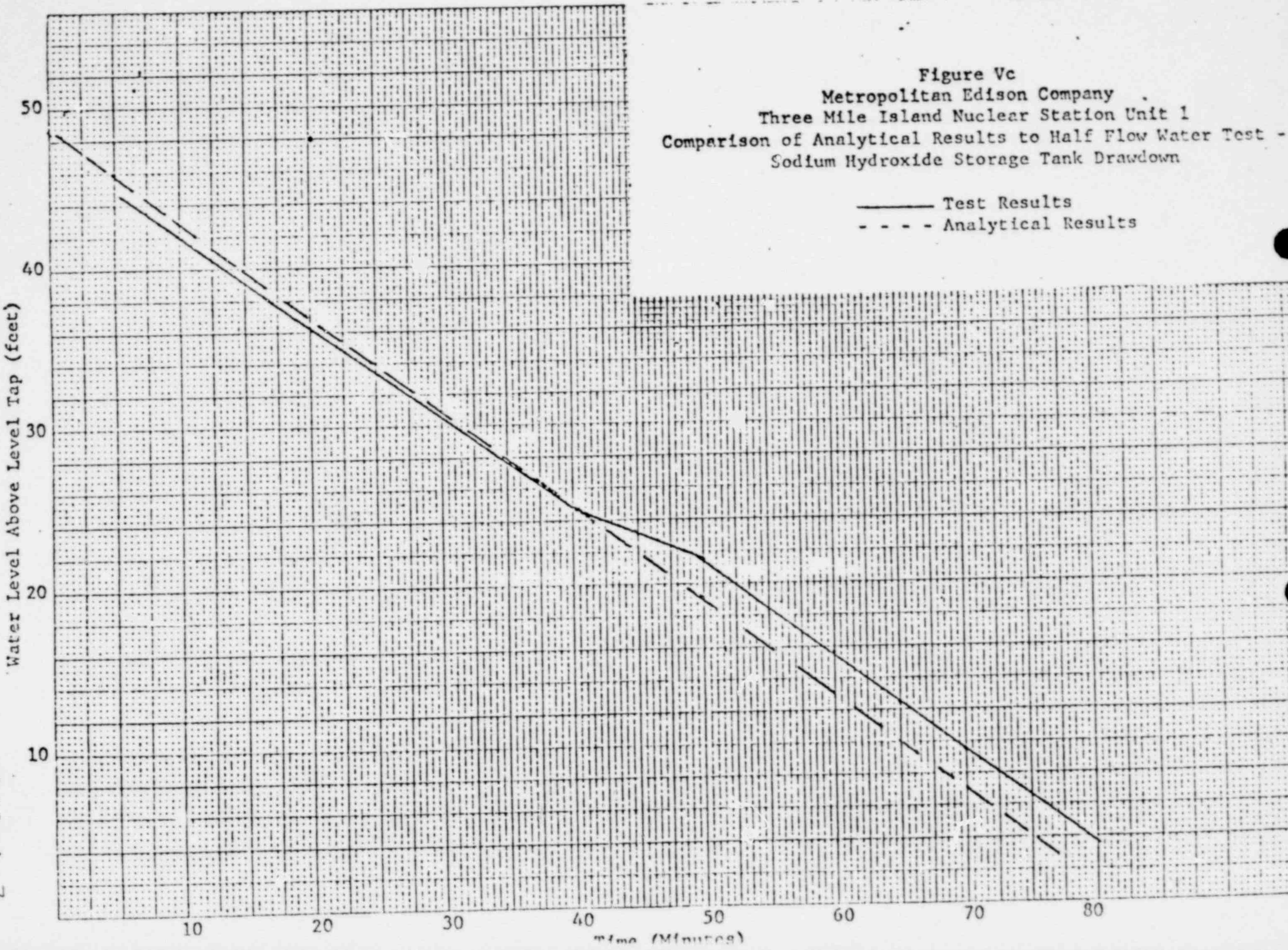

Figure Vc
Metropolitan Edison Company
Three Mile Island Nuclear Station Unit 1
Comparison of Analytical Results to Half Flow Water Test - Sodium Hydroxide Storage Tank Drawdown

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TABLE I

Metropolitan Edison Company
Three Mile Island Nuclear Station Unit I
Borated Water Storage Tank Drawdown Transient Analysis
Comparison of Analytical Results to Full Flow Water Test

Time	BSWT				NaOH				NaThio			
	Observed		Calculated		Observed		Calculated		Observed		Calculated	
(Minutes)	Level*	Drop	Level*	Drop	Level*	Drop	Level*	Drop	Level*	Drop	Level*	Drop
0	45.2	-	45.20	-	36.0	-	36.0	-	36.47	-	36.47	-
5	39.4	5.80	38.49	6.71	32.16	3.84	32.98	3.02	32.34	4.13	32.59	3.88
10	32.8	6.60	31.86	6.63	27.30	4.86	28.77	4.21	27.49	4.85	28.13	4.46
15	26.3	6.50	25.27	6.59	22.33	4.97	23.94	4.83	22.57	4.92	23.26	4.87
20	19.88	6.42	18.71	6.56	17.46	4.87	18.71	5.23	17.65	4.92	18.09	5.17
25	13.5[illegible]	6.37	12.17	6.54	12.60	4.86	13.18	5.53	12.70	4.95	12.69	5.40
30	7.10	6.41	5.65	6.52	7.60	5.00	7.44	5.74	7.73	4.97	7.09	5.60
35	3.19	3.91	-0.86	6.51	4.24	3.30	1.53	5.91	4.48	3.25	1.34	5.75

*Levels are relative to tank level tap.

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TABLE II

Metropolitan Edison Company
Three Mile Island Nuclear Station Unit I
Borated Water Storage Tank Drawdown Transient Analysis
Comparison of Analytical Results to Half Flow Water Test

Time	BSWT				NaOH				NaThio			
	Observed		Calculated		Observed		Calculated		Observed		Calculated	
(Minutes)	Level*	Drop	Level*	Drop	Level*	Drop	Level*	Drop	Level*	Drop	Level*	Drop
0	54.08	-	54.08	-	48.5	-	48.50	-	49.0	-	49.00	-
5	52.58	1.50	50.82	3.26	43.0	5.50	46.00	2.50	43.5	5.50	45.94	3.06
10	49.58	3.00	47.57	3.25	42.0	1.00	43.26	2.74	41.0	2.50	42.84	3.10
15	46.29	3.29	44.33	3.24	39.4	2.60	40.36	2.90	37.9	3.10	39.73	3.11
20	43.06	3.23	41.09	3.24	37.0	2.40	37.37	2.99	35.2	2.70	36.60	3.13
25	39.92	3.14	37.91	3.18	34.1	2.90	34.38	2.99	32.4	2.80	33.51	3.09
30	36.83	3.09	34.73	3.18	31.0	3.10	31.35	3.03	29.4	3.00	30.40	3.11
35	33.74	3.09	31.57	3.16	28.0	3.00	28.30	3.05	26.3	3.10	27.31	3.09
40	30.38	3.36	28.45	3.12	24.8	3.20	25.26	3.04	23.2	3.10	24.24	3.07
45	27.31	3.07	25.33	3.12	23.4	1.40	22.19	3.07	20.2	3.00	21.18	3.06
50	[illegible] 27	3.04	22.21	3.12	21.6	1.80	19.14	3.05	17.9	2.30	18.09	3.09
55	[illegible]	3.31	19.09	3.12	18.7	2.90	16.05	3.09	15.5	2.40	15.01	3.08
60	17.9[illegible]	3.00	15.98	3.11	15.7	3.00	12.96	3.09	13.9	1.60	11.95	3.06
65	[illegible]	2.99	12.92	3.06	12.25	3.45	9.91	3.05	10.8	3.10	8.92	3.03
70	11.64	3.33	9.86	3.06	9.5	2.75	6.86	3.05	7.85	2.95	5.89	3.03
75	8.67	2.97	6.80	3.06	6.2	3.30	3.83	3.03	4.45	3.40	2.83	3.06

* Levels are relative to tank level tap.

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TABLE A-I

Metropolitan Edison Company
Three Mile Island Nuclear Station - Unit 1
BWST Drawdown Transient Analysis
Branch Data

No.	From Junction	To Junction	Pipe ID (Inch)	Straight Pipe (Feet)	90° Elbow	45° Elbow	Gate Valve	Check Valve	Tee Run	Tee Branch	Total Equivalent Diameters (L/D)	Total Equivalent Length (Feet)	Elevation Change (Feet)
1	2	22	23.25	98	2	2	0	0	0	0	72	237.50	-12.36
2	22	3	13.25	16-1/2	0	0	0	0	0	0	24*	43.00	0.0
3	3	4	13.25	8	2	1	1	1	0	1	264	299.50	-13.25
4	4	5	13.13	5	2	0	0	0	0	0	40	[illegible].77	- 6.75
5	5	6	13.13	44	5	1	1	0	0	1	189	250.80	-11.42
6	3	8	13.25	10-1/2	2	1	1	1	1	1	284	324.08	-13.25
7	8	9	13.13	14	1	0	0	0	0	0	20	35.88	- 7.25
8	9	10	13.13	40-1/2	4	1	1	0	0	1	169	225.41	-10.92
9	18	19	4.026	153-1/2	13	5	0	0	0	0	340	267.57	- 9.0
10	19	4	4.026	22-1/4	7	0	3	1	5	1	474	181.28	-16.75
11	19	8	4.026	26-3/4	6	1	3	1	3	2	490	191.14	-16.75
12	5	23	13.13	33-1/2	3	1	0	0	2	1	176	226.07	-10.50
13	23	15	10.02	4	1	0	1	1	1	1	248	211.08	1.5
14	15	16	10.02	20-1/2	6	0	0	0	0	0	120	120.70	- 3.5
15	9	24	13.13	49-1/2	5	0	0	0	1	2	240	312.10	-10.0
16	24	12	10.02	4	1	0	1	1	1	1	248	211.08	1.5
17	12	13	10.02	21-1/2	6	0	0	0	0	0	120	121.70	- 3.5
18	20	21	4.026	149-1/2	12	4	0	0	0	0	304	251.49	- 7.75
19	21	12	4.026	50-1/4	8	0	3	1	3	1	454	202.57	-33.75
20	21	15	4.026	60-1/6	8	0	3	1	2	2	494	225.91	-33.75

* Note - The effect of a 24"-14" reducer was included.

POOR ORIGINAL

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REFERENCES

1. Keenan and Keyes, Thermodynamic Properties of Steam, John Wiley and Sons, Inc. (1936).

2. ASME Steam Tables, 1967

3. Vennard, J.K., Elementary Fluid Mechanics, John Wiley & Sons, Inc. (1961).

4. Flow of Fluids Through Valves, Fittings, and Pipe, Crane Technical Paper No. 410.

5. Letter from J. F. Fritzen, Met Ed, to R. F. Ely, Jr., GAI dated 3 June 1975, Number GEL 1115.

Attachment 2
Metropolitan Edison Company
Three Mile Island Nuclear Station Unit 1
Decay Heat and Reactor Building Spray Systems
Maximum Flow and Velocities in Suction Lines

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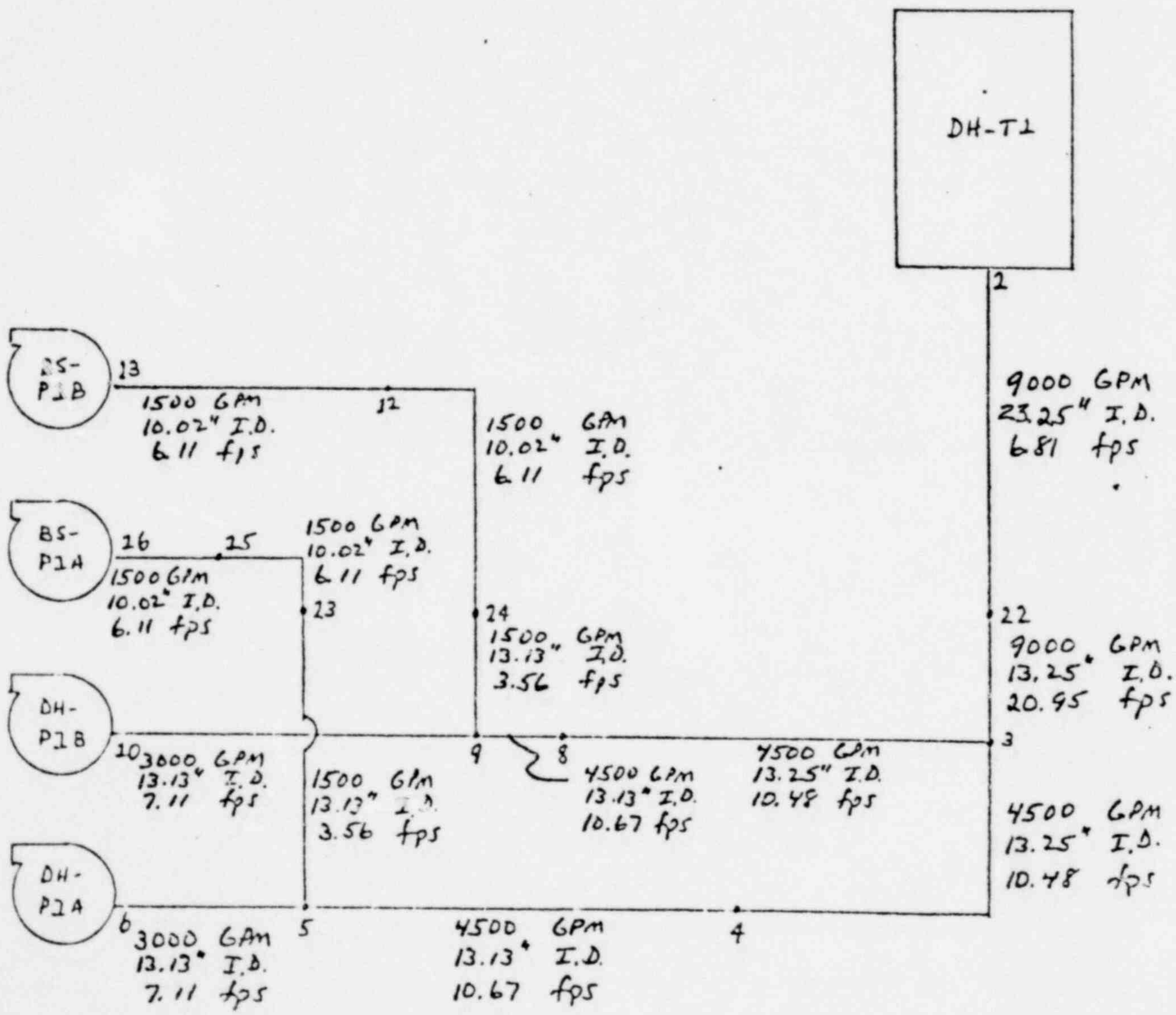

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