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1800 M STREET, N. W.
WASHINGTON, D. C. 20036

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JOHN H. SHARON
EDWARD B. CROSLAND
COUNSEL

August 7, 1979

George Frampton, Esquire
NRC/TMI Special Inquiry Group
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear George:

Enclosed are the following documents in response to Item 3 of the NRC/TMI Special Inquiry Group's request of July 12, 1979:

Requested Documents and/or Information	Identification Number of Response
Information relating to the "hydrogen bubble" problem (Items 3.a through d, f)	G/712-3.a-f (Memorandum of J. P. Moore, Jr.)
Bubble book (Item 3.e)	G/712-3.e-1
Other documents reflecting hydrogen bubble data and analysis (Item 3.e)	G/712-3.e-2 to 65

Copy to Mr Pickleshine
Del. 8/13

Sincerely,

Mat

Matias F. Travieso-Diaz

MFTD:ry

Enclosures

~~8001200089~~

8001270013 P

G/712-3.a-f

Inter-Office Memorandum

GPU Service

ate August 7, 1979

Subject NRC/TMI Special Inquiry - Item 3 of July 12, 1979, Request

To Mr. J. E. Guerin

Location Parsippany

This memorandum responds to Item 3 of the July 12, 1979, request by the Nuclear Regulatory Commission's TMI Special Inquiry Group. Item 3 asks for certain information concerning the "hydrogen bubble" problem from March 28, until April 2, 1979. The specific questions raised and the answers to these questions are as follows.

> Item 3.a Who were the principal people within the company ... who considered and evaluated this problem?

Response: The principal people who considered and evaluated the "hydrogen bubble" problem were T. G. Broughton and I at the TMI site, as well as the GPUSC personnel stationed in the Control Room during the post-accident period. We received analytical support from John Daniel at GPUSC headquarters in Parsippany, New Jersey.

> Item 3.b Who were the principal people from outside the company ... whose advice or assistance was sought?

Response: The main outside parties whose advice or assistance was sought with respect to this problem were William W. Lowe of Pickard, Lowe & Garrick, Inc. and D. A. Nitti of Babcock & Wilcox.

> Item 3.c What plant data were acquired or gathered together in an effort to address the problem of the bubble, and how was it acquired?

Response: The primary coolant parameters collected between March 28, and April 2, 1979, were used to calculate the size and removal rate of the hydrogen bubble. These parameters were obtained from computer print-outs and control meter readings by GPUSC personnel stationed in the control room; the data thus collected have been gathered in what is referred to as the "bubble book".

> Item 3.d What analyses were performed and what determinations were made concerning the bubble (including its size, dangerousness, etc.) and approximately when and by whom were they made?

Response: I derived the equation for calculating the bubble size at about 3:00 a.m. on March 30, 1979. The equation was immediately used to calculate the bubble size from plant data for 1:00 p.m. of March 29, 1979. Frequent bubble size computations were made thereafter through April 3, 1979, when it was concluded that the bubble had been removed. We also performed analyses to determine the hydrogen removal rate, including analysis of parameters (such as pressurizer spray flow rate and letdown flow rate to the makeup tank) which could affect the hydrogen removal rate.

In performing our analyses, our primary concern about the hydrogen bubble was that it could prevent natural circulation of the reactor coolant in the event we could not operate a reactor coolant pump, and it could impede depressurizing the reactor coolant system by depressing the water level. Therefore, our efforts were directed towards removing the bubble as soon as possible. We were not concerned about a hydrogen detonation in the reactor coolant system because we determined that there was no oxygen available to support it. We concluded that there was no oxygen to support an explosion for the following reasons:

(1) There was an overpressure of hydrogen on the reactor coolant system prior to the incident. This ensured that any oxygen produced by radiolytic decomposition of water or added with the makeup water subsequent to the metal-coolant water reaction would be rapidly recombined with hydrogen to form water.

(2) When the metal-water reaction took place in the core leading to the formation of large amounts of hydrogen, the associated oxygen was consumed in oxydizing the metal.

Our evaluation and analysis were confirmed by independent analysis by Babcock and Wilcox on April 1, 1979, and subsequently by others.

Item 3.e Provide any documents reflecting the data mentioned in (c) and (d), above, including the "bubble book".

Response: A copy of the "bubble book" is attached as document G/712-3.e-1. It contains the bubble size calculations and related data. Also attached are copies of correspondence concerning the removal of hydrogen and the problems associated with the hydrogen bubble. These are identified as document nos. G/712-3.e-2 to 65.

Item 3.f Provide any report that has been prepared or is acquired concerning the bubble and/or the company's evaluation of the bubble.

Response: The reactor coolant system data are being analyzed to gain a better understanding of the hydrogen removal process. A report will be issued as a result of this effort; the report will be forwarded to the NRC/TMI Special Inquiry Group upon its completion.

JP Moore Jr

J. P. Moore

JPM:ry

MAY 16 1979

4-19-79
J Moore
SHEET 1

G/712-3.e-1

DATE	TIME	CALC BUBBLE w/o TEMP COMP	CALC BUBBLE w/ TEMP COMP	Absolute Error
3-29-79	~1300	1624 FT³	1839 FT³	± 71%
3-30-79	0625	1055	828	± 600%
—	0730	1136	893	± 84%
—	1240	393	308	± 183%
—	1445	798	839	± 195%
—	1630	512	366	± 772%
—	1745	328	225	± 224%
—	1907	2298	1806	± 184%
3-31-79	0630	1098	850	
	1032	1093	860	
	1351	—	879	
	1619		621	
	1735		742	
	1925		901	
	2030		765	
	2139		999	
	2245		894	
	2355		717	
04-01-79	0107		848	NOT VALID DATA
	0200		818	
	0321		800	
	0403		833	
	0455		606	
	0620		710	
	0731		564	
	0825		535	

4-19-79
JPMoore
SHEET 2

DATE	TIME		CALC BUBBLE W/TEMP COMP	ABSOLUTE ERROR
04-01-79	0946		501	
	1044		627	
	1211		486	
	1305		343	
	1456		224	
	1510		347	
	1645		224	
	1710		635	
	1758		223	
	1910		438	
	2059		199	
04-02-79	0020		215	
	0128		543	INVALID - VENTING
	0215		211	
	0315		205	
	0415		253	
	0500		130	
	0550		203	
	0650		152	
	0740		47	
	0850		60	
	1208		208	
	1225		195	
	1315		174	
	1600		47.5	
	1803		149	
	2025		221.5	

4-19-79
JR Moore
Sheet 3

DATE	TIME		CALC BUBBLE W/TEMP COMP	
04-03-79	0453		118	
	0537		89	
	0620		163	
	1525		-14.0	
	1604		81.5	

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

DICK W
or
GARY BROUGHTO

To
[illegible] DH ROY

From
WN BISHOP

BDS 660.3

Cust.

File No.
or Ref.

Subj.
COMPOSITION OF GAS BUBBLE

Date
APRIL 1, 1979

This letter to cover one customer and one subject only.

After review of the postulated sequence of events on March 28, we conclude that there is no significant amount of oxygen in the bubble. At the time of reactor trip a hydrogen over pressure was present in the primary system. This hydrogen over pressure would have remained until boiling occurred about 3 hours after the trip. During the period of boiling some small generation of oxygen probably occurred. Shortly thereafter, a metal-water reaction began, generating large amounts of hydrogen. The metal-water reaction produced most of the gas in the bubble. After the metal-water was quenched, the hydrogen in the bubble inhibited oxygen generation. Thus only during the short time of boiling was oxygen generated.

If we make the conservative assumption of boiling for 15 hours we calculate a oxygen production of 1100 SCF by radiolysis. In addition, there is a small contribution from air dissolved in the BWST. This BWST contribution is 198 SCF. The total oxygen, 1298 SCF, is 27 cubic feet at RCS pressure and temperature. If this small amount of oxygen had been present on the 28th, it is likely that radiolytic recombination would have removed the oxygen.

WNB:jws

DH

4/1/79

DATE ~~4~~ 4/8/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 0120 AM PM

DATA TAKEN BY: BSW

34 RC PRESSURE ~~(398)~~ 399 RCS TEMP (394)

30 P_1 = 629.1 PSIG = ______ PSIA T_1 = 281.0 °F

27 P_2 = 693.9 PSIG = ______ PSIA T_2 = 280.8 °F

25 ΔP = 64.8 PSI

29

27 PRESSURIZER LEVEL (1682) PRESSURIZER TEMP (~~405~~ 359)

26

27 L_1 = 216.1 INCHES T_1 = 504.0 °F

32 L_2 = 213.3 INCHES T_2 = 514.9 °F

26 ΔL = 2.8 INCHES

31

(35 MAKEUP TANK LEVEL (347) MAKEUP TANK TEMP 161 (CONTROL BOARD METER)

L_1 = 80.2 INCHES T_1 = 94.5 °F

02 L_2 = 81.6 INCHES T_2 = 94.0 °F

93 ΔL = − 1.4 INCHES

88

98

05 $\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 2.8 × 2.515 = 7.04 FT^3

3 $\Delta V_{MUT} = \Delta L \times 4.244 =$ −1.4 × 4.244 = −5.94 FT^3

0 ΔV_{TOTAL} = 1.1 FT^3

96

94 $V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(\quad \times \quad)}{(\quad)}$ = ______ FT^3 @ P_1

84

91

03 $V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) =$ 8.85 FT^3 @ 875 psia.

(94 86

90 90 94

91 90

65

DATE ~~4~~ 4/8/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 0120 AM PM

DATA TAKEN BY: RSW

34 RC PRESSURE 379 (~~398~~) RCS TEMP (394)

30 P_1 = 629.1 PSIG = ______ PSIA T_1 = 241.0 °F

27 P_2 = 693.9 PSIG = ______ PSIA T_2 = 280.8 °F

25 ΔP = 64.8 PSI

29

27 PRESSURIZER LEVEL (1682) PRESSURIZER TEMP (359 ~~405~~)

26 L_1 = 216.1 INCHES T_1 = 504.0 °F

27 L_2 = 213.3 INCHES T_2 = 514.9 °F

32 ΔL = 2.8 INCHES

26

31 161

35 MAKEUP TANK LEVEL (347) MAKEUP TANK TEMP (CONTROL BOARD METER)

L_1 = 90.2 INCHES T_1 = 94.5 °F

02 L_2 = 91.6 INCHES T_2 = 94.0 °F

93 ΔL = − 1.4 INCHES

88

93

05 $\Delta V_{PZR} = \Delta L \cdot 2.515$ = 2.8 × 2.515 = 7.04 FT³

3 $\Delta V_{MUT} = \Delta L \times 4.244$ = −1.4 × 4.244 = −5.94 FT³

0 ΔV_{TOTAL} = 1.1 FT³

96

456 94 $V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(694 \times 1.1)}{(64.8)}$ = 11.78 FT³ @ P_1

84

91

03 $V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right)$ = 8.5 FT³ @ 875 PSIA.

98 86

90 90 94

91 90

85

RCS Bubble Calc. 4/8/79
0610
RSW

63 RCS P_1 556.5 T_1 280.2
65 P_2 605.5 T_2 280.0
58 ΔP 49.0 ΔT $-.2$
54
52 PZR L_1 229.5 T_1 492.8
47 L_2 228.4 T_2 501.5
43 ΔL 1.1
54
60 MUT L_1 81.6 T_1 95.5
62 L_2 80.2 T_2 95.3
63 ΔL 1.4
59
56 $\Delta L' = \Delta L + \Delta T(2''/{}^\circ) = 1.1 + (-.2)(2) = .7$
55 $\Delta V_{PZR} = \Delta L' \times \frac{.0204}{.0173} \times 3.2\ \text{ft}^3/\text{in}$
56 $= .7 \times 1.179 \times 3.2 = 2.18\ \text{ft}^3$
58 $\Delta V_{MUT} = \Delta L \times 4.244 = 1.4 \times 4.244 = 5.94$
84 8.12
54

01	97
11	11
04	14
6	16
16	18
1	10
91	06
96	00
10	99
06	02
3	04

$V_1 = \frac{(605.5)(8.12)}{49} = 100.4\ \text{ft}^3$

$-57.$
$89.$

4/8/79 0345

Bubble calculation data

[illegible]	P_1
80	663
46	1
38	94
36	94
45	95
56	90
60	85
56	83
53	90
49	94
44	04
51	13
2	05
52	93
45	03
41	06

RCS P 597.6 Temp 281.3
649.0 Δ 51.4 280.7

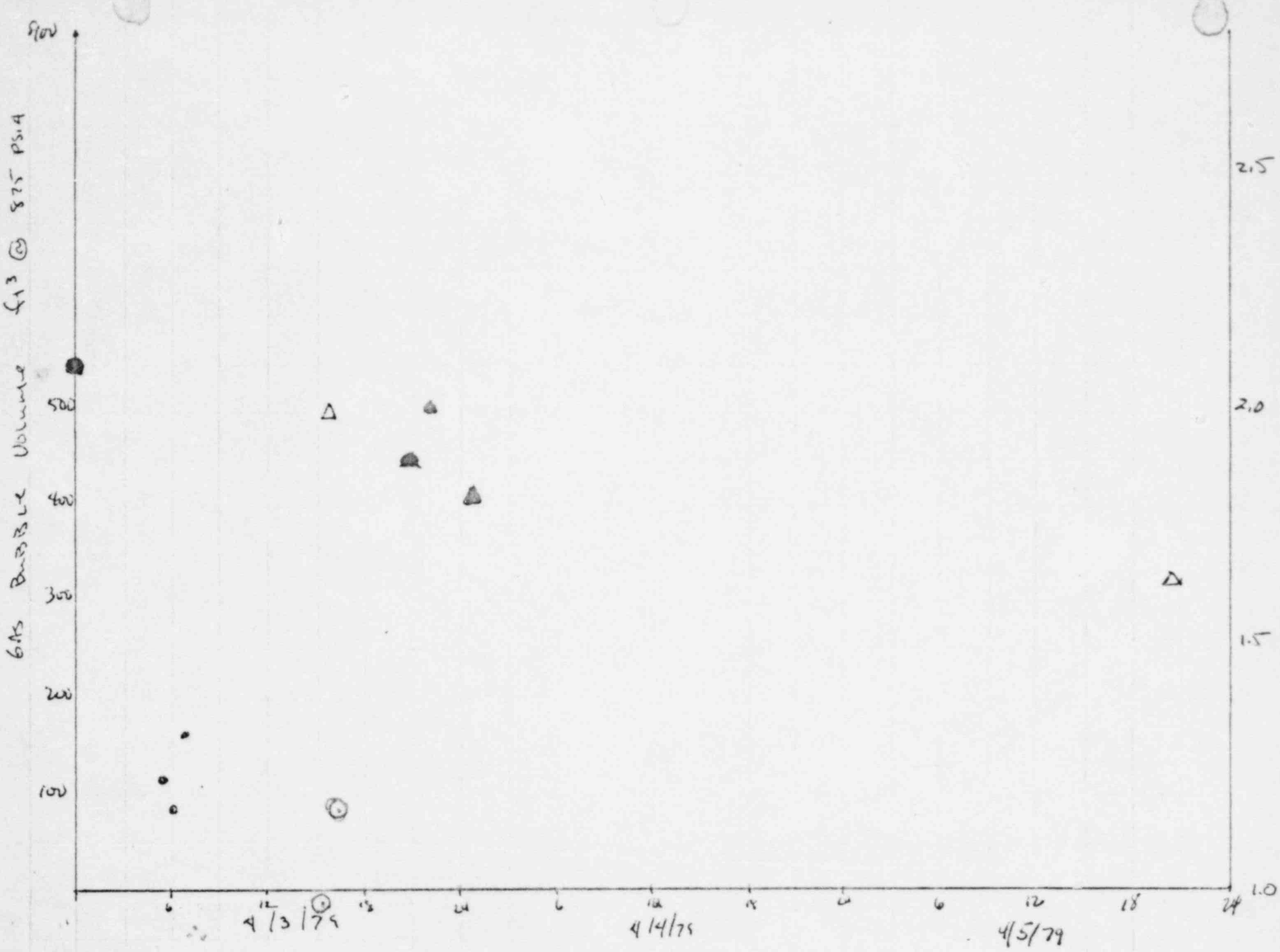
PZR L 207.7 Temp 500.0
207.8 508.4
Δ 1.9

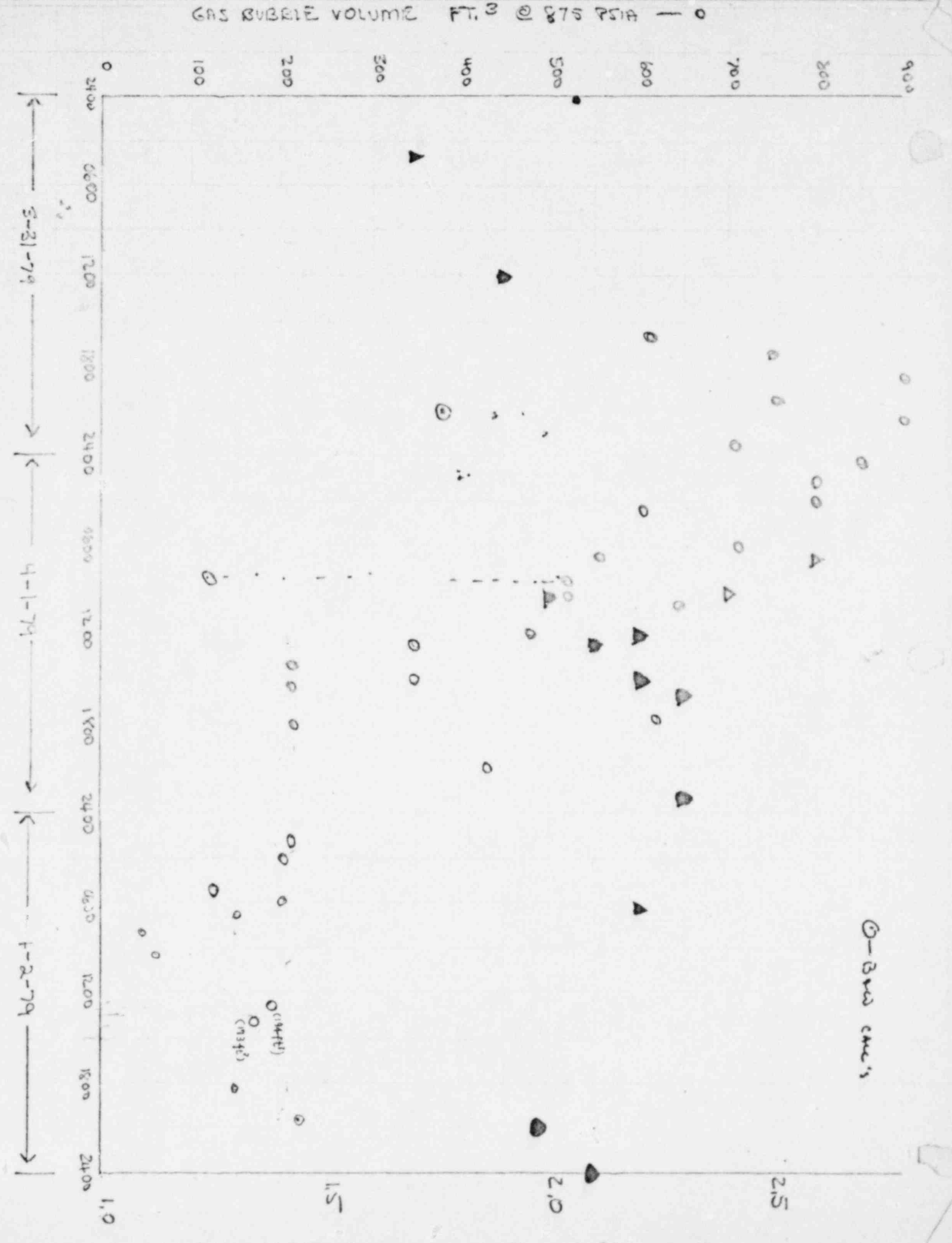
MUT L 94.6 Temp 93.8
95.4 94.0
Δ .8

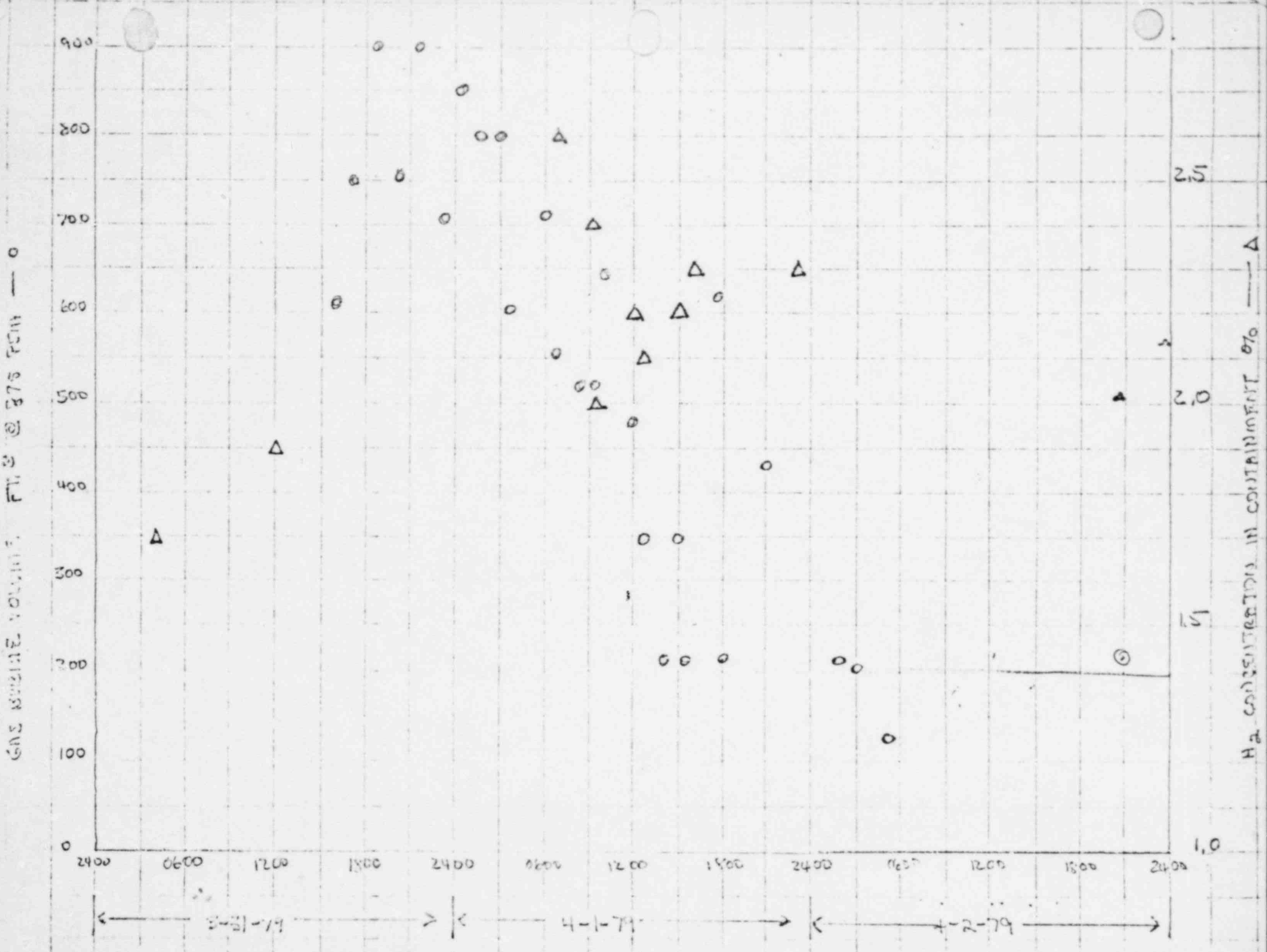
PZR ΔV = 1.9 × 2.515 = 4.78
MUT ΔV = .8 × 4.244 = 3.39
8.17

$$V_1 = \frac{649\,(8.17)}{51.4} = 103.2$$

− 166.6 ft³
+ .6 ft³


GAS BUBBLE VOLUME ft³ @ 875 PSIA
600
500
400
300
200
100
2.5
2.0
1.5
1.0
6
12
18
24
6
12
18
24
6
12
18
24
4/3/79
4/4/79
4/5/79


GAS BUBBLE VOLUME FT.^{3} @ 875 PSIA — o
0
100
200
300
400
500
600
700
800
900
H$_2$ CONCENTRATION IN CONTAINMENT % — Δ
1.0
1.5
2.0
2.5
2400
0600
1200
1800
2400
0600
1200
1800
2400
0600
1200
1800
2400
3-31-79
4-1-79
4-2-79
(1444 ft^3)
(1334 ft^3)
⊙ - B&W calc's


GAS BUBBLE VOLUME FT³ @ 875 PSIA — o
0
100
200
300
400
500
600
700
800
900
H₂ CONCENTRATION IN CONTAINMENT % — Δ
1.0
1.5
2.0
2.5
2400
0600
1200
1800
2400
0600
1200
1800
2400
0600
1200
1800
2400
3-31-79
4-1-79
4-2-79

$\frac{1063}{473-1063} = -11.8$ BUBBLE SIZE CALC,

② $3.178 \left[\frac{.10172}{.0219}(202.5) - \frac{.10172}{.02159}(201.9) \right] = -5.738$

③ $4.128 \; \frac{.0172}{.016064} \left[53.1 - 54.3 \right] = -5.3$

④ $6.166 \times 10^5 (9 \times 10^{-6})(.3) = 1.665$

⑤ $6.166 \times 10^5 (-10^{-7})(90) = -5.5$

⑥ $6.166 \times 10^5 (5.839 \times 10^{-7})(90) = 32.4$

$V = -11.8 \left[-5.738 + (-5.3) - 1.665 - (-5.5) + 32.4 \right]$

Volume − 297.4

Check of 4/2/79 7:40 data

4/3/79 0200

One check of 4/2/79 6:50 data

1. $$\frac{1063}{98}\left[\left\{3.178\left[\frac{.0172}{.02198}(202.9) - \frac{.0172}{.02159}(201.7)\right]\right\} +\right.$$

158.775 − 160.68

−6.0541

$$4.128\left(\frac{.0172}{.016052}\right)(46.1 - 49.8) - \cancel{6.166\times10^{5}[9\times10^{-6}}($$

−16.36

$$-6.166\times10^{5}\left[9\times10^{-6}(278.5 - 278.8)\right] =$$

−1.665

$$-6.166\times10^{5}(-10^{-7})(1063 - 965)$$

−6.04

$$+6.166\times10^{5}(5.839\times10^{-7})(1063 - 965) =$$

35.528

$$\frac{1063}{98}\left[-6.0541 - 16.36 + 1.665 + 6.04 + 35.528\right]$$

= 225.8 ? Bubble gone

4/3/79 0200

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

Dick Wilson
NRC

BCS 653-5

To: DICK WILSON, MET ED OPERATIONS

From: D. W. BERGER, MANAGER, B&W OPERATIONS

Cust.

File No. or Ref.

Subj. REACTOR BUBBLE SIZE CALCULATION PACKAGE

Date: APRIL 1, 1979

0153

This letter to cover one customer and one subject only.

ATTACHED ARE 12 PAGES OF THE CALCULATIONS FOR THE REACTOR BUBBLE.

OUR CALCULATIONS FROM DATA POINT 4 IS THAT THE BUBBLE HAS DISAPPEARED.

THIS IS SUBSTANTIATED BY NOISE MONITORING ON THE "B" LOOP PRESSURE TRANSMITTER.

STATISTICAL ANALYSIS LATER

D W Berger

D. W. BERGER

DWB/CMW
ATTACHMENTS

NOTE: ALSO ATTACHED IS "REVIEW OF SODIUM SULFITE ADDITION ON RCS SYSTEM," DATED APRIL 1, 1979, 1 PAGE; AND 2) "COMPOSITION OF GAS BUBBLE," DATED APRIL 1, 1979, 1 PAGE.

LEE ROGERS - TRANSMIT THIS PACKAGE TO G. BROUGHTON

4/1/79

Volume of Bubble Calculation

$$V_{Bubble} = \frac{P_2}{P_1 - P_2}\left[C_{PZR}\left(\frac{V_{f_2}^{RCS}}{V_{f_2}^{PZR}} L_2^{PZR} - \frac{V_{f_1}^{RCS}}{V_{f_1}^{PZR}} L_1^{PZR}\right) + C_{MUT}\left(\frac{V_f^{RCS}}{V_f^{MUT}}\right)\left(L_2^{MUT} - L_1^{MUT}\right) - M_{RCS}\left(\frac{\partial V^{RCS}}{\partial T^{RCS}}\right)\left(T_2^{RCS} - T_1^{RCS}\right) - M_{RCS}\left(\frac{\partial V^{RCS}}{\partial P^{RCS}}\right)\left(P_2 - P_1\right) + M_{RCS}\left(\frac{\partial S}{\partial P}\right)\left(P_2 - P_1\right)\right]$$

P_2 = RC Sys Press After Change
P_1 = RC Sys Press Before Change
C_{PZR} = Level to Volume Conversion for Pzr. = 3.178 ft³/in
C_{MUT} = " " " " " MUT = 4.128 ft³/in
V_f^{RCS} = Specific Volume of water at RCS temp, superheated steam tables
$V_{f_2}^{PZR}$ = " " " " " Pzr. " after change, saturated steam tables
$V_{f_1}^{PZR}$ = " " " " " " " before ", " "
V_f^{MUT} = " " " " " MUT " , saturated steam tables
L_2^{PZR} = Level in pressurizer after change, inches
L_1^{PZR} = " " " before ", "
L_2^{MUT} = " " makeup tank after change, inches
L_1^{MUT} = " " " " " before ", "
$\frac{\partial V^{RCS}}{\partial T^{RCS}}$ = change in RCS specific vol per °F = 9×10^{-5} ft³/lbm-°F
$\frac{\partial V^{RCS}}{\partial P^{RCS}}$ = Change in RCS specific volume per pound pressure = -10^{-7} ft³/lbm-psi
$\frac{\partial S}{\partial P}$ = Change in solubility of H_2 per pound pressure = 5.839×10^{-7} ft³/lbm-psi

M_{RCS} = Mass of RCS = 5.166×10^{5} lbs

Calc of Volume of Bubble from Data @ 1510 - 1650 hr, 4/1/79

	Time t_1	Time t_2
RCS Pressure	955 psia	1065 psia
Temp	280.9°F	281.3°F
PZR Level	216.8"	208.3"
Temp	545.9°F	558.2°F
MUT Level	53.3"	50.6"
Temp	75°F	74°F

① $\frac{P_2}{P_1-P_2} = \frac{1055}{955-1065} = -\frac{1065}{110} = -9.682$ ✓

② $c_{PZR}\left(\frac{v_{f_2}^{RCS}}{v_{f_2}^{PZR}} L_2^{PZR} - \frac{v_{f_1}^{RCS}}{v_{f_1}^{PZR}} L_1^{PZR}\right) = 3.178\left(\frac{.01720}{.02202}(208.3) - \frac{.01721}{.02163}(216.8)\right) = -31.$

③ $c_{MUT}\left(\frac{v_f^{RCS}}{v_f^{MUT}}\right)\left(L_2^{MUT} - L_1^{MUT}\right) = 4.128\left(\frac{.01721}{.01606}\right)\left(50.6 - 53.3\right) = -11.944$ ✓

④ $M_{RCS}\left(\frac{\partial v^{RCS}}{\partial T^{RCS}}\right)\left(T_2^{RCS} - T_1^{RCS}\right) = (6.166\times10^5)(9\times10^{-6})(281.3 - 280.9) = 2.220$ ✓

⑤ $m_{RCS}\left(\frac{\partial v^{RCS}}{\partial P^{RCS}}\right)\left(P_2 - P_1\right) = (6.166\times10^5)(-10^{-7})(1065 - 955) = -6.783$ ✓

⑥ $m_{RCS}\left(\frac{\partial S}{\partial P}\right)\left(P_2 - P_1\right) = (6.166\times10^5)(5.839\times10^{-7})(1065 - 955) = 39.604$ ✓

V = ① [② + ③ − ④ − ⑤ + ⑥]

$V = (-9.682)\left[(-31.122) + (-11.944) - (2.220) - (-6.783) + (39.604)\right]$

$V = (-9.682)\left[-31.122 - 11.944 - 2.220 + 6.783 + 39.604\right]$

$V = -10.660$

Calc. of Volume of Bubble from Data @ 2200 hrs, 3/31/79:

		Time t_1	Time t_2
RCS	Pressure	955	1046
	Temp	278.2°F	277.7°F
PZR	Level	196"	192.2"
	Temp	595.6°F	556.6°F
MUT	Level	49.5"	33"
	Temp	81°F	81°F

① $\frac{P_2}{P_1-P_2} = \frac{1046}{955-1046} = -\frac{1046}{91} = -11.495$

② $C_{PZR}\left(\frac{v_{f_2}^{RCS}}{v_{f_2}^{PZR}} L_2^{PZR} - \frac{v_{f_1}^{RCS}}{v_{f_1}^{PZR}} L_1^{PZR}\right) = 3.178\left(\frac{.01719}{.02162}\left(\overset{192.2}{\cancel{196}}\right) - \frac{.01718}{.02196}\left(\overset{196}{\cancel{192.2}}\right)\right) = \overset{1.65}{\cancel{-12.5}}$

③ $C_{MUT}\left(\frac{v_f^{RCS}}{v_f^{MUT}}\right)\left(L_2^{MUT} - L_1^{MUT}\right) = 4.128\left(\frac{.01718}{.01607}\right)\left(\overset{33\ -\ 49.5}{\cancel{77 - 93}}\right) = -72.817$

④ $M_{RCS}\left(\frac{\partial v^{RCS}}{\partial T^{RCS}}\right)\left(T_2^{RCS} - T_1^{RCS}\right) = \left(6.166\times10^{5}\right)\left(9\times10^{-6}\right)\left(277.7-278.2\right) = -2.775$

⑤ $M_{RCS}\left(\frac{\partial v^{RCS}}{\partial P^{RCS}}\right)\left(P_2 - P_1\right) = \left(6.166\times10^{5}\right)\left(-10^{-7}\right)\left(955-1046\right) = -5.611$

⑥ $M_{RCS}\left(\frac{\partial s}{\partial P}\right)\left(P_2 - P_1\right) = \left(6.166\times10^{5}\right)\left(5.839\times10^{-7}\right)\left(955-1046\right) = +32.763$

$V = ①\left[② + ③ - ④ - ⑤ + ⑥\right]$

$V = (-11.495)\left[\left(\overset{-1.65}{\cancel{-12.599}}\right) + (-72.817) - (-2.775) - (-5.611) + (+32.763)\right]$

$V = (-11.495)\left[\overset{-1.65}{\cancel{-12.599}} - 72.817 + 2.775 + 5.611 + 32.763\right]$

$V = (-11.495)\left[\overset{-33.32}{\cancel{-49.067}}\right] = \overset{383.}{\cancel{569.02}}\ \cancel{ft^3}$

		t_1	t_2
RCS	P	957	1055
	Temp	280	279.4
PZR	Level	195.1	192.7
	Temp	545.7	557.9
MUT	Level	53.3	39.6
	Temp	72	70

① $\dfrac{P_2}{P_1 - P_2} = \dfrac{1055}{957-1055} = -10.765$ ✓ ✓

② $C_{PZR}\left(\dfrac{v_{f_2}^{RCS}}{v_{f_2}^{PZR}} L_2^{PZR} - \dfrac{v_{f_1}^{RCS}}{v_{f_1}^{PZR}} L_1^{PZR}\right) = 3.178\left(\dfrac{.01719}{.02200}(192.7) - \dfrac{.01720}{.02163}(195.1)\right) = -14.53$

③ $C_{MUT}\left(\dfrac{v_f^{RCS}}{v_f^{MUT}}\right)\left(L_2^{MUT} - L_1^{MUT}\right) = 4.128\left(\dfrac{.01720}{.016052}\right)\left(39.6-53.3\right) = -60.598$

④ $M_{RCS}\left(\dfrac{\partial V}{\partial T}\right)^{RCS}\left(T_2^{RCS} - T_1^{RCS}\right) = 6.166\times10^5\left(9\times10^{-6}\right)\left(279.4-280\right) = -3.33$

⑤ $M_{RCS}\left(\dfrac{\partial V}{\partial P}\right)^{RCS}\left(P_2 - P_1\right) = 6.166\times10^5\left(-10^{-7}\right)\left(1055-957\right) = -6.043$ ~~[illegible]~~

⑥ $M_{RCS}\left(\dfrac{\partial S}{\partial P}\right)\left(P_2 - P_1\right) = 6.166\times10^5\left(5.839\times10^{-7}\right)\left(1055-957\right) = \cancel{217.56}$ 35.28

$V = ①\left[② + ③ - ④ - ⑤ + ⑥\right] = (-10.765)\left[-0.742\right] = $ ~~[illegible]~~ ~~528.0~~

-30.475

$=$ 328.0 ft^3

.01721 .01720

0830 4/1

RCS temp 280.5 $v_{f2}^{RCS} = .01720$ ft³/lb
press 1050 P_2

$P_2 = 1050$ v_2^{RCS} .01720 ~~.0172~~
$P_1 = 945$ v_1^{RCS} .01720 ~~.0172~~
T_2
T_1

pressurizer
T_1 544.6 $v_{f1}^{PZR} = .02159$ L_1^{PZR} 201.2

T_2 557.1 $v_{f2}^{PZR} = .02198$ L_2^{PZR} 192.6

makeup tank
L_1^{MUT} 50.7
T 765 $v_f^{MUT} = .016064$
L_2^{MUT} 45.3

① $$\frac{P_2}{P_1 - P_2} = \frac{1050}{945 - 1050} = -10.0$$

② $$C_{PZR}\left(\frac{v_{f2}^{RCS}}{v_{f2}^{PZR}} L_2^{PZR} - \frac{v_{f1}^{RCS}}{v_{f1}^{PZR}} L_1^{PZR}\right) = 3.173\left(\frac{.01720 \; \cancel{.02198}}{.02198}(192.6) - \frac{.01720}{.02159}(201.2)\right) = \overset{-30.4}{\cancel{-30.4}}$$

③ $$C_{MUT}\left(\frac{v_f^{RCS}}{v_f^{MUT}}\right)\left(L_2^{MUT} - L_1^{MUT}\right) = 4.128\left(\frac{.01720}{.016064}\right)\left(45.3 - 50.7\right) = -23.868$$

④ $$M_{RCS}\left(\frac{\partial v^{RCS}}{\partial T^{RCS}}\right)\left(T_2^{RCS} - T_1^{RCS}\right) = \left(6.166\times10^5\right)\left(9\times10^{-6}\right)\left(280.5 - 280.5\right) = 0$$

⑤ $$M_{RCS}\left(\frac{\partial v^{RCS}}{\partial P^{RCS}}\right)\left(P_2 - P_1\right) = \left(6.166\times10^5\right)\left(-10^{-7}\right)\left(1050 - 945\right) = -6.474$$

⑥ $$M_{RCS}\left(\frac{\partial S}{\partial P}\right)\left(P_2 - P_1\right) = \left(6.166\times10^5\right)\left(5.839\times10^{-7}\right)\left(1050 - 945\right) = \cancel{38.451} \; \overset{37.497}{\cancel{37.4}}$$

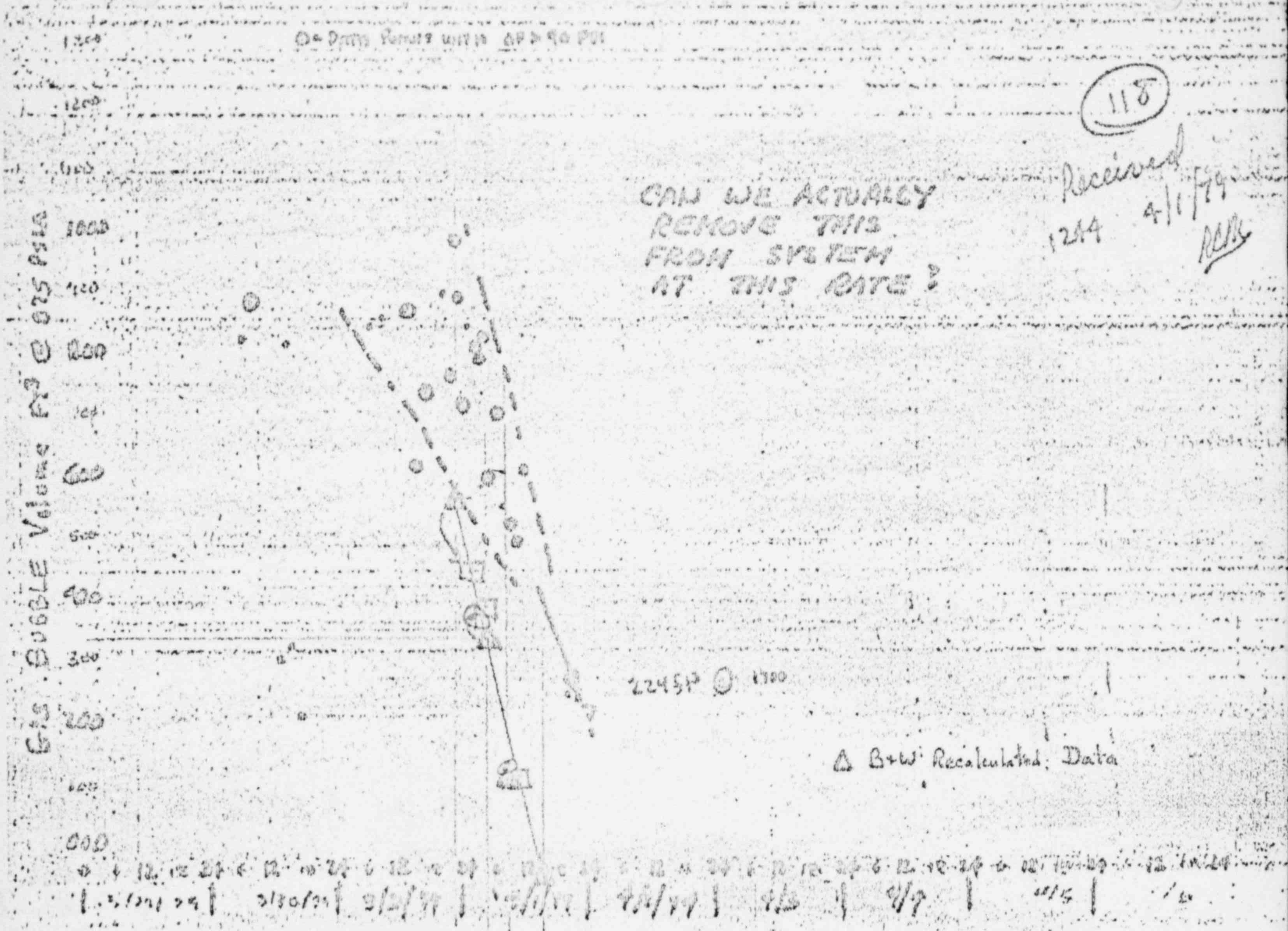
37.80

$$V = ①\left[② + ③ - ④ - ⑤ + ⑥\right]$$

$$V = -10\left[-30.426 + (-23.868) - 0 - (-6.474) + \overset{37.497}{\cancel{38.451}}\right]$$

$$V = -10\left[-9.369\right] = \underline{\overset{103.23}{\cancel{93.69}} \text{ ft}^3}$$

RCS BUBBLE

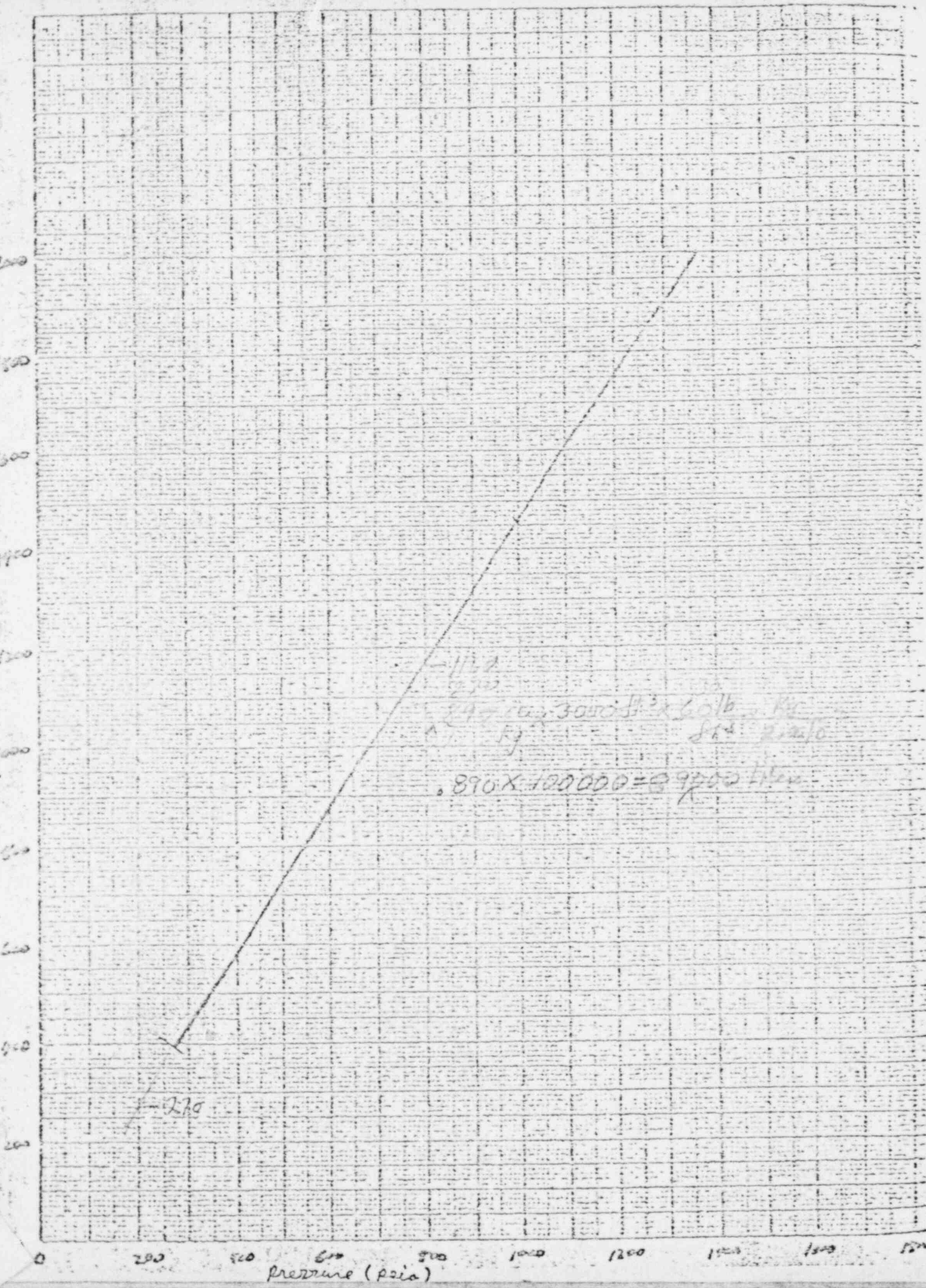


CAN WE ACTUALLY
REMOVE THIS
FROM SYSTEM
AT THIS RATE?

△ B+W Recalculated Data

Received
1214 4/1/79
RCM

118



-1162
1950

84 = ca, 3000 ft³ × 60 lb = Kg
Kg ft³ 2.2 lb

.890 X 100000 = 89000 liters

RATE OF CHANGE OF SOLUBILITY AS A FUNCTION OF PRESSURE

$T = 280°F = 137.8°C$

CONC (cc/Kg)		CONC (SCF/LB)	CONC (CF/LB)*	PRESS ATM	PRESS (P
400		6.41×10^{-3}	1.59×10^{-4}	18.6	273
600	200	9.61×10^{-3}	2.39×10^{-4}	27.9	410
800		—	3.18×10^{-4}	37.2	547
1000		—	3.98×10^{-4}	46.5	684
1200		—	4.78×10^{-4}	55.8	820
1400	1500	—	5.57×10^{-4}	65.1	957
1600		—	6.37×10^{-4}	74.4	1094
1800		—	7.16×10^{-4}	83.7	1230
2000		0.032	7.96×10^{-4}	93.0	1367

$$\text{Conc}\left(\frac{SCF}{LB}\right) = \text{Conc}\left(\frac{cc}{Kg}\right) \times \frac{0.4536\ Kg/LB}{28,317\ cc/SCF}$$

$$\text{Conc}\left(CF/LB\right) = \text{Conc}\left(\frac{cc}{Kg}\right) \times \frac{0.4536\ Kg/LB}{28\,317\ cc/FT^3} \times \frac{14.7\ PSIA}{890\ PSIA} \times \frac{740°R}{492°R}$$

$$-\frac{dC}{dP} \cong -\left(\frac{C_2 - C_1}{P_2 - P_1}\right) = -\left(\frac{5.57 \times 10^{-4} - 4.78 \times 10^{-4}}{957 - 820}\right) = -5.766 \times 10^{-7} \left(\frac{FT^3/LB}{PSI}\right)$$

* REFERENCE CONDITIONS 875 PSIG & 280°F

TMI-2 RCS BUBBLE CALC SHEET

TIME 2355 hrs

Jim Moore

DATA TAKEN BY: [illegible]

RC PRESSURE (398)

P1 = ______ PSIG = 958 PSIA

P2 = ______ PSIG = 1057 PSIA

ΔP = 99 PSI

RCS TEMP (394)

T1 = 279.4 °F

T2 = 279.6 °F

PRESSURIZER LEVEL (1682)

L1 = 197.0 INCHES

L2 = 192.0 INCHES

ΔL = 5.0 INCHES

557

PRESSURIZER TEMP (405)

T1 = 556.5 °F

T2 = 557.4 °F

MAKEUP TANK LEVEL (342)

L1 = 52.1 INCHES

L2 = 40.6 INCHES

ΔL = 11.5 INCHES

MAKEUP TANK TEMP (CENTER BOARD METER)

T1 = 81.0 °F

T2 = 79 °F

$\Delta V_{PZR} = \Delta L \times 2.515 =$ 50 $\times 2.515 =$ 12.6 ft³

$\Delta V_{MUT} = \Delta L \times 4.214 =$ 11.5 $\times 4.214 =$ 48.5 ft³

$\Delta V_{TOTAL} =$ 61.30 ft³

$V_1 = \frac{P_2 \Delta V_T}{P_2 - P_1} = \frac{(1057)\times(61.39)}{(99)} =$ 655.34 ft³ @ P1

$V_{(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) =$ ~~655.34~~ 717.5 ft³ @ 875 psia

2353 Repressurization
0015 Time 25 min
~~2353~~ 2353
~~[illegible]~~ 0018

TMI-2 RCS BUBBLE CALC SHEET

TIME — [illegible] 1342 [illegible]

DATA TAKEN BY: [illegible]

RC PRESSURE (582)

P_1 = ______ PSIG = 957 PSIA

P_2 = ______ PSIG = 1055 PSIA

ΔP = 98 PSI

RCS TEMP (706)

T_1 = 280 °F

T_2 = 279.4 °F

PRESSURIZER LEVEL (1682)

L_1 = 195.1 INCHES

L_2 = 192.7 INCHES

ΔL = 2.4 INCHES

PRESSURIZER TEMP (405)

T_1 = 545.7 °F

T_2 = 557.9 °F

MAKEUP TANK LEVEL (347)

L_1 = 53.3 INCHES

L_2 = 37.6 INCHES

ΔL = 13.7 INCHES

MAKEUP TANK TEMP (CENTER BOARD METER)

T_1 = 72 °F

T_2 = 70 °F

ΔV_{PZR} = ΔL × 2.515 = 2.4 × 2.515 = 6.04 FT³

ΔV_{MUT} = ΔL × 4.244 = 13.7 × 4.244 = 58 FT³

ΔV_{TOT} = 64.2 FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1055 \times \quad)}{(98)} = 690.9 \text{ FT}^3 @ P_1$$

$V_1(875) = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right)$ = 755.1 FT³ @ 875 psia.

S 0403

S 0437

Representation Time [illegible]

Start 0403 Stop 04[illegible]

ΔE = 95

TMI-2 RCS BUBBLE CALC SHEET

TIME [illegible]

DATA TAKEN BY: GAC

RC PRESSURE (393)

P_1 = ______ PSIG = 945 PSIA

P_2 = ______ PSIG = 1050 PSIA

ΔP = 105 PSI

RCS TEMP ([illegible])

T_1 = 280.5 °F

T_2 = 280.5 °F

38

PRESSURIZER LEVEL (1682)

L_1 = 201.2 INCHES

L_2 = 193.6 INCHES

ΔL = 8.6 INCHES

PRESSURIZER TEMP (455)

T_1 = 544.6 °F

T_2 = 557. °F

MAKEUP TANK LEVEL (347)

L_1 = 50.7 INCHES

L_2 = 45.3 INCHES

ΔL = 5.4 INCHES

MAKEUP TANK TEMP ([illegible])

T_1 = 78. °F

T_2 = 75 °F

ΔV_{PZR} = $\Delta L \times 2.515$ = 8.6 × 2.515 = 21.63 FT³

ΔV_{MUT} = $\Delta L \times 4.244$ = 5.4 × 4.244 = 22.92 FT³

ΔV_{TOTAL} = 44.5 FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1050)(44.5)}{(105)} = 445.5 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = \overset{534.6}{\cancel{445.5}} \text{ FT}^3 @ 875 \text{ PSIA.}$$

TMI-2 RCS BUBBLE CALC SHEET   TIME 1510-1550 pm

DATA TAKEN BY: Oeta

RC PRESSURE (338)

P_1 = ______ PSIG = 955 PSIA

P_2 = ______ PSIG = 1065 PSIA

ΔP = 110 PSI

RCS TEMP ([illegible])

T_1 = 280.9 °F

T_2 = 284.3 °F

PRESSURIZER LEVEL (1682)

L_1 = 216.8 INCHES

L_2 = 208.3 INCHES

ΔL = -8.5 INCHES

PRESSURIZER TEMP ([illegible])

T_1 = 545.9 °F

T_2 = 558.2 °F

MAKEUP TANK LEVEL (347)

L_1 = 53.3 INCHES

L_2 = 50.6 INCHES

ΔL = -2.7 INCHES

MAKEUP TANK TEMP ([illegible])

T_1 = 75° °F

T_2 = 74°F °F

$\Delta V_{PZR} = \Delta L \times 2.515 = 8.5 \times 2.515 = 21.38$ ft³

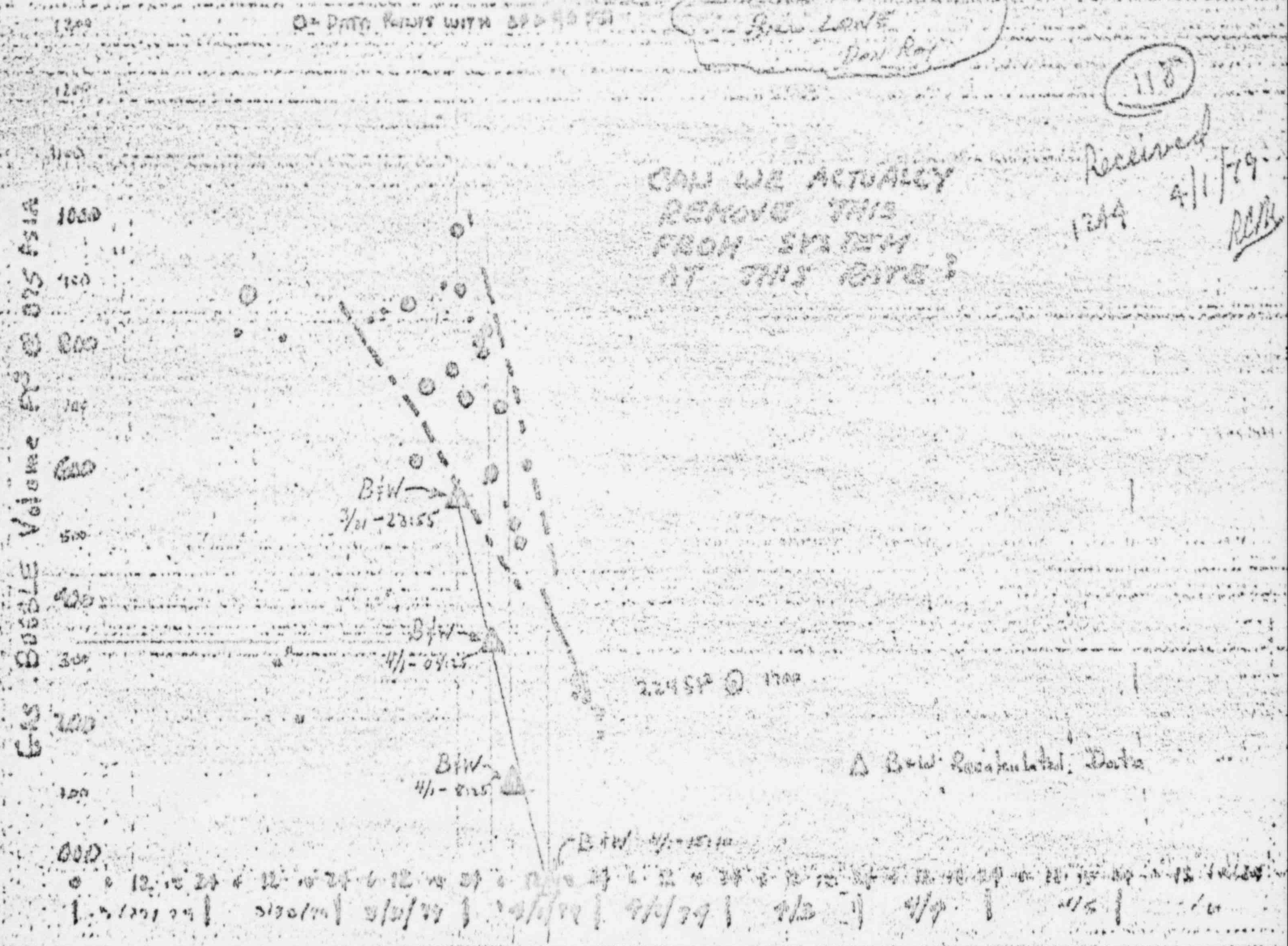
$\Delta V_{MUT} = \Delta L \times 4.244 = 2.7 \times 4.244 = 11.46$ ft³

$\Delta V_{TOTAL} = 32.84$ ft³

$$V_1 = \frac{P_2 \Delta V_T}{P_2 - P_1} = \frac{(1065 \times 32.84)}{(110)} = 317 \text{ ft}^3 @ P_1$$

$$V_1(875) = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 347 \text{ ft}^3 @ 875 \text{ psia.}$$

RCS BUBBLE



See

Give this to
Bob Long
Don Roy

118

CAN WE ACTUALLY
REMOVE THIS
FROM SYSTEM
AT THIS RATE?

Received
1244 4/1/79
RCM

4/1/79

Adj not normaliz to 815 psia.

Volume of Bubble Calculation

$$V_{Bubble} = \frac{P_2}{P_1 - P_2}\left[C_{PZR}\left(\frac{v_{f_2}^{RCS}}{v_{f_2}^{PZR}}L_2^{PZR} - \frac{v_{f_1}^{RCS}}{v_{f_1}^{PZR}}L_1^{PZR}\right) + C_{MUT}\left(\frac{v_f^{RCS}}{v_f^{MUT}}\right)\left(L_2^{MUT} - L_1^{MUT}\right) - M_{RCS}\left(\frac{\partial v^{RCS}}{\partial T^{RCS}}\right)\left(T_2^{RCS} - T_1^{RCS}\right) - M_{RCS}\left(\frac{\partial v^{RCS}}{\partial P^{RCS}}\right)\left(P_2 - P_1\right) + M_{RCS}\left(\frac{\partial S}{\partial P}\right)\left(P_2 - P_1\right)\right]$$

P_2 = RC Sys Press After Change
P_1 = RC Sys Press Before Change
C_{PZR} = Level to Volume Conversion for Pzr. = 3.178 ft³/in
C_{MUT} = " " " " " MUT = 4.128 ft³/in
v_f^{RCS} = Specific Volume of water at RCS temp, superheated steam tables
$v_{f_2}^{PZR}$ = " " " " " Pzr. " after change, saturated steam
$v_{f_1}^{PZR}$ = " " " " " " " " before " , " " "
v_f^{MUT} = " " " " " MUT " , saturated steam tables
L_2^{PZR} = Level in pressurizer after change, inches
L_1^{PZR} = " " " before " , "
L_2^{MUT} = " " makeup tank after change, inches
L_1^{MUT} = " " " " before " , "
$\frac{\partial v^{RCS}}{\partial T^{RCS}}$ = change in RCS specific vol. per °F = 9×10^{-6} ft³/lbm-°F
$\frac{\partial v^{RCS}}{\partial P^{RCS}}$ = Change in RCS specific volume per pound pressure = -10^{-7} ft³/lbm-psi
$\frac{\partial S}{\partial P}$ = Change in solubility of H_2 per pound pressure = 5.839×10^{-7} ft³/lbm-psi

M_{RCS} = Mass of RCS = $6.166 \times 10^{+5}$ lbs

MEMO from:

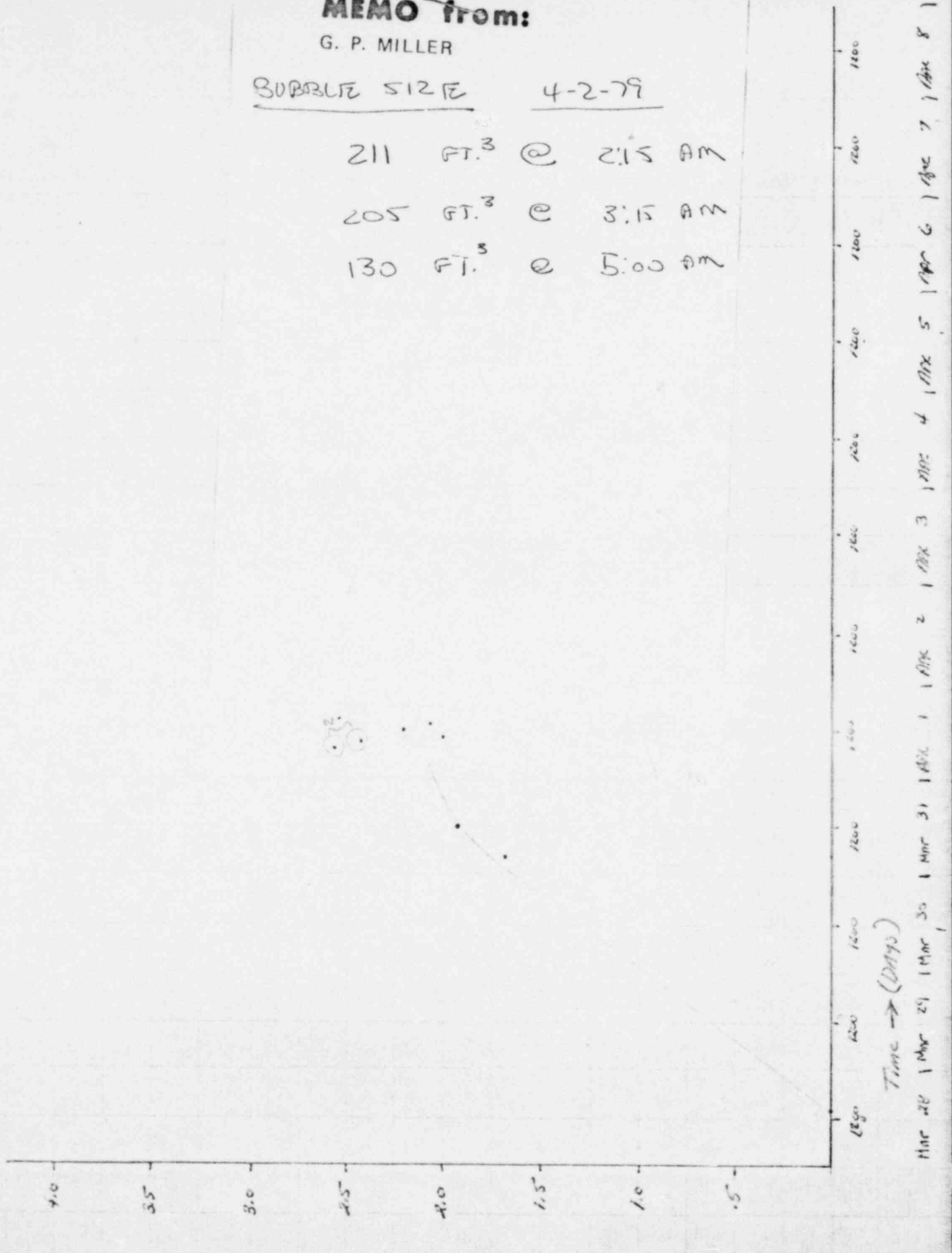
G. P. MILLER

BUBBLE SIZE 4-2-79

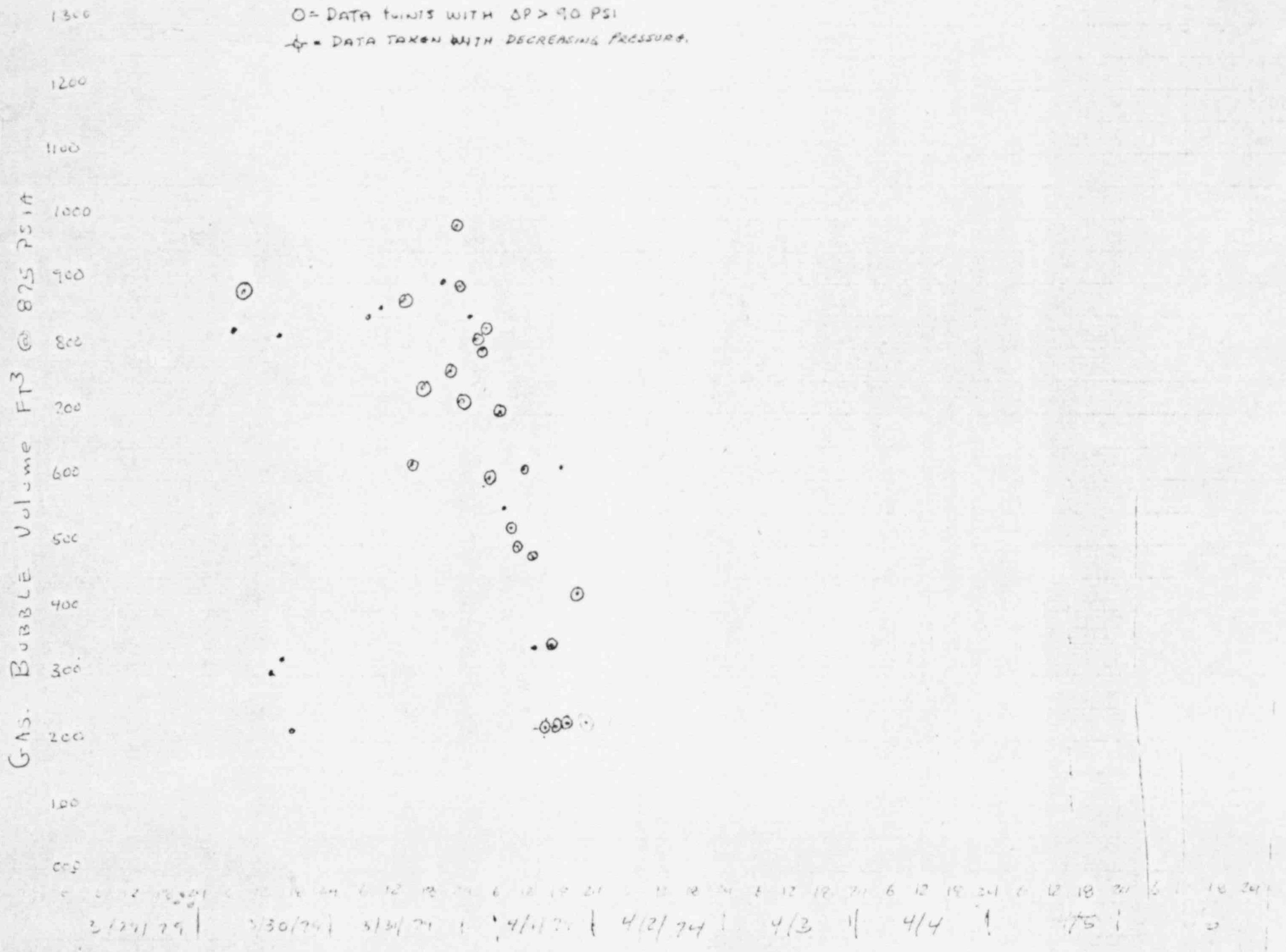
211 FT.^{3} @ 2:15 AM

205 FT.^{3} @ 3:15 AM

130 FT.^{3} @ 5:00 AM



RCS BUBBLE


O = DATA POINTS WITH ΔP > 90 PSI
-◇- = DATA TAKEN WITH DECREASING PRESSURE.
GAS. BUBBLE Volume FT3 @ 875 PSIA
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
000
3/29/79
3/30/79
3/31/79
4/1/79
4/2/79
4/3
4/4
4/5
6
12
18
24

Pat Walsh.

Make Up Tank Makeup Data from Operators Log

3/28

1720 BWST @ 26½'
1800 BWST @ 24'
1820 23'
1847 22'
1953 22'

3/29

BWST 20.5' @ 0615

3/30

0800 371
0815 300
1502 462
1719 200

1853 Start filling BWST Level @ 15.5'

2036 300
2307 190
2347 300
2310 Started PZR Vent
2353 Start PZR Spray

Total Makeup 2123

3/31

0033 300
0315 Started degas proc
0445 150
0547 150
0705 150
0737 Started Degas
0830 546
1042 130
1120 900
1427 303
1530 413
1543 100
1705 370
1820 370
2000 470
2120 480
2228 470
2330 470

Total 5762

4/1

0825 460
0945 400
1041 301
1200 446
1306 400
1508 456
1650 505
1805 456
1900 455
2015 454
2118 454
2225 455

0112 470
0127 470
0325 470
0435 470
0645 470

Total 8553

110
2 hrs

4/2

0150 -455
0300 455
0445 455
0630 455
0723 455
0853 455
1310 456
1458 671
1658 455
1828 455

16438

From Alarm Data on day of accident

One RB Sump Pump on for 31 min
Other " " " " for 28 min

4/1/79

AVG MAKEUP FLOW TO MAKEUP TANK

Calculate average rate of makeup to Makeup Tank for comparison with the calculated rate of decrease in bubble size. The first data is for makeup is from 0730 to 0825. This is ~~for~~ the depressurization half of the cycle. The pressurization half of this cycle started at about 0700. Therfore the rate will be calculated on the basis of Time = 0 @ 0700.

$\times \left(\frac{1}{7.481}\right)$ $\times 1.075$ From 0700 4/1/79

Date	TIME OF MAKE-UP TO MU TK	GAL ADDED	FT³ ADDED AT 70°F	FT³ ADDED AT 280°F	TOTAL FT³/ADDED	TOTAL Δ TIME (HR)	MAKEUP RATE FT³/HR @ 280°F
4/1/79	0730-0825	460	61.5	66	66	1.42	46
	0903-0945	400	53.47	57.5	123.5	2.75	44.9
	1020-1041	301	40.24	43.25	166.8	3.68	45.3
	1140-1200	446	59.62	64.1	230.9	5.00	46.2
	1238-1306	400	57.46	61.8	292.7	6:10	48.0
	-1506	456	60.95	65.52	358.2	8.10	~~35.47~~ 44.2
	1650	505	67.5	72.567	430.8	9.83	43.83
	1805	456	60.95	65.52	496.3	11.01	45.08
	1900	455	60.82	65.38	561.68	12:00	46.8
	2015	454	60.69	65.24	626.92	13.25	47.31
	2120	455	60.82	65.38	692.3	14.33	
	2225	455	60.82	65.38	757.64	1.01 15.41	
	2347	455	60.82	65.38	823.06	16.77	

~~0151~~ .. - See Next page

4/1/79 4/2
2347 → 0853 Avg = 30.9

		Ft3 @ 875 psia	DP	
3/29	1300	1839.3	95	DATA FROM J. FLOYD - SOURCES UNKNOWN
3/30	0625	*828.6	16	MU TK Δ LEVEL - BELIEVED TO BE ZERO IN.
	0730	892.5	115	
	1240	*308	32	
	1445	839	42	
	1630	*365.6	17	
	1745	*224.6	25	
	1907	*1806.0	38	
	0630	850	55	
3/31	1032	859.5	47	
	1351	879.4	92	

~~1351~~

TMI-2 RC GAS BUBBLE CALCS

Moore
3/31/79

$$V_1 = \frac{P_2\left[a\,(L_2-L_1)_A + b\,(L_2-L_1)_B\right]}{P_1 - P_2}$$

P = RC System Pressure - Computer point 398

L_A = PRESSURIZER LEVEL - " " 1682

L_B = MAKEUP TANK LEVEL - " " 347

SUBSCRIPTS

1 - INITIAL DATA POINT
2 - FINAL DATA POINT
A - PRESSURIZER
B - MAKEUP TANK

To Convert PZR ΔV to equivalent ΔV at RC Temp.

$$a = \left(3.2\ \frac{FT^3}{IN}\right)\left(\frac{0.0173}{0.[illegible]22}\right) = 2.515$$

where v_f for RC TEMP = 0.0173
v_f for PRESSURIZER TEMP = 0.0163 BAS

To Convert MUTK ΔV to equivalent ΔV at RC TEMP

$$b = \left(4\ \frac{ft^3}{IN}\right)\left(\frac{0.0173}{0.0163}\right) = 4.244$$

where: v_f for RC Temp = 0.0173
v_f for ~~[illegible]~~ Makeup Tank Temp = 0.0163

TC
493 - 544

DATE 4/3/79

TIME 1604 - 1634 AM PM

TMI-2 RCS BUBBLE CALC SHEET

DATA TAKEN BY: PB

RC PRESSURE (398)

P_1 = ______ PSIG = 949 PSIA

P_2 = ______ PSIG = 1050 PSIA

ΔP = 101 PSI

RCS TEMP (394)

T_1 = 280.2 °F

T_2 = 280.7 °F

PRESSURIZER LEVEL (1682)

L_1 = 193.5 INCHES

L_2 = 186.7 INCHES

ΔL = -3.2 INCHES

PRESSURIZER TEMP (~~405~~ 311)

T_1 = 546.2 °F

T_2 = 557.4 °F

MAKEUP TANK LEVEL (347)

L_1 = 45.0 INCHES

L_2 = 41.4 INCHES

ΔL = 3.6 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 76 °F

T_2 = 74 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ -3.2 × 2.515 = -8.05 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 3.6 × 4.244 = 15.28 FT^3

ΔV_{TOTAL} = 7.23 FT^3

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1050)(7.23)}{(101)} = 75.2 \ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 81.5 \ FT^3 @ 875 \text{ psia.}$$

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DATE 4/3/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 1525 AM PM

DATA TAKEN BY: PSW

RC PRESSURE (398)

P_1 = ______ PSIG = 958 PSIA

P_2 = ______ PSIG = 1056 PSIA

ΔP = 98 PSI

RCS TEMP (394)

T_1 = 277.6 °F v_f = .017228

T_2 = 280.0 °F v_f = .017246

$v_{1\&2}$ = .017264.

$\Delta v = 1.8 \times 10^{-5}$ ft³/lb

PRESSURIZER LEVEL (1682)

L_1 = 182.3 INCHES

L_2 = 187.5 INCHES

ΔL = −5.2 INCHES

PRESSURIZER TEMP (~~435~~ 389)

T_1 = 547.7 °F

T_2 = 554.6 °F

MAKEUP TANK LEVEL (347)

L_1 = 50.2 INCHES

L_2 = 47.4 INCHES

ΔL = 2.8 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 75 °F

T_2 = 75 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = −5.2 × 2.515 = −13.07 FT³

$\Delta V_{MUT} = \Delta L \times 4.244$ = 2.8 × 4.244 = 11.88 FT³

ΔV_{TOTAL} = −1.19 FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1056 \times -1.19)}{(98)} = -12.8 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = -14.0 \text{ FT}^3 @ 875 \text{ PSIA.}$$

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DATE 4/3/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 86:20 - 645 [✓ AM] PM

DATA TAKEN BY: JL

RC PRESSURE (398)

P_1 = 962 PSIG = 977 PSIA

P_2 = 1035 PSIG = 1050 PSIA

ΔP = 73 PSI

RCS TEMP (394)

T_1 = 280.1 °F

T_2 = 280.2 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.3 INCHES

L_2 = 205.2 INCHES

ΔL = -3.9 INCHES

PRESSURIZER TEMP (359 ~~405~~)

T_1 = 547.4 °F

T_2 = 556.6 °F

MAKEUP TANK LEVEL (347)

L_1 = 52.5 INCHES

L_2 = 47.8 INCHES

ΔL = 4.7 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 70 °F

T_2 = 70 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 3.9 × 2.515 = -9.8 FT³

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 4.7 × 4.244 = 19.9 FT³

ΔV_{TOTAL} = 10.14 FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1050 \times 10.14)}{(73)} = 145.8 \text{ FT}^3 \text{ @ } P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_{1\,977}}{875}\right) = 162.8 \text{ FT}^3 \text{ @ } 875 \text{ psia.}$$

DATE 4/3/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 5:37 – 6:02 [✓ AM] PM

DATA TAKEN BY: Joe

RC PRESSURE (398)

P_1 = 960 PSIG = 975 PSIA

P_2 = 1061 PSIG = 1076 PSIA

ΔP = 101 PSI

RCS TEMP (394)

T_1 = 280.0 °F

T_2 = 280.1 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.8 INCHES

L_2 = 205.9 INCHES

ΔL = -4.1 INCHES

PRESSURIZER TEMP (389 ~~405~~)

T_1 = 548.0 °F

T_2 = 558.8 °F

MAKEUP TANK LEVEL (347)

L_1 = 45.4 INCHES

L_2 = 41.2 INCHES

ΔL = 4.2 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 68 °F

T_2 = 68 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = -4.1×2.515 = -10.31 FT³

$\Delta V_{MUT} = \Delta L \times 4.244$ = 4.2×4.244 = 17.82 FT³

ΔV_{TOTAL} = 7.513 FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1076)(7.513)}{(101)} = 80.04 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 89.19 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 4/3/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 4:53 - 5:23 [✓ AM] PM

DATA TAKEN BY:

RC PRESSURE (398)

P_1 = 941 PSIG = 956 PSIA

P_2 = 1055 PSIG = 1070 PSIA

ΔP = 114 PSI

RCS TEMP (394)

T_1 = 279.7 °F

T_2 = 280.0 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.5 INCHES

L_2 = 206.7 INCHES

ΔL = -5.2 INCHES

PRESSURIZER TEMP ($\overset{389}{405}$)

T_1 = 546.2 °F

T_2 = 558.8 °F

MAKEUP TANK LEVEL (347)

L_1 = 53.8 INCHES

L_2 = 48.0 INCHES

ΔL = 5.8 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 69 °F

T_2 = 69 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = -5.2 \times 2.515 = -13.08\ FT^3$

$\Delta V_{MUT} = \Delta L \times 4.244 = 5.8 \times 4.244 = 24.61\ FT^3$

$\Delta V_{TOTAL} = 11.53\ FT^3$

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1070)(11.53)}{(114)} = 108.28\ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 118.13\ FT^3 @ 875\ psia.$$

DATE 4/2/79

TIME 2025 AM/PM

TMI-2 RCS BUBBLE CALC SHEET

DATA TAKEN BY: PS

RC PRESSURE (390)

P_1 = ____ PSIG = 964 PSIA

P_2 = ____ PSIG = 1062 PSIA

ΔP = 98 PSI

RCS TEMP (394)

T_1 = 275.8 °F

T_2 = 275.9 °F

PRESSURIZER LEVEL (1682)

L_1 = 204.0 INCHES

L_2 = 202.7 INCHES

ΔL = 1.3 INCHES

PRESSURIZER TEMP (405)

T_1 = 546.8 °F

T_2 = 559.1 °F

MAKEUP TANK LEVEL (347)

L_1 = 52.8 INCHES

L_2 = 49.2 INCHES

ΔL = 3.6 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 72 °F

T_2 = 72 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 1.3 × 2.515 = 3.30 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 3.6 × 4.244 = 15.28 FT^3

ΔV_{TOTAL} = 18.5 FT^3

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1062)(18.5)}{(98)} = 201.0 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 221.5 \text{ FT}^3 @ 875 \text{ psia.}$$

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DATE 4/2/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 1803 AM PM

DATA TAKEN BY: PSW

RC PRESSURE (398)

P_1 = ______ PSIG = 976 PSIA

P_2 = ______ PSIG = 1063 PSIA

ΔP = 87 PSI

RCS TEMP (394)

T_1 = 275.9 °F

T_2 = 275.5 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.9 INCHES

L_2 = 202.8 INCHES

ΔL = −.9 INCHES

PRESSURIZER TEMP (~~485~~ 389)

T_1 = 553.1 °F

T_2 = 554.5 °F

MAKEUP TANK LEVEL (347)

L_1 = 41.5 INCHES

L_2 = 38.4 INCHES

ΔL = 3.1 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 72 °F

T_2 = 72 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = -.9 \times 2.515 = -2.26$ FT³

$\Delta V_{MUT} = \Delta L \times 4.244 = 3.1 \times 4.244 = 13.16$ FT³

$\Delta V_{TOTAL} = 10.9$ FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1063)(10.9)}{(87)} = 133.1 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 148.5 \text{ FT}^3 @ 875 \text{ psia.}$$

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DATE 9/2

TIME 1600-1650 AM PM

TMI-2 RCS BUBBLE CALC SHEET

DATA TAKEN BY: ASW

RC PRESSURE (398)

P_1 = PSIG = 960 PSIA

P_2 = PSIG = 1045 PSIA

ΔP = 85 PSI

RCS TEMP (394)

T_1 = 277.6 °F

T_2 = 278.0 °F

PRESSURIZER LEVEL (1682)

L_1 = 209.5 INCHES

L_2 = 213.5 INCHES

ΔL = − 4.0 INCHES

PRESSURIZER TEMP (405)

T_1 = 548.1 °F

T_2 = 557.3 °F

MAKEUP TANK LEVEL (347)

L_1 = 46.3 INCHES

L_2 = 43.1 INCHES

ΔL = 3.2 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 76 °F

T_2 = 76 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = -4.0 \times 2.515 = 10.06$ FT³

$\Delta V_{MUT} = \Delta L \times 4.244 = 3.2 \times 4.244 = 13.58$ FT³

$\Delta V_{TOTAL} = 3.52$ FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1045)(3.52)}{(85)} = 43.3 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 47.5 \text{ FT}^3 @ 875 \text{ psia.}$$

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DATE 4/2/79
TIME ~~155~~ 1315 AM [✓ PM]
DATA TAKEN BY: TRF/

TMI-2 RCS BUBBLE CALC SHEET

1065 RC PRESSURE (398) RCS TEMP (394)
72 P_1 = ____ PSIG = 942 PSIA T_1 = 228.4 °F
73
72 P_2 = ____ PSIG = 1063 PSIA T_2 = 228.5 °F
71 ΔP = 121 PSI
70
65
61 PRESSURIZER LEVEL (1682) PRESSURIZER TEMP (405)
53 L_1 = 206.4 INCHES T_1 = 545.1 °F
48
44 L_2 = 204.0 INCHES T_2 = 558 °F
48 ΔL = 2.4 INCHES
60
65 MAKEUP TANK LEVEL (347) MAKEUP TANK TEMP (CONTROL BOARD METER)
64 L_1 = 47.4 INCHES T_1 = 78 °F
61 L_2 = 44.5 INCHES T_2 = 78 °F
58 ΔL = 2.9 INCHES
60
70 $\Delta V_{PZR} = \Delta L \cdot 2.515$ = 2.4 × 2.515 = 6.04 FT^3
74 $\Delta V_{MUT} = \Delta L \times 4.244$ = 2.9 × 4.244 = 12.31 FT^3
65 ΔV_{TOTAL} = 18.35 FT^3
57
66 $V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1063)(18.35)}{(121)}$ = 161.2 FT^3 @ P_1
59
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61 $V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right)$ = 173.5 FT^3 @ 875 PSIA.

DATE 4/2/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 1225 - 1305 ~~1:35~~ ~~1225~~ AM [✓ PM]

DATA TAKEN BY: RAF

RC PRESSURE (398)

P_1 = ______ PSIG = 936 PSIA

P_2 = ______ PSIG = 1056 PSIA

ΔP = 120 PSI

RCS TEMP (394)

T_1 = 280.1 °F

T_2 = 280.1 °F

PRESSURIZER LEVEL (1682)

L_1 = 208.3 INCHES

L_2 = 207.6 INCHES

ΔL = ~~105~~ .7 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 547.5 °F

T_2 = 557.9 °F

MAKEUP TANK LEVEL (347)

L_1 = 45.5 INCHES

L_2 = 41.6 INCHES

ΔL = 3.9 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 74° °F

T_2 = 75 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ .7 × 2.515 = 1.76 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 3.9 × 4.244 = 16.55 FT^3

ΔV_{TOTAL} = 18.3 FT^3

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1056 \times 18.3)}{(120)} = 161.1 \text{ FT}^3 \text{ @ } P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 194.5 \text{ FT}^3 \text{ @ 875 psia.}$$

DATE 4/2/79

TMI-2 RCS BUBBLE CALC SHEET

TIME ~~0449~~ OAF /1208 AM PM

DATA TAKEN BY: OAF

RC PRESSURE (398)

P_1 = ______ PSIG = 942 PSIA

P_2 = ______ PSIG = 1036 PSIA

ΔP = 78 PSI

RCS TEMP (394)

T_1 = 280.1 °F

T_2 = 280.1 °F

PRESSURIZER LEVEL (1682)

*L_1 = 201.5 INCHES

L_2 = 211.3 INCHES

ΔL = .8 INCHES

PRESSURIZER TEMP (~~435~~ 389)

T_1 = 54~~8~~5.1 °F 54[illegible]5

T_2 = 558.8 °F

MAKEUP TANK LEVEL (347)

L_1 = 47.6 INCHES

L_2 = 45.8 INCHES

ΔL = 4.6 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78° °F

T_2 = 76° °F

$\Delta V_{PZR} = \Delta L \times 2.515 =$ .8 × 2.515 = -2.01 FT³

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 4.6 × 4.244 = 19.52 FT³ OAF

ΔV_{TOTAL} = ~~20~~ ~~21.55~~ 17.51 FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1036)(\cancel{21.53}\ 17.5)}{(78)} = \cancel{285}\ 175 \text{ FT}^3 \text{ @ } P_1$$

OAF

L.7

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = \cancel{338.6}\ 208.17 \text{ FT}^3 \text{ @ } 875 \text{ psia.}$$

DATE / TIME 4/1/79 / 2205

Rc Pressure 1030

Rc TEMP 277.1

PZR TEMP 389 550.

RCP RUNNING 1A

Rc make up Tank Level 49.8

letdown to Make up TK 0

S/G A level 35

S/G A press 30

S/G B level 94

S/G B press 24

Cond Vac. 28

Cont temp 84-90

Cont press -.9

Cont H2 2.3%

PZR Level 201.8

Bubble size 198.5 (11:00p)

Plant Status.

every 4 hrs

DATE 4/2/79
TIME @ 0850/0929 AM PM
DATA TAKEN BY:
TF

TMI-2 RCS BUBBLE CALC SHEET

RC PRESSURE (398)

P_1 = 950 PSIG = 965 PSIA

P_2 = ____ PSIG = 1056 PSIA

ΔP = 106 PSI

RCS TEMP (394)

T_1 = 279.9 °F

T_2 = 278.5 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.7 INCHES

L_2 = 202.9 INCHES

ΔL = + 1.2 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 546.4 °F

T_2 = 558.1 °F

MAKEUP TANK LEVEL (347)

L_1 = 47.9 INCHES

L_2 = 48.5 INCHES

ΔL = + 0.6 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 75 °F

T_2 = 76 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = +1.2 \times 2.515 = 3.02$ FT³

$\Delta V_{MUT} = \Delta L \times 4.244 = +0.6 \times 4.244 = 2.55$ FT³

$\Delta V_{TOTAL} = 5.57$ FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1056)(5.57)}{(106)} = 55.49 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 60 \text{ FT}^3 @ 875 \text{ psia.}$$

Start 0850
Stop. 0929

DATE 4/2/79

TIME 7:40 [✓ AM] PM

DATA TAKEN BY:

TMI-2 RCS BUBBLE CALC SHEET

RC PRESSURE (398)

P_1 = 958 PSIG = 973 PSIA

P_2 = 1048 PSIG = 1063 PSIA

ΔP = 90 PSI

RCS TEMP (394)

T_1 = 278.4 °F

T_2 = 279.1 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.9 INCHES

L_2 = 202.5 INCHES

ΔL = -.6 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 548.5 °F

T_2 = 558 °F

MAKEUP TANK LEVEL (347)

L_1 = 40.5 INCHES

L_2 = 53.1 INCHES

ΔL = 1.2 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 72 °F

T_2 = 72 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = -.6 × 2.515 = 1.51 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244$ = 1.2 × 4.244 = 5.09 FT^3

ΔV_{TOTAL} = 3.583 FT^3

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1063)(3.583)}{(90)} = 42.3 \; FT^3 \; @ \; P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 47.07 \; FT^3 \; @ \; 875 \text{ psia.}$$

DATE 4/2/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 6:50 [✓ AM] PM

DATA TAKEN BY: Jk

RC PRESSURE (398)

P_1 = ~~957~~ 950 PSIG = 965 PSIA

P_2 = 1048 PSIG = 1063 PSIA

ΔP = 98 PSI

RCS TEMP (394)

T_1 = 277.8 °F

T_2 = 278.5 °F

PRESSURIZER LEVEL (1682)

L_1 = ~~202.1~~ 201.7 INCHES

L_2 = 202.9 INCHES

ΔL_{1-2} = -1.2 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 546 °F

T_2 = 558.5 °F

MAKEUP TANK LEVEL (347)

L_1 = ~~36~~ 49.8 INCHES

L_2 = 46.1 INCHES

ΔL_{1-2} = 3.7 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 71 °F

T_2 = 71 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 1.2 × 2.515 = -3.02 FT³

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 3.7 × 4.244 = 15.703 FT³

ΔV_{TOTAL} = 12.6848 FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1063)(12.685)}{(98)} = 137.6 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 151.7 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 4/2/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 5:50 [✓ AM] PM

DATA TAKEN BY:

RC PRESSURE (398)

P_1 = 977 PSIG = 992 PSIA

P_2 = 1059 PSIG = 1074 PSIA

ΔP = 92 PSI

RCS TEMP (394)

T_1 = 278.5 °F

T_2 = 278.2 °F

PRESSURIZER LEVEL (1682)

L_1 = 203.3 INCHES

L_2 = 201.6 INCHES

ΔL = 1.7 INCHES

PRESSURIZER TEMP (~~425~~ 389)

T_1 = 549.8 °F

T_2 = 558.6 °F

MAKEUP TANK LEVEL (347)

L_1 = 48.9 INCHES

L_2 = 46.4 INCHES

ΔL = 2.5 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 72 °F

T_2 = 75 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = 1.7 × 2.515 = 4.75 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244$ = 2.5 × 4.244 = 10.61 FT^3

ΔV_{TOTAL} = 15.36 FT^3

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1074 \times 15.36)}{(92)} = 179 \ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1 (992)}{875}\right) = 203.3 \ FT^3 @ 875 \text{ psia.}$$

DATE 4/2/79
TIME 5:00 [✓ AM] PM
DATA TAKEN BY: JL

TMI-2 RCS BUBBLE CALC SHEET

RC PRESSURE (398)
P_1 = 960 PSIG = 975 PSIA
P_2 = 1060 PSIG = 1075 PSIA
ΔP = 100 PSI

RCS TEMP (394)
T_1 = 277.7 °F
T_2 = 279.4 °F

PRESSURIZER LEVEL (1682)
L_1 = 217.6 INCHES
L_2 = 215.8 INCHES
ΔL = 1.8 INCHES

PRESSURIZER TEMP (~~405~~ 389)
T_1 = 548.6 °F
T_2 = 559.6 °F

MAKEUP TANK LEVEL (347)
L_1 = 39.3 INCHES
37.8 fluid
L_2 = 52.8 INCHES
ΔL = 1.5 INCHES

52.8
15.0
37.8

MAKEUP TANK TEMP (CONTROL BOARD METER)
T_1 = 73 °F
T_2 = 75 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 1.8 \times 2.515 = 4.527$ FT³
$\Delta V_{MUT} = \Delta L \times 4.244 = 1.5 \times 4.244 = 6.366$ FT³
$\Delta V_{TOTAL} = 10.89$ FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1075)(10.89)}{(100)} = 117 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 130.4 \text{ FT}^3 @ 875 \text{ psia}.$$

DATE 4/2/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 4:15 AM [✓ PM]

DATA TAKEN BY: JK

RC PRESSURE (398)

P_1 = 869 PSIG = 884 PSIA

P_2 = 1055 PSIG = 1070 PSIA

ΔP = 186 PSI

RCS TEMP (394)

T_1 = 276.4 °F

T_2 = 277.7 °F

PRESSURIZER LEVEL (1682)

L_1 = 231.7 INCHES

L_2 = 223.8 INCHES

ΔL = 7.9 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 534.6 °F

T_2 = 558.1 °F

MAKEUP TANK LEVEL (347)

L_1 = 48.0 INCHES

L_2 = 42.4 INCHES

ΔL = 5.6 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 77 °F

T_2 = 74 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 7.9 \times 2.515 = 19.8$ FT³

$\Delta V_{MUT} = \Delta L \times 4.244 = 5.6 \times 4.244 = 23.76$ FT³

$\Delta V_{TOTAL} = 43.56$ FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1070)(43.56)}{(186)} = 250.6 \text{ FT}^3 \text{ @ } P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 253.2 \text{ FT}^3 \text{ @ 875 psia.}$$

DATE 4/2/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 3:15 [✓ AM] PM

DATA TAKEN BY: J Z

RC PRESSURE (398)

P_1 = 956 PSIG = 971 PSIA

P_2 = 1025 PSIG = 1040 PSIA

ΔP = 69 PSI

RCS TEMP (394)

T_1 = 275.6 °F

T_2 = 275.5 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.5 INCHES

L_2 = 202.5 INCHES

ΔL = 1 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 547.2 °F

T_2 = 554.7 °F

MAKEUP TANK LEVEL (347)

L_1 = 54.4 INCHES

L_2 = 52.1 INCHES

ΔL = 2.3 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 70 °F

T_2 = 75 °F

$\Delta V_{PZR} = \Delta L \times 2.515 =$ 1 × 2.515 = 2.515 FT³

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 2.3 × 4.244 = 9.76 FT³

ΔV_{TOTAL} = 12.27 FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1040 \times 12.27)}{(69)} = 185 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 205.3 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 4/2/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 2.15 [✓ AM] PM

DATA TAKEN BY:

RC PRESSURE (398)

P_1 = 945 PSIG = 960 PSIA

P_2 = 1056 PSIG = 1073 PSIA

ΔP = 113 PSI

RCS TEMP (394)

T_1 = 276.1 °F

T_2 = 276.4 °F

PRESSURIZER LEVEL (1682)

L_1 = 210.8 INCHES

L_2 = 201.6 INCHES

ΔL = 9.2 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 546.6 °F

T_2 = 558.7 °F

MAKEUP TANK LEVEL (347)

L_1 = $\overset{57}{47.0}$ INCHES

L_2 = 49.3 INCHES

ΔL = 10.3 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 69 °F

T_2 = 72 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 9.2 \times 2.515 = 23.1$ FT³

$\Delta V_{MUT} = \Delta L \times 4.244 = 10.3 \times 4.244 = 43.7$ FT³

$\Delta V_{TOTAL} = 20.6$ FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1056)(20.6)}{(113)} = 192.6 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 211.3 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 4/2/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 1:28 [✓ AM] PM

Done while Venting

DATA TAKEN BY: JG

RC PRESSURE (398)

P_1 = 1056 PSIG = 1071 PSIA

P_2 = 971 PSIG = 986 PSIA

ΔP = 85 PSI

RCS TEMP (394)

T_1 = 276.4 °F

T_2 = 275.7 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.6 INCHES

L_2 = 201.7 INCHES

ΔL = -.1 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 558.7 °F

T_2 = 549.0 °F

MAKEUP TANK LEVEL (347)

L_1 = 49.3 INCHES

L_2 = 40.2 INCHES

ΔL = 9.1 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 72 °F

T_2 = 70 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ -.1 × 2.515 = -.2515 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 9.1 × 4.244 = 38.6 FT^3

ΔV_{TOTAL} = 38.3 FT^3

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(986)(38.3)}{(85)} = 444.3 \ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 543 \ FT^3 @ 875 \text{ psia.}$$

Done while Venting

DATE ~~4/1/79~~ /4/2/79
TIME 0020 AM [✓ PM]
DATA TAKEN BY: JR

TMI-2 RCS BUBBLE CALC SHEET

RC PRESSURE (398)

P_1 = 953 PSIG = ~~970~~ 968 PSIA

P_2 = 1058 PSIG = 1073 PSIA

ΔP = 105 PSI

RCS TEMP (394)

T_1 = 276.5 °F

T_2 = 276.6 °F

PRESSURIZER LEVEL (1682)

L_1 = 220.0 INCHES

L_2 = 217.5 INCHES

ΔL = 2.5 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 549.9 °F

T_2 = 559.3 °F

MAKEUP TANK LEVEL (347)

L_1 = ~~45.7~~ 53.0 INCHES

L_2 = 50.0 INCHES

ΔL = 3.0 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = ~~75~~ 72 °F

T_2 = 70 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = 2.5 × 2.515 = 6.2875 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244$ = 3 × 4.244 = 12.732 FT^3

ΔV_{TOTAL} = 19.0195 FT^3

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1073)(19.0195)}{(105)} = 194.36 \ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 215.01 \ FT^3 @ 875 \text{ psia.}$$

TMI-2 RCS BUBBLE CALC SHEET

DATE 4/11

TIME 10:59 AM [✓ PM]

DATA TAKEN BY: JC

RC PRESSURE (398)

P_1 = 945 PSIG = 960 PSIA

P_2 = 1045 PSIG = 1060 PSIA

ΔP = 100 PSI

RCS TEMP (394)

T_1 = 277.8 °F

T_2 = 278.0 °F

950
947
944
942
933
945
946
937

PRESSURIZER LEVEL (1682)

L_1 = 201.4 INCHES

L_2 = 201.7 INCHES

ΔL = .3 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 545 °F

T_2 = 557.3 °F

MAKEUP TANK LEVEL (347)

L_1 = 53.6 INCHES

L_2 = 49.4 INCHES

ΔL = -4.2 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78 °F

T_2 = 76 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = .3 × 2.515 = .755 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244$ = 4.2 × 4.244 = 17.825 FT^3

ΔV_{TOTAL} = 17.07 FT^3

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1060 \times 17.07)}{(100)} = 180.942 \ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 198.5 \ FT^3 @ 875 \text{ psia.}$$

DATE 4/01/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 1910-2000 AM PM

DATA TAKEN BY: JPM

RC PRESSURE (398)

P_1 = ______ PSIG = [illegible] 954 Avg PSIA

P_2 = ______ PSIG = 1058 AVG PSIA

ΔP = 104 PSI

RCS TEMP (394)

T_1 = 278.2 °F

T_2 = 278.8 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.7 INCHES

L_2 = 201.0 INCHES

ΔL = -0.7 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 547 °F

T_2 = 559.1 °F

MAKEUP TANK LEVEL (347)

L_1 = 51.2 INCHES

L_2 = 42.3 INCHES

ΔL = -8.9 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78. °F

T_2 = 75 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = -0.7 \times 2.515 = 1.76$ FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 = -8.9 \times 4.244 = 37.77$ FT^3

$\Delta V_{TOTAL} = 39.53$ FT^3

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1058 \times 39.53)}{(104)} = 402 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 438 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE

TMI-2 RCS BUBBLE CALC SHEET

TIME 1758 - 1847 AM PM

DATA TAKEN BY: ____

RC PRESSURE (398)

P_1 = ____ PSIG = 955 PSIA

P_2 = ____ PSIG = 1053.6 PSIA

ΔP = 98.6 PSI

RCS TEMP (394)

T_1 = 279.4 °F

T_2 = 278.6 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.3 INCHES

L_2 = 201.3 INCHES

ΔL = 0 INCHES

PRESSURIZER TEMP (389 ~~405~~)

T_1 = 557.8 °F

T_2 = 558.9 °F

MAKEUP TANK LEVEL (347)

L_1 = 47.1 INCHES

L_2 = 42.6 INCHES

ΔL = 4.5 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78. °F

T_2 = 78 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 0 \times 2.515 = 0$ FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 = 4.5 \times 4.244 = 19.1$ FT^3

$\Delta V_{TOTAL} = 19.1$ FT^3

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1053.6)(19.1)}{(98.6)} = 204 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 222.73 \text{ FT}^3 @ 875 \text{ psia.}$$

TMI-2 RCS BUBBLE CALC SHEET

TIME 1710 - 1800 AM PM

DATA TAKEN BY: ______

RC PRESSURE (398)

P_1 = ______ PSIG = 972 PSIA

P_2 = ______ PSIG = 1050 PSIA

ΔP = 78 PSI

RCS TEMP (394)

T_1 = 280.1 °F

T_2 = 279.7 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.4 INCHES

L_2 = 201.2 INCHES

ΔL = - 0.2 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 548.1 °F

T_2 = 557.8 °F

MAKEUP TANK LEVEL (347)

L_1 = 50.0 INCHES

L_2 = 40.1 INCHES

ΔL = ~~50.0~~ - 9.9 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78 °F

T_2 = 78 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 0.2 \times 2.515 = 0.503$ FT³

$\Delta V_{MUT} = \Delta L \times 4.244 = 9.9 \times 4.244 = 42.02$ FT³

$\Delta V_{TOTAL} = 42.52$ FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1050)(42.52)}{(78)} = 572.4 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 635 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 4-01-79

TMI-2 RCS BUBBLE CALC SHEET

TIME -1645 AM PM

DATA TAKEN BY: ______

RC PRESSURE (398)

P_1 = ______ PSIG = 962 PSIA

P_2 = ______ PSIG = 1064 PSIA

ΔP = 102 PSI

RCS TEMP (394)

T_1 = 280.7 °F

T_2 = 280.5 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.1 INCHES

L_2 = 201.1 INCHES

ΔL = 0 INCHES

PRESSURIZER TEMP ($\overset{389}{405}$)

T_1 = 548.4 °F

T_2 = 558.6 °F

MAKEUP TANK LEVEL (347)

L_1 = 45.6 INCHES

L_2 = 41.0 INCHES

ΔL = 4.6 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 75. °F

T_2 = 78 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 0 × 2.515 = 0 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 4.6 × 4.244 = 19.52 FT^3

ΔV_{TOTAL} = 19.52 FT^3

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1064)(19.52)}{(102)} = 203.6 \ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 223.8 \ FT^3 @ 875 \text{ psia.}$$

DATE

TMI-2 RCS BUBBLE CALC SHEET

TIME 1510-1550 AM PM

DATA TAKEN BY: JPM

RC PRESSURE (398)

P_1 = ______ PSIG = 955 PSIA

P_2 = ______ PSIG = 1065 PSIA

ΔP = 110 PSI

RCS TEMP (394)

T_1 = 280.9 °F

T_2 = 281.3 °F

PRESSURIZER LEVEL (1682)

L_1 = 216.8 INCHES

L_2 = 208.3 INCHES

ΔL = -8.5 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 545.9 °F

T_2 = 558.2 °F

MAKEUP TANK LEVEL (347)

L_1 = 53.3 INCHES

L_2 = 50.6 INCHES

ΔL = -2.7 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 75°F °F

T_2 = 74°F °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 8.5 \times 2.515 = 21.38$ FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 = 2.7 \times 4.244 = 11.46$ FT^3

$\Delta V_{TOTAL} = 32.84$ FT^3

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1065 \times 32.84)}{(110)} = 317 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 347 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 04·01·79

TMI-2 RCS BUBBLE CALC SHEET

TIME 1456-1505 AM PM

DATA TAKEN BY: JM

RC PRESSURE (398)

P_1 = 1055 PSIG = 1055 PSIA

P_2 = ______ PSIG = 962 PSIA
456

ΔP = 93 PSI

RCS TEMP (394)

T_1 = 280.5 °F

T_2 = 280.7 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.8 INCHES

L_2 = 210.5 INCHES
214.5/215.2

ΔL = +8.7 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 557.9 °F

T_2 = 547.0 °F

MAKEUP TANK LEVEL (347)

L_1 = 42.8 INCHES

L_2 = 42.3 INCHES

ΔL = −0.5 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 75 °F

T_2 = 75 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = +8.7 \times 2.515 = +21.88$ FT³

$\Delta V_{MUT} = \Delta L \times 4.244 = -0.5 \times 4.244 = -2.122$ FT³

$\Delta V_{TOTAL} = 19.758$ FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(962)(19.758)}{(93)} = 204 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 224 \text{ FT}^3 @ 875 \text{ psia.}$$

NOTE! THIS DATA WAS TAKEN DURING A FAIRLY RAPID DEPRESSURIZATION

DATE 4/1/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 1305-1355 AM PM

DATA TAKEN BY: JP Moore

RC PRESSURE (398)

P_1 = ______ PSIG = 967 PSIA

P_2 = ______ PSIG = 1040 PSIA

ΔP = 73 PSI

RCS TEMP (394)

T_1 = 279.8 °F

T_2 = 279.6 °F

PRESSURIZER LEVEL (1682)

L_1 = 194.3 INCHES

L_2 = 195.6 INCHES

ΔL = +1.3 INCHES

PRESSURIZER TEMP (405)

T_1 = 547.3 °F

T_2 = 558.5 °F

MAKEUP TANK LEVEL (347)

L_1 = 53.2 INCHES

L_2 = 47.3 INCHES

ΔL = −5.9 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78 °F

T_2 = 78 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = +1.3 \times 2.515 = +3.27$ FT³

$\Delta V_{MUT} = \Delta L \times 4.244 = -5.9 \times 4.244 = -25.04$ FT³

$\Delta V_{TOTAL} = -21.77$ FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1040)(21.77)}{(73)} = 310 \text{ FT}^3 \text{ @ } P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 343 \text{ FT}^3 \text{ @ 875 psia.}$$

NOTE: ADDED 400 gal Makeup After The above data was taken.

DATE

TMI-2 RCS BUBBLE CALC SHEET

TIME 1211/1238 AM PM

DATA TAKEN BY: J. Moore

RC PRESSURE (398)

P_1 = ______ PSIG = 952 PSIA

P_2 = ______ PSIG = 1049 PSIA

ΔP = 97 PSI

RCS TEMP (394)

T_1 = 279.8 °F

T_2 = 279.7 °F

PRESSURIZER LEVEL (1682)

L_1 = 196.0 INCHES

L_2 = 192.9 INCHES

ΔL = -3.1 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 545.7 °F

T_2 = 557.2 °F

MAKEUP TANK LEVEL (347)

L_1 = 51.6 INCHES

L_2 = 43.7 INCHES

ΔL = -7.9 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 75. °F

T_2 = 77 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 3.1 \times 2.515 = 7.8$ FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 = 7.9 \times 4.244 = 33.53$ FT^3

$\Delta V_{TOTAL} = 41.33$ FT^3

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1049)(41.33)}{(97)} = 447 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 486 \text{ FT}^3 @ 875 \text{ psia.}$$

Confirming Calc on
4/1/79 1238 DATA

① $\frac{1049}{452-1049} = -10.814$

② $3.178\left[\frac{.0172}{.02199}(192.9) - \frac{.0172}{.02159}(196.0)\right] = -16.73$

③ $4.128\left(\frac{.0172}{.01606}\right)(-51.6+43.7) = -34.91$

④ $(6.166\times10^{5})(9\times10^{-6})(-279.8+279.7) = -.55$

⑤ $(6.166\times10^{5})(-10^{-7})(97) = -5.98$

⑥ $6.166\times10^{5}(5.839\times10^{-7})(97) = 34.92$

$① [② + ③ - ④ - ⑤ + ⑥] =$

$-10.814\left[-16.73 - \cancel{34.91} + [.55] + [-5.98] + \overset{.01}{34.92}\right]$

$\boxed{170.45}$

DATE

TMI-2 RCS BUBBLE CALC SHEET

TIME 1044/1140 AM PM

DATA TAKEN BY: J Moore

1

RC PRESSURE (398)
P_1 = ______ PSIG = 956 PSIA
P_2 = ______ PSIG = 1056 PSIA
ΔP = 100 PSI

RCS TEMP (394)
T_1 = 280 °F
T_2 = 279.8 °F

PRESSURIZER LEVEL (1682)
L_1 = 196.8 INCHES
L_2 = 192.4 INCHES
ΔL = -4.4 INCHES

PRESSURIZER TEMP (~~405~~ 389)
T_1 = 546.2 °F
T_2 = 557.9 °F

MAKEUP TANK LEVEL (347)
L_1 = 52.6 INCHES
L_2 = 42.4 INCHES
ΔL = -10.2 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)
T_1 = 79 °F
T_2 = 77 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = -4.4 \times 2.515 = 11.07$ FT³
$\Delta V_{MUT} = \Delta L \times 4.244 = -10.2 \times 4.244 = 43.29$ FT³
$\Delta V_{TOTAL} = 54.36$ FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1056 \times 54.36)}{(100)} = 574 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 627 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE

TMI-2 RCS BUBBLE CALC SHEET

TIME 0946/1020 AM PM

DATA TAKEN BY: J Moore

RC PRESSURE (398)

P_1 = ______ PSIG = 953 PSIA

P_2 = ______ PSIG = 1056 PSIA

ΔP = 103 PSI

RCS TEMP (394)

T_1 = 280.2 °F

T_2 = 281.2 °F

PRESSURIZER LEVEL (1682)

L_1 = 196.5 INCHES

L_2 = 193 INCHES

ΔL = -3.5 INCHES

PRESSURIZER TEMP (~~405~~) 389

T_1 = 545.3 °F

T_2 = 557.9 °F

MAKEUP TANK LEVEL (347)

L_1 = 53.4 INCHES

L_2 = 44.9 INCHES

ΔL = -8.5 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78. °F

T_2 = 79 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 3.5 × 2.515 = 8.80 FT³

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 8.5 × 4.244 = 36.07 FT³

ΔV_{TOTAL} = 44.87 FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1056 \times 44.87)}{(103)} = 460 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 501 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 4/1/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 0825/0903 [✓ AM] PM

DATA TAKEN BY:

RC PRESSURE (398)

P_1 = ______ PSIG = 945 PSIA

P_2 = ______ PSIG = 1050 PSIA

ΔP = 105 PSI

RCS TEMP (394)

T_1 = 280.5 °F

T_2 = 280.5 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.2 INCHES

L_2 = 192.6 INCHES

ΔL = 8.6 INCHES

PRESSURIZER TEMP (~~405~~ 384)

T_1 = 544.6 °F

T_2 = 557.1 °F

MAKEUP TANK LEVEL (347)

L_1 = 50.7 INCHES

L_2 = 45.3 INCHES

ΔL = 5.4 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78 °F

T_2 = 75 °F

LANCASTER

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = 8.6 × 2.515 = 21.63 FT³

$\Delta V_{MUT} = \Delta L \times 4.244$ = 5.4 × 4.244 = 22.92 FT³

ΔV_{TOTAL} = 44.5 FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1050 \times 44.5)}{(105)} = 445.5 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = \text{~~445.5~~ } 534.6 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 4/1/79

TMI-2 RCS BUBBLE CALC SHEET

TIME →0731 [✓ AM] PM

DATA TAKEN BY:

RC PRESSURE (398)

P_1 = ____ PSIG = 971 PSIA

P_2 = ____ PSIG = 1055 PSIA

ΔP = 84 PSI

RCS TEMP (394)

T_1 = 280.1 °F

T_2 = 280.1 °F

PRESSURIZER LEVEL (1682)

L_1 = 196.0 INCHES

L_2 = 193.0 INCHES

ΔL = 3.0 INCHES

PRESSURIZER TEMP (405)

T_1 = 545.9 °F

T_2 = 557.7 °F

MAKEUP TANK LEVEL (347)

L_1 = 49.1 INCHES

L_2 = 42.1 INCHES

ΔL = 7.0 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 73. °F

T_2 = 73 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 3.0 \times 2.515 = 7.54$ FT³

$\Delta V_{MUT} = \Delta L \times 4.244 = 7.0 \times 4.244 = 29.71$ FT³

$\Delta V_{TOTAL} = 37.25$ FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1055 \times 37.25)}{(84)} = 467 \text{ FT}^3 \text{ @ } P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 564 \text{ FT}^3 \text{ @ } 875 \text{ psia.}$$

Repressurize Time 23 mi

Start 0731 Stop 0754

3.6 $\frac{psi}{min}$

DATE 4/1/7

TMI-2 RCS BUBBLE CALC SHEET

TIME 0620 [✓ AM] PM

DATA TAKEN BY: OAT

RC PRESSURE (398)

P_1 = ______ PSIG = 960 PSIA

P_2 = ______ PSIG = 1053 PSIA

ΔP = 93 PSI

RCS TEMP (394) 1088

T_1 = 280.6 °F

T_2 = ______ °F

PRESSURIZER LEVEL (1682)

L_1 = 200.6 INCHES

L_2 = 192.7 INCHES

ΔL = 7.9 INCHES

PRESSURIZER TEMP (405)

T_1 = ~~557.9~~ °F 545.9

T_2 = 551.9 °F

MAKEUP TANK LEVEL (347)

L_1 = 46.1 INCHES

L_2 = 39.1 INCHES

ΔL = 7.0 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 72.0 °F 5

T_2 = 70° °F 53.

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 7.9 \times 2.515 = 19.9\ FT^3$

$\Delta V_{MUT} = \Delta L \times 4.244 = 7.0 \times 4.244 = 32.4\ FT^3$

$\Delta V_{TOTAL} = 52.144\ FT^3$

$$V_1 = \frac{P_2\,\Delta V_{TOT}}{P_2 - P_1} = \frac{(1053 \times 52.14)}{(93)} = 590\ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 710\ FT^3 @ 875\ psia.$$

944 - 4411

Repressurization Time

Start 0620 Stop 0655 $\frac{35}{min}$

2.67 $\frac{psi}{min}$

DATE ____

TIME 4:55 [✓ AM] PM

DATA TAKEN BY: DDF

TMI-2 RCS BUBBLE CALC SHEET

RC PRESSURE (398) 926

P_1 = ____ PSIG = ~~446~~ PSIA

P_2 = ____ PSIG = 1056 PSIA

ΔP = 130 PSI

RCS TEMP (394)

T_1 = 279.8 °F

T_2 = 280.5 °F

PRESSURIZER LEVEL (1682)

L_1 = 209.9 INCHES

L_2 = ~~202.8~~ ~~201.9~~ ~~204.7~~ ~~209.1~~ 200.1 INCHES

ΔL = 9.8 INCHES

PRESSURIZER TEMP (405)

T_1 = 543.2 °F

T_2 = 558 °F

MAKEUP TANK LEVEL (347)

L_1 = 59.9 INCHES

L_2 = 50.1 INCHES

ΔL = 8.8 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78 °F

T_2 = 72 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = 9.8 × 2.515 = 24.6 FT³

$\Delta V_{MUT} = \Delta L \times 4.244$ = 8.8 × 4.244 = 37.3 FT³

ΔV_{TOTAL} = 61.9 FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1056)(61.9)}{(130)} = 502.8 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 605.8 \text{ FT}^3 @ 875 \text{ psia.}$$

5|0800
5|0844

Repressurization Time 44 min

Start 0455 Stop 0539

$\frac{130\#}{44 \text{ min}}$

DATE 4/1/79

TIME ~~0405~~/0425 [✓ AM] PM

TMI-2 RCS BUBBLE CALC SHEET

DATA TAKEN BY: OAF

RC PRESSURE (398)

P_1 = ____ PSIG = 957 PSIA

P_2 = ____ PSIG = 1055 PSIA

ΔP = 98 PSI

RCS TEMP (394)

T_1 = 280 °F

T_2 = 279.4 °F

PRESSURIZER LEVEL (1682)

L_1 = 195.1 INCHES

L_2 = 192.7 INCHES

ΔL = 2.4 INCHES

PRESSURIZER TEMP (389 ~~405~~)

T_1 = 545.7 °F

T_2 = 557.9 °F

MAKEUP TANK LEVEL (347)

L_1 = 53.3 INCHES

L_2 = 39.6 INCHES

ΔL = 13.7 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 72 °F

T_2 = 70 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 2.4 × 2.515 = 6.04 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 13.7 × 4.244 = 58 FT^3

ΔV_{TOTAL} = 64.2 FT^3

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1055 \times \quad)}{(98)} = 696.9 \text{ FT}^3 \text{ @ } P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 833.1 \text{ FT}^3 \text{ @ } 875 \text{ psia.}$$

S 0403

S 0425

Repressurization Time 22min

Start 0403 Stop 0425

$\frac{\Delta P}{min} = \frac{98}{22 \, min}$

DATE 4/11/7

TMI-2 RCS BUBBLE CALC SHEET

TIME 0321 [✓ AM] PM

DATA TAKEN BY: MAF

RC PRESSURE (398)

P_1 = ~~960~~ PSIG = 960 PSIA

X P_2 = ______ PSIG = 1058 PSIA

ΔP = 98 PSI

RCS TEMP (394)

T_1 = 279.9 °F

T_2 = 280.1 °F

PRESSURIZER LEVEL (1682)

L_1 = 199.3 INCHES

X L_2 = 192.3 INCHES

ΔL = 7.0 INCHES

PRESSURIZER TEMP (~~405~~ 389)

T_1 = 546.3 °F

X T_2 = 558.4 °F

MAKEUP TANK LEVEL (347)

X L_1 = 47.5 INCHES

L_2 = 37.2 INCHES

ΔL = 10.3 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 72 °F

T_2 = ______ °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 7.0 × 2.515 = 17.6 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 10.3 × 4.244 = 43.7 FT^3

ΔV_{TOTAL} = 61.3 FT^3

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1058 \times 61.3)}{(98)} = 661.9 \ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 806.3 \ FT^3 @ 875 \text{ psia.}$$

S 0253

S 0321

Repressurization Time ~~[illegible]~~ 30 min

Start 0253

Stop 0321

$\Delta P/min$

DATE 4/1/79

TIME 0200/0230 [✓ AM] PM

TMI-2 RCS BUBBLE CALC SHEET

DATA TAKEN BY: DAF

RC PRESSURE (398)

P_1 = ~~956~~ PSIG = 956 PSIA

P_2 = ~~1056~~ PSIG = 1050 PSIA

ΔP = 94 PSI

RCS TEMP (394)

T_1 = 279.5 °F

T_2 = 279.3 °F

PRESSURIZER LEVEL (1682)

L_1 = 196.2 INCHES

L_2 = 192.2 INCHES

ΔL = 4.0 INCHES

PRESSURIZER TEMP (405)

T_1 = 545.6 °F

T_2 = 557.0 °F

MAKEUP TANK LEVEL (347)

L_1 = 59.9 INCHES

L_2 = 47.9 INCHES

ΔL = 12.0 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 73° °F

T_2 = 75° °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 = 4 \times 2.515 = 10.1\ FT^3$

$\Delta V_{MUT} = \Delta L \times 4.244 = 12 \times 4.244 = 50.9\ FT^3$

$\Delta V_{TOTAL} = 61.0\ FT^3$

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1050 \times 61.0)}{(94)} = 681.7\ FT^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 818.03\ FT^3 @ 875\ psia.$$

5/0205
0225

Repressurization Time 20min
Start 0205 Stop 0225
$\frac{\Delta p}{min}$

DATE 8 4/1/79

TMI-2 RCS BUBBLE CALC SHEET

TIME 0104 AM PM

DATA TAKEN BY: JAF

1:00

RC PRESSURE (398)

P_1 = ______ PSIG = 958 PSIA

P_2 = ______ PSIG = 1008 PSIA

ΔP = 50 PSI

RCS TEMP (394)

T_1 = 279.4 °F (*)

T_2 = ______ °F

PRESSURIZER LEVEL (1682)

L_1 = 193 INCHES

L_2 = 191.9 INCHES

ΔL = 1.1 INCHES

PRESSURIZER TEMP (405)

T_1 = 546.1 °F (*)

T_2 = ______ °F

MAKEUP TANK LEVEL (347)

L_1 = 41.8 INCHES

L_2 = 33.4 INCHES

ΔL = 8.4 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 78 °F

T_2 = ______ °F (*)

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 1.1 × 2.515 = 2.77 FT³

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 8.4 × 4.244 = 35.65 FT³

ΔV_{TOTAL} = 38.42 FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1008 \times 38.42)}{(50)} = 774.6 \text{ FT}^3 \text{ @ } P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 848.1 \text{ (*) FT}^3 \text{ @ 875 psia.}$$

(*) Note: MUT refilled so test period cut short (data not informed)

@ 33.4 1008 191.9

Repressurization Time
NA (*)

1:23

add ~~458.~~ 465

41.4 / 1058 192.3 [illegible]

DATE 3/31

TMI-2 RCS BUBBLE CALC SHEET

TIME 2355 AM PM

DATA TAKEN BY: MSW

RC PRESSURE (398)

P_1 = ______ PSIG = 958 PSIA

P_2 = ______ PSIG = 1057 PSIA

ΔP = 99 PSI

RCS TEMP (394)

T_1 = 278.4 °F

T_2 = 279.0 °F

PRESSURIZER LEVEL (1682)

L_1 = 197.0 INCHES

L_2 = 192.0 INCHES

ΔL = 5.0 INCHES

389

PRESSURIZER TEMP (405)

T_1 = 546.5 °F

T_2 = 557.8 °F

MAKEUP TANK LEVEL (347)

L_1 = 52.1 INCHES

L_2 = 40.6 INCHES

ΔL = 11.5 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 81. °F

T_2 = 79 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 5.0 × 2.515 = 12.6 FT³

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 11.5 × 4.244 = 48.8 FT³

ΔV_{TOTAL} = 61.38 FT³

$$V_1 = \frac{P_2\,\Delta V_{TOT}}{P_2 - P_1} = \frac{(1057 \times 61.38)}{(99)} = 655.34 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = \cancel{655.34}\ 717.13 \text{ FT}^3 @ 875 \text{ psia.}$$

$$\frac{2353}{0018}$$

2353 Repressurization
0018 Time 25 min
Start 2353
Stop 0018

DATE 3/31

TIME 2245 AM PM

TMI-2 RCS BUBBLE CALC SHEET

DATA TAKEN BY: RSW

RC PRESSURE (398)

P_1 = ______ PSIG = 955 PSIA

P_2 = ______ PSIG = 1050 PSIA

ΔP = 95 PSI

RCS TEMP (394)

T_1 = 277.6 °F

T_2 = 277.1 °F

PRESSURIZER LEVEL (1682)

L_1 = 196.4 INCHES

L_2 = 192.4 INCHES

ΔL = 4.0 INCHES

PRESSURIZER TEMP (405)

T_1 = 545.6 °F

T_2 = 556.9 °F

MAKEUP TANK LEVEL (347)

L_1 = 50.1 INCHES

L_2 = 35.0 INCHES

ΔL = 15.1 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 81. °F

T_2 = 81 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 4.0 × 2.515 = 10.06 FT³

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 15.1 × 4.244 = 64.08 FT³

ΔV_{TOTAL} = 74.14 FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1050)(74.14)}{(95)} = 819.4 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 894.4 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE

TMI-2 RCS BUBBLE CALC SHEET

TIME 2139 AM PM

DATA TAKEN BY: RSW

RC PRESSURE (398)

P_1 = ______ PSIG = 955 PSIA

P_2 = ______ PSIG = 1046 PSIA

ΔP = 91 PSI

RCS TEMP (394)

T_1 = 278.2 °F

T_2 = 277.7 °F

PRESSURIZER LEVEL (1682)

L_1 = 196.0 INCHES

L_2 = 192.2 INCHES

ΔL = 3.8 INCHES

PRESSURIZER TEMP (405)

T_1 = 545.6 °F

T_2 = 556.6 °F

MAKEUP TANK LEVEL (347)

L_1 = 49.5 INCHES

L_2 = 33.0 INCHES

ΔL = 16.5 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 81 °F

T_2 = 81 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = 3.8 × 2.515 = 9.56 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244$ = 16.5 × 4.244 = 70.03 FT^3

ΔV_{TOTAL} = 79.6 FT^3

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1046)(79.6)}{(91)} = 914.8 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 998.5 \text{ FT}^3 @ 875 \text{ psia.}$$

TMI-2 RCS BUBBLE CALC SHEET

DATE 5/31

TIME 2030 AM PM

DATA TAKEN BY: PSL

RC PRESSURE (398)

P_1 = ______ PSIG = 953 PSIA

P_2 = ______ PSIG = 1053 PSIA

ΔP = 100 PSI

RCS TEMP (394)

T_1 = 228.7 °F

T_2 = 228.3 °F

PRESSURIZER LEVEL (1682)

L_1 = 193.9 INCHES

L_2 = 191.0 INCHES

ΔL = 2.9 INCHES

PRESSURIZER TEMP (405)

T_1 = 545.6 °F

T_2 = 557.4 °F

MAKEUP TANK LEVEL (347)

L_1 = 48.4 INCHES

L_2 = 34.4 INCHES

ΔL = 14.0 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 81 °F

T_2 = 81 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 2.9 × 2.515 = 7.29 FT³

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 14.0 × 4.244 = 59.42 FT³

$\Delta V_{TOTAL} =$ 66.7 FT³

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1053)(66.7)}{(100)} = 702.5 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 765.1 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 3/31

TMI-2 RCS BUBBLE CALC SHEET

TIME 1925 AM PM

DATA TAKEN BY: PSW

RC PRESSURE (398)

P_1 = ______ PSIG = 966 PSIA

P_2 = ______ PSIG = 1049 PSIA

ΔP = 83 PSI

RCS TEMP (394)

T_1 = 278.3 °F

T_2 = 278.3 °F

PRESSURIZER LEVEL (1682)

L_1 = 205.2 INCHES

L_2 = 191.0 INCHES

ΔL = 14.2 INCHES

PRESSURIZER TEMP (405)

T_1 = 547.1 °F

T_2 = 556.8 °F

MAKEUP TANK LEVEL (347)

L_1 = 41.8 INCHES

L_2 = 35.0 INCHES

ΔL = 6.8 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 82 °F

T_2 = 82 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = 14.2 × 2.515 = 35.713 ~~28.85~~ FT^3

$\Delta V_{MUT} = \Delta L \times 4.244$ = 6.8 × 4.244 = 28.85 FT^3

ΔV_{TOTAL} = 64.57 ~~57.71~~ FT^3

$V_1 = \dfrac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \dfrac{(1049)(\overset{64.57}{\cancel{57.71}})}{(83)}$ = 816.1 ~~729.5~~ FT^3 @ P_1

$V_{1(875)} = (V_1 \text{ at } P_1)\left(\dfrac{P_1}{875}\right)$ = 901.0 ~~805.3~~ FT^3 @ 875 psia.

DATE 5/31

TMI-2 RCS BUBBLE CALC SHEET

TIME 1735 AM PM

DATA TAKEN BY: PSW

RC PRESSURE (398)

P_1 = ______ PSIG = 946 PSIA

P_2 = ______ PSIG = 1046 PSIA

ΔP = 100 PSI

RCS TEMP (394)

T_1 = 279.4 °F

T_2 = 279.1 °F

PRESSURIZER LEVEL (1682)

L_1 = 201.0 INCHES

L_2 = 191.6 INCHES

ΔL = 9.4 INCHES

PRESSURIZER TEMP (405)

T_1 = 545.0 °F

T_2 = 556.7 °F

MAKEUP TANK LEVEL (347)

L_1 = 46.9 INCHES

L_2 = 37.0 INCHES

ΔL = 9.9 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = 81. °F

T_2 = 81 °F

$\Delta V_{PZR} = \Delta L \cdot 2.515 =$ 9.4 × 2.515 = 23.64 FT^3

$\Delta V_{MUT} = \Delta L \times 4.244 =$ 9.9 × 4.244 = 42.0 FT^3

ΔV_{TOTAL} = 65.64 FT^3

$$V_1 = \frac{P_2 \Delta V_{TOT}}{P_2 - P_1} = \frac{(1046)(65.64)}{(100)} = 686.6 \text{ FT}^3 @ P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 742.3 \text{ FT}^3 @ 875 \text{ psia.}$$

DATE 3/31
TIME 1619 AM PM
DATA TAKEN BY: PSL
Checked JBM 3/31/79

TMI-2 RCS BUBBLE CALC SHEET

RC PRESSURE (398)
P_1 = ______ PSIG = 949 PSIA
P_2 = ______ PSIG = 1046 PSIA
ΔP = 97 PSI

RCS TEMP (394)
T_1 = 278.3 °F
T_2 = 279.2 °F

PRESSURIZER LEVEL (1682)
L_1 = 197.3 INCHES
L_2 = 191.7 INCHES
ΔL = 5.6 INCHES

PRESSURIZER TEMP (405)
T_1 = 544.9 °F
T_2 = 556.7 °F

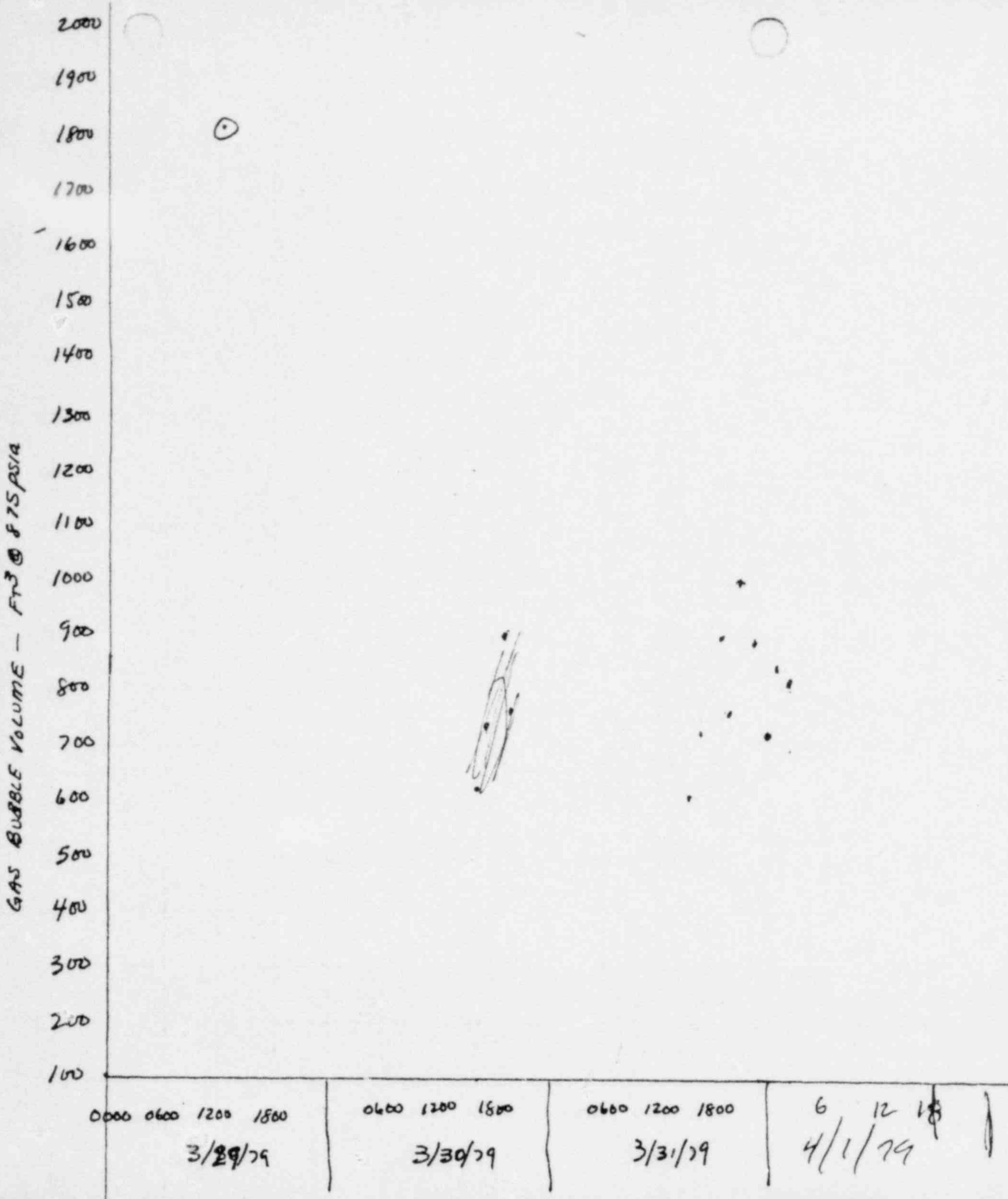
MAKEUP TANK LEVEL (347)
L_1 = 42.2 INCHES
L_2 = 33.0 INCHES
ΔL = 9.2 INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)
T_1 = — °F
T_2 = — °F

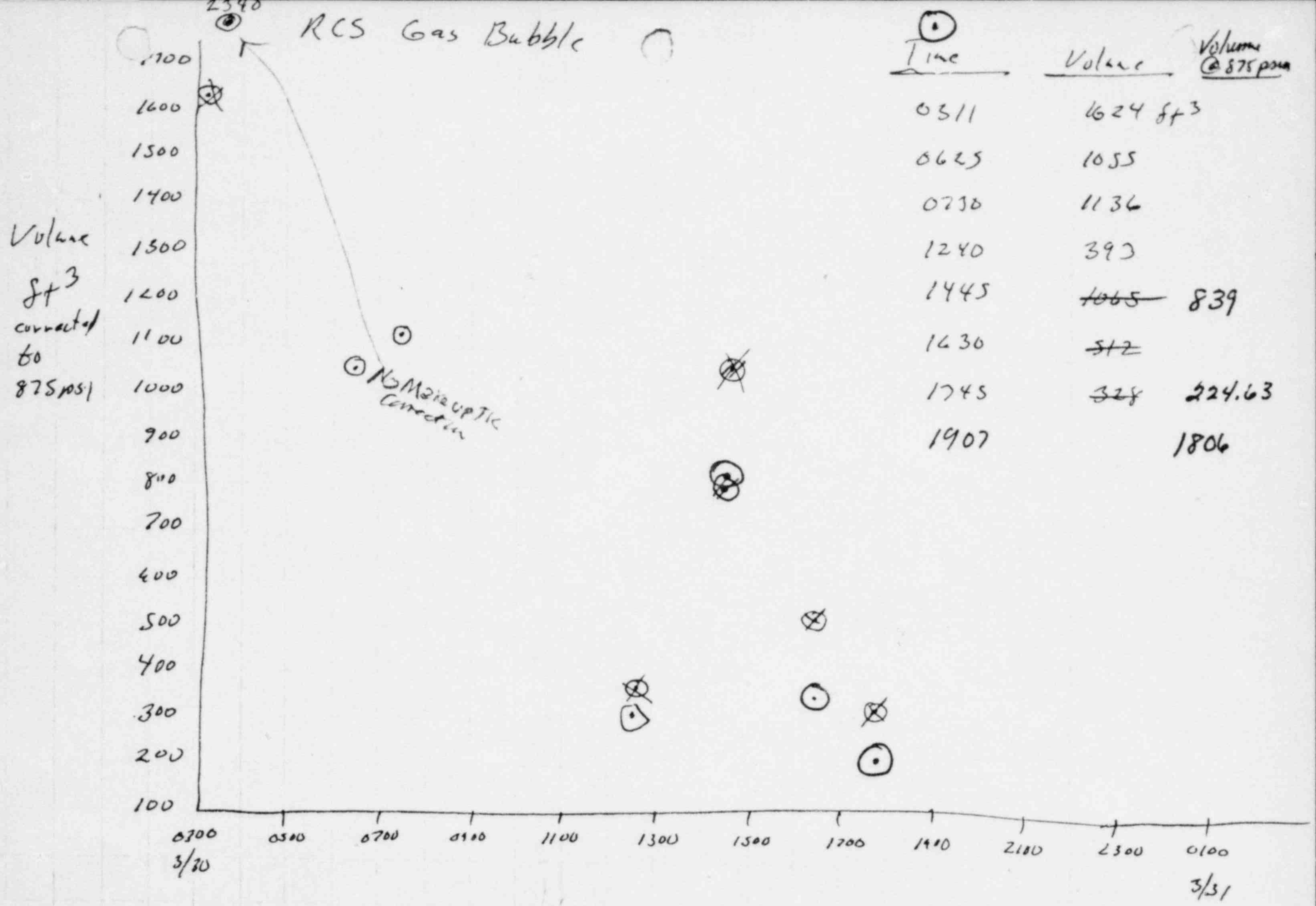
$\Delta V_{PZR} = \Delta L \cdot 2.515 = 5.6 \times 2.515 = 14.08$ FT³
$\Delta V_{MUT} = \Delta L \times 4.244 = 9.2 \times 4.244 = 39.04$ FT³
$\Delta V_{TOTAL} = 53.13$ FT³

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(1046)(53.13)}{(97)} = 572.9 \text{ FT}^3 \text{ @ } P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = 621.4 \text{ FT}^3 \text{ @ 875 psia.}$$

GAS BUBBLE VOLUME — FT³ @ 875 psia
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0000 0600 1200 1800
3/29/79
0600 1200 1800
3/30/79
0600 1200 1800
3/31/79
6 12 18
4/1/79

RCS Gas Bubble



⊙ Time	Volume	Volume @ 875 psia
0311	1624 ft³	
0625	1055	
0730	1136	
1240	393	
1445	~~1065~~	839
1630	~~512~~	
1745	~~328~~	224.63
1907		1806

point 347

Time	Pressure	Level		Temp		Flow	
	Pzr	Pzr	MU Tank	RCS	Pzr	Letdown	Seal
1907	1005	216.0	56	279.9	551.4	—	19
1909	1005	216.0	56	279.9	551.4	—	19
1911	1005	215.7	54	279.9	551.4	—	19
1913	1006	215.8	54	279.8	551.6	—	19
2017	1029	215.0	47"	279.5 ~~291.4~~	554.5	—	19
2020	1031	215.4	46"	279.4	555.1	—	19
2029	1043	215.8	44"	279.4	556.5	—	19
2030	1043	216.0	43.5"	279.4	556.5	—	19
2031	1042	216.5	43.5	279.4	556.4	—	19
			before				
	1017						
	1070	215.6	44.5	281.2 ~~280~~	553.7		

3/31/79 0630

Jgm
3/31/79

	Pzr	MU
L_1	215.8	41.8
	~~Not Recorded~~!	
L_2	233.1	41.0
ΔL	+ 17.3"	$\Delta L = -0.8"$

$P_1 = 1038$
$P_2 = 983$ } assumed to be psia Jgm
$\Delta P = 55$ psi

$\Delta V_{pzr} = +(17.3)(2.515) = 43.51\ ft^3$

$\Delta V_{mu} = -(0.8)(4.244) = 3.4\ ft^3$

~~NOTE~~
~~Original Calcs used difference between these volumes, indicating that one volume increased and the other decreased – Can't be confirmed since data wasn't recorded.~~

OK - See Raw Data Jgm

$\Delta V_{Total} = 43.51 - 3.4 = 40.11\ ft^3$

$V_1 = \dfrac{(983)(40.11)}{55} = 716.9\ ft^3$ @ 1038 psi

$V_1 = (716.9)\dfrac{(1038)}{(875)} = 850\ ft^3$ @ 875 psi

$P_1 =$ 1038 psia $T_1 = 280.°$ 0630

$P_2 =$ 983 psia   3/31

$P_1 V_1 = P_2 V_2$

$= P_2 (V_1 + \Delta V)$

.8 in × 4 $\frac{ft^3}{in}$ 3.2 cuft   MWT

17.3 in × 3.2 $\frac{ft^3}{in}$ 55. cuft.

55 - 3.2 = 51.8 cuft

$\frac{1038}{(55)}$ 51.8 cuft = ΔV $\frac{1}{T}$ = 977 cuft.

526 cuft

Compare $\frac{1038}{875}$ 977 = 1098.3 cuft. @ 875 #/psia

Questions from Gronsberger

1. H_2 Recombiner when will it be ready

2. H_2 Concentration & Activity in <u>70R</u> Gas Decay Tank

3. Gas Decay Tank line disch. filter is plugged dirt or activity can someone get close to it?

4. Portable Rad. Monitors for Radwaste gas tanks

<u>Tag Nos.</u>

		<u>Elev.</u>
HP-R-223	Spent Fuel Area	347'-6"
-224	Aux. Bldg.	280'-6"

~~2303 03~~ 0630 3/31

					1025	1032
394	RCS T	280.4	280.3	280.3	~~279.7~~	~~279.5~~
1612	Pzr LL	215.8	233.1	232.5	~~190.7~~	~~187.0~~
0389	Press T	554.2	547.1	547.1	~~549.9~~	~~550.8~~
SA100	M/U level	41.8	41.0	41.2	fn. ~~39.1~~	~~39.0~~
398	RCS Pr	1025	967.	968	~~988~~	~~976~~
	M/U TK T	78°	77°	77	~~79~~	~~79~~

3/31/79 1032/1039

3/31/79

Pzr	MU	Press
L_1 = 187.0	39.0	P_1 = 995 psi
L_2 = 201.9	39.0	P_2 = 948 psi
ΔL = +14.9"	ΔL = 0	ΔP = 47 psi

} assumed to be psia

$$\Delta V = +(14.9)(2.515) = 37.4_x735 \text{ ft}^3$$

$$V_1 = \frac{(948)(37.4_x735)}{(47)} = 755.85 \text{ ft}^3 \text{ @ } 995 \text{ psi}$$

$$V_1 = (755.85)\left(\frac{995}{875}\right) = 859.5 \text{ ft}^3 \text{ @ } 875 \text{ psi}$$

RCS Bubble Calculation 3/31/79

Time	Level		Pressure	Temp		
	Pzn	MUT	Pzn	RCS	Pzn	MUT
1037	187.0	39.0	995	279.8	550.8	79
1039	201.9	39.0	948	280.2	544.5	80
	ΔL 14.9"	0	47 psi			

~~$\Delta V = 14.9'' \times 3.2\ ft^3/in = 47.68\ ft^3$~~

~~$V_1 = \frac{P_2 \Delta V}{\Delta P} = \frac{948\ (47.68)}{47} = 961.7$ @ 995 psi~~

~~$V_1 = 961.7 \times \frac{995}{875} = 1093.6$ psi @ 875~~

See Revised Calcs
3/31/79 JPM

3/31/79
1351

RCS Bubble Calc 3/31/79 1351 P. Walsh.

	L_{PZR}	P_{RCS}	T_{RCS}	[illegible]	L_{MUT}
1351	197.4	954	279.7	534.6	45.9
~~1352~~	~~196.2~~	~~961~~	~~279.8~~	~~534.6~~	~~45.9~~
1425	190.8	1046	280.0	534.6	33.1
	6.6	92			12.8"

Correction to RCS temp

$\Delta Vol_{PZR} = 6.6'' \times 3.2\ ft^3/in = 21.1 \qquad \frac{.0173}{.022} = 16.6\ ft^3$

$\Delta Vol_{MUT} = 12.8 \times 4\ ft^3/in = 51.2 \qquad \frac{.0173}{.0163} = 54.3\ ft^3$

$\Delta V_{Total} = 70.94\ ft^3$

$\Delta P = 92\ psi$

$$V_1 = \frac{P_2 \Delta V}{\Delta P} = \frac{1046(70.94)}{92} = 806.6\ ft^3$$

@ 954

$$V_1 = 806.6\left(\frac{954}{875}\right) = 879.4\ ft^3$$

$\Delta V_{PZR} = -(6.6)(2.515) = -16.6$

$\Delta V_{MUT} = -(12.8)(4.244) = -54.3$

$\Delta V_{Total} = -70.9$

$$V_1 = \frac{(1046)(70.9)}{92} = 806.6$$

Check on

3/31/79

About 1300 3/29/79 Per J. Floyd

Pzr
$L_1 = 373$
$L_2 = 325$
$\Delta L = -48''$

MUTK
$L_1 = 52''$
$L_2 = 38''$
$\Delta L = 14''$

$P_1 = 875$ psia
$P_2 = 970$ psia
$\Delta P = 95$ psi

$\Delta L_{pzr} = -48''$ $\quad \Delta V_{pzr} = (-48)(\overset{2.515}{\cancel{4.244}}) = -\overset{-120.72}{\cancel{12.072}}$

$\Delta L_{MU} = -14''$ $\quad \Delta V_{MU} = (-14)(4.244) = -59.416$

$\Delta V_{TOT} = \cancel{71.488}$ 180.136

$$V_1 = \frac{P_2 \Delta V}{P_1 - P_2} = \frac{(970)(\overset{180.136}{\cancel{71.488}})}{95} = \boxed{\begin{matrix}1839.3 \\ \cancel{729.9}\ ft^3\end{matrix}}$$

~~2311~~ 1300

RC System

Size of ~~Pressurizer~~ Gas Bubble
Outside the Pressurizer

(T=0311)

3/30/79
J Moore

Temp was about 280°F at this time per Jim Floyd.

Data taken about 14 hrs ago

(Time ~ 1300 3/29/79)

$L_1 = 373''$
$L_2 = 325''$
$\Delta L = 48''$

$P_1 = 860 \text{ psig} = 875 \text{ psia}$
$P_2 = 955 \text{ psig} = 970 \text{ psia}$
$\Delta P = 95 \text{ psi}$

Pressurizer Capacitance = 3.2 ft³/in.

$\Delta V = 48 \times 3.2 = 153.6$

$$P_1 V_1 = P_2 V_2$$
$$V_2 = V_1 + \Delta V$$

$$P_1 V_1 = P_2 (V_1 + \Delta V)$$
$$P_1 V_1 = P_2 V_1 + P_2 \Delta V$$

$$V_1 (P_1 - P_2) = P_2 \Delta V$$

$$V_1 = \frac{P_2 \Delta V}{P_1 - P_2}$$

$$V_1 = \frac{\overset{229.2}{153.6} \times 970}{95} = \underset{2340.3 \text{ ft}^3}{1568 \text{ ft}^3}$$

See Next.

$\Delta V_{pzr} = 153.6 \text{ ft}^3$
$\Delta V_{MU\ Tank} = 56 \text{ ft}^3 \times 1.35$
$= 75.6 \text{ ft}^3$
$\text{Total } \Delta V = 229.2$

See Revised Calcs dated 3/31/79 JM.

Volume of head = 800 ft³ per B&W

RV diameter = 14 ft.

The MU Tank level dropped during this time period

3/30/79

MU Tank Δ Volume

L_1 52"
L_2 38"
ΔL = 14"

$$\frac{\Delta V}{\Delta L} = 30 \text{ gal/inch}$$

$$14 \times 30 = \frac{420 \text{ gal}}{7.481 \frac{\text{gal}}{ft^3}} = 56 \; ft^3$$

$$V_1 = 1568 \; ft^3 + 56 \; ft^3 = 1624 \; ft^3$$

Total Volume Above RV Nozzles = 5855 ft^3

RV outlet plenum	158
" upper "	411
" " Head	560
	1129 ft^3

Doesn't include CRDM volume

Rec'd from B&W
0325 3/30/79

This includes total volume of RV head, RC Loops, Pressurizer etc above the Rtr Coolant Loops.

RC Bubble Size Calcs

Data Taken: 0625/3-30-79
Moore

$L_1 = 356.2''$ $P_1 = 1065$ psig $= 1080$ psia

$L_2 = 352.3$ $P_2 = 1081$ psig $= 1096$ psia

$\Delta L = -3.9''$ $\Delta P = 16$ psi

$$V_1 = \frac{P_2 \, \Delta V}{P_1 - P_2}$$

$$\Delta V = 3.2 \frac{ft^3}{in} \times 3.9\ in = 12.48\ ft^3$$

$$V_1 = \frac{(1096)(12.48)}{16} = 854.88\ ft^3 \text{ @ } 1080\ psia$$

$$= 854.88 \times \frac{1080}{875} = 1055\ ft^3 \text{ @ } 875\ psia$$

Note: 3/31/79

3/31/79 JJM

I believe that there was little or no change in the MU Tank Level during these measurements. ∴ The calc below is based on zero MU Tank Level Change.

~~ΔV = (12.48)([illegible])~~

$$\Delta V = -(\overset{3.9}{\cancel{12.48}})(2.515) = -\overset{9.8\ ft^3}{\cancel{31.3872}}$$

$$V_1 = \frac{(1096)(9.8)}{16} = 671.3\ ft^3 \text{ @ } 1080\ psia$$

$$V_1 = 671.3 \left(\frac{1080}{875}\right) = 828.576\ ft^3 \text{ @ } 875\ psia$$

03/30/79 0730 AM

3/31/79

Pzr	MU Tk
$L_1 = 360$	?
$L_2 = 390$	
$\Delta L = +30''$	

$P_1 = 1150$
$P_2 = 1035$
$\Delta P = 115$

$\left.\begin{matrix} P_1 \\ P_2 \end{matrix}\right\}$ assumed to be psia

$$\Delta V_{pzr} = +(30'')(2.515) = 75.45\ ft^3$$

$$V_1 = \frac{(1035)(75.45)}{115} = 679.1\ ft^3 @ 1150\ psia$$

$$V_1 = \left(\frac{1150}{875}\right)(679.1) = 892.5\ ft^3 @ 875\ psia.$$

0730 AM
3/30/79

RCS Bubble Calculation

From recordings on control panel

360 1150 7:30 am 3/30

390 1035

$\Delta L = 30''$ $\Delta p = 115$

$$\Delta V = 30'' \times \overset{3.2}{\cancel{3.9}}\ ft^3/in = \overset{96}{\cancel{117}}\ ft^3$$

$$V_1 = \frac{P_2 \Delta V}{P_1 - P_2} \qquad V = \frac{1035\ (\overset{96}{\cancel{117}}\ ft^3)}{115}$$

$$V_1 = \overset{864}{\cancel{1053}}\ ft^3 \ @\ 1150\ psia$$

$$V_1 = \frac{\overset{864}{\cancel{1053}}}{875} \times 1150 = \overset{1136}{\cancel{1384}}\ ft^3$$

@ 875 psia

3/30/79 1240/1340

$\Delta L_{pzr} = -22.1''$

$\Delta V_{pzr} = (-22.1)(2.515) = -55.58\ ft^3$

$\Delta L_{mu} = +15''$

$\Delta V_{mu} = (+15)(4.244) = +63.66$

$\Delta V_{TOT} = 8.08\ ft^3$

$V_1 = \frac{(1018)(8.08)}{32} = 257.\ ft^3$ @ 1050

$V_1 \approx (257)\frac{(1050)}{(875)} = 308\ ft^3$ @ 875

RCS Bubble calculation 3/30/79

	Pzr LvL		WR Press Loop A		Temp Loops B	MU − 80°F
Time	Comp	Recorder	Recorder	Computer	Comp	Tank
1240	250.5"	256"	1100	1050	280.3	40"
1340	228.4	228"	1065	1018	279.5	55
	22.1	28	35	32		15"

MU Tank Volume Change

15" × 30 gal/in = 450 gal

4 ft³/in = 60 ft³ @ 80°F × $\frac{.022}{.0163}$ = 80.98 ft³ at 550°F

Change in pzr volume =

$\overset{22.1}{\cancel{28"}} \times \overset{3.2}{\cancel{3.9}}$ ft³/in = $\overset{\cancel{89.6}}{\cancel{109.2}}$ ft³ @ 555°F
70.7

Increase in vol due to bubble expansion =

$-\Delta V_{pzr} + \Delta V_{MU\,Tank}$ = $\cancel{109.2 - 80.0}$ = $\overset{10.3}{\cancel{29.2}}$ ft³
81 − 70.7

$$V_1 = \frac{P_2 \Delta V}{P_1 - P_2} = \frac{(1018)(\overset{10.3}{\cancel{29.2}})}{32} = \overset{327.7}{\cancel{928.9}}\ \text{ft}^3 \ @\ 1050$$

$$V_1 = \overset{327.7}{\cancel{929.9}}\ \text{ft}^3 \left(\frac{1050}{875}\right) = \overset{393.2}{\cancel{1115}}\ \text{ft}^3$$

@ time 1240

See Revised calc 3/31/79 JM

. Bubble Calcs

3/31/79

3/30/79 1445/1510

$\Delta L\ PZR = +2''$

$$\Delta V_{PZR} = (2)(3.2\ \tfrac{ft^3}{in})\left(\overset{0.786}{\tfrac{0.0173}{0.022}}\right) = (6.4)(0.786) = {}^{+}5.0\ ft^3$$

$\Delta L\ MUTK = -8''$

$$\Delta V_{MU} = -(8)(4\ \tfrac{ft^3}{in})\left(\overset{1.061}{\tfrac{0.0173}{0.0163}}\right) = -(32)(1.061) = \underline{-33.96\ ft^3}$$

$$\Delta V = -28.96\ ft^3$$

$$V_1 = \frac{P_2 \Delta V}{P_2 - P_1} = \frac{(1053)(28.96)}{42} = 726\ ft^3 \text{ @ 1011 psia}$$

$$V_1 = (726)\left(\frac{1011}{875}\right) = 839\ ft^3 \text{ @ 875 psia}$$

RCS Bubble Calc 3/30/79

	L pzr		P pzr		T		MU
	C	R	C	R	Pzr	Loop B	Tank
1445	214.5	215	1011	1050	552.3	278.9	47" → 37
1510	214.5	215	1053	1100	557.9	221.2	50" ← ≈330 g
	+ 2"		42 psi				ΔL ≈ 8" 452 gal added ↓ 18"

$\Delta V_{pzr} = 2'' \times$ ~~3.9~~ 3.2 ft³/in = ~~7.8~~ 6.4 ft³

* V_f @ 280°F = 0.0173 = RC Temp.

$\Delta V_{MU\ Tank} = 8'' \times 4$ ft³/in = 32 ft³ $\left(\frac{0.0173}{.0163}\right)$ ~~.022~~ = ~~43.2~~ 33.96 ft³

ΔV_{Total} = ~~39.4~~ ~~51 ft³~~ ~~43.2 − 7.8 = 35.4 ft³~~ 33.96 − 6.4 = ~~36.8~~ 27.56

$$V_1 = \frac{P_2\,\Delta V}{P_2 - P_1}$$

= 1053 (~~35.4~~ ~~36.8~~ 27.56 ft³) / 42 psi = ~~887.5~~ ~~922.6~~ 691.0 ft³ at ~~1053~~ 1011

V_1 = (~~887.5~~ ~~922.6~~ 691) $\left(\frac{1011}{875}\right)$ = ~~1068~~ ~~1110~~ 798 ft³ at 875

~~1068~~ at time 1445

See Revised Calc 3/31/79 JPM

* ΔWater volume in MU Tank is interchanged with RC loop water rather than pressurizer level.

Therefore the ratio is $\left(\frac{0.0188}{0.0163}\right)$ rather than $\left(\frac{0.022}{0.0163}\right)$

where V_f @ 285°F = 0.0173

V_f @ 1100 psia Sat = 0.022

JPM 3/31/79

3/31/79
Jpm

3/30/79 1630/1735

$\Delta L\ Pzr = {}^{+}0.2''$

$\Delta V\ Pzr = {}^{+}(0.2)(2.515) = {}^{+}0.503\ ft^3$

$\Delta L\ mu = {}^{-}1.3''$

$\Delta V\ mu = (-1.3)(4.244) = -5.517\ ft^3$

$\Delta V_{TOT} = 5.0142\ ft^3$

$V_1 = \frac{(1033)(5.0142)}{17} = 304.7$ @ 1050

$V_1 = 304.7\left(\frac{1050}{875}\right) = 365.6\ ft^3$

RCS Bubble Calc

	L_{Pzr}		P_{pzr}		T		MU Tank Level
	C	R	C	R	Pzr	RCS Loop O	
1630	215.8	215	1050	1100	557.2	281.0	50"
1735	216.0	215	1058	1080	554.6	280.4	48.7" ~~[illegible]~~
	.2"		17 psi				-1.3"

$P_{zr}\ \Delta V = .2'' \times 3.9\ ft^3/in = \overset{.64}{\cancel{.28}}\ ft^3$

$MV\ \Delta V = 1.3'' \times 4\ ft/in = \underline{5.2\ ft^3} \times \overbrace{\left(\frac{1022}{1017}\right)}^{1.35} = 7.0\ ft^3$

~~Total ΔV = 7.0 ft³~~ – 6.36

$V_1 = \frac{P_2 \Delta V}{\Delta P} = \frac{1033\,(7.0\,ft^3)}{17\,psi} = 426.5$ @ 1050 psi

$V = 426.5 \times \frac{1050}{875} = 511.8\ ft^3$ @ 875

See Revised Calc 3/31/79 Jm

3/31/79

3/30/79 1745/1910

$\Delta L_{pzr} = +0.2''$

$\Delta V_{pzr} = +(0.2)(3.2)(0.786) = +0.2(2.515) = 0.503\ ft^3$

$\Delta L_{mu} = +1''$

$\Delta V_{mu} = (+1)(4)(1.061) = (+1)(4.244) = 4.244\ ft^3$

$\Delta V = 4.747\ ft^3$

$V_1 = \frac{(1005)(4.747)}{25} = 190.82\ ft^3$ @ 1030 psi

$V_1 = (190.82)(\frac{1030}{875}) = 224.63\ ft^3$ @ 875

RCS Bubble Calc 3/30/79

	L_{pzr} Comp	P_{pzr} Comp	T Pzr	T RCS	$L_{MU\ Tank}$
1745	215.8	1030	554.3	280.3	55"
1910	216.0	1005	551.4	279.9	56"
	+ .2"	25 psi		.4°	+ 1"

~~ΔVol pzr = .2" × 3.2 ft³/in = .64 ft³~~

~~ΔVol MU = 1" × 4 ft³/in = 4 ft³ × 1.35 = 5.4 ft³~~

~~Total ΔVol = 6.04 ft³~~

~~$V_1 = \frac{P_2 \Delta V}{\Delta P} = \frac{1005\,(6.04)}{25} = 242.8$ ft³ @ 1030 psi~~

~~$V_2 = 242.8\left(\frac{1030}{875}\right) = 327.8$ ft³ @ 875~~

See Revised
Calc
3/31/79
JOM

3/30/79 1907/2030

3/31/79

$\Delta L\ P_{zr} = 0$

$\Delta V\ P_{zr} = 0$

$\Delta L\ MU = 13.5''$

$\Delta V_{MU} = (13.5)(4.244) = 57.294\ ft^3$

$\Delta V_{TOT} = 57.294$

$$V_1 = \frac{(1043)(57.294)}{38} = 1572.5 \text{ @ } 1005$$

$$V_1 = \frac{(1005)}{(875)}(1572.5) = 1806 \text{ @ } 875$$

RCS Bubble Calc 3/30/79

	L_{PZR}	L_{MU}	P_{PZR}	T RCS	T PZR
1907	216.0	56"	1005	279.9	551.4
2030	216.0	43.5"	1043	279.4	556.5
	0	13.5"	38 psi		

$\Delta Vol = 13.5" \times 4\ ft^3/in = 54 \times 1.35 = 72.9\ ft^3$

@ 1005 psi

$V_1 = \frac{1043(72.9)}{38} = 2000.9\ ft^3 = 2258\ ft^3$ @ 875/4

See Revised Calc
3/31/79 JPM

DATE ________

TMI-2 RCS BUBBLE CALC SHEET

TIME ________ AM PM

DATA TAKEN BY: ________

RC PRESSURE (398)

P_1 = ________ PSIG = ________ PSIA

P_2 = ________ PSIG = ________ PSIA

ΔP = ________ PSI

RCS TEMP (394)

T_1 = ________ °F

T_2 = ________ °F

PRESSURIZER LEVEL (1682)

L_1 = ________ INCHES

L_2 = ________ INCHES

ΔL = ________ INCHES

PRESSURIZER TEMP (405)

T_1 = ________ °F

T_2 = ________ °F

MAKEUP TANK LEVEL (347)

L_1 = ________ INCHES

L_2 = ________ INCHES

ΔL = ________ INCHES

MAKEUP TANK TEMP (CONTROL BOARD METER)

T_1 = ________ °F

T_2 = ________ °F

$\Delta V_{PZR} = \Delta L \cdot 2.515$ = ________ × 2.515 = ________ FT^3

$\Delta V_{MUT} = \Delta L \times 4.244$ = ________ × 4.244 = ________ FT^3

ΔV_{TOTAL} = ________ FT^3

$$V_1 = \frac{P_2 \, \Delta V_{TOT}}{P_2 - P_1} = \frac{(\qquad)(\qquad)}{(\qquad)} = \_\_\_\_\_\_\_\_ \ FT^3 \text{ @ } P_1$$

$$V_{1(875)} = (V_1 \text{ at } P_1)\left(\frac{P_1}{875}\right) = \_\_\_\_\_\_\_\_ \ FT^3 \text{ @ } 875 \text{ psia.}$$

RCS Bubble Calc Data Sheet

Time	Level		Pressure	Temp		(Control Board Meter)
	(1682)	(347)	(398)	(394)	(405)	
	PZR	MUT	RCS	RCS	PZR	MUT

	E/R		Ft3 @ 875 psia	DP	
3/29	±0.91	1300	1839.3	95	DATA FROM J. FLOYD – SOURCES UNKNOWN
3/30	±6.04	0625	*828.6	16	MU TK Δ LEVEL – BELIEVED TO BE ZERO IN.
	±0.84	0730	892.5	115	
	±1.8276	1240	* 308	32	
	±1.948	1445	839	42	
	±7.715	1630	* 365.6	17	
		1745	* 224.6	25	
		1907	* 1806.0	38	
		0630	850	55	
3/31		1032	859.5	47	
		1351	879.4	92	
		1619 ~~1351~~	621.4	97	
		1925	901		
		2030	765		

JAM
3/31/79

①

ERROR ANALYSIS FOR BUBBLE VOLUME CALCS

$$P_1 V_1 = P_2 V_2$$

$$V_2 = V_1 + \Delta V$$

$$P_1 V_1 = P_2 (V_1 + \Delta V)$$

$$\cancel{P_1 V_1 = P_2)(}$$

$$P_1 V_1 = P_2 V_1 + P_2 \Delta V$$

$$V_1 (P_1 - P_2) = P_2 \Delta V$$

$$V_1 = \frac{P_2 \Delta V}{P_1 - P_2} = \frac{P_2 \Delta V}{\Delta P}$$

$$V_1 = \frac{P_2 \left[a(L_2 - L_1)_A + b(L_2 - L_1)_B\right]}{P_1 - P_2}$$

Per Jim Floyd 3/31/79

			Range	Accuracy
V_A = PRESSURIZER LEVEL	Computer Point	1682	0-400"	1% FS
V_B = MAKEUP TANK LEVEL	" "	347	0-100"	$\boxed{\approx 1\% FS}$
P = RC PRESSURE	" "	398	0-2500 psig	1% FS

$r\ a = 2.515$

$\Delta\ b = 4.244$

Jpm
3/31/79

Assume Error Of Inst's = 1% of Range.

VARIABLE	RANGE	ESTIMATED UNCERTAINTY
P	2500 ~~3000~~	$E_p = E_{R1} =$ ~~30~~ 25
L_A	4.00 ~~6.00~~ IN	$E_{LA} =$ ~~6~~ 4
L_B	100 IN	E_{LB} 1 ✓

$a = 2.515$

$b = 4.244$

$R_1 = \frac{P_2}{\cancel{R_4 R_2}} (P_1 - P_2)$

$R_2 = a(L_2 - L_1)_A$

$R_3 = b(L_2 - L_1)_B$

~~$R_6 = \frac{R_5[(R_2)+(R_3)]}{(R_1)}$~~

$R_4 = P_2$

$R_5 = [R_2 + R_3]$

$R_6 = \frac{R_4 \; R_5}{R_1}$

~~$\left(\frac{E_R}{R_1}\right)_1$~~

~~$(E_R)_1 = \pm\left[(r\cancel{R})\frac{E_p}{\cancel{R}} + (\gamma R)\frac{E_p}{\cancel{R}}\right]$~~

~~$= \pm\left[rE_p + \gamma E_p\right] = \pm\left[E_p(r+\gamma)\right]$~~

~~$= \pm\left[2rE_p\right]$~~

$$(E_R)_1 = \pm\left[(\cancel{\rho})\left(\frac{E_p}{\cancel{\rho}}\right) + \cancel{\rho}\left(\frac{E_p}{\cancel{\rho}}\right)\right] = \pm\left[2E_p\right]$$

~~$E_{R2} =$~~

$$E_{R2} = \pm\left[(a\cancel{L_A})\left(\frac{E_{LA}}{\cancel{L_A}}\right) + (a\cancel{L_A})\left(\frac{E_{LA}}{\cancel{L_A}}\right)\right]$$

$$= \pm\left[2aE_{LA}\right]$$

$$E_{R3} = \pm \left[2b \; E_{LB} \right]$$

$$E_{R4} = (\cancel{R})\left(\frac{E_p}{R}\right) = E_p$$

$$E_{R5} = \pm \left[E_{R2} + E_{R3} \right]$$

$$\frac{E_{R6}}{R_6} = \pm \left[\frac{E_{R4}}{R_4} + \frac{E_{R5}}{R_5} + \frac{E_{R1}}{R_1} \right]$$

$$E_{R1} = \pm[2E_P] = \pm[2 \times \overset{25}{\cancel{36}}] = \pm[\overset{50}{\cancel{60}}]$$

$$E_{R2} = \pm[2a\,E_{LA}] = \pm[(2)(2.515)(\overset{4}{\cancel{6}})] = \pm[\overset{20.12}{\cancel{30.18}}]$$

$$E_{R3} = \pm[2b\,E_{LB}] = \pm[(2)(4.244)(1)] = \pm[8.488]$$

$$E_{R4} = \pm[E_P] = \pm[\overset{25}{\cancel{36}}]$$

$$E_{R5} = \pm[E_{R2} + E_{R3}] = \pm[\overset{20.12}{\cancel{30.18}} + 8.488] = \cancel{38.668}\ \ 28.608$$

$$\frac{E_{R6}}{R_6} = \pm\left[\frac{E_{R4}}{R_4} + \frac{E_{R5}}{R_5} + \frac{E_{R1}}{R_1}\right]$$

$$R_4 = P_2$$

$$R_5 = [R_2 + R_3) = [a(L_2 - L_1)_A + b(L_2 - L_1)_B]$$

$$= [2.515)(\Delta L)_A + (4.244)(\Delta L)_B]$$

$$R_1 = (P_1 - P_2)$$

$$\frac{E_{R6}}{R_6} = \pm\left[\frac{\overset{25}{\cancel{36}}}{P_2} + \frac{\overset{28.608}{\cancel{38.668}}}{2.515(\Delta L)_A + 4.244(\Delta L_B)} + \frac{\overset{50}{\cancel{60}}}{(P_1 - P_2)}\right]$$

3/31/79
1351 Data

$$\frac{E_{R6}}{R_6} = \pm\left[\frac{\cancel{36}^{5}}{961} + \frac{\overset{28.608}{\cancel{38.668}}}{\underbrace{(2.515)(6.6) + (4.244)(12.8)}_{70.922}} + \frac{\overset{50}{\cancel{60}}}{92}\right]$$

$$\frac{E_{R6}}{R_6} = \pm\left[\left(\overset{2.60\times10^{-2}}{\cancel{2.12\times10^{-2}}}\right) + \left(\overset{0.4034}{\cancel{0.5452}}\right) + \left(\overset{0.543}{\cancel{0.652}}\right)\right]$$

$$\frac{E_{R6}}{R_6}\ \ \cancel{\pm 1.2286}\ \ \pm 0.973$$

ERROR ANALYSIS

$$\boxed{\frac{E_{R6}}{R_6} = \pm\left[\frac{25}{P_2} + \frac{28.608}{\underbrace{2.515(\Delta L_A)+4.244(\Delta L_B)}_{\Delta V_{TOT}}} + \frac{50}{(P_1-P_2)}\right]}$$

3/29/79 – 1300

$$\frac{E_{R6}}{R_6} = \pm\left[\frac{25}{970} + \frac{28.608}{(2.515)(48)+(4.244)(14)} + \frac{50}{95}\right]$$

$$= \pm\left[(0.02577) + (0.1588) + (0.526)\right]$$

$$= \pm\left[0.7105\right]$$

3/30/79 – 0625

$$\frac{E_{R6}}{R_6} = \pm\left[\frac{25}{1096} + \frac{28.608}{(2.515)(3.9)+0} + \frac{50}{16}\right]$$

$$= \pm\left[0.0228 + \overset{2.9166}{\cancel{2.9166}} + 3.125\right]$$

$$= \pm\ 6.06$$

3/30/79 – 0730

$$\frac{E_{R6}}{R_6} = \pm\left[\frac{25}{1035} + \frac{28.608}{(2.515)(30)+0} + \frac{50}{115}\right]$$

$$= \pm\left[0.0242 + 0.379 + 0.435\right]$$

$$= \pm\ 0.84$$

3/30/79 - 1240

$$\frac{E_{R6}}{R_6} = \pm\left[\frac{25}{1018} + \frac{28.608}{(2.515)(22.1) + (4.244)(15)} + \frac{50}{32}\right]$$

$$= \pm\left[0.0246 + 0.240 + 1.563\right]$$

$$= \pm\ 1,8276$$

3/30/79 - 1445

$$\frac{E_{R6}}{R_6} = \pm\left[\frac{25}{1053} + \frac{28.608}{(2.515)(2) + (4.244)(8)} + \frac{50}{42}\right]$$

$$= \pm\left[0.0237 + 0.7338 + 1.1905\right]$$

$$= \pm\ 1.948$$

3/30/79 - 1630

$$\frac{E_{R6}}{R_6} = \pm\left[\frac{25}{1080} + \frac{28.608}{(2.515)(0.2) + (4.244)(1.3)} + \frac{50}{17}\right]$$

$$= \pm\left[0.0231 + 4.752 + 2.94\right]$$

$$= \pm\ 7.715$$

4/1/79 1211/1238

$$\frac{E_R}{R} = \pm\left[\frac{25}{1049} + \frac{28.608}{41.33} + \frac{50}{97}\right] = \pm\left[0.0238 + 0.692 + 0.515\right]$$

$$= \pm\left[1.23\right]$$

4/1/79 1044/1140

$$\frac{E_R}{R} = \pm\left[\frac{25}{1056} + \frac{28.608}{54.36} + \frac{50}{100}\right] = \pm\left[0.0237 + 0.526 + 0.5\right]$$

$$= \pm\left[1.076\right]$$

4/1/79 0946/1020

$$\frac{E_R}{R} = \pm\left[\frac{25}{1056} + \frac{28.608}{44.87} + \frac{50}{103}\right] = \pm\left[0.0237 + 0.638 + 0.485\right]$$

$$= \pm\left[1.147\right]$$

4/1/79 0825/0903

$$\frac{E_R}{R} = \pm\left[\frac{25}{1050} + \frac{28.608}{44.5} + \frac{50}{105}\right] = \pm\left[0.0238 + 0.643 + 0.476\right]$$

$$= \pm 1.143$$

4/1/79 - 0731

Stet

$$\cancel{\frac{E_R}{R} = \pm\left[\frac{25}{1055} + \frac{28.608}{37.25} + \frac{50}{84}\right]} = \pm\left[0.0237 + 0.768 + 0.595\right]$$

$$= \pm 1.387$$

TO: Jack Devine.

From: Jim Henrie.

4/4/79.
05:00
(509-942-7811 x 587)
Home 509-976-2192
([illegible] 907)

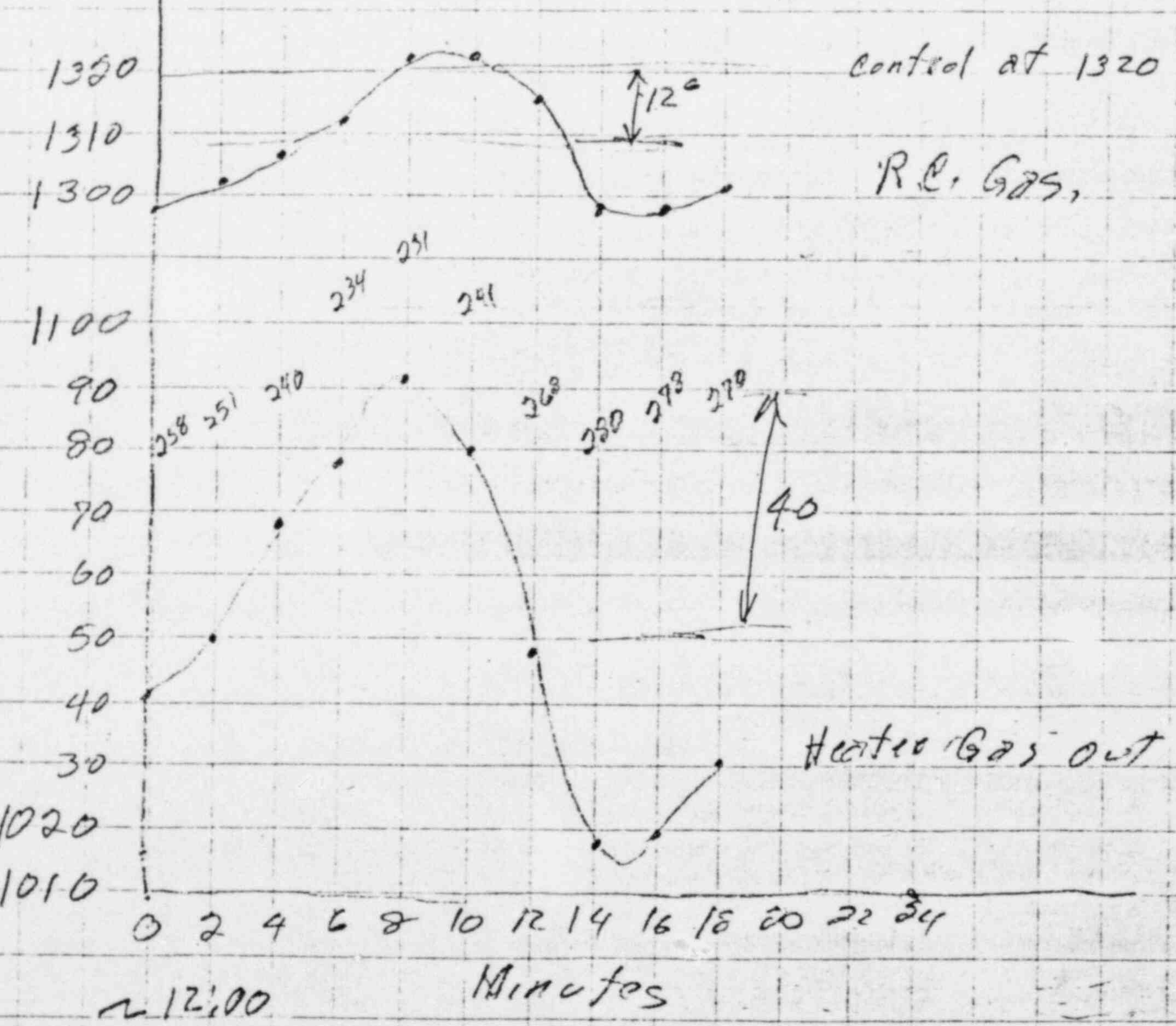
Subject: Work Summary.

Left Richland Wa., Sat., 3/31, 10:00
Arived Harrisberg AP. Sun., 4/1, 11:00

1. Assigned by Dieckamp to recombiner problems. Advised in Installation, Checkout, safety & reliability considerations, review of start-up procedures, start-up, op. analysis, Stability analysis, recommended corrections to improve stability. (Fig 1, 2, 3 & 4). Hydrogen analysis, error correlation. (Fig 5). Analysis of H_2 removal from Containment, without consideration of H_2 generation. (Fig 6) Recommended operation of single recombiner.
2. Made gross evaluation of apparent hydrogen burn on 3/28/79 at 13:50 (Fig 7) this is crude. Includes many assumptions and lacks good corrections for initial (unknown to me) conditions.
3. Worked on procedures and safety of transferring hydrogen from WDGT-1B. See Fig 8, Fig 9 (checklist), and Procedure Z-2,

Sorry no more time, Good Luck, J Henrie

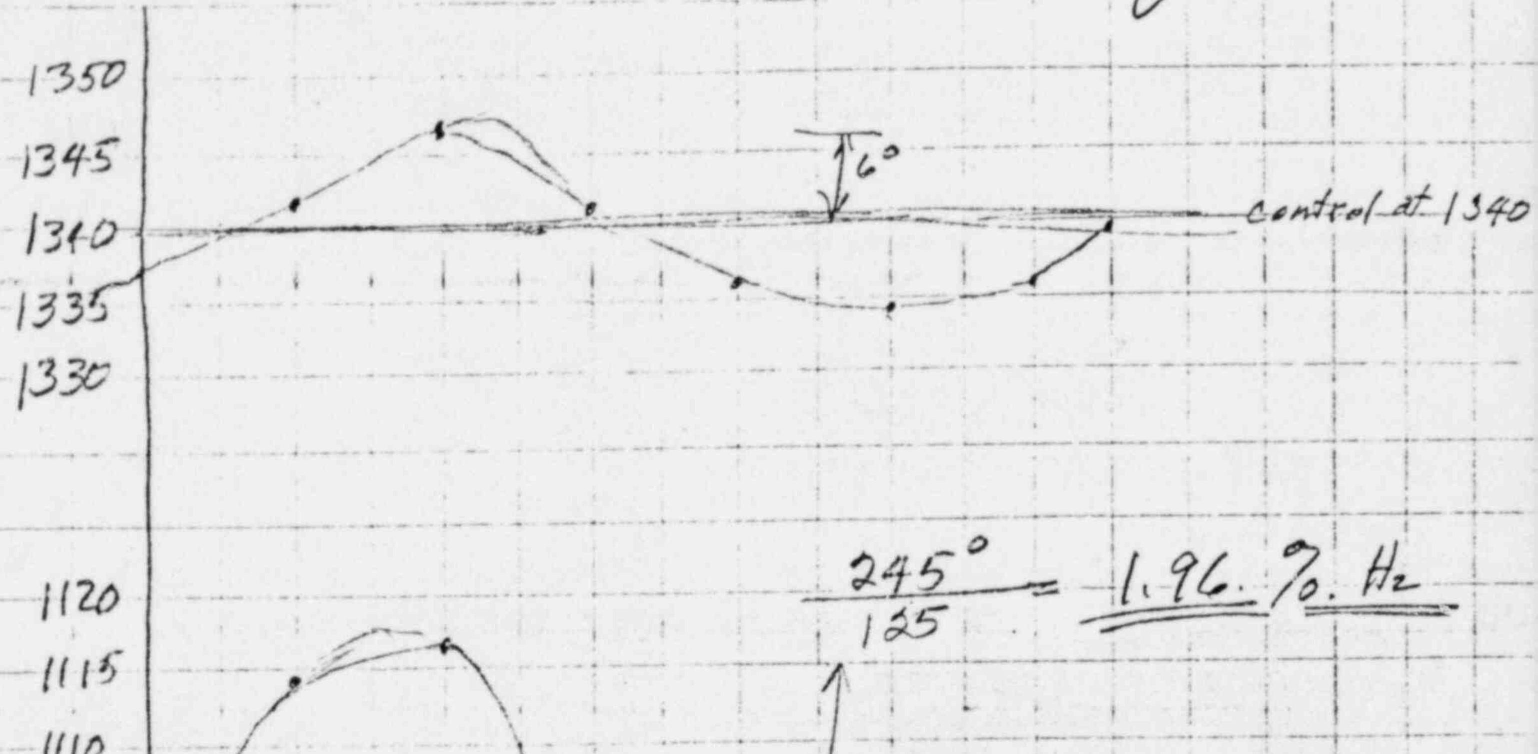
Recombiner Control.



4/13/79

Fig 1

Recombiner Control
JHenrie



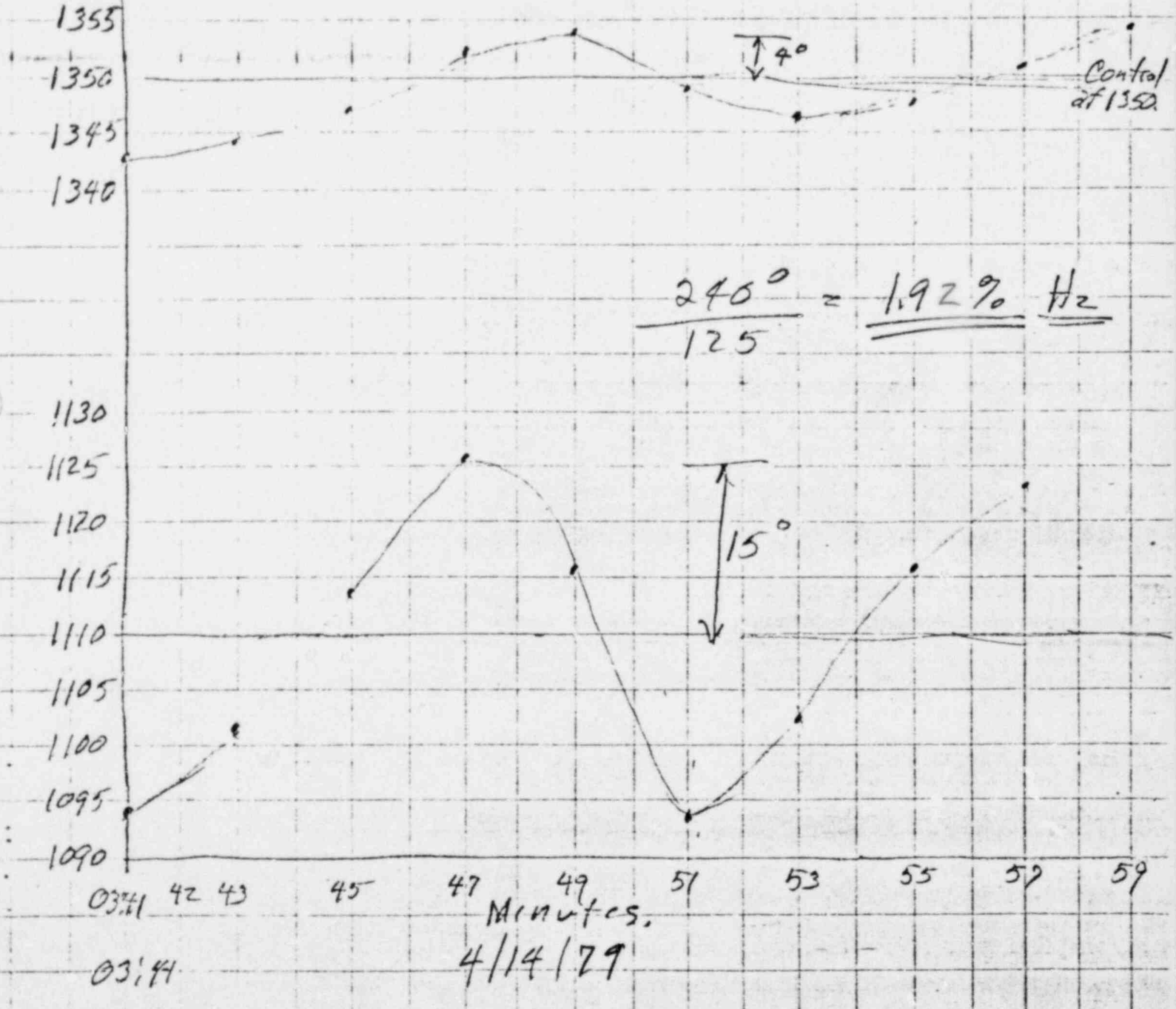
$\frac{245°}{125} = 1.96\ \%\ H_2$

02:45

4/4/79

Fig 2

Recombiner Control

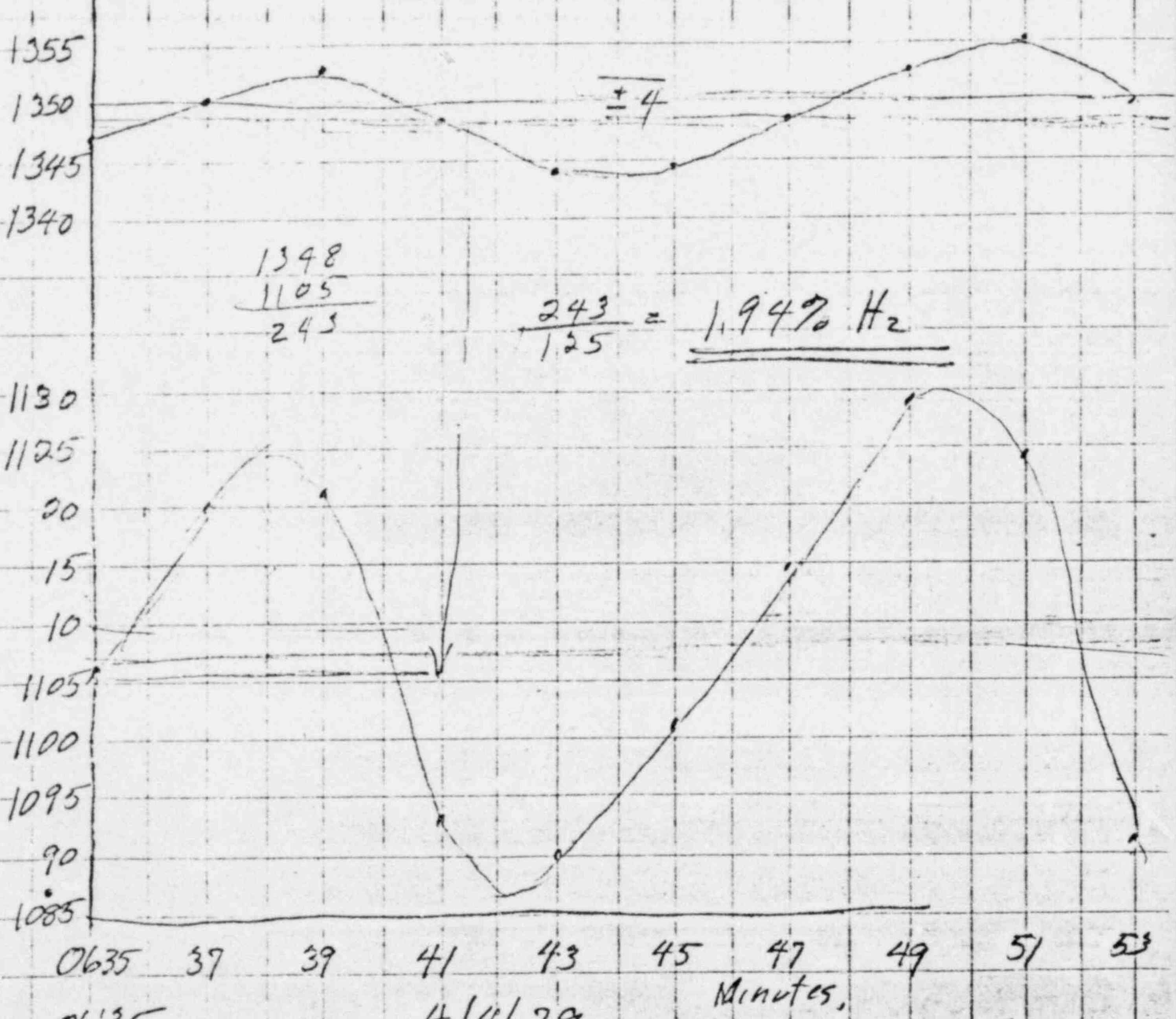


$$\frac{240^\circ}{125} = 1.92\%\ H_2$$

Fig 3

Recombineo Contrd.

J Henrie



1348
1105
243

$\frac{243}{125}$ = 1.94% H_2

06:35

4/4/79.

Fig 4.

JOHenrie

Date	Time	H_2	O_2	N_2	
Sat. 3 31	0700	1.7	16.5	81.7	100
	1500	1.9	21.2	76.9	100. *
	0600	2.6			
Sun 4/1	0645	2.4	18.1	79.5	100. *
	1000	2.01			
H_2 calc. —	1200	2.2	19	78.8	100.
	1330	2.0.			
	1500	2.0	19.0	78.8	99.8
	1830	2.0	19.0	78.8.	99.8
	23:30	2.3	18.9	78.9	100.1*
4/2	6:00	2.4	17.6	79.9	99.9*
	10:30	2.1	18.4	79.5	1000
4/3	22:35	2.01	18.6	81.	101.01

- Sampling all from same spot.
- Same procedure, under water, 1500 to 1800,
- Prior procedure could have leaked in air.
- Results computed adjust.

* Same operator.

~~Activity of containment atmosphere dropped by a factor of 3. at surface of rise sample.~~

Fig 5.

944 4041 Unit 2 Control Room

Dick Dubiel
mgr of chemists

Hydrogen Concentration 2.1%.

Cont. Volume 2,000,0.00 FT³. X 2.1% = 42,000 FT³ H_2

Recombiner flow 9.0 SCFM.

90 X 60 X 24 = 130,000 FT³/day. X 2.1% = 2,722 FT³ H_2/day

Start 15:45, 4/2/79		H_2 (start)	Remove	H_2 (end)	%
First day.	4/3	42.0K	2.7	39.3	1.96.
Second day.	4/4	39.3.	2.5	36.8	1.84
Third day	4/5	36.8	2.4	34.4	1.72
Fourth "	4/6	34.4	2.2	32.2	1.61
	4/7	32.2	2.1	30.1	1.50
	4/8	30.1	1.9	28.2	1.41
	4/9	28.2	1.8	26.4	1.32
	4/10	26.4	1.7	24.7	1.24
	4/11	24.7	1.6	22.1	1.10
	4/12	22.1	1.4	20.7	1.04
	4/13	20.7	1.3	19.4	.97

Assume No Net H_2 imput to Containment

Fig 6.

Gary Miller.
Joe Logan, Plant Superintendent.
Jack Herbine V.P. Generation
Kreitz
Dieckamp.

JOHenrie

Analysis of hydrogen burn which appears to have occurred at about 13:50 on 3/28/79, Wednesday, about 9.8 hrs after start of incident.

Initial Conditions, Prior to burn, Pressure = 16 PSIA.
Humidity: Unknown. Temp: unknown.

Pressure spike increased to 42.6 PSIA in <1 minute,
reduced to 17.8 PSIA in ~10 minutes.
13.8 PSIA in 4½ hours.

Correlation of the 27 PSI spike with a 33.3 PSI spike observed in tests (AI-73-29,-fig 12, attached). the hydrogen concentration was about $16 \times 27/33.3 = 13\%$. Subsequent oxygen analysis showing ~18% O_2 suggests that less than 13% H_2 burned, Assume 10% H_2.

Inventories were about as follows:

	H_2	O_2	N_2
$O_2 = .21 \times 2\times10^6 \times \frac{530}{575} =$		386,400	
$N_2 = .79 \times 2\times10^6 \times .92 =$			1,454,000
H_2, metal/water reaction, 10% =	200,000		
Burn of H_2, 90% eff. =	-180,000	-90,000	
Radiolysis, first week. =	+20,000	+10,000	
Air inleakage*, first week =	[illegible]	800	2,900
Total Inventory	40,000	307,200	1,454,900
% of total. (1,804,000) =	2.2%	17.0%	80.8%
Analysis of gas, 4/3, 22:35 =	2.0%	18.0%	81%

Pressure: $\frac{1,804,000}{2,000,000} \times \frac{460+86}{460+70} \times 14.7 = 13.6$ PSIA.; Measured 13.4 PSIA.

Reasonable correlation. 10% H_2 at time of burn appears to be reasonable.

* based on .2%/day, 56 PSI ΔP, corrected to 1 PSI ΔP.

$Q = .2\% \times 2\times10^6 \times \sqrt{\frac{1}{56}}^{.55} \times 7\text{ days} = 3,700\text{ FT}^3 \times .21 = 800; \times .79 = 2,900.$

Fig 7.

4/4/79

Gas in WDGT-1B.

Volume 1937 FT^3
Pressure 86 PSIG.
Temperature 100°F.

$$\text{Volume} = 1937 \times \frac{\overset{6.85}{86+14.7}}{14.7} \times \frac{\overset{\overset{.95}{530}}{460+70}}{\underset{560.}{460+100}} = 12{,}605.\ \text{SCF.}$$

Reducing to 15 PSIG, Subtract $\underline{3{,}874}$

Net transfer $\frac{8.7}{2{,}000} = \underline{.44\%\ H_2}$ $= \underline{\underline{8{,}731\ \text{SCF}}}$

Max rate of 3 PSI/HR, $\frac{3}{100} \times 12{,}605/\text{HR} = 378\ \text{SCF/HR}.$

$$\frac{378}{60} = \underline{\underline{6.3\ \text{SCFM.}}}$$

$a = \pi \frac{D^2}{4}(\frac{1}{4})$
$= .04\pi$.

$$\text{Velocity} = \frac{Q}{A} = \frac{6\ \text{FT}^3/\text{min}}{.04\pi\ \text{in}^2} \times \frac{144\ \text{in}^2}{1\ \text{FT}^2} \times \frac{1\ \text{min}}{60\ \text{sec}} = 115\ \text{ft/sec}$$

Flowrate 6½#/min, 31 SCFM.

$$31\ \text{SCFM} \times 60\ \text{m/Hr} = \frac{1{,}860\ \text{SCFH}}{12605\ \text{SCF}} \times 100\ \text{PSIG} = \underline{\underline{14.7\ \text{PSI/Hr}}}$$

4.9 x rate max.

$$\frac{31\ \text{CFM} \times .6\ H_2}{6{,}000\ \text{CFM Total}} = \underline{\underline{.3\%\ \text{increase.}}}$$

Location of exhaust line = 293'6"
227° 38" Zero = South.

Needle Valve is 1½ needle, Velan, 150#, 200°F.

Need turns open to limit flow to 6.3 SCFM. Fig 8

1. Temp of Tank. 100 to 200°F. too hot to read,

2. Calc gas. ✓

3. Flowrate [illegible], 50', 1/2" tubing,

4. calculate,
Pressure drop rate 3PSI/HR,
Can do it only by use the throttle valve.

5. Ext. detach - No 1/2" nipple.

6. Assess failure modes.
   a. operator errors - Dumps H_2, Alarms, Close Valve
   → Add precautionary measures. (Tag Positions)
   b. Equipment - Has been tested at 125% of max. measured,
   Walk to see if OK.

7. Consider Recombiner Running.

Mike 8. Check N_2 Source & Pressure.

21 9. Check for equipment near R571 C. Pen.

Jul. 10. Valve position to limit flow to 4 to 8 SCFH.

11 Check Compressor logic. ~~leave on if pumps to low flow~~

12 Consider flame arrestor. - Talk to Chemist

13. Consider H_2 Charge total. .44% Fig 9

AP 1001
Figure 1001-8

Three Mile Island Nuclear Station
Special Operating Procedure

SIDE 1
SOP No. Z-2
(From SOP Log Index)

NOTE: Instructions and guidelines in AP 1001 must be followed when completing this form.

Unit No. 2
Date 4-4-79

1. Title DISCHARGE OF WDG-T-1B TO REACTOR BLDG.

2. Purpose (include purpose of SOP)
TO DISCHARGE WDG-T-1B TO REACTOR BLDG.

3. Attach procedure to this form written according to the following format.
   A. Limitations and Precautions
      1. Nuclear Safety
      2. Environmental Safety
      3. Personnel Safety
      4. Equipment Protection
   B. Prerequisites
   C. Procedure

SEE ATTACHED

4. Generated by Julien Abramovici / Jim Henrie Date 4-4-79

5. Duration of SOP – Shall be no longer than 90 days from the effective date of the SOP or (a) or (b) below – whichever occurs first.

(a) SOP will be cancelled by incorporation into existing or new permanent procedure submitted by ______ ☐

(b) SOP is not valid after ______ ______ ☐
(fill in circumstances which will result in SOP being cancelled)

6. (a) Is the procedure Nuclear Safety Related?
If "yes", complete Nuclear Safety Evaluation. (Side 2 of this Form) . . . . Yes ☐ No ☐

(b) Does the procedure affect Environmental Protection?
If "yes", complete Environmental Evaluation. (Side 2 of this Form) . . . . Yes ☐ No ☐

(c) Does the procedure affect radiation exposure to personnel? . . . . Yes ☐ No ☐

NOTE: If all answers are "no", the change may be approved by the Shift Supervisor. If any questions are answered "yes", the change must be approved by the Unit Superintendent.

7. Review and Approval

Approved – Shift Supervisor ______ Date

Reviewed – List members of PORC contacted ______ Date
______ Date
______ Date

Approved - Unit Superintendent ______ Date

8. SOP is Cancelled

______ Shift Supervisor/Shift Foreman ______ Date

SPECIAL OPERATION PROCEDURE
TMI-2 NUCLEAR STATION
DISCHARGE OF WDG-T-1B TO REACTOR BUILDING

1.0 CONDITIONS

1.1 PRIMARY SYSTEM

a) PRIMARY PRESSURE BETWEEN 1000 AND 1050 PSIG.

b) PRESSURIZER LEVEL BETWEEN 175 AND 210 IN. H_2O

c) PRIMARY PRESSURE/TEMPERATURE CONTROL USING PRESSURIZER HEATERS AND SPRAY.

d) ONE R.C. PUMP OPERATING.

1.2 SECONDARY SYSTEM

a) CONDENSER VACUUM BETWEEN 5 AND 29 IN. HG.

b) ONE OTSG STEAMING TO CONDENSER.

1.3 REACTOR BUILDING (RB.)

a) R. B. TEMPERATURE BETWEEN 50 AND 125 °F.

b) R.B. HYDROGEN CONCENTRATIONS LESS THAN 4%.

2.0 PRECAUTIONS

2.1 DO NOT ALLOW THE WGD-T-1B PRESSURE TO DECREASE AT A RATE GRATER THAN 3 PSI/HR.

2.2 DO NOT ALLOW THE WGD-T-1B PRESSURE TO DECREASE BELOW 15 PSIG.

2.3 A FLAME ARRESTERS HAS BEEN INSTALLED TO PRECLUDE FLAME PROPAGATION.

2.4 THE SYSTEM IS GROUNDED.

3.0 PROCEEDURE

3.1 VERIFY TEMPORARY VALVES T-V1 AND T-V2 ARE CLOSED

3.2 HAVE CONTROL ROOM DEFEAT RMS INTERLOCKS ~~[illegible]~~ USING KEYLOCK SWITCHES FOR WDG-R-1480 WDG R-1485, WDG-R-1486 AND HP-R-219. -

3.3 VERIFY WDG-V-32 IS CLOSED.

3.4 VERIFY WDG-V-33 IS CLOSED.

3.5 VERIFY WDG-V-170 IS CLOSED.

3.6 VERIFY WDG-V-24 IS CLOSED.

3.7 VERIFY WDG-V-142 A AND V-143 A ARE CLOSED.

3.8 VERIFY WDG-V-30A IS CLOSED.

3.9 VERIFY WDG-V-143B IS OPEN.

3.10 VERIFY WDG-V-54B IS OPEN.

3.11 VERIFY WDG-V-188B IS CLOSED.

3.12 VERIFY T-V2 ~~[illegible]~~ IS ~~ARE~~ CLOSED.

3.13 VERIFY ~~V6 AND~~ T-V7 ~~ARE~~ OPEN AND T-V6 CLOSED

3.14 VERIFY WDG-V-30B IS CLOSED AT RADWASTE PANEL.

3.15 CLOSE SHUT WDG-V-26B AT RADWASTE PANEL TO ISOLATE COMPRESS ✓

3.16 VERIFY WDG-V-142 B IS CLOSED

3.17 OPEN BS-V-149.

3.18 OPEN WDG-V-30B FROM RADWASTE PANEL

3.19 OPEN WDG-V-188B BY TURNING 1/2 TURN OR AS NECESSARY TO ACIEVE LESS THAN 3PSI PER HOUR DECREASE IN WASTE GAS DECAY TANK PRESSURE AT THE RADWASTE PANEL.

3.20 WHEN THE WASTE GAS DECAY TANK (WTG-T-1B) REACHES 15PSIG SECURE DISCHARGING BY CLOSING WDG-V-30B AT RADWASTE PANEL.

3.21 CLOSE WDG-V-188B.

3.22 CLOSE WDG-V-54B.

3.23 CLOSE BS-V-149.

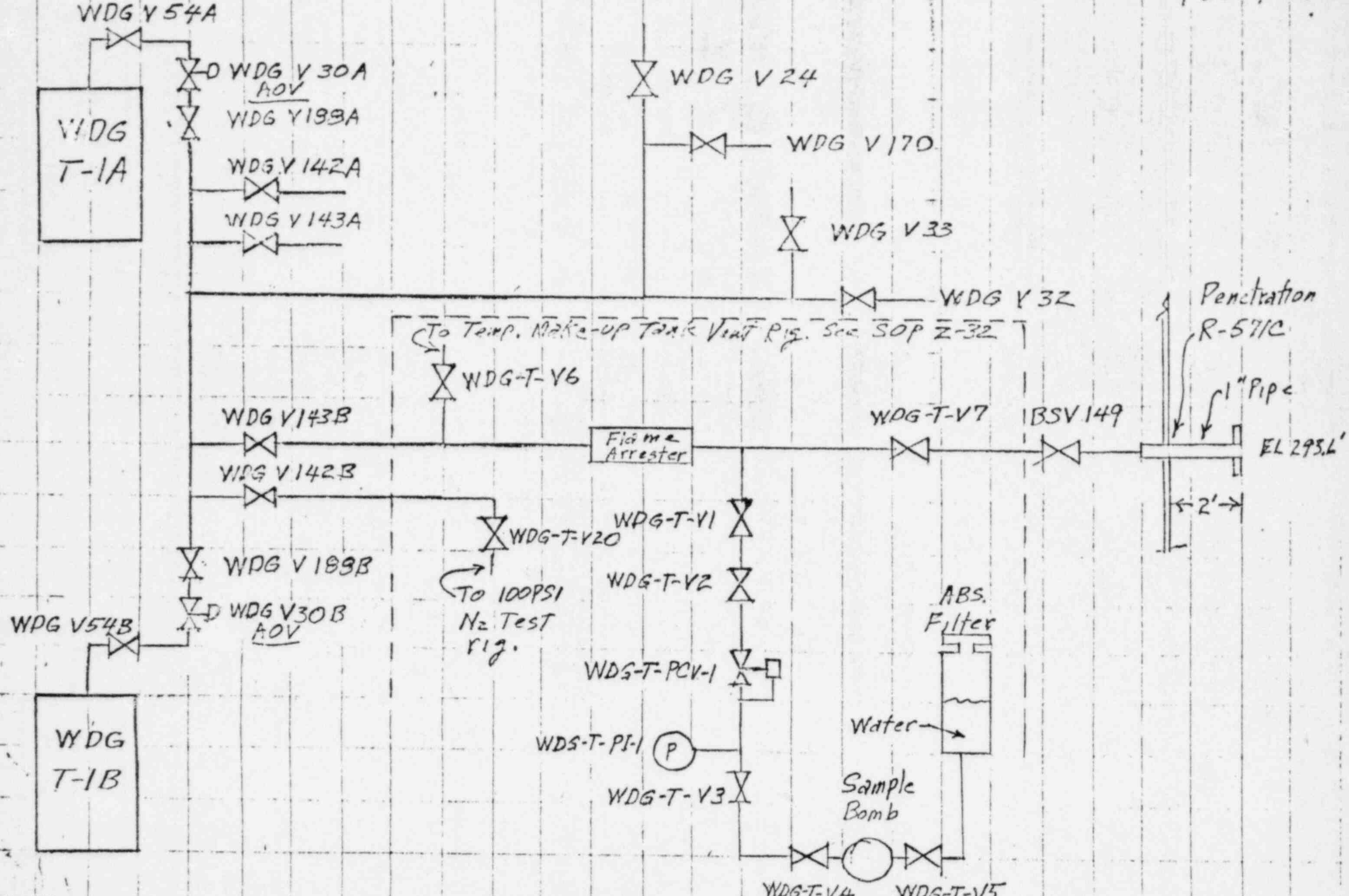
3.34 CLOSE WDG-V-143B

3.35 ~~CLOSE WDG-V-~~ OPEN WDG-V-26B.

NOTES 1) ALL VALVES UNLESS OTHERWISE NOTED ARE WDG.

2) ALL VALVES OTHER THAN VALVES THAT ARE CYCLED SHOULD BE "DANGER" TAGGED.

3) VALVES THAT ARE INSTALLED AS PART OF THE TEMPORARY RIG SHOULD BE BRASS TAGGED.


WDG V54A
WDG V30A
AOV
WDG V189A
WDG T-1A
WDG V142A
WDG V143A
WDG V24
WDG V170
WDG V33
WDG V32
Penetration R-57/C
To Temp. Make-up Tank Vent Rig. See SOP Z-32
WDG-T-V6
1" Pipe
WDG V143B
Flame Arrester
WDG-T-V7
BSV 149
EL 295.6'
2'
WDG V142B
WDG-T-V20
WDG-T-V1
WDG V189B
To 100PSI N2 Test rig.
WDG-T-V2
WDG V54B
WDG V30B
AOV
ABS. Filter
WDG-T-PCV-1
WDG T-1B
Water
WDS-T-PI-1
P
Sample Bomb
WDG-T-V3
WDG-T-V4
WDG-T-V5

Sheets — Dates (4-3)

Ed Fuhrer
Ext.

← Jim Floyd → C.R.

Station Daily Log Sheet.

4/3/79

1050 - 85
0700 - 87
0525 - 86
0100 - 87
0000 - 87

WG Decay TK
Pressure

In think tank

$$\begin{array}{r} \overset{2}{2}4 \\ \underline{60} \\ 1440 \end{array}$$

MEMO from:
G. P. MILLER

WASTE GAS DECAY TANK

1A				1B			
DATE	TIME	P.	T	DATE	TIME	P.	T.
3/30	2400			3/30	2400		
3/31	2320 ~~2400~~	84		3/31	2320 ~~2400~~	84	
4/1	0100 ~~2400~~	86		4/1	0100 ~~2400~~	86	
4/2	1200	87		4/2	1200	86	

FIRST
READING
AFTER
ACCIDENT

944-0415, 0423, 367-0318, 6868

MEMO from:
G. P. MILLER.

~~Jim Flynn~~

~~Jim Lloyds~~ →

Waste gas decay Tank.

203 Call Dennis Olson at
1250, ~~0D~~

MEMO from:
CECILIA KORCHNAK

~~JOHN JOHNSON~~

Waste Gas Decay Tk

① First Reading (PRESS.) after accident

② 3/30/79 2400 hr

③ 3/31/79 2400 hr

④ 4/1/79 2400 hr

⑤ 4/2/79 1200 hr

~~⑥~~ FOR BOTH TANKS

AUX. OPERATOR LOGS.

PLUS TEMP.

Marshall Biers →

WDG T 1A 85 PSIG
1B 85 PSIG

MEMO from:
G. P. MILLER

file

WASTE GAS DECAY TANK: WHICH IN SERVICE?
CALL DENNIS ~~MOORE~~ OLSON AT 1250.4

1050 85 in both

2400 87A, 86b 4/2
0400 87A 85B 4/1

4/2

	A	B
0700	86	86
1100	85	85
1400	86	86
2200	86	86

	A	B
4/3 0200	87	86
0500	87	86
0700	87	87

MEMO from:
G. P. MILLER

WASTE GAS DECAY TANK PRESSURE

	TIME	PRESS.
4/2	2400 ~~2200~~	A- 87 B- 85
	2200	A- 86 B- 86
	1400	A-86 B-86
	1100	A-85 B-85
	0700	A-86 B-86
4/1	0400	A-87 B-85
4/3	0200	A-87 B-86
	0500	A-87 B-86
	0700	A-87 B-87

RCV 137 - ON 21:-- periodic jogs

22:17 CLOSED
23:10 OPPENED
2:29 depes PZR - open spray Vlve
3:15 CLOSED

---

18 20 open RC-V-137
18:28 450 TO MU-T-1
18:35 Shut RC-V-137
19:06 open RC V-137
1918 Shut = // =
19:48 added 456 TO MU-T-1
20:07 open RC-V-137
20:27 Closed
20:42 Open
21:13 Closed
21:36 open
21:32 Closed ??
22:17 open
22:33 closed
22:45 added 45 to MU-T-1
22:57 open
23:10 closed

R 571 C

⑦

4/3/79
Jem

0712 450 — Makeup Addition mi gal
0720 open
0737 Closed — RC-V-137 (Pzr vent)
0805 open
0849 Closed
0914 open
0822 Closed
829 450
840 open. — ? closed
913 open
927 Closed
934 450
939 open
1006 closed
1027 open
1041 Closed
1050 450
1107 open
1123 Closed
11 ~~55~~ Open
'13 Closed

0520 open
0536 close
0600 open
0605 added 450 to MU-T-1
0615 closed
0642 open
0652 closed
0712 added 450 to MU-T-1
0720 open
0737 closed
0805 open
0849 closed
0930 open

23:35 open
23:49 closed

0006 added 450 to MU-T-1
0024 open
0038 closed
0111 open
0127 closed
0130 added 450 to MU-T-1
0152 open
0206 close
0227 open
0243 close
0326 added 450 gal to MU-T-1
0306 open
0325 closed
0346 open
0404 close
0419 open
0449 added 450 to MU-T-1
0450 closed

Make Up Tank Makeup Data from Operators Log

/28
1720 BWST @ 26½'
1800 BWST @ 24'
1820 23'
1847 22'
195[illegible]

3/29
BWST 20.5' @ 0615

3/30
0800 371
0815 300
1502 462
1719 200

1853 Start filling BWST Level @ 15.5'

2036 300
2307 190
2347 300
2310 Started PZR Vent
2353 Start PZR Spray

Total Makeup
2123

3/31
0033 300
0315 Scanned degas proc
0445 150
0547 150
0705 150
0757 Started Degas
0830 546
1042 130
1120 900
1427 303
1530 413
1543 900
1705 370
1820 370
2000 470
2120 480
2228 470
2330 470

Total 5762

4/1
0825 460
0945 400
1041 301
120 446
1306 400
1508 456
1650 505
1805 456
1900 455
2015 454
2118 454
2225 455
0112 470
0127 470
0325 470
0435 470
0645 470

Total 8553

4/2
01.0 -455
0300 455
0445 455
0630 455
0723 455
0853 455
1310 436
1458 671
1658 455
1828 455

$$\underbrace{\qquad\qquad\qquad\qquad}_{16438}$$

From Alarm Data on day of accident
One RB Sump Pump on @ for 31 min
Other " " " " for 28 min

4/3/79
8PM

Makeup Tank - Addition of water.

3/29/79

TIME 2240	GAL. ADDED	Δ Time (min)	gpm
2315	300 gal	35	8.57 gpm
0020	300	65	4.62
0105	300	45	6.67
0145	303	40	7.58
0250	303	65	4.66
0332	303	42	7.21
	ΣGal = 1809	ΣTime = 292	

$$\frac{1809}{292} = 6.19 \text{ @ } 2155 \text{ psig}$$

This may have been due to Pressurizer Safety Valve leakage. Since this is critical flow, the leak rate at present plant conditions would be:

$$6.19 \times \left(\frac{1000+15}{2155+15}\right) = 2.9 \text{ gpm}$$

MEMO from:
G. P. MILLER

Makeup Results

Date	Avg MU (gpm)	a	a/ΔTavg
3/30/79	2.39		
3/31/79	5.52	680.9	$\frac{680.9}{\cancel{80.44}\ 78.2} = 8.71$
4/1/79	5.52	408.7	$\frac{408.7}{80.94} = 5.05$
4/2/79	4.77	540	5.05
4/3/79	5.325	450	$\frac{450}{84.5} = 5.325$ THRU 0712

MEMO from:
G. P. MILLER

4/3/79
GPM

Makeup – 4/3/79 0006 → 0727

$y = a + bx$

I. $\Sigma(y) = Na + b\,\Sigma(x)$

II $\Sigma(xy) = a\,\Sigma(x) + b\,\Sigma(x^2)$

I. $2700 = 6a + b(507)$ $\frac{507}{6} = 84.5$

II $228{,}150 = 507a + b(44{,}227)$

$-228{,}156 = -\cancel{507a} + 42841.5\,b$

$228{,}150 = \cancel{507a} + 44{,}227\,b$

I. $2700 = 6a + 507b$

II $228{,}150 = 507a + 44{,}227\,b$

~~235528.4 = 44227 F~~

235,528

I. ~~24,565,788~~ $= 523.4a + 44227$

II $-228{,}150 = -507a \mp 44227$

~~20,317,638~~ $= 16.4a$

7,378

~~a = 12,388,880~~

$a = 450$ →

$6a = 2700$

$2700 = (6)(450) + 507b$

$507b = 0$

CK

$\frac{2700}{6} = 450$

$\text{Avg} = \frac{2700}{507} = 5.325$ gpm

MEMO from:
G. P. MILLER

Makeup 4/2/79 0150 → 2245

$\text{I} \quad 5654 = 12a + 1433b$

$\text{II} \quad 669{,}512 = 1433a + 337{,}455$

$\dfrac{337{,}455}{1433} = 235.49$ ~~235.418~~

$\text{I} \quad 133{,}145.9 = 2825.9(a) + \cancel{337{,}455}(b)$

$\text{II} \quad {}^{-}669{,}512 \quad 1433(a) + \cancel{337{,}455}(b)$

$-536{,}366 = 1392.9a$

$a = -385\ ?$

Ignore data point for 1310 – There must be one or more data points missing between 0853 and 1310.

N = 11

$\Sigma(y) = 5654 - 432 = 5612$

$\Sigma(x) = 1433 - 257 = 1176$

$\Sigma(xy) = 669{,}512 - 111{,}024 = 558{,}488$

$\Sigma(x^2) = 337{,}455 - 66{,}049 = 271{,}406$

$\text{I.} \quad 5612 = 11a + 1176b$

$\text{II.} \quad 558{,}488 = 1176a + 271{,}406$

$\dfrac{271{,}406}{1176} = 230.79$

~~Avg MU~~ Without 1310 data

$\boxed{\dfrac{5612}{11} = 510}$

$\text{I.} \quad 1{,}295{,}179 = 2539(a) + \cancel{271{,}406}(b)$

$\text{II} \quad {}^{-}558{,}488 = {}^{-}1176(a) + \cancel{271{,}406}(b)$

$736{,}691 = 1363a$

$a = 540$

$11a = 5940$

~~MU~~ = -

$\Delta T_{Avg} = \dfrac{1156}{11} = 107$

$\text{Avg MU} = \dfrac{5612}{1176} = 4.77$

MEMO from:
G. P. MILLER

4/3/79
gpm

Makeup 4/1/79 0112 → 2347

Ck
$\frac{8047}{18} = 447$

I. $8047 = 18a + 1457b$

II. $657{,}754 = 1457a + 131{,}231b$

I. $724{,}788 = 1621a + \cancel{131{,}231b}$

II. $-657{,}754 = -1457a + \cancel{131{,}231b}$

$67034 = 164a$

$a = 408.7$

$\Delta T_{avg} = 80.94$ min

Avg MU $= \frac{8047}{1457} = 5.52$ gpm

MEMO from:
G. P. MILLER

Makeup - 3/31/79 0035 → 2339

omit 0445 data point

I. $6212 = 15a + 1173b$

II $432{,}040 = 1173a + 141{,}345b$

$\frac{141{,}345}{1173} = 120.5$

I. $748538 = 1807.5(a) + \cancel{141345(b)}$

II. $432{,}040 = 1173(a) + \cancel{141{,}345(b)}$

$\frac{6212}{15} = \boxed{414}$

$316{,}498 = 634.5\,a$

$a = \boxed{680.9}$

Poor Correlation

~~$\Delta T_{avg} = \frac{1457}{18} = 80.94$~~

$\Delta T_{Avg} = \frac{1173}{15} = 78.2$

$\text{Avg mw} = \frac{8047}{1457} = 5.52$

RCS Makeup – (Cont'd)

4/2/79

	Time	(y) M-U Gal	(x) ΔTime (MIN)	(xy)	(x^2)
Previous actuation 2347 4/1/79 →	0150	455	123 ~~205~~	55965	15129
	0300	455	115	52325	13225
	0445	455	115	52325	13225
	0630	455	105	47775	11025
	0723	455	53	24115	2809
	0853	455	90	40950	8100
Missing data point? →	1310	432	257	111,024	66049
	1458	671	108	72468	11664
	1658	455	120	54600	14400
	1828	455	90	40950	8100
	1948	456	80	36480	6400
	2245	455	177	80535	31329
		5654	1433	669,512	337,455

(0150–0853) Avg = $\frac{2730}{601}$ = 4.54 gpm

(1458–2245) ~~Avg = 2494~~ Avg = $\frac{2492}{575}$ = 4.33 gpm

(0150–2245) Avg = $\frac{5654}{1433}$ = 3.95 gpm

4/3/79

		(y)	(x)	(xy)	(x^2)
	0006	450	81	36450	6561
	0130	450	84	37800	7056
?	0326	450	116	52200	13,456
	0449	450	83	37350	6889
	0605	450	76	34200	5776
	0712	450	67	30150	4489
		Σ(y) = 2700	507	228,150	44,227

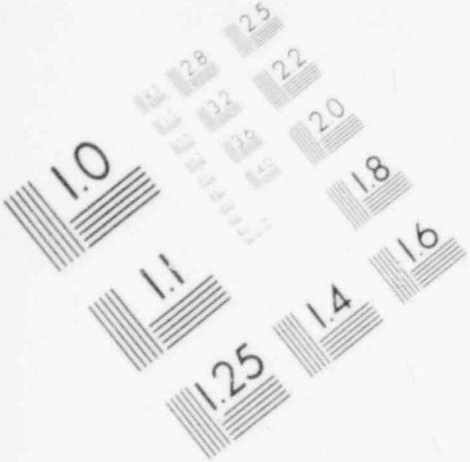
(0006–0130) Avg = $\frac{900}{165}$ = 5.45

(0449–0712) Avg = $\frac{1350}{226}$ = 5.97

(0006–0712) Avg = 5.325 gpm

Avg = $\frac{2700}{507}$ = 5.325 gpm

Tavg = $\frac{507}{6}$ = 84.5



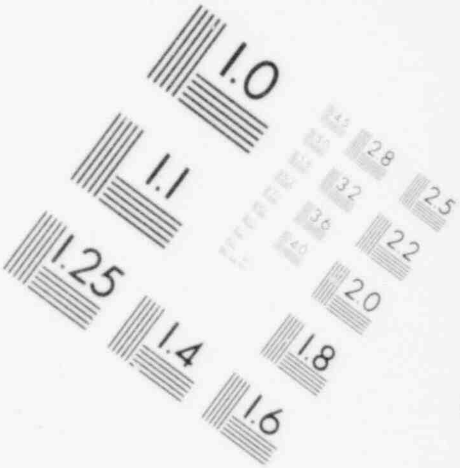
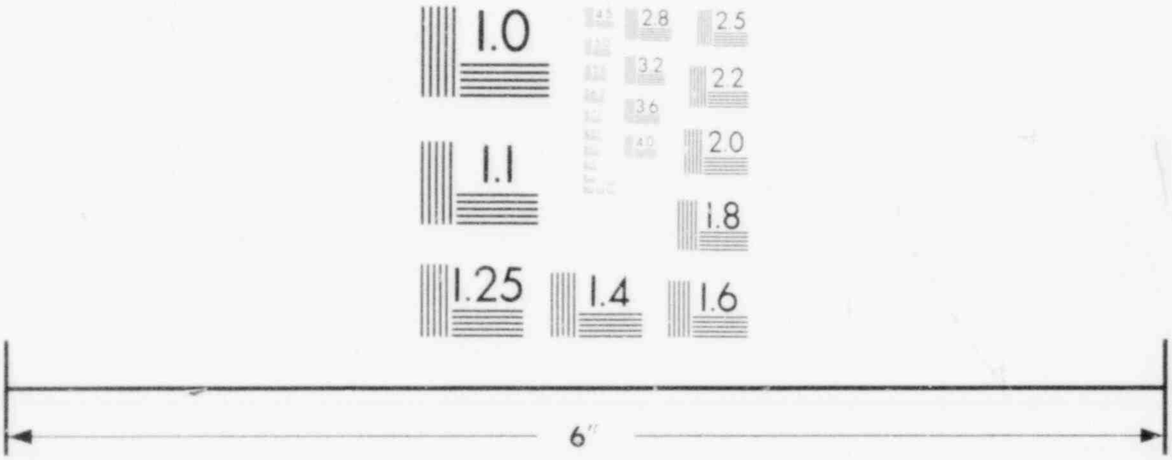
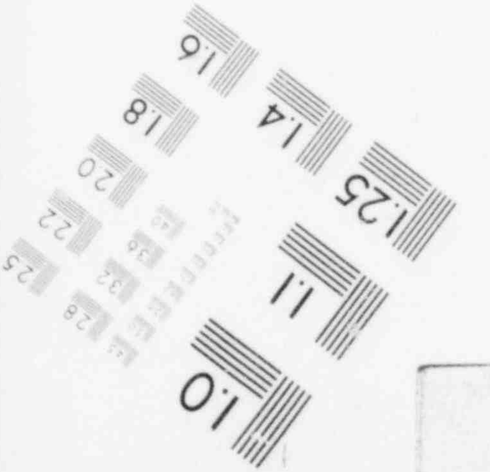
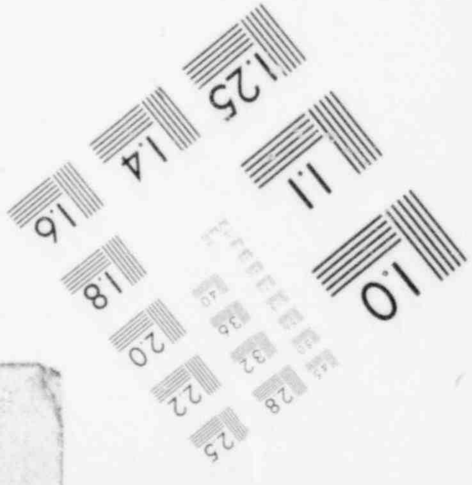


IMAGE EVALUATION
TEST TARGET (MT-3)



MICROCOPY RESOLUTION TEST CHART





RCS Makeup –(Contd)

3/31/79 (Contd.

TIME	(y) M-U Gal	(x) Δ Time	(xy)	(x²)
2000	470	100	47,000	10,000
2120	450	80	39,200	6400
2228	470	68	31,960	4624
2330	470	62	29,140	3844

$\Sigma(y) = 6212$

$\Sigma(x) = 1173$

$\Sigma(xy) = 433,040$

$\Sigma(x^2) = 141,345$

$N = 15$

4/1/79	Y	X	XY	X²
0825	460	100	46000	10,000
0945	400	80	32000	6400
1041	301	56	16856	3136
1200	446	79	35234	6241
1306	400	66	26400	4356
1508	456	122	55632	14884
1650	505	102	51510	10404
1805	456	75	34200	5625
1900	455	55	25025	3025
2015	454	75	34050	5625
2118	454	63	28602	3969
2225	455	67	30485	4489
2347	455	82	37310	6724
0112	470	102	47940	10404
0127	470	15	7050	225
0325	470	118	55460	13924
0435	470	70	32900	4900
0645	470	130	61100	16900
	8047	1457	657,754	131 231

$Avg = \frac{8047}{1457} = 5.52\ gpm$

$\Delta T_{avg} = \frac{1457}{18} = 80.94$

MAKEUP TO RCS

DATA FROM CONTROL ROOM LOG.

4/3/79
Jgm

3/30/79

Missing Data ?

Time	M-U (Y) (GAL)	(X) ΔTime	(XY)	(X^2)
0800	371	?		
0815	300	15		
1502	462	407 ?		
1719	200	137		
2036	300	197		
2307	190	151		
2347	300	40		
~~2310~~	1752	947		

$$\frac{1752 \text{ gal}}{947 \text{ min}} = 1.85$$

Omit 1502 Data.

$$\frac{1752-462}{947-407} = \frac{1290}{540} = 2.39$$

3/31/79

Must be missing data Jgm

	Y	X	XY	X^2
0035	300	48	14400	2304
0445	150	~~205.25~~ 250	37500	62500 — omit
0547	150	62	9300	22500
0705	150	78	11700	6084
0830	566	85	48110	7225
1042	130	132	17160	17424
1120	900	38	34200	1444
1427	303	187	56661	34969
1530	413	63	26019	3969
1543	700	13	9100	169
1805	370	142	52540 ~~22,540~~	20164
1820	370	15	5550	225

— CONTD —

JIM MORE,

I couldn't find the error in your calculations, so I changed the time to minutes and did my own. I also dropped the first data entry because I couldn't verify it. Final formula came out to be:

$$Y = 339 + 1.266(x)$$

	x ΔT-MIN	x^2 SEC.	Y	XY
0825				
0945	80	6400	400	32000
.041	56	3136	301	16856
1200	79	6241	446	35234
1306	66	4356	400	26400
1506	120	14400	456	54720
1650	104	10816	505	52520
1805	75	5625	456	34200
1900	55	3025	455	25025
2015	75	5625	454	34050
2120	65	4225	455	29575
2225	65	4225	455	29575
2347	82	6724	455	37310
	922	74798	5238	407465

$Y = 5238$

$\Sigma x = 922$

$\Sigma x^2 =$ 74798

$m = 12$

$\Sigma xy =$ 407465

Σx

$Y = a + bx$

$Y = 339 + 1.266\,(x)$

$$\boxed{\begin{aligned} 5238 &= (12)(a) + (b)(922) \\ 407465 &= 922(a) + (b)(74798) \end{aligned}}$$

$$\begin{aligned} {}^{-}402453 &= {}^{-}922\,(a) + \bar{(b)}\ 70840. \\ 407465 &= 922\,(a) + (b)\ 74798 \\ \hline 5012 &= 3958\,(b) \end{aligned}$$

$$\boxed{1.266 = b}$$

$407465 = 922(a) + (1.266)(74798)$

$407465 = 922(a) + 94694$

$312771 = 922(a)$

$$\boxed{339 = a}$$

From
B&W

Volume of CRDM
motor Housings
is 58 ft^3 total

$y = a + bx$

y = Makeup in time x (gal)

x = Time)

b = Makeup Rate (gal/hr)

N = No of Data Points

λ = 0700 to 2347

$\Sigma(y) = 5698$ $N = 13$

$\Sigma(x) = 16.78$

$\Sigma(xy) = 7442$

$\Sigma(x^2) = 22.78$

$$y = a + bx$$

I. $\Sigma(y) = Na + b\,\Sigma(x)$

II $\Sigma(xy) = a\,\Sigma(x) + b\,\Sigma(x^2)$

$5698 = 13a + b(16.78)$

$7442 = a(16.78) + b(22.78)$

$\frac{13}{16.78} = 0.7747$

$-5698 = -13a \mp 16.78b$

$5766 = 13a + 17.65b$

$68 = 0.87b$

$b = 78$

$5766 = 13a + (17.65)(78)$

$5766 = 13a + 1379.5$

$13a = 5766 - 1379.5$

$a = 337$

$y = 337 + 78x$

Integrated Makeup = 337 + 78 (Time)

(MAKE-UP DATA)

4/1/79	Y Gal Added	$\times \frac{1}{7.481}$ → Ft³ @ 70°F	$\times 1.075$ → Ft³ @ 280°F	X (HR) ΔTIME	XY Ft³/hr ~~Makeup Rate~~	~~XY~~	X^2
0825	460			1.42	653 ~~653.2~~		2.02
0945	400			1.33	532 ~~532~~		1.77
1041	301			0.93	280		0.86
1200	446			1.32	589		1.74
1306	400			1.10	440		1.21
1506	456			2.00	912		4.00
1650	505			1.73	874		2.99
1805	456			1.25	570		1.56
1900	455		6.538	0.92	419		0.85
2015	454			1.25	568		1.56
2120	455		65.38	1.08	491		1.17
2225	455		65.38	1.08	491		1.17
2347	455		65.38	1.37	623		1.88
	5698			16.78	7442		22.78
4/2/79					Ft³/HR		
0150	455		65.38	2.05	31.89	933 ~~932.75~~	4.20
0300	455		65.38	1.16	56.36	528	1.35
0445	455		65.38	1.75	37.36	796	3.06
0630	455		65.38	1.75	37.36	796	3.06
0723	455		65.38	0.88	74.30	400	0.77
0853	455	60.82	65.38	1.5	43.59	683	2.25
	2730			9.09		4136	14.69

(over)

	ΔTime	Gal/hr	
1310 - 430			~~6.32 148.5~~
1458 - 671	1.8	372	
1658 - 455	2.0	227.5	
1848 - 455	2.0	227.5	

2347 - 0853

$\Sigma(y) = 2730$ $N = 6$

$\Sigma(x) = 9.09$

$\Sigma(xy) = 4136$

$\Sigma(x^2) = 14.69$

$$2730 = 6a + 9.09b$$
$$\underline{4136 = 9.09a + 14.69b}$$

$$2730 = \cancel{6a} + 9.09b$$
$$\underline{2730 = \cancel{6a} + 9.7b}$$

$a = 0$

$b = \frac{300 \text{ gal/hr}}{60} = 5 \text{ gpm}$

Sheet 1

MAKE-UP RATE

4/1/79	GAL ADDED	Δ TIME	MAKEUP RATE
0825	460	1.42	324
0945	400	1.33	301
1041	301	0.93	324
1200	446	1.32	338
1306	400	1.10	364
1506	456	2.00	228
1650	505	1.73	292
1805	456	1.25	365
1900	455	0.92	495
2015	454	1.25	363
2120	455	1.08	421
2225	455	1.08	421
2347	455	1.37	332
	5698	16.78	

LEAST SQUARES FIT FLOW RATE = 337 gal/hr

4/2/79	GAL ADDED	ΔTIME	MAKE-UP RATE
0150	455	2.05	222
0300	455	1.16	392
0445	455	1.75	260
0630	455	1.75	260
0723	455	0.88	568
0853	455	1.5	303
	2730	9.09	

LEAST SQUARES FIT FLOW RATE = 300 gal/hr

Makeup Rate

Sheet 2

4/2/79	GAL ADDED	Δ TIME	MAKEUP RATE
1310	430		
1458	671	1.8	372
1658	455	2.0	227.5
1848	455	2.0	227.5

Cont. Hydrogen VS. time

–	1.7%
–	1.9%
–	2.0%
–	1.9%
0600	2.6% ?
0845	2.4% ?
4/1 1030	2.0%
1200	2.2%
1330	2.1%
1500	2.2%

Data Points H_2 Concentration In Containment

Recombiner flow = 90 ft³
at -1.2 psig : 82 → 94°F
.02 × 90 = 1.8 cfm of H_2 burned/hr. Started recombiner at 1547 on 4/2/79

Date	Time	Concentration	
3-28-79	1400	0 %	(Assumed Detonation Event)
3-31-79	0400	1.7 %	
3-31-79	1200	1.9 %	
?	?	2.0 %	
?	?	1.9 %	
4-1-79	0700	2.6 %	
4-1-79	0900	2.4 %	
4-1-79	1030	2.0 %	Calculated Removal Rate and Gen. Rate
4-1-79	1200	2.2 %	Generation Rate slowed - 2.6 & 2.4 Readings Appear to be erroneous.
4-1-79	1330	2.1 %	
4-1-79	1500	2.2%	
4-1-79	1600	2.1 %	
4-1-79	2200	2.3 %	
4-2-79	0215	2.3 %	
4-2-79	2100	1.9 %	
4-3-79	0001	2.1 %	IN LINE MONITOR
4-3-	2100	1.9 %	

\# H_2 in Containment is @ 2% = .02 × 2 × 10⁶ = 40,000 ft³

$$\text{Removal rate} = \frac{24 \times 16 \times 1.8 \times 100\%}{2 \times 10^6} = .034\%/\text{day}$$

G/72-3.e-2

MICROFILM

DOCUMENT INDEX TARGET

DESCRIPTION

GAS ANALYSIS RESULTS

HG-0002

(55 spaces maximum)

DATE

05-03-79 (18 spaces maximum)

DESCRIPTION CONTINUATION

FILE NUMBER

(20 spaces maximum)

NOTE: Maximum spaces include all punctuation marks, dashes and spaces between words.

Description continuation should only be used when abbreviations are not appropriate.

REEL NO. ____________ BLIP NO. ____________

MF 174 (5 42) 7 78

```
GAS ANALYSIS RESULTS

AIR

DATE: 3  31  79
 VOLUME % HYDROGEN= 0.0
VOLUME % OXYGEN= 20.5
VOLUME % NITROGEN= 79.5
```

Gas Partitioner to check analyzer

Chart UNITS

H_2 - 0

O_2 - 16

N_2 - 46½

3/31/79

0600 Hrs

```
GAS ANALYSIS RESULTS

UNIT 2 R. BLDG

DATE: 3  31 / 79
 VOLUME % HYDROGEN= 1.7
VOLUME % OXYGEN= 15.7
VOLUME % NITROGEN= 82.6
```

Chart Units

H_2 - 14.5

O_2 - 12

N_2 - 47½

```
GAS ANALYSIS RESULTS

UNIT 2 R. BLDG

DATE:    31 / 78
 VOLUME % HYDROGEN= 1.7
VOLUME % OXYGEN= 16.5
VOLUME % NITROGEN= 81.8
```

0

Chart UNITS

H_2 - 16

O_2 - 14

N_2 - 52

RADIOLYTIC HYDROGEN GENERATION D.A. NITTI

@ 22:00 HRS 3/29

20 HRS ON 3/28
22 HRS ON 3/29
(42) HRS @ 22:00 HRS

EV = 1.7×10³⁰ — ASSUMES TOO HIGH AN ENERGY ABSORB. EFFICIENCY

$$\frac{0.45}{6.03\times10^{23}\ \frac{}{g\ mol}} \times \frac{1.7\times10^{30}\ (eV)}{100\ \left(\frac{ev}{}\right)} \times \frac{22{,}400\ \frac{cc}{g\ mol}}{28317\ \frac{cc}{ft^3}} = 10{,}036\ FT^3\ H$$

EV IN CORE FOR PMHA	8.1×10^{29}	REF: TMI-2 FS
10% EV IN SOL'N FOR PMHA	0.85×10^{29}	APPENDIX-15
TOTAL EV FOR PMHA	8.95×10^{29}	

$$\frac{0.45 \times 8.95\times10^{29} \times 22400}{6.03\times10^{23} \times 100 \times 28317} = 5284\ FT^3\ H_2$$

FOR G_{H_2} OF 0.5 VOL OF H_2 WOULD BE 5871 FT^3 H_2
FOR G_{O_2} OF 0.25 " " O_2 " " 2936 FT^3 O
8807 FT^3

{275 FT^3 COMPRE

$$\text{COMPRESSION RATIO} = \frac{935\ PSIA}{14.7\ PSIA} \times \frac{502°R}{997°R} = 32$$

$$\frac{275\ ft^3}{42\ hr} = 6.5\ ft^3/hr.$$

I.e. to release to Met Ed, then Sam will draw

AIR ADDED TO RCS WITH WATER FROM BWST

PERRY'S CHE HANDBOOK P.675 IN 3RD ED.

AIR: $H = 5 \times 10^4$ @ 6°C (42°F)
$H = 6.6 \times 10^4$ @ 20°C (68°F)

VOLUME IN HEAD REGION
HEAD 800 FT³
RISER 1000 FT³
[illegible] 500 FT³
2300 FT³

935 PSIA @ 537°F

$p = Hx$

H = HENRY'S LAW CONST
p = PARTIAL PRESS. IN ATMOSPHERES
x = MOLE FRACTION

$$x = \frac{p}{H} = \frac{1\text{ atm}}{5 \times 10^4} = 2 \times 10^{-5} = \frac{[illegible]}{\frac{[illegible]}{29\,(g/gmol)} + \frac{1000\text{ gm}}{18\,(g/gmol)}}$$

[illegible]

$m_a\,(g/l) = 0.0322$ gm air
$m_a\,([illegible]) = 1.11 \times 10^{-3}$
$V_a\,(cc/kg) = 24.9$ cc/kg

$$\frac{473{,}000\text{ gal in BWST}}{55\text{ FT (FULL)}} \times 33\text{ FT LEVEL CHANGE} = 284{,}000\text{ gal}$$

$$284{,}000\text{ gal} \times 8.33\,\frac{LBS}{gal} \times 0.4536\,\frac{Kg}{LB} = 1.072 \times 10^6\text{ Kg BWST L}$$

$$\text{VOLUME OF AIR ADDED} = \frac{1.072 \times 10^6\text{ Kg} \times 24.9\,\frac{cc}{Kg}}{28{,}317\,\frac{cc}{FT}} \times \frac{14.7\text{ PSIA}}{935\text{ PSIA}} \times \frac{997°R}{502°R} = 29\text{ FT}^3$$

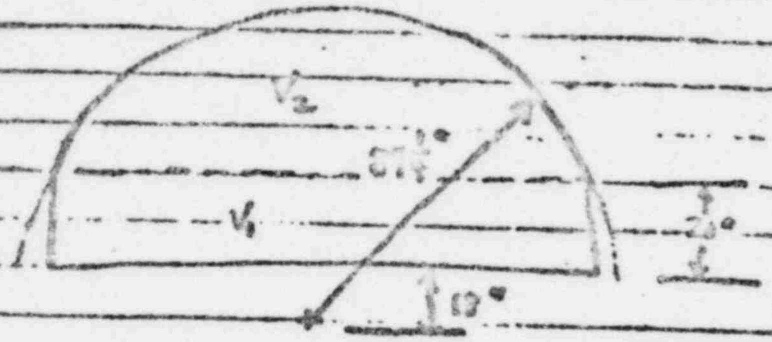
AT TEMP =
PRESS =

$$\frac{1.072 \times 10^6\text{ Kg} \times 24.9\,\frac{cc}{Kg}}{28{,}317} = 943\text{ FT}$$ AT TEMP = [illegible]
PRESS = 14.7 P

Volume Calculations

CWP 3/29/79

Reactor Vessel Head Volume



$$V_1 = \pi r^2 h = \pi(82")^2(20")$$

$$V_1 = 422{,}481 \text{ in}^3$$

$$V_1 = 244 \text{ ft}^3$$

$$V_2 = \sim \tfrac{2}{3}\pi R^3 - V_1$$

$$V_2 = \tfrac{2}{3}\pi\left(\tfrac{87}{12}\right)^3 - 244$$

$$V_2 = 554 \text{ ft}^3$$

$$V_{head} = V_1 + V_2 = \underline{\underline{798 \text{ ft}^3}}$$

Plenum Volume

$$V = \pi r^2 h = \pi(49)13$$

$$V_{plenum} = \underline{2000 \text{ ft}^3}$$

PARTIAL PRESSURE OF H_2 NORMALLY [in] MU TANK WHICH IS SUFFICIENT TO SUPPRESS RADIOLYTIC DECOMPOSITION

$H_a = 7.65 \times 10^4$ @ 60°C (140°F) — CRE.[illegible] P.G 5

$V_g = 20 \frac{cc}{Kg}$

$X_g = \frac{20\ cc\ H_2}{Kg\ H_2O} \times \frac{18\ gm/gmmol}{1000\ gm/Kg} \times \frac{1}{22,400\ \frac{cc\ H_2}{gmmol}} = 1.607 \times 10^{-6}$

$p = H X_g = 7.65 \times 10^4 \times 1.607 \times 10^{-5} = 1.23$ ATM → 18 PSI H_2 IN MAKEUP

PARTIAL PRESSURE OF H_2 IN RCS REQUIRED TO SUPPRESS RADIOLYTIC DECOMPOSIT

$H = 11 \times 10^5 \frac{psi}{gmmol} \times \frac{atm}{14.7\ psi} = 7.5 \times 10^4$ ✓ @ 77°F

$H = 2.53 \times 10^5 \frac{psi}{gmmol}$ @ 537°F

} BMI-T-25 TABLE 2

2.90
2.52
1.86

$p = y P \quad p = H X$

$y = \frac{H}{P} X$

$y = \frac{2.53 \times 10^5}{936} \times 1.607 \times 10^{-5}$

FOR SAT. W VAPOR = $y = 4.32 \times 10^{-3}$ ✓

$p = H X = 2.53 \times 10^5 \frac{psi}{gmmol} \times \frac{20\ cc\ H_2}{Kg\ H_2O} \times \frac{18\ [illegible]}{1000\ gm/Kg}$ and $\frac{1}{22,400\ cc} = 4.05$

ASSUME AN 500 FT³ BUBBLE

Vol Air @ 537°F & 935 PSI = 29 FT³ = 1192 gm mol
Vol H_2 @ " " = 179 FT³ = 7418 gm mol
Vol O_2 @ " " = 92 FT³ = 3709 gm mol
Vol Steam @ " " = 185 FT³ = 23,[illegible] gm mol
500

0.478 — y_0 = 0.153

X in 800 FT³ BUBBLE IS 45 TIMES [illegible]ER THAN X OF 4.32 × 10

G/712-3.e-3

P

Primary Sample

11. COLLECTION OF GASES FROM WATER

1.0 Introduction

Dissolved gases are obtained from water samples by pumping a vacuum over the sample and stripping the water vapor from the gas stream in a cold trap. The apparatus used to separate the gases from the water and to measure the gas volume is shown in Figure 1. The maximum volume of gas that can be collected is limited by the mercury depth in the base of the Toepler pump. This maximum volume is approximately 100 standard cc; however, optmum gas collection is 25 standard cc or less. Avoid overpressuring the system because the glass apparatus may shatter.

2.0 Apparatus

The components as described in Figure 4 include a 500-cc ballast volume, a cold trap, a Toepler pump, and a gas burette with leveling bulb. Mercury is the working fluid in both the gas burette and the Toepler pump. One mechanical pump is used to evacuate the gas system and to operate the Toepler pump; another pump is used to evacuate the sampling bulb. A Pirani tube is sealed into the apparatus to determine the quality of the vacuum and to test for leaks in the system. The small sampling bulb (approximately 5 to 10-cc) is used to separate a portion of the gas collected from the sample for analysis by mass spectrometry.

Water samples to be degassed usually are supplied in stainless steel bombs of about 500-cc, and these bombs are connected to the ballast volume by a length of flexible tubing. Other size samples can be accommodated but require that the quantity of gas obtained be compatible with the volumetric limitations of the apparatus.

2.1 Normal Operation

The sample bomb is connected to the empty ballast volume with flexible tubing. The mercury in the Toepler pump is lowered by carefully opening and adjusting stopcock D, which is connected to the mechanical pump. Stopcock B is then turned to connect the Toepler pump and cold trap, and the system is evacuated by opening stopcock A to the mechanical pump.

While the gas system with the cold trap is degassing, the gas burette, sampling bulb, and small section of tubing between stopcocks B and C are evacuated with another mechanical pump. The mercury is outgassed by raising and lowering the leveling bulb while pumping. Stopcock C is turned so that the gas burrette and tubing between B and C can be filled with mercury by raising the leveling bulb. The mechanical pump is left pumping on the sampling bulb.

When the Pirani gauge indicates that the pressure in the gas system is less than 50 μ, stopcock A is closed to check the system for leaks. Leaks are evidenced by a rapid rise in pressure on the Pirani gauge. Stopcock D should be closed during the leak test because mercury can be forced out of the Toepler pump system into the mechanical pump if a large leak should appear in the gas system. The most common source of leakage is the connection to the sample bomb; the valve on the sample bomb may not be tightly closed; or water might still be evaporating from the bomb fitting under the partial vacuum.

When all leaks have been eliminated, the system is pumped down to less than 50 μ, and liquid nitrogen is added to the cold trap. (Note: if carbon dioxide is a component of interest in the sample, dry ice and acetone must be substituted as a coolant). The pressure shown by the Pirani gauge should now be less than 10 μ. Stopcock A is closed next; no significant rise in system pressure should occur. At this stage, the mercury in the Toepler pump can be in either the raised or lowered position.

The valve on the sample bomb is opened to allow water to run into the ballast volume. As soon as the ballast volume is partially filled, the sample bomb is lowered so that no more water flows into the ballast volume (do not allow the flexible tubing to become kinked). The ballast volume is filled only partially so as to leave considerable water surface area exposed to the vacuum system; this assures maximum release of the gases from the sample. A rise in pressure usually is observed as the gases are released and generally is followed on the "Leak Test" scale of the Pirani gauge since the pressures are normally higher than can be read on the two pressure scales. When no further increase in pressure is observed, the release of dissolved gases is considered complete.

If the mercury has been in the raised position in the Toepler pump, the mercury now is lowered by carefully opening stopcock D to the vacuum pump. Stopcock B is examined to make sure it is open to the cold trap. Approximately 1 min is allowed for the gases to come to equilibrium in the system. The gas is transferred from the Toepler pump to the gas burette by opening stopcock B to the gas burette and by raising the mercury in the Toepler pump by carefully opening stopcock D to the atmosphere. When the gas in the Toepler pump has emptied into the burette, stopcock C is turned to close off the gas in the burette. The leveling bulb is used to equalize the pressure in the gas burette with atmospheric pressure, and the gas volume is read.

A second Toepler pump stroke is taken by dropping the mercury in the Toepler pump after opening stopcock B to the cold trap and repeating the operation as described. Toepler pump strokes are repeated until no increase in gas volume is observed. As many as 10 Toepler pump strokes may be required. The measured volume of gas is corrected to standard conditions with the following equation:

$$V_{stp} = \frac{P1\ Tstp}{Pstp\ T1}\ V1 \qquad (1)$$

where

Vstp = volume of gas at standard conditions, cc

Tstp = 273.16 °K

Pstp = 760 mm Hg

P1 = barometric pressure mm Hg

T1 = room temperature °K

V1 = volume as gas measured, cc.

Another method for calculating the volume of gas recovered arises from the fact that each Teopler pump stroke in a fixed percent of the total volume of the system. If the first Teopler pump stroke delivers 40% of the total gas in the system, then the second will deliver 40% of the residual 60% or 24% of the total. Using this relationship, a value for the total gas in the sytem can be calculated from each Toepler pump stroke although it is better to take several pump strokes to minimize any forcible fractonation of the gas during release from the water or from the cold trap. The percent of each Teopler pump stroke to the total volume must be determined for each size sample container but can be calculated from the normal data taken from the accumulated gas volume and numbers of Toepler pump strokes as follows:

Toepler Pump Stroke	Gas Accumulated (cc)	Gas each Stroke(cc)
1	5.7	5.7
2	9.4	3.7
3	11.5	2.1
4	12.8	1.3

The percent of gas remaining in system after each pump stroke is:

$$\frac{3.7}{5.7} = 64.8\% \qquad \frac{1.3}{2.1} = 62\%$$

$$\frac{2.1}{3.7} = 57\% \quad \text{average} = 60\%$$

Therefore, a pump stroke in this example is 40% of the total volume. Table 11 shows a typical gas volume calculation using this relationship. This calculated total volume also must be corrected to standard conditions. After the gas has been collected and measured, a portion is expanded into the sampling bulb for analysis by mass spectrometry.

TABLE 13
GAS VOLUME CALCULATION

Toepler Pump Strokes	Gas Accumulated (cc)	Total Gas (%)	Calculated Total Vol. (cc)
1	5.7	40	14.3
2	9.4	64	14.7
3	11.5	78	14.7
4	12.8	87	14.7
5	13.5	92	14.7

3.0 Type of Samples

3.1 Reactor Primary Coolant Water Samples

The gases normally observed in these samples are H_2, He, N_2, O_2, Ar, and CO_2. If carbon dioxide is requested in the analysis, dry ice and acetone must be used as the coolant in the cold trap to remove water vapor. This type of sample usually is received in a 500-cc stainless stell Hoke bomb. A 50-ml gas burette is used to collect the released gases. Results are reported as standard cc/liter of water for total gas recovered, and from the mass analysis of the gas, standard cc/liter for each of the observed components. The volume of water for each sample is measured after recovering it from the gas collection apparatus and the sample bomb.

3.2 Miscellaneous

When samples are received with no estimation of the quantity of gases per sample, the 50-ml gas burette is used during gas collection because this burette is suitable for volumes from approximately 1 to 50 ml. A 5-ml gas burette is available for use with samples known to contain less gas than can be accurately measured with the 50-ml burette.

When opening any sample container to the gas collection apparatus, care must be taken because a sample containing a large volume of gas under pressure could break the glass system. Watching the Pirani gauge while opening the sample container is good practice; although, some acceptable samples will have sufficient gas to be off scale on the gauge. An abnormally large volume of gas will cause pressure sufficient to force gas and mercury through the tube in the Toepler pump into its reservoir. Approximately 80-mm Hg pressure in the system is required or about 50 standard cc of gas if the Toepler pump reservoir is evacuated as it is during normal operation. If this occurs, the valve on the sample container should be closed immediately.

The sample arrived in Idaho Falls at 0640 hrs. MST on 4/14/79 via air transportation. Figure 1 illustrates how the sample was packed, with activity readings. Smears of the air craft and shipping drum indicated no external contamination.

At 0715 the sample left the Idaho Falls Airport, it arrived at INEL (CPP-602) at 0845 hrs. Upon arrival at CPP the sample (shipping drum) was off-loaded with an overhead hoist onto a four-wheeled dolly and transferred to lab 103C. At no time was the shipping drum allowed in a nonvertical position.

In lab 103C, the shipping drum was opened and the 8" diameter pipe lifted into a chemical fume hood. In the fume hood a sample of the argon atmosphere within the 8" pipe was taken. The method used for taking this sample involved the following. When valve 8 was opened on the TMI sample (~1105 hrs. MST) only a small rise in pressure was observed on the Pirani gauge (Figure 2) which indicated a small amount of gas compared to the ATR sample. Consequently, the TMI sample gas was collected for approximately 1 hr. or 10 Teopler pump strokes. The volume of gas collected was 0.8 + .2 cc and had the following composition:

H_2 1.5 ± .1*

He $<$ 0.01 (vol. percent)

N_2 89.4 ± .1

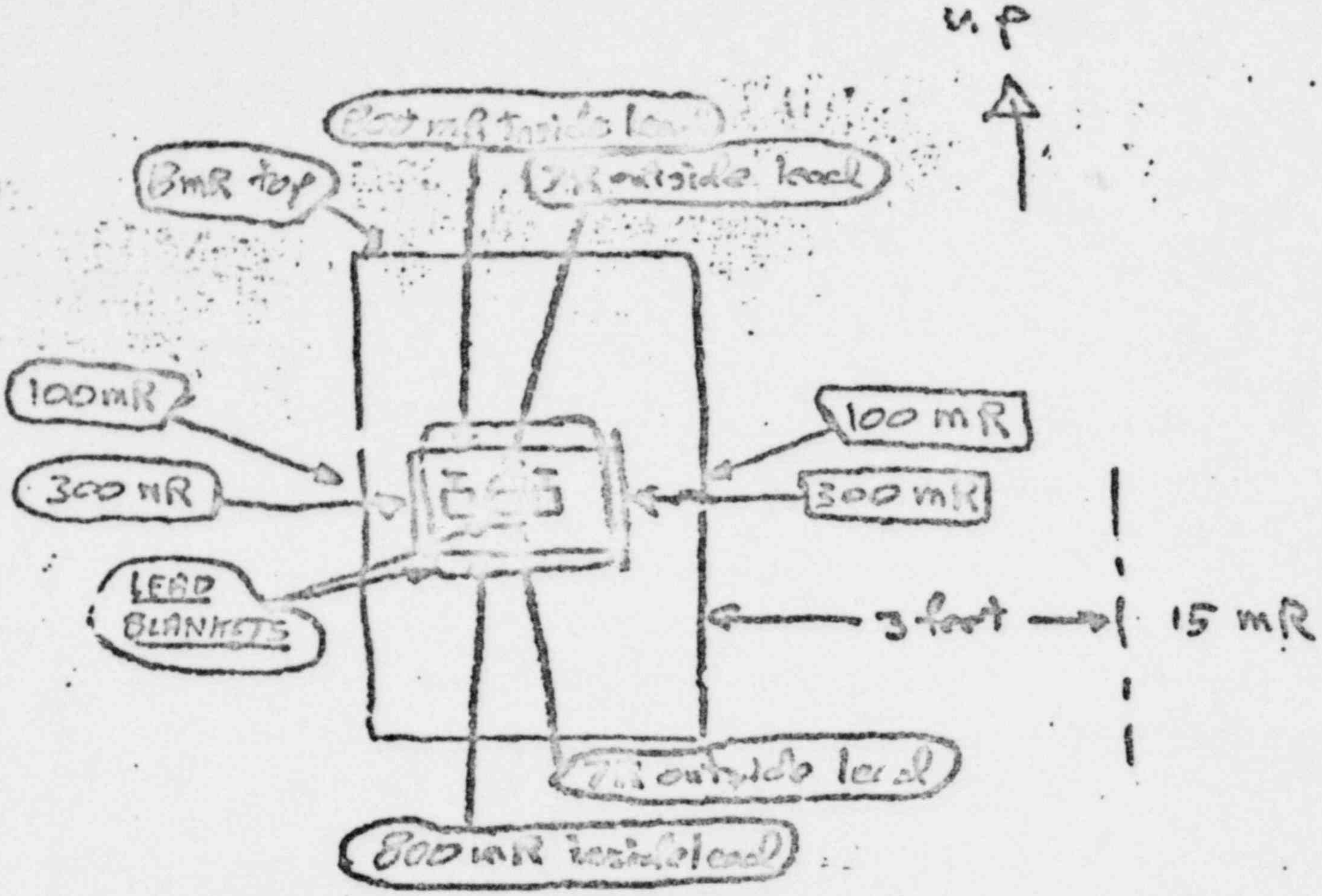
O_2 8.1 ± .1

Ar 1.00 ± 0.02

*Uncertainties are based on mass spectrometry measurements only. The mass spectrometry analysis is detailed in reference ICP-1031.

A gamma-ray pulse height analysis of the TMI gas sample indicated no observable activities above background.

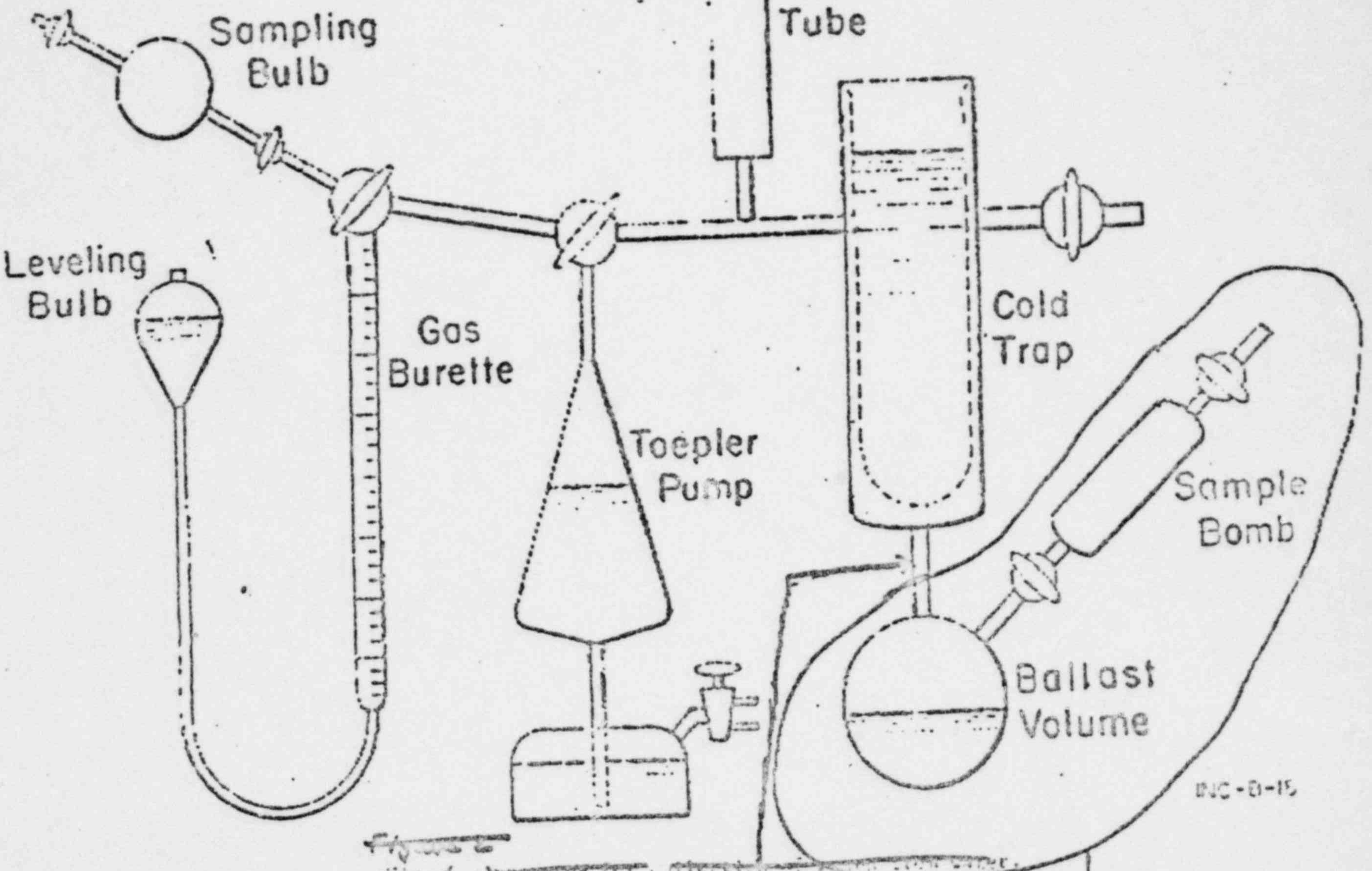
Fig I



31.5 ml sample total
~ 2 ml gas

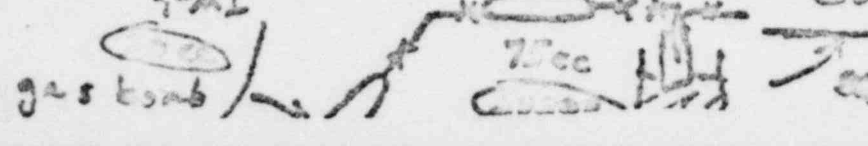
Transferable Contamination: none detectable

(From TMI Shipper)
4/4/79



~~Figure~~

Fig 2 Apparatus for Collection of Gases From Water



Replaced by remote apparatus for TMI test

APPENDIX A

Volume Measurement

Due to the sensitive nature of the analysis, we initially attempted to be extremely conservative and include all possible sources of error (no matter how remote they may be). The measurements indicated a total gas volume of 0.8 cc, but to be conservative a range of 0.8-1.7 cc was reported.

The initial measurement of the total gas volume performed at the gas collector is supported by the pressure measurement performed when the gas from the 10 cc sample bulb was expanded into the mass spectrometer inlet.

Based upon detailed analysis of the data, we conclude that the best estimate of the total gas in the 31.5 ml bomb is 0.8 std. cc and that this value is good to ± 30%.

Air Inleakage

We estimate that the air inleakage to the TMI sample was less than 0.07 std. cc. This estimate is based on the results using the ATR sample. To obtain an upper limit for air inleakage, it was assumed that all the oxygen detected in the ATR sample was due to air inleakage. Pumping time for the ATR sample was about 15 minutes.

APPENDIX B

Leakage to Cover Gas

Based on evaluation of the cover gas analysis, the maximum detectable hydrogen leakage from the 31.5 ml bomb to the cover gas is estimated to be 0.2 std. cc. This is based on the detection limit for hydrogen (i.e., 0.004%) and the assumption that the gas volume in the 8 inch pipe was 5000 cc.

$$\text{Max. } H_2 \sim \frac{0.00004\ (150)}{150/5000} = 0.2\ \text{cc}$$

6/712-3.e-4

MICROFILM

DOCUMENT INDEX TARGET

DESCRIPTION

HG-0001

(55 spaces maximum)

DATE

05-03-79 (18 spaces maximum)

DESCRIPTION CONTINUATION

FILE NUMBER

(20 spaces maximum)

NOTE: Maximum spaces include all punctuation marks, dashes and spaces between words.

Description continuation should only be used when abbreviations are not appropriate.

REEL NO. ______________ BLIP NO. __________

MF 174 (5 42) 7 78

4-1-79 @ 1000

1 Calculation of Hydrogen Generation Rate

1. Sample Data

3-31-79	0600	1.5% H_2
3-31-79	1200	1.9% H_2
4-1-79	0700	2.6% H_2
4-1-79	0900	2.4% H_2

2. From 0600 on 3-31-79 to 0900 on 4-1-79

$\Delta \% H_2 = .9\%$

$\Delta t = 27$ hours

3. Hydrogen Generated:

Cont. Free Air Vol $= 2.1 \times 10^6$ ft³

Change in H_2 Conc. $= .9\%$

2.1×10^6 ft³ $\times .009 = 1.89 \times 10^4$ ft³

4. Generation Rate:

$\Delta t = 27$ hrs

H_2 Generated $= 1.89 \times 10^4$ ft³

GR $= 1.89 \times 10^4 / 27$ hrs $\times$ 1 hr/3600 sec

GR $= .194$ ft³/sec

Assumptions.

1. Data points are correct and worst case
2. Information in FSAR is correct

B Calculation of Recombiner Removal Rate (ft^3/sec)

1 Data on Recombiner:

a. Removal Rate = 4.4×10^{-3} moles/sec @ 57 SCFM flow + 5% H_2

b Removal eff = 99%

2. Conversion:

a. Factors:

1. 1 mole = 22.4 l @ STP

2 1 ft^3 = 28.32 l @ STP

b Calculations:

1 4.4×10^{-3} moles/sec = .00348 ft^3/sec

$4.4 \times 10^{-3} \times 22.4 \left(\frac{l}{mole}\right)\left(\frac{moles}{sec}\right) = 9.86 \times 10^{-2}\ l/sec$

$9.86 \times 10^{-2} / 28.32 \left(\frac{l}{sec}\right)\left(\frac{ft^3}{l}\right) = .348\ ft^3/sec \times 10^{-2}$

3 Removal Rate:

* .00348 ft^3 H_2/sec

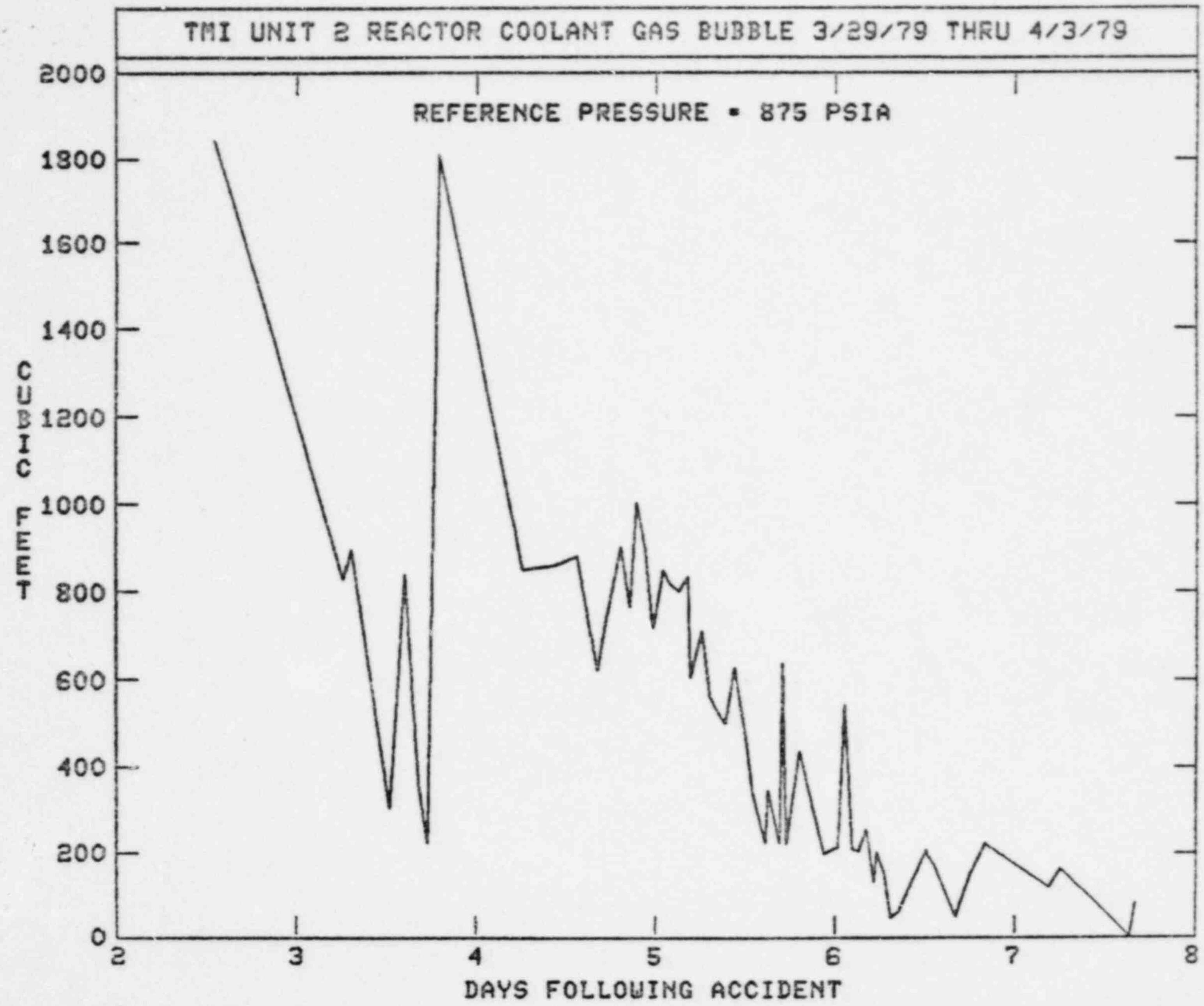
4. Based on Flow Rate of 57 SCFM 3% H_2

1 3% × 57 SCFM = 1.71 ft^3 H_2/min

2 $1.71 \times \frac{1}{60} \left(\frac{ft^3 H_2}{min}\right)\left(\frac{min}{sec}\right) = .0285\ ft^3/sec$

* Removal Rate = .0285 ft^3 H_2/sec

G/712-3.e-5


TMI UNIT 2 REACTOR COOLANT GAS BUBBLE 3/29/79 THRU 4/3/79

```
QTIME   BUB      QTIME   BUB      QTIME   BUB      QTIME   BUB      QTIME   BUB      QTIME   BUB
*****  *****     *****  *****     *****  *****     *****  *****     *****  *****     *****  *****
 2.54   1839      4.56    880      5.13    809      5.61    224      6.09    211      6.51    195
 3.26    829      4.67    821      5.18    827      5.63    347      6.13    205      6.55    174
 3.3     893      4.72    742      5.19    626      5.69    224      6.17    254      6.67     48
 3.58    308      4.8     901      5.26    710      5.71    635      6.21    130      6.75    148
 3.6     839      4.85    765      5.3     584      5.73    203      6.23    203      6.84    222
 3.68    368      4.89    893      5.34    535      5.8     438      6.27    152      7.19    118
 3.73    225      4.94    894      5.39    501      5.94    199      6.31     47      7.26    163
 3.79   1[illegible]      4.98    717      5.44    627      6.01    215      6.35     68      7.64      0
 4.28    [illegible]      5.04    848      5.5     486      6.05    543      6.5     208      7.67     82
 4.43    869      5.08    812      5.54    343

*_
```

6/712-3e-6

TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401

0/712-3.e-7

April 2, 1979

Metropolitan Edison Company

Attention: Mr. Gibb Staudt

LOAN OF HYDROGEN RECOMBINERS

Attached for execution by an authorized representative of your company is an agreement regarding liability for nuclear energy hazards and incidents applicable to two hydrogen recombiner systems.

The recombiners are being loaned with the understanding that they will be returned to TVA in the same condition as they were received, otherwise TVA will be equitably compensated for the equipment.

The equipment consists of 2 PWR hydrogen recombiner systems P/N [illegible]001-3 Serial Numbers 111A and 111B; 2 control consoles P/N [illegible]-01 Serial Numbers 111A and 111B; one thermocouple test panel P/N [illegible]-01 Serial Number 77027-4; and two operating and maintenance manuals [illegible]-35-HYB.

TENNESSEE VALLEY AUTHORITY

Marcel Anderson
J. Marcel Anderson
Purchasing Agent

Attachment

[illegible]

[illegible]

Metropolitan Edison Co., in consideration of TVA's loaning two hydrogen recombiner systems to it, agrees that if said property is used in a nuclear facility owned or operated by Metropolitan Edison Co., or by its subcontractor, Metropolitan Edison Co. will furnish nuclear liability protection in accordance with section 170 of the Atomic Energy Act (42 U.S.C. § 2210) and applicable regulations of the Atomic Energy Commission. Should this system of protection be repealed or changed, Metropolitan Edison Co. will undertake to maintain in effect during the period of operation of the plant, to the extent available on reasonable terms, liability protection which would not result in a material impairment of the protection afforded to TVA, Atomic International Division of Rockwell International Corp., or their subcontractors under the existing system.

Metropolitan Edison Co. waives any claim it might have against TVA, Atomic International Division of Rockwell International Corp., or their subcontractors because of damage to, loss of, or loss of use of Metropolitan Edison Co.'s property at the site of the nuclear facility resulting from nuclear energy hazards or nuclear incidents. Metropolitan Edison Co. will indemnify TVA its agents and employees and save each of them harmless from any and all liability to Metropolitan Edison Co.'s employees or any other third parties for personal injuries, property damage, or loss of life or property resulting from or in any way connected with the loaning of the hydrogen recombiners.

The foregoing provisions will apply to the full extent permitted by law and regardless of fault. The subcontractors referred to above include any of TVA's or Atomic International Division of Rockwell International Corp.'s suppliers of material, equipment, or services for the work, regardless of tier.

"Nuclear Energy Hazards" shall mean the hazardous properties of nuclear material. "Hazardous Properties" shall include radioactive, toxic, or explosive properties of nuclear material. "Nuclear Material" shall include source material, special nuclear material, or byproduct material as those are defined in the Atomic Energy Act (42 U.S.C. § 2014). "Nuclear Incident" shall have the meaning given that term in the Atomic Energy Act (42 U.S.C. § 2014(q)).

Metropolitan Edison Co. shall not transfer any interest in the said property without first providing TVA and Atomic International Division of Rockwell International Corp. with written assurances of limitation of and protection against liability following the proposed removal or transfer in an amount at least equivalent to that afforded under this agreement. In the event of a transfer, such assurances shall be obtained by Metropolitan Edison Co. from the transferee. Transfer contrary to the provision of this agreement shall, in addition to any other legal or equitable rights of TVA or Atomic International Division of Rockwell International Corp., make Metropolitan Edison Co. the indemnitor of TVA and Atomic International Division of Rockwell International Corp., and their subcontractors, to the same extent that TVA and Atomic International Division of Rockwell International Corp., and their subcontractors, would have been protected had no such transfer taken place.

ATTEST:

______________________________ METROPOLITAN EDISON CO.

G/712-3.e-8

TASK TRACKING SHEET 3107

INITIATED BY Jack Devine

TASK DESCRIPTION:

1. How Much Gas (Particularly H_2 + N_2) Could Be In The R.C. System Now?
2. Under Max. Degas. & 100 gpm Letdown How Much Gas Will Come Out of Solution Into M.U. Tank?

ASSIGNED TO: Daniels "Urgent"

DATE/TIME ASSIGNED: 4-4-79 1645

RESPONSE REQUIRED BY: ASAP
(Time)

TYPE RESPONSE EXPECTED:
R

- ___ WRITTEN PROCEDURE
- ___ GENERAL DESCRIPTION
- _X_ QUICK ANSWER
- ___ OTHER ___

RESOLUTION:

R C Pressure - 168 psia
R C Temp - 545 °F

pressurizer - 210"
11,300 ft³ = primary coolant.

*1. Gas solubility calculations based on H_2 and N_2, assuming saturation conditions, shows that there is approximately 15,000 cu ft (based on standard conditions, i.e. 14.7 psia) of gas in the Reactor Coolant System.

2. Assuming complete degasification in the make-up tank, the degasification rate will be 18 cu ft per minute.

*Note: Per Information from J.P. Moore at TMI Site on 4/5/79, R.C System conditions used for these calculations are 1000 psig and 280°F. The temperature of 545°F above seems to be the local high temp. in the Pressurizer for the operation of the Pressurizer heaters.

PREPARED BY: Stanley B. Chan / T.M. Dempsey

DATE/TIME RESPONSE GIVEN: 4/5/79, 12:10

TRANSMITTED TO: 4/5/79 12:40

VIA:
- ✓ TELECON
- ___ TELECOPY
- ___ MAIL
- ___ HAND CARRIED BY: R A Gower

J A Daniels

4/6/77

Maximum H_2-Concentration in Reactor Coolant

Reactor Coolant inventory: (ft^3)

Reactor	4010
2 × Steam gen's	4214
4 × RC pumps	392
RC inlet	750
RC outlet	738
Pressurizer Surge	20
	10,524
Pressurizer Water	800
	11,324

(Steam = 700 ft^3) (Total volume = 1500 ft^3)

Total reactor coolant inventory = 11,324 ft^3 = 320,660 liters

$1 ft^3 = 30.48^3 cm^3 = 28,316.8 cm^3 = 28.3168$ liters

From Figure 3: (@ 1000 psia and 258°F)

Max H_2 Concentration = 525 cc H_2/liter @ STP

Maximum Inventory of H_2 in Reactor Coolant:

= 525 (cc (STP)/liter) × 320,660 (liters) = 168.35×10^6 cc H_2 @ STP

= 168,350 liters (STP) = 5,945 scf

~~Density of dry Air @ 0°C, 760 mmHg = 1.2929 g/liter~~

What is the conversion factor between 1 cc (STP) and lb-mole of H_2?

Zirconium-Water Reactions:

$Zr + 2H_2O \rightarrow ZrO_2 + 2O_2$

1 lb Zr → 0.043953 lb H_2

1 lb Zr → 0.021978 lb-mole H_2

Assuming ideal gas law:

$$V = \frac{nRT}{P} = \frac{0.021978(10.71)(530)}{14.7} = 8.4866 \text{ scf/lb Zr}$$

$$\therefore \quad 1 \text{ lb-mole } H_2 = \frac{8.4866}{.021978} \text{ scf } H_2 = 10,934.3 \text{ liters } H_2 \text{ @ STP}$$

386.14

$\boxed{1 \text{ ft}^3 = 28.3168 \text{ liters}}$

Because:

$$\boxed{\frac{0.021978 \text{ lb-mole } H_2}{1 \text{ lb Zr}} = \frac{0.043956 \text{ lb } H_2}{1 \text{ lb Zr}} = \frac{8.4866 \text{ scf } H_2}{1 \text{ lb Zr}}}$$

$$\because \quad \boxed{1 \text{ liter } H_2 \text{ @ STP} = 91.4553 \times 10^{-6} \text{ lb-mole } H_2}$$

(Appendix A to SRP 6.2.5: "Combustible Gas Inside Containment")

Finally,

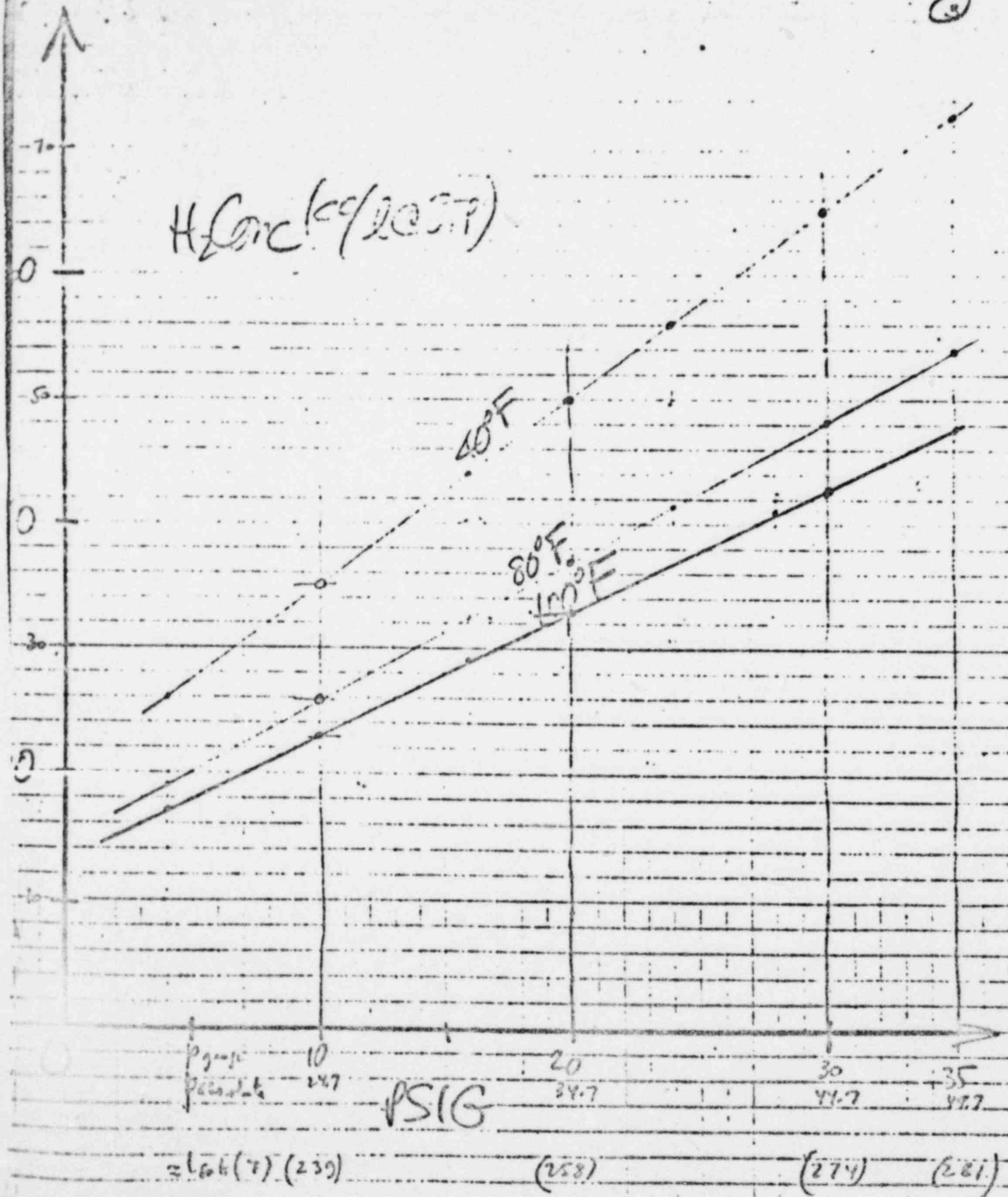
Maximum H_2 Inventory in Reactor Coolant @ 283°F, 1000 psia

$$= 168,350 \left[\text{liters } H_2 \text{ @ STP}\right] \times 91.4553 \times 10^{-6} \left[\frac{\text{lb-mole } H_2}{\text{liter } H_2 \text{ @ STP}}\right]$$

$= \underline{15.3965}$ lb-mole H_2

$= \underline{30.8 \text{ lb } H_2}$

③



Source: F. R. Cronson (NUS)'s Training Manual for an Army SM-1 Test Reactor (Water Chemistry

FIGURE 1

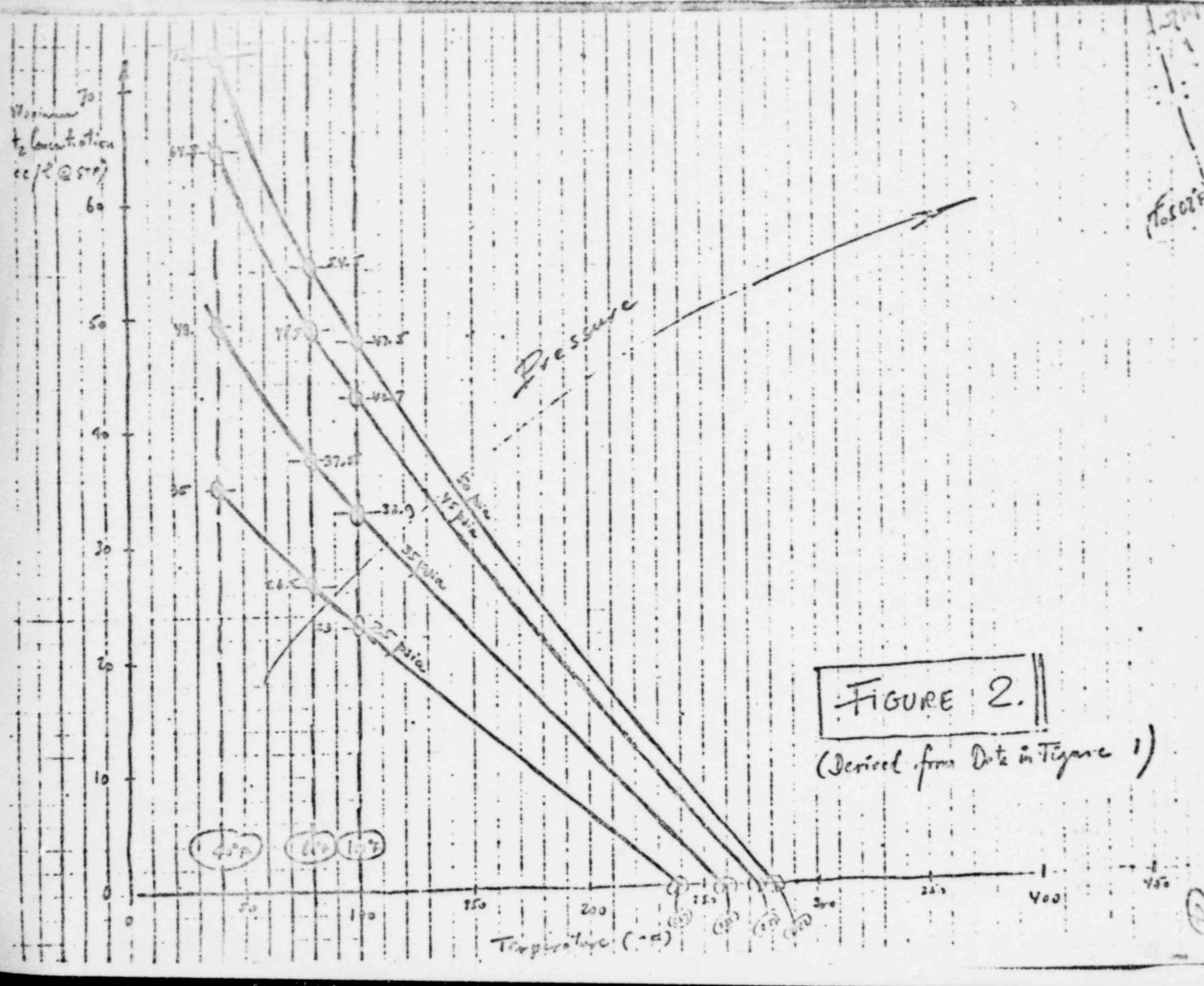
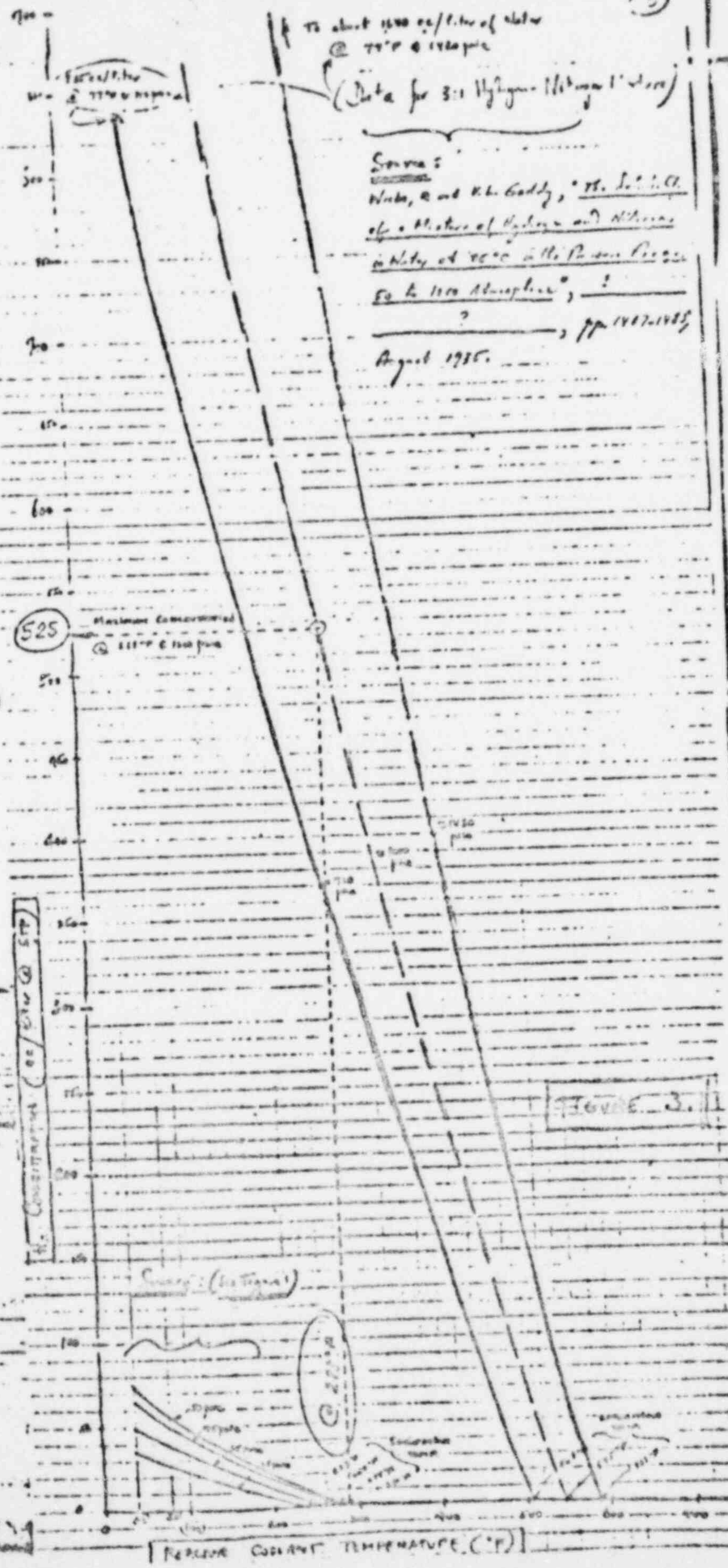


FIGURE 2.

(Derived from Data in Figure 1)

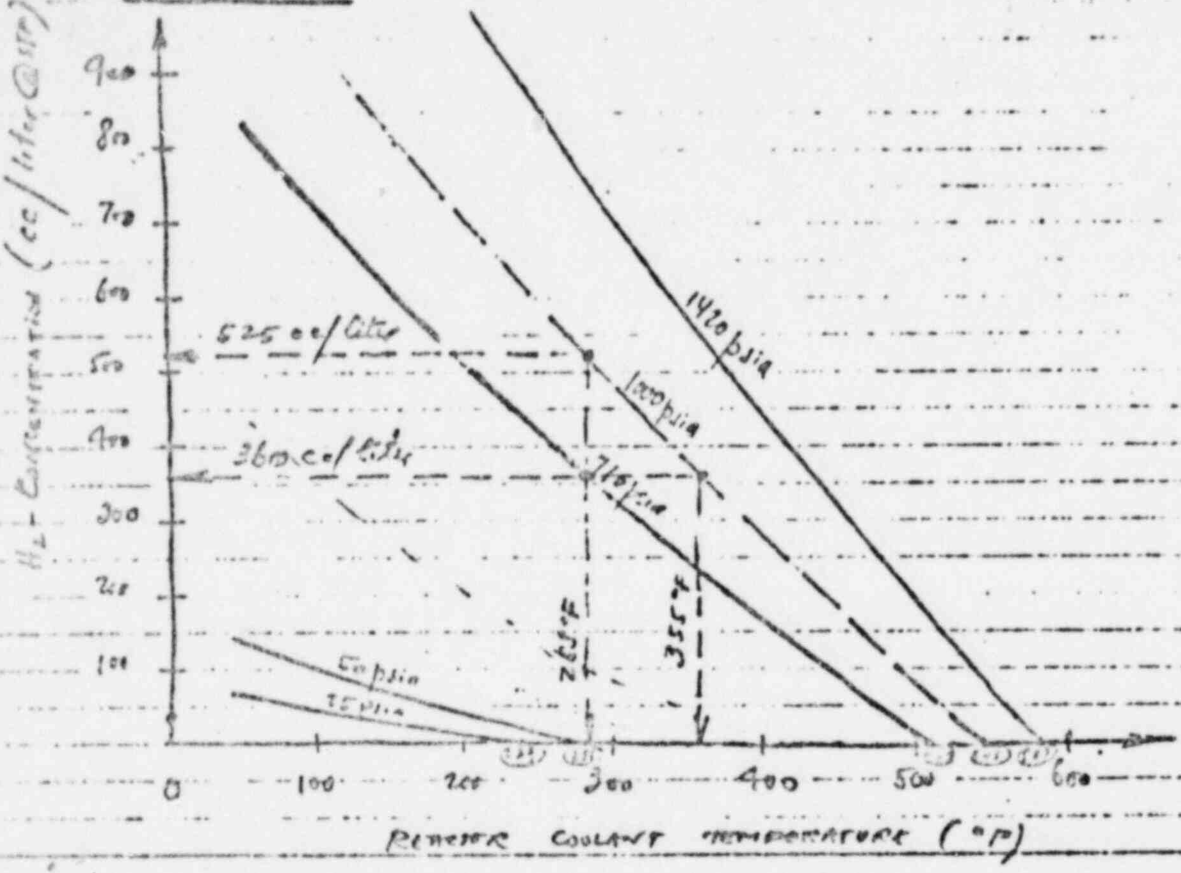


(Data for 3:1 Hydrogen-Nitrogen Mixture)

Source:
Wiebe, R. and V. L. Gaddy, "The Solubility of a Mixture of Hydrogen and Nitrogen in Water at 25°C in the Pressure Range 50 to 1000 Atmospheres", ?, pp 1487-1488, August 1935.

FIGURE 3.

Discussion



Case I: Assume that H_2-Concentration is equal to maximum value ($525 \frac{cc}{liter}$) in reactor coolant at 1000 psia and 288°F.

If: (a) RC pressure decreases from 1000 psia to 710 psia while RC temperature is maintained constant at 288°F, then (525 − 360) = 165 cc of H_2/liter will be released from RC to form H_2 bubbles.

(b) RC temperature increases from 288°F to 355°F while RC pressure is maintained constant at 1000 psia, then (525 − 360) = 165 cc of H_2/liter will be released from RC to form H_2 bubbles.

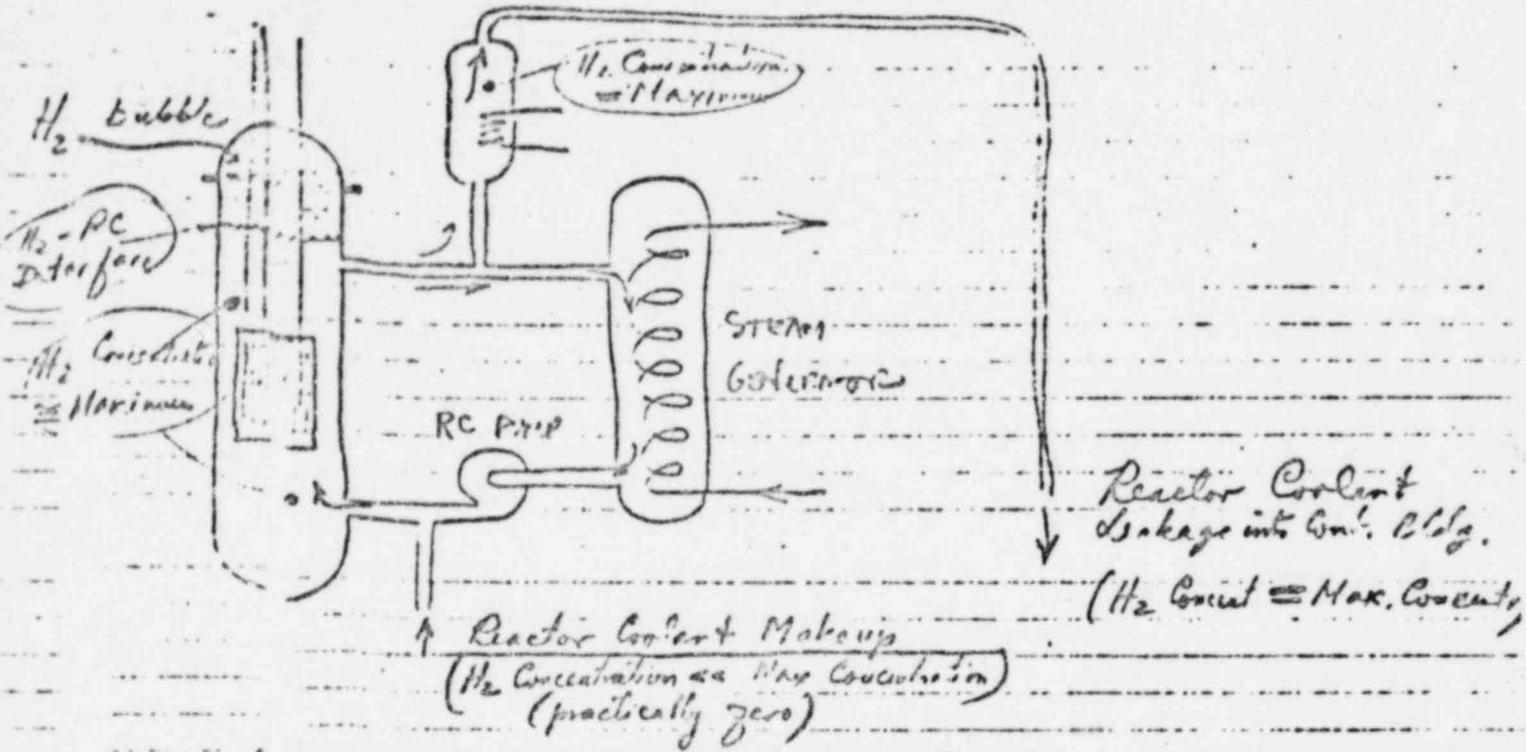
Case II: Assume that H_2-concentration is 360 cc/liter in reactor coolant at 1000 psia and 285°F

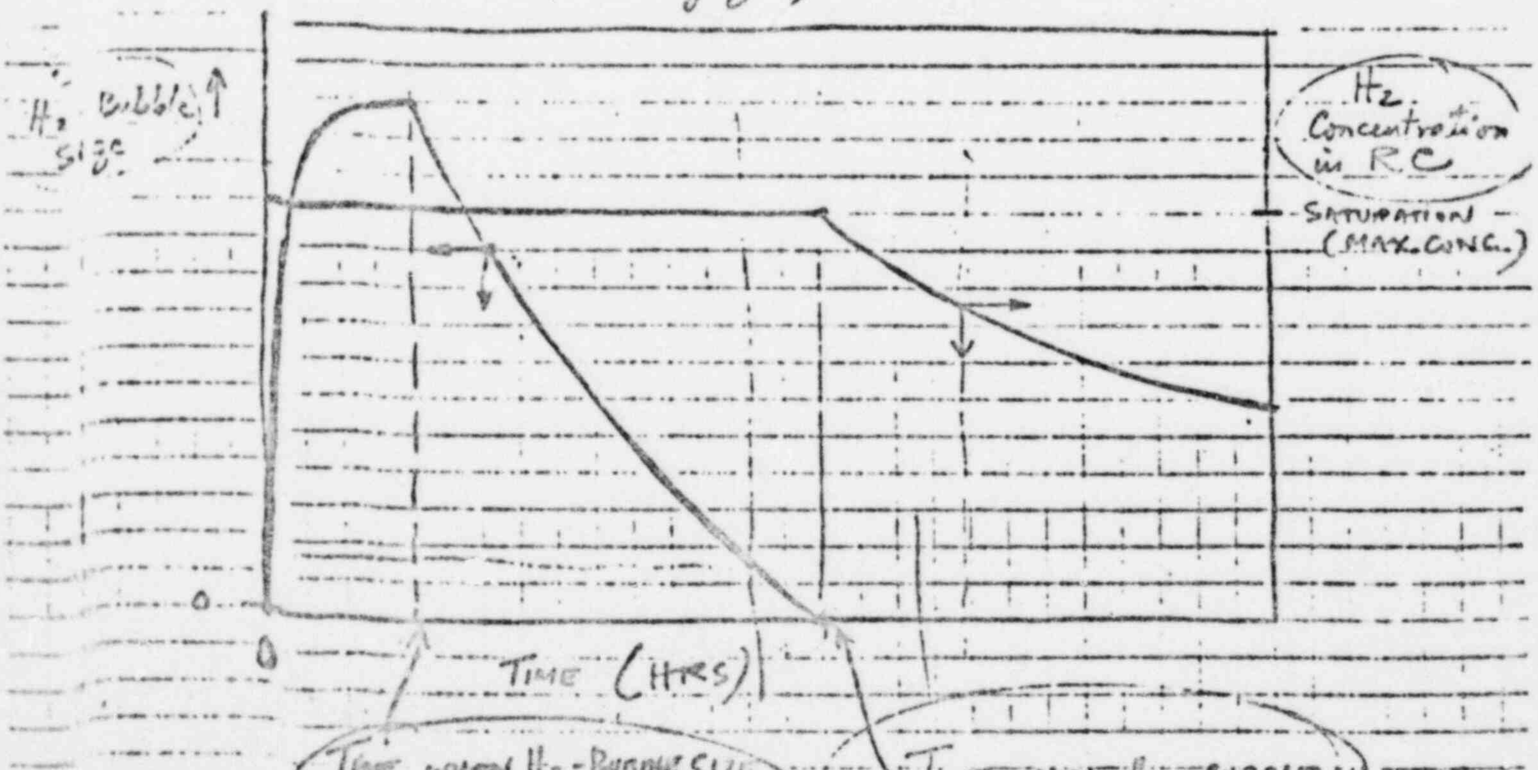
If: (a) RC pressure decreases from 1000 psia to 710 psia while RC temperature is maintained constant at 255°F, then no H_2 will be released from RC, but only the maximum H_2-concentration (at new conditions) will be obtained

(b) RC temperature increases from 285°F to 355°F while RC pressure is maintained constant at 1000 psia, then no H_2 will be released from RC, but only the maximum H_2-concentration (at new conditions) will be reached.

Transient Behavior:

H_2-Removal from Reactor Coolant





DEGASSING FILE

ALSO See Back OF PAGE

GAS Diffusion:

[illegible] not think he is the one [illegible] talk to.

② Dr R.L. Pigford
300 Wilson Rd
Newark Del
302 366-1237

No answer ① Dr Aaron Teller
293 Turnpike Rd
Apt 804-E
Westboro Mass.
617-366-8046

DR. SHELBY MILLER.
ARGONNE, NAT LAB - CHICAGO
1-312

Jim Dunavan recommended [illegible] recommended Vivian

③ ARTISAN Industries
WALTHAM MASS 617-893-6800

Chem Seps: Oakridge Tenn
615-483-7424.

⑥ phone not in service

David Rose (617) 494-8266
Hoyt Hotel (617) 727-3873

Pat Nesbitt to contact

④ Manny Sneylon, Lloyd Nesbitt
Bill DeHollander
Chem Technology GE

good comments on let down system

already contacted

[illegible]

⑤ Dr J. Edward Vivian, MIT, (617) 646-3129 (home)
(617) 253-4592

8:00 pm will call

auxiliary stripper on letdown system

Per [illegible] (4) is written good comments on let down system

Contacted

Manny Sugler, Lloyd Nesbitt
Bill DeHollander
Chem Technology, T E

[illegible] (5) [illegible]
8:00pm will call back

Dr J. Edward Vivian, MIT, (617) 646-3129 (home)
(617) 253-4592

Results to be written to GPU per 4/8/79 discussion — T DA [illegible]

auxiliary stripper on letdown system
. reduce makeup tank press
more steam flow in [illegible]
let down probably more effective

C. J. King Univ Calif Berkeley Chem Engr
P.L.T Brian VP Engr Air Products Allentown Pa
325 [illegible]
Kenneth A Smith, MIT, Manchester, Mass (617) 526-1743

How to Maximize degas · Starting from 1000psi – 285°F
Results Available

How to Maximize degas. Starting from
1000 psi – 285°F

<u>Routes Available</u>

Pressurizer – Spray rate & height
– bubble conditions

M/U TK

Diffusion (Hex gassed # S/G TUBES)

Other?

Method – draw what's in RV bubble
– Shrink bubble
– Mix bubble
– Control Pumps

<u>Fundamental Principles</u> →

MIT, 253-4561
<u>Professor Vivian</u> → MIT. Chem Engg.
Exec Dir

Lower Temp. ?

FIND OTHER EXPERTS TOO

Tom

4/7/79 20:00

Dr. J. Edward Vivian, MIT, Consultation on Press/Temp that is most desirable in the primary system to accelerate degassing.

F Degas

Notes on Discussion with D.A. Rockwell

1. Adjust temperature upward in letdown so saturated at makeup tank
2. Higher spray temp better, lower partial gas press better, high htr temp
3. Both spray & letdown should be used
4. Pressure increase good 1) inc letdown flow 2) spray heated to higher temp
5. Temp not clear relative to desirable vessel conditions

4/8/79 14:50

Additional discussion w/ Vivian

1) Best pressurizer performance at low press & low temp.
2) Best letdown performance at low temp. Vivian is checking on press effect
3) H_2 solubility is a weak function of temp in 200-300°F range 300°F .7
200°F .6
4) Has found what he considers to be applicable data.

4/8/79 18:35

Tom —

Per Vivian conversation (telephone) w/ D.A. Rockwell
For improved letdown degassing we want —

1) higher vessel pressure
2) higher temp gives lower H_2 concentration of H_2 left in soln but much higher void fraction (lower mass flow rate) so prob better to go to low temp to maximize the H_2 removal.

Nucleation press = 535 psi (300°F)

~~300 psi~~	~~.018 vol gas / vol liquid~~
~~100 psi~~	~~.116~~
~~20 psi~~	~~1.5~~

Cooled to (200°F) ← strips H_2 better but larger volume to handle

gives → 515 psia nucleation press

		concentration
		.63 $\frac{ml\ H_2}{gm\ H_2O}$ (left in soln)
500 psia	.0008 $\frac{vol\ gas}{vol\ liq}$	.61 $\frac{ml\ H_2}{gm\ H_2O}$ S.T.P.
300	.018	.36
100	.116	.11
20	1.44 < stm H_2	.011

P_V = 11.5 psi stm
P_V 8.5 psi H_2

Cooled to (140°F)

gives 506 psia nucleation press		.63
500 psi	.003	.62
300	.016	.37
100	.094	.12
20	.64	.021 ie 3% of starting concentration

Higher pres good
1) higher driving head
2) more subcooling so less 2 ϕ flow.

Tom Crimmins 4/8/79 15:5 P ~~For~~ Degos

Request: Provide add'l guidance on use of
verbal
potassium permanganate - potential problems,
metal interaction, any precipitate, how
is it removed if it needs to be removed, what
is end product?

Requested from Pit 4/8/79 15:40

<u>Response</u>

Manny Siegler, Lloyd Nesbitt 4/9/79 1440 Telecon

500psi 285 °F sol of H_2

Would require the addition 1.2×10^4 kg of saturated $KMnO_4$

This is 5% of total loop volume.

Will make 600 kg of sludge & could increase pH to a value >10

Conclusion: sludge could plug letdown filters

Dont Use $KMnO_4$

H_2O_2 forms soluble product (H_2O)

Will form free O_2 (not good)

If necessary, add very slowly

H_2O_2 possible if req'd

Verbal response DAR to Dick Wilson, T. Crimmins 4/9/79 1500

Copy to ——→ " " 4/9/79 1505

Ⓡ DEBAS

Tom Crimmins (GPU) 8/9/79 0840

Request: Get second opinion, perhaps G.E., to confirm Vivian's opinion that temperature should be reduced.

Requested from San Jose (Pat Marriott) 4/9/79 0915

Response per telecon of Manny Ziegler, Lloyd Nesbitt on 4/9/79 1455

1) increased press OK

2) temp effect not important on stripping

3) 200°F would be better to maximize flow

Confirming telex to be sent.

Verbal response to T. Crimmins, Dick Wilson 4/9/79 1500 from D.P.M.

Copy to " " 4/9/79 1505

Tom

1. We told Wilson [illegible] of our degassing calculations and that they generally agree with the Combustion Engineering results. We also [illegible] that the [illegible] calculations were [illegible]

2. As per John [illegible] ([illegible]), we told Wilson to [illegible] the [illegible] to the tubes [illegible] cool down the [illegible] with minimum [illegible] [illegible] to [illegible] the [illegible] River [illegible] that a [illegible] temperature between the tube and the shell of [illegible] give a [illegible] stress of [illegible] psia. A [illegible]°F ΔT would give [illegible] therefore [illegible] both shell and tubes [illegible] at nearly same temperature [illegible] the tubes.

There doesn't [illegible] be a thermal shock problem with the shell wall. [illegible] told them to [illegible] out their transient accident analysis for loss of feed water [illegible] did not have it in an [illegible] copy). John Chiriguta [illegible] ([illegible]) examined thermal shock and crack growth [illegible] SG tube [illegible] vessel if they would have to go to natural c[illegible]

Their calculations [illegible] no crack initiation in the vessel and the SG [illegible] take 1/4" [illegible] (i.e., it would not fail).

[illegible] the action items [illegible] agreed to on 4/4/79.

L. E. [illegible]

Degassing questions asked by [illegible]

[illegible]culate the amount of gas in solution at 1000 psi, T = 320°F (saturated [illegible]nditions)

CE	[illegible]	[illegible] Pettis
[illegible] cc(STP)/kg	[illegible] cc(STP)/kg	[illegible] cc(STP)/kg

[illegible]culate the time to degas from 1000 psi (sat) to 500 psi (sat) with T = 320°F

CE	[illegible]	[illegible] Pettis
[illegible] hrs	[illegible] hrs	[illegible] hrs

[illegible]culate the volume of gas that comes out of solution at 500 psi (sat)

CE	[illegible]	[illegible] Pettis
[illegible] ft³	[illegible] cc(STP)/kg	[illegible] cc(STP)/kg

1400, 4/4/79

G/712-3e-9

RCA
RFW

Subj: Containment Bldg Pressure

E.C. Brolin called r.e. negative pressure design of Containment Building.
Tech Spec limit --2.5 psi (FSAR APPENDIX 3B page 14)
Negative design pressure based on tornado not long term negative pressure - the concern is that buckling of the liner may occur. i.e. popin
B&R does not recommend exceeding the -2.5 limit, they are going to provide the safety factor built into the calcs. they hadn't discussed this with the NRC.

RCA
RFW

Subj: Containment Bldg Pressu

E.C. Brolin Called: Safety factor for building design = 2 Said he does not recommend raising it, in fact, he recommends getting pressure down to 1 psi. He has a concern for buckling of the liner since the design basis was for a tornado.

a

C/712-3e-10

GPU Service

[illegible] 4, 1979

[illegible] Reactor Coolant System Pressure

To R. F. Wilson

Location Three Mile Island

The attached discussion and data is forwarded for your consideration as plans are made for where to go from here. There is general consensus among engineers on back shift at Mt. Lakes that starting to slowly reduce primary pressure (about 50 psi every six hours) is the most prudent course of action. Would propose reducing pressure to 350 (+50 -0) psi.

Dave Slear

D. G. Slear

DGS/al
ATT

Ash
Kepton
Cumming

[illegible] Plant Operating Pressure -

Benefits:

1. Drive dissolved gasses back out of solution due to reduced solubility at lower pressures so they can leak out(if we have leak path in head). If we have no spray flow, this gas in solution is not being removed very efficiently and could present a real hazard if we loose pressure rapidly. Could cause 1) RCP gas binding, 2) gas bind natural circulation flow, 3) gas blanket the core.

   NOTE: @ 1000 psia can hold 1.3 ml H_2 @ STP/gm H_2O in solution (Figure 4). This equates to 18,314 cuft of H_2 @ STP possibly dissolved in primary coolant.
   $(311,643,660 \text{ gms } H_2O \times 1.3 \frac{ml}{gm} \times 3.53 \times 10^{-5} \frac{ft^3}{ml} = 18,314 \text{ ft}^3)$

   If we do not drive dissolved gasses out while we have flow, any pressure reduction while on natural circulation may result in gas binding of candy cane. If lost flow at 1000 psi, we may have to stay at 1000 psi indefinitely with only pressurizer or HPI pumps available to maintain pressure.

2. Get to point where we have a backup pressure control mechanism that is relatively passive. Below 600 psi could float on core flood tanks to preclude further pressure reduction.

3. Less cycling of pressurizer heaters so may extend their life.

4. Below 300 psi decay heat system is usable.

5. Below 125 psi, spent fuel cooling and cleanup system is usable if interconnected thru decay heat.

Liabilities of Reduced Pressure:

1. Closer to pump NPSH limits. However, at 1000 psi and 280 F, we are approximately 650 psi higher than NPSH requirements. At 600 psi, we would still have approximately 250 psi cushion before reach pump NPSH curve.

2. Lower pressures require higher natural recirculation flows to keep temperature [illegible] below T_{sat}. Data available to us is as follows:

RC-2 Required [illegible] Circulation Flow (GPM) [illegible] Heat	Reactor Pressure
[illegible]	1000
[illegible]	400
[illegible]	300
[illegible]	250
[illegible]	200
[illegible]	150
327	100

[illegible] Natural Circulation Flow Test

Decay Heat	Required Natural Circulation Flow @ 300psi	Measured Natural Circulation Flow
$1.66 \times 10^8 \frac{BTU}{Hr}$	$.99 \times 10^6$ lbm/Hr = 2226PM	7.6×10^6 lbm/Hr

NOTE: We are working with EI to run RETRAN for natural circulation mode and predict flow analytically. Also using model to see if one loop by itself will establish natural circulation.

3. If need higher pressures later on, reducing pressure now may complicate raising pressure later if pressurizer heaters or level is lost.

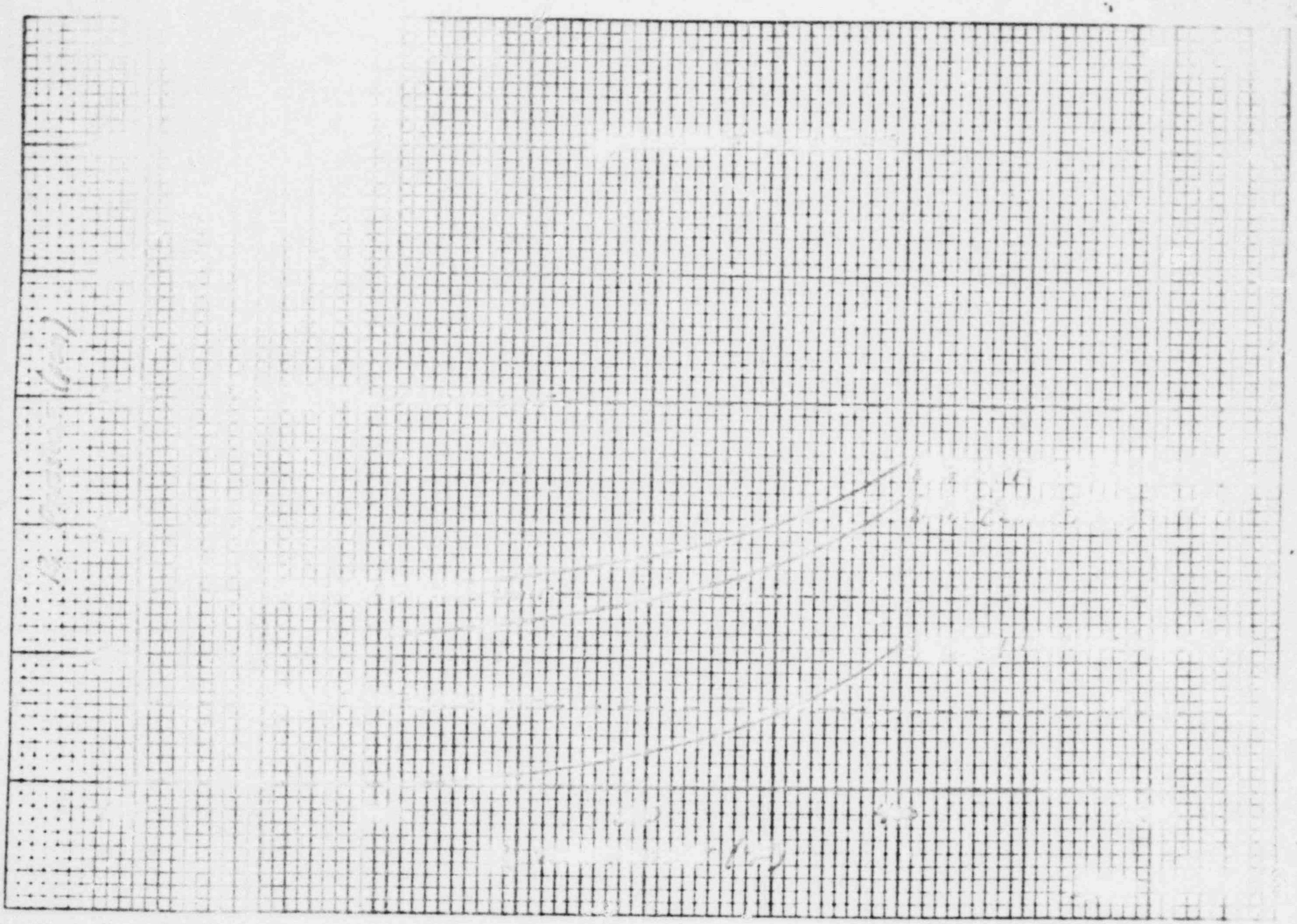
Another Benefit of Reduced Pressure:

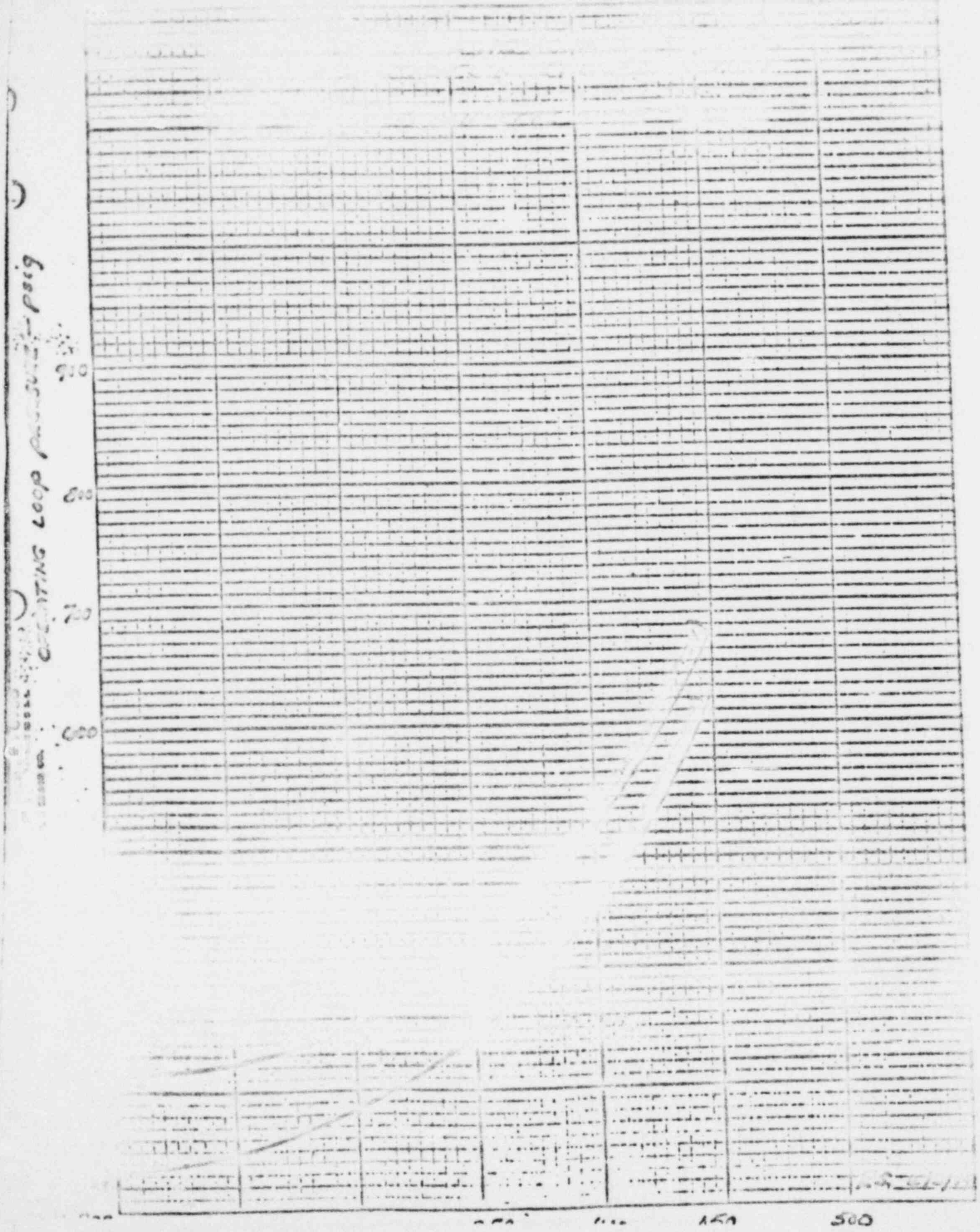
DHV-1, DHV-2 and DHV-171 are all inside containment and operators may become inoperable due to high radiation. There is a school of thought that they should be opened as soon as practical and left open to give us assurance that Decay Heat is a viable option. They are interlocked to not open above 320 psi.

ANOTHER LIABILITY

- THERE IS A PRECHARGE PRESSURE OF 400±25 psi IN FUEL RODS. PRESSURE BELOW THIS MAY RESULT IN FURTHER DAMAGE TO DISTRESSED RODS. SHOULD MONITOR CORE CLOSELY AS GO BELOW 425psi.

DGG


46 0700


OPERATING LOOP PRESSURE - psig
900
800
700
600
450
500

Message to 1700 4/1/79

Dick Wilson / Tom Crimmons

From: Larry Hochreiter
WE

As per our phone conversation last night, scoping calculations indicate that the reactor vessel looks okay from thermal shock point of view. Information on the decompression calculations and other thermal shock calculations given to Dick Wilson.

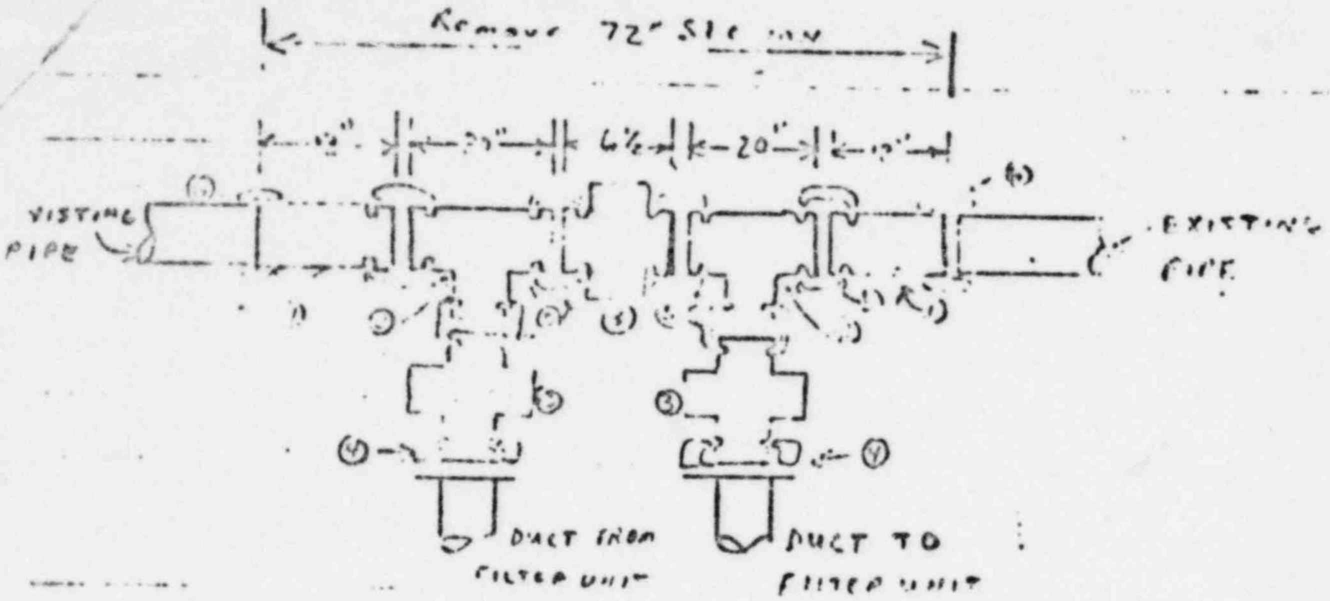
DICK WILSON

4-4-79

PIPING TIE-IN FOR VACUUM DEGASSIFIER EXHAUST FILTRATION UNIT

The piping tie-in for the vacuum degassifier filtration unit is composed of standard Victaulic couplings. No welding in the shop or in the field is required. The fittings, which will be located near column lines TJ-TH and T38-T39, will require that a 72" section of straight pipe be cut. Equipment location, ductwork layout, and exact piping tie in will be provided later. It will be located on elevation 280'-6" in the turbine Bldg.

See Drwg. M011



① Victaulic, 12" NIPPLE, grooved by plain end. (2)
② Victaulic, Tee #20, 12"X12"X12" (2)
③ Victaulic Butterfly Valve 701, 12" manual (3)
④ Victaulic Vic-Flange 741, 12" (2)
⑤ Victaulic Standard Coupling, Style 77, 12" (6)
⑥ Victaulic Plain End Pipe Coupling, 12" (2)

Dick Wilson Location @ TMI-2

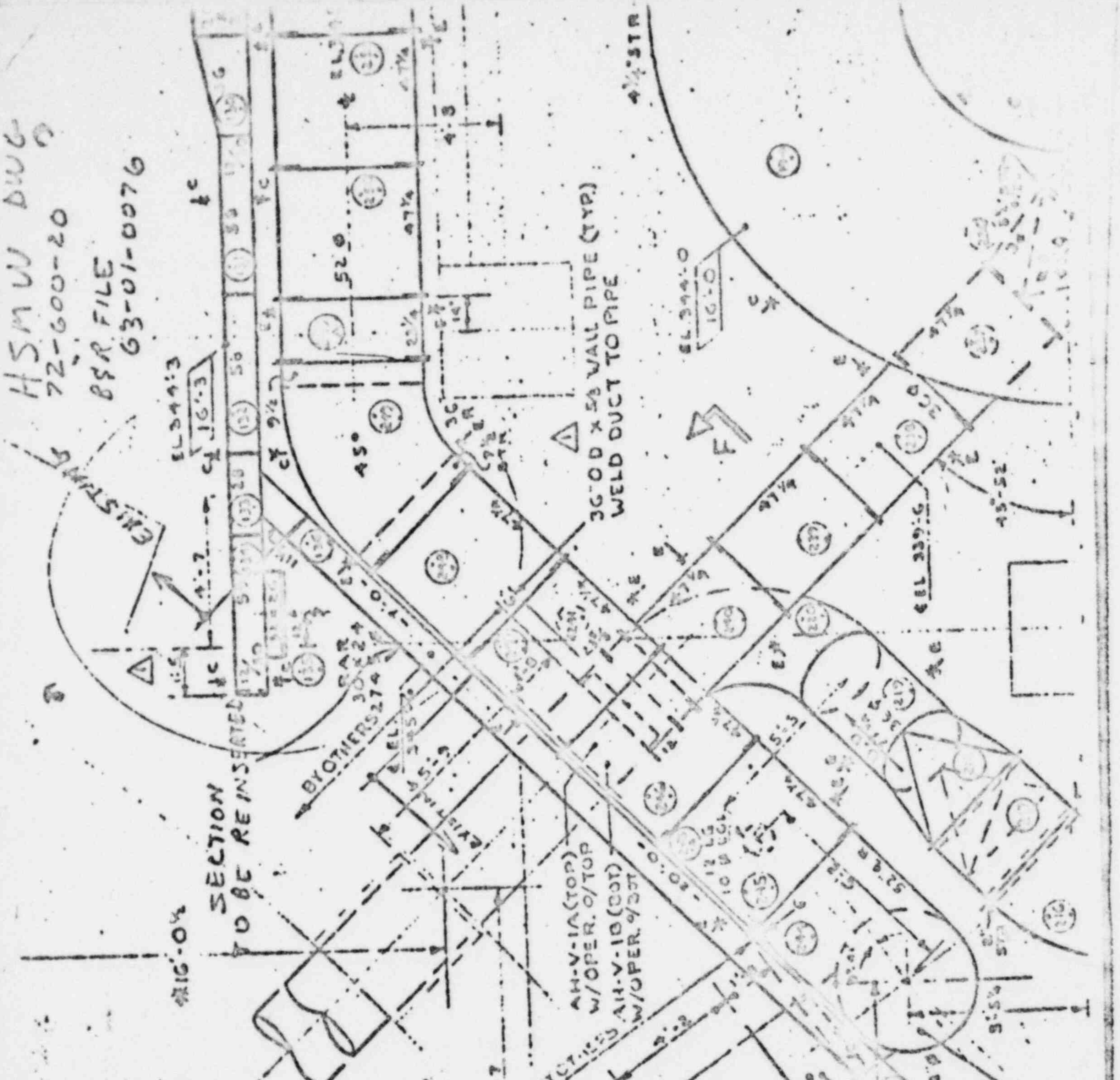
4-4-79

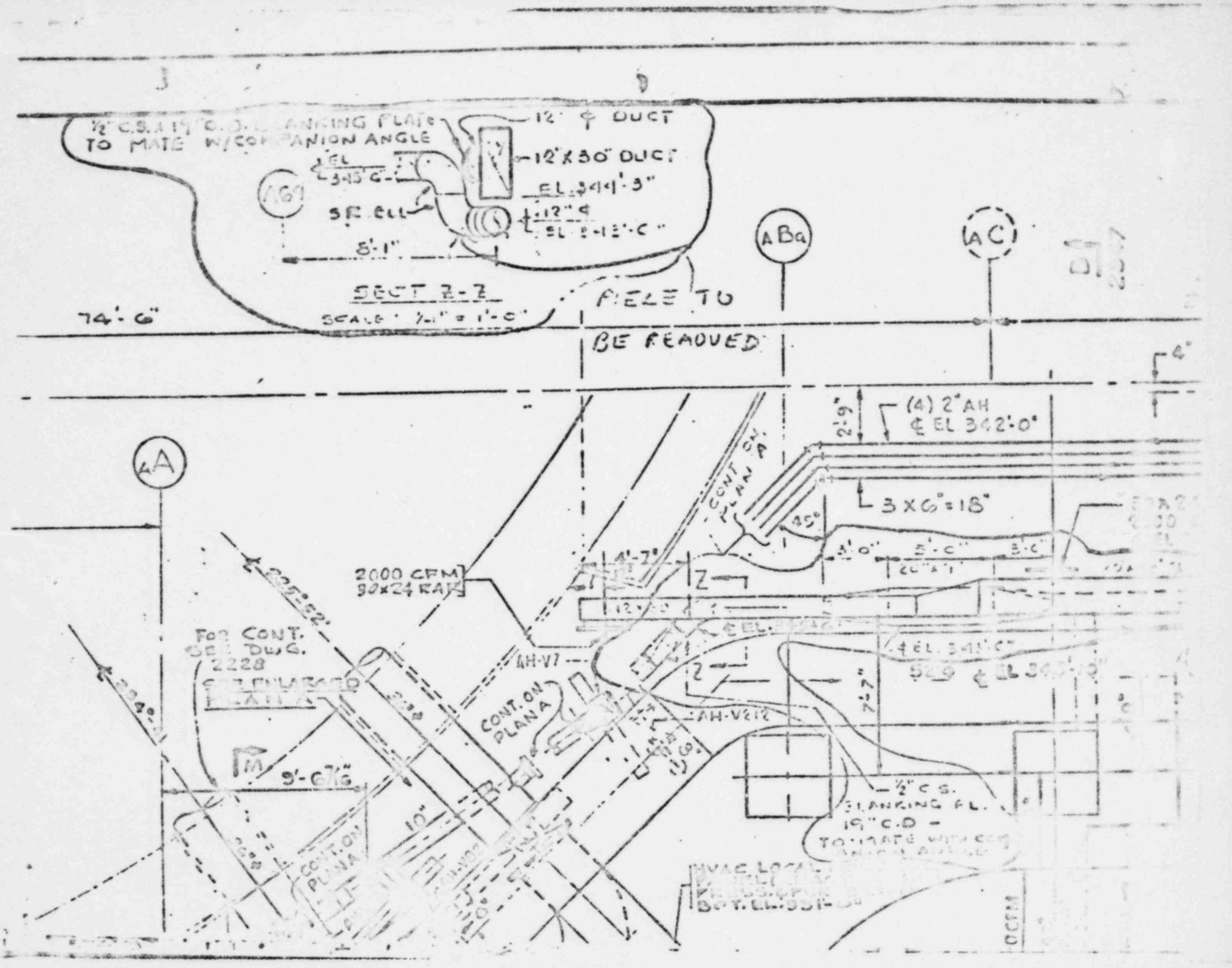
VACUUM DEGASSIFIER DISCHARGE INTO AUXILIARY BUILDING HEPA

1. HERSHMAN DWG 77-600-20 SHOWS
2. B&R FILE NO 63-01-0076

THE ABOVE AS-BUILT DWG BY HERSHMAN WAS SUBMITTED 9/21/78. IT SHOWS THE connection of the duct where GPU desire it. PCN 5292 revised it to the new location. It is possible that Hershman piece # (136) still exists at the site and can be installed by removing the blind flange on piece # (133) and removing the new ductwork where it attaches to (#137). The blind flange can be moved from the existing location to the newly exposed duct.

HSMW DWG
72-600-20
BSR FILE
63-01-0076




1/2" C.S. 19" O.D. BLANKING PLATE TO MATE W/COMPANION ANGLE
12" ¢ DUCT
12"X30" DUCT
EL 344'-3"
¢ EL 343'-6"
A61
5R ELL
12" ¢
EL 342'-0"
8'-1"
SECT Z-Z
SCALE: 1/2" = 1'-0"
74'-6"
FIELD TO BE REMOVED
ABa
AC
D
2047
4"
(4) 2" AH
¢ EL 342'-0"
2'-9"
3 X 6" = 18"
45°
CONT. ON PLAN A
4A
2000 CFM
30x24 RAF
4'-7"
3'-0"
5'-0"
3'-0"
Z
Z
¢ EL 343'-6"
529
¢ EL 343'-10"
AH-V7
AH-V212
FOR CONT. SEE DWG. 2228
SEE ENLARGED PLAN A
CONT. ON PLAN A
CONT. ON PLAN A
M
9'-6 7/16"
10"
7'-7"
1/2" C.S. BLANKING PL. 19" O.D. - TO MATE WITH COMPANION ANGLE
HVAC LOCAL
BOT. EL. 351'-6"
CCFM

6/712-3.e-11

RF WILSON

TO RF WILSON
4/6/79
2244

[illegible] DICK WILSON / L Rogers

R. W. [illegible]

TMI-II

OF C.F.

VOLUME OF CONTROL ROD DRIVES AND HEAD NOZZLES

4-6-79 - 5:23 p.m.

THE VOLUME OF THE CONTROL ROD DRIVES AND HEAD NOZZLES IS 64 CUBIC FEET. A TABULATION OF THE CALCULATED NOZZLE VOLUMES IS ATTACHED. THE CONTROL ROD DRIVE VOLUME CALCULATIONS WERE PERFORMED AT DIAMOND POWER.

fdm

cc: F. R. Burke [illegible] for FR Burke
R. A. Wallin
E. E. Suhrke

[illegible] (In.)	No. of Nozzles	Individual Volume* In Nozzle (In.^{3})	Total Nozzle Volume (In^3)
	1	106.71	106.71
[illegible]	4	108.35	433.40
[illegible]	4	111.50	446.00
33.2813	4	117.60	470.40
34.1813	8	120.76	966.08
37.6875	4	129.91	519.64
38.6875	4	133.06	532.24
39.7188	8	136.31	1090.48
42.8125	8	146.06	1168.48
46.0313	4	156.20	624.80
47.1250	8	159.65	1277.20
48.2500	4	163.20	652.80
50.5313	8	170.13	1361.07
	69	-	9649.30

No. of Drives	Individual Drive Volume (In^3)	Total Drive Volume (In^3)
69	1466.6	101,195.4

Total Volume = 110,845 In^3
= 64 ft.^{3}

*Nozzle Volume less leadscrew and support tube displacement

[illegible] CRD CD 32-1100571-00

4/5/79 at 4:45 p.m. Tom Crimmins or Jim Cunningham

1. We told him of the results of our degassing calculations and that they generally agreed with the Combustion Engineering results. We also mentioned that the W Bettis calculations were also consistent.

2. As per John Houchman ([illegible]), we told Wilson to have B&W examine the stresses in the tubes if you would cool down the SG quickly with minimum temperature feedwater flow. We told him to consult the Crystal River PSAR which indicated that a differential temperature between the tube and the shell of [illegible]°F would give a compressive stress of 12000 psia. A 150°F ΔT would give ~23000 psi. Therefore must bring both shell and tubes down at nearly same temperature to prevent buckling of the tubes.

   There doesn't seem to be a thermal shock problem with the shell wall. We also told them to have B&W dig out their transient accident analysis for loss of feedwater heater (we did not have it in an FSAR copy). John Chiriggs's people (Ted Meyer and Warren Bamford) examined thermal shock and crack growth in the SG tube sheet and reactor vessel if they would have to go to natural circulation.

   Their calculations indicated no crack initiation in the vessel and the SG could take 1/4" flaw (i.e., it would not fail).

This completes the action items W agreed to on 4/4/79.

L. E. Hochreiter

Telcon with Dick Wilson

XC: TMC
RFW
RK
TGB (2)
IRCA
J Golerbein
D Montgomery
G. Stoudt/File

Tom Crimmins cf- Jim Cunningham

Question: what pressure can the seamless steel pipe (ASME - Class II Section III pipe) and the fuel pool coolers really take?

Answer:

1. From Shelly Morrison of B&R. (201-262-
the piping into and out of the coolers is

10" & 8" — Seamless
ASME-A-376
A-312 Type 3

Based on this pipe

	Code Allowable	Yields at
8"	850 [illegible]	2.5 x C[illegible]
10"	750 [illegible]	2.5 x C[illegible]

2. Coolers
Bourbon Doylee [illegible] W
cold hydro [illegible] - shell [illegible]
- Tube [illegible]
Vendor (Ametek) [illegible] [illegible] [illegible]
to use cold hydro [illegible] upper bound
given the following conditions.
1. [illegible] [illegible] 100 [illegible]
2. ΔP [illegible] - shell < 45 p[illegible]
3. ΔT [illegible] shell [illegible] < 3[illegible]
[illegible] [illegible]

If any of the conditions [illegible] [illegible]
GPU must conduct [illegible] [illegible]

G/712-3.e-12

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

To: DICK WILSON, GPU OP. CENTER (TELECOPY TO 717-944-5070)

From: R. S. [illegible], B&W OP. [illegible]

BWB 603-5

Cust.

File No. or Ref.

Subj. ESTIMATE OF HYDROGEN CONCENTRATION IN THE REACTOR COOLANT

Date APRIL 6, 1979 0703

This space to show one customer and one subject only

ATTACHED IS A PLOT WHICH SHOWS THE DISSOLVED HYDROGEN CONCENTRATION IN THE REACTOR COOLANT AS A FUNCTION OF TIME AND DEGASSIFICATION RATE. THE CURVES ARE BASED ON THE ASSUMPTION THAT THE SUDDEN APPEARANCE OR DISAPPEARANCE OF A HIGH AC NOISE IN THE PRESSURE SIGNAL FROM THE B-LOOP PRESSURE TRANSMITTER ARE INDICATIONS THE APPEARANCE AND DISAPPEARANCE OF BUBBLES, AND THUS ARE INDICATIVE OF WHEN THE COOLANT JUST REACHES ITS SATURATION POINT. WE HAVE THE FOLLOWING TWO DATA SETS:

	RC PRESS. (PSIG)	SAT. H_2 PRESS. (PSIA)	SOLUBILITY AT SATURATION (STD. CC/KG)
APRIL 1 @ 15:10	920	885	1300
APRIL 2 @ 3:33	886	882	1200

ALSO BASED ON THESE TWO DATA POINTS, WE ESTIMATE AN EFFECTIVE REMOVAL RATE OF K = 3.7 GPM.

MASS OF RCS WATER @ 280°F 1000 PSIG INCLUDING 1000 FT^3 IN PRESSURIZER IS 303,260 KG.

WE HAVE CONTACTED BETTIS (BAPL) TO OBTAIN THEIR ESTIMATE OF THE HYDROGEN REMOVAL RATE, BUT THEY COULD NOT PROVIDE US WITH ANY INFORMATION SINCE THEY ARE NRC'S CONSULTANTS.

NOTE: ALSO TRANSMIT TO LEE ROGERS.
LEE ROGERS TRANSMIT TO GARY BROUGHTON

RSE:DMD

ATTACHMENT

Effective Degassing Flow Rate: GPM

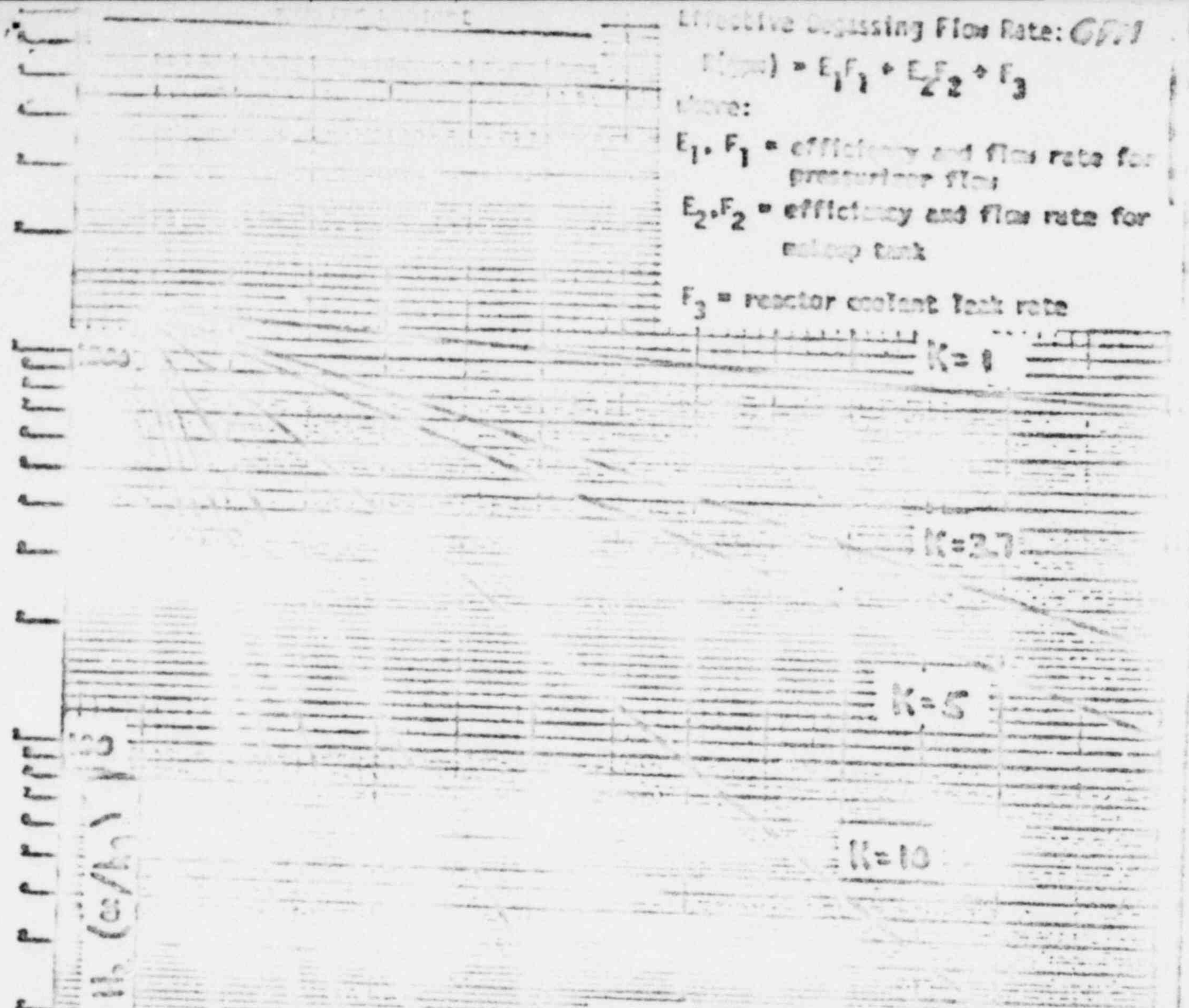
$F(gpm) = E_1F_1 + E_2F_2 + F_3$

where:

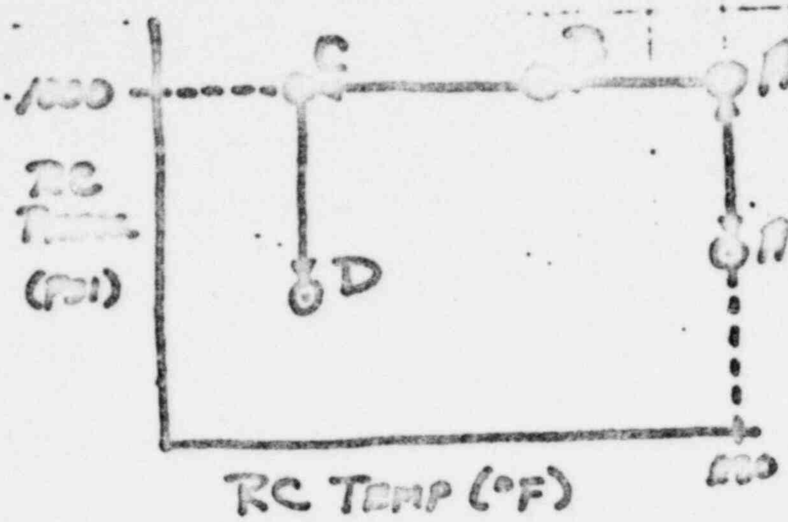
E_1, F_1 = efficiency and flow rate for pressurizer flow

E_2, F_2 = efficiency and flow rate for makeup tank

F_3 = reactor coolant leak rate



[illegible] CASE SUMMARY ([illegible])



① DEGAS AT A; LOWER PRESSURE (A→A') WHILE DEGASSING, THEN RETURN TO A.

② CONTINUE DESIGN/INSTALLATION OF STATIC AND ACTIVE SYSTEMS FOR PRIMARY MAKEUP/PRESSURE CONTROL AND SECONDARY COOLING SYSTEM FOR "B" S/G

③ REDUCE TEMPERATURE (A→B) BY STEAMING ON "A" S/G

④ TAKE "A" S/G SOLID - DROP PRIMARY TEMP. TO MINIMUM (B→C)

⑤ TRIP RC PUMP "A" - ESTABLISH NATURAL CONVECTION - [illegible] COOLING TO "B" S/G IF AVAILABLE

[illegible] PRIMARY PRESSURE TO SELECTED VALUE (C→D)

[illegible] SYSTEMS [illegible] [illegible] [illegible] &

[illegible] [illegible] [illegible]

[illegible]

PRIMARY - NAT'L CIRC, SOLID LIQUID, LONGTERM [illegible] COOL[illegible]

SECONDARY - SOLID WATER, LONGTERM HEAT DUMP SYSTEM

G/712-3.e-13

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

telecopier II

717-944-5070

[illegible] #63

To: BOB KEATON, GPU

From: N. S. EMBREY

Cust.

File Copy
1-JGH-LG
1-RCA
1-RFW
1-[illegible]
2-G. Broughton

BD3 663.5

File No. or Ref.

Subj. RESPONSE TO QUESTIONS RELATIVE TO FREE GAS TESTING PLANNED FOR 1200, FRIDAY, APRIL 6, 1979

Date: APRIL 6, 1979 0725

THE FOLLOWING ARE RESPONSES TO YOUR QUESTIONS RELATIVE TO THE PLANNED TESTING TO DETERMINE THE PRESSURE LEVEL AT WHICH FREE GAS PRESENT IN THE REACTOR COOLANT SYSTEM WILL COME OUT OF SOLUTION:

1. WHAT IS THE VOLUME OF THE PRIMARY SIDE OF THE CONTROL ROD DRIVE?

   ANSWER: THE PRIMARY SIDE VOLUME OF THE CONTROL ROD DRIVES IS 58 CUBIC FEET.

2. WHAT IS B&W'S POSITION ON LOWERING PRESSURE AND CHECKING FOR GAS. THAT IS, WHAT IS THE LOWEST PRESSURE WE WOULD RECOMMEND GOING TO IN DETERMINATION OF THE COMING OUT OF SOLUTION OF DISSOLVED GAS?

   ANSWER: THE LIMITS ON PRESSURE FOR THIS TEST SHOULD BE THE SAME AS THOSE PROVIDED IN THE MEMO FROM R. E. KOSIBA TO LEE ROGERS DATED 4/04/79 TRANSMITTED AT 11:10 P.M. TRANSMITTAL LOG #275. THESE LIMITS ARE THOSE RELATIVE TO THE NPSH CURVE FOR THE PUMPS.

3. BE SURE THE REACTOR DIAGNOSTIC GROUP IS READY FOR MONITORING DURING THE SUBJECT TEST.

   THE REACTOR DIAGNOSTICS GROUP HAS BEEN INFORMED OF THE PENDING TEST AT NOON ON APRIL 6, 1979 AND WILL BE READY FOR TAKING OF DATA DURING THIS TEST.

4. DOES B&W'S TEST PROCEDURE WHICH REQUIRES LOWERING PRESSURE TO DETERMINE THE PRESSURE AT WHICH GAS COMES OUT OF SOLUTION WORK AT LOWER PRESSURES THAN THOSE PREVIOUSLY USED. THAT IS WILL GAS BE DETECTED IF THE PRESSURE IS REQUIRED TO BE LOWERED IN THE 400-500 PSI RANGE?

   ANSWER: THE PROCEDURES SHOULD BE JUST AS EFFECTIVE IN THE LOWER PRESSURE RANGES AS AT THE UPPER PRESSURE RANGES AND AT THE TEMPERATURE OF 280°F BECAUSE THE SAME RELATIVE VOLUME OF GAS COMING OUT OF SOLUTION APPPLIES AND HENRY'S LAW IS A LINEAR FUNCTION WITH PRESSURE.

5. CAN B&W SUGGEST AN ALTERNATIVE METHOD FOR DETERMINING THE PRESSURE AT WHICH GAS COMES OUT OF SOLUTION THAN THE USE OF PRESSURE SIGNAL NOISE CONDITIONS?

   ANSWER: ANOTHER POTENTIAL METHOD IS TO MEASURE THE PRESSURE BUILDUP IN THE MAKEUP TANK WITH THE VENT VALVE CLOSED. BY KNOWING THE MAKEUP TANK PRESSURE, WATER LEVEL AND PRESSURE AT THE BEGINNING AND END OF THE TEST, AND THE LETDOWN FLOW, THE DISSOLVED GAS IN THE REACTOR COOLANT SYSTEM CAN BE ESTIMATED WITH AN ASSUMED GAS REMOVAL EFFICIENCY IN THE MAKEUP TANK. BASED ON WHAT WE THINK THE DISSOLVED GAS LEVELS IN THE RCS ARE NOW, THE REMOVAL EFFICIENCY SHOULD BE VERY CLOSE TO 100%.

IF YOU HAVE ANY FURTHER QUESTIONS WITH RESPECT TO THE GAS BUBBLE TEST PLANNED FOR THIS NOON, PLEASE LET US KNOW.

D.W. Berger
0841 4/6/79

NSE:dh

WASTE GAS TK 4/6/79 1000

4/6/79 10:10 GE response to GPU request

Assumed
1) Pressurizer spray @ 25 gpm (75% of the time)
2) " temp 540°F
3) " venting at 3 gpm
4) Letdown operating continuous
5) PZR & MU tank have $P_H < 50$ psi (of non condensibles)
6 Letdown flow ≈ 20 gpm
7 [illegible]

PZR 75% @ 25 gpm 400 ft³ (at pressure)
MU tank ($P_H \approx 0$) 265 ft³ (280°F)
385 ft³ (350°F)
Bring water to H_2 saturation 300 ft³ (280°F)
847 ft (350°F)

50 HR

13 ft³/hr removal rate excluding any gas going into solution. Therefore letdown & pzr spray could be primary means of removing one small bubble — not critical with leakage.

Radiolysis small

Estimated not to be diffusion limited

Boiling water pressure should be 100-200 psia

Boiling mode, 1 atm, letdown can't handle radiolysis
100 psi, solid water can remove "

Give procedure for analyzing primary loop when we have a sample.

?

Waste Gas Decay Tank Hydrogen concentration — still explosive!
Concentrate from draft when venting based on [illegible]

WASTE GAS TANKS ..

G/712-3.e-14

R F Wilson

6040 - out

5040 - In

-DKC PASS TO:

JIM KUNKEL

HIRST TRAILER, TMI

•
GPU PARY

WU INFOMASTER 4-0723355E096 04/06/79
ICS IPMRNGZ CSP
ZCZC 2058375660 TDBN HUNTSVILLE AL 276 04-06 0743P EST
TLX 136432 GPU PARY
KEN PASTOR, THE G.P. UTILITY, TLX IMMY, RUSH
260 CHERRY HILL RD
PARSIPPANY NJ 07054

BT
REFERENCE THREE MILE ISLAND HYDROGEN HIGH PRESSURE STORAGE TANKS AND HYDROGEN CORBLIN COMPRESSORS. THESE ITEMS AVAILABLE FOR IMMEDIATE DELIVERY NOTE USUAL LEAD TIME FOR OBTAINING THESE ITEMS IS 6 TO 9 MONTHS. SIX EACH HYDROGEN STORAGE TANKS, MAXIMUM CODE DESIGN MULTILAYER TANKS FOR SAFEST SERVICE IN CRITICAL APPLICATIONS, AS FOLLOWS: 3 EACH HIGH PRESSURE TANKS WITH HORIZONTAL STANDS 4 FEET DIAMETER BY 9 FEET OAL, WV 45 CF MAXIMUM DESIGN WP 6600 PSIA, CAPACITY EACH TANK 20,000 SCF ORIGINALLY DESIGNED FOR HELIUM OR HYDROGEN FLOOR SPACE REQUIRED ONLY 4 FEET BY 9 FEET. TANKS WILL STACK FOR MINIMUM SPACE STORAGE. ONE EACH HIGH PRESSURE TANK WITH HORIZONTAL STAND 28 INCHES DIA. BY 16 FEET OAL. WV 44CF MAX WP 4400 PSIA. TANK STORES 13000 SCF. FLOOR SPACE REQUIRED 28 INCHES BY 16 FEET. ORIGINALLY DESIGNED FOR HELIUM OR HYDROGEN SERVICE.

TWO EACH HIGH PRESSURE TANKS WITH VERTICAL STANDS 4 FEET DIA BY 5 FEET 6 INCHES OAH, WV APPROX 25CF MAX WP 6000 PSIA, EACH TANK STORES APPROX 13200 SCF, FLOOR SPACE REQUIRED FOR EACH TANK IS SQUARE 4 FEET BY 4 FEET. ORIGINALLY DESIGNED FOR HELIUM OR HYDROGEN. OTHER SUITABLE ASME AND NATIONAL BOARD TANKS AVAILABLE.

TWO EACH HYDROGEN COMPRESSORS MFR CORBLIN DIAPHRAGM TYPE. SECTION 250 PSIA UP TO 4000 PSIA. DISCHARGE PRESSURE 3000 PSIA TO 9000 PSIA. SKIDDED UNITS WITH ALL ACCESSORIES INTEGRATED INTO SKID. MAX THRUPUT UP TO 285 SCFM. SKID SPACE 50 INCHES BY 110 INCHES. TOTAL HOURS ONLY ABOUT 30. LIKE NEW.

ALL TANKS AND COMPRESSORS ORIGINALLY NASA SPECIFICATIONS. DRAWINGS AND SPECS AVAILABLE. ALL AVAILABLE FOR INSPECTION. FOB HUNTSVILLE ALABAMA. INSPECTION AND ACCEPTANCE HUNTSVILLE ALABAMA. IMMEDIATE SHIPMENT AVAILABLE
L L MCCLURE, CONSUMER FUELS INC, FONE 205-8375660

NNNN
1946 EST
•
GPU PARY

→ R.F. Wilson

→ W. H. Hirst

4/7/79 19:30

Tom —

Dr. E. mentioned again that you may want to consider injecting potassium permanganate to assist in getting H_2 out of solution. Could it be added to makeup water?

Jon Rockwell

G/712-3.e-16

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

FILE
RCVD 0110 4/7/79

Time: 0110

TELECOPY #77

To: Dick Wilson, GPU
L. C. Rogers, TMI-2

From: R. E. Kosiba

[illegible]

Cust.

File No. or Ref.

Subj. Pressure Reduction Procedure During Degasification (Z-57)

Date April 7, 1979

This letter to cover one customer and one subject only

ATTACHED PLEASE FIND, THE B&W COMMENTS ON THE SUBJECT PROCEDURE.

REK/cmm

CC: A. F. McBRIDE
N. H. [illegible]
C. F. [illegible]
J. S. TULENKO

COMMENTS ON SOP 42-57

Limits and Precautions:

65.C - Minimum pressure for RC pump operation is limited to pump pressure curve in Figure 1 provided that 100 psi is added for instrument error.

65.D - RC pump vibration should not exceed limits of 30 mils peak-to-peak shaft vibration and 5 mils frame vibration.

65.E - The highest core outlet thermocouple reading shall be maintained at least 10°F below the saturation temperature for the RCS pressure existing at the given point in time. (NOTE: This information replaces the previous criterion.)

65.I - (To be added) Terminate further pressure reduction steps in RCS pressure at the end of the 50 psi step sequence if during the sequence the B&W Noise Monitoring personnel indicate that the solubility limit has been reached based on signal noise.

65.J - (To be added) The maximum rate of pressure reduction during any sequence should be 5 psi per minute.

Prerequisites:

66.A - Should align RCP 1A as the backup RC pump.

66.B - Pressurizer heater control should be in manual. (Note: If heater control is automatic, B&W is concerned about status of heater control during depressurization steps).

66.C - Spray flow adjusted to maximize degasification rate and balance the existing heater input.

66.G - (To be added) B&W Noise Monitoring Personnel increase strip chart speed to 2 mm/min.

Procedure:

#7.C - Lower primary system pressure by controlling spray flow (and heater operation) and intermittent venting of pressurizer via the 1 inch vent valve (RC-V137).

#7.E - See limit and precautions #5.J (to be added). If during the pressure reduction sequence either #5.D or #5.E are exceeded, return to the pressure level at the end of the previous sequence.

#7.F - Upon completion of each of the 50 psi pressure reduction sequences calculate the pressurizer bubble size based on the RCS parameter changes over the 50 psi pressure reduction sequence.

All core outlet thermocouple readings should be submitted to B&W for continuing evaluation.

If B&W Noise Monitoring Personnel report that noise signals indicate that the solubility limit has been reached during the sequence, maintain the plateau pressure of this sequence until noise analysis indicates bubbles are no longer present.

#7.G - Do not proceed to next pressure reduction sequence until all perturbations of incore thermocouple readings have been stabilized.

#7.H - B&W recommends that after test is completed, the RCS pressure be slowly raised to ≈1000 psi.

Data Required for Bubble Calculation

1. RCS Pressure (Loop A & B)
2. RCS (T_H & T_C)
3. MU Tank Level and Temperature
4. Pressurizer Level and Temperature
5. Pressurizer Heater Heat Input

Prepared By ______ Date
Reviewed By ______ Date
Approved By ______ Date

[illegible] Degas

4/7 1080

B&W

Degas half-life

old number → 4 days

now - based on
fast info → 50 days
based on three [illegible]
point data

Present estimate : Gas content
2327 [illegible] 4/6/79
[illegible]

1130 cc/kg* →

on 4/1/79
1300 cc/kg

* at STP

4/7/79 1000

File → Degas – B&W

→ Pressure ≈ 30 ± 10

These possibly are between doing → need flo in controlled fashion → The degass

G/712-3.e-16

[illegible] COMPANY · [illegible]

[illegible]

[illegible] TIME: [illegible]

PRESSURE REDUCTION PROCEDURES

DATE APRIL 7, [illegible]

This will confirm that limitation of [illegible] psig minimum RCS pressure has been removed. This deletion was made in Revision [illegible] of [illegible] Procedure [illegible] which was not sent because we are now working from [illegible] [illegible]-57.

Limitation is RC Pump suction pressure. Use curve of RC Pressure vs. RC Temperature which is Attachment A of Z-57, adding 100 psi for instrument error.

RSE/cms

Telecopy to R. Keaton
Telecopy to L. Rogers.

To: Milt Levenson

Subject: Hydrogen in PRCS

Copies: J. Hurley

Date: April 6, 1979

From: F. E. Haskin
J. W. Thiesing

Of: Industrial Advisory Group

At: TMI

Degassing History

Rapid degassing of reactor coolant occurred in the make-up tank, with the letdown system in normal alignment (except for bypassing the block orifice), until about 0716 on 3/29/79 at which time the waste gas decay tank pressures approached the shutoff head of the waste gas compressors. At this time, letdown was diverted to the B reactor coolant bleed tank. Letdown continued using the A, B, and C RCB tanks until 1920 on 3/30/79 when the A tank went full. During this time, makeup to the makeup tanks was demineralized water and boric acid which reduced makeup tank pressure from a 65 psig level by redesolving makeup tank gases and injecting them into the PRCS. By 1440 on 3/30/79, both waste gas decay tanks were essentially at the waste gas compressor shutoff head. At 2036 on 3/30/79, makeup to the makeup tanks was shifted to the bleed tanks, letdown from the PRCS was still to the bleed tanks, which also vent to the waste gas compressor. Operation in this mode continued until at least 4/2/79 at 1835 (the end of available operator log data). Sometime after this time, letdown was shifted back to the makeup tank and apparently continues in this mode at this time. RCS makeup to balance RCS leakage and pressurizer leakage is being taken from the reactor coolant bleed tanks.

Clearly, the waste gas decay tanks have been unable to accomodate additional hydrogen gas since about 1440 on 3/30/79 at which time the tank pressures were about 84 psig, estimated to be the compressor shutoff head. During the ensuing period, regardless of whether the makeup tank or the bleed tanks are receiving letdown, offgas must have followed one or more of the following paths:

1. Released to the auxiliary building via the reactor coolant bleed tanks relief valves.
2. Leaked to the auxiliary building through leakage paths, probably downstream of the compressor.
3. Leaked to the auxiliary building from waste gas collection header upstream of compressors.

[illegible]

We estimate that this mode of degassing is probably quite efficient and it is possible, if not probable, that hydrogen concentrations in the PRCS are quite low.

F. E. Haskin

J. W. Thiesing

FEH/JWT/dms

It is also of importance that, prior to 2036 on 3-30-79, letdown to the makeup tank resulted in rapid pressurization of the tank, surmised to be a result of rapid degassing of RCS water coupled with inability to vent the tank to the waste gas decay tanks, which were approaching the compressor shutoff head. This inability to vent still exists, but letdown to the makeup tanks no longer results in rapid (or perhaps any) tank pressurization. The implication is a low degas rate at present, and thus a low PRCS hydrogen concentration.

FEH
JWT

9-6-79
[illegible], T[illegible]
[illegible].

PROCEDURE FOR MEASURING REACTOR COOLANT HYDROGEN CONCENTRATION

1. Bring MU tank level to approximately 55" ~~pumping~~ by transferring, if necessary, liquid from RC Bleed Tank. Maintain letdown flow at maximum available rate, hold constant. (Flow < 25 gpm).

   Align MU-V8 to take reactor coolant letdown directly to makeup tank.

2. Open either MU-V13 or MU-V134 and pull the makeup tank pressure down as far as possible with the waste gas compressor.

3. Promptly close MU-V13 and MU-V134 to <u>isolate</u> gas space in makeup tank. (H_2, N_2, and sampling lines should be isolated). 5-15 psi [illegible]

4. Record:
   - a. Time
   - b. WDG vent header pressure
   - c. Makeup tank pressure
   - d. Makeup tank level
   - e. Makeup tank temperature
   - f. Letdown flow, seal return flow.

   Record these parameters at the initiation of Step 3 and every time the make-up tank pressure increases 1 to 5 psig, depending on rate of pressure increase.

5. Continue procedure for as long as possible, consistent with makeup tank pressure limits and plant operating necessities. > 15 psi

6. Secure from procedure, return to normal operating mode. ← Pump in fresh water to [illegible] pressure before venting

[illegible] CASES OF [illegible]/TEMPERATURE
[illegible] THE [illegible] COOLANT PUMP OPERATION

DATE

APRIL 6, 1979- 0217

THE ATTACHED INFORMATION IS IN RESPONSE TO YOUR QUESTION REGARDING THE [illegible] CASES ASSUMED IN THE PRESSURE TEMPERATURE CURVE.

REK/leb

cc: JIM TAYLOR

ATTENTION: E.D. WALLACE

Page 1 of 2 G1712-3.e-17

Inter-Office Memorandum

Task 3107

GPU Service

Date April 7, 1979

Subject (P) DEGAS

To J. C. DeVine

Location TMI Site

xc: TMC
RFW
TGB
RKeaton

On 4/5/79 you received a reply to TTS #3107 concerning the amount of gas in the RC system and how much will come out of solution into the makeup tank.

Later calculations indicate that the original estimate of 15,000 ft.^{3} was high by at least a factor of two. A calculation showing that the equilibrium concentration of hydrogen in the primary loop at 235°F and 1000 psig is approximately 6000 ft.^{3} (STP) is enclosed (Note: Hydrogen is the predominant gas by far so 6000 ft.^{3} is probably a good estimate for total gas).

Also enclosed is a proposed method for degassing without releasing any gas bubble.

If you have any questions, contact John Daniel or Jack Thorpe at Mt. Lakes.

Jack/e
J. R. Thorpe

JRT:ejm
att.

PRIMARY PLANT CONDITIONS

Pressure - 1000 psig
Temperature - 290°F

1. Maintain temperature and pressure while degassing via a "bleed and feed" process.
   a) Degas letdown being returned as much as possible.
   b) Makeup with degassed water only.
2. Continue process until hydrogen concentration in the primary coolant is approximately 40 cc/liter. This is the equilibrium conditions for 290°F and 100 psig.
3. Slowly depressurize primary loop to 100 psig, holding primary temperature at 290°F. Monitor primary system inventory to assure that no gas bubbles are being evolved (Note: There should be none).
4. Maintain the primary pressure at 100 psig and cool the primary. This will increase the solubility of gas in the liquid, increasing our safety margin in this area.
5. Continue to makeup with degassed water.

NOTE: Since hydrogen is the predominant gas dissolved in the primary loop, control of it will assure control of other gases in the loop.

[illegible] 4/8/79 18:35

Tom —

Per Vivian (↑ PAIT GAS EXPERT) consultation (telephone) w/ D.A. Rockwell
For improved letdown degassing we want
1) higher vessel pressure
2) higher temp gives lower H_2 concentration of H_2 left in soln but much higher void fraction (lower mass flow rate) so not better to go to low temp to maximize H_2 removal.

Nucleation press = 535 psi (300°F)

~~500 psi~~	~~.018~~	~~vol gas / vol liquid~~
~~100 psi~~	~~.116~~	
~~20 psi~~	~~1.5~~	

Cooled to (200°F) ← strips H_2 better but larger volume to handle;

gives → 515 psia nucleation press / concentration .63 $\frac{ml\ H_2}{gm\ H_2O}$ (left in soln)

500 psia	.0008 $\frac{vol\ gas}{vol\ liq}$	.61	$\frac{ml\ H_2}{gm\ H_2O}$ S.T.P.
300	.018	.36	
100	.116	.11	
20	1.44 < stm H_2	.011	P_v = 11.5 psi STM P_v 8.5 psi H_2

Cooled to (140°F)

gives 506 psia nucleation press .63

500 psi	.003	.62
300	.016	.37
100	.094	.12
20	.64	.021 is 3% of starting concentration

Higher press good 1) higher driving head [illegible]

G/712-3.e-19

CWN | Keaton
April 3, 1979

J. [illegible]

Subj Primary Sample. Degas

The highest priority from Tech Support for the Rx Coolant Sample Anal is Total Gas content. This requires a pressurized sample for which additional precautions (shielding, more people etc) may be required. Nevertheless it is very important for our existing & pressing. Other analyses are needed ~~as is [illegible]~~ Boron concentration is 2nd priority to assure subcriticality. Other analyses ie activity total and isotopic would

If H_2 content of the total gas could be determined easily this would be important —

TM Grimm J

INITIATED BY RS

61712-3e-20

3061

RC: RFW

TASK TRACKING SHEET

TASK DESCRIPTION:

WHAT IS SOLUTION TO LONG TERM DISPOSAL OF CONTAINMENT ATMOSPHERE.

ASSIGNED TO: JOHN DANIEL

DATE/TIME ASSIGNED: 4/2 22.50

(F) CONTAINMENT

DETAILS/STATUS:

RESOLUTION: containment atmosphere will level off approximately april 30, 1979 at 500,000 Ci, most of which is Sr-89 & 90. Significant quantities of Kr-85 are also present.

Long term disposal may be accomplished by cryogenic storage (may take 4-5 years) or by filtered release to the environment, at variable purge after as atmospheric conditions permit. Dose calculations are being performed by Richard Lowe & Derrick.

DATE/TIME RESOLVED: J. A. Daniel 4/8/79

Wilson — Mail
J. Devine

G/712-3e-21

14.01 (2)
(4.04.79)
Standt/Eale

TO: D.A. Rockwell April 9, 197

SUBJECT: RESPONSES TO GPU QUESTIONS ON HYDROGEN

This memo summarizes our comments on several hydrogen-related subjects requested by GPU over the past two days.

I. Relation of Coolant Temperature to Maximize Net Degassing.

BNF calculations report that a) for 15 psia of H_2 pressure at 200°F the amount of H_2 dissolved in the water is 0.03 ml/gm (we get 0.03 ml/gm).

b) for 500 psia of H_2 pressure at 140°F the amount of H_2 dissolved in the water is 0.63 ml/gm (we get 0.57 ml/gm).

c) the amount of H_2 dissolved in water at 20 psia of H_2 and a temperature of 200°F is 0.02 (we get 0.025 ml/gm).

d) the amount of H_2 dissolved in water at 20 psia of H_2 and a temperature of 140°F is 0.01 (we get 0.022).

The practical conclusions are:

1) We agree as high a pressure as practical will get the maximum amount of H_2 dissolved in the water, and therefore, the maximum release on the let down.

2) We believe, based on GE experience in de supersaturation of H_2 in water, that the temperature is not important in the range of 140 to 200°F.

3) There is a possibility that flashing from 280°F (but not from 200°F) could interfere with flow in the let down line. Therefore, 200°F would be better than 280°F for net degassing.

II. Hydrogen Generation Rate Long-Term

Input: Thermal Power 5 MWT

Case 1. Without any boiling in the core, and with an overpressure of H_2 in the let down Tank at T=120°F of 1 ata of H_2 the radiolysis should be zero = 0.

Case 2. Without any boiling in the core, and with an intact core, the rate based on NEDO-0502 pg. 8 and comparison with BWR data should be

$$5(MW_T) \times 0.03 \left(\frac{scfm}{MW_T}\right) \times 60 \left(\frac{min}{hr}\right) \times 0.03 \left(\frac{non\ boiling}{boiling}\right) = \quad s \quad H_2 = 0.3\ s$$

Case 3. Using RG 1.3 and 1.7 assumptions on fission product release, boiling where radiolysis is occurring, for a degraded core. (G=0.5 for H_2 and O's). The generation rate of a mature 2700 MW_T core at 10 days is 73 scfh of H_2

19.61
04.09-79

Case 4. Experience data from GE BWRs on shut down at 5 MW_T (as in 2 above) 9 scfh

Case 5. The most likely value is case 3 with the ANL6565 non boiling corrective factor of 0.03: 73 (scfh) x 0.03 $\left(\frac{\text{non boiling}}{\text{boiling}}\right)$ 2.2 scfh

H_2 removal rate by solubility based on 515 psia and 200°F. we can remove 100 scfh.

Conclusion: Even in the worst case at 515 psi the radiolysis H_2 can be removed even at 10 gpm with a factor of safety greater than 10 (based on non boiling).

As per 1300 PST this date we have data from plant that shows possibility of some boiling in core - if we use BWR boiling data our rates would be 10-20 scfh.

III. Potassium Permanganate as a Hydrogen Getter

We have considered what problems might be encountered. In using $KMnO_4$ to remove H_2. Assuming H_2 saturated loop at 500 psi 200°F: this would require the addition of 1.6×10^4 kg of saturated $KMnO_4$ water solution - about 6% of the total primary loop volume or about 1400 minutes at 3 gpm.

This would add about 1000 Kg of $KMnO_4$ and yield about 600 kg MnO_2 sludge if all the H_2 were reacted. This much sludge could interfere with the letdown flow. KOH is an end product of the reaction, so the coolant could become quite basic (pH ≈ 12). Materials properties are still being studied. A better additive might be H_2O_2 because the reaction product is H_2O. The major question is the decomposition of H_2O_2 to form O_2 (free) which could lead to H_2+O_2 and the possibility of rapid reaction. The decomposition would be less troublesome with slow injection so that the H_2O_2 could immediately react with ample H_2 in the vicinity of the injection point.

P. W. Marriott, Chairman
Three Mile Island Task Force

/evp

Hydrogen Concentration 2.1%.

Cont. Volume 2,000,000 FT³. X 2.1% = 42,000 FT³ H_2.
Recombiner flow 9.0 SCFM.
90 X 60 X 24 = 130,000 FT³/day. X 2.1% = 2,722 FT³ H_2/day.

		H_2 (start)	Remove	H_2 (end)	%
Start 15:05	4/2/79				
First day.	4/3	42.0K	2.7	39.3	1.96.
Second day,	4/4	39.3.	2.5	36.8	1.84
Third day	4/5	36.8	2.4	34.4	1.72
Fourth "	4/6	34.4	2.2	32.2	1.61
	4/7	32.2	2.1	30.1	1.50
	4/8	30.1	1.9	28.2	1.41
	4/9	28.2	1.8	26.4	1.32
	4/10	26.4	1.7	24.7	1.24
	4/11	24.7	1.6	22.1	1.10
	4/12	22.1	1.4	20.7	1.04
	4/13	20.7	1.3	19.4	.97

Assume No Net H_2 input to Containment

Gary Miller
Joe Logan, Plant Superintendent.
Jack Herbein V.P. Generation
Kreitz
Dieckamp.

OPERATING PRESSURE CONSIDERATIONS

Operation in a boiling mode at atmospheric pressure has the advantage of maintaining the system at the final desired end conditions. However, there are several concerns that suggest this may not be the best operating condition:

1. Low vapor density will make system less stable, particularly due to large changes in vapor volume with changes in condensation rate (S.G. level oscillation concern).
2. Relatively lower H_2 concentrations in water would require higher bleed flows to compensate for any continuous H_2 source.
3. Eliminates driving potential to operate letdown system or other degas techniques.
4. Maximizes volumes of non-condensible gas.

These same considerations suggest that "higher is better" for the boiling mode operating pressure. The maximum pressure may be determined by other considerations (e.g. back-up RHR limits).

Task VII

Pat Marriott 4/8/79 1605

Request: Copy of IA&G (Milt Levingston) procedure
for setting up boiling mode.
(BW Memo 63)

Requested from Tom Crimmins @ 1620 4/8/79 verbally
" " " 0955 4/9/79 written

Done

Pat Marriott 4/9/79 0925

Request: Copy of fig showing planned maneuvers
on Press/Temp plot

Telecopied 4/10/79 1020 to Marriott

To: Milt Levenson

Subject: RCS Behavior

Copies: J. C. Judd

Date: April 9, 1979

From: J. W. Thiesing

Of: TMI - IAG

The following is an assessment of RCS behavior in the "perculating" mode <u>before</u> large amounts of noncondensibles build up:

Initial Conditions

~ 2"

1. Secondary side solid -- cold water
2. Pressurizer vented to containment atmosphere, either by relief valve open or through 3/8" sample line re-plumbed to containment.
3. Primary system solid
4. Core flood tanks floating -- either under N_2 head or on head tank
5. Little or no non-condensibles
6. RC pumps off
7. Assume little or no natural circulation

Behavior

1. Heat generation in core will form steam
2. Steam will form bubble in top of vessel
3. Steam bubble will displace water and raise pressurizer level (~~and head tank level if in place.)~~
4. When bubble uncovers top of hot legs, steam will (eventually) slide out hot leg, forming bubble at top of candy cane quite rapidly (roughly 5000 - 10000 cfm).
5. The increasing bubble volume continues to drive water into pressurizer ~~(and core flood, if on head tank).~~
6. The increasing bubble volume in candy cane uncovers cold tubes in steam generator until such time as the condensing rate in steam generator equals or exceeds the steaming rate in the core.
7. Then,
   a. If the system is heavily damped, a steady state steaming in core/condensing in steam generator condition will result.

      <u>Or</u>

   b. If the system is undamped which is more likely the bubble in the steam generator and candy cane will collapse rapidly, and the process will begin at Step 3 above again and repeat itself, <u>ad infinitum.</u>

In this mode before significant non-condensibles build up, I do not believe there will be any perculating through the pressurizer, only a rising and falling of water level in the pressurizer.

Non-condensibles formed during this time will be swept to the top of the candy cane where they will form a bubble at the top of the bend.

Perculation may occur every 0.05 to 0.5 sec^{-1}

4/8/79
M. Levenson

Step I Go to Natural Circulation-with Pressurizer Solid

A. Float core flood tanks at B&W set pressure, but with tanks solid and pressure coming from N_2 tanks outside containment. This is to expedite conversion to Step II if and when deemed desirable.

B. All valves from primary system to Auxiliary Building closed except for occasional use of core flood tank fill line to make up losses.

Step II Conversion to Benign Building

A. Remove high pressure N_2 supply from core flood tanks.

B. Open Pressurizer Vent valve. Leave open. Pressurizer Sample Line should have been rigged in reentrant mode back to containment so that if the vent block valve cannot be opened, the sample line is a fall back.

C. Eventual steady state may result in occasional bubbles rising through flooded pressurizer.

  1. Water (plus additives such as H_2O_2 if desired) can be added via core flood tank fill line.

D. Eventual state may permit isolation of steam generator secondaries and use of hot drain coolers as heat sinks--needs to be looked at.

G/712-3.e-23

TMI-2 OPERATIONS

TRANSMITTAL TO:

D. G. ROGERS TRANSMITTAL # [illegible]

ALSO TELECOPY TO: ☑ R. WILSON TRANSMITTAL #

☐ B&W TRAILER 26 TRANSMITTAL #

TIME 1400 DATE 4/9/79

SUBJECT RCS HYDROGEN CONCENTRATION

APPROVED BY [illegible]
OPERATION MANAGER

B&W ACTION # 237 (PART)

This letter to cover one customer and one subject only

ATTACHED IS AN EVALUATION OF THE PAST AND PRESENT HYDROGEN GAS SITUATION IN THE REACTOR COOLANT SYSTEM.

DAN:dsf

cc: W. N. BISHOP
R. B. COAD
M. J. BELL
J. H. HICKS
W. R. STAGG

OVERVIEW OF HYDROGEN GAS PROBLEM IN THE REACTOR COOLANT SYSTEM

THE FOLLOWING SUMMARY ATTEMPTS TO CONNECT THE KNOWN TECHNICAL FACTS ASSOCIATED WITH THE QUANTITY OF HYDROGEN CONTAINED IN THE REACTOR COOLANT SYSTEM. THE METAL WATER REACTION WHICH APPARENTLY OCCURRED DURING INITIAL PHASES OF THE ACCIDENTS GENERATED LARGE QUANTITIES OF HYDROGEN GAS. THE TECHNIQUES FOR MEASURING THE AMOUNT OF GAS IN THE REACTOR COOLANT SYSTEM WERE NOT IMMEDIATELY AVAILABLE AND REQUIRED SEVERAL DAYS TO DEVELOP. AFTER THE TECHNIQUES WERE DEVELOPED, MEASUREMENTS OF BUBBLE SIZE SEEMED TO CORRELATE VERY WELL AS EVIDENCED BY FIGURE 1. FIGURE 1 INDICATES THAT THE BUBBLE VOLUME TENDED TO DECREASE AT A LINEAR RATE WHICH IS REASONABLE CONSIDERING THAT THE REACTOR COOLANT SYSTEM WAS HELD AT CONSTANT PRESSURE. FIGURE 1 ALSO INDICATES THAT WHEN GAS SOLUBILITY IS CONSIDERED, THE BUBBLE VOLUME SHOULD HAVE DECREASED TO 0 AT ABOUT 1500 HOURS ON APRIL 1. AT 1510 ON APRIL 1 WE OBSERVED A MARKED INCREASE IN THE AMOUNT OF NOISE ON THE PRESSURE SIGNAL FROM THE TRANSMITTER MONITORING THE REACTOR COOLANT SYSTEM PRESSURE ON A LOOP. THIS CAN BE SEEN BY REFERRING TO FIGURE 2. FIGURE 2 IS INTERPRETTED AS FOLLOWS: THE RIGHT HAND TRACE IS A TRACE OF THE REACTOR COOLANT SYSTEM PRESSURE MONITORED ON LOOP A. THIS IS THE DC PRESSURE SIGNAL. THE LEFT HAND TRACE IS THE AC NOISE COMPONENT OF THE DC SIGNAL FROM THE A LOOP PRESSURE TRANSMITTER. KEEPING IN MIND THAT TIME PROGRESSES FROM THE BOTTOM TO THE TOP OF THE CHART, THE NOISE SIGNAL IS INTERPRETTED AS FOLLOWS: THE LOWER PORTION OF THE SIGNAL IS AT A VERY HIGH GAIN SETTING AND THEREFORE EXHIBITS HIGH AMPLITUDE. THAT GAIN SETTING WAS REDUCED AT ABOUT 1555 HOURS; THE NEXT PORTION OF THE CHART IS THE 15 MINUTE PERIOD AT LOW GAIN SETTING

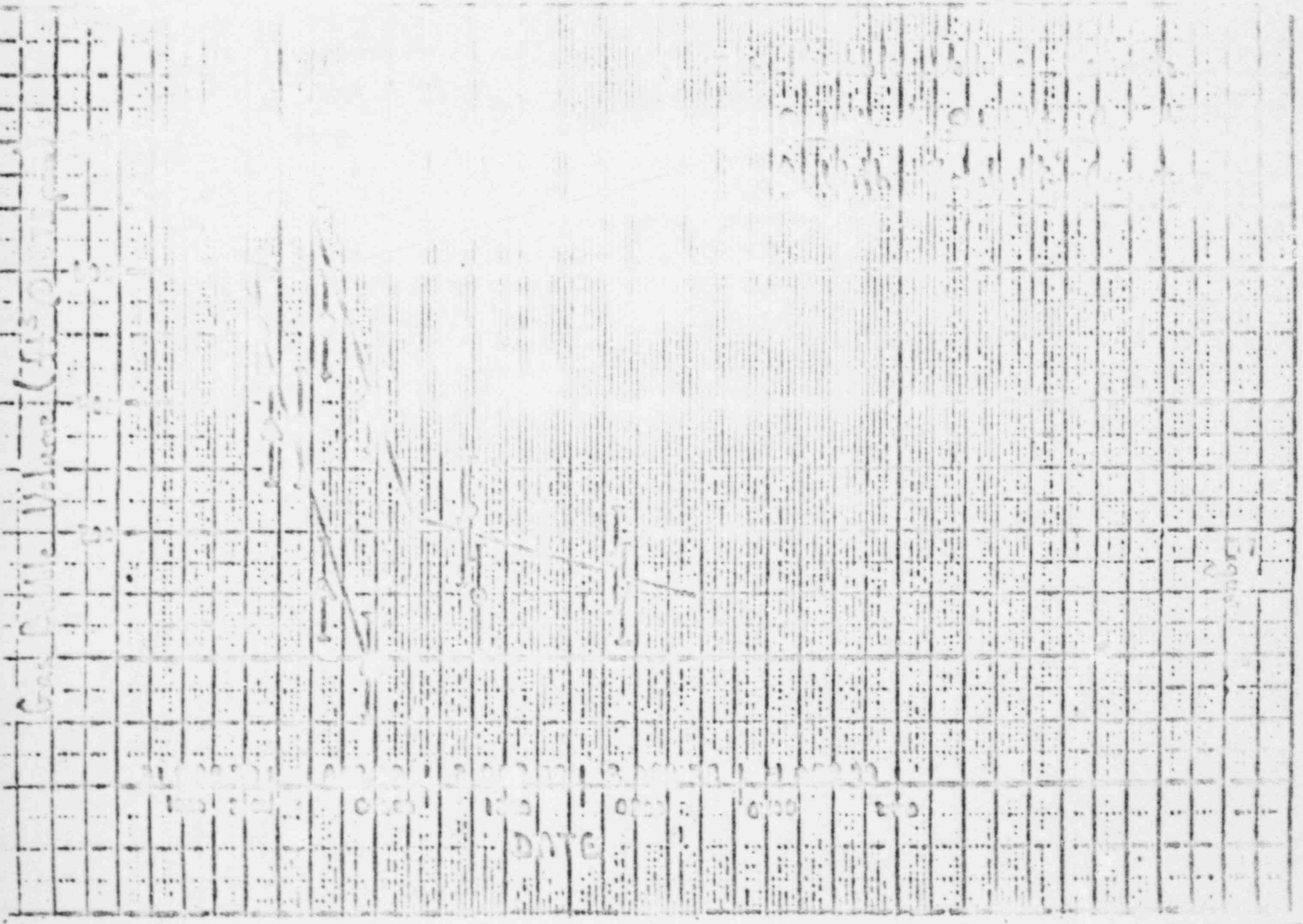
FROM 1555 TO 1610 HOURS; THE UPPER PORTION OF THE CHART WHICH STARTS AT 1510 HOURS IS THE PORTION THAT REFLECTS THE HIGH NOISE COMPONENT WHEN BUBBLES ARE NOT PRESENT IN THE REACTOR COOLANT. WE BELIEVE THAT A BUBBLE WILL DAMP THE VIBRATION. INITIALLY THIS WAS INTERPRETTED TO MEAN THAT ALL OF THE HYDROGEN GAS VOID VOLUME HAD BEEN REMOVED FROM THE REACTOR COOLANT SYSTEM. SUBSEQUENT THINKING HAS LED US TO BELIEVE THAT IT IS ONLY INDICATIVE OF THE ABSENCE OF BUBBLES WHICH ARE CIRCULATING AROUND THE LOOP IN THE REACTOR COOLANT. IT CAN BE SEEN BY AGAIN REFERRING TO FIGURE 1 THAT IF SOLUBILITY OF THE GAS IS NOT INCLUDED IN THE BUBBLE SIZE CALCULATION ONE WOULD ESTIMATE THAT THERE IS STILL A SMALL VOLUME OF HYDROGEN REMAINING IN THE REACTOR COOLANT SYSTEM. OUR PRESENT THINKING IS THAT THIS GAS IS CONTAINED IN THE CONTROL ROD DRIVE HOUSING AND AS SUCH IS NOT READILY AVAILABLE FOR REMOVAL BY ABSORPTION INTO THE REACTOR COOLANT. ONE WOULD EXPECT THAT UPON PRESSURE REDUCTION THIS GAS CAUGHT IN THE CONTROL ROD DRIVE WOULD EXPAND AND BE SWEPT INTO THE REACTOR COOLANT FLOW STREAM. SUCH AN EVENT IS DOCUMENTED IN FIGURE 3 WHICH SHOWS THE EFFECTS OF A PRESSURE REDUCTION WHICH OCCURRED AT 0333 HOURS ON APRIL 2. NOTE THAT THE HIGH NOISE LEVEL CONTINUED UNTIL 0330 HOURS ON APRIL 2 AND THEN SHOWED A MARKED DECREASE IN AMPLITUDE FOR THE TEN MINUTE PERIOD THAT THE PRESSURE WAS BELOW 900 PSIG. THE MINIMUM PRESSURE REACHED DURING THIS PRESSURE TRANSIENT WAS ABOUT 865 POUNDS AS SHOWN IN FIGURE 4. DURING THE PERIOD FROM APRIL 2 TO APRIL 6 EXTENSIVE EFFORTS WERE MADE TO DEGAS THE REACTOR COOLANT SYSTEM VIA THE PRESSURIZER AND THE MAKEUP TANK. BASED ON THESE EFFORTS ONE WOULD EXPECT THAT THE DISSOLVED HYDROGEN CONCENTRATION IN THE REACTOR COOLANT SYSTEM SHOULD HAVE DECREASED FROM ABOUT 1300 STANDARD CC'S PER KILOGRAM TO ABOUT 300 STANDARD CC'S PER KILOGRAM. HOWEVER, AT 0041 HOURS ON APRIL 7, WHEN ANOTHER REACTOR COOLANT SYSTEM PRESSURE DECREASE OCCURRED SOME ADDITIONAL GAS WAS EXPELLED FROM THE CONTROL ROD DRIVE AREA. FIGURE 5 SHOWS THAT WHEN THE PRESSURE WAS DECREASED TO 825 POUNDS, WHICH IS 35 POUNDS LOWER THAN THE PREVIOUS PRESSURE REDUCTION, A CORRESPONDING REDUCTION WAS INDICATED IN THE NOISE SIGNAL ASSOCIATED WITH THAT SAME

PRESSURE TRACE. IN CONCLUSION, WE FEEL THAT THERE IS STILL SOME GAS TRAPPED IN THE CONTROL ROD DRIVE AREA, THAT THAT GAS IN THE CONTROL ROD DRIVE WILL EXPAND UPON EACH SUCCESSIVE PRESSURE REDUCTION AND WILL BE SWEPT INTO THE REACTOR COOLANT FLOW, THAT THE AC NOISE TRACE WILL OBSERVE THE APPEARANCE OF THESE BUBBLES UPON RELEASE INTO THE FLUID STREAM, AND THAT IF THE PRESSURE IS HELD CONSTANT AT THE LOW VALUE THE BUBBLES CIRCULATING IN THE COOLANT WILL SLOWLY DISSOLVE AND THE HIGH AMPLITUDE AC NOISE SIGNAL SHOULD RETURN. THE TIME REQUIRED TO DISSOLVE THE BUBBLE IS AN INDICATION OF THE COOLANT'S PROXIMITY TO SATURATION. THAT IS, IF THE COOLANT IS SATURATED THE BUBBLES WILL REMAIN SUSPENDED INDEFINITELY PROVIDED THAT THE COOLANT SYSTEM PRESSURE REMAINS CONSTANT, BUT IF THE SOLUTION IS FAR FROM ITS SATURATION CONDITION, THE BUBBLES SHOULD DISSOLVE RATHER RAPIDLY. IT IS THEREFORE IMPERATIVE THAT WE CONDUCT THE TESTING PER PROCEDURE GPUZ57 WHILE THE RC PUMPS ARE AVAILABLE AND BEFORE ATTEMPTS ARE MADE TO GO TO NATURAL CIRCULATION.

SIGNED,

Donald A Nitti by MJ Beil

DONALD A. NITTI


Gas Bubble Volume
DATE

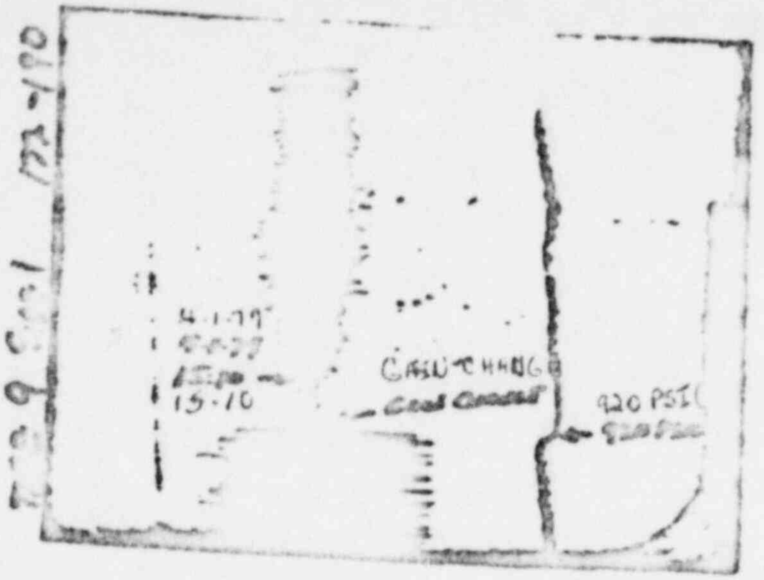


Figure 2

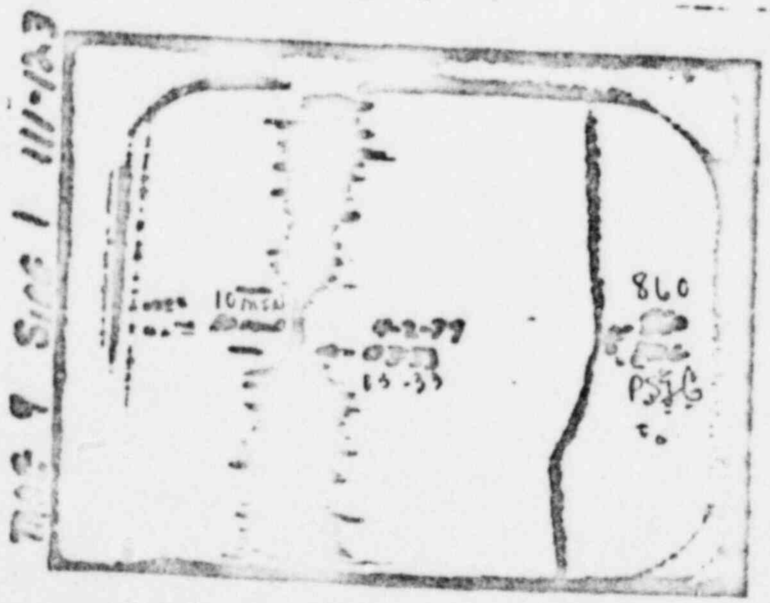


Figure 3

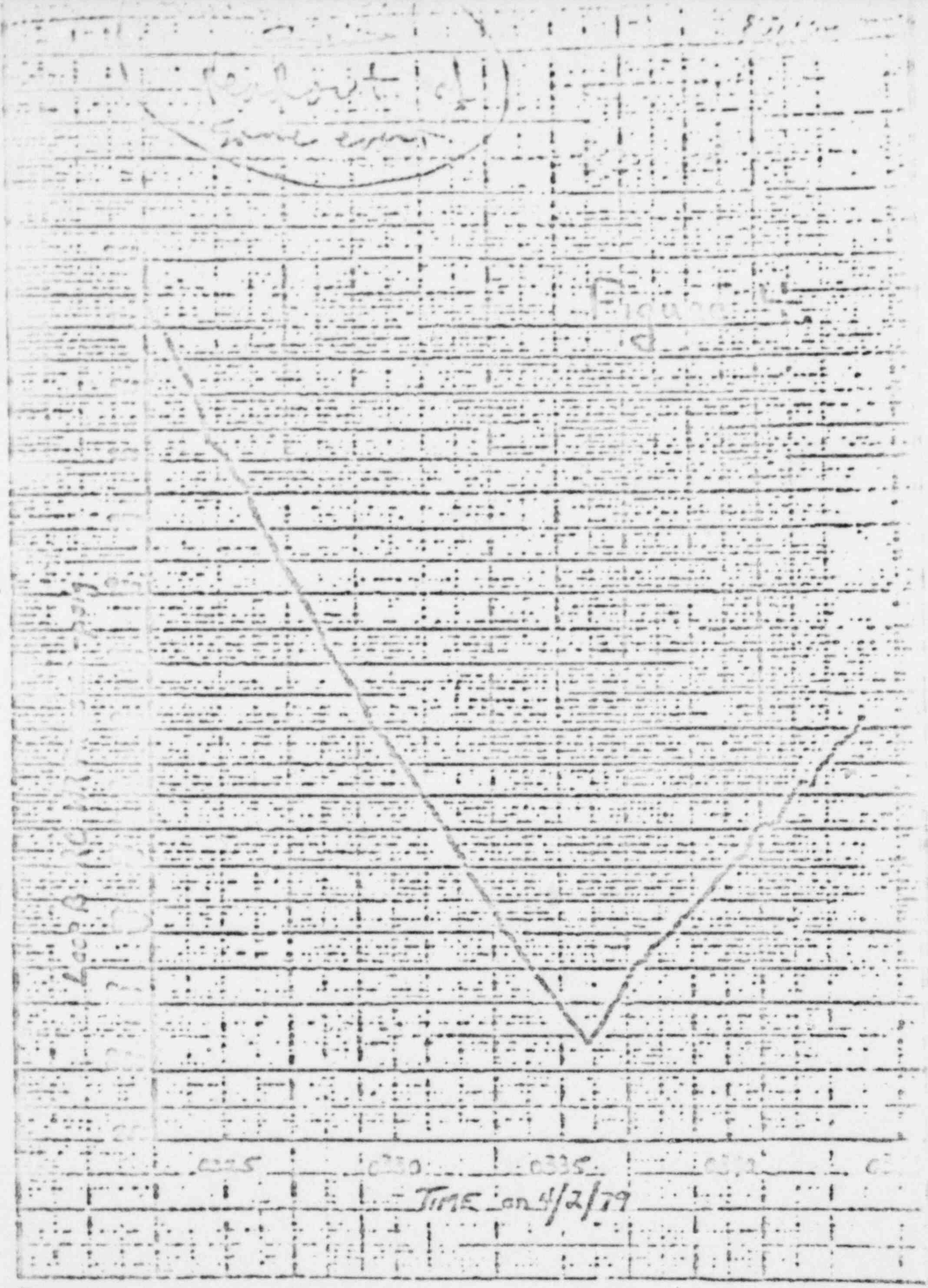


Figure
Loop B
0325
0330
0335
TIME on 4/2/79

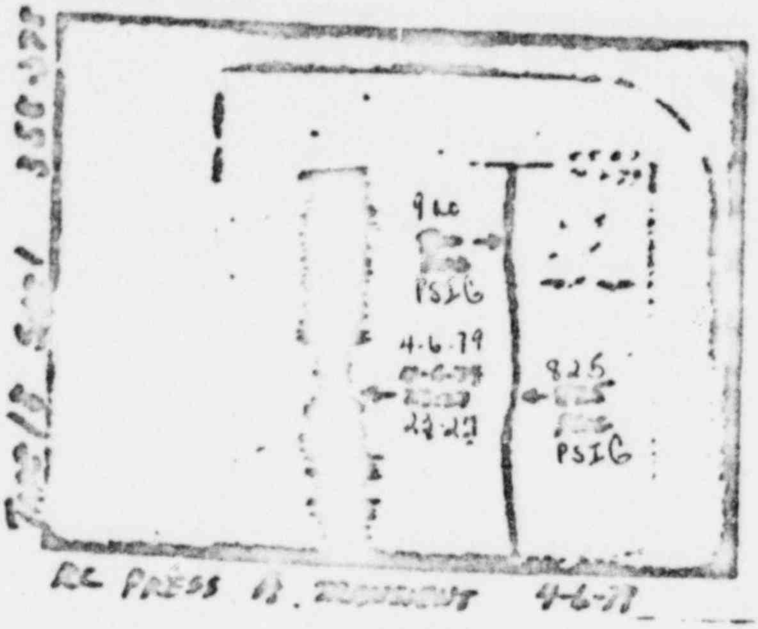


Figure 5

[illegible] #42

Page 1 of 3

For: Eric Maskin of Bechtel
717-944-1012
or 717-944-4756

April 4, 1979

From: D.A. Nitti - B&W

TABLE 2. SOLUBILITY OF HYDROGEN IN WATER

H_2 Partial Pressure, p.s.i.a.	Source	ml. H_2(S.T.P.)/g. of Water						Average	Probable Error	Maximum Deviation		
		75°F.										
300	W. and O.(2)	- - - -						0.32	-		- -	m = y/x = .32/300 = .0
367	"	- - - -						0.44	-		- -	m = y/x = .44/367 = .0 Avg = .0
		125°F.										
200	B.M.I.	0.33	0.32	0.32	0.31	0.37	0.30	0.33	0.01	+0.05	-0.03	m =
300	"	0.41	0.42	0.40	0.41			0.41	0.00	+0.01	-0.01	m =
350	"	0.47	0.44	0.44	0.44	0.46		0.45	0.01	+0.02	-0.01	m = avg =
		300°F.										
100	I. and T.(3)	- - - -						0.13	-		- -	m = .13/100 = .0013
200	"	- - - -						0.28	-		- -	m = .28/200 = .0014
300	"	- - - -						0.40	-		- -	m = .40/300 = .001
375	"	- - - -						0.52	-		- -	m = .53/375 = .001
500	"	- - - -						0.70	-		- -	m = .70/500 = .001 avg = .001
		345°F.										
100	I. and T.(3)	- - - -						0.15	-		- -	m = .15/100 = .0015
200	"	- - - -						0.30	-		- -	m = .30/200 = .0015
300	"	- - - -						0.43	-		- -	m = .43/300 = .0014
375	"	- - - -						0.56	-		- -	m = .56/375 = .00149
500	"	- - - -						0.75	-		- -	m = .75/500 = .0015 avg = .
		390°F.										
100	I. and T.(3)	- - - -						0.18	-		- -	m = .18/100 = .0018

Reference: BMI-T-25

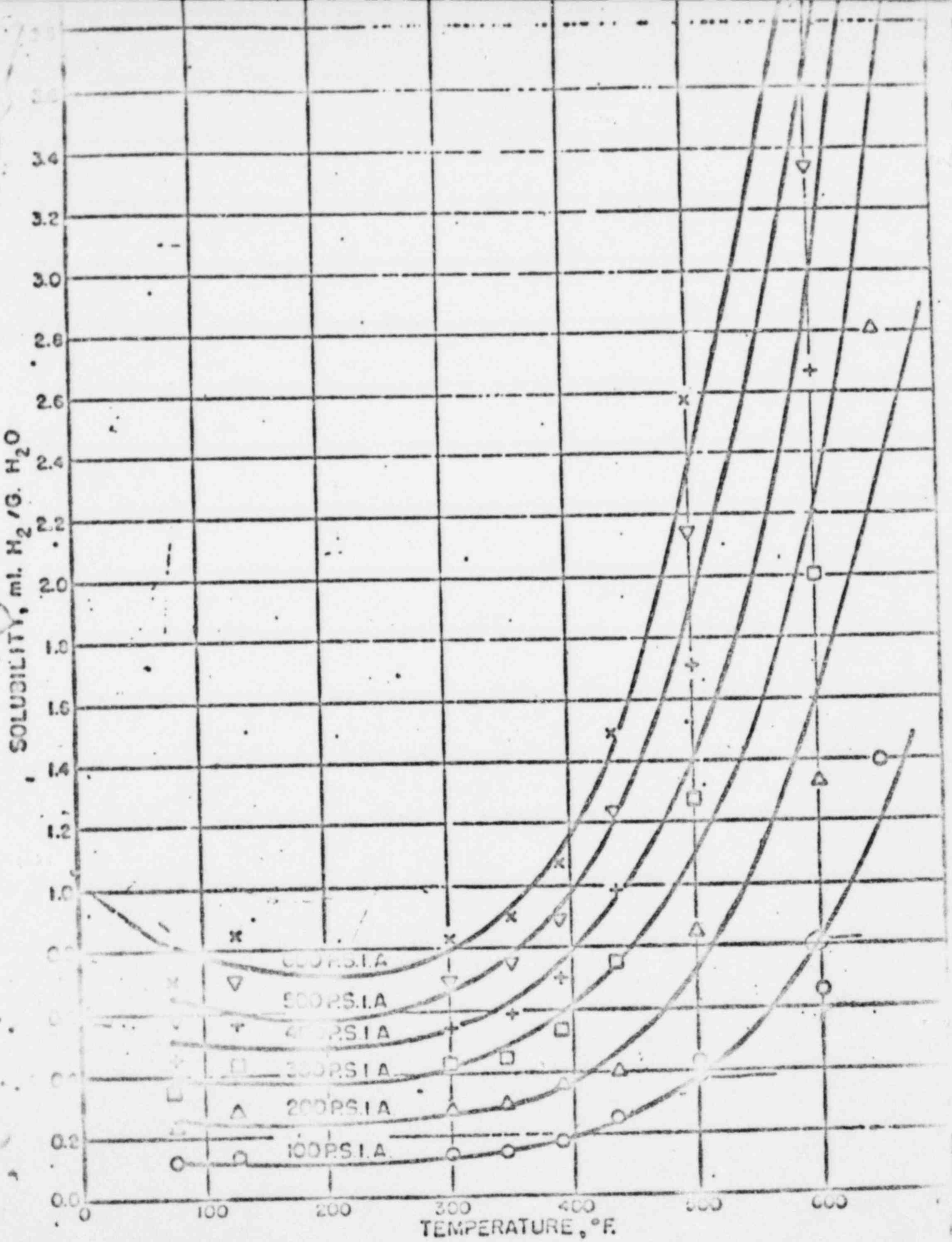


FIGURE 7. SOLUBILITY OF HYDROGEN IN WATER

0-15[illegible]

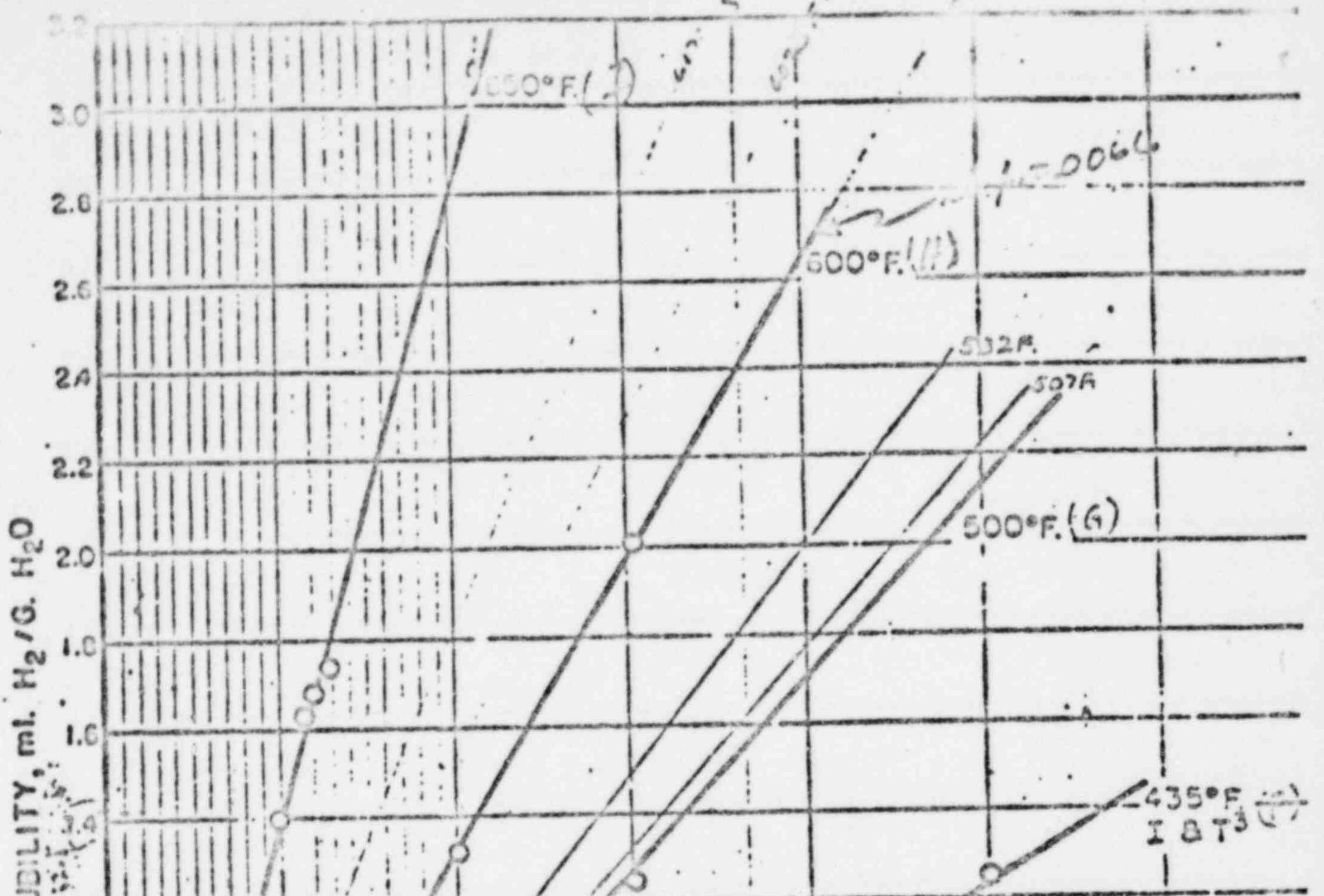


FIGURE 5. SOLUBILITY OF HYDROGEN IN WATER

STAUDT

Hydrogen Concentration 2.1%.

Cont. Volume 2,000,000 FT³. X 2.1% = $\underline{42,000}$ FT³ H₂.

Recombiner flow 90 SCFM.

90 X 60 X 24 = 130,000 FT³/day. X 2.1% = 2,722 FT³ H₂/day.

		H_2 (start)	Remove	H_2 (end)	%
Start 15:05	4/2/79				
First day.	4/3	42.0K	2.7	39.3	1.96.
Second day.	4/4	39.3.	2.5	36.8	1.84
Third day	4/5	36.8	2.4	34.4	1.72
Fourth "	4/6	34.4	2.2	32.2	1.61
	4/7	32.2	2.1	30.1	1.50
	4/8	30.1	1.9	28.2	1.41
	4/9	28.2	1.8	26.4	1.32
	4/10	26.4	1.7	24.7	1.24
	4/11	24.7	1.6	22.1	1.10
	4/12	22.1	1.4	20.7	1.04
	4/13	20.7	1.3	19.4	.97

Assume No Net H_2 input to Containment

Gary Miller.
Joe Logan, Plant Superintendent.
Jack Herbein V.P. Generation
Creitz
Dieckamp.

Hydrogen Concentration 2.1%.

Cont. Volume 2,000,000 FT³. X 2.1% = $\underline{\underline{42,000}}$ FT³ H_2.

Recombiner flow 9.0 SCFM.

90 X 60 X 24 = 130,000 FT³/day. X 2.1% = 2,722 FT³ H_2/day.

<u>Start 15:05</u>	4/2/79	H_2 (start)	Remove	H_2 (end)	%
First day.	<u>4/3</u>	42.0K	2.7	39.3	1.96.
Second day.	4/4	39.3.	2.5	36.8	1.84
Third day	4/5	36.8	2.4	34.4	1.72
Fourth "	4/6	34.4	2.2	32.2	1.61
	4/7	32.2	2.1	30.1	1.50
	4/8	30.1	1.9	28.2	1.41
	4/9	28.2	1.8	26.4	1.32
	4/10	26.4	1.7	24.7	1.24
	4/11	24.7	1.6	22.1	1.10
	4/12	22.1	1.4	20.7	1.04
	4/13	20.7	1.3	19.4	.97

Assume No Net H_2 input to Containment

Gary Miller.
Joe Logan, Plant Superintendent.
Jack Herbein V.P. Generation
Creitz
Dieckamp.

Hydrogen Concentration 2.1%.

Cont. Volume 2,000,000 FT³. X 2.1% = 42,000 FT³ H₂.

Recombiner flow 90 SCFM.

90 X 60 X 24 = 130,000 FT³/day. X 2.1% = 2,722 FT³ H₂/day.

		H₂ (start)	Remove	H₂ (end)	%
Start 15:05	4/2/79				
First day.	4/3	42.0K	2,7	39.3	1.96.
Second day.	4/4	39.3.	2.5	36.8	1.84
Third day	4/5	36,8	2.4	34.4	1.72
Fourth "	4/6	34.4	2,2	32,2	1.61
	4/7	32,2	2,1	30.1	1.50
	4/8	30.1	1.9	28.2	1.41
	4/9	28,2	1.8	26.4	1.32
	4/10	26.4	1.7	24,7	1.24
	4/11	24.7	1.6	22.1	1.10
	4/12	22.1	1.4	20,7	1.04
	4/13	20.7	1.3	19.4	.97

Assume No Net H_2 input to Containment

Gary Miller

Joe Logan, Plant Superintendent.

Jack Herbein VP. Generation.

Creitz

Dieckamp.

Hydrogen Concentration 2.1%.

Cont. Volume 2,000,0.00 FT³. X 2.1% = $\underline{\underline{42,000}}$ FT³ H₂.

Recombiner flow 9.0 SCFM.

90 X 60 X 24 = 130,000 FT³/day. X 2.1% = 2,722 FT³ H₂/day.

		H_2 (start)	Remove	H_2 (end)	%
Start 15:05	4/2/79	42.0K	2.7	39.3	1.96.
First day.	4/3	39.3.	2.5	36.8	1.84
Second day.	4/4	36.8	2.4	34.4	1.72
Third day	4/5	34.4	2.2	32.2	1.61
Fourth "	4/6	32.2	2.1	30.1	1.50
	4/7	30.1	1.9	28.2	1.41
	4/8	28.2	1.8	26.4	1.32
	4/9	26.4	1.7	24.7	1.24
	4/10	24.7	1.6	22.1	1.10
	4/11	22.1	1.4	20.7	1.04
	4/12	20.7	1.3	19.4	.97
	4/13				

Assume No Net H_2 input to Containment

Gary Miller.
Joe Logan, Plant Superintendent.
Jack Herbein VP. Generation
Creitz
Dieckamp.

4/10/79 0600
G/712-3.E-24

Action Item Response.

I.B.5 Define end point for degas mode

I think the reactor coolant system should be degassed until the total gas concentration is less than 5 STD cc/kg. This should preclude the possibility of any gas g coming out of solution if the reactor coolant system was depressurized to atmospheric conditions.

B+W document 57-00 dated 4-7-79 (original issue) states that the generation of radiolytic gas should be small. They recommend that 15 STD cc/KG of H_2 be maintained in the coolant to suppress gas formation.

I question whether this is necessary as the H_2 will only minimize O_2.

If minimizing O_2 is important during long term cooling, would it be better to do it with N_2H_4 addition?

Can we continue some degas with the letdown system while in the 100 PSI range?

How much gas would be produced by the radiation present in the coolant?

The total gas should be kept low so that gas g coming out of solution when depressurizing would not hinder natural circ

Herb Potts Comb-Eng

G/712-3,e-25

Degas

ACTION ITEM RESPONSE

I.B.5 define end point for degas mode.

Requirements:

Do depressurization test to determine gas content of coolant.

Do MU tank measurement procedure to measure gas content/degas rate, if possible.

Get results of gas content from primary pressurized sample, if available.

Plan:

Using results from above tests & samples, as start point, project the gas content by calculating the degas rate and rate of coolant gas concentration. Plot against time.

Continue to degas at high pressure, approximately 1000 psi while cooling down to point B on the "Base Case Summary". (about 220 - 230°F primary temperature). At that point determine value of proceeding further considering;

1 Ultimate condition pressure; 2 time needed for further degas;
3. compatability of degas operations with next cooldown
(solid SG) mode. 4 Radiolysis generation rate.
5 Need to keep radiolytic gas in solution.

G/712-3.e-26

(H) + L.A.

REC'D FROM COX-[illegible]
COMBUSTION ENGINEERING
1800 HRS 4/10/79
PAGE 1 OF 5

PRELIMINARY

Problem

Estimate the volume of gas released, if any, as a result of cooling and depressurizing the reactor coolant system, taking into account continuous gas removal by feed and bleed at approximately 20 GPM.

Initial Conditions

- Pressure ≈ 1,000 PSIA/985 PSIG
- Temperature ≈ 280°F

Assumptions

- Bubble disappeared at 1200, April 2, 1979
- RC saturated with H_2 at that time (1,550 cc H_2 @ STP/Kg)
- Letdown flow 20 GPM @ 120°F (9,000 #/HR) not recycled
- Makeup flow same, air-saturated water (18 cc/Kg air, assume 100% H_2 for most limiting case)
- Ideal Gas Law assumed for all gases and water vapor
- Perfect mixing in RCS

Results

1. Calculation of limiting dissolved H_2 gas concentrations.

The approach was to calculate limiting dissolved gas concentrations relative to:

-- bubble nucleation

-- formation of 100 ft³ of bubble

Results are presented on Table I.

These figures should be taken as targets for degasification.

Conclusions

(1) H_2 must be reduced to < 1,100 cc/Kg to avoid bubble formation due to cooling while maintaining 1,000 PSIA. The maximum bubble, assuming no degasification, would be approximately 75 ft³ at 1,000 PSIA/150°F.

(2) H_2 must be reduced to < 10 cc/Kg to avoid bubble formation due to cooling and depressurizing to 50 PSIG.

(3) Total gases (H_2 plus air) must be reduced to < 30 cc/Kg to avoid bubble formation due to cooling and depressurizing to 50 PSIG.

4/10/79

Calculation of Rate of Gas Removal

Based on a RCS mass of 5 × 10^5 lb and 9.0 × 10^3 lb/hr bleed, H_2 concentrations will be reduced with a half-life of approximately 37 hours (1-3/4 [illegible]). Coolant air concentration will increase to saturation (12 cc/Kg) with the same half-life. Results are plotted on Figure 1.

Also plotted are the minimum pressures to prevent bubble formation at 200°F and 150°F as a function of time. These curves include the partial pressures of air (assumed N_2), H_2, and water vapor.

Conclusions

(1) In order to meet a target concentration of 30 cc H_2/Kg, degasification should continue until approximately noon on April 12.

(2) In order to depressurize to 50 PSIG at 200°F without forming gas bubbles, degasification should continue until early on April 12.

Note: As final temperature increases, the vapor pressure of water becomes more significant and reduces the allowed gas concentration (extends degasification times).

Slightly increasing system pressure will compensate for the additional water vapor pressure.

Note: The above calculations assume no input of gases from radiolysis.

Summary Conclusion

Based on coolant bleed/feed and the associated assumptions, a gas bubble will not form at 150°F primary temperature and 50 psig primary pressure after 4/12/79.

4/10/79

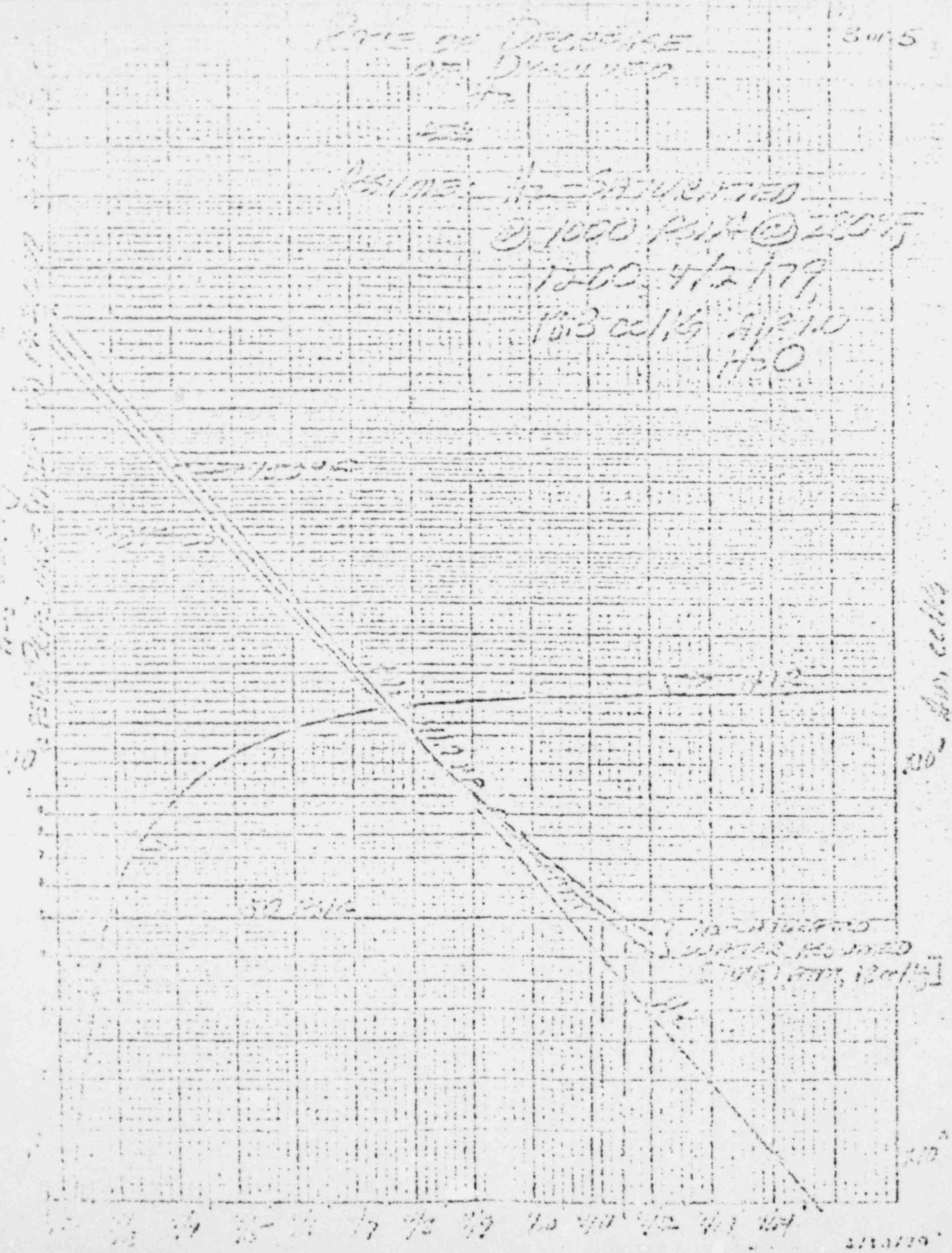

3 of 5
Assume: H2 Saturated
@ 1000 psia @ 200°F
1200 ft³ ≈ 177
183 cells
H2O
50 psia
H2
200°

TABLE 1 [illegible] CONCENTRATIONS FOR VARIOUS CONDITIONS

PRELIMINARY

Conditions: Initial Pressure - 1000 psia
Initial Temp - 250°F

	Pressure psia (psig)	[illegible] Temperature 150°F	200°F	25[illegible]
		[illegible]		
1. Cool while maintaining pressure				
a. To prevent bubble formation	985 (1000)	1130	1020	1[illegible]0
b. To prevent bubble > 1000 ft³ in hot leg	"	No excess over sat @ 1000 psia [illegible]		
Then bubble [illegible] [illegible]		75 ft³	150 ft³	[illegible]
2. Cool first, then depress to 50 psia	50 (65)			
a. To prevent bubble formation				
(assuming [illegible] [illegible])	"	144	37	34 [illegible]
(assuming [illegible] [illegible])	"	110	33	30 [illegible]
b. To prevent bubble > 1000 ft³ in hot leg	"			
(assuming all bubble to one HL)	"	75	62	55 [illegible]
(assuming 50% of bubble to HL)	"	157	130	115 [illegible]
[illegible] (H₂ & [illegible]) to [illegible]		[illegible]		

1800 hrs 5/

PRELIMINARY

Based on discussions with Dr. Paul Cohen (consulting chemical engineering from Westinghouse, retired), review of data in his book, and discussions with Dr. Jenks of ORNL, it is their opinions that net recombination, VIZ no coolant radiolysis persists in the TMI-II core.

From my experience with a pressurized heavy water cooled and moderated reactor, net radiolysis occured only under power operation, with a thermal neutron flux of 10^{14} n/cm^2, a dissolved hydrogen content of <1.5 cc/kgm coolant, and sub-cooled boiling in the core. Even there, oxygen concentrations were ≤2 ppb in the coolant.

Thus, with current and anticipated primary system conditions at TMI-II, we do not expect any hydrogen generation from radiolysis.

References

1. Cohen, P. Water Coolant Technology of Power Reactors, Gordon and Breach, 1969, page 100,101.
2. Jenks, ORNL 3848, 1965
3. Jenks and Griess – ORNL 4173, 1967

[illegible]/mac

5/10/79

G1712-3.e-27

Degas

Telecopy to

[illegible] - O2

[illegible]

③ We can estimate degassing time w/recycle.

Please note 5 pages that follow

reviews by P. Bryant / [illegible] [illegible]

Please review with AMESC staff &

telecopy to Zebroski in the AM.

Jack

① Calculations are correct given the assumption of no recycle.

② There has been, for the most part, total recycle. Therefore, all times and dates are incorrect (times too short, dates when total depressurization could be accomplished are too early.

JWThiesing 9:1[illegible]
4-11-79

6/712-3.P-28

REC'D FROM
COMBUSTION ENGINEERING
1800 HRS 4/10/79
PAGE 1 OF 5

PRELIMINARY

Problem

Estimate the volume of gas released, if any, as a result of cooling and depressurizing the reactor coolant system, taking into account continuous gas removal by feed and bleed at approximately 20 GPM.

Initial Conditions

- Pressure = 1,000 PSIA/985 PSIG
- Temperature = 220°F

Assumptions

- Bubble disappeared at 1200, April 2, 1979
- RC saturated with H_2 at that time (1,500 cc H_2 @ STP/Kg)
- Letdown flow 20 GPM @ 220°F (9,000 #/HR) not recycled
- Makeup flow same, air-saturated water (18 cc/Kg air, assume 100% N_2 for most limiting case)
- Ideal Gas Law assumed for all gases and water vapor
- Perfect mixing in RCS

needed

and/or RCBT.

Results

1. Calculation of limiting dissolved H_2 gas concentrations

The approach was to calculate limiting dissolved gas concentrations relative to:

-- bubble nucleation

-- formation of 100 ft^3 of bubble

Results in all

Results are presented on Table I.

These figures should be taken as targets for degasification.

Conclusions

(1) H_2 must be reduced to < 1,100 cc/Kg to avoid bubble formation due to cooling while maintaining 1,000 PSIA. The maximum bubble, assuming no degasification, would be approximately 75 ft^3 at 1,000 PSIA/150°F.

(2) H_2 must be reduced to < 50 cc/Kg to avoid bubble formation due to cooling and depressurizing to 50 PSIG.

(3) Total gases (H_2 plus air) must be reduced to < 50 cc/Kg to avoid bubble formation due to cooling and depressurizing to 50 PSIG.

?

4/10/79

1800 HRS 4/10/79

2. Calculation of Rate of Gas Removal

given the no-recycle

Based on a RCS mass of 6 X 10^5 lb @ 9.5 X 10^3 lb/hr [illegible] H_2 concentrations will be reduced with a half-life of approximately 42 hours (1-3/4 day). Coolant air concentration will increase to saturation (13 cc/Kg) with the same half-life. Results are plotted on Figure 1.

Also plotted are the minimum pressures to prevent bubble formation at 200°F and 150°F as a function of time. [illegible] curves include the partial pressures of air (assumed [illegible]) H_2, and water vapor.

Conclusions

(1) In order to meet a target concentration of 30 cc H_2/[illegible] degasification should continue until approximately noon on April 12.

→ Too soon — there [illegible] recycle

(2) In order to depressurize to 50 PSIG at 200°F without forming gas bubbles, degasification should continue until early on April 12.

→ Same Comment

Note: As final temperature increases, the vapor pressure of water becomes more significant and reduces the allowed gas concentration (extends degasification times).

Slightly increasing system pressure will compensate for the additional water vapor pressure.

Note: The above calculations assume no input of gases from radiolysis.

✓ OK per attached notes (i.e. zero net radiolysis effect)

Summary Conclusion

Based on coolant bleed/feed and the associated assumptions, a gas bubble will not form at 150°F primary temperature and 50 psig primary pressure after 4/12/79.

gm

→ too soon! the operating mode is recycle!

gm

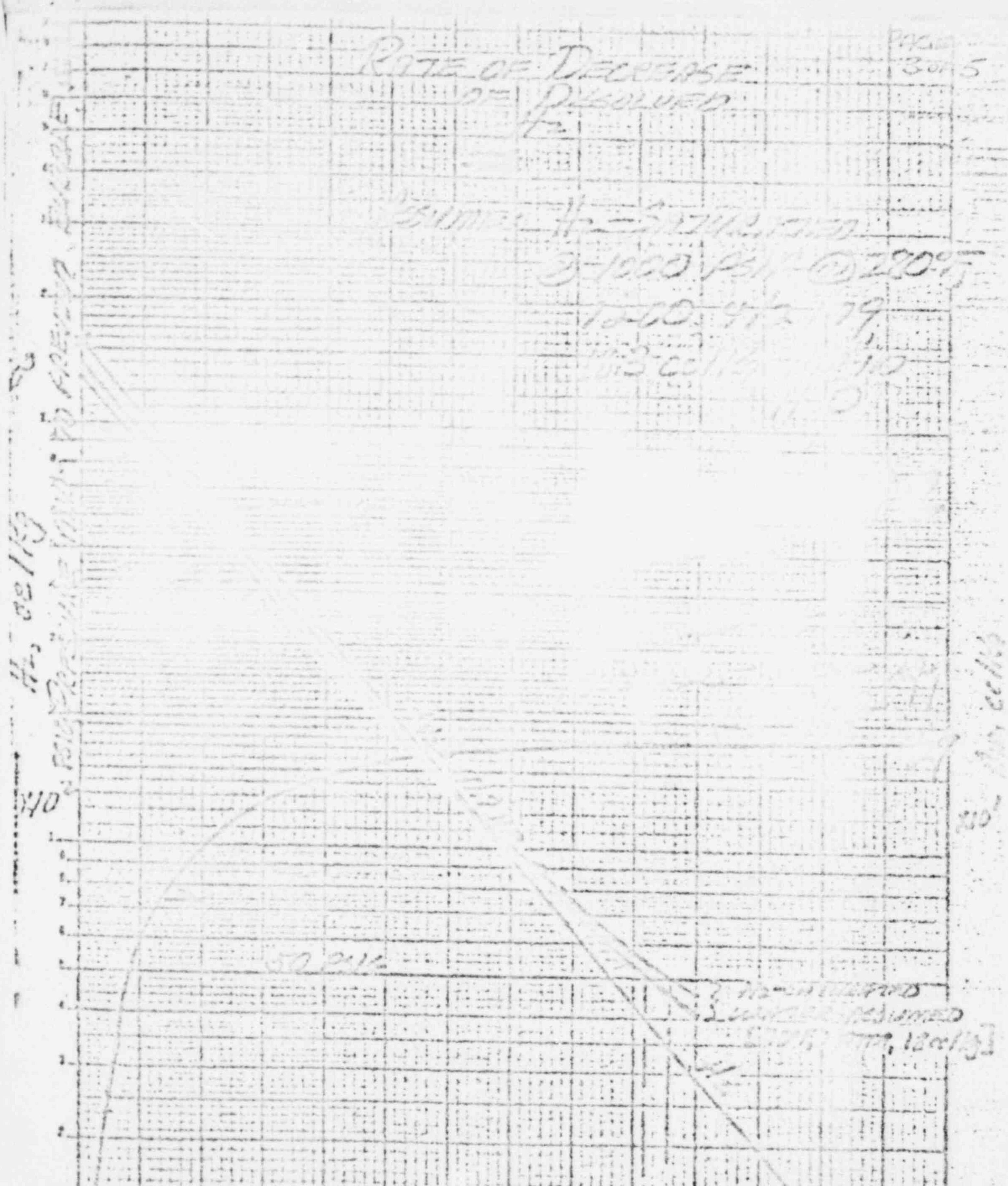
4/10/79

TABLE [illegible] H₂ CONCENTRATIONS FOR VARIOUS CONDITIONS

CONDITIONS: INITIAL PRESSURE - 1000 PSIA
INITIAL TEMP - 280°F

	FINAL PRESSURE PSIG (PSIA)	TEMPERATURE 150°F	200°F	220°F
		UNITS - cc (STP)/kg of H₂O		
1. COOL WHILE [illegible]	985 (1000)	1150	1220	✓1500
a. TO [illegible]	"	IN EXCESS OF SAT @ 1000 PSIA / 280°F		
b. TO [illegible] ft³ in 1st leg		75 ft³	65 ft³	57 ft ✓
TOTAL [illegible] H₂ SAT WATER				
2. COOL FIRST, [illegible] TO 50 PSIA	50 (65)			
a. TO [illegible] FORMATION. [illegible]	"	44	38	(34
(assuming [illegible] not [illegible])	"	40	33	(30
*(assuming [illegible] ft³ in 1st leg)				
b. TO [illegible] ([illegible])	"	75	62	(55
([illegible])	"	157	128	(115
[illegible]		ADD 18 cc/kg to above		
3. TO THE [illegible]				

4/19/79


RATE OF DECREASE
OF DISSOLVED
H_2
PAGE
3 OF 5
ASSUME H_2 – SATURATED
@ 1000 PSIA @ 280°F
1000 PSIA 79
10
50 PSIA
H_2 – SATURATED
WATER ASSUMED
FOR 1 PSIA, 12cc/Kg
H_2, cc/Kg
10^2
10^1
10^1
10^0
4/2
4/3
4/4
4/5
4/6
4/7
4/8
4/9
4/10
4/11
4/12
4/13
4/14

1800 Hrs 5 of 5

PRELIMINARY

Based on discussions with Mr. Paul Cohen (consulting chemical engineering from Westinghouse, retired), review of data in his book, and discussions with Dr. Jenks of ORNL, it is their opinions that net recombination, VIZ no coolant radiolysis persists in the TMI-II core.

From my experience with a pressurized heavy water cooled and moderated reactor, net radiolysis occured only under power operation, with a thermal neutron flux of 10^{13} n/cm^2, a dissolved hydrogen content of <1.5 cc/kgm coolant, and sub-cooled boiling in the core. Even there, oxygen concentrations were <2 ppb in the coolant.

Thus, with current and anticipated primary system conditions at TMI-II, we do not expect any hydrogen generation from radiolysis.

References

1. Cohen, P. Water Coolant Technology of Power Reactors, Gordon and Breach, 1969, page 100,101.
2. Jenks, ORNL 3043, 1965
3. Jenks and Greiss - ORNL 4173, 1967

PB/mac

4/10/79

G/712-3.e-29

BABCOCK & WILCOX CO.
POWER GEN. GROUP
TMI-2 OPERATIONS

TRANSMITTAL TO: TOM CRIMMINS/DICK SKILLMAN

☒ L. ROGERS TRANSMITTAL # ____________

ALSO TELECOPY TO: ☒ R. WILSON TRANSMITTAL # B-162
☒ GPU TRAILER 25 TRANSMITTAL # ____________

TIME 0240 DATE 4/11/79

SUBJECT RECLASSIFICATION PARAMETER STUDY

APPROVED BY 0805
OPERATIONS MANAGER 4/11/79

B&W ACTION # [illegible]

RCVD 0555
4-11-79

R C ARNOLD
G BROUGHTON
J HERBEIN
D. MONTGOMERY
R. KOSTICH
R. WILSON
T. CRIMMINS
~~Spaulding~~ FILE

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

INSTRUCTION #120

To

Cust. TMI [illegible]

From

CHEMISTRY & RADIATION SAFETY GROUP

Ext. [illegible]

Cust.

File No. or Ref.

Subj.

[illegible] TRANSIENT STUDY

Date

APRIL 13, 1979 [illegible]

This letter to cover one customer and one subject only

ATTACHED ARE CURVES FOR THE MAKEUP TANK PRESSURE INCREASE FOR VARIOUS LETDOWN FLOWRATES AND H2 GAS CONCENTRATIONS. SEVERAL ASSUMPTIONS WAS MADE IN THE CONSTRUCTION OF THE CURVES:

MAKEUP TANK LEVEL = 72 INCHES

MAKEUP FLOW IS SAME AS LETDOWN FLOW

MAKEUP TANK TEMPERATURE 93F

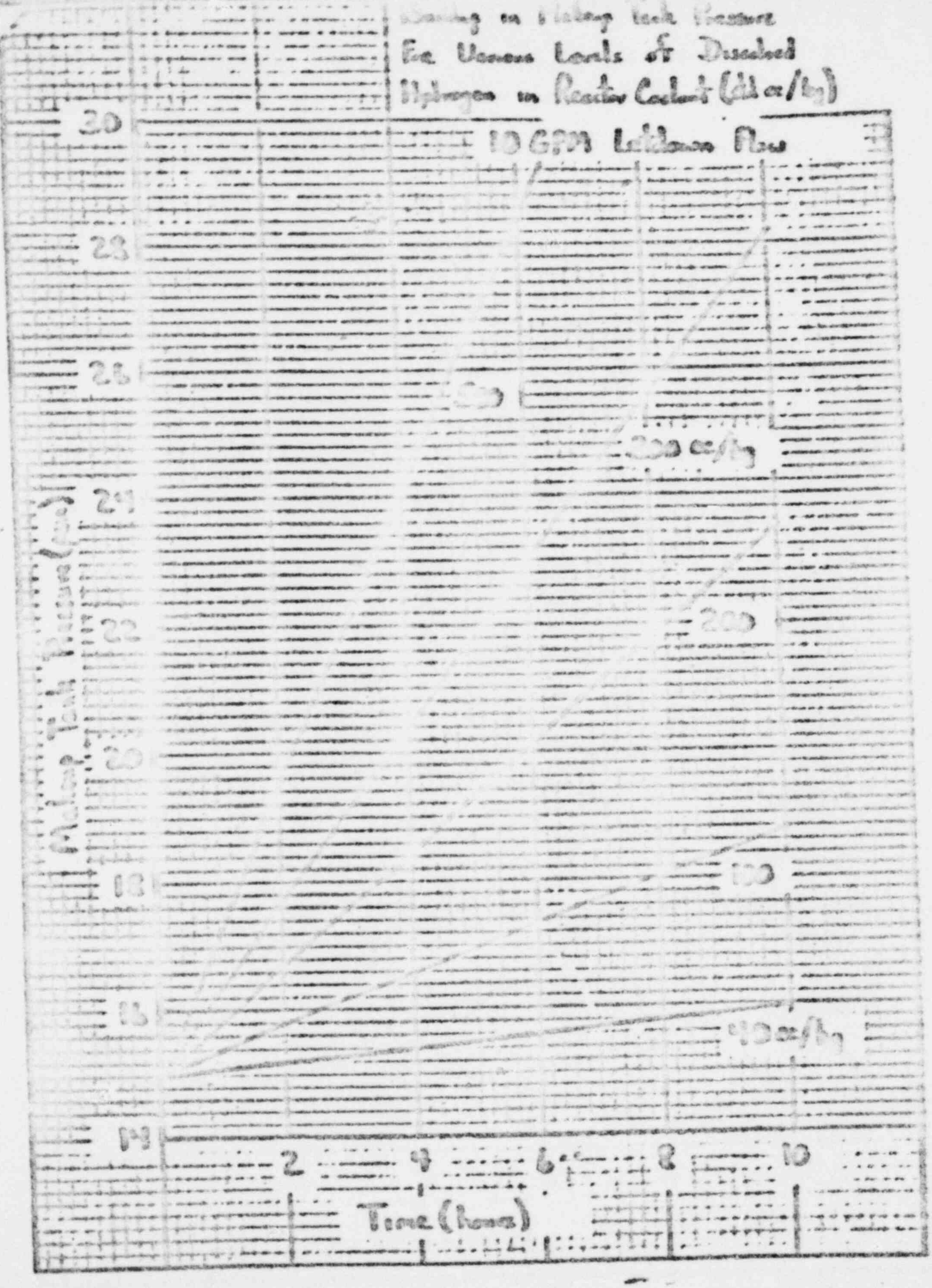
PRESSURIZER LEVEL IS CONSTANT

HYDROGEN CONCENTRATION EXITING MUT IS AT SATURATION LIMIT FOR MUT T&P

MAKEUP TANK PRESSURE = 15 PSIA AT START OF TEST

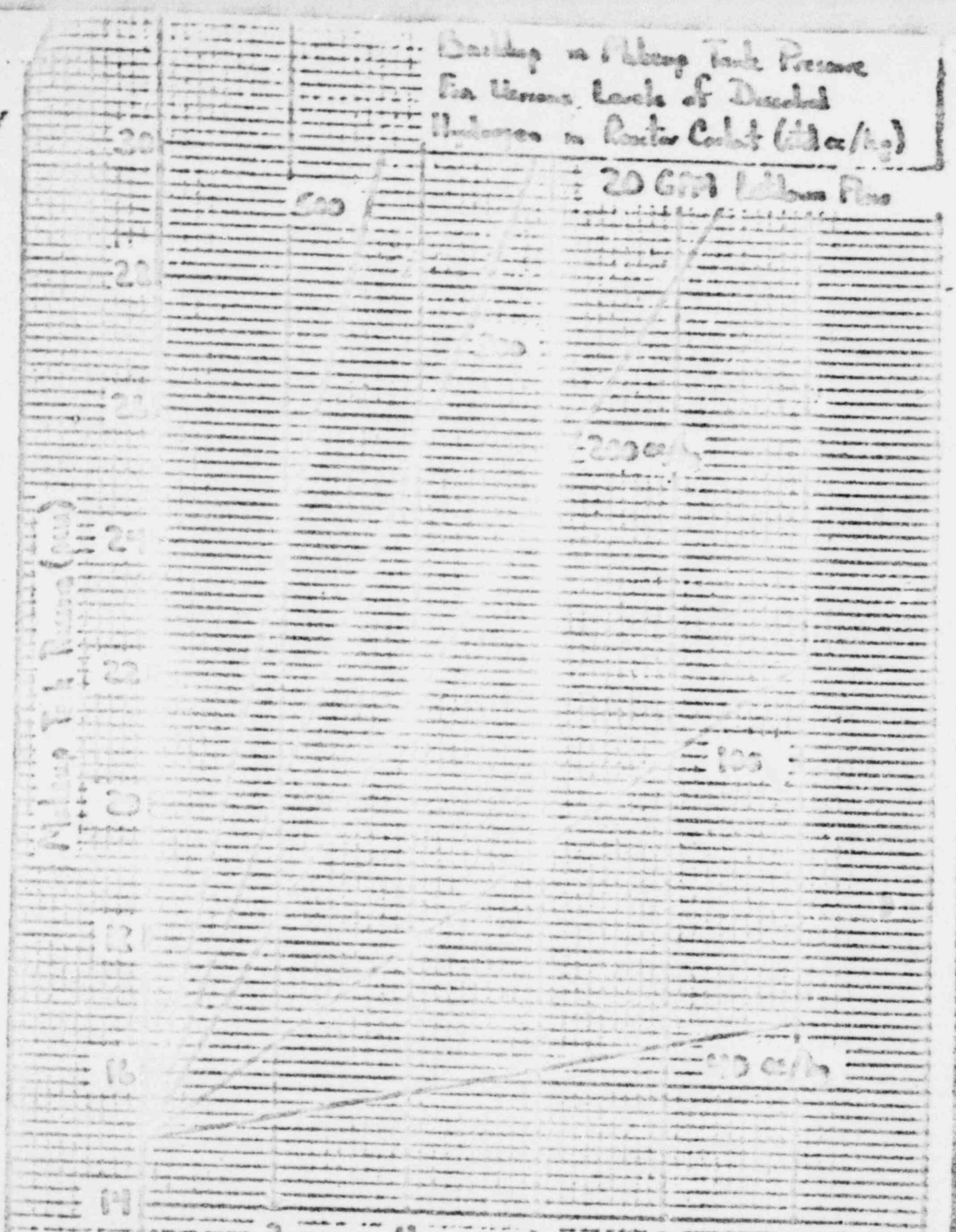
lfd

ATTACHMENT

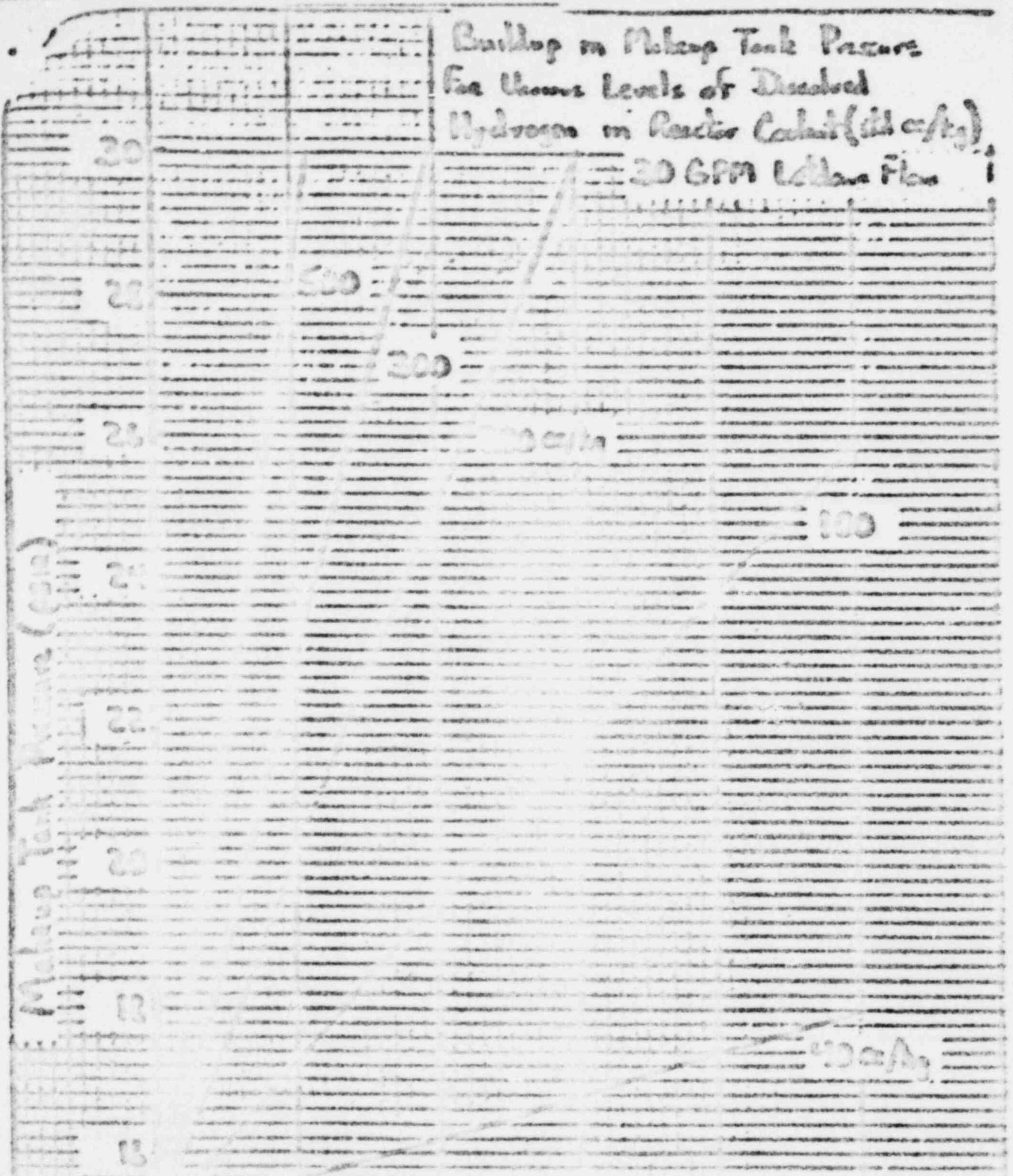


[illegible] on Makeup Tank Pressure For Various Levels of Dissolved Hydrogen in Reactor Coolant (std cc/kg)

10 GPM Letdown Flow


Buildup in Makeup Tank Pressure For Various Levels of Dissolved Hydrogen in Reactor Coolant (std cc/kg)

20 GPM Letdown Flow



G/712-3.e-30

4/11/79
1100

F D3318

April 11, 1979
1030 AM

Telecopy to:

Branch Elam / Jack DeVine

from W. A. Crandall

cc RFW
TMC
R. Keaten
E. Montgomery

GPU Service Corporation

DATA SHEET

No. ____

Date ____

Location GPUSC

Mountain Lakes, N.J.

Prepared by W. A. Crandall

Consulting Engineer

Subject

SOLUBILITY OF HYDROGEN GAS IN PRIMARY COOLANT

(System Temperature and Pressure vs. Concentration in cc/kg)

			System Pressure, psia							
Temp. °F	Sat. Press. psia	[illegible]	10	20	30	40	50	60	80	100
50	0.18	6.55								
60	0.26	6.60	12.5	25.3	38.0	50.9	63.7	76.5	102.1	127.7
70	0.36	6.85								
80	0.51	7.10	11.8	23.2	35.1	47.0	58.9	70.8	94.6	118.4
90	0.70	7.30								
100	0.95	7.50	10.2	21.5	32.7	44.0	55.3	66.5	89.1	111.6
110	1.27	7.60	9.7	20.8	31.9	43.1	54.2	65.3	87.5	109.8
120	1.70	7.60								
130	2.22	7.55								
140	2.89	7.50								
150	3.72	7.45	7.1	18.5	29.8	41.2	52.5	63.8	86.5	109.2
200	11.53	6.81	—	10.5	22.9	35.3	47.7	60.2	85.0	109.8
250	29.83	5.93	—	—	0.2	14.6	28.9	43.3	72.0	100.7
300	67.01	4.91	—	—	—	—	—	—	22.0	56.8
350	134.6	4.01								
400	247.3	3.30								
450	422.6	2.51								
500	680.8	1.94								
550	1045.2	1.47								
600	1542.9	1.08								

Note: System Pressure = $P_{H_2} + P_{H_2O}$, P_{H_2O} = Sat. Press. in psia.

[illegible] Service Corporation

DATA SHEET

Location [illegible]

[illegible]

(System Temperature and Pressure vs. Concentration in cc/kg)

[illegible]	[illegible]	[illegible]	System Pressure, psig							
			100	200	300	400	500	600	800	1000
[illegible]	[illegible]	6.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1110.[illegible]
[illegible]	0.[illegible]	[illegible]	[illegible]	255.7	[illegible]	411.[illegible]	620.[illegible]	[illegible]	[illegible]	1120.[illegible]
[illegible]	0.[illegible]	6.83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.[illegible]	7.10	[illegible]	227.9	325.4	475.5	[illegible]	[illegible]	[illegible]	1182.[illegible]
[illegible]	0.[illegible]	7.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.[illegible]	7.[illegible]	111.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	7.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	7.[illegible]	109.2	227.6	336.0	[illegible]	[illegible]	672.[illegible]	[illegible]	1170.0
[illegible]	[illegible]	6.87	125.2	233.2	357.3	462.0	636.1	[illegible]	[illegible]	1226.2
[illegible]	[illegible]	[illegible]	103.7	241.1	337.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	157.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	413.2	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	2.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1.47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Note: System Pressure = [illegible])

FIGURE 12. SOLUBILITY OF NITROGEN IN WATER

G/712-3.e-31

RECD. 0550
4/12/79

[illegible] #

☐ [illegible] TRANSMITTAL # [illegible]
☐ NRC TRAILER 25 TRANSMITTAL #

DATE

SUBJECT [illegible] (4-12-79)

REQUESTED BY [illegible] NRC ACTION # 377

0603

2. [illegible] OF THE GAS CONCENTRATION IN THE RC SYSTEM BASED ON [illegible] CONDITIONS [illegible] 1.

THE GAS [illegible] THE RC PRESSURE WAS LOWERED TO [illegible]. BASED ON [illegible] GAS WAS BELOW SOLUBILITY LIMIT AT [illegible] PSI AND [illegible] °F. [illegible] CONCENTRATION [illegible] CC/KG.

AT 0001 ON 4/[illegible], PRESSURE WAS 625 PSI. AT 1000 HOURS ON 4/[illegible], PRESSURE WAS [illegible] PSI. BASED ON ABOVE ANALYSIS, GAS WAS BELOW SOLUBILITY LIMIT AT BOTH OF THESE TIMES. SINCE PRESSURE HAS BEEN RELATIVELY CONSTANT DURING THE PERIOD 4/[illegible] TO 4/[illegible], WE WOULD EXPECT THE GAS CONCENTRATION TO BE [illegible] AT THE PRESENT TIME.

xc: RCA
RFW
Transmittal No.
128(2) w/att
TMC
JGH
D. Montgomery

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

To: BOB KEATON - GPU TECHNICAL SUPPORT

From: NELSON [illegible]

Cust.

File No. or Ref.

Subj.: RESPONSE TO QUESTIONS RELATIVE TO FREE GAS TESTING [illegible] FRIDAY, APRIL 6, 1979

Date: APRIL 8, 1979 0910

This letter to cover one customer and one subject only

THE FOLLOWING ARE RESPONSES TO YOUR QUESTIONS RELATIVE TO THE PLANNED TESTING TO DETERMINE THE PRESSURE LEVEL AT WHICH FREE GAS PRESENT IN THE REACTOR COOLANT SYSTEM WILL COME OUT OF SOLUTION.

1. WHAT IS THE VOLUME OF THE PRIMARY SIDE OF THE CONTROL ROD DRIVES?

<u>ANSWER</u>: THE PRIMARY SIDE VOLUME OF THE CONTROL ROD DRIVES IS 58 CUBIC FEET.

2. WHAT IS B&W'S POSITION ON LOWERING PRESSURE IN CHECKING FOR GAS, THAT IS, WHAT IS THE LOWEST PRESSURE WE WOULD RECOMMEND GOING TO IN DETERMINATION OF THE COMING OUT OF SOLUTION OF DISSOLVED GAS?

<u>ANSWER</u>: THE LIMITS ON PRESSURE FOR THIS TEST SHOULD BE THE SAME AS THOSE PROVIDED IN THE MEMO FROM R. E. KOSIBA TO LEE ROGERS DATED 4/4/79, TRANSMITTED 11:10 P.M. TRANSMITTAL LOG NO. 275. THESE LIMITS ARE THOSE RELATIVE TO THE NPSH CURVE FOR THE PUMPS.

3. BE SURE THE REACTOR DIAGNOSTICS GROUP IS READY FOR MONITORING DURING THE SUBJECT TEST. THE REACTOR DIAGNOSTICS GROUP HAS BEEN INFORMED OF THE PENDING TEST AT NOON ON APRIL 6, 1979 AND WILL BE READY FOR TAKING OF DATA DURING THIS TEST.

4. DOES B&W'S TEST PROCEDURE WHICH REQUIRES LOWERING PRESSURE TO DETERMINE THE PRESSURE AT WHICH GAS COMES OUT OF SOLUTION WORK AT LOWER PRESSURES THAN THOSE PREVIOUSLY USED; THAT IS, WILL GAS BE DETECTED IF THE PRESSURE

IS REQUIRED TO BE LOWERED IN THE 400 TO 500 PSI RANGE?

ANSWER: THE PROCEDURE SHOULD BE JUST AS EFFECTIVE IN THE LOWER PRESSURE RANGES AS AT THE UPPER PRESSURE RANGES AND AT THE TEMPERATURE OF 200°F BECAUSE THE SAME RELATIVE VOLUMES OF GASES COMING OUT OF SOLUTION APPLY IN HENRY'S LAW AS A LINEAR FUNCTION WITH PRESSURE.

5. CAN B&W SUGGEST AN ALTERNATIVE METHOD FOR DETERMINING THE PRESSURE AT WHICH GAS COMES OUT OF SOLUTION THAN THE USE OF PRESSURE SIGNAL NOISE CONDITIONS?

ANSWER: ANOTHER POTENTIAL METHOD IS TO MEASURE THE PRESSURE BUILD-UP IN THE MAKE-UP TANK WITH THE VENT VALVE CLOSED. BY KNOWING THE MAKE-UP TANK PRESSURE WATER LEVEL AND PRESSURE AT THE BEGINNING AND END OF THE TEST AND THE LETDOWN FLOW, THE DISSOLVED GAS IN THE REACTOR COOLANT SYSTEM CAN BE ESTIMATED WITH AN ASSUMED GAS REMOVAL EFFICIENCY IN THE MAKE-UP TANK. BASED ON WHAT WE THINK THE DISSOLVED LEVELS IN THE RCS ARE NOW, THE REMOVAL EFFICIENCY SHOULD BE VERY CLOSE TO 100%.

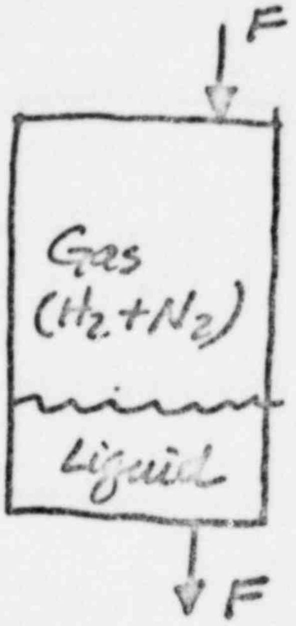
IF YOU HAVE ANY FURTHER QUESTIONS WITH RESPECT TO THE GAS BUBBLE TEST PLANNED PLEASE LET US KNOW.

WLE/sm

[illegible] Gas Problems [illegible] 4-4-79 ①

Feil, SVT

PROCEDURE FOR STEADY-STATE ANALYSIS OF PRCS H_2 CONCENTRATION



RC Makeup tank in steady-state gas stripping mode, no discharge to waste gas tank.

Let: n_ℓ = moles H_2 in liquid phase
n = total moles H_2 in tank
n_g = moles H_2 in gas phase

F = Total feed rate to and discharge rate from tank
C_ℓ = H_2 concentration in liquid phase
C_F = H_2 concentration in feed stream
P_{H_2} = H_2 partial pressure in gas phase
T = Tank fluid temperature (assume isothermal operation)

$$\frac{dn(t)}{dt} = FC_F - FC_\ell(t)$$

$$n_g(t) = \frac{P_{H_2}(t)\,V_g}{\quad}$$ V_g = gas space volume

[illegible]
4-4-79

$$C_e(t) = K\, P_{H_2}(t)$$

where K = equilibrium constant for H_2 (gas / liquid)

$$n_e = V_e C_e = V_e K P_{H_2}(t)$$

$$n(t) = V_e K P_{H_2}(t) + \frac{P_{H_2}(t) V_g}{RT}$$

$$n(t) = P_{H_2}(t)\left(K V_e + \frac{V_g}{RT}\right)$$

$$\frac{dn(t)}{dt} = \left(K V_e + \frac{V_g}{RT}\right)\frac{dP_{H_2}(t)}{dt}$$

$$\left(K V_e + \frac{V_g}{RT}\right)\frac{dP_{H_2}(t)}{dt} = F C_F - F K P_{H_2}(t)$$

$$\frac{dP_{H_2}(t)}{dt} = \frac{F C_F R T}{V_g + RTKV_e} - \frac{RTFK}{V_g + RTKV_e} P_{H_2}(t)$$

define

$$K_1 = \frac{F C_F R T}{V_g + RTKV_e} \qquad K_2 = +\frac{RTFK}{V_g + RTKV_e}$$

[illegible]
4-4-79

③

Thus

$$\frac{dP_{H_2}(t)}{dt} = K_1 \cancel{+} - K_2 P_{H_2}(t)$$

$$\frac{dP_{H_2}(t)}{dt} + K_2 P_{H_2}(t) = K_1$$

$$e^{K_2 t}\frac{dP_{H_2}(t)}{dt} + K_2 e^{K_2 t} P_{H_2}(t) = K_1 e^{K_2 t}$$

$$\frac{d\left\{P_{H_2}(t)\, e^{K_2 t}\right\}}{dt} = K_1 e^{K_2 t}$$

$$P_{H_2}(t)\, e^{K_2 t} = \frac{K_1}{K_2} e^{K_2 t} + C_1$$

$$P_{H_2}(t) = \frac{K_1}{K_2} + C_1 e^{-K_2 t} \quad \longleftarrow$$

$$P_{H_2}(t) = \frac{C_E}{K} + C_1 e^{-K_2 t}$$

[illegible] At start of operation, purge tank with nitrogen, thus $P_{H_2}(0) = 0$

[illegible]

[illegible] 4-4-79 ②

$$0 = \frac{C_F}{K} + C_1 \qquad C_1 = -\frac{C_F}{K}$$

$$P_{H_2}(t) = \frac{C_F}{K}\left(1 - e^{-K_2 t}\right) \quad \Longleftarrow$$

<u>OR</u>

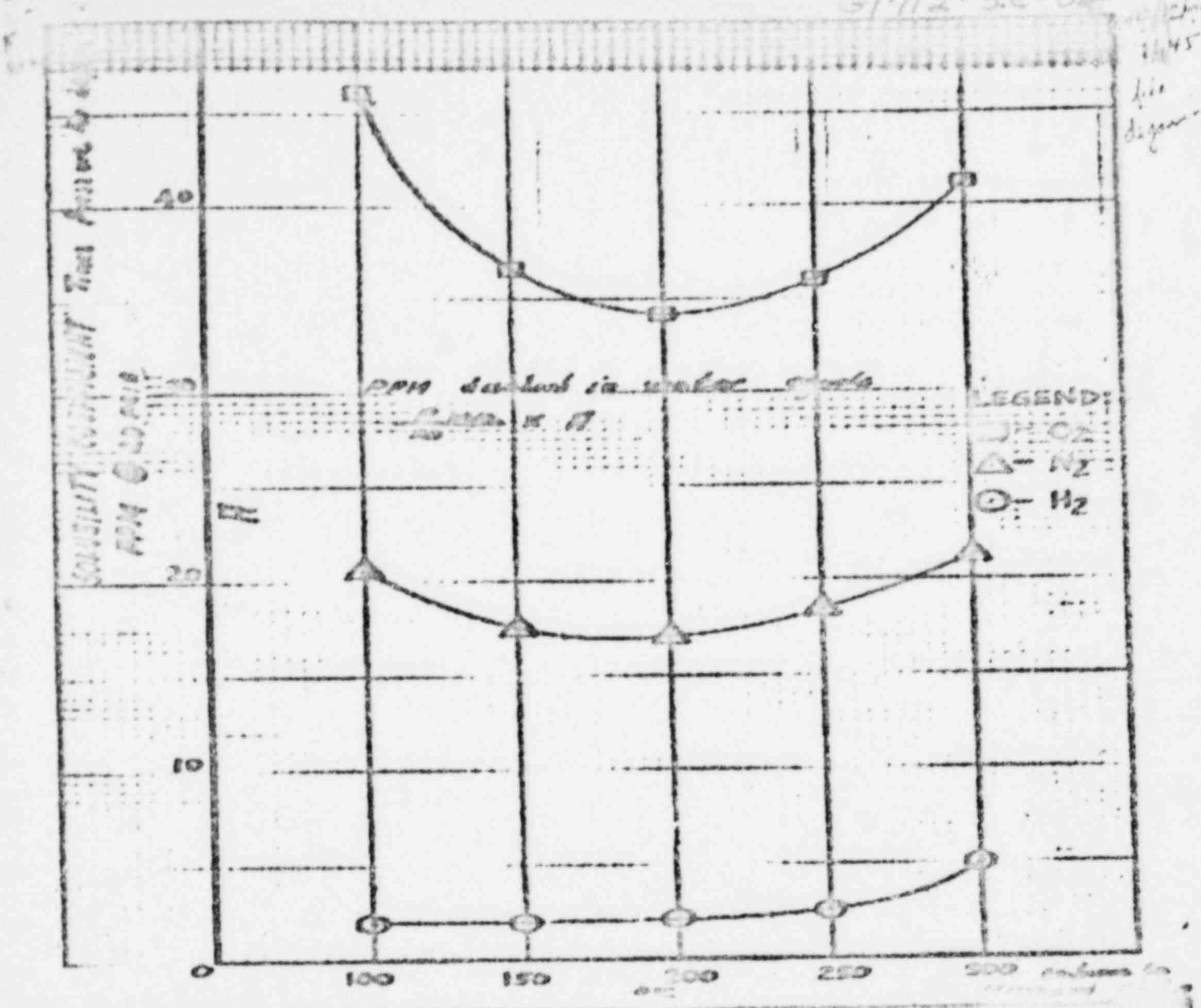
$$\boxed{C_F = \frac{K\, P_{H_2}(t)}{\left(1 - e^{-K_2 t}\right)}} \quad \Longleftarrow$$

Operate letdown system at steady state liquid flow through makeup tank; after pressure builds up, say to 15 psig, note time and tank pressure, temperature. Check tank for isothermal approximation.

$$P_{total} = P_{N_2} + P_{H_2}$$

$$P_{N_2} = \frac{n_{N_2} R T}{V_g} \quad \therefore \quad P_{H_2}(t) = P_{total}(t) - P_{N_2}(t)$$

G/712-3.e-32



1145
file
dizziness

$\frac{gm\ H_2}{136\ ft}$

6712

4/13 MEMOS

6/712-3.e-33

THREE MILE ISLAND BOILING MODE EVALUATION

- NON-CONDENSIBLE GAS EFFECTS ON BOILING MODE
- OTHER POTENTIAL PROBLEMS
- METHODS TO VERIFY EXISTENCE OF BOILING
- METHODS TO DETERMINE STATE OF SYSTEM
- CONTROL NEEDS AND METHODS WHILE IN BOILING MODE
- TRANSITION FROM FORCED CIRCULATION TO SINGLE PHASE NATURAL CIRCULATION
- REVIEW OF IAG DOCUMENT
- OPERATING PRESSURE CONSIDERATIONS

PRELIMINARY AND UNVERIFIED
NOT TO BE USED IN DESIGN

NON-CONDENSIBLE GAS EFFECTS ON BOILING MODE

The presence of significant quantities of non-condensible gas (presumably hydrogen) can significantly affect the boiling mode operation. The affects result primarily from a degradation of the condensation heat transfer coefficient in the primary side of the steam generator. The boiling in the core will strip some hydrogen out of solution and into the steam. The hydrogen will be transported with the steam to the steam generator (note that no separation of the hydrogen from the steam is expected until the steam condenses on the cooled tubes of the steam generator). As the steam is condensed, the hydrogen concentration will increase in the steam generator. The hydrogen causes a diffusion controlled limitation in the condensation process. The resulting lower heat transfer rate will cause more of the heat transfer surface to be exposed. For a given rate of hydrogen flow into the steam generator, a final condition can be achieved where the liquid level is low enough (i.e. sufficient condensing surface) to condense the total steam flow, and the hydrogen concentration is sufficient to drive the total hydrogen flow back into solution.

If the total hydrogen flow into the steam generator is steady, then the above condition would represent a stable operating mode for the system. However, if the hydrogen content of the system continuously increases, then the steam generator liquid level would continuously recede. A limit to this process would occur if a change in liquid level caused the system hydrogen content to stabilize. Such a change could result by uncovering the surge line, with subsequent venting of steam and hydrogen out of the pressurizer.

There are two possible sources of hydrogen generation in the system. The first, Zr-H_2O reaction, would imply localized high temperatures in the core. Such a source could be relatively continuous, and independent of the hydrogen concentration that exists. The second, radiolysis of H_2O, can be suppressed when the hydrogen concentration reaches a sufficient value. From this, there appear to be three possible operating modes that should be considered. One mode is with a continuous source of H_2. Another mode is with a continuous source of H_2 and a system bleed rate that will remove hydrogen to compensate for the source. The third mode is assuming no continuous source (i.e. radiolysis only). Expected operating characteristics for these three modes are indicated in the attached table and figures 1 and 2. Analyses requirements to define these modes are also attached.

PRELIMINARY AND UNVERIFIED
NOT TO BE USED IN DESIGN

WHAT MAY HAPPEN ASSOCIATED WITH NON-CONDENSIBLES

CONTINUOUS SOURCE OF H_2	CONTINUOUS SOURCE OF H_2 WITH SYSTEM BLEED	RADIOLYSIS ONLY
Continuous H_2 buildup	H_2 buildup to equilibrium level (dependent on bleed rate)	H_2 buildup to equilibrium level (sufficient to balance radiolysis)
Continuous degradation of heat transfer	Heat Transfer degradation to associated equilibrium level	Heat transfer degradation to associated equilibrium level
Reduction of level in S.G. and hot leg, with venting through pressurizer when surge line uncovers	Reduction of S.G. and hot leg levels, determined by heat transfer coefficient (expect above surge line)	Reduction of S.G and hot leg levels determined by heat transfer coefficient (expect above surge line)
Equilibrium H_2 level achieved due to pressurizer venting. Part of heat load out S.G. and remainder through vented steam.	Heat load out S.G.	Heat load out S.G.

PRELIMINARY AND UNVERIFIED
NOT TO BE USED IN DESIGN

WHAT SHOULD BE DONE TO EVALUATE PERFORMANCE WITH NON-CONDENSIBLES

I. Assume Continuous Source of H_2

- Calculate level in S.G. when surge line uncovers
- Estimate equilibrium H_2 concentration after pressurizer venting starts
- Estimate the associated H_2 concentration in the condensing loop of the S.G.
- Determine value of heat transfer coefficient associated with S.G. H_2 concentration
- Calculate heat load out of S.G.
- Calculate steam venting rate from pressurizer
- Calculate system pressure to achieve vent rate
- Re-estimate equilibrium H_2 concentration (iterate above)

II. Assume Continuous Source of H_2 with System Bleed

- Specify bleed flow rate
- Calculate H_2 concentration in bleed flow to compensate for H_2 source
- Estimate the associated H_2 concentration in the condensing loop of the S.G.
- Determine value of heat transfer coefficient associated with S.G. H_2 concentration
- Calculate expected mixture levels in S.G. and hot leg (for entire heat load out steam generator)
- Determine operating pressure required to achieve bleed rates

PRELIMINARY AND UNVERIFIED
NOT TO BE USED IN DESIGN

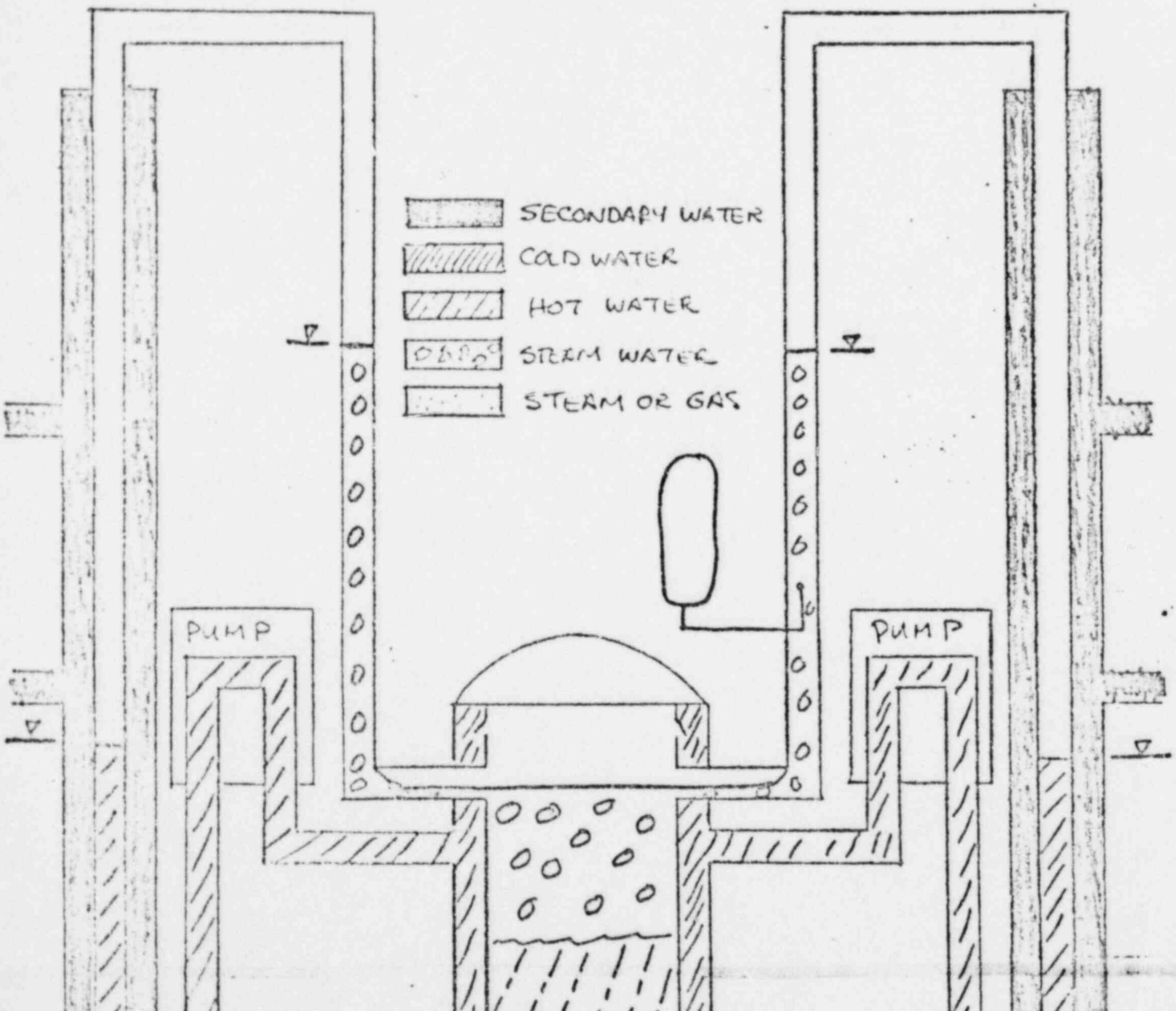
III. Assume Radiolysis is Only Source of H_2

- Determine equilibrium H_2 concentration to prevent radiolysis
- Estimate the associated H_2 concentration in the condensing loop of the S.G.
- Determine value of heat transfer coefficient associated with the S.G. H_2 concentration
- Calculate expected mixture levels in S.G. and hot leg (for entire heat load out steam generator).

PRELIMINARY AND UNVERIFIED
NOT TO BE USED IN DESIGN

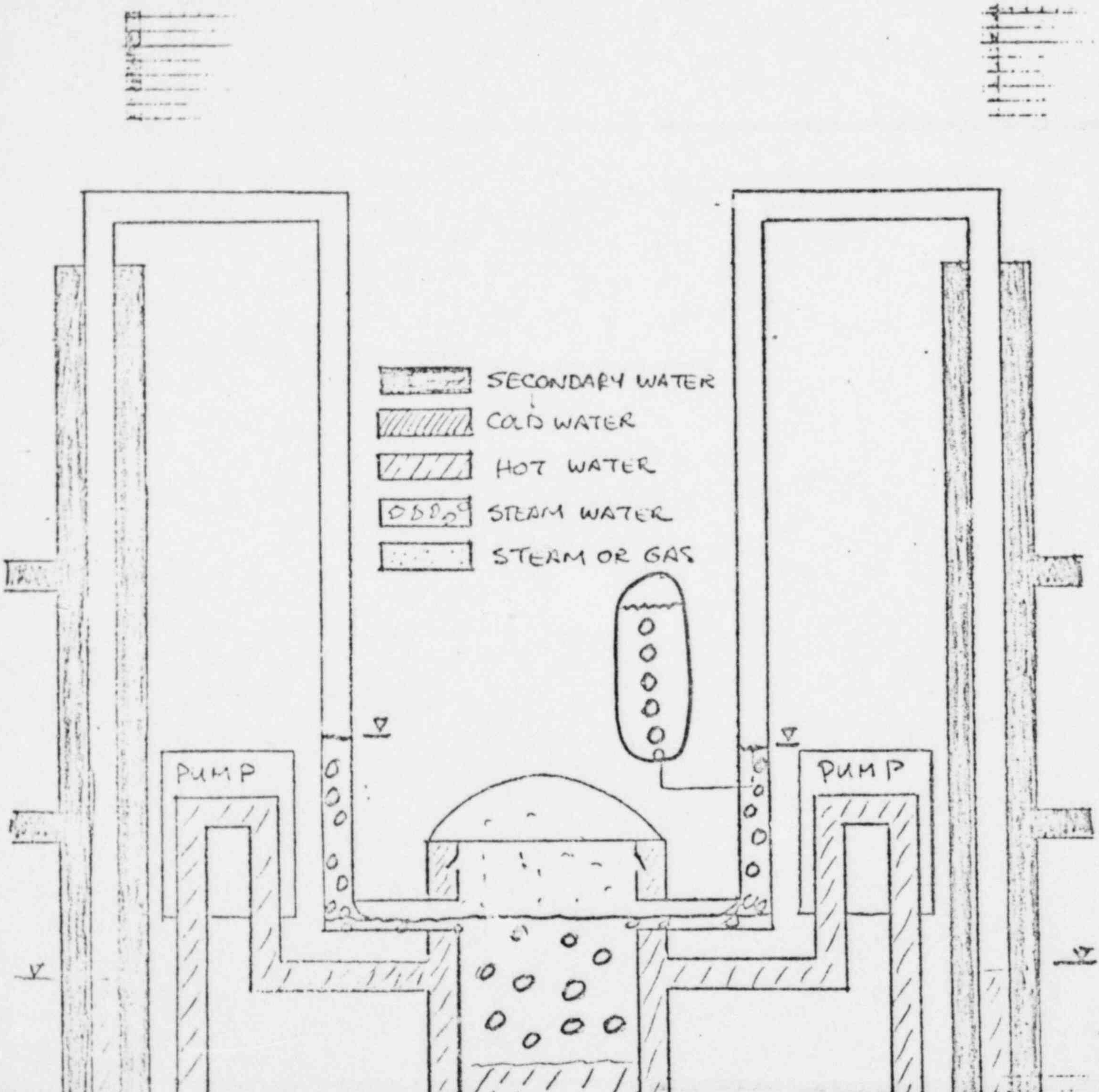
Figure 1. Final Mode With Stable* Quantity Non-condensible Gas

* Radiolysis only
or
Continuous source with Compensating Bleed



PRELIMINARY AND UNVERIFIED
NOT TO BE USED IN DESIGN

Figure 2. Final Mode - Noncondensible Gas Source
(Both Secondaries Assumed Solid)



PRELIMINARY AND UNVERIFIED
NOT TO BE USED IN DESIGN

OTHER POTENTIAL PROBLEMS

- LOSS OF STEAM GENERATOR FEEDWATER PUMP
- LOSS OF HEAT EXCHANGER
- LOSS OF PRIMARY FEEDWATER PUMP
- STUCK OPEN RELIEF VALVE
- FURTHER CORE DAMAGE - DUE TO PRESSURE OSCILLATION
- CAN VENTING KEEP UP WITH STEAMING?
- CONDENSATION SHOCKS/WATERHAMMER
- CONDENSATION (INSTABILITIES)
- VENT VALVE INTERACTION
- INADVERTENT CHANGE IN S.G. COOLANT FLOW TO SECONDARY SIDE
- CORE HEAT TRANSFER - LOCAL LARGE BUBBLES BELOW BLOCKAGE

---

* MUST BE RE-EVALUATED AFTER SYSTEM ANALYSES COMPLETED.

PRELIMINARY AND UNVERIFIED
NOT TO BE USED IN DESIGN

METHODS TO VERIFY EXISTANCE OF BOILING

- T.C.'S TOP OF CORE → T_{sat} (P)
- DECREASED NATURAL CIRCULATION FLOW DETECTED IN HOT LEGS FLOW INSTRUMENTS (DEPENDS ON FLOWMETER RANGE)
- SYSTEM PRESSURE INCREASES OR PRESSURIZER LEVEL CHANGES
- DECREASE IN TEMPERATURE RISE ACROSS S.G. (SECONDARY SIDE)

METHOD TO DETERMINE STATE OF SYSTEM

- ULTRASONIC DETECTOR
- INTEGRATE BLEED OUT FLOW
- FEED FLOW
- DECREASE IN TEMPERATURE RISE ACROSS S.G. (SECONDARY SIDE)
- DECREASE IN NATURAL CIRCULATION FLOW DETECTED IN HOT LEGS FLOW INSTRUMENTATION

CONTROL NEEDS & METHODS WHILE IN BOILING MODE

- BLEED AND FEED SYSTEMS
- FEEDWATER HEAT ECHANGE AND FLOW CONTROL
- PRESSURIZER (MAINTAIN VAPOR BUBBLE)

TRANSITION FROM FORCED CIRCULATION TO SINGLE PHASE NATURAL CIRCULATION

EXPECTED PERFORMANCE

- HOT LEG TEMPERATURE SHOULD HEATUP TO NEAR STEADY TEMPERATURE IN A FEW HOURS

DEVIATION LIMITS

- CORE TEMPERATURE RISE AT HOT LEG,

  $\Delta T / \Delta t > 0.1\ {}^{o}F/sec$

- PRESSURIZER WATER LEVEL SHOULD NOT CHANGE--AN INCREASE IMPLIES BULK BOILING IN CORE
- NOT STEADY SYSTEM PRESSURE
- IN-CORE T.C.'s $> T_{sat} (P_{sys})$

PRELIMINARY AND UNVERIFIED
NOT TO BE USED IN DESIGN

REVIEW OF IAG DOCUMENT

"Behavior of RCS with Steam Generators in Condensing Mode", 4/10/79.

Document recommends system to operate in boiling mode at atmospheric pressure. Several problems exist with such low pressure operation, as identified on attached, "Operating Pressure Considerations". The scenario suggested to occur with non-condensible gas identifies separation of the hydrogen and formation of a bubble at the top of the hot leg. Such separation of hydrogen and steam is unlikely (the expected phenomena are discussed elsewhere). The suggestion that hydrogen concentration in S.G. would approach 100% is unlikely due to it going into solution in the water on the condensing tubes. Postulated level reduction and venting through the pressurizer is possible if a continuous hydrogen source exists in the system. However, even for that case, the steam generator should have some effectiveness to handle part of the heat load.

Task VII
G/712-3.e-34

cc DRW/FDJ
GE Dix
M Siegler

TO: EP Stroupe
FROM: PW Marriott

SUBJECT: Review of IAG Task 12a Close Out Document, "Evaluate the Effect of Non-Condensibles in the REFLUX Boiling Mode".

REFERENCE: Three Mile Island Boiling Mode Evaluation: Non-Condensible Gas Effects on Boiling Mode, General Electric Review 4/13/79.

The subject document departs somewhat from the previous IAG boiling mode description, but still centers upon the possibility of a non-condensible gas bubble forming in the "candycane" of the TMI plant under boiling mode operation. It is felt that such a bubble is extremely unlikely. The most likely operation mode has previously been defined (cf. Reference).

The formation of a gas bubble could occur in the single phase natural circulation mode due to gas coming out of solution as the pressure is reduced. Such a bubble could fill the candycane and stop the circulation. However, the significantly increased driving potential that would result from subsequent boiling should carry such a bubble into the steam generator and provide thorough mixing with the steam. Thereafter, the non-condensible gas would move with steam flow and by diffusion while remaining well mixed with steam. Hence, the conclusion that a gas bubble with boiling mode is unlikely. If a gas bubble is assumed to occur in the candycane during the boiling mode, it would subsequently be eliminated. Steam generated by the boiling would rise through the candycane and increase the gas bubble size by mixing with the non-condensibles, and thus lowering the liquid level in the steam generator. The liquid level would continue to drop. Eventually, a portion of the tube surface would become exposed and steam condensation would occur. With the on-set of condensation, non-condensible gas would be absorbed in the liquid film. As more tube surface became exposed, more condensation and absorption would occur. With time, the non-condensible gas bubble would diminish in size and be eliminated.

The recommended actions of the subject document are appropriate in any case, except for the recommended scaled test on breaking the "gas seal", which may not be necessary as discussed above. However, a representative test of condensation effectiveness in a B&W steam generator geometry with non-condensible gas would be beneficial to define the expected liquid levels that would result in the TMI system.

Another possible concern is the system response in the boiling mode if the pressurizer relief valve control is lost with the valve closed. This could result in high pressures to relieve the vaporization volume changes. This raises associated ductility concerns.

TMI-2 OPERATIONS

310 4-14-79 1302 19/of 6

G/712-3.e-35

TRANSMITTAL TO: Attn: Tom Crimmins

☒ L. ROGERS TRANSMITTAL # 766

ALSO TELECOPY TO: ☒ R. WILSON TRANSMITTAL # W737

☐ B&W TRAILER 26 TRANSMITTAL # ______

TIME 12:30 DATE 4/14/79

SUBJECT Gas Solubility Curves

APPROVED BY ______ OPERATIONS MANAGER B&W ACTION # 264

Pg 2 of 6

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

RESPONSE TO INSTRUCTIO
#264

805 663

To
ENGINEERING OPERATIONS MANAGER

From
J. D. CARLTON JDCarlton

Cust.

File No.
or Ref.

Subj.
GAS SOLUBILITY CURVES (RESPONSE TO INSTRUCTION #264)

Date
APRIL 14, 1979 - 12:07 P

This letter to cover one customer and one subject only.

ATTACHED ARE SOLUBILITY CURVES FOR O_2, H_2, He. AND N_2 IN WATER.

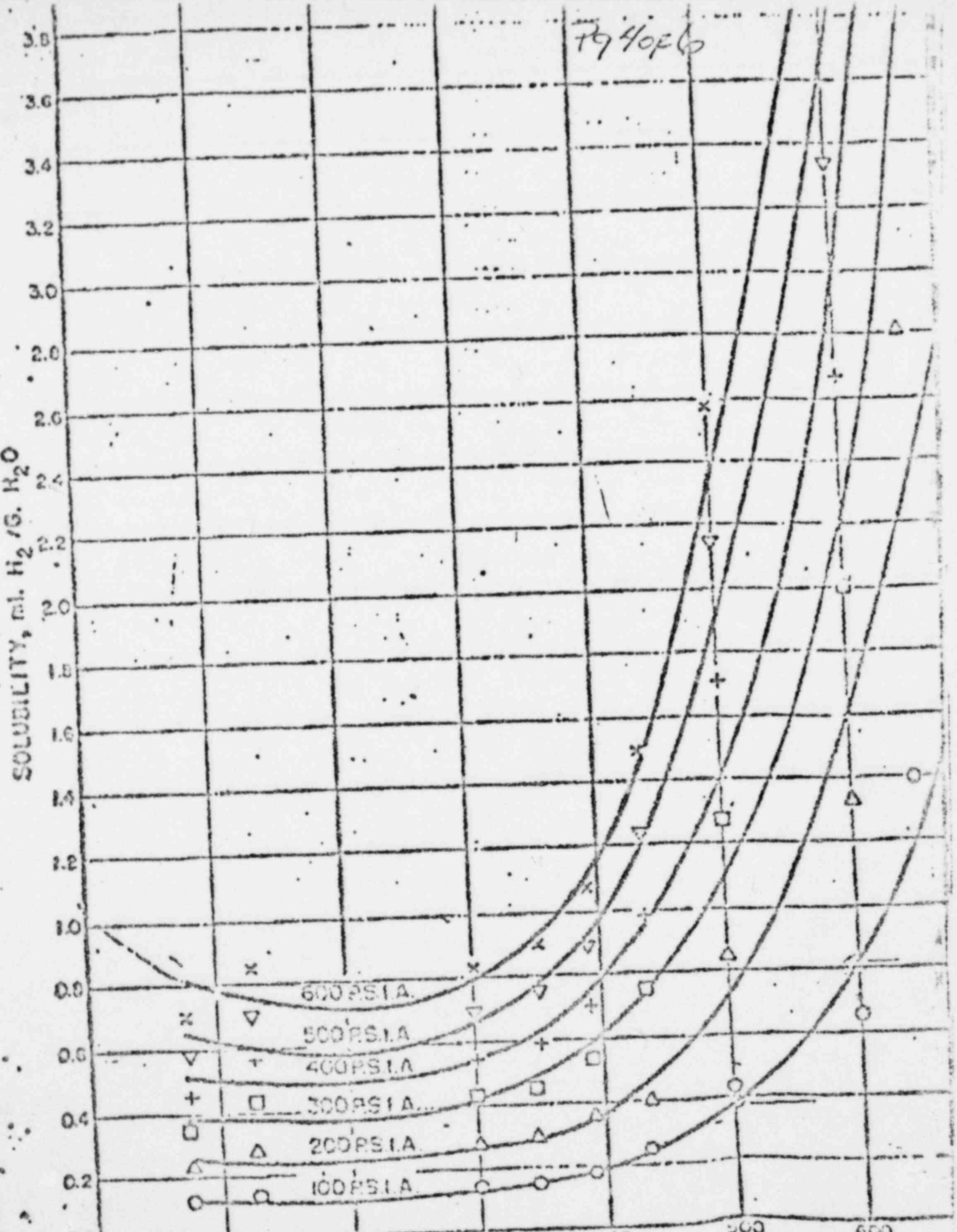
THIS INFORMATION SHOULD BE FORWARDED TO THE SITE AND TO THE ATTENTION OF TOM CRIMMINS.

JDC/fcb
ATTACHMENTS
CC: E. A. WOMACK
B. A. KARRASCH
J. H. HICKS
C. C. ENGLAND

Pg 3 of 6

FIGURE 4. SOLUBILITY OF OXYGEN IN WATER

Pg 4 of 6



SOLUBILITY, ml. H_2/G. H_2O
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
TEMPERATURE, °F.
600 P.S.I.A.
500 P.S.I.A.
400 P.S.I.A.
300 P.S.I.A.
200 P.S.I.A.
100 P.S.I.A.

Pg 5 of 6

FIGURE 10. SOLUBILITY OF HELIUM IN WATER

0-15

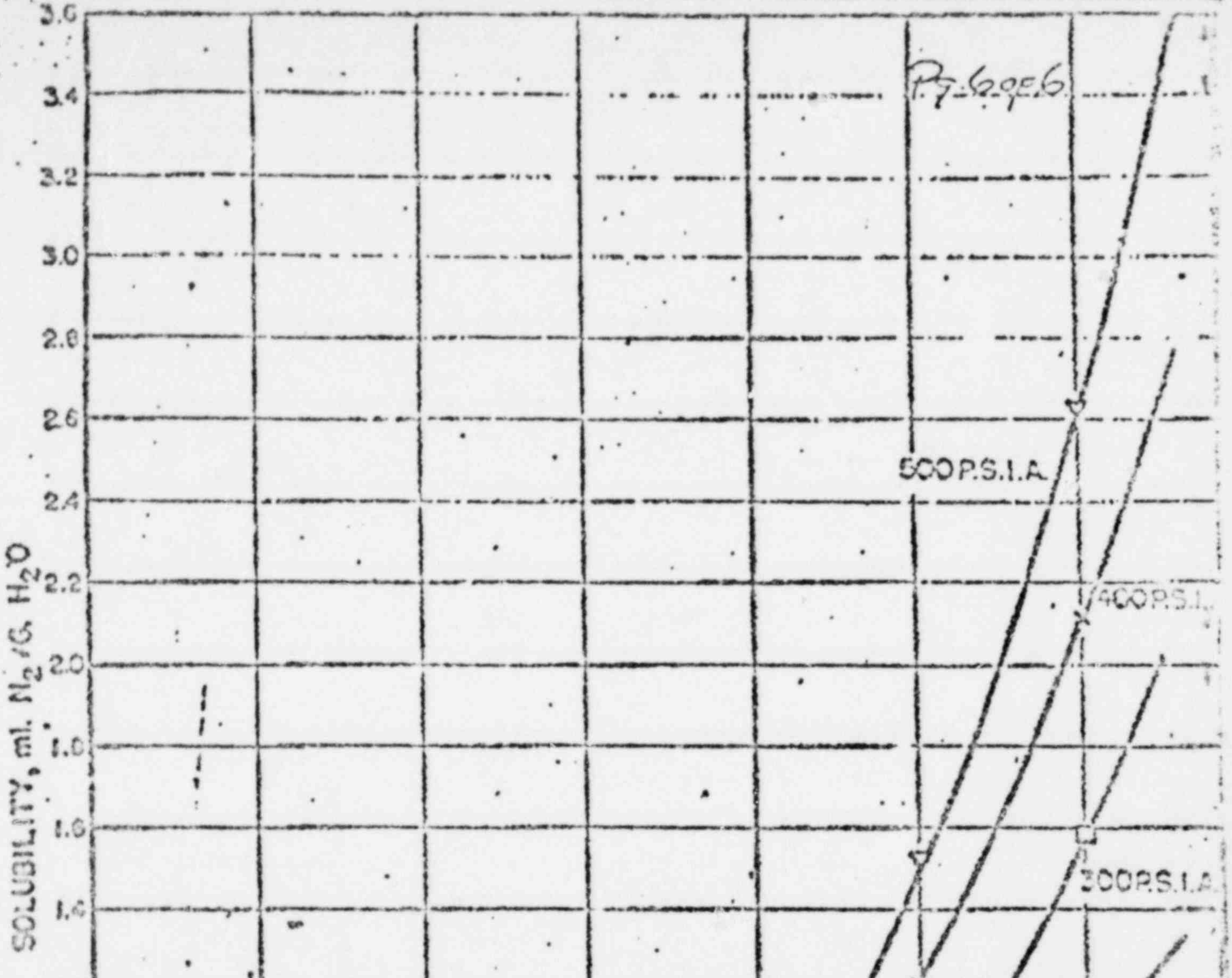


FIGURE 13. SOLUBILITY OF NITROGEN IN WATER

G/712-3.e-36

GE Conversation 9/14/79
RELAP IV - can handle noncondensables

(1) Refer to Fig 24 in GE transmittal
(a) Calculate Relap/Retran for confirm Figure in page 24 - steady state
(b) start out in 1 phase natural circulation - run thru the transient into boiling

major concern - sensitivity to large amount of surface area in the S.Generators - collapse of bubble, oscillation flashing

to reduce sensitivity - heat up secondary side and become much less sensitive. May be hard since 1 phase requires cold secondary

(2) Surging/oscillations can be driven by steam generator alone
set up steady state - perturb S.G. heat.
bleed primary - raise secondary temperature, noncondensable may help to stabilize surges

Run Primary System at 1000 psi - looks good most stable
important in boiler - change volume δV
change in enthalpy δh

S.F

non condensable gas -
may help to stabilize oscillation - solution of H_2 into water, - diffusion to surface, etc complicated

Can we bound min/max term or heat transfer coefficient

Source of H_2 — $Zr + H_2O \rightarrow H_2 + \ldots$ starts to be significant at ~800°F, will be some at very low temperatures

is source of H_2 — stay at high temperatures, if we use H_2
if ~65 ml/kg_{H_2O} ≈ 2 atmospheres ~400-500 ft^3 H_2 total
at STP

biggest problem is inventory control - ie level in SG.

Experiment at Alliance - set up whole boiling experiment

Probably don't have to worry about bubble collapse as it affects piping loads

6/712-3.e-37

Degas

WHAT IS COMPOSITION OF MAKEUP TANK VAPR SPACE

(re Venting to Containment or [illegible] [illegible]) ①

V = [illegible] Total pressure is 13 psig = 28 psia

V/H = [illegible] [illegible] = 60.6" = 1371 gal

H = [illegible] Gas Vol = 4500-1371 = 2629 gal

[from Plant Status [illegible]] [illegible] 101 °F

Assume [illegible] [illegible] [illegible] [illegible] [illegible] Atmosphere; And amount And is in equilibrium with [illegible] [illegible] in Vapor space in [illegible] proportion to relative Solubility

(PRIMARY GAS [illegible] per [illegible]3) (SOLUBILITIES PER [illegible]4)

$\frac{[illegible]}{31.5\,MT}$ = .025 [illegible]	(cc/kg H₂O)	[illegible]	[illegible]	% [illegible]
H_2 as .015	22.4	70.6/22.4	.047	1.13
N_2 as .894	16.	70.6/16	3.94	94.7
O_2 as .081	32.2	70.6/32.2	.19	4.3
[illegible] Ar .01	—	—	4.16	100.1
1.00	70.6			

$$2629\ gal \times \frac{ft^3}{7.46\ gal} \times .0113\ \frac{ft^3\ O_2}{ft^3} \times \frac{29\ psia}{15\ psia} = 7.7\ SCF\ O_2\ at\ [illegible]$$

$$\frac{1730\ ft^3}{[illegible]} \times \frac{31\ psig\ \text{in waste TK}}{15\ psig}\ ([illegible]) = 3989\ SCF\ at\ [illegible]$$

[illegible] O_2 in waste gas tank [illegible] [illegible] [illegible]

[illegible] [illegible] = 7.7 × $\frac{15}{21}$ = 4.0 "SCF" of O_2

$$\frac{4.0\ SCF\ O_2 \times 100\%}{[illegible]} = 0.1\%\ O_2$$

Limiting Case: All [illegible] [illegible] Vol as O_2

$$2629\ [illegible] \times \frac{[illegible]}{[illegible]} \times \frac{29}{15\ [illegible]} = 680\ SCF\ O_2$$

$$\frac{680\ SCF\ O_2}{[illegible]} = 7.8\%\ O_2$$

If N₂ the Atmosphere [illegible] % will be
78 % × [illegible] = ~1.4 %

ΔP if tank level begins at 52" @ 10 psig
liq Space = 60.6' × 30.97 = 1870
52 × 30.97 = 1605
265 gal

Gas Space 4500 − 1870 = 2630
4500 − 1605 = 2895
265 gal

$\frac{2630}{2895}$ × 28 psia = 25.4 psia = 10.7 psig.

Preliminary Data on Pressurizer Sample

Cover Gas analyzed as follows:

③

Argon - 71.8%
~~He~~ N_2 - 20.8%
O_2 7.3%
CO_2 0.07%

Gas Sample - 0.8 cc (STP); Liquid volume 31.5 ml

H_2 - 1.5%
He - < 0.01%
N_2 - 89.4%
O_2 - 8.1%
Argon - 1%

Calc (25 Kg)
25 cc/Kg

What were the extraction conditions

NRC 4/15/79
R. Mattson
J. Murphy

$\frac{.8\,cc}{31.5\,g} \times \frac{[illegible]}{Kg} = 25.4\,cc [illegible] = .0254 \frac{cc\ STP}{gm\ (or\ cc)}$

Approx. 350 mrem [illegible]
20 mrem [illegible]

$\frac{.025\,cc\ STP}{gm\ H_2O} \times \frac{[illegible]}{[illegible]} \times \frac{[illegible]\ gm\ H_2O}{ft^3\ H_2O} \times \frac{12,000\ ft^3}{prim\ syst} = 300\ ft^3$

$C = $ [illegible]

$m^3 = 10^6 cc$

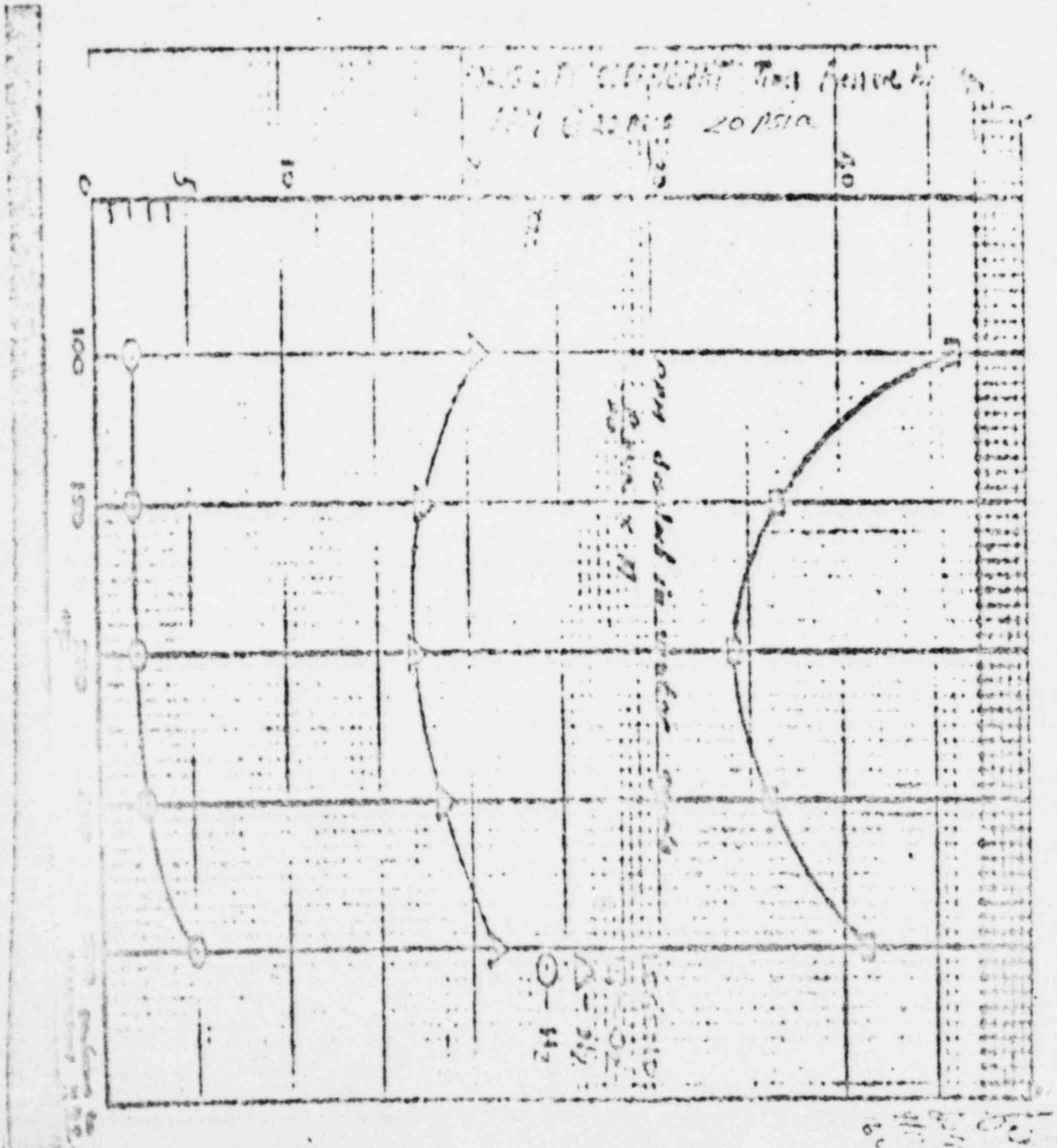
④

$1 ppm^{H_2} = \frac{1 gm H_2}{1000 kg H_2O} \times \frac{22,400 cc H_2 STP}{2 gm H_2} = \frac{11.2 cc H_2}{Kg H_2O}$

$1 ppm O_2 = \frac{1 gm O_2}{1000 kg H_2O} \times \frac{22,400 cc O_2 STP}{32 gm O_2} = \frac{0.7 cc O_2}{Kg H_2O}$

$1 ppm H_2 = \frac{1 gm H_2}{1000 kg H_2O} \times \frac{22,400 cc H_2 STP}{28 gm H_2} = \frac{.8 cc N_2}{Kg H_2O}$

From Dave Pollen
4/16/79



G/712-3e-38

MICROFILM

DOCUMENT INDEX TARGET

DESCRIPTION

GPU SITE TECH SUPPOR
T COMPLETED TASKS
(55 spaces maximum)

DATE

(12 spaces maximum)

DESCRIPTION CONTINUATION

FILE NUMBER

(20 spaces maximum)

NOTE: Maximum spaces include all punctuation marks, dashes and spaces between words.

Description continuation should only be used when abbreviations are not appropriate.

REEL NO. ______ BLIP NO. ______

Hand Mail, Mr.

APR 17 1979
10:00

Memo No. [illegible]

[illegible]

APR 17 1979
10:00

Memo No. [illegible]
R Wilson

TASK CLOSE OUT DOCUMENT

Task Scope Review of Sandia/NRC Emergency Containment Vent Design Package

To: M. Levenson
S. Levy
E. Zebroski

Task No. ______ Date Complete 4-16-79

Reason felt task is complete:

Review complete, to the extent consistent with lack of design detail. Comments attached.

Members of Committee

James W. Thiesing

James W. Thiesing
Signed
Committee Leader

To: Milt Levenson

Date: April 16, 1979

Subject: Emergency Containment
Venting Package

From: J. W. Thiesing

Comments on emergency containment venting package received from Sandia/NRC follow:

(1) Page 1 - 10^6 Ci I release represents about 10% of current total activity of I-131 (core & RCS) seems reasonable - given core melt (no containment or vessel cooling) and containment failure above grade.

(2) Page 2 - "Steam-condense" and "Steam-no condense" labels appear to be interchanged.

(3) Page 3 - Containment pressure -
Spike up to 70 psig at 374 hours is too fast. Would expect only about a 12 psig per hour (superheat from core heat) at today's decay heat level. I do not understand rapid drop in containment pressure after vessel failure (no cooling of containment was assumed). Pressure would remain constant at 70 psig until debris heated water pool in containment and began steaming. End result is the same, however, failure above grade.

(4) Page 4 - Appears to postulate 2.% Core I-131 becomes airborne.

(5) Page 5 - System Design

1. All air handling systems should be designed for 150 psig if maximum utility is to be gained (150 is probable containment failure pressure).

2. What is purpose of N_2 system - I presume it is inerting for H_2 but the utility of this is questionable. (Prevent H_2 burn in exhaust line, I suppose).

3. 3×10^6 Btu/hr cooling on diffuser tanks will not keep up with decay heat until about July 1, 1979.

4. Why install return line to containment. The presumption of containment overpressure mitigates against its use except as a routine cleanup tool! If there is urgency to install this system, it can probably not be well-enough thought out to serve as the ultimate clean up mechanism.

5. Diffuser tanks should be buried in yard outside aux building. Line from containment to diffuser tanks should also be buried. Cooling system must also be shielded.

6. Need valves in filter bypass.

(6) Page 6 - Options

1. Backup filters (Option 2) will require demisters, and perhaps coolers and could defeat system by becoming clogged - Recomment HEPA only, with bypass capability.

2. Option #3 - There is not a recombiner in the world that will handle the flow rates that will be required.

3. Option #1 - Should not put tanks in fuel pool - it's being used for tank farm. Also, violates last constraint on page 7.

4. Option #6 - What is a "Hydrogen combustion mechanism."

G/712-3.e-39

[illegible] CO.
[illegible] GEN. GROUP
TMI-2 OPERATIONS

D-500 [illegible]

FOR JH [illegible]

TRANSMITTAL TO:
☐ L. ROGERS TRANSMITTAL # ______
ALSO TELECOPY TO: ☐ R. WILSON TRANSMITTAL # [illegible]
☐ B&W TRAILER 25 TRANSMITTAL # [illegible]

TIME 14:02 DATE [illegible]

SUBJECT Gas Production from Hydrazine Addition to RCS

APPROVED BY [illegible] B&W ACTION # ______

1555 [illegible]

CC: R. C. ARNOLD
R. F. WILSON
R. W. KEATEN
T. M. CRIMMINS
J. DANIELS
J. G. HERBEIN
D. MONTGOMERY
ADM. ASST. GPU ON SITE
TECH SUPPORT
DATA REDUCTION & MGMT
STAUDT/FILE (ORIGINAL)

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

To	D. M. BERGER	CC:	[illegible] JIM VEENSTRA, TMI SITE
From	P. L. DOSS		BOS 683-8
Cust.		File No. or Ref.	
Subj.	GAS PRODUCTION FROM HYDRAZINE ADDITION TO RCS	Date	APRIL 10, 1979-2:00 PM

This letter to cover one customer and one subject only.

A CALCULATION WAS PERFORMED TO DETERMINE THE TOTAL AMOUNT OF GAS (N_2 & H_2) PRODUCED FROM A POSTULATED ADDITION OF 25 LITERS OF 30 WT % HYDRAZINE TO THE REACTOR COOLANT SYSTEM. ASSUMING COMPLETE DECOMPOSITION OF THE HYDRAZINE AND NO OXYGEN SCAVENGING, THE MAXIMUM GAS PRODUCTION WAS CALCULATED TO BE 56 cc/kgm. CONSIDERING THE SCAVENGING OF 1.8 cc/kgm O_2 (LAB SAMPLE AT 2140 HOURS ON 4/10/79), THE TOTAL GAS CONCENTRATION WOULD INCREASE BY 51 cc/kgm.

AT APPROXIMATELY 1300 HOURS TODAY, TMI PERSONNEL MADE A HYDRAZINE ADDITION TO THE REACTOR COOLANT SYSTEM OF 7.5 LITERS OF 35 WT % HYDRAZINE SOLUTION. THIS CHEMICAL ADDITION WAS VERIFIED DURING A TELEPHONE CONVERSATION WITH JIM VEENSTRA IN THE CONTROL ROOM TO ENSURE THAT THE TOTAL GAS PRODUCED IN THE RCS WOULD BE LESS THAN 30 cc/kgm. THE CALCULATED TOTAL GAS PRODUCED WOULD INCREASE BY 14 cc/kgm BASED ON SCAVENGING THE 1.8 cc/kgm OXYGEN. THE MAXIMUM TOTAL GAS CONCENTRATION WOULD HAVE INCREASED BY ONLY 19.6 cc/kgm ASSUMING NO SCAVENGING AND COMPLETE DECOMPOSITION.

FUTURE ADDITIONS OF HYDRAZINE WILL BE BASED UPON THE OXYGEN GAS ANALYSIS OF PRESSURIZED REACTOR COOLANT SAMPLES TO BE TAKEN PERIODICALLY. BATCH HYDRAZINE ADDITIONS OF 25 LITERS OR LESS ARE ACCEPTABLE.

P. L. DOSS
P.L.D

PLD/jmc

G/712-3.e-40

ME(2)
4/12/79
[illegible]

B&W Sample results (Sample of 4/13/79)

$\frac{31.2\ cc\ H_2}{Kg}$

$\frac{4.9\ cc}{Kg}\ O_2$

$\frac{32.3\ cc}{Kg}\ N_2$

$\overline{68.4\ cc/Kg} = .0684\ cc/gm$

$H_2\ (Vol\ \%) = \frac{31.2\ cc}{68.4\ cc} = 45.6\%$

$O_2 = \frac{4.4\ cc}{68.4\ cc} = 6.4\%$

$N_2 = \frac{32.3\ cc}{68.4\ cc} = \underline{47.8}$

99.8 %

Cover Gas in MU TK could be as follows if in equilibrium at 100°F & 13 psig with primary water for

	Relative liq conc.	Relative solubility	Relative release to gas phase	Relative gas in gas phase	
H_2	.456	22.4	70.6/22.4	1.44	39.0
N_2	.478	16	70.6/16	2.11	57.2
O_2	.064	32.2	70.6/32.2	.14	3.8
		70.6		3.69	100.0

So mixture in MU TK vapor space is not explosive

Babcock & Wilcox

ME (2)
4/17/79: 1315 hrs
[illegible]

[illegible] Mc Cracken

303 [illegible] 1711
= Ext [illegible]

How much of which gas will be left at Steady State Conditions

Condition 1.

Primary liquid T = 215°F
p = 245 psig
Makeup liquid T = 90°F ?
P = 0 psig
gas = Air Saturated
Liquid in [illegible] make up tk
T = 100°F
p = 0 psig

Dissolved gas in primary is
31.2 cc H_2 STP
9.4 cc O_2 "
32.8 cc H_2 "
per kg

Condition 2.

Condition 2
Primary

Gordon Bird
-returning your call

See next pg

Dave Morgan 2093
Connie McCracken
203-688-1911

Via
Mr. Hall
X 4134

ME(2)
4/17/75 1350 hrs
ur.

What dissolved gas will be in Primary liquid at Steady State for following Conditions. Asked

	Condition 1	Condition 2	Condition 3
Primary liquid			
T (°F)	235	160°F	160°F
P psig	850	830	0
Dissolved gas	4/15/79 ([illegible])		
H_2 (cc STP/kg H_2O)	31.2	—	—
O_2 "	4.4	—	—
N_2 "	32.8	—	—
Other "	—	—	—
Radiolysis ($H_2O + \gamma \rightarrow H_2 + O_2$)	?	?	?
Oxidation ($Zr + 2H_2O \rightarrow 2H_2 + ZrO_2$)	?	?	?
Volume (gal)	85,000	85,000	95000
Activity (Ci/cc)	1.0	1.0	
Recycle liquid (From Make up Tk Spray)			
Make up Tk Cover gas	N_2	H_2	
T_1 (°F)	91	91	91
P_1 (psig)	0	0	0
Flow in (gpm)	20	20	20
Vol (gal)	3500	3500	3500
ΔVol (gal/hr)	30.87	30.87	30.87
Make up T (°F)	70	70	70
P (psig)	0	0	0
Dissolved gas	Aerated	deaerated	deaerated
Make up rate (gpm)	2.5	2.5	2.5
Vent [illegible] ([illegible])	2.5	2.5	2.5

ME2

4/17/79 1230 hr
WR

CAN PRIMARY BE DEPRESSURIZED NOW
(ie 850 psig; 250°F → 0 psig; 100°F)

Calculation of Candy Canes

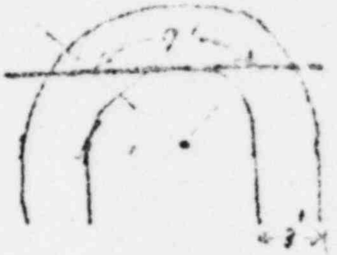
Vol – 9' length of 36" I.D. pipe

$V = \frac{\pi D^2}{4} H$

$H = 9'$

$D = 3'$

$V = \frac{\pi 3^2}{4} \times 9' = 63 ft^3$



Dissolved gas in primary loop @ 250°F + 850 psig.

as measured. = $\frac{63.4\ cc\ STP}{Kg\ sample}$

$\frac{(8.5\times10^4)(3.785\times10^3)(63.4)}{(10^3)(2.83\times10^4)}$

$\frac{85000\ gal}{primary\ system} \times \frac{3785.4\ cc}{gal} \times \frac{63.4\ cc\ STP}{1000\ gm} \times \frac{1\ gm}{cc} \times \frac{ft^3}{28{,}320\ cc}$

= 778

Equilib dissolved gas at MoTK conditions of 15 psia + 100°F: is 22.4 cc H_2/Kg H_2O or 16 cc N_2/Kg of H_2O: Assume it is H_2

$\frac{85000\ gal}{prim\ syst} \times \frac{3785.4\ cc}{gal} \times \frac{22.4\ cc\ STP}{1000\ gm} \times \frac{1\ gm}{cc} \times \frac{ft^3}{28{,}320\ cc} = 255\ ft^3$

Δ = 778 − 255 = 523 ft³ would be evolved going from measured conditions @ 850 psig + 250°F → 0 psig + 100°F.

1) CONCLUSION: DONT DEPRESSURIZE or will bind candy canes and defeat circulation especially Natural Circ.

CAUTION: conclusion based on only one sample meas of gas in primary.

2) CONCLUSION: Must strip down to ~ 20 cc (STP) of dissolved gas in primary before depressurizing.

Note: CE (Connie McCracken) has been asked to check conclusion + estimate rate of degassing.

[illegible] Klemen [illegible]
Connie McCracken   Via Mr. Hall
203-688-1911   X 4134

[illegible]
5/3/79 1350 hrs
WR

What dissolved gas will be in primary liquid at steady state for following conditions

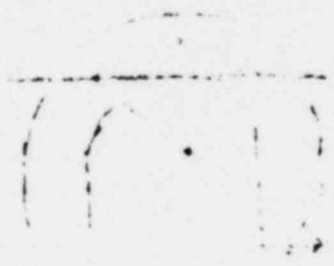
	Condition 1	Condition 2	Condition 3
Primary liquid			
T (°F)	225	160°F	130°F
P (psig)	850	950	0
Dissolved gas	[illegible] ([illegible])		
H_2 (cc STP/kg H_2O)	31.2	–	–
O_2 "	[illegible]	–	
N_2 "	32.0	–	
Other "	—	—	
Radiolysis ($2H_2O \to 2H_2 + O_2$)	?	?	?
Oxidation ($Zr + 2H_2O \to 2H_2 + ZrO_2$)	?	?	?
Volume (gal)	85,000	85,000	95,000
Activity (Ci/cc)	1.0	1.0	
Recycle liquid ([illegible])			
[illegible] Cover gas	N_2 H_2		
T_1 (°F)	91	91	91
P_1 (psig)	0	0	0
Flow in (gpm)	20	20	20
Vol (gal)	3500	3500	3500
ΔVol (gal/hr)	30.81	30.87	30.77
Makeup T (°F)	70	70	70
P (psig)	0	0	0
Dissolved gas	Aerated	deaerated	deaerated
Makeup rate (gpm)	2.5	2.5	2.5
Vent [illegible] ([illegible])	2.5	2.5	2.5

4/17/79 1123 hrs
162

(H2 release on depressurization
(fr 650 psig, 280°F → 0 psig, 100°F)

[illegible]

[illegible]



[illegible]

[illegible] = [illegible]

= 770

Equilibrium [illegible] at conditions of 15 psia + 100°F
is 22.4 cc H2/kg H2O or 16 cc H2/kg H2O [illegible] H2.

$\frac{250 \ldots}{\ldots} \times \ldots \times \frac{\ldots}{cc} \times \frac{ft^3}{28{,}310\,cc} = 255\ ft^3$

Δ = 770 − 255 = 515 ft³ released to coolant going from
pressurized conditions (@ 650 psig + 280°F → 0 psig + 100°F

1) CONCLUSION: DON'T DEPRESSURIZE at this time
[illegible] and continue circulation
especially through core,
CAUTION: [illegible] only one source means of [illegible]
in [illegible].

2) CONCLUSION: MUST Stay above ~ 20 cc(STP)
[illegible] before depressurizing,
Note: CE (Combustion Eng) has been asked to
[illegible].

Inter-Office Memorandum

GPU Service

Date April 18, 1979
TSG-057

Subject Primary System Dissolved Gases
(Degas File)

To R. F. Wilson

Location Three Mile Island

I asked Conrad McCracken to estimate the equilibrium dissolved gases in primary liquid for the three conditions shown on the attached. The request was made the afternoon of April 17, 1979.

I also asked him to think about how long it might take to go from Condition 1 to equilibrium in Condition 2 and in Condition 3 assuming a step change from Condition 1 to Condition 2 and from Condition 2 to Condition 3.

W. W. Lowe

WWL/al
ATT

cc: T. M. Crimmins
Staudt/File

6/712.3.c-42

(F) DEGAS

C-E Power Systems
Combustion Engineering, Inc
1000 Prospect Hill Road
Windsor, Connecticut 06095

Tel. 203/688-1911
Telex 9-9297

POWER SYSTEMS

CC W. Lowe
G. Broughton
Dan

April 17, 1979

Mr. Tom Crimmins
Three Mile Island
Visitors Center and Trailer Camp
Trailer #11
Route 441
Middletown, Pennsylvania

Subject: Estimate of Volume of Non-Condensable Gas vs. Time

Dear Mr. Crimmins:

Confirming our telecopy of 4/10/79, attached is the C-E writeup regarding the subject gas release. One comment received back was that the letdown flow was "recycled", not as assumed by C-E to be "not recycled". We do not see this assumption as changing our conclusions as long as the makeup water tank is of sufficient volume and at a pressure where degassing will occur in the letdown stream. This appears to be the case.

The only potentially significant source of error would be the estimated 20 GPM flow rate (given to C-E for pump seal leakoff). Based on 20 GPM it would have taken 10 days to reach a safe condition (i.e., April 2 to April 12, 1979, 10 days, as shown on the curves). In the event actual seal leakoff was less, the necessary degas time would increase proportionally (i.e., at 10 GPM degassing would have to continue for 20 days, until April 22, and at 5 GPM degassing would have to continue for 40 days, until May 12, 1979).

Very truly yours,

V C Hall

V. C. Hall

VCH/es
Attachment

PRELIMINARY

Problem

Estimate the volume of gas released, if any, as a result of cooling and depressurizing the reactor coolant system, taking into account continuous gas removal by feed and bleed at approximately 20 GPM.

Initial Conditions

- Pressure = 1,000 PSIA/985 PSIG
- Temperature = 280°F

Assumptions

- Bubble disappeared at 1200, April 2, 1979
- RC saturated with H_2 at that time (1,560 cc H_2 @ STP/Kg)
- Letdown flow 20 GPM @ 120°F (9,900 #/HR) not recycled
- Makeup flow same, air-saturated water (18 cc/Kg air, assume 100% N_2 for most limiting case)
- Ideal Gas Law assumed for all gases and water vapor
- Perfect mixing in RCS

Results

1. Calculation of limiting dissolved H_2 gas concentrations.

   The approach was to calculate limiting dissolved gas concentrations relative to:

   -- bubble nucleation

   -- formation of 100 ft^3 of bubble

   Results are presented on Table I.

   These figures should be taken as targets for degasification.

Conclusions

(1) H_2 must be reduced to < 1,100 cc/Kg to avoid bubble formation due to cooling while maintaining 1,000 PSIA. The maximum bubble, assuming no degasification, would be approximately 75 ft^3 at 1,000 PSIA/150°F.

(2) H_2 must be reduced to < 30 cc/Kg to avoid bubble formation due to cooling and depressurizing to 50 PSIG.

(3) Total gases (H_2 plus air) must be reduced to < 50 cc/Kg to avoid bubble formation due to cooling and depressurizing to 50 PSIG.

4/10/79

2. Calculation of Rate of Gas Removal

Based on a RCS mass of 6×10^5 lb @ 9.9×10^3 lb/hr bleed, H_2 concentrations will be reduced with a half-life of approximately 42 hours (1-3/4 day). Coolant air concentration will increase to saturation (18 cc/Kg) with the same half-life. Results are plotted on Figure 1.

Also plotted are the minimum pressures to prevent bubble formation at 200°F and 150°F as a function of time. These curves include the partial pressures of air (assumed N_2), H_2, and water vapor.

onclusions

1) In order to meet a target concentration of 30 cc H_2/Kg, degasification should continue until approximately noon on April 12.

2) In order to depressurize to 50 PSIG at 200°F without forming gas bubbles, degasification should continue until early on April 12.

ote: As final temperature increases, the vapor pressure of water becomes more significant and reduces the allowed gas concentration (extends degasification times).

Slightly increasing system pressure will compensate for the additional water vapor pressure.

te: The above calculations assume no input of gases from radiolysis.

mmary Conclusion

sed on coolant bleed/feed and the associated assumptions, gas bubble will not form at 150°F primary temperature and psig primary pressure after 4/12/79.

4/10/79

PRELIMINARY

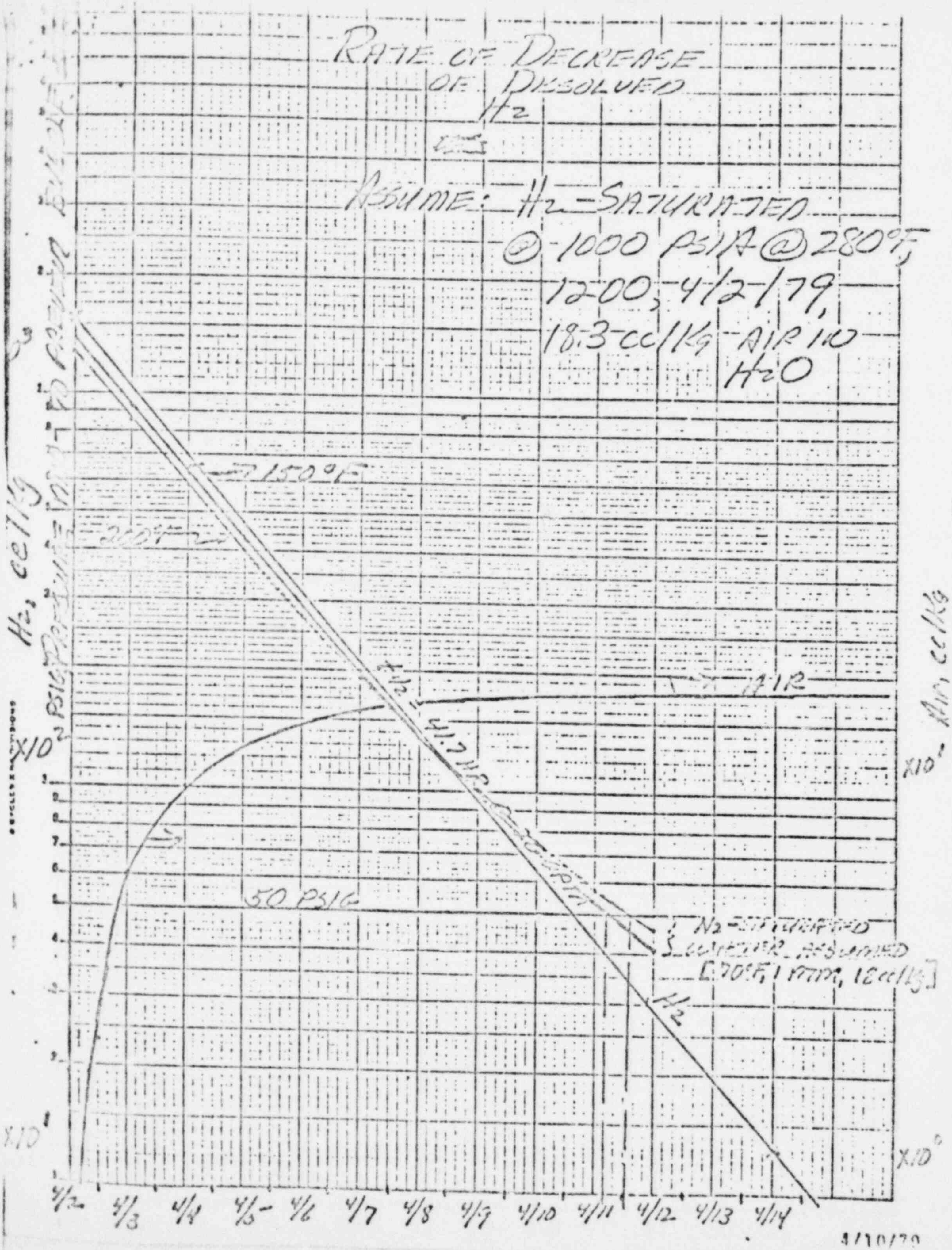
TABLE I

DISSOLVED H_2 CONCENTRATIONS FOR VARIOUS CONDITIONS

CONDITION: INITIAL PRESSURE - 1000 PSIA
INITIAL TEMP - 280°F

	FINAL			
	PRESSURE / PSIG (PSIA)	TEMPERATURE 150°F	200°F	220°F
		UNITS - CC (STD)/Kg unless indicated		
1. COOL WHILE MAINTAINING PRESSURE				
a. TO PREVENT BUBBLE FORMATION	985 (1000)	1130	1220	1300
b. TO PREVENT BUBBLE > 100 ft³ IN Hot Leg	" "	IN EXCESS OF SAT @ 1000 PSIA / 280°F		
TOTAL BUBBLE FORMED BY COOLING H_2 SAT WATER		75 ft³	65 ft³	57
2. COOL FIRST, THEN DEPRES TO 50 PSIG	50 (65)			
a. TO PREVENT BUBBLE FORMATION				
(assuming air-saturated make-up, 70°F-atm)	" "	44	38	34 [illegible]
*(assuming N_2-saturated make-up, 70°F-1 atm)	" "	40	33	36 [illegible]
b. TO PREVENT BUBBLE > 100 ft³ in Hot Leg	" "			
(assuming all bubble to one HL)	" "	75	62	55 [illegible]
(assuming 30% of bubble to HL)	" "	157	128	115 [illegible]
3. TOTAL GAS (H_2 + AIR) TO PREVENT ABOVE		ADD 18 cc/Kg to above		

4/10/79


RATE OF DECREASE
OF DISSOLVED
H_2
ASSUME: H_2-SATURATED
@ 1000 PSIA @ 280°F,
12:00, 4/2/79,
18.3 cc/Kg AIR IN
H_2O
150°F
200°F
$t_{1/2}$ = 41.7 HR. ~ 20 GPM
AIR
50 PSIG
N_2-SATURATED
WATER ASSUMED
[70°F, 1 ATM, 18 cc/Kg]
H_2
H_2, cc/Kg
PSIG
X10²
X10¹
Air, cc/Kg
X10¹
X10⁰
4/2
4/3
4/4
4/5
4/6
4/7
4/8
4/9
4/10
4/11
4/12
4/13
4/14

4/10/79

PRELIMINARY

Based on discussions with Mr. Paul Cohen (consulting chemical engineering from Westinghouse, retired), review of data in his book, and discussions with Dr. Jenks of ORNL, it is their opinions that net recombination, VIZ no coolant radiolysis persists in the TMI-II core.

From my experience with a pressurized heavy water cooled and moderated reactor, net radiolysis occured only under power operation, with a thermal neutron flux of 10^{13} n/cm^2, a dissolved hydrogen content of <1.5 cc/kgm coolant, and sub-cooled boiling in the core. Even there, oxygen concentrations were <2 ppb in the coolant.

Thus, with current and anticipated primary system conditions at TMI-II, we do not expect any hydrogen generation from radiolysis.

References

1. Cohen, P. Water Coolant Technology of Power Reactors, Gordon and Breach, 1969, page 100,101.
2. Jenks, ORNL 3843, 1965
3. Jenks and Greiss - ORNL 4173, 1967

PB/mac

4/10/79

6/712.3.c-43

MICROFILM

DOCUMENT INDEX TARGET

DESCRIPTION

HYDROGEN BUBBLE DATA

HC-0002

(55 spaces maximum)

DATE

05-03-79

(18 spaces maximum)

DESCRIPTION CONTINUATION

FILE NUMBER

(20 spaces maximum)

NOTE: Maximum spaces include all punctuation marks, dashes and spaces between words.

Description continuation should only be used when abbreviations are not appropriate.

REEL NO __________ BLIP NO __________

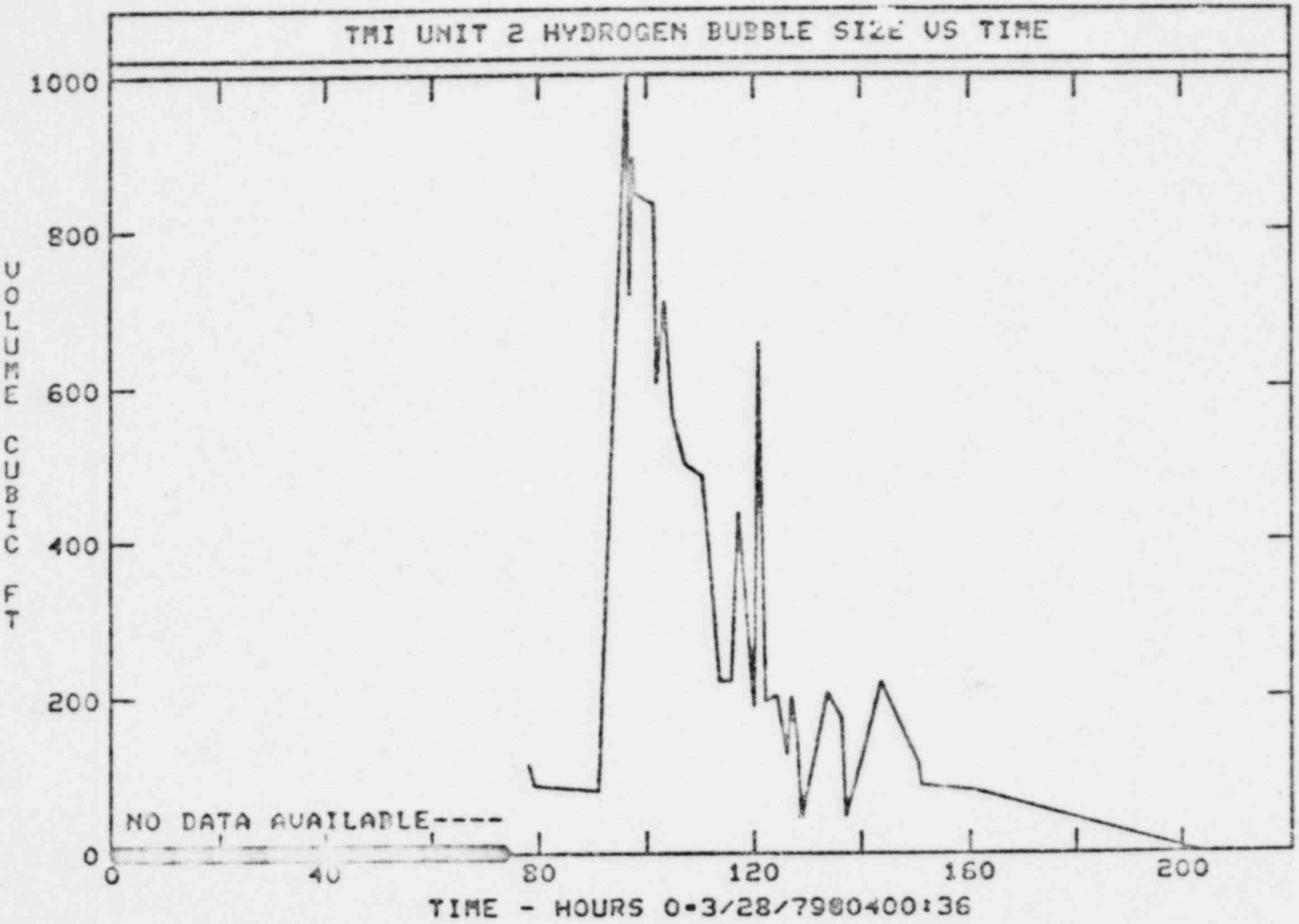
MF 174 (5 42) 7 78

HC-0002

HYDROGEN BUBBLE DATA
TMI UNIT 2

(4/18/79 DRMG)

TIME (HRS) 0·3/2800400	HYDROGEN BUBBLE SIZE
============	============
78	118.3
79	89.2
91	82
96.3	999
95.9	717
97.3	894
98	848
101.4	833
101.9	606
103.3	710
104.75	564
106	535
107.3	501
110.3	486
113.7	224
115.7	223
117	438
120	191
120.9	655
122	193
124.25	205
126.1	139
127	203
127.9	152
129.7	47
133.5	203
134.5	194
136.25	175
137	48
143.5	221
160.42	118
161	89
161	82
202.7	0


TMI UNIT 2 HYDROGEN BUBBLE SIZE VS TIME
VOLUME CUBIC FT
1000
800
600
400
200
0
NO DATA AVAILABLE----
0
40
80
120
160
200
TIME - HOURS 0=3/28/7980400:36

		[illegible]
411	[illegible]	[illegible]
3,[illegible]	2355	117
[illegible]	[illegible]	849
	[illegible]	353.[illegible]
	[illegible]	[illegible]
	[illegible]	913
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	501
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	2240
	[illegible]	437
		[illegible]
	[illegible]	[illegible]
[illegible]	[illegible]	111
	[illegible]	[illegible]
	[illegible]	[illegible]
		[illegible]
		[illegible]
	[illegible]	[illegible]
	1255	208
	1350	[illegible]
	[illegible]	[illegible]

HYDROGEN
BUBBLE SIZE

TIME (HRS)
0 = 3/28 @ 0400

-YGBUB T

HYGBUB TIME (HRS)

6/712.3.e-44

THE
RCS Total
Gas Concentration

We received two questions on April [illegible], 1979, via you, from Bill Lowe on total gas, as follows.

1. Can they add hydrazine (N_2H_4) to scavenge the oxygen in the RCS?

   If hydrazine is added to scavenge oxygen, the RCS total gas concentration will be increased. This occurs because hydrazine reacts not only with the O_2 being scavenged ($N_2H_4 + O_2 \rightarrow 2H_2O + N_2\uparrow$) but also with metal oxides. In both cases N_2 is released. Extensive experience indicates that in a RCS you will produce approximately 2 cc/kg of N_2 for every cc of O_2 which is scavenged. Thus, in this case, 4.4 cc/kg of O_2 would be replaced with approximately 8.8 cc/kg of N_2.

   If their concern is total gas, then adding N_2H_4 would not be a good choice.

   If their concern is chloride stress corrosion cracking due to chlorides (?) and O_2 in the RCS, then it is obviously a weighted decision (i.e., add N_2H_4 to reduce chloride stress corrosion worry at the expense of total gas).

2. Based on their April 14, 1979, gas analysis (H_2-31.2 cc/kg, N_2-3[illegible] cc/kg, O_2-4.4 cc/kg, total-[illegible] cc/kg); how big would a bubble be if temperature were reduced to [illegible] and pressure were reduced to atmospheric pressure (14.7 [illegible])?

   Based on the April 14, 1979, gas analysis, a bubble of approximately 1,020 ft^3 would be formed. This includes 763 ft^3 of non-condensables and 257 ft^3 water vapor, with a percentage distribution as follows:

   N_2 -- 37.6
   H_2 -- 33.0
   O_2 -- 4.5
   H_2O -- 24.9

   At the above stated condition, 10.1 cc/kg of gas would remain in solution at the following concentrations.

   N_2 -- 3.8 cc/kg
   H_2 -- 5.5 cc/kg
   O_2 -- 0.8 cc/kg

Concerning the above sentence, the solubility of gases in the RCS at 14.7 PSIA and 150°F is approximately 10.1 cc/kg. Therefore, that is the concentration necessary prior to depressurization if no bubble is to be formed. Degassing the RCS to 10.1 cc/kg can only be accomplished (in a reasonable time frame) if fully deaerated makeup is used. This can be accomplished in two ways:

A. Pull a vacuum on the RCS makeup tank (if it is so constructed as not to collapse);

B. Discard letdown flow and only use deaerated makeup (or somehow put the letdown flow through the deaerator).

Other data which may be of interest in understanding the problem:

-- At this point the major problem prior to depressurization is total gas, not its individual constituents.

-- To prevent a bubble of less than 100 ft^3 (assuming it forms at one location) at 14.7 PSIA, 150°F, the RCS total gas must be less than approximately 16 cc/kg.

-- The major difference in bubble size between full depressurization and 50 PSIG (64.7 PSIA) is that at 50 PSIG total gas solubility in coolant is approximately 40 cc/kg while it is only approximately 10.1 cc/kg at 1 ATM.

-- The conservative thing to do would be degas to approximately 10 cc/kg prior to securing the reactor coolant pump. Once the pump is secured and natural circulation initiated, perfect mixing of the RCS which is assumed and probably correct with a pump running, would no longer be the case.

In the natural circulation mode degassing rate or success will be virtually impossible to predict or measure because of imperfect mixing.

C. E. McCracken

CE Corp

6/712.3.e-45

APR 10 1979

13.41

April 10, 1979

N Lowe
cc T. [illegible]
[illegible]
[illegible]
[illegible]
[illegible]

[illegible] Corp

[illegible] Construction

[illegible] C. [illegible]

[illegible] of [illegible] subject [illegible] Licensed [illegible] April 10, 1979.

Very truly yours,

COMBUSTION ENGINEERING, INC.

J. C. [illegible]
Project Manager

[illegible]

[illegible]

III
RCS Total
Gas Concentration

We received two questions on April 22, 1979, via you, [illegible] gas, as follows.

1. [illegible] hydrazine (N_2H_4) to scavenge the oxygen [illegible]

   If hydrazine [illegible] to scavenge oxygen, the RCS total gas concentration will be increased. [illegible] but also [illegible] 0.6 cc/kg of O_2 would be replaced with approximately 0.8 cc/kg of N_2.

   If [illegible] is total gas, then adding N_2H_4 would not be a [illegible].

   [illegible] chloride stress corrosion cracking [illegible] O_2 in the [illegible] decision (i.e., [illegible] to [illegible] worry at the expense of [illegible]).

2. [illegible] 22, 1979, gas analysis [illegible].

   [illegible]

   [illegible] 22, 1979, gas analysis, [illegible] would be [illegible] bubbles and 257 [illegible] vapor [illegible] distribution as follows:

   H_2 -- 57.6
   N_2 -- 53.0
   O_2 -- 4.5
   H_2O ≈ 23.9.

   At this phase of total equilibrium, 10.1 cc/kg of gas would remain in [illegible] at the following concentrations.

   H_2 -- 3.8 cc/kg
   N_2 -- 5.5 cc/kg
   O_2 -- 0.8 cc/kg

Restating the above sentence, the solubility of gases [illegible] [illegible] and F is [illegible] 10.1 cc/kg, [illegible]. This is the concentration necessary prior to [illegible] is to [illegible] to 10.1 [illegible] can only be accomplished (in a [illegible] [illegible]ated makeup is used. This can be accomplished in two ways:

A. [illegible] return tank (if it is so constructed as not to collapse);

B. [illegible] and only use deaerated makeup [illegible] through the [illegible].

Other data which may be of interest in understanding the [illegible]:

-- [illegible] prior to [illegible] is [illegible], [illegible] individual constituents.

-- [illegible] less than 100 ft³ [illegible] at 10.7 [illegible], [illegible] approximately 10 cc/kg.

-- [illegible] in bubble size between [illegible] 10.7 [illegible] only approximately 10.1 [illegible].

-- [illegible] to do would be [illegible] to [illegible] the reactor [illegible] natural circulation [illegible] of the RCS which is [illegible] running, would no longer [illegible].

In the [illegible] of solution mole [illegible] rate or [illegible] to [illegible] or measure [illegible] of imperfect mixing.

C. [illegible] McCracken

cj

G/712.3.e+46.

APR 22 1979
8am

C-E Power Systems
[illegible]
1000 Prospect Hill Road
Windsor, [illegible]

Tel 203/588 1911
Telex [illegible]

POWER
SYSTEMS

April 19, 1979

Mr. Tom Crimmins
Three Mile Island
Visitors Center and Trailer Camp
Trailer #11
Route 441
Middletown, Pennsylvania 17057

Subject: TMI RCS Total Gas Concentration

Dear Mr. Crimmins:

Please note the attached of same subject that was prepared per your request. Copies are telecopied herewith and will be sent to you on April 19, 1979.

Very truly yours,

COMBUSTION ENGINEERING, INC.

JC Moulton

J. C. Moulton
Project Manager

bk

Attachment

cc RFW
RWK
JAD
GPU on Site Tech. Su
DRMG
G. Stoudt/file

TMI
RCS Total
Gas Concentration

We received two questions on April 18, 1979, via you, from Bill Lowe on total gas, as follows.

1. Can they add hydrazine (N_2H_4) to scavenge the oxygen in the RCS?

   If hydrazine is added to scavenge oxygen, the RCS total gas concentration will be increased. This occurs because hydrazine reacts not only with the O_2 being scavenged ($N_2H_4 + O_2 \rightarrow 2H_2O + N_2\uparrow$) but also with metal oxides. In both cases N_2 is released. Extensive experience indicates that in a RCS you will produce approximately 2 cc/kg of N_2 for every cc of O_2 which is scavenged. Thus, in this case, 4.4 cc/kg of O_2 would be replaced with approximately 8.8 cc/kg of N_2.

   If their concern is total gas, then adding N_2H_4 would not be a good choice.

   If their concern is chloride stress corrosion cracking due to chlorides (?) and O_2 in the RCS, then it is obviously a weighted decision (i.e., add N_2H_4 to reduce chloride stress corrosion worry at the expense of total gas).

2. Based on their April 14, 1979, gas analysis (H_2-31.2 cc/kg, N_2-32.8 cc/kg, O_2-4.4 cc/kg, total-68.4 cc/kg); how big would a bubble be if temperature were reduced to 150°F and pressure were reduced to one atmosphere (14.7 PSIA)?

   Based on the April 14, 1979, gas analysis, a bubble of approximately 1,020 ft^3 would be formed. This includes 767 ft^3 of non-condensables and 257 ft^3 water vapor, with a percentage distribution as follows:

N_2 -- 37.6
H_2 -- 33.0
O_2 -- 4.5
H_2O ~ 24.9

At the above stated condition, 10.1 cc/kg of gas would remain in solution at the following concentrations.

N_2 -- 3.8 cc/kg
H_2 -- 5.5 cc/kg
O_2 -- 0.8 cc/kg

Restating the above sentence, the solubility of gasses in the RCS at 14.7 PSIA and 150°F is approximately 10.1 cc/kg, therefore, that is the concentration necessary prior to depressurization if no bubble is to be formed. Degassing the RCS to 10.1 cc/kg can only be accomplished (in a reasonable time span) if fully deaerated makeup is used. This can be accomplished in two ways:

A. Pull a vacuum on the RCS makeup tank (if it is so constructed as not to collapse);

B. Discard letdown flow and only use deaerated makeup (or somehow put the letdown flow through the deaerator).

Other data which may be of interest in understanding the problem:

-- At this point the major problem prior to depressurization is total gas, not its individual constituents.

-- To prevent a bubble of less than 100 ft^3 (assuming it forms at one location) at 14.7 PSIA, 150°F, the RCS total gas must be less than approximately 16 cc/kg.

-- The major difference in bubble size between full depressurization and 50 PSIG (64.7 PSIA) is that at 50 PSIG total gas solubility in coolant is approximately 40 cc/kg while it is only approximately 10.1 cc/kg at 1 ATM.

-- The conservative thing to do would be degass to approximately 10 cc/kg prior to securing the reactor coolant pump. Once the pump is secured and natural circulation initiated, perfect mixing of the RCS which is assumed and probably correct with a pump running, would no longer be the case.

In the natural circulation mode degassing rate or success will be virtually impossible to predict or measure because of imperfect mixing.

C. E. McCracken

C. E. McCracken

tj

6/712-3.e-47

[illegible]
[illegible] Inc.
[illegible]
[illegible]

[illegible]
[illegible]

APR 19 1979

(F) [illegible]

13 41

[illegible]
Wilson
[illegible]

April 19, 1979

Mr. Tom Cri[illegible]
[illegible]
Visitors Center and Trailer Camp
[illegible]
[illegible]
[illegible], Pennsylvania 17057

Subject: [illegible] Total Gas Concentration

Dear Mr. Crimmins:

Please note the attached of same subject that was prepared [illegible]. Copies are telecopied herewith and will be sent to you on April 19, 1979.

Very truly yours,

COMBUSTION ENGINEERING, INC.

J. C. Moulton
Project Manager

[illegible]

Attachment

BABCOCK & WILCOX CO.
POWER GEN. GROUP
TMI-2 OPERATIONS

6/712.3.e-48

APR 20 1979
11:45 pm

TRANSMITTAL TO:

☒ C. ROGERS TRANSMITTAL # ______

ALSO TELECOPY TO: ☒ R. WILSON TRANSMITTAL # W311

☒ B&W TRAILER 26 TRANSMITTAL # W311

TIME ______ DATE APRIL 20, 1979

PROJECT REACTOR COOLANT CHEMISTRY RECOMMENDATION

APPROVED BY ____________ B&W ACTION # 543
OPERATIONS MANAGER

F Degor

CC: R. C. ARNOLD
R. F. WILSON
R. W. KEATEN
T. H. CRIMMINS
J. DANIELS
J. G. HERBEIN
D. MONTGOMERY
ADM. ASST. GPU ON SITE
TECH SUPPORT
DATA REDUCTION & MGMT
STAUDT/FILE (ORIGINAL)

BABCOCK & WILCOX COMPANY
ER GENERATION GROUP

D. W. [illegible]	INSTRUCTION NO. 543
M. J. BELL	[illegible]
	File No. or Ref.
REACTOR COOLANT CHEMISTRY RECOMMENDATION	Date APRIL 19, 1979 0945

This letter is to cover one customer and one subject only.

ADDITIONAL INFORMATION OBTAINED FROM THE LATEST PRESSURIZED REACTOR COOLANT SAMPLE INDICATES MODIFICATION TO THE PREVIOUS TRANSMITTAL (N-303) IS IN ORDER. A SUMMARY OF RC GAS DATA (H_2, N_2, O_2) FROM PRESSURIZED SAMPLES IS SHOWN IN THE ATTACHED CHART. A MAJOR DISCREPANCY IS NOTED BETWEEN THE IDAHO (4/13) AND THE B&W HYDROGEN RESULTS (4/16,18). BASED ON TELEPHONE INFORMATION, IDAHO HAS TESTED A SAMPLE "BOMB" AND FOUND SIGNIFICANT HYDROGEN LEAKAGE AFTER ABOUT A THREE HOUR TIME INTERVAL. THIS MAY ACCOUNT FOR THE LOW HYDROGEN VALUE REPORTED BY IDAHO SINCE THE B&W SAMPLES WERE ANALYZED AFTER A SHORTER TIME INTERVAL. THE NITROGEN AND THE LAST TWO HYDROGEN DATA POINTS WOULD INDICATE SOME DEGASSING IS OCCURRING WITH ABOUT A 4 DAY HALF TIME. SINCE THE DATA BASE IS ONLY TWO SAMPLES (B&W), WE RECOMMEND THAT SAMPLING BE CONTINUED UNTIL A CONFIRMED TREND IS ESTABLISHED

ALL OF THE SAMPLES INDICATE THE PRESENCE OF OXYGEN (1.8-4.4 cc/kg). AS DISCUSSED IN TRANSMITTAL #N-303, ABOUT 67,000 cc OF OXYGEN MAY BE ADDED TO THE RCS AT A 2 GPM MAKEUP RATE. THIS OXYGEN WOULD BE EXPECTED TO RECOMBINE WITH THE 22-31 cc/kg OF HYDROGEN INDICATED TO BE PRESENT FROM THE SAMPLE ANALYSES. HOWEVER, WE RECOMMEND THAT IT WOULD BE PRUDENT TO ADD HYDRAZINE TO THE RCS TO INSURE A REDUCING ENVIRONMENT AND MINIMIZE THE POTENTIAL FOR MATERIAL DAMAGE. BASED ON 1.8 cc O_2/kg, ABOUT 7.5 LITERS OF 35% HYDRAZINE SOLUTION BE ADDED TO THE RCS. THIS IS EQUIVALENT TO ABOUT 300% OF THE STOICHIOMETRIC OXYGEN CONCENTRATION.

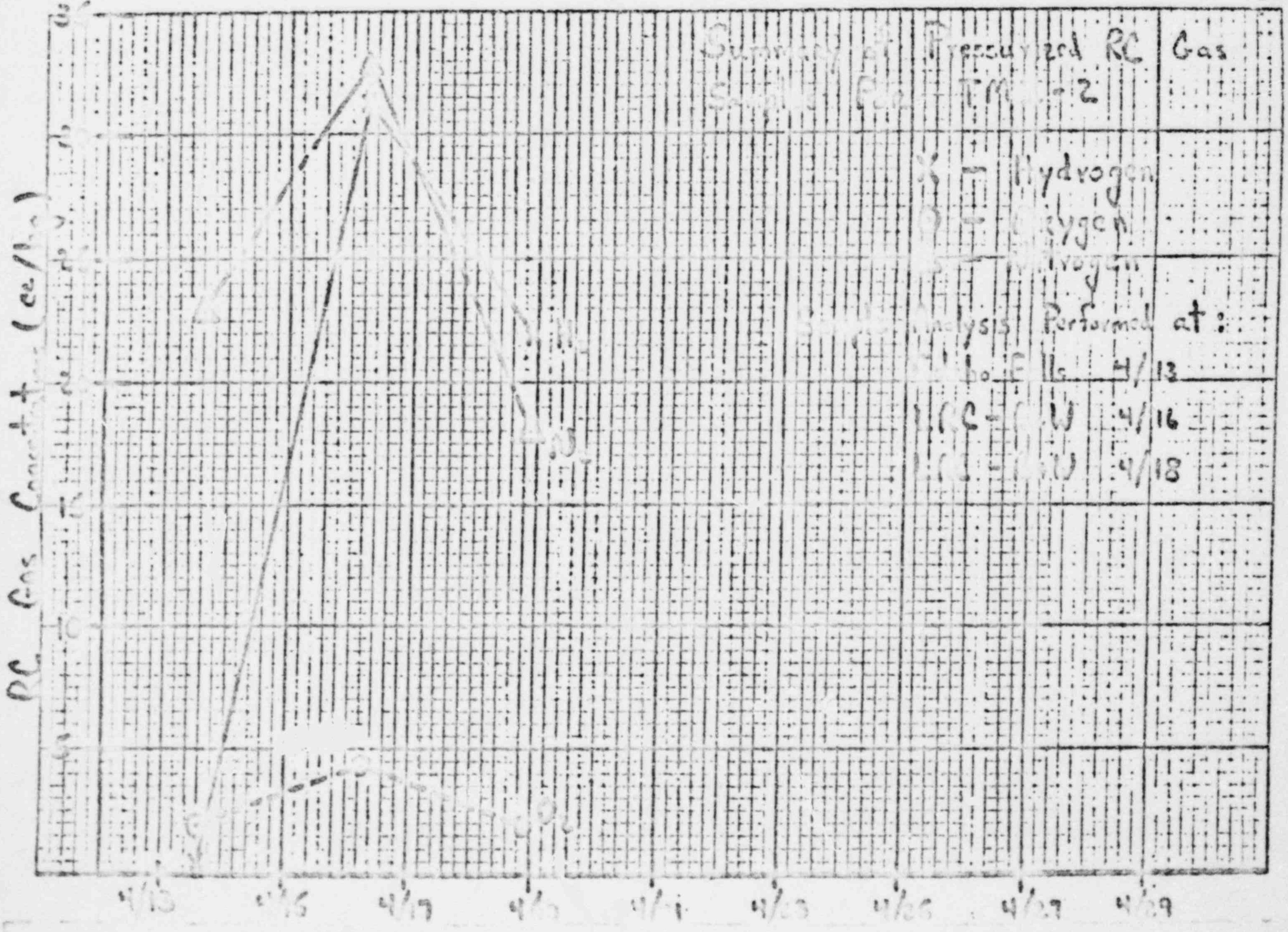
THE ADDITION OF HYDRAZINE MAY RESULT IN THE FORMATION OF SOME INERT GAS IN THE RCS. IF IT IS ASSUMED THAT ALL OF THE HYDRAZINE DECOMPOSES TO NITROGEN AND HYDROGEN, EACH POUND OF HYDRAZINE COULD CONTRIBUTE ABOUT 3.5 cc/kg OF GAS IF NO OXYGEN REACTION OCCURS. FOR 7.5 LITERS OF HYDRAZINE SOLUTION (35%) ADDED TO THE RCS, ABOUT 20 cc/kg OF INERT GAS (H_2 AND N_2) WOULD BE GENERATED. IF THE 1.8 [illegible]

REACTS WITH THE HYDRAZINE, 16.4 cc/kg OF INERT GAS RESULTS. THIS REACTION IS UNLIKELY SINCE HYDRAZINE WOULD BE EXPECTED TO DECOMPOSE IN THE RADIATION FIELDS TO NITROGEN, HYDROGEN, AND AMMONIA. IN THIS CASE, ONLY 6.4 cc/kg OF INERT GAS WOULD BE GENERATED (FOR THE 7.5 LITERS OF SOLUTION ADDED). THIS IS THE REACTION BY WHICH WE BELIEVE THE MAJORITY OF THE DECOMPOSITION WILL OCCUR.

IN SUMMARY, THE INDICATIONS ARE THAT THE LIQUID SAMPLE ANALYSES MAY BE LOW DUE TO LEAKAGE. HOWEVER, SOME DEGASSING MAY BE INDICATED FROM THE NITROGEN DATA. WE RECOMMEND ADDITIONAL SAMPLING UNTIL A CONFIRMED TREND IS OBSERVED. [illegible] THE [illegible] OF OXYGEN. IT IS OUR RECOMMENDATION THAT IT IS PRUDENT TO ADD HYDRAZINE (7.5 LITERS OF 35% SOLUTION) TO THE RCS TO REACT [illegible] INTRODUCED WITH THE AERATED MAKEUP.

RJB/sm
cc: RAD CHEM. GROUP

6/212-3-8-49



RC Gas Concentration (cc/kg)
10
15
20
25
30
4/13
4/15
4/17
4/19
4/21
4/23
4/25
4/27
4/29
Summary of Pressurized RC Gas
Samples For TMI-2
X = Hydrogen
O = Oxygen
Δ = Nitrogen
Sample Analysis Performed at:
Idaho Falls 4/13
[illegible] 4/16
[illegible] 4/18

G/712-3.e-50

Hydrogen Concern

APR 20 1979

: R. C. ARNOLD
[illegible]
R. W. [illegible]
[illegible]
J. [illegible]
[illegible]
D. [illegible]
[illegible]
[illegible]
[illegible]
STAUDT/FILE (ORIGINAL)

20 April 1979

To: D. A. Pullen

From: P. W. Marriott

Subject: FLAMMABILITY OF H_2 AT HIGH PRESSURE

On April 3, Dr. Richl of NASA, who was consulting for GPU, telephoned us directly to request our comments on his proposed flammability and detonability limits for H_2 at 1000 psia. Since the request did not come through Rockwell from GPU, we have treated the request as second priority. I realize the need has passed, but for the record our comments follow. Please give them to GPU: I do not know how to contact Dr. Richl.

For the conditions of 1000 psia, 300°F water, H_2 and O_2 mixtures, the referenced sources give the following for the limits of flammability.

	%H_2	%O_2	
Lower limit of flammability	4	6	(1)
Flammability limit for 100% combustion	8	7-1/2	(2)
Lower limit for detonability	15	10	(3)

Reference (1): Bureau of Mines Bulletin #503

Reference (2): NACA Report #1383

Reference (3): CE SAR Advanced Design Memo #25

a) The conditions listed give about 7% (mole fraction) of H_2O in the gas, really a very small influence.

b) The lower limit of detonability is an extrapolation of KAPL experimental data.

In summary, our sources show Dr. Richl's proposed limits to be conservative with the exception of the O_2 concentration required for detonation.

P. W. Marriott, Chairman
Three Mile Island Task Force
M/C 194 Ext. 56948

/aim

cc: LB Nesbitt
LR Wilkins/FD Judge

[illegible]
[illegible] WILSON
R. W. [illegible]
T. M. CRIMMINS
J. [illegible]
J. G. HERBEIN
D. [illegible]
[illegible] ASST. GPU ON SITE
[illegible]
DATA [illegible]
STATION FILE (ORIGINAL)

6/712-3, e-51

5[illegible]
APR 20 1979

20 April 1979

To: E. P. Stroupe
D. A. Pullen

From: P. W. Marriott

Subject: REABSORPTION OF NONCONDENSIBLE GASES IN BOILING MODE

This memorandum summarizes the information in the eleven pages of calculations and notes telecopied to Ditmore at IAG on April 17. EPS - it is for your use as you see fit. DAP - it is for you to give to GPU, who asked the same question on April 3.

The TID 14844/RG 1.7 radiolysis source term, i.e., for 1% of the core diffused into water, 100% of the NG released, 50% of the halogen in the water, will be about 60 scfh for H_2 and approximately 30 scfh for O_2.

If the H_2 concentration in the water near the ionizing source is 2 ppm or above, it is expected that radiolysis will be essentially completely suppressed, i.e., H_2 generation rate below 3 scfh.

The case for boiling in the reactor, condensing in the steam generator was analyzed for mass transfer of H_2 into the condensed film on the inside of the tubes and for the maximum possible amount of H_2 (or O_2) that could be transferred to the condensed steam.

Assumptions:
1) About 27 feet of tube was available for condensing and mass transfer from the gas to the liquid.
2) 15,500 tubes with 0.030" wall, 0.625 OD.
3) Cooling water approximately 120°F.
4) Heating rate 3 MWt = boiling mass transfer of approximately 10^4 lb/hr.

Conclusions:
1) Under these conditions it is calculated that at 2 ata of H_2 and 1 ata of O_2 in the noncondensible gas portion of the steam generator tubes, the maximum rate of removal of H_2 is, conservatively 5.6 scfh; for O_2 the rate is approximately 3 scfh (water saturated with H_2 and O_2).

2) If the H_2 pressure was 15 ata, the removal rate would be about 49 scfh and O_2 of 7.5 ata about 22 scfh (water saturated with H_2 and O_2).

3) In both cases the concentration of H_2 in the liquid would be in excess of 2.9 ppm.

4) Under these conditions, with P_{H_2} = 2 ata, and assuming that all the steam is condensed in the first 12 feet of the tube and mass transfer in the remaining 15 feet, more than 255 scfh of H_2 could be transferred to the film versus a maximum of 5.6 needed. (i.e., the process is limited by the solubility of H_2 in H_2O, not by film transfer).

P. W. Harriott, Chairman
Three Mile Island Task Force
M/C 194 Ext. 56948

/aim

cc: DC Ditmore
LB Nesbitt
M Siegler
DR Wilkins/FD Judge

5:15 pm
APR 20 1979

Task 1A 6/712-3.0.32

C: R. C. ARNOLD
R. F. WILSON
R. W. KEATEN
T. M. CRIMMINS
J. DANIELS
J. G. HERBEIN
D. MONTGOMERY
ADM. AST. GPU ON SITE
TECH SUPPORT
DATA REDUCTION & MGMT
STAUDT/FILE (ORIGINAL)

20 April 1979

To: D. A. Pullen

From: P. W. Marriott

Subject: FLAMMABILITY OF H_2 AT HIGH PRESSURE

On April 3, Dr. Riehl of NASA, who was consulting for GPU, telephoned us directly to request our comments on his proposed flammability and detonability limits for H_2 at 1000 psia. Since the request did not come through Rockwell from GPU, we have treated the request as second priority. I realize the need has passed, but for the record our comments follow. Please give them to GPU: I do not know how to contact Dr. Riehl.

For the conditions of 1000 psia, 300°F water, H_2 and O_2 mixtures, the referenced sources give the following for the limits of flammability.

	%H_2	%O_2	
Lower limit of flammability	4	6	(1)
Flammability limit for 100% combustion	8	7-1/2	(2)
Lower limit for detonability	15	10	(3)

Reference (1): Bureau of Mines Bulletin #503

Reference (2): NACA Report #1383

Reference (3): GE SAR Advanced Design Memo #56

a) The conditions listed give about 7% (mole fraction) of H_2O in the gas, really a very small influence.

b) The lower limit of detonability is an extrapolation of KAPL experimental data.

In summary, our sources show Dr. Riehl's proposed limits to be conservative with the exception of the O_2 concentration required for detonation.

PWMarriott

P. W. Marriott, Chairman
Three Mile Island Task Force
M/C 194 Ext. 56948

/aim

cc: LB Nesbitt
DR Wilkins/FD Judge

6/712-3.0-53

Inter-Office Memorandum

GPU Service

Date April 21, 1979
TSG-081

Subject Recommendation for End Point of Degas Mode

To T. M. Crimmins

Location Three Mile Island

Recommendations from CE (Conrad McCraken, Herb Cato, V.C. Hall) and B&W (J. H. McMillan) all focus on total gas content of the primary coolant rather than individual partial contributors such as hydrogen.

The objective of the degas mode is to lower primary coolant gas content sufficiently to assure that gas evolution will not occur as primary coolant pressure and temperature are lowered to ultimate cold depressurized conditions (< 100°F atmospheric pressure).

For the ultimate cold depressurized conditions, CE and B&W recommendations for degas end point are 20 cc/kg (STP) total gas and 15 cc/kg (STP) total gas respectively.

Recommendation: Establish the end point for degassing as ≤ 15 cc/kg (STP) total gas content of primary coolant.

K. Ellison
K. Ellison

KE/al

cc: R. W. Keaten
R. F. Wilson
Staudt/File

6/712-3.e-54

Inter-Office Memorandum

GPU Service

Date April 21, 1979 Dyer.
TSG-031

Subject Recommendation for End Point of Degas Mode

To T. M. Crimmins

Location Three Mile Island

Recommendations from CE (Conrad McCraken, Herb Cato, V.C. Hall) and B&W (J. H. McMillan) all focus on total gas content of the primary coolant rather than individual partial contributors such as hydrogen.

The objective of the degas mode is to lower primary coolant gas content sufficiently to assure that gas evolution will not occur as primary coolant pressure and temperature are lowered to ultimate cold depressurized conditions (< 100°F atmospheric pressure).

For the ultimate cold depressurized conditions, CE and B&W recommendations for degas end point are 20 cc/kg (STP) total gas and 15 cc/kg (STP) total gas respectively.

Recommendation: Establish the end point for degassing as ≤ 15 cc/kg (STP) total gas content of primary coolant.

K. Ellison
K. Ellison

KE/al

cc: R. W. Keaten
R. F. Wilson
Staudt/File

6112-3.e.55

Inter-Office Memorandum

GPU Service

April 22, 1979
TSG-082

Alternate Recommendation for End Point of Degas Mode (Including Long Term Radiolysis Control) (Task AA9 and AA22)

T. M. Crimmins

Three Mile Island

Reference: Memo K. Ellison to T. M. Crimmins, Recommendation for End Point of Degas Mode, April 21, 1979

The referenced memo identified a recommended end point for the degas mode of ≤15 cc/kg (STP) total gas content of primary coolant. This recommendation was based on the ultimate cold depressurization of the primary system (<100°F, atmospheric pressure).

Since ultimate depressurization to atmospheric pressure will not occur in the near future, the end point for the current degas mode may be redefined to address long term cooling with the primary system in natural circulation (<100°F, ≥50 psig). To prevent gas evolution from the primary coolant which could jeopardize successful natural circulation, CE and B&W have recommended <50 cc/kg and <40 cc/kg (STP) total gas content of the primary coolant.

In addition to limiting total gas content, B&W has recommended that 5-15 cc/kg (STP) of hydrogen be maintained in the primary coolant to suppress the possibility of long term radiolysis. In addition, Paul Cohen has indicated that no radiolysis is expected even with <1.5 cc/kg H_2 in the primary coolant. P. W. Marriott has indicated that with 1 atm. of H_2 overpressure in the makeup tank (approximately 15 cc/kg H_2) no radiolysis would occur.

Recommendation:

1. Establish the end point for degassing (to support long term natural circulation) as ≤40 cc/kg (STP) total gas content of primary coolant.
2. To suppress the possibility of long term radiolysis, maintain 5-15 cc/kg (STP) of hydrogen in the primary coolant.

K E Ellison

K. Ellison

KE/al

cc: R. F. Wilson
R. W. Keaten

6/712-3.e-56

MICROFILM

DOCUMENT INDEX TARGET

DESCRIPTION

Temp. & Flow Readings Start up of Hydrogen Recombiners (55 spaces maximum)

05-03-79 DATE

(18 spaces maximum)

DESCRIPTION CONTINUATION

ATP-0001

FILE NUMBER

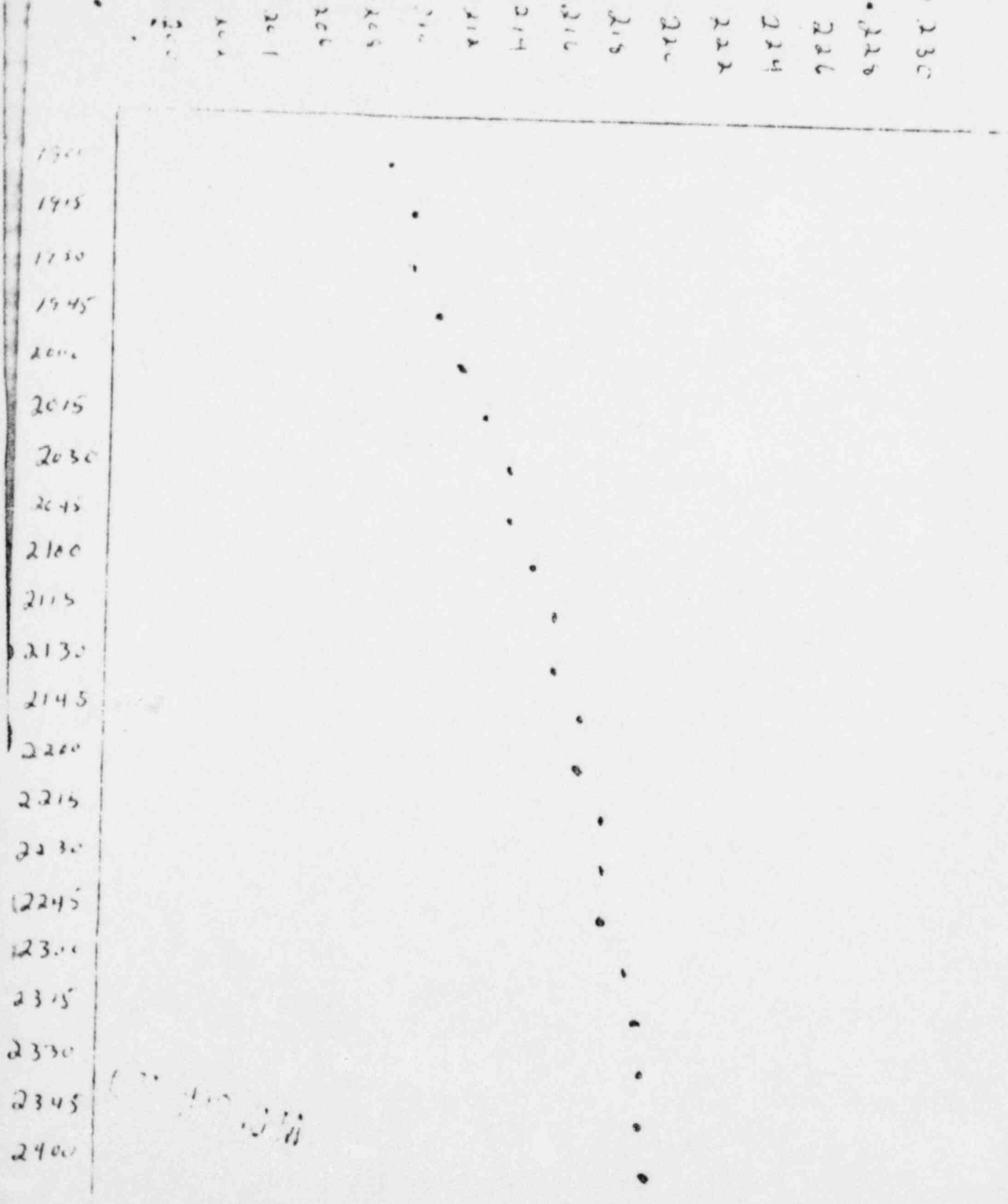
(20 spaces maximum)

NOTE: Maximum spaces include all punctuation marks, dashes and spaces between words.

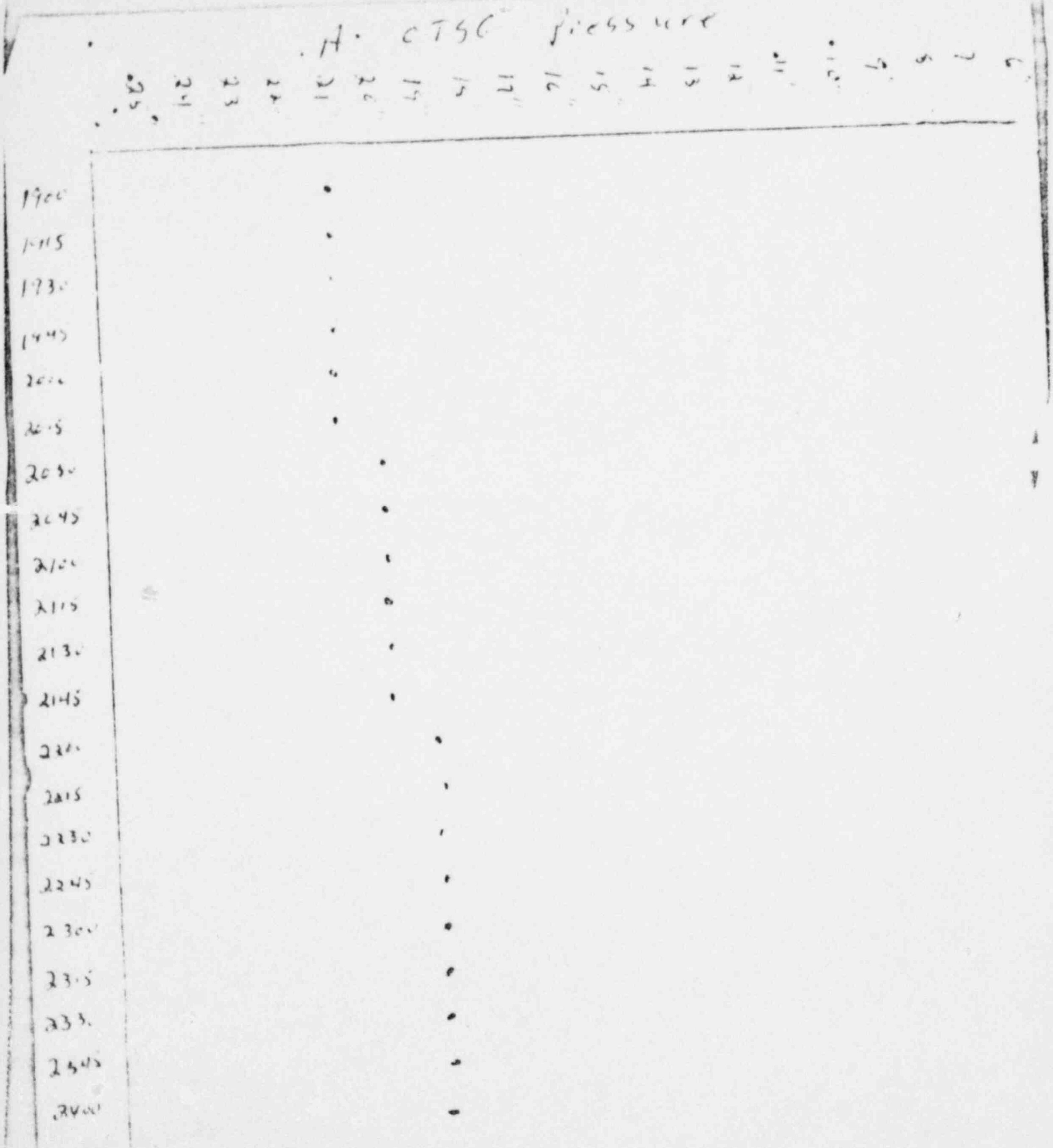
Description continuation should only be used when abbreviations are not appropriate.

REEL NO. ______________ BLIP NO. __________

Pzr Temp [illegible] 4-24-79



Cancelled - Put on 1 min Rec. at OPCA.
Grp B.


A. OTSG pressure
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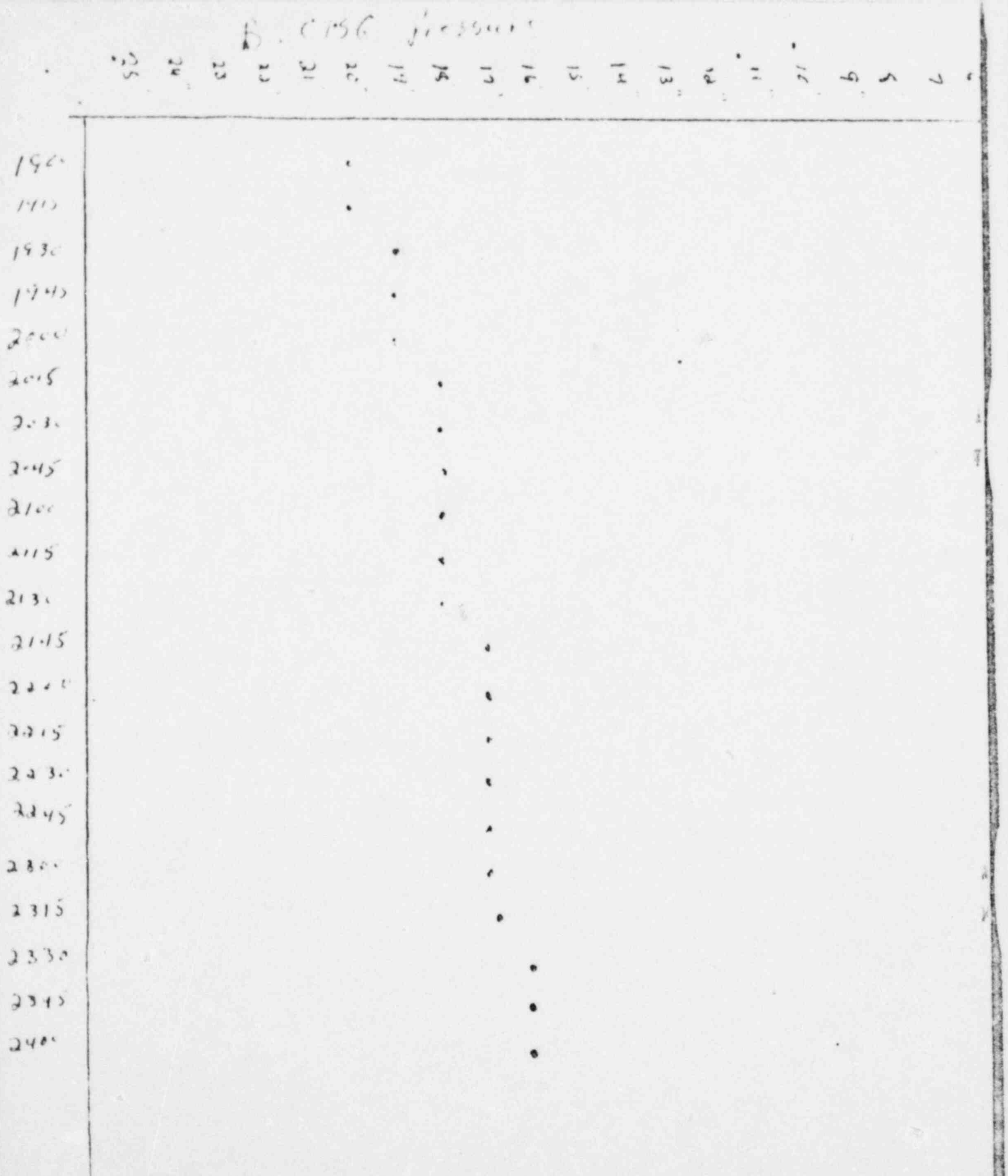

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

Room number: 66-350
Cambridge, Massachusetts
02139
Telephone: (617) 253-4561

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April 25, 1979

xc: RFW
R Long
J Daniel
DRMG
Adm. Assist. - GPU
File

Mr. Tom Crimmins
Three Mile Island
General Public Utilities
Trailer 11
Middletown, Pennsylvania 17057

Dear Mr. Crimmins:

I must apologize for the omission of the copy of the article by Pray et al, "Solubility of Hydrogen, Oxygen, Nitrogen and Helium", Ind. and Eng. Chem. 44, 1146 (1952) which was supposed to be attached to my recent memorandum on Hydrogen Degassing.

Please find a copy enclosed.

Sincerely,

J Edward Vivian

J. Edward Vivian
Professor of Chemical Engineering
Executive Officer

JEV:sje

Attach.

TABLE VIII. COMPARISON OF CYCLOPARAFFIN CONTENT OF C_9 AND HEAVIER FRACTIONS

(By mass spectrometer analysis and refractivity intercept method)

Boiling Range of Fraction, ° F.	Volume % of Naphtha						
				Uncorrected		Corrected[b]	
	Paraffins	Mono-cyclo-paraffins	Dicyclo-paraffins[a]	Paraffins	Cyclo-paraffins	Paraffins	Cyclo-paraffins
	Mass Spectrometer Analysis			Refractivity Intercept Method			
270-306	56	44	0	57	43	57	43
306-358	55	40	5	44	56	54	46
358-391	54	40	6	33	67	46	54
391 and higher	53	38	9	25	75	45	55

[a] May also include small amounts of tricycloparaffins.

[b] Refractivity intercept of the cycloparaffins corrected for the presence of dicycloparaffins indicated in mass spectrometer analysis.

fractions. A serious discrepancy is shown in Table VIII between the paraffin-cycloparaffin splits in the C_9 and heavier distillate fractions boiling above 306° F. as calculated by the mass spectrometer and refractivity intercept methods. It is believed that much of this difference is due to the presence of dicycloparaffins and possibly tricycloparaffins which are shown in Table VIII to as high as 9% in one fraction. The data of Ward and Kurtz (*12*) show that the difference in refractivity intercept between paraffins and dicycloparaffins is several times greater than that between paraffins and monocycloparaffins. By correcting the value of the refractivity intercept of cycloparaffins for the presence of dicycloparaffins, a fair agreement was reached between the two methods of analysis for paraffin content. Exact agreement can hardly be expected since a small deviation in the mass spectrometer analysis for dicycloparaffins produced change in the refractivity inter termination for paraffins.

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RECEIVED for review May 2, 1951. ACCEPTED December 31, Presented as part of the Symposium on Composition of Petroleum Hydrocarbon Derivatives presented before the Division of Petroleum istry at the 119th Meeting of the AMERICAN CHEMICAL SOCIETY, Cleve Ohio, April 1951.

Solubility of Hydrogen, Oxygen, Nitrogen, and Helium in Water

AT ELEVATED TEMPERATURES

H. A. PRAY, C. E. SCHWEICKERT, AND B. H. MINNICH[1]
Battelle Memorial Institute, Columbus 1, Ohio

THE increasing application of high temperatures and pressures to various processes has made a knowledge of the solubilities of compressed gases in water necessary for purposes of engineering design. A survey of the literature has revealed that considerable data are available on the solubilities of gases under partial pressures of more than 25 atmospheres and at relatively low temperatures. Data in the region from about 5 to about 25 atmospheres and from about 125° F. to temperatures near the critical point of water are very meager and incomplete. A determination of the solubilities of oxygen, hydrogen, helium, and nitrogen in water at temperatures from 125° to 650° F. and at pressures up to about 500 pounds per square inch absolute was, therefore, undertaken.

EXPERIMENTAL PROCEDURE. For determining the solubilities of gases in water, the apparatus shown in the schematic diagram (Figure 1) was used. A typical example of the use of this apparatus is as follows:

Valves *A* and *B* are closed, valves *C* and *D* are opened, and the 3-liter bomb contained in the rocking autoclave, *E*, is evacuated by means of the vacuum pump, *F*. Valve *A* is then opened and about 1500 ml. of distilled water are admitted to the bomb from

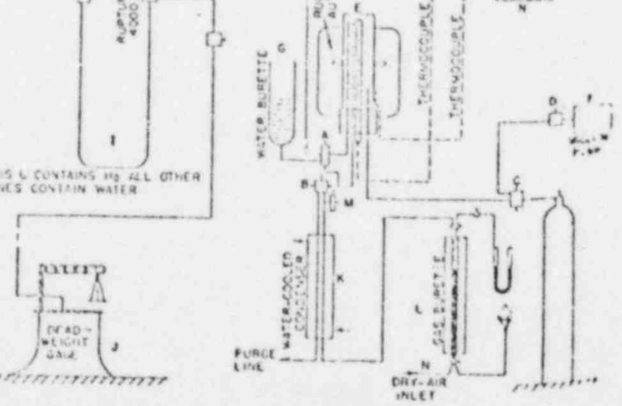

Figure 1. Diagram of Solubility Apparatus

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[1] Present address, Naval Ordnance Testing Station, Inyokern, Calif.

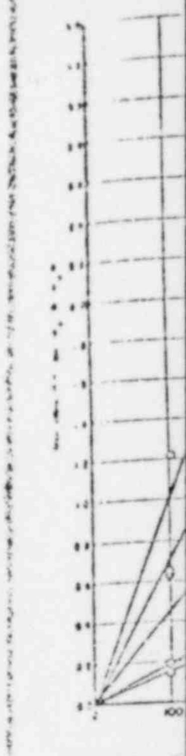

Figure 2.

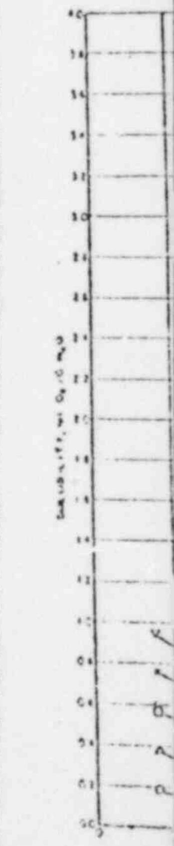

Figure 3.

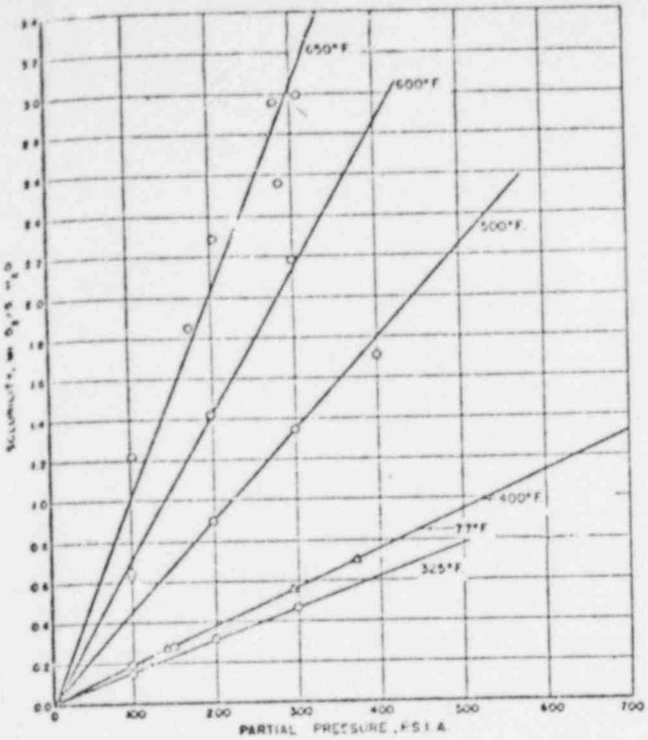

Figure 2. Solubility of Oxygen in Water with Varying Pressure

O. Authors
Δ. Frohlich *et al.* (*1*)

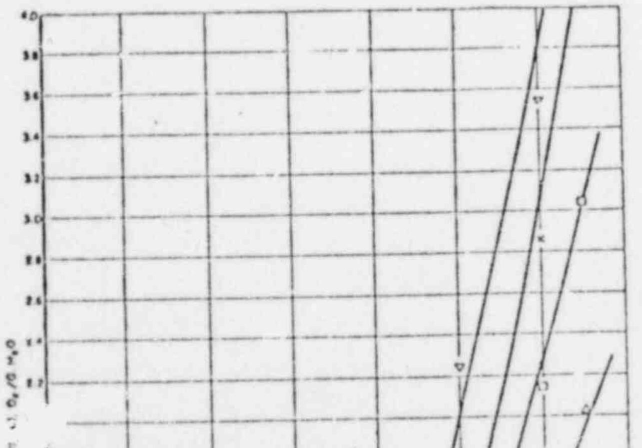

Figure 3. Solubility of Oxygen in Water with Varying Temperature

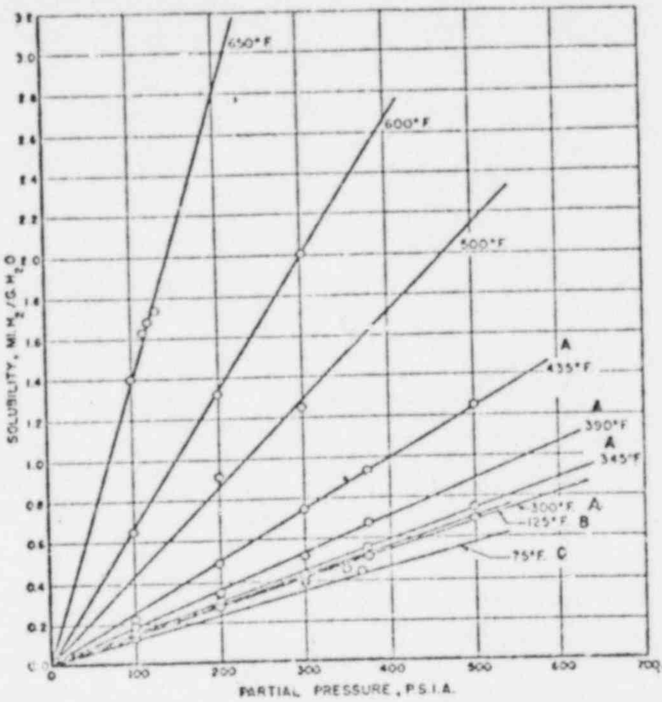

Figure 4. Solubility of Hydrogen in Water with Varying Pressure

A. Ipatieff and Teodorovish (*2*)
B. Authors
C. Wiebe and Gaddy (*3*)

Figure 5. Solubility of Hydrogen in Water with Varying Temperature

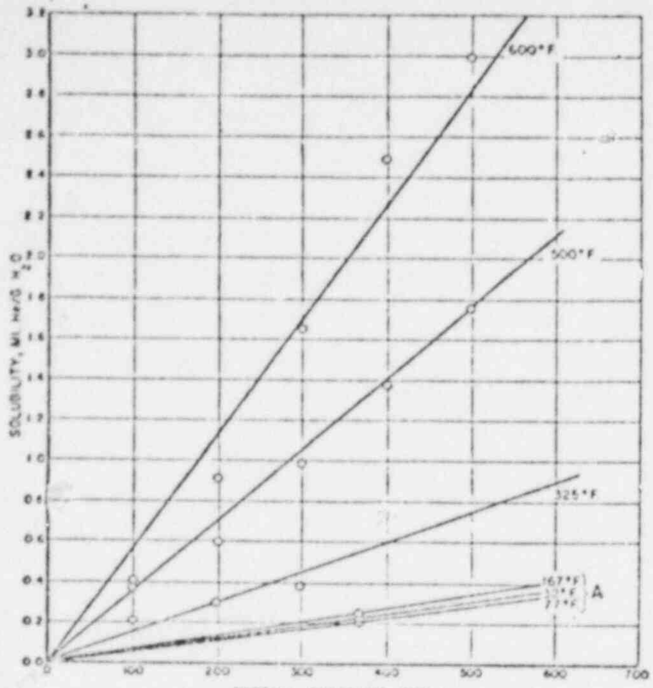

Figure 6. Solubility of Helium in Water with Varying Pressure

A. Wiebe and Gaddy (4)
○. Authors

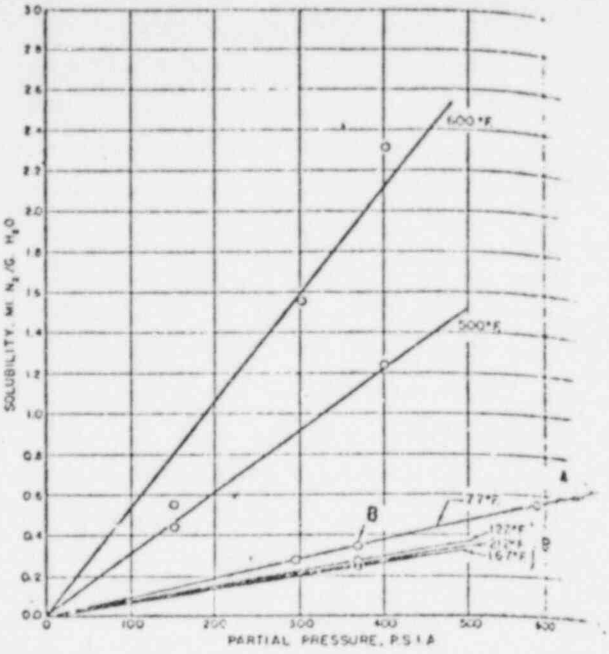

Figure 8. Solubility of Nitrogen in Water with Var

Pressure

A. Frohlich *et al.* (1)
B. Wiebe and Gaddy (5)

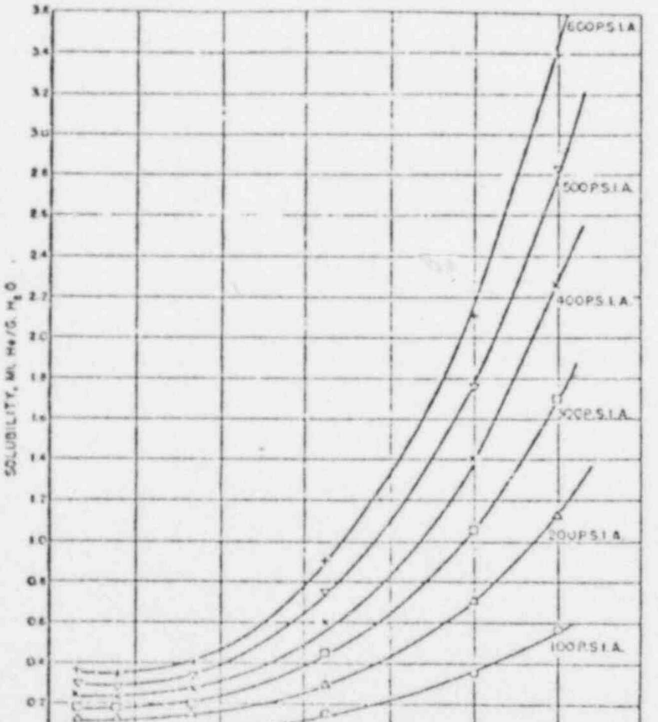

Figure 7. Solubility of Helium in Water with Varying Temperature

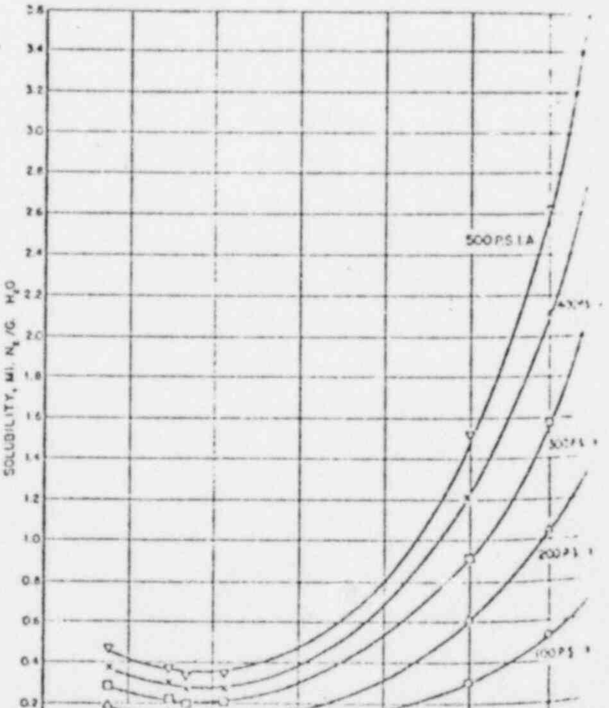

Figure 9. Solubility of Nitrogen in Water with Var

Temperature

the water buret, *G*. Valve *A* is then closed and the system is evacuated to a pressure corresponding to the saturated vapor pressure of water at room temperature. Valve *C* is then closed and the rocking autoclave, which is heated electrically, is set in motion and brought to some predetermined temperature. The temperature of the autoclave is controlled by a Leeds & No

Micromax temperature controller and recorder, *N*. Th

perature inside of the bomb is determined by means of a c

alumel thermocouple inserted in a stainless steel well insi

bomb. The electromotive force of the thermocouple is

Table I. Solubility of Oxygen in Water

O_2 Partial Pressure, Lb./Sq. In. Abs.	Source	Cc. O_2[a]/G. of Water					Average	Probable Error	Maximum Deviation
				77° F.					
140	(1)	..	..	..	..	..	0.28	..	...
295		..	..	..	..	..	0.56	..	...
370		..	..	..	..	..	0.70	..	...
				325° F.					
100	Authors	0.14	0.16	0.16	..	..	0.15	0.01	+0.01 to −0.01
200	Authors	0.31	0.31	0.31	..	..	0.31	0.00	+0.00 to −0.00
300	Authors	0.47	0.47	0.45	..	..	0.46	0.01	+0.01 to −0.01
				400° F.					
100	Authors	0.19	0.18	0.17	..	..	0.18	0.01	+0.01 to −0.01
150	Authors	0.30	0.28	0.27	..	..	0.28	0.01	+0.02 to −0.01
				500° F.					
100	Authors	0.68	0.63	0.62	0.51	..	0.61	0.04	+0.35 to −0.17
		0.47	0.99	0.69	0.56	..			
200	Authors	0.92	0.89	0.91	..	..	0.91	0.02	+0.01 to −0.02
300	Authors	1.52	1.68	1.18	1.09	..	1.35	0.06	+0.33 to −0.26
		1.37	1.24	..	..	..			
400	Authors	1.80	1.63	1.70	..	..	1.71	0.03	+0.09 to −0.17
				600° F.					
100	Authors	0.63	0.60	0.69	0.62	..	0.63	0.01	+0.06 to −0.03
200	Authors	1.39	1.45	1.43	..	..	1.42	0.02	+0.03 to −0.03
300	Authors	2.22	2.14	2.34	2.02	2.24	2.19	0.04	+0.15 to −0.17
				650° F.					
104	Authors	1.17	1.26	..	..	..	1.22	0.01	+0.04 to −0.05
175	Authors	1.85	..	..	..	..	1.85	..	...
205	Authors	2.39	2.28	2.19	..	..	2.29	0.03	+0.10 to −0.10
280	Authors	2.96	..	..	..	..	2.96	..	...
289	Authors	2.51	2.61	..	..	..	2.56	0.03	+0.05 to −0.05
309	Authors	2.99	..	..	..	..	2.99	..	...

[a] At standard temperature and pressure.

mined with the aid of a Leeds & Northrup Semi-Precision potentiometer, *H*. The thermocouple was calibrated against the melting points of metals obtained from the Bureau of Standards for that purpose. The temperature during any one run is held constant to within 2° F. After the temperature inside of the bomb reaches the desired temperature, the outlet valve, *A*, leading to the mercury U-tube is opened and the saturated vapor pressure of water is determined with the dead-weight gage, *J*. The mercury U-tube isolates the material in the bomb from the oil in the dead-weight gage. The pressure, as determined by the dead-weight gage, is checked against the vapor pressure of water given in the steam tables. The gas under investigation is then admitted to the bomb by opening one side of valve *C*. The pressure is allowed to build up to slightly over the desired partial pressure at which the solubility of the gas is to be determined. Valve *C* is then closed and the system is allowed to come to equilibrium. This is done by keeping the autoclave in motion overnight at the desired temperature. The temperature is then readjusted, if necessary, and the pressure of the gas is readjusted to its desired partial pressure. When the temperature and pressure have remained constant for about 2 hours, a sample is taken. This is done by circulating ice water through the condenser, *K*, and then opening the purging line side of valve *B*. After about 25 ml. of water have been taken off, the purging line valve is closed and the sampling line side of valve *B* is opened. About 25 ml. of water containing an amount of gas which depends on the partial pressure and water temperature are then collected over mercury in the measuring buret, *L*, which is surrounded by a water thermostat. The gas and water volumes are then measured and the needle valve, *M*, is opened. This allows the water that remained in the sample line, because of capillary action, to drain into the buret. After the total amount of gas and water have been determined, dry air is blown in through the inlet at *N* and allowed to escape through *M*. This procedure dries all of the sampling lines in preparation for the next sample. The solubility of the gas in water is then determined by reducing the gas and water volumes, as found in the measuring buret, to cubic centimeters of gas at normal temperature and pressure per gram of water.

EXPERIMENTAL RESULTS

The present experimental results and certain previously reported data for the solubility of hydrogen, oxygen, helium,

Table II. Solubility of Hydrogen in Water

H_2 Partial Pressure, Lb./Sq. In. Abs.	Source	Cc. H_2[a]/G. of Water						Average	Probable Error	Maximum Deviation
					75° F.					
300		..	..	..	..	..	..	0.32	..	...
367	(3)	..	..	..	..	..	..	0.44	..	...
					125° F.					
200	Authors	0.38	0.32	0.32	0.31	0.37	0.30	0.33	0.01	+0.05 to −0.03
300	Authors	0.41	0.42	0.40	0.41	..	..	0.41	0.00	+0.01 to −0.01
350	Authors	0.47	0.44	0.44	0.44	0.46	..	0.45	0.01	+0.02 to −0.01
					300° F.					
100	(2)	..	..	..	..	..	..	0.13	..	...
200	(2)	..	..	..	..	..	..	0.28	..	...
300	(2)	..	..	..	..	..	..	0.40	..	...
375	(2)	..	..	..	..	..	..	0.52	..	...
500	(2)	..	..	..	..	..	..	0.70	..	...
					345° F.					
100	(2)	..	..	..	..	..	..	0.15	..	...
200	(2)	..	..	..	..	..	..	0.30	..	...
300	(2)	..	..	..	..	..	..	0.43	..	...
375	(2)	..	..	..	..	..	..	0.56	..	...
500	(2)	..	..	..	..	..	..	0.75	..	...
					390° F.					
100	(2)	..	..	..	..	..	..	0.18	..	...
200	(2)	..	..	..	..	..	..	0.34	..	...
300	(2)	..	..	..	..	..	..	0.52	..	...
375	(2)	..	..	..	..	..	..	0.68	..	...
					435° F.					
100	(2)	..	..	..	..	..	..	0.22	..	...
200	(2)	..	..	..	..	..	..	0.49	..	...
300	(2)	..	..	..	..	..	..	0.75	..	...
375	(2)	..	..	..	..	..	..	0.94	..	...
500	(2)	..	..	..	..	..	..	1.26	..	...
					500° F.					
100	Authors	0.45	0.38	0.31	0.32	..	..	0.39	0.02	+0.06 to −0.08
200	Authors	0.98	0.91	0.84	0.92	..	..	0.91	0.10	+0.07 to −0.09
300	Authors	1.24	1.23	1.28	..	..	..	1.25	0.01	+0.03 to −0.02
					600° F.					
100	Authors	0.68	0.61	0.68	0.62	..	..	0.65	0.01	+0.03 to −0.04
200	Authors	1.24	1.31	1.34	1.41	..	..	1.32	0.02	+0.09 to −0.08
300	Authors	2.05	2.06	1.98	1.94	..	..	2.01	0.02	+0.05 to −0.03
					650° F.					
100	Authors	..	..	..	..	..	..	1.40	..	...
115	Authors	..	..	..	..	..	..	1.63	..	...
120	Authors	..	..	..	..	..	..	1.68	..	...
125	Authors	..	..	..	..	..	..	1.74	..	...

[a] At standard temperature and pressure.

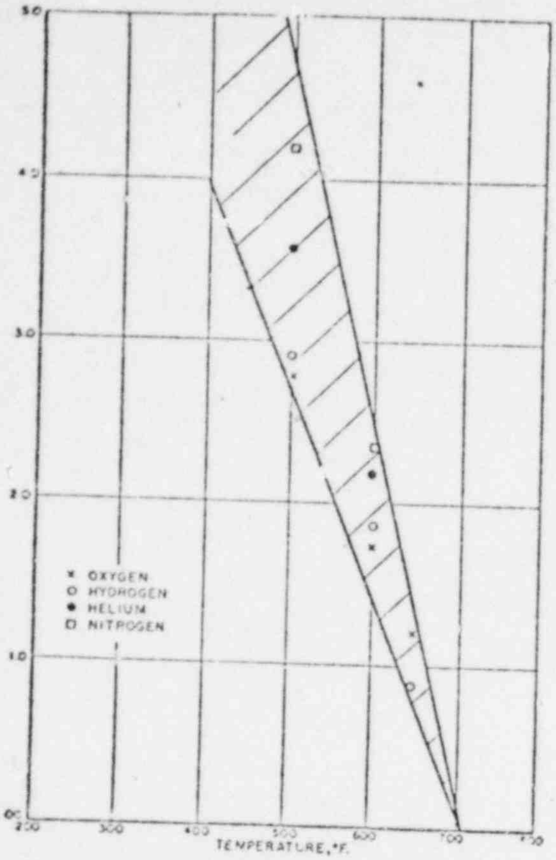

Figure 10. Solubility Constant versus Temperature near the Critical Point

Table IV. Solubility of Nitrogen in Water

N_2 Partial Pressure, Lb./Sq. In. Abs.	Source	Cc. N_2ᵃ/G. of Water			Average	Probable Error	Maximum Deviation
			77° F.				
294	(1)	..	..	..	0.28	..	...
367	(5)	..	..	..	0.35	..	...
588	(1)	..	..	..	0.55	..	..
			122° F.				
367	(5)	..	..	..	0.27	..	...
			167° F.				
367	(5)	..	..	..	0.25	..	...
			212° F.				
367	(5)	..	..	..	0.26	..	...
			500° F.				
150	Authors	0.47	0.43	0.41	0.44	0.01	+0.03 to −0.0
400	Authors	1.21	1.34	1.18	1.24	0.02	+0.10 to −0.0
			600° F.				
150	Authors	0.56	0.54	0.56	0.55	0.00	+0.01 to −0.0
300	Authors	1.56	..	..	..	..	...
400	Authors	2.40	2.29	2.26	2.32	0.02	+0.08 to −0.0

ᵃ At standard temperature and pressure.

Table V. Henry's Law Constant, K, for Various Gasesᵃ

Temp., ° F.	Gas, $K \times 10^{-4}$			
	Oxygen	Hydrogen	Helium	Nitrogen
32	..	..	20.40	...
75	..	11.0	...	...
77	6.56	..	21.75	13.20
122	..	..	...	16.60
125	..	8.72	...	...
167	..	..	18.10	18.60
212	..	..	...	18.00
300	..	9.30	...	...
325	8.00	..	8.04	...
345	..	8.34	...	...
390	..	6.98	...	...
400	6.56	..	...	...
435	..	4.98	...	...
500	2.77	2.90	3.56	4.18
600	1.74	1.86	2.20	2.38
650	1.22	0.885	...	...

ᵃ $K = \frac{P_A}{N_A}$, where P_A = partial pressure of gas, A, in pounds per square inch and N_A = mole fraction of gas, A, in solution.

and nitrogen are listed in Tables I, II, III, and IV, and are also shown graphically in Figures 1 to 9. The probable error shown in column 5 of the tables was calculated from the usual formula

$$\text{probable error} = 0.6745\sqrt{\frac{\Sigma\Delta^2}{n(n-1)}}$$

which gives an indication of the precision of the data, where $\Sigma\Delta$ = the arithmetical sum of the deviations and n = the number of measurements.

It is interesting to observe from the tables and graphs that the solubilities of these gases in water increase with increasing temperature, in the high temperature range, whereas it has been established that at temperatures in the region from about 20° to 200° F. the solubilities decrease with increasing temperature.

Within experimental accuracy, the solubilities of hydrogen, oxygen, helium, and nitrogen appear to be linear functions of pressure over the range investigated. The resulting straight lines (Figures 2, 4, 6, and 8) show that the solubilities in question follow Henry's law and may be predicted within the limits of engineering accuracy over a fairly wide range of temperatures and pressures from the Henry's law constants, which are listed in Table V.

Table III. Solubility of Helium in Water

He Partial Pressure, Lb./Sq. In. Abs.	Source	Cc. Heᵃ/G. of Water					Average	Probable Error	Maximum Deviation
				32° F.					
367	(4)	..	..	..	..	..	0.23	..	...
				77° F.					
367	(4)	..	..	..	..	..	0.22	..	...
				167° F.					
367	(4)	..	..	..	..	..	0.24	..	...
				325° F.					
100	Authors	0.20	0.20	0.19	..	..	0.20	0.00	+0.00 to −0.01
200	Authors	0.31	0.31	0.30	..	..	0.31	0.00	+0.00 to −0.01
300	Authors	0.39	0.37	0.37	..	..	0.38	0.00	+0.01 to −0.01
				500° F.					
100	Authors	0.42	0.38	0.42	0.38	0.40	0.40	0.01	+0.02 to −0.02
200	Authors	0.58	0.60	0.64	0.59	..	0.60	0.01	+0.01 to −0.03
300	Authors	1.36 1.15	0.13 1.07	0.62 0.87	0.81 1.03	0.57 1.03	.. 0.99	.. 0.05	... +0.37 to −0.37
400	Authors	1.31	1.41	1.32	1.47	..	1.38	0.03	+0.09 to −0.07
500	Authors	1.74	1.64	1.86	1.70	1.85	1.76	0.03	+0.10 to −0.12
				600° F.					
200	Authors	0.92	0.95	0.89	0.93	..	0.92	0.01	+0.03 to −0.04
300	Authors	1.64	1.61	1.70	1.66	..	1.66	0.01	+0.04 to −0.05
400	Authors	2.44 2.84	2.37 2.37	2.59 ..	2.31 ..	.. ..	.. 2.49	.. 0.05	... +0.35 to −0.18
500	Authors	2.72	3.12	3.07	3.23	2.82	2.99	0.06	+0.23 to −0.27

ᵃ At standard temperature and pressure.

At and above the critical temperature of water (705° F.), the gases must be infinitely soluble and the Henry's law constant must become relatively very small. The constants for the four gases in the region of the critical temperature are plotted in Figure 10. It is apparent that in this region the solubility constants tend to converge and approach very low values at 705° F., thus indicating that the data are consistent with the fact that the gases are miscible in all proportions at the critical point for water.

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Selection of Surface Active Agents for Detergent Applications

SUSPENDING POWER AND MICELLAR SOLUBILIZATION

A. M. MANKOWICH
Paint & Chemical Laboratory, Aberdeen Proving Ground, Aberdeen, Md.

SELECTION of surface active agents (surfactants) for specific metal cleaning applications is usually made on a trial and error basis, using laboratory detergency tests which have been correlated with field test results. Experience plus the fragmentary available information on such properties as molecular structure, type and chemical stability of surfactant, surface and interfacial tensions, and Draves and Clarkson sinking times (*2*) may be used as empirical screening media. It is imperative that all possible combinations of compatible types of surfactants be studied, since it is not possible at present to predict synergistic combinations. Builder action varies with type of agent and soil, which necessitates investigation of additional combinations. The development of a laboratory detergency test that can be correlated with field results is a problem. An obviously considerable amount of research must be performed even when only a limited number of surfactants are tested. This process has to be repeated for every detergent application in which the soil and/or substratum is varied.

The time-consuming, trial and error approach in determining the suitability of various surfactants for use in cleaning compounds intended for the removal of specific soils from specific substrata is viewed unfavorably in this laboratory. It is believed that the selection of surfactants for specific detergent applications can be accomplished more scientifically and economically by determining the fundamental or prime factors in the detergency process; studying each factor to establish numerical criteria for the various types of surfactants and builders under varying pH, concentration, and temperature conditions; and classifying soils with reference to the numerical values of the prime factors, obtaining cofactors (minimum numerical criteria for each prime factor necessary to accomplish soil removal in specific soil-surface combinations).

Once the prime factors for various types of surfactants and the cofactors for the soils are determined, an inspection of the data will indicate appropriate surfactants or combinations of surfactants, as well as suitable temperature, pH, concentration, and builder data. This is done by selecting the surfactant, or combination of surfactants, whose prime factors have equal or greater numerical ratings than the corresponding *cofactors*. The principle advanced is that detergency in a specific soil-surface application is accomplished only if the numerical ratings of all the cofactors are equaled or exceeded by the prime factors of the cleaning solution. The need for utilizing more than one surfactant for a specific detergency application will be readily apparent in those cases where an otherwise satisfactory agent is deficient in one or more prime factors. When it is necessary to select two or more surfactants, the maximum numerical rating for each prime factor of the combination is estimated by adding the respective ratings of the individual surfactants involved. Preliminary work indicates that the numerical rating of a prime factor approaches a definite maximum which is not exceeded, regardless of the number of surfactants combined for a specific detergent application. This maximum is usually the highest value attained by any of the individual surfactants investigated. However, additiveness of numerical ratings of a combination of surfactants is obtained until the maximum for the prime factors is reached. It is intended to cover the determination of cofactors and classification of soils and substrata in a later paper.

An advantage of the proposed method of selection is that it will indicate a number of surfactants or combinations of surfactants for each soil-surface application, thus permitting a final selection on an economic basis. No attempt is made to evaluate the relative importance of the various prime factors, and the method does not depend on such evaluation. The proposed method is not to be confused with the speculations (*21*) that detergency will eventually be calculated from a formula containing weighted physicochemical factors. Assuming that these speculations are realized eventually, they will not aid in the selection of surfactants for specific detergent applications. The formula will only give an index of detergency. The proposed method indicates the minimum physicochemical requirements for a detergent application, together with a number of surfactants or combinations of surfactants capable of meeting the requirements. It is important to realize that the proposed method indicates synergistic combinations of surfactants.

PHYSICOCHEMICAL FACTORS OF DETERGENCY

Present-day knowledge indicates that detergency is the resultant of many factors (*1, 12, 20, 22*). It is understandable, therefore, that attempts to correlate detergency with one factor only have been unsuccessful. Reich and Snell (*18*) emphasize a further error made in attempting to evaluate detergency with one factor. Detergency is dependent on three groups of variables (*12*): those originating in the soil, in the surfactant, and in the surface. A factor involving only one of the groups, such as surface tension, or two of the groups, such as micellar solubilization, is basically not in correlation with detergency.

MAY 2 1979

MAY 8 1979
1500

MEMORANDUM TO: Mr. Tom Crimmins
Three Mile Island
General Public Utilities
Trailer 11
Middletown, Pa. 17057

FROM: J. Edward Vivian
Professor of Chemical Engineering
Massachusetts Institute of Technology
Cambridge, Mass. 02139

SUBJECT: Hydrogen Degassing

DATE: April 17, 1979

In response to a telephone call from Donald Rockwell on April 7 asking me to consider the operating conditions which would expedite the degassing of hydrogen from the Primary System loop during cool-down this memorandum is submitted to you and confirms my comments to Mr. Rockwell by telephone on April 8.

This analysis is based on the description given to me of the Primary System loop and its interaction with the Pressurizer and the Let-down System. The simplified schematic shown in Figure 1 was assumed. It was also assumed that the high recirculation rate in the Primary System gave the equivalent of a well stirred reactor and that the overall system was in pseudo-steady state for the two cases analyzed, i.e. hydrogen generation rate equalled venting rate. No data on the geometry of the system were available by which to allow input-output rates and accumulation or depletion to be included in the analysis. However, the pseudo-steady state assumption serves to indicate the effect of system parameters on the hydrogen venting rate.

Solubility data for the hydrogen-water system for the high temperature region are given by Pray, Schweickert and Minnich (Ind. Eng. Chem. 44, 1146 (1952)). A copy of this reference is attached. Low temperature solubility data given by Lange: Handbook of Chemistry were also used to prepare the smoothed data on Henry's law constant given in Figure 2. Solubilities are expressed in milliliters of hydrogen at standard conditions per gram of water and pressures in lb/sq. in. absolute. The Henry's law constant varies widely with temperature but appears to be independent of pressure at a given temperature.

The two pseudo-steady state cases analyzed are based on data provided by telephone concerning the pressure at which nucleation in the core began to occur. The nucleation pressure is taken to be the same as the saturation pressure for the mixture of hydrogen and water. Case I is based on a nucleation pressure of 950 lb/sq. in. and core outlet temperatures of 300°F to 350°F. Case II is based on a nucleation pressure of 535 lb/sq. in. and core outlet temperature of 300°F. These data permit estimates of the hydrogen concentration in the Primary System. For Case I the concentration was calculated to be in the range of 1.15 to 1.22 ml/g H_2O (or an average of about 1.2 ml/g H_2O) and for Case II 0.61 ml/g H_2O. (Appendix A)

Because of the increase of hydrogen solubility with temperature above 200°F the effect of temperature on nucleation pressure is complex: at high hydrogen concentration increase in temperature lowers the nucleation pressure while at low concentration increase in temperature raises the nucleation pressure (Table I). Alternatively at high temperature and pressure the effect of change in solubility with temperature appears to reduce the effect of increase in vapor pressure of water.

An analysis of the Pressurizer venting system to remove hydrogen from the Primary System, within the assumptions indicated, is given in Appendix B. The calculations are summarized in Tables II and III to show the effect of venting rate and temperature (or pressure) in the Pressurizer. Since no information was available concerning the actual venting rate (either continuous or intermittent), the venting rate of steam with the hydrogen has been expressed as a fraction of the water supplied in the spray. The spray rate was assumed constant, and the indicated temperatures were assumed to be maintained by heat input to the Pressurizer. The relative hydrogen venting rate is given by the fraction of the constant spray water rate which is vented multiplied by the mols hydrogen per mole water in the vapor phase.

The calculations show that for both Case I and Case II at a given water vapor venting rate an increase in temperature (and pressure) reduces the hydrogen venting rate, although the effect is not large except at low venting rates. Thus unless other factors such as the effect of total pressure on the let-down rate indicate otherwise, the lowest feasible pressure to prevent nucleation in the Primary System appears to give the highest hydrogen purge rate through the Pressurizer vent for the assumed conditions.

The effect of temperature on vapor formation in the Let-down System is shown in Table IV for the reactor conditions assumed in Case II. Data on the geometry of the system were not available so that pressure drop considerations could not be included in the calculations. However, if it is assumed that the maximum mass discharge will occur with minimum vaporization in the system, the calculations indicate the advantage of cooling the let-down liquid before reducing the pressure significantly, even though the solubility of hydrogen decreases with decrease in temperature in the range above 200°F. These calculations are summarized in Table IV.

The Let-down System was assumed to discharge into a vented vessel at approximately atmospheric pressure (15 lb/sq. in. abs). The volume of vapor phase, v, generated in the system as the pressure is reduced at selected temperatures, (assuming essentially adiabatic conditions) has been expressed as ml vapor per gram water. These values may be interpreted to indicate approximately the volume of vapor flowing per volume of liquid at various locations in the Let-down System.

The calculations indicate that the residual hydrogen concentration in the liquid discharge decreases with increasing system temperature. However, the volume of vapor to be handled by the vapor venting system increases significantly with increase in temperature. At a Let-down system temperature of about 200°F there appears to be a reasonable balance between vent steam generation and hydrogen removal for Case II conditions.

Since my telephone conversation with Mr. Rockwell on April 8 Appendix C has been prepared to give a brief comparison of the relative venting rates of hydrogen by the Pressurizer vent system and by the Let-down System for conditions existing in Case II and an assumed Pressurizer vent rate (B = 0.01) and assumed spray and let-down rates. The venting rates appear to be the same order of magnitude for the conditions assumed.

J Edward Vivian

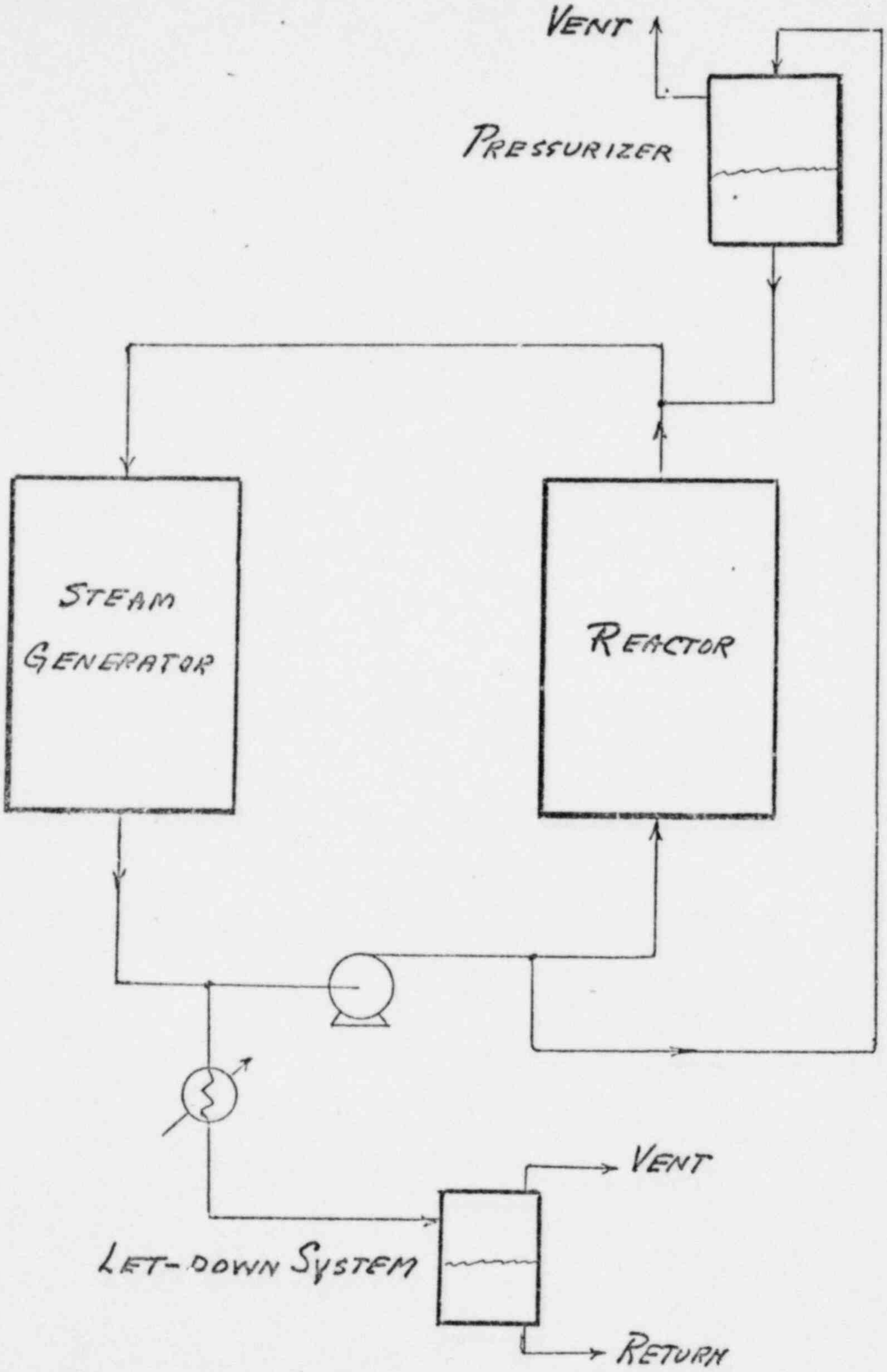
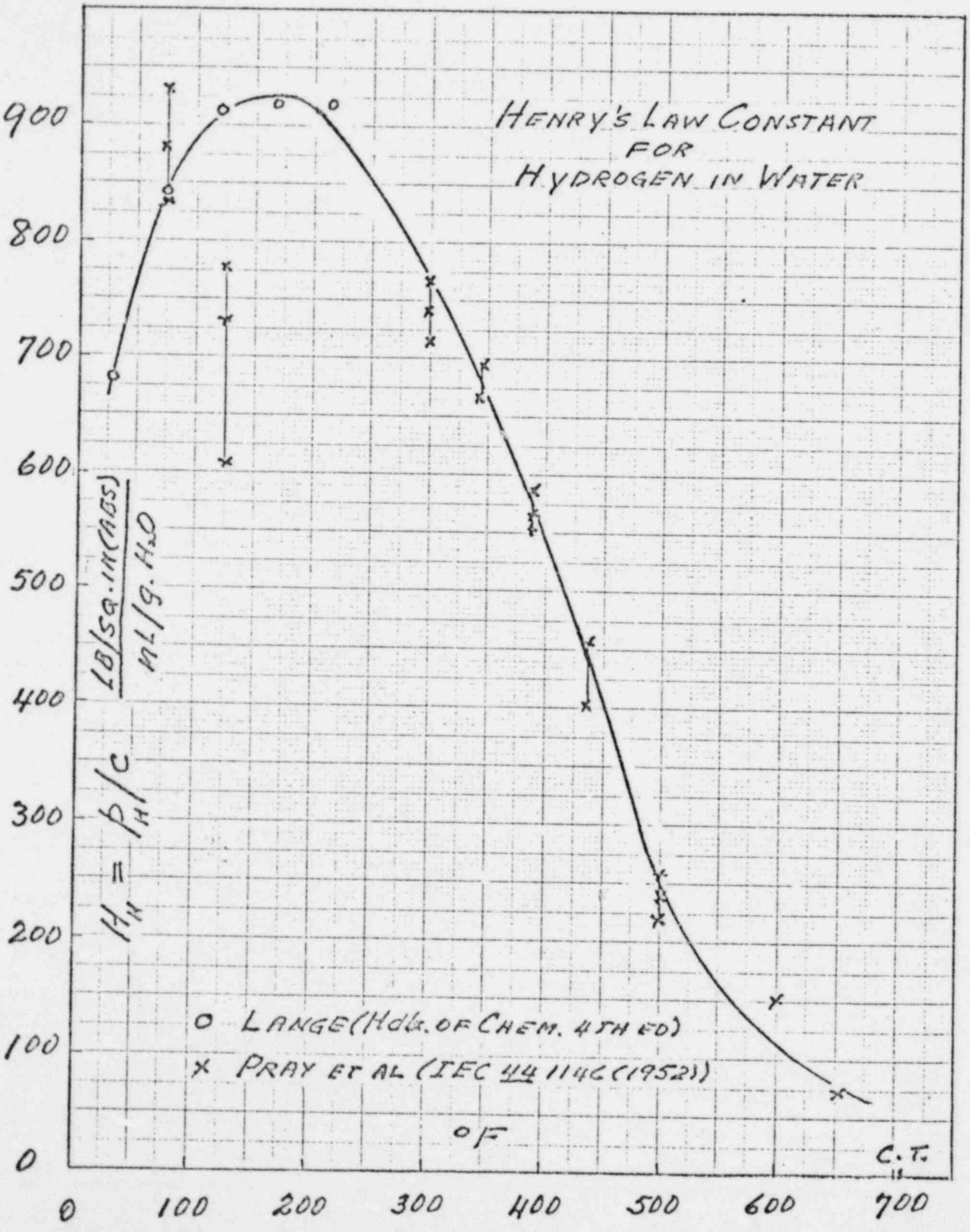

VENT
PRESSURIZER
STEAM GENERATOR
REACTOR
VENT
LET-DOWN SYSTEM
RETURN

FIG. 1

FIG. 2


HENRY'S LAW CONSTANT
FOR
HYDROGEN IN WATER
$H_H = p_H / c$
LB/SQ. IN. (ABS)
ML/g. H2O
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
°F
C.T.
o LANGE (Hdb. OF CHEM. 4TH ED)
× PRAY ET AL (IEC 44 1146 (1952))

APPENDIX A

Estimation of hydrogen concentration in Primary System

Operating conditions (Case I)

Core outlet temperature: 300°F to 350°F

Minimum pressure without nucleation: 950 lb/sq. in. abs.

At 300°F

Steam partial pressure: 67.0 lb/sq. in. abs.

Hydrogen partial pressure: 950 - 67 = 883 lb/sq. in. abs.

Henry's law constant: $H_H = 765$

Hydrogen concentration: $C = 883/765 = 1.15$ ml/g H_2O

At 350°F

Steam partial pressure: 135.5 lb/sq. in abs.

Hydrogen partial pressure: 950 - 135.5 = 814.5 lb/sq. in abs.

Henry's law constant: $H_H = 665$

Hydrogen concentration: $C = 814.5/665 = 1.22$ ml/g H_2O

Case I average hydrogen concentration: $C \sim 1.2$ ml/g H_2O

Operating conditions (Case II)

Core outlet temperature: 300°F

Minimum pressure without nucleation: 535 lb/sq. in. abs.

At 300°F

Steam partial pressure: 67.0 lb/sq. in. abs.

Hydrogen partial pressure: 535 - 67 = 468 lb/sq. in. abs.

Henry's law constant: $H_H = 765$

Case II hydrogen concentration: $C = 468/765 = 0.61$ ml/g H_2O

TABLE I

Effect of core temperature on nucleation pressure

(P = lb/sq. on. abs. and C = ml/g H_2O at STP)

T°F	H_H	P_W	P(at C=1.2)	P(at C=0.61)	P(at C=0.3)
280	800	49	1009	537	289
300	765	67	985	534	297
350	665	135	933	540	335

APPENDIX B

Hydrogen removal in Pressurizer vent

Assumptions:

(1) The liquid and vapor in the Pressurizer are in equilibrium (including the spray liquid after contact with the vapor).

(2) A fraction, B, of the inlet spray water is vented continuously as steam with the hydrogen.

(3) Steady-state conditions.

(4) Only hydrogen and water are present in the Pressurizer.

Let C_0 = concentration of hydrogen outlet liquid, ml/g H_2O

P = total pressure in vapor space, lb/sq. in. abs.

p_H = partial pressure hydrogen, lb/sq. in abs.

p_W = steam partial pressure, lb/sq. in. abs.

H_H = Henry's law constant, (lb/sq. in.)/(ml/g H_2O)

y = vent composition, mol fraction hydrogen

Then $P = p_W + p_H$

$p_H = H_H C_0$

and $y = p_H/P$

Vent composition, expressed as ml H_2/g H_2O at NTP

$$= \frac{(p_H)\ (22{,}400)}{(p_W)\ (18)}$$

$$= \frac{(H_H C_0)(1244)}{p_W}$$

Hydrogen balance around Pressurizer

(Basis: 1.0 g spray water)

APPENDIX B (cont'd)

$$C_s = (1244)B\ H_H\ C_0/p_W + (1.0 - B)C_0$$

where C_s = concentration of hydrogen in spray, assumed to be the same as in the Primary System.

B = water vented with hydrogen, expressed as a fraction of the spray water.

Solving for C_0 gives:

$$\frac{C_0}{C_s} = \frac{1.0}{[(1244)\ B\ H_H/p_W + (1 - B)]}$$

Calculations to show the effect of Pressurizer temperature and venting rate on hydrogen removal are summarized in Tables II and III.

The relative rates of hydrogen renting, given by the product of B and $y/(1 - y)$, are expressed in Tables I and II as $[B\ y/(1 - y)](10^3)$

TABLE II

Effect of Pressurizer Vent Rate and Temperature

Case I (C_s = 1.2 ml/g H_2O)

B	T	$\frac{C_0}{C_s}$	C_0	p_H	P	y	Relative H_2 Vent Rate
0.1	520	0.030	0.036	8	*820	0.010	1.01
	540	0.041	0.050	9	972	0.009	0.91
	550	0.049	0.059	10	1055	0.009	0.91
0.01	520	0.237	0.285	60	*872	0.068	0.73
	540	0.301	0.360	65	1027	0.063	0.65
	550	0.339	0.407	67	1112	0.060	0.64
0.001	520	0.757	0.908	191	1003	0.218	0.28
	540	0.812	0.974	175	1138	0.154	0.18
	550	0.837	1.004	165	1210	0.136	0.16
0	550	1.00	1.2	198	1243	0.159	0

* Below core nucleation pressure for assumed core temperature.

TABLE III

Effect of Pressurizer Vent Rate and Temperature

Case II (C_s = 0.61 ml/g H_2O)

B	T	$\frac{C_o}{C_s}$	C_o	p_H	P	y	Relative H_2 Vent Rate
0.1	460	0.010	0.0062	2	*469	0.0048	0.48
	480	0.015	0.0091	3	569	0.0048	0.48
	500	0.021	0.013	3	684	0.0047	0.47
	550	0.049	0.030	5	1050	0.0047	0.47
0.01	460	0.093	0.057	21	*488	0.043	0.45
	480	0.132	0.080	24	590	0.041	0.43
	500	0.180	0.110	27	708	0.039	0.41
	550	0.339	0.207	34	1079	0.032	0.33
0.001	460	0.507	0.309	113	580	0.194	0.24
	480	0.602	0.367	111	677	0.163	0.19
	500	0.687	0.419	105	786	0.133	0.15
	550	0.837	0.511	84	1130	0.074	0.08
0	500	1.00	0.61	153	834	0.183	0
	550	1.00	0.61	101	1146	0.088	0

* Below core nucleation pressure for assumed core temperature.

TABLE IV

Vapor Generation during Let-down

Let-down temperature: 300°F

P lb/sq. in. abs.	>535	500	300	100	15
* v ml/g H_2O	0	0.0026	0.030	0.390	~186
* c ml/g H_2O	0.61	0.560	0.305	0.043	4.8×10^{-6}

Let-down temperature: 200°F

P lb/sq. in. abs.	>570	500	300	100	15
v ml/g H_2O	0	0.0032	0.020	0.114	3.41
c ml/g H_2O	0.610	0.530	0.315	0.097	0.0038

Let-down temperature: 140°F

P lb/sq. in. abs.	>564	500	300	100	15
v ml/g H_2O	0	0.0025	0.0157	0.0933	0.891
c ml/g H_2O	0.610	0.540	0.323	0.105	0.013

v = actual volume of vapor, ml/g H_2O

c = dissolved hydrogen concentration, ml at STP per g water.

APPENDIX C

Comparison of vent rates (Case II)

Pressurizer vent rate

Spray rate (assumed) = 20 gpm (or 167 lb/min.)

Steam vent rate = B (167)

Assume B = 0.01

At 550°F: y = 0.032 (TABLE III)

$$\frac{\text{lb } H_2}{\text{lb steam}} = \frac{0.032(2)}{0.968(18)} = 0.00367 \text{ lb } H_2/\text{lb steam}$$

H_2 vent rate = (0.01)(167)(0.00367)(60)

= 0.37 lb H_2/hr.

Let-down vent rate

Flow rate (assumed) = 20 gpm (or 167 lb/min.)

Inlet H_2 conc. = 0.61 ml/g H_2O

$$= \frac{(0.61)(2)}{22400} \quad \frac{\text{lb } H_2}{\text{lb water}}$$

= 0.0000545 lb H_2/lb water

H_2 removal = 99% at 200°F (TABLE IV)

H_2 vent rate = (167)(0.99)(0.0000545)(60)

= 0.54 lb/min.

G/712-3.e-58

7 1979
1400

TASK CLOSE OUT DOCUMENT

Task Scope [illegible]

[illegible]

xc: RFW
RLong
JDaniel
DRMG
ADB. Asst.-GPU
File

To: M. Levenson
S. Levy
E. Zebroski

Task No. 13

Date Complete [illegible]

Reason felt task is complete:

[illegible]

Members of Committee

[illegible]

R. Christensen

[illegible]
Committee Chairman

5/5/79
Kolar

TASK 14 BORON AND GAS CONCENTRATIONS IN PRIMARY SYSTEMS

Problem:

Identify important factors in determining the boron and gas concentrations in the primary system in current mode of operation. (i.e. natural circ on "A", "B" stratified.)

Boron Concentration:

1) Make-up line enters primary system on discharge side of RCP 1B. Flow splits with part going into "B" steam generator and part going into Reactor Vessel.

2) Boron could be concentrating at Bottom of "B" steam generator if Tcold B is less than the make-up temperature.

3) Boron in pressurizer is concentrating because of low (or zero) flow out of pressurizer into coolant lines and because of steaming in pressurizer.

4) Let-down line comes off of suction side of RCP 1A. As long as there is natural circulation in "A" loop, boron concentrations measured from the let-down flow is representative of boron concentrations in core. However, if natural circulation on "A" loop is lost, it will be very difficult to interpret the results of boron concentration measurements. Depending on the mode of cooling, the measurements could be completely unreliable. In that case [illegible] operation would be the preferred alternative method of operation.

Gas Concentration:

1) Gas in make-up system should be reduced by degassing make-up water.

2) If local boiling occurs in the core, gas can be released. The gas content measured in the let-down line sample will be subject to the same uncertainties as the boron concentration.

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Rcvd 5/8/79
1943

copy
FILE

8 May 1979

To: R. A. Ambrosino

From: P. W. Marriott

Subject: THOUGHTS ON REDUCING PRESSURE TO ONE ATMOSPHERE AT TMI-2

Per your request, here are some further thoughts on reducing pressure to one atmosphere (earlier thoughts were sent to Rockwell on April 10).

Desirable Features of Cooling Mode

(1) Remove decay heat in any of four ways:

- natural circulation to OTSG
- RHR operation
- pot boiling to containment via pressurizer
- reflux boiling to OTSG

(2) Minimize chance of core mechanical disruption

Another feature thought previously to be desirable for its own sake is avoidance of local boiling. It will be shown that local boiling may be a minor concern.

Removal of Decay Heat. Natural circulation may not persist indefinitely at one atmosphere without degassing because, assuming some local boiling in the core, a noncondensible bubble may form at the top of the hot leg candy-cane.* It is possible that noncondensibles stripped out by local boiling would go back into solution, depending on the extent of local boiling. The uncertainty could be avoided by installing a system which would degas primary coolant from one atmosphere (vacuum degasser). Given this, natural circulation will remove heat from the core indefinitely as long as the steam generator is cooled. So if the coolant can be kept degassed, there is no need to depart from natural circulation even at atmospheric pressure.

RHR operation will probably give dependable core flow. How much core flow is uncertain, because due to the higher-than-normal core resistance there will be more backflow in the steam generators than in normal RHR operation. We suggest that RHR operation be calculated, now that the core resistance can be inferred, before it is attempted.

---

* It is noted that degassing will also be needed while pressure is being reduced due to the lower solubility of noncondensibles at lower pressure.

Pot boiling and reflux boiling are modes of last resort. Either mode seems feasible, but both are subject to considerable uncertainty, and calculations are needed. Reflux boiling should work at one atmosphere even with some noncondensibles present, but some degassing is necessary and stability is of concern. With pot boiling and steaming out the pressurizer, noncondensibles should not matter. However, in pot boiling it may not be possible to attain one atmosphere for some time due to the small size of the pressurizer relief valve; and whether it will work at all without uncovering the core due to the loop seal in the pressurizer surge line has yet to be evaluated.

Avoidance of Mechanical Disruption of Core. The uncertain condition of the core makes it desirable to avoid pressure or flow surges or other mechanical movement. Natural circulation is best. RHR is not greatly different from natural circulation except for the startup transient. The RHR startup transient could be accomplished gently by slowly opening the injection valve: in any event, it is hard to see why it would be more severe than when primary coolant pump 2A was started on April 6, which (apparently) had no ill effects. Reflux boiling is quite uncertain at least until calculations are done, because it is possibly very susceptible to flow and pressure surges. Pot boiling, though probably gentle mechanically, is yet to be evaluated for its feasibility.

Local boiling in the core may cause some potential for rearrangement of core fragments due to bubble formation. This is the best reason to avoid local boiling, but it is now well to consider how important it is.

Avoidance of Local Boiling. The criterion for subcooling (ref. IAS memo #IA-21, [illegible]) has been for T_{hot} (bulk) to be at least 100F subcooled. At the current core ΔT of 13F, this would require the cold leg temperature to be 212-100-13 = 99F, which sounds attainable given the new water/water secondary side heat exchange equipment. But core exit TC #H9 has consistently been about 135F over T_{hot} since natural circulation was attained on April 27, and this difference ($T_{H9} - T_{hot}$) does not seem to be decreasing like the other "hot spots." The ($T_{TC} - T_{hot}$) values in the others, for reasons unknown, have been falling fairly consistently, approximately as the square root of core power. At this rate, it would take several months for the next hottest TC (#H8) to reach 100F subcooling at one atmosphere. Thus at one atmosphere some local boiling appears to be inevitable, even if only in a few locations.

The effect of local boiling on heat transfer would probably not be of concern. This is certainly true for intact rods, and can be examined using scoping arguments for loose pellets. On July 1, when core power is down to 1.0 MW, the average power per fuel pellet will be about 0.1 watt. Assuming the pellets are still intact (or even fragmented into fairly large fragments) it is hard to imagine a geometry in which 0.1 watt per pellet could not be dissipated as long as the core region is entirely full of water (0.1 watt is about 0.0001 B/sec, which means that if pellet cooling were entirely by vaporization, about 10^{-7} lb/sec of water, certainly a miniscule amount, would have to find its way into the vicinity of each pellet). The vapor formation per pellet would be equivalent to about 10 bubbles of 0.1 inch diameter per second even if all the cooling were due to vaporization, which it would not be except perhaps in extremely obstructed regions. To check the significance of this semi-quantitatively, it would take about 1000 of such bubbles clinging to a pellet to lift it in water. The surface area of a pellet is such that less than 100 such bubbles could form on the pellet surface. The pellets could also be disturbed by rising bubbles from lower pellets. However, a typical bubble rise velocity in stagnant water is about 1 ft/sec. Average flow velocity of subcooled liquid with one circulation pump running (a condition the core is known to be able to withstand) is about 4 ft/sec, and it would require at least 4 ft/sec to suspend a pellet in flowing subcooled water. Thus the chance of disruption due to rising bubbles seems small. These arguments (which, though numerically stated, are really only qualitative) suggest that local boiling does not pose much of a problem as far as core mechanical disruption is concerned.

In summary, the one real concern due to local boiling is exaggerated formation of nondissolved gases, which could threaten natural circulation or reflux boiling if degassing of primary coolant is not possible.

These thoughts suggest that operation at one atmosphere after July 1 would not be undesirable. There is, of course, no clear cutoff date; similar arguments could be made for operating at one atmosphere now, particularly with RHR in service. The biggest advantage in waiting a month or two is to see what the core exit thermocouples do in that time. And as suggested in my April 10 memo, the core exit TC's could be monitored carefully during the depressurization for evidence of sudden increases, which would suggest the incidence of local boiling.

I hope these thoughts are useful in assisting in a decision on the end-point pressure and the timing of depressurization.

P. W. Marriott, Chairman
Three Mile Island Task Force
M/C 184 Ext. [illegible]

/blm

cc: DC Dilmore
CC Dix
LE Nesbitt
M Siegler
FF [illegible]
DR Wilkins/FD Judge

To [illegible]
GE @ TMI-2

MAY 9 1979

Notes from Telecon with PW Marriott 2pm
on two phase flow volume swell"
for boiling at TMI-2

Assume: 2.7 Mwth, Nat. circ.
150°F cold leg temp

The following is a manometer imbalance problem results summary with boiling in the hot leg.

Hot leg level	Cold leg level (S.G.)	
	14.7 psia	100 psia
Top of active fuel	19.6'	23'
surge line level	23.0'	29.0'
top inside of candy cane	31.0'	45'

cc RFW
RWK
JAD
RL
DEMB
GAU on site Tech Sup.
Stoudt/File

Notes by
DA [illegible]

[illegible]

GE @ TMI-2

4/21/79

Notes from Telecon with PW Marriott on two phase flow volume swell for boiling at TMI-2

Assume: 2.7 Mwth, Nat. circ.
150 °F cold leg temp

The following is a manometer balance problem results summary with boiling in the hot leg

Hot leg level	Cold leg level (ft in SG)	
	14.7 psia	100 psia
Top of active fuel	19.6'	23'
ir surge line level	23.0'	29.8'
[illegible] inside of candy cane	31.0'	43'

Notes by
DJ [illegible]

1

G/7/2-3.e-60

PICKARD, LOWE AND GARRICK, INC.
1200 18TH STREET, N. W., SUITE 612
WASHINGTON, D. C. 20036

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WASHINGTON, D. C.
TELEPHONE 202 296-8633

IRVINE, CALIFORNIA
TELEPHONE 714 752-2596

May 8, 1979

Mr. John Potman
Three Mile Island
Box 480
Middletown, Pennsylvania - 17057

Dear Mr. Potman:

I found that I have the original of the attached copy of bubble calculations. I thought a copy should probably be in your collection.

Very truly yours,

William W. Lowe

:jam

HOW TO FIND REACTOR VESSEL BUBBLE VOLUME

3/30/79 2:45A
WR.

①

$$P_1 V_1 = P_2 V_2$$

A

3A'd numbers
373"
326"
875 PSIg
951 PSIg,

$P_1 = 860$ PSIG $+ 15 = 875$ psia
$P_2 = 955$ psig $+ 15 = 970$ psia
$V_1 - V_2 = (373^{in} - 325^{in})\,3.2\ ft^3/in$
$V_1 = (373-325)\,3.2 + V_2 = 153.6\ ft^3 + V_2$

At 12:45P 3/~~29~~30/79

~~$P_1 V_1$~~

~~$P_1\left[(373-325)\,3.2 + V_2\right] = P_2 V_2$~~

~~$V_2 = \frac{860}{955}\left[(373-325)\,3.2\right.$~~

$(875)(153.6 + V_2) = 970\,V_2$

$\overset{134400^*}{\cancel{132096}} + 875\,V_2 = 970\,V_2$

$\overset{134400^*}{\cancel{132096}} = 95\,V_2$

$V_2 = \overset{1414.7^*}{\cancel{1390}}\ ft^3$ at $P_2 = 970$ ~~psig~~ psia (280°F)

~~970~~
~~875~~
~~94~~

Pressurizer Volume @ 7' Dia

$A = \pi r^2 = \frac{3.14\,(7')^2}{4} = \frac{153.86}{12 \times 4}\ ft^3/ft = \frac{12.8}{4} = 3.2\ ft^3/in$

Makeup Tank Changed 30 gal/inch 52-38

$\frac{30\ gal}{inch} \times (52-38) = \frac{420\ gallons}{7.48\ gal/ft^3} = 56\ ft^3$

$V_2 = \overset{1414.7^*}{\cancel{1390}} + 56 = \overset{1471^*}{\cancel{1446}}\ ft^3$

(15CC/Kg) of H_2 in normal coolant.

* Refined correction made ~ 4/1/79 10PM

ur

Joe:

②

B+W reports Reactor Vessel Volume Above nozzle: free Volumes (Don Nitty & Jim Taylor)

Upper head = 560 ft³ 650 / 1"
R.V. Upper Plenum 411.
R.V. Outlet 158
1129 ft³ free Vol.

Procedure for Reducing gas bubble in Reactor Vessel head,

$Zr + H_2O \rightarrow ZrO_2 + \overrightarrow{H_2}$

100 000 ft³

$\frac{970\ psi}{15\ psi} \times 1446\ ft^3 = 93{,}508\ ft^3$ STP of H_2

$93{,}508\ ft^3\ H_2:STP \times \frac{mole}{\overset{459}{356}\ ft^3} \times$ [illegible] $= 203$ lb Moles

203 lb Moles of Zr. $\times \frac{119\ lb\ Zr}{lb\ Mole} = 24{,}157 = $ 12 Tons

$\frac{22.4\ l}{gm\ mole} \times \frac{454\ gm}{lb} \times \frac{.035\ ft^3}{l} = 356\ ft^3/lb\ mole$

Clad = 20 mils = .020" = 2×10^{-3} ft. thick
= 10^{-1} ft. wide
= 12 ft. long
= $2 \times 10^{-3}\ ft^3$/rod.

$\frac{200\ lb}{ft^3\ Zr} \times 2 \times 10^{-3} \frac{ft^3}{rod} \times .4$ lb/rod.

$\frac{24{,}000\ lb}{.4} = 60\ 000$ rods ? Note: H_2 explosion

---

[illegible] 177 × 208 = 36,816 rods

Bubble has to be H_2. Vent out per using Sprays. Use let down max extent. w/o over free [illegible] [illegible]

3:30 PM
③

Second try

$P_1 = 1065$ psig $= 1080$ $P_2 = 1081 = 1096$ $= +16$ lbs

$V_1 = 356.2''$ $V_2 = 352.3$

$(356.2-352.3)\,3.2\ \text{ft}^3/\text{in} = 12.48\ \text{ft}^3 = V_1 - V_2$ $V_1 = 12.48 + V_2$

$1065 V_1 = 1081 V_2$

~~$V_1 = \frac{1081 V_2}{1065} = 1.0150234$~~ $V_1 = 12.48 + V_2$

~~$\frac{1065 \times 1.0150234}{1081} = V_2$~~

$1065(12.48 + V_2) = 1081 V_2$

$13291 + 1065 V_2 = 1081 V_2$

$13291 = 16 V_2$

$V_2 = 830.69$

$V_1 = 830.69 \times \frac{1081}{875} = 1026\ \text{ft}^3$ at 1081 psig

$P_1 V_1 = P_2 V_2$

$V_1 - V_2 = \Delta V$

$V_2 = V_1 - \Delta V$

$P_1 V_1 = P_2 (V_1 - \Delta V)$

$$V_1 = \frac{P_2 \Delta V}{P_1 - P_2}$$

$$V_2 = \frac{P_1 \Delta V}{P_2 - P_1}$$

$$\Delta V = \frac{(P_2 - P_1) V_2}{P_1}$$

$\Delta V = \frac{1096}{1080} \times 352.3 - 352.3 = 5.2$

w File

Inter-Office Memorandum

6/712-3.e-61

GPU Service

Date May 14, 1979

Subject TDR-TMI-104: PRIMARY SYSTEM GAS ANALYSES

To T. G. Broughton

Location Hartz Building

Enclosed is a collection of reports, memos, correspondence, etc. regarding the TMI-2 primary system gas analyses. This collection was assembled by Bob Ryan, a Combustion Engineering staff member temporarily assigned to the GPU Technical Planning Group. In addition to this material, J. Moore's 3-ring "Bubble Notebook" is on file in the TMI-2 Data Reduction and Management Center. Jerry Weiser is making a copy of the notebook which will be delivered to Parsippany in the next day or two.

The collection of material is probably not complete, but I hope it will serve as a basis for starting on TDR-TMI-104.

R L Long

R. L. Long
Manager - Generation Productivity

RLL:g
Enclosure
cc: w/o encl.
R. W. Keaten
R. F. Wilson

6/712-3.e-62

Jim
RFW wants us
to use TDR format
where possible, i.e.
1. Purpose & Summary
2. References
etc per EP-001.
RLL

OUTLINE
TDR-TMI-104

PRIMARY SYSTEM GAS ANALYSES

Outline in preparation by J. Moore.

Suggestions as to content and approach to presentation are welcomed.

Jim Moore,

I have a copy of Bill Lowe's original H_2 calculations on the way. Will get you a copy [illegible].

RLLong

Should exclude Containment bldg gas analyses – but should probably contain cross reference to TDR-TMI-107 (G. Capodanno).

From RFW
- include all early work on bubble analyses
- gas solubilities
- degassing info.
- etc
- coolant gas analyses

NOTE: TDR-TMI-103 will have brief discussion of primary system gas analyses w/ cross reference to -104. Effort should be made between J. Moore and G. Bond to be certain that information in each TDR is consistent.

RLL
6/5/79

From MetED 5/15/79 submittal to NRC

3.5 HYDROGEN EVALUATION

METAL-WATER REACTION WITH THE FUEL CLADDING GENERATED LARGE QUANTITIES OF HYDROGEN DURING THE INITIAL PHASES OF THE TMI-2 INCIDENT ON MARCH 28, 1979. THIS HYDROGEN FORMED A BUBBLE WHICH BECAME TRAPPED IN THE HEAD OF THE REACTOR VESSEL. THE LARGE QUANTITY OF HYDROGEN IN THE BUBBLE PRODUCED A HIGH PARTIAL PRESSURE WHICH CAUSED THE REACTOR COOLANT TO BECOME SATURATED WITH HYDROGEN. AFTER THE BULK OF THE BUBBLE WAS REMOVED ON APRIL 1, THE COOLANT REMAINED SATURATED WITH 1300 TO 1400 STD. CC OF HYDROGEN PER KILOGRAM OF COOLANT. EXTENSIVE DEGASSING OF THE REACTOR COOLANT DURING THE TIME PERIOD FROM APRIL 2 THROUGH APRIL 12 HAS SIGNIFICANTLY REDUCED THE CONCENTRATION OF DISSOLVED HYDROGEN. THE ANALYSIS OF A PRESSURIZED SAMPLE OF REACTOR COOLANT TAKEN ON APRIL 25, 1979 SHOWED THE FOLLOWING DISSOLVED GAS CONTENT:

HYDROGEN	41.6	STD. CC/Kg
NITROGEN	4.6	STD. CC/Kg
TOTAL	46.2	STD. CC/Kg

A SMALL PORTION OF THE ORIGINAL GAS BUBBLE BECAME TRAPPED IN THE CONTROL ROD DRIVE MECHANISMS (CRDMs) AND HAS NOT READILY DISSOLVED INTO THE REACTOR COOLANT. DURING THE PERIOD FROM APRIL 1 THROUGH APRIL 12, MUCH OF THE TRAPPED HYDROGEN WAS REMOVED FROM THE CRDMs BY CYCLING THE REACTOR COOLANT SYSTEM PRESSURE TO PROGRESSIVELY LOWER PRESSURES, REACHING A MINIMUM PRESSURE OF 300 PSIG. THESE PRESSURE REDUCTIONS EXPANDED THE GAS TRAPPED IN THE CONTROL ROD DRIVES AND ALLOWED THE GAS TO BE ENTRAINED IN THE RC FLOW. THE AC NOISE SIGNALS ON THE

REACTOR COOLANT PRESSURE TRANSMITTERS CONFIRMED THAT BUBBLES WERE INDEED RELEASED EACH TIME THE PRESSURE REACHED A NEW LOW. THEREFORE, IT IS CLEAR THAT, AT PRESSURES ABOVE 300 PSIG, THE GAS WILL BE COMPRESSED BACK INTO THE CRDMs.

THE 46.2 CC OF GAS PER KILOGRAM OF REACTOR COOLANT CAN EXERT A MAXIMUM PARTIAL PRESSURE OF 74 PSI REGARDLESS OF THE COOLANT TEMPERATURE OR THE RELATIVE AMOUNTS OF HYDROGEN AND NITROGEN IN THE GAS MIXTURE. THEREFORE, ANY PRESSURE GREATER THAN 74 PSI ABOVE THE VAPOR PRESSURE OF WATER WILL KEEP ALL THE GAS IN SOLUTION. IF ALL THE GAS IN THE CRDM WERE TO DISSOLVE INTO THE COOLANT, IT WOULD INCREASE THE PARTIAL PRESSURE OF GAS BY A MAXIMUM OF 138 PSI. IF IT WERE TO BE ASSUMED THAT HALF OF THE FUEL RODS STILL CONTAINED THEIR PRE-PRESSURIZATION GAS AND STABLE FISSION GASES, FAILURE OF THESE FUEL RODS COULD INCREASE THE PARTIAL PRESSURE OF THE GAS BY 88 PSI. FIGURE 3.5-1 SHOWS A PLOT OF THE COMBINATION OF THESE THREE PRESSURES WHICH ACCOUNT FOR ALL THE GAS KNOWN TO BE IN THE REACTOR COOLANT SYSTEM. FIGURE 3.5-1 ALSO SHOWS THE AMOUNT OF MARGIN NEED TO ACCOMMODATE MAKEUP REQUIREMENTS AND RADIOLYTIC GAS GENERATION FOR ONE WEEK. THE MAKEUP RATE WAS ASSUMED TO AVERAGE 1 GPM AND WAS ASSUMED TO BE SATURATED WITH AIR AND TREATED WITH 20 PPM HYDRAZINE TO REMOVE THE OXYGEN. EVEN THOUGH NO NET RADIOLYTIC GAS PRODUCTION IS EXPECTED IF THE COOLANT IS DEOXYGENATED AND 5 TO 15 STD. CC OF H_2 REMAIN DISSOLVED IN THE WATER (REF. 1). FIGURE 3.5-1 ALLOWS MARGIN FOR A WEEKS BUILDUP OF RADIOLYTIC GAS PRODUCTION, USING A G-VALVE OF 0.025 HYDROGEN ATOMS PER 100 EV OF

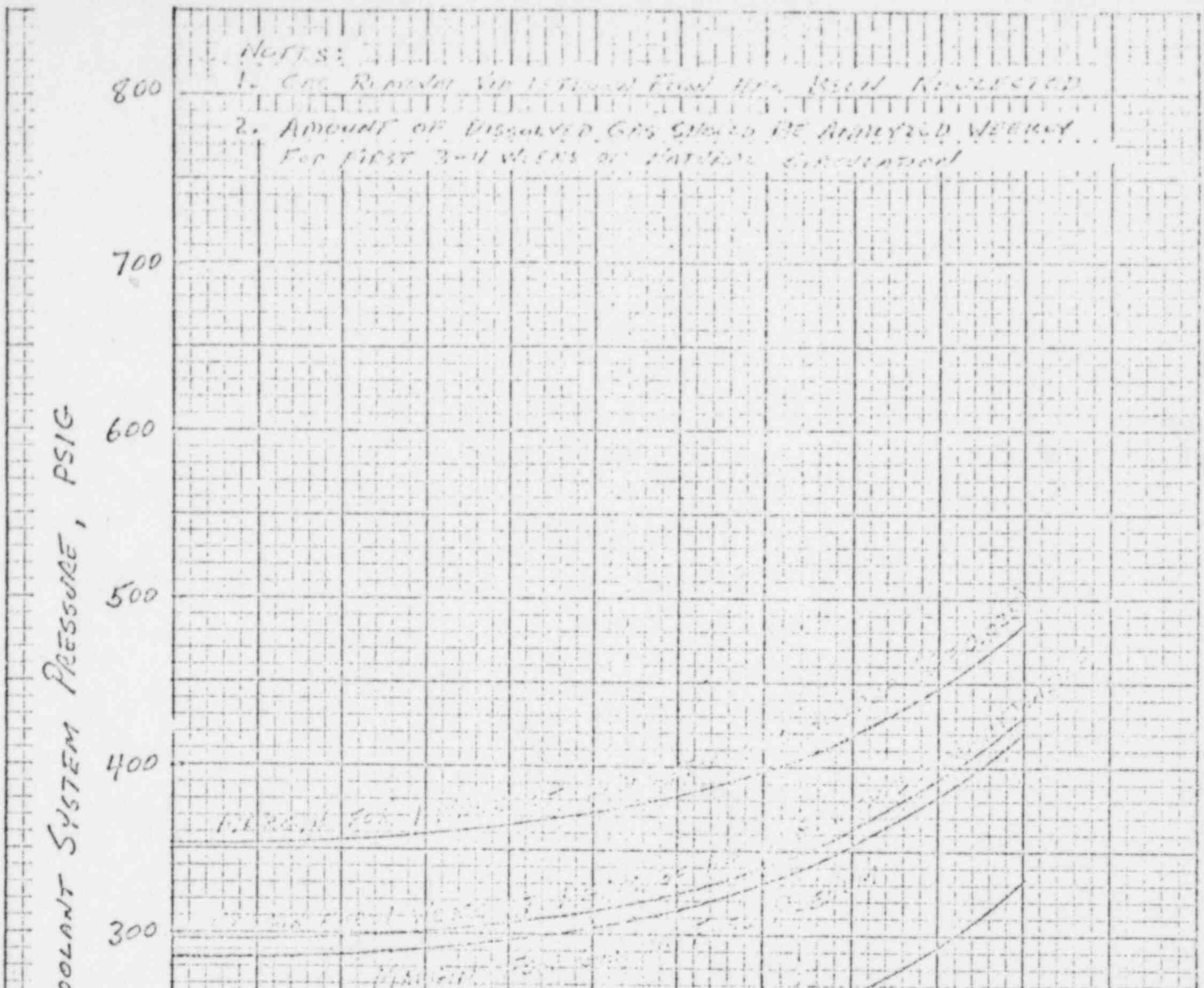
ABSORBED IRRADIATION. AN ADDITIONAL MARGIN INCLUDED IN THE MINIMUM PRESSURE CURVES SHOWN IN FIGURE 3.5-1 IS THAT THE AMOUNT OF GAS REMOVED FROM THE SYSTEM WITH COOLANT LETDOWN AND LEAKAGE WAS NEGLECTED AND AT HIGH DISSOLVED GAS CONCENTRATIONS AMOUNT TO A SIGNIFICANT REMOVAL RATE.

PERIODIC ANALYSIS OF REACTOR COOLANT SAMPLES WILL PROVIDE A DIRECT MEASURE OF THE GAS CONTENT OF THE COOLANT AND WILL PROVIDE THE BASIS FOR REDUCING SOME OF THE CONSERVATISM.IN FIGURE 15.3-1 THUS PERMITTING FURTHER PRESSURE REDUCTIONS.

REFERENCES:

1. WATER COOLANT TECHNOLOGY OF POWER REACTORS, BY PAUL COHEN, GORDON AND BREACH SCIENCE PUBLISHERS OF NEW YORK, 1969.

REQUIRED TO KEEP GASES FROM FORMING BUBBLES



NOTES:

1. GAS REMOVAL VIA LETDOWN FLOW HAS BEEN NEGLECTED
2. AMOUNT OF DISSOLVED GAS SHOULD BE ANALYZED WEEKLY FOR FIRST 3-4 WEEKS OF NATURAL CIRCULATION

STANDARD NO.: EP-001

ORIG. ISSUE DATE: 8/1/78

PAGE 1 OF 11

TITLE

PREPARATION OF TECHNICAL DATA REPORTS

REVISION	DATE	DESCRIPTION	APPROVAL
1	12/7/78	Basic reformat, clarification of format and how distribution is handled.	Rw
2	3/27/79	Added requirement for interfacing section review.	Rw 3/27/79

PREPARATION R.W. Keaton 12/12/78 DATE

AUTHORIZATION J.A. Daniel 12/13/78 DATE

APPROVAL 12/13/78 DATE

322 002A

CONTENTS

I PURPOSE AND SCOPE

A. This procedure establishes the methods for preparation and control of Technical Data Reports (TDR's).

TDR's consolidate and record results and conclusions generated in technical studies (e.g., trade studies, plant performance evaluations, plant transient analyses, material selection studies, nuclear fuel cycle options, economic evaluations, safety studies, evaluations of operating plants, and failure analyses, etc.) and summarize their impact on overall plant design, operating plant recommendations or input to baseline documents (e.g., plant criteria, SDD, tech specifications).

II APPLICABILITY

This procedure applies to activities performed by all departments within the Technical Functions Group, Generation Division.

III REFERENCES

EP-006 "Preparation, Documentation & Control of Calculations"
EP-016 "Records Retention and Control"

IV DEFINITIONS

Refer to "Glossary of Engineering Terms"

V PREPARATION of TDR's

A. Requirements

Each TDR shall:

1. Comprise a written document, prepared in accordance with the format as discussed in B below.
2. Be assigned a unique document number from Engineering Standards.
3. Be distributed by the Responsible Engineer and the master filed by the Engineering Standards Manager.

B. Format

1. Page 1

The first page of every TDR shall be the cover sheet shown in Appendix A. If additional pages are required, the numbering shall be 1a, 1b, 1c, etc.

The cover sheet shall be typed and include the following technical information in the abstract:

a. Brief statement of problem
b. Summary or Key Results
c. Conclusion
d. Recommendations

The Responsible Engineer(s) who prepared the TDR shall sign and date the document in the space provided on the cover sheet.

2. Revision Page

The page following the abstract shall be as shown in Appendix B. A brief description of each revision including page numbers shall be given and approval of the revision shall be signified by the initials of the Responsible Engineer and the Responsible Engineer's Manager. The revision pages shall be numbered page i, ii, etc.

3. Table of Contents

The next page of each TDR shall be a Table of Contents. A suggested format is as follows:

1. Purpose & Summary
2. References

3. Methods
4. Evaluation
5. Results
6. Conclusions
7. Recommendations
8. Appendices

The format may be modified as necessary to suit the particular subject being addressed. However, the above format should be used whenever possible.

4. Subsequent Pages

All pages shall be sequentially numbered, starting with 2.

a. Discussion of Major Headings

(1) Purpose & Summary

This section clearly states the purpose of the TDR and a summary of what the report covers and how the material is used within the Report. Initials and acronyms to be used in the text such as HWR (Heavy Water Reactor) shall be identified the first time it occurs in the text.

(2) References

References such as Documents, Specifications, Drawings, Codes, Standards, Calculations, Texts, Reports, Computer Data and Equations shall be clearly noted to identify the source of the particular statement or formula. The reference shall be identified as to number, title, edition, date, volume, page or figure number, publisher, and revision number as appropriate.

Each reference in the list shall be consecutively numbered. The text of the Report shall indicate by reference No. the reference document for a particular operation or set of data. Where extensive referencing of pages in one document is required, page numbers shall be part of the text reference and shall not be shown in the Reference Listing.

(3) Methods

The Methods section shall clearly indicate the sequence of steps that have been used such that a competent Engineer can trace the analysis process without recourse to the originator.

(4) Evaluation

All significant sections of the material or referenced material should be highlighted.

(5) Results

All calculations and computer printouts upon which the results were based should be referenced. Extensive calculations shall not be reported in a TDR (see EP-006) but rather referencing to such documents using their results and conclusions to substantiate the point of the TDR. Graphs, tables, charts, etc. should be used and included to support the results, conclusions and/or recommendations generated by the TDR.

(6) Conclusions

State the conclusions reached based on the results.

(7) Recommendations

State any recommendations made based on the conclusions.

(8) Appendices

Appendices should be attached which serve to make the meaning of the report explicitly clear.

C. Directions to Prepare a TDR
(Refer to Procedural Flow Diagram Appendix C)

RESPONSIBLE ENGINEER	The Responsible Engineer prepares the draft according to the format described in this procedure, obtains a TDR number from the Engineering Standards Manager, and forwards the TDR to his Manager and affected Section Managers for support or review.	2
ORIGINATING SECTION MANAGER	The Responsible Engineer's Manager reviews the draft to insure that the TDR is technically sound and meets the requirements of this procedure. He may, at his discretion, request review by others.	2
RESPONSIBLE ENGINEER	The Responsible Engineer resolves comments and obtains the concurrence signature of his Section Manager.	2

RE SECTION MANAGER	Reviews final TDR to insure that all comments were resolved and proper distribution is evident. The TDR is signed indicating approval for internal GPUSC distribution and forwarded to Engineering Standards Manager.
DIRECTOR OF TECHNICAL FUNCTIONS	The Director of Technical Functions authorizes distribution outside of GPU by his approval signature in the appropriate block on the cover page.

VI RESPONSIBILITIES

A. Director of Technical Functions

° Authorizes Distribution Outside of GPUSC

B. Responsible Engineer's Manager

° Assigns Responsible Engineer
° Reviews and Approves TDR
° Establishes Distribution

C. Responsible Engineer

° Prepares TDR
° Obtains TDR Number
° Signs TDR as Responsible Engineer
° Arranges for Typing
° Obtains Approval from Section Manager.

D. Engineering Standards Manager

° Issues TDR Numbers
° Files Originals

VII REVISIONS

1. The first issue of the approved TDR shall be identified as Revision 0. Subsequent revisions shall be identified in ascending numerical sequence.

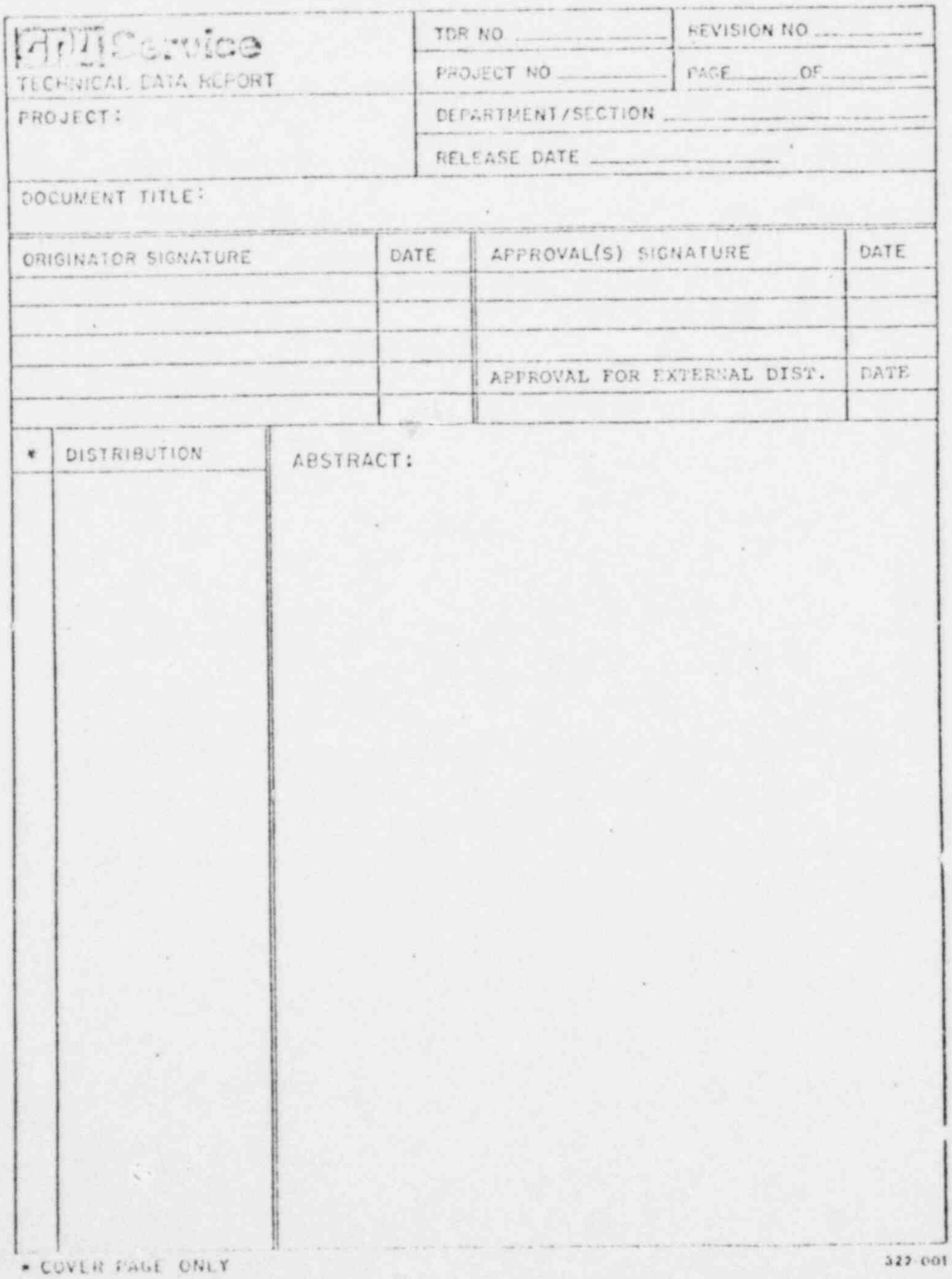
2. Revisions shall be reviewed and approved by the Manager(s) that approved the original document.

3. A brief summary of the revision and the approval signatures of the originator(s) and manager(s) shall be documented as shown in Appendix B and placed immediately behind the abstract. Additional revisions can be documented on the same page or subsequent pages.

4. Minor changes to analyses shall be made as revisions on the original sheets. Revisions shall be identified by drawing a vertical line in the right hand margin next to the entire length of the revision. The revision shall be identified by placing the revision number immediately under the vertical line.

5. Revisions which cannot be completed on existing sheets shall be continued on additional sheets. Added sheets will be placed immediately after the revised page carrying the same page number with a suffix letter added. Example: page 10 supplemented by page 10a.

APPENDIX A



GPU Service
TECHNICAL DATA REPORT

GPU Service TECHNICAL DATA REPORT	TDR NO ______	REVISION NO ______
	PROJECT NO ______	PAGE ____ OF ____
PROJECT:	DEPARTMENT/SECTION ______	
	RELEASE DATE ______	
DOCUMENT TITLE:		

ORIGINATOR SIGNATURE	DATE	APPROVAL(S) SIGNATURE	DATE
		APPROVAL FOR EXTERNAL DIST.	DATE

*	DISTRIBUTION	ABSTRACT:

* COVER PAGE ONLY

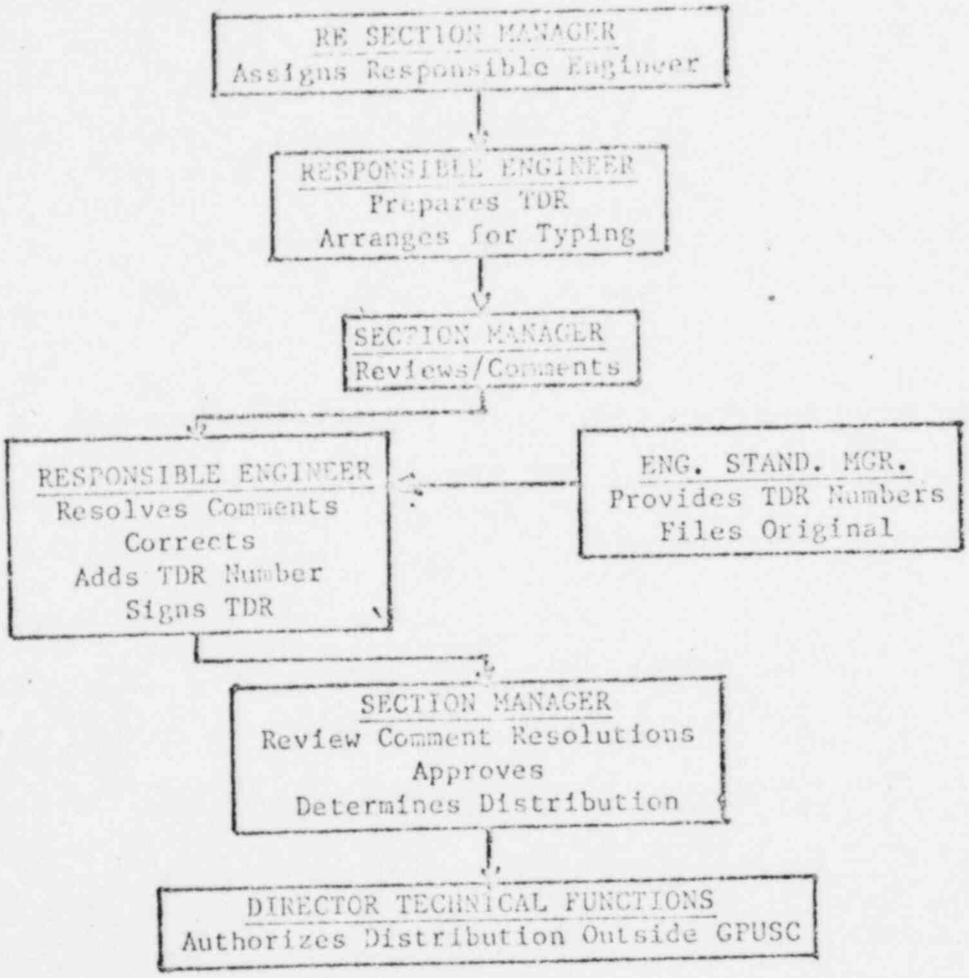
322-001

APPENDIX B

Service	TDR NO.
TITLE	PAGE OF

REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	Corrected values shown on page 32, Table IV.	John Doe C. Smith	6/12/78 6/13/78
2	Added Appendix A to provide additional details on method used to calculate present worths for pages 42, 56 and 74.	John Doe C. Smith	6/18/78 6/19/78

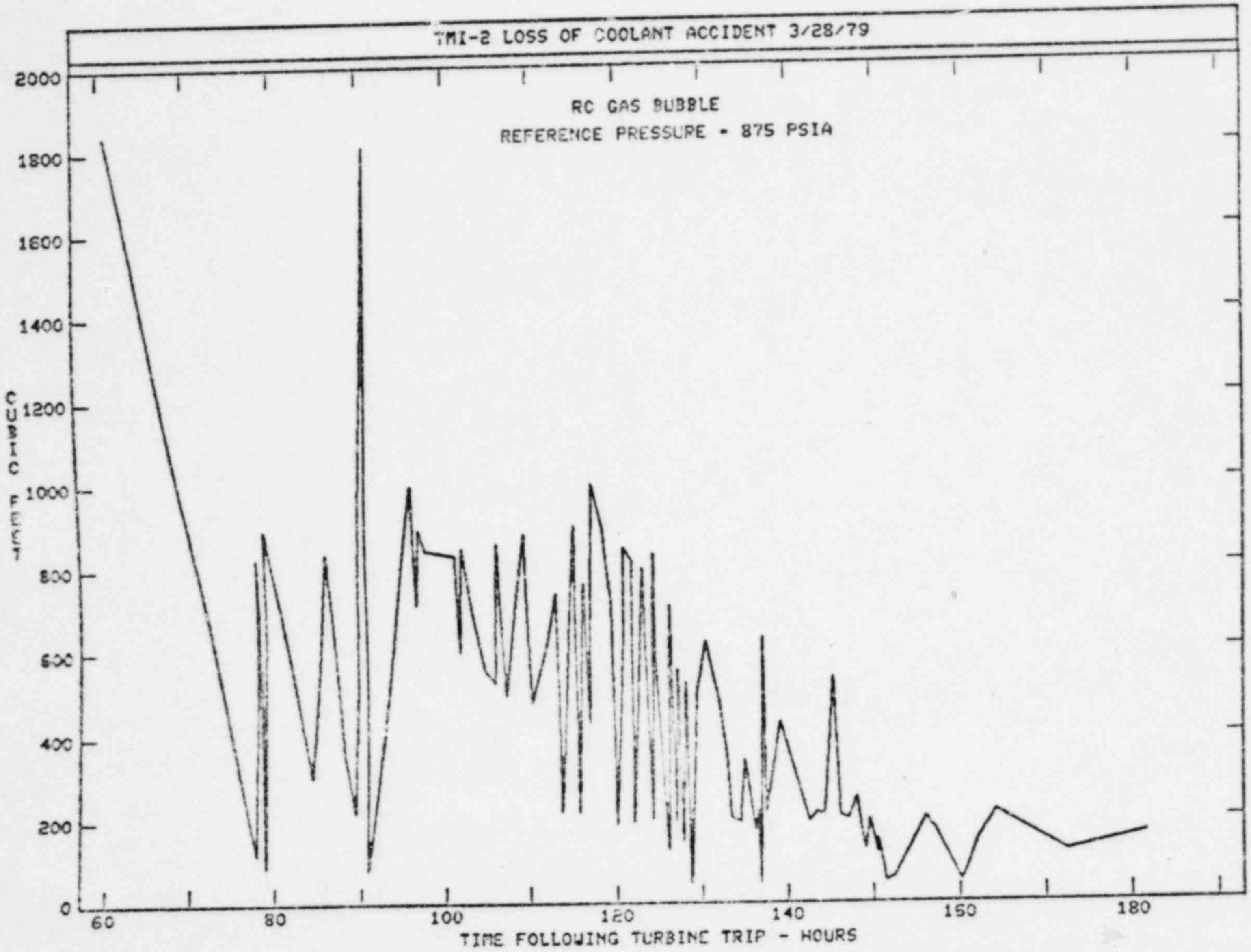
PROCEDURAL FLOW DIAGRAM
APPENDIX C



DATA USED TO GENERATE TMI-2 RC GAS BUBBLE

TIME	BUBSIZE	LOCATION	TIME	BUBSIZE	LOCATION
60.96	1839	0	127	203	
78	118.3		127.2	564	
72.24	829		127.9	152	
79	89.2		128.16	535	
79.2	893		128.7	47	
84.48	308		129.36	501	
86.4	839		130.56	627	
88.32	366		132	486	
89.52	225		132.96	343	
90.96	1806		133.5	208	
91	82		134.5	194	
96.3	999		134.64	224	
96.9	717		135.12	347	
97.3	894		136.25	175	
98	848		136.56	224	
101.4	333		137	48	
101.9	606		137.04	635	
102.24	850		137.52	223	
103.3	710		139.2	438	
104.75	564		142.56	199	
106	535		143.5	221	
106.32	560		144.24	215	
107.3	501		145.2	543	
109.44	880		146.16	211	
110.3	486		147.12	205	
112.08	621		148.08	254	
113.28	742		149.04	130	
113.7	224		149.52	203	
115.2	901		150.42	118	
115.7	223		150.48	152	
116.4	765		151	89	
117	438		151.44	47	
117.36	999		152.4	60	
118.56	894		156	208	
119.52	717		156.24	195	
120	191		157.2	174	
120.9	655		160.08	48	
120.96	848		161	82	
121.92	818		162	143	
122	198		164.16	222	
123.12	800		172.56	118	
124.25	205		181.44	163	
124.32	833		183.36	0	
124.56	606		184.08	82	
126.1	130		202.7	0	
126.24	710				

6/712-3.2-63


TMI-2 LOSS OF COOLANT ACCIDENT 3/28/79
RC GAS BUBBLE
REFERENCE PRESSURE - 875 PSIA
CUBIC FEET
0
200
400
600
800
1000
1200
1400
1600
1800
2000
60
80
100
120
140
160
180
TIME FOLLOWING TURBINE TRIP - HOURS

G/712-3.0-64

6/712-3.c 65

[illegible] of our [illegible]

2. [illegible] (...), we told [illegible]

[illegible] a thermal [illegible]

[illegible] have it in [illegible]

[illegible] vessel [illegible]

[illegible] on crack [illegible] on to the vessel and the SG [illegible] (i.e., it could not fail).

[illegible] the action items H agreed to on 4/4/79.

L. E. Sechreiter

Regarding questions asked by NRC

[illegible] the amount of gas in solution at 1000 psi, T = 280°F (saturated [illegible]tions)

GE	W	B & W's
[illegible] cc(STP)	1000 cc(STP)	[illegible] cc(STP)

[illegible] the time to degas from 1000 psi (sat) to 500 psi (sat) with T = 280°F

GE	W	B & W's
[illegible] hrs	[illegible] hrs	[illegible] hrs

[illegible] volume of gas that comes out of solution at 500 psi (sat)

	W	B & W's
[illegible]	[illegible]	[illegible]