32-9745 00

BWNP-20032A-3(10-76)

cys to (1) Hebdon (2) Mainus

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PART/TASK-GROUP-SEQ.	B&W DOCUMENT NO.	DOCUMENT TITLE	PUL STAT.	RRL NO.
09-000-00	32-9745-00	Pressurizer Level Change Due to Makeup Flowrate		

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RELEASED BY: R W Winks (NAME) 10/2/78 (DATE)

Principal Engineer

REVIEWED BY: [illegible] (NAME) [illegible] (DATE)

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52-9145 00 BWNP-20210-1 (1-78)

CALCULATION DATA/TRANSMITTAL SHEET

DOCUMENT IDENTIFIER

CALC. 32 - 9745 - 00

TRANS. 86 - _____ - _____

TYPE: ___RESEARCH & DEVELOPMENT ___SAFETY ANALYSIS REPORT ___NUC. SERV. INPUT ___DESIGN RQMT. ___DESIGN VERIF. X OTHER

TITLE Pressurizer Level Change Due to MakeUp Flowrate

PREPARED BY R.W. Winks REVIEWED BY R.M. Hemmitter

TITLE Principal Engineer DATE 10/2/78 TITLE Senior Engineer DATE 10-4-78

PURPOSE:

To amend an existing calc file and report submitted to TECO predicting Pressurizer level changes after reactor trips at Davis-Besse 1. This report is to account for a net makeup flowrate into the RC System and its effect on the change in Pressurizer level.

SUMMARY OF RESULTS (INCLUDE DOC. ID'S OF PREVIOUS TRANSMITTALS & SOURCE CALCULATIONAL PACKAGES FOR THIS TRANSMITTAL)

References:

Calculational File: 32-9538-00 by R.W. Winks

Transmittal Document: 86-2226-00 by R.W. Winks

Summary:

Corrections to Calculated Per level Change (Table 2 of 86-2226-00) are shown below:

Rx Trip Date	Calculated Per level	Correction to Calc. Per Level
2/24/78	184	8.3
4/2/78	167	8.2
8/2/78	206	22.9
11/29/77	181	14.7

DISTRIBUTION

BABCOCK & WILCOX
GENERAL CALCULATIONS

Problem: The results of calculating Pressurizer level change during reactor trip transients at Davis-Besse 1 did not contain any account of net makeup flowrate into the RC system which will in turn affect the final pressurizer level.

Review all available RC System flowrate data during the four reactor trips analyzed in my Calculational File 32-9538-00 and transform the net volume added during the transient into equivalent pressurizer level change.

The simple pressurizer level - RC volume model used in Calculational File 32-9538-00 assumed mass in the RC system as constant.

This study shall determine the correction that could be applied to the calculated change in pressurizer level during a reactor trip transient due to the net addition of makeup flow into the RC System.

Approach:

After achieving agreement with TECO Engineering on validity of measured flowrates, use Post Trip Review log data to determine profile of net makeup flowrate according to the expression:

$$\dot{W}_{net} = \dot{W}_{seal\ injection} + \dot{W}_{makeup} - \dot{W}_{letdown}$$

and integrate this over period to reach minimum pressurizer level to obtain volume added to RCS. Then, account for density change as 100°F water is heated to equilibrium with cold leg temperature in the RCS. Add a final column to Table "2" in my Transmittal package 86-2226-00.

CUSTOMER TECO	PROP NO FILE NO
SUBJECT Pzr Level Due to MakeUp Flow	DWG NO COMP NO
CONT NO 820.00 14	GROUP NO
CALC BY R. W. Winks DATE 10/3/78	SHEET NO 2 of 22

DS-21036 (2-73)

32-9745 00

32 DOC I.D. | SERIAL NUMBER | REV.

BABCOCK & WILCOX

GENERAL CALCULATIONS

Post Trip Review Log

Reactor Trip Time from Alarm Printer (SIE-431 File)
= 05:51:06

Clock Time	Net Time	F-740 H.U. Flow	F-717 Letdown Flow	F-782 Seal Inject Flow - gpm	RC Pressure psig	
-	sec	gpm	gpm			
05:50:00	-66	—	54.45	—		
05:50:15	-51	16.53	"	36.38	2153	
05:50:30	-36	"	54.36	"	"	
05:50:45	-21	29.24	"	35.71	2146	
05:51:00	-6	"	54.19	"	"	
(05:51:06)	0	—	—	—	~~2155~~	
05:51:15	9	38.60	"	34.92	2140	
05:51:30	24	"	54.05	"	"	
05:51:45	39	(-$)	"	22.35	~~1750~~ 1770	330
05:52:00	54	(-$)	46.62	"	~~1920~~ "	330
05:52:15	69	(-$)	"	24.25	~~1725~~ 1743	330
05:52:30	84	(-$)	0.0	"	"	330

Note: At 31 seconds (net) the second makeup pump was turned on.

(-$) symbol means off-scale (maximum flowrate)

On Telephone call on Sept 26, 1978 Sushil Jain (TECo) stated that maximum flowrate for 2 H.U pumps will be 320 gpm at 1800 psig or 290 gpm at 1900 psig RC Pressure.
(Assume 340 gpm at 1700 psig) Appendix FIG 6

Assume H.U Flow temperature is approximately 100 F as is letdown flowrate and seal injection flowrate. Therefore, net flowrate will be measured at approximately 100 F but will expand to a larger flowrate after injected into the RCS.

POWER TECO	PROP NO / FILE NO
SUBJECT PZR LEVEL DUE TO MakeUp Flow	DWG NO / COMP NO
CONT NO 020.00 14	GROUP NO
CALC BY R. W. Winks DATE 9/28/78	SHEET NO 3 of 22
CHKD BY DATE	

Reactor Trip on 2/24/78 (SPR #431)

$\dot{W}_{net} = \dot{W}_{sI} + \dot{W}_{mu} - \dot{W}_{ld}$

Time sec	$\dot{W}_{sI}$ gpm	$\dot{W}_{mu}$ gpm	$\dot{W}_{ld}$ gpm	$\dot{W}_{net}$ gpm
0	35	36	54	17
31	25	45	52	18
35	23	330	51	302
60	23	330	37	316

Volume of net makeup flow into RCS at 100°F:

$Vol = \frac{31}{60}(17.5) + \frac{4}{60}(18+142) + \frac{25}{60}(309)$ gallons

$= 9.0 + 10.7 + 128.75 = 148.5$ gallons

At time of minimum pressurizer level (τ + 60 secs)

RC pressure = 1740 psia (Reactimeter)

and T_{cold} = 550 F

$\rho_{add\ m.u.}$ = 62.32 lbs/ft³ @ 100 F

$\rho_{hot\ l.c.}$ = 46.50 lbs/ft³ @ 550 F

Density ratio = 1.34

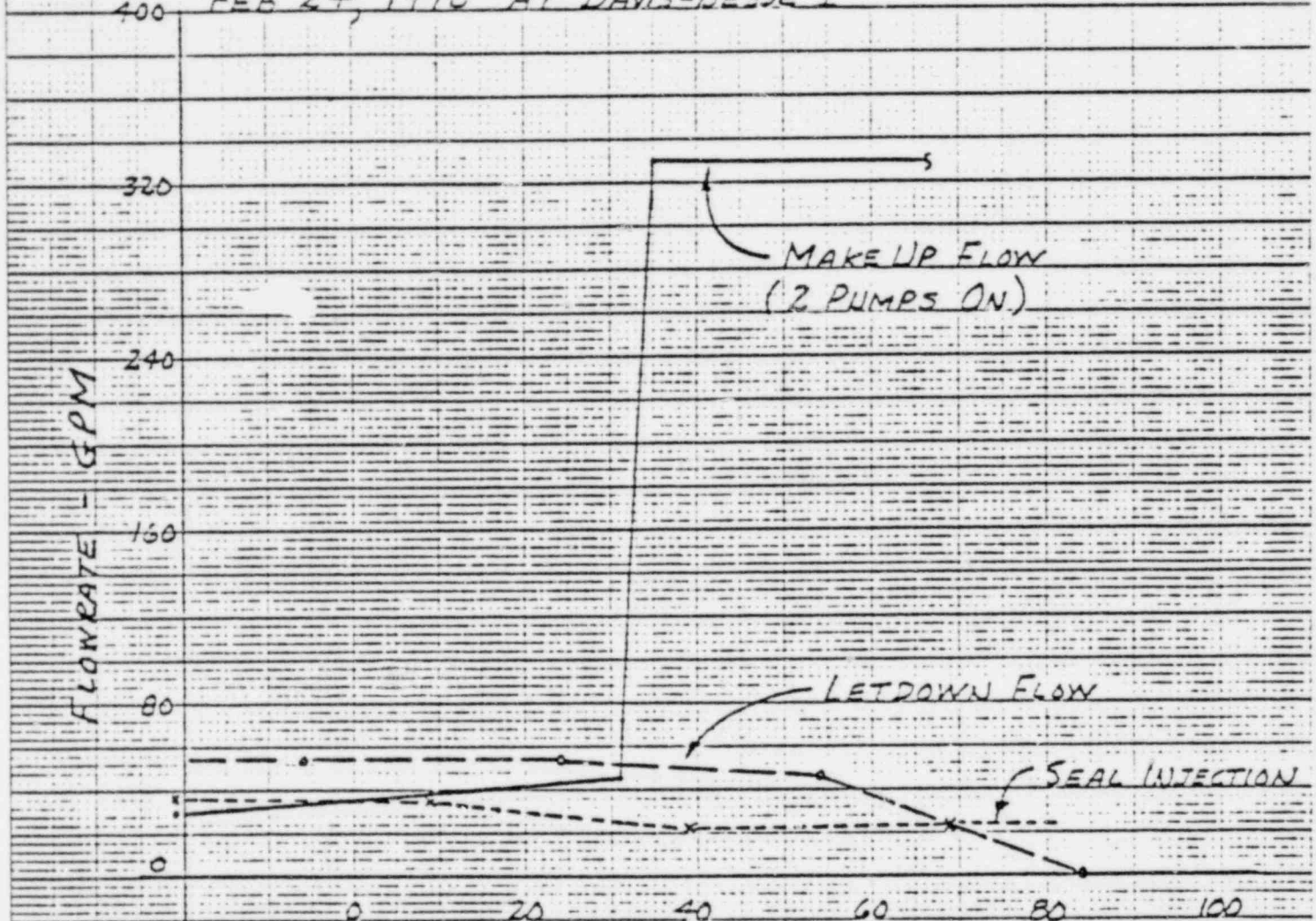
Volume of 550 F water added into RC System is:

$1.34 \times 148.5 = 199$ gallons

Δ Pzr level = $\frac{199}{7.4805 \times 3.2}$ = 8.3 inches

OWNER TECO	PROP NO / FILE NO
SUBJECT PZR LEVEL DUE TO MAKEUP FLOW	DWG NO / COMP NO
CONT NO 820-00 14	GROUP NO
CALC BY R. W. Winks DATE 9/28/78	SHEET NO 4 of 22
CHKD BY DATE	

R.C. SYSTEM FLOWRATES AFTER REACTOR TRIP ON FEB 24, 1978 AT DAVIS-BESSE 1



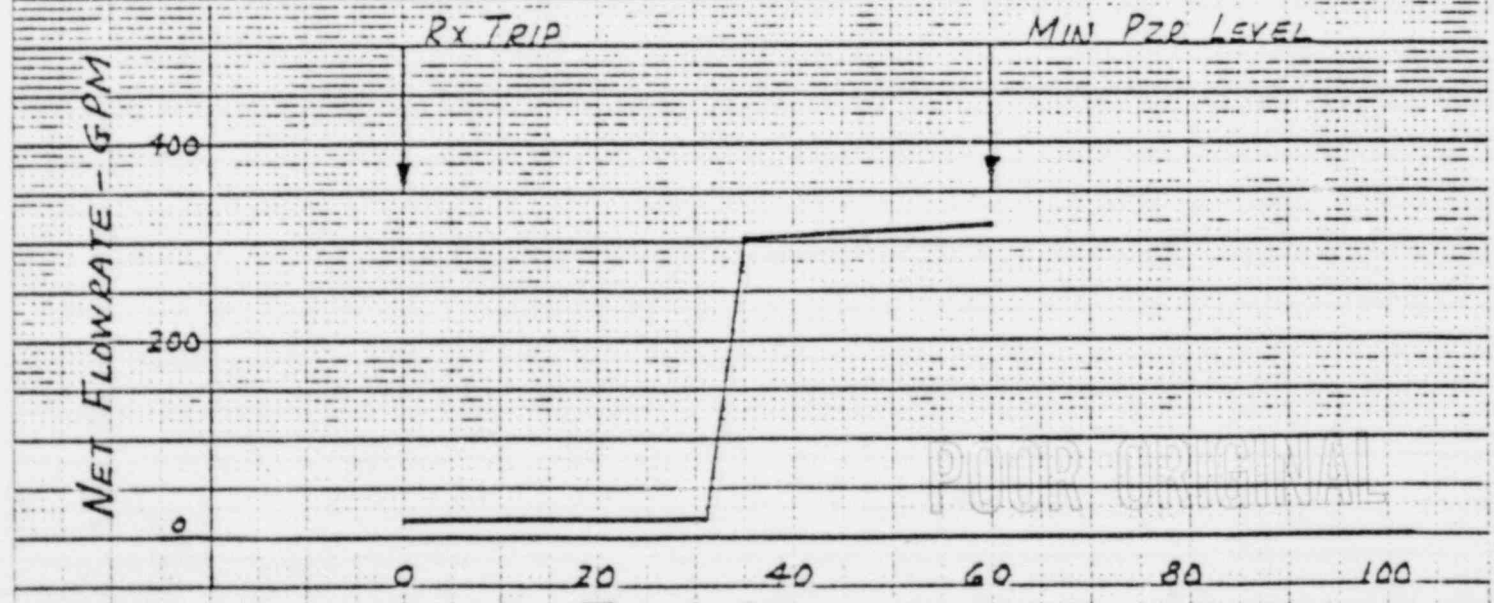


FIG 1

DS-21036 (2-73)

32-9745 00
DOC I.D. SERIAL NUMBER REV

BABCOCK & WILCOX
GENERAL CALCULATIONS

Post Trip Review log for 4/2/78 Rx Trip
SPR # 435

Rx Trip Time = 8:30:12 (Phone call from S. Tolin)

Clock Time	Net Time	F-740 M.U. Flow	F-717 l.d. Flow	F-782 Seal Inj Flow	RC Press	Calc M.U. Flow
	sec	gpm	gpm	gpm	psig	gpm
08:29:30	-42	27.8	—	—	2189	
08:29:45	-27	"	57.6	33.36	"	
08:30:00	-12	16.7	"	36.68	2048	
08:30:12	0	"	"	"	"	
08:30:15	3	"	136.5	"	"	
08:30:30	18	-$	"	"	1710	(225) *
08:30:45	33		52.9	21.6	"	(340)
08:31:00	48		"	"	1653	(350)
08:31:15	63	▼	0	33.07	"	(350)

TECO said #2 MU Pump started 22 seconds after Rx Trip

* To be conservative let us assume at 18 seconds 1 mu pump is on but valve is wide open and flow is 225 gpm. Then, at 22 seconds mu pump #2 is started and by 25 seconds flow is 340 gpm.

$$\dot{W}_{net} = \dot{W}_{sI} + \dot{W}_{mu} - \dot{W}_{ld}$$

Time	$\dot{W}_{sI}$	$\dot{W}_{mu}$	$\dot{W}_{ld}$	$\dot{W}_{net}$
sec	gpm	gpm	gpm	gpm
0	33	13	57	-11
3	32	50	136	-54
18	28	225	93	+160
25	26	340	74	292
45	26	348	31	343
10	30	132	116	+46

OWNER TECO
SUBJECT PZR LEVEL DUE TO MAKE UP FLOW
CONT NO 920.0014
CALC BY R.W. Winks DATE 10/2/78
CHKD BY DATE
PROP NO FILE NO
DWG NO COMP NO
GROUP NO
SHEET NO 6 of 22

4/2/78 Ex Trip Continued

Volume of net makeup flow added to RCS:

$$Vol = \frac{-3}{60}\left(\frac{54}{2}\right) - \frac{4}{60}\left(\frac{54}{2}\right) + \frac{18}{60}\left(\frac{292}{2}\right) + \frac{20}{60}\left(\frac{292+343}{2}\right)$$

$$= -3 + 44 + 106 = 147 \text{ gallons (at 100 F)}$$

At time of minimum pressurizer level RC pressure was 1665 psia and Tave was 550 °F

ρ_{cold} at 100 F = 62.32 lbs/ft³

ρ_{hot} at 550 F & 1665 psia = 46.45 lbs/ft³

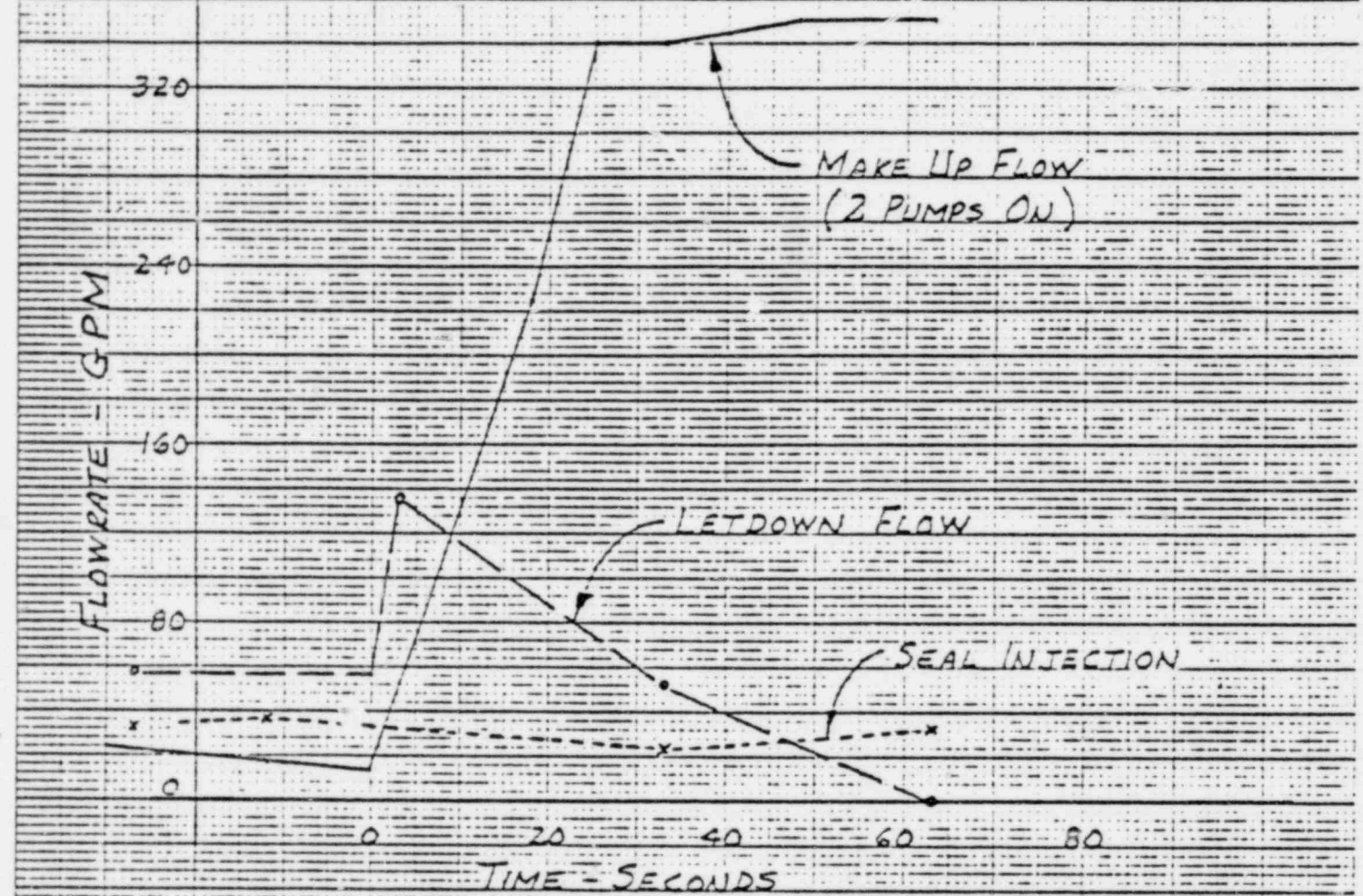
Density ratio = 1.34

Volume of water added to RCS at 550 F is:

$$1.34 \times 147 = 197 \text{ gallons}$$

$$\Delta \text{ Pzr level} = \frac{197}{7.4805 \times 3.2} = 8.2 \text{ Inches}$$

NET RC SYSTEM FLOW AFTER REACTOR TRIP ON APRIL 2, 1978 AT DAVIS-BESSE 1



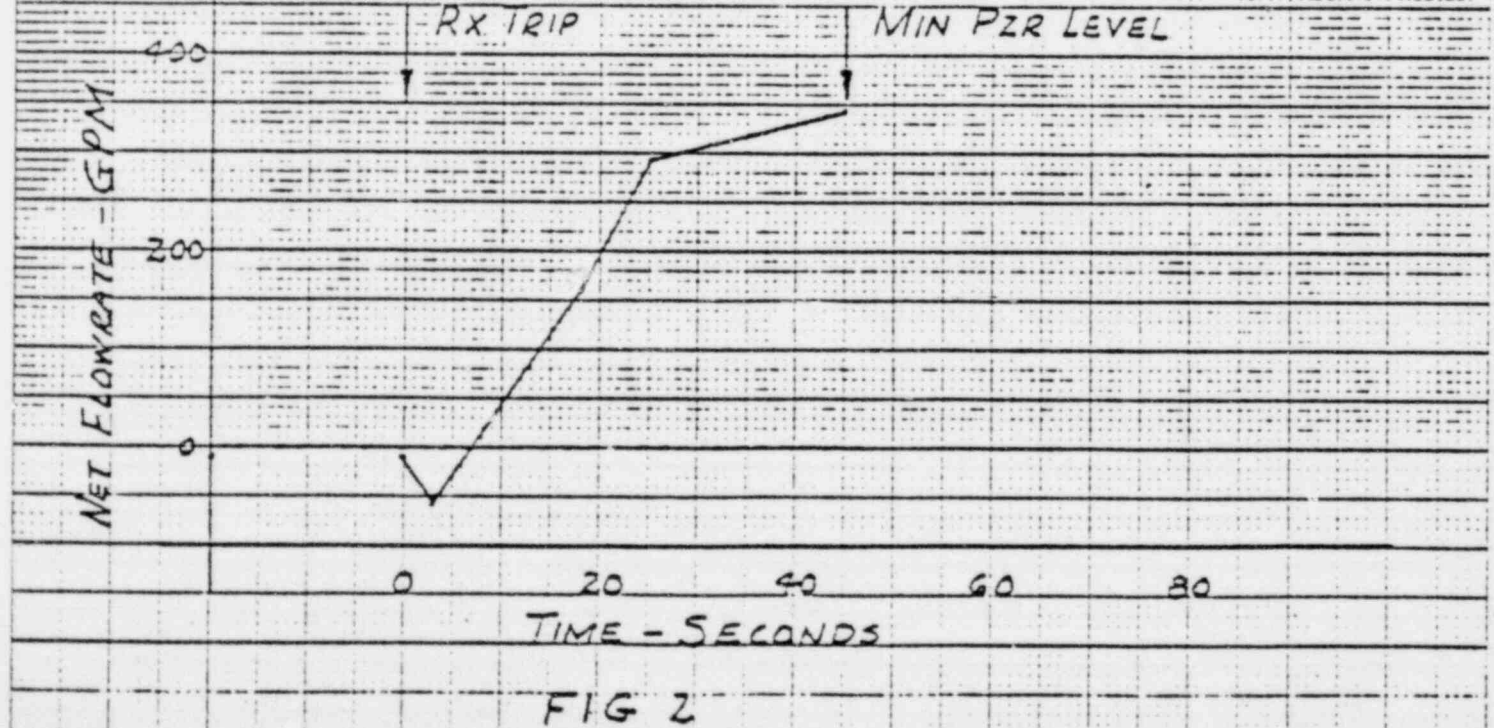


FIG 2

BABCOCK & WILCOX
GENERAL CALCULATIONS

Post Trip Review Log for Rx Trip on 8/2/78

Rx Trip Time 09:50:44 (Alarm Printer)
★ 2nd M.U. Pump on 13 seconds after Rx Trip
Post Trip Review Log Data:

Clock Time	Net Time	F-740 M.U. Flow	F-717 L.D. Flow	F-782 S.I. flow	RC Press	"Calc" M.U Flow
		gpm	gpm	gpm	gpm	gpm
09:49:30	-74	19.3	90.7	38.4	2108	
09:49:45	-59	"	"	"	"	
09:50:00	-44	19.3	92.3	35.5	2238	
09:50:15	-29	"	"	"	"	
09:50:30	-14	13.5	92.3	37.2	2110	
09:50:45	+1	"	"	"	"	—
★ 09:51:00	16	(-5)	87.2	25.2	1869	(310)
09:51:15	31		"	"	"	"
09:51:30	46		38.9	35.3	1776	(327)
09:51:45	61		"	"	"	"
09:52:00	76		38.8	34.9	1783	(326)
09:52:15	91		"	"	"	"
09:52:30	106		39.1	34.2	1827	(318)
09:52:45	121	(-5)	"	"	"	"

$\dot{w}_{net} = \dot{w}_{SI} - \dot{w}_{mu} - \dot{w}_{ld}$

Time sec	$\dot{w}_{SI}$ gpm	$\dot{w}_{mu}$ gpm	$\dot{w}_{ld}$ gpm	$\dot{w}_{net}$ gpm
0	38	12	92	-42
16	25	310	97	+248
46	35	327	39	+323
90	35	322	39	+318

OWNER TECO | PROP NO | FILE NO
SUBJECT PZR LEVEL DUE TO MAKE UP FLOW | DWG NO | COMP NO
CONT NO 920 00 14 | GROUP NO
CALC BY R. W. Winks DATE 10/2/78 | SHEET NO 9 of 22
CHKD BY DATE

Rx Trip of 8/2/78 Continued:

Volume added to RC System in 90 second period:

$$Vol = -\frac{2}{60}\left(\frac{42}{2}\right) + \frac{14}{60}\left(\frac{248}{2}\right) + \frac{30}{60}\left(\frac{248+323}{2}\right) + \frac{44}{60}\left(\frac{323+318}{2}\right)$$

$Vol = -0.7 + 28.9 + 143 + 235 = 406$ gallons

Cold H.U. water density = 62.32 lbs/ft3 at 100F

Hot H.U. water density at 555F & 1800 psia
(Page 25 of 55 in Calc File 32-9538-00 by RW Wicks)

$\rho_{hot} = 46.20$ lbs/ft^3

Density Ratio = 1.35

Volume of 555F net makeup volume = 548 gallons

Change in Pzr level due to net makeup volume:

$$\frac{548}{7.4805 \times 3.2} = 22.9 \text{ inches}$$

OWNER TECO	PROP NO / FILE NO
SUBJECT Pzr LEVEL DUE TO MAKEUP FLOW	DWG NO / COMP NO
CONT NO 920.30 14	GROUP NO
CALC BY R. W. Wicks DATE 10/2/78	SHEET NO 10 of 22
CHKD BY DATE	

RC SYSTEM FLOWRATES AFTER REACTOR TRIP ON AUG 2, 1978 AT DAVIS-BESSE 1

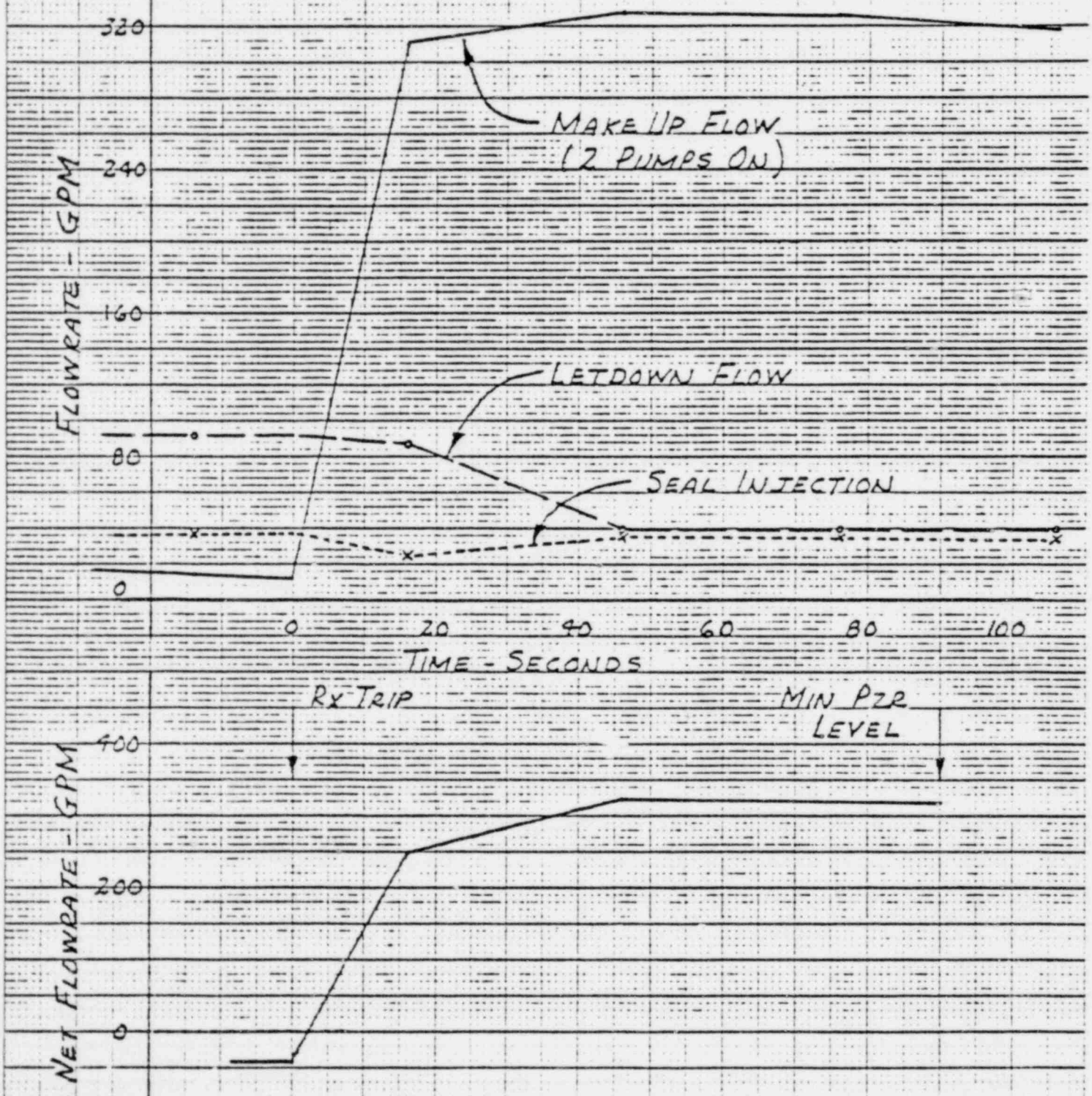


FIG 3

BABCOCK & WILCOX
GENERAL CALCULATIONS

Post Trip review for Rx Trip on Nov 29, 1977

Rx Trip Time 22:43:24 } See Alarm Printer Output
#1 MU Pump on until 22:43:55 }
#2 MU Pump started 22:46:52 (Single Pump Running)

Clock Time	Net Time sec	F-740 MU Flow	F-717 l.d. Flow	F-782 S.I. Flow	RC Press psig *	Calc MU Flow
22:42:30	-54	27.3	50.8	35.8		
22:43:00	-24	27.0	50.8	35.6		
22:43:24	0	—	—	—	2123	
22:43:30	6	125.6	50.8	24.8	2070	
22:43:45	21	"	50.7	"	1990	
22:44:00	36	119	"	(-5)	1950	
22:44:15	51	"	0.0	"	"	
22:44:30	66 =(1.1)	16.1	0.0	"	1960	
22:45:30	126=(2.1)	16.0	0.0	"	=0 gpm 1935	
22:46:30	186 =(3.1)	15.8	0.0	(-5)	1845	—
22:46:52	208=(3.47)	#2 Started				(220)
22:47:30	246 =(4.1)	18.0	0.0	"	1755	(220)
22:48:00	276= (4.60)	"	"	26.4	1725	(225)
22:48:15	291 =(4.85)	18.0	0.0	"	1650	(233)
22:49:15	351 =(5.85)	18.0	0.0	27.2	1625	(235)

* Refer to Page 30 of 55 of Calc File 32-9538-00 by R.W. Winks

To be very conservative, assume one make up pump is on at full flow at 22:46:52 time as shown in Alarm Printer but not indicated as M.U. flow in Post Trip Review log.

SUBJECT TECO	PROP NO FILE NO
SUBJECT PZR LEVEL DUE TO MAKEUP FLOW	DWG NO COMP NO
CONT NO 000-00-14	GROUP NO
CALC BY R. W. Winks DATE 10/2/78	SHEET NO 12 of 22
CHKD BY DATE	

Nov 29, 1977 Rx Trip

$\dot{W}_{net} = \dot{W}_{SI} + \dot{W}_{mu} - \dot{W}_{ld}$

Time min	$\dot{W}_{SI}$ gpm	$\dot{W}_{mu}$ gpm	$\dot{W}_{ld}$ gpm	$\dot{W}_{net}$
0	28	27	51	+4
0.1	25	125	51	99
0.6	0	119	25	94
0.85	0	70	0	70
1.1	0	16	0	16
3.1	0	16	0	16
3.5	0	220	0	220
4.1	0	220	0	220
4.6	27	225	0	252
5.25	27	235	0	262

Volume Added to RC System between 0 & 4.0 Minutes:

$$Vol = 0.1\left(\frac{100}{2}\right) + 0.5(96.5) + 0.5\left(16 + \frac{94-16}{2}\right) + 2.0 \times 16 + 0.4\left(16 + \frac{220-16}{2}\right) + 0.5(220)$$

Note: At T = 240 seconds after Rx Trip $T_{cold} \approx 529$ F
(Ref.: Pg 30 of Calc File 32-9538-00 by RW Winks)

$Vol = 5.0 + 48.3 + 27.5 + 32 + 47.2 + 110$

$Vol = 270$ gallons

Density ratio = $\frac{62.32 \text{ lbs/ft}^3}{\rho_{HOT} @ 529\text{F \& } 1640 \text{ psia}} = \frac{62.32}{47.78} = 1.304$

Volume Added to RCS at 529 F = $1.304 \times 270 = 352$ gallons

Δ Pzr level change = $\frac{352}{7480 \times 3.2} = 14.7$ Inches At 4.0 Minutes

RC System Flowrates After Reactor Trip And Station Blackout On Nov 29, 1977

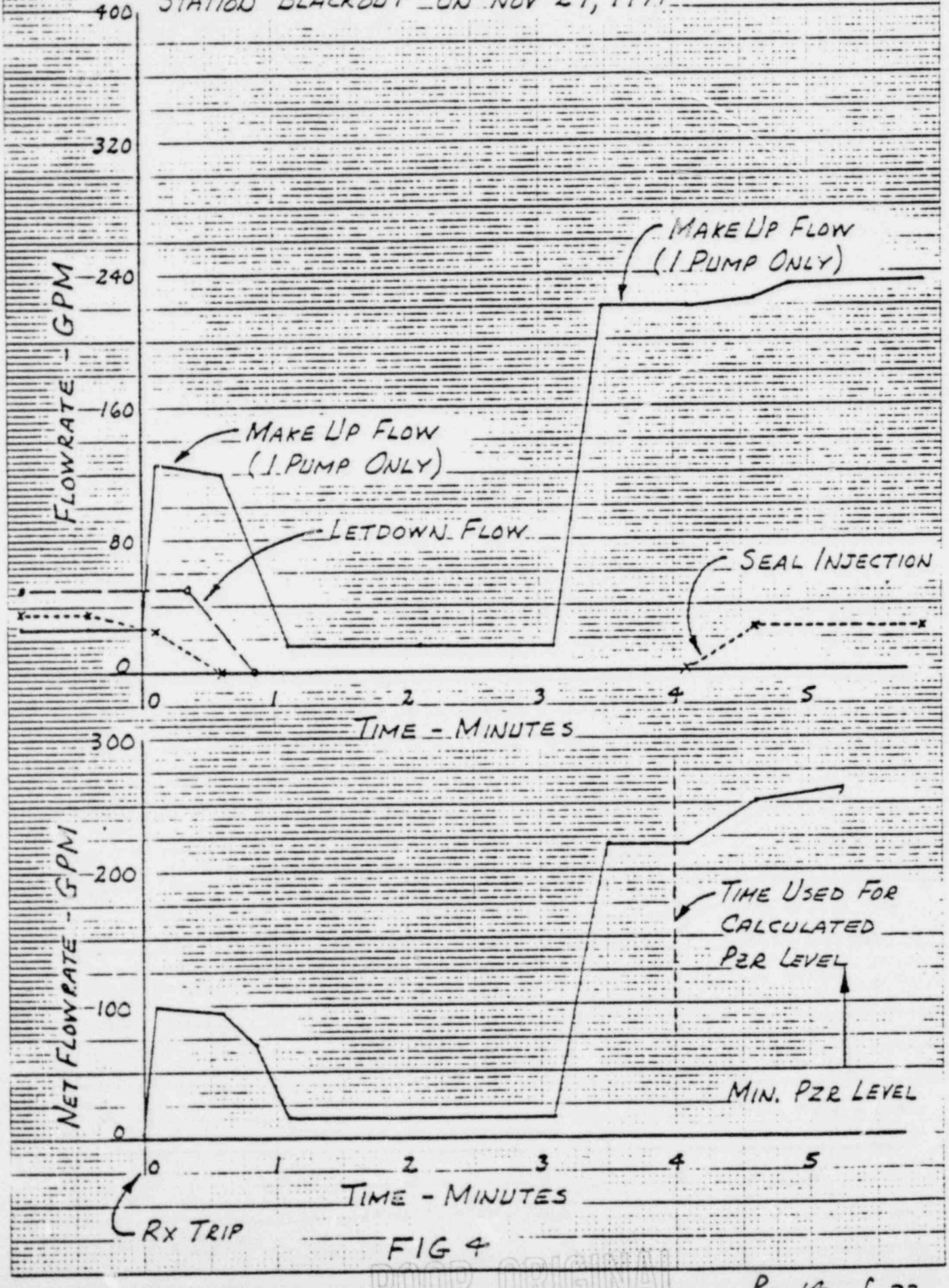


FIG 4

Conclusion:

The "possible" correction to the calculated change in Pzr level contained in Table II of my Transmittal package 96-2226-00 is displayed below:

Date of Rx Trip	Measured Change in Pzr level Inches	Time to Minimum Pzr Level sec	Calculated Pzr level Change	Correction to Calc. Pzr Level	
2/24/78	191	60	184	-8.3	(176)
4/2/78	162	45	167	-8.2	(159)
8/2/78	196	90	206	-22.9	(183)
11/29/78	184	240	181	-14.7	(166)

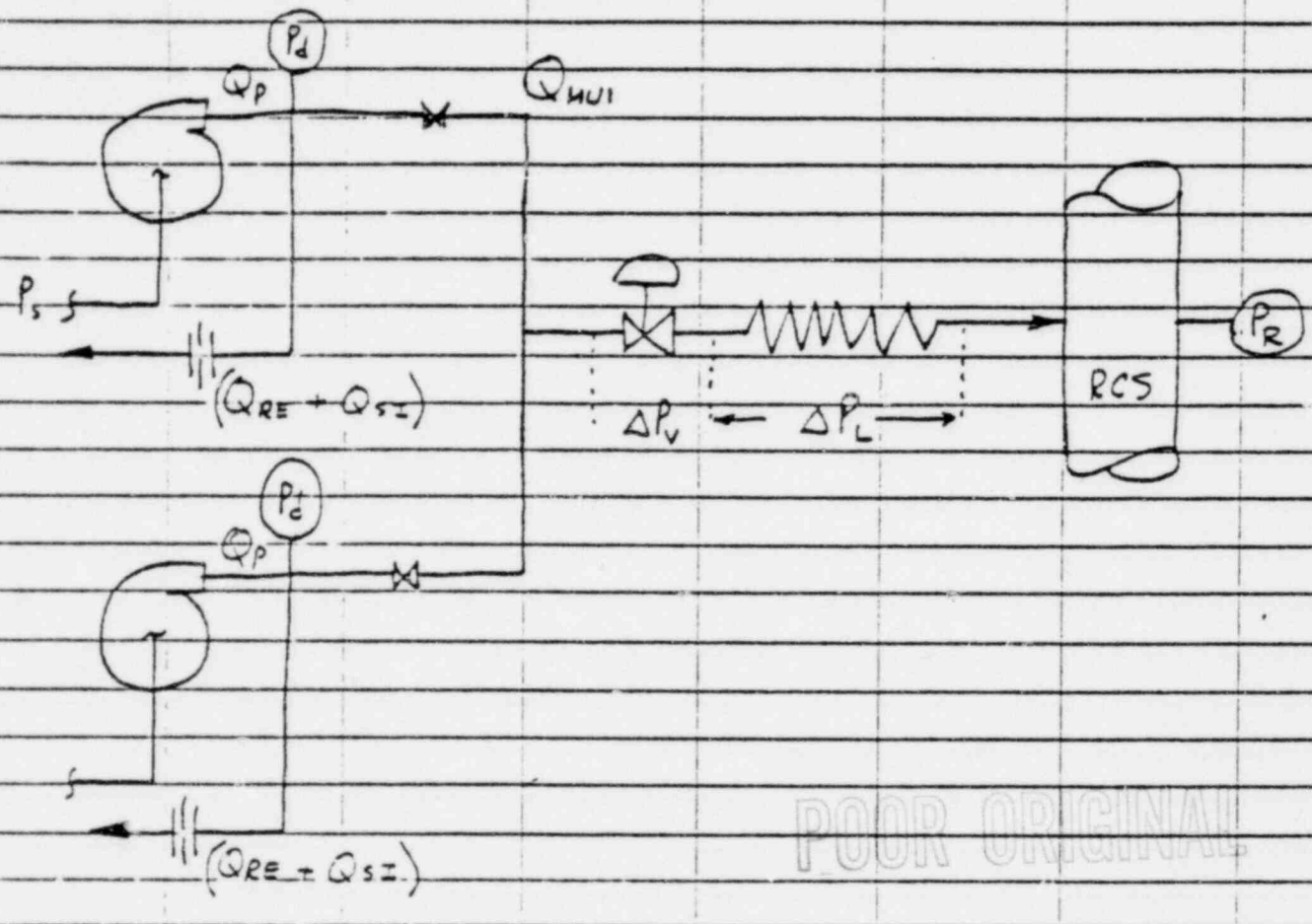
Though the original assumption is too simple by assuming no change in RC System mass, the careful attention to recorded flowrates and net volume added to the RC System does not appear to add accuracy to the mathematical technique. Possible causes of error in this corrective method includes the following:

(1) The Post Trip Review log contains updated data once every 30 seconds which is insufficient to accurately define flowrates during the normal 60 second transient

(2) The unmeasured total makeup flowrate into the RC System is based on calculated values which have not been confirmed and could lead to significant errors in estimating the net change to Pressurizer Level

Calculation of Make Up System Performance

System Schematic



$P_d = P_R + \Delta P_V + \Delta P_L$; $Q_p = Q_{RE} + Q_{MU}$

$(P_d - P_s) = (P_R - P_s) + \Delta P_{SYS} = \Delta P_{pump}$

$\Delta P_p (f Q_p) = (P_R - P_s) + \Delta P_{SYS} (f Q_{MU})$

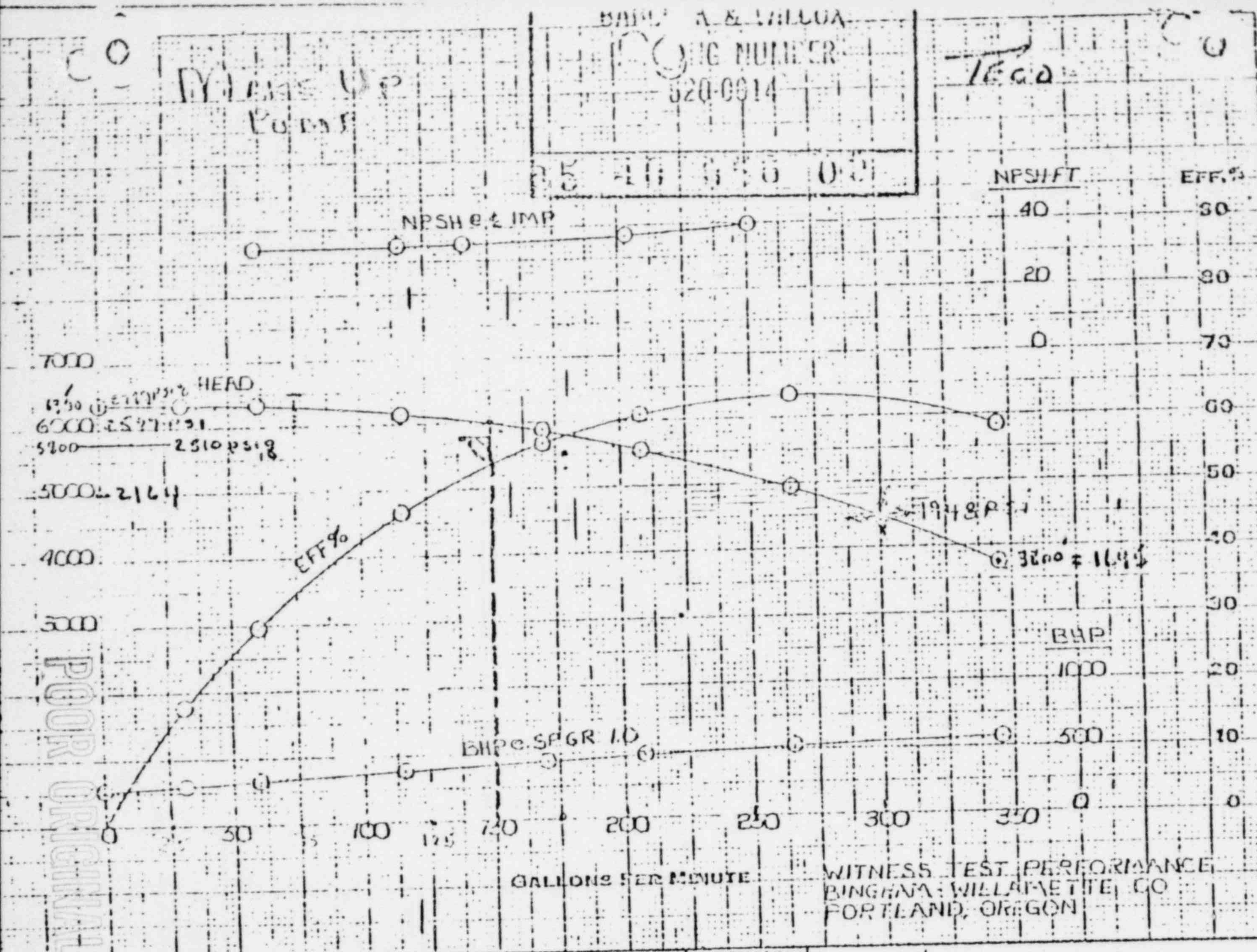
Assume $Q_{RE} + Q_{SI} \approx 70$ gpm constant

$\Delta P_p (f Q_{MU} + 70) = (P_R - P_s) + \Delta P_{SYS} (f Q_{MU})$

For 1&2 MU Pump Operation let RC pressure vary from 2200 psig down to 1200 psig Use the DB-1 MU Pump H-Q curve.

Let $P_s \approx 15$ psig

MAKE UP 32-9745 00



THE BABCOCK & WILCOX CO TOLEDO EDISON CO MAKE UP & SEAL INJECTION	CHARACTERISTIC CURVE SHEET BINGHAM PUMP DIVISION BINGHAM-WILLAMETTE COMPANY	IMPELLER DIA MAX 7½ DIA MIN DIA EYE	2X3X7½ CP 12 STG PUMP DIA IMPELLER 7 3/16 NPSH REQUIRED	IMPELLER PATT 1) 313MSD-26 2-12) 313MSD-24125 REFERENCE 5404 R.P.M. CURVE NO 30854

32-9745 00

M U PUMP DISCHARGE PRESSURE VERSUS PUMP FLOWRATE FOR DAVIS-BESSE 1

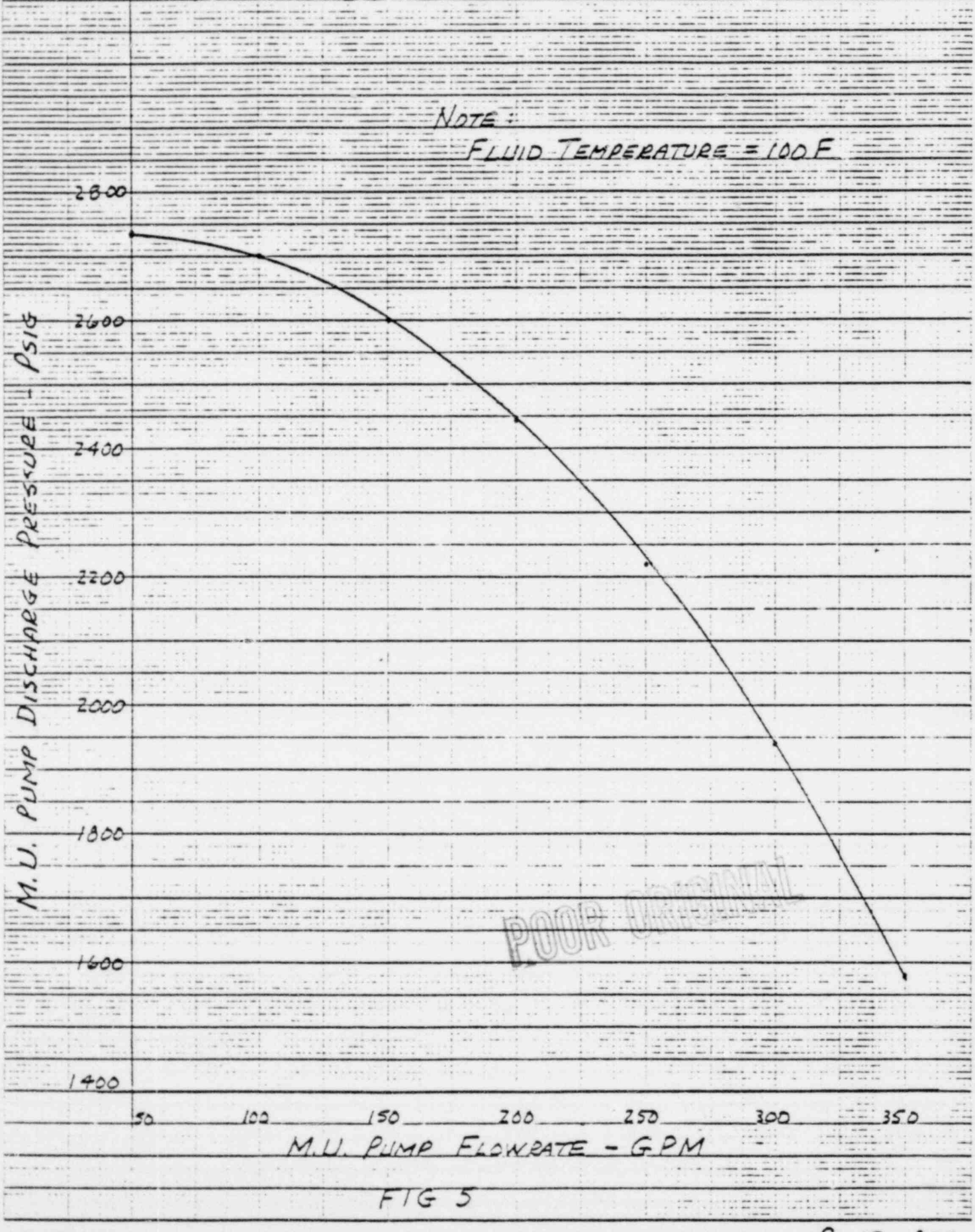


FIG 5

Babcock & Wilcox

32-9745 00

1 MU Pump Operation:

K_1 = 0.010 and 0.0050

= (psid / gpm^2)

Prc psig	Q_{MU} gpm	Q_{RETST} gpm	Q_{pump} gpm	Pd psig	ΔP_{sys} psi	K_1	Q_{MU}' gpm
2200	142	70	212	2402	202	0.010	141
2000	169	70	239	2290	290	.010	170
1800	192	70	262	2169	369	.010	192
1700	203	70	273	2108	408	.010	202
2200	160	70	230	2325	125	.0052	158
2000	190	70	260	2180	180	.0050	190
1800	215	70	285	2036	236	.0050	217
1700	227	70	297	1960	260	.0050	228

2 MU Pump Operation with same system Resistance

$K_2 = K_1$ = 0.010 and 0.0050 psi/gpm^2

Prc	Q_{MU}	Q_{Pump}	Q_{TOT}	Pd	ΔP_{sys}	K_1	Q_{TOT}'
2200	95	165	190	2562	362	.010	190
2000	112.5	182.5	225	2508	508	.010	225
1800	127.5	197.5	255	2456	656	.010	256
1700	135	205	270	2430	730	.010	270
2200	119	189	238	2485	285	.0050	239
2000	142	212	284	2402	402	.0050	284
1800	161	231	322	2322	522	.0050	323
1700	170	240	340	2280	580	.0050	340

CALCULATED MAKEUP FLOWRATES FOR EITHER 1 OR 2 MAKE UP PUMPS VERSUS R.C. PRESSURE AT DAVIS-BESSE 1

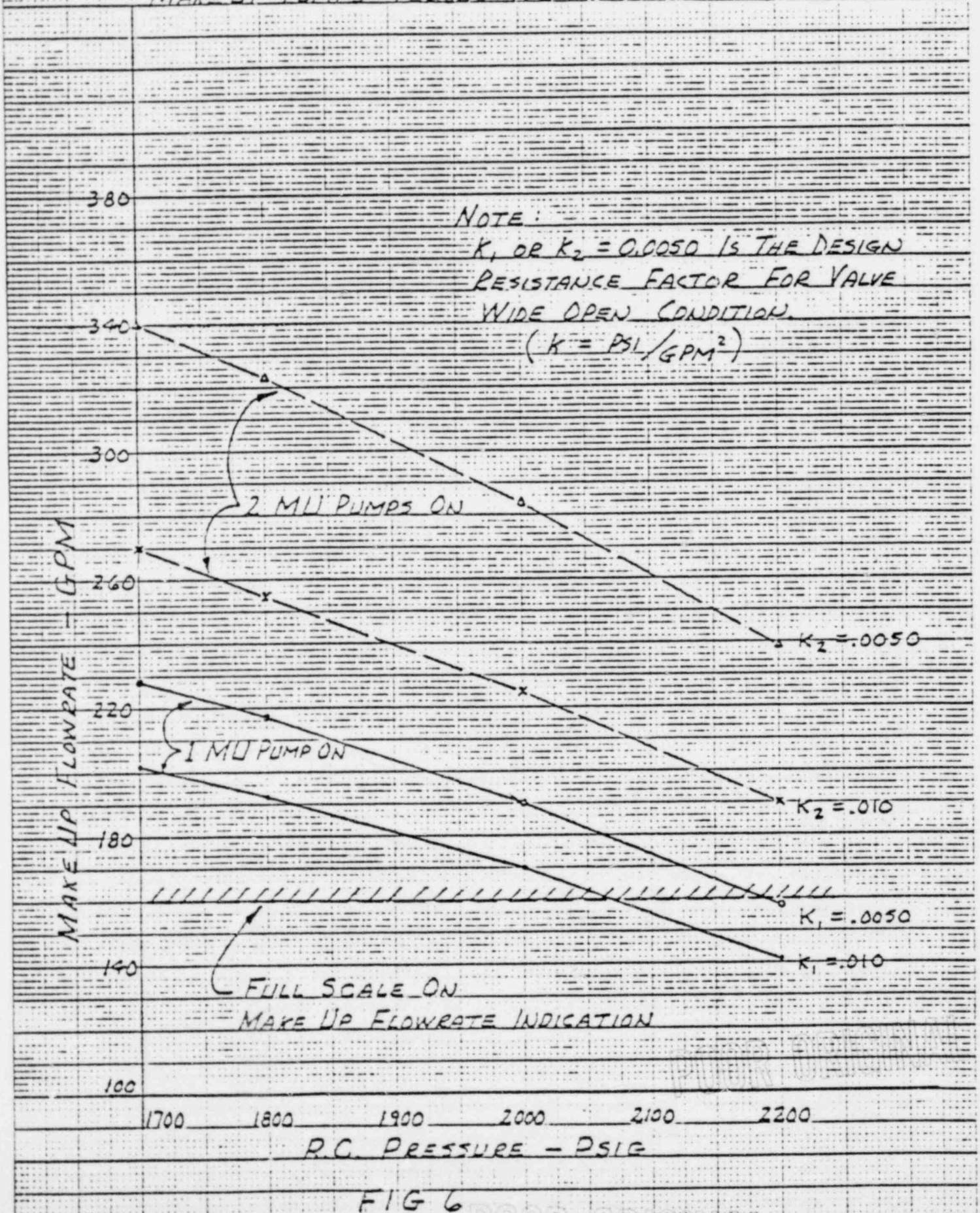


FIG 6

32-9745 00

CALCULATED M.U. SYSTEM FLOWRATE VERSUS RC PRESSURE FOR VALVE WIDE OPEN CONDITIONS

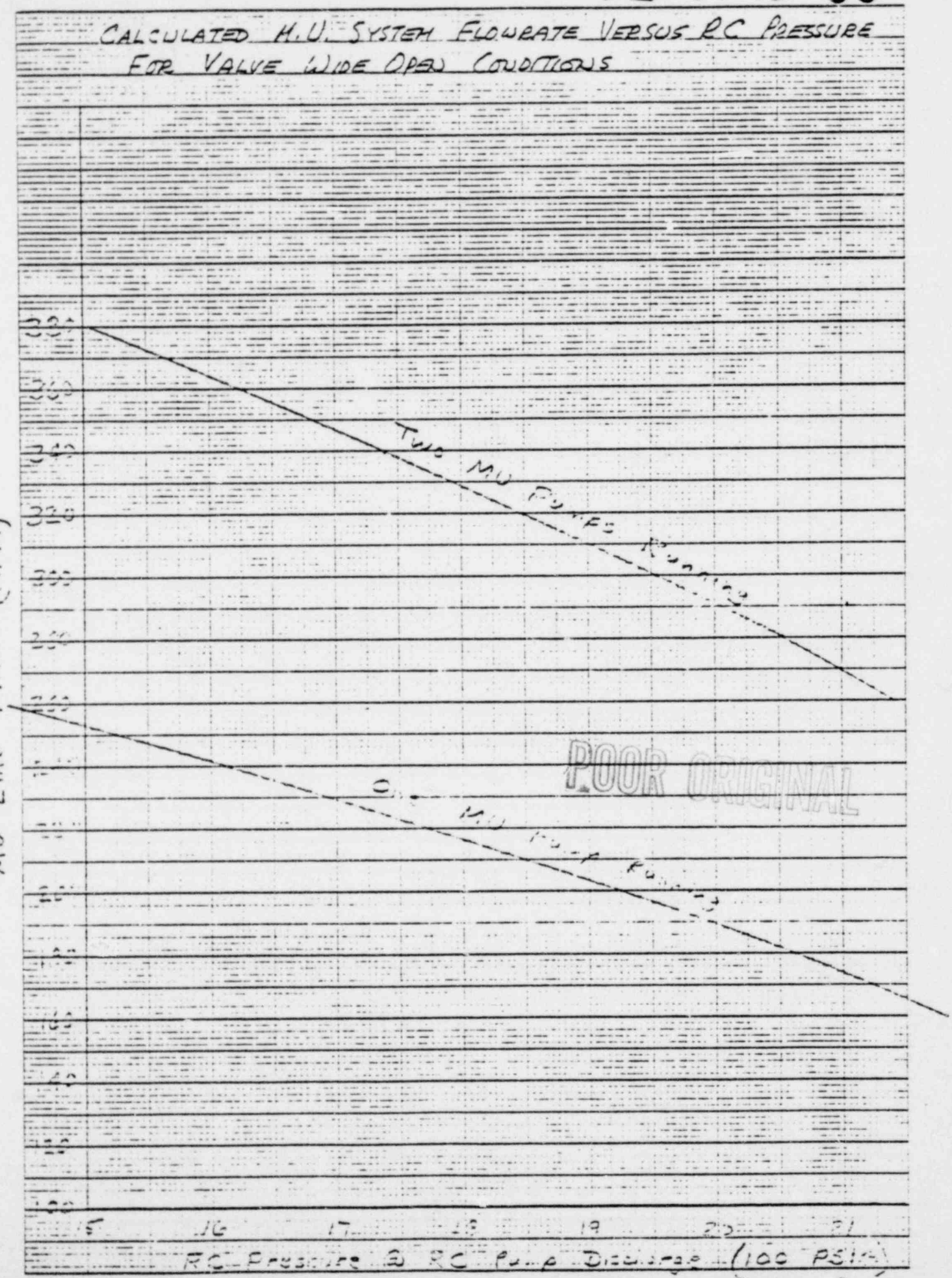


FIG 7

[illegible] CALCULATIONS

①	②	③	④	⑤		
[illegible] Flow (GPM)	MU Line Flow (GPM)	① + ② GPM	MU Line ΔP (PSI)	MU Pump TDH (PSI)	RC Press @ HPI Nozzle ⑤-④ (PSIG)	
One Pump						MU Line ΔP = 67.48 PSI @ 114 GPM (valve wide open)
32	[illegible]	[illegible]	102	2400	[illegible]	k_1 = .0052 psi/gpm²
32	150	182	117	[illegible]	[illegible]	
[illegible]	160	[illegible]	[illegible]	[illegible]	[illegible]	
32	180	212	146	[illegible]	2062	
[illegible]	200	[illegible]	[illegible]	2180	[illegible]	
[illegible]	220	252	[illegible]	[illegible]	1772	
[illegible]	240	[illegible]	299	1915	[illegible]	
[illegible]	[illegible]	[illegible]	351	1790	1439	
Two Pumps						
		(① + ②) / 2				
32	160	96	133	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	136	[illegible]	[illegible]	[illegible]	
			407	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	531	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	673	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	2055	[illegible]	
32	370	[illegible]	710	2240	1570	
	[illegible]		[illegible]	[illegible]		
32	340	[illegible]	600	[illegible]	[illegible]	
32	260	146	351	2490	2139	

CUSTOMER: TECO

SUBJECT: Appendix to 32-9745-00

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J.R. Merchant for R W Winks

DATE 10/3/78