

CALCULATION DATA/TRANSMITTAL SHEET

90*

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CALC. 32 - 9745 - 00

TRANS. 86 - - -

TYPE: RESEARCH & DEVELOPMENT SAFETY ANALYSIS REPORT Nuc. SERV. INPUT DESIGN REQMT. DESIGN VERIF. OTHER

TITLE Pressurizer Level Change Due to MakeUp Flowrate

PREPARED BY R. W. Winks

REVIEWED BY R. M. Hummer

TITLE Principal Engineer DATE 10/2/78

TITLE Senior Engineer DATE 11/4/78

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 Pwr level Change (Table 2 of 86-2226-00) are shown below:

Rx Trip Date	Calculated Pwr level	Correction to Calc. Pwr 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

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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:

$$W_{net} = W_{seal-injection} + W_{makeup} - W_{letdown}$$

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.

TECO

Per Level Due to MakeUp Flow

14

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10/3/78

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Post Trip Review Log

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

Clock Time	Net Time sec	F-740 H.U. Flow gpm	F-717 Letdown Flow gpm	F-782 Seal Inject Flow - gpm	RC Pressure psig	
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	"	1720 "	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 3 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.

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PZR LEVEL DUE TO MakeUp Flow

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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:

$$\begin{aligned} Vol &= \frac{31}{60} (17.5) + \frac{4}{60} (18 + 142) + \frac{25}{60} (309) \text{ gallons} \\ &= 9.0 + 10.7 + 128.75 = 148.5 \text{ gallons} \end{aligned}$$

At time of minimum pressurizer level ($\approx +60$ seconds)

RC pressure = 1740 psia (Reactimeter)

and $T_{cold} = 550$ F

$$\rho_{cold \text{ m.u.}} = 62.32 \text{ lbs/ft}^3 @ 100 \text{ F}$$

$$\rho_{hot \text{ r.c.}} = 46.50 \text{ lbs/ft}^3 @ 550 \text{ F}$$

$$\text{Density ratio} = 1.34$$

Volume of 550 F water added into RC System is:
 $1.34 \times 148.5 = 199$ gallons

$$\Delta P_{ZR} \text{ level} = \frac{199}{7.4805 \times 3.2} = 8.3 \text{ inches}$$

TECO

PZR LEVEL DUE TO MAKEUP FLOW

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RC SYSTEM FLOWRATES AFTER REACTOR TRIP ON
FEB 24, 1978 AT DAVIS-BESSE 1

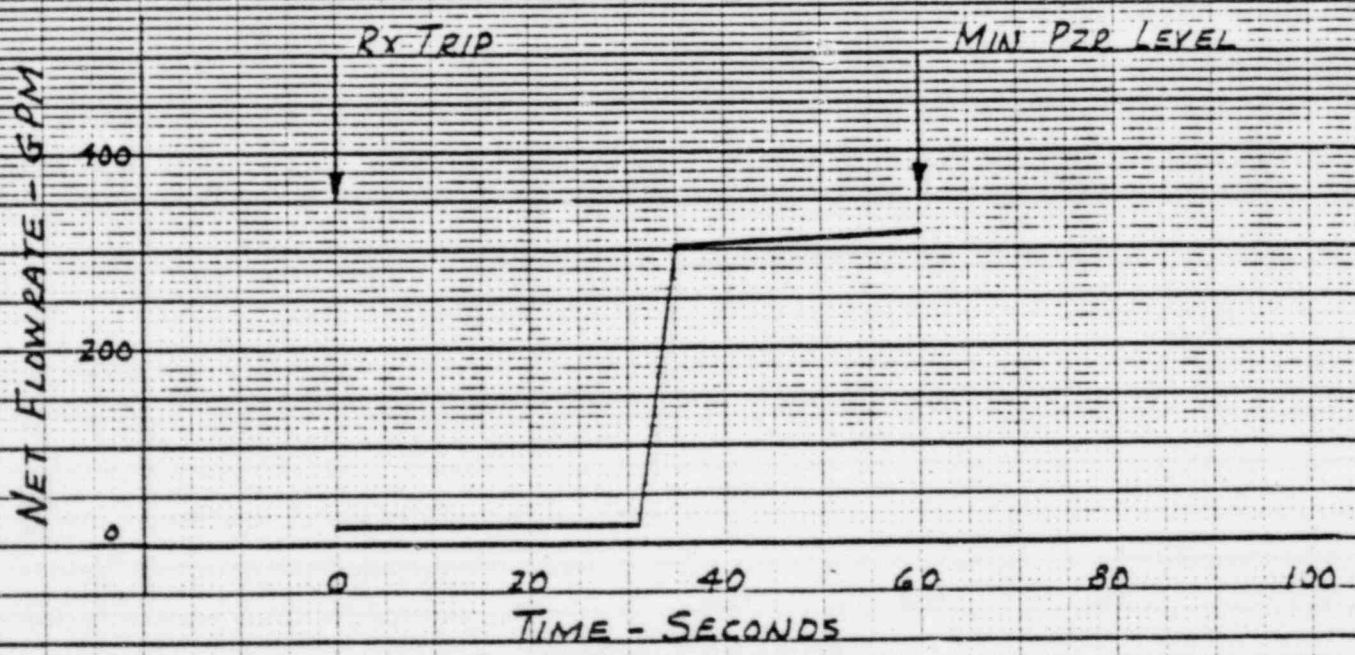
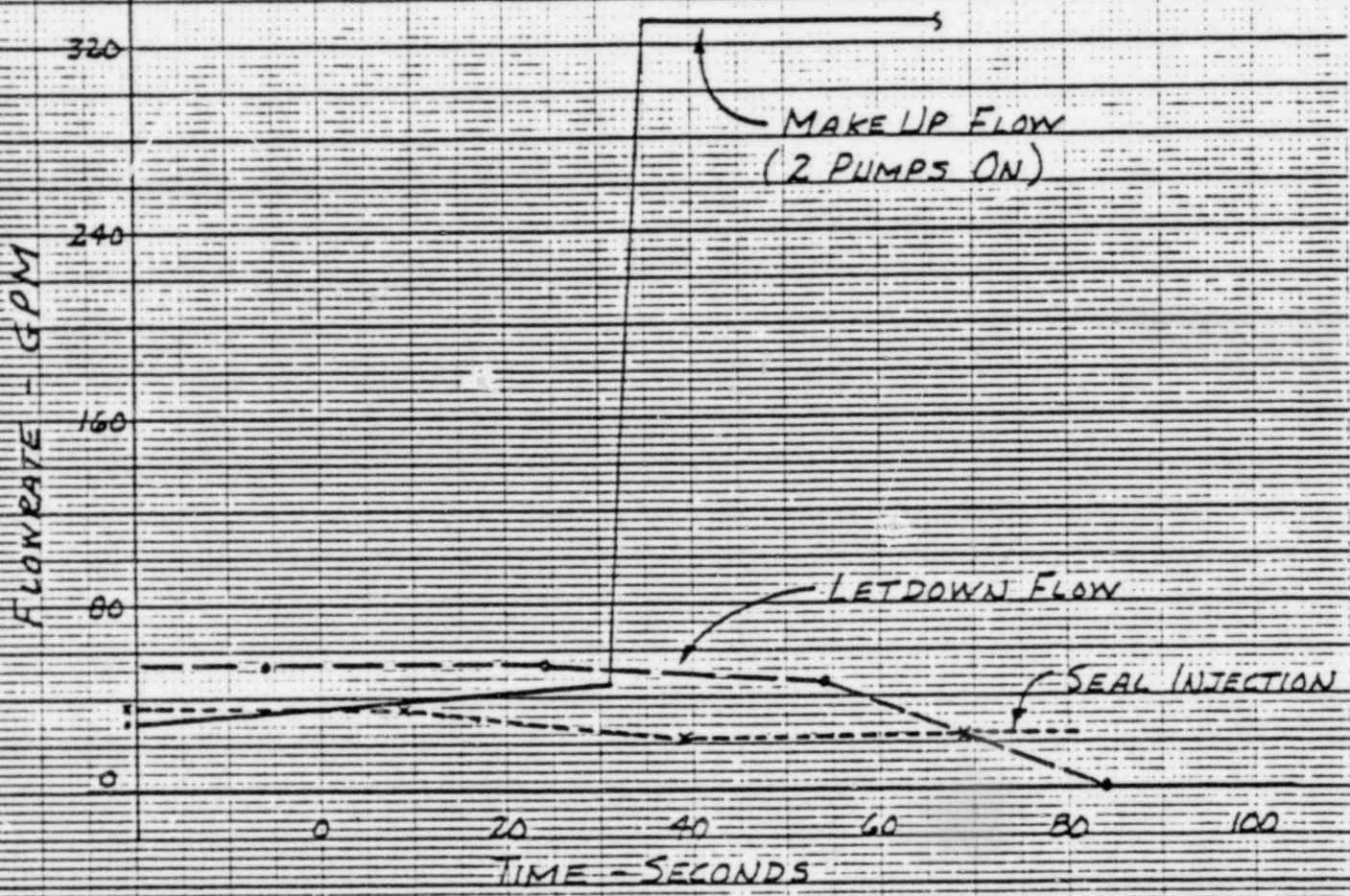


FIG 1

46 1470

16-E
10 X 10 TO 1/2 INCH * 7 1/2 X 10 PER INCH
KEUFEL & ESSER CO. MADE IN U.S.A.

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

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

Clock Time	Net Time sec	F-740 H.U. Flow gpm	F-717 l.d. Flow gpm	F-782 Seal Inj Flow gpm	RC Press psig	Calc H.U. Flow 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	-5	"	"	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.

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

Time sec	\dot{w}_{sz} gpm	\dot{w}_{mu} gpm	\dot{w}_{ld} gpm	\dot{w}_{net} 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

TECO
 PER LEVEL DUE TO MAKE UP FLOW

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4/2/78 Ex Trip Continued

Volume of net makeup flow added to RCS:

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

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

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

$$\rho_{\text{cold at } 100 \text{ F}} = 62.32 \text{ lbs/ft}^3$$

$$\rho_{\text{hot at } 550 \text{ F \& } 1665 \text{ psia}} = 46.45 \text{ lbs/ft}^3$$

$$\text{Density ratio} = 1.34$$

Volume of water added to RCS at 550 F
is:

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

$$\Delta \text{ PZR level} = \frac{197}{7.4805 \times 3.2} = 8.2 \text{ inches}$$

TECO

PZR LEVEL DUE TO MAKEUP FLOW

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10/2/78

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

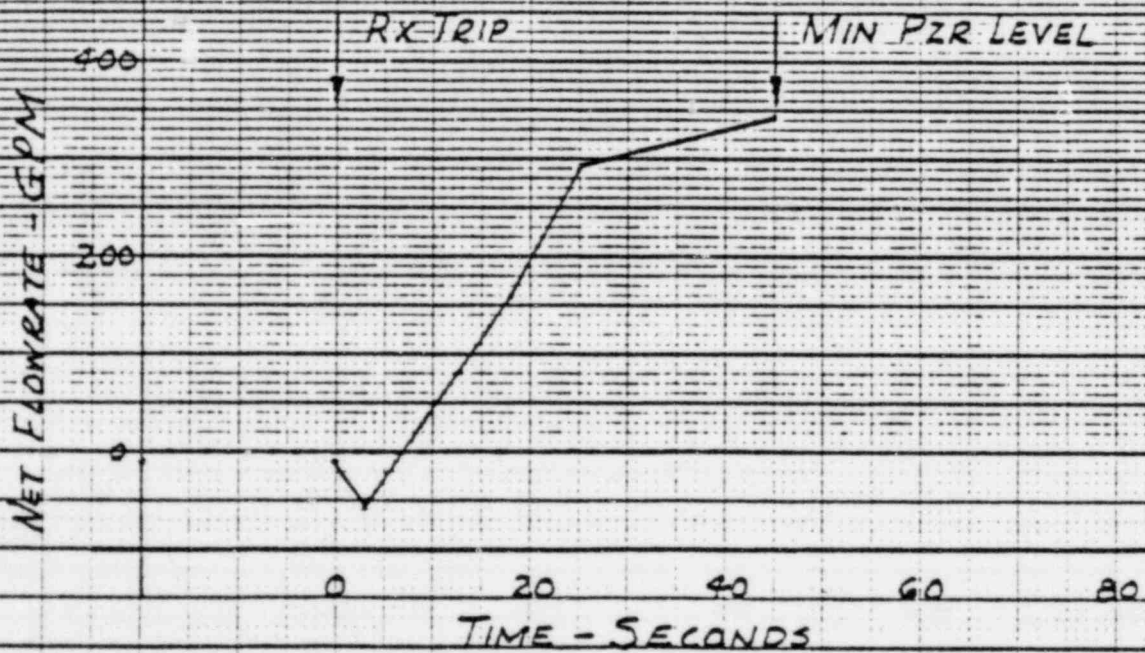
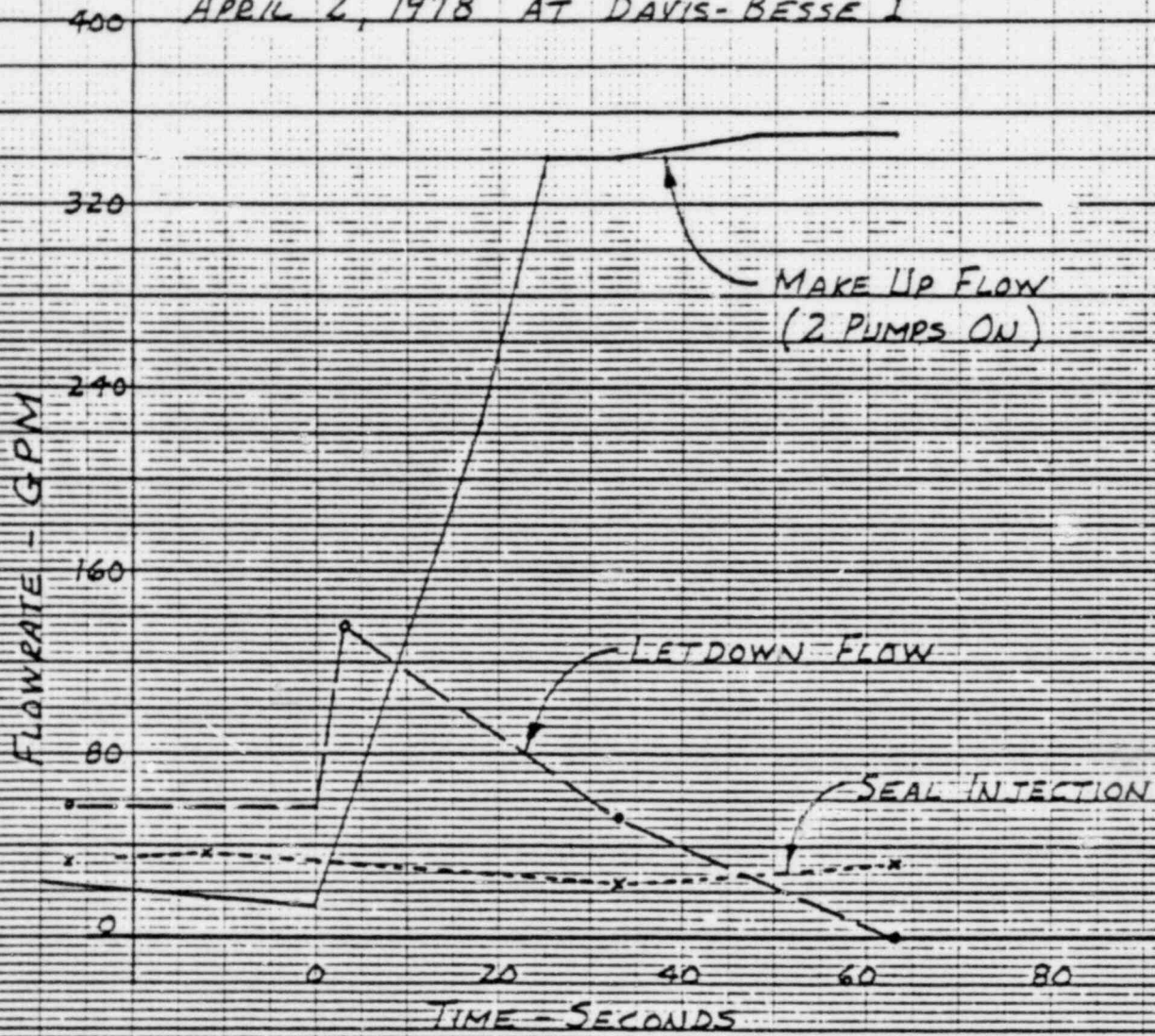


FIG 2

46 1470

K-E 10 X 10 TO 1/2 INCHES REUFEL & ESSER CO. MADE IN U.S.A.

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

Rx Trip Time 09:50:44 (Alarm Printer)

★ 2nd H.U. Pump on 13 seconds after Rx Trip

Post Trip Review Log Data:

Clock Time	Net Time	F-740 H.U. Flow	F-717 L.d. Flow	F-782 S.I. flow	RC Press	"Calc" MU Flow
09:49:30	-74	9pm 19.3	9pm 90.7	9pm 38.4	9pm 2108	9pm
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	(-3)	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	(-3)	"	"	"	"

$$W_{net} = W_{SI} + W_{mu} - W_{ld}$$

Time sec	W _{SI} gpm	W _{mu} gpm	W _{ld} gpm	W _{net} gpm
0	38	12	92	-42
16	25	310	87	+248
46	35	327	39	+323
90	35	322	39	+318

TECO

PER LEVEL DUE TO MAKE UP FLOW

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10/2/78

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Rx Trip of 8/2/78 Combined:

Volume added to EC System in 90 second period:

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

$$\text{Vol} = -0.7 + 28.9 + 143 + 235 = 406 \text{ gallons}$$

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

Hot H.U. water density at 555 F & 1800 psia

(Page 25 of 55 in Calc File 32-9538-00 by RW Winks)

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

$$\text{Density Ratio} = 1.35$$

Volume of 555 F net makeup volume = 548 gallons

Change in Per level due to net makeup volume:

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

TECO

PER LEVEL DUE TO MAKEUP FLOW

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10/2/78

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RC SYSTEM FLOWRATES AFTER REACTOR TRIP ON
AUG 7 1978 AT DAVIS-BESSE I

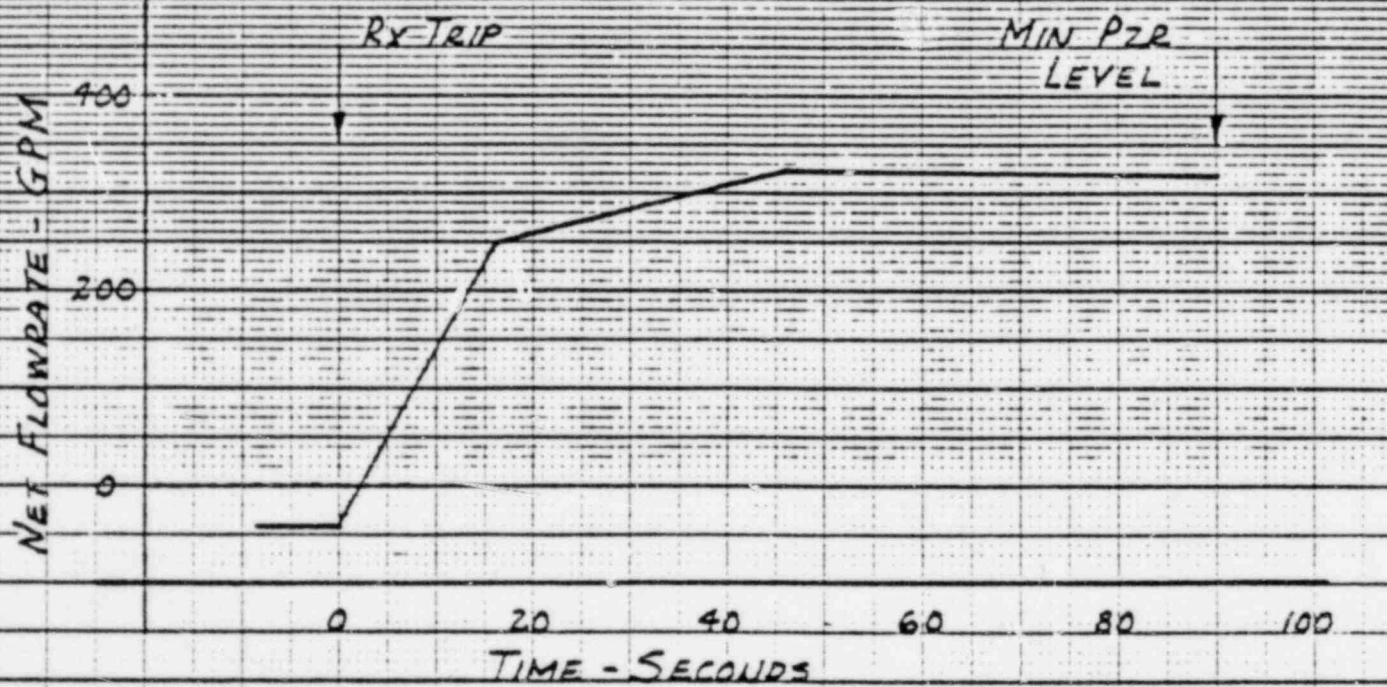
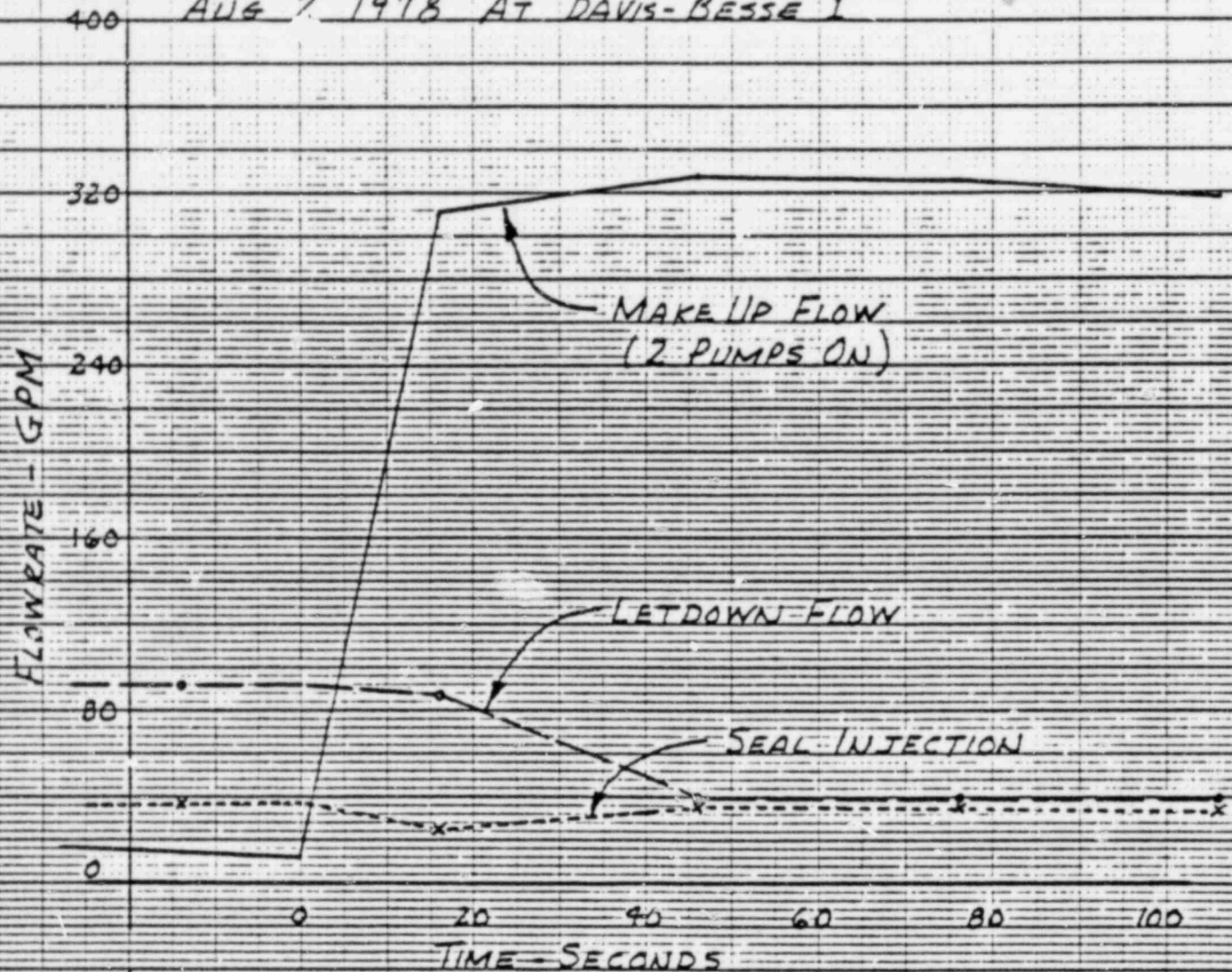


FIG 3

46 1470

K-E 10 X 10 TO 1/2 INCH • 7 1/2 X 10 PICTURES
HEUFFEL & ESSER CO. MADE IN U.S.A.

Post Trip Review for Ex 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	F-740 MU Flow	F-717 l.d. Flow	F-782 S.I. Flow	RC Press psig *	Calc H.U. Flow
22:42:30	-5.4	27.3	50.8	35.8		
22:43:00	-2.4	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	"	(- \$)	1950	
22:44:15	51	"	0.0	"	"	
22:44:30	66 (1.1)	16.1	0.0	"	1960	
22:45:30	126=(2.1)	0.0	0.0	"	1935	
22:46:30	186=(3.1)	15.8	0.0	(- \$)	1845	
22:46:52	208=(3.4)	#2 Started				(220)
22:47:30	246=(4.1)	18.0	0.0	"	1755	(220)
22:48:00	276=(4.6)	"	"	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 30/55 of Calc File 32-9538-00 by R.W.Winks

To be very conservative, assume one makeup 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.

TECO
 PER LEVEL DUE TO MAKEUP FLOW

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10/2/78

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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:

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

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

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

$$Vol = 270 \text{ gallons.}$$

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

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

$$\Delta \text{ Per level change} = \frac{352}{74805 \times 3.2} = 14.7 \text{ Inches At 4.0 Minutes}$$

TECO

PER LEVEL DUE TO MAKE UP FLOW

14

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10/3/78

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RC SYSTEM FLOWRATES AFTER REACTOR TRIP AND STATION BLACKOUT ON NOV. 29, 1977

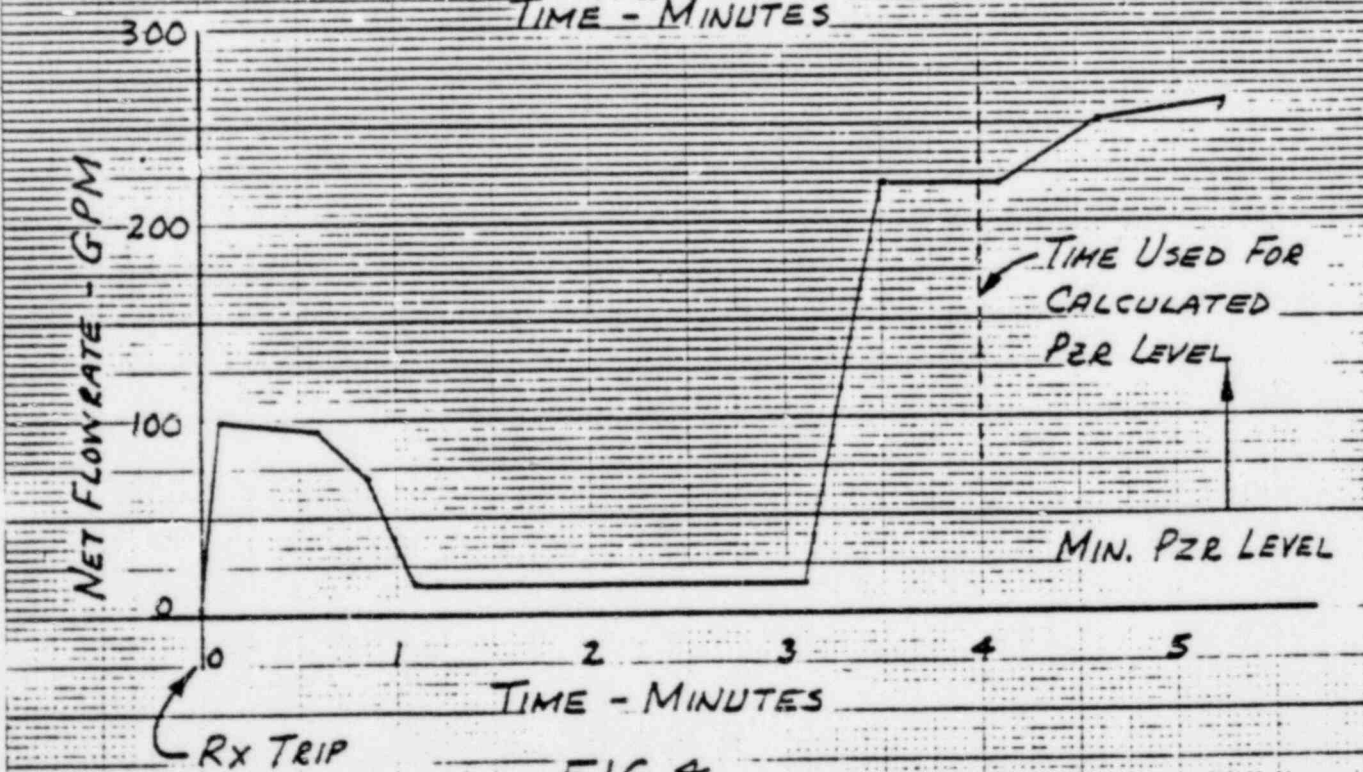
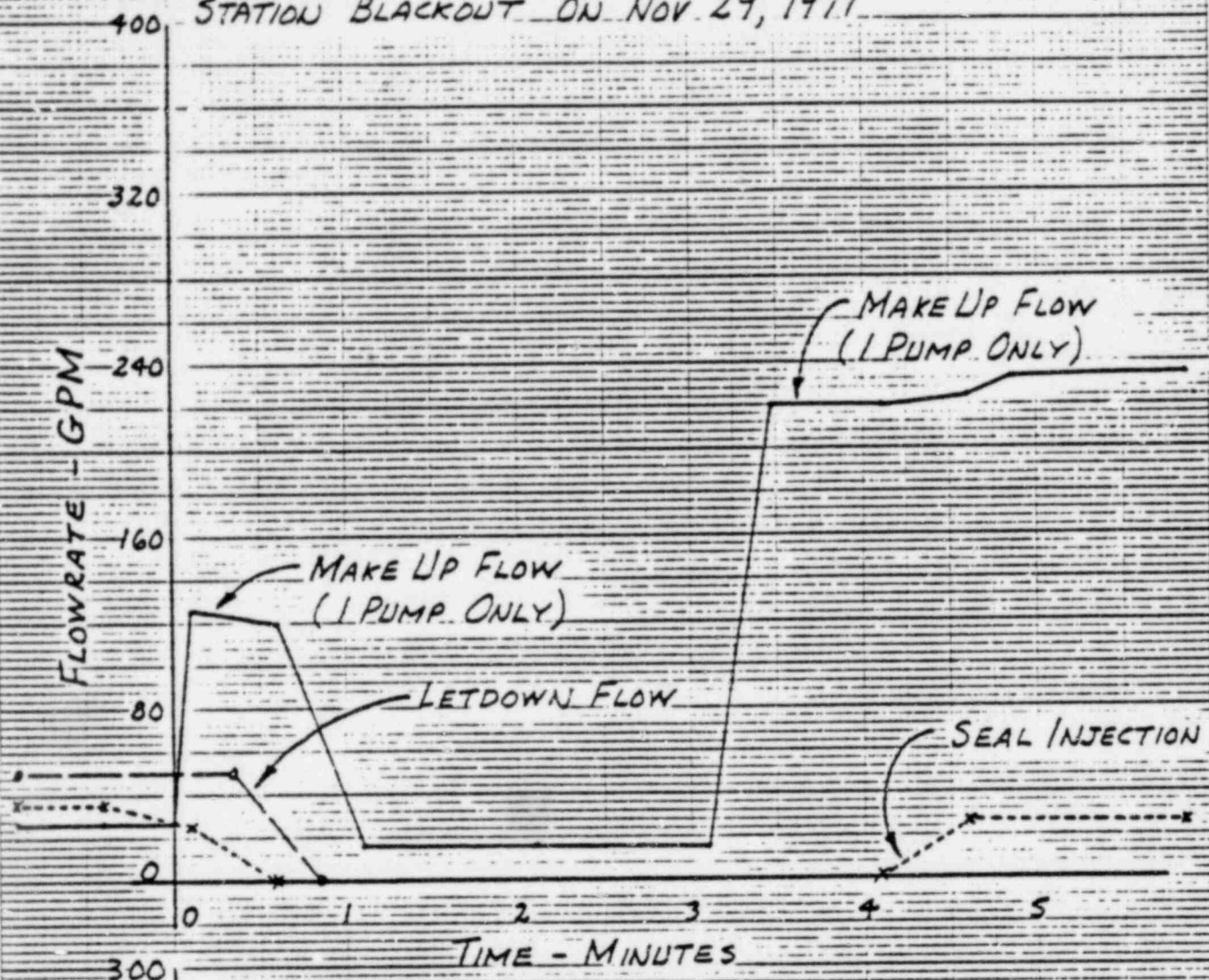


FIG 4

46 1323

K-E 18 X 10 10 1/2 INCHES J X 10 1/2 INCHES NEUPPE & ESSER CO. MADE IN U.S.A.

Conclusion:

The "possible" correction to the calculated change in PZR level contained in Table II of my Transmittal package 86-2226-00 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 nominal 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.

TECO
PZR Level DUE TO Make Up Flow

14

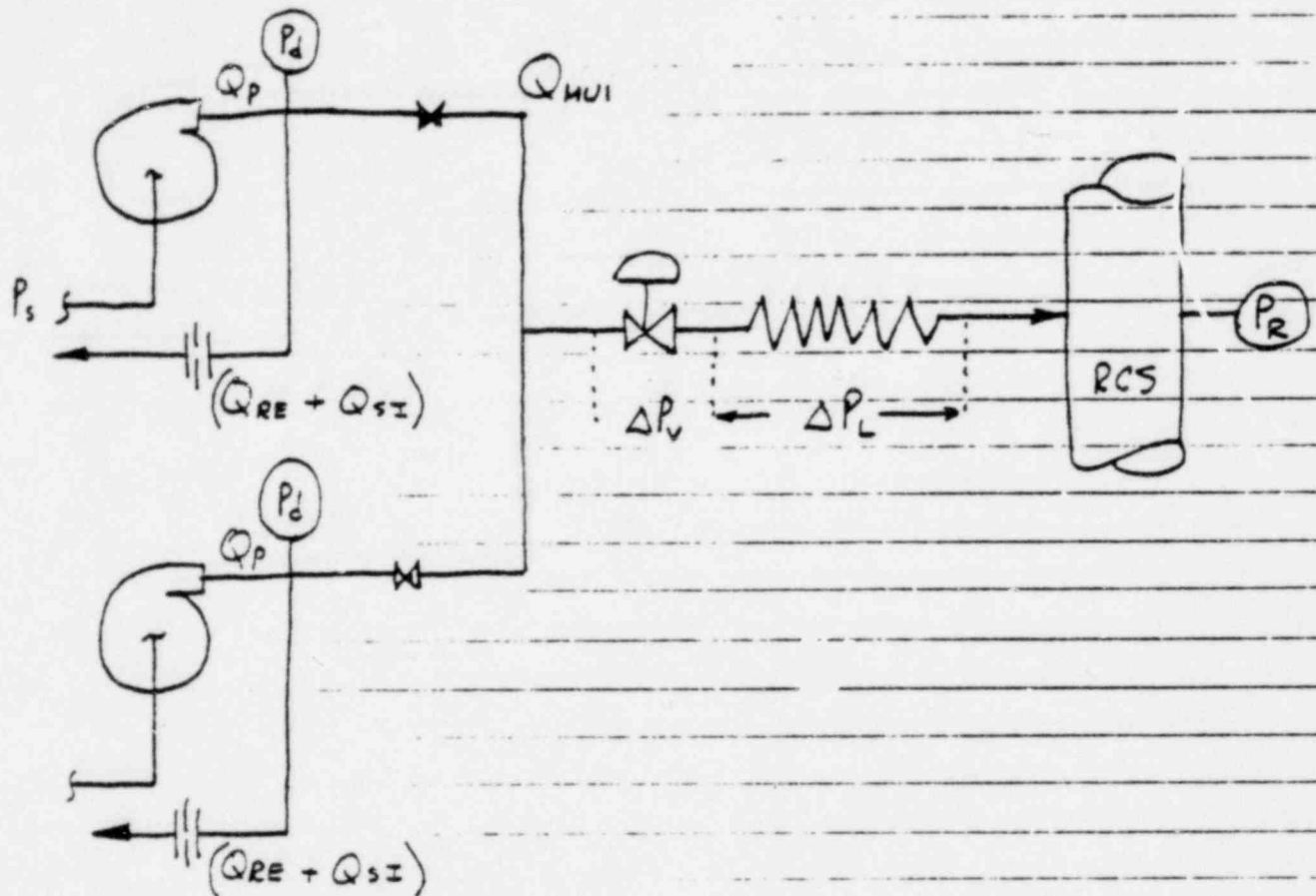
R. W. Winks

10/3/78

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Calculation of Make Up System Performance

System Schematic



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

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

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

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

WILCOX & WILCOX
 CURVE NUMBER
 320-0014

2X3X7 1/2 CP

WILCOX W.P.
 PUMP

NPSH/FT

EFF. %

NPSH @ IMP

7000

HEAD

5350

6000

5800

5000

4000

5000

5000

5000

5000

5000

5000

5000

5000

5000

5000

5000

5000

5000

5000

5000

5000

5000

5000

TOTAL DYNAMIC HEAD IN FEET

EFF %

BHP @ 50 GPM

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

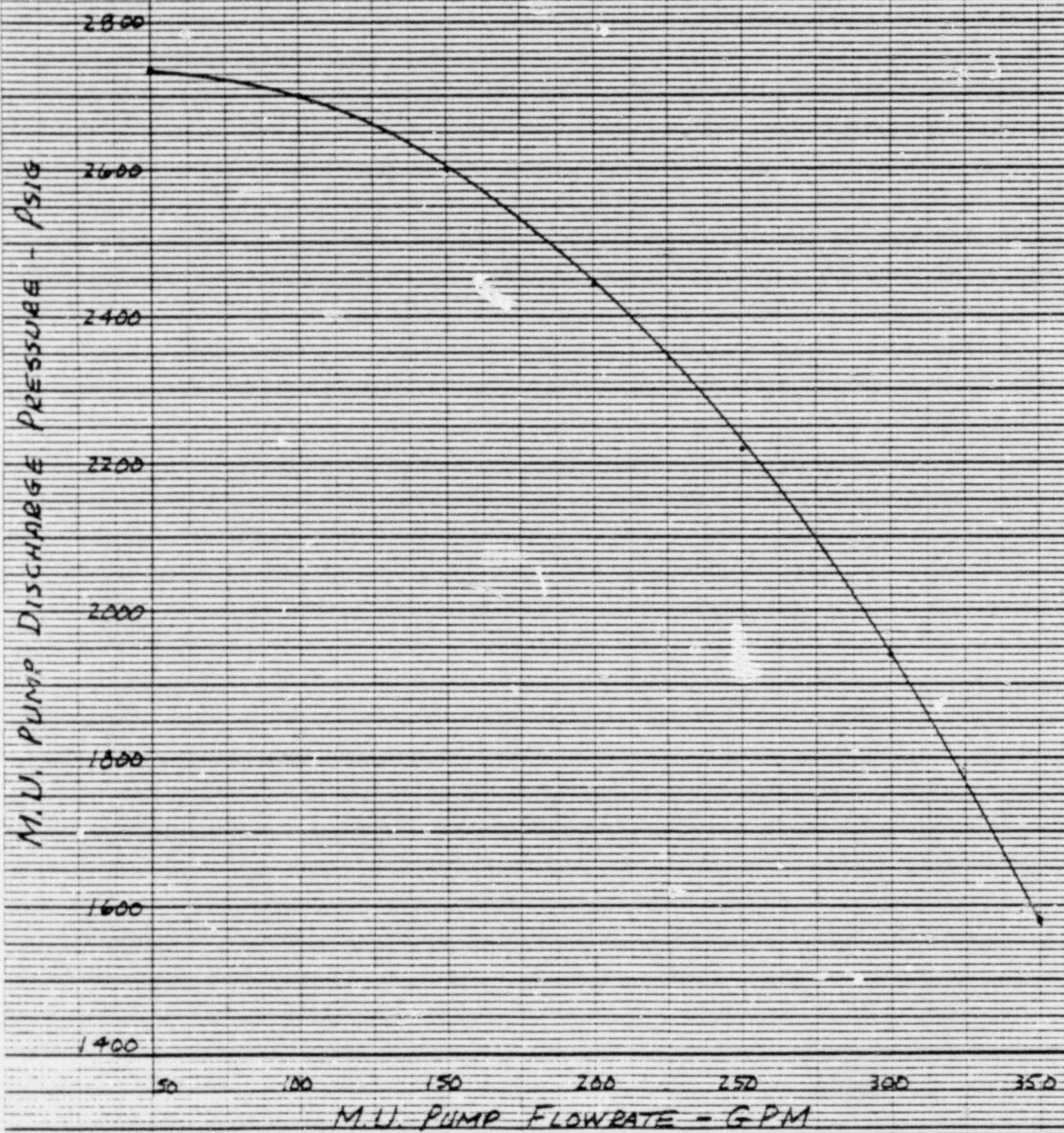
WITNESS EST PERFORMANCE
 BINGHAM WILLAMETTE CO
 PORTLAND, OREGON

CHARACTERISTIC CURVE SHEET		2X3X7 1/2 CP		12.5TG PUMP	
BINGHAM PUMP DIVISION		DIA IMPELLER		IMPELLER PART	
BINGHAM-WILLAMETTE COMPANY		7 3/16		1) 313MSD-26	
TOLEDO EDISON CO		DIA IMPELLER EYE		2) 313MSD-24/25	
WILCOX & WILCOX		9.8		REFERENCE	
TOLEDO EDISON CO		50		5404 R.P.M.	
WILCOX & WILCOX		9.8		CURVE NO	
TOLEDO EDISON CO		9.8		30856	

32-9745 00

M.U. PUMP DISCHARGE PRESSURE VERSUS PUMP FLOWRATE
FOR DAVIS-BESSE I

NOTE:
FLUID TEMPERATURE = 100 F



46 1470

K&E
10 X 10 TO 1/2 INCHES
REDFIL & ENGERCO. MADE IN U.S.A.

M.U. PUMP FLOWRATE - GPM

FIG 5

32-9745 00

1 MU Pump Operation:

$$k_1 = 0.010 \text{ and } 0.0050$$

$$= (\text{psid} / \text{gpm}^2)$$

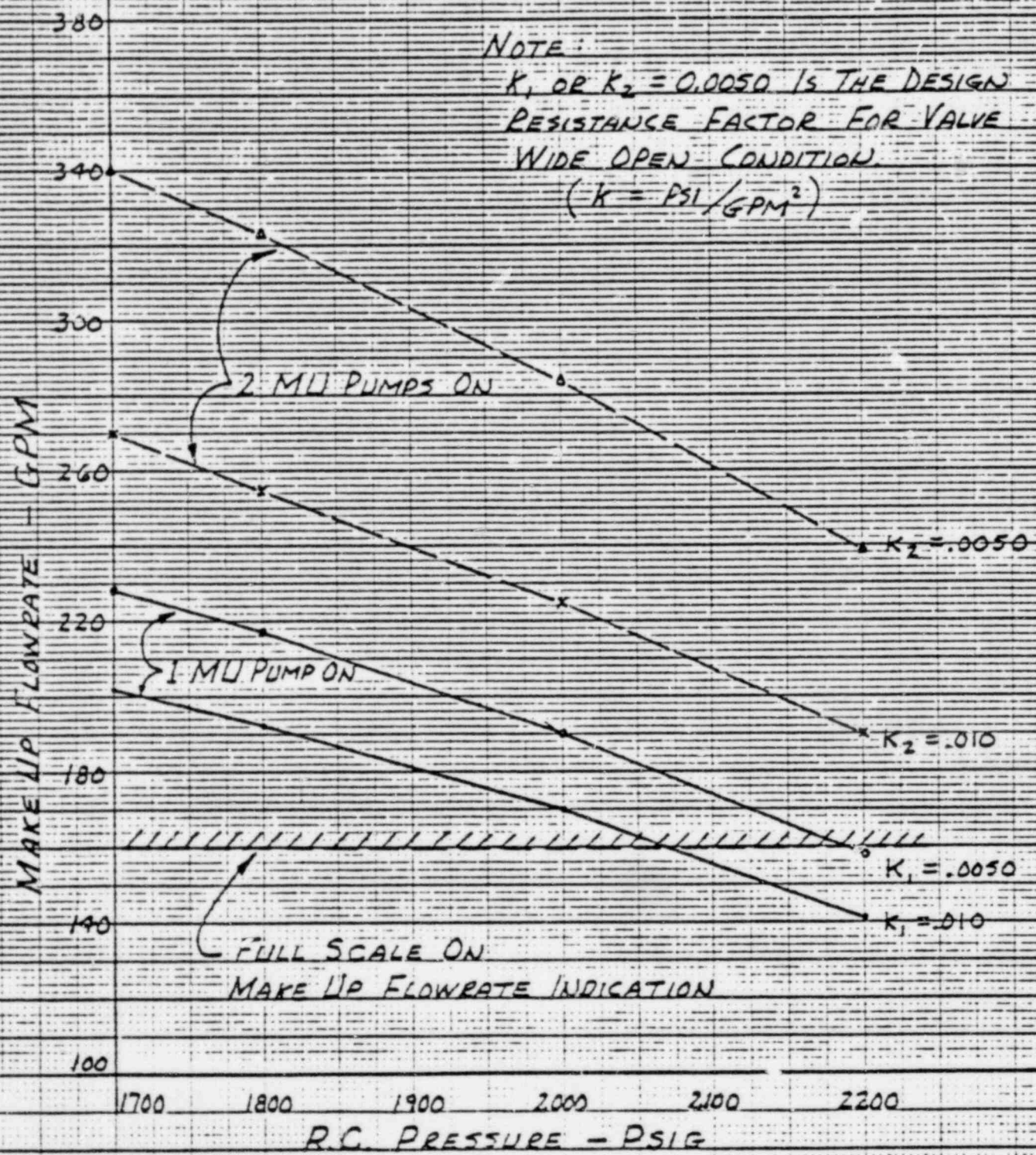
Pre psig	Q _{MU} gpm	Q _{RE+SI} gpm	Q _{pump} gpm	P _d psig	ΔP _{sys} psi	k ₁	Q _{MU'} gpm
2200	142	70	212	2400	200	0.010	141
2000	169	70	239	2290	290	.010	170
1800	192	70	262	2169	369	.010	192
1700	203	70	273	2108	408	.010	202

2200	160	70	230	2325	125	.0050	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
 $k_2 = k_1 = 0.010 \text{ and } 0.0050 \text{ psi/gpm}^2$

Pre	Q _{MU}	Q _{pump}	Q _{TOT}	P _d	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



46 1470

K-E 10 X 10 TO 1/2 INCH 7/16 X 10 INCHES KRUPP & ESSER CO. MADE IN U.S.A.

FIG 6

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

46 1320

K-E 10 X 10 TO 1/2" CH 7 X 10 INCHES
REUFEL & ESSE CO MANUFACT

100 L/min (GPM)

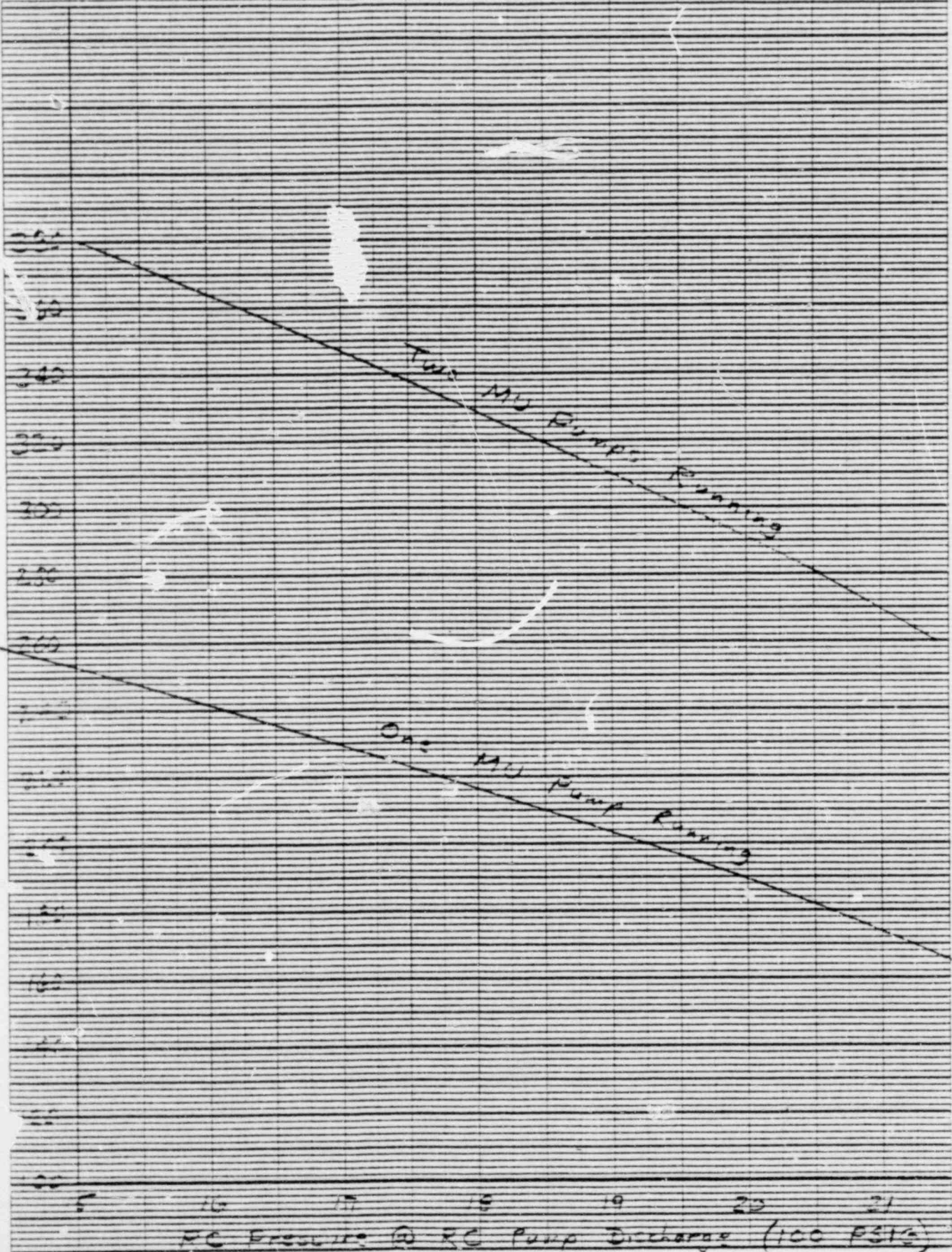


FIG 7

①	②	③	④	⑤	⑥
Flow (GPM)	MU Line Flow (GPM)	① + ② GPM	MU Line ΔP (PSI)	MU Pump ΔH (PSI)	FC Press @ HPI Nozzle ⑤ - ④ (PSI)
120	150	270	102	2400	2203
150	150	300	117	2355	2235
160	160	320	123	2315	2182
180	180	360	163	2200	2062
200	200	400	208	2130	1952
220	220	440	251	2025	1774
240	240	480	299	1915	1616
260	260	520	351	1790	1439

Two Pump

MU = 31
 = 67.44 PSI @
 114 GPM (valve
 wide open)
 $k_1 = .0052 \text{ psi/gpm}^2$

Two Pump

① - ②

160	96	133	2330	2297	
200	116	206	2590	2372	
240	136	299	2520	2221	
280	156	407	2460	2053	✓
320	176	531	2390	1949	✓
360	196	673	2300	1627	✓
400	216	830	2215	1385	
480	296	1140	2255	1506	✓
370	281	710	2280	1570	
340	261	607	2420	1743	
340	261	600	2340	1743	
260	146	351	2490	2139	

TECO
 Appendix to 32-9745-00
 14
 J.R. Merchant for
 R.W. Winks

10/3/78