~~RS-1-62~~

Calculation Title Page

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Project SONGS-1 Job Order No. 3587 Discipline MECH.

Subject AFW FLOW VENTURI SIZING

Calculation No. DC-2836 SUPPL. B QA Class SR No. Pages 62+8a 4A, 6A, B, C, 4B, E

Responsible Engineer R. A. [signature] SIGNATURE Date 3/23/90

Independent Review Engineer [signature] SIGNATURE Date 5/9/90

ORIGINAL ISSUE

	NAME	DATE	SIGNATURE
Group Leader	I. KATTER		
Discipline Sup. Engineer	M. WHARTON		
Professional Engineer (if required)			

RECORD OF REVISIONS

NO.	REASON FOR REVISION	DATE	RESP. ENGR.	IRE	GL	DSE	PE

PROFESSIONAL ENGINEER'S SEAL

SCE 26-121 REV 10/84

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SUBJECT: AFW FLOW VENTURI SIZING   DESIGN CALCULATION NO. DC-2836 REVISION 5

J.O. NO. ______ MADE BY R.A.[signature] DATE 3/22/90 CHK. BY ______ DATE ______

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SUBJECT: AFW FLOW VENTURI SIZING — DESIGN CALCULATION NO. DC-2386 REVISION 0

J.O. NO. ____ MADE BY R. A. [signature] DATE 3/22/90 CHK. BY [signature] DATE 5/9/90

1.0 PURPOSE

THE PURPOSES OF THIS CALCULATION ARE TO SIZE THE VENTURIS THAT LIMIT AUXILIARY FEEDWATER (AFW) TO THE STEAM GENERATORS AND DETERMINE MARGINS FOR THE REVISED AFW FLOW LIMITS AND VENTURI DESIGNS

DUE TO THE CHANGED VENTURI SIZE AND FLOW REQUIREMENTS, THIS SUPPLEMENT SUPERCEDES FLOW RATES AND MARGINS CALCULATED IN PREVIOUS REVISIONS OF THIS CALCULATION.

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2.0 RESULTS

1. THE VENTURIS WILL MEET ALL AFW FLOW REQUIREMENTS. TABLE 2-1 COMPARES EXPECTED VENTURI FLOW RATES WITH FLOW RATE LIMITS AND PROVIDES MARGINS FOR EACH DESIGN CONDITION
2. VENTURIS WILL HAVE THROAT DIAMETERS OF APPROXIMATELY 0.377 INCH. (SUPPLIER WILL DETERMINE EXACT DIAMETER.)
3. THE REQUIRED VENTURI PRESSURE DROPS AND PRESSURE DEPENDENT FLOW LIMITS ARE PROVIDED IN TABLE 2-2
4. THE RECOMMENDED VENTURI SIZE IS 140 +0, -10 GPM AT 1160 PSIG INLET PRESSURE.
5. IT WILL NOT BE NECESSARY TO EQUALIZE FLOW AMONG THE STEAM GENERATORS NOR ISOLATE BLOWDOWN IF THE REVISED FLOW LIMITS FOR POSTULATED FEEDWATER LINE BREAK EVENTS ARE INCORPORATED.
6. DUE TO CHANGES IN VENTURI SIZE AND FLOW REQUIREMENTS, THE FLOW RATES AND MARGINS CALCULATED IN THIS REVISION SUPERCEDE THOSE OF PREVIOUS REVISIONS.

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SUBJECT: AFW FLOW VENTURI SIZING DESIGN CALCULATION NO. DC-2836 REVISION 0

J.O. NO. ______ MADE BY R.a.W. DATE 5/10/90 CHK. BY [initials] DATE 10 May 90

7. THIS CALCULATION DOES NOT CHANGE TECHNICAL SPECIFICATIONS, SURVEILLANCE PROCEDURES, OR THE OPERATING LICENSE, BUT DOES CONSIDER PROPOSED REVISIONS TO AFW FLOW LIMITS THAT WILL BE IMPLEMENTED PRIOR TO INSTALLING NEW AFW FLOW VENTURIS, AS NOTED IN TABLE 2-1. (RaW 5/10/90)

8. RESULTS FOR A 140 GPM FLOW VENTURI, BASED ON BEST ESTIMATES OF VENTURI PRESSURE LOSSES ARE PRESENTED ON FIGURE 2-1.

9. RESULTS FOR A 140 GPM FLOW VENTURI, BASED ON MAXIMUM ALLOWABLE VENTURI PRESSURE LOSSES ARE PRESENTED ON FIGURE 2-2.

10. CASE 5 CONDITIONS, BASED ON MAXIMUM ALLOWABLE PRESSURE LOSSES, ARE PRESENTED ON FIGURE 2-3.

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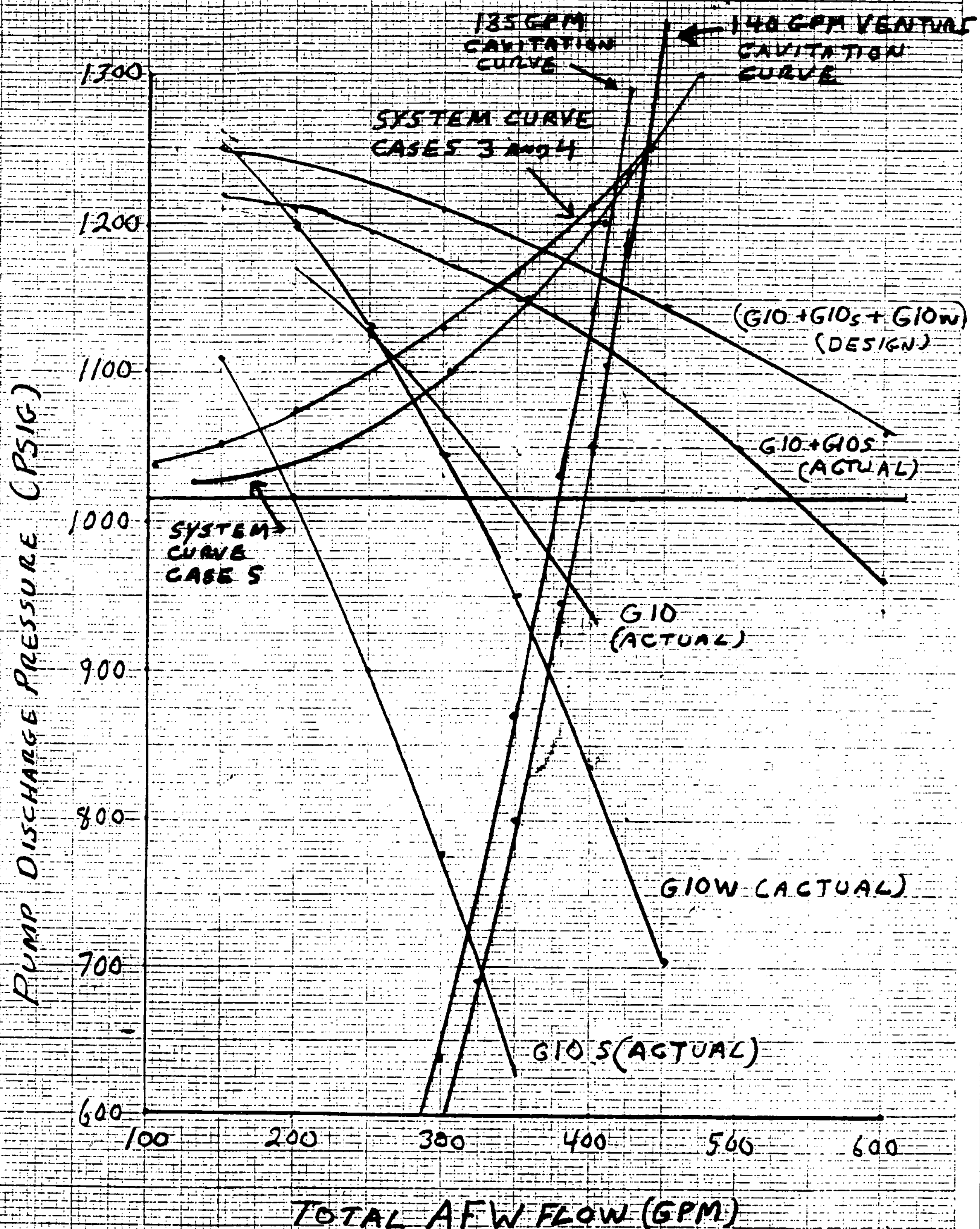

FIGURE 2-1
SUMMARY PLOT BEST ESTIMATE LOSSES FOR FLOW VENTURIS

20 Squares to the Inch

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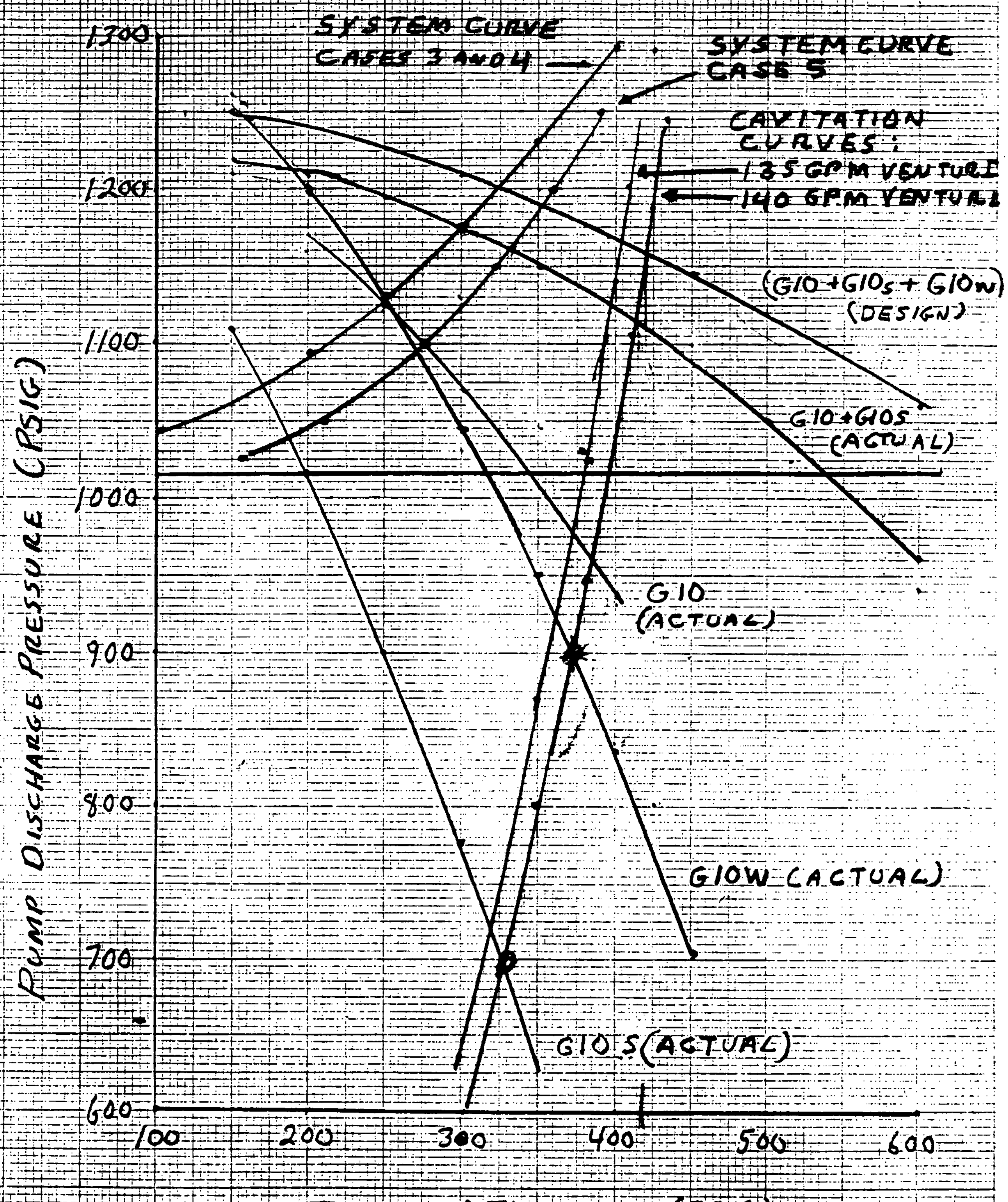

FIGURE 2-2

SUMMARY PLOT - MAXIMUM VENTURI PRESSURE LOSSES

20 Squares to the Inch

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SUBJECT: AFW FLOW VENTURI SIZING — DESIGN CALCULATION NO. SUPPL. B DC-2836 REVISION 0

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TABLE 2-1

VENTURI FLOW RATES & MARGINS

DESIGN CONDITION	FLOW LIMIT (GPM)	EXPECTED FLOW (GPM)	MARGIN	BOUNDING CASE
1. ANY PUMP TO ANY DEPRESSURIZED S.G.	<150/SG	130-140 PER SG	7% TO 13%	(1) (G10+G10S
2. G10W OR G10S TO 2 DEPRESS. S.G WITH A FW LINE BREAK	>87.5/SG (175 TOTAL)	206-212 TOTAL	18% TO 21%	(2) (G10S)
3. G10W OR (G10+G10S) TO 3 S.G. AT 1015 PSIG	>61.7/SG (185 TOTAL)	260-265 TOTAL	41% TO 43%	(3) (G10W)
4. G10 TO 3 S.G. AT 1015 PSIG	>55/SG (165 TOTAL)	268-263 TOTAL	62% TO 59%	
5 G10W OR (G10+G10S) TO 2 SG AT 1015 PSIG WITH A FW LINE BREAK	>50/SG (100 TOTAL)	146 TOTAL	46%	(3) (G10W)
6 G10S	<420 TOTAL	335-320 TOTAL	20% TO 24%	

(1) BOUNDING CASE IS (G10 + G10S + PARTIAL G10W). ALL OTHER CASES PROVIDE LESS FLOW

(2) VALUES ARE FOR G10S. G10W PROVIDES MORE FLOW & MORE MARGIN

(3) VALUES ARE FOR G10W. (G10 + G10S) PROVIDES MORE FLOW & MORE MARGI[N]

(4) MARGINS ARE BASED ON PROPOSED (REF. 4 AND 5) CHANGES TO FLOW REQUIREMENTS. CURRENTLY APPROVED FLOW LIMITS (REF.3) AND THEIR ASSOCIATED MARGINS ARE:

CASE 2 : 250 GPM TOTAL (−18% TO −21%)

CASE 5 : 125 GPM TOTAL (17%)

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TABLE 2-2

VENTURI FLOW DEPENDENT PRESSURES OR PRESSURE DROP

DESIGN CONDITION	
1. (G10 + G10S) TO ANY DEPRESS. ST. GEN. (INCLUDES PARTIAL G10 W FLOW)	140 +0, -10 GPM AT 1160 psig
2. G10W or G10S TO 2 DEPRESS. ST. GEN. WITH A FW BREAK	GREATER THAN 100 GPM AT 775 psig
3 G10W on (G10 + G10S) TO 3 ST. GEN @ 1015 PSIG	LESS THAN 40 PSID LOSS AT 62 GPM
4 G10 TO 5 ST. GEN AT 1015 PSIG.	BOUNDED BY CASE 3
5. G10W on (G10 + G10S) TO 2 ST. GEN AT 1015 PSIG WITH AFW BREAK	BOUNDED BY CASE 3
6. G10S	BOUNDED BY CASE 1

DWG. NO.

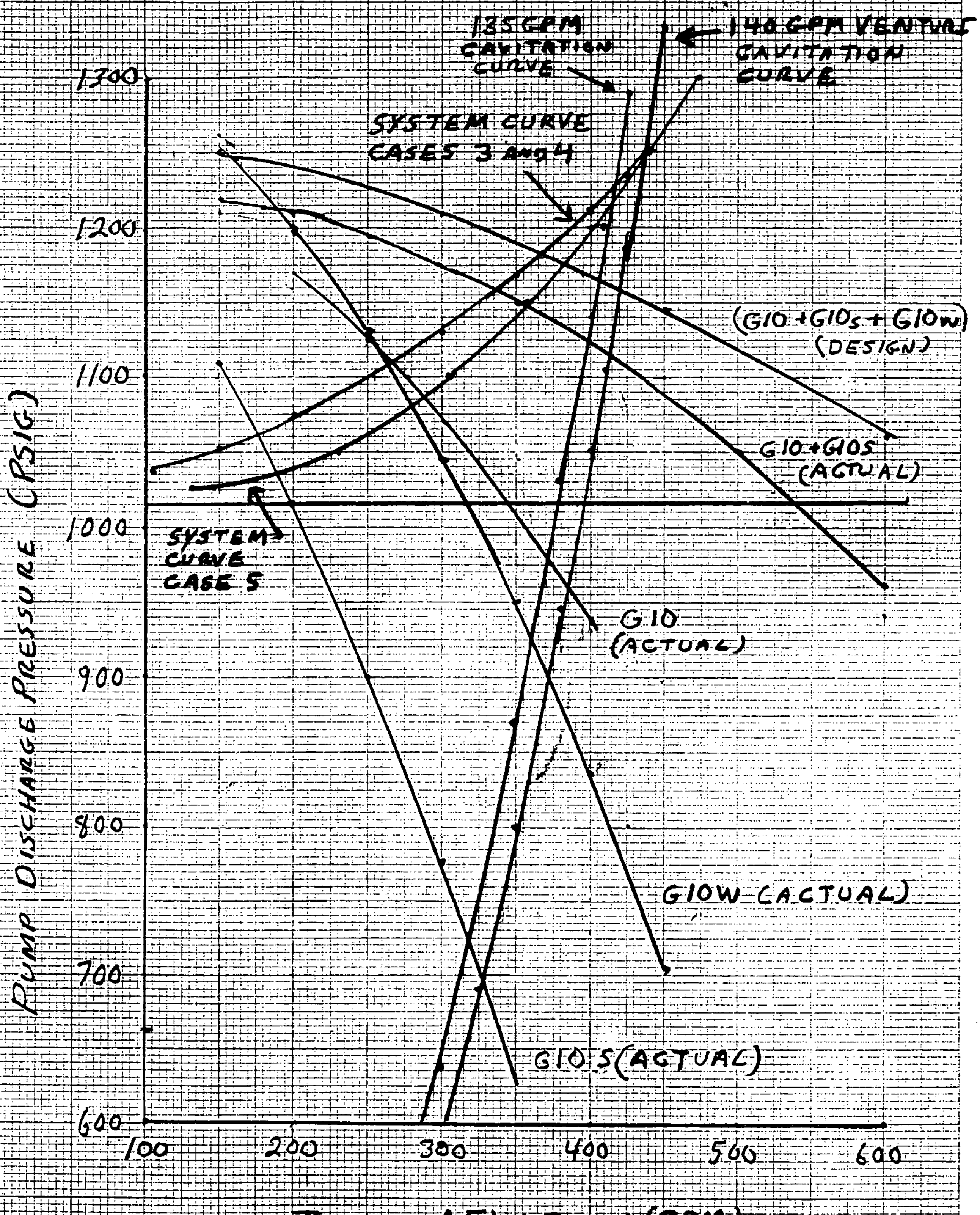

FIGURE 2-1
SUMMARY PLOT BEST ESTIMATE LOSSES FOR FLOW VENTURIS

20 Squares to the Inch

Made By R.A.W. Date 5-21-96

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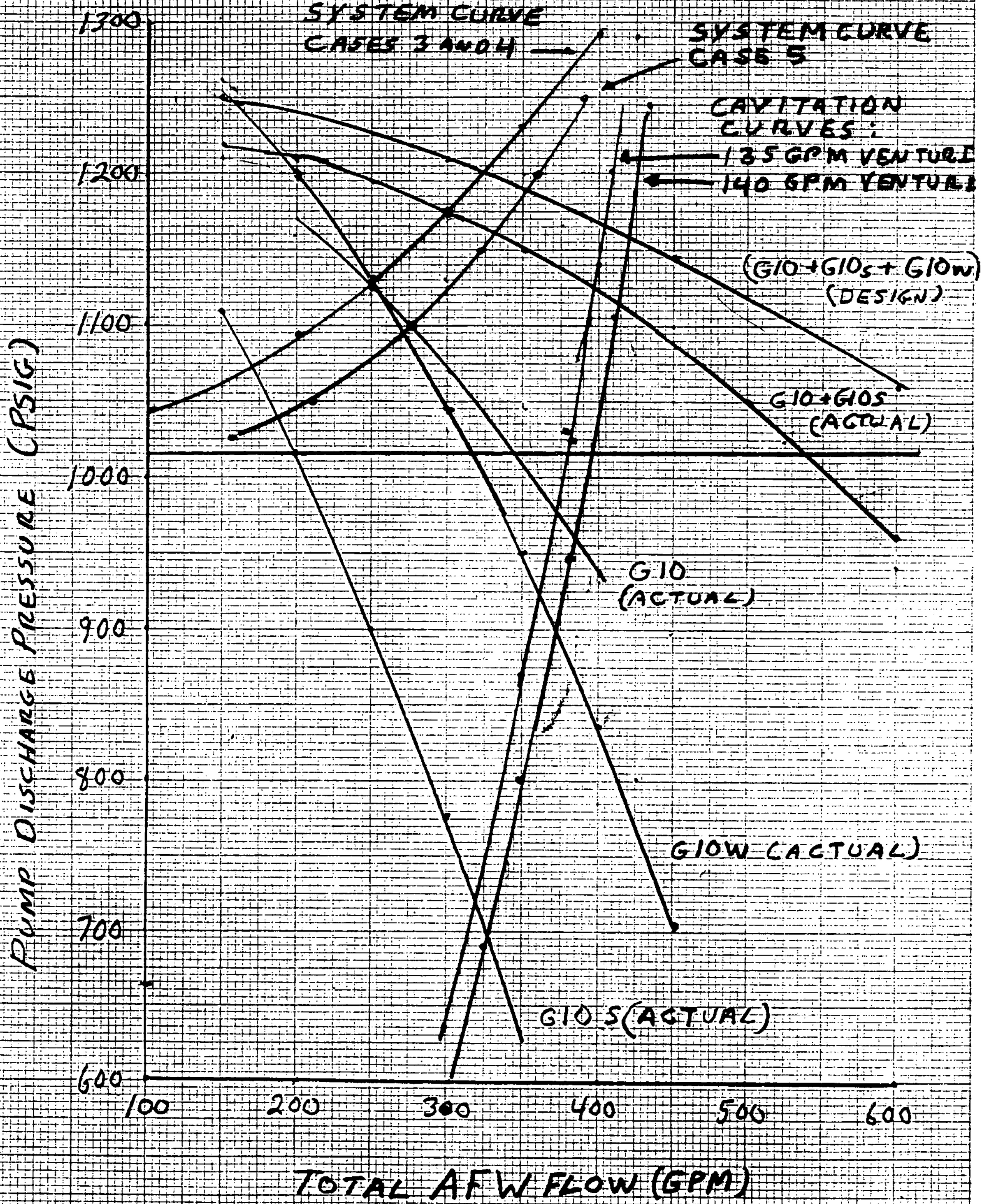

FIGURE 2-2

SUMMARY PLOT · MAXIMUM VENTURI PRESSURE LOSSES

20 Squares to the Inch

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SUBJECT: AFW FLOW VENTURI SIZING — DESIGN CALCULATION NO. SUPPL. B DC-2836 — REVISION 0

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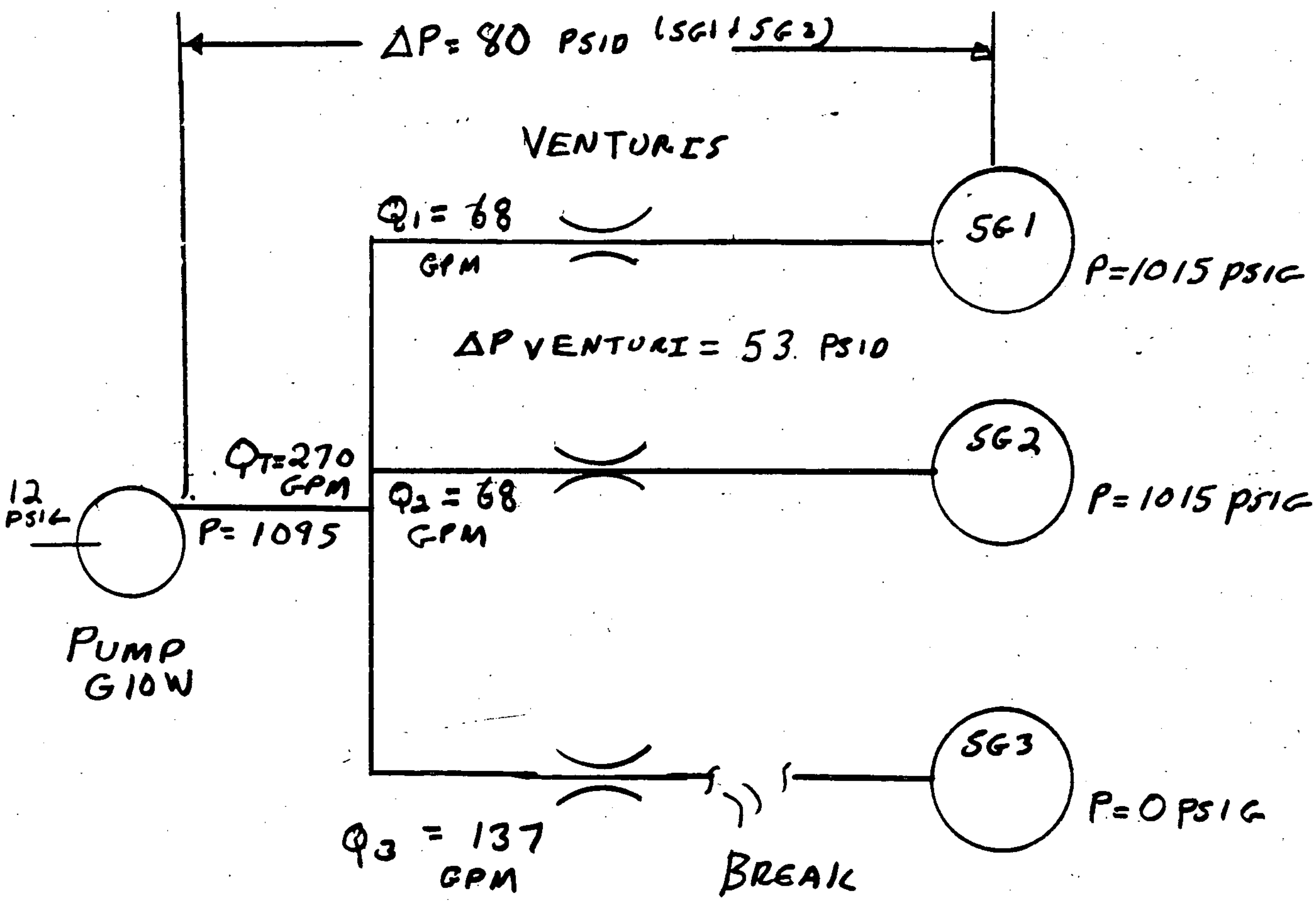

FIGURE 2-3

CASE 5 CONDITIONS BASED ON MAXIMUM VENTURI ΔP

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3.0 ASSUMPTIONS

1. AUXILIARY FEEDWATER TEMPERATURE IS 70°F
2. VENTURI RECOVERY FACTORS WILL BE THE SAME AS THOSE REPORTED DURING THE CALIBRATION TESTING OF THE EXISTING AFW VENTURIS
3. AFW FLOW REQUIREMENTS FOLLOWING POSTULATED FEEDWATER LINE BREAKS WILL BE REDUCED TO THE VALUES PROVIDED IN 5.1.2 AND 5.1.5.
4. THE EFFECTS OF FRICTION AND ELEVATION LOSSES ARE NEGLIGIBLE WHEN CALCULATING CAVITATING VENTURI FLOW, THESE EFFECTS WILL BE ACCOUNTED FOR WHEN CALCULATING NON-CAVITATING FLOW TO THE STEAM GENERATORS. (THE VALIDITY OF THIS ASSUMPTION WILL BE VERIFIED IN THE CALCULATION
5. LOSSES AND FLOW COEFFICIENTS OF THE THREE VENTURIS AND THE THREE AFW LOOPS ARE EQUAL

DWG. NO.

4.0 METHODOLOGY

4.1 DETERMINE THE CAVITATING FLOW COEFFICIENT FOR THE EXISTING VENTURI DESIGN, USING DATA FROM REFERENCE 6.

4.2 DETERMINE AN AVERAGE NON-CAVITATING PRESSURE LOSS COEFFICIENT FOR THE EXISTING VENTURIS, USE REFERENCE 1 TEST DATA.

4.3 RESIZE THE FLOW VENTURIS FOR MAXIMUM FLOW RATES OF 150, 145, 140, AND 135 GPM, BASED UPON THE PUMP CURVE FOR (G10 + G10S + G10W) TAKEN FROM REFERENCE 6. FOR EACH SIZE VENTURI, CALCULATE:

- CAVITATING FLOW COEFFICIENT (C),
- NON-CAVITATING PRESSURE LOSS COEFFICIENT (K_V),
- AREA, AND DIAMETER OF BORE.

4.4 CALCULATE FLOW RATES FOR EACH OF THE DESIGN CONDITIONS OF 5.1 FOR EACH SIZE VENTURI.

4.4.1 FLOW RATES ARE BASED ON THE INTERSECTIONS OF THE BOUNDING PUMP CURVES FOR EACH CASE OF 5.1 AND EITHER THE CAVITATING FLOW CURVE OR THE SYSTEM

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CURVE FOR EACH SIZE VENTURI

4.4.2 SYSTEM CURVES ARE DEVELOPED BY ADJUSTING THE FLOW COEFFICIENT OF THE EXISTING SYSTEM (REFERENCE 2) TO ACCOUNT FOR THE CHANGE IN THE VENTURI FLOW COEFFIENT.

4.4.3 THE SYSTEM CURVES FOR CASE 5, WHICH PROVIDES FLOW TO A BREAK AND TWO PRESSURIZED STEAM GENERATORS, ACCOUNTS FOR BOTH THE EFFECTS OF MODIFIED KV AND C FOR EACH SIZE VENTURI.

4.4.4 DETERMINE MARGINS IN PRESSURE LOSS FOR EACH OF THE CASES.

4.5 DETERMINE MARGINS FOR EACH CASE BY COMPARING CALCULATED AND REQUIRED FLOWS FOR A VENTURI OF 140 GPM +0, -10 GPM DESIGN. (130 GPM) VALUES ARE EXTRAPOLATED.

4.6 DETERMINE REQUIRED AND RECOMMENDED PRESSURE-FLOW AND PRESSURE LOSS-FLOW RELATIONS FOR THE RECOMMENDED VENTURI SIZE

NOTE - FOR CONSERVATISM, MAXIMIUM FLOW LIMITS WILL BE EVALUATED USING THE LARGER OF DESIGN OR ACTUAL PUMP CURVES. MINIMUM FLOW LIMITS WILL BE EVALUATED USING THE SMALLER OF DESIGN BASIS OR ACTUAL PUMP CURVES.

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5.0 DESIGN INPUT SHEET

[X] Design Requirements
[ ] Design Input Change

SUBJECT		PROJECT
AFW FLOW VENTURI SIZING		501
QUALITY CLASS	SEISMIC CLASS	SPECIFICATION REFERENCE
SR	A	

Design Input 5.1 THE VENTURIS MUST BE SIZED TO MEET THE FOLLOWING CRITERIA:

5.1.1 MAXIMUM FLOW PER UNPRESSURIZED STEAM GENERATOR WITH PUMPS G10 AND G10S OPERATING - 150 GPM (REF. 3, Pg. 3)

5.1.2 MINIMUM FLOW TO TWO UNPRESSURIZED STEAM GENERATORS WITH AN FW LINE BREAK FROM EITHER PUMP G10W OR G10S - 175 GPM (REF. 4)

5.1.3 MINIMUM FLOW TO THREE STEAM GENERATORS AT 1015 PSIG FROM EITHER G10W PUMP OR G10 AND G10S PUMPS - 185 GPM (REF. 3, Pg 2)

5.1.4 MINIMUM FLOW TO THREE STEAM GENERATORS AT 1015 PSIG FROM G10 PUMP ALONE - 165 GPM (REF. 3, Pg. 2)

5.1.5 MINIMUM FLOW TO TWO STEAM GENERATORS (AT 1015 PSIG) [RAW 3/28/90] WITH A FEEDLINE BREAK FROM PUMP G10W OR PUMPS G10 AND G10S - 100 GPM (REF. 5, Pg 6)

5.1.6 MAXIMUM FLOW PUMP G10S - 420 GPM (REF 3, Pg 3).

RESPONSIBLE ENGINEER	DATE	INDEPENDENT REVIEW ENGINEER	DATE	GROUP LEADER	DATE
R. A. [signature]	3/22/90	[signature]	5/9/90		

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DESIGN INPUT SHEET

[X] Design Requirements
[ ] Design Input Change

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SUBJECT		PROJECT
AFW FLOW VENTURI SIZING		SO1
QUALITY CLASS: SR	SEISMIC CLASS: A	SPECIFICATION REFERENCE:

Design Input

5.2 CONDITION 5.1.1 SHALL ALSO CONSIDER FLOW FROM PUMP G10W AT ITS LOW FLOW TRIP POINT.

5.3 G10W LOW FLOW SIGNAL TO START PUMPS G10 AND G10S IS 57 GPM (REF. 6, pg. R4-29)

5.4 THE THROAT DIAMETER OF THE EXISTING VENTURIS IS 0.440, +0, -.005 IN. (REF. 7)

5.5 ALL PUMP CURVES ARE TAKEN FROM REFERENCE 6, WHICH MODIFIED PUMP CURVES IN REFERENCE 2, TO CONSIDER BOTH DESIGN AND ACTUAL PERFORMANCE AND THE EFFECTS OF TURBINE INLET PRESSURE CONTROL ON G10 PUMP PERFORMANCE.

5.6 ALL MAXIMUM FLOW RATES SHOULD INCLUDE MARGIN (REF. 9)

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R. A. [signature]	3/22/90	[signature]	5/9/90		

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7. DRAWING 1810-AA 319-M007 (PERMUTIT NO. 556-34196 REV 0), PERMUTIT, PARAMUS NJ

8. TECHNICAL PAPER NO. 410, "FLOW OF FLUIDS THROUGH VALVES, FITTINGS, AND PIPE", CRANE CO., CHICAGO, IL.

9. DESIGN CRITERIA FOR AUXILIARY FEEDWATER SYSTEM MODIFICATIONS, M86315 REV. 7, SCE.

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7.0 NOMENCLATURE

A - FLOW AREA

AFW - AUXILIARY FEEDWATER

C - FLOW COEFFICIENT FOR VENTURI WHEN CAVITATING ($C \equiv Q^2/\Delta P$)

D - DIAMETER

°F - DEGREES FAHRENHEIT

FW - FEEDWATER

g_c - NEWTON'S CONSTANT = 32.2 (LBM/LBF)(FT/SEC²)

GPM - GALLONS PER MINUTE

IN - INCH

K - PROPORTIONALITY CONSTANT FOR PRESSURE LOSS

K_{sys} - SYSTEM PRESSURE LOSS COEFFICIENT ($K_{sys} \equiv \Delta P/Q^2$)

K_V - PRESSURE LOSS COEFFICIENT FOR VENTURI WHEN NOT CAVITATING ($K_V \equiv \Delta P/Q^2$)

P - STATIC PRESSURE

P_D - PUMP DISCHARGE PRESSURE

P_o - TOTAL PRESSURE

PSI - POUNDS PER IN²

PSID - POUNDS PER IN² PRESSURE DROP

PSIG - POUNDS PER IN² GAUGE

R - RECOVERY FACTOR

SG - STEAM GENERATOR

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P_V - VAPOR PRESSURE

Q - VOLUMETRIC FLOW RATE

V - VELOCITY

ΔP - PRESSURE DROP

ρ - DENSITY

150, 145, 140, 135 - VENTURI SIZES BASED ON MAXIMUM DESIGN FLOW RATE OF VENTURI

SUBSCRIPTS

T - TOTAL (FOR ALL THREE STEAM GENERATORS.

1, 2, 3 - ANY OF THREE INDIVIDUAL STEAM GENERATORS

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8.0 CALCULATIONS

8.1 EXISTING VENTURIS

THE MAXIMUM FLOW RATE WILL OCCUR WITH PUMPS G10 AND G10S OPERATING AND PARTIAL FLOW COMING FROM PUMP G10W AT THE LOW FLOW PUMP G10 + G10S START SIGNAL LEVEL. FIGURE 1 (FIGURE 10 OF REFERENCE 6), SHOWS THAT THE (G10 + G10S + G10W) PUMP CURVE INTERSECTS THE VENTURI CURVE AT 555 GPM AND 1090 PSIG. THUS, THE CURRENT VENTURIS LIMIT SG FLOW TO 555 GPM OR 555/3 = 185 GPM / STEAM GENERATOR.

FOR A CAVITATING VENTURI, FLOW IS LIMITED BY FLUID FLASHING.

$$\therefore \Delta P = P_{INLET} - \text{VAPOR PRESSURE} \quad (1)$$

$$\Delta P = \frac{\rho V^2}{2g_c} = \frac{\rho \left(\frac{Q^2}{A^2}\right)}{2g_c} \quad (2)$$

@ 70 °F VAPOR PRESSURE = 0.4 PSIA (REF. 8)

$\Delta P = 1090 + 14.7 - 0.4 = 1104$ PSID.

IF $\frac{\rho}{A^2 2g_c} \equiv C$, THEN

$$\Delta P = \frac{Q^2}{C} \quad (3)$$

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REARRANGING, $C = Q^2/\Delta P$ (4)

FOR THE CURRENT VENTURI

$C = 185^2/1104 = 30.99$

THE THROAT DIAMETER OF THE EXISTING VENTURI = 0.440'' (REF. 7)

∴ THE AREA OF THE EXISTING VENTURI

$= \frac{\pi}{4} (.440/12)^2 = 1.056E-3\ ft^2$

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8.2 NON-CAVITATING VENTURI PRESSURE LOSSES

WHEN FLOW ENTERS A VENTURI, ITS STATIC PRESSURE DROPS, AS VELOCITY INCREASES, REACHING A MINIMUM AT THE THROAT. IF CAVITATION DOES NOT OCCUR, MOST OF THE PRESSURE LOSS IS RECOVERED IN THE VENTURI EXIT.

FROM BERNOULLI, $P_0 - P = \frac{\rho V^2}{2g_c} = \frac{\rho}{2g_c}\left(\frac{Q}{A}\right)^2$ (5)

THE IRREVERSIBLE LOSSES ARE:

$(1-R)\frac{\rho}{2g_c}\left(\frac{Q}{A}\right)^2$ (2), WHERE R = RECOVERY FACTOR

DEFINE $K_v' \equiv (1-R) \equiv$ NON CAVITATING LOSS FACTOR

THUS $\Delta P = K_v' \frac{\rho}{2g_c}\left(\frac{Q}{A}\right)^2$ (6)

OR COMBINING ALL CONSTANTS INTO K_v''

$\Delta P = K_v''\left(\frac{Q}{A}\right)^2$ (7)

IF $K_v' \equiv \Delta P / Q^2$ (8)

FOR ANY GIVEN VENTURI

OR $\Delta P = K_v Q^2$ (9)

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TEST DATA FROM REFERENCES 1 AND 2 SHOW:

TABLE 8-1

Q (GPM)	ΔP (PSI)	K_v (CALCULATED FROM EQ (4))	VENTURI S/N
39.49	5.49	3.52 E-3	5413
60.30	13.97	3.84 E-3	5413
42.69	5.64	3.09 E-3	5414
62.58	13.04	3.33 E-3	5414
40.0	6.79	4.24 E-3	5415
61.52	16.39	4.33 E-3	5415

AVG. K_v @ 50 TO 62 GPM (AREA OF INTEREST) ~ 3.8 E-3

USE THIS VALUE TO DETERMINE LOSSES DUE TO VENTURI, WHEN OPERATING ON THE SYSTEM CURVES.

THERE ARE THREE SCENARIOS IN WHICH THE NON-CAVITATING LOSSES THRU THE VENTURIS MIGHT AFFECT VENTURI SIZING, NAMELY:

- 185 GPM TO 3 SGS = 61.7 GPM/SG (SEE 5.1.3)
- 165 GPM TO 3 SGS = 55.0 GPM/SG (SEE 5.1.4)
- 100 GPM TO 2 SGS = 50.0 GPM/SG (SEE 5.1.4)

FROM EQ (5) ΔP VENTURI =

@ 50 GPM $\Delta P = 3.8E\text{-}3 \cdot 50^2 =$ 9.50 PSI

@ 55 GPM $\Delta P = 3.8E\text{-}3 \cdot 55^2 =$ 11.50 PSI

@ 61.7 GPM $\Delta P = 3.8E\text{-}3 \cdot 61.7^2 =$ 14.47 PSI

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8.3 RESIZE VENTURIS

RESIZE VENTURIS FOR THE FOLLOWING FLOW RATES: 150, 145, 140 AND 135 GPM, AS FOLLOWS:

1) OBTAIN PRESSURE CORRESPONDING TO EACH FLOW RATE FROM (G10+G10S+G10W) PUMP CURVE (FIGURE 1.)

2) CALCULATE A VENTURI FLOW COEFFICIENT (C) FOR EACH FLOW RATE SIZED VENTURI USING THE EQUATION: $C = \frac{Q^2}{P - P_v}$ (10)

$$C = \frac{Q^2}{P + 14.7 - 0.4} = \frac{Q^2}{P + 14.3}$$

TABLE 8-2

Q (GPM)	P (PSIG)	C
150	1159	19.41
145	1167	18.02
140	1174	16.70
135	1184	15.36

FROM EQUATIONS (2) AND (10)

$$Q^2 \sim A^2 \Delta P \sim C \Delta P \quad (11)$$

$$\therefore \quad A^2 \sim C \quad (12)$$

$$A \sim \sqrt{C} \quad (13)$$

$$\therefore \quad D \sim C^{1/4} \quad (14)$$

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FROM SECTION 8.1, $C_{EXISTING} = 30.99$

$A_{EXISTING} = 1.056E\text{-}3\ ft^2$

$D_{EXISTING} = 0.440\ IN$

RATIONG BY EQUATIONS (12) AND (13) YIELDS THE FOLLOWING:

TABLE 8-3

VENTURI SIZE	A (FT²) * E3	D (IN)
185 (EXIST) GPM	1.056	0.440
150	0.835	0.391
145	0.804	0.384
140	0.774	0.377
135	0.743	0.369

FROM EQ. (8); $K_V \cdot \Delta P / Q^2$ & $C = Q^2 / \Delta P$ (FROM (10))

$\therefore K_V \sim 1/C$ (15)

CALCULATE K FROM K_V OF 9.2, RATIONG BY $1/C$ (Eq 15)

TABLE 8-4

VENTURI SIZE	K_V
185	3.8E-3
150	6.07
145	6.55
140	7.07
135	7.67

NOTE - DURING THE REST OF THIS CALCULATION, VENTURIS WILL BE IDENTIFIE BY MAXIMUM FLOW THEY WILL PASS. i.e.

150, 145, 140, or 135

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CALCULATE EFFECT OF NEGLECTING PRESSURE LOSSES BETWEEN PUMPS AND VENTURIS WHEN CALCULATING VENTURI FLOW RATES.

FROM PAGES 80 TO 81 OF REFERENCE 2:

AT A FLOW OF 131 GPM/SG

PUMP DISCH PRESSURE = 1244.7 PSIG
VENTURI INLET PRESSURE = 1224.1 PSIG
20.6 PSID

% ERROR = 20.6/1224.1 = 1.7%

VENTURIS SIZING IS BASED ON INLET PRESSURE, ∴ RESULTS WILL BE ≤1.7% CONSERVATIVE FOR ALL CASES IN WHICH IT IS DESIRABLE TO LIMIT FLOW. (CASES 1, 5, AND 6). THERE WILL BE NO EFFECT ON CASES 3 AND 4, BECAUSE VENTURIS DO NOT CAVITATE IN THESE CASES. CASE 2 WILL BE CALCULATED CORRECTLY BECAUSE VENTURI SPECIFICATION AND CALCULATION ARE BOTH BASED ON VENTURI INLET PRESSURE.

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J.O. NO. ______ MADE BY R. C. W DATE 3/22/90 CHK. BY ______ DATE 5/9/90

8.4 CALCULATE FLOW RATES AT EACH DESIGN CONDITION

FLOW RATES WILL BE PROVIDED FOR EACH VENTURI SIZE AT EACH OF THE FOLLOWING DESIGN CONDITIONS:

1. CASE 1 (SEE 5.1.1) MAX FLOW (G10+G10S+G10W) TO 3 UNPRESSURIZED SGS (MAX = 150 GPM/SG)
2. CASE 2 (SEE 5.1.2) MIN. FLOW G10W OR G10S TO 2 UNPRESS. S.G.S + 1 BREAK (MIN = 175 GPM/2SG)
3. CASE 3 (SEE 5.1.3) MIN. FLOW G10W OR (G10 + G10S) TO 3 SGS @ 1015 PSIG (MIN = 185 GPM / 3 SG)
4. CASE 4 (SEE 5.1.4) MIN. FLOW G10 TO 3 SGS @ 1015 PSIG (MIN = 165 GPM / 3 SG)
5. CASE 5 (SEE 5.1.5) MIN. FLOW G10W OR (G10 + G10S) TO 2 SGS @ 1015 PSIG + 1 BREAK (MIN = 100 GPM)
6. CASE 6 (SEE 5.1.5) MAX FLOW G10S = 420 GPM

8.4.1 CASE 1 MAX. (G10+G10S+G10W) FLOW TO 3 SGS

BY DEFINITION (SEE 8.3) FLOWS ARE 150, 145, 140 & 135 GPM.

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SUPPL. 13

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J.O. NO. ____ MADE BY R.a.W DATE 3/22/90 CHK. BY [initials] DATE 5/9/90

8.4.2 CASE 2 G10W OR G10S FLOW TO 2 UNPRESS. SGs + 1 FW BREAK

BY INSPECTION OF FIGS 1 & 3, G10S IS A SMALLER PUMP THAN G10W.

∴ ANALYZE FOR G10S ONLY, AS IT BOUNDS G10W.

USING EQUATION(10) AND THE FLOW COEFFICIENTS FOR EACH FLOW, CALCULATE VENTURI (CAVITATING) CURVES FOR EACH SIZE VENTURI IN THE REGION OF INTERSECTION WITH THE G10S ACTUAL PUMP CURVE AND PLOT TO FIND INTERSECTION ON FIG. 2.

RESULTS ARE SHOWN IN TABLE 8-5, BELOW.

TABLE 8-5

VENTURI SIZE (GPM)	C	Q (CURVE) (1) 1SG (1)	Q (CURVE) (1) 3SGs	$P=Q^2/C$ (2)	Q CALC'D (3) 1SG	Q CALC'D (3) 2SG	Q CALC'D (3) 3SG	P CALC (3)
150	19.41	115	345	681	113	227	340	@ 665
		110	330	623				
145	18.02	110	330	671	111	223	335	@ 680
		115	345	734				
140	16.70	110	330	725	108	217	325	@ 705
	-	105	315	660				
135	15.39	105	315	716	106	212	318	@ 730
		110	330	786				

(1) USED TO CALCULATE VENTURI CURVE FROM EQ. (10)

(2) CALC'D FROM (1) AND EQ. (10) TO DEVELOP VENTURI CURVE

(3) CALC'D FROM INTERSECTION OF VENTURI CURVES (POINTS (1) AND (2)) AND G10S ACTUAL PUMP CURVE (FIG. 2)

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8.4.3 CASE 3 G10W OR (G10+G10S) FLOW TO 3 SG AT 1015 PSIG

INSPECTION OF FIGURE 3 SHOWS THAT IN THE AREA OF INTEREST (≈185GPM), THE PUMP CURVES FOR G10W AND (G10+G10S) INTERSECT EACH OTHER. THEREFORE, EVALUATION WILL CONSIDER BOTH PUMP CURVES, AS APPROPRIATE.

FLOW TO THE STEAM GENERATORS IS CONTROLLED BY FRICTION AND ELEVATION LOSSES (RATHER THAN VENTURI CAVITATION) BECAUSE OF THE HIGH STEAM GENERATOR PRESSURE. THESE LOSSES HAVE BEEN DEFINED BY REF. 6, pg R4-26 IN A SYSTEM CURVE FOR THE EXISTING DESIGN. BECAUSE REDUCING THE SIZE OF THE VENTURIS WILL INCREASE SYSTEM LOSSES, THE SYSTEM CURVE MUST ~~BE~~ RECALCULATED FOR EACH SIZE VENTURI. LOSS COEFFICIENTS FOR EACH VENTURI SIZE WERE CALCULATED IN SECTION 8.3. A NEW SYSTEM LOSS COEFFICIENT WILL BE CALCULATED FOR EACH VENTURI, BY ADDING THE INCREASE IN LOSS COEFFICIENT FOR EACH VENTURI TO THE EXISTING SYSTEM LOSS COEFFICIENT.

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DATA TO PLOT FIGURE 3

PLOT G10W AND (G10+G10S) ON THE SAME PLOT. USE AN EXPANDED SCALE THAT ENCOMPASSES AREA OF INTEREST (100 GPM TO 300 GPM)

G10 W (FROM G10W ADJUSTED CURVE, SHEET R4-57 OF REF. 6):

Q	P
100	1290
150	1260
200	1200
250	1130
300	1045

(G10 + G10S) (FROM G10+G10S ACTUAL CURVE, SHEET R4-59)* OF REF 6, (FIGURE 2 OF THIS CALCULATION):

Q	P
132	1225
150	1220
200	1210
250	1195
300	1175

* (G10 + G10S) ACTUAL AND (G10 + G10S ACTUAL MERGE AT 300 GPM.

AT THIS TIME, ALSO PLOT G10 ACTUAL CURVE FOR FUTURE USE.

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G.10 FROM G10 ACTUAL CURVE OF REF. 6
(FIG. 2 THIS CALCULATION)

Q	P	
150	1210	EXTRAPOLATED
200	1170	EXTRAPOLATED
250	1125	EXTRAPOLATED
275	1100	
300	1070	

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SUPPL. 3

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FROM REFERENCE 6, SHEET R4-26, THE PRESSURE LOSS DUE TO ELEVATION = 10.6 PSID

FROM REFERENCE 6, SHEET R4-27

Q_{TOTAL} = 604 GPM @ 300 PSID OR 201.3 GPM/SG @ 300 PSI

FRICTION LOSS = 300 - 10.6 = 289 PSI

$$\text{SYSTEM } K \equiv \Delta P / Q^2 = \frac{289}{201.3^2} = 7.13E-3$$

FROM 8.3, CURRENT VENTURI K = 3.8E-3

∴ K OF SYSTEM WITHOUT VENTURI =

(7.13 - 3.8)E-3 = 3.33E-3

CALCULATE A SYSTEM K FOR EACH SIZE VENTURI. THEN, CALCULATE LIMITED SYSTEM CURVES FOR EACH SIZE VENTURI NEAR INTERSECTIONS WITH PUMP CURVES.

$$\Delta P = KQ^2 + \text{ELEV. LOSS} = KQ^2 + 11.$$

FOR AN SG AT 1015 PSIG, P = 1015 + ΔP

= 1026 psig + KQ^2

TABLE 8-6, BELOW SHOWS: THE ESTIMATED ΔP FOR EACH VENTURI AT THE MINIMUM FLOW OF 185/3 = 61.7 GPM/VENTURI, NEW SYSTEM K'S FOR EACH VENTURI AND THE TOTAL FLOW TO THE THREE STEAM GENERATORS

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DESIGN CALCULATION NO. SUPPL B DC2836 REVISION C

J.O. NO. ______ MADE BY R.A. [signature] DATE 3/22/90 CHK. BY [signature] DATE 5/9/90

TABLE 8-6

VENTURI SIZE	Kv (1)	ΔP VENT (2) @ 185 GPM TOTAL	K SYS (3)	Q CURVE (4)	P (5)	Q CALC (6)
150	6.07E-3	23.1	9.41E-3	270	1102	268
				240	1086	
145	6.55	24.9	9.88	270	1106	266
				240	1089	
140	7.07	26.9	10.40	270	1110	265
				240	1093	
135	7.67	29.2	11.00	270	1115	263
				240	1096	

(1) FROM TABLE 8.4

(2) $\Delta P = K * 61.7^2$ (61.7 = 185/3)

(3) $K_{sys} = 3.33E{-}3 + K_v$

(4) INPUT VALUE FOR SYS. CURVE

(5) CALC'D FROM $P = 1026 + K_{sys}\, Q^2$

(6) FROM INTERSECTION OF SYS. CURVE WITH G10W PUMP CURVE (FIG 3)

ALL VENTURIS HAVE LARGE MARGIN

CALCULATE MAXIMUM K & ΔP VENTURI AT 61.7 gpm/SG = 185 gpm TOTAL

AT 185 GPM P = 1214 (G10 + G10S PUMP CURVE)

$\Delta P_{sys} = 1214 - (1015 + 11) = 188$ PSID

$K = 188 / \left(\frac{185}{3}\right)^2 = 49.4\,E{-}3$

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$K_{ALLOWABLE\ VENTURI} = 49.4\ E{-}3\ - 3.33\ E{-}3$

$= 46.3\ E{-}3$

$\Delta P_{ALLOWABLE} = 46.3E{-}3 * \left(\frac{185}{3}\right)^2 = 175\ PSI$

WHICH IS MUCH LARGER THAN ESTIMATED ΔP'S OF 23.4 TO 29.2 PSI. ∴ THIS CASE WILL NOT CONTROL THE DESIGN, BUT MAY BE THE LIMITING CASE WITH RESPECT TO PRESSURE DROP.

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8.4.4 CASE 4 G10 TO 3SGs AT 1015 psig

ANALYSIS IS SIMILIAR TO CASE 3, EXCEPT THAT FLOWS ARE DETERMINED BY INTERSECTION OF NEW SYSTEM CURVES, CALCULATED IN 8.4.3, WITH G10 PUMP CURVE.

IN THIS FLOW RANGE G10 CURVE IS VERY CLOSE TO G10W CURVE (SEE FIG. 3). ∴ USE SYSTEM CURVES CALCULATED IN 8.4.3 TO DETERMINE FLOWS. FROM FIG. 3:

TABLE 8.-7

VENTURI SIZE	G10 FLOW GPM
150	272
145	270
140	268
135	265

AT 165 GPM P_D of G10 ≈ 1198 psig

$\Delta P = 1198 - 1026 = 172$ psi

$K = 172/\left(\frac{165}{3}\right)^2 = 56.9E-3$

LARGER THAN FOR CASE 3

∴ CASE 3 K BOUNDS CASE 4

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J.O. NO. ______ MADE BY R. A. Wolf DATE 3/22/90 CHK. BY ______ DATE 5/9/90

8.4.5 CASE 5 G10W OR (G10+G10S) TO 2SG AT 1015 PSIG AND 1 BREAK

FROM FIGURE 3, G10W AND (G10+G10S) PUMP CURVES INTERSECT NEAR AREA OF INTEREST. BOUNDING CASE WILL BE DETERMINED DURING ANALYSIS. BOUNDING CASE IS PUMP THAT PROVIDES THE LEAST FLOW TO THE BREAK.

THE SYSTEM CURVE WILL CHANGE WHEN THERE IS A BROKEN LINE, BECAUSE

$$Q_T = Q_1 + Q_2 + Q_3 \qquad (16)$$

WHERE:

Q_T = TOTAL FLOW

$Q_1 = Q_2$ = FLOW TO PRESSURIZED STEAM GENERATOR

Q_3 = FLOW THROUGH BREAK

$$Q_1 = Q_2 = K_{1,2}\sqrt{(P_D - P_{SG} - P_{EL})} \qquad (17)$$

P_D = PUMP DISCH. PRESS

P_{SG} = ST. GEN. PRESS.

P_{EL} = ELEV. PRESS. LOSS

$$Q_3 = C_3\sqrt{(P_D - P_V)} \qquad (18)$$

C = VENTURI COEFFICIENT

P_V = VAPOR PRESSURE

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COMBINING (16), (17) AND (18) YIELDS

$$Q_T = 2K_{1,2}\sqrt{P_0 - P_{SG} - \Delta P_{EL}} + C_3\sqrt{P_0 + (14.7 - P_V)} \qquad (19)$$

FOR SG PRESSURE OF 1015 PSIA, ΔP_{EL} = 11 PSID (SEE 8.4.3) AND P_V = 0.4 PSIA (SEE 8.1.7), YIELDING:

$$Q_T = 2K_{1,2}\sqrt{P_0 - 1026} + C_3\sqrt{P_0 + 14.3}$$

KSYS VALUES WERE CALCULATED IN SECTION 8.2 FOR USE IN EQUATION (9), $\Delta P = K_{SYS} Q^2$

OR $K_{SYS} = \Delta P / Q^2$ (NOTE: KSYS IS FOR 1 LOOP TO SG)

BUT IN EQ. (9) $K_{1,2} = Q/\sqrt{\Delta P}$

$$\therefore K_{1,2} = 1/\sqrt{K_{SYS}} \qquad (20)$$

C VALUES WERE DEVELOPED IN SECTION 8.3 FOR USE IN EQ. (10), $\Delta P = Q^2/C$ OR $C = Q^2/\Delta P$

BUT IN EQ. (19) $C_3 = Q/\sqrt{\Delta P}$

$$\therefore C_3 = \sqrt{C} \qquad (21)$$

CALCULATE $K_{1,2}$ & C_3 FOR EACH VENTURI SIZE.

RESULTS ARE SUMMARIZED IN TABLE 8-8

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SUBJECT: AFW FLOW VENTURI SIZING — DESIGN CALCULATION NO. DC-2876 — REVISION 0

J.O. NO. ______ MADE BY R.A. W — DATE 3/22/90 — CHK. BY [initials] — DATE 5/9/90

TABLE 8-8

VENTURI SIZE	Ksys ×E3	$K_{1,2}$	C	C_3
150	9.40	10.31	19.47	4.41
145	9.88	10.06	18.02	4.24
140	10.40	9.81	16.70	4.09
135	11.00	9.53	15.39	3.92

- USING THE ABOVE VALUES, DEVELOP SYSTEM CURVES FOR EACH VENTURI SIZE IN AREA THAT WILL INTERSECT G10W OR (G10 + G10S) PUMP CURVES, USING EQUATION (19).
- CALCULATE Q_T AND P_D FROM INTERSECTION WITH PUMP CURVE (SEE FIGURE 2)
- CALCULATE $Q_1 = Q_2$ & Q_3 FROM EQUATIONS (17) AND (18).

LIST ALL VALUES IN TABLE 8-9, BELOW

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J.O. NO. ______ MADE BY R.I. ___ DATE 3/22/90 CHK. BY ___ DATE 5/4/90

TABLE 8 9

VENTURI SIZE	$K_{1,2}$ (1)	C_3 (1)	P_D CURVE (2)	Q_T CURVE (3)	Q_T CALC (4)	P_D CALC (4)	Q_1+Q_2 (5)	Q_3 (6)
150	10.31	4.41	1080	297	285	1072	140*	145
			1070	282				
145	10.06	4.24	1070	273	284	1076	142*	140
			1080	288				
140	9.81	4.09	1080	279	281	1081	146*	135
			1090	292				
135	9.53	3.92	1080	270	278	1086	148*	130
			1090	283				

(1) FROM TABLE

(2) INPUT FOR SYSTEM CURVE

(3) CALCULATED FROM EQ. (19)

(4) FROM INTERSECTION OF SYS. CURVE & PUMP CURVE FIG 3

(5) FROM EQ. (17) AND PD CALC

(6) FROM EQ. (18) AND PD CALC.

*NOTE - ALL FLOWS GREATER THAN 100 GPM REQUIREMENT

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ALL VENTURI SIZES IN TABLE 8-9 PROVIDE SUFFICIENT MARGIN, AS $(Q_1 + Q_2)$ RANGES FROM 139 GPM to 148 GPM. THE REQUIRED VALUE IS 100 gpm BECAUSE REDUCING VENTURI SIZE HAS A GREATER EFFECT ON FLOW LOST THROUGH THE LEAK, THAN ON SYSTEM FLOWS, THE SMALLER VENTURIS PERMIT MORE FLOW TO THE STEAM GENERATORS.

CHECK MARGIN ON ΔP

AT 100 GPM P_D (G10 + G105) = 1250

$\Delta P = 1250 - 1026 = 224$

$K = 224/\left(\frac{100}{2}\right)^2 = 89.6E\text{-}3$

$89.6E\text{-}3 > 50.5E\text{-}3$ CALCULATED IN 8.4.3

∴ THE LOSSES ARE BOUNDED BY CASE 3.

8.4.6 CASE 6 G105 FLOW LIMIT

SECTION 8.4.2 CALCULATED FLOW TO EACH STEAM GENERATOR USING THE ACTUAL G105 CURVE. EXTRAPOLATING THE VENTURI CURVES TO THE G105 DESIGN CURVE YIELDS THE RESULTS PRESENTED, BELOW, IN TABLE 8-10

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TABLE 8.10

VENTURI SIZE	G10S FLOW GPM
150	350
145	342
140	335
135	325

THUS, ALL VENTURIS PROVIDE LARGE MARGINS WITH RESPECT TO 420 GPM LIMIT.

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8.5 DESIGN MARGINS

8.5.1 CASE 1   150 GPM MAX / S.G

REVIEW OF PREVIOUS CALCULATIONS SHOW ALL SIZES (135 → 150) PROVIDE LARGE MARGIN FOR ALL CASES.

IF 140 GPM +0, -10 GPM IS SELECTED MARGIN FOR CASE 1 IS $\frac{150-140}{150} = 6.7\%$

AT 130 GPM MARGIN = $\frac{150-130}{150} = 13.3\%$

8.5.2 CASE 2   175 MIN. TO TWO DEG. SG + BREAK

FROM SECTION 8.4.

FOR 135 GPM VENTURI 212 GPM PROVIDED

MARGIN = $\frac{212-175}{175} = 21\%$

REVIEW OF ALL CASES INDICATES CASE 2 WILL CONTROL DESIGN FOR CASE 1. PLOT CASE 1 FLOW VS. CASE 2 FLOW (FIGURE 4).

EXTRAPOLATING FLOW TO 130 GPM SHOWS 206 GPM TO 2 SGs

MARGIN = $(206-175)/175 = 18\%$

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8.5.3 CASE 3 185 GPM TO 3 PRESS. SG (G10W) OR (G10+G10...

140 GPM DESIGN PROVIDES 265 GPM TO 3 SGS (8.4.3) TABLE 8-6

MARGIN = $\frac{265-185}{185}$ = 43% (80 GPM)

EXTRAPOLATING TO 130 GPM SHOWS:

260 GPM TO 3 SG

MARGIN = $\frac{260-185}{185}$ = 41% (75 GPM)

8.5.4 CASE 4 165 GPM TO 3 PRESS. SG (G10)

FROM 8.4.4 TABLE 8-7

140 GPM DESIGN PROVIDES 265 GPM

MARGIN = $\frac{268-165}{165}$ = .62% (103 GPM)

EXTRAPOLATING TO 130 GPM YIELDS 262 gpm

MARGIN = $\frac{263-165}{165}$ = 59% (98 GPM)

8.5.5 CASE 5 100 GPM TO 2 PRESS. SG + BREAK (G10W) OR (G10+G1...

FROM 8.4.5

A 140 DESIGN YIELDS 146 GPM.

MARGIN = $\frac{146-100}{100}$ = 46% (46 GPM)

REDUCING ORIFICE SIZE, INCREASES FLOW.

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SUPPL. B

SUBJECT: AFW FLOW VENTURI SIZING — DESIGN CALCULATION NO. DC-2836 — REVISION 0

J.O. NO. ____ MADE BY R. A. Uff — DATE 3/22/90 — CHK. BY ____ — DATE 5/9/90

8.5.6 CASE 6 MAXIMUM G105 FLOW

FROM 8.4.6

140 DESIGN YIELDS 335 GPM

MARGIN = $\frac{420 - 335}{420}$ = 20% (85 GPM)

EXTRAPOLATING TO 130 GPM YIELDS 320

MARGIN = $\frac{420 - 320}{420}$ = 24%

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ENGINEERING DEPARTMENT
CALCULATION SHEET

DKH 7/25/90 P. ~~125~~ ~~59~~ 132 167
SUPPL. B

SUBJECT: AFW FLOW VENTURI SIZING DESIGN CALCULATION NO. DC 2836 REVISION 0

J.O. NO. ______ MADE BY R.A. [signature] DATE 3/22/90 CHK. BY [signature] DATE 5/9/90

8.6 DESIGN PARAMETERS

THIS SECTION PROVIDES THE PARAMETERS FOR SPECIFYING ORIFICE PERFORMANCE.

BASED ON CALCULATED MARGINS, A DESIGN OF 140 GPM +0, -10 GPM APPEARS REASONABLE FROM (G10 + G10S + G10W) CURVE & SECTION 8.3 140 GPM OCCURS AT 1160 PSIG.

∴ SPECIFY VENTURIS FOR 140 +0, -10 GPM AT 1160 PSIG. TO SATISFY CASE 1.

TO SATISFY CASE 2, EACH VENTURI MUST PASS 87.5 GPM. SPECIFY 100 GPM TO PROVIDE A MARGIN. 100 GPM INTERSECTS G10S ACTUAL CURVE (FIGURE 2) AT 775 PSIG.

∴ SPECIFY THAT EACH VENTURI SHALL PASS AT LEAST 100 GPM AT 775 PSIG.

CASE 3 IS THE LIMITING CASE FOR NON-CAVITATIV PRESSURE LOSS.

THE MAXIMUM ALLOWABLE PRESSURE DROP IS 175 PSID AT 61.7 GPM / VENTURI

HOWEVER, TABLE 8-6 SHOWS THAT THE 140 GPM VENTURI SHOULD HAVE A 27 PSI PRESSURE DROP

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SUBJECT: AFW FLOW VENTURI SIZING DESIGN CALCULATION NO. DC-2836 REVISION 0

J.O. NO. ______ MADE BY R.G. [illegible] DATE 3-22-90 CHK. BY [illegible] DATE 5/5/90

EXTRAPOLATING TO A 130 GPM VENTURI YIELDS A 32 PSID PRESSURE DROP.

∴ SPECIFY PRESSURE DROP NOT TO EXCEED 40 PSID AT 62 GPM. THIS SHOULD BE EASILY ATTAINABLE, PROVIDE AN EFFICIENT VENTURI, AND STILL PROVIDE CONSIDERABLE MARGIN $\left(\frac{175-40}{40}\right) = 338\%$.

THE VENTURI DIAMETER SHOULD BE APPROXIMATELY 0.377" FROM TABLE 8.3 TO PASS 140 GPM AT 130 GPM AND THE SAME PRESSURE, THE DIAMETER IS $\approx 0.377\left(\frac{130}{140}\right)^{1/4} = 0.370$

THIS APPEARS TO BE READILY ATTAINABLE BECAUSE, IT REQUIRES A TOLERANCE OF +0, -0.007 INCH. OLD VENTURI TOLERANCE IS +0, -0.005 INCH (REF. 7)

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SUPPL. B

SUBJECT: AFW FLOW VENTURI SIZING
DESIGN CALCULATION NO. DC-2836 REVISION 6

J.O. NO. ______ MADE BY R.A.W. DATE 5-21-96 CHK. BY ______ DATE ______

8.7 SUMMARY FIGURES

THE FOLLOWING SUMMARY FIGURES WILL BE PREPARED FOR THE RESULTS SECTION:

FIGURE 2-1 "SUMMARY PLOT - BEST ESTIMATE LOSSES FOR FLOW VENTURIS"

FIGURE 2-2 "SUMMARY PLOT MAXIMUM VENTURI PRESSURE LOSSES

FIGURE 2-3 " CASE 5 CONDITIONS BASED ON MAXIMUM VENTURI ΔP.

PUMP CURVES OBTAINED FROM FIGURES 1, 2, 3 AND ATTACHMENT H WILL BE PLOTTED ON FIGURES 2-1 AND 2-2. SYSTEM AND VENTURI CURVES, BASED ON THE BEST ESTIMATE OF VENTURI ΔP WILL BE CALCULATED IN 8.7.1 AND PLOTTED ON FIGURE 2-1. SIMILAR CURVES BASED ON THE MAXIMUM ALLOWABLE VENTURI ΔPs WILL BE CALCULATED IN 8.7-2 AND PLOTTED ON FIGURE 2-2

FIGURE 2-2 AND SECTION 8.4 RESULTS WILL BE SHOWN ON FIGURE 2-3, WHICH DEPICTS THE SYSTEM UNDER CASE 5 POSTULATED CONDITIONS

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CALCULATION SHEET

SUBJECT: AFW FLOW VENTURE SIZING DESIGN CALCULATION NO. DC-2836 REVISION 0

J.O. NO. ______ MADE BY R.A. Hff DATE 5-21-90 CHK. BY ______ DATE ______

8.2.1 CALCULAZATE SYSTEM CURVES AND CAVITATION CURVES AND SUPERIMPOSE ON PLOT OF PUMP CURVES

DO FOR 135 AND 140 GPM VENTURIS

SYSTEM CURVE:

$\Delta P = KQ^2 + \Delta P_{ELL} = KQ^2 + 11.$

FROM TABLE 8-6 K(140) = 10.4E-3 & K(135) = 11.00E-3

FOR 1 SG FOR 3 SG'S DIVIDE K'S BY 3^2 =

1.16 E-3 (140) AND 1.22E-3 (135)

CAVITATING FLOW CURVE:

$\Delta P = Q^2/c$ OR $P = Q^2/c - 14$

c (140) = 16.70 & c (135) = 15.39 FOR 1 SG

FOR 3 SG C(140) = 16.7×9 = 150.3 C (135) = 15.39×9 = 138.5

	Q	140 SYS + 1015 SG.	135 SYS + 1015 SG		CAV (140)	CAV (135)
1	100	1038	1038			
2	150	1052				
3	200	1072	1075	1077		
4	300	1130	1136	1142	585	636
	325				689	
5	350	1168			801	870
	1 380				946	1029
6	400	1212	1221	1232	1050	1141
	2 410				1104	1200
7	425	1236			1188	1290
	3 435				1245	1352
[illegible]	450	1261	1273		1333	1448

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8.7.2 EFFECT OF HIGHER VENTURI PRESSURE LOSSES

THE PREVIOUS CALCULATIONS USED Ks FOR NON-CAVITATING VENTURI PRESSURE LOSSES BASED ON TEST DATA FOR THE EXISTING VENTURIS MODIFIED TO ACCOUNT FOR THE CHANGED SIZES, AS CALCULATED IN SECTIONS 8.2 AND 8.3. LARGER VENTURI Ks WERE SPECIFIED AT THE VENTURI VENDOR'S REQUEST. THIS SECTION CALCULATES SYSTEM CURVES BASED ON THE SPECIFIED VENTURI LOSSES.

IF ΔP_{MAX} @ 55 gpm = 35 psid:

$$K_v = \Delta P / Q^2 \text{ (Eq. 8)} = \frac{35}{55^2} = 1.157E-2$$

$$K_{sys} = 3.33E-3 + 1.157E-2 = 1.49E-2$$

IF ΔP_{MAX} @ 62.5 gpm = 45 psid:

$$K_v = 45/62.5^2 = 1.152E-2 < 1.157E-2$$

∴ 55 GPM CASE GOVERNS

$$P_{sys} = P_{SG} + \Delta P_{EL} + \Delta P_{sys}$$

@ 1015 psi SG & 11 psi ΔP_{EL}

$$P_{sys} = 1026 + 1.49E-2 \left(\frac{Q}{3}\right)^2$$

$$= 1026 + 1.656E-3\, Q^2$$

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SUPPL. B

SUBJECT: AFW FLOW VENTURI SIZING
DESIGN CALCULATION NO. DC-2836 REVISION 0

J.O. NO. ______ MADE BY R.A. [signature] DATE 5.21.90 CHK. BY ______ DATE ______

SYSTEM CURVE

TOTAL FLOW (GPM)	PUMP DISC PRESS (PSIG)
100	1044
200	1094
300	1176
350	1230
400	1292
450	1363

FOR CASE 5 (FROM 8.4.5)

$$Q_T = 2K_{1,2}\sqrt{P_0 - P_{SA} - \Delta P_{GL}} + C_3\sqrt{P_0 + (14.7 - P_{PV})} \quad \text{Eq. 11}$$

$$= 2K_{1,2}\sqrt{P_0 - 1026} + C_3\sqrt{P_0 + 14}$$

$$K_{1,2} = 1/\sqrt{K_{SYS}} \;\; (\text{Eq. (20)}) = 1/\sqrt{1.49E-2} = 8.19$$

$$Q_T = 2 * 8.19\sqrt{P_0 - 1026} + 4.09\sqrt{P_0 + 14}$$

PUMP DISCH. PRESS (P_D) (PSIG)	TOTAL FLOW (Q_T) (GPM)
1050	212
1100	277
1150	322
1200	359
1250	390
1300	419

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For CASE 5; $q_T = 2k_{1,2}\sqrt{P_0 - 1026} + C_3\sqrt{P_0 + 14.3}$

FOR 140 GPM VENTURI $2k_{1,2} = 19.62$, $C_3 = 4.09$

135 GPM VENTURI $2k_{1,2} = 19.06$ $C_3 = 3.92$

P	QT 140	QT 135
1026	132.	126.
1050	230	
1100	305	295
1150	358	
1200	401	388
1250	439.	
1300	473	458

DUE TO THE CLOSENESS OF THE VALUES FOR THE 135 GPM AND 140 GPM SYSTEM CURVES, PLOT VALUES FOR 140 GPM VENTURI SYSTEM CURVES ONLY.

ΔP VENTURI AT CALCULATED FLOW OF 68 GPM/SG

$= 1.157E\text{-}2\ (68)^2 = 53.5$ psid

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SUPPL. B
DC-2836 REV 0

MADE BY R.L.H. DATE 3/22/90 CHECKED BY [illegible] DATE 5/9/90

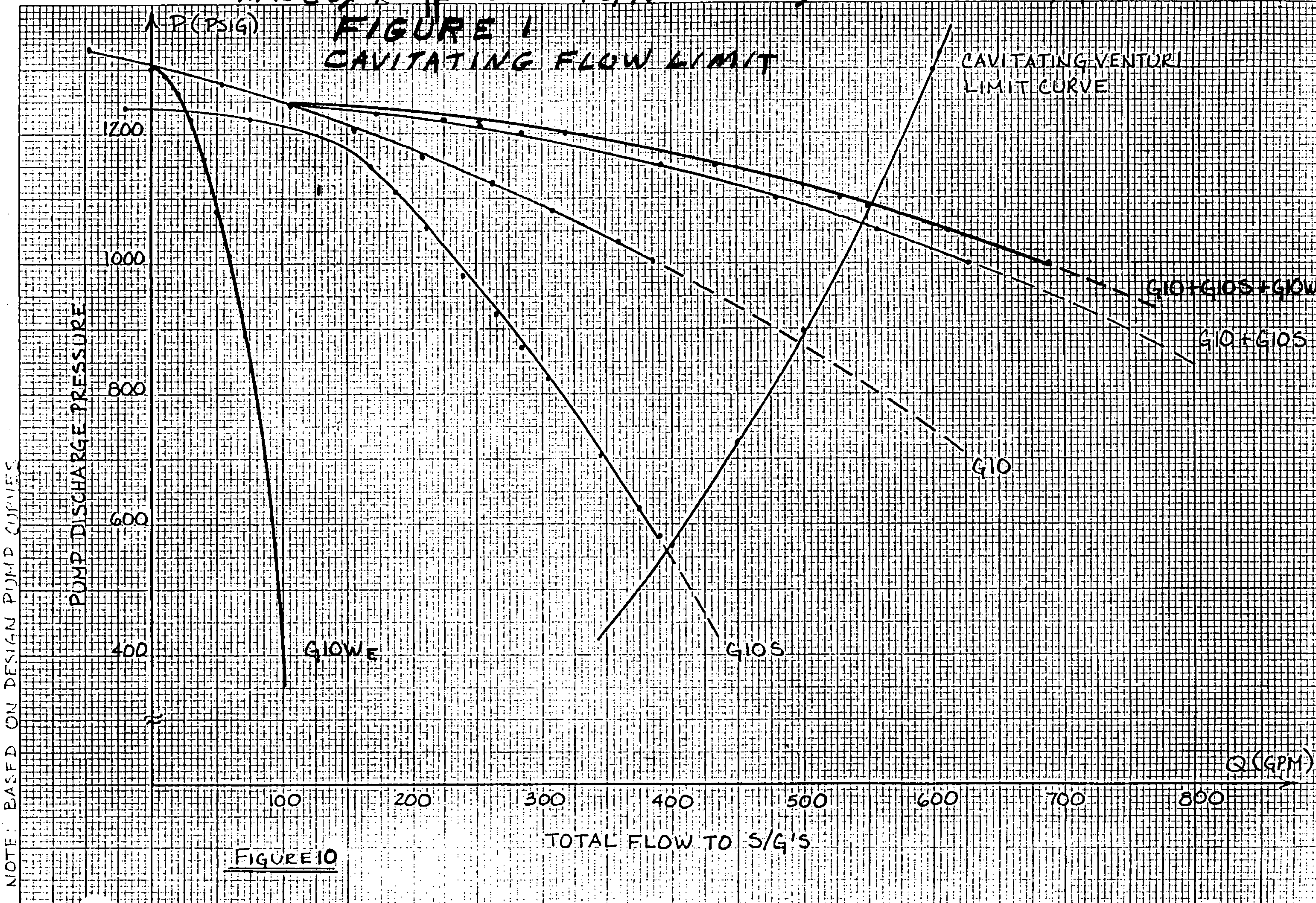

FIGURE 10

NOTE: BASED ON DESIGN PUMP CURVES

20 Squares to the Inch

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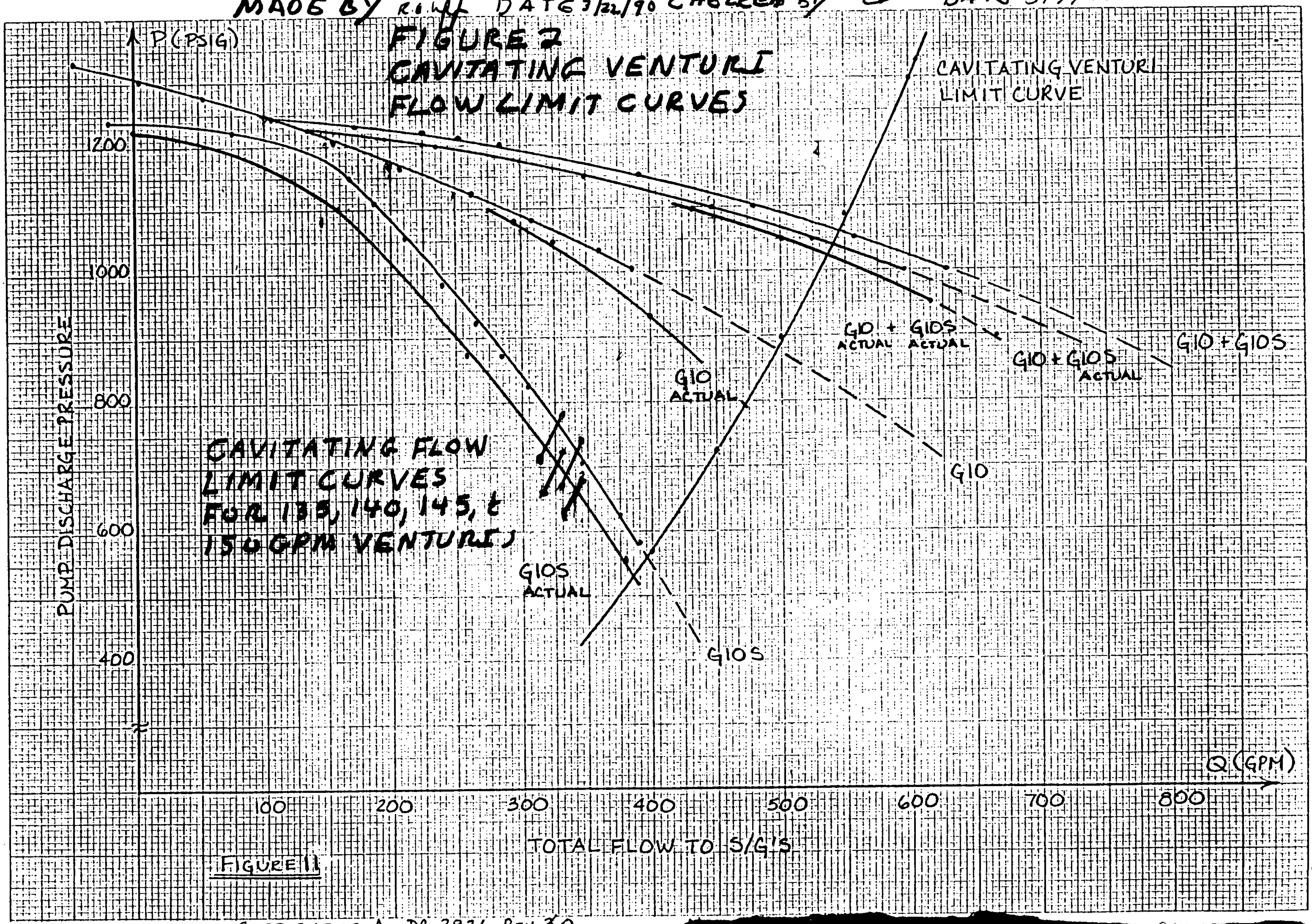

[redacted]

SUPPL. 8

Made By R.A.U. Date 5/1/90

Ckd By Date 5/9/90

Calc No. DC2836 Rev. 0

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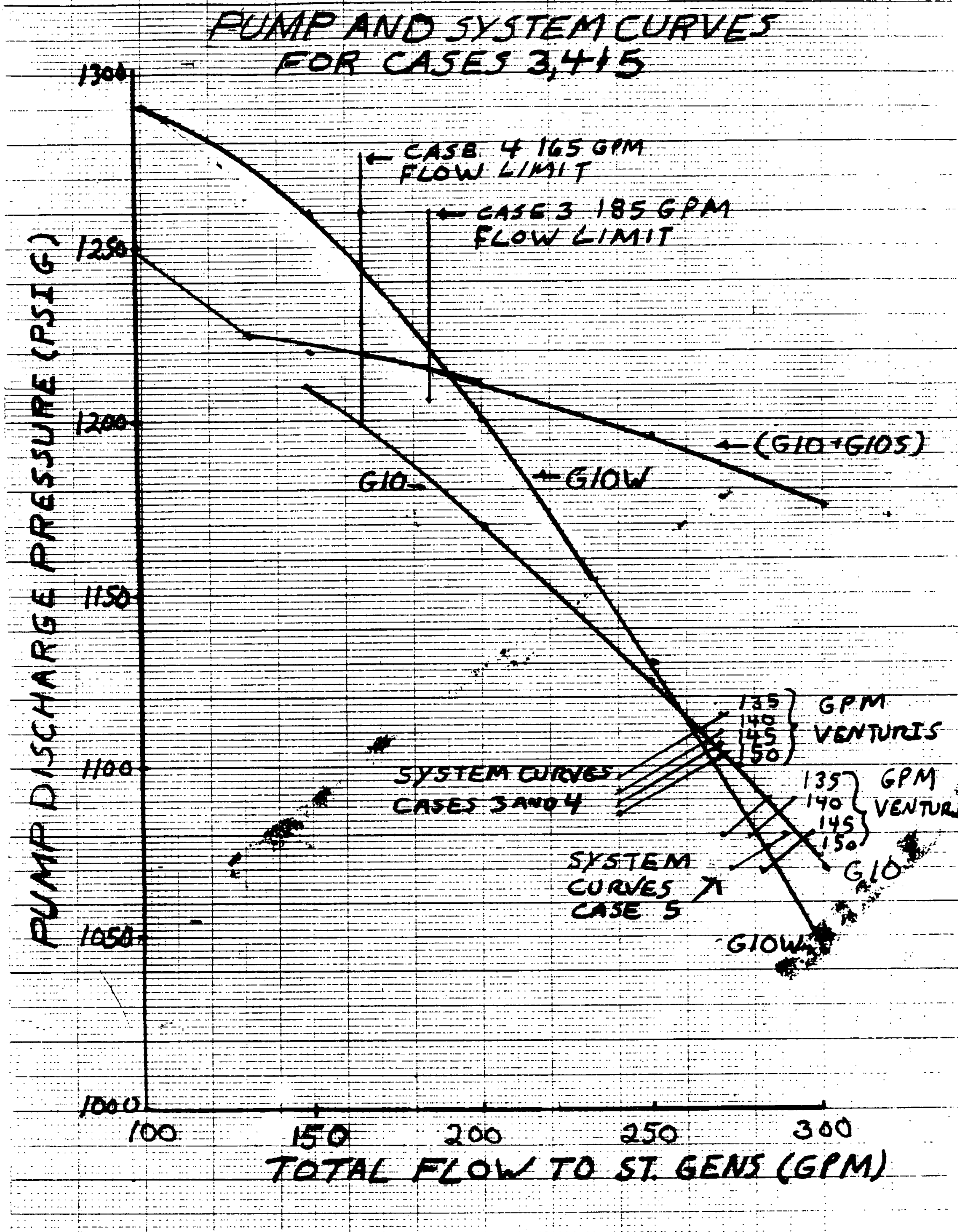
FIGURE 3



20 Squares to the Inch

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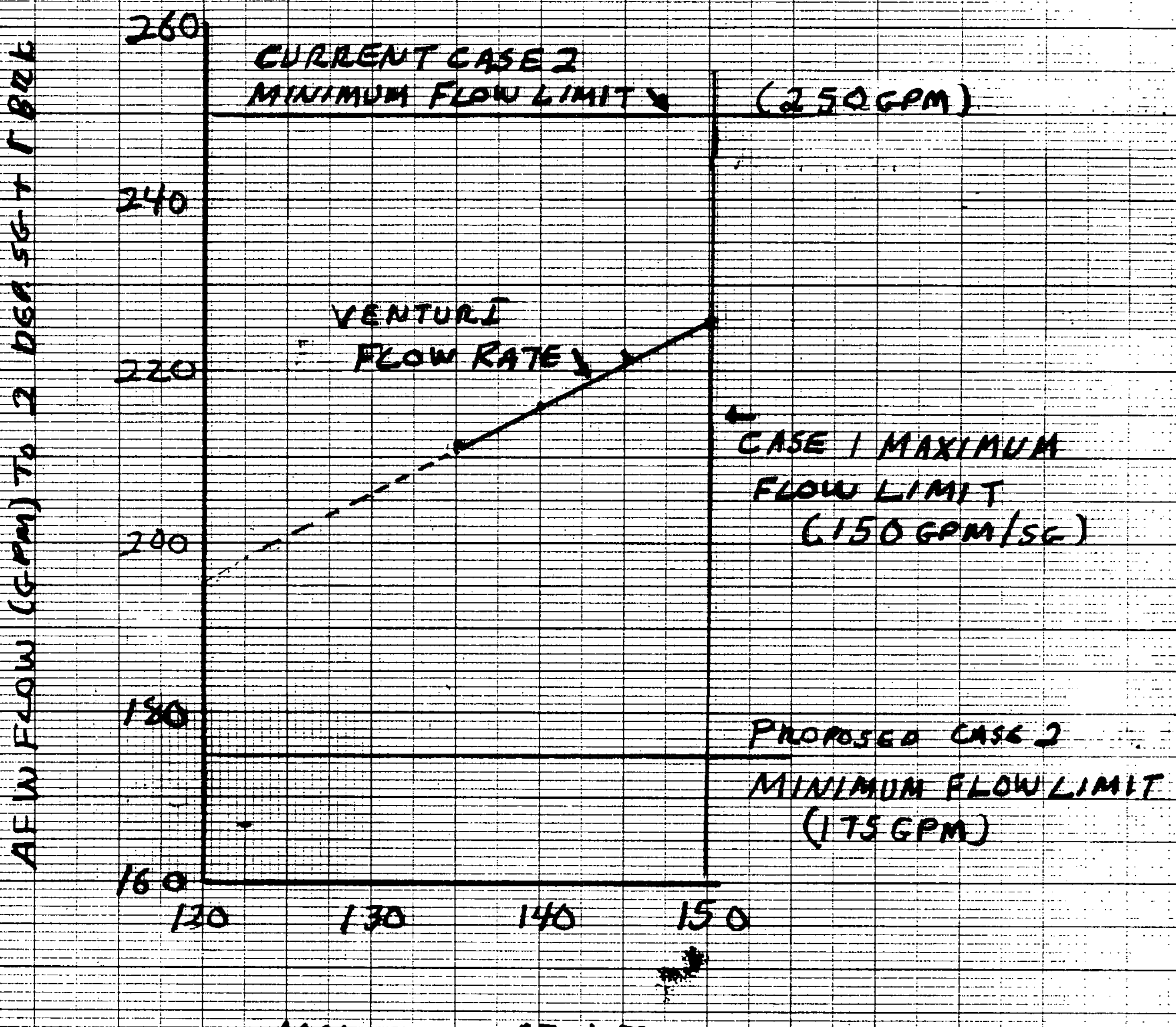
SUPPL. B. DC-2836 RGV0

MADE BY R.G. DATE 3/26/90 CHECKED BY DATE 5/9/90

FIGURE 4
COMPARISON OF
CASE 1 AND CASE 2
FLOWS WITH LIMITS



K+E 10 X 10 TO 1/2 INCH • 7 1/2 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1470

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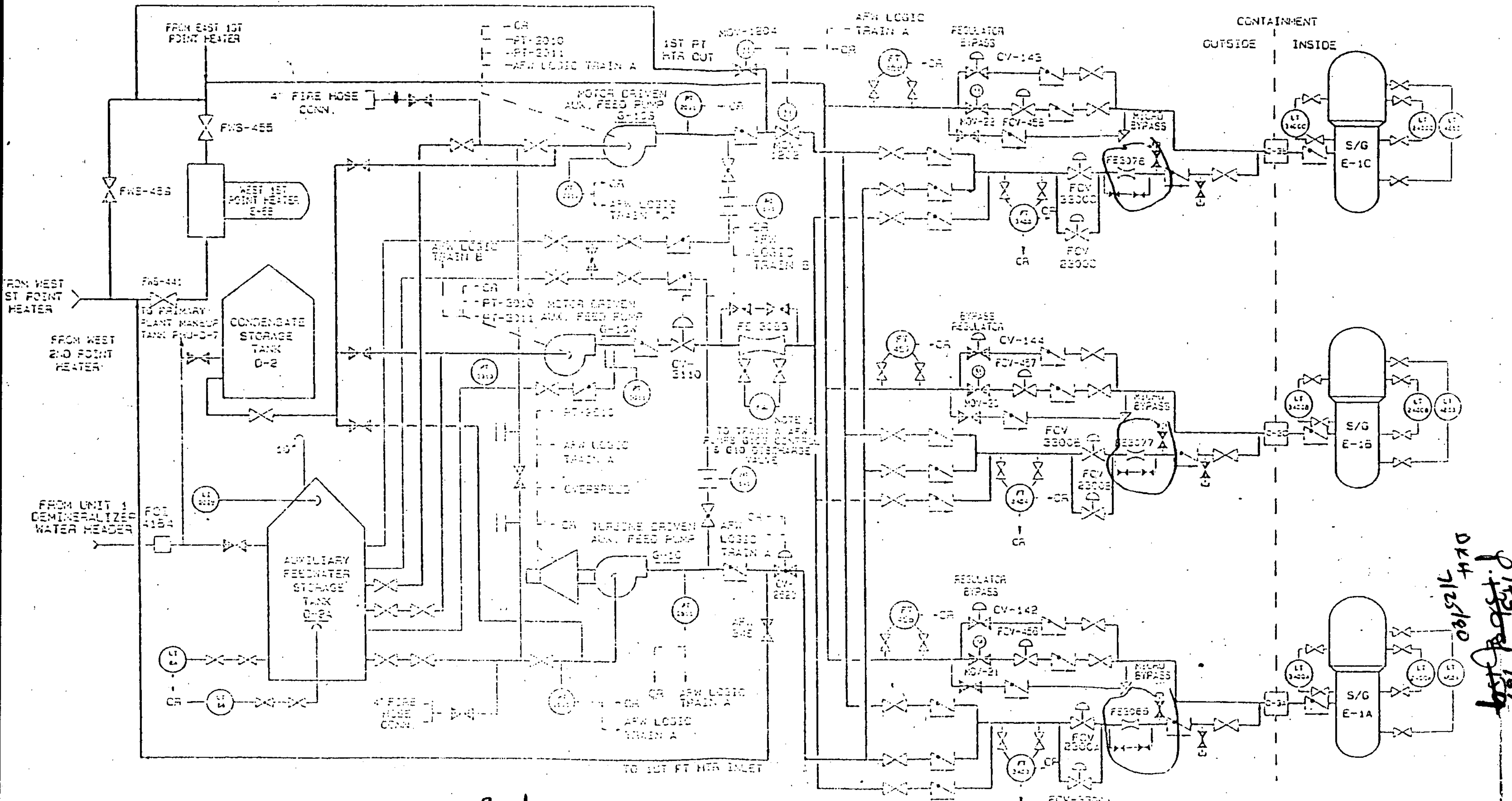
ATTACHMENT A CHECKED BY DATE 5/9/93

P&ID

FROM REF. 2

NUCLEAR GENERATION SITE
UNIT 1

AUXILIARY FEEDWATER SYSTEM



NOTE 1: TYPICAL OF FOUR LOW FLOW SWITCHES

FIGURE 1
SD-S01-620-01-5

FIGURE 1 ~~- Ref. 8~~ R.4

SUPPL. A ~~DC-2836 Rev. 3~~

0253W.AUT

MADE BY DATE

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ATTACHMENT B SUP[illegible] DC-2836 REV 0
VENTURI DWG

SH R5-47 [illegible] 62

SCE Southern California Edison Company
Songs (1) ~~2 & 3~~

INTERIM DCN NO.

MADE BY E. [illegible] 3/23/90
CHECKED BY [illegible] DATE 5/4/90

INTERIM DESIGN CHANGE NOTICE (IDCN)/~~DESIGN CHANGE NOTICE (DCN)~~

SUPPLEMENTAL PAGE

IDCN NUMBER S-1					
DRAWING NO.	SHEET NO.	REV. NO.	DCN CONV. DATE: DWG. REV.	DCN NO.	QUALITY CLASS
1810-AA319-M0007	-	0			SR.

MMP# 1-3587.01SM REV A SHT ______

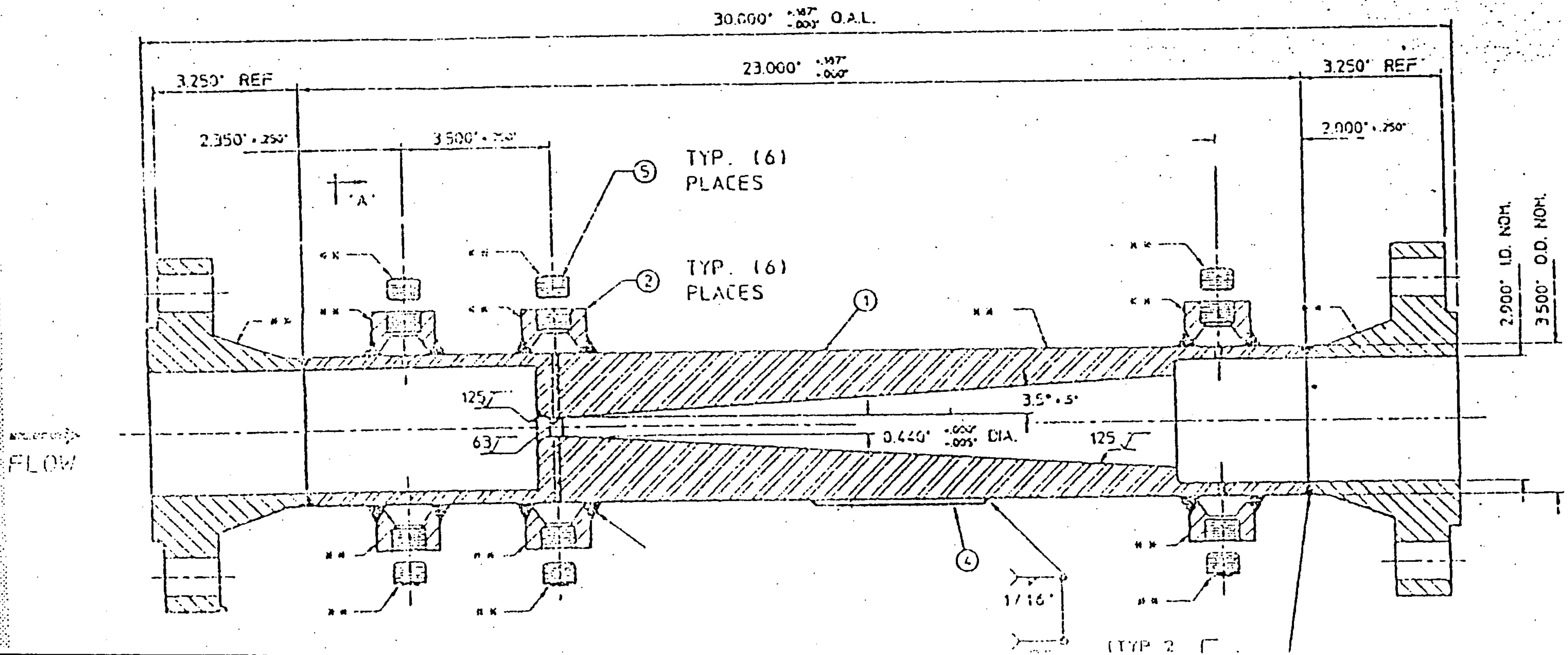
DESCRIPTION OF CHANGE

Date 3-8-90 Page 2 of 3

By A. REYES

BEFORE

CUSTOMER TAG NUMBER	PERMUTIT SERIAL NO	PIPE SIZE	BETA RATIO	DESIGN		OPERATING		DESIGN FLOW RATE (CAVITATING MODE)	FLUID
				PRESSURE	TEMP	PRESSURE	TEMP		
[illegible]	N-5413	3" - SCH 80	.1517	600 PSIG	850 °F	524 PSIG	40°F	131 GPM @ 40 °F	WATER
[illegible]	N-5414	3" - SCH 80	.1517	600 PSIG	850 °F	524 PSIG	40°F	131 GPM @ 40 °F	WATER
FE-1077	N-5415	3" - SCH 80	.1517	600 PSIG	850 °F	524 PSIG	40°F	131 GPM @ 40 °F	WATER



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DEA 7/25/90

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ATTACHMENT C
SYSTEM DESCRIPTION (REF. 3)

AUXILIARY FEEDWATER SYSTEM

1.0 FUNCTIONS/DESIGN BASES

1.1 The Auxiliary Feedwater System has the following main functions:

1.1.1 To provide feedwater to the steam generators during abnormal or emergency conditions which result in a loss of Main Feedwater.

1.1.2 To provide feedwater to the steam generators during normal start-up, normal shutdown and hot stand-by conditions.

1.2 The Auxiliary Feedwater System has the following additional functions:

1.2.1 To provide a means of filling and venting the Main Feedwater System in Modes 4, 5, or 6.

1.2.2 To provide a means of filling and/or feeding the steam generators via the Main Feedwater System in Modes 4, 5 or 6.

1.3 The Auxiliary Feedwater System has the following design bases:

1.3.1 The Auxiliary Feedwater System is designed to provide sufficient steam generator feedwater flow and volume to achieve and maintain the Reactor Coolant System in 'HOT STANDBY' (Mode 3) for at least 32 hours, with no offsite power available, following a reactor trip from full power. The Steam Dump System is used in conjunction with the Auxiliary Feedwater System to meet this design basis.

1.3.2 The Auxiliary Feedwater System is designed such that the Reactor Coolant System can be cooled down to less than 350°F from normal operating conditions with no offsite power available.

1.4 The Auxiliary Feedwater System has the following additional design bases:

1.4.1 The total minimum delivered flow to the steam generators from either AFW pumps G-10 and G-10S (operating concurrently) or AFW pump G-10W (operating alone) for loss of feedwater events shall be 185 gpm (plus margin) at a steam generator pressure of 1015 psig.

1.4.2 The total minimum delivered flow to the steam generators from AFW pump G-10 for station blackout events shall be 155 gpm (plus margin [1]) at a steam generator pressure of 1015 psig.

[1] This requirement anticipates the future application of generic Station Blackout requirements.

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ATTACHMENT C
(CONT)

MADE BY [illegible] 3/23/91 SH 25-49 of 62
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AUXILIARY FEEDWATER SYSTEM

1.0 FUNCTIONS/DESIGN BASES (Continued)

1.4.3 The total minimum delivered flow to the unaffected steam generators from AFW pump G-10W for feedwater line break events (upstream of the in-containment check valves) shall be 125 gpm (plus margin) at a steam generator pressure of 1015 psig with operator action to equalize flow in each AFW line.

1.4.4 The total minimum delivered flow to the unaffected steam generators from AFW pump pumps G-10 and G-10S, operating concurrently, for feedwater line break events (upstream of the in-containment check valves) shall be 125 gpm (plus margin) at a steam generator pressure of 1015 psig without operator action to equalize flow in each AFW line.

1.4.5 The total minimum delivered flow to the unaffected steam generators from AFW pump G-10W or G-10S for feedwater line break events (downstream of the in-containment check valves) shall be 250 gpm (plus margin) at depressurized steam generator conditions.

1.4.6 The maximum flow from AFW pump G-10S shall be limited to 420 gpm (pump runout limit) at depressurized steam generator conditions, considering the most limiting single active failure and using only passive mechanical means.

1.4.7 The maximum automatically delivered flow from AFW pump G-10W or G-10S shall be limited to 150 gpm per steam generator (water hammer limit) at depressurized conditions considering the most limiting single active failure and using only passive mechanical means.

CASE 4 Main Feedwater Line Break Downstream of In-Containment Check Valves at 50% Power

4a. The plant is initially operating at 53% of rated power.

4b. Initial reactor coolant average temperature is 4°F above the nominal value (551.5°F) corresponding to 50% power level on the nominal average temperature program (575.15°F at full power).

4c. Initial pressurizer water level is 30.0% narrow range span (NRS).

4d. Main feedwater to all steam generators is assumed to stop at the time of the feedline break.

4e. Pressurizer power-operated relief valves are available, but no credit is taken for the pressurizer sprays.

4f. AFW is assumed to be manually actuated and the system manually aligned to deliver flow of 225 gpm to two steam generators 15 minutes after the initiation of the event (feedline break).

4g. The steam flow/feed flow mismatch reactor trip is assumed not available.

4h. The feedline break size is assumed to be 0.7854 ft2. All three steam generators depressurize since SONGS-1 does not have main steamline isolation valves.

RESULTS

CASE 1 Main Feedwater Line Break Upstream of In-Containment Check Valves at 100% Power

The results of the feedline break at full power located upstream of inside containment check valve transient are shown in Figures 1 through 4. The time sequence of events is presented in Table 2. Reactor trip is provided by the steam flow/feed flow mismatch signal. The results show that an AFW flow of 100 gpm initiated 30 minutes after the break is sufficient to remove core decay heat. Calculations of this case show that the core remained in a coolable geometry during this FLB scenario. The detailed calculations involved showing that the mass relieved through the pressuizer PORVs (between the time of initial relief through the PORVs and the time the PORVs reseat due to the heat removal capability of the AFW exceeding the core decay heat) was not sufficient to uncover the core. As such, the acceptance criterion for a FLB event that the core remains in a coolable geometry during the transient was shown to be met.

MADE BY R.A. Hff 3/23/91 CHECKED BY [signature] DATE 5/9/91

SUPPL.B DC-L836 REV0
ATTACHMENT D
(PG. 6 OF REF. 5)

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CASE 2 Main Feedwater Line Break Upstream of In-Containment Check Valves at 50% Power

The results of the feedline break at 50% power located upstream of inside containment check valve transient are shown in Figures 5 through 8. The time sequence of events is presented in Table 3. Reactor trip is provided by the high pressurizer water level (50% NRS) signal. The results show that an AFW flow of 100 gpm initiated 15 minutes after the break is sufficient to remove core decay heat. The reactor coolant system (RCS) remains subcooled and the pressurizer does not fill. Thus, the core remains covered with water. As such, the acceptance criterion for a FLB event that the core remains in a coolable geometry during the transient was shown to be met.

CASE 3 Main Feedwater Line Break Downstream of In-Containment Check Valves at 100% Power

The results of the feedline break at full power located downstream of inside containment check valve transient are shown in Figures 9 through 12. The time sequence of events is presented in Table 4. Reactor trip is provided by the steam flow/feed flow mismatch signal. The results show that an AFW flow of 225 gpm initiated 20 minutes after the break is sufficient to remove core decay heat. Calculations of this case show that the core remained in a coolable geometry during this FLB scenario. The detailed calculations involved showing that the mass relieved through the pressuizer PORVs (between the time of initial relief through the PORVs and the time the PORVs reseat due to the heat removal capability of the AFW exceeding the core decay heat) was not sufficient to uncover the core. As such, the acceptance criterion for a FLB event that the core remains in a coolable geometry during the transient was shown to be met.

CASE 4 Main Feedwater Line Break Downstream of In-Containment Check Valves at 50% Power

The results of the feedline break at full power located downstream of inside containment check valve transient are shown in Figures 13 through 16.. The time sequence of events is presented in Table 5. Reactor trip is provided by the high pressurizer pressure signal. The results show that an AFW flow of 225 gpm initiated 15 minutes after the break is sufficient to remove core decay heat. Calculations of this case show that the core remained in a coolable geometry during this FLB scenario. The detailed calculations involved showing that the mass relieved through the pressuizer PORVs (between the time of initial relief through the PORVs and the time the PORVs reseat due to the heat removal capability of the AFW exceeding the core decay heat) was not sufficient to uncover the core. As such, the acceptance criterion for a FLB event that the core remains in a coolable geometry during the transient was shown to be met.

CONCLUSIONS

The reanalysis of the Rupture of a Main Feedwater Pipe supports SONGS 1 operation with the reduced AFW flows presented in Table 1. The reanalysis is applicable for SONGS 1 operation on both the Nominal Tavg Program and Reduced Tavg Program. The radiological consequences following a feedline break were not addressed in this safety evaluation.

MADE BY R.A. [signature] 3/23/90
CHECKED BY [signature] DATE 5/9/90

SAN ONOFRE UNIT 1

FEEDLINE BREAK REANALYSIS WITH REDUCED AUXILIARY FEED FLOW

BACKGROUND

Due to waterhammer concerns, Southern California Edison (SCE) is investigating possible modifications to the auxiliary feedwater (AFW) system. The potential modifications will reduce their (AFW) flow rates. SCE has requested Westinghouse to reanalyze the feedline break event to support the reduced AFW flows. The feedline break event is the only accident that was reanalyzed.

The previous analyses, documented in Reference 1, contains four cases. Breaks are assumed both upstream and downstream of the in-containment check valves initiated when operating at 100% and 50% of Rated Thermal Power. The analyses documented in this report model only breaks downstream of the in-containment check valves. The specific cases that are modeled for this analysis are as follows:

Case 1 - Downstream FLB initiated at 103% power with 200 gpm AFW initiated 20 minutes after the break.

Case 2 - Downstream FLB initiated at 53% power with 200 gpm AFW initiated 15 minutes after the break.

Case 3 - Downstream FLB initiated at 103% power with 175 gpm AFW initiated 20 minutes after the break.

Case 4 - Downstream FLB initiated at 53% power with 175 gpm AFW initiated 15 minutes after the break.

Case 5 - Downstream FLB initiated at 53% power with 30 gpm AFW initiated 1 minute after the break and increased to 125 gpm 20 minutes after the break.

ATTACHMENT E
(REF. 4)

Made By RLWF Date 5/8/90 SUPPL B Calc No. 062836 Rev. 0

Ckd By [illegible] Date 5/9/90 Document Transmittal Sh RS-53 of 62

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Westinghouse Proprietary Class 2

Preliminary

CASE 3 Main Feedwater Line Break Downstream of the In-Containment Check Valves at 100% Power with 175 gpm AFW

The Case 3 FLB results are shown in Figures 9 through 12. The time sequence of events is presented in Table 4. Reactor trip is provided by the steam flow/feed flow mismatch signal. The results show that an AFW flow of 175 gpm initiated 20 minutes after the break is sufficient to remove core decay heat. Calculations show that the mass relieved through the pressurizer PORVs was not sufficient to uncover the core and thus, the core remained in a coolable geometry during this FLB scenario. As such, the acceptance criterion for a FLB event that the core remains in a coolable geometry during the transient was shown to be met.

CASE 4 Main Feedwater Line Break Downstream of the In-Containment Check Valves at 50% Power with 175 gpm AFW

The results of the Case 4 FLB are shown in Figures 13 through 16. The time sequence of events is presented in Table 5. Reactor trip is provided by the high pressurizer water level (50% NRS) signal. The results show that an AFW flow of 175 gpm initiated 15 minutes after the break is sufficient to remove core decay heat. Calculations show that the mass relieved through the pressurizer PORVs was not sufficient to uncover the core and thus, the core remained in a coolable geometry during this FLB scenario. As such, the acceptance criterion for a FLB event that the core remains in a coolable geometry during the transient was shown to be met.

ATTACHMENT E

(REF. 4)

WYLE LABORATORIES

ATTACHMENT F (REF 1)

DATA SHEET

CUSTOMER PERMUTIT

Test Title: WATER FLOW TEST ON CAVITATING VENTURI

Specimen 3" CAV. VENTURI

Part No.

Job No. 57347

S/N 5413

Date 10/13/88

CALC # DC-2836

PT ~~RUN~~ NO.	Q (GPM)	T1 (DEG. F)	P1 (PSIA)	P2 (PSIA)	P3 (PSIA)	P1-P2 (PSID)	P1-P3 (PSID)	BY	CK'D	DATE
1.	18.83	70.80	537.98	529.16	537.49	8.82	0.49			
2.	39.49	71.11	537.34	501.21	531.85	36.13	5.49	Q - FLOWRATE		
3.	60.30	71.19	538.13	458.95	524.16	79.18	13.97	T1 - INLET TEMP		
4.	82.90	71.25	538.91	376.11	506.58	162.79	32.32	P1 - INLET PRESSURE		
5.	95.93	71.37	537.83	334.90	496.13	202.93	41.70	P2 - THROAT PRESSURE		
6.	104.27	71.47	539.08	291.30	487.83	247.78	51.25	P3 - OUTLET PRESSURE		
7.	110.75	72.65	539.18	254.07	478.14	285.11	61.03			
8.	114.03	73.06	539.25	238.86	474.50	300.39	64.75			
9.	119.60	73.31	539.18	212.64	465.93	326.54	73.24			
10.	127.20	73.64	536.69	135.51	447.23	401.17	89.46			
11.	128.92	73.77	538.01	0.601	436.98	537.40	101.03			
12.	128.23	73.86	538.44	0.61	318.25	537.83	220.19			
13.	128.25	73.92	538.08	0.61	250.45	537.47	287.62			
14.	128.02	73.94	537.39	0.61	218.86	536.78	318.53			
15.	128.37	73.99	537.25	0.61	144.21	536.64	393.04			
16.	128.80	76.59	538.11	0.70	390.84	537.41	147.27			
17.	128.60	76.61	539.13	0.70	355.39	538.43	183.74			
18.	129.77	76.52	538.93	0.70	300.84	538.23	238.09			
A	128.90	76.48	537.86	0.70	280.70	537.16	257.16			

TESTED BY: Miki R. Miranda

Douglas G. Anderson

10-13-88 WYLE 233

Q.C. Form Approval [signature]

MADE BY R.A. Uffe 3/23/90 CHECKED BY [signature] DATE 5/9/90

SUPPL B DC-2836 REV 0

SH. R5-5 5 OF 62

ATTACHMENT F
(REF. 1)

P. ~~145~~ ~~59~~ ~~152~~ 167 DKH 7/25/90 FINAL

Page No. 15

Revision A

WYLE LABORATORIES

DATA SHEET

CUSTOMER PERMUTIT CO. INC.

Test Title: WATER FLOW TEST ON CAVITATING VENTURIS

Specimen 3" CAVITATING VENTURI

Part No.

Job No. 57347

S/N 5414

Date 9/23/88

PT. ~~RUN~~ NO.	Q (GPM)	T1 (DEG. F)	P1 (PSIA)	P2 (PSIA)	P3 (PSIA)	P1-P2 (PSID)	P1-P3 (PSID)	CALC # DC 2836 BY / CK'D		DATE / DATE
1.	20.31	65.47	541.04	538.81	541.72	2.22	-0.681			
2.	42.69	66.49	537.35	500.43	531.71	36.92	5.64	Q - FLOWRATE		
3.	62.58	66.61	536.37	448.31	523.34	88.06	13.04	T1 - INLET TEMP		
4.	82.22	66.88	538.69	387.40	515.60	151.29	23.10	P1 - INLET PRESSURE		
5.	111.09	67.37	539.72	255.39	496.06	284.33	43.65	P2 - THROAT PRESSURE		
6.	115.85	67.67	539.45	223.99	490.18	315.46	49.27	P3 - OUTLET PRESSURE		
7.	130.62	69.62	540.82	129.71	472.75	526.46	68.07			
8.	134.97	70.39	537.42	.579	303.78	536.84	233.64			
9.	133.49	70.38	539.50	.575	272.72	538.92	266.77			
10.	133.49	70.43	540.38	.577	178.34	539.80	362.04			
11.	134.60	70.47	537.30	.584	171.72	536.72	365.58			
12.	133.17	70.43	536.30	.591	154.76	535.71	381.54			
13.	134.48	73.02	539.03	.606	235.03	538.42	304.02			
14.	132.59	72.93	538.67	.591	157.28	538.08	381.40			

TESTED BY: Mike R. Miranda
Douglas G. Adams

9-23-88

MADE BY R.G. W 3/23/90 CHECKED BY D DATE 5/9/90

SUPPL. B - DC2836 REV 1

ATTACHMENT F (REF 1)

P. ~~146~~ ~~of 159~~ ~~153~~ 167 DKH 7/25/90

WYLE LABORATORIES

DATA SHEET

Page No. R5-56 OF 62

Revision A

FINAL

CUSTOMER: PERMUTIT CO. INC.

Test Title: WATER FLOW TEST ON CAVITATING VENTURI

Specimen: 3" CAVITATING VENTURI

Part No.:

Job No. 57347

S/N 5515

Date 9/27/88

~~PT~~ ~~RUN~~ NO.	Q (GPM)	T1 (DEG. F)	P1 (PSIA)	P2 (PSIA)	P3 (PSIA)	P1-P2 (PSID)	P1-P3 (PSID)	CALC # DC-2836 BY / CK'D	DATE
1.	20.05	74.46	538.25	527.34	537.18	10.91	1.08		
2.	40.0	74.30	539.79	500.30	533.00	39.50	6.79	Q - FLOWRATE	
3.	61.52	74.36	537.77	449.46	521.46	88.31	16.31	T1 - INLET TEMP	
4.	81.01	73.41	538.38	383.22	508.15	155.15	30.23	P1 - INLET PRESSURE	
5.	98.96	73.13	539.72	310.54	493.87	229.17	45.85	P2 - THROAT PRESSURE	
6.	120.93	73.02	539.89	194.65	462.98	345.24	76.91	P3 - OUTLET PRESSURE	
7.	123.70	73.05	540.30	168.14	457.05	372.17	83.25		
8.	128.98	72.78	536.57	0.716	455.07	535.85	81.49		
9.	128.94	72.86	541.69	0.818	436.62	540.88	105.08		
10.	128.28	72.82	539.96	0.852	374.07	539.11	165.89		
11.	128.97	72.76	537.84	0.864	317.57	536.97	220.27		
12.	128.60	72.77	538.13	0.764	233.74	537.37	304.39		
13.	128.87	72.81	537.55	0.538	147.19	537.01	390.36		

TESTED BY: Mitzi R. Muiamida, Douglas G. Anderson

9-22-88

2239 3124

MADE BY R.A. Wff 3/23/90 CHECKED BY [illegible] DATE 5/9/90

SUPPL B DC 2836 - REV 0

ATTACHMENT G
(FROM REF. 2)

SUPPL. 8 TO DC2836 REV. 0

SH R5-5 7 of 62

MADE BY R.I. 3/23/96 CHECKED BY DATE

CASE 1 - P.3

al 6-13-88

CALC NO. M-DC-2836
P. 80 OF P. 125
BY M. Locascio DATE 1-6-88
CHK BY FA DATE 1/11/88

DKH 7/25/90 P. 147 of 159 153 167 154

28	.00	15.00	41	42	43
29	.00	15.00	42	43	44
30	.00	21.70	44	45	46
31	.00	21.70	45	46	47
32	.00	31.50	47	48	
33	.00	18.10	34	35	49
34	.00	17.00	35	49	50
35	.00	23.15	50	51	
36	.00	23.15	51	52	

OUTPUT SELECTION: ALL RESULTS ARE OUTPUT EACH PERIOD

THIS SYSTEM HAS 52 PIPES WITH 33 JUNCTIONS , 11 LOOPS AND 9 FGNS

THE RESULTS ARE OBTAINED AFTER 4 TRIALS WITH AN ACCURACY = .00027

Pipe Network Test System
AFW-G-10S IN OPERATION

CONTRACT NO. 468000

PIPE NO.	NODE NOS.		FLOWRATE	HEAD LOSS	PUMP HEAD	MINOR LOSS (ΔP ORIFICE)	VELOCITY	HL/1000
LINE 1 IS CLOSED								
2	2	11	.00	.00	.00	.00	.00	.00
3	11	0	.00	.00	.00	.00	.00	.00
4	2	3	.00	.00	.00	.00	.00	.00
5	3	4	.00	.00	.00	.00	.00	.00
THE CHECK VALVE IN LINE NUMBER 6 IS CLOSED								
THE CHECK VALVE IN LINE NUMBER 7 IS CLOSED								
THE CHECK VALVE IN LINE NUMBER 8 IS CLOSED								
9	5	6	131.13	3.70	.00	.00	5.68	39.38
10	6	7	65.56	13.75	.00	.00	2.84	10.72
11	6	7	65.56	13.75	.00	.00	2.84	10.72
12	7	8	131.13	3.07	.00	.00	5.68	39.38
13	8	9	131.13	.32	.00	1178.42	5.68	39.38
LINE 14 IS CLOSED								
15	9	10	131.13	4.02	.00	.00	5.68	39.38
16	10	0	131.13	.02	.00	.00	.56	.13
THE PUMP IN LINE 17 IS OPERATING OUT OF RANGE Q_{MAX} = 405 gpm (ok for 405.45)								
17	0	13	405.45	2.18	1296.30	.00	17.57	345.81
18	13	22	12.00	1248.93	.00	.00	4.44	94.95
19	22	0	12.00	4.48	.00	.00	1.89	11.38
20	13	14	393.45	47.62	.00	.00	17.05	326.15
21	14	15	393.45	18.15	.00	.00	9.90	81.38
22	15	16	131.14	.87	.00	.00	5.68	39.39
23	15	5	131.13	.52	.00	.00	3.65	13.02
24	15	27	131.19	.55	.00	.00	3.65	13.03
25	16	17	131.14	2.32	.00	.00	3.65	13.03
26	17	18	65.56	13.77	.00	.00	5.68	39.39
27	17	18	65.58	13.77	.00	.00	2.84	10.72
28	18	19	131.14	3.27	.00	.00	2.84	10.73
29	19	20	131.14	.32	.00	1178.61	5.68	39.39
LINE 30 IS CLOSED							5.68	39.39
31	20	21	131.14	4.65	.00	.00	5.68	39.39
32	21	0	131.14	.02	.00	.00	.56	.13

SH RS-58F 62

ATTACHMENT G
(FROM REF 2)

SUPPL. B TO
DC2836 REV0

MADE BY [illegible] 3/23/90 CHECKED [illegible] DATE 5/9/95

CALC NO. M-DC-2836

P. 81 OF P. 125

BY [illegible] DATE 1-6-88

CHK BY FA DATE 1/11/88

CASE 1-P.4

LINE 33 IS CLOSED								
34	24	33	.00	.00	.00	.00	.00	.00
LINE 35 IS CLOSED								
36	24	25	.00	.00	.00	.00	.00	.00
37	25	26	.00	.00	.00	.00	.00	.00
THE CHECK VALVE IN LINE NUMBER 38 IS CLOSED								
THE CHECK VALVE IN LINE NUMBER 39 IS CLOSED								
THE CHECK VALVE IN LINE NUMBER 40 IS CLOSED								
41	27	28	131.19	2.36	.00	.00	5.69	39.42
42	28	29	65.59	13.76	.00	.00	2.84	10.73
43	28	29	65.59	13.76	.00	.00	2.84	10.73
44	29	30	131.19	3.19	.00	.00	5.69	39.42
45	30	31	131.19	.32	.00	1179.43	5.69	39.42
LINE 46 IS CLOSED								
47	31	32	131.19	4.18	.00	.00	5.69	39.42
48	32	0	131.19	.03	.00	.00	.56	.13
49	33	34	.00	.00	.00	.00	.00	.00
50	34	35	.00	.00	.00	.00	.00	.00
51	35	36	.00	.00	.00	.00	.00	.00
52	36	0	.00	.00	.00	.00	.00	.00

P ~~148~~ ~~159~~ ~~154~~ 167 155 DKH 7/25/90

JUNCTION NUMBER	DEMAND	GRADE LINE	ELEVATION	PRESSURE
2	.00	57.92	17.00	17.73
3	.00	57.92	16.00	18.17
4	.00	57.92	16.70	17.86
5	.00	1244.66	18.30	531.42
6	.00	1240.96	15.75	530.93
7	.00	1227.22	15.75	524.97
8	.00	1224.14	23.20	520.41
9	.00	45.40	23.20	9.62
10	.00	41.39	31.50	4.28
11	.00	57.92	21.80	15.65
13	.00	1310.95	16.80	560.80
14	.00	1263.33	16.80	540.16
15	.00	1245.18	16.70	532.34
16	.00	1244.32	15.00	532.70
17	.00	1241.99	15.00	531.70
18	.00	1228.23	15.00	525.73
19	.00	1224.96	22.40	521.11
20	.00	46.04	22.40	10.24
21	.00	41.39	31.50	4.28
22	.00	62.40	20.50	18.16
24	.00	57.92	18.80	16.95
25	.00	57.92	21.70	15.70
26	.00	57.92	22.70	15.26
27	.00	1244.64	16.70	532.11
28	.00	1242.27	15.00	531.82
29	.00	1228.52	15.00	525.86
30	.00	1225.32	21.70	521.57
31	.00	45.58	21.70	10.35
32	.00	41.40	31.50	4.29
33	.00	57.92	18.10	17.26
34	.00	57.92	17.00	17.73
35	.00	57.92	23.15	15.07
36	.00	57.92	23.15	15.07

THE NET SYSTEM DEMAND = .00

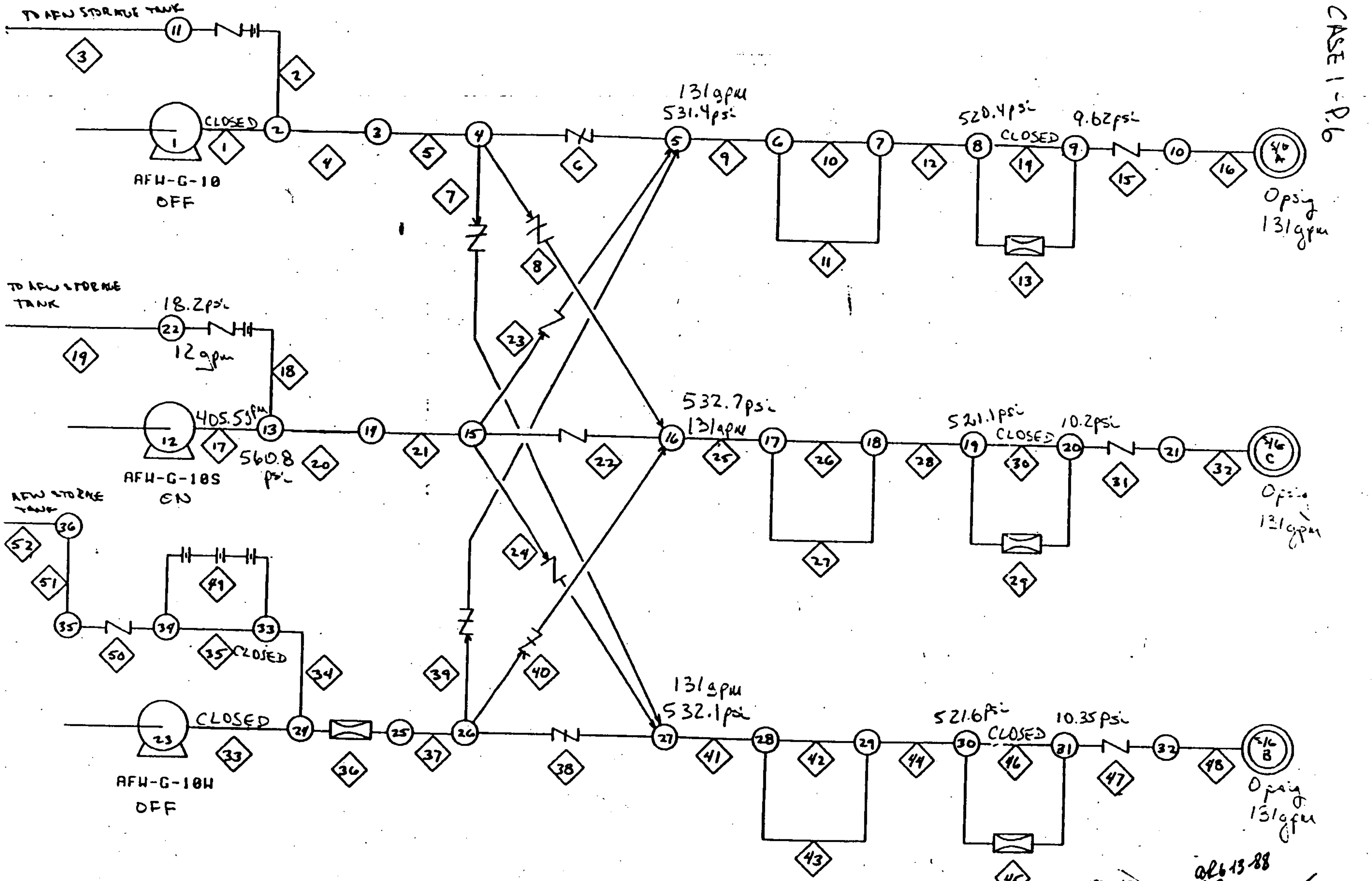
SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

ATTACHMENT G SUPPL 3 DC-2836 Rev 0 SH RS-5? 63

(FROM REF. 2)

MADE BY [signature] 3/23/90 CHECKED BY [signature] DATE 5/9/90

CASE 1 - P.6



CALC NO. M-DC-2836 Rev

P. 83 OF P. 125

BY [signature] DATE 1-6-88

CHK BY FH DATE 1/12/88

DC4 7/25/90 P. 156 167

ATTACHMENT A — SUPPL. B C-2836 REV 0 — SH RS-60 OF

G10W CURVES (FROM REF. 6) — MADE BY R.A. Uff 3/23/90 — CHECKED BY — DATE 5/9/90

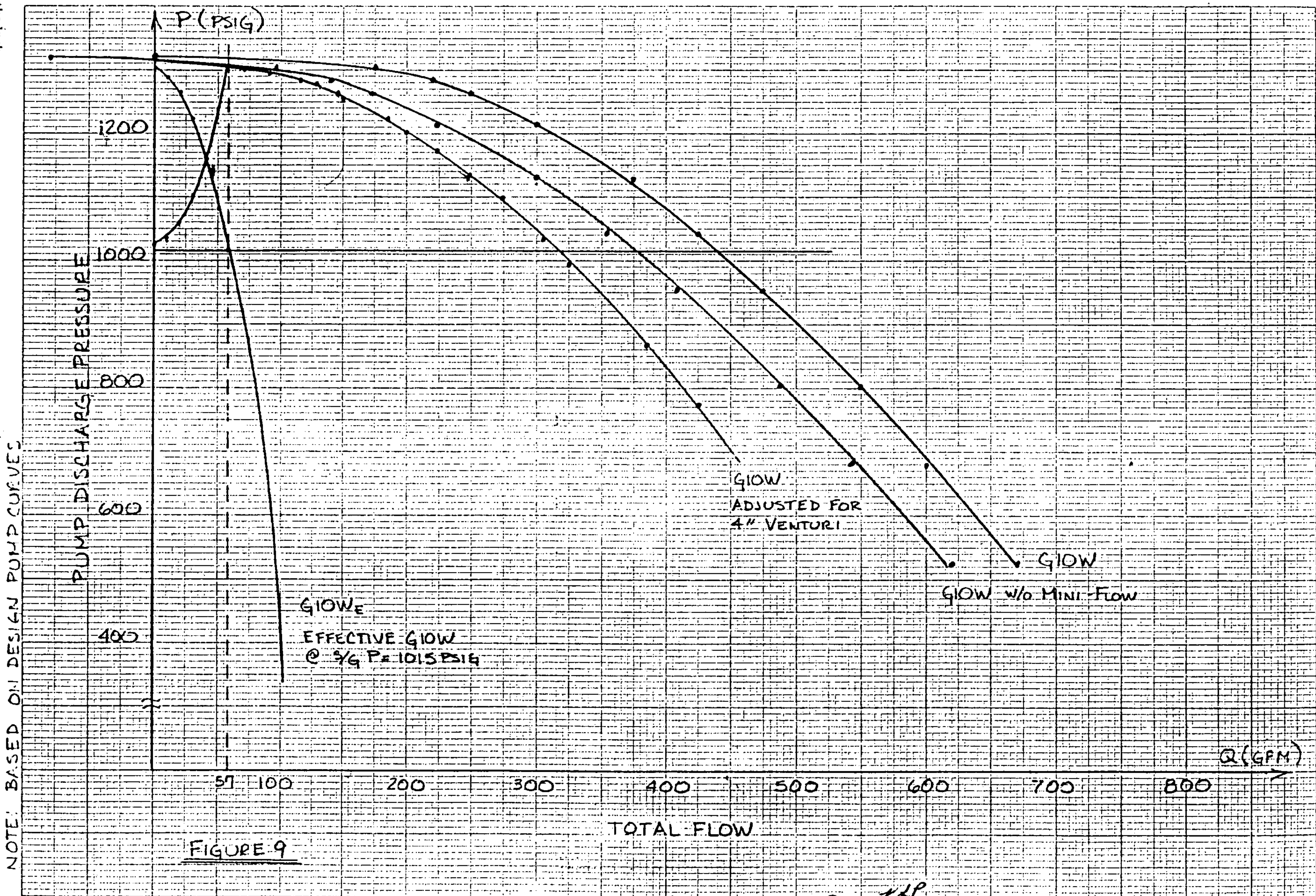


FIGURE 9

~~SUPPLEMENT A DC-2836 REV 0~~ MA[redacted]

R A Uff 3/23/90

DKH 7/25/90 P. 157

SHEET [redacted] SHEETS

ENGINEERING DEPARTMENT

CALCULATION SHEET

[illegible] 3/23/90

Supplement A

SUBJECT: SONGS 1 Hydraulic Calculation For AFW Lines - Flow Requirements CALC NO. 2836 REV. 3

J.O.NO.____ MADE BY [redacted]

$$Q_1 = \sqrt{\frac{Q_2^2(\Delta P_1 - \Delta P_E)}{\Delta P_2 - \Delta P_E}}$$

From G10+G10S test data:

Q_2 = Total G10+G10S flow to S/G's ÷ 3 S/G's

Q_2 = 526 gpm ÷ 3

Q_2 = 175.3 gpm

$\Delta P_2 = P_{DISCHARGE} - P_{S/G}$

ΔP_2 = 1030 psig - 800 psig

ΔP_2 = 230 psig

$$Q_1 = \sqrt{\frac{(175.3)^2(\Delta P_1 - \Delta P_E)}{230 - \Delta P_E}}$$

Loss due to elevation:

From Ref. 14, 17, 18, 19: $Z_{S/G}$ = 41' - 4 7/16" = 41.37 ft

$Z_{PUMP\ G10}$ = 17' - 0" = 17.0 ft

$Z_{PUMP\ G10S}$ = 16' - 10" = 16.83 ft

For the largest difference in height, use elevation of Pump G10S.

$h_L = Z_{S/G} - Z_{PUMP\ G10S}$

h_L = 41.37 ft - 16.83 ft

h_L = 24.54 ft

Ref. 7, 3-5: $\Delta P_E = \frac{h_L \rho}{144}$

ΔP_E = [illegible] 10.62 psid

SCE OD 397-B REV 10/84 (CW)

ATTACHMENT I SUPPL. B DC 2836 SH. 25-62 OF 62
(FROM REF. 6) DKH 7/25/90 P. 159/167

MADE BY [illegible] 3/23/90 CHECKED BY [illegible] DATE 5/9/90

[redacted]ETS

ENGINEERING DEPARTMENT

CALCULATION SHEET

Supplement A

SUBJECT: SONGS 1 Hydraulic Calculation For AFW Lines - Flow Requirements [redacted]

J.O.NO.____MAD[redacted]

$$Q_1 = \sqrt{\frac{(175.3)^2(\Delta P_1 - 10.62)}{230 - 10.62}}$$

Sample calculation:

$$Q_1 = \sqrt{\frac{(175.3)^2(200 - 10.62)}{(230 - 10.62)}} = 162.87 \text{ GPM}$$

$$Q_T = 162.87 \times 3 = 488.6 \quad \text{TOTAL FLOW TO S/G'S.}$$

Data to plot System Loss Curve - Refer to Figure 6:

P_1 (psig)	Q_1 (gpm)	Q_T (gpm)
300	201.3	604.0
250	183.1	549.4
200	162.9	488.6
180	154.0	462.1
160	144.7	433.9
140	134.6	403.9
100	111.9	335.7
60	83.2	249.5
20	36.2	108.6
10.62	0	0

System curve can be validated with the G10 test data for FCV's fully open with S/G pressure at 800 psig. Refer to Figure 6 for test data points.