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RECIP.NAME RECIPIENT AFFILIATION
YOUNGBLOOD,B.J. Licensing Branch 1

SUBJECT: Forwards calculations which indicate adequate flow capacity for piping & valves required in alternate shutdown path & show that requirements for worst path resistances are met. Calculations close SER Outstanding Issue 38.

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May 15, 1981

Mr. B. J. Youngblood, Chief
Licensing Branch No. 1
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Docket Nos. 50-387
50-388

SUSQUEHANNA STEAM ELECTRIC STATION
SER OUTSTANDING ITEM 38
ER 100450 FILE 841-2
PLA-782

Dear Mr. Youngblood:

Attached are the Susquehanna SES calculations to show sufficient flow capacity for all piping and valves required in the alternate shutdown path and which show that the pump head-flow requirements for the worst path resistances are met.

These calculations complete our action to close SER Outstanding Issue 38.

Very truly yours,

N W Curtis

N. W. Curtis
Vice President-Engineering and Construction-Nuclear

CTC/mks

Attachment

cc: R. M. Stark - NRC

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SUSQUEHANNA STEAM ELECTRIC STATION, UNITS 1 AND 2
CALCULATION COVER SHEET

BECHTEL

JOB NO. 8856

DISCIPLINE MECHANICAL

COVER SH. 4 OF 4
CALC. NO. M152-7.
NO. OF SHEETS 10.
Q NO. 510

TITLE ALTERNATE SHUTDOWN COOLING

MAY 4 '81

CALC. SHEET CONTROL: 138930

SUBJECT CORE SPRAY PUMP OPERATION IN THE ALTERNATE SHUTDOWN COOLING MODE.

STATEMENT OF PROBLEM DETERMINE CORE SPRAY PUMP OPERATING POINTS IN ALTERNATE SHUTDOWN COOLING MODE WITH ONE OR MORE MAINSTEAM RELIEF VALVES OPEN.

SAR CHECKED ☐ SAR CHANGE REQ'D. ☐ SAR CHANGE NOTICE INITIATED ☐

SOURCES OF DATA ISOMETRICS: HBB-104-1, REV. 8, GBB-101-2, REV. 3 DBB-113-1 REV 3, DCA-109-1 REV. 5, DCA-107-1, REV. 11.

SOURCES OF FORMULAE & REFERENCES
1) CORE SPRAY PUMP CALCS M152-6, REV. 1
2) CRANE TECHNICAL PAPER No. 410, 1979 EDITION
3) CORE SPRAY PUMP PERFORMANCE CURVE 8856-M1-E21-30-1
4) GE CORE SPRAY PROCESS DIAGRAM 8856-M1-E21-15-2
5) CROSBY VALVE ENGINEERING AND CAPACITY DATA, CAT. #302, SUP. 1
6) PSV OUTLINE DWG. 8856-M1-B21-64-2

PRELIMINARY CALC. ☐ FINAL CALC. ☒ SUPERSEDES CALC. NO. ______

4/23/81	J. J. Brunner / [signature]	David Yang	5/4/81	E Connell Jr	5/4/81
DATE	CALCULATION BY	**CHECKED BY	DATE	APPROVED BY	DATE

*Preliminary calcs checked only at group supervisor's request.
**Considers PSAR, codes and standards, redundancy and separation, operability and maintainability, technical adequacy, accuracy and clarity.

QA-2(1/74)

MAY -4 '81 138930

CALCULATION SHEET

BECHTEL

CALC. NO. M 152-7 REV. NO. 0

ORIGINATOR J. J. Brunner DATE 4/23/81 CHECKED D. Yang DATE 5-4-81

PROJECT SUSQUEHANNA JOB NO. 8856

SUBJECT CORE SPRAY PUMPS IN ALTERNATE SHUTDOWN COOLING MODE SHEET NO. 1 of 10

ASSUMPTIONS

1. Based on vendor catalog information the C_V value for fully open main steam relief valve (PSV F013) is assumed to be within the range of 400 to 500 gpm. Both values (400 & 500) were used in these calculations. An estimate of the C_V value is presented in Appendix A of this calculation.

2. Backpressure in PSV discharge line is neglected because of large line diameter (12").

3. Friction losses in main steam piping are negligeable and thus are omitted.

4. Calculation reflects a steady state condition. Inlet flow is equal to outlet flow. Water level in RPV is assumed to be 3 ft above center line of main steam nozzle.

5. No venting of RPV dome occurs.

SUMMARY AND CONCLUSIONS

a) With only one PSV open, pumps will pressurize RPV above shutdown initiation pressure of 98 psig. This could be prevented by throttling with core spray valve. It is preferable, however, that a second PSV be opened to lower reactor pressure below shutdown initiation pressure.

b) Calculations show (see page 9) that with 4 PSV open, runout flow of 7900 gpm will be reached with a valve C_V of 500.

P-20768 Rev. (6/76) ED-69 (5/76)

CALCULATION SHEET

BECHTEL

CALC. NO. M152-7 REV. NO. 0

ORIGINATOR J. J. Brunner DATE 4/23/81 CHECKED gwy DATE 5-4-81

PROJECT SUSQUEHANNA JOB NO. 8856

SUBJECT Core Spray Pumps in Alt. Shutdown Cooling Mode SHEET NO. 2 OF 10

MAY -4 '81 138930

Use Core Spray Mode D

P_{RPV} = 105 psig (use 98 psig for shutdown coolg. initiation)

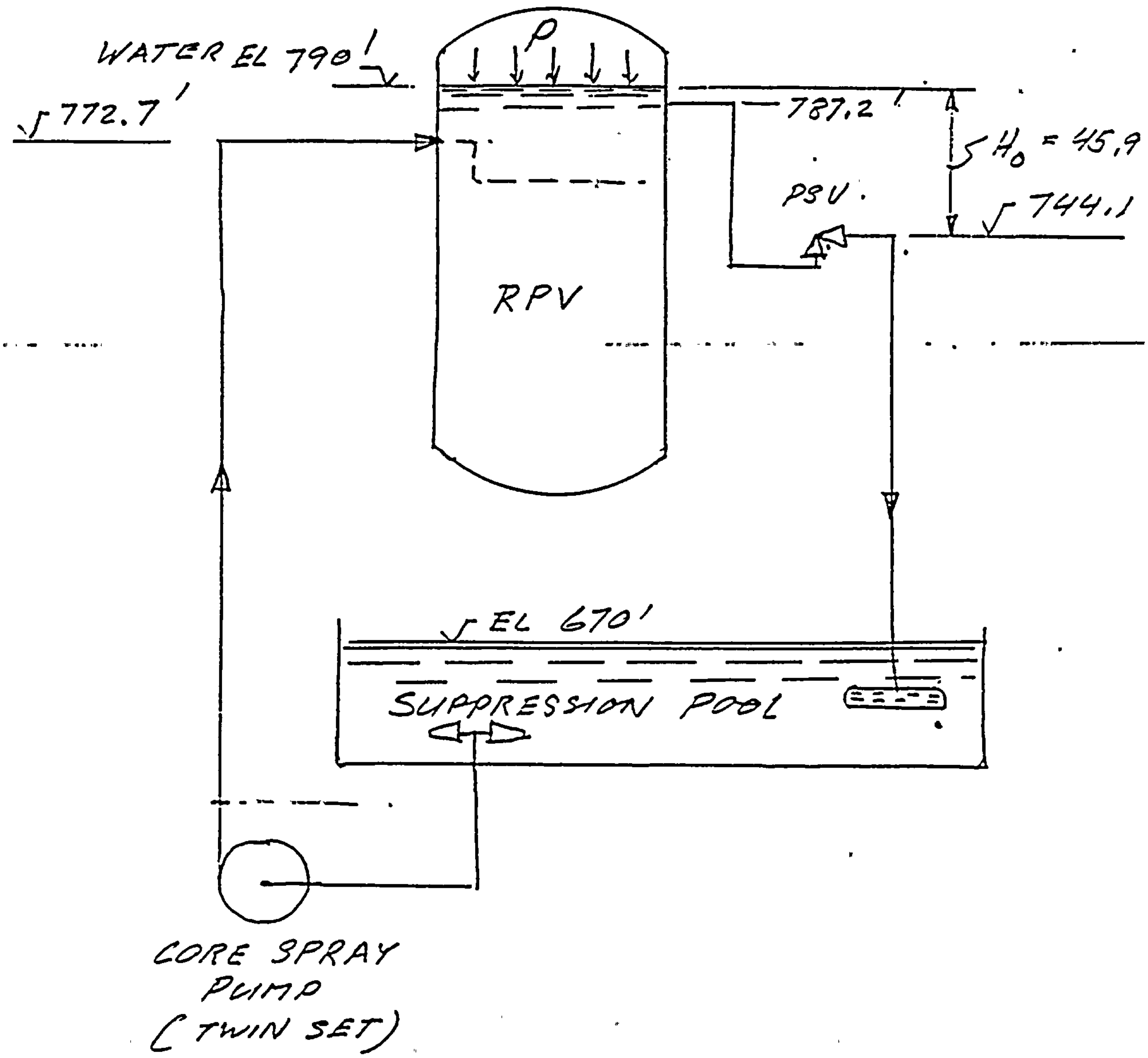
T_{RPV} = 332 °F

T_{pool} = 170 °F

P_{pool} = 14.7 psia

$\}$ (Ref. 4)

Assume water level ~3 ft above M.S. nozzle ℄



SFP-20768 Rev. (6/76) ED-69 (5/76)

MAY -4 '81 138930

TOTAL SYSTEM'S RESISTANCE

$$H_T = H_s + H_p + H_f$$

Static Head - with water level at approx. 3 ft above main steam nozzle ℄

$$H_s = 790' - 670' = 120'$$

Pressure Head

$$H_p = \frac{144}{\rho} P_{PSV} - H_0$$

where:

$$\Delta P_{PSV} = \frac{\rho}{62.4}\left(\frac{Q}{C_V}\right)^2 \quad \text{(Ref. 2)}$$

with zero back pressure $\Delta P_{PSV} = P_{PSV}$

H_0 = stat. head at PSV ℄ = 45.9' (see page 9)

Friction Head

$$H_f = \left(\frac{Q}{Q_C}\right)^2 H_{fc}$$

condition calculated for Mode D (see Ref. 1 sht. 78)

Q_C (2 pumps) = 6350 gpm

H_{fc} = 277.3 ft

$$\boxed{H_T = H_s + \frac{144}{62.4}\left(\frac{Q}{C_V}\right)^2 - H_0 + \left(\frac{Q}{Q_C}\right)^2 \cdot H_{fc}}$$

RPV Pressure $= P_{PSV} - \frac{\rho}{144} \cdot H_0$

CALCULATION SHEET

BECHTEL

CALC. NO. M152-7 REV. NO. 0

ORIGINATOR J. J. Brimmer DATE 4/23/81 CHECKED [illegible] DATE 5-4-81

PROJECT SUSQUEHANNA JOB NO. 8856

SUBJECT Core Spray Pumps in Alternate Shutdown Mode SHEET NO. 4 of 10

ONE PSV IS OPEN

MAY -4 '81 138930

$C_V = 400$

Q	2000	4000	6000	~~8000~~
H_S	120	120	120	120
$H_P = \frac{144}{62.4}\left(\frac{Q}{400}\right)^2 - 45.9$	11.8	184.9	473.3	877
$H_f = \left(Q/6350\right)^2 \times 277.3$	27.5	110	247.5	440
H_{tot}	159.3	414.9	840.8	1437

$C_V = 500$

H_S	120	120	120	120
$H_P = \frac{144}{62.4}\left(\frac{Q}{500}\right)^2 - 45.9$	$-.9$	101.8	286.	545
H_f	27.5	110	247.5	440
H_{tot}	N/A	331.8	653.5	1105

P_{RPV} with 1 PSV @ $C_V = 400$ $Q = 5{,}450$ gpm

$$P = \frac{56.2}{144} \cdot \left[\frac{144}{62.4}\left(\frac{5450}{400}\right)^2 - 45.9\right] = 149.3 \text{ psig}$$

P_{RPV} with 1 PSV @ $C_V = 500$ $Q = 6{,}130$ gpm

$$P = \frac{56.2}{144}\left[\frac{144}{62.4}\left(\frac{6{,}130}{500}\right)^2 - 45.9\right] = 117.4 \text{ psig}$$

BECHTEL

CALCULATION SHEET

ORIGINATOR J.J. Brummer DATE 4/23/81
CALC. NO. M152-7 REV. NO. 0
CHECKED [illegible] DATE 5-4-81
PROJECT SUSQUEHANNA
JOB NO. 8856
SUBJECT Core Spray Pumps in Alternate Shutdown Cooling Mode
SHEET NO. 5 of 10

TWO PSV OPEN

MAY -4 '81 138930

$C_V = 400$

Q_{TOTAL}	2000	4000	6000	8000
Q_{PSV}	1000	2000	3000	4000
H_S	120	120	120	120
$H_P = \frac{144}{62.4}\left(\frac{Q_V}{400}\right)^2 - 45.9$	−31.5	11.8	83.9	184.9
$H_f = (Q/6350)^2 \cdot 277.3$	27.5	110	247.5	440
H_{tot}	N/A	241.8	451.4	744.9

$C_V = 500$

H_S	120	120	120	120
$H_P = \frac{144}{62.4}\left(\frac{Q_V}{500}\right)^2 - 45.9$	−36.7	−9	37.2	101.8
$H_f = (Q_T/6350)^2 \cdot 277.3$	27.5	110	247.5	440
	N/A	N/A	404.7	661.8

P_{RPV} @ $C_V = 400$ $\qquad Q_{PSV} = 7{,}150/2 = 3{,}575$ gpm

$$P_{RPV} = \frac{57.2}{144} \cdot \left[\frac{144}{62.4}\left(\frac{3575}{400}\right)^2 - 45.9\right] = 55 \text{ psig}$$

P_{RPV} @ $C_V = 500$ $\qquad Q_{PSV} = 7420/2 = 3{,}710$ gpm

$$P_{RPV} = \frac{58}{144}\left[\frac{144}{62.4}\left(\frac{3710}{500}\right)^2 - 45.9\right] = 32.7 \text{ psig}$$

CALCULATION SHEET

BECHTEL

CALC. NO. M152-7 REV. NO. 0

ORIGINATOR J. J. Bruinner DATE 4/23/81 CHECKED Guy DATE 5-4-81

PROJECT Susquehanna JOB NO. 8856

SUBJECT Core Spray Pumps in Alternate Shutdown Cooling Mode SHEET NO. 6 of 10

THREE PSV OPEN

MAY -4 '81 138930

$C_V = 400$

Q_{TOTAL}	3000	6000	9000
Q_{PSV}	1000	2000	3000
H_S	120	120	120
$H_P = \frac{144}{62.4}\left(\frac{Q_V}{400}\right)^2 - 45.9$	−31.5	11.8	83
$H_f = (Q_T/6350)^2 \cdot 277.3$	61.9	247.5	557
H_{tot}	N/A	379.3	760

$C_V = 500$

H_S	120	120
$H_P = \frac{144}{62.4}\left(\frac{Q_V}{500}\right)^2 - 45.9$	−9.	37.
$H_f = (Q_T/6350)^2 \cdot 277.3$	247.8	557.
H_{tot}	N/A	714.

P_{RPV} @ $C_V = 400$ $\quad Q_{PSV} = 7600/3 = 2{,}533$ gpm

$$P_{RPV} = \frac{58.4}{144}\left[\frac{144}{62.4}\left(\frac{2{,}533}{400}\right)^2 - 45.9\right] = 18.9 \text{ psig}$$

P_{RPV} @ $C_V = 500$ $\quad Q_{PSV} = 7770/3 = 2{,}590$ gp.

$$P_{RPV} = \frac{59.5}{144}\left[\frac{144}{62.4}\left(\frac{2{,}590}{500}\right)^2 - 45.9\right] = 6.6 \text{ psig}$$

CALCULATION SHEET

BECHTEL

ORIGINATOR J. J. Brunner DATE 4/23/81 CALC. NO. M152-7 REV. NO. 0

CHECKED Dwy DATE 5-4-81

PROJECT Susquehanna JOB NO. 8856

SUBJECT Core Spray Pumps in Alternate Shutdown Cooling Mode SHEET NO. 7 of 10

MAY -4 '81 138930

FOUR PSV OPEN

$C_V = 400$

Q_{TOT}	6000	8000	9000
Q_V	1500	2000	2250
H_S	120	120	120
$H_P = \frac{144}{62.4}\left(\frac{Q}{400}\right)^2 - 45.9$	−13.4	11.8	27.1
$H_f = (Q_T/6350)^2 \cdot 277.3$	247.8	440	557
H_{tot}	N/A	571.8	704.

$C_V = 500$

H_S	120	120
$H_P = \frac{144}{62.4}\left(\frac{Q_V}{500}\right)^2 - 45.9$	−9	0.
$H_f = (Q_T/6350)^2 \cdot 277.3$	440	557
H_{tot}	N/A.	677.

P_{RPV} @ $C_V = 400$ $\qquad Q_{PSV} = 7780/4 = 1945$ gp

$$P_{RPV} = \frac{59.6}{144}\left[\frac{144}{62.4}\left(\frac{1945}{400}\right)^2 - 45.9\right] = 3.5 \text{ psig}$$

P_{RPV} @ $C_V = 500$ $\qquad Q_{PSV} = 7900/4 = 1975$ gp.

$$P_{RPV} = \frac{59.8}{144}\left[\frac{144}{62.4}\left(\frac{1975}{500}\right)^2 - 45.9\right] = \text{atmospheric}$$

(NEG)

CALCULATION SHEET

CALC. NO. M152-7 REV. NO. 0

ORIGINATOR J. J. Brunner DATE 4/23/81 CHECKED [illegible] DATE 5-4-81

PROJECT SUSQUEHANNA JOB NO. 8856

SUBJECT CORE SPRAY PUMPS IN ALTERNATE SHUTDOWN COOLING MODE SHEET NO. 8 of 10

MAY -4 '81 138930

Determine Amount of Throttling Required to Match Initiation Pressure of 98 psig with one PLV open.

With 0 back pressure:

$$P_{PSV} = P_{RPV} + \frac{\rho H_0}{144} = 98 + \frac{56.2 \cdot 45.9}{144} = 115.9 \text{ p}$$

Flow through PSV

$$P_{PSV} = \frac{\rho}{62.4}\left(\frac{Q}{C_V}\right)^2$$

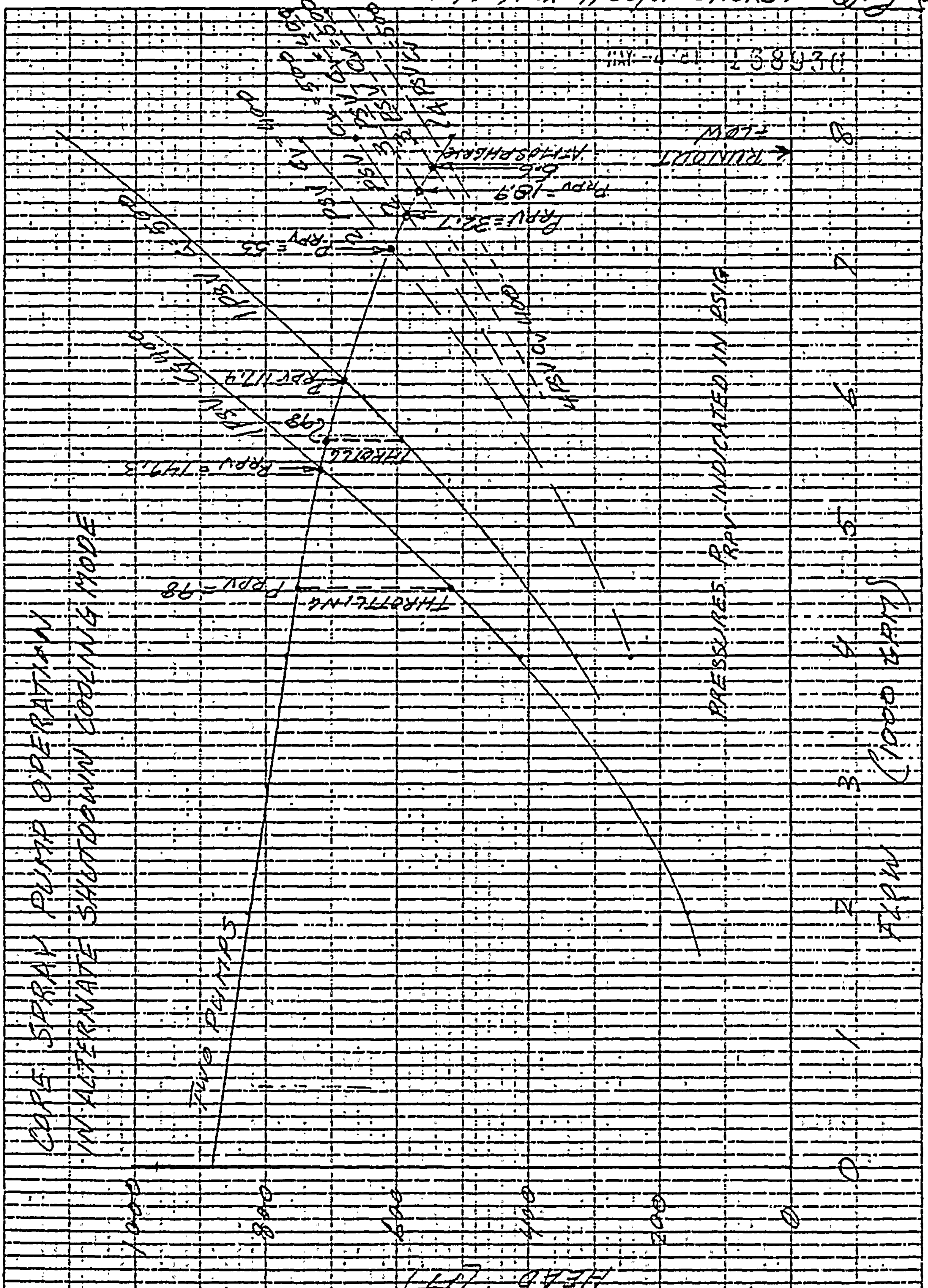
$$\therefore Q = \left(P_{PSV}\,\frac{62.4}{\rho}\cdot C_V^2\right)^{0.5} = C_V\cdot\left(P_{PSV}\cdot\frac{62.4}{\rho}\right)^{0.5}$$

For $C_V = 400$: $Q = 400\cdot\left(115.9\cdot\frac{62.4}{56.2}\right)^{.5} = 4528$

For $C_V = 500$: $Q = 500\left(115.9\cdot\frac{62.4}{56.2}\right)^{.5} = 5,666$ gpm

Amount of throttling for above flows are shown on sht. 9.

BY: [illegible] 4/22/81 CHCKD: [illegible] 5-4-8



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CALCULATION SHEET

CALC. NO. M1K2-7 REV. NO. 0

ORIGINATOR V. V. Brunner DATE 4/30/81 CHECKED Guy DATE 5-4-81

PROJECT SUSQUEHANNA JOB NO. 8856

SUBJECT CORE SPRAY PUMPS IN ALTERNATE SHUTDOWN COOLING MODE SHEET NO. 10 OF 10

MAY -4 '81 138930

APPENDIX A

ESTIMATE OF VALVE FLOW COEFFICIENT C_V

Valve capacity (per Ref. 5 for liquid)

$$Q = 27.2\, C_A\, A\, K_{sg} \sqrt{\underbrace{p - P_b}_{\Delta p}}$$

(gpm)

where: C_A = correction factor for accum. press. assume 1

K_{sg} = 1 (for water)

P_b = 0 assuming no back pressure.

A = 16" orifice area for Crosby style 6 R10 HB-65-BP (see Ref. 5 & 6)

$$Q = 27.2 \cdot 16 \cdot \sqrt{\Delta p} = 435.2 \sqrt{\Delta p}$$

From flow equation $\Delta p = \frac{\rho}{62.4}\left(\frac{Q}{C_V}\right)^2$

or: $Q = C_V \sqrt{\frac{62.4}{\rho}\,\Delta p}$

By substitution:

$$435.2 \cancel{\sqrt{\Delta p}} = C_V \sqrt{\frac{62.4}{\rho}} \cancel{\sqrt{\Delta p}}$$

$\therefore$ $$\boxed{C_V = \frac{435.2}{\sqrt{\frac{62.4}{\rho}}}}$$

for: $\rho = 59.8$ lb/ft³

P = 14.7 psia

T = 212 °F

$$C_V = \frac{435.2}{\sqrt{\frac{62.4}{59.8}}} = 427$$