PP&L Pennsylvania Power & Light Company
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Harold W. Keiser
Vice President-Nuclear Operations
215/770-7502

NOV 14 1986

Director of Nuclear Reactor Regulation
Attention: Ms. E. Adensam, Project Director
BWR Project Directorate No. 3
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUSQUEHANNA STEAM ELECTRIC STATION
POSTULATED PIPE RUPTURE
PLA-2756 FILE R-26,R41-2

Dear Ms. Adensam:

Attached you will find calculations M-MSS-010 and M-MSS-006 as requested by Mr. M. Thadani during a telecom on November 12, 1986.

If you have any additional question, please contact us.

Very truly yours,

HWKeiser

H. W. Keiser
Vice President-Nuclear Operations

Attachment

cc: L. R. Plisco - NRC
M. C. Thadani - NRC

A001
1/1

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CALCULATION COVER SHEET

CALC. NO. M-MSS-010	SAFETY-RELATED ☑
FILE NO. R-26	ASME III OR XI ☐
SUPERSEDED BY	OTHER QUALITY ☐
	NON QUALITY ☐

OJECT SUSQUEHANNA STEAM ELECTRIC STATION

ER/CTN NO. 741058-003

DESIGN ACTIVITY/PMR NUMBER IREIR 101155

PAGE 1 OF 29

TITLE/DESCRIPTION JET IMPINGEMENT ON MSIV'S

STATEMENT OF PROBLEM

DETERMINE IF THE INBOARD MSIV'S WILL FAIL DUE TO THE JET IMPINGEMENT FROM A POSTULATED BREAK OF THE 28" RECIRC. SUCTION LINE AT NOZZLE N1A AT THE PIPE-TO-SAFE-END WELD.

IF FAILURE DOES OCCUR DETERMINE THE JET PRESSURE FOR WHICH THE VALVES DO NOT FAIL.

DESIGN BASIS (DC020.0 OR DC020.1)

THIS CALC. IS PERFORMED ASSUMING THAT THE JET EXIT ANNULUS CONFIGURATION CAN BE REPRESENTED AS AN OPEN ENDED PIPE OF THE SAME AREA.

ERENCES/FORMULAE

1. DESIGN MEMO # MDE145-0685, SUPPLEMENT #1 ATTACHED TO G.E. LTR. G-KR-6-028, 1/21/86
2. MPR ASSOCIATES LTR. RPT. DATED 6-24-85 (ATTACHMENT 5 TO CALC M-MSS-006, REV.1)

GE DWG. FF113011, SH 6101, REV.1, N1 RECIRC OUTLET NOZZLE SAFE END.

4. ANS 58.2 -1980, DESIGN BASIS FOR PROTECTION OF LIGHT WATER REACTOR POWER PLANTS AGAINST EFFECTS OF POSTULATED PIPE RUPTURE.
5. ASME PUB. 69-HT-31, F.T. MOODY, PREDICTION OF BLOWDOWN THRUST AND JET FORCES
6. FSAR TABLES 6A-1 (a) & (b).
7. ATWOOD & MORRILL CO. DWG. 21190-H, SHEETS 1 & 2, 26" W.E. MAIN STEAM ISOLATION VALVE.
8. ATWOOD & MORRILL CO. MSIV INSTRUCTION MANUAL, FILE 204-03, IOM 17.
9. GE MSIV DYNAMIC QUAL. REPORT, KR1-821-F022, F028, REV. 2, MPL REF. 238X113AE, REV.25
10. ATWOOD & MORRILL CO. DWG. 21283-H, FF 114510, SH. 3291.
11. LTR. FM. ATWOOD & MORRILL TO G.D. MILLER, 4-3-85 (ATTACHMENT 3).
12. BAUMEISTER & MARKS, STANDARD HANDBOOK FOR MECHANICAL ENGINEERS, SEVENTH EDITION
13. METALS PROGRESS HANDBOOK - 2ND EDITION
14. MSIV ACTUATOR DYNAMIC QUAL. TEST REPORT, NEDC-22177A, AUGUST, 1983.
15. GE PLANT PIPING DESIGN MEMO # MDE 31-0286 TRANSMITTED BY G-KR-6-135 OF APRIL 11, 1986

SUMMARY/CONCLUSIONS

MSIV OPERATORS ON THE A & D INBOARD VALVES WILL FAIL DUE TO THE JET IMPINGEMENT LOAD. THE MAXIMUM JET PRESSURE THEY CAN WITHSTAND IS 17.8 PSIG.

THIS CALCULATION SUPERSEDES CALC. # M-MSS-008.

REV NO.	DATE	PREPARED BY	REVIEWED/CHECKED BY	DATE	APPROVED BY	DATE
	3-25-86			4/16/86		4-28-86

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PROJECT CALC. M-MSS-010
LOOP A RECIRC. OUTLET
0° AZIMUTH

ER No.
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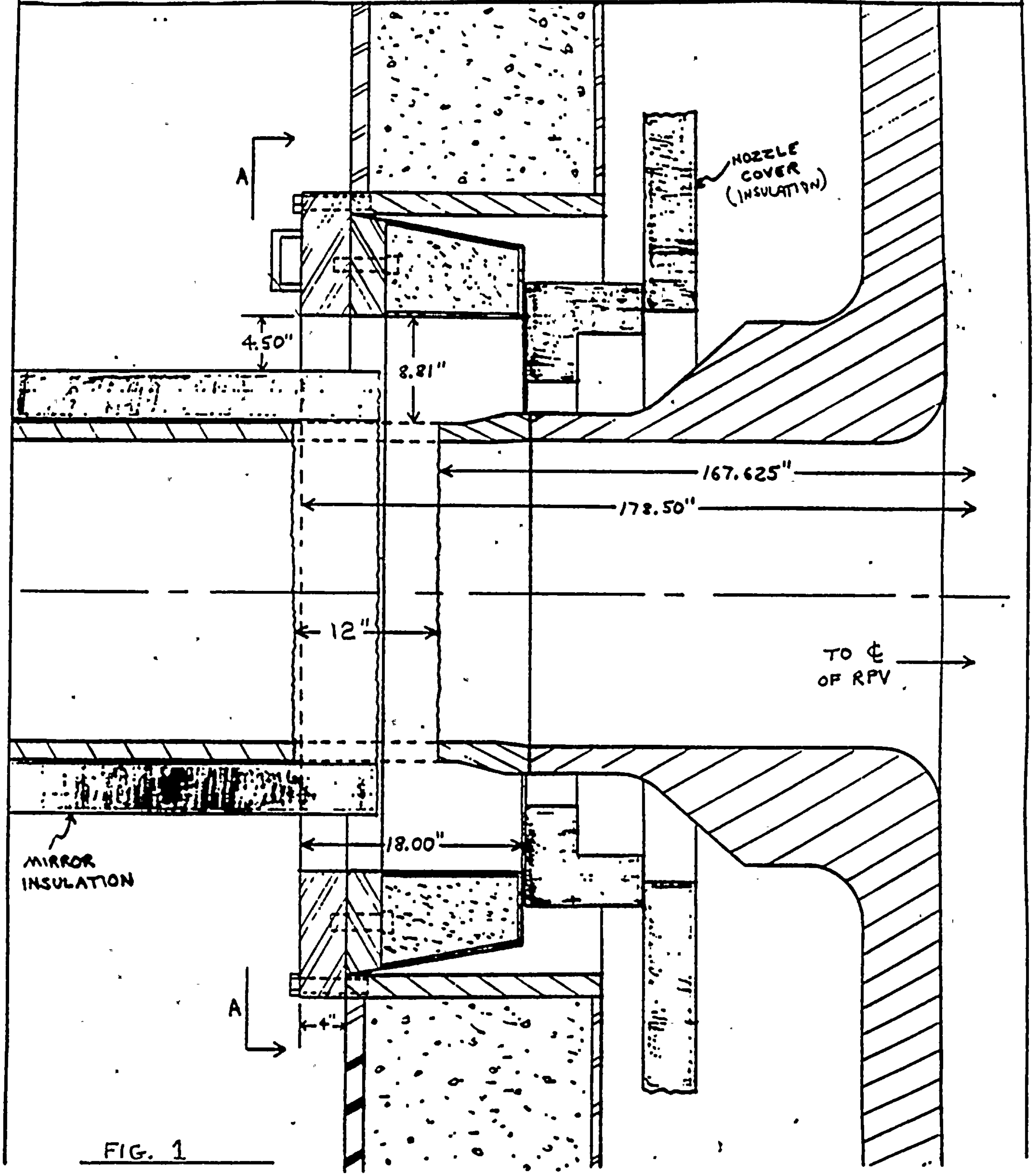

FIG. 1

SHEET 3 OF 29

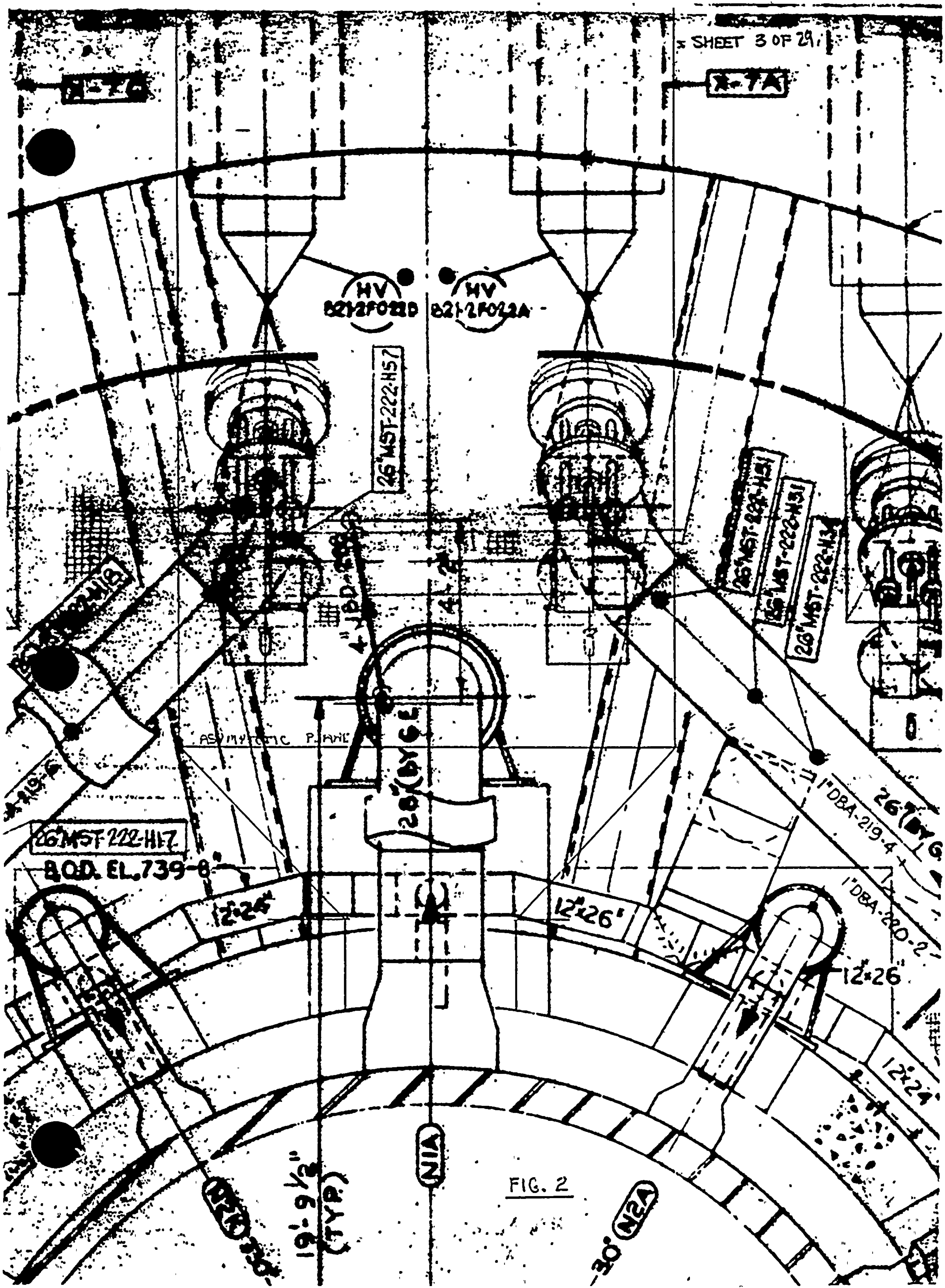

FIG. 2

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FIGURE 1 DESCRIBES THE PHYSICAL SITUATION THAT WOULD EXIST AT THE TIME THE RECIRC PUMP SIDE OF THE BREAK COMES TO REST AT A STEADY STATE CONDITION. SATURATED WATER ESCAPING FROM THE TWO OPEN ENDS WOULD MEET AND TURN RADIALLY OUTWARD WHERE IT WOULD ENCOUNTER THE I.D. OF THE SACRIFICIAL SHIELD DOORS. THESE WOULD TURN THE FLOW AXIALLY ALONG THE OUTSIDE OF THE PIPE IN BOTH DIRECTIONS. THE INSULATION IS ASSUMED TO BLOW AWAY. THE FLOW TOWARD THE RPV WOULD PRESSURIZE THE ANNULUS BETWEEN THE RPV AND THE SACRIFICIAL SHIELD. THE OUTWARD FLOW WOULD EXIT INTO THE AREA OF THE INBOARD MSIV'S PER FIGURE 2. ASSUME EQUAL FLOW IN BOTH DIRECTIONS.

FROM REF 1 THE AT-REST SEPERATION OF THE PIPE ENDS IS 12 INCHES.

FROM REF. 2 THE FLOW FROM THE VESSEL SIDE OF THE BREAK IS 18,349 lb/SEC, FROM THE PUMP SIDE 5,481 lb/SEC. TOTAL FLOW IS 23,830. FLOW OUTWARD IS HALF TOTAL OR 11,915 lb/SEC.

CIRCUMFERENTIAL AREA OF THE GAP BETWEEN THE BREAK ENDS IS:

$$A_{GAP} = (\text{INSIDE CIRCUMFERENCE})(\text{GAP}) = \pi(\text{I.D.})(\text{GAP}) = \pi(\underbrace{25.469\ \text{IN}}_{\text{FROM REF. 3}})(12\ \text{IN})$$

$$A_{GAP} = 960.16\ \text{IN}^2 = 6.668\ \text{FT}^2$$

EXIT ANNULUS AREA BETWEEN PIPE O.D. AND SHIELD DOOR I.D.:

$$A_{EXIT} = \frac{\pi}{4}\left[\text{I.D.}^2 - \text{O.D.}^2\right] = \frac{\pi}{4}\left[(3'10'')^2 - (28'')^2\right]$$

$$A_{EXIT} = 1046.15\ \text{IN}^2 = 7.265\ \text{FT}^2$$

FROM REF. 4, PAGE 10, EQUATION 6-2, THE STEADY STATE THRUST FORCE IS:

$$T = \rho_e U_e^2 A_e + P_e A_e$$

WHERE: ρ_e = EXIT MASS DENSITY = 3.182 lb/FT^3 (REF. 2)
U_e = EXIT VELOCITY
A_e = A_{EXIT} = EXIT AREA
P_e = EXIT PRESSURE = 282.3 lb/IN^2 (REF. 2)

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$$\text{VOLUMETRIC FLOW RATE} = \frac{\text{MASS FLOW RATE}}{\text{DENSITY}} = \frac{11{,}915\ \text{lb/SEC.}}{3.182\ \text{lb/FT}^3} = 3{,}744.5\ \text{FT}^3\text{/SEC}$$

$$U_e = \frac{\text{VOLUMETRIC FLOW RATE}}{A_e} = \frac{3{,}744.5\ \text{FT}^3\text{/SEC}}{7.265\ \text{FT}^2} = 515.4\ \text{FT/SEC}$$

SUBSTITUTING INTO THE THRUST EQUATION:

$$T = \rho_e U_e^2 A_e + P_e A_e$$

$$T = \frac{(3.182\ \text{lb/FT}^3)(515.4\ \text{FT/SEC})^2(7.265\ \text{FT}^2)}{32.2\ \text{FT/SEC}^2} + (282.3\ \text{lb/IN}^2)(7.265\ \text{FT}^2)(144\ \text{IN}^2\text{/FT}^2)$$

$$T = 190{,}708\ \text{lb} + 295{,}331\ \text{lb}$$

$$T = 486{,}039\ \text{lb}$$

FROM REF. 5, EQUATION 29, THE JET PRESSURE AT THE ASYMPTOTIC PLANE IS:

$$P_\infty = \frac{F_J}{A_\infty} = \frac{g_c\left(\frac{T}{A_e}\right)^2}{G_e^2\ v_{m\infty}}$$

WHERE: $F_J = T =$ FORCE AT ASYMPTOTIC PLANE

$A_\infty =$ AREA OF ASYMPTOTIC PLANE

$g_c = 32.2\ \text{FT/SEC}^2$

$A_e =$ EXIT AREA

$G_e =$ MASS FLUX AT EXIT PLANE $= \frac{\dot{m}}{A_e} = \frac{11{,}915\ \text{lb/SEC}}{7.265\ \text{FT}^2} = 1{,}640.1\ \text{lb/SEC FT}^2$

$v_{m\infty} =$ ASYMPTOTIC JET SPECIFIC VOL.

$$= \left[x v_g + (1-x) K v_f\right]\left(x + \frac{1-x}{K}\right)$$

WHERE: $v_g =$ STEAM SP. VOL. AT AMBIENT $= 26.80\ \text{FT}^3\text{/lb}$

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V_f = WATER SPECIFIC VOL AT AMBIENT = .0167 FT^3/lb

$K = U_g / U_f$ = VELOCITY RATIO (REF. 5, EQ. 5)

$$U_g = \frac{x}{\alpha} G V_g$$

$$U_f = \frac{1-x}{1-\alpha} G V_f$$

α = VAPOR VOL. FRACTION $= \dfrac{V_g}{V_f + V_g} = \dfrac{26.80}{26.80 + .0167} = .999$

x = STEAM JET QUALITY = $\dfrac{\text{ENTHALPY CHANGE (STAG. TO AMBIENT)}}{\text{ENTHALPY CHANGE (TOTAL CHANGE OF STATE)}}$

ASSUME CONSTANT ENTHALPY PROCESS. FROM REF. 6 VESSEL STAGNATION CONDITIONS:

$h_0 = 527.85$ BTU/lb
$P_0 = 1031.2$ PSIA

AT AMBIENT FROM ASME STEAM TABLES:

$h_f = 180.2$ BTU/lb.
$h_{fg} = 970.3$ BTU/lb

$$x = \frac{h_0 - h_f}{h_{fg}} = \frac{527.9 \text{ BTU/lb} - 180.2 \text{ BTU/lb}}{970.3 \text{ BTU/lb}} = .358$$

$$U_g = \frac{x}{\alpha} G V_g = \left(\frac{.358}{.999}\right)(1640.1 \text{ lb/sec FT}^2)(26.80 \text{ FT}^3/\text{lb}) = 15{,}751.5 \text{ FT/SEC}$$

$$U_f = \frac{1-x}{1-\alpha} G V_f = \left(\frac{1-.358}{1-.999}\right)(1640.1 \text{ lb/SEC FT}^2)(.0167 \text{ FT}^3/\text{lb}) = 17{,}584.2 \text{ FT/SEC}$$

$$K = \frac{U_g}{U_f} = \frac{15{,}751.5 \text{ FT/SEC}}{17{,}584.2 \text{ FT/SEC}} = .896$$

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$$V_{m\infty} = \left[.358\,(26.80\,FT^3/lb) + (1-.358)(.896)(.0167\,FT^3/lb)\right]\left(.358 + \frac{1-.358}{.896}\right)$$

$$V_{m\infty} = 10.320\ FT^3/lb$$

$$P_\infty = \frac{(32.2\ FT/SEC^2)\left(\frac{486{,}039\ lb}{7.265\ FT^2}\right)^2}{\left(1640.1\ lb/SEC\,FT^2\right)^2(10.320\ FT^3/lb)} = 5{,}191\ lb/FT^2 = \underline{\underline{36.05\ lb/in^2}}$$

$$A_\infty = \frac{F_J}{P_\infty} = \frac{486{,}039\ lb}{5{,}191\ lb/ft^2} = 93.6\ FT^2$$

FROM REF. 4, EQ C-2, THE DISTANCE FROM THE EXIT TO THE ASYMPTOTIC PLANE IS:

$$\frac{L_a}{D_e} = \frac{1}{2}\left(\sqrt{\frac{A_a}{A_e}} - 1\right)$$

WHERE: L_a = DISTANCE TO ASYMPTOTIC PLANE
D_e = EXIT DIA.

THE EQUIVALENT DIAMETER FOR THE ANNULAR EXIT IS:

$$D_e = 2\sqrt{\frac{A_e}{\pi}} = 2\sqrt{\frac{7.265\ FT^2}{\pi}} = 3.041\ FT$$

DISTANCE FROM EXIT TO ASYMPTOTIC PLANE:

$$L_a = .5\,(3.041\ FT)\left(\sqrt{\frac{93.6\ FT^2}{7.265\ FT^2}} - 1\right) = 3.94\ FT$$

FROM REF. 4, PAGE E-6, CASE 2, REGION 2 OF THE JET BLAST IS DEFINED BY:

$$L_a \leq L \leq \frac{1}{2}\left[\sqrt{\frac{4A_a}{\pi}} - D_e\right] \cot 10^\circ$$

$$L \leq \frac{1}{2}\left[\sqrt{\frac{4(93.4\ FT^2)}{\pi}} - 3.041\ FT\right] \cot 10^\circ$$

$$L \leq 22.3\ FT$$

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SINCE THE VALVE AND OPERATOR ARE AT APPROXIMATELY 8 FT RANGE, THEY ARE IN REGIMN 2 AND SUBJECTED TO THE SAME JET PRESSURE AS THE ASYMPTOTIC PLANE.
THE AREA OF THE ASYMPTOTIC PLANE IS REPRESENTED BY:

$$A_{TOTAL} = A_{\infty} + A_{PIPE}$$

$$\frac{\pi D^2}{4} = 93.6\,FT^2 + \frac{\pi (28\,IN)^2}{4} \cdot \frac{1\,FT^2}{144\,IN^2}$$

$$D = 11.16\,FT$$

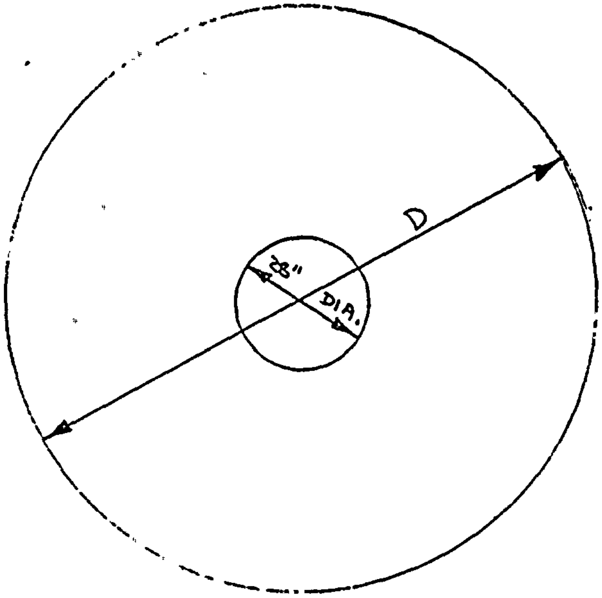

FIG. 3

FROM REF. 4, EQ. D-5, THE IMPINGEMENT FORCE IS:

$$\vec{F}_{IMP} = \vec{K}_{\Phi}\, P_{JET}\, A_{TARGET}$$

WHERE: $\vec{K}_{\Phi}$ = SHAPE FACTOR FOR THE TARGET
A_{TARGET} = TARGET AREA
P_{JET} = JET PRES. AT THE TARGET.

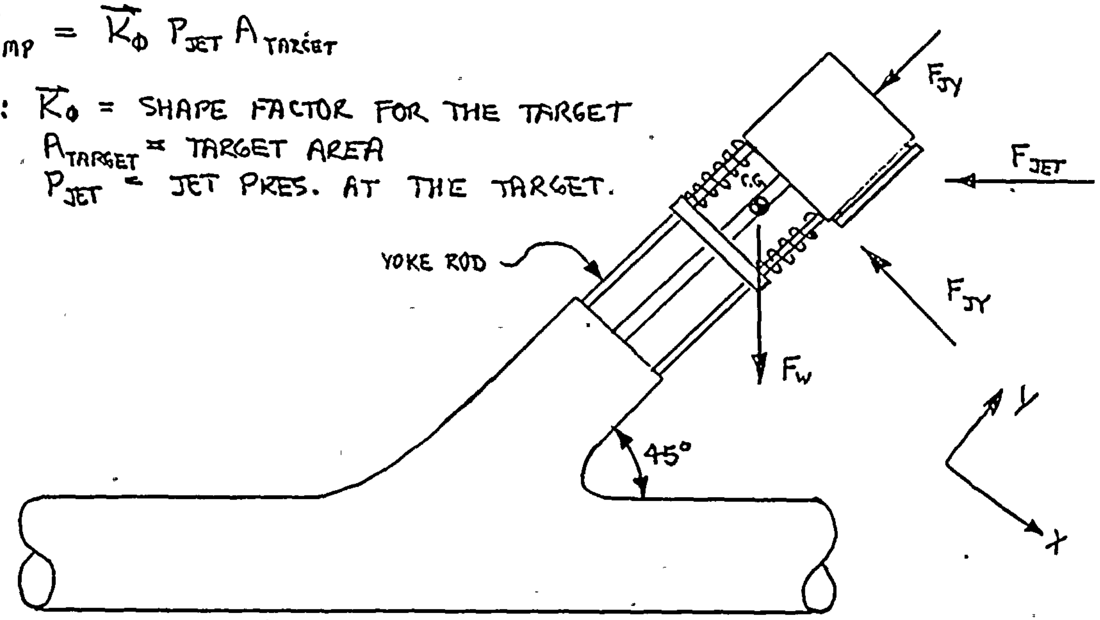

FIG. 4

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BY INSPECTION OF REF. 7 IT IS LIKELY THAT THE MAXIMUM STRESSES IN THE VALVE DUE TO LOADS ON THE OPERATOR WOULD BE IN THE THREADED PORTION OF THE YOKE RODS WHERE THEY SCREW INTO THE BONNET AND WHERE THEY ARE BOLTED TO THE TOP SPRING SEAT.

F_{JY} = FORCE OF JET ON OPERATOR IN Y-DIRECTION.

F_{JX} = FORCE OF JET ON OPERATOR IN X- DIRECTION

F_W = WEIGHT FORCE OF OPERATOR = 2440 lb (REF 8., PAGE 26, ITEM 14)

FROM REF. 4, PAGE 20, A DYNAMIC LOAD FACTOR MUST BE APPLIED. THIS FACTOR IS THE INVERSE FUNCTION OF THE STIFFNESS OF THE TARGET. ASSUME 1.0 IN THE Y-DIRECTION SINCE THE RODS ARE VERY STIFF IN COMPRESSION AND 2.0 IN THE X-DIRECTION SINCE THEY ARE RELATIVELY FLEXIBLE IN THAT DIRECTION.

FIND THE FORCE DOWN ON THE TOP PLATE OF THE OPERATING CYLINDER:

$$F_{Y_1} = \overrightarrow{K_\Phi}\, P_{JET}\, A_{TARGET}\, \text{D.L.F.}$$

FROM REF. 1, FIG. D-1, $\overrightarrow{K_\Phi}$ FOR FLAT PLATE = SIN INCIDENCE ANGLE

FROM REF. 7, $A_{TAR} = 22\text{ IN} \times 22\text{ IN} = 484\text{ IN}^2$

$$F_{Y_1} = (\sin 45^\circ)(36.05\text{ lb/IN}^2)(484\text{ IN}^2) = \underline{12,338\text{ lb.}}$$

FIND THE FORCE ON THE SIDE OF THE OPERATING CYLINDER. SINCE THE AIR CONTROL MANIFOLD IS LOCATED ON THE SIDE OF THE OPERATING CYLINDER, IT IS TREATED AS A FLAT PLATE.

BY MEASUREMENT, $A = 22\tfrac{9}{16}'' \times 21\tfrac{3}{4} = 490.7\text{ IN}^2$

$$F_{X_1} = (\sin 45^\circ)(36.05\text{ lb/IN}^2)(490.7\text{ IN}^2)(2.0) = \underline{25,017\text{ lb.}}$$

FIND THE FORCE ON THE SIDE OF THE SPRINGS IN THE OPEN POSITION. BACK SPRINGS WOULD BE ESSENTIALLY SHADOWED. ASSUME TOTAL EFFECT OF ALL THESE BY MODELING THE FRONT SPRINGS ONLY. SINCE THE FLOW THROUGH THE SPRINGS IS VERY CIRCUITOUS, ASSUME ALL OF THE INCIDENT ENERGY OF THE JET IS ABSORBED. THEREFORE, THEY WOULD ACT AS FLAT PLATES WITH AN

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AREA EQUAL TO THE PROJECTED AREA.

SPRING LENGTH, VALVE OPEN = 21.67 IN
SPRING O.D. = 6.33 IN
} SCALED FROM REF. 7

PROJECTED AREA = (21.67 IN)(6.33 IN)(2)(SIN 45°) = 194.0 IN^2

$$F_{X2} = \frac{F_{Y2}}{2} = P_{JET} \cdot A_{PROJ} \cdot \sin 45° \cdot 2$$

$$F_{X2} = \frac{F_{Y2}}{2} = (36.05\ lb/in^2)(194\ in^2)(.707)(2) = \underline{9{,}891\ lb/in^2}$$

FIND FORCE ON LIMIT SWITCH MOUNTING PLATES:

AREA OF PLATES = (2 PLATES)(24 IN)(5.5 IN) BY ACTUAL MEASUREMENT
= 264 IN^2

$$F_{X3} = (36.05\ lb/in^2)(264\ in^2)(\sin 45°)(2) = \underline{13{,}459\ lb}$$

FIND FORCE ON JUNCTION BOX:

AREA OF BOX SIDE = (5 IN)(12 IN) = 60 IN^2 BY MEASUREMENT

$$F_{X4} = (36.05\ lb/in^2)(60\ in^2)(\sin 45°)(2) = \underline{3{,}059\ lb}$$

AREA OF BOX TOP = (5 IN)(9 IN) = 45 IN^2

$$F_{Y3} = (36.05\ lb/in^2)(45\ in^2)(\sin 45°)(1) = \underline{1{,}147\ lb}$$

FIND THE MOMENT AT THE TOP OF THE BONNET DUE TO THE JET LOADS.

$$M_{APPLIED\ JET} = (F_{X1})(Y_1) + (F_{X2})(Y_2) + (F_{X3})(Y_3) + (F_{X4})(Y_4)$$

WHERE Y_1, Y_2, Y_3, & Y_4 ARE THE RESPECTIVE LEVER ARMS FROM APPROX. CENTERS OF AREA TO THE BONNET TOP. THEY ARE FOUND BY ACTUAL MEASUREMENT AND INSPECTION OF PHOTOS.

$$M_{APPLIED\ JET} = (25{,}017\ lb)(67\ in) + (9{,}891\ lb)(37\ in) + (13{,}459\ lb)(21\ in) + (3{,}059\ lb)(20\ in)$$

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$$\boxed{M_{\substack{APPLIED\\JET}} = 2,385,925 \text{ IN lb}}$$

FIND TOTAL JET APPLIED FORCES:

$$F_{JET\,X} = F_{X_1} + F_{X_2} + F_{X_3} + F_{X_4} = (25,017\text{ lb}) + (9,891\text{ lb}) + (13,459\text{ lb}) + (3,059\text{ lb})$$

$$\underline{F_{JET\,X} = 51,426\text{ lb}}$$

$$F_{JET\,Y} = F_{Y_1} + F_{Y_2} + F_{Y_3} = 12,338\text{ lb} + 4,945\text{ lb} + 1,147\text{ lb}$$

$$\underline{F_{JET\,Y} = 18,430\text{ lb}}$$

IND THE MOMENTS AND FORCES DUE TO VIBRATORY MOTIONS. ASSUME THE JET LOAD IS COINCIDENT WITH SSE. FROM REF. 9, ATTACHMENT 1, FOR THE FAULTED CONDITION, SSE, IN THE X-DIRECTION (ATTACHMENT 1), THE RRS PEAK IS 1.44 G'S. FOR SSE IN THE Y-DIRECTION (ATTACHMENT 2), THE RRS PEAK IS 8.6 G'S. (HERE X & Y DENOTE DIRECTIONS FOR TEST REPORT ONLY.). FOR THE X-COMPONENT THE ACCELERATION PERPENDICULAR TO AND PARALLEL TO THE ACTUATOR AXIS ARE:

$$G_{x,y} = (\sin 45^\circ)(1.44\text{ G's}) = 1.01\text{ G's}$$

FOR THE Y-COMPONENT:

$$G_{XY} = (\sin 45^\circ)(8.6\text{ G's}) = 6.08\text{ G's}$$

TOTAL $\text{G-LOAD}_{xy} = 1.01 + 6.08 = 7.09$ G'S

FROM REF. 6, PAGE 26, ITEM 14, WEIGHT OF OPERATOR IS 2,440 lb.

$\text{FORCE}_{X,Y}$ DUE TO SSE ACCELERATIONS:

$$F_{SSE\,XY} = (7.09\text{ G's})(2,440\text{ lb}) = 17,300\text{ lb}$$

FROM REF 10. CENTER OF GRAVITY OF OPERATOR IS $45\frac{13}{16}$" ABOVE BONNET TOP.
FROM REF 7, SCALING, YOKE RODS JOIN BONNET 2.67 INCHS ABOVE BONNET TOP.

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LEVER ARM OF C.G. TO POINT OF YOKE ROD ATTACHMENT :

$$L = 45.8125\text{ in} - 2.6667\text{ in} = 43.1\text{ in.}$$

MOMENT AT ATTACHMENT DUE TO SSE :

$$\boxed{M_{SSE} = (17{,}300\text{ lb})(43.1\text{ in.}) = 745{,}630\text{ in.lb}}$$

SINCE IT IS EXTREMELY UNLIKELY THAT THE PEAK JET FORCE AND THE PEAK SSE ACCELERATION WILL OCCUR SIMULTANEOUSLY, THE TWO FORCES AND RESULTANT MOMENTS ARE COMBINED AS THE SQUARE ROOT OF THE SUM OF THE SQUARES (SSRS).

$$M_{\substack{TOTAL\\APPLIED}} = \left(M^2_{\substack{APPLIED\\JET}} + M_{SSE}^2\right)^{1/2}$$

$$M_{\substack{TOTAL\\APPLIED}} = \left(2{,}385{,}925^2 + 745{,}630^2\right)^{1/2}$$

$$\boxed{M_{\substack{TOTAL\\APPLIED}} = 2{,}499{,}720\text{ in lb}}$$

$$F_{Y_{TOTAL}} = \left(F^2_{JET\,Y} + F^2_{SSE,Y}\right)^{1/2}$$

$$F_{Y_{TOTAL}} = \left(18{,}430\text{ lb}^2 + 17{,}300\text{ lb}^2\right)^{1/2}$$

$$\boxed{F_{Y_{TOTAL}} = 25{,}278\text{ lb}}$$

$$F_{X_{TOTAL}} = \left(F^2_{JET\,X} + F_{SSE,X}^2\right)^{1/2}$$

$$F_{X_{TOTAL}} = \left(51{,}426\text{ lb}^2 + 17{,}300\text{ lb}^2\right)^{1/2}$$

$$\boxed{F_{X_{TOTAL}} = 54{,}258\text{ lb}}$$

FIND LOADING OF YOKE RODS AT CONNECTION TO BONNET.

1. ALL OF THE APPLIED MOMENT AND FORCE MUST ULTIMATELY BE ABSORBED/RESISTED BY THE VALVE BODY, THROUGH THE VALVE BONNET, THROUGH THE YOKE RODS.

$$M_{\substack{TOTAL\\APPLIED}} = M_{VALVE} = M_{BONNET} = M_{RODS}$$

2. THERE ARE TWO POSSIBLE MECHANISMS FOR THE APPLIED MOMENT TO BE TRANSMITTED TO THE BONNET - a) THROUGH MOMENTS TRANSMITTED BY THE INDIVIDUAL RODS, AND b) THROUGH A COUPLE BETWEEN THE UPPER AND LOWER RODS.

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PROJECT M-MSS-010

ER No. ____

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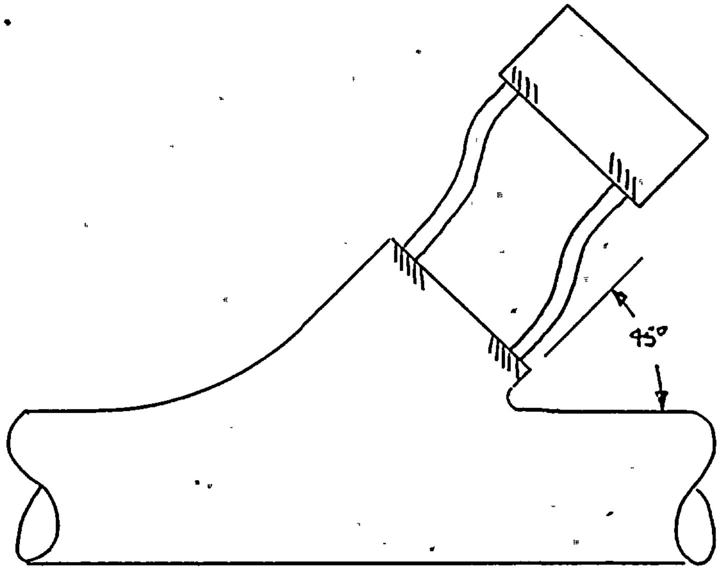
3. THE RODS ARE FIXED AT THE BONNET END.

4. THE RODS ARE FIXED AT THE TOP SPRING SEAT END.

5. THE SPRING RATES OF THE BONNET AND TOP SPRING SEAT IN BENDING AND THE YOKE RODS IN TENSION AND COMPRESSION ARE VIRTUALLY INFINITE COMPARED TO THE SPRING RATE OF THE RODS IN BENDING. THEREFORE, WHEN ACTED ON BY A LATERAL FORCE, BENDING TAKES PLACE IN THE RODS AND THE TOP SPRING SEAT IS DISPLACED LATERALLY PARALLEL TO THE BONNET. THE RODS BEND IN AN S-SHAPED CURVE. THIS IS CONFIRMED BY OBSERVATION OF THE G.E. SEISMIC QUALIFICATION TEST MOVIE.

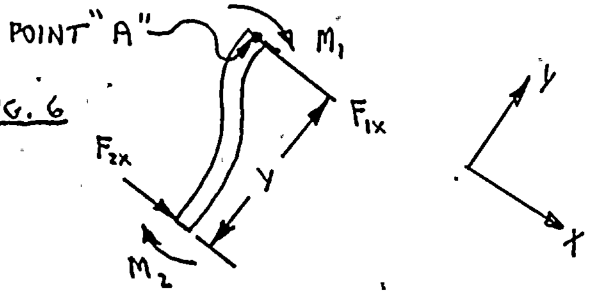
FIG. 5



6. THE RODS HAVE ESSENTIALLY A UNIFORM X-SECTION, TOP TO BOTTOM. WHEN DISPLACED THE CURVATURE OF THE RODS IS THE SAME AT THE TOP AS AT THE BOTTOM. IF THE X-SECTION AND THE CURVATURE ARE THE SAME, THEM THE MOMENT AT THE TOP AND BOTTOM ENDS MUST BE THE SAME.

FREE BODY DIAGRAM OF ROD SHOWING LATERAL FORCES AND RESULTING MOMENTS.

FIG. 6



$M_1 = M_2$

$\Sigma F_x = 0 = F_{2x} - F_{1x}$

$\Sigma M_A = M_1 + M_2 - F_{2x} Y = 0$

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7. ASSUME ALL FOUR RODS REACT THE SAME.

8. ASSUME LATERAL DISPLACEMENT IS SMALL COMPARRED TO ROD LENGTH. THEREFORE, MOMENTS INDUCED BY AXIEL FORCES TIMES DISPLACEMENT ARE NOT CONSIDERED.

9. DETERMINE THE EFFECTIVE LEVER ARM OF THE JET FORCE.:

$$Y_{JET} = \frac{M_{\underset{JET}{APPLIED}}}{F_{JET_X}} = \frac{2{,}385{,}925 \text{ IN lb}}{51{,}426 \text{ lb}} = 46.4 \text{ IN.}$$

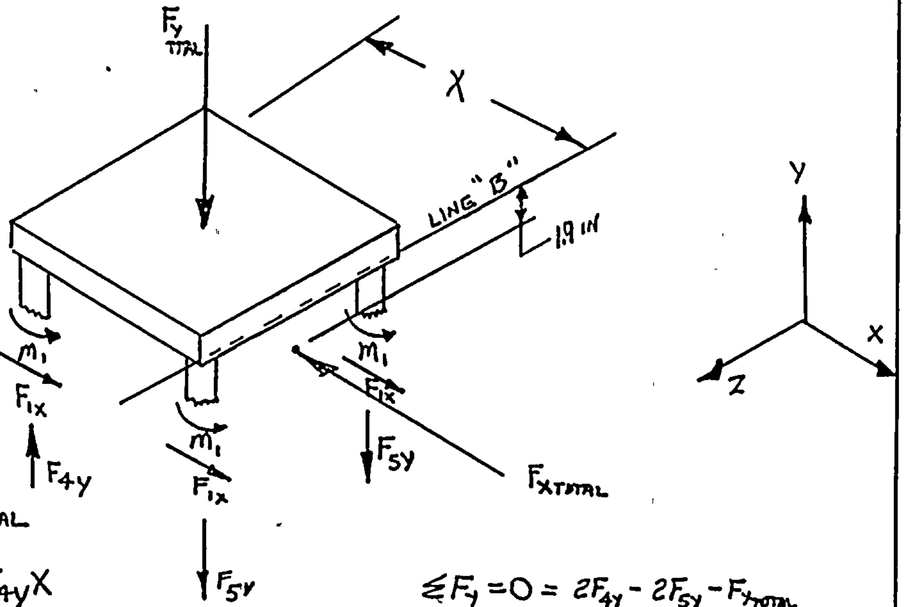
10. DETERMINE THE TOTAL EFFECTIVE LEVER ARM OF THE JET & SSE FORCE:

$$Y_{TOTAL} = \frac{M_{TOTAL}}{F_{X\ TOTAL}} = \frac{2{,}499{,}720 \text{ IN lb}}{54{,}258 \text{ lb}} = 40.1 \text{ IN}$$

11. SCALING FROM REF. 7, DISTANCE FROM BONNET TOP TO TOP SPRING SEAT BOTTOM IS 48 IN. THEREFORE TOTAL EFFECTIVE FORCE IS 1.9 INCHES BELOW THE TOP SPRING SEAT.

12. DRAW FREE BODY DIAGRAM OF TOP SPRING SEAT

FIG. 7



$$\Sigma F_X = 0 = 4F_{1X} - F_{X\ TOTAL}$$

$$\Sigma M_B = 0 = -4M_1 + 2F_{4Y}X$$
$$+ (F_{X\ TOTAL})(1.9 \text{ IN}) - F_{Y\ TOTAL}\left(\frac{X}{2}\right)$$

$$\Sigma F_Y = 0 = 2F_{4Y} - 2F_{5Y} - F_{Y\ TOTAL}$$

$$F_{5Y} = F_{4Y} - \frac{F_{Y\ TOTAL}}{2}$$

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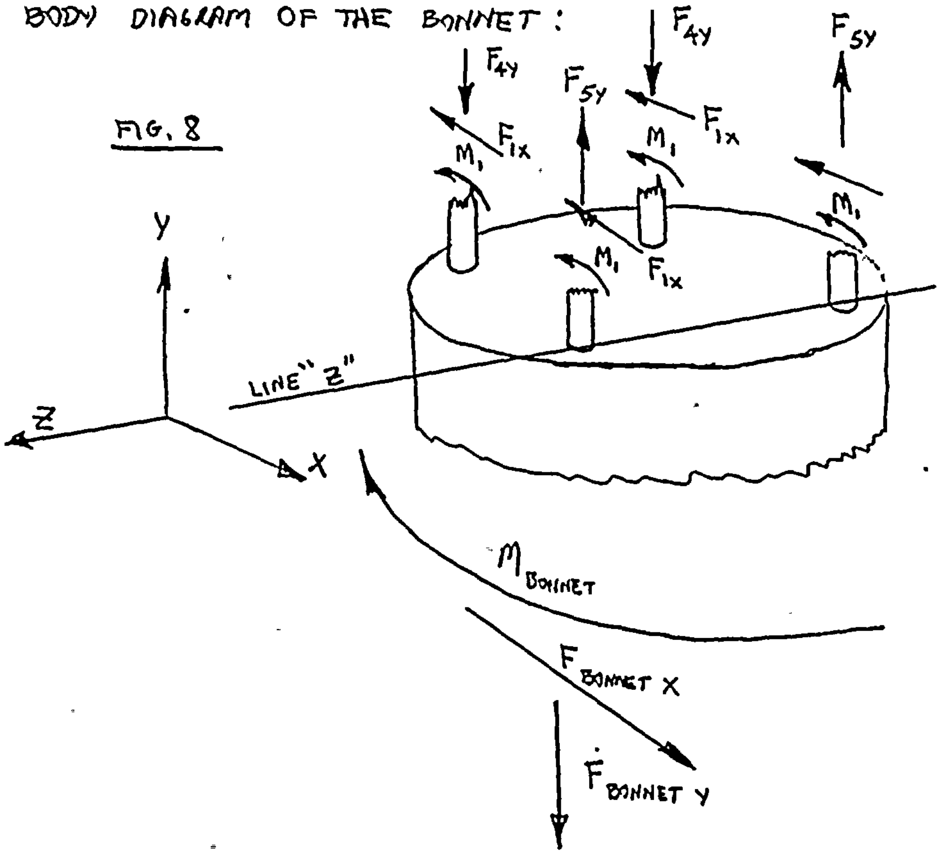
13. DRAW A FREE BODY DIAGRAM OF THE BONNET:

FIG. 8



14. SUM MOMENTS AND FORCES ON THE BONNET

$$\Sigma F_y = 0 = 2F_{5y} - 2F_{4y} - F_{BONNET\ y}$$

$$\Sigma F_X = 0 = F_{BONNET\ X} - 4F_{1x}$$

$$\Sigma M_Z = 0 = M_{BONNET} - 4M_1 - 2F_{4y}X$$

$$.\ M_{BONNET} = 4M_1 + 2F_{4y}X$$

15. FROM STEP 1, $M_{APPLIED} = M_{BONNET}$

$$\therefore M_{APPLIED} = 4M_1 + 2F_{4y}X$$

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BUT FROM STEP 12:

$$2F_{4Y}X = 4M_1 - F_{X_{TOTAL}}(1.9\text{ IN}) + F_{Y_{TOTAL}}\left(\frac{X}{2}\right)$$

$$\therefore\ M_{\substack{TOTAL\\APPLIED}} = 4M_1 + 4M_1 - F_{X_{TOTAL}}(1.9\text{ IN}) + F_{Y_{TOTAL}}\left(\frac{X}{2}\right)$$

$$\boxed{M_1 = \frac{M_{\substack{TOTAL\\APPLIED}} + F_{X_{TOTAL}}(1.9\text{ IN}) - F_{Y_{TOTAL}}\left(\frac{X}{2}\right)}{8}}$$

16. SUBSTITUTING:

$$M_1 = \frac{2{,}499{,}720\text{ IN lb} + 54{,}258\text{ lb}(1.9\text{ IN}) - 25{,}278\text{ lb}\left(\frac{17.67\text{ IN}}{2}\right)}{8}$$

$$\boxed{M_1 = 297{,}435\text{ IN lb}}$$

DRAW FREE BODY DIAGRAM OF FRONT ROD END. WHEN A MOMENT IS APPLIED TO THE ROD IT WILL TEND TO PIVOT ABOUT POINT "C". THIS MOTION WILL BE RESISTED BY THE DOWNWARD. COMPONENTS OF THE JET & SSE PLUS THE PRELOAD TENSION IN THE THREADS.

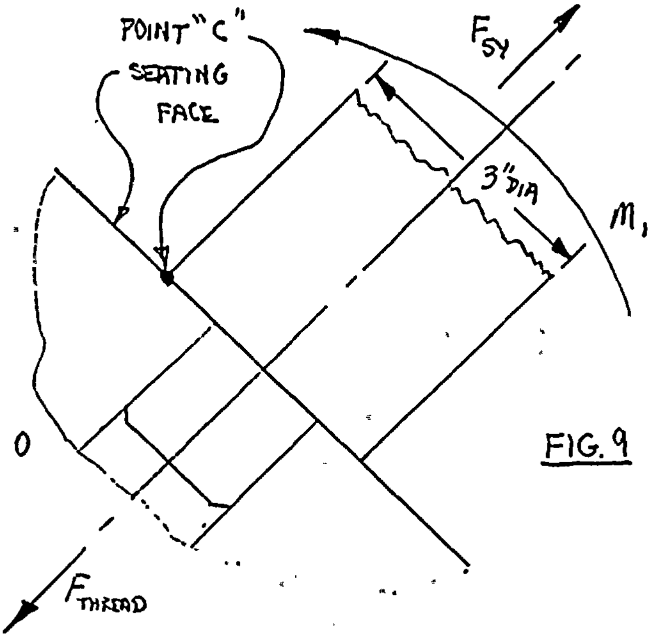

FIG. 9

$$\Sigma M_C = \left(F_{THREAD} - F_{5Y}\right)\frac{3\text{IN}}{2} - M_1 = 0$$

SUBSTITUTING FOR F_{5Y} FROM STEP 12:

$$\left(F_{THREAD} - F_{4Y} + \frac{F_{Y\,TOTAL}}{2}\right)\frac{3\text{IN}}{2} - M_1 = 0$$

$$F_{THREAD} = \frac{2}{3\text{IN}}M_1 + F_{4Y} - \frac{F_{Y\,TOTAL}}{2}$$

FROM STEP 16 ABOVE:

$$2F_{4Y}X = 4M_1 - F_{X_{TOTAL}}(1.9\text{ IN}) + F_{Y_{TOTAL}}\left(\frac{X}{2}\right)$$

$$F_{4Y} = \frac{4M_1 - F_{X_{TOTAL}}(1.9\text{ IN}) + F_{Y_{TOTAL}}\left(\frac{X}{2}\right)}{2X}$$

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$$F_{THREAD} = \frac{2}{3IN} M_1 + \frac{4M_1 - F_{X TOTAL}(1.9 IN) + F_{Y TOTAL}\left(\frac{X}{2}\right)}{2X} - \frac{F_{Y TOTAL}}{2}$$

FROM REF. 7, SCALING X = 17.67 IN

SUBSTITUTING:

$$F_{THREAD} = \frac{4(297,435\ IN\ lb) - (54,258\ lb)(1.9 IN) + 25,278\ lb\left(\frac{17.67 IN}{2}\right)}{2(17.67 IN)} - \frac{25,278\ lb}{2} + (297,435\ IN\ lb)\left(\frac{2}{3 IN}\right)$$

$$\boxed{F_{THREAD} = 222,719\ lb}$$

$$STRESS = \frac{FORCE_{THREAD}}{AREA_{THREAD}}$$

FROM REF. 11 THREADED PORTION OF YOKE ROD IS 2IN - 8UN - 3A THREADS (ATTACHMENT 3, SKETCH WITH LETTER). MATERIAL IS 1018 COLD DRAWN STEEL.

FROM REF. 12, PAGE 8-17, TABLE 4, MINOR DIA. IS 1.8466 IN.

$$STRESS\ \frac{222,719\ lb}{\frac{\pi(1.8466 IN)^2}{4}}$$

$$\boxed{STRESS = 83,161\ lb/IN^2}$$

FROM REF. 13, YIELD STRENGTH OF THE MATERIAL IS 45,000 PSI, ULTIMATE STRENGTH IS 55,000 PSI (SEE ATTACHMENT 4, COPY OF APPLICABLE PAGE.)

FROM TESTING (REF. 14, SECTION 3.6.2) YIELDING WAS OBSERVED IN THE RODS FOR THE T.R.S. YET THE VALVES OPERATED AS DESIGNED. THEREFORE, ANY STRESS UP TO YIELD WILL BE SATISFACTORY.

FIND JET PRESSURE AT WHICH YIELDING OCCURS:

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FORCE IN THREADS TO CAUSE YIELDING

$$F_{YIELD} = (45,000\ lb/in^2)(\pi)\frac{(1.8466\ IN)^2}{4}$$

$$\underline{F_{YIELD} = 120,017\ lb}$$

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RATIO PRESSURE DOWN BY FORCE IN THREAD TO YIELD:

$$P = \frac{120,017\ \text{lb}}{222,719\ \text{lb}} \cdot 36.05\ \text{lb/in}^2 = 19.43\ \text{lb/in}^2$$

TRY THIS PRESSURE - USE EQUATIONS ON PAGES 9 THRU 17:

$F_{Y_1} = 6,650\ \text{lb}$

$F_{X_1} = 13,484\ \text{lb}$

$F_{X_2} = 5,331\ \text{lb}$

$F_{Y_2} = 2,665\ \text{lb}$

$F_{X_3} = 7,254\ \text{lb}$

$F_{X_4} = 1,649\ \text{lb}$

$F_{Y_3} = 618\ \text{lb}$

$$M_{\substack{\text{APPLIED}\\\text{JET}}} = (13,484\ \text{lb})(67\ \text{in}) + (5,331\ \text{lb})(57\ \text{in}) + (7,254\ \text{lb})(21\ \text{in}) + (1,649\ \text{lb})(20\ \text{in})$$

$$M_{\substack{\text{APPLIED}\\\text{JET}}} = 1,285,989\ \text{lb}\cdot\text{in}$$

$$F_{\text{JET}X} = (13,484\ \text{lb} + 5,331\ \text{lb} \div 7,254\ \text{lb} + 1,649\ \text{lb}) = 27,718\ \text{lb}$$

$$F_{\text{JET}Y} = (6,650\ \text{lb} + 2,665\ \text{lb} + 618\ \text{lb}) = 9,933\ \text{lb}$$

$$M_{\substack{\text{TOTAL}\\\text{APPLIED}}} = (1,285,989\ \text{lb in}^2 + 745,630\ \text{lb in}^2)^{1/2}$$

$$M_{\substack{\text{TOTAL}\\\text{APPLIED}}} = 1,486,517\ \text{in lb}$$

$$F_{Y\,\text{TOTAL}} = (9,933\ \text{lb}^2 + 17,300\ \text{lb}^2)^{1/2} = 19,949\ \text{lb}$$

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$$F_{X_{TOTAL}} = \left(27{,}718\ lb^2 + 17{,}300\ lb^2\right)^{1/2} = 32{,}674\ lb$$

$$Y_{SET} = \frac{1{,}285{,}989\ in\ lb}{27{,}718\ lb} = 46.4\ in$$

$$Y_{TOTAL} = \frac{1{,}486{,}517\ in\ lb}{32{,}674\ lb} = 45.5\ in$$

EFFECTIVE FORCE IS 2.5 IN. BELOW TOP SPRING SEAT

$$M_1 = \frac{1{,}486{,}517\ in\ lb + 32{,}674\ lb(2.5\ in) - 19{,}949\ lb\left(\frac{17.67}{2}in\right)}{9}$$

$$M_1 = 173{,}994\ in\ lb$$

$$F_{THREAD} = \frac{4(173{,}994\ in\ lb) - (32{,}674\ lb)(2.5\ in) + (19{,}949\ lb)\left(\frac{17.67\ in}{2}\right)}{2(17.67\ in)} - \frac{19{,}949\ lb}{2} + \left(\frac{2}{3\ in}\right)(173{,}994\ in\ lb)$$

$$F_{THREAD} = 128{,}391\ lb$$ TOO HIGH

RATIO PRESSURE AGAIN:

$$P = \frac{120{,}017\ lb}{128{,}391\ lb} \cdot 19.43\ lb/in^2 = 18.16\ lb/in^2$$

TRY 18 lb/in²

$F_{Y_1} = 6{,}160\ lb$

$F_{X_1} = 12{,}491\ lb$

$F_{X_2} = 4{,}938\ lb$

$F_{Y_2} = 2{,}469\ lb$

$F_{X_3} = 6{,}720\ lb$

$F_{X_4} = 1{,}527\ lb$

$F_{Y_3} = 573\ lb$

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ER No. ____
Sht. No. 21 of 29

$$M_{\substack{APPLIED\\JET}} = (12{,}491\ lb)(67\ in) + (4{,}938\ lb)(37\ in) + (6{,}720\ lb)(21\ in) + (1{,}527\ lb)(20\ in)$$

$$M_{\substack{APPLIED\\JET}} = 1{,}191{,}263\ in\ lb$$

$$F_{JET\,X} = 25{,}676\ lb$$

$$F_{JET\,Y} = 9{,}202\ lb$$

$$M_{\substack{TOTAL\\APPLIED}} = 1{,}405{,}372\ in\,lb$$

$$F_{Y\,TOTAL} = 19{,}595\ lb$$

$$F_{X\,TOTAL} = 30{,}960\ lb$$

$$Y_{JET} = \frac{1{,}191{,}263\ in\,lb}{25{,}676\ lb} = 46.4\ in$$

$$Y_{TOTAL} = \frac{1{,}405{,}372\ in\,lb}{30{,}960\ lb} = 45.4\ in$$

EFFECTIVE FORCE IS 2.6 IN BELOW TOP SPRING SEAT.

$$M_1 = \frac{1{,}405{,}372\ in\,lb + (30{,}960\ lb)(2.6\ in) - 19{,}595\ lb\left(\frac{17.67\ in}{2}\right)}{8}$$

$$M_1 = 164{,}093\ in/lb$$

$$F_{THREAD} = \frac{4(164{,}093\ in\,lb) - 30{,}960\ lb\,(2.6\ in) + 19{,}595\ lb\left(\frac{17.67\ in}{2}\right)}{2(17.67\ in)} - \frac{19{,}595\ lb}{2} + \left(\frac{2}{3\ in}\right)(164{,}093\ in\,lb)$$

$$F_{THREAD} = 120{,}792\ lb$$

RATIO PRESSURE AGAIN'

$$P = \frac{120{,}017\ lb}{120{,}792\ lb}\ .18\ lb/in^2 = 17.9\ lb/in^2$$

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ER No.
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TRY 17.8 lb/in^2

$F_{X1} = 12{,}352$ lb

$F_{Y1} = 6{,}092$ lb

$F_{X2} = 4{,}884$ lb

$F_{Y2} = 2{,}442$ lb

$F_{X3} = 6{,}646$ lb

$F_{X4} = 1{,}510$ lb

$F_{Y3} = 566$ lb

$M_{\substack{APPLIED \\ JET}} = 1{,}178{,}058$ in lb

$F_{JETX} = 25{,}392$ lb

$F_{JETY} - 9{,}100$ lb

$M_{\substack{TOTAL \\ APPLIED}} = 1{,}394{,}197$ in lb

$F_{Y\,TOTAL} = 19{,}547$ lb

$F_{X\,TOTAL} = 30{,}725$ lb

$$Y_{JET} = \frac{1{,}178{,}058 \text{ in lb}}{25{,}392 \text{ lb}} = 46.4 \text{ in}$$

$$Y_{TOTAL} = \frac{1{,}394{,}197 \text{ in lb}}{30{,}725 \text{ lb}} = 45.4 \text{ in}$$

EFFECTIVE FORCE IS 2.6 IN BELOW TOP SPRING SEAT.

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ER No.

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$$M_1 = \frac{1{,}394{,}197\ \text{in lb} + 30{,}725\ \text{lb}\,(2.6\ \text{in}) - 19{,}547\ \text{lb}\left(\frac{17.67\ \text{in}}{2}\right)}{8}$$

$$M_1 = 162{,}673\ \text{in lb}$$

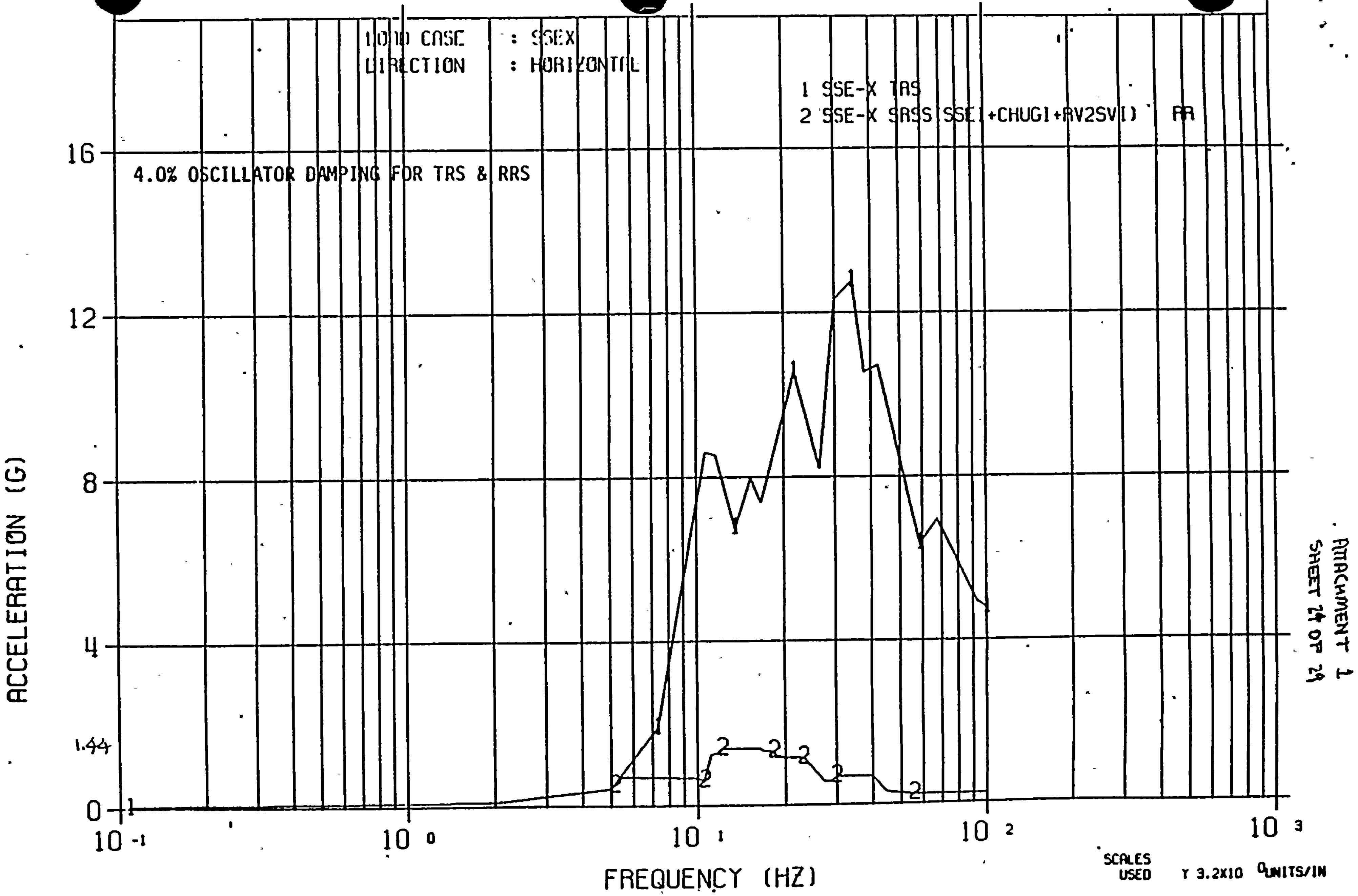
$$F_{\text{THREAD}} = \frac{4(162{,}673\ \text{in lb}) - (30{,}725\ \text{lb})(2.6\ \text{in}) + 19{,}547\ \text{lb}\left(\frac{17.67\ \text{in}}{2}\right)}{2(17.67\ \text{in})} - \frac{19{,}547\ \text{lb}}{2} + \left(\frac{2}{3\ \text{in}}\right)(162{,}673\ \text{in lb})$$

$$F_{\text{THREAD}} = 119{,}714\ \text{lb}$$

SINCE THIS IS LESS THAN F_{YIELD} OF 120,017 lb, THE VALVE CAN WITHSTAND UP TO 17.8 lb/in^2 JET PRESSURE.

FAULTED COND. SS[illegible]X TRS & RRS COMPARISON

FEBRUARY [illegible]983

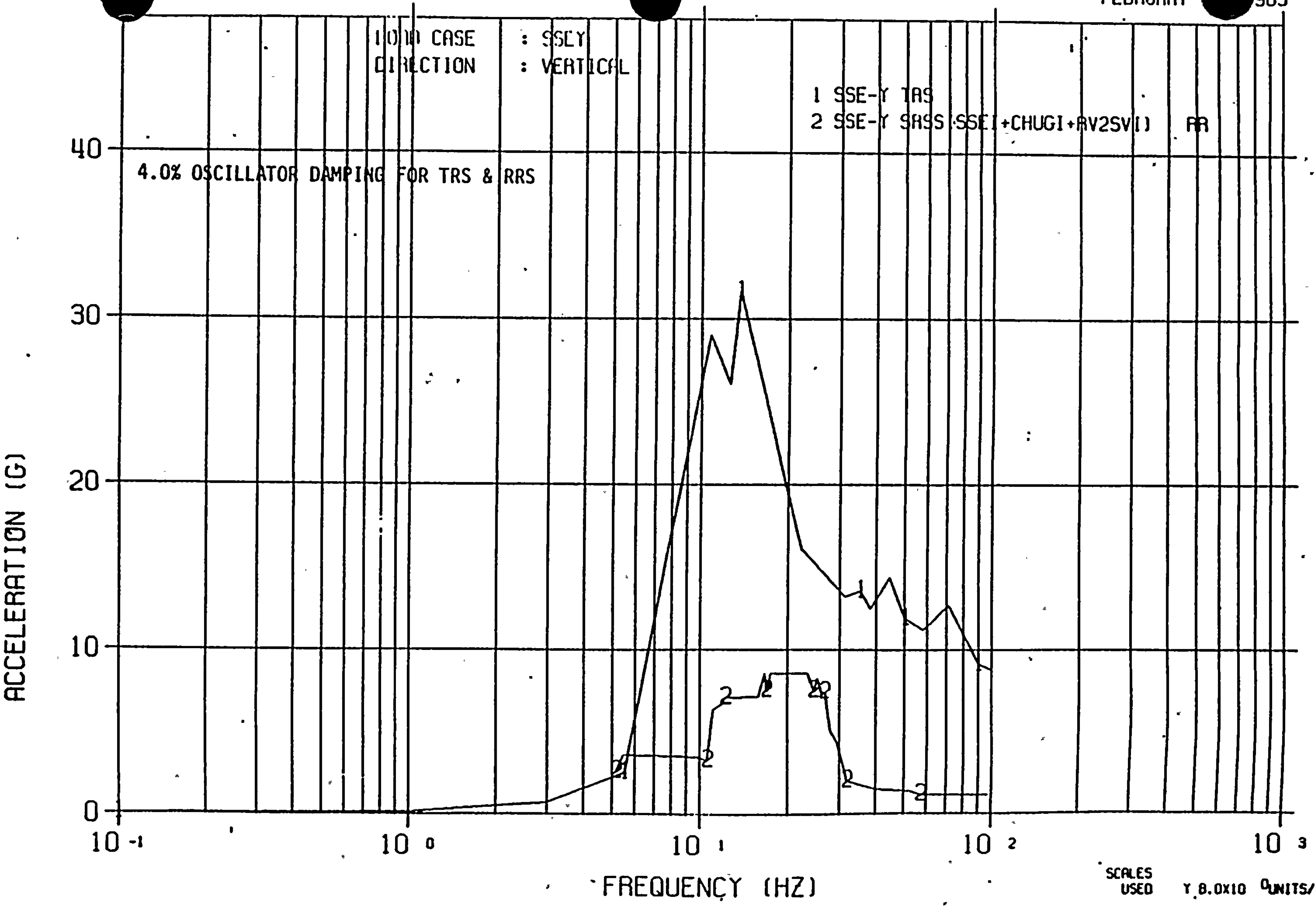


ATTACHMENT 1
SHEET 24 OF 29

PL 1

FAULTED COND. SSE-Y TRS o RRS COMPARISON

FEBRUARY [illegible]983



SCALES USED Y 8.0X10 0 UNITS/IN

ATTACHMENT 2
SHEET 25 OF 29

PL 1

VALVE AND FLOW CONTROL EQUIPMENT SPECIALISTS
POWER PLANT, OIL & GAS INDUSTRY & INDUSTRIAL SERVICE

ATTACHMENT 3, SHEET 26 OF 29

ATWOOD & MORRILL CO. INC.
DESIGNERS AND MANUFACTURERS SINCE 1900

285 CANAL STREET • SALEM, MASSACHUSETTS 01970 • 617 744-5690 • TELEX 94-0299 XXXXXXXXXXXX

April 3, 1985

Pennsylvania Power & Light Company
Two North Ninth Street
Allentown, PA 18101

Attention: Mr. G.D. Miller

Subject: Susquehanna MSIV's

Gentlemen:

The following is the information you requested on your letter dated March 29, 1985 to Mr. Webber:

1 - See enclosed drawing detail for yoke rod threaded portion.

2 - The material of the yoke rod is steel 1018. COLD DRAWN PER TELECON WITH Y.L. BRIGHT. 5/1/85

3 - The inside diameter of the hole in the poppet for the pilot valve is *3.500.

4 - The maximum diameter of the valve stem at the end which forms the pilot poppet is *4.000.

5 - The diameter of the valve stem at the point where it passes through the bonnet is 2.000 +.000 -.002.

6 - The dimension of the opening formed between the pilot poppet and its seat in the valve poppet whenever the valve is in the open position is one inch.

7 - The outside diameter of the poppet at its upper end stellite facing is *21.475 +.000 -.005.

8 - The inside diameter of the valve body against which the stellite facing of the poppet slides is *21.500 +.010 -.000.

NOTE: All dimensions marked * are to be concentric within .003 total indicated reading (TIR).

The dimensions given are proprietary information of Atwood & Morrill Co. and are to be kept confidential. Reproduction of any part thereof or use for purposes other than those expressly designated by Atwood & Morrill Co. is not permitted.

Should you have any questions, please feel free to contact us.

Very truly yours,

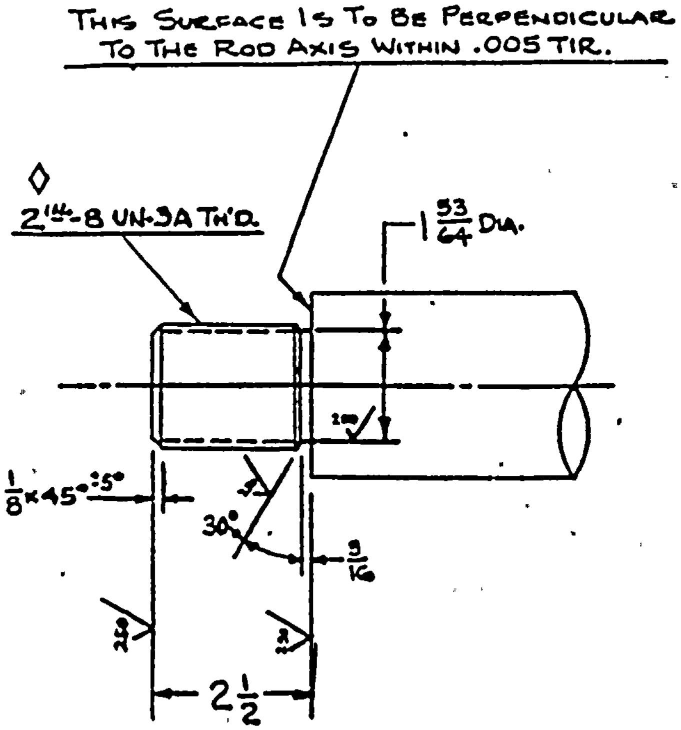
ATWOOD & MORRILL CO., INC.

Virgil L. Bright

Virgil L. Bright
Supervisor, Product Service

VLB/dab

Enclosure



FOR PLANNING PURPOSES ONLY

From Metal Progress Databook. - Second Edition

Mechanical Properties of Cold-Drawn, Carbon-Steel Bars

The tensile and yield strengths of carbon-steel bars are improved by cold drawing. By comparison, the tensile strength of hot-rolled bars is about 10% less, and their yield strength is some 40% less. For example, a low-carbon steel with a yield-to-tensile-strength ratio of about 0.55 in the form of hot-rolled bars will have a ratio of about 0.85 after cold drawing. While there is some sacrifice in elongation, reduction in area, and impact strength, these changes are relatively insignificant in most structural applications or engineering components.

This improvement is of interest to the design engineer seeking a better strength-to-weight ratio or a reduction in costs by the elimination of alloy contents and heat treatment. The enhanced properties may also be useful in applications involving threads, notches, cut-outs, and in other design requirements that might effect strength adversely.

Turned and polished and turned, ground, and polished bars have the mechanical properties of hot-rolled bars.

	As Cold Drawn					Cold Drawn Followed by Low-Temperature Stress Relief					Cold Drawn Followed by High-Temperature Stress Relief				
	Strength					Strength					Strength				
AISI No. Size, In.	Tensile, 1,000 Psi	Yield, 1,000 Psi	Elongation in 2 In., %	Reduction in Area, %	Hardness, Bhn	Tensile, 1,000 Psi	Yield, 1,000 Psi	Elongation in 2 In., %	Reduction in Area, %	Hardness, Bhn	Tensile, 1,000 Psi	Yield, 1,000 Psi	Elongation in 2 In., %	Reduction in Area, %	Hardness, Bhn
1018, 1025															
⅝ to ⅞ incl.	70	60	18	40	143						65	45	20	45	131
Over ⅞ to 1¼ incl.	65	55	16	40	131						60	45	20	45	121
Over 1¼ to 2 incl.	60	50	15	35	121						55	45	16	40	111
Over 2 to 3 incl.	55	45	15	35	111						50	40	15	40	101
1117, 1118															
⅝ to ⅞ incl.	75	65	15	40	149	80	70	15	40	163	70	50	18	45	143
Over ⅞ to 1¼ incl.	70	60	15	40	143	75	65	15	40	149	65	50	16	45	131
Over 1¼ to 2 incl.	65	55	13	35	131	70	60	13	35	143	60	50	15	40	121
Over 2 to 3 incl.	60	50	12	30	121	65	55	12	35	131	55	45	15	40	111
1035															
⅝ to ⅞ incl.	85	75	13	35	170	90	80	13	35	179	80	60	16	45	163
Over ⅞ to 1¼ incl.	80	70	12	35	163	85	75	12	35	170	75	60	15	45	149
Over 1¼ to 2 incl.	75	65	12	35	149	80	70	12	35	163	70	60	15	40	143
Over 2 to 3 incl.	70	60	10	30	143	75	65	10	30	149	65	55	12	35	131
1040, 1140															
⅝ to ⅞ incl.	90	80	12	35	179	95	85	12	35	187	85	65	15	45	170
Over ⅞ to 1¼ incl.	85	75	12	35	170	90	80	12	35	179	80	65	15	45	163
Over 1¼ to 2 incl.	80	70	10	30	163	85	75	10	30	170	75	60	15	40	149
Over 2 to 3 incl.	75	65	10	30	149	80	70	10	30	163	70	55	12	35	143
1045, 1146, 1145															
⅝ to ⅞ incl.	95	85	12	35	187	100	90	12	35	197	90	70	15	45	179
Over ⅞ to 1¼ incl.	90	80	11	30	179	95	85	11	30	187	85	70	15	45	170
Over 1¼ to 2 incl.	85	75	10	30	170	90	80	10	30	179	80	65	15	40	163
Over 2 to 3 incl.	80	70	10	30	163	85	75	10	25	170	75	60	12	35	149
1050, 1137, 1151															
⅝ to ⅞ incl.	100	90	11	35	197	105	95	11	35	212	95	75	15	45	187
Over ⅞ to 1¼ incl.	95	85	11	30	187	100	90	11	30	197	90	75	15	40	179
Over 1¼ to 2 incl.	90	80	10	30	179	95	85	10	30	187	85	70	15	40	170
Over 2 to 3 incl.	85	75	10	30	170	90	80	10	25	179	80	65	12	35	163
1141															
⅝ to ⅞ incl.	105	95	11	30	212	110	100	11	30	223	100	80	15	40	197
Over ⅞ to 1¼ incl.	100	90	10	30	197	105	95	10	30	212	95	80	15	40	187
Over 1¼ to 2 incl.	95	85	10	30	187	100	90	10	25	197	90	75	15	40	179
Over 2 to 3 incl.	90	80	10	20	179	95	85	10	20	187	85	70	12	30	170
1144															
⅝ to ⅞ incl.	110	100	10	30	223	115	105	10	30	229	105	85	15	40	212
Over ⅞ to 1¼ incl.	105	95	10	30	212	110	100	10	30	223	100	85	15	40	197
Over 1¼ to 2 incl.	100	90	10	25	197	105	95	10	25	212	95	80	15	35	187
Over 2 to 3 incl.	95	85	10	20	187	100	90	10	20	197	90	75	12	30	179

Minimum values rounds, squares, and hexagons.

Source: AISI Committee of Hot Rolled and Cold Finished Bar Producers.

ATTACHMENT 4 SHEET 28 OF 28

PP&L

CALCULATION COVER SHEET

CALC. NO. M-MSS-006

FILE NO. 922-60

SUPERSEDED BY

SAFETY-RELATED ☑
ASME III OR XI ☐
OTHER QUALITY ☐
NON QUALITY ☐

ROJECT SUSQUEHANNA STEAM ELECTRIC STATION

ER/CTN NO. 741058-003

DESIGN ACTIVITY/PMR NUMBER IREIR 101155

PAGE 1 OF 27X

TITLE/DESCRIPTION JET IMPINGEMENT ON MISC. MSIV HARDWARE

STATEMENT OF PROBLEM DETERMINE THE JET IMPINGEMENT EFFECTS OF A 28" RECIRCULATION LINE BREAK AT WELD S1 ON THE HARDWARE ASSOCIATED WITH THE INBOARD MAIN STEAM ISOLATION VALVES WITH RESPECT TO THE PERFORMANCE OF ITS SAFETY FUNCTIONS.

DESIGN BASIS (DC020.0 OR DC020.1)

IT IS ASSUMED THAT AFTER THE BREAK THE PIPE ENDS SEPERATE BY ~~14~~ 10.88 INCHES. THE CALCULATION IS PERFORMED ASSUMING THAT THE JET EXIT ANNULUS CONFIGURATION CAN BE REPRESENTED AS AN OPEN ENDED PIPE OF THE SAME AREA AND THAT THE RESULTS YIELDED ARE REASONABLE APPROXIMATIONS OF THE ACTUAL LOADS. SINCE THE BASIC FORMULAE YIELD CONSERVATIVE RESULTS, THIS SUBSTITUTION WOULD PROBABLY BE SIMILARLY CONSERVATIVE. △1

FERENCES/FORMULAE

1. BECHTEL DRAWING C-919, SHEET 1, REV. 6, REACTOR SHIELD DOORS
2. G.E. DWG. FF 113011, SH. 6101, REV 1, N1 RECIRC. OUTLET NOZZLE SAFE END
3. G.E. DWG. 4556-M1-B11-149-2, RECIRC OUTLET NOZZLE N1.
4. TELECON BETWEEN MR. HANS GIESECKE OF MPR ASSOCIATES & MR. D.C. PREVATTE (ATTACHMENT 1).
5. ANS 58.2-1980, "... EFFECTS OF POSTULATED PIPE RUPTURE."
6. FSAR TABLE 6A-1 (b).
7. HICKS, STANDARD HANDBOOK OF ENGINEERING CALCULATIONS, 1972, McGRAW-HILL
8. ATWOOD & MORRILL CO. DWG 21190-H, 26 IN W.E. MAIN STEAM ISOLATION VALVE
9. BAUMEISTER & MARKS, STANDARD HANDBOOK FOR MECHANICAL ENGINEERS, 1967
10. RAYMOND J. ROARK, FORMULAS FOR STRESS AND STRAIN, 1965
11. ANSI B18.6.3-1972, MACHINE SCREWS AND MACHINE SCREW NUTS
12. AISC SPEC FOR DESIGN, FAB. AND ERECTION OF STRUCTURAL STEEL FOR BLDGS., 1978
13. ASME CODE SECT III, SUBSECT NC-3000, TABLE 3673.2(b)-1
14. SUSQUEHANNA PICTURE PROGRAM BOOKS FOR DRYWELL, EL. 738'
15. LETTER REPORT FM. MPR ASSOCIATES, INC. DATED JUNE 24, 1985. (ATTACHMENT 5) △1

SUMMARY/CONCLUSIONS

1. FLEX CONDUIT ASSOCIATED WITH MSIV'S WOULD FAIL CAUSING LOSS OF CONTROL ROOM INDICATION AND LOSS OF OPERATING PERMISSIVE FOR INBOARD MSIV LEAKAGE CONTROL SYSTEM.
2. LARGE CONDUIT BOX ATTACHMENT TO MOUNTING PLATE WILL NOT FAIL.
3. CONDUIT BETWEEN POSITION SWITCH AND SMALL JUNCTION BOX WOULD FAIL CAUSING FAILURE OF MSIV-LCS PERMISSIVE.
4. THE MOUNTING PLATE FOR THE LARGE CONDUIT BOX WILL FAIL AT ITS ATTACHMENT TO THE VALVE CAUSING A LOSS OF CONTROL ROOM POSITION INDICATION. THE SMALL BOX MOUNTING BRACKET WILL NOT FAIL.
5. LIMIT SWITCHES WILL NOT FAIL
6. HYDRAULIC SPEED CONTROL HARDWARE WILL NOT FAIL.
7. IF BRAIDED FLEX CONDUIT IS SUBSTITUTED FOR REGULAR FLEX CONDUIT, ITEM 1 FAILURE WILL NOT OCCUR.
8. IF 1" XXS PIPE IS SUBSTITUTED FOR 1" CONDUIT ON SMALL JUNCTION BOX, ITEM 3 FAILURE WILL NOT OCCUR. △1

NO.	DATE	PREPARED BY	REVIEWED/CHECKED BY	DATE	APPROVED BY	DATE
0	5/24/85	D C Prevatte	J. A. Wales	6-25-85	Frank J. Cizyz	6/28/85
1	10/14/85	D C Prevatte	J. A. Wales	10-18-85	Frank J. Cizyz	10/21/85

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PROJECT JET IMPINGEMENT ON MSIV HARDWARE, CALC. # M-MSS-006

ER No. 741058-003

Sht. No. 2 of 27X

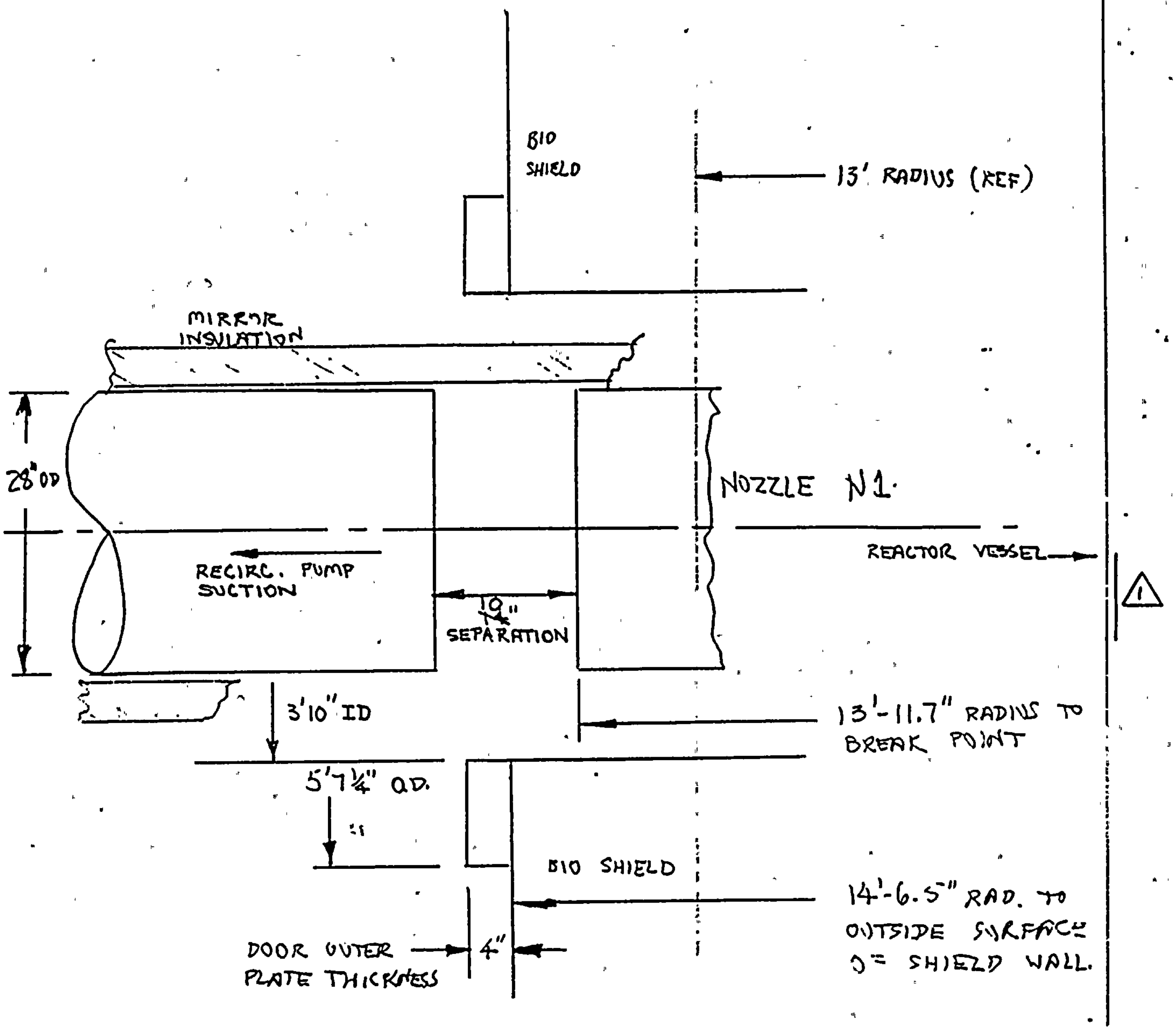

FIGURE 1

SCALE: ¾" = 1'

(SKETCHED FROM DIMENSIONS GIVEN ON REFS. 1, 2, & 3.)

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FIGURE 1 DESCRIBES THE PHYSICAL SITUATION THAT EXISTS AT THE TIME THE RECIRC. PUMP SIDE OF THE BREAK COMES TO REST AT A STEADY STATE CONDITION. STEAM ESCAPING FROM THE TWO OPEN ENDS WOULD MEET AND TURN RADIALLY OUTWARD. WHERE IT WOULD ENCOUNTER THE INSIDE DIAMETER OF THE BIOLOGICAL SHIELD DOORS WHICH WOULD TEND TO DEFLECT THE FLOW AXIALLY ALONG THE PIPE OUTWARD IN BOTH DIRECTIONS. IT IS ASSUMED THE INSULATION WOULD BE BLOWN AWAY. THE FLOW TOWARD THE REACTOR VESSEL WOULD PRESSURIZE THE ANNULUS BETWEEN THE VESSEL AND THE BIO SHIELD. THE FLOW OUTWARD WOULD EXHAUST INTO THE DRYWELL. DUE TO THE HIGHER BACK PRESSURE IN THE BIO SHIELD ANNULUS AND THE LOCATION OF THE BREAK GAP AT THE DRYWELL SIDE OPENING IN THE SHIELD DOOR, MOST OF THE FLOW WOULD BE IN THE DIRECTION AWAY FROM THE REACTOR VESSEL. ADDITIONALLY, BECAUSE OF THE RELATIVELY LOW FLOW RESISTANCE THROUGH THE NOZZLE N1 COMPARRED TO THE RESISTANCE THROUGH THE PUMP SIDE PIPING, THE FLOW FROM THE VESSEL SIDE WOULD BE THE PREDOMINANT SOURCE, AND PART OF ITS MOMENTUM WOULD CARRY OVER TO THE JET MOVING AWAY FROM THE VESSEL.

FROM REF. ~~4~~ 15 THE FLOW IN THE OUTWARD DIRECTION IS ~~10,644~~ 11,541 lb/SEC, AND THE PRESSURE IN THE ANNULUS AROUND THE BREAK IS ~~335~~ 279 PSIG. FOR A BREAK SEPARATION OF ~~14~~ 10 INCHES. △1

CIRCUMFERENTIAL AREA OF THE GAP BETWEEN THE BREAK ENDS:

$$A_{GAP} = \pi(d)(GAP) = \pi(28\,IN)(14\,IN)$$

$$A_{GAP} = 1231.50\,IN^2 = 8.552\,FT^2$$

EXIT ANNULUS AREA BETWEEN PIPE O.D. AND SHIELD DOOR I.D.:

$$A_e = \pi/4\left[(3'10'')^2 - (28'')^2\right]$$

$$A_e = 1046.15\,IN^2 = 7.265\,FT^2$$

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FROM REF. 5, PAGE 10, EQUATION 6-2, THE THRUST FORCE FOR STEADY STATE IS:

$$T = \rho_e U_e^2 A_e + P_e A_e$$

WHERE: ρ_e = MASS DENSITY OF THE FLUID AT EXIT = 3.122 lb/ft^3 (PER REF. 15)
U_e = EXIT VELOCITY OF THE FLUID
A_e = EXIT AREA = 7.265 FT^2
P_e = EXIT PRESSURE = 279 PSIG (PER REF. 15)

$$\text{VOLUMETRIC FLOW RATE} = \frac{\text{MASS FLOW RATE}}{\text{DENSITY}} = \frac{\dot{m}}{\rho_e} = \frac{11{,}541 \text{ lbm/SEC}}{3.122 \text{ lbm/ft}^3} = 3696.7 \text{ ft}^3\text{/SEC}$$

5 1. [illegible]

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$$\text{exit velocity}, U_e = \frac{\text{volumetric flow rate}}{\text{exit area}, A_e} = \frac{\overset{3{,}696.7}{\cancel{2{,}369.8}}\ ft^3/sec}{7.265\ ft^2} = \overset{508.8}{\cancel{326.2}}\ ft/sec$$

SUBSTITUTING INTO THRUST EQUATION:

$$T = \rho_e U_e^2 A_e + P_e A_e$$

$$T = (\overset{3.122}{\cancel{7.0603}}\ lbm/ft^3)(\overset{508.8}{\cancel{326.2}}\ ft/sec)^2 (7.265\ ft^2) + (\overset{279}{\cancel{325}}\ lb/in^2) \times (7.265\ ft^2)(144\ in^2/ft^2)$$

$$T = (\overset{5{,}871{,}685}{\cancel{5{,}457{,}743}}\ ft\ lbm/sec^2) \times \frac{1\ lbf}{32.2\ ft\ lbm/sec^2} + \overset{291{,}879}{\cancel{340{,}002}}\ lb$$

$$T = \overset{182{,}350}{\cancel{107{,}383}}\ lb + \overset{291{,}879}{\cancel{340{,}002}}\ lb$$

$$T = \overset{474{,}229}{\cancel{447{,}385}}\ lb$$

⚠1

ASSUME THE JET IS EQUIVALENT TO AN OPEN ENDED PIPE WITH AN AREA EQUAL TO THE ACTUAL ANNULUS EXIT AREA, A_e. SINCE THE LENGTH OF TRAVEL OF THE STEAM IN THE AXIAL DIRECTION AFTER LEAVING THE BREAK GAP IS VERY SHORT, AND SINCE THE PUMP SIDE END IS ACTUALLY SLIGHTLY OUTSIDE THE SHIELD DOOR, ASSUME THE MAXIMUM EXPANSION GIVEN BY FIGURE C-2 OF REF. 5 FOR SATURATED WATER.

$$\frac{A_a}{A_e} = 100$$ where A_a = area of asymptotic plane per Appendix C of Ref. 5.

$$A_a = 100\ A_e = 100(7.265\ ft^2)$$

$$A_a = 726.5\ ft^2$$

Find exit and asymptotic plane diameters.

$$D_e = \sqrt{\frac{4A_e}{\pi}} = \sqrt{\frac{4(7.265\ ft^2)}{\pi}} = 3.0414\ ft$$

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$$D_a = \sqrt{\frac{4\,A_a}{\pi}} = \sqrt{\frac{4(726.5\text{ ft}^2)}{\pi}} = 30.414\text{ ft}$$

From equation C-2, Ref. 5,

$$\frac{L_a}{D_e} = \frac{1}{2}\left(\sqrt{\frac{A_a}{A_e}} - 1\right)$$

$$L_a = 4.5\,D_e = 4.5\,(3.0414\text{ ft})$$

$$L_a = 13.686\text{ ft}$$

BY ACTUAL MEASUREMENT, THE DISTANCE TO IMPINGEMENT TARGETS ON INBD. MSIV'S RANGES FROM APPROXIMATELY 8' TO 13' FROM THE EXIT AREA. PER APPENDIX C, REF. 5, THE EXPANSION IS ASSUMED TO BE LINEAR OUT TO THE ASYMPTOTIC PLANE. THE AREA GIVEN BY EQUATION C-4 IS (USE T SUBSCRIPT FOR TARGETS):

$$A_{JET} = A_e + \frac{L_T}{L_a}\left(A_a - A_e\right)$$

$$A_{JET} = 7.265\text{ ft}^2 + 52.55\text{ ft}\,(L_T)$$

FOR $L_T = 8'$, $D_T = 23.335$ ft, $A_T = 427.67$ ft^2

$L_T = 9'$, $D_T = 24.727$ ft, $A_T = 480.22$ ft^2

$L_T = 10'$, $D_T = 26.045$ ft, $A_T = 532.79$ ft^2

$L_T = 11'$, $D_T = 27.300$ ft, $A_T = 585.32$ ft^2

$L_T = 12'$, $D_T = 28.500$ ft, $A_T = 637.87$ ft^2

$L_T = 13'$, $D_T = 29.650$ ft, A_T 690.42 ft^2

ASSUMING THE TOTAL FORCE AT ANY TARGET DISTANCE IS CONSTANT AND EQUAL TO THE THRUST FORCE (A CONSERVATIVE ASSUMPTION), THEN THE PRESSURE ON ANY TARGET IN THE TARGET PLANE WOULD BE THE THRUST

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DIVIDED BY THE TARGET PLANE AREA:

$$P_T = \frac{T}{A_T} = \frac{\overset{474,229}{\cancel{447,385}}\ \text{lb}}{A_T}$$

FOR $L_T = 8'$, $P_T = 7.7\ \text{lb/in}^2$

$L_T = 9'$, $P_T = 6.9\ \text{lb/in}^2$

$L_T = 10'$, $P_T = 6.2\ \text{lb/in}^2$ △1

$L_T = 11'$, $P_T = 5.6\ \text{lb/in}^2$

$L_T = 12'$, $P_T = 5.2\ \text{lb/in}^2$

$L_T = 13'$, $P_T = 4.8\ \text{lb/in}^2$

MISC. MSIV TARGETS POTENTIALLY AFFECTING SAFETY FUNCTION:

1. CONDUIT (FLEX & RIGID), SIZES 3/4", 1", & 1 1/2".
2. JUNCTION BOXES (LARGE & SMALL).
3. JUNCTION BOX MOUNTING PLATES.
4. LIMIT SWITCHES.
5. HYDRAULIC SPEED CONTROL HARDWARE.
6. I-BEAM IN FRONT OF OPERATOR

CONDUIT

THE CLOSEST CONDUIT TARGET IS AT VALVES A & D AT ≈ 9 FT RANGE. THE MOST EXPOSED CONDUIT IS THE FLEX CONDUIT SUPPLIED BY THE AMERICAN BOA COMPANY. PER THE VENDOR CATALOG, THE FOLLOWING DATA IS APPLICABLE FOR THE THREE SIZES USED:

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NOMINAL DIA.	OUTSIDE DIA.	MAX. ALLOWABLE INTERNAL PRES. (INCLUDES 4 TO 1 SAFETY FACTOR)
3/4"	1.04"	72 PSI
1"	1.24"	60 PSI
1 1/2"	1.91"	40 PSI

THE PRESSURES INDICATED ARE THE PRESSURES AT WHICH THE BELLOWS TUBING STARTS TO STRETCH OUT. THE EQUIVALENT TENSILE LOAD WOULD BE:

$$L_T = PA$$

$$L_{T\,3/4''} = (72\ lb/in^2)(\pi)\left(\frac{1.04\ in}{2}\right)^2 = 61\ lb$$

$$L_{T\,1''} = (60\ lb/in^2)(\pi)\left(\frac{1.24\ in}{2}\right)^2 = 72\ lb$$

$$L_{T\,1\frac{1}{2}''} = (40\ lb/in^2)(\pi)\left(\frac{1.91\ in}{2}\right)^2 = 115\ lb$$

FLEX CONDUIT TYPICAL EXPOSURE LENGTHS ≈ 3 FT.

$$\text{TARGET AREA} = A_t = (DIA)(LENGTH)$$

$$\therefore A_{t\,3/4''} = (1.04'')(36'') = 37.44\ in^2$$

$$A_{t\,1''} = (1.24'')(36'') = 44.64\ in^2$$

$$A_{t\,1\frac{1}{2}''} = (1.91'')(36'') = 68.76\ in^2$$

FROM EQ D-5 & D-6 REF 5, $F_{imp} = K_\phi P_{JET} A_{target}$

when $K_\phi = \frac{1}{2} C_D$ (DRAG COEF.)

FROM TABLE D-1 FOR CIRCULAR CYLINDER FOR TURBULENT FLOW, $C_D = 1.2$

$$\therefore K_\phi = .6$$

$$F_{imp\,3/4''} = .6\,(6.9\ lb/in^2)(37.44\ in^2) = 155.0\ lb$$

△1

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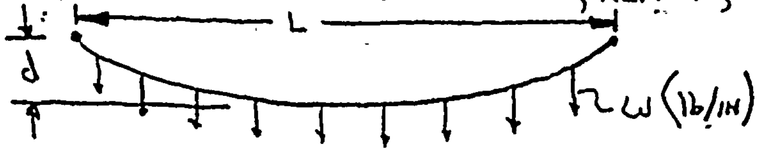
$$F_{imp\,1"} = .6(6.9\,lb/in^2)(44.44\,in^2) = 184.8\ lb$$ △1

$$F_{imp\,1\frac{1}{2}"} = .6(6.9\,lb/in^2)(68.76\,in^2) = 284.7\ lb$$

SINCE FLEX CONDUIT CAN ONLY SUPPORT A TENSILE LOAD, IT WILL FORM A CATENARY WHEN UNIFORMLY LOADED. FROM PAGE 1-17, REF. 7, MID-SPAN TENSION:

$$H = \omega L^2 / 8d$$



WHERE W = LOAD / UNIT LENGTH HORIZONTAL
L = LENGTH BETWEEN SUPPORTS
d = SAG ≈ ASSUME 9" TYPICAL.

$$H_{3/4"} = \frac{\left(155.0\,lb / 36\,in.\right)(36\,in)^2}{8(9\,in)} = 77.5\ lb$$

$$H_{1"} = \frac{\left(184.8\,lb / 36\,in.\right)(36\,in)^2}{8(9\,in)} = 92.4\ lb$$ △1

$$H_{1\frac{1}{2}"} = \frac{\left(284.7\,lb / 36\,in\right)(36\,in)^2}{8(9\,in)} = 142.4\ lb$$

SINCE EACH OF THESE LOADS IS SOMEWHAT HIGHER THAN THE MAXIMUM ALLOWABLE FOR THE RESPECTIVE CONDUITS INCLUDING THEIR 4-TO-1 SAFETY FACTORS, THESE CONDUITS WOULD FAIL BY STRETCHING OUT POSSIBLY CAUSING THE CABLE INSIDE TO BREAK OR BE DETERMINATED.

MAXIMUM DISTANCE OF CONDUIT BLAST TARGET ≃ 13 FT, $P_T = 4.8\,lb/in^2$.

$$F_{imp\,3/4"} = .6(4.8\,lb/in^2)(37.44\,in^2) = 107.8\ lb$$

$$F_{imp\,1"} = .6(4.8\,lb/in^2)(44.44\,in^2) = 128.6\ lb$$ △1

$$F_{imp\,1\frac{1}{2}"} = .6(4.8\,lb/in^2)(68.76\,in^2) = 198.0\ lb$$

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$$H_{3/4''} = \frac{\left(\frac{108\ \text{lb}}{36\ \text{in}}\right)(36\ \text{in})^2}{8\ (9\ \text{in})} = 54\ \text{lb}$$

$$H_{1''} = \frac{\left(\frac{124\ \text{lb}}{36\ \text{in}}\right)(36\ \text{in})^2}{8\ (9\ \text{in})} = 65\ \text{lb}$$

$$H_{1\frac{1}{2}''} = \frac{\left(\frac{198.\ \text{lb}}{36\ \text{in}}\right)(36\ \text{in})^2}{8\ (9\ \text{in})} = 99.\ \text{lb}$$

EACH OF THESE LOADS IS LESS THAN THE ALLOWABLE LOAD IF THERE IS NO FACTOR OF SAFETY. HOWEVER, THE TENSION AT THE END CONNECTIONS MAY BE HIGHER.

FROM REF. 7, PAGE 1-17, TENSION AT SUPPORTS:

$$T = \left[H^2 + (WL/2)^2\right]^{.5}$$

$$T_{3/4''} = \left[(54\ \text{lb})^2 + \left(\frac{108\ \text{lb}}{2}\right)^2\right]^{.5} = 76.4\ \text{lb}$$

$$T_{1''} = \left[(65\ \text{lb})^2 + \left(\frac{124\ \text{lb}}{2}\right)^2\right]^{.5} = 91.9\ \text{lb}$$

$$T_{1\frac{1}{2}''} = \left[(99\ \text{lb})^2 + \left(\frac{198.\ \text{lb}}{2}\right)^2\right]^{.5} = 140.0\ \text{lb}$$

△1

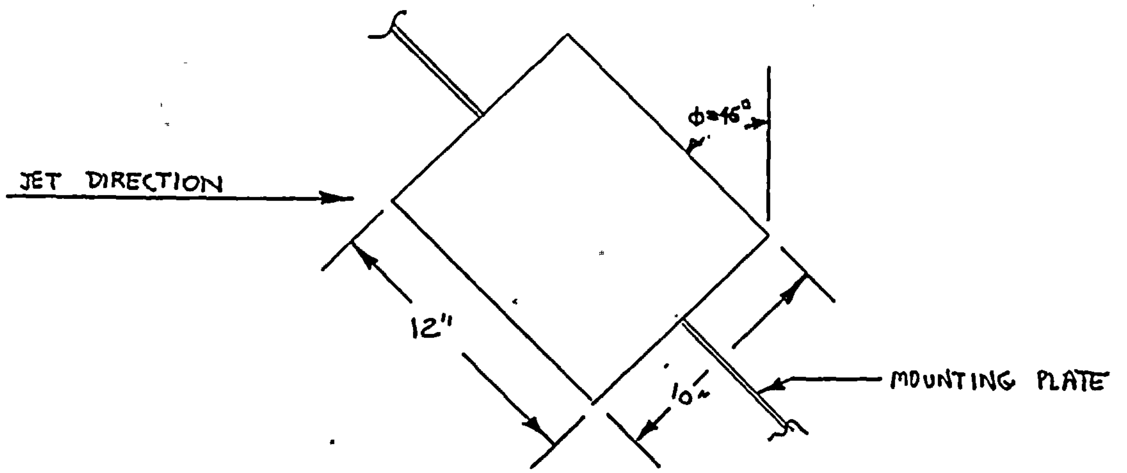
SINCE THESE FORCES ARE GREATER THAN THE RESPECTIVE ALLOWABLES, THE CONDUITS WOULD FAIL.

JUNCTION BOXES

LOADS ON JUNCTION BOXES = DIRECT BLAST LOADS + LOADS IMPOSED BY FLEX CONDUIT DUE TO BLAST.

FROM REF. 8 DIMENSIONS OF LARGE JUNCTION BOX − 10" X 12" X 5"

RANGE TO JUNCTION BOX, VALVE D ≃ 9 FT, $P_T = 6.9\ \text{lb/in}^2$ △1



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PROJECT JET IMPINGEMENT ON MSIV HARDWARE, CALC # M-MSS-006

ER No. 741056-0C3

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FOR FLAT SURFACE $K_\phi = \cos\phi$ (FM FIG D-1, REF. 5)

IMPINGEMENT FORCE ON 12" SIDE OF BOX:

$$F_{imp} = (\cos 45°)(\text{AREA})(\text{PRES.})$$

$$F_{imp} = (.707)(12'' \times 5'')(6.9\ lb/in^2)$$

$$F_{imp} = 293\ lb$$

VALVE D'S LARGE JUNCTION BOX HAS ONE 1½" FLEX CONDUIT ATTACHED, THREE 1 INCHERS, & ONE ¾ INCHER. FORCES APPLIED BY THESE CONDUITS TO THE BOX ARE GIVEN BY REF 7, PAGE 1-17.

TENSION AT SUPPORTS (CONNECTIONS TO BOX) $= T = \left[H^2 + (WL/2)^2\right]^{0.5}$

$$T_{3/4''} = \left[(77.5\ lb)^2 + \left(\frac{155.0\ lb}{2}\right)^2\right]^{0.5} = 109.6\ lb$$

$$T_{1''} = \left[(92.4\ lb)^2 + \left(\frac{184.8\ lb}{2}\right)^2\right]^{0.5} = 130.7\ lb$$

$$T_{1\frac{1}{2}''} = \left[(142.4\ lb)^2 + \left(\frac{284.7\ lb}{2}\right)^2\right]^{0.5} = 201.4\ lb$$

ASSUME THAT DUE TO SHADOWING, ANGLE, ETC., ONLY HALF THE FORCE IS TRANSMITTED TO THE BOX. THEN, FORCE IN JET DIRECTION ON BOX IS:

$$F_{COND} = \frac{109.6\ lb + 3(130.7\ lb) + 201.4\ lb}{2} = 351.6\ lb$$

COMPONENT OF F_{COND} PERPENDICULAR TO 12" SIDE $= 351.6\ lb \times \cos\phi$

$$= 248.6\ lb$$

TOTAL FORCE IN DIRECTION PERPENDICULAR TO MOUNTING PLATE = DIRECT JET + CONDUIT FORCE

$$= 293\ lb + 249\ lb = 542\ lb$$

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Cat. #973401

Dept. NPE-MECH
Date 5/24/ 19 85
Designed by D.C.Peretta
Approved by

PENNSYLVANIA POWER & LIGHT COMPANY
CALCULATION SHEET

PROJECT JET IMPINGEMENT ON MSIV HARDWARE, CALC # M-MSS-006

ER No. 741058-003

Sht. No. 12 of 27X

LOOKING AT THE ATTACHMENT OF THE BOX TO THE MOUNTING PLATE (SEE REF 8, SHEET 2) THE FORCE ON THE 12" SIDE WOULD CREATE A MOMENT WHICH WOULD BE RESISTED PRIMARILY BY A COUPLE BETWEEN THE TWO TOP LIMIT SWITCHES' CONDUITS (1") (SEE REF 14.)

LEVER ARM FROM CENTER OF AREA OF 12" SIDE TO CONDUIT THREADS AT LIMIT SWITCHES = 4.5 IN.

$$\text{MOMENT} = (\text{FORCE})(\text{LEVER ARM}) = (542\text{ lb})(4.5\text{ in}) = 2439\text{ in lb}$$

SEPARATION BETWEEN CONDUIT CENTERS = 3.5 IN

$$\text{FORCE IN CONDUIT} = \frac{\text{MOMENT}}{\text{SEPERATION}} = \frac{2439\text{ in lb}}{3.5\text{ in}} = \pm 697\text{ lb}$$

ATTACHMENTS 2 & 3 ARE PAGES FROM AN ELECTRICAL SUPPLY CATALOG. ASSUME THAT THE PROPERTIES GIVEN ARE TYPICAL FOR RIGID CONDUIT. FOR 1" RIGID CONDUIT:

O.D. = 1.315"
I.D. = 1.049"
WALL THICKNESS = .133"
MATERIAL – MILD STEEL, 35,000–40,000 PSI YIELD STRENGTH

ASSUME THAT FAILURE OF CONDUIT WOULD BE MOST LIKELY TO OCCUR IN THE THREADS AT THE MINOR DIAMETER.
ASSUME CONDUIT THREADS ARE "FREE FITTING" PER TABLE 15, PAGE 8-25, OF REF. 9. MINOR DIAMETER = 1.181", 11½ THREADS / IN.

$$\text{MINIMUM AREA} = \frac{\pi}{4}\left[\text{O.D.}^2 - \text{I.D.}^2\right] = \frac{\pi}{4}\left[(1.315\text{ in})^2 - (1.181\text{ in})^2\right] = .2627\text{ in}^2$$

$$\text{ASSUME RADIUS AT BOTTOM OF THREADS} = \tfrac{1}{8}\text{ PITCH} = .125\left(\frac{1}{11.5\text{ THDS/in}}\right)$$

$$= .01087\text{ in}$$

$$\text{RATIO OF ROOT RADIUS TO MINOR DIA.} = \frac{r}{d} = \frac{.01087\text{ in}}{1.181\text{ in}} = .0092$$

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PROJECT JET IMPINGEMENT ON MSIV HARDWARE, CALC # M-MSS-006

ER No. 741058-003

Sht. No. 13 of 27X

FM. REF. 10, TABLE XVIII, CASE 12, FOR ELASTIC STRESS IN TENSION, THE STRESS CONCENTRATION FACTOR, K = 3.4 FOR $\frac{r}{d} = .05$, THE HIGHEST K SHOWN.

FROM REF. 13, STRESS CONCENTRATION FACTOR FOR THREADED PIPE IS 2.3. USE 3.0

$$\text{THEN STRESS} = \sigma = \frac{P}{A} \cdot K = \frac{697.1 \text{ lb}}{.2627 \text{ in}^2} \cdot 3 = 7{,}960 \text{ lb/in}^2$$ △1

SINCE THIS IS LESS THAN THE YIELD STRENGTH OF THE MATERIAL, WE WILL HAVE NO FAILURE.

SMALL JUNCTION BOX (SEE REF. 14)

DIMENSIONS OF EXPOSED SURFACE (FROM PICTURE BOOKS) ≈ 5" x 4" = 20 in²

TARGET DISTANCE ≈ 9 FT., PRESSURE = 6.9 lb/in² △1

ANGLE OF TARGET ≈ 0°

$$\text{FORCE} = PA = (6.9 \text{ lb/in}^2)(20 \text{ in}^2) = 138 \text{ lb.}$$

DUE TO SHADOWING, ASSUME ONLY HALF THE CONDUIT LOAD IS TRANSMITTED TO THE BOX. THERE IS ONE 1" CONDUIT ATTACHED.

$$F_{COND} = \frac{130.8 \text{ lb}}{2} \text{ (FM. SHEET 11)} = 65.4 \text{ lb}$$

TOTAL FORCE ON BOX = PRES. FORCE + CONDUIT FORCE

$$= 138 \text{ lb} + 65 \text{ lb} = 203 \text{ lb}$$ △1

THIS FORCE WOULD CREATE A MOMENT IN THE 1" CONDUIT ATTACHING IT TO THE LIMIT SWITCH. STRESS IN THE CONDUIT WOULD BE;

$$\sigma = \frac{Mc}{I}$$

where M = MOMENT = 203 lb × 4.5 in = 913.5 in lb
c = MINOR DIA. = 1.181 in

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Approved by ______

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CALCULATION SHEET

PROJECT JET IMPINGEMENT ON MSIV HARDWARE, CALC # M-MSS-006

ER No. 741058-003

Sht. No. 14 of 27X

$$I = .25\pi\left[r_o^4 - r_i^4\right] = .25\pi\left[\left(\frac{\text{MIN DIA.}}{2}\right)^4 - \left(\frac{\text{I.D}}{2}\right)^4\right]$$

$$I = .25\pi\left[\left(\frac{1.181\text{ IN}}{2}\right)^4 - \left(\frac{1.049\text{ IN}}{2}\right)^4\right]$$

$$I = .03605\text{ IN}^4$$

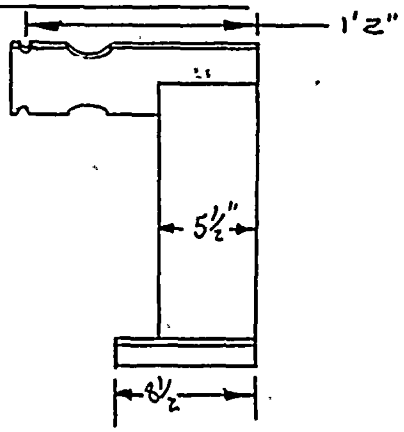
$$\sigma = \frac{(913.5\text{ IN lb})(1.181\text{ IN})}{.03605\text{ IN}^4} = 29,926\text{ lb/IN}^2$$

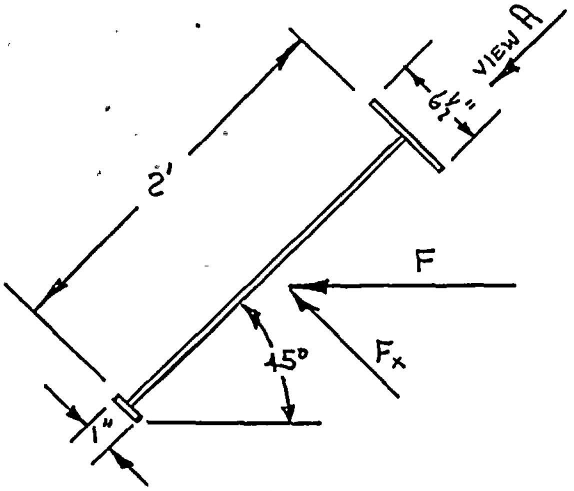
APPLYING A STRESS CONCENTRATION FACTOR AT THE THREADS OF 3.0;

$$\sigma = 3.0 \times 29,926\text{ lb/IN}^2 = 89,779\text{ lb/IN}^2$$

SINCE THIS STRESS IS GREATER THAN THE MAX. YIELD STRESS OF THE MATERIAL BY A FACTOR OF APPROXIMATELY 124%, THIS CONDUIT WOULD BEND AND POSSIBLY CAUSE FAILURE OF THE CABLE INSIDE.

JUNCTION BOX MOUNTING PLATE





AREA OF MOUNTING PLATE IN X-DIRECTION = 5.5" X 24" = 132 IN²

RANGE OF MOUNTING PLATE ≅ 9 FT, $P = 6.9\text{ lb/IN}^2$

FORCE IN X-DIRECTION = $F_x = PA \sin\phi = (6.9\text{ lb/IN}^2)(132\text{ IN}^2)(\sin 45^\circ) = 644.0\text{ lb}$

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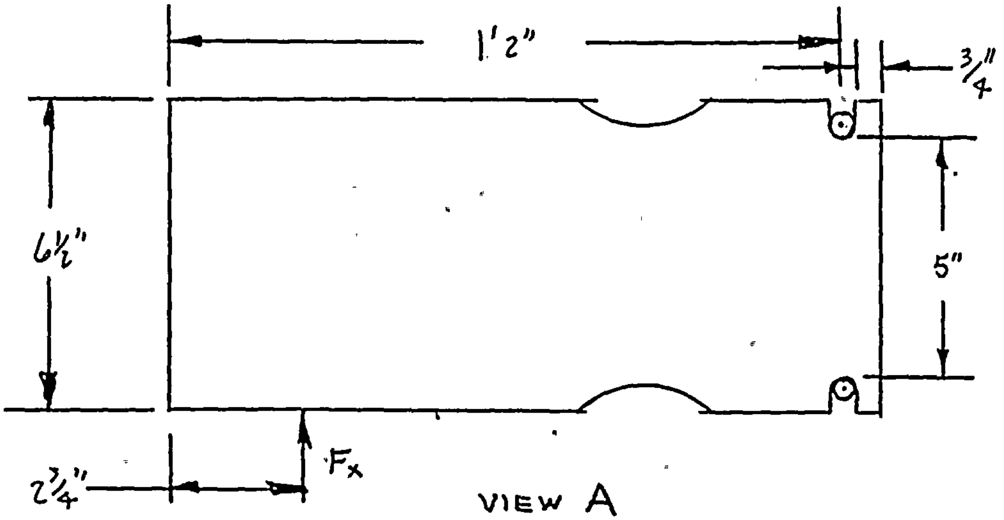
PROJECT JET IMPINGEMENT ON MSIV HARDWARE, CALC # M-MSS-006

ER No. 741058-003
Sht. No. 15 of 27X



VIEW A

THE BOTTOM ATTACHMENT FOR THE SWITCH PLATE CAN PROVIDE VERY LITTLE MOMENT RESISTANCE IN X DIRECTION. ∴ ASSUME ALL MOMENT IS ABSORBED BY TOP PLATE. MOMENT AT BOLT SLOT HOLES DUE TO FORCE F_x IS:

$$M_x = (F_x)(\text{LEVER ARM}) = (644 \text{ lb})(11.25 \text{ in}) = 7{,}245 \text{ in lb}$$

MOMENT DUE TO LARGE CONDUIT BOX FORCES IN X-DIRECTION IS:

$$M = (F)(\text{LEVER ARM})$$

where $F = 542$ lb (FROM SHEET 11)

LEVER ARM = 4.5 IN (FROM SHT. 12) + 14 IN (FROM SKETCH ABOVE)

= 18.5 IN

$$M = (542 \text{ lb})(18.5 \text{ in}) = 10{,}027. \text{ in lb}$$

$$\text{TOTAL MOMENT} = M_T = M_x + M = 7{,}245 \text{ in lb} + 10{,}027 \text{ in lb} = 17{,}272 \text{ in lb}$$

TWO BOLTS ≈ 5½" APART IN THE SLOTS SHOWN IN THE SKETCH ABOVE RESIST THIS MOMENT WITH A COUPLE WHICH GENERATES A FORCE WHICH TENDS TO OPEN THE SLOT ON THE SAME SIDE AS THE APPLIED FORCE.

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ER No. 741058-003
Sht. No. 16 of 27X

THIS FORCE IS $= \dfrac{M_T}{\text{DISTANCE BETWEEN CTRS.}} = \dfrac{17,272 \text{ in lb}}{5.5 \text{ in}} = 3,140 \text{ lb.}$ △1

THIS FORCE CREATES A SHEAR PLANE ACROSS THE EAR OF THE SLOT. THE PLATE IS 1/4" THCK BY 3/4" WIDE.

$$\text{SHEAR AREA} = \tfrac{1}{4}'' \times \tfrac{3}{4}'' = .1875 \text{ in}$$

FROM REF. 10, TABLE <u>XVII</u>, CASE 8, ASSUME STRESS CONCENTRATION FACTOR FOR BENDING AND SHEAR ARE THE SAME, $b/r \doteq 2$, & $r/d = .5$. THEN $k = 1.23$

$$\text{SHEAR STRESS} = \left(\frac{3,140 \text{ lb}}{.1875 \text{ in}}\right) 1.23 = 20,598 \text{ lb/in}^2 .$$ △1

FROM TABLE 3.8-8 OF FSAR, FOR ABNORMAL LOADS, ALLOWABLE SHEAR STRESS = 1/2 YIELD STRENGTH. PER TELECON WITH ATWOOD & MORRILL, MATERIAL IS A-515, GRADE 70. PER ASME B& PV CODE, SECT II, PART A, SPEC SA-515, YIELD STRENGTH IS 38,000 PSI.

$$\sigma_{\substack{\text{ALLOW}\\\text{SHEAR}}} = .5\,(38,000 \text{ lb/in}^2) = 19,000 \text{ lb/in}^2$$

SINCE THE ACTUAL SHEAR STRESS EXCEEDS THE ALLOWABLE, THE MOUNTING BRACKET WILL FAIL AT THE BOLT SLOTS. SUCH A FAILURE COULD INCAPACITATE THE CONTROL ROOM INDICATION CLOSED LIMIT SWITCH.

FOR SMALL CONDUIT BOX SIDE:

$$M = (203 \text{ lb})(18.5 \text{ in}) = 3,756 \text{ lb in.}$$

$$\text{TOTAL MOMENT} = M_x + M = 7,245 \text{ lb in} + 3,756 \text{ lb in} = 11,001 \text{ in lb}$$

$$\text{SHEAR FORCE} = \frac{11,001 \text{ in lb}}{5.5 \text{ in}} = 2,000 \text{ lb}$$ △1

$$\text{SHEAR STRESS} = \left(\frac{2,000 \text{ lb}}{.1875 \text{ in}^2}\right) 1.23 = 13,120 \text{ lb/in}^2$$

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ER No.
Sht. No. 17 of 27X

THIS STRESS DOES NOT EXCEED THE ALLOWABLE. THE MOUNTING BRACKET WILL NOT FAIL.

LIMIT SWITCHES

ALL LIMIT SWITCHES ARE MOUNTED IN SUCH A MANNER AS TO BE SHADOWED. BY OTHER HARDWARE OR OTHERWISE PROTECTED FROM THE DIRECT JET EFFECTS. HOWEVER, IN THE CASE OF THE "A" & "B" VALVES THE BENDING MOMENT APPLIED BY THE BLAST ON THE SMALL JUNCTION BOX MAY CREATE EXCESSIVE STRESSES IN THE ATTACHMENTS FOR THE SWITCH (4 MACHINE SCREWS).

FROM SHEET 13, TOTAL FORCE ON LIMIT SWITCH FROM SMALL JUNCTION BOX IS 203 lb. ATTACHMENT 4 SHOWS THE DIMENSIONS FOR THE W MOUNTING 2NO-2NC SWITCH USED. USING THESE DIMENSIONS, THE DISTANCE FROM THE CENTER OF FORCE TO THE PIVOT POINT IS : (4.5 IN FROM CENTER OF AREA TO SWITCH.)

$4.5\,in + 7.06\,in - .41\,in - .66\,in - .53\,in + .28\,in = 10.24\,in$

DISTANCE FROM CENTER OF FORCE TO SCREWS NEAREST BOX IS:

$4.5\,in + 7.06\,in - .41\,in - .66\,in - .53\,in - 4.38\,in = 5.58$

FORCE AT SCREWS NEAREST BOX IS $= \frac{10.24\,in}{5.58\,in}(203\ lb) = 373\ lb$

ASSUME EACH SCREW HOLDS HALF THE LOAD. THEN LOAD PER SCREW IS:

$$L = \frac{373\ lb}{2} = 187\ lb$$

LIMIT SWITCHES ARE MOUNTED WITH 1/4" MACHINE SCREWS (SEE ATTACHMENT 4).

FROM REF 11, SECT. 2.7, MINIMUM TENSILE STRENGTH OF MACHINE SCREW MATERIALS IS 60,000 PSI

FROM REF 12, TABLE 1.5.2.1, ALLOWABLE STRESSES ON FASTENERS, FOR MACHINE SCREWS THE ALLOWABLE STRESS IS .33 TIMES TENSILE STRENGTH BASED ON "STRESS AREA". FOR MACHINE SCREWS THE ALLOWABLE

$$\sigma_{ALLOW} = .33\,(60{,}000\ PSI) = 20{,}000\ PSI$$

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Designed by
Approved by

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CALCULATION SHEET

PROJECT CALC # M-MSS-006

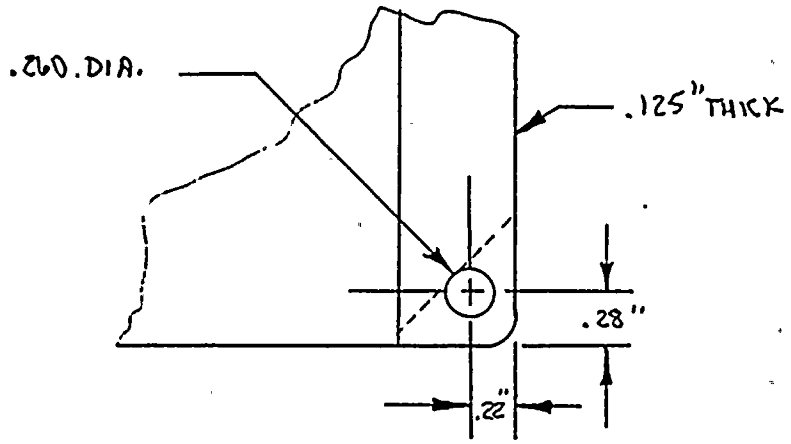
ER No.
Sht. No. 18 of 27X

FROM TABLE 1, PAGE 8-14, REF 9, FOR 1/4" UNC FASTENER, THE "STRESS AREA" IS .0317 IN².

$$\therefore \text{STRESS} = \frac{187 \text{ lb}}{.0317 \text{ in}^2} = 5{,}899 \text{ lb/in}^2$$

SINCE THIS IS LESS THAN THE ALLOWABLE, THE SCREWS WILL NOT FAIL.

LOOK AT STRESS ACROSS THE CORNER OF THE SWITCH AT THE MOUNTING HOLE.



WITH SCREW PULLED DOWN TO PROPER TIGHTNESS, ASSUME FAILURE WOULD OCCUR IN SHEAR ACROSS THE PLANE DEFINED BY THE DASHED LINE. LENGTH OF THIS LINE IS 15/16 IN.

$$\text{SHEAR AREA} = (15/16")(.125 \text{ in}) = .11719 \text{ in}^2$$

LOAD FROM PAGE 17 IS 187 lb

$$\text{STRESS} = \frac{187 \text{ lb}}{.11719 \text{ in}^2} = 1596 \text{ lb/in}^2$$

THIS STRESS IS LOWER THAN STRENGTH OF ANY MATERIAL THAT MIGHT BE USED. THEREFORE, FAILURE IN THIS MODE WOULD NOT OCCUR.

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Date 5/24 1985
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CALCULATION SHEET

PROJECT CALC # M-MSS-006

ER No. ________

Sht. No. 19 of 27X

HYDRAULIC SPEED CONTROL HARDWARE

THE HYDRAULIC SPEED CONTROL HARDWARE IS MOUNTED ON THE BACK SIDE OF THE OPERATOR WHERE IT IS SHADOWED BY THE OPERATOR FOR VALVES A & D AND PARTIALLY SHADOWED ON VALVES B & C. VALVE C HAS THE MAX. EXPOSED AREA.

a) APPROXIMATE AREA OF EXPOSED TUBING = (.75" DIA) (14" LENGTH) = 10.5 IN^2

b) APPROXIMATE AREA OF ACCUMULATOR = (1.5" DIA)(4" LENGTH) = 6 IN^2

c) APPROXIMATE AREA OF FLOW CONTROL VALVE = (2")(3") = 6 IN^2

d) TOTAL AREA OF CYLINDRICAL TARGETS = a) + b) = 10.5 IN^2 + 6 IN^2 = 16.5 IN^2

EFFECTIVE TARGET AREA, CYLINDRICAL TARGETS = (AREA)($\sin \phi$)(K_ϕ)

FROM SHEET 8, K_ϕ = .6. HARDWARE IS AT 45° TO THE VERTICAL PLANE PERPENDICULAR TO THE VALVE ℄. THE JET BLAST IS AT 45° TO THE VERTICAL PLANE THROUGH THE VALVE ℄. THE RESULTANT ANGLE OF INCIDENCE OF THE JET TO THE HARDWARE IS 67.5°.

EFFECTIVE CYLINDER TARGET AREA = (16.5 IN^2)(SIN 67.5°)(.6) = 9.15 IN^2

EFFECTIVE AREA, FLOW CONTROL VALVE = (6 IN^2)(SIN 67.5°) = 5.54 IN^2

TOTAL EFFECTIVE AREA = 9.15 IN^2 + 5.54 IN^2 = 14.69 IN^2

RANGE TO HYDRAULIC HARDWARE TARGETS ≈ 12 FT, P_T = ~~4.9~~ 5.2 lb/in^2 △1

FORCE ON TARGET = P × A = (~~4.9~~ 5.2 lb/in^2)(14.69 in^2) = ~~72.0~~ 76.4 lb

BY INSPECTION, THE POINT OF MAXIMUM STRESS DUE TO THIS FORCE WOULD BE AT THE CONNECTIONS TO THE HYDRAULIC CYLINDER - THIS IS THE POINT OF MAXIMUM BENDING MOMENT. ASSUME LOAD IS EVENLY DISTRIBUTED TO THE TWO END CONNECTIONS. THE DISTANCE FROM THE LOAD APPLICATION POINT TO THE CONNECTION POINT IS APPROXIMATELY 8 IN.

∴ MOMENT AT EACH CONNECTION = ($\frac{\cancel{72.0}\ 76.4}{2}$ lb)(8 in) = ~~288~~ 306 IN lb △1

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Cat. #973401

Dept.
Date 5/24/ 1985
Designed by DPloeratt

Approved by

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CALCULATION SHEET

PROJECT CALC # M-MSS-006

ER No.

Sht. No. 20 of 27 X

PIPE IS 1/4", ASSUME SCH 80, O.D. = 1.05", I.D. = .742 IN. ASSUME THREAD DEPTH 1/2 WALL THICKNESS FOR SCH 40. RESULTANT EFFECTIVE O.D. = .937 IN. FROM REF. 13, STRESS CONCENTRATION FACTOR FOR THREADED PIPE IS 2.3

MOMENT OF INERTIA, $I = .25\pi\left[r_o^4 - r_i^4\right]$

$$C = .937\ \text{IN}$$

BENDING STRESS, $\sigma = \frac{MC}{I} \times K$

$$\sigma = \left(\frac{(\overset{306}{\cancel{288}}\ \text{in lb})(.937\ \text{in})}{.25\pi\left[\left(\frac{.937\ \text{in}}{2}\right)^4 - \left(\frac{.742\ \text{in}}{2}\right)^4\right]}\right) \times (2.3)$$

$$\sigma = \overset{28,724}{\cancel{27,034}}\ \text{lb/in}^2$$

FROM ASME B&PV CODE, SECT II, PART A, FOR ASTM A 106, GR C MATERIAL WHICH THIS PIPE IS PER REF 8, YIELD STRENGTH IS 40,000 PSI. SINCE THE BENDING STRESS IS LESS, NO YIELDING WILL OCCURE.

I-BEAM IN FRONT OF OPERATOR

THIS PORTION OF CALCULATION TO BE PERFORMED BY CIVIL GROUP.

RANGE IS ≈ 9 FT, $P_T = 6.9\ \text{lb/in}^2$

FROM TABLE D-1, REF. 5, FOR A "SEMITUBLAR" SHAPE WHICH THE SHAPE OF THE I-BEAM APPROXIMATES IN THE WEAK AXIS, THE DRAG COEFFICIENT IS 2.3. PER EQUATION D-6 THE SHAPE FACTOR

$$K_\phi = \tfrac{1}{2} C_D = .5(2.3) = 1.15$$

APPLYING THIS TO THE PRESSURE TO GET THE EFFECTIVE PRESSURE YIELDS:

$$P_{T_{eff}} = (6.9\ \text{lb/in}^2)(1.15) = 7.9\ \text{lb/in}^2$$

THIS VALUE IS SUPPLIED TO CIVIL FOR THEIR CALCULATION.

SHEET 21 OF [illegible] X
ATTACHMENT 1
CALC # M-MSS-006

Date 5/14/85

TELEPHONE CALL

Subject ANALYSIS OF RECIRC. LINE BREAK Route

Caller DON PREVATTE of PP&L

To HANS GIESECKE of MPR ASSOCIATES

File No. 922-60

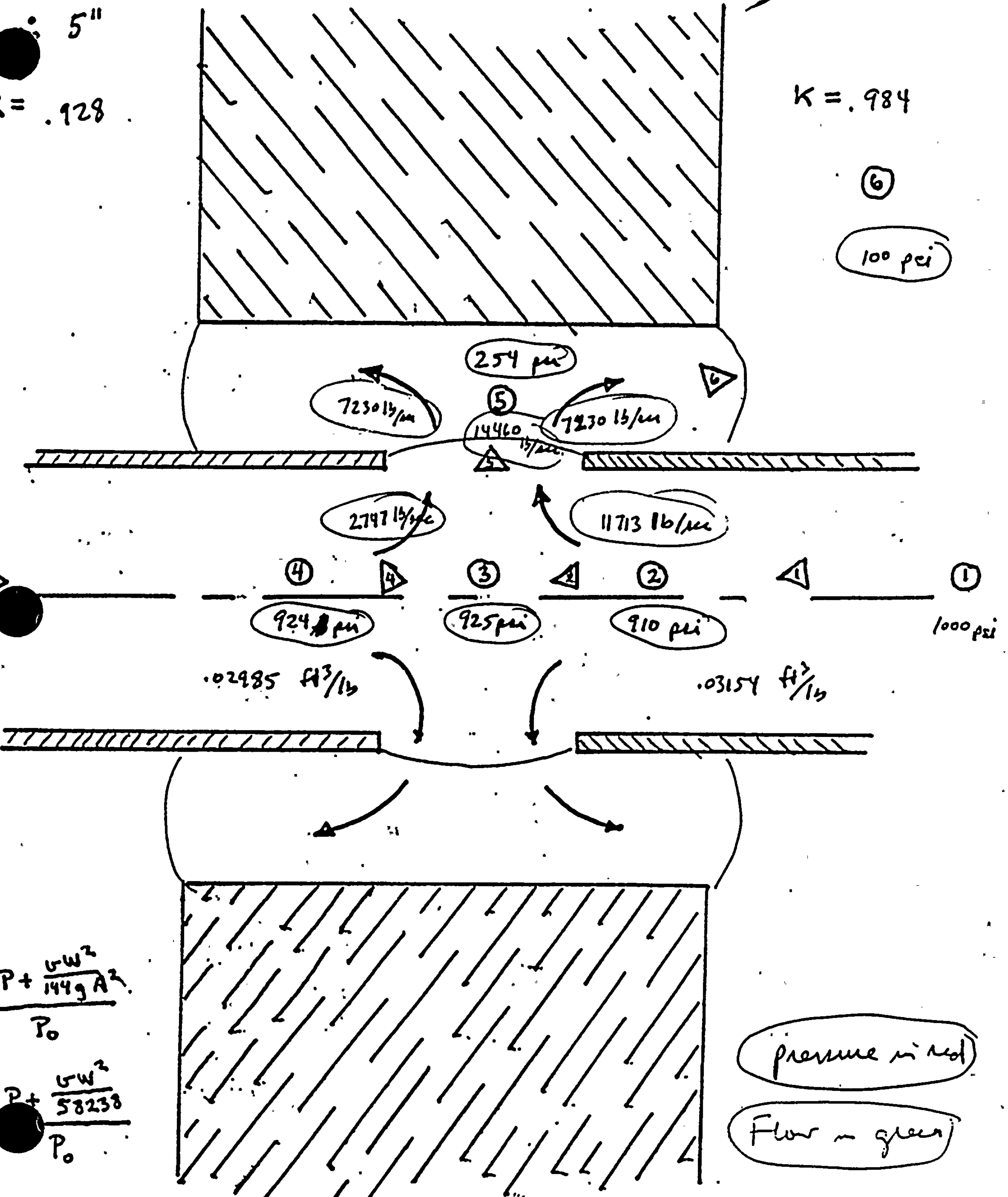
CALL WAS MADE TO HANS TO DETERMINE THE RESULTS OF THE MPR CALCULATION PERFORMED ON THE FLOWS FROM A POSTULATED 28" RECIRC. LINE BREAK. THE ATTACHED SKETCHES DESCRIBE THE GIST OF THE CONVERSATION AND THE RESULTS OF THE CALCULATION.

Don Prevatte

Case: Homogeneous - Dual Flow

5''

K = .928

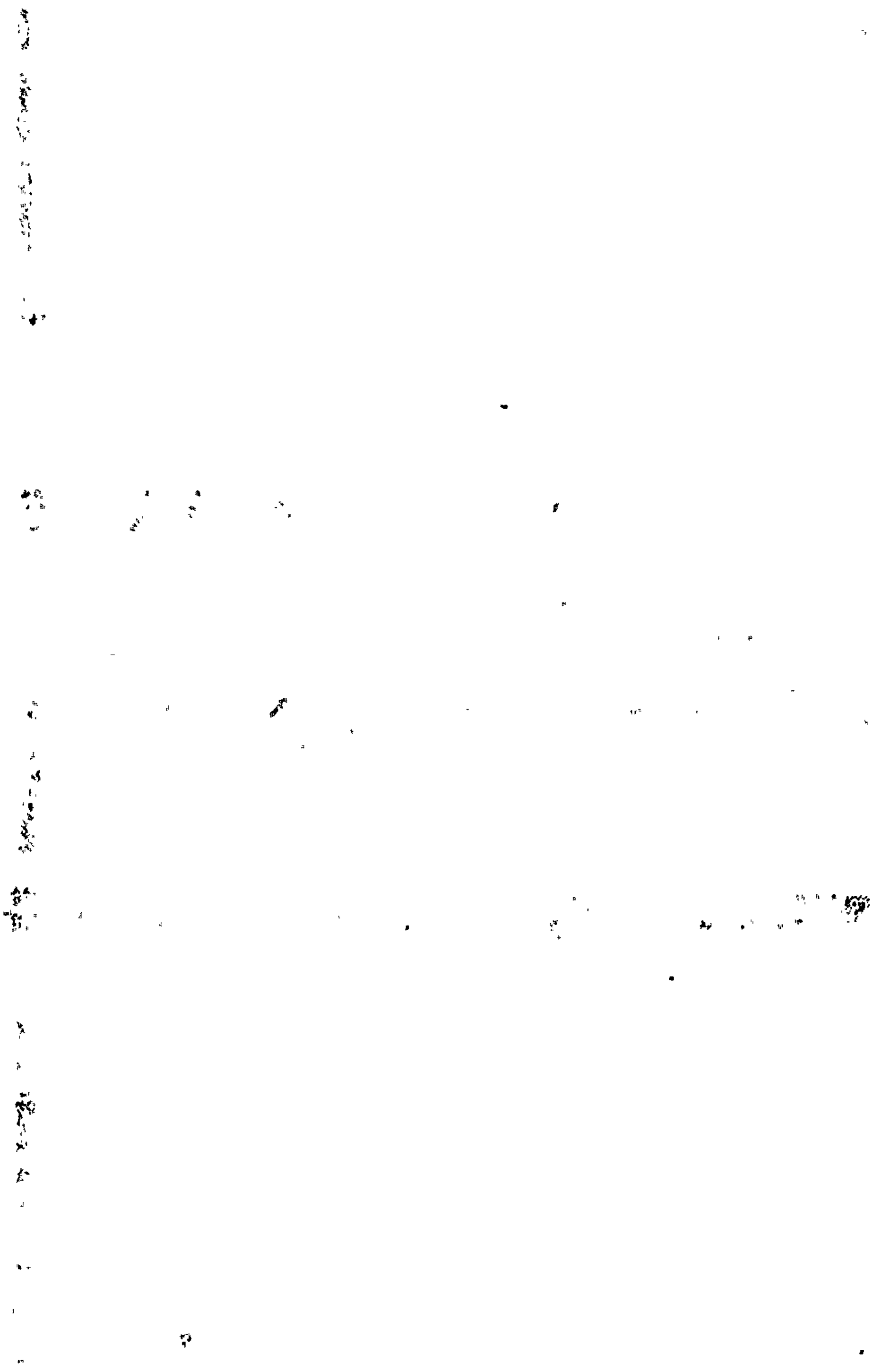


$$= \frac{P + \frac{vW^2}{144 g A^2}}{P_o}$$

$$\frac{P + \frac{vW^2}{58238}}{P_o}$$

pressure in red

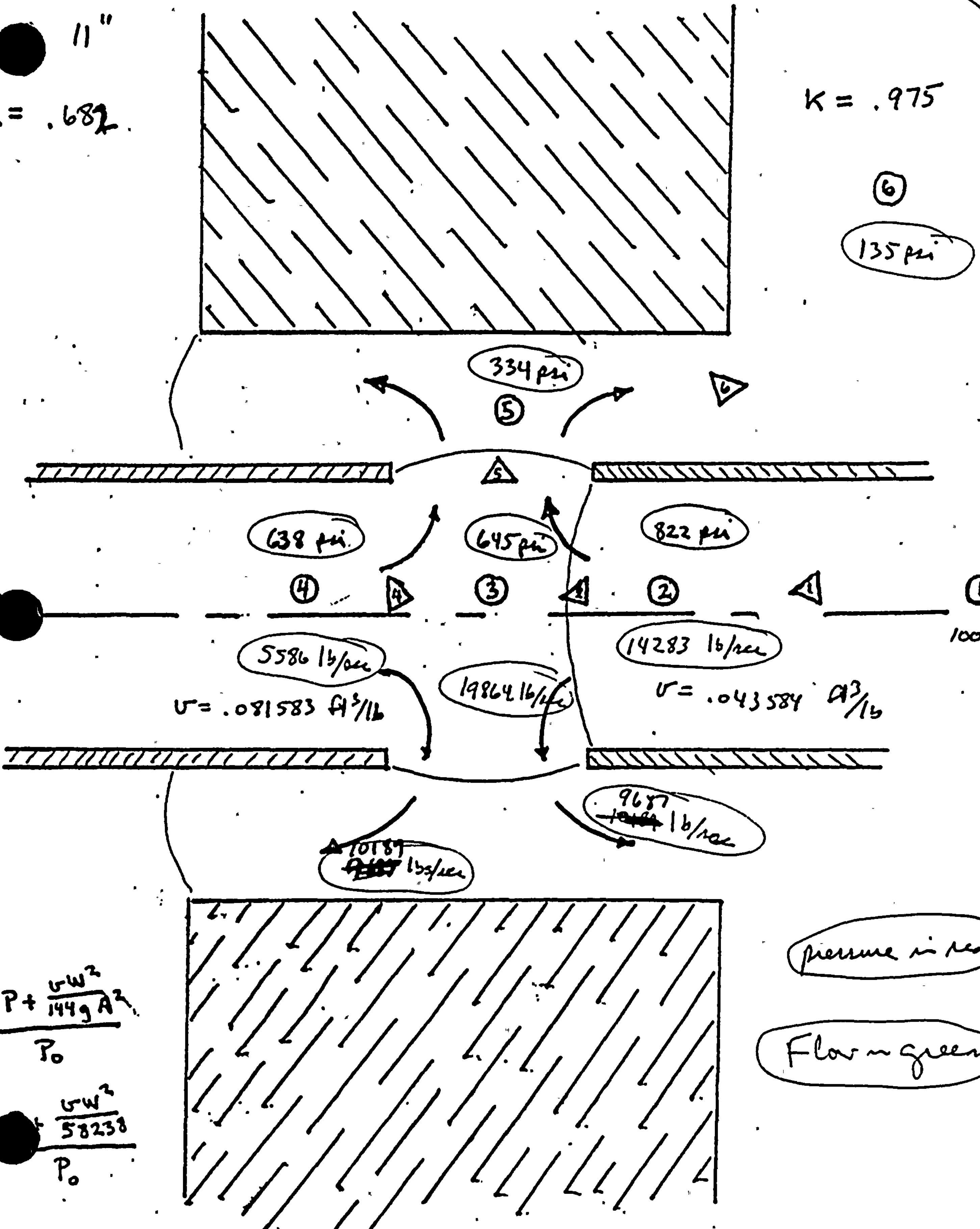
Flow in green



ase: Homogeneous - Dual Flow

11"

K = .682



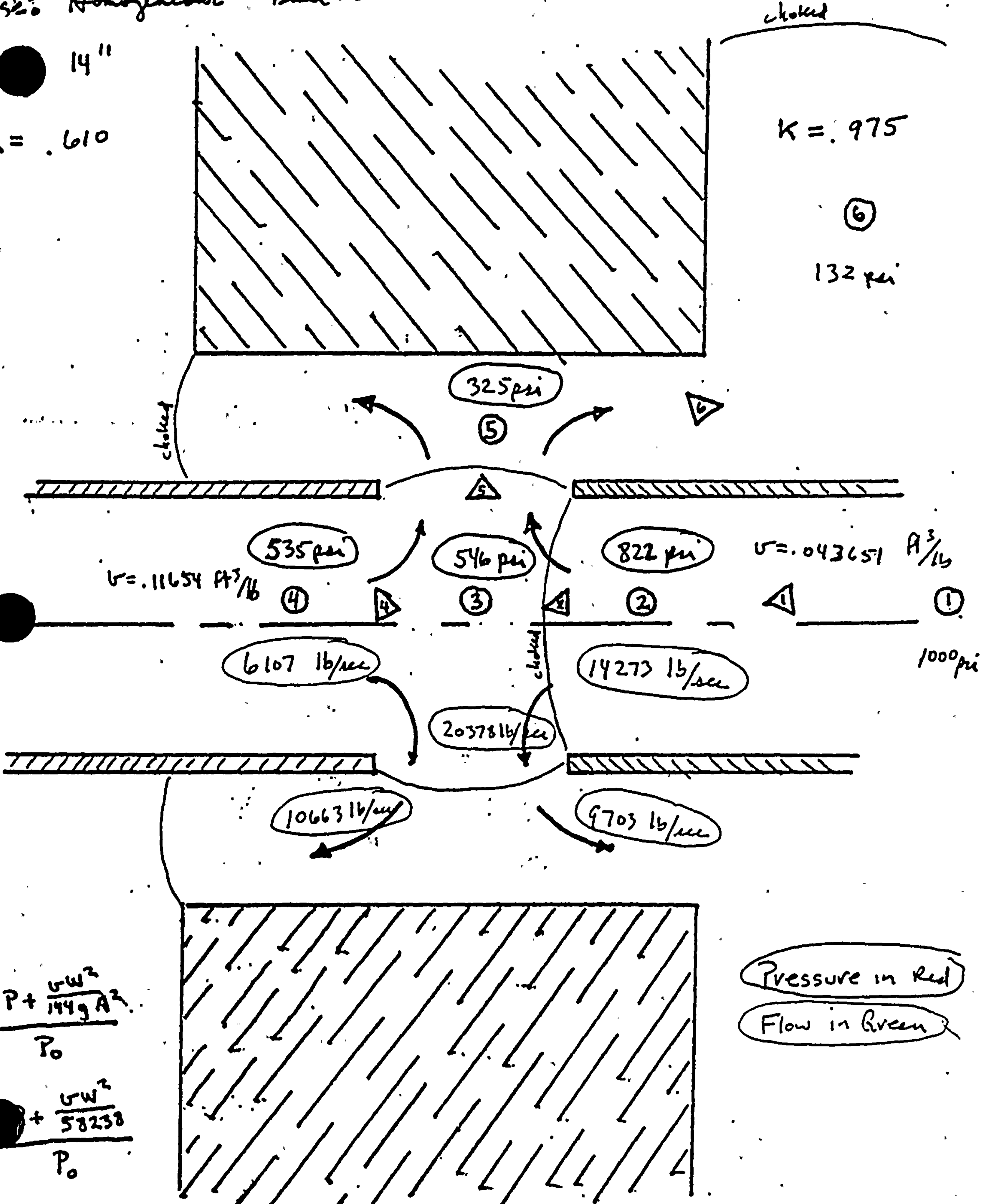
pressure in red

Flow in green

$$= \frac{P + \frac{vW^2}{144 g A^2}}{P_0}$$

$$= \frac{+ \frac{vW^2}{58238}}{P_0}$$

ase 2 Homogeneous - Dual Flow



$$K = \frac{P + \frac{vW^2}{144 g A^2}}{P_0}$$

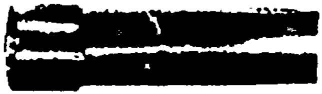
$$K = \frac{P + \frac{vW^2}{58238}}{P_0}$$

Pressure in Red

Flow in Green

SHEET 25 OF 27X ATTACHMENT 2
CALC. # M-MSS-006

RIGID STEEL CONDUIT



Steelduct hot dip galvanizing offers the protection of a uniformly heavy coating of zinc on both the inside and outside surfaces of the conduit. This coating will not chip or flake under the most severe bending conditions.

Our galvanized threads and improved thread protectors assure fast smooth coupling run-up and lower installation costs. Steelduct Black Enameled Conduit is coated inside and outside with a tough, elastic, baked on enamel that will withstand severe bending.

WEIGHTS AND DIMENSIONS

Nom. Size Inches	Wght. Per C Ft.	Diameters External Inches	Diameters Internal Inches	Wall Thick.	Length w/o Cplg. (Ft.& In.)
1/2	79	.840	.622	.109	9-11-1/4
3/4	105	1.050	.824	.113	9-11-1/4
1	153	1.315	1.049	.133	9-11
1-1/4	201	1.660	1.380	.140	9-11
1-1/2	249	1.900	1.610	.145	9-11
2	329	2.375	2.067	.154	9-11
2-1/2	527	2.875	2.469	.203	9-10-1/2
3	690	3.500	3.068	.216	9-10-1/2
3-1/2	831	4.000	3.548	.226	9-10-1/4
4	982	4.500	4.026	.237	9-10-1/4
5	1316	5.563	5.047	.258	9-10
6	1770	6.625	6.065	.280	9-10

ELBOWS AND COUPLINGS

Nom. Size Inches	Cplgs. Wght. Per C in Lbs.	Standard 90° Elbows Wght. Per C in Lbs.	Radius Inches	Offset Inches
1/2	12	75	4.000	7.312
3/4	17	111	4.500	6.312
1	30	165	5.750	9.375
1-1/4	37	250	7.250	12.000
1-1/2	52	420	8.250	13.625
2	68	671	9.500	15.000
2-1/2	148	1154	10.500	17.625
3	203	1807	13.000	21.375
3-1/2	260	2153	15.000	24.625
4	280	3173	16.000	27.437
5	750	7259	24.000	37.437
6	975	12247	30.000	45.312

RIGID CONDUIT NIPPLES

Available in hot dipped galvanized or electro-galvanized.

Also available in black enameled.
Special large radius elbows available.

LENGTH OF NIPPLES

Nom. Size Inches	Close Length (In.)	Close	1½"	2"	3"	4"	5"	6"	8"
		Approx. Weight per 100 pcs. (lbs.)							
1/2	1-1/8	6	12	13	19	24	31	40	54
3/4	1-3/8	9	14	17	26	35	43	52	73
1	1-1/2	16	22	28	35	43	64	78	109
1-1/4	1-5/8	22	32	37	47	65	85	100	135
1-1/2	1-3/4	28	35	45	56	80	103	122	170
2	2	44		55	73	103	132	160	220
2-1/2	2-1/2	84			100	150	192	240	310
3	2-5/8	118			170	200	260	300	411
3-1/2	2-3/4	140				245	270	312	510
4	2-7/8	160				265	318	344	600
5	3	240					485	600	815
6	3-1/4	350					650	850	1125

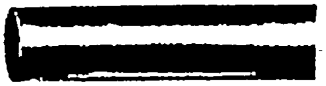
RUNNING THREAD

TYPE "B" - 3' LENGTHS

Pipe Size	Lgths. Per Ctn.	Approx. Wt. Lbs. 100 Ft.
1/8"	34	15
1/4"	28	25
3/8"	24	35
1/2"	20	61
3/4"	16	76
1"	10	110
1-1/4"	12	160
1-1/2"	10	200
2"	8	260
2-1/2"	4	430
3"	3	530
3-1/2"	3	600
4"	2	830
5"	1	1060
6"	1	1440

CROWDER

ELECTRICAL METALLIC TUBING



Steelduct Electrical Metallic Tubing is high quality tubing manufactured for the electrical industry. It is cut into ten foot lengths before it is Electro Galvanized. The inside of the tubing is protected with a baked on silvery lacquer, the best for easy wire pulling.

WEIGHTS AND DIMENSIONS

Nom. Size Inches	Wgt. per 1000 Ft. Pounds	Diameter Interior Inches	Diameter Exterior Inches	Wall Thick. Inches	No. Of Ft. To A Bdl.
3/8	250	.493	.577	.042	200
1/2	300	.622	.706	.042	100
3/4	470	.824	.922	.049	100
1	680	1.049	1.163	.057	100
1-1/4	1000	1.380	1.510	.065	50
1-1/2	1140	1.610	1.740	.065	50
2	1470	2.067	2.197	.065	30
2-1/2	2200	2.731	2.875	.072	10
3	2700	3.356	3.500	.072	10
4	4000	4.334	4.500	.083	10

E. M. T. ELBOWS

Elbow Size Ins.	Wgt. Per C Elbows Pounds 45°	90°	Radius To Center Line 45	Ins.	90	Offset 45	90
1	52.31	84	5.000		5.750	[illegible]	7.312
1-1/4	112.50	143	5.500		7.375	[illegible]	9.375
1-1/2	131.50	193	6.875		8.625	[illegible]	10.625
2	221.50	290	7.000		9.500	[illegible]	12.375
2-1/2	410.0	540		10-1/2		8.0625	17.500
3	520.0	750		13		[illegible]	20.500
4	1240.0	1410		16		11.0250	23.000

COUPLINGS AND CONNECTORS

Trade Size	Item	Wgt. Per C Pcs.	Nominal Outside Dia.	Nom. Lgth.
2-1/2	Coupling	163 lbs.	3"	3"
2-1/2	Connector	244 lbs.	3-1/16"	1"
3	Coupling	216 lbs.	3-21/32"	3"
3	Connector	300 lbs.	3-27/32"	1-1/2"
4	Coupling	328 lbs.	4-11/16"	3"
4	Connector	494 lbs.	4-27/32"	1-1/2"

LIQUID-TIGHT FLEXIBLE STEEL CONDUIT

U.L. & C.S.A. LABELED

DESCRIPTION: Liquid-tight cover made of polyvinyl chloride synthetic resin. Flexible galvanized steel core with a copper wire positive ground. Sizes 3/8" 1/2", and 3/4" feature extra-heavy cores with square locked construction. Sizes 1" and 1-1/2" have fully interlocked galvanized steel core construction. U. L. Approved for positive protection for electrical wiring in wet or damp areas.

SPECIFICATIONS

Trade Size Inches	Inside Diameter In Inches Min.	Max.	External Dia. Over Jacket (Inch) Min.	Max.	Est. Wght. (lbs) Per C Ft.	Feet Per Std. Coil
3/8	0.484	0.504	0.690	0.710	30	200
1/2	0.620	0.640	0.820	0.840	36	200
3/4	0.820	0.840	1.030	1.050	48	150
1	1.041	1.066	1.290	1.315	87	100
1-1/4	1.380	1.410	1.630	1.660	116	50

J.I.C. APPROVED SEALED SKIN

DESCRIPTION: Flexible galvanized steel core made from continuous strip metal to give lasting mechanical protection. The sturdy flexible core is covered with a water tight hide of tough, durable, polyvinyl chloride with special qualities for added protection. Made to meet Joint Industry Conference (J.I.C.) requirements. Packaged in a handy "play-out" carton.

SPECIFICATIONS

Trade Size Ins.	Inside Diameter Min.	Max.	Outside Diameter Min.	Max.	Appr. Inside Bend Diam.	Est. Wght. (lbs) Per C Ft.	Feet Per Std. Coil
3/8"	.485	.505	.690	.710	5	24.0	250'
1/2"	.620	.640	.820	.840	6	29.0	200'
3/4"	.815	.835	1.030	1.050	9	39.5	175'
1"	1.030	1.056	1.290	1.315	10	67.5	100'
1-1/4"	1.370	1.396	1.630	1.666	13	87.0	100'
1-1/2"	1.575	1.600	1.875	1.900	15	117.0	50'
2"	2.020	2.045	2.350	2.375	17	145.0	50'
2-1/2"	2.480	2.506	2.860	2.875	20	198.0	50'
3"	3.070	3.095	3.470	3.500	27	282.0	20'
4"	4.000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

RIGID ALUMINUM CONDUIT

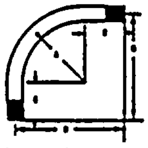
A combination of light weight and high strength supplied in 10' lengths. Alloy, 6063 Aluminum T-1 temper. Aluminum conduit resists most corrosive atmospheres and industrial environments that usually attack other types of metallic conduit. Aluminum is non-sparking and non-magnetic.

WEIGHTS AND DIMENSIONS

Trade Size Inches	Nominal Dimensions Outside Diameter Inches	Nominal Dimensions Inside Diameter Inches	Nominal Wgt. Lbs. Per C Ft. Including Coupling	Standard Packing Ft. Per Bundle
1/2	.840	.622	25.8	100
3/4	1.050	.824	39.8	100
1	1.315	1.049	58.9	100
1-1/4	1.660	1.380	79.8	50
1-1/2	1.900	1.610	95.6	50
2	2.375	2.067	128.8	50
2-1/2	2.875	2.469	204.7	50
3	3.500	3.068	268.0	50
3-1/2	4.000	3.548	321.3	50
4	4.500	4.026	382.1	50
5	5.563	5.047	527.5	30
6	6.625	6.065	677.5	30

RIGID ALUMINUM 90° ELBOWS

Trade Size Inches	A Ins.	B Ins.	C Ins.	Nom. Wt/Pr. C Pc. In Lb.
1/2	4.00	6.250	2.250	25
3/4	4.50	7.250	2.750	43
1	5.75	8.625	2.875	71
1-1/4	7.25	10.250	3.000	110
1-1/2	8.25	11.625	3.375	153
2	9.50	13.780	4.280	249
2-1/2	10.50	15.250	4.750	437
3	13.00	19.000	6.000	767
3-1/2	15.00	21.800	6.800	1036
4	16.00	23.500	7.500	1228
5	24.00	34.310	10.310	2490
6	30.00	41.440	11.440	3350



Standard 90° Elbow Dimensions

RIGID ALUMINUM COUPLINGS

Trade Size Inches	O.D. In Inches	Length In Inches	Nominal Wt. Per 100 Pcs. In Lbs.
1/2	1-5/64	1.56	6.1
3/4	1-21/64	1.62	9.1
1	1-9/16	2.00	12.5
1-1/4	1-61/64	2.06	18.9
1-1/2	2-7/32	2.06	23.3
2	2-3/4	2.12	34.6
2-1/2	3-9/32	3.12	68.3
3	3-15/16	3.25	91.4
3-1/2	4-7/16	3.37	108.0
4	5	3.50	142.0
5	6-7/32	3.75	241.9
6	7-5/16	4.00	321.0

GALVANIZED STEEL FLEXIBLE CONDUIT

U.L. & C.S.A. LABELED

DESCRIPTION: Made to U.L. and C.S.A. specifications in a complete range of sizes. Special zinc coating (above the specifications) gives longer rust resistance--greater protective qualities. International Metal Hose Co.'s specially designed, late model equipment perfectly forms the metal for correct flexibility.

SPECIFICATIONS

* Trade Size of Conduit in Ins.	Minimum Wgt. Of C Ft. of Conduit in Lbs.	External Dia. of Conduit in Ins. Min.	Max.	Radius Of Cylindrical Test Surface in Ins.	Appr. Feet Per Std. Coil
5/16"	15.0	0.470	0.510	1-3/4"	250'
3/8"	25.5	0.560	0.610	2"	250'
1/2"	47.0	0.860	0.920	3"	100'
3/4"	59.5	1.046	1.105	4"	100'
1"	102.0	1.300	1.380	5"	50'
1-1/4"	129.0	1.550	1.630	6-1/4"	50'
1-1/2"	162.5	1.850	1.930	7-1/2"	25'
2"	212.5	2.350	2.450	10"	25'
2-1/2"	263.0	2.960	3.060	12-1/2"	25'
3"	313.0	3.460	3.560	15"	25'
3-1/2"	363.0	3.860	4.060	17-1/2"	25'
4"	413.5	4.360	4.560	20"	25'

*Fits regular armored cable or flexible conduit connectors.

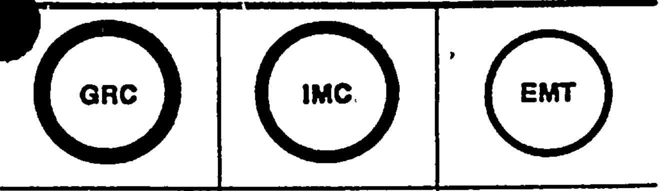
Also available:
flexible aluminum

SHEET 26 OF 27 ATTACHMENT 3
CALC # M-MSS-006

(312) 339-1610 IMC INFORMATION OPER.

How Allied IMC compares

Dimension comparison (nominal) of 3/4" trade sizes



GRC	IMC	EMT
O.D. 1.050"	O.D. 1.029"	O.D. 0.922"
I.D. 0.824"	I.D. 0.863"	I.D. 0.824"
Wall 0.113"	Wall 0.083"	Wall 0.049"

Weight comparison of trade sizes
Approximate Lbs. per 100 Ft.

Trade Size	GRC W/Coupling	IMC W/Coupling*	E.M.T.
1/2"	79	60	28
3/4"	105	82	43
1"	153	116	64
1-1/4"	201	150	95
1-1/2"	249	182	110
2"	332	242	140
2-1/2"	527	401	205
3"	683	493	250
2"	831	573	325
	972	638	370

*Weight specifications are for comparative purposes only. They are not a requirement of U.L. 1242.

A Strength Comparison

The results of the various beam strength and deflection tests, which follow later in this brochure, may create questions as to how this relative strength of IMC is achieved.

Allied's method of manufacture increases the average tensile strength of IMC to such an extent that its wall strength is over 50% greater per unit of thickness than that of representative samples of GRC measured by Allied.

The wall strength characteristics are functions of both the yield strength of the material and the section modulus. The accompanying table gives a comparison of IMC and GRC for various trade sizes.

Comparison of Maximum Moments IMC Vs. GRC Calculated from Section Moduli & Yield Strengths

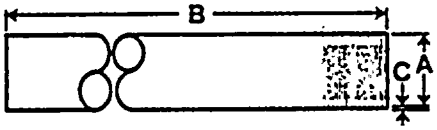
Trade Size	IMC	GRC
1/2"	1905	1424
3/4"	3432	2763
1"	6130	4405
1-1/4"	10423	8915
1-1/2"	14574	12070
2"	24660	19622
2-1/2"	47044	37241
3"	63085	60343
3-1/2"	83641	83785
4"	103000	112507

Average Yield Strengths

GRC 35,000— 40,000 psi: All sizes

IMC 55,000— 60,000 psi: 3" and under sizes
IMC 50,000— 52,000 psi: over 3" sizes

Allied IMC Dimensions



Trade Size (in)	A *Nominal Outside Diameter (in)	A *Nominal Outside Diameter (mm)	B Length of Finished Conduit Without Coupling (ft and in)	B Length of Finished Conduit Without Coupling (meters)	C **Wall Thickness (in)	C **Wall Thickness (mm)
1/2"	0.815	20.7	9' 11-1/4"	3.03	0.070	1.8
3/4"	1.029	26.1	9' 11-1/4"	3.03	0.075	1.9
1"	1.290	32.8	9' 11"	3.02	0.085	2.2
1-1/4"	1.638	41.6	9' 11"	3.02	0.085	2.2
1-1/2"	1.883	47.8	9' 11"	3.02	0.090	2.3
2"	2.360	59.9	9' 11"	3.02	0.095	2.4
2-1/2"	2.857	72.6	9' 10-1/2"	3.01	0.130	3.3
3"	3.476	88.3	9' 10-1/2"	3.01	0.130	3.3
3-1/2"	3.971	100.9	9' 10-1/4"	3.00	0.130	3.3
4"	4.466	113.4	9' 10-1/4"	3.00	0.130	3.3

side diameter tolerances:
005 in (.13 mm) for trade sizes 1/2" and 3/4".
±.0075 in (.19 mm) for trade sizes 1-1/4" through 2".
±.010 in (.25 mm) for trade sizes 2-1/2" through 4".

**Wall thickness tolerance is +.015 in (.38 mm) and −.000 for IMC 1/2" through 2" and +.020 in (.51 mm) and −.000 for IMC 2-1/2" through 4". There is no specific wall thickness or tolerance for rigid conduit.

SHEET 27 OF 27X ATTACHMENT 4
CALC # M-MSS-006

Series EA700
Snap-Lock® Limit Switches

Specifications

1. Enclosure is water, oil and dust tight.
2. Enclosure meets NEMA Type 1, 4 and 13 requirements.
3. Contacts made of silver alloy. Contact shifting mechanism is locked in position by the latches until switch lever is actuated.
4. Standard Temperature Range: —20°C TO +90°C
5. Operating lever is adjustable to any required position.
6. Operating Lever Angles (travel either clockwise or counterclockwise) maximum degrees of trip travel, reset travel, as well as total lever travel, are determined by the cam selected.
7. Operating Torques — Trip Torque varies from 15 to 33 in. lbs. depending on switch size and cam selected.
8. Underwriters' Laboratories, Inc. Listed. File No. E12967. (Except neutral position module)
9. Current ratings:

Voltage		For Neutral Position Only
125V-A.C.	20.0 Amps*	10.0 Amps*
250V-A.C.	15.0 Amps*	7.5 Amps*
480V-A.C.	10.0 Amps*	5.0 Amps*
600V-A.C.	5.0 Amps*	2.5 Amps*
125V-D.C.	5.0 Amps	2.5 Amps
250V-D.C.	1.5 Amps	.75 Amps

*75-100% Power Factor.

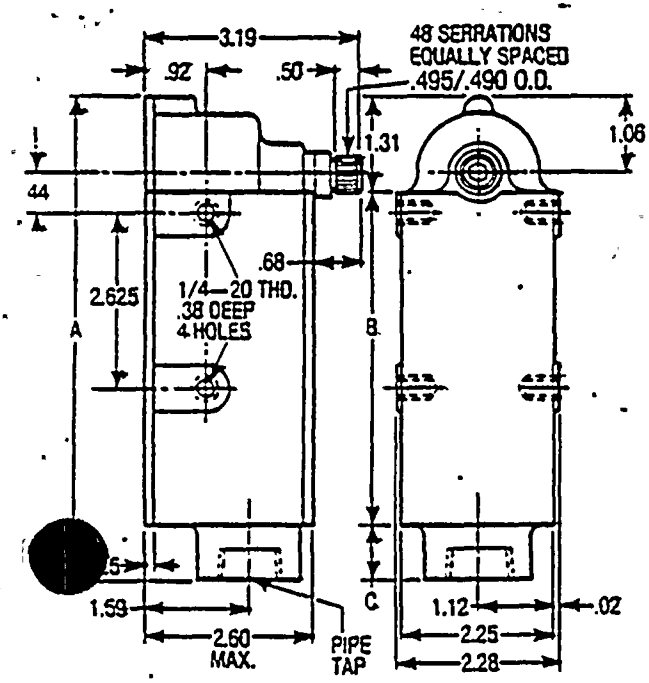
For Marine or Off-Shore Requirements, See EA780, EA790 Series.
For Hazardous Location Requirements, See EA800 Series.

Mounting Styles and Dimensions

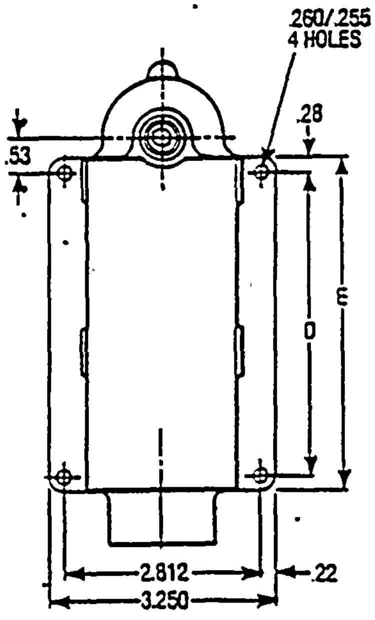
Se[illegible] EA700 Snap-Lock Limit Switches are [illegible]d for flexibility in mounting arrangements. [illegible]ign permits mounting for either side or bac[illegible]wn here are the (1) STANDARD for side mounting; (2) W (wide for back mounting); (3) L (long for back mounting). Style W or L mounting plates for back mounting, are available at no extra cost.

CONTACT SEQUENCE	STANDARD SWITCH				MOUNTING STYLE			
	PIPE TAP SIZE	A	B	C	"W"		"L"	
					D	E	F	G
1NO-1NC	1/2-14NPT	4.94	3.00	.62	2.44	3.00	4.22	4.84
2NO-2NC	1-11½NPT	7.06	4.94	.81	4.38	4.94	6.41	7.06
3NO-3NC	1-11½NPT	9.62	7.50	.81	6.94	7.50	8.97	9.62

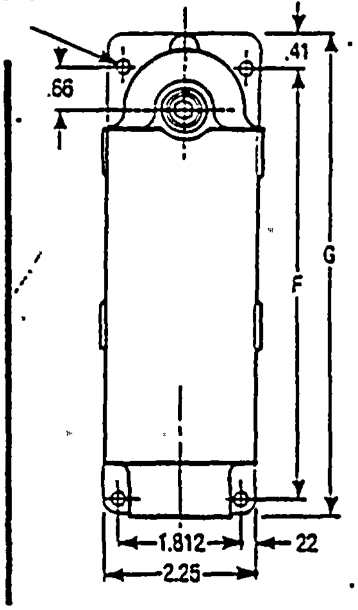
Standard Mounting



W Mounting



L Mounting



PP&L Form 2454 (10/83)
Cat. #973401

Dept. NPE-MECH
Date 10-14 1985
Designed by
Approved by

PENNSYLVANIA POWER & LIGHT COMPANY
CALCULATION SHEET

PROJECT CALC M-MSS-006, REV 1

ER No. 741 058-005

Sht. No. 27a of 27x

CONDUIT RECALCULATION (FLEX CONDUIT)

CONSIDER SUBSTITUTING TB1-1 BRAIDED FLEX CONDUIT FOR THE UNBRAIDED TYPE PRESENTLY USED. FROM THE AMERICAN BOA VENDOR CATALOG:

NOMINAL DIA	O.D.	MAX ALLOWABLE INTERNAL PRES (NOT INCLUDING 4 TO 1 SAFETY FACTOR)	WITH SHOCK (1/6 X MAX ALLOWABLE)
3/4"	1.04"	700 PSI	117 PSI
1"	1.24"	600 PSI	100 PSI
1 1/2"	1.91"	400 PSI	67 PSI

THESE ARE THE PRESSURES AT WHICH THE BELLOWS TUBING STARTS TO STRETCH OUT: THE EQUIVALENT TENSILE LOAD WOULD BE:

$$L_T = PA$$

$$L_{T\,3/4''} = (117\ \mathrm{lb/in}^2)(\pi)\left(\frac{1.04\ \mathrm{IN}}{2}\right)^2 = 99.4\ \mathrm{lb}$$ △1

$$L_{T\,1''} = (100\ \mathrm{lb/in}^2)(\pi)\left(\frac{1.24\ \mathrm{IN}}{2}\right)^2 = 120.8\ \mathrm{lb}$$

$$L_{T\,1\frac{1}{2}''} = (67\ \mathrm{lb/in}^2)(\pi)\left(\frac{1.91\ \mathrm{IN}}{2}\right)^2 = 192.0\ \mathrm{lb}$$

FROM SHEET 9, MID-SPAN LOADS ARE:

$H_{3/4''} = 77.5\ \mathrm{lb}$ $H_{1''} = 92.4\ \mathrm{lb}$ $H_{1\frac{1}{2}''} = 142.4\ \mathrm{lb}$

FROM REF. 7, PAGE 1-17, TENSION AT CONDUIT ENDS IS:

$$T = \left[H^2 + \left(\frac{WL}{2}\right)^2\right]^{.5}$$

$$T_{3/4''} = \left[(77.5\ \mathrm{lb})^2 + \left(\frac{155.0\ \mathrm{lb}}{2}\right)^2\right]^{.5} = 109.6\ \mathrm{lb}$$

$$T_{1''} = \left[(92.4\ \mathrm{lb})^2 + \left(\frac{184.8\ \mathrm{lb}}{2}\right)^2\right]^{.5} = 130.7\ \mathrm{lb}$$

PP&L Form 2454 (10/83)
Cat. #973401

Dept. NPE-MECH
Date 10-14 19 85
Designed by DRPawlitz
Approved by

PENNSYLVANIA POWER & LIGHT COMPANY
CALCULATION SHEET

PROJECT CALC. M-MSS-006, REV. 1

ER No. 741 058-005

Sht. No. 27b of 27x

$$T_{1\frac{1}{2}"} = \left[(142.4\ lb)^2 + \left(\frac{284.7\ lb}{2} \right)^2 \right]^{.5} = 201.4\ lb$$

FOR ALL THREE CONDUIT SIZES THE LOADS ARE SLIGHTLY HIGHER THAN THE "ALLOWABLE". HOWEVER, THE "ALLOWABLE" INCLUDES A 4-TO-1 SAFETY FACTOR, THE ACTUAL LOADS YIELD SAFETY FACTORS OF 3.62, 3.70 AND 3.81 RESPECTIVELY WHICH ARE ACCEPTABLE.

SMALL JUNCTION BOX CONDUIT RECALCULATION

EXISTING CONDUIT IS 1". CONSIDER SUBSTITUTING 1" XXS PIPE. FROM REF. 9, PAGE 8-200:

$$I.D. = .599"$$

SUBSTITUTING INTO FORMULA FOR I FROM SHEET 14:

$$I = .25\pi \left[r_o^4 - r_i^4 \right] = .25\pi \left[\left(\frac{1.181\ in}{2} \right)^4 - \left(\frac{.599}{2} \right)^4 \right]$$ △1

$$I = .0892\ in^4$$

SUBSTITUTING INTO FORMULA FOR BENDING STRESS FROM SHEET 14:

$$\sigma = \frac{(913.5\ in\ lb)(1.181\ in)}{.0892\ in^4} = 12{,}095\ lb/in^2$$

APPLYING A STRESS CONCENTRATION FACTOR OF 3.0:

$$\sigma = (12{,}095\ lb/in^2)(3) = 36{,}284\ lb/in^2$$

SINCE THIS STRESS IS JUST IN THE RANGE OF YIELD STRENGTHS FOR TYPICAL CARBON STEEL PIPE (35,000 PSI TO 40,000 PSI), YIELDING, IF ANY, WOULD BE VERY SLIGHT AND WOULD NOT HAVE ANY DETRIMENTAL EFFECT ON THE VALVE FUNCTION OR THE FUNCTION OF ANY OF THE MISCELLANEOUS HARDWARE.

CALC. M-MSS-006, REV. 1
ATTACHMENT 5
SHEET 27C OF 27X

MPR ASSOCIATES, INC.

June 24, 1985

Mr. Frank Czysz
Pennsylvania Power and Light Company
Two North Ninth Street
Allentown, PA 18101

Subject: Susquehanna Nuclear Station -- Recirculation Piping Blowdown Thrust Loads

Dear Mr. Czysz:

This letter forwards the results of our analyses of thrust loads that would be expected for the Susquehanna BWR recirculation piping in the unlikely event that a complete pipe rupture occurred at the point where the recirculation piping passes through the biological shield surrounding the reactor vessel. Preliminary results of these analyses have been discussed with you, Mr. Herb Clarke, Mr. Don Prevatte, and Ms. Patty Mikus at our meeting at General Electric on May 9, 1985, and were sent to Mr. Prevatte shortly after our return from the meeting.

The purpose in establishing the thrust loads which would act on the pump end of the recirculation piping as a result of a postulated break within the biological shield was to ensure that the pipe whip restraint designed by General Electric was adequate to limit the final separation between the two broken pipe ends at the break such that the pump end of the broken pipe would remain in a position to shield the MSIV's from direct jet impingement from the reactor vessel side of the break. The original analysis for the pipe restraints done by General Electric was based on a generic approach covering several plants and pipe break locations which did not include the special case of a break within the biological shield.

The General Electric analysis modeled the thrust load as a dynamic part associated with the break dynamics and wave propagation effects followed by a steady state part which would occur after full flow has been established at the break. Pipe reaction to this loading sequence was obtained by a time history stress analysis which included the plastic deformation of the pipe and pipe restraint. Due to the active participation of the shield to the flow field around the break and the large resistance to flow in the

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pump side of the recirculation piping, the steady state thrust load on the pump end of the broken pipe would be significantly larger in the presence of the shield than the steady state load which was used in the General Electric generic analysis and which assumed no shield. The higher thrust load occurs because the higher pressure which exists at the break in the presence of the shield will reduce the amount of flow which is expelled from the pump side of the break. For lines with a large amount of resistance (such as the pump and other substantial resistances present in this line) reduced flow at the break tends to increase thrust. Consequently, the generic analysis done by General Electric was considered not to envelope the condition where the break was postulated to occur within the biological shield. In this regard, we understand that General Electric has revised their analysis to include a conservative steady state thrust load and has determined that no significant increase in pipe separation will result as a consequence of the higher steady state load because almost all the pipe and restraint deformation occurs during the period when the dynamic thrust load is acting on the pipe and before the thrust load reaches a steady state value.

Our analyses, which are documented in the enclosure to this letter, include the determination of a realistic steady state thrust load which would act on the pump end of the recirculation line as a result of a break within the biological shield. Several cases were analyzed assuming several different values for the final separation distance between the broken ends of the pipe. These analyses include revisions to remove simplifying assumptions regarding the differences between static and stagnation pressure in determining critical flow rates as discussed with you at our May 9, 1985 meeting at General Electric. A review of the results from these more refined analyses indicates that the thrust loads are similar to those discussed in our meeting of May 9, 1985 and are still well within the values used in the revised General Electric analysis.

Also included in the attachment is a short description of a compressible flow field analysis of the blowdown of an ideal gas from a vessel through an open ended pipe. Results from this analysis are instructive in providing some insight as to why the maximum thrust load that can be established

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during a blowdown from a vessel will exceed the product of the original stagnation pressure times the flow area of the broken pipe.

If you should have any questions regarding our results, please call.

Sincerely,

Hans D. Giesecke

Hans D. Giesecke

Enclosure

Enclosure 1

THRUST LOADS FOR POSTULATED BREAK OF BWR RECIRCULATION LINE WITHIN BIOLOGICAL SHIELD

I. Introduction

In the event of an unlikely pipe rupture inside containment for a Nuclear Power Plant, adequate pipe restraints must be designed to accept thrust loads acting on the free ends of the broken pipe and prevent damage to other equipment in the containment. As a secondary consideration, the effects of jet impingement loads on equipment must also be considered to ensure that the plant can be reliably secured in the event that any such postulated pipe break accident occurs.

In the design of the piping restraints for the boiler recirculation piping for the Susquehanna Nuclear Power Plant, General Electric used a generic analysis which covered several plants and analyzed a series of worst cases regarding the location of the postulated breaks. An apparently conservative thrust load history was applied by GE to the broken ends of the pipe at the postulated break by using the maximum attainable theoretical value for the thrust load during that period of time when dynamic pressure wave propagation affects the pipe flow, and then reducing this value to the steady state thrust load after a steady state blowdown of the reactor vessel through the two broken pipe ends has been established.

At Susquehanna the recirculation line passes through a biological shield which surrounds the reactor vessel and the pipe to safe-end weld is located near the center of the biological shield. If the postulated break were to occur at this weld the effect of the biological shield, which was not considered in the generic analysis done by General Electric, would tend to increase the steady state value of the thrust load applied to the pump end of the recirculation piping. The thrust load from the pump end of the break is strongly affected by the considerable resistance to flow generated by the recirculation pump and the jet pump which exist in that line. Interference of the shield with the break flow at the break would cause the steady state thrust load on this pipe leg to be higher than it would be if the shield were not there. Consequently, the steady state thrust load used by General Electric would not be conservative for the

special case where the postulated break in the recirculation line occurs within the biological shield.

The Main Steam Isolation Valves at Susquehanna, which are necessary to isolate the containment in the unlikely event of a pipe break accident, are located close to the reactor recirculation lines and would be susceptible to impingement loads from a jet originating from the reactor end of the break if a break were to occur at the point where the piping passes through the biological shield. Shielding from the impingement jet provided by the pump end of the broken line was utilized in the analysis of jet impingement loads on the isolation valves. This was considered acceptable because the General Electric analysis of the pipe restraint showed that the pipe separation between the broken ends of the recirculation lines in the worst case would be less than 11 inches.

The dynamic response of the pipe was determined by General Electric using a detailed time history analysis of the pipe motion with the aforementioned thrust load as input. Plastic deformation of the pipe and pipe restraint were included. Initial restraint to pipe motion is very low because the pipe must be designed to accommodate the effects of thermal expansion. As a result the pipe deflects a considerable amount before the pipe restraint becomes active and the built up kinetic energy obtained early in the transient must be absorbed by plastic deformation of the restraint as the restraint begins to react to the motion of the pipe. Consequently, it is feasible that the steady state thrust load used in the analysis has only a small effect on the final separation that would occur between the broken ends of the pipe in the event of a break. Nevertheless, the actual steady state thrust load which would occur if the postulated break is located within the biological shield should be used to determine the final separation between the pipe ends so that the assumption of shielding for the MSIVs can be properly justified.

Calculated results for the steady state thrust load on the pump end of the recirculation line which were obtained for various amounts of pipe separation at the break when the postulated break is located within the biological shield are discussed in the remainder of this report. These values should be used for the

steady state thrust load as applied to the pump end of the broken recirculation pump in a revised analysis of the pipe motion.

II. Results of Analysis

A schematic of the model used to determine the flow rates and pressures near the break for a postulated break in the recirculation line where it passes through the biological shield is shown in Figure 1. In this figure the right side of the pipe is attached directly to the reactor vessel with the postulated break occurring at the weld between the pipe and the reactor vessel nozzle safe-end. The left end of the pipe leads to an elbow where the pipe turns down vertically and a pipe restraint is located several feet from the elbow. The pipe continues back to the reactor vessel after passing through the recirculation pump and several other points of high flow resistances. A one-dimensional solution technique which solves the mass, energy, and momentum conservation equations was used to obtain the steady state thrust load for several different values of pipe separation. The model divides the region near the break into six control volumes and six flow paths as shown in Figures 1 and 2. The reactor vessel and the containment are modeled as boundary control volumes at 1000 psi saturated water and 15 psi ambient conditions respectively. Due to the one dimensional nature of the model the exit flow from the annulus around the pipe, although it splits in two different directions, is modeled as a single flow path of twice the area of each individual path. The resistance in the pump end of the line (flow coefficient 56) was obtained from the steady state flow which exists in the loop at full power. This is conservative since the resistance in reverse flow through the pipe would be considerably larger than the resistance for flow in the normal direction and the resistance of the pump is neglected. The flow in each path is determined from the integrated momentum equation and is limited in magnitude by a homogeneous equilibrium thermodynamic critical flow model. The thrust is calculated from the static pressure, static density, and mass flow rate at the pipe exit plane as discussed in Reference 1. Input data and computer results for each case run are provided in Appendix A.

Calculated mass flow rates and static pressures for the model as determined for different values of pipe separation at the break are tabulated in Table 1.

These results are used to obtain the thrust factors, defined as the thrust load divided by the product of reactor vessel stagnation pressure times pipe flow area, given in Table 2 for each pipe end. The results indicate that the thrust force for the pump end of the broken pipe is largest when the separation at the break is smallest and diminishes as a function of the separation distance until choking occurs at the pipe exit plane. In the presence of the biological shield, choking at the exit plane of the pump end of the broken pipe will not occur until the separation distance between the broken ends is well in excess of the eleven inches calculated by General Electric. Consequently, a steady state value of about 0.7 to 0.8 times the product of vessel stagnation pressure times pipe area should be used for the steady state thrust load in the General Electric time history analysis. Although this considerably exceeds the factor of 0.33 that General Electric used in their original generic analysis, the higher steady state thrust load may have only a small effect on the final pipe separation since it is expected that most of that separation is caused by the initial response of the pipe to the dynamic thrust load which occurs before the restraint begins to act to limit the pipe separation.

III. Flow Field Analysis for Blowdown of an Ideal Gas

An axisymmetric flow field analysis for a compressible ideal gas flowing from a short pipe attached to a large vessel was used to obtain some insight as to why the thrust load from a vessel can be larger than the product of the vessel stagnation pressure times the pipe area. Thermodynamic models of the flow predict that the thrust load for an ideal gas would be 1.26 times the product of vessel stagnation pressure and pipe area, and for incompressible flow the factor can become as high as 2.0. A contour plot of the stream function for an axisymmetric model of the region near a pipe attached to a large vessel is shown in Figure 3. An iterative finite difference technique was used to solve the two-dimensional partial differential equation which describes the compressible flow of an ideal gas in terms of a stream function. Boundary conditions imposed on the model included defining the stream function along the axis of the pipe and the wall of the vessel for a particular mass flow rate and requiring that the flow be normal to the spherical surface chosen as a boundary far enough away from the pipe inlet so that the flow field at the inlet was not significantly affected.

The difference in the stream function values as imposed at the pipe axis and the vessel wall was used to adjust the mass flow rate flowing through the pipe leaving the vessel. The method of solution used to solve the flow field equations is limited to calculating subsonic flow fields so that the solution at which the exit plane of the pipe begins to choke could only be approached. The thrust load for each case was determined by integrating the pressure over the projected surface normal to the pipe axis along the vessel and pipe boundary and subtracting this value from the integration of the stagnation pressure over the same area which is assumed to be acting over the back wall of the vessel opposite the pipe inlet. The results for the thrust load obtained in this manner for several different values of mass flow are graphed in Figure 4. As can be seen from the figure, as the mass flow is increased such that the exit plane of the pipe approaches a choked value, the thrust load approaches the theoretical value of 1.26 times the product of the vessel stagnation pressure times the pipe flow area. Figure 5 shows the pressure contours which exist at a mass flow near the choked condition value. Thrust loads greater than the product of stagnation pressure times pipe area occur because there is a substantial area in the region of the nozzle at radii larger than the pipe inside radius where a reduction in pressure takes place due to the velocity of the flow as it enters the pipe. This lowered pressure region is offset by an equivalent area on the back side of the vessel which is essentially acted upon by the vessel stagnation pressure. Consequently, thrust loads greater than stagnation pressure times pipe area require that the flow originate in a vessel which has a cross-sectional area much larger than the pipe and where the flow is forced to turn into the pipe. Momentum and energy conservation requires that the momentum imparted to the fluid by pressure variations which accelerate the flow into the nozzle and along the pipe is equivalent to that which crosses the exit plane of the pipe.

IV. References

1. F. J. Moody, "Prediction of Blowdown Thrust and Jet Forces," General Electric Company, ASME, 1969.

TABLE OF VALUES FOR THRUST CALCULATION

(Definitions given in Figure 1)

inches	lb/sec		lbs/sq in				lbs/cu ft		
GAP	W1	W2	P1	P2	PX	PA	DEN1	DEN2	DENA
2	5980	804	990	993	993	102	44	45	.9
4	11523	1606	957	972	973	178	38	41	1.7
6	16178	2426	890	937	938	235	30	35	2.5
8	18349	3590	759	861	863	274	19	26	3.0
10	18348	4733	760	755	760	279	19	18	3.1
12	18349	5481	759	666	676	282	18	14	3.2

TABLE 1

Mass Flow Rates, Pressures, and Densities
Obtained in Analysis

TABLE OF VALUES FOR THRUST COEFFICIENTS

inches	vessel end	pump end
GAP	K1	K2
2	1.0038	0.9933
4	1.0166	0.9735
6	1.0417	0.9398
8	1.0661	0.8692
10	1.0661	0.7758
12	1.0661	0.7041

TABLE 2

Thrust Coefficients from Calculated Results

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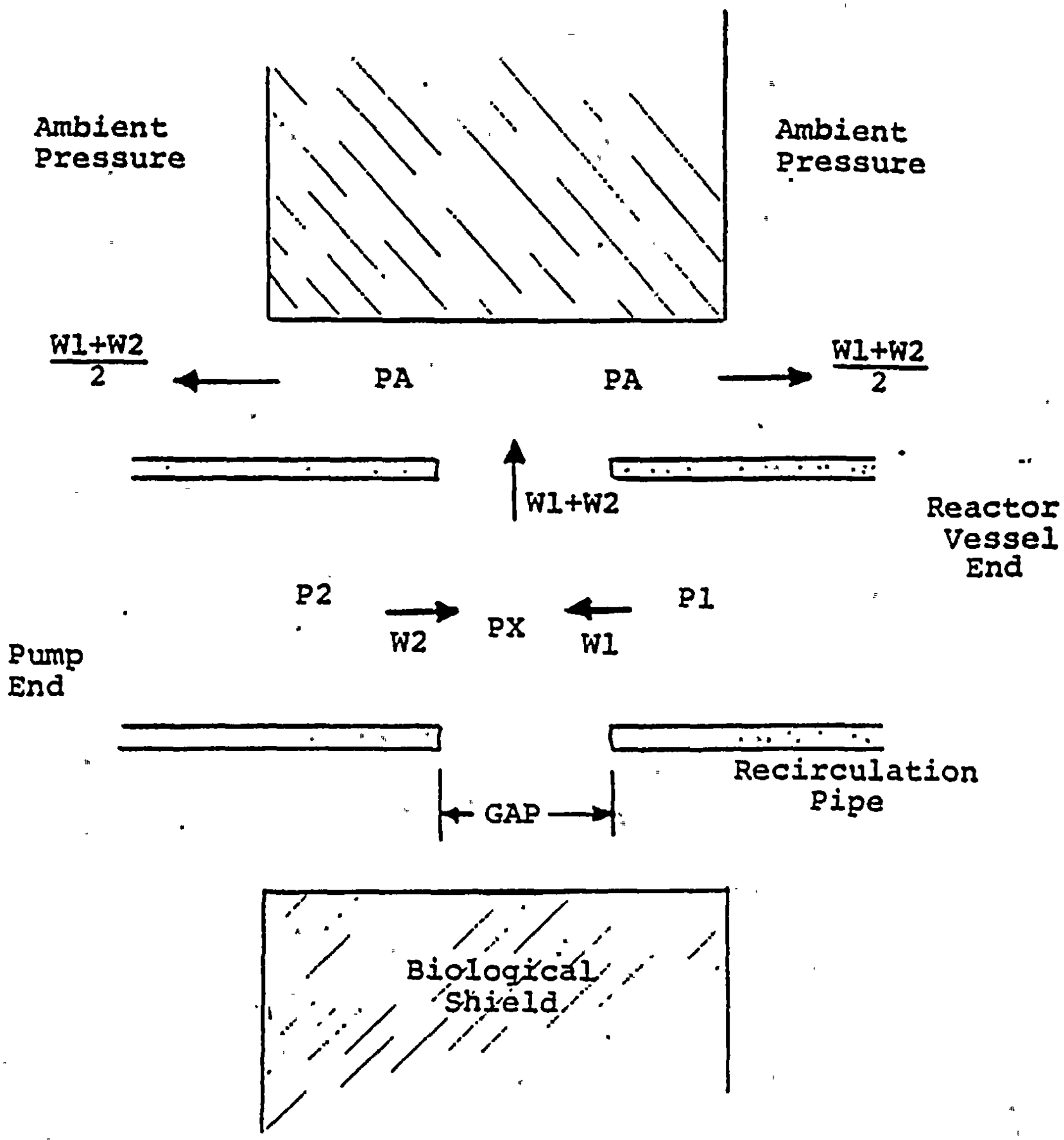

FIGURE 1

Schematic of Break

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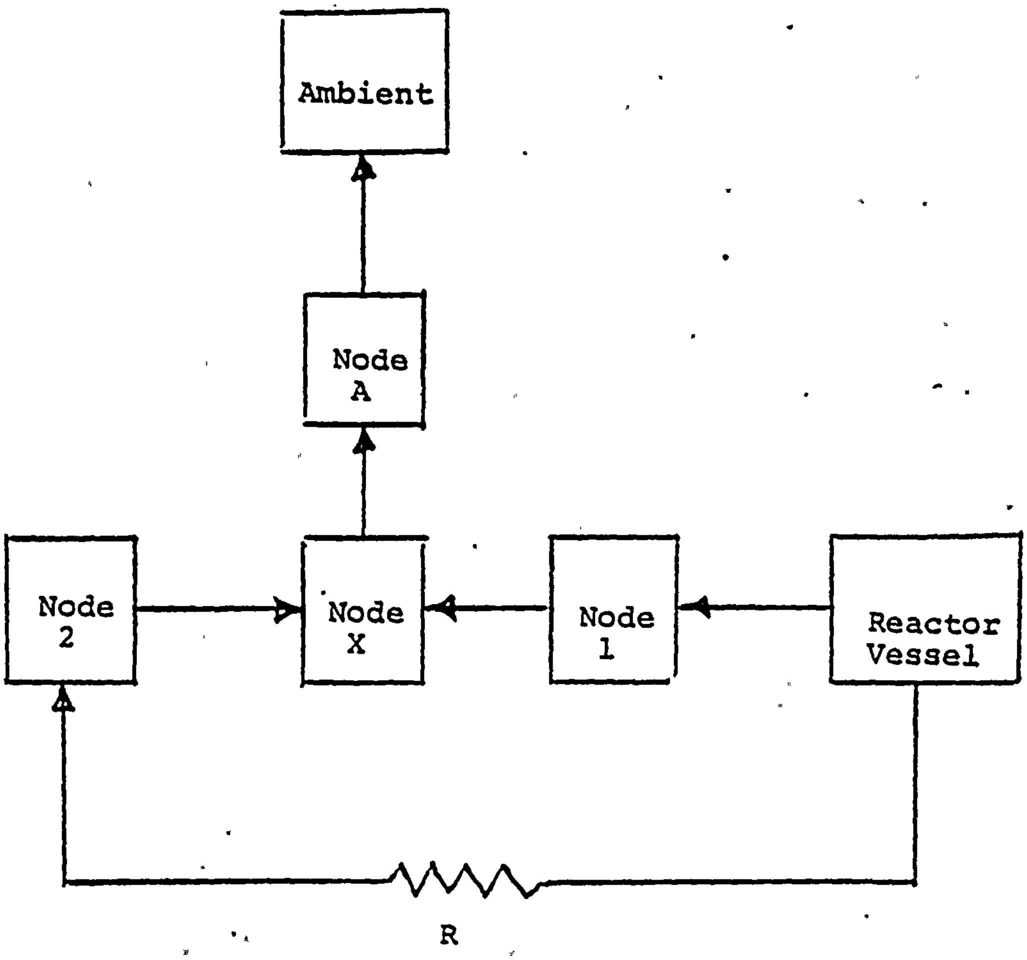

FIGURE 2
Computer Model of Break

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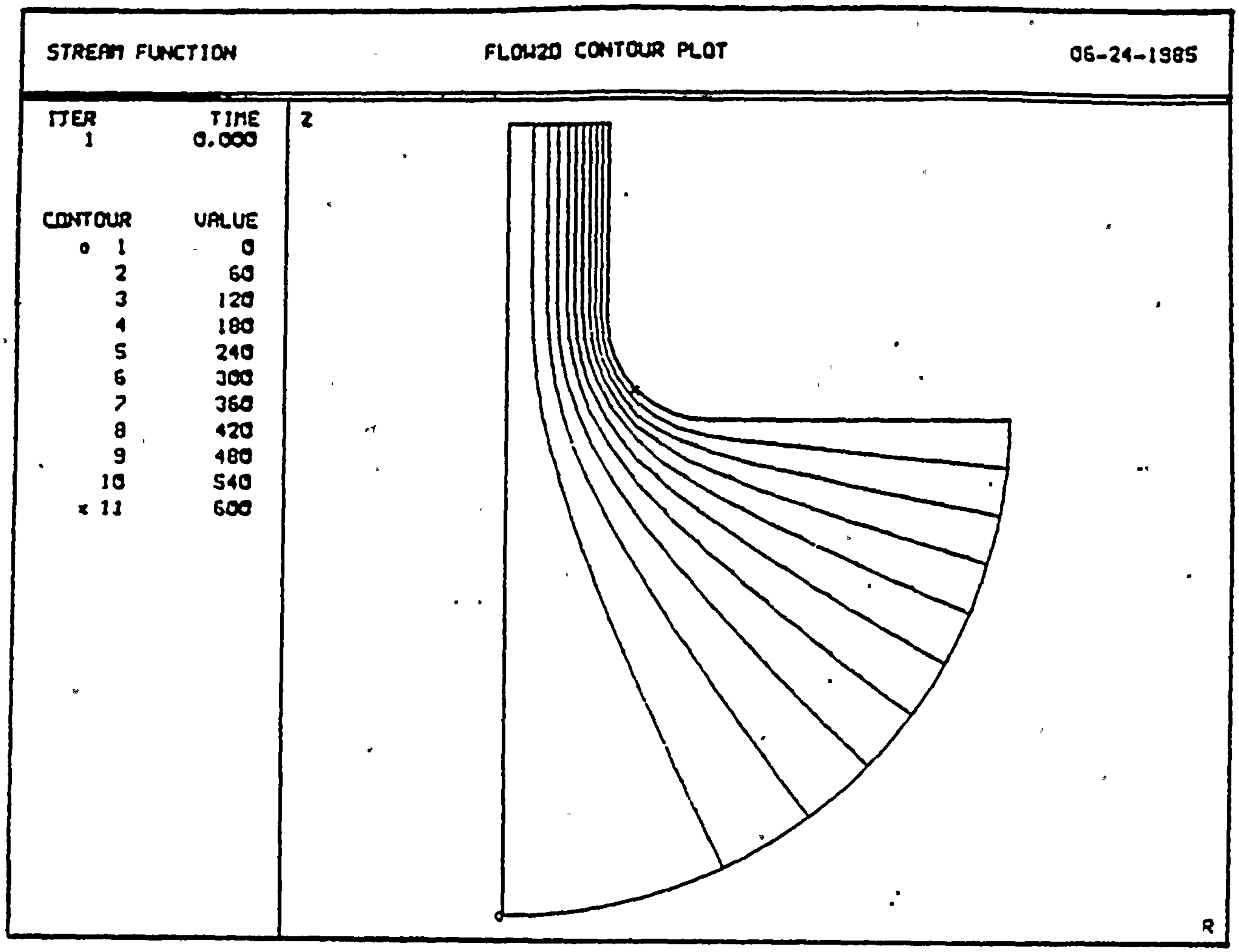

STREAM FUNCTION FLOW2D CONTOUR PLOT 06-24-1985

ITER	TIME
1	0.000

CONTOUR	VALUE
o 1	0
2	60
3	120
4	180
5	240
6	300
7	360
8	420
9	480
10	540
x 11	600

FIGURE 3

Stream Function Contours for
Flow Field Analysis of Pipe from Vessel

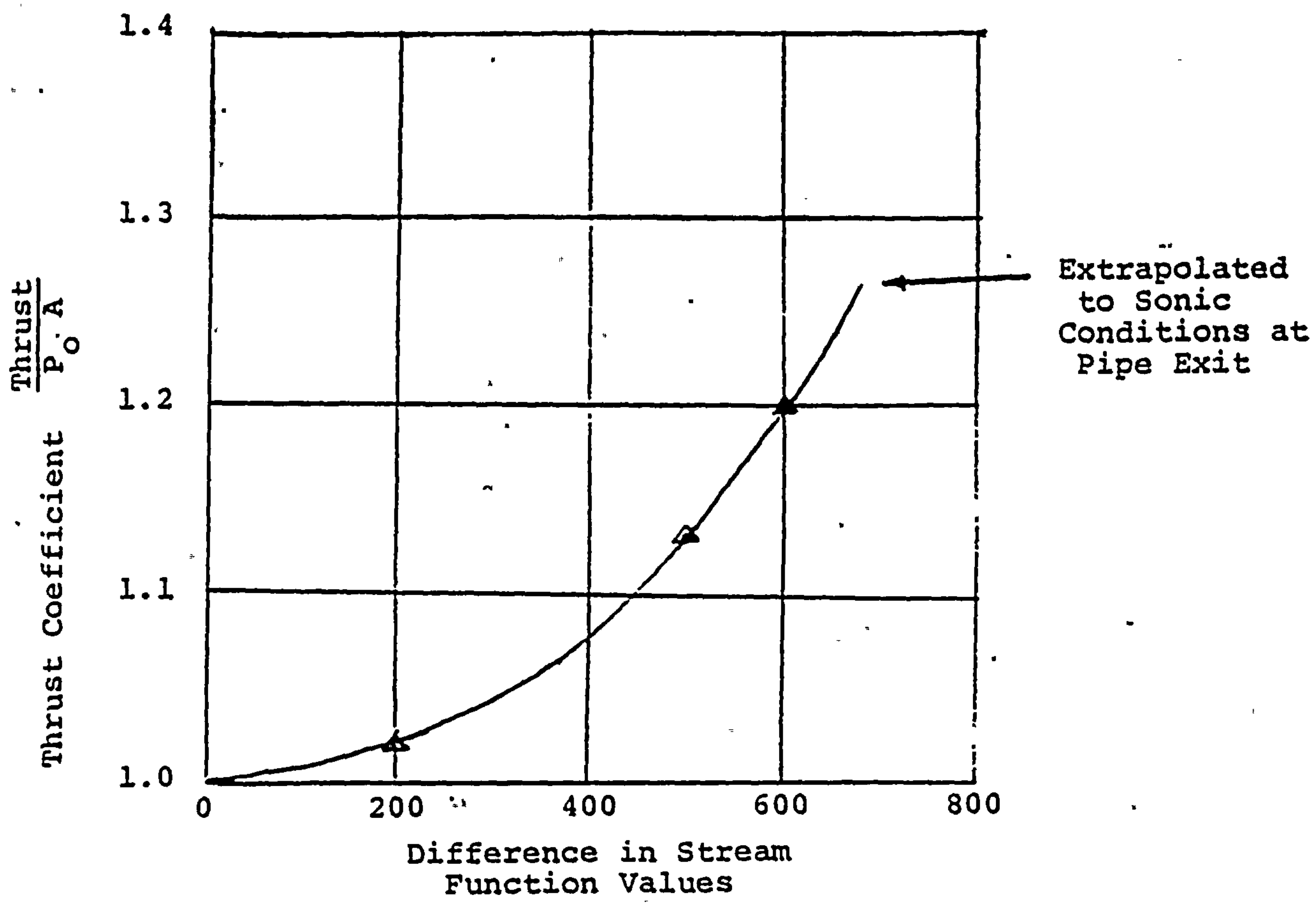

FIGURE 4

Asymtotic Solution for Thrust Coefficient from Series of Flow Field Analyses

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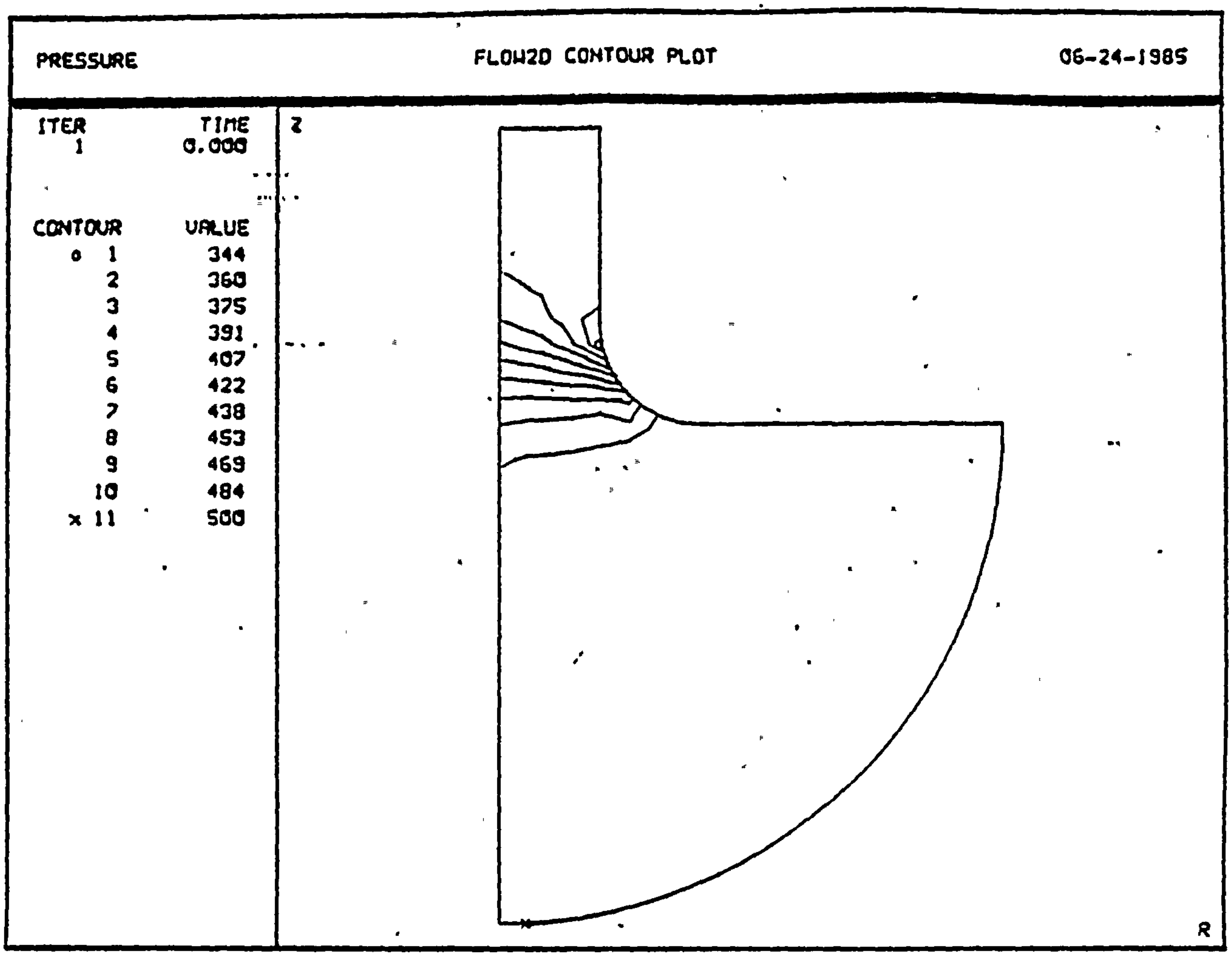

PRESSURE FLOW2D CONTOUR PLOT 06-24-1985

ITER	TIME
1	0.000

CONTOUR	VALUE
o 1	344
2	360
3	375
4	391
5	407
6	422
7	438
8	453
9	469
10	484
x 11	500

FIGURE 5

Pressure Contours for Flow
Field Analysis of Pipe from Vessel

Appendix A

COMPUTER OUTPUT OF RESULTS

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```
SUSQUEHANNA BWR REACTOR RECIRC PIPE BREAK IN BIOLOGICAL SHIELD - 2 INCH GAP

OUTPUT AT TIME    .00000
 VAR            Y   NAME
   1   .597961E+04  W1
   2   .804317E+03  W2
   3   .996639E+03  P01
   4   .993218E+03  P02
   5   .993156E+03  P0X
   6   .139203E+03  P0A


GEOMETRY DATA
DPIPE--------------    .212200E+01
DIN----------------    .240000E+01
DOUT---------------    .380000E+01
GAP----------------    .166667E+00
APIPE--------------    .353656E+01
ABREAK-------------    .125664E+01
AANUL--------------    .681726E+01


NODE DATA
                          VESSEL       NODE 1       NODE 2       NODE X       NODE A         BACK
STAGNATION PRESSURE    .10000E+04   .99664E+03   .99322E+03   .99316E+03   .13920E+03   .15000E+02
CRITICAL PRESSURE                   .78931E+03   .78472E+03   .78370E+03   .86805E+02
STATIC PRESSURE                     .98979E+03   .99309E+03   .99316E+03   .10245E+03
STATIC DENSITY                      .44069E+02   .44673E+02   .44685E+02   .85949E+00
THERMO DENSITY                      .44069E+02   .44673E+02   .44685E+02   .85949E+00
CRITICAL DENSITY                    .20365E+02   .20638E+02   .20568E+02   .71777E+00


FLOW DATA
                          FLOW V       FLOW L       FLOW 1       FLOW 2       FLOW A       FLOW B
MASS FLUX              .16908E+04   .22743E+03   .16908E+04   .22743E+03   .00000E+00   .49756E+03
MASS FLOW              .59796E+04   .80432E+03   .59796E+04   .80432E+03   .67839E+04   .67839E+04
                                                                            CRITICAL
CRITICAL MASS FLOW     .19301E+05   .19301E+05   .19199E+05   .19094E+05   .67839E+04   .70611E+04
K-FACTOR               .50000E+00   .56000E+02   .50000E+00   .50000E+00   .30000E+00   .10000E+01
MODIFIED K-FACTOR      .33596E-07   .10483E-04   .97820E-07   .96497E-07   .45645E-06   .26396E-05
THRUST FACTER                                    .10038E+01   .99334E+00
```

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```
SUSQUEHANNA BWR REACTOR RECIRC PIPE BREAK IN BIOLOGICAL SHIELD - 4 INCH GAP

OUTPUT AT TIME    .00000
 VAR              Y  NAME
   1  .115227E+05  W1
   2  .160568E+04  W2
   3  .987573E+03  P01
   4  .972974E+03  P02
   5  .972702E+03  P0X
   6  .250694E+03  P0A


GEOMETRY DATA
DPIPE-----------------   .212200E+01
DIN-------------------   .240000E+01
DOUT------------------   .380000E+01
GAP-------------------   .333333E+00
APIPE-----------------   .353656E+01
ABREAK----------------   .251327E+01
AANUL-----------------   .681726E+01


NODE DATA
                          VESSEL      NODE 1      NODE 2      NODE X      NODE A        BACK
STAGNATION PRESSURE    .10000E+04  .98757E+03  .97297E+03  .97270E+03  .25069E+03  .15000E+02
CRITICAL PRESSURE                  .77833E+03  .76350E+03  .76424E+03  .15914E+03
STATIC PRESSURE                    .95715E+03  .97244E+03  .97270E+03  .17771E+03
STATIC DENSITY                     .38488E+02  .40874E+02  .40916E+02  .16963E+01
THERMO DENSITY                     .38488E+02  .40874E+02  .40916E+02  .16963E+01
CRITICAL DENSITY                   .20192E+02  .19196E+02  .19242E+02  .14885E+01


FLOW DATA
                          FLOW V      FLOW L      FLOW 1      FLOW 2      FLOW A      FLOW B
MASS FLUX              .32582E+04  .45402E+03  .32582E+04  .45402E+03  .00000E+00  .96288E+03
MASS FLOW              .11523E+05  .16057E+04  .11523E+05  .16057E+04  .13128E+05  .13128E+05
                                                                         CRITICAL
CRITICAL MASS FLOW     .19301E+05  .19301E+05  .18922E+05  .18482E+05  .13128E+05  .13347E+05
K-FACTOR               .50000E+00  .56000E+02  .50000E+00  .50000E+00  .30000E+00  .10000E+01
MODIFIED K-FACTOR      .93596E-07  .10483E-04  .11200E-06  .10547E-06  .12517E-06  .13678E-05
THRUST FACTER                                  .10166E+01  .97353E+00
```

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```
SUSQUEHANNA BWR REACTOR RECIRC PIPE BREAK IN BIOLOGICAL SHIELD - 6 INCH GAP

OUTPUT AT TIME    .00000
 VAR           Y   NAME
   1  .161778E+05  W1
   2  .242572E+04  W2
   3  .975504E+03  PO1
   4  .938318E+03  PO2
   5  .937600E+03  POX
   6  .340194E+03  POA


GEOMETRY DATA
DPIPE----------------  .212200E+01
DIN------------------  .240000E+01
DOUT-----------------  .380000E+01
GAP------------------  .500000E+00
APIPE----------------  .353656E+01
ABREAK---------------  .376991E+01
ANNUL----------------  .681726E+01


NODE DATA
                          VESSEL      NODE 1      NODE 2      NODE X      NODE A        BACK
STAGNATION PRESSURE    .10000E+04  .97550E+03  .93832E+03  .93760E+03  .34019E+03  .15000E+02
CRITICAL PRESSURE                  .76739E+03  .72601E+03  .72545E+03  .22265E+03
STATIC PRESSURE                    .89008E+03  .93694E+03  .93760E+03  .23459E+03
STATIC DENSITY                     .29765E+02  .35334E+02  .35421E+02  .24518E+01
THERMO DENSITY                     .29765E+02  .35334E+02  .35421E+02  .24518E+01
CRITICAL DENSITY                   .19450E+02  .16914E+02  .16882E+02  .22950E+01


FLOW DATA
                          FLOW V      FLOW L      FLOW 1      FLOW 2      FLOW A      FLOW B
MASS FLUX              .45744E+04  .68590E+03  .45744E+04  .68590E+03  .00000E+00  .13644E+04
MASS FLOW              .16178E+05  .24257E+04  .16178E+05  .24257E+04  .18603E+05  .18603E+05
                                                                         CRITICAL
CRITICAL MASS FLOW     .19301E+05  .19301E+05  .18557E+05  .17472E+05  .16604E+05  .18675E+05
K-FACTOR               .50000E+00  .56000E+02  .50000E+00  .50000E+00  .30000E+00  .10000E+01
MODIFIED K-FACTOR      .93596E-07  .10483E-04  .14483E-06  .12200E-06  .64261E-07  .34636E-06
THRUST FACTER                                  .10417E+01  .93981E+00
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```
SUSQUEHANNA BWR REACTOR RECIRC PIPE BREAK IN BIOLOGICAL SHIELD - 8 INCH GAP

OUTPUT AT TIME     .00000
 VAR           Y   NAME
   1  .183486E+05  W1
   2  .359037E+04  W2
   3  .968489E+03  PO1
   4  .864870E+03  PO2
   5  .662769E+03  POX
   6  .392669E+03  POA


GEOMETRY DATA
DPIPE----------------  .212200E+01
DIN------------------  .240000E+01
DOUT-----------------  .380000E+01
GAP------------------  .666670E+00
APIPE----------------  .353656E+01
ABREAK---------------  .502657E+01
AANUL----------------  .681726E+01


NODE DATA
                             VESSEL       NODE 1       NODE 2       NODE X       NODE A         BACK
STAGNATION PRESSURE      .10000E+04   .96849E+03   .86487E+03   .86277E+03   .39267E+03   .15000E+02
CRITICAL PRESSURE                     .75928E+03   .65187E+03   .64902E+03   .27002E+03
STATIC PRESSURE                       .75928E+03   .86079E+03   .86277E+03   .27439E+03
STATIC DENSITY                        .18921E+02   .26449E+02   .26626E+02   .30430E+01
THERMO DENSITY                        .18921E+02   .26449E+02   .26626E+02   .30430E+01
CRITICAL DENSITY                      .18921E+02   .13198E+02   .13073E+02   .29790E+01


FLOW DATA
                             FLOW V       FLOW L       FLOW 1       FLOW 2       FLOW A       FLOW B
MASS FLUX                .51882E+04   .10152E+04   .51883E+04   .10152E+04   .00000E+00   .16091E+04
MASS FLOW                .18349E+05   .35904E+04   .18349E+05   .35904E+04   .21939E+05   .21939E+05
                                                     CRITICAL                   CRITICAL     CRITICAL
CRITICAL MASS FLOW       .19301E+05   .19301E+05   .18348E+05   .15489E+05   .21939E+05   .21983E+05
K-FACTOR                 .50000E+00   .56000E+02   .50000E+00   .50000E+00   .30000E+00   .10000E+01
MODIFIED K-FACTOR        .93596E-07   .10483E-04   .22783E-06   .16299E-06   .48087E-07   .76247E-06
THRUST FACTER                                      .10661E+01   .86320E+00
```

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```
SQUEHANNA BWR,REACTOR RECIRC PIPE BREAK IN BIOLOGICAL SHIELD - 10 INCH GAP

OUTPUT AT TIME    .00000
 VAR           Y   NAME
   1  .183484E+05  W1
   2  .473259E+04  W2
   3  .968490E+03  P01
   4  .765214E+03  PG2
   5  .759916E+03  P0X
   6  .408974E+03  PGA


GEOMETRY DATA
DPIPE--------------   .212200E+01
DIN----------------   .240000E+01
DOUT---------------   .380000E+01
GAP----------------   .833330E+00
APIPE--------------   .353656E+01
ABREAK-------------   .628316E+01
AANUL--------------   .681726E+01


NODE DATA
                         VESSEL       NODE 1       NODE 2       NODE X       NODE A        BACK
STAGNATION PRESSURE   .10000E+04   .96849E+03   .76521E+03   .75992E+03   .40897E+03   .15000E+02
CRITICAL PRESSURE                  .75904E+03   .55640E+03   .55218E+03   .27485E+03
STATIC PRESSURE                    .75997E+03   .75465E+03   .75992E+03   .27900E+03
STATIC DENSITY                     .18965E+02   .18224E+02   .18525E+02   .31223E+01
THERMO DENSITY                     .18965E+02   .18224E+02   .18525E+02   .31223E+01
CRITICAL DENSITY                   .18906E+02   .95546E+01   .94157E+01   .30604E+01


FLOW DATA
                         FLOW V       FLOW L       FLOW 1       FLOW 2       FLOW A       FLOW B
MASS FLUX             .51882E+04   .13382E+04   .51882E+04   .13382E+04   .00000E+00   .16928E+04
MASS FLOW             .18348E+05   .47326E+04   .18348E+05   .47326E+04   .23081E+05   .23081E+05
                                                 CRITICAL                  CRITICAL
CRITICAL MASS FLOW    .19301E+05   .19301E+05   .18349E+05   .13110E+05   .23081E+05   .23092E+05
K-FACTOR              .50000E+00   .56000E+02   .50000E+00   .50000E+00   .30000E+00   .10000E+01
MODIFIED K-FACTOR     .93596E-07   .10483E-04   .22731E-06   .23655E-06   .44235E-07   .74313E-06
THRUST FACTER                                   .10661E+01   .77585E+00

ITERATION   7 FRAC CHANGE   .535047E+01 AT POINT  6
     YDOT 1     YDOT 2     YDOT 3     YDOT 4     YDOT 5     YDOT 6
   .3408E-04 -.5316E-04  .1875E+00 -.2350E-03  .6836E-01 -.5350E+01
        Y 1        Y 2        Y 3        Y 4        Y 5        Y 6
   .1835E+05  .4733E+04  .9685E+03  .7652E+03  .7599E+03  .4090E+03
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CALC. M-MSS-006, REV 1

ATTACHMENT 5

SHEET 27X OF 27X

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SUSQUEHANNA BWR REACTOR RECIRC PIPE BREAK IN BIOLOGICAL SHIELD - 12 INCH GAP

OUTPUT AT TIME    .00000
 VAR            Y    NAME
   1  .183487E+05   W1
   2  .548104E+04   W2
   3  .968495E+03   PO1
   4  .685133E+03   PO2
   5  .675546E+03   POX
   6  .420013E+03   POA


GEOMETRY DATA
DPIPE---------------  .212200E+01
DIN-----------------  .240000E+01
DOUT----------------  .380000E+01
GAP-----------------  .100000E+01
APIPE---------------  .353656E+01
ABREAK--------------  .753982E+01
AANUL---------------  .681726E+01


NODE DATA
                          VESSEL       NODE 1       NODE 2       NODE X       NODE A        BACK
STAGNATION PRESSURE   .10000E+04   .96849E+03   .68513E+03   .67555E+03   .42001E+03   .15000E+02
CRITICAL PRESSURE                  .75857E+03   .47109E+03   .48165E+03   .28226E+03
STATIC PRESSURE                    .75857E+03   .66575E+03   .67555E+03   .28226E+03
STATIC DENSITY                     .18881E+02   .13504E+02   .13912E+02   .31815E+01
THERMO DENSITY                     .18881E+02   .13504E+02   .13912E+02   .31815E+01
CRITICAL DENSITY                   .18877E+02   .70733E+01   .73328E+01   .31784E+01


FLOW DATA
                          FLOW V       FLOW L       FLOW 1       FLOW 2       FLOW A       FLOW B
MASS FLUX             .51883E+04   .15498E+04   .51883E+04   .15498E+04   .00000E+00   .17477E+04
MASS FLOW             .18349E+05   .54810E+04   .18349E+05   .54810E+04   .23830E+05   .23830E+05
                                                  CRITICAL                  CRITICAL
CRITICAL MASS FLOW    .19301E+05   .19301E+05   .18349E+05   .11351E+05   .23831E+05   .23828E+05
K-FACTOR              .50000E+00   .56000E+02   .50000E+00   .50000E+00   .30000E+00   .10000E+01
MODIFIED K-FACTOR     .93596E-07   .10483E-04   .22832E-06   .31922E-06   .40902E-07   .72929E-06
THRUST FACTER                                   .10660E+01   .70411E+00
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PP&L

DOCUMENT REVIEW

1\. REVIEWERS (CATEGORY)

T.G. Wales ( )

2\. DATE SENT: ______ RETURN TO: ______ BY: ______

3\. DOCUMENT (TITLE/NUMBER/REV.): Jet Impingement on Misc. MSIV Hardware
Calc. No. M-MSS-806 Rev. 0

4\. ORIGINATOR: ☐ PP&L ☐ OTHER

5\. ☐ SAFETY REL. ☐ ASME ☐ OTHER ______

6\. STATUS: ☐ PRELIM ☐ FINAL ☐ REV. ☐ FILE NO. ______

7\. REFERENCES ATTACHED: ______

8. COMMENT:	10. RESOLUTION:
1. p1 - Calculation is safety-related.	1. CHANGED.
2. p5 - "As" should be "Aa."	2. CHANGED.
3. pp5&6 - State here, or under design basis on the coversheet, that the annular area will be converted to a circular area to allow use of the Reference 5 formulas. Also state that this assumption is conservative, because it will result in higher-than-actual jet pressures.	3. THE FIRST STATEMENT OF THE PARA. ON PAGE 5 DESCRIBES THE SUBSTITUTION OF A CIRCULAR AREA (DESCRIBED AS OPEN ENDED PIPE) FOR THE ANNULAR AREA. THE LAST STATEMENT OF THIS PARA. AND SUBSEQUENT NOTES AND FORMULAE REFER TO REF. 5. THIS ASSUMPTION IS NOT NECESSARILY CONSERVATIVE. HOWEVER, IT IS THE BEST METHOD OF GETTING A REASONABLE APPROXIMATION OF WHAT IS HAPPENING THAT I AM AWARE OF. (SEE NOTE ADDED IN DESIGN BASIS ON PAGE 1.)
4. p6 - state that the "T" subscript is for "target."	4. ADDED NOTE
5. p7 - T = 447,385 lb, but P_T calculations are correct.	5. CORRECTED
6. The attachment pages should be numbered, and should list the calculation number.	6. DONE

9\. T.G. Wales 6-13-85
SUBMITTED DATE

11\. 6-24-85
RESOLVED DATE

PAGE 1 OF 4

FORM NDI-QA-8.1.3A
REV.1 (1/83)

PP&L

DOCUMENT REVIEW

1. (CONT.) REVIEWER: T.G. Wales

3. (CONT.) DOCUMENT: Calc. No. M-MSS-806 Rev. 0

8. (CONT.) COMMENT	10. (CONT.) RESOLUTION:
7. p8 - The heading of "internal pressure" implies hoop stresses, etc., rather than axial or bending loads. Are you sure these pressure ratings apply to the jet impingement loadings?	7. THE FLEX CONDUIT IS ACTUALLY CORRUGATED STAINLESS TUBING. THE ALLOWABLE "INTERNAL PRESSURE" IS THE PRESSURE AT WHICH THE CORRUGATIONS BEGIN TO STRAIGHTEN OUT. HOOP STRESS LIMITATIONS ARE NOT IMPLIED.
8. Clarify where the 9" sag comes from. Is it the unloaded deflection, or is the catenary only formed from the jet load? The wording implies that the conduit is straight until loaded from the jet blast.	8. WHEN FLEX CONDUIT IS INSTALLED, A BIT OF SLACK IS LEFT BETWEEN THE RIGID CONDUIT ON ONE END AND THE EQUIPMENT AT THE OTHER END TO ALLOW RELATIVE MOVEMENT WHICH IS THE REASON FOR FLEX CONDUIT TO BEGIN WITH. THE 9" ASSUMED SAG IS THE TYPICAL AMOUNT OF SLACK IN THIS CASE IN THE INSTALLED, UNLOADED CONDITION. IT IS ALSO THE AMOUNT OF SAG IN THE LOADED CONDITION UNTIL IT BEGINS TO STRETCH WHICH IS THE FAILURE POINT.
9. p10 - On the figure, show where the conduit penetration locations are on the junction box. Identify where ϕ is measured.	9.&10. THIS CALCULATION IS INTENDED TO BE GENERIC FOR ALL INBOARD VALVES, BOTH UNITS. HOWEVER, IN ACTUALITY EACH VALVE IS SLIGHTLY DIFFERENT IN CONDUIT CONFIGURATION. IT ATTACHES TO THE BOXES AT DIFFERENT LOCATIONS AND IS ROUTED IN RANDOM DIRECTIONS. IT IS THEREFORE ASSUMED THAT THE RESULTANT CONDUIT LOAD IS IN THE DIRECTION OF THE JET BLAST WHICH IS AT 45° ANGLE TO THE DIRECTION OF LOADING BEING ANALYZED HERE. THIS RESULTANT LOAD IS REDUCED BY ½ TO ACCOUNT FOR THE ANGLE, SHADOWING OF SOME OF THE CONDUIT, ETC.
10. p11 - You seem to be assuming that the conduit penetrates the box at a 45° angle. If so, state this assumption.	
11. p12 - Use dimensions for flex conduit rather than rigid conduit.	11. NO. THE ANALYSIS IS OF THE 1" RIGID CONDUIT THAT CONNECTS THE JUNCTION BOX TO THE LIMIT SWITCH PER THE DESCRIPTION ON PAGE 12.
12 p12 - 3145,5 in-lb should be 2295 in-lb.	12. DONE.

PP&L

DOCUMENT REVIEW

1. (CONT.) REVIEWER: T.G. Wales

3. (CONT.) DOCUMENT: Calc. No. M-MSS-806 Rev. 0

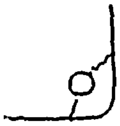
8. (CONT.) COMMENT	10. (CONT.) RESOLUTION:
13. p12 - Show the 4.5" dimension on the sketch on p10.	13. NO. THE CONFIGURATION IS BETTER ILLUSTRATED BY REF. 8, SHEET 2 PER THE DESCRIPTION ON PAGE 12.
14. p12- Put parentheses around the numbers for OD and ID in the minimum area equation.	14. DONE.
15. p13 - State which reference Table XVII is from,	15. DONE.
16. p13- Be more explicit than "picture books." Does this refer to vendor catalogs, or drywell photographs?	16. THESE ARE THE PICTURE PROGRAM BOOKS IN THIS CASE OF THE DRYWELL OF COURSE. THEY HAVE NO MORE EXPLICIT DESIGNATION.
17. p13 - Will $\sigma = \frac{Mc}{I}$ apply to flexible conduit?	17. NO, IT DOES NOT. HOWEVER, AGAIN, THIS IS RIGID CONDUIT AS CAN BE SEEN IN THE "PICTURE BOOKS" REFERRED TO. THEREFORE, $\sigma = \frac{Mc}{I}$ DOES APPLY.
18. p11 states flex conduit, but p14 implies rigid conduit.	18. THEY ARE TWO DIFFERENT CASES, FLEX AND RIGID RESPECTIVELY.
19. p15 - Label figure as view A.	19. DONE.
20. pp10 and 14 - It is not clear how junction box mounts on mounting plate. Is there a vendor drawing which can be referenced?	20. THERE IS NO VENDOR DRAWING. HOWEVER, THE "PICTURE BOOKS" GIVE A FAIRLY GOOD REPRESENTATION.
21. p16 - It is not clear where the 3/4" plate width comes from.	21. THIS IS THE WIDTH OF THE TAB ON THE PLATE THAT FORM ONE SIDE OF THE MOUNTING BOLT SLOT.

PP&L

DOCUMENT REVIEW

1. (CONT.) REVIEWER: T.G. Wales

3. (CONT.) DOCUMENT: Calc. No. M-MSS-806 Rev. 0

8. (CONT.) COMMENT	10. (CONT.) RESOLUTION:
22. p17- Provide a diagram to show the basis for 9.67 inches and 5.33 inches.	22. PAGE 17 REVISED, DIMENSIONS REVISED, CALCULATION REDONE. DIAGRAM IS ATTACHMENT 4.
23. p12- Reference attachment 3 for yield strength values.	23. ATTACHMENT 3 IS ALREADY REFERENCED.
24. p17 - $\sigma_{allowable} = 19800$ psi	24. .33(TENSILE STRENGTH) IS A ROUNDED OFF FACTOR REPRESENTING 1/3. 1/3 OF 60,000 PSI TENSILE STRENGTH IS 20,000 PSI AS SHOWN. FURTHER, IT DOSEN'T MATTER SINCE THE ACTUAL STRESS IS APPROXIMATELY 1/4 OF THE ALLOWABLE.
25. p17- State that limit switches have "W" mounting, if this is the case.	25. DONE.
26. p18- For conservatism, assume a failure mechanism like this: 	26. DISAGREE. IF THE MOUNTING SCREW IS PROPERLY TIGHTENED AS STATED, ITS HEAD WILL TRAP THE AREA UNDER IT AND WILL PREVENT IT FROM FLEXING AS MUCH AS THE AREA OUTSIDE THE CLAMPING INFLUENCE OF THE SCREW HEAD. AGAIN, THE DIFFERENCE WOULD NOT HAVE ANY EFFECT ON THE RESULT OF THE CALCULATION.
27. p19 - Show the 67.5° angle on a diagram.	27. INSUFFICIENT SPACE FOR A DIAGRAM. WORD EXPLAINATION ADDED INSTEAD.
28. p19- Explain why a shape factor is not used for the flow control valve area.	28. THE FLOW CONTROL VALVE IS A FLAT SURFACE. THE SHAPE FACTOR FOR A FLAT SURFACE IS 1 PER REF. 5.
29. p20- It is not clear where OD = 0.937 in came from.	29. THE O.D. MINUS 2 TIMES 1/2 THE WALL THICKNESS FOR SCHEDULE 40 PIPE AS STATED IN THE CALC.

PAGE 4 OF 4

FORM NDI-QA-8.1.3B
REV.0 (1/83)

PP&L

DOCUMENT REVIEW

1. REVIEWERS (CATEGORY)

T.G. Wales (1)	( )	( )
( )	( )	( )
( )	( )	( )
( )	( )	( )

2. DATE SENT: 10-16-85 RETURN TO: D.C. Prevatte BY: 10-18-85

3. DOCUMENT (TITLE/NUMBER/REV.): JET IMPINGEMENT ON MISC MSIV HARDWARE M-MSS-006 Rev. 1

4. ORIGINATOR: ☒ PP&L ☐ OTHER

5. ☒ SAFETY REL. ☐ ASME ☐ OTHER

6. STATUS: ☐ PRELIM ☐ FINAL ☒ REV. ☐ FILE NO.

7. REFERENCES ATTACHED: N/A

8. COMMENT:

None

10. RESOLUTION:

9. T.G. Wales 10-18-85
SUBMITTED DATE

11. RESOLVED DATE

PAGE 1 OF 1

FORM NDI-QA-8.1.3A
REV.1 (1/83)