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PIPING CHANGES FOR INCREASED PRODUCTION
AT B, D, DR, F, C AND H REACTORS
CALCULATIONS

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March 24, 1960

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TABLE OF CONTENTS

	<u>Page</u>
I. Purpose of Study	3
II. General	3
III. Rear Face Piping Changes - Present Operating Levels, 105-B, D & F	5
IV. Rear Face Piping Changes - Present Operating Levels, 105-DR & H	9
V. Rear Face Piping Changes - Present Operating Level, 105-C	10
VI. Rear Face Piping Changes For Increased Flows at 105-B, D, F, DR, H & C	12
VII. Front Face Piping Changes - 105-B, D, F, DR & H	39
VIII. Stress Calculations	65
IX. Downcomer and Effluent Line Calculations	124
X. Drawing & Reference Documents	124

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PIPING CHANGES FOR INCREASED PRODUCTION
AT B, D, DR, F, C AND H REACTORS
CALCULATIONS

I. PURPOSE OF STUDY

On January 22, 1960, HW-63487 Piping Changes for Increased Production at B, D, DR, F, C, and H Reactors, was published. This study investigates the valve pit piping, front and rear face piping, and effluent lines between the 105 Buildings and the retention basins to determine modifications necessary to increase power levels in the 100-B, D, DR, F, C, and H Areas by increasing either or both temperatures and flows. The study was based on detailed hydraulic and stress calculations of the existing and proposed piping systems which because of their detailed and voluminous nature were not included in the study. It is the purpose of this study to document, in so far as possible, these calculations together with pertinent information which was not included in the original study.

II. GENERAL

Computations have been made for varying flows and temperatures. In the early work on the study the flows considered varied from the existing flows to 150,000 gpm. and the temperatures varied from the existing temperatures to 120°C. In the later work the upper flow was reduced to 120,000 gpm and the upper temperature to 95°C, and just prior to issuing the report the upper flow was further reduced to 115,000 gpm. For this reason the conditions shown throughout the calculations are not continuous and in some cases correlation between the calculations and HW-63487 is not exact.

The majority of the essential hydraulic computations are presented in graphical form so that they can be used for comparison of estimated performance over a wide range of conditions and for various combinations of rear face piping components. For the 95°C. condition the analysis has been based on the operation of the rear face piping in accordance with existing philosophy, that is, with discharge to the downcomers at atmospheric pressures. For temperatures above 95°C. pressurization of the rear face piping has been considered necessary to suppress boiling and the analysis has been made on that basis.

The flow and temperature distribution across the face of a reactor influences to a large extent maximum flow and temperature conditions existing on the rear face. Curves (Figure 1) have been obtained showing this distribution for a typical reactor (105-DR) and the distribution shown by these curves is used as a basis for all of the calculations which this information affects.

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FIG. 1

For the purpose of discussion and comparison the rear face piping is divided into the following components:

- (1) Rear nozzle barrel outlet connection
- (2) Tubing connector ("Pig-Tail")
- (3) Manifold (Section of crossheader containing connector fittings)
- (4) Header Loop (Adjacent to riser)
- (5) Riser
- (6) Crossover Line
- (7) Effluent line to downcomer

III. REAR FACE PIPING CHANGES - PRESENT OPERATING LEVELS 105-B, D, & F

Examination of previous reports and calculations indicates that the following conditions exist on the rear face when operating under present flows and temperatures.

- (1) The largest pressure loss occurs in the rear nozzle barrel outlet and tubing connector. This amounts to about 95 psi. with velocities of 100 ft/sec.
- (2) The next largest loss occurs in the 4" manifold and header. There are sufficient crossheaders to provide one for each mid-section row of tubes, but due to the present tube connection pattern they are not now utilized in this manner. The present connection arrangement places as many as 88 tubes on one header (44 for 1/2) and as few as 30 tubes on one header (15 for 1/2). This results in unbalanced loading of the present headers, resulting in excess pressure loss in the mid-section headers. Present headers with 44 tubes per side have a flow of about 1900 gpm. at 200°F. with a velocity of 47 ft/sec. and a calculated pressure loss of 52.5 psi.
- (3) The riser and crossover line losses are nominal amounting to 2.5 psi. which includes the velocity head. The velocity is 13.45 ft/sec.
- (4) Addition of the pressure losses: $95\cancel{4} + 53.5\cancel{4} + 2.5\cancel{4} = 150$ psi.
- (5) At the present flow rate about 65 electrical horsepower for each one (1) pound of pressure is required. The above loss, not counting static head, is equivalent to 9,750 electrical horsepower per reactor.

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FIG 2
PRESSURE GRADIENT
105 D AREA
(MEASURED)

DISTANCE - (FT)

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K-E 10X10 TO THE INCH 359-5
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The above pressure losses indicate that for the present conditions changes would be desirable particularly in the areas of high loss. These not only waste power but in doing so produce destructive vibrations. Changes which would minimize the existing difficulties include replacing the existing connectors with 1" O.D. tubing and replacing the connector fittings to suit. In addition, in order to minimize downtime costs new crossheaders and risers are recommended.

Since the highest velocities exist in the connector fittings reaming of these fittings was considered as an alternate method of reducing losses, velocity heads and vibration. It was abandoned because the fittings are nitrided and difficulty was expected with reaming. Further, it was not possible to determine the amount of reaming that could be done without dangerously weakening the fittings.

An additional alternate that was investigated is shown by Figure 5 and 6. This scheme would have reduced the velocities to one-half of the existing and would not have required replacing the crossheaders. It was abandoned because it would require twice the number of pigtails and it was expected it would be expensive and result in high maintenance costs.

IV. REAR FACE PIPING CHANGES - PRESENT OPERATING LEVELS 105-DR, & H

As in B, D, and F, high velocities exist in the outlet tube connectors, manifolds and headers and the loss in the 5/8" O.D. tube connections is comparable.

With only one (1) manifold and crossheader for each two (2) rows of tubes the flow is about 2,000 gpm at 93°C (200°F) with a header velocity of 50 ft/sec. This high flow rate in the header results in a combined header and riser loss of 63 psi for DR, and 68 psi. for H, the riser loss accounting for only 2.5 psi. Combining the losses, not including static head gives 158 psi. for DR and 163 psi. for H.

These values are slightly higher but basically the same as was found for 105-B, D, and F and the same modifications are recommended.

V. REAR FACE PIPING CHANGES - PRESENT OPERATING LEVEL - 105-C

Hydraulically, the rear face piping at the 105-C reactor is adequate for the existing flows. At a flow rate of 95,000 gpm. with the water entering at 60°F and leaving at 200°F (existing conditions) the maximum flow from each end of a header is 1250 gpm. For this condition the connector loss is about 25 psi and the manifold, header, and riser loss is about 26 psi. resulting in a total loss of 51 psi between the tube outlet and downcomer. This is not considered excessive and no changes are recommended to improve the hydraulic conditions.

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BOUAY AD-0024-M
DO-1121

DUAL CONNECTION
105 B, D, F
FIG. 5

E.C. SHOCKEY 12-2-59

ARRANGEMENT "A"

3"=1'-0"

B-B

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C-C

A-A
8"=1'-0"

8"=1'-0"
4 H.C. A.V.E.N.

3/4" O.D.
1.625" I.D.
1.625"

BY E.G. SHOCKLEY DATE 12-2-59

SUBJECT Reactor Study
Rear Face Piping
Proposed Dual Outlet Fitting

SHEET NO. OF
JOB NO. AD-0024-M
DC-1121

CHKD. BY DATE
BORAY

SIDE ELEVATION
DUAL CONNECTOR
3/8" = 1" ±
FIG. 6

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VI. REAR FACE PIPING CHANGES FOR INCREASED FLOWS AT 105-B, D, F, DR, H & C

Calculations for increased flows are based on a flow distribution over the faces of the reactors as shown by Figure 1 and result in a series of curves for head losses for various components and combinations of components.

Although early instructions were to consider outlet temperatures as high as 120°C later instructions were to use temperatures below boiling and as earlier explained the curves are based on an inlet temperature of 60°F (16°C) and an outlet temperature of 200°F (93°C). These curves which are the basis of the recommendations made in HW-63487 are included in this section of the report and can be used for further hydraulic studies of the reactors for flows other than those already considered.

Reviewing the curves the following observations are made:

1. Because of space limitations a 4-5/8" I.D. (5" O.D.) manifold was selected. However, if space had been available a 5" I.D. manifold would have reduced the pressure loss only 3 psi. at a flow of 120,000 gpm.
2. At a flow rate of 120,000 gpm. a 36" riser has only 3.00 psi. and a 42" riser only 1.23 psi. more loss than a 48" riser.
3. Use of a 1" connector, a 4-5/8" manifold, a 5" header, and a 42" riser results in a total pressure loss on the rear face of 18 psi. between the tube outlet and the downcomer for a gravity flow of 80,000 gpm. This corresponds to 150 psi. for the present 105-B, D, and F reactors; 158 psi. for the 105-DR reactor; 163 psi. for the 105-H reactor; and 51 psi. for the 105-C reactor at a flow of 95,000 gpm. If it is assumed that a pressure of 600 psi. plus static head is available the increased flows due to the decreased pressure losses shown above can be calculated as:
 - (a) 105-B, D and F
$$\text{Flow} = 80000\sqrt{600/(600-132)} = 90,500 \text{ gpm}$$
 - (b) 105-DR
$$\text{Flow} = 80000\sqrt{600/(600-140)} = 91,400 \text{ gpm}$$
 - (c) 105-H
$$\text{Flow} = 80000\sqrt{600/(600-140)} = 92,000 \text{ gpm}$$
4. The connector factor used, including entrance and exit losses and velocity head is equivalent to the loss in about 5 ft. of .900" I.D. tubing. Careful design of inlet and outlet fittings will be required to realize this.

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5. At a flow of 120,000 gpm. the maximum flow rate is about 75 gpm. through a connector and at a flow of 150,000 gpm. the rate is 94 gpm. This represents velocities of 38 and 47.5 ft/sec. respectively with associated pressure losses of 22 and 34.5 psi.
6. At flow rates over 120,000 gpm. it appears that a well designed .900" I.D. connector would be highly loaded. Stainless steel tubing diameters larger than 1" O.D. do not appear feasible, considering the axial thermal expansion and mechanical misalignment a connector must accommodate. For these high flows dual connectors (Figures 5 and 6) offer attractive possibilities. Using dual .875" I.D. connectors will result in velocities of 19 and 24 feet per second for flows of 120,000 gpm. and 150,000 gpm. respectively. This results in pressure losses of only 5.5 and 8.6 psi.

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DO-1121

(2) " " " - - - - - **RECORDED** " "

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BY E. G. Shockey DATE 11-9-59
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(Boray)

SUBJECT Reactor Study
Effluent Data

HW-63561
1 of 15
SHEET NO. 2 OF 14
JOB NO. AD-0024-M
DD-1121

(3) 120,000 Flow: $= 120,000 / 81,000 = 1.48 = 48\%$

GPM MAX PER TUBE $= 46.8 \times 1.48 = 69.2$ - SAY 70

GPM AVG. FOR CENTER TUBES $= 45.75 \times 1.48 = 67.6$ - SAY 68

GPM AVG. FOR ROWS 5, 41 & 56, 91 $= 40.25 \times 1.48 = 59.7$ - SAY 60

GPM AVG. FOR 4 OUTER ROWS $= 27.9 \times 1.48 = 41.25$ - SAY 41

MAX CROSS HEADER FLOW ($\frac{1}{2}$) $= (1000 \times 1.48) 1440$ SAY 1500 GPM

(4) BULK FLOW DISTRIBUTION - INLET CONDITIONS

1296 TUBES @ 68 GPM $= 88,128$

148 " " 60 " $= 8,880$

560 " " 41 " $= 22,960$

TOTAL BULK FLOW $= 119,968$ GPM SAY 120,000

(5) FOR 150,000 GPM; INCREASE IN FLOW $= 150/81 = 1.85 = 85\% +$

GPM MAX PER TUBE $= 46.8 \times 1.85 = 86.6$ SAY 87

GPM AVG FOR CENTER TUBES $= 45.75 \times 1.85 = 84.6$ SAY 85

GPM AVG FOR ROWS 5, 41 & 56, 91 $= 40.25 \times 1.85 = 74.6$ SAY 75

GPM AVG FOR 4 OUTER ROWS $= 27.9 \times 1.85 = 51.6$ SAY 52

MAX CROSS HEADER FLOW ($\frac{1}{2}$) $= (1000 \times 1.85) 1850$ SAY 1900 GPM

(6) CORRECTING OUTLET FLOWS FOR TEMPERATURES - 120,000 GPM

MAX TUBE @ 140C (284F) $= 70 \times 1.08 = 75.6$ GPM (OUTLET)

MAX CROSS HEADER @ 130C (266F) $= 1500 \times 1.07 = 1605$ SAY 1650 GPM

MAX RISER BULK @ 115C (239F) $= 120,000 \times 1.056 = 126,720$ GPM

(7) CORRECTING OUTLET FLOWS FOR TEMPERATURES - 150,000 GPM

MAX TUBE @ 140C (284F) $= 87 \times 1.08 = 94$ GPM (OUTLET)

MAX CROSS HEADER @ 130C (266F) $= 1900 \times 1.07 = 2018$ SAY, 2000

MAX RISER BULK @ 115C (239F) $= 150,000 \times 1.056 = 158,400$ GPM

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BY E. J. SHARKEY DATE 11-5-59
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(BOKAY)

SUBJECT Reactor Study
Effluent Data

W-63581
Page 10
SHEET NO. 3 OF 14
JOB NO. AD-0024-M
DO-1121

2. GRAVITY Effluent system - Present Temperatures

(1) 120,000 GPM @ 18C = (64.4F)

BULK FLOWS SAME AS 2.a.(3) & (4)

(2) 150,000 GPM @ 18C

BULK FLOWS SAME AS 2.a.(5)

(3) CORRECTING OUTLET FLOWS FOR TEMPERATURES - 120,000 GPM
SEE 1.3 & 2.a.(3)

MAX TUBE = $70 \times 1.045 = 73.3$ (OUTLET)

MAX CROSS HEADER = $1500 \times 1.038 = 1558$ SAY 1600 GPM

MAX RISER BULK = $120,000 \times 1.032 = 124,000$ GPM

(4) CORRECTING OUTLET FLOWS FOR TEMPERATURES - 150,000 GPM
SEE 1.3 & 2.a.(5)

MAX TUBE = $87 \times 1.045 = 91$ (OUTLET)

MAX CROSS HEADER = $1900 \times 1.038 = 1975$ SAY 2000 GPM

MAX RISER BULK = $150,000 \times 1.032 = 155,000$ GPM

3. SUMMARY

ITEM	PRESENT OPERATING TEMP. GRAVITY OUTLET						INCREASED OPERATING TEMP. PRESSURIZED OUTLET					
	81,000		120,000		150,000		81,000		120,000		150,000	
INLET FLOW GPM	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
MAX. FLOW/TUBE	47	50	70	74	87	91	47	51	70	76	87	94
MAX. CROSS HDR.	1000	1050	1500	1600	1900	2000	1000	1075	1500	1650	1900	2050
MAX TUBE TEMP.	102 C (215F)						140 C (284F)					
MAX HDR. TEMP.	93 C (200F)						130 C (266F)					
RISER BULK TEMP.	88 C (190F)						110 C (230F)					
OUTLET FLOW GPM TOTAL	83,500		124,000		155,000		85,500		126,200		158,400	
OUTLET FLOW NEAR SIDE RISER (UNBALANCED)	42,500		63,000		78,500		43,700		65,500		81,000	

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BY E. G. SHARKEY DATE 11-9-59

SUBJECT Reactor Study

SHEET NO. 4 OF 14

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 Typical Flow Distribution
 Temperature & Flow @ 150% Rating
 120,000 GPM @ 180

 JOB NO. AD-0024-M
 D.O-1121

DR-REACTOR 38-37 CROSS HEADERS					150% PRESENT OPR.				
NEAR SIDE -180					FAR SIDE -180				
Tube No.	t ₀	t ₀ -t _i	GPM	Δt GPM	Tube No.	t ₀	t ₀ -t _i	GPM	Δt GPM
23 73	151	133	69	9170	74	153	135	69	9300
72	150	132	69.4	9150	75	153	135	68.8	9290
71	147	129	69.5	8970	76	153	135	68.5	9245
70	147	129	69.6	8995	77	153	135	68.5	9245
69	146	128	69.6	8910	78	152	134	68	9105
68	146	128	69.6	8910	79	152	134	67.5	9040
67	145	127	69.7	8850	80	151	133	67.2	8935
66	144.5	126.5	69.6	8805	81	151	133	67	8900
65	144	126	69.6	8770	82	150	132	66.5	8770
64	143	125	69.6	8700	83	148.5	130.5	66.5	8680
63	142.5	124.5	69.6	8675	84	147	129	66.5	8580
62	141	123	69.6	8550	85	144.5	126.5	66.5	8420
61	139.5	121.5	69.6	8470	86	142.5	124.5	66.6	8300
60	138	120	69.5	8348	87	139.5	121.5	67	8150
59	136.5	118.5	69.6	8270	88	136.5	118.5	67.2	7950
58	135	117	70.2	8210	89	138.5	120.5	67.6	8160
57	132	114	70.2	8000	90	129	111	68.7	7635
56	129	111	69.4	7700	91	129	111	68	7550
* 55	126	108	65	7010	92	132	114	54.9	6490
54	121	103	41.4	4260	93	132	114	42.8	4895
53	115	97	40.8	3960	94	129	111	42.2	4680
52	108	90	40.8	3675	95	112.5	104.5	42.5	4445
51	97.5	79.5	41.6	3310	96	93	75	43.2	3240

(23) + 3124.5 2710.5 1482.5 177,668

(19) * → 2683 2341 1317.9 162,463

 $\bar{t}_0$ Δt GPM $\Delta t / \bar{t}_0 + 18$

(23) + 136 118 64.5 120-138

(19) * → 140.5 123.5 69.9 123.5-141.5

 MEAN AVG. 138.25 120.7 66.9 121.75
 139.75

+ 3221.5 2817.5 1441.2 179,005

* → 2755 2413 1270.5 161,745

 $\bar{t}_0$ Δt GPM $\Delta t / \bar{t}_0 + 18$

(23) 140 122.5 62.7 124-142

(19) 145 127 67 127-141

 M. AVG. 142.5 124.75 64.75 125.5
 143.5

Outlet GPM = 1.08 X Inlet GPM

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BY E.G. Shockey DATE 11-12-59

SUBJECT Reactor Study

SHEET NO. 5 OF 14

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(BOVAY)

Effluent Flow Data

JOB NO. A0-0024-M
DO-1121

REAR CROSS HEADER PRESSURE DROP

For analysis the header is divided into the following sections:

(1) "Manifold" section; from vertical ϕ to pressure and sample tap, down-stream from last tube inlet (pigtail), or 16'-4" from ϕ .

(2) From "Pressure tap" to riser.

Pressure loss in the "Manifold" section is difficult to estimate and can only be determined by test, or predicted from accurate operating data. The following estimated pressure losses are based on the following data available to the writer:

(1) Report No. HW-40287, Dated 12-1-55. Pressure-flow characteristics of the 190-105 systems after completion of projects CG-558 and CG-600, By L.E. FOSTER and E.R. RUDOCK.

(2) "Manifold pressures" down-stream from last inlet for various flows. (2.3 PSI @ 500 GPM - 8.6 PSI @ 1000 GPM) From E.R. RUDOCK 11-10-59. Typical for 4" headers for reactors B, D, F, DR, H & C.

(3) Rear header pressures from "DR" operating data 11-4-59, 80,000 GPM inlet, apx. 93C cross header bulk temperature. Max cross header flow estimated 2100 GPM. Top and bottom headers, 27 TO 34 PSI. Mid section 35 PSI. P₂ Pressures.

From the above data, centerline manifold pressures and friction losses may be estimated and factors determined for use in manifold and header design for increased flow and pressure.

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BY E. G. SHOCKY DATE 11-12-59
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 SUBJECT Reactor Study
 Effluent Flow Data

 SHEET NO. 6 OF 14
 JOB NO. A0-0024-M
 DO-1121

	93C	101C	110C	130C	140C
VISCOSITY:	60F	200F	214F	230F	266F
				284F	

KINEMATIC C.S.	1.120	0.310	0.290	0.275	0.200	0.175
ABSOLUTE C.P.	1.120	0.300	0.278	0.262	0.186	0.162

 PRESSURE DROP - FANNING EQUATIONS AND HYDRAULIC INSTITUTE
 FRICTION FACTOR CURVES FOR SMOOTH PIPE (C=APX. 130 WILLIAMS & HAZEN)

$$\Delta h_f = \frac{f L V^2}{2 g D} \quad f = \text{Friction factor} \quad L = \text{length ft.} \quad \Delta h = \text{ft.} \quad (1)$$

$V = \text{Velocity} \quad g = 32.2, \quad D = \text{I.D. Ft.}$

$$R = \text{Reynolds No.} = \frac{3162 Q}{d K} \quad Q = \text{Flow GPM} \quad d = \text{I.D. inches} \quad (2)$$

$K = \text{Kinematic Viscosity C.S.}$

$f = \text{From curves - Hydraulic Institute}$

4" Sch 40 PIPE I.D. = 4.026 in. = .335 Ft.

$$h_f = \frac{f 1 V^2}{64.4 \times .335} = 0.0464 f V^2 \text{ per ft.} \quad (3)$$

$$R = \frac{3162 Q}{d K} = \frac{3162 Q}{4.026 K} = \frac{786 Q}{K} \quad (4)$$

5" Sch 40 PIPE I.D. = 5.047" = .420 Feet.

$$h_f = 1.0370 f V^2 \text{ per ft.} \quad (5)$$

$$R = \frac{629 Q}{K} \quad (6)$$

$$A \text{ in}^2 \text{ (4" PIPE)} = 4.026^2 \times .7854 = 12.730 \text{ in}^2$$

$$\text{(5" PIPE)} = 5.047^2 \times .7854 = 20.00 \text{ in}^2 \quad (7)$$

$$\text{Velocity} = \frac{\text{GPM} \times .320}{A} \quad 4" \phi = \text{GPM} \times 0.0251$$

$$5" \phi = \text{GPM} \times 0.0160 \quad (8)$$

$$\text{Velocity Head ft.} = \left(\frac{\text{GPM} \times .320}{A} \right)^2 \quad 4" \phi = \text{GPM}^2 \times \frac{0.025^2}{64.4} = \text{GPM}^2 \times \frac{1.000625}{64.4}$$

$$= \text{GPM}^2 \times 0.0000975 \quad (9)$$

$$5" \phi = \text{GPM}^2 \times 0.0000396 \quad (10)$$

OR

$$h_v = \frac{V^2}{64.4}$$

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BY E. G. SHARKEY DATE 11-13-59

SUBJECT Reactor Study

SHEET NO. 7 OF 14

CHKD. BY DATE

Effluent Flow Data

JOB NO. AD-0029-M

(BOVAY)

DO-1121

CROSS HEADER FRICTION FACTORS f

Three different diameters considered:

- (1) Present 4" sch. 40 I.D. = 4.026" = .335 Ft., A = 12.73 in²
- (2) 5" O.D. x .187" wall (3/16") I.D. = 4.625" = .385 Ft., A = 16.80 in²
- (3) New 5" sch. 40 I.D. = 5.047" = .420 Ft., A = 20.00 in²

Reynolds numbers ~ R @ 200 F (93C) K = 0.31 cent. st.

$$(1) 4"-40 @ 1000 \text{ GPM} = \frac{786 \times 1000}{.31} = 2,520,000 \quad f = .0163$$

$$(2) 5" \text{ O.D. } \times \frac{3}{16} @ 1000 \quad \frac{685 \times 1000}{.31} = 2,210,000 \quad f = .0159$$

$$(3) 5"-40 @ 1000 \quad \frac{629 \times 1000}{.31} = 2,030,000 \quad f = .0157$$

For flows above 1000 GPM, or temperatures above 200 F (lower K values) Reynolds Numbers increase and friction factors remain constant at the values shown.

Velocity, Velocity², Velocity head feet

PIPE SIZE	FLOW	VELOCITY	VELOCITY ²	VELOCITY HEAD FE.
4"-40	1000	25.10	630	9.80
	2000	50.20	2520	39.20
5" O.D. x 3/16"	1000	19.05	364	5.670
	2000	38.10	1455	22.650
5"-40	1000	16.00	256	3.96
	2000	32.00	1024	15.95

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BY E. G. SHAW DATE 11-17-59

SUBJECT Reactor Study

SHEET NO. 8 OF 14

CHKD. BY DATE

Effluent Flow Data

JOB NO. 40-0029-M

DPMAY

DO-1121

 Friction loss, feet of head per foot of pipe = h_f'

Temperature; 200F and above

PIPE SIZE	FLOW	F	CONSTANT	V^2	$h_f \text{ FE./FE.}$
4"-40	1000	$\pm .0163$	$\times .0464$	$\times 630$	$= .476$
"	2000	$= .0163$	$\times "$	$\times 2520$	$= 1.900$

5"O.D. X $\frac{3}{8}$ "W	1000	$= .0159$	$\times .0404$	$\times 364$	$= .234$
"	2000	$= .0159$	$\times "$	$\times 1455$	$= 1.935$

5"-40	1000	$= .0157$	$\times .0370$	$\times 256$	$= .1475$
"	2000	$= .0157$	$\times "$	$\times 1024$	$= .5950$

 CONVERTING h_f' TO $P_f \text{ PSI.}$: @ 200F = $\frac{(930)}{2.395 \text{ FE./"}}$ @ 266F = $\frac{(1300)}{2.467 \text{ FE./"}}$

$P_f \text{ PSI./FT}$							
200F	4"-40	5"O.D.	5"-40	266F	4"-40	5"O.D.	5"-40
1000 GPM	.1995	.098	.0617	1000 GPM	.193	.095	.0598
2000 "	.7950	.391	.249	2000 GPM	.770	.0379	.2410

For the pipe sizes considered, with flows of 1000 GPM or more and temperatures 200F or higher, the friction loss varies as the square of the velocity.

Friction loss in "MANIFOLD" Section:

Using curve FIG. 5, HW-40287, overall pressure drop from & rear header to crossover line for 4" header, which is based on inlet GPM, and plotting the downstream manifold pressures (P_2) FIG. 1, 2, 3. referred to previously, the estimated "MANIFOLD" friction loss is as follows:-

(FIG. 5 -) Inlet GPM	OUTLET GPM-200F	TOTAL LOSS P_1	MANIF. PRES. P_2	MANIFOLD LOSS $P_1 - P_2$	VELOCITY HEAD P_v	MANIFOLD FRICT. P_f
1000	1050	14.60	8.60	6.00	-4.5 =	1.50
1500	1575	31.60	18.00	13.60	-10.2 =	3.40
2000	2100	55.00	31.00	24.00	-18.0 =	6.00

* Velocity head at outlet GPM.

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BY E. G. SHOOTER DATE 11-17-59

SUBJECT Reactor Study

SHEET NO. 9 OF 14

CHKD. BY DATE

Effluent Flow Data

JOB NO. AD-0024-M

(Bonyay)

DO-1121

Converting manifold friction loss into equivalent length of 4" pipe at quantity and flowing temperature (200F) we have:

1000 GPM IN. - 1050 GPM OUT -	$1.5 / .215 =$	6.98 Ft eq. length
1500 " " - 1575 " " -	$3.4 / .483 =$	7.00 " "
2000 " " - 2100 " " -	$6.0 / .857 =$	<u>7.00</u> " "

Within the accuracy of curves and slide rule the manifold friction loss is assumed to be equivalent to 7'-0" of pipe. This value is used in the following calculations.

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CHKD. BY DATE EFFLUENT FLOW DATA JOB NO. A0-0029-M
(BOVAY) CROSS HEADER DO-1121

"M" = MANIFOLD SECTION d_1 = MANIFOLD DIA. INCHES (NOMINAL I.D.)
 "H" = HEADER SECTION d_2 = HEADER " " "
 "R" = RISER AND EFFLUENT d_3 = RISER " " (O.D. INCHES)
 "C" = CROSS-OVER CONN. d_4 = CROSSOVER " " "

FIG. 1 - 4" OR 5" MANIFOLD AND HEADER - TYPICAL B, D, F, DR

FIG. 2 - 4 5/8" OR 5" MANIFOLD WITH 5" HEADER - TYPICAL B, D, F, DR

NOTE: REFERENCE DIMENSIONS ONLY -

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BY AG Shetty DATE 11-17-59 SUBJECT Reactor Study
 CHKD. BY (DORAY) DATE Effluent Flow Data
Crossheader

 SHEET NO. 11 OF 12
 JOB NO. 40-0024-M
D0-1121

EQUIVALENT length of pipe - Manifolds & cross headers

Fig.1 Present 4" Manifolds and Headers B, D, F, DR

Header		
4" Header	PIPE	28'-5"
2 - 1'-8" R Bends @ 4'-6"		9'-0"
1 - 4" Gate Valve		2'-1"
1 - 4" Tee thru run		2'-0"
Eq header	—	41'-6"
4" Manifold	—	7'-0"
TOTAL EQ	—	48'-6"

$$P_1 = P_f + P_v$$

$$P_2 = P_1 \text{ MINUS } (MP_f + P_v) \text{ OR}$$

$$P_2 = P_f \text{ MINUS } MP_f$$

OUTLET GPM	Losses @ 200 F (93C)	Pf	Velocity head PV	P ₁	P ₂
1000	* Pf = 48.5 X .1995 =	* 9.67	PV = 4.09"	P ₁ = 13.76"	P ₂ = 8.27"
2000	* Pf = " X .795 =	* 38.60	PV = 16.40"	P ₁ = 55.00"	P ₂ = 33.0"

 * NOTE: At 266 F (130C) for same flow Pf, Pv, P₁ & P₂ are 3% less.

Fig.1 New 5" Manifolds and Headers B, D, F, DR.

5" Header	PIPE	30'-0"
1 - 1'-8" 90°	Bend	4'-6"
1 - 1'-8" 135°	Bend	5'-3"
1 - 5" Gate Valve		2'-9"
1 - 5" Tee thru run		1'-6"
Eq. header	—	54'-0"
5" Manifold	—	7'-0"
Eq. Total	—	61'-0"

OUTLET GPM	Losses @ 200 F (93C)	Pf	Velocity head PV	P ₁	Manifold P _f	P ₂
1000	Pf = 61.0 X .0617 =	3.7	1.68	5.43"	.432	3.33"
2000	Pf = " X .249 =	15.2	6.66"	21.86"	1.74	13.45"

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BY P.G. Shockey DATE 11-18-59

 SUBJECT Reactor Study

 SHEET NO. 12 OF 14

 CHKD. BY BORAY DATE 11-18-59
Effluent Flow Data

 JOB NO. AD-0024-M
BORAY
Crossheader
DO-1121

Equivalent length (cont'd.)

② Fig. 2 - New 4" Manifolds and 5" Headers B, D, F, DR

5" Header, Fig. 1 minus 2'-0" EQ. PIPE = 52'-0"

1- 4" Pipe $P_{2 \text{ to red. } 2'-0"} = 2.0 \times .1995 / .0617 = 6'-9"$

1- 4" Manifold, EQ. 5" = $7.0 \times " = 22'-9"$

Total EQ. 5" = 81'-6"

OUTLET-GPM	Losses @ 200F (93%) P_f	$P_v(4")$	P_1	$M.P_f$	P_2
1000	$P_f = 81.5 \times .0617 = 5.025$	4.09	9.115	1.40	3.625*
2000	$P_f = " \times .249 = 20.30$	16.40	36.70	5.65	14.65*

③ Fig. 2 - New 4 $\frac{5}{8}$ " (5" O.D.) Manifolds and 5" Headers B, D, F, DR

5" Header, Fig. 1 minus 2'-0" EQ. PIPE = 52'-0"

2'-0" 4 $\frac{5}{8}$ " Pipe $P_{2 \text{ to red. }} = 2.0 \times .098 / .0617 = 3'-2"$

1- 4 $\frac{5}{8}$ " Manifold, EQ. 5" = $7.0 \times .098 / .0617 = 11'-2"$

Total EQ. 5" = 66'-4"

OUTLET GPM	Losses @ 200F (93%) P_f	$P_v(4\frac{5}{8}')$	P_1	$M.P_f$	P_2
1000	$P_f = 66.33 \times .0617 = 4.08$	2.37	6.45	.688	3.40
2000	$P_f = " \times .249 = 16.50$	9.50	26.00	2.770	13.75

Fig. 2 - New 5" Manifolds and headers B, D, F, DR

Same as all 5" Fig. 2 @ 1000 GPM

$P_1 = 5.43"$

$P_2 = 3.33"$

@ 2000

$P_1 = 21.86"$

$P_2 = 13.45"$

FIG. 3 Present 4" Manifolds and Headers - "H" & "C"

4" Header EQ. PIPE = 43'-0"

1- 4" Manifold EQ. Len = 7'-0" = 50'-0"

OUTLET GPM	Losses @ 200F (93%) P_f	$P_v(4")$	P_1	$M.P_f$	P_2
1000	$P_f = 50.0 \times .1995 = 9.95$	4.09	14.04	1.40	8.57*
2000	$P_f = " \times .795 = 39.70$	16.40	56.10	5.56	34.15*

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5" Header	STRAIGHT PIPE =	20'-9"
2'-0" - 4" PIPE P ₂ TOTAL = 2.0 X .1995/.0617	=	6'-9"
1- 4" MANIFOLD, EQ. 5" - 7.0 X "	=	22'-9"
4- 5" 90° L.R. ELL @ 4.9'	=	19'-7"
1- 5" 45° L.R. ELL @ 3.6'	=	3'-8"
1- 5" GATE VALVE	=	2'-9"
1- 5" Tee thru P4H	=	1'-6"
TOTAL EQ. 5" =		77'-9"

OUTLET GPM	Losses @ 200F (93.3)	P_f	P_v (4")	P_1	MP_f	P_2
1000	$P_f = 77.75 \times .0617 =$	4.8	4.09	8.89	1.40	3.4
2000	$P_f = \quad \times .249 =$	19.35	16.40	35.75	5.60	13.7

Same as above except 3 - 1'-8" R Bands instead of 5U's.

5" Header straight pipe = 13'-6"
2'0" - 4" Pipe = 6'-9"
1- 4" Manifold = 2'-9"
3- 1'-8" R. 90° Bends @ 4'-6"
1- 90° L.R. Ell, 1-45° L.R. Ell, Gate Valve & Tee
(CONT'D) TOTAL L.F. 5" = 69'-3"

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BY E.G. SHACKLEY DATE 11-18-57

SUBJECT

Reactor Study

SHEET NO. 14 OF 14

CHKD. BY DATE

Effluent Flow Data

JOB NO. AP-0024-M

BOVAY

crossheader

FIG. 3 (cont'd.) 4" Manifold and 1'-8" R. Bends.

OUTLET GPM	Losses @ 200°F (93°C)	P _f	P _v (4")	P _i	MP _f	P ₂
1000	P _f = 69.25 X .0617 =	4.27	4.09	8.36	1.40	2.87
2000	P _f = " X .249 =	17.25	16.40	33.65	5.60	11.60

FIG. 3 New 4 7/8" (5" O.D.) Manifolds and 5" Headers H, (L.R. ELLS)

5" Header With L.R. ELLS EQ. 5" PIPE = 48'-3"
 1- 4 7/8" Manifold & 1- 4 7/8" Pipe sec X 2'-0" = 14'-4"
 TOTAL EQ. 5" = 62'-7"

OUTLET GPM	Losses @ 200°F (93°C)	P _f	P _v (4 7/8")	P _i	MP _f	P ₂
1000	P _f = 62.6 X .0617 =	3.87	2.37	6.24	.688	3.18
2000	P _f = " X .249 =	15.60	9.50	25.10	2.770	12.80

FIG. 3 Same as above except with 1'-8" R. Bends H,

5" Header With 1'-8" R. Bends & 1- L.R. ELL. EQ. 5" = 39'-9"
 1- 4 7/8" Pipe X 2'-0" = 3'-2"
 1- 4 7/8" Manifold = 11'-2"
 TOTAL EQ = 54'-1"

GPM		P_f	P_v (4 7/8")	P_i	MP_f	P_2
1000	$P_f = 54.0 \times .617 =$	3.33	2.37	5.70	.688	2.65
2000	$P_f = \quad \times .249 =$	13.45	9.50	22.95	2.770	10.70

FIG. 3 New 5" Manifolds and Headers - L.R. ELLS H,

5" Header With L.R. ELLS EQ. 5" PIPE = 50'-0"
 1- 5" MANIFOLD = 7'-0"
 TOTAL EQ 5" = 57'-0"

Losses @ 200°F (93°C)

GPM		P_f	$P_v (5")$	P_i	MP_f	P_2
1000	$P_f = 57 \times .617 =$	3.52	1.68	5.20	.432	3.08
2000	$P_f = \quad \times .249 =$	14.18	6.66	20.84	1.740	12.45

FIG. 3. Same as above except 1'-8" R. Bends & 1- L.R. ELL
 1000 P_f = 48.33 X .0617 = 2.98 1.68 4.66 .432 2.550
 2000 P_f = " X .249 = 12.00 6.66 18.66 1.740 10.270

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NAVY AO-0024-M
DO-1121

EG 12-1159

FIG. 7

FRICTION LOSS PER 100 FT. SMOOTH I.D. TUBING
FANNING EQUATIONS HYDRAULIC INSTITUTE F FACTOR

K-E LOGARITHMIC 959-103
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 X 1 CYCLES

BOVAY AD-0024-M

DO-1121

12-10-59

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P1 AND P2 PSIG (2) [AT 266°F (100°C) INCREASE 3%]
 → BASED ON 60 F INLET 4 PPM

MANIFOLD AND HEADER LOSS $\neq$ REACTOR TO RISER.
 P_1 = TOTAL LOSS $\neq$ TO RISER. P_2 = FRICTION LOSS MANIFOLD TO RISER
 $P_1 - P_2$ = MANIFOLD FRICTION LOSS PLUS VELOCITY HEAD

DD-1121
SOXAY AD-0024-M

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P₁ AND P₂ PSIG (2) [AT 266F (130C) INCREASE 39%]

MANIFOLD AND HEADER LOSS & REACTOR TO RISER
P₁ - TOTAL LOSS & TO RISER P₂ = FRICTION LOSS MANIFOLD TO RISER
P₁ - P₂ = MANIFOLD FRICTION LOSS PLUS VELOCITY HEAD

FIG. 10

DO-1121

BOVAY AO-0024-M

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FIG. 11

CENTERLINE REAR HEADER TO CROSSOVER LINE
PRESSURE LOSS VS FLOW (P_i PRESSURE)

GRAVITY FLOW

AREAS B,D,F,DR,H,C
BULK TEMP 200F (93C)

* NOTE: STATIC HEAD TO BE ADDED

ACTUAL HEADER FLOW GPM @ 200F (93C) - ONE SIDE
BASED ON ONE (1) HEADER FOR EACH MID-SECTION TUBE ROW

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DO-1121

DO-1121

SOVA, AO-0024-M

Ref. 11-24-59

ΔP TOTAL

HW-63581
Type 33

PRESSURIZED EFFLUENT SYSTEM
PRESSURE LOSS VS FLOW (P)
CENTERLINE REAR HEADER TO DOWNCOMER

FIG. 13

AREA: B, D, F, DR, H, C
BULK TEMP. 240°F (115°C)

*NOTE: STATIC HEAD TO BE ADDED

ACTUAL HEADER GPM @ 266°F (130°C) - RISER & EFFLUENTS 240°F
BASED ON ONE (1) HEADER. FOR EACH MID-SECTION ROW

GRAVITY EFFLUENT SYSTEM PRESSURE LOSS VS FLOW 36"-42"-48" RISER TO CROSSOVER

AREAS: B, D, F, DR, H, C
BULK TEMP. 200°F (93°C)

EUGENE DITZEN CO.
MADE IN U. S. A.

NO. 3201 1-20 DITZGEN GRAPH PAPER
20 X 30 PER INCH

REACTOR STUDY-MODIFIED REAR FACE PIPING

RM-63581
Page 37

TUBE OUTLET TO DOWNCOMER PRESSURE LOSS VS FLOW

P = TUBE OUTLET, P₁ = MANIFOLD, P₂ = DOWNSTREAM MANIFOLD, PRESSURE.

AREAS: B, D, F, DR, H, C

BULK TEMP. 200F (93C)

DD-1121

DDNAV- AO-0025M

Fig. 16

100 → TUBE OUTLET GPM @ 200F (93C)

AP PRESSURE PSIG

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12-10-59

psyc

VII. FRONT FACE PIPING CHANGES - 105-B, D, F, DR & H

The following calculations show the pressure drop in the existing piping between the valve pit manifold and the centerline of the front face crossheader at flows of 80,000; 120,000; and 150,000 gpm. Also the calculations show the pressure drop after recommended changes have been made.

Pressure loss through the pipes is based on the Hazen-Williams empirical formula which has been derived from tests of flow of water under turbulent conditions. In a convenient form it is:

$$h_L = 2083 \left(\frac{100}{C} \right)^{1.85} \frac{q^{1.85}}{d^{4.8655}}$$

Where: h_L = friction head loss in ft. of water per 100 ft. of pipe

d = inside diameter of pipe in inches

q = flow in gallons per minute

c = constant accounting for surface roughness

The commonly used value of c for design purposes for welded and seamless steel pipe is $c = 100$ which is conservative and allows a small safety factor.

For flows greater than the present the calculations indicate that velocities are high. At a flow of 120,000 gpm. the velocity in the 36" pipe is 22 ft/sec., in the 5" sch. 80 pipe 22 ft/sec. and in the 5/8" connector 132 ft/sec. At 150,000 gpm. the velocity in the 36" pipe is 30 ft/sec. and in the 5" sch. 80 pipe 33 ft/sec.

At present flows (80,000 gpm) the pressure drop between the valve pit manifold and the venturi on the front face is 54 psi. and between the riser and the venturi 52 psi. This indicates that the largest pressure drop exists between the riser outlet nozzle and the inlet to the venturi. Therefore modification of this piping can reduce the pressure loss considerably. These modifications consist of changing all piping between the riser and the venturi except the crossheader manifold to 5" sch. 80 and all fittings to 5" -400#; using smooth bends with a r/d ratio equal to (4) instead of standard elbows; and using well rounded connections into the crossheader.

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 SUBJECT PRESSURE DROP OF
FRONT FACE PIPING FROM
HEADER TO F.F. CONNECTOR

 SHEET NO. 1 OF 23

 JOB NO. D.O. 1121

FIG (1)

CALCULATE HEAD LOSS FROM POINT Ⓐ TO
 POINT Ⓑ FOR THE FOLLOWING FLOWS

I.	40,000 GPM	80000 TOTAL
II.	60,000 GPM	120,000 "
III	75,000 GPM	150000 "

$$H_{L A-B} = H_{L1} + H_{L2} + H_{L3} + H_{L4}$$

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 SUBJECT PRESSURE DROP
FRONT FACE

 SHEET NO. 2 OF 23
 JOB NO. DO 1121

H_{L1} = Head loss from valve pit crossheader to 5" outlet from riser

H_{L2} = Riser outlet to 4" crossheader flange

H_{L3} = 4" crossheader

H_{L4} = Outlet fitting in 4" crossheader,

Fig (2)

$$H_{L1} = h_{L1-2} + h_{2-3} + h_{LECECW}$$

CASE I: 40,000 GPM

$$V = \frac{.320 Q}{A} \quad \text{Where}$$

V = velocity in ft/sec
 Q = Flow in GPM
 A = Area in sq in

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 SUBJECT PRESSURE DROP
FRONT FACE

 SHEET NO. 3 OF 23
 JOB NO. DO-1121

$$A_p = \frac{\pi D^2}{4} = \frac{\pi (33.5)^2}{4} = 881 \text{ in}^2$$

$$V = \frac{(.320)(40,000)}{881} = \underline{\underline{14.55 \text{ Ft/sec}}}$$

WILLIAMS & HAZEN FORMULA FOR WATER @ 60°F

$$\text{EQ (1)} \quad h_L = (.2083) \left(\frac{100}{C_{hw}} \right)^{1.85} \frac{Q^{1.85}}{D^{4.8655}}$$

 h_L = HEAD LOSS IN FT OF WATER / 100 FT PIPE

 C_{hw} = CONSTANT FOR SURFACE ROUGHNESS

= 100 COMMONLY USED FOR DESIGN VALUE

 Q = FLOW IN GPM

 D = INSIDE DIA OF PIPE IN INCHES

$$h_L = .2083 \left(\frac{100}{100} \right)^{1.85} \frac{(40,000)^{1.85}}{(33.5)^{4.8655}}$$

$$h_L = (.2083) \frac{(40,000)^{1.85}}{(33.5)^{4.8655}} = \frac{(.2083)(13 \times 10^6)^{1.85}}{359 \times 10^{3 \times 1.8655}} = \underline{\underline{2.565}}$$

73.5

 CASE I.
 40,000

$$h_{L-2} = \frac{2.565}{100} (80) = \underline{\underline{2.05}} \text{ FT OF } H_2O$$

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 4 OF 23
JOB NO. DD-1121

CASE II. $h_L = .2083 \frac{(60,000)^{1.85}}{(33.5)^{4.8655}} = \frac{(.2083)(25)^{2.75} 6^{1.85} \times 10^3}{(359)(73.5)} =$

$h_L = 5.43 \text{ FT OF H}_2\text{O}/100 \text{ FT}$

$h_{L1-2} = \frac{5.43 (80)}{100} = \underline{\underline{4.34 \text{ FT OF H}_2\text{O}}}$ ←

FOR 33.5" ID PIPE

EQ (2) $h_L = .198 Q^{1.85}$

where Q is in 10,000's GPM
+ h_L = Head loss per 100ft

CASE III
75,000

$h_L = .198 (7.5)^{1.85} = 8.3 \text{ FT OF H}_2\text{O}/100 \text{ FT OF PIPE}$

$h_{L1-2} = \frac{8.3 (80)}{100} = \underline{\underline{6.65 \text{ FT OF H}_2\text{O}}}$ ←

FROM FIG 2) CALCULATION OF h_{L2-3}

Q VARIES FROM TOTAL FLOW TO 0

FRICTION LOSS VARIES FROM MAX TO ZERO

USE EQ (2) & AVERAGE FLOW TO CALCULATE h_{L1-2}

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 5 OF 23
JOB NO. DO-1121

$$h_L = .198 Q_{AV}^{1.85} \text{ FT H}_2\text{O}/100 \text{ FT PIPE}$$

CASE I: $Q_{AV} = 20,000 \text{ GPM}$

$$h_L = .198 (20)^{1.85} = .67$$

$$h_{L2.3} = \frac{.67}{100} 32 = \underline{.214 \text{ FT OF H}_2\text{O}}$$

CASE II

$$h_L = .198 (3)^{1.85} = 1.51 \text{ FT H}_2\text{O}/100 \text{ FT}$$

$$h_{L2.3} = \frac{1.51}{100} (32) = \underline{.482 \text{ FT OF H}_2\text{O}}$$

CASE III

$$h_L = .198 (3.75)^{1.85} = 2.3 \text{ FT H}_2\text{O}/100 \text{ FT}$$

$$h_{L2.3} = \frac{2.3}{100} 32 = \underline{.735 \text{ FT OF H}_2\text{O}}$$

CALCULATE HEAD LOSS DUE TO BASE ELBOW

$$\frac{r}{d} = \frac{54''}{33.5} = 1.61 \quad \text{SIMILAR TO LONG RAD EL}$$

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BY: MONDT DATE: _____
CHKD. BY: V.H. DATE: _____

SUBJECT: PRESSURE DROP
FRONT FACE

SHEET NO. 6 OF 23
JOB NO. DO-1121

$$h_L = K_L \frac{V^2}{2g}$$

Where: $K_L = 0.60$ FOR $\frac{V}{d}$ OF 1.5 TO 1.6

CASE I: $V = \frac{Q \cdot .32}{A} = \frac{(.32) 40,000}{881} = 14.55 \text{ FT/sec}$

$$h_{LFC} = \frac{.60 (14.55)^2}{2 (32.2)} = \underline{1.97 \text{ FT OF H}_2\text{O}}$$

CASE II: $V = \frac{.32 Q}{A} = \frac{.32 (60,000)}{881} = 21.8 \text{ FT/sec}$

$$h_{LFC} = \frac{.60 (21.8)^2}{2 (32.2)} = \underline{4.43 \text{ FT OF H}_2\text{O}}$$

CASE III: $V = \frac{.32 Q}{A} = \frac{(.32) 75,000}{881} = 27.25 \text{ FT/sec}$

$$h_{LFC} = \frac{.60 (27.25)^2}{2 (32.2)} = \underline{6.94 \text{ FT OF H}_2\text{O}}$$

80,000 GPM

I. $H_{L1} = 2.05 + .214 + 1.97 = \underline{4.234 \text{ FT OF H}_2\text{O}}$

120,000 GPM

II. $H_{L1} = 4.34 + .482 + 4.43 = \underline{9.252 \text{ FT OF H}_2\text{O}}$

150,000 GPM

III. $H_{L1} = 6.65 + .735 + 6.94 = \underline{14.325 \text{ FT OF H}_2\text{O}}$

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 7 OF 13
JOB NO. DA-1121

JOB NO. DA-112-1

CALCULATIONS FOR H_2

Fig (3)

5" SCH 80 JD = 4.81"

4" SCH 40 IO = 4.026"

$$H_{L2} = h_{LN} + h_{L1-2} + h_{L2-3} + h_{LST}$$

h_{hn} = head loss across veld in nozzle

$$h_{L1-2} = \text{head loss in 5" PIPE \& FITTINGS}$$

h_{2-3} = head loss in 9" PIPE & FITTINGS

$h_{L, s} =$ head loss across the screen or

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 8 OF 23
JOB NO. DO-1121

CALCULATIONS FOR h_{LN}

$$h_{LN} = K_L \frac{V^2}{2g}$$

FOR SHARP CORNER INLET $K_L = .50$

CASE I: 1,000 GPM MAX CROSS HEADER FLOW

$$V = \frac{(1.32) Q}{A} = \frac{(1.32)(1,000) 4}{\pi (5)^2} = 16.4 \text{ FT/sec}$$

$$h_{LN} = \frac{.50 (16.4)^2}{(2) 32.2} = 2.09 \text{ FT OF H}_2\text{O} \leftarrow$$

CASE II: 1500 GPM MAX. CROSS HEADER FLOW

$$V = C Q \text{ For } 5" \text{ ID } C = .0164$$

$$V = (.0164) 1500 = 24.6 \text{ FT/sec}$$

$$h_{LN} = \frac{.50 (24.6)^2}{(2) 32.2} = 4.70 \text{ FT OF H}_2\text{O} \leftarrow$$

CASE III 1900 GPM MAX CROSS HEADER FLOW

$$V = .0164 (1900) = 32.2 \text{ FT/sec}$$

$$h_{LN} = \frac{.50 (32.2)^2}{(2) 32.2} = 8.05 \text{ FT OF H}_2\text{O} \leftarrow$$

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 SUBJECT PRESSURE DROP
FRONT FACE

 SHEET NO. 9 OF 22
 JOB NO. DD-114

CALCULATIONS FOR h_{L-2}

FITTING LOSSES GIVEN IN EQUIVALENT LENGTH
 OF PIPE FROM WILLIAM & HAZEN FORMULAS

- (2) 5" LR ELBOW = 17.0 FT OF PIPE
 5" 45° " = 5.9 FT OF PIPE
 5" TLT DISC CHECK = 13.0 FT OF PIPE
 5" SCH 80 PIPE = 15.0 FT OF PIPE

EQUIVALENT 5" SCH 80 PIPE = 50.9 FT

ASSUMING $C_{hl} = 100$ STD CONSTANT IN PIPE DESIGN
 FOR ROUGHNESS

CASE I: 1000 GPM

$$h_{L-2} = \frac{\text{FIT LOSS} \times \text{LENGTH OF PIPE}}{\text{FT OF PIPE}}$$

$$h_{L-2} = (.354) (50.9) = \underline{18.0 \text{ FT OF H}_2\text{O}}$$

CASE II 1500 GPM

$$h_{L-2} = .748 (50.9) = \underline{38.1 \text{ FT OF H}_2\text{O}}$$

CASE III 1900 GPM

$$h_{L-2} = .2083 \left(\frac{100}{C} \right)^{1.85} \frac{Q^{1.85}}{d^{4.8655}} \times \frac{L}{100}$$

$$h_{L-2} = .2083 \left(\frac{100}{1900} \right)^{1.85} \frac{1900^{1.85}}{(4.813)^{4.8655}} \times \frac{50.9}{100} = \underline{59.0 \text{ FT OF H}_2\text{O}}$$

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SUBJECT PRESSURE DROP
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SHEET NO. 10 OF 23
 JOB NO. 00-1121

CALCULATION FOR h_{L2-3}

FITTING LOSSES GIVEN IN EQUIVALENT LENGTH
 OF PIPE FROM WILLIAM & HAZEN FORMULAS:

PIPE FROM 2-3 = 4" SCH 40 PIPE

GATE VALUE (FULL OPEN) = 2.1 FT OF PIPE

(2) 4" LR ELBOW = 13.6 FT OF PIPE

4" SCH 40 PIPE = 5.8 FT OF PIPE

EQUIVALENT LENGTH OF 4" PIPE = 21.5 FT

ASSUMING $C_{HL} = 100$ STD CONSTANT FOR
 ROUGHNESS OF PIPE USED BY WILLIAM & HAZEN

CASE I: 1000 GPM

$$h_{L2-3} = \frac{(84.3)(21.5)}{100} = \underline{18.1 \text{ FT OF } H_2O}$$

CASE II: 1500 GPM

$$h_{L2-3} = \frac{179(21.5)}{100} = \underline{38.5 \text{ FT OF } H_2O}$$

CASE III 1900 GPM

$$h_{L2-3} = .2083 \left(\frac{100}{C} \right)^{1.85} \frac{Q^{1.85}}{d^{4.8655}} \times \frac{L}{100} =$$

$$h_{L2-3} = (.2083) \frac{(3.28 \times 35.5 \times 10^4)^{1.85}}{(1900)^{4.8655}} \times \frac{21.5}{100} = \underline{60.4 \text{ FT OF } H_2O}$$

$\frac{865}{281 \text{ FT}/100 \text{ FT} \times}$

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 SUBJECT PRESSURE DROP
FRONT FACE

 SHEET NO. 11 OF 23
 JOB NO. DO-1121

CALCULATION FOR h_{LST}

TEST DATA FOR B, D & F STRAINER (NEW & CLEAN)

SHOWED FOR 1000 GPM; $\Delta P = 3$ TO 4 PSI

ASSUME AN ΔP @ INSTALLATION = 5 PSI @ 1000 GPM

CALCULATE K_L FOR STRAINER

$$K_L = \frac{h_L \cdot 2.9}{V^2} \quad \& \quad h_L = \Delta P (2.31)$$

$$V = \frac{.32 Q}{A} = \frac{(.32)(1000)}{18.19} = 17.6 \text{ FT/sec}$$

$$K_L = \frac{(5)(2.31)(2)(32.2)}{(17.6)^2} = \underline{2.4}$$

CASE I. 1000 GPM

$$h_{LST} = K_L \frac{V^2}{2.9} = \frac{2.4 (17.6)^2}{2 (32.2)} = \underline{11.55 \text{ FT OF } H_2O}$$

CASE II 1500 GPM

$$V = \frac{(.32) Q}{A} = \frac{(.32)(1500)}{18.19} = 26.4 \text{ FT/sec}$$

$$h_{LST} = K_L \frac{V^2}{2.9} = \frac{(2.4)(26.4)^2}{2 (32.2)} = \underline{26.0 \text{ FT OF } H_2O}$$

CASE III 1900 GPM

$$V = \frac{.32 Q}{A} = \frac{.32 (1900)}{18.19} = 33.5 \text{ Ft/sec}$$

$$h = K_L \frac{V^2}{2.9} = \frac{2.4 (33.5)^2}{2.9} = \underline{72.8 \text{ FT OF } H_2O}$$

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 SUBJECT PRESSURE DROP
FRONT FACE

 SHEET NO. 12 OF 23
 JOB NO. DO-1121

FROM PAGE 7

$$H_{L2} = h_{L1-2} + h_{L2-3} + h_{L3-4}$$

CASE I 1000 GPM

$$H_{L2} = 2.09 + 18.0 + 18.1 + 11.55 = \underline{49.74 \text{ FT } H_2O}$$

CASE II 1500 GPM

$$H_{L2} = 4.70 + 38.1 + 38.5 + 26.0 = \underline{107.3 \text{ FT } H_2O}$$

CASE III 1900 GPM

$$H_{L2} = 8.05 + 59.0 + 60.4 + 42.0 = \underline{169.45 \text{ FT } H_2O}$$

CALCULATIONS FOR H_{L3} (Head loss in 4" cross header)
 HEAD LOSS IS APPROX SAME AS Q_{AV} FOR STD PIPE
 FOR length OF PIPE WITH FITTINGS

$$Q_{AV} = \frac{Q}{2} \quad h_{La} \text{ FOR } Q \quad \& \quad h_{Lb} \text{ FOR } Q_{AV}$$

CASE I 1000 GPM

$$H_{L3} = \frac{h_{La} L_a}{100} + \frac{h_{Lb} L_b}{100} = (.843)(7.3) + (.234)(15.7) = \underline{9.83 \text{ FT OF } H_2O}$$

CASE II 1500 GPM

$$H_{L3} = \frac{h_{La} L_a}{100} + \frac{h_{Lb} L_b}{100} = 1.79(7.3) + .495(15.7) = \underline{18.1 \text{ FT OF } H_2O}$$

CASE III 1900 GPM

$$H_{L3} = \frac{h_{La} L_a}{100} + \frac{h_{Lb} L_b}{100} = 2.81(7.3) + .766(15.7) = \underline{32.15 \text{ FT OF } H_2O}$$

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 13 OF 23
 JOB NO. DD-1121

EXISTING PIPING

TOTAL LOSS FROM $\frac{1}{2}$ RISER TO $\frac{1}{2}$ CROSS HEAD

$$H_L = H_{L2} + H_{L3}$$

CASE I 1000 GPM

$$H_L = 49.74 + 9.83 = \underline{\underline{59.57 \text{ FT OF } H_2O}}$$

$$\Delta P = 25.8 \text{ PSI}$$

CASE II 1500 GPM

$$H_L = 107.3 + 20.82 = \underline{\underline{128.12 \text{ FT OF } H_2O}}$$

$$\Delta P = 55.5 \text{ PSI}$$

CASE III 1900 GPM

$$H_L = 169.5 + 32.15 = \underline{\underline{201.65 \text{ FT OF } H_2O}}$$

$$\Delta P = 87.2 \text{ PSI}$$

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 14 OF 23
JOB NO. DA-1121

h_{L2-3} Fig (3) Page 7

MODIFICATION TO INCLUDE 5" SCH 80 PIPE,
5" GATE VALVE & 5" 45° ELBOW

FITTING LOSS IN EQUIVALENT LENGTH OF PIPE

5" GATE VALVE = 2.7 FT OF PIPE

2 5" 45° ELBOWS = 11.8 " " "

5" SCH 80 PIPE = 5.8

EQUIVALENT LENGTH = 20.3 FT

CASE I: 1000 GPM

$$h_{L2-3} = \frac{(35.4) 20.3}{100} = \underline{7.2 \text{ FT OF H}_2\text{O}}$$

CASE II: 1500 GPM

$$h_{L2-3} = \frac{74.8 (20.3)}{100} = \underline{15.2 \text{ FT OF H}_2\text{O}}$$

CASE III 1900 GPM

$$h_{L2-3} = \frac{116 (20.3)}{100} = \underline{23.6 \text{ FT OF H}_2\text{O}}$$

FOR 5" GATE VALVE @ 1500 GPM ①
SAVE A H_L OF 23.3 FT OF H_2O

FOR 5" GATE VALVE @ 1900 GPM
SAVE A H_L OF 36.8 FT OF H_2O

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 15 OF 23
JOB NO. DO-1121

Fig 5

ROUND ENTRANCE TO NOZZLE TO $\frac{3}{4}"$ RADIUS

$$h_L = K_L \frac{V^2}{2g}$$

$$K_L = .04$$

FOR 1500 GPM
 $V = 24.6$ Ft/sec

$$h_L = K_L \frac{V^2}{2g} = \frac{.04 (24.6)^2}{2 (32.2)} = \underline{.375 \text{ FT OF } H_2O}$$

FOR 1900 GPM
 $V = 32.2$ Ft/sec

$$h_L = K_L \frac{V^2}{2g} = \frac{.04 (32.2)^2}{2 (32.2)} = \underline{.644 \text{ FT OF } H_2O}$$

FOR RADIUS NOZZLE @ 1500 GPM

SAVE A H_L OF 4.3 FT OF H_2O ← ②

FOR RADIUS NOZZLE @ 1900 GPM

SAVE A H_L OF 7.4 FT OF H_2O ← ②

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 16 OF 23
 JOB NO. DD-1121

ADD NEW PIPE BENDS IN PLACE OF 90° ELLS

PIPE BENDS WITH $\frac{r}{d} = 4$

$$K_L = .2$$

$$H_L = K_L \frac{V^2}{2g}$$

For 5" SCH 80 PIPE

FOR 1500 GPM

$$V = 26.4 \text{ ft/sec}$$

$$H_L = (.2) \frac{(26.4)^2}{64.4} = \underline{2.16 \text{ FT OF H}_2\text{O}}$$

FOR 1900 GPM

$$V = 33.5 \text{ ft/sec}$$

$$H_L = .2 \frac{(33.5)^2}{64.4} = \underline{3.5 \text{ FT OF H}_2\text{O}}$$

H_L FOR LONG SWEEP ELBOW = 3 X LOSS FOR PIPE BEND

FOR TWO ELBOW @ 1500 GPM

SAVE H_L OF 8.6 FT OF H₂O

FOR TWO ELBOW @ 1900 GPM

SAVE H_L OF 19.0 FT OF H₂O

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 17 OF 23
JOB NO. DD-1121

ADD 5" CROSSHEADER IN PLACE OF 4"

FOR 11500 GPM = Q

$$H_c = \frac{h_{La} L_a}{100} + \frac{h_{Lb} L_b}{100}$$

h_{La} = LOSS IN SCH 80, 5" PIPE FOR Q

L_a = Length of PIPE WITHOUT FITTINGS

h_{Lb} = LOSS IN SCH 80 5" PIPE FOR $\frac{Q}{2}$

L_b = Length of PIPE WITH FITTINGS

$$H_c = .748 (7.3) + .208 (15.7) = \underline{\underline{8.72 \text{ FT OF } H_2O}}$$

FOR 19000 GPM = Q

$$H_c = 1.16 (7.3) + 1.322 (15.7) = \underline{\underline{13.53 \text{ FT OF } H_2O}}$$

FOR 5" CROSS-HEADER @ 1500 GPM
SAVE A H_c OF 12.10 FT OF H_2O 4

FOR 5" CROSSHEADER @ 1900 GPM
SAVE A H_c OF 18.62 FT OF H_2O 4

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SUBJECT PRESSURE DROP

SHEET NO. 18 OF 23

CHECKED BY V.H. DATE

FRONT FACE

JOB NO. DO-1121

PROPOSED PIPING FROM & RISER TO

& CROSS HEADER.

REACT
&

FIG 6

TOTAL HEAD LOSS SAVED = H_{LS} = SUM OF H_L SAVED

Pages 14 THRU 17 NUMBERS 1 THRU 4

FOR 1500 GPM

$$H_{LS} = 23.3 + 4.3 + 8.6 + 12.1 = 48.3 \text{ FT OF } H_2O$$

& RISER TO

& CROSS HEADER.

$$\text{HEAD LOSS} = H_{LP} = 128.12 - 48.3 = 79.82 \text{ FT OF } H_2O$$

34.5 PSI

FOR 1900 GPM

$$H_{LS} = 36.8 + 7.4 + 14.0 + 18.6 = 76.8 \text{ FT OF } H_2O$$

$$\text{HEAD LOSS} = H_{LP} = 201.65 - 76.8 = 124.85 \text{ FT OF } H_2O$$

54 PSI

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SUBJECT: PRESSURE DROP
FRONT FACE

SHEET NO. 19 OF 23
JOB NO. 00-1121

OVERALL LENGTH OF 6" LOOP = $L \hat{=} 28'$

ASSUME TWO CONDITIONS

CASE I FLOW THRU LOOP = 1500 GPM

CASE II FLOW THRU LOOP = 1900 GPM

CALCULATE HEAD LOSS FROM POINT 1 TO 2 = H_L

$$H_L = h_{L1} + h_{L2} + h_{L3} + h_{L4}$$

h_{L1} = HEAD LOSS ACROSS NOZZLE

h_{L2} = HEAD LOSS IN 6" PIPE & FITTINGS

h_{L3} = HEAD LOSS IN 5" PIPE

h_{L4} = HEAD LOSS IN 6" STRAINER

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SUBJECT PRESSURE DROP
FRONT FACE

Page 59
SHEET NO. 20 OF 23
JOB NO. DO-1121

1. CALCULATIONS FOR h_{L1}

$$h_L = K_L \frac{V^2}{2g} \quad \text{where}$$

$$K_L = .04 \quad \text{FOR ROUNDED NOZZLE} \quad R = .14 \text{ DIA}$$

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

$$\text{PIPE} = 6" \text{ SCH 80} \quad \text{ID} = \underline{5.761"} \quad \leftarrow$$

FOR CASE I.

$$V = 18.5 \text{ FT/SEC}$$

$$h_{L1} = (.04) \frac{(18.5)^2}{2(32.2)} = \underline{.212 \text{ FT OF H}_2\text{O}} \quad \leftarrow$$

FOR CASE II.

$$V = 23.4 \text{ FT/SEC}$$

$$h_{L1} = (.04) \frac{(23.4)^2}{2(32.2)} = \underline{.336 \text{ FT OF H}_2\text{O}} \quad \leftarrow$$

2. CALCULATIONS FOR h_{L2}

FITTINGS IN EQUIVALENT LENGTH OF PIPE

(1)	6" LR 90° ELBOW	=	10.2 FT OF PIPE
(4)	6" 45° ELBOW	=	28.4 FT OF PIPE
(1)	6" GATE VALVE	=	3.2 FT OF PIPE
(1)	6" TILT DISC CHECK	=	16.0 FT OF PIPE

$$\begin{aligned} \text{FITTING TOTAL EQUIV 6" PIPE} &= \underline{57.8} \text{ FT OF PIPE} \\ \text{TOTAL 6" PIPE} &= \underline{28.0} \text{ FT OF PIPE} \\ &= \underline{85.8} \end{aligned}$$

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SUBJECT PRESSURE DROP
FRONT FACE

SHEET NO. 21 OF 23
JOB NO. DO-1121

$L \approx 86$ FT OF 6" PIPE
FOR CASE I.

USE $C = 100$ & HAZEN-WILLIAMS EMPIRICAL
FORMULAS

$$h_{L2} = (6.312)(86) = \underline{26.8 \text{ FT OF } H_2O} \leftarrow$$

FOR CASE II.

$$h_{L2} = (6.483)(86) = \underline{41.5 \text{ FT OF } H_2O} \leftarrow$$

CALCULATIONS FOR h_{L3}

FROM PAGE 17 THIS REPORT:

CASE I

$$h_{L3} = \underline{8.72 \text{ FT OF } H_2O} \leftarrow$$

CASE II

$$h_{L3} = \underline{13.53 \text{ FT OF } H_2O} \leftarrow$$

CALCULATIONS FOR h_{L4} : (REF: PAGE 7 THIS REPORT)

$$K_L = 2.4 \quad h_L = K_L \frac{V^2}{2g}$$

FOR CASE I

$$h_{L4} = (2.4) \frac{(18.5)^2}{2(32.2)} = \underline{12.72 \text{ FT OF } H_2O} =$$

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BY: MOUNT DATE
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SUBJECT: PRESSURE DROP
FRONT FASE

SHEET NO. 22 OF 23
JOB NO. 60-1121

FOR CASE II

$$h_{L1} = 2.4 \frac{(23.4)^2}{2 (32.2)} = \underline{20.16 \text{ FT OF } H_2O}$$

FOR CASE I (1500 GPM)

$$H_L = h_{L1} + h_{L2} + h_{L3} + h_{L4}$$

$$H_L = .212 + 26.8 + 8.72 + 12.72 = \underline{\underline{48.45 \text{ FT OF } H_2O}}$$

$$P = \underline{21 \text{ PSI}}$$

FOR CASE II (1900 GPM)

$$H_L = h_{L1} + h_{L2} + h_{L3} + h_{L4}$$

$$H_L = .336 + 41.5 + 12.72 + 20.16 = \underline{\underline{74.71 \text{ FT OF } H_2O}}$$

$$P = 32.4 \text{ PSI}$$

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SUBJECT

PRESSURE DROP
FRONT FACE

Page (2)
SHEET NO. 23 OF 23
JOB NO. DA-1121

Connector Loss Comparison

Present Connector:

$$h_L = K_L \frac{V^2}{2g}$$

Flow of 80,000 gpm

Flow through connector app. 47.5 gpm

$$V = \frac{(9 \text{ pm}) \cdot (0.322)}{A(\text{inside})} = \frac{47.5 \cdot (0.322)}{\frac{\pi}{4} (0.4687)^2} = 88.4 \text{ ft/sec}$$

$K_L = 0.50$ for square entrance from pipe

$$h_L = \frac{(0.50)(88.4)^2}{(2)(32.2)} = 60.6 \text{ ft. H}_2\text{O or } 26.3 \text{ psi}$$

New Connector:

$$h_L = K_L \frac{V^2}{2g}$$

Flow of 80,000 gpm

Flow through connector app. 47.5 gpm

$$V = \frac{(9 \text{ pm}) \cdot (0.322)}{A(\text{inside})} = \frac{47.5 \cdot (0.322)}{\frac{\pi}{4} (0.875)^2} = 25.4 \text{ ft/sec}$$

$K_L = 0.04$ for well rounded bellmouth connector

$$h_L = 0.04 \frac{(25.4)^2}{2 \cdot 32.2} = 0.4 \text{ ft. H}_2\text{O or } 0.173 \text{ psi}$$

Conclusions: Decrease in pressure loss of 26.1 psi can be realized by using new connector. This increase in efficiency will be reflected in lower pumping costs.

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PROCESS PIPING FRONT FACE B, D & F PRESSURE LOSS FROM RISER TO CROSSHEADER

DECLASSIFIED

PROCESS PIPING FRONT FACE DR™ H

11-03501

PRESSURE LOSS & RISER TO & CROSSHEADER

Page 64

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Pressure Loss

PSI

TOTAL FLOW IN THOUSAND GAL/MIN

VIII. STRESS CALCULATIONS

Stress calculations for the present headers of the 105-B, D, and F reactors assuming installation at 70°F without "cold-springing", and operation at 227°F indicate a maximum stress in the piping of about 17,000 psi. This assumes a moveable anchor or guide pipe support of the header at the second support from the riser and a fixed support where the crossheader is attached to the riser. The allowable stress for 304 stainless steel (ASA Code) under these conditions is 27,500 psi.

Because of the large effect "cold-spring" or "self-spring" has on stresses, if the present headers are to remain in service, this should be checked. It can be done by loosening the bolts of a valve flange on each side and noting whether the flanges move apart. A total of 3/4" "cold-spring" (3/8" on each side) is desirable for the mid-section headers to reduce overall stress.

Calculations of the riser wall stresses at the point of attachment of the headers in the 105-B, D, and F reactors indicate a stress in excess of 600,000 psi. This is based on an elastic analysis and on the assumption that the riser is 100% fixed at its anchors. An elastic analysis for stresses above the yield point does not yield true stresses and a slight amount of rotation and lateral movement will materially reduce the calculated stresses, therefore, the high value shown is not interpreted as being a true stress but only an indication that the riser wall in this area is probably operating in the plastic range. If this is the case failure can be expected as the reactors age.

Thermal stresses in the present 105-DR crossheaders are the same as those indicated above for 105-B, D and F.

Stresses calculated for the 105-H and C crossheaders based on the assumptions made in the calculations for the 105-B, D, and F crossheaders are in the order of 44,500 psi. Although this is considerably in excess of a normal allowable stress, failure has not occurred, and it must be assumed "self-springing" and riser movement have reduced the actual stresses to a value lower than that calculated. Because it is not possible to determine the actual stresses it is considered that continued operation under existing conditions in view of the high calculated stresses may lead to failure.

In order to improve conditions it is suggested that the risers be supported on rollers. This will relieve the stresses in the crossheaders and in the riser walls at the point of connection of the crossheaders.

A set of stress calculations is included for a pressure reducing station to be used when pressurization of the rear face is contemplated. In addition, in connection with this facility is information on a suitable pressure reducing valve. Although this latter information is not in the nature of a stress calculation it is design information that is pertinent.

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BY RE 540 DATE 10-5-59SUBJECT Reactor SecuritySHEET NO. 14 OF 14

CHECKED BY DATE

Plant Chief Engineer SeriesJOB NO. AC-0024-M

(Barry)

B, D, E & D RD.R. U.S.I.

REFERENCE: S.W. SPIELVOGEL - PIPING SERIES SIMPLIFIED, 5TH ED. 1952

ASSUMPTIONS:

1. Straight portion of 4" header between risers is guided at approximately 9'-6" centers and is not free to assume the elastic curve.
2. For an approximate solution it is assumed that the header is anchored at the second guide. (Free to move in X direct.)
3. That piping is installed at 70F without cold spring.
4. That one half of the expansion is taken by each half of header.

DATA:

4" Schedule 40 pipe 304 stainless steel

Max. operating temperature	140C = 284F	} $\Delta t = 216F$
Min. "	20C = 68F	

 $I = 7.23 \text{ in}^4$ $S = 3.21 \text{ in}^3$ $O.D. = 4.5"$ $E = 28 \times 10^6$

Expansion per 100' = 2.45 in.

 $\Delta x = \frac{2.45 \times 79}{2} = 0.97 \text{ in.}$ $\Delta y = 2.45 \times 0.051 = 0.125 \text{ in.}$
 $\Delta x EI = 0.97 \times 28 \times 10^6 \times 12^3 \times 7.23 / 12 \times 129 = 20796$
 $\Delta y EI = 0.125 \times 28 \times 10^6 \times 12^3 \times 7.23 / 12 \times 129 = 74,643$

 113,539
 UNCLASSIFIED
 74,643

BY: G. Shackey DATE: 10/6/59

SUBJECT: Reactor Steady

SHEET NO. 2 OF 14

CHKD BY: DATE:

Reactor Cross Header Stress

JOB NO. AD-0024-M

(Berry)

B.D.F.B.D.R

D.O. 1121

Centroid.

	l, ft	X', ft	lX'	Y', ft	lY'
ab	13.66	6.83	93.23	0	0
bc	5.1	13.66	69.66	2.55	13.0
cd	2.5	12.41	22.99	5.10	12.75

21.26'

185.88'

25.75'

$$\bar{X} = \frac{185.88}{21.26} = 8.74'$$

$$\bar{Y} = \frac{25.75}{21.26} = 1.21'$$

Brch.	Length l'	X	Y	$lX^2 + I_o$	$lY^2 + I_o$	lXY
ab	13.66	-1.91	-1.21	$\begin{matrix} 49.83 \\ + I_o 213.00 \end{matrix}$	19.94	+ 81.57
bc	5.1	+ 4.92	+ 2.34	$\begin{matrix} 123.43 \\ + I_o 11.05 \end{matrix}$	28.00	+ 58.71
cd	2.5	+ 3.67	+ 3.89	$\begin{matrix} 33.67 \\ + I_o 1.30 \end{matrix}$	37.90	+ 34.70

$$I_y = 421.22$$

$$I_x = 96.89$$

$$I_{xy} = 124.98$$

DECLASSIFIED

BY E. G. Shockey DATE 10/13/59
CHKD. BY (BOVAY) DATE _____SUBJECT Reactor Study
Reactor Cross Header Stress
B, D, F & D RSHEET NO. 3 OF 14
JOB NO. AW-0024-M
DO-1121

DECLASSIFIED

BY E. Shockey DATE 10/2/59

SUBJECT Reactor Stray

SHEET NO. 4 OF 14

CHKD. BY DATE
(Boray)Heat Cross Header Stress
B, D, F & DRJOB NO. AO-0024-M
D.O. 1121

1. FORCES

$$F_x = \frac{421.22 \times 113,600 + 125 \times 14,643}{96.9 \times 421.22 - 125^2} = 1,972^*$$

$$F_y = \frac{96.9 \times 14,643 + 125 \times 113,600}{96.9 \times 421.22 - 125^2} = 620^*$$

MOMENTS

$$M_a = -1,972 \times 1.21 + 620 \times 8.74 = +3,033 \text{ Ft}^* = \text{Reacting M}$$

$$M_b = -1,972 \times 1.21 - 620 \times 4.92 = -5,436$$

$$M_c = +1,972 \times 3.89 - 620 \times 4.92 = +4,621$$

$$M_d = +1,972 \times 3.89 - 620 \times 2.42 = +6,171$$

= Bending M

2. STRESSES

$$S_a = \frac{3,033 \times 12}{3.21} = 3,033 \times 3.738 = 11,337^*/\text{in}^2$$

$$S_b = \frac{5,436 \times 3.738}{3.21} = 20,319^*/\text{in}^2$$

$$S_c = \frac{4,621 \times 3.738}{3.21} = 17,273^*/\text{in}^2$$

$$S_d = \frac{6,171 \times 3.738}{3.21} = 23,067^*/\text{in}^2$$

a. Allowable Stress (SA) A.S.A. Code B31.1 - 1955

Division A Refinery and Oil Piping

ASTM A312 Type 304 Seamless stainless Steel pipe

-20 TO 100 F	200 F	300 F	
18,750	16,650	15,000	Seamless
16,000	14,150	12,750	Welded

Expected number of full temperature cycles over
 expected life $\approx 7000 \approx$ nearly one cycle/day for 20%
 $f = 1.0$

$$SA = 1(1.25 S_c + 0.25 S_h) = 18,750 \times 1.25 = 23,450$$

$$+ 15,000 \times 0.25 = 3,750$$

$$SA = 27,200^*/\text{in}^2$$

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SUBJECT Reactor Stand
Rear Cross Header Stress
B.D.F. & V.R.

BY E. S. Shockey
DATE 10/10/59
CHKD. BY (BOVAY)
DATE

NOTE: Moments & Forces
Shown for Eh
140C (284F)

MOMENT DIAGRAM
&
CALCULATION CHECK

BY E.G. Sherry DATE 10/8/59

SUBJECT Reactor Study

SHEET NO. 6 OF 14

CHKD. BY DATE

Reat Cross Header Stress

JOB NO. AO-0024-M

(BORAY)

B.D.F. & D.R.

DO-1121

b. The Code, ASA B31.1, stipulates that flexibility calculations for the expansion stress " S_E " be based on the modulus of elasticity " E_c " at room temperature, including the effect of stress intensification. (i)

c. It is customary to make flexibility calculations for the entire expansion range using " E_h " at operating temperature, the resulting stress must be increased by the factor " E_c/E_h " to obtain the expansion stress " S_E ". On the other hand if calculations for the entire expansion range is made with " E_c " the result gives " S_E " which in this case signifies either: (a) the stress in the cold condition for a system which is cold-sprung 100%, or (b) the stress in the cold condition for a system which, operating in the creep range, has relaxed completely and becomes stressless at operating temperature.

d. For this problem $E_c/E_h = 29 \times 10^6 / 28 \times 10^6 = 1.038$
 The stress intensification factor " i " for 4" SCH 40 long radius Ell is: characteristic $h = \frac{tR}{r^2} = \frac{.237 \times 6}{2.132^2} = .312$
 From chart, " i " = 2.

e. " i " for unreinforced fabricated tee (riser connection 36" O.D. x 3/4" wall) $h = \frac{t}{r} = \frac{.187}{17.937} = .0105$ " i " = 18 (off chart)

for $h = .02$ " i " = 14. This indicate excess stress at riser which must be evaluated by other methods (see calculations by V.R. Hill 10/9/59)

f. The maximum moment occurs in straight pipe at riser connection, point "d" = $6,171 \times 1.038 = 6,400 \text{ ft}^*$.

$$S_E = \frac{6400 \times 12}{3.21} = \underline{24,000 \text{ psi}}$$

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BY E.G. Sheikoy DATE 10/9/57

SUBJECT Reactor Study

SHEET NO. 7 OF 14

CHKD. BY DATE

Reactor Header Stress

JOB NO. AD-0024-M

B, D, F & DR

D.D. - 11.21

g. SE in elbow at point "C" = $2 \times 1.038 \times 17,273$
 $= 2 \times 1.038 \times 17,273 = \underline{35,800 \text{ } ^\circ/\text{in}^2}$

h. SE in elbow at point "b" = $2 \times 1.038 \times 20,319 = \underline{42,100 \text{ } ^\circ/\text{in}^2}$

j. SE in straight pipe at "a" = $11,337 \times 1.038 = \underline{11,550 \text{ } ^\circ/\text{in}^2}$

3. REACTION FORCES AND COLD-SPRING. ASA B31.1

a. The flexibility calculations for this problem are based on $E_h = 28 \times 10^6 \text{ psi}$, without cold-spring, $C = \text{cold-spring factor} = 0$. Subsequent relaxation of the piping, if any, will reduce the reactions. The method of evaluating reactions for various amount of cold spring is as follows: $C = \text{Cold Spring } \%$, $R = \text{reaction}$

b. No Cold-spring $C = 0$, $R_c = CR = 0$. Initially no reactions exist in the cold condition. However, should self-springing occur, reactions will appear in the cold condition which are appraised to assume in time intensities equal to:

$$\left(1 - \frac{S_h}{S_e} \times \frac{E_c}{E_h}\right) R_c$$

$$\frac{S_h = 15,000 \text{ psi}}{S_e = 42,100 \text{ psi}} = .356$$

$$\frac{E_c = 29 \times 10^6}{E_h = 28 \times 10^6} = 1.038$$

$$R = R_c (1 - .356 \times 1.038) = .639 R_c$$

c. Tabulation of reactions and stresses which may in time occur in the cold condition are:

(i) Calculation based on E_h

$$R_x = 1,972 \text{ } ^\circ$$

$$R_y = 620 \text{ } ^\circ$$

Calculation based on E_c

$$1.038 \times 1,972 = 2,045 \text{ } ^\circ$$

$$" 620 = 644 \text{ } ^\circ$$

$$S_a = (i) 11,337 \text{ } ^\circ/\text{in}^2 =$$

$$S_b = (2 \times 20,319 \text{ } ^\circ/\text{in}^2) =$$

$$S_c = (2 \times 17,273 \text{ } ^\circ/\text{in}^2) =$$

$$S_d = 23,067 \text{ } ^\circ/\text{in}^2 =$$

$$(ii) " 11,337 = 11,550 \text{ } ^\circ/\text{in}^2$$

$$2 \times 1.038 \times 20,319 = 42,100 \text{ } ^\circ/\text{in}^2$$

$$2 \times " 17,273 = 35,800 \text{ } ^\circ/\text{in}^2$$

$$23,067 = 24,000 \text{ } ^\circ/\text{in}^2$$

$$1,972 \times 1.038 = 2,045 \text{ } ^\circ/\text{in}^2$$

$$620 \times 1.038 = 644 \text{ } ^\circ/\text{in}^2$$

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BY E. G. Shook DATE 10/9/59

SUBJECT Reactor Steady
Reactor Cross Header Stress
B.D.F. & DR

SHEET NO. 8 OF 14

CHKD. BY _____ DATE _____

JOB NO. AD-0024-M
DO-1121

(2) The reactions and stresses in the cold condition (E_c) may become: (Due to relaxation and self-springing)

$$R_{xc} = .639 \times 2045 = 1310 \text{ *}$$

$$R_{yc} = \text{ " } 644 = 410 \text{ *}$$

$$S_{xc} = \text{ " } 11,550 = 7,370 \text{ */in}^2$$

$$* S_{bc} = \text{ " } 42,100 = 27,000 \text{ */in}^2$$

$$S_{cc} = \text{ " } 35,800 = 22,900 \text{ */in}^2$$

$$S_{dc} = \text{ " } 24,000 = 15,350 \text{ */in}^2 \quad (M_{dc} = 4,080 \text{ Ft *})$$

(3) The reactions and stresses in the hot condition may become: $1.000 - .639 = .361 R_h \text{ \& } S_h (E_h)$

$$R_{xh} = .361 \times 1,972 = 711 \text{ *}$$

$$R_{yh} = \text{ " } 620 = 224 \text{ *}$$

$$S_{xh} = \text{ " } 11,237 = 4,050 \text{ */in}^2$$

$$S_{bh} = \text{ " } 40,638 = 14,700 \text{ */in}^2$$

$$S_{ch} = \text{ " } 34,546 = 12,460 \text{ */in}^2$$

$$S_{dh} = \text{ " } 23,067 = 8,340 \text{ */in}^2 \quad (M_{dh} = 2225 \text{ Ft *})$$

(4) Based on the above Code theory there will be sufficient self-springing to bring the stresses within the allowable limit of $S_A = 27,200 \text{ */in}^2$

d. For 100% cold-spring the values are as follows: $C=1.0$

Cold condition	Hot condition
$F_{xc} = 2,045 \text{ *}$	$\frac{1}{3} \times 1,972 = 656 \text{ *}$
$F_{yc} = 644 \text{ *}$	$\text{ " } 620 = 206 \text{ *}$
$S_{xc} = 11,550 \text{ */in}^2$	$\text{ " } 11,237 = 3,740 \text{ PSI}$
$S_{bc} = 42,100 \text{ */in}^2$	$\text{ " } 40,638 = 13,550 \text{ *}$
$S_{dc} = 35,800 \text{ */in}^2$	$\text{ " } 34,546 = 11,500 \text{ *}$
$S_{dc} = 24,000 \text{ */in}^2 \quad (M_{dh} = 2055 \text{ Ft *})$	$23,067 = 7,660 \text{ *}$

(1) Stress too high in cold condition

e. For 50% Cold-spring the values are as follows: $C=0.5$

Cold condition	Hot condition
$F_{xc} = 0.5 \times 2,045 = 1,022 \text{ *}$	$\frac{2}{3} \times 1,972 = 1335 \text{ *}$
$F_{yc} = \text{ " } 644 = 322 \text{ *}$	$\text{ " } 620 = 413 \text{ *}$
$* S_{bc} = 42,100 = 21,050 \text{ *}$	$\text{ " } 40,638 = 27,200 \text{ */in}^2$
$M_{dc} = 3,200 \text{ Ft *}$	$M_{dh} = 4,100 \text{ Ft *}$

* (1) Just meets $S_A = 27,200 \text{ */in}^2$ in hot condition

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BY E. G. Shockey DATE 12/9/59

SUBJECT Reactor Study
Peak Gross Header Stress
B, D, E & D

SHEET NO. 9 OF 14
JOB NO. AP-0029-M
DO-1121

F. The code permits credit for 2/3 of the cold-spring in the hot condition. Values shown for 100% (d) and 50% (e) cold-spring are based on the following:

$$R_c = CR \text{ --- } R \text{ is based on } E_c$$

$$R_h = (1 - 2/3 C) R \text{ --- } R \text{ is based on } E_h \text{ (original calc)}$$

5. COMPARISON OF REACTION FORCES AND STRESS FOR OTHER OPERATING TEMPERATURES

For purposes of comparison it is assumed that, for the comparatively small temperature range, the forces and stresses will vary directly as the operating temperatures, or as follows:

a. Present Operating Conditions

Header temperature equals 10BC = 227F

$$\text{correction factor for } F(R) \text{ and } S_c = \frac{227 - 70}{284 - 70} = \frac{157}{214} = .734 = 73.4\% \text{ of calculated values.}$$

$$S_c = 18,750 \text{ PSI} \quad S_h = 16,200 \text{ PSI} \quad E_c = 29 \times 10^6 \quad E_h = 28.3 \times 10^6$$

$$S_A = 1.25 \times 18,750 + 0.25 \times 16,200 = 23,450 + 4,250 = \underline{27,700 \text{ PSI}}$$

$$\frac{E_c}{E_h} = \frac{29 \times 10^6}{28.3 \times 10^6} = 1.025$$

(1) Reactions and stress based on E_h and E_c are:

<u>For E_h</u>		<u>For E_c</u>	
$R_x = .734 \times 1972 =$	1450*	$\times 1.025 =$	1490*
$R_y = \quad \quad \times 670 =$	454*	" =	465*
* $S_h = \quad \quad \times 40,638 =$	35,000 PSI	" =	35,900 PSI
$S_c = \quad \quad \times 34,546 =$	25,300 "	" =	26,000 "
$S_d = \quad \quad \times 23,067 =$	16,900 "	" =	17,350 "
$M_d = \quad \quad \times 6.171 =$	4,530 ft*	" =	4,650 ft*

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BY E. G. Sharkey DATE 10/13/59
CHKD. BY DATE

SUBJECT Reactor Study
Reactor Cross Header Stress
B, D, F & D.R.

HW-63501
Page 75
SHEET NO. 10 OF 14
JOB NO. A0-0029-M
DO-1121

5. a. (contd)

(2) With zero cold-spring reactions may become: C=0

$$\left(1 - \frac{16,200}{35,000} \times 1.025\right) = R_c = .562 \quad R_c \quad S_c = .562 \quad S_c$$

(Self-Spring factor)

Cold Condition (Ec)

Hot Condition (Eh)

$$\begin{aligned} R_x &= 0.562 \times 1490'' = \\ R_y &= '' \quad 465'' = \\ * S_b &= '' \quad 35,900 = \\ S_c &= '' \quad 26,000 = \\ S_d &= '' \quad 17,350 = \\ M_d &= '' \quad 4,650 = \end{aligned}$$

$$\begin{aligned} &835'' \\ &261'' \\ &20,100 \text{ PSI} \\ &14,600'' \\ &9,740'' \\ &2,610 \text{ ft}'' \end{aligned}$$

$$\begin{aligned} 0.438 \times 1450 &= 635'' \\ '' \times '' \quad 454 &= 199'' \\ '' \times '' \quad 35,000 &= 15,350 \text{ PSI} \\ '' \times '' \quad 25,300 &= 11,100'' \\ '' \times '' \quad 16,900 &= 7,420'' \\ '' \times '' \quad 4,530 &= 1,990 \text{ ft}'' \end{aligned}$$

(3) With 100% Cold-Spring the reactions are as follows: C=1

Cold Condition (Ec)

Hot Condition (Eh)

From 5. a. (1)

$$\begin{aligned} R_x &= 1490'' \\ R_y &= 465'' \\ * S_b &= 35,900 \text{ PSI} \\ S_c &= 26,000'' \\ S_d &= 17,350'' \\ M_d &= 4,650 \text{ ft}'' \end{aligned}$$

$$\begin{aligned} \frac{1}{3} \times 1450 &= 483'' \\ '' \times '' \quad 454 &= 152'' \\ '' \times '' \quad 35,000 &= 11,650 \text{ PSI} \\ '' \times '' \quad 25,300 &= 8,330'' \\ '' \times '' \quad 16,900 &= 5,625'' \\ '' \times '' \quad 4,530 &= 1,510 \text{ ft}'' \end{aligned}$$

(4) With 50% Cold-spring the reactions are as follows: C=.5

Cold Condition (Ec)

Hot Condition (Eh)

$$\begin{aligned} R_x &= 0.50 \times 1490'' = 745'' \\ R_y &= '' \quad 465'' = 233'' \\ * S_b &= '' \quad 35,900 = 17,850 \text{ PSI} \\ S_c &= '' \quad 26,000 = 13,000'' \\ S_d &= '' \quad 17,350 = 8,675'' \\ M_d &= '' \quad 4,650 = 2,325 \text{ ft}'' \end{aligned}$$

$$\begin{aligned} \frac{2}{3} \times 1450 &= 966'' \\ '' \times '' \quad 445 &= 304'' \\ 35,000 &= 23,300 \text{ PSI} \\ 25,300 &= 16,660'' \\ 16,900 &= 11,250'' \\ 4,530 &= 3,020 \text{ ft}'' \end{aligned}$$

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BY E. G. Shackley DATE 10/11/59 SUBJECT Reactor Study SHEET NO. 11 OF 14
CHKD BY (B. V. A.) DATE REAL Cross Header Stress JOB NO. AO-0029-M
B. D. F. & D. R. DO-1121

b. Intermediate Operating Conditions

Header temperature equals $125C = 257F$

Correction factor for $F(R)$ and $S_1 = \frac{257-70}{284-70}$

$$= \frac{187}{214} = .877 = 87.7\%$$

$S_c = 18,750 \text{ PSI}$, $S_h = 15,725$, $E_c = 29 \times 10^6$, $E_h = 28.2 \times 10^6$

$$S_A = 1.25 \times 18,750 + 0.25 \times 15,725 = \underline{27,390 \text{ PSI}}$$

$$\frac{E_c}{E_h} = \frac{29}{28.2} = 1.03$$

(1) Reactions and Stresses based on E_h and E_c are:

For E_h

$$R_x = .877 \times 1972 =$$

$$R_y = " 620 =$$

$$* S_b = " 40,638 =$$

$$S_c = " 34,546 =$$

$$S_d = " 23,067 =$$

$$M_d = " 6,171 =$$

$$1730 =$$

$$544 =$$

$$35,600 \text{ PSI}$$

$$30,300 "$$

$$20,250 "$$

$$5,420 \text{ ft}^{\#}$$

For E_c

$$\times 1.03 =$$

$$1780 =$$

$$560 =$$

$$36,600 \text{ PSI}$$

$$31,200 "$$

$$20,850 "$$

$$5,580 \text{ ft}^{\#}$$

(2) With zero cold-spring Reactions may become: $C=0$

$$1 - (15,725/36,600) \times 1.03 = 1 - .444 = \underline{0.556}$$

Cold Condition (E_c)

$$R_x = 0.556 \times 1780 =$$

$$R_y = " 560 =$$

$$* S_b = " 36,600 =$$

$$S_c = " 31,200 =$$

$$S_d = " 20,850 =$$

$$M_d = " 5,580 =$$

$$990 =$$

$$312 =$$

$$20,400 \text{ PSI}$$

$$17,350 "$$

$$11,600 "$$

$$3,100 \text{ ft}^{\#}$$

Hot Condition (E_h)

$$0.444 \times 1730 =$$

$$" 544 =$$

$$" 35,600 =$$

$$" 30,300 =$$

$$" 20,250 =$$

$$" 5,420 =$$

$$765 =$$

$$241 =$$

$$16,000 \text{ PSI}$$

$$13,450 "$$

$$9,960 "$$

$$2,400 \text{ ft}^{\#}$$

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BY E. G. Shockey DATE 10/12/59

SUBJECT Reactor Study
Reactor Cross Header Stress
B.D.F. & D.R.SHEET NO. 12 OF 14
JOB NO. AP-0024-M
DO-1121

5. b. (contd)

(3) With 100% Cold-Spring the reactions are as follows: $C=1$
Cold Condition (E_c) Hot Condition (E_h)

FROM 5. b. (1)

$R_x =$	1780*	$\frac{1}{3} \times 1730 =$	576*
$R_y =$	560*	" 544 =	181*
* $S_b =$	36,600 PSI	" 35,600 =	11,850 PSI
$S_c =$	31,200 "	" 30,300 =	10,100 "
$S_d =$	20,850 "	" 20,250 =	6,740 "
$M_d =$	5,580 "	" 5,420 =	1,805 ft*

(4) With 50% Cold-Spring the reactions are as follows: $C=0.5$
Cold Condition (E_c) Hot Condition (E_h)

$R_x = 0.50 \times 1780 =$	890*	$\frac{2}{3} \times 1730 =$	1,152*
$R_y =$	560 =	" 544 =	362*
* $S_b =$	36,600 =	35,600 =	23,700 PSI
$S_c =$	31,200 =	30,300 =	20,200 "
$S_d =$	20,850 =	20,250 =	13,500 "
$M_d =$	5,580 =	5,420 =	3,610 ft*

6. REVIEW OF CALCULATIONS

For comparison at the three operating temperatures only maximum stress at point "b" (90° sch 40 L.R.E.II), and moment acting on riser at "d" will be considered. It is assumed that stress in riser will vary directly as the moment at "d". 100% cold-spring is not practical and is not included.

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BY E. G. Shockey DATE 10/4/59

SUBJECT REACTOR STUDY

SHEET NO. 13 OF 14

CHND. BY DATE

REAR CROSS HEADER STRESS

JOB NO. AD-0024-M

(BOVAY)

H.D. F&DR

DO-1121

- a. Present operating conditions - $108^{\circ}\text{C} = 227^{\circ}\text{F}$ (70° to 227°F)
SA = 27,700 PSI

VALUES POINT "S" & "d"	COLD CONDITION			HOT CONDITION		
	INITIAL COND. ZERO C.S.	RELAXATION SELF-SPRING	50% C.S.	INITIAL COND. ZERO C.S.	RELAXATION SELF-SPRING	50% C.S.
Rx 76	0	- 835	- 745	1450	635	966
Ry 76	0	- 261	- 233	454	199	304
S "c" PSI	0	-20,100	-17,850	35,000	15,350	23,300
ft #						
M "d"	0	- 2,610	- 2,325	4,530	1,990	3,020
S "d" PSI RISER	0	-23,200	-20,700	39,600	17,700	26,900

- b. Intermediate operating conditions - $125^{\circ}\text{C} = 257^{\circ}\text{F}$ (70° to 257°F)
SA = 27,390 PSI

VALUES POINT "S" & "d"	COLD CONDITION			HOT CONDITION		
	INITIAL COND. ZERO C.S.	RELAXATION SELF-SPRING	50% C.S.	INITIAL COND. ZERO C.S.	RELAXATION SELF-SPRING	50% C.S.
Rx 76	0	- 990	- 890	1730	765	1,150
Ry 76	0	- 312	- 280	544	241	362
S "c" PSI	0	-20,400	-18,300	35,600	16,000	23,700
M "d"						
ft #	0	- 3,100	- 2,790	5,420	2,400	3,610
Riser						
S "d" PSI	0	-27,600	-24,900	48,400	21,400	32,200

- c. High operating conditions - $140^{\circ}\text{C} = 284^{\circ}\text{F}$ (70° to 284°F)
SA = 27,200 PSI

VALUES POINT "S" & "d"	COLD CONDITION			HOT CONDITION		
	INITIAL COND. ZERO C.S.	RELAXATION SELF-SPRING	50% C.S.	INITIAL COND. ZERO C.S.	RELAXATION SELF-SPRING	50% C.S.
Rx 76	0	-1310	-1,022	1972	711	1,335
Ry 76	0	- 410	- 322	620	224	413
S "c" PSI	0	-27,000	-21,050	40,638	14,700	27,200
M "d"						
ft #	0	- 4,080	- 3,200	6,171	2,225	4,110
RISER						
S "d" PSI	0	-36,400	-28,500	55,000	19,400	36,600

BY E. G. Shockey DATE 10/14/59

CHKD BY DATE

(BORAY)

SUBJECT Reactor Study
Reactor Cross Header Stress
B.D.F. & D.R.

10-00001
Page 7.
SHEET NO. 14 OF 14
JOB NO. A0-0024-M
DO-1121

7. SUMMARY

7.1 The above calculations are based on:

- a. ASA B31.1 code requirements, SA, stress intensification factor (I), $\frac{2}{3}$ cold spring allowed in hot position. Relaxation factor, but no credit for flexibility factor (K).
- b. Anchor at "a" is free to move in X direction but prevents rotation. Anchor at "d" is fixed and prevents rotation
- c. These factors provide a large factor of safety and tend to be pessimistic compared with probable conditions.

7.2 To offset the above factors we have:

- a. The anchor at "a" (Present Guide) will not prevent rotation and becomes more nearly a hinged joint, which will reduce forces and stress.
- c. The anchor at "d" (36" $\frac{3}{16}$ " thick) will also rotate due to thin wall of riser. A small rotation here will reduce forces and stress considerably.
- d. The flexibility factor (K) for a 4"-40 L.R. ell is 5.3. No allowance is made for this, but some credit may be considered to reduce forces and stress.

7.3 From this it appears that calculated Reactions and stresses may be 15 to 25% higher than actual operating conditions.

B. CONCLUSIONS

- a. For present (100C) and intermediate (125C) operations it appears that present headers are satisfactory. This assumes that: (1) headers were initially installed with 50% or more cold spring, (2) that they have relaxed to approximate values shown.

- b. For high operating condition (140C) 36 riser and headers require further study. Reinforcing of riser and additional flexibility are indicated.

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BY Z.M. Ballchish DATE 11-3-59
CHKD. BY F.G.S. DATE 11-9-59
(BONAY)

SUBJECT Reactor Study
Rear Cross Header Stress
B, D, F, & DR

Page 30
SHEET NO. 1 OF 11
JOB NO. AO-0029-M
D.O. - 1121

ASSUMPTIONS: (See work of E.G. Shockey 10-5-59).

1. Straight portion of 4" header between risers is guided at approximately 9'-6" centers and is not free to assume the elastic curve.
2. For an approximate solution it is assumed that the header is anchored at the second guide. (Free to move in X direction).
3. Piping installed at 70°F without cold spring.
4. One half of expansion taken by each half of header.

Note: 20" radius bends to be used.

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BY R. M. Baltusch DATE 11-3-59
CHKD. BY E.G.S. DATE 11-9-59
(BOVAY)

SUBJECT Reactor Study
Rear Cross-header Stress
B, D, E & DF

SHEET NO. 2 OF 11
JOB NO. AD-0029-M
DO-1121

Data: 4" Sch 40, 304 Stl. St
 $I = 7.23 \text{ in}^4$, $Z = 3.71 \text{ in}^3$
O.D. = 4.5", $E = 29 \cdot 10^6 \text{ #/in}^2$
 $t = 0.237 \text{ in}$
Lin. Thermal Expans = $2.45 \frac{\text{in}}{100}$

Max. Temp. 294°F
Min. Temp. 69°F

$$\Delta x = \frac{2.45 \cdot 79}{100 \cdot 2} = 0.97 \text{ in}$$

$$\Delta y = \frac{2.45 \cdot 5.1}{100} = 0.125 \text{ in}$$

$$\Delta x EI = 0.97 \cdot 29 \cdot 10^6 \cdot 7.23 = 196 \cdot 10^6 \text{ in}^3 \cdot \text{lb} \text{ or } 113,650 \text{ lb ft}^3$$

$$\Delta y EI = 0.125 \cdot 29 \cdot 10^6 \cdot 7.23 = 25 \cdot 10^6 \text{ in}^3 \cdot \text{lb} \text{ or } 14,650 \text{ lb ft}^3$$

From page 57 of S.W. Spielvogel's pipe stress handbook:

$$r = \frac{4.5 - 0.237}{2} = 2.131 \text{ in} \quad R = 2.0 \text{ in}$$

$$\text{Flexibility Characteristic} = \frac{tR}{c^2} = \frac{0.237 \cdot 2.0}{(2.131)^2} = 1.045$$

$$\text{Length Modification Factor} = \frac{12\lambda^2 + 10}{12\lambda^2 + 1} = \frac{23.1}{14.1} = 1.64$$

$$\text{Modified length of bend} = \frac{\pi \cdot 1.67 \cdot 1.64}{2} = 4.3 \text{ ft}$$

Centroid

Line	L, ft	X, ft	1x'	Y, ft	1y'
ab	12	6	72	0	0
bc	4.3	13.06	56.2	0.60	2.61
cd	1.77	13.66	24.2	2.55	4.52
de	4.3	13.06	56.2	4.49	19.3
ef	0.84	11.58	9.62	5.1	4.23
	23.21		218.22		30.66

$$\bar{X} = \frac{218.22}{23.2} = 9.4 \text{ ft}$$

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BY K.M. Balthasar DATE 11-3-59
CHKD. BY E.G.S. DATE 11-9-59
(BOWAY)

SUBJECT Reactor Study
Rear Cross Header Stress
B, D, F, & DF

SHEET NO. 3 OF 11
JOB NO. A0-0024-M
D.O. 1121

ELEMENT	l	X	Y	$I_x^2 + I_{oy}$	$I_y^2 + I_{ox}$	I_{xy}
a b	12.	-3.4	-1.32	139.	20.9	53.9
b c	4.3	+3.66	-0.72	144.	0	0
c d	1.77	+4.26	+1.22	57.5	2.23	-11.3
d e	4.3	+3.66	+2.16	1.12	1.12	1.03
e f	0.84	+2.18	+3.78	32.2	2.64	9.2
				0	0.46	0
				57.5	43.	49.8
				1.12	1.12	1.03
				4.	12.	6.92
				0.05	0	0
				$I_y = 436.49$		
				$I_x = 83.47$		
				$I_{xy} = 110.58$		

1. Forces

$$\text{Force } X = \frac{436.5 \cdot 113,600 + 110.6 (14,650)}{436.5 \cdot 83.5 - (110.6)^2} = 2110^*$$

$$\text{Force } Y = \frac{83.5 \cdot 14,650 + 110.6 \cdot 113,600}{83.5 \cdot 436.5 - (110.6)^2} = 567^*$$

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BY R.M. Baiteusch DATE 11-4-59
CHKD BY E.G.S. DATE 11-9-59
(HORA-V)

SUBJECT Reactor Study
Rear Cross Header Stress
B, D, F & DR

HW-63581
Page 83
SHEET NO. 4 OF 11
JOB NO. A0-0024M
DO-1121

2. Moments:

$$M_a = -2110 \cdot 4.32 + 567 \cdot 9.4 = -2780 + 5340 = 2560 \text{ ft.} \cdot \# \quad \text{Reacting Moment}$$

$$M_b = -2110 \cdot 1.32 - 567 \cdot 2.6 = -2780 - 1475 = -4255 \text{ ft.} \cdot \#$$

$$M_c = 2110 \cdot 0.34 - 567 \cdot 4.26 = 718 - 2420 = -1702 \text{ ft.} \cdot \#$$

$$M_d = 2110 \cdot 2.11 - 567 \cdot 4.26 = 4460 - 2420 = 2040 \text{ ft.} \cdot \#$$

$$M_e = 2110 \cdot 3.78 - 567 \cdot 2.6 = 7990 - 1475 = 6515 \text{ ft.} \cdot \#$$

$$M_f = 2110 \cdot 3.78 - 567 \cdot 1.76 = 7990 - 1000 = 6990 \text{ ft.} \cdot \#$$

Bending
Moments

3. Stresses:

$$S = \frac{M}{Z} \quad Z = 3.21$$

$$S_a = 2560 \cdot 12 / 3.21 = 2560 \cdot 3.74 = 9575 \text{ } \# / \text{in}^2$$

$$S_b = 4255 \cdot 3.74 = 15,900 \text{ } \# / \text{in}^2$$

$$S_c = 1702 \cdot 3.74 = 6360 \text{ } \# / \text{in}^2$$

$$S_d = 2040 \cdot 3.74 = 7630 \text{ } \# / \text{in}^2$$

$$S_e = 6515 \cdot 3.74 = 24,400 \text{ } \# / \text{in}^2$$

$$S_f = 6990 \cdot 3.74 = 26,200 \text{ } \# / \text{in}^2$$

a) Allowable stress (S_A) A.S.A. Code BEI.1-1955 Division A.
Refinery and Oil Piping. ASTM A312 Type 304 Seamless Stl. St. pipe:

- 20 to 100F

200F

300F

18,750

16,650

15,000

Expected number of full temperature cycles over expected life ≤ 7000
or nearly one cycle/day for 20 yrs. $f = 1.0$

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$$S_A = f(1.25S_c + 0.25S_b) = 1(18,750 \cdot 1.25 + 0.25 \cdot 15,000) = 27,200 \text{ } \# / \text{in}^2$$

BY R. M. Baltusch DATE 11-4-59

CHKD. BY F.S.S. DATE 11-9-59

(BORAY)

SUBJECT Reactor Study
Rear Cross Header Stress
B, D, F & DR

SHEET NO. 5 OF 11

JOB NO. AD-0024-M

D.O. - 1121

Note: Moments & Forces
Shown For Eh.
140c (204F)

MOMENT DIAGRAM

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BY E. M. Ballerich DATE 11-6-59
 CHKD. BY E. G. S. DATE 11-9-59
(BERRY)

SUBJECT Reactor Study
Rear Cross Header Stress
B, D, F, & D.R.

IN-63581
 Page 65
 SHEET NO. 6 OF 11
 JOB NO. A0-0024-M
 D.O. -1121

Moments & Forces for
 E.H. 140C (284F)

Moment Diagram.

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BY R. M. Balltrunk DATE 11-5-59
CHKD. BY E. G. S. DATE 11-9-59

SUBJECT Reader Study
Rear Cross Header Stress
B, D, F & D R

SHEET NO. 7 OF 11
JOB NO. A0-0034-M
D.O. - 1121

3. b. See work sheets: made by
c. E. G. Shockey 10-8-59

- d. For this problem $E_c/E_h = 28 \cdot 10^6 / 28 \cdot 10^6 = 1.038$
The stress intensification factor "i" for 4" sch 40 20" radius bend is:

$$h = \frac{4R}{r^2} = \frac{0.237 \cdot 20}{(2.131)^2} = 1.045$$

From Stress Intensification Chart pg. 55 of Spielvogel: $i < 1$
however 1 is used

- e. "i" for unreinforced fabricated tee (riser connection 36" O.D. x $\frac{3}{16}$ " wall).

$$h = \frac{t}{r} = \frac{0.187}{17.937} = 0.01045$$

"i" > 18 (off chart)

This indicates excessive stress at riser. Other means must be used to evaluate these stresses. See calculations by V. R. Hill 10-3-59

- f. The maximum moment occurs in the straight pipe at riser connection, point f. $S_{E_f} = 6990 \cdot 1.038 \cdot 12 / 3.21 = 27,100 \text{ in}^2$

- g. Expansion Stresses at E_c :

$$S_{E_c} = 24400 \cdot 1.038 = 25,300 \text{ psi}$$

$$S_{E_H} = 7630 \cdot 1.038 = 7920 \text{ psi}$$

$$S_{E_D} = 6360 \cdot 1.038 = 6600 \text{ psi}$$

$$S_{E_L} = 15,900 \cdot 1.038 = 16,500 \text{ psi}$$

$$S_{E_0} = 9575 \cdot 1.038 = 9940 \text{ psi}$$

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BY K. M. E. DATE 11-5-59

SUBJECT Reactor Study

SHEET NO. 8 OF 11

CHKD. BY E. G. S. DATE 11-9-59

Rear Cross Header Stress

JOB NO. AP-0024-M

(BOMAY)

B, D, F & DR

D.O. - 1121

4. Reaction Forces and Cold Spring ASA B31.1

a. The flexibility calculations for the problem are based on $E_h = 29.10^6$ without cold spring. Cold spring factor $C = 0$. Subsequent relaxation of the piping, if any, will reduce the reactions. Evaluation of reactions for various amounts of cold spring follows.

b. No Cold Spring: $C = 0$, $R_c = CR = 0$. Initially no reactions exist in the cold condition. In the event of self-spring reactions will appear in the cold condition. In time these will assume values equal to:

$$\left(1 - \frac{S_h}{S_E} \cdot \frac{E_c}{E_h}\right) R_c = R_{cs}$$

$$\frac{S_h}{S_E} = \frac{15000}{27100} = 0.554$$

$$\frac{E_c}{E_h} = \frac{29.10^6}{29.10^6} = 1.038$$

$$R_c(1 - 0.554 \cdot 1.038) = 0.425 R_c$$

$$1 - 0.425 = 0.575$$

c. Tabulation of reactions & stresses that may in time occur for cold conditions. $C = 0$

I. Based on E_h

$R_x =$	2110*
$R_y =$	567*
$S_a =$	9575*/in ²
$S_b =$	15900*/in ²
$S_c =$	6360*/in ²
$S_d =$	7630*/in ²
$S_e =$	24,400*/in ²
$S_f =$	26,200*/in ²
$M_f =$	6990 ft.*

Based on E_c

$R_x =$	2110 · 1.038 = 2190*
$R_y =$	567 · 1.038 = 589*
$S_a =$	9575 · 1.038 = 9940*/in ²
$S_b =$	15900 · 1.038 = 16500*/in ²
$S_c =$	6360 · 1.038 = 6600*/in ²
$S_d =$	7630 · 1.038 = 7920*/in ²
$S_e =$	24400 · 1.038 = 25,300*/in ²
$S_f =$	26200 · 1.038 = 27,100*/in ²
$M_f =$	6990 · 1.038 = 7,250 ft.*

II. Reactions & stresses in cold condition may become: (Relaxation & self-springing)

$$R_{xc} = 0.425 \cdot 2190 = 931*$$

$$R_{yc} = " 589 = 250*$$

$$S_{ac} = " 9940 = 4220*/in²$$

$$S_{bc} = " 16500 = 7000*/in²$$

$$S_{cc} = " 6600 = 2820*/in²$$

$$S_{dc} = " 7920 = 3370*/in²$$

$$S_{ec} = " 25300 = 10760*/in²$$

$$S_{fc} = " 27100 = 11530*/in²$$

On basis of E_c

$$M_f = 7250* \cdot ft \cdot 0.425 = 3080 ft.*$$

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BY: M. R. K. DATE: 11-5-59	SUBJECT: Reactor Study	SHEET NO. 9 OF 11
CHKD. BY: E. J. DATE: 11-9-59	React. Cross Section Stress	JOB NO. 40-0029-M
(Boray)	B, D, F, & D R	D.O. 1121

4. C. III. Reactions and stresses in hot condition may become:

$E_h = 0.575 \cdot 2110 = 1210$	$R_h = 567 = 326$
$S_h = 9575 = 510 \text{ #/in}^2$	$S_h = 9575 = 510 \text{ #/in}^2$
$S_h = 15900 = 9150 \text{ #/in}^2$	$S_h = 15900 = 9150 \text{ #/in}^2$
$S_h = 6360 = 3660 \text{ #/in}^2$	$S_h = 6360 = 3660 \text{ #/in}^2$
$S_h = 7630 = 4390 \text{ #/in}^2$	$S_h = 7630 = 4390 \text{ #/in}^2$
$S_h = 24900 = 14000 \text{ #/in}^2$	$S_h = 24900 = 14000 \text{ #/in}^2$
$S_h = 26200 = 15100 \text{ #/in}^2$	$S_h = 26200 = 15100 \text{ #/in}^2$

ix. Based on the above Code theory there will be sufficient self-springing to bring the stresses within the allowable limit of $E_h = 271200 \text{ #/in}^2$.

d. For 50% Cold - springing Values will be:

$E_c = 0.5 \cdot 2130 = 1095$	$R_h = 567 = 326$
$S_c = 9040 = 4970 \text{ #/in}^2$	$S_h = 9575 = 510 \text{ #/in}^2$
$S_c = 16800 = 9250 \text{ #/in}^2$	$S_h = 15900 = 9150 \text{ #/in}^2$
$S_c = 6400 = 3300 \text{ #/in}^2$	$S_h = 6360 = 3660 \text{ #/in}^2$
$S_c = 7920 = 3960 \text{ #/in}^2$	$S_h = 7630 = 4390 \text{ #/in}^2$
$S_c = 25200 = 12650 \text{ #/in}^2$	$S_h = 24900 = 14000 \text{ #/in}^2$
$S_c = 27100 = 13550 \text{ #/in}^2$	$S_h = 26200 = 15100 \text{ #/in}^2$

5. Reactions and stresses at Present Operating Temperature: 108°C

a. For purposes of comparison it is assumed that, for the comparatively small temperature range, the forces & stresses will vary directly as the operating temperature.
 Present operating temperature = 108°C or 227°F
 Correction factor = $(227-70)/(224-70) = 0.734$
 All reactions & stresses at 108°C will be 73.4% of those at 140°C

$S_c = 18750 \text{ psi}$; $S_h = 16,200 \text{ psi}$; $E_c = 29 \cdot 10^6$; $E_h = 28.3 \cdot 10^6$
 $S_A = (125 \cdot 18750 + 0.25 \cdot 16,200) = 23,450 + 4050 = 27,500 \text{ psi}$
 $\frac{E_h}{E_c} = \frac{28.3 \cdot 10^6}{29 \cdot 10^6} = 1.025$

RECALCULATED

BY E.M. BALT. DATE 11-6-59
CHKD. BY E.C. DATE 11-9-59
(BODY)

SUBJECT Reactor Study
Rear Cross Header Stress
B, D, F & DR

SHEET NO. 10 OF 11
JOB NO. AD-0024-M
D.O. - 1121

5. b. Reactions & stresses based on E_h & E_c :

For E_h	For E_c
$R_x = 0.734 \cdot 2110 = 1550 \#$	$1550 \cdot 1.025 = 1590 \#$
$R_y = \quad \cdot \quad 567 = 417 \#$	$417 \cdot \quad = 427 \#$
$S_a = \quad \cdot 9575 = 7030 \#/\text{in}^2$	$7030 \cdot \quad = 7210 \#/\text{in}^2$
$S_b = \quad \cdot 15900 = 11700 \#/\text{in}^2$	$11700 \cdot \quad = 12000 \#/\text{in}^2$
$S_c = \quad \cdot 6360 = 4670 \#/\text{in}^2$	$4670 \cdot \quad = 4790 \#/\text{in}^2$
$S_d = \quad \cdot 7630 = 5600 \#/\text{in}^2$	$5600 \cdot \quad = 5740 \#/\text{in}^2$
$S_e = \quad \cdot 29900 = 17900 \#/\text{in}^2$	$17900 \cdot \quad = 18370 \#/\text{in}^2$
$S_f = \quad \cdot 26200 = 19200 \#/\text{in}^2$	$19200 \cdot \quad = 19700 \#/\text{in}^2$
$M_t = \quad \cdot 6990 = 5130 \text{ ft} \cdot \#$	$5130 \cdot \quad = 5260 \text{ ft} \cdot \#$

I: With zero cold-spring reactions & stresses may become:

$$C = 0 \quad R_{cs} = R_c (1 - \frac{15900}{14700} \cdot 1.025) = 0.157$$

For E_c	For E_h
$R_{xc} = 0.157 \cdot 1590 = 250 \#$	$R_{xh} = 0.843 \cdot 1550 = 1310 \#$
$R_{yc} = \quad \cdot 427 = 67 \#$	$R_{yh} = 0.843 \cdot 417 = 361 \#$
$S_{ac} = \quad \cdot 7210 = 1130 \#/\text{in}^2$	$S_{ah} = \quad \cdot 7030 = 5930 \#/\text{in}^2$
$S_{bc} = \quad \cdot 12000 = 1885 \#/\text{in}^2$	$S_{bh} = \quad \cdot 11700 = 9870 \#/\text{in}^2$
$S_{cc} = \quad \cdot 4790 = 752 \#/\text{in}^2$	$S_{ch} = \quad \cdot 4670 = 3940 \#/\text{in}^2$
$S_{dc} = \quad \cdot 5740 = 902 \#/\text{in}^2$	$S_{dh} = \quad \cdot 5600 = 4720 \#/\text{in}^2$
$S_{ec} = \quad \cdot 18370 = 2880 \#/\text{in}^2$	$S_{eh} = \quad \cdot 17900 = 15100 \#/\text{in}^2$
$S_{fc} = \quad \cdot 19700 = 3095 \#/\text{in}^2$	$S_{fh} = \quad \cdot 19200 = 16200 \#/\text{in}^2$
$M_{tc} = \quad \cdot 5260 = 826 \text{ ft} \cdot \#$	$M_{th} = \quad \cdot 5130 = 4323 \text{ ft} \cdot \#$

II: With 50% cold-spring reactions & stresses may become:

For E_c	For E_h
$R_{xc} = 0.5 \cdot 1590 = 795 \#$	$R_{xh} = \frac{2}{3} \cdot 1550 = 1033 \#$
$R_{yc} = \quad \cdot 427 = 213 \#$	$R_{yh} = \quad \cdot 417 = 275 \#$
$S_{ac} = \quad \cdot 7210 = 3605 \#/\text{in}^2$	$S_{ah} = \quad \cdot 7030 = 4680 \#/\text{in}^2$
$S_{bc} = \quad \cdot 12000 = 6000 \#/\text{in}^2$	$S_{bh} = \quad \cdot 11700 = 7800 \#/\text{in}^2$
$S_{cc} = \quad \cdot 4790 = 2395 \#/\text{in}^2$	$S_{ch} = \quad \cdot 4670 = 3120 \#/\text{in}^2$
$S_{dc} = \quad \cdot 5740 = 2870 \#/\text{in}^2$	$S_{dh} = \quad \cdot 5600 = 3740 \#/\text{in}^2$
$S_{ec} = \quad \cdot 18370 = 9185 \#/\text{in}^2$	$S_{eh} = \quad \cdot 17900 = 11900 \#/\text{in}^2$
$S_{fc} = \quad \cdot 19700 = 9850 \#/\text{in}^2$	$S_{fh} = \quad \cdot 19200 = 12800 \#/\text{in}^2$
$M_{tc} = \quad \cdot 5260 = 2630 \text{ ft} \cdot \#$	$M_{th} = \quad \cdot 5130 = 3220 \text{ ft} \cdot \#$

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BY R.M. Balthus DATE 11-6-59
CHKD. BY R.G.S. DATE 11-9-59
(B.V.A.Y.)

SUBJECT Reactor Study
Rear Cross Header Stress
B, D, F, & DR

17-53561
Page 90
SHEET NO. 11 OF 11
JOB NO. A0-0029-M
D.O. 1121

6. Summary of Calculations.

a. Present Operating Conditions - $105^{\circ}\text{C} = 227^{\circ}\text{F}$ - $S_A = 27,500\text{ psi}$

VALUES	COLD CONDITIONS			HOT CONDITIONS		
	Initial Conditions Zero C.S.	Relaxation Self-Spring	50% C.S.	Initial Conditions Zero C.S.	Relaxation Self-Spring	50% C.S.
R_x #	0	-250	-795	1550	1310	1023
R_y #	0	-67	-213	417	361	278
S_a psi	0	-1130	-3605	7030	5920	4680
S_b psi	0	-1885	-6000	11700	9870	7800
S_c psi	0	-752	-2395	4670	3940	3120
S_d psi	0	-902	-2870	5600	4720	3740
S_e psi	0	-2880	-9185	17900	15100	11900
S_f psi	0	-3095	-9850	19200	16200	12800
Mf ft	0	-826	-2630	5130	4233	3420
Stresser	0	-7380	-23400	45800	38600	30500

Riser stresses assumed to vary in direct proportion to M.
See calculations by V.R. Hill 10-3-59 for stress of known moment.

b. High Operating Conditions - $140^{\circ}\text{C} = 284^{\circ}\text{F}$ - $S_A = 27,200\text{ psi}$

VALUES	COLD CONDITIONS			HOT CONDITIONS		
	Initial Conditions Zero C.S.	Relaxation Self-Spring	50% C.S.	Initial Conditions Zero C.S.	Relaxation Self-Spring	50% C.S.
R_x #	0	-931	-1095	2110	1210	1410
R_y #	0	-259	-295	567	326	378
S_a psi	0	-4220	-4970	9575	5510	6980
S_b psi	0	-7000	-8250	15900	9150	10600
S_c psi	0	-2820	-3300	6360	3660	4250
S_d psi	0	-3370	-3960	7630	4390	5090
S_e psi	0	-10760	-12650	21400	14090	16300
S_f psi	0	-11530	-13550	26200	15100	1750
Mf ft	0	-3060	-3625	6990	4020	4670
Stresser	0	-27500	-32400	62400	35900	41700

7. Conclusions:

a. Stresses at 108°C and 50% C.S. border on being excessive,
for 140°C stresses are definitely excessive. Further study
of latter case is indicated by results. (Riser stress only)

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BY E.G. SHUCKY DATE 12-7-59

SUBJECT Reactor Study

SHEET NO. 1 OF 5

CHKD. BY DATE

REAR FACE PIPING "H & C"

JOB NO. AD-202A-M

BWAY

CROSSHEAD Thermal Stress

DO-1121

Note: See calculations for B.D.P. & D.P. DATED 10-5-59 & 11-3-59

27'-10" TOTAL $\Delta @ 225^\circ\text{F}$ (1070) = .49"

PIPE: 4" SCH. 40 TYPE 304 STAINLESS STL, SEAMLESS

OPERATING TEMP. 225F INSTALLATION TEMP. 70F

 $I = 7.23 \text{ in}^4$, $Z = 3.22 \text{ in}^3$, $E_c = 29.2 \times 10^6$, $E_h = 28.63 \times 10^6$ O.D. = 4.5", $\Delta = (70^\circ\text{F TO } 225^\circ\text{F}) 1.74"/100' \times 1.28 = .490"$

TOTAL EXPANSION ASSUMED ABSORBED BY BEND SHOWN HEAVY

APPROXIMATE REACTIONS AND STRESSES:

S.W. SPIEGEL, PIPING STRESS SIMPLIFIED 5TH ED 1995
COMMON SHAPES, U" WITH SINGLE TANGENT PAGE 56 $C = 278$ FOR 13.5' FOR TOTAL $\Delta @ 225^\circ\text{F} = 28/13.5 \times 278 = 576$ $\frac{L}{a} = \frac{13.5}{4.5} = 3.0$ $\frac{L}{h} = \frac{3.5}{2.5} = 5.4$ $K_x = 221$ $K_y = 41$ $K_b = 193$

DOES NOT
ADAPT TO ANCHOR
A MOUNTING
SEE CALCULATIONS
4.5'

$$F_x = 221 \times 576 \times 7.23 \times \left(\frac{E_c}{h}\right) = 5150 \text{ lb}$$

$$S_b = 193 \times 576 \times 4.5 = 37,000$$

$$F_y = 5150 \times 41/221 = 956 \text{ lb}$$

STRESS INTENSIFICATION FACTOR 4" 40 L.R. BULL = 2.0

$$S_e = 37,000 \times 1.02 \times 2 = 75,500 \text{ psi}$$

$$S_A = 27,900 \text{ psi}$$

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BY E.G. Shockey DATE 12-7-59

 SUBJECT Reactor Steady
Heat Face Piping "H.E.C."
Crossmember Thermal Stress

 SHEET NO. 2 OF 5
JOB NO. AC-0024-M
DO-1121

CHKD. BY BOVAY DATE

Centroid

Branch	7 ft	X'	7X'	Y'	7Y'
ab	4.00	2.50	11.00	11.5	46.00
bc	.65	2.18	1.42	9.5	6.16
cd	5.00	2.50	12.50	7.0	35.00
de	2.50	1.25	3.13	4.5	11.25
ef	4.50	0	0	2.25	10.10
fg	2.50	1.25	3.12	0	0
gh	1.00	2.50	2.50	.5	.50
	20.15		33.67		109.01

$$\bar{X} = \frac{33.67}{20.15} = 1.68'$$

$$\bar{Y} = \frac{109}{20.15} = 5.41'$$

Line Inertias

Branch	Length 7	X	Y	7X ² + I ₀	7Y ² + I ₀	7XY
ab	4.00	-6.09	-0.17	148.00 5.30	0.116	+ 4.15
bc	.65	-4.09	-0.50	10.90	0.163	+ 1.33
cd	5.00	-1.59	-0.82	12.65 10.40	3.370	+ 6.53
de	2.50	+0.91	+0.43	2.06	0.464 1.300	+ 0.97
ef	4.50	+3.16	+1.68	45.00 7.59	12.700	+ 23.90
fg	2.50	+5.41	+0.43	73.20	0.464 1.300	+ 5.83
gh	1.00	+4.91	-0.82	24.10 0.08	0.670	+ 4.03

$$I_y = 339.28 \quad I_x = 20.547 \quad I_{xy} = + 38.68$$

 Reference
S.W. Spiegel
5TH. Edition, 1955

 See Sheet-1
for data.

 $S_h = 16,200 \text{ PSI}$
 $S_c = 18,750 \text{ PSI}$
 304 seamless S.S.
 $S_A = 27,500 \text{ PSI}$

UNCLASSIFIED

BY E. G. Shockey DATE 12-7-59

SUBJECT Reactor Steady
Heat Face Piping "H.F.C."
Crosshead Thermal Stress

SHEET NO. 3 OF 5

CHKD. BY DATE
Boray

JOB NO. AD-0029-M
DO-1121

$$\Delta x = (\$ \text{ rise to } \$ \text{ Reactor}) = 28.0' = .28 \times 1.74 = .490''$$

$$\Delta y = 1.85 = .0185 \times 1.74 = .0322''$$

A.S.A. CODE B31.1 1955

$$E_c = 29.2 \times 10^6, \quad S_A = 27,500 \text{ PSI} \quad \lambda = 4" \text{ L.R. SCH. 40 ELL} = 2.0$$

$$\Delta x EI = \frac{.490 \times 29.2 \times 10^6 \times 12^2 \times 7.23}{12 \times 12^4} = 60,000 \text{ }^{\circ}\text{ft}^3$$

$$\Delta y EI = \frac{.0322}{.490} \times 60,000 = 3,940 \text{ }^{\circ}\text{ft}^3$$

$$R_x = \frac{339.28 \times 60,000 + 38.68 \times 3,940}{20.547 \times 339.28 - 38.68^2} = 3,770^{\circ}$$

$$R_y = \frac{20.547 \times 3,940 + 38.68 \times 60,000}{20.547 \times 339.28 - 38.68^2} = 442^{\circ}$$

$$\text{Reacting Moment @ a} = + 3770 \times .17 = + 641 \quad - 442 \times 8.09 = - 3562 \quad \} = - 2921 \text{ ft}^{\circ}$$

$$\text{Bending Moment @ b} = + 3770 \times .17 = + 641 \quad - 442 \times 4.09 = - 1805 \quad \} = - 1164 \text{ ft}^{\circ}$$

$$\text{" " @ c} = + 3770 \times .82 = + 3095 \quad - 442 \times 4.09 = - 1805 \quad \} = + 1290 \text{ ft}^{\circ}$$

$$\text{" " @ d} = + 3770 \times .82 = + 3095 \quad + 442 \times .91 = + 401 \quad \} = + 3496 \text{ ft}^{\circ}$$

$$\rightarrow \text{Max. Bendg. " @ e} = - 3770 \times 1.68 = - 6345 \quad + 442 \times .91 = + 401 \quad \} = - 5944 \text{ ft}^{\circ}$$

$$\text{" " @ f} = - 3770 \times 1.68 = - 6345 \quad + 442 \times 5.41 = + 2390 \quad \} = - 3955 \text{ ft}^{\circ}$$

$$\text{" " @ g} = + 3770 \times .82 = + 3090 \quad + 442 \times 5.41 = + 2390 \quad \} = + 5480 \text{ ft}^{\circ}$$

$$\text{" " @ h} = + 3770 \times .82 = + 3090 \quad + 442 \times 4.41 = + 1810 \quad \} = + 4900 \text{ ft}^{\circ}$$

Factor λ

$$\text{Max. Stress in ELL @ e, } S_e = 2 \times 5955 \times 12 / 3.22 = 44,500 \text{ PSI}$$

$$\text{Max. Stress in Pipe @ h } S_h = 4900 \times 12 / 3.22 = 18,300 \text{ PSI}$$

Max. Stress in Riser @ h based on V.R. Hill's calculations
9-28-59, Reducing Moment to 4900 ft[°] and increasing
Reaction to 3770[°] indicate possible stress of 55,400 PSI.

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BY E. G. SHOOKY DATE 12-7-59

CHKD. BY BOVAY

SUBJECT Reactor Study
Rear Face Piping "H" & C
Crossheader Thermal Stress

SHEET NO. 4 OF 5
JOB NO. AO-0024-M
DD-1121

MOMENT DIAGRAM

Moments & Forces For $E_c = 29.2 \times 10^6$

Maximum expansion stress of 44,500 PSI shown for elbow at e includes the stress intensification factor of 2.0 as mandated in the A.S.A. code B31.1. This stress exceeds the allowable 27,900 PSI. Since there have been no failures reported since the headers have been in service, it is apparent that the stresses have relaxed due to "SELF-SPRINGING".

The extent of self-spring may be estimated by use of the Code formula: $R_c = (1 - \frac{S_h}{S_E}) R_c$ present stress based on E_c . Also, Reactions X & Y.

$$R_c = (1 - \frac{16,200}{44,500}) R_c = .636 R_c \text{ or } S_{EC} \begin{bmatrix} R_H = .364 \frac{E_h}{E_c} R_c \\ R_V = .358 R_c \end{bmatrix}$$

Cold Condition

Hot Condition

$$R_x = 3770 \times .636 = 2400^*$$

$$R_y = 442 \times .636 = 282^*$$

$$S_{E \text{ Riser}} = 55,400 \times .636 = 35,000 \text{ PSI } (\frac{3}{16} S_h)$$

$$S_{EC} = 44,500 \times .636 = 28,400 \text{ PSI}$$

$$R_x = 3770 \times .358 = 1350^*$$

$$R_y = 442 \times .358 = 158^*$$

$$S_{E \text{ Riser}} = 55,400 \times .358 = 20,000 \text{ PSI}$$

$$S_{EC} = 44,500 \times .358 = 15,950 \text{ PSI}$$

Conclusions:

The above calculations are based on 100% fixed anchors and no movement of the riser. For example: $\frac{3}{16}$ " movement of the riser and slight rotation at the anchors would reduce the apparent stress and reactions by $\frac{1}{2}$. This no doubt accounts for the satisfactory operation to date. Any further increase in operating temperature may result in failure of piping.

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

2 of 2

BY E.G. SHAW DATE 12-14-59 SUBJECT Reactor Study SHEET NO. 5 OF 5
 CHKD. BY DATE Root Face PIPING H & C JOB NO. AP-0029-M
 BOWAY Crossheader thermal stress. Addenda, DO-1121

RE-EVALUATION OF CROSSHEADER STRESS

Due to recent failure of riser, cracking near header connections, at DR reactor, it is apparent that high stress indicated by V.R. Hill's calculations of 9-28-59 is resulting in crystallization of the metal at this point.

The fact that it is showing up now at DR is evidence that it will eventually occur at the other reactors unless corrections are made.

Relaxation and "self springing" as outlined in the stress calculations apparently is not sufficient to prevent eventual failure at the risers at B, D, F, DR. As indicated elbows in the header loop at "C & H" are also overstressed.

The calculations dated 11-3-59 for B, D, F, DR with a header temperature of 229 F (108 C) indicate the following:

SA = 27,500 PSI

Max. SE hot cond. Zero C.S. - Pipe, 19,200 PSI. Riser, 45,800 PSI

Expected relaxation after OPR. - Pipe, 16,200 PSI. Riser, 38,600 PSI.

The calculations dated 12-7-59 for H & C with a header temperature of 225 F (107 C) indicate the following:

Max. SE hot cond. Zero C.S. - Pipe 18,300 PSI,

- ELBOW 44,500 PSI, Riser, 55,400 PSI

Expected relaxation cold - Pipe - 11,650 PSI, ELBOW, 28,400 PSI
Riser, 35,000 PSI.

Expected relaxation hot - Pipe - 6,600 PSI, ELBOW, 16,000 PSI
Riser - 20,000 PSI.

The above figures are based on $\frac{3}{16}$ " thick 36" O.D. S.S. RISERS
 "C" Riser is clad S.S. 1.00" S.S. 400" carbon, $\frac{1}{2}$ " total.

This will reduce apparent riser stress at "C".

DECLASSIFIED
 [REDACTED]

BY V.R. HALL DATE 9-28-59SUBJECT REACTOR EXPANSIONIN-63581
Page 90

CHKD. BY _____ DATE _____

REAR CROSS HEADER STRESSESSHEET NO. 1 OF _____
JOB NO. DD 1121REF: ASA B 31.1 - 1955 PIPE: STAINLESS STEELEXPANSION: 12°C TO 108°C = $1.68''$ = Y 12°C TO 140°C = 2.22

$$\frac{DY}{(L-U)^2} \leq 0.03$$

 D = NOMINAL PIPE SIZE IN INCHES = $4''$ Y = RESULTANT OF MOVEMENTS ABSORBED BY SYST. IN INCHES U = ANCHOR DISTANCE IN FT. = $79'$ L = DEVELOPED LENGTH OF PIPE - FT. = $79 + 8 + 10 = 97'$

$$\frac{4 \times 1.68}{(79-97)^2} = \frac{4 \times 1.68}{(18)^2} = \underline{0.0207} \quad @ 108^{\circ}\text{C} \quad \text{OK.}$$

$$\frac{4 \times 2.22}{18^2} = \underline{0.0274} \quad @ 140^{\circ}\text{C} \quad \text{OK.}$$

DECLASSIFIED

BY V.R. Hill DATE 10-3-59

SUBJECT REACTOR EXPANSION

SHEET NO. 2 OF

CHKD. BY DATE

REAR CROSS HEADER TO RISER

JOB NO. DD. 1121

REF: DESIGN BASIS FOR
REACTOR PRESS VESSELS
U.S. NAVY
PR. 1958

STRESSES

CROSS HEADER TEMP. = 140°C.

$$a = 18''$$

$$r_0 = 2.25''$$

$$L = 16\frac{3}{4}''$$

$$M = 6610 \text{ FT}^* = 79,300 \text{ IN}^*$$

$$1720^* = P.$$

$$B = \frac{0.875 r_0}{a} = \frac{0.875 \times 2.25}{18} = 0.109$$

①

$$\gamma = \frac{a}{t} = \frac{18}{.1875} = 96$$

$$\textcircled{2} \text{ FROM CURVE FIG. A.5-4 } \frac{M\phi}{P} = 0.09$$

$$\textcircled{3} \text{ FROM CURVE FIG. A.5-5 } \frac{N\phi}{P/a} = 10$$

$$\textcircled{4} 0.09 \times \frac{6 \times 1720}{.1875^2} = 2645 = \frac{N\phi}{t} \quad 10 \times \frac{1720}{18 \times .1875} = 5100 = \frac{6M\phi}{2t^2}$$

$$\textcircled{5} \sigma_z = 2645 \pm 5100 = \underline{7745} \text{ PSI. DUE TO LOAD P}$$

$$\text{A.5-10 } \textcircled{2} \frac{Mx}{M/a^2} = 0.043$$

$$\textcircled{3} \text{ A.5-11 } \frac{M\phi}{M/a^2} = 0.0825$$

$$\text{A.5-12 } \frac{N_x}{M/a^2} = 6.3$$

$$\text{A.5-13 } \frac{N\phi}{M/a^2} = 3.8$$

$$\textcircled{4} 0.043 \times \frac{6 \times 79,300}{18 \times .109 \times .1875^2} = 296,500 = \frac{6Mx}{t^2}$$

$$0.0825 \times \frac{6 \times 79,300}{18 \times .109 \times .1875^2} = 570,000 = \frac{6M\phi}{t^2}$$

DECLASSIFIED

BY V.R. Hill DATE 10-3-59SUBJECT REACTOR EXPANSIONSHEET NO. 3 OF CHKD. BY DATE REAR CROSS HEADER TO RISER
STRESSES.JOB NO. DO. 1121

$$\textcircled{5} \quad \frac{6.3 \times 79,300}{.1875 \times 78^2 \times .109} = 75,400 = \frac{N_x}{t}$$

$$\frac{3.8 \times 79,300}{.1875 \times 78^2 \times .109} = 45,400 = \frac{N_y}{t}$$

$$\textcircled{6} \quad \sigma_x = 75,400 \pm 296,500 = \underline{\underline{371,900 \text{ PSI.}}}$$

$$\sigma_y = 45,400 \pm 570,000 = \underline{\underline{615,400 \text{ PSI.}}}$$

MAXIMUM STRESS ON RISER CONN.

$$S_{\max} = \sigma_x + \sigma_y = 7,745 + 615,400 = \underline{\underline{623,145 \text{ PSI.}}}$$

THE ABOVE STRESS IS ASSUMING NOZZLE INTO HEADER IS A RIGID INSERT, THAT THE SHELL IS OF UNIFORM THICKNESS AROUND THE NOZZLE; AND THAT THE NOZZLE IS NOT NEAR THE END OF THE SHELL.

THIS VERY HIGH STRESS WHICH IS SEVERAL TIMES THE YIELD POINT OF THE MATERIAL, INDICATES THAT THE RISER WALL HAS FLEXED OR DEFORMED TO RELIEVE THE STRESS TO THE YIELD POINT FOR ANY OPERATING TEMPERATURE. ANY MOVEMENT OR ROTATION OF THE RISER WOULD ALSO DECREASE THIS STRESS.

THIS CALCULATION INDICATES THAT A PROBLEM AREA EXISTS AT THIS CONNECTION. AT DR FAILURES HAVE OCCURRED AT THIS JOINT.

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BY F. G. Shackey DATE 10/15/59

SUBJECT Reactor Study

SHEET NO. 1 OF 1

CHKD. BY (BOVAY) DATE

Allowable Working Pressures
Rear Face Riser & Cross-over

JOB NO. A0-0024-M
DO-1121

1. 36" O.D. Vertical Riser - 0.187" nom. thickness shell, 0.312" nom. thickness dished head. TP-304 or TP-347 Stainless steel. 350 F (assumed) max. operating temp.
Allowable stress, welded pipe (ASA B31.1) 14,000 psi
Allowable " " " (ASME-UPV) 14,000 psi

1.1 Allowable working pressure - Pipe - ASA B31.1

$$t_m = t_{nom.} - [C \text{ (plain end} = 0.065\text{)} + 0.010\text{"} \text{ mfg. toler.}]$$

$$t_m = 0.187 - (0.065 + 0.010) = \underline{0.112\text{'}}$$

a. 36" O.D. = D, S = 14,000 psi, Y = coeff. = 0.4, P = allow. w.p. psi

$$P = \frac{2St_m}{D - 2Yt_m} = \frac{2 \times 14,000 \times 0.112}{36 - 2 \times 0.4 \times 0.112} = \frac{28,000 \times 0.112}{35.91} = \underline{87.4 \text{ psi}}$$

b. 42" O.D. cross-over conn.

$$P = \frac{35.91}{42.0 - 0.09} \times 87.4 = \frac{35.91}{41.91} \times 87.4 = \underline{75 \text{ psi}}$$

c. IF allowance for C (0.065") is disregarded t_m becomes 0.112 + 0.065 = 0.177" and P may be increased by the factor (0.177/0.112) $\times P$, = 1.58 P = P', then for:

(1) 36" O.D., $P' = 87.4 \times 1.58 = \underline{138 \text{ psi}}$

(2) 42" O.D., $P' = 75 \times 1.58 = \underline{118.5 \text{ psi}}$

1.2 Allowable working pressure - Dished head - ASME-UPV

$$t_m = 0.312 - 0.065 = 0.247\text{' say } 0.25\text{'}, D = 35.5\text{'}$$

$$E = 1$$

a. $P = \frac{2SEt}{D + 0.2t} = \frac{2 \times 14,000 \times 0.250}{35.5 + 0.2 \times 0.25} = \frac{28,000 \times 0.250}{35.55} = \underline{197 \text{ psi}}$

b. $P' (t_m = \text{full thick} = 0.312) = (0.312/0.250) \times 197 = \underline{248 \text{ psi}}$

1.3 The above values are based on new material.

No allowance is included for non-reinforced nozzles and connections.

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BY E.G. Shockey DATE 10/22/59

SUBJECT Reactor Study

W-63501
Page 100

CHKD. BY DATE
(BOVAY)

Rear Face Effluent Piping
150,000 GPM FLOW

SHEET NO. 1 OF 4

JOB NO. A0-0024-M
DO-1121

Saturation pr. @ 250F = 15 PSIG.
= 120C BUICK

1. DESIGN FOR 100PSIG AT 300F.

2. PIPE: RISERS - WELDED Φ S

S.Stl. { ASTM A312 TP-304 - 12,750 PSI. +
ASTM A312 TP-316 - 15,200 +
ASTM A312 TP-347 - 14,450 +

DOWNCOMER - WELDED Φ S
G.Stl. { ASTM A134 GR. A245C - 10,100 PSI. +
SA-30 FIREBOX, A - 13,750 *
SA-30 " B - 12,000 *

* Minus Allowance for welding (.8)

A = 11,000 PSI, B = 9,600 PSI

+ S-Values include welding allowance

P = 35 PSIG

P₁ = 62*

DIMENSIONS ARE APPROXIMATE

P₂ = 68 PSIG

3. WALL THICKNESS - ASA B31.1 CODE FOR
PRESSURE PIPING, SECTION 1 POWER PIPING

FIG. 1

$$t_m = \frac{PD}{2S + 2YP} + C \text{ For } 48" \text{ O.D. } P=100, D=48, S=12,750, Y=0.4$$

$$C = 0.065"$$

a. FOR 48" RISER:

$$t_m = \frac{100 \times 48}{2 \times 12,750 + 2 \times 0.4 \times 100} = .188 + 0.065$$

$$t_m = .253$$

$$t_{nom.} = .253 + 12\frac{1}{2}\% \text{ mfr. tolerance} = .253$$

$$\text{Use } 5/16" \Phi = .3125" \quad \frac{.253}{.875} = .290"$$

b. FOR 60" DOWNCOMER

P=100, D=60, S=10,100, Y=0.4, C=0.065

$$t_m = \frac{100 \times 60}{2 \times 10,100 + 2 \times 0.4 \times 100} = .296 + 0.065$$

$$t_m = .361"$$

$$t_{nom.} = .361 / .875 = .413" \quad \text{Use } 7/16" \Phi = .437"$$

OR

t_{nom.} - With tolerance allowance for plate of 0.012" instead of 12 1/2%, t_{nom.} = .361 + 0.012 = .373" = 3/8" Φ .

4. 100PSIG Design includes static pressures. 35 psig min. oper. pressure is 20 psig above saturation pr. (15 psig).

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BY E.G. SHACKY DATE 10/23/59

SUBJECT Reactor Study

SHEET NO. 2 OF 4

CHKD. BY DATE

Rear Face Effluent Piping

JOB NO. A0-0024-M

(BOVAY)

150,000 GPM Flow

DO-1121

5. WEIGHTS AND LOADING

a. 48" O.D. RISER, $\frac{5}{16}" \text{R} = 12.75" / \text{Ft}^2$, Water @ 60F = 62.37 $" / \text{ft}$.

$$(1) \text{ Weight of cylinder} = \pi 47.687 / 12 \times 12.75 = 160" / \text{Ft} \times 62' = 9,900 \#$$

$$(2) \text{ Wt. Water} = (47.375 / 12)^2 \times .7854 \times 62 \times 62.37 = 46,700$$

$$\text{Pressure force} = 100 - 26.5 = 73.5 \text{ PSIG}$$

$$(3) = 47.375^2 \times .7854 \times 73.5 = 1760 \times 73.5 = 129,300$$

$$(4) \text{ Cross headers, supports \& miscellaneous} = 12,100$$

$$(5) \text{ Total load on pipe wall @ 100 PSIG design} = \boxed{198,000 \#}$$

$$(6) \text{ Hydrostatic test @ 150 PSIG} = (150 - 100) \times 1760 = + 88,000 \#$$

$$(7) \text{ — Test-Max. Pipe Wall load} = \boxed{286,000 \#}$$

b. 60" O.D. Downcomer $\frac{3}{8}" \text{R} = 15.3" / \text{Ft}^2$

$$(1) \text{ Wt. cylinder} = \pi 59.625 / 12 \times 15.3 = 240" / \text{Ft} \times 75' = 18,000 \#$$

$$(2) \text{ Pressure force} = 100 - 26.5 = 73.5 \text{ PSIG. } = 18,000 \#$$

$$= 59.25^2 \times .7854 \times 73.5 = 2750 \times 73.5 = 202,000$$

$$(3) \text{ Wt. Water} = (59.25 / 12)^2 \times .7854 \times 75 \times 62.37 = 90,000$$

$$(4) \text{ Supports, flanges \& miscellaneous} = 10,000$$

$$(5) \text{ Max load on pipe wall @ 100 PSIG design (Top Surt)} = \boxed{320,000 \#}$$

$$(6) \text{ Hydrostatic test @ 150 PSIG} = (150 - 100) \times 2750 = + 137,500 \#$$

$$(7) \text{ — Test-Max. Pipe Wall load} = \boxed{457,500 \#}$$

6. LONGITUDINAL STRESS IN PIPE WALL

a. 48" O.D. RISER, metal area = $\pi 47.687 \times .188 = \frac{t_m \text{ Min.}}{28.2 \text{ in}^2}$

$$(1) \text{ Static stress @ 100 PSIG} = 198,000 / 28.2 = 7,250 \text{ PSI}$$

$$(2) \text{ Test " " 150 " } = 286,000 / 28.2 = 10,150 \text{ PSI}$$

b. 60" O.D. Downcomer, metal area = $\pi 59.625 \times .296 = \frac{t_m \text{ Min.}}{55.5 \text{ in}^2}$

$$(1) \text{ Static stress @ 100 PSIG} = 320,000 / 55.5 = 5,760 \text{ PSI}$$

$$(2) \text{ Test " " 150 " } = 457,500 / 55.5 = 8,250 \text{ PSI}$$

7. HOOP STRESS BASED ON $t_m .253"$ AND $t_m .296"$

$$48" \text{ O.D. } = .188 / .253 = .744 \times 12,750 = 9,500 \text{ PSI @ 150 PSIG} = (14,250 \text{ test})$$

$$60" \text{ O.D. } = .296 / .361 = .820 \times 10,100 = 8,300 \text{ PSI " " } = (12,400 \text{ "})$$

DECLASSIFIED

BY E.G. Shockey DATE 10/22/59

SUBJECT Reactor Study

SHEET NO. 3 OF 4

CHKD. BY DATE

Peak Face Effluent Piping

JOB NO.

(BOVAY)

150,000 GPM Flow

8. VELOCITIES, 150,000 GPM @ 60F = ^{INCREASE} (1.062) = 159,000 GPM @ 250F

$$\text{Velocity Ft/sec} = \frac{\text{GPM} \times .322}{A} \quad A = \text{Area in}^2, \text{I.D., } 48" = 1760, 60" = 2750$$

a. 48" O.D. RISER = $\frac{1}{2}$ FLOW = 75,000 GPM @ 60, OR 79,500 @ 250F

$$V = \frac{75,000 \times .322}{1760} = 13.7 \text{ Ft/sec}, \quad V = \frac{79,500 \times .322}{1760} = 14.55 \text{ Ft/sec}$$

b. 60" O.D. DOWNCOMER

$$V = \frac{150,000 \times .322}{2750} = 17.5 \text{ Ft/sec}, \quad V = \frac{159,000 \times .322}{2750} = 18.65 \text{ Ft/s}$$

9. CENTRIFUGAL FORCE 90° ELL, $F_c = \frac{2AYV^2}{g} \sin \frac{\theta}{2}$

F_c = Thrust #, θ = change in direction degrees, A = Inside Area Sq. Ft.

γ = Density #/cf., V = Velocity Ft/s, g = Acceleration due to gravity. 32.17

a. 48" O.D. PIPE, $A = 12.225 \text{ Ft}^2$, $\frac{\theta}{2} = .7071$, $V = 62.37$ OR 58.82

$$F_c = \frac{2 \times 12.225 \times 58.82 \times 14.55^2}{32.17} \times .7071 = 6,730 \text{ #} \rightarrow$$

b. 60" O.D. PIPE, $A = 19.1 \text{ Ft}^2$

$$F_c = \frac{2 \times 19.1 \times 58.82 \times 18.65^2}{32.17} \times .7071 = 17,200 \text{ #} \rightarrow$$

c. WITH FREE FALL IN DOWNCOMER:

$$\text{Maximum Velocity} = \sqrt{2gh} = \sqrt{2 \times 32.17 \times 70} = 67 \text{ Ft/sec.}$$

$$F_c = \frac{2 \times 19.1 \times 58.82 \times 67^2}{32.17} \times .7071 = 222,500 \text{ #} \rightarrow$$

10. PRESSURE DROP = About 1.1 Ft/100' For 48" PIPE

About 1.25 Ft/100' For 60" PIPE

11. THERMAL EXPANSION - 70F TO 250F = 2.0 in/100' For Stainless Stl.
= 1.45 " " Carbon Stl.

DECLASSIFIED

BY E. G. Shockey DATE 10/22/59
 CHKD. BY DATE
 (Bovay)

SUBJECT REACTOR STUDY
 REAR FACE EFFLUENT PIPING
 150,000 GPM FLOW

Page 103
 SHEET NO. 4 OF 4
 JOB NO. 40-0024-M
 DO-1121

FIG. 2

FOR FREE FALL
 MAY BE 222,500#

130,100 ± NORMAL
 157,000
 287,100 ±

DECLASSIFIED

BY DLH

DATE

SUBJECT

SHEET NO.

OF

CHKD. BY

DATE

STLSTACK

JOB NO.

A2 2224

CALC t OF STL STACK SHOWN:

MAKE ALLOWANCE OF $\frac{1}{16}$ "
ON THICKNESS OF PL
FOR CORROSION

DECLASSIFIED

WIND MOMENT

LOWER LEVEL

120" DIAM

$$\Sigma M = M_1 + M_2$$

$$M_1 = \frac{P_w D_1 h^2}{2}$$

$$\Sigma M = 207,000 \#'$$

$$M_1 = \frac{(25)(6)(50)^2}{2} = 187,000 \#'$$

$$\Sigma M = 2,480,000 \#''$$

$$M_2 = \frac{P_w D_2 h^2}{2}$$

$$M_2 = \frac{(25)(4)(20)^2}{2} = 20,000 \#'$$

SECTION MODUL

LOWER LEVEL

try using $\frac{3}{16}$ in (structural thickness)

$$S = (.8)(d_m^2)(t)$$

where d_m = mean diam
 $d_m = 120" - \frac{3}{16}" = 119.8$
 t = thickness = $\frac{3}{16}$
 $t = .1875$

$$S = (.8)(119.8)^2(.1875)$$

$$S = 2,150 \text{ in}^3$$

STRESS IN STL DUE TO WIND ONLY

$$f_s = \frac{M}{S} = \frac{2,480,000}{2,150} = 1150 \text{ psi OK}$$

continue with $\frac{3}{16}$ in ASSUMPTION

WT OF STACK

ADD $\frac{1}{16}$ " to assumed width for corrosion

$$\Sigma W = W_1 + W_2$$

$$W_1 = 2\pi r t \rho_s h = (2\pi)(60) \cdot 25(500)(20)$$

(144)

$$\Sigma W = 12,400$$

$$W_1 = 6500 \#$$

ASSUME $\frac{1}{4}$ IN UPPER LEVEL

$$W_2 = 2\pi 36 \cdot 25 500 320$$

$$W_2 = 2900 \#$$

REASSUMED

BY DLH DATE _____
CHKD. BY _____ DATE _____

SUBJECT STL STACK

17-3541
1 of 10
SHEET NO. 3 OF _____
JOB NO. AD 0024

AREA OF SECTION @ BASE

$$A = 2\pi r t = (2\pi)(60)(.25) = 95 \text{ in}^2$$

$$f_{s \text{ BRG}} = \frac{2W}{A} = \frac{12400}{95} = 130 \text{ psi}$$

$$f_{s \text{ total}} = \frac{W}{A} \pm \frac{M}{S} = 130 \pm 1150 = 1280 \text{ psi (COMPRESSION) OR}$$

$$f_s = -1150 + 130 = -1020 \text{ psi (TENSION) OR}$$

$$\text{allowable } f_s = 2,000,000 \frac{t}{d} \left(2^{3/8} \right) \left(200 \frac{t}{d} \right)$$

COMPRESSION

$$f_s \text{ ALLOW} = (2) 10^6 \left(\frac{.187}{.120} \right) (2.67) \left(200 \frac{.187}{.120} \right)$$

$$f_s = 2,600 \text{ psi ALLOWED}$$

USE $\frac{1}{4}"$ PL (THIS INCLUDES ALLOWANCE FOR $\frac{1}{16}"$ RUST)

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$$\begin{aligned} h_s &= 24 \sqrt{DT} = 24 \sqrt{10 \cdot 187} \\ h_s &= 24 \sqrt{187} = (24) (1.37) \\ h_s &= 33' \end{aligned}$$

MOBILE RFQD

$$\text{Spacing } h_s = 120 \sqrt{\frac{DT}{P_u}} = 120 \sqrt{\frac{DT}{25}}$$

STIFFENERS : LOUVER SECTION

BY <u>DLH</u>	CHKD. BY	DATE	SUBJECT	SHEET NO.	JOB NO.
			<u>STOCK</u>		<u>0024</u>

11-13501
10/10

BY DLH DATE _____
CHKD. BY _____ DATE _____

SUBJECT STL STACK

SHEET NO. 5 OF 3
JOB NO. AD 0224

100-63581
Page 108

WIND MOMENT UPPER LEVEL

$$M = \frac{P_w D h^2}{2} = \frac{(25)(6)(30)^2}{(2)} = 67,500 \text{ #'}^2$$

$$M = 810,000 \text{ #''}$$

SECTION MODULUS UPPER LEVEL

TRY USING $3/16''$ PL STRUCTURAL

$$S = (.8) d_m^2 t = (.8)(71.7^2)(.187) = 770 \text{ in}^3$$

BENDING STRESS

$$f_s = \frac{M}{S} = \frac{810,000}{770} = 1050 \text{ psi}$$

BENDING S .

$$W = (2\pi r t) \left(\frac{p_s h}{144} \right) = (2\pi)(86)(.187) \left(\frac{500.33}{144} \right)$$

$$W = (42.4)(104.5) = 4430 \text{ #}$$

$$A = 42.4 \text{ in}^2$$

$$f_s = \frac{W}{A} = \frac{4430}{42.4} = 104.5 \text{ psi}$$

TOTAL STRESS

$$f_s \text{ TOTAL} = \frac{W}{A} \pm \frac{M}{S} = 104.5 \pm 1050 \text{ psi}$$

$$f_s = +1154 \text{ psi (COMPRESSION)}$$

$$f_s = -946 \text{ psi (TENSION)}$$

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USE $1/4''$ PL (THIS INCLUDES ALLOWANCE FOR $1/16''$ RUST)

BY DLH DATE _____
CHKD. BY _____ DATE _____

SUBJECT STL STRUCK

17-03501
Page 105
SHEET NO. 6 OF _____
JOB NO. RD 0024

STIFFENERS

UPPER SECTION

SPACING $h_s = 24 \sqrt{D E} = 24 \sqrt{(6)(18)}$

$$h_s = 24 \sqrt{1.12} = (24)(1.06) = 25.4'$$

USE 1 - INTERMEDIATE STIFFENER

$$h_s = 15'$$

$$S_{\text{STIFFENERS}} = \frac{h_s D^2}{800} = \frac{(15)(6)^2}{800} = .675 \text{ in}^3$$

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BY DLH DATE 23 NOV 57 SUBJECT ENERGY DISIP
STACK
CALC t
 CHKD. BY _____ DATE _____

SHEET NO. _____ OF _____
 JOB NO. AD 0024

CALCULATE t for chimney shown.
 CONCRETE

TYP SECTION
 UPPER SECTION

TYP SECTION
 BASE SECTION

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BY DLH DATE _____ SUBJECT ENERGY DISP
 CHKD. BY _____ DATE _____ CONCRETE STACK
CAL t

SHEET NO. 8 OF _____
 JOB NO. A0 0024

DIRECT STRESSES BASE SECTION ($t = 6''$ ASSUMED)
 FROM HULL & KINNE
"REINF CONCR & MASONRY STRUCTURES"
PG 635

$t_{tip} = 4''$ MIN

DETERMINE WIND MOMENT.

DESIGN FOR 100 MPH WIND

$$P_w = .0025 V^2 = .0025 100^2$$

$P_w = 25 \text{ \#/ft}^2$ OF PROJECTED AREA

$$\Sigma M_w = M_1 + M_2 \text{ where } M_1 = \frac{P_w D (50)^2}{2}$$

$$M_w = 207,000 \text{ \#'} \text{ BASE}$$

$$M_1 = \frac{(25)(6)(50)^2}{(2)} = 187,500 \text{ \#'} \text{ BASE}$$

$$M = (207,000)(12)$$

$$M = 2,480,000 \text{ \#''}$$

$$M_2 = \frac{P_w D_c h_c^2}{2}$$

$$M_2 = \frac{(25)(4)(20)^2}{2} = 20,000 \text{ \#'} \text{ BASE}$$

DETERMINE WT OF STACK

ASSUME $t_{tip} = 4''$ $h_1 = 30'$

$t_{base} = 6''$ $h_2 = 20'$

$$W_{tip} = \frac{(2\pi)(36)(4)(150)(30)}{(144)} = 40,800 \text{ \#}$$

$$W_{base} = \frac{(2\pi)(60)(6)(150)(20)}{(144)} = 47,500 \text{ \#}$$

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BY DLH 28 NOV 59 SUBJECT

CHKD. BY DATE

STACK
CALC tSHEET NO. 8 OFJOB NO. A00024

$$e = \frac{M}{N} = \frac{2,480,000}{88,120} = 28.1"$$

$$\frac{e}{r} = \frac{28.1}{60} = .47 \quad \text{less than .5}$$

$\therefore$ no stl reqd. for direct str.
as resultant lies within
 $\frac{r}{2}$ from diameter

FIND f_c :

$$f_c = \frac{W}{A} \pm \frac{M}{S} \quad \text{where } A = 2\pi r t = (2)(\pi)(58)(6)$$

$$A = 2200 \text{ in}^2$$

$$f_c = \frac{88,120}{2,200} \pm \frac{2,480,000}{46,000} \quad \& \quad S = S_1 - S_2$$

$$S_1 = (.0782)(120)^3 = 172,000 \text{ in}^3$$

$$S_2 = (.0782)(108)^3 = 124,000 \text{ in}^3$$

$$f_c = 40 \pm 54$$

$$f_c = 104 \text{ psi OK}$$

DECLASSIFIED

BY DLH

DATE

SUBJECT

W-63501

Page 113

SHEET NO. 10 OF

CHKD. BY

DATE

STACKJOB NO. HO 0024

DIRECT STRESSES

UPPER SECTION. $t = 4"$

WIND MOMENT (OVERTURNING)

$$M = (6)(25)(30) = 4500 \text{ #'} = \underline{540,000 \text{ #'}}$$

SECTION MODULUS

$$S = S_1 - S_2$$

$$S = \underline{12,800 \text{ in}^3}$$

$$S_1 = (.0981)(72)^3 = 36600$$

$$S_2 = (.0981)(64)^3 = \underline{25800}$$
$$12,800 \text{ in}^3$$

WT OF SECTION

$$W = 2\pi r t 150h = \frac{(2\pi)(36)(4)(150)(30)}{(144)}$$

$$W = \underline{28,200 \text{ #}}$$

AREA

$$A = 2\pi r t = (2\pi)(36)(4) = \underline{900 \text{ in}^2}$$

$$f_c = \frac{1M}{S} + \frac{W}{A} = \frac{540,000}{12,800} + \frac{28,200}{900}$$

ASSUME
NO STL

$$f_c = 50 + 31.4 = \underline{81.4 \text{ psi}} \text{ OK}$$

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BY DLH 23 NOV 59 SUBJECT STACK

11-23581
Page 114
SHEET NO. 11 OF 11
JOB NO. AO 0024

CALC TEMP STRESSED. BASE SECTION t=6"

Horiz:

$$f_c = .000006 E_c F \frac{kd}{t}$$

where $E_c = 3,000,000$

F : Temp drop $-^{\circ}F$
(say 225 $^{\circ}F$)

kd : Same as km kd

t : thickness of wall.

$$f_c = (.000006)(3,000,000)(225) \frac{(4)(5)}{(6)}$$

$$f_c = \underline{1350} \text{ psi} \leftarrow$$

$$f_s = .000006 E_s F t' \frac{(1-k)}{(e)}$$

$$f_s = .000006 30,000,000 \frac{(225)}{(6)} \frac{(5)(.6)}{(1)}$$

$$f_s = \underline{20,300} \text{ psi} \leftarrow$$

$$\epsilon_c = f_c \frac{kt'}{2} = 1350 \frac{1.6}{2} = 1080 \text{ } \mu$$

$$\epsilon_t = 20,300 \text{ } \mu \quad p t' = (20,300)(p)(5) - \epsilon_c$$

$$p = \frac{\epsilon_c}{(20,300)(5)} = \frac{1080}{(20,300)(5)} = .0106$$

$$A_s = p A_c = (.0106)(5)(12) =$$

6 @ 8 Horiz OS. face 4" cover

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[REDACTED]

BY DLH DATE 23 NOV 59 SUBJECT

SHEET NO. 12 OF JOB NO. AR 0024

CHKD. BY DATE STACK

(TEMP STRESSES)
VERTICAL STL

BASE SECTION $t = 6'$

(place 1/2 of horz stl.)
 $t' = 4''$

$$f_c = .000006 E_c \frac{kt'}{t} F$$

$$f_c = (.000006) (3,000,000) \frac{(.4)(4)}{(6)} (225)$$

$$f_c = 1080 \text{ psi}$$

$$f_s = .000006 E_s F \frac{t'(1-k)}{t}$$
$$= (.000006) (30,000,000) \frac{(225)(4)(.6)}{(6)}$$

$$f_s = 16,100 \text{ psi}$$

$$ZC = 1080 \frac{kt'}{2} = (1080) \frac{(.4)(4)}{(2)} = 864 \#$$

$$ZT = 16,100 \text{ p } t' ; p = \frac{(864)}{(16,100)(4)} = .0133$$

$$As = p Ac = (.0133)(4)(12) = .64$$

#6 @ 8 Vert. $1\frac{1}{2}''$ cover from 0.5

BY DLH 28 NOV 59 DATE SUBJECT STACK
CHKD. BY _____ DATE _____

SHEET NO. 13 OF 116
JOB NO. AO 0024

TEMP STRESSES UPPER STACK $t = 4"$

Horiz

$$f_c = .000006 E_c F \frac{k d}{t}$$

see "temp stresses
OF BASE SECTION
FOR DEFINITION TERM"

$$f_c = (.000006) (3,000,000) (225) \frac{(.4)(3)}{(4)}$$

$$f_c = \underline{1210} \text{ psi} \text{ ---}$$

$$f_s = (.000006) E_s F t' \frac{(1-k)}{t}$$

$$f_s = (.000006) (3,000,000) (225) \frac{(3)(.6)}{(4)}$$

$$f_s = \underline{18,200} \text{ psi} \text{ ---}$$

$$\epsilon_c = f_c \frac{k t'}{2} = \frac{(1210)(.4)(3)}{(2)} = 725 \mu$$

$$T = f_s p t' = \epsilon_c$$

$$p = \frac{\epsilon_c}{f_s t'} = \frac{(725)}{(18200)(3)} = .0133$$

$$A_s = p A_c = (.0133)(3)(12) = .48$$

#6 @ 11 Horiz 0.5 FARE ($\frac{3}{4}"$ cover)

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BY DLH DATE 23 NOV 59 SUBJECT STACK
CHKD. BY _____ DATE _____

SHEET NO. 18 OF _____
JOB NO. AO 0024

TEMP STRESSES

(UPPER SECTION)
 $t = 4"$

VERTICAL

$$t' = 2"$$

$$f_c = .000006 E_c \frac{Et' F}{t}$$

$$f_c = (.000006) (9,000,000) \frac{.4(2)(225)}{(4)}$$

$$f_c = \underline{810} \text{ psi} \leftarrow$$

$$f_s = .000006 E_s F \frac{t' (1-k)}{t}$$

$$f_s = (.000006) (30,000,000) \frac{(225)(2)(.6)}{(4)}$$

$$f_s = \underline{12,150} \text{ psi} \leftarrow$$

$$\epsilon_c = 810 \frac{(.4)(2)}{(2)} = 324 \mu$$

$$p = \frac{\epsilon_c}{f_s t'} = \frac{(324)}{(12,150)(2)} = .0133$$

$$A_s = p A_c = (.0133) (2)(12) = .32$$

4 @ 7½ Vertical (1½" clear)
O.S. face.

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BY DLH DATE 23 NOV 59 SUBJECT STACK
CHKD. BY _____ DATE _____

11-63551
1pg 116
SHEET NO. _____ OF _____
JOB NO. 10 0224

EARTHQUAKE STRESSES.

$$F = C W \quad \text{CHIMNEYS; } C = .1$$

$$M = F h = C W h = (.1)(88100)(25)$$

$$M = 210,000 \text{ #}$$

MOMENT LESS THAN
PRODUCED BY WIND,
∴ EARTHQUAKE STRESSES
ARE TAKEN CARE OF
BY WIND STRESSES.

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HAMMEL-DAHL
DIV. OF GENERAL CONTROLS CO.
WARWICK, RHODE ISLAND

APPLICATION DATA BULLETIN NO.2

SUBJECT: Flash-Flo Plug in Power Station Applications

The H--D Flash-Flo plug has been a phenomenal success on every application where our engineers have decided its use was warranted. Because it is an unusual construction, and because it solves a problem whose nature is not commonly understood, this plug could not be "talked" into wide usage. It had to prove its worth by solving problems after they developed.

We now have the data on successful applications, and the value of the design is being recognized throughout several industries. The time has come when we can cite cases, name names, and get this plug specified in the first place to prevent the problem from materializing. We begin with this bulletin to present: (1) the industries involved (2) the flow conditions requiring this plug, and (3) the information about the heart of the problem that this plug solves.

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PROBLEM:

On boiler feed water applications, where valves control the level of liquid condensate in heater tanks or control the flow to feed pumps or boiler, the following problems arise:

Erosion of valve, trim and piping

Terrific noise

Destructive vibration

TYPICAL POWER PLANT INSTALLATIONS:

NARRAGANSETT ELECTRIC COMPANY

PROVIDENCE, RHODE ISLAND

When this installation was started up in 1955, a competitor's valve was in operation for a very few minutes. The noise level was so intolerably high and the vibration so great that the valve had to be removed immediately. Our competitor spent a great deal of time changing trim and even the piping configurations -- to no avail.

The next valve installed in 1955 was the 6" Hammel-Dahl valve with Flash-Flo plug. The trim was examined at our request in 1957 and showed no wear. Noise and vibration are non-existent and the original Flash-Flo Plug is still in the valve at this writing.

The personnel at this installation are very much impressed with the Hammel-Dahl valve. It is a real "workhorse" - continuously throttling twenty-four hours a day, year in and year out.

NEW ENGLAND POWER COMPANY

SALEM, MASSACHUSETTS

Same type installation as Narragansett Electric except a 10" Flash-Flo Plug Valve is used between the No. 1 and No. 2 heaters. Conditions: P=222psig, dP=10 psi, T=104°F., Q=950,000 PPH.

This was a new installation for which the customer specified the Flash-Flo Plug. Conditions were not as severe, but it is significant that the customer was willing to pay a large extra charge for Flash-Flo trim to avoid any possibility of trouble.

Stone & Webster was the contractor on this job, and through their experience with the plug on this installation we hope to have them establish our valves as standard for liquid condensate service.

CAUSE OF THE PROBLEM:

Cavitation: When fluid in a pipe or valve is deflected from its course, a vacuum is formed on the downstream side of the curve or bump causing the deflection. This vacuum, just outside the main flow stream, takes the form of perfectly spherical bubbles which move along the surface of the pipe, and then collapse. All the water which formed the outside surface of the bubble meets at a point where the center of the bubble was with almost infinite deceleration. Instantaneous pressures can reach values well over 100,000 psi, and it is thousands of such implosions which cause damage to valve and downstream piping. Whether or not cavitation occurs, depends, of course, on the velocity of the fluid, its temperature, boiling point, static pressure, and nature of the deflection.

To look at the problem another way, consider the following arrangement of a pump and valve:

Assume that the pipe size is uniform throughout, that static pressure at point "A", is 0 psig, and that 1000 H.P. is imparted to the water by the pump - raising the pressure to a given value at point "B". The pressure at point "C" is 0 psig.

Since the fluid is incompressible, and the pipe of uniform diameter, the velocity is the same at points "A", "B", and "C"; hence, the kinetic energy of the fluid is the same at "A", "B", and "C". The 1000 H.P. is represented principally by the static pressure at point "B".

If the H.P. represented by the static and kinetic pressure at points "A", and "C" is negligible and the H.P. at point "B" is 1000, what happened to the H.P. between "B" and "C"?

The following changes in energy occur: In a conventional valve, a negligible amount of energy is converted to heat by turbulence and the resulting friction of the liquid upon itself and on the surfaces of the valve. Most of the potential energy becomes kinetic. Then, through the mechanisms of cavitation, the thousands of bubble-bursting implosions turn the kinetic energy of the fluid into destructive vibration of the valve and piping. This vibration generates heat which is dissipated in the surrounding air. Since a high amount of mechanical energy can be produced by a relatively small amount of heat (e.g. the H.P. of a large pump in a large pipe line can be dissipated by a temperature rise of less than one degree), the rise in temperature of the valve and piping is unnoticeable.

HOW THE FLASH-FLO PLUG SOLVES THE CAVITATION PROBLEM:

In the Flash-Flo Plug design, threaded holes are geometrically spaced around the plug skirt to create turbulence and distribute energy release over a large surface area. Thus, potential energy is converted directly to heat by means of the internal turbulence of the liquid - with the result that less kinetic energy is available for damage to the valve and piping.

LATEST POWER PLANT APPLICATION:

POTOMAC ELECTRIC COMPANY

DICKERSON, MARYLAND

This valve has a rating of 2500 lb. ASA, with butt welding end connections. Body material is 4-6% chrome, 1/2% moly.

The valve will be used during start-up periods only. Under normal operation the valve will be wide open, and variable speed pumps will govern the flow of condensate

This installation will be operating in 1959. You will be informed of the performance of the valve as soon as data is available.

OTHER INDUSTRIES:

Hammel-Dahl valves with Flash-Flo Plugs are installed in refinery and pipe line applications in sizes up to 16". We also have a 1" Flash-Flo Plug valve order going through our factory now for E. I. duPont de Nemours & Company, Inc. Later application data bulletins will provide information on these specific applications.

IX. DOWNCOMER AND EFFLUENT LINE CALCULATIONS

The downcomer and effluent line systems are analyzed for non-pressurized flows up to 120,000 gpm. The analyses are based on work done by the R. L. Allbrook Hydraulic Laboratory at Washington State University which is reported in the following studies:

- GEH-24162 - Hydraulic Model Studies of the 100-F Downcomer & Effluent System Contract No. DDR-41, Work Phase I
- GEH-24387 - Hydraulic Model Studies of the 100-F Downcomer and Effluent System, Phase II
- GEH-24477 - Supplemental Report on 100-F Downcomer and Effluent System
- GEH-24522 - Hydraulic Model Studies of 100-DR and 100-F Downcomers Supplemental Contract No. 3 - DDR-41

In the dual areas; that is 100-B, C and 100-D, DR; the calculations are based on the assumption that the effluent systems for the reactors are interconnected and that each system has to have sufficient capacity to enable it to carry the effluent from its reactor plus the shut down flow from the other reactor. At 100-C, DR and H where two downcomers and effluent lines per reactor exist the downcomers and effluent lines can be used simultaneously as one.

X. DRAWING AND REFERENCE DOCUMENTS

Drawings and documents pertinent to this document are listed in HW-63487 to which the reader is directed for this information.

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BY GHB DATE 12/18/59 SUBJECT 105-F DOWNCOMER

105-63501
Page 125

SHEET NO. 1 OF 28

CHKD. BY _____ DATE _____ EFFLUENT LINE

JOB NO. DO 1121

CHECK SYSTEM FOR 120000 GPM USING METHOD DEVELOPED IN REPORT NUMBER GEH 24522

FIGURES REFERRED TO ARE FROM ABOVE REPORT. FROM FIGURE 6

ELEVATIONS

DOWNCOMER BASE	424.7
VENA CONTRACTA	422.4
EXIT OF PIPE	422.6

TOTAL $\frac{L}{D}$ FOR EXISTING LINE = 465

LINE HEAD LOSS

$$H_L = f \frac{L}{D} \frac{V^2}{2g}$$

$$f = 0.01$$

PRESSURE GRADIENT DIP AT VENA CONTRACTA

$$H_{vc} = \left(\frac{1}{C_c^2} - 1 \right) \frac{V^2}{2g}$$

ASSUME $C_c = .50$

$$H_{vc} = \frac{3.00 V^2}{2g}$$

FOR PERFORATED
BAFFLES

THIS ANALYSIS WILL ASSUME USE OF EXISTING EFFLUENT LINE WITH INSTALLATION OF NEW DOWNCOMER

BY GHP DATE 12/18/79 SUBJECT 105-F DOWNCOMER
CHKD. BY _____ DATE _____ EFFLUENT LINE

SHEET NO. 2 OF 28
JOB NO. DO 1121

ASSUME FLOW OF 60000 GPM THROUGH EACH DOWNCOMER. NEW DOWNCOMER WILL BE CRITICAL SINCE ITS EFFLUENT LINE IS LONGEST AND HAS MOST ELBOWS.

$\frac{L}{D}$ FOR NEW EFFLUENT LINE

A TO B FLOWS 60,000 GPM; FROM B ON FLOW IS 120,000 GPM; THEREFORE CONSIDER TWO SECTIONS OF LINE

A-B

$$LENGTH = 350'$$

$$D = 5'$$

$$\frac{L}{D} = \frac{350}{5} = 70$$

$$1-90^\circ \text{ ELBOWS} = 16$$

$$2-45^\circ \text{ ELBOWS} = 20$$

$$TOTAL \frac{L}{D} = 106$$

B TO END

$$LENGTH = 1993 - 68 = 1925$$

$$D = 5'$$

$$\frac{L}{D} = \frac{1925}{5} = 385$$

SUBTRACT

$$1-45^\circ \text{ ELBOW } 55$$

$$TOTAL \frac{L}{D} = 440$$

AREA OF 5' DIA PIPE

$$A = (5^2)(.7854) = 19.65 \text{ sq'}$$

FLOW CFS

$$Q_{120000} = (.00223)(120000) = 268 \text{ cfs}$$

$$Q_{60000} = 139 \text{ cfs}$$

VELOCITY

$$V_{120000} = 13.62 \text{ fps}$$

$$V_{60000} = 6.81 \text{ fps}$$

HEAD LOSSES

A-B

$$H_{A-B} = f \frac{L}{D} \frac{V^2}{2g} = (.015)(106) \left(\frac{6.81^2}{64.4} \right) = 1.15 \text{ ft}$$

B TO OUTFALL

$$H_{B-OUTFALL} = (.015)(440) \left(\frac{13.62^2}{64.4} \right) = 18.78 \text{ ft}$$

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BY G.H.B. DATE 12/18/57 SUBJECT 105-F DOWNCOMER

 SHEET NO. 3 OF 28

 CHKD. BY _____ DATE _____ EFFLUENT LINE

 JOB NO. D.O. 1121

PRESSURE GRADIENT DIP AT VENA CONTRACTA

$$H_{vc} = 1.3 \frac{V^2}{2g} = \frac{(3.0)(6.81^2)}{64.4} \quad C_c = .5$$

$$H_{vc} = 2.16 \text{ FT.}$$

HYDRAULIC GRADE LINE AT VENA CONTRACTA

$$\text{EXIT OF PIPE} = 422.60$$

$$\text{LINE LOSS} \quad \underline{17.93}$$

$$442.53$$

$$\text{VENA CONTRACTA DIP} = \underline{2.16}$$

$$440.37$$

$$\text{VENA CONTRACTA ELEV.} = \underline{422.40}$$

$$17.97 \text{ FT. OF HEAD DOWNSTREAM OF VENA CONTRACTA.}$$

SINCE THE PRESSURE AT THE VENA CONTRACTA IS POSITIVE AND ABOVE THE VAPOR PRESSURE (212°F) THE LINE WILL FLOW FULL AND NO HYDRAULIC JUMP WILL FORM.

FROM FIG. 8 FOR 60000 GPM FLOW, 3.2 FT OF HEAD ARE REQUIRED TO FORCE WATER THROUGH BORDA MOUTH PIECE.

HEAD ABOVE BOTTOM OF DOWNCOMER WILL BE:

$$H = 17.97 + 3.2 - 2.5$$

$$H = 18.67'$$

REFERRING TO TABLE 4 IT IS SEEN THAT THIS IS A LESS SEVERE CONDITION THAN 70,000 GPM WITH EXISTING EFFLUENT SYSTEM WITH MODIFIED DOWNCOMER. THEREFOR SYSTEM WITH MODIFIED DOWNCOMERS WILL HANDLE FLOW.

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BY GHB DATE 12/24/58 SUBJECT 105-B DOWNCOMER SHEET NO. 9 OF 28
 CHKD. BY _____ DATE _____ EFFLUENT LINE JOB NO. DP-1121

BY GHB DATE 12/21/88 SUBJECT 10.5-B DOWNCOMER SHEET NO. 5 OF 28
CHKD. BY _____ DATE _____ EFFLUENT LINE JOB NO. 00-1121

CHECK SYSTEM FIRST FOR 120000 GPM FLOW.
IN ADDITION TO ABOVE FLOW SYSTEM MUST CARRY
AN ADDITIONAL FLOW OF 10000 GPM SHUT DOWN
WATER FROM "C" COMING IN AT EXPANSION BOX #19.

$$\text{FLOW INTO BASIN} = 130000 \text{ GPM}$$

$$Q = (130000)(0.0223) = 290 \text{ cfs.}$$

$$\text{WATER SURFACE ELEV. IN BASIN} = 441.00'$$

BASIN IS SEPARATED FROM INLET CHAMBER
BY TWO 6'x6' SLUICE GATES

HEAD TO FORCE WATER THROUGH SLUICE GATES

$$Q = 0.62A\sqrt{2gh}$$

$$290 = (0.62)(72)\sqrt{(64.4)(h)}$$

$$84100 = (1995)(64.4)(h)$$

$$h = \frac{84100}{(1995)(64.4)}$$

$$h = .656'$$

$$\text{ELEV IN INLET CHAMBER} = 441.66'$$

CHECK SYSTEM BACK TO EXPANSION BOX #19

$$\frac{L}{D} = \frac{750}{5} = 150$$

$$V = \frac{290}{19.65}$$

$$1-90^\circ \text{ ELBOW} \quad 16$$

$$1-22\frac{1}{2}^\circ \text{ MITER} \quad 6$$

$$\text{HEAD LOSS} \quad 172$$

$$H_L = \frac{(0.015)(172)(14.75)}{64.4}$$

$$H_L = 8.71 \text{ FT}$$

HYDRAULIC GRADE LINE AT BOX #19

$$E = 441.66 + 8.71 = 450.37$$

CHECK WATER SURFACE ELEVATION AT DISTRIBUTION
BOX

$$\frac{L}{D} = \frac{30}{4.5} = 6.67$$

$$H_L = \frac{(0.015)(6.67)(16.82)}{64.4} = .44$$

$$V = \frac{268}{15.92} = 16.82 \text{ FPS}$$

$$\text{HYDRAULIC GRADE AT DIST. BOX} = 450.37 + .44 + .50 = 451.31$$

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FORMALITY HEAD LOSS
80

BY GHB DATE 12/21/58 SUBJECT 105-B DRYWYCAMER
CHKD. BY _____ DATE _____ # EFFLUENT LINE

SHEET NO. 6 OF 28
JOB NO. D.O. - 1121

CHECK WATER SURFACE ELEVATION AT UPPER DISTRIBUTION BOX (DWG. H-1-26098 SHT. 2)

$$\frac{L}{D} = \frac{1660}{5.5} = 302$$

$$H = \frac{(0.15)(302)(11.28^3)}{64.4}$$

$$H = 8.95'$$

ELEVATION OF WATER IN BOX

$$E = 451.31 + 8.95 + 0.50 = 460.76$$

$\frac{1}{4}$ OF VELOCITY HEAD LOST IN BOX

HYDRAULIC GRADE LINE ELEVATION AT DOWN COMER VENA CONTRACTA

$$\frac{L}{D} = \frac{135}{5.5} = 24.5$$

$$1-90^\circ \text{ ELBOW } \frac{12.0}{36.5}$$

$$H = \frac{(0.15)(36.5)(11.28^3)}{64.4}$$

$$H = 1.08$$

$$V = \frac{268}{23.79}$$

$$V = 11.28 \text{ FPS}$$

$$\frac{V^2}{2g} = 1.98$$

$$V = 11.28 \text{ FPS}$$

CHECK WITH AN ADDITIONAL 60" LINE BETWEEN 107-B AND EXPANSION BOX #19

$$V = \frac{17.05}{2} = 8.52 \text{ F.P.S.}$$

$$\frac{8.52^2}{2} = 36.2$$
$$\frac{17.05^2}{2} = 145.0$$

HEAD LOSS EQUALS $\frac{1}{4}$ OF ORIGINAL

$$H = (11.65)(.25) = 2.92$$

$$72.5/291.0 = .25$$

HYDRAULIC GRADE LINE ELEVATION AT BOX #19

$$H = 441.87 + 2.92 = 444.79$$

HYDRAULIC GRADE LINE ELEVATION AT DISTRIBUTION BOX

$$H = 444.79 + 4.4 + .46 = 449.65'$$

HYDRAULIC GRADE LINE ELEVATION AT UPPER DISTRIBUTION BOX

$$H = 449.65 + 8.25 + .46 = 458.36$$

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BY G.H.B. DATE 1/5/60

 SUBJECT 105-B DOWNCOMER

 SHEET NO. 7 OF 28

CHKD. BY _____ DATE _____

EFFLUENT LINE

 JOB NO. DD-1121

VENA CONTRACTA DIP

$$H_{vc} = \frac{3V^2}{2g}$$

$$V = 11.28$$

$$H_{vc} = \frac{(3)(11.28^2)}{64.4} = 5.93'$$

$$ELEV = 460.76 + 1.08 - 5.93 = 455.91$$

$$\pm \text{PIPB ELEV.} = 453.04$$

UNDER THESE CONDITIONS POSITIVE PRESSURE EXISTS AND NO POCKET WILL BE FORMED. NO HYDRAULIC JUMP WILL EXIST.

ENERGY LEVEL AT BOTTOM OF DOWNCOMER

 VELOCITY HEAD PLUS ENTRANCE LOSS EQUALS $1.5 \frac{V^2}{2g}$

$$h = (1.5)(1.98) = 2.97$$

$$ELEV = 460.76 + 1.08 + 2.97 = 464.81$$

ABOVE BOTTOM OF DOWNCOMER

$$H = 464.81 - 450.29 = 14.52 \text{ FT}$$

DOWNCOMER LOSS PER BAFFLE (PERFORATED)

$$H_L = \frac{V^2}{2g}$$

ASSUME

$$C_d = 0.6$$

PERFORATED AREA

$$\text{OF BAFFLE} = 5.75 \text{ D}$$

ORIFICE AREA

$$A_o = (6.59)(4.49) = 29.02$$

$$H_L = \left[\frac{Q}{(0.6)(29.0 + 5.75)} \right]^2 \left[\frac{1}{29} \right]$$

$$H_L = \left[\frac{268}{20.85} \right]^2 \left[\frac{1}{69.4} \right]$$

$$H_L = 2.57'$$

DECLASSIFIED

SHEET NO. 8 OF 28
JOB NO. 20-1121

DOWN CORNER WILL HANDLE FLOW IF MODIFIED
IN ACCORDANCE WITH ALLBROOK LAB. RECOMM.

DECLASSIFIED

BY G.H.B. DATE 1/5/60 SUBJECT 105-B DOWNCOMER
CHKD. BY _____ DATE _____ & EFFLUENT LINE

HM-635-1
Page 133
SHEET NO. 9 OF 28
JOB NO. DA-1121

THE CONDITION ANALYZED ABOVE IS THE GREATEST FLOW THE 105-B SYSTEM WILL HAVE TO HANDLE SINCE THE EXISTING SYSTEM WILL HANDLE THIS FLOW WITH MINOR MODIFICATIONS THEY ARE RECOMMENDED FOR ALL INCREASED FLOW CONDITIONS THEY INCLUDE:

1. PERFORATE BAFFLES IN DOWNCOMERS.
2. REMOVE VENT PIPES IN DOWNCOMER.
3. VENT EFFLUENT LINE IMMEDIATELY DOWNSTREAM FROM DOWNCOMER.

DECLASSIFIED

BY GHB DATE 12/23/59 SUBJECT 105-B DOWNCOMER SHEET NO. 10 OF 28
 CHKD. BY _____ DATE _____ * EFFLUENT LINE JOB NO. DD 1121

CHECK FOR 120,000 GPM TO 107-CW
 DETERMINE HYDRAULIC GRADIENT

AT 107-CW

$$WS. ELEV. = 445.5$$

AT DISTRIBUTION BOX

$$\frac{L}{D} = \frac{200}{5.5} = 36.3$$

$$h = \frac{(0.15)(36.3)(10.82^2)}{64.4} = 0.99$$

$$D = 5.5$$

$$Q = 268 \text{ CFS}$$

$$V = 10.82$$

$$\frac{V^2}{2g} = 1.82$$

$$ELEV. = 445.5 + 0.99 + 1.96 = 446.95$$

64.4 1/2 OF VELOCITY HEAD LOST IN BOX.

THIS IS A BETTER CONDITION THAN FOR FLOW
 THROUGH 107-B BASIN SO ANALYSIS WILL BE
 CARRIED NO FARTHER.

DECLASSIFIED

BY G.H.B. DATE 12/23/59 SUBJECT 105C DOWNCOMERSSHEET NO. 11 OF 28CHKD. BY _____ DATE _____ # EFFLUENT LINESJOB NO. DO 1121

DECLASSIFIED

BY G.H.B. DATE 12/29/57 SUBJECT 105-C DOWNCOMERS SHEET NO. 12 OF 28
CHKD. BY _____ DATE _____ EFFLUENT LINES JOB NO. DO 1121

SYSTEM MUST BE ABLE TO HANDLE 120,000 GPM
AND ALSO 10,000 GPM SHUTDOWN FLOW FROM 105-B
WORST CONDITION WILL BE WHEN FLOW IS TO 107-CB
ASSUME BOTH DOWNCOMERS ARE IN USE SIMULTANEOUSLY
THEN EACH LINE WILL CARRY 60,000 GPM WHERE IT
LEAVES 105-C AND THE NEAR LINE BELOW THE 105-B
CROSS-TIE WILL CARRY 70,000 GPM. AS THE NEAR LINE
CARRIES THE GREATEST FLOW AN ANALYSIS WILL BE
MADE ON IT.

CHECK FLOW FROM DIVERSION BOX TO 107-CB
W.S. ELEV. IN BASIN = 445.5'

$$Q = 120,000 + 10,000 = 130,000 \text{ GPM}$$

$$Q = (130,000)(1.00223) = 290 \text{ CFS}$$

FLOW WILL BE THROUGH TWO PARALLEL LINES

ONE 60" LINE

$$L = 173 + 164 + 105 + 150 = 592'$$

ONE 66" LINE

$$L = 10 + 251 + 20 + 20 + 30 = 331'$$

FLOW THROUGH PARALLEL PIPES

$$\frac{Q_2}{Q_1} = \sqrt{\frac{(D_2/D_1)^5}{L_2/L_1}}$$

$$\frac{Q_2}{Q_1} = \sqrt{\frac{(5.5/5.0)^5}{331/592}} = \sqrt{\frac{1.61}{.559}} = \sqrt{2.88}$$

$$\frac{Q_2}{Q_1} = 1.696$$

$$Q_2 = 1.696 Q_1$$

$$Q_2 + Q_1 = 290$$

$$1.696 Q_1 + Q_1 = 290$$

60" LINE $Q_1 = 107.5 \text{ CFS}$

66" LINE $Q_2 = 182.5 \text{ CFS}$

HYDRAULIC GRADIENT WHERE LINES COME TOGETHER

90° MITER

$$L = 30 + 319 = 349'$$

$$L/D = 349/5.5 = 63.5$$

DECLASSIFIED

BY G.H.B. DATE 12/29/59 SUBJECT 10.5-C DOWNCOMER
 CHKD. BY _____ DATE _____ # EFFLUENT LINES

SHEET NO. 13 OF 28
 JOB NO. DD 1121

$$H = f \frac{L}{D} \frac{V^2}{2g}$$

$$H = (.015)(63.5)(2.31)$$

$$H = 2.20$$

$$ELEV = 445.5 + 2.20 = \underline{447.70}$$

$$f = .015$$

$$V = 12.20 \text{ FPS}$$

$$\frac{V^2}{2g} = 2.31$$

HYDRAULIC GRADIENT AT DIVERSION BOX (EAST SIDE)
 LINE LOSS (CONSIDER 66" LINE)

$$\frac{L}{D} = \frac{331}{5.5} = 60.2$$

$$H = (.015)(60.2)(0.915)$$

$$H = 0.826 \text{ SAY } 0.83$$

$$V = 7.68 \text{ FPS}$$

$$\frac{V^2}{2g} = 0.915$$

ENTRANCE LOSS PLUS DISCHARGE LOSS EQUALS
 1.5 TIMES DISCHARGE VELOCITY HEAD

$$H = (1.5)(2.31) = 3.46$$

$$ELEV = 447.70 + 0.83 + 3.46 = \underline{451.99}$$

HYDRAULIC GRADIENT AT DIVERSION BOX (WEST SIDE)
 HEAD TO FORCE WATER THROUGH SLUICE GATE

$$Q = 0.62A \sqrt{2gh}$$

$$156.2 = (0.62)(36.0) \sqrt{64.4h}$$

$$h = 0.76$$

$$Q = 70,000 \text{ GPM}$$

$$Q = 156.2 \text{ CFS}$$

$$ELEV = 451.99 + 0.76 = \underline{452.75}$$

HYDRAULIC GRADIENT AT DIVERSION BOX (AT
 OUTLET OF HEAR LINE) REPLACE 60"X60" GATE NO. 2
 WITH A 72"X72" GATE

$$ELEV. = 452.75 + 0.76 = \underline{453.51}$$

HYDRAULIC GRADIENT AT CROSS OVER BOX

TWO 45" MITERS

$$L = 122 + 36 + 1233 + 82.5 + 82.5 = 1556$$

$$\frac{L}{D} = \frac{1556}{5.5} = 283$$

$$H = (0.5 + (.015)(283) + 1.0) \frac{V^2}{2g}$$

$$H = 3.85'$$

$$Q = 70000 \text{ GPM}$$

$$Q = 156.2 \text{ CFS}$$

$$V = 6.56 \text{ FPS}$$

$$\frac{V^2}{2g} = 0.67$$

$$ELEV. = 453.51 + 3.85 = 457.36$$

HYDRAULIC GRADIENT AT 10.5-B CROSS OVER BOX

$$L = 379 \text{ FT}; D = 4.5' \quad \frac{L}{D} = \frac{379}{4.5} = 84.2; Q = 10,000 \text{ GPM} = 22.3 \text{ CFS}$$

DECLASSIFIED

BY GMB DATE 12/19/59 SUBJECT 105-C DOWNY COM. R.A.
CHKD. BY _____ DATE _____ \$ EFFLUENT LINES

70-63581
Page 130
SHEET NO. 19 OF 28
JOB NO. DO 1121

$$h = [0.54(.015)(84.2) + 1.0] [0.0305] = .084$$

$$V = 1.4$$

$$\text{ELEV} = 457.36 + .08 = 457.44$$

$$\frac{V^2}{2g} = .0305$$

WEIR ELEV. = 462.5, THEREFORE O.K.

CHECK SYSTEM WITHOUT 100-B SHUTDOWN FLOW.

$$\text{TOTAL FLOW} = 120,000 \text{ GPM} = 268 \text{ CFM}$$

$$\text{FLOW (NEAR LINE)} = 60000 \text{ GPM} = 134 \text{ CFM}$$

$$Q_1 + Q_2 = 268$$

$$2.696 Q_1 = 268$$

$$60'' \text{ LINE } Q_1 = 99.9 \text{ CFS}$$

$$66'' \text{ LINE } Q_2 = 168.6 \text{ CFS}$$

} SEE PAGE 12

HYDRAULIC GRADIENT WHERE LINES COME TOGETHER

$$H = (.015)(163.5)(1.98)$$

$$f = .015$$

$$H = 1.89$$

$$V = 11.3 \text{ FPS}$$

$$\text{ELEV.} = 445.5 + 1.89 = \underline{447.39}$$

$$\frac{V^2}{2g} = 1.98$$

AT DIV. BOX (EAST SIDE)

$$H = (.015)(60.2)(1.78) = .704$$

$$V = 7.08$$

ENTRANCE & DISCHARGE LOSS

$$\frac{V^2}{2g} = .78$$

$$H = (1.5)(1.98) = 2.97$$

$$\text{ELEV.} = 447.39 + .70 + 2.97 = \underline{451.06}$$

AT DIV. BOX (WEST SIDE)

HEAD TO FORCE WATER THROUGH CENTER SLUICE GATE

HEAD VARIES AS Q^2

$$Q = 60000 \text{ GPM}$$

$$H = \frac{(0.76)(134)^2}{156.2} = .557$$

$$Q = 134 \text{ CFS}$$

$$\text{ELEV.} = 451.06 + .56 = \underline{451.62}$$

AT DIV. BOX (AT OUTLET OF NEAR LINE)

$$H = \frac{(1.557)(134)^2}{28} = 1.16$$

$$\text{ELEV.} = 451.62 + 1.16 = \underline{452.78}$$

AT CROSS-OVER BOX

$$H = \frac{(3.85)(134)^2}{156.2} = 2.83$$

$$\text{ELEV.} = 452.78 + 2.83 = \underline{455.61}$$

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AT 105-C BLDG.

$$L = 247 + 119 + 1164 + 235 + 16 + 82.5 + 82.5 + 27.5 + 192.5$$

$$L = 2166$$

$$\frac{L}{D} = \frac{2166}{5.5} = 394$$

$$H = (.015)(394)(.492)$$

$$H = 2.91$$

$$ELEV. = 456.07 + 2.75 + 2.91 = 461.73$$

THERE IS NO PROBLEM IN THIS SECTION OF LINE OR DOWNCOMERS.

CHECK FOR SHUTDOWN FLOW INTO 100-B EFF. LINE

CRITICAL POINT WILL BE IN DIV. BOX.

$$HYDRAULIC GRADIENT AT EXP. BOX \#19 = 450.37$$

REQUIRED W.S. ELEV. AT DIV. BOX.

$$H = (0.5 + f \frac{L}{D} + 1) \frac{V^2}{2g}$$

$$L = 158 + 366 + 98 = 614$$

$$\frac{L}{D} = \frac{614}{5} = 123$$

$$H = [0.5 + (.015)(123) + 1.0](1.02)$$

$$H = .067$$

$$ELEV. = 450.37 + .07 = \underline{450.41}$$

$$Q = 10000 \text{ GPM}$$

$$Q = 22.3 \text{ CFS}$$

$$A = 19.65 \text{ ft}^2$$

$$V = 1.135 \text{ FPS}$$

$$\frac{V^2}{2g} = .02$$

CHECK FOR 105000 GPM FLOW

HEAD LOSSES WILL BE PROPORTIONAL TO Q^2

$$Q = 105000 \text{ GPM} = 234 \text{ CFS}$$

AT DIV. BOX (WEST SIDE)

HEAD LOSS FOR 120000 GPM FLOW

$$H_{120} = 451.62 - 445.5 = 6.12'$$

HEAD LOSS FOR 105000 GPM FLOW

$$H_{105} = \frac{(6.12)(234^2)}{268^2} = 4.67$$

$$ELEV. = 445.5 + 4.67 = 450.17$$

DECLASSIFIED

BY GHB DATE 1/5/60 SUBJECT 105-C DOWNGOMER
CHKD. BY _____ DATE _____ EFFLUENT LINE

HW-63501
Page 140
SHEET NO. 16 OF 28
JOB NO. D.D. 1121

CHECK FOR 105000 GPM FLOW WITH 10000 GPM SHUT DOWN
FLOW FROM 105-B

CRITICAL ITEM WILL BE DIVERSION BOX
HEAD LOSSES WILL BE PROPORTIONAL TO Q^2
AT DIV. BOX (EAST SIDE)

HEAD LOSS FOR 130000 GPM FLOW

$$H_{11} = 451.99 - 445.50 = 6.49'$$

HEAD LOSS FOR 115000 GPM FLOW

$$H_{115} = \frac{(6.49)(115000^2)}{130000^2} = 5.08$$

$$ELEV. = 445.50 + 5.08 = \underline{450.58}$$

AT DIV. BOX (WEST SIDE)

LOSS IN GATE

$$H_g = \frac{(0.76)(62500^2)}{70000^2} = .606$$

$$ELEV. = 450.58 + 0.61 = 451.19$$

AT DIV. BOX (OUTLET OF NEAR LINE)
USING 60" GATE REPLACED WITH 72"
ELEV. = 451.19 + 0.61 = 451.80

CHANGES REQUIRED TO SYSTEM

95000 GPM FLOW

PRESENT CONDITION - NO CHANGES.

105000 GPM FLOW

ALL CHANGES ARE IN DIV. BOX

1. REPLACE NO. 2 GATE WITH ONE 72" x 72"
2. RAISE WEIRS TO ELEV. 454.00'
3. RAISE TOP OF BOX 3 FT.

120000 GPM FLOW

1. REPLACE NO. 2 GATE WITH ONE 72" x 72"
2. RAISE WEIRS TO ELEV. 455.50
3. RAISE TOP OF BOX 4.5 FT.

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BY GHR DATE 12/30/59 SUBJECT 105-D DOWNCOMER
 CHKD. BY _____ DATE _____ EFLUENT SYSTEM

SHEET NO. 17 OF 28
 JOB NO. DD-1121

DECLASSIFIED

CHECK SYSTEM FOR 120,000 GPM FLOW FROM 105-D PLUS 10,000 GPM SHUT DOWN FLOW FROM 105-DR. ASSUME FLOW IS DISCHARGED INTO EACH OF TWO 107-B BASINS SIMULTANEOUSLY.

TO SIMPLIFY SOLUTION ASSUME EQUAL DISCHARGE INTO EACH BASIN

CALCULATE HYDRAULIC GRADIENT AT "T"

LOSS OF HEAD

$$L/D \text{ OF ELBOW} = 16$$

$$L/D \text{ OF GATE} = 13$$

$$L/D \text{ OF "T"} = 60$$

$$9' \text{ OF TRANSITION} \quad \frac{1.5}{104}$$

$$H = (0.15)(104)(0.82)$$

$$H = 1.28 \text{ FT}$$

$$\text{ELEV.} = 448.25 + 1.28 = 449.53$$

AT BOX #1 (PG. 17)

$$\frac{L}{D} = \frac{739}{5} = 147.8$$

$$H = (.5 + (0.15) \frac{L}{D} + 1.0) \frac{V^2}{2g}$$

$$H = (.5 + (0.15)(147.8) + 1.0)(3.38)$$

$$H = 12.58$$

$$\text{ELEV.} = 449.53 + 12.58 = 462.11$$

AT BOX #2 (PG. 17)

$$\frac{L}{D} = \frac{1312}{5.5} = 239$$

BECAUSE INLET AND OUTLET OF BOX ARE ON SAME CENTER LINE ASSUME ONLY $\frac{1}{4} \frac{V^2}{2g}$ LOST IN BOX

$$Q = 290 \text{ CFS}; A = 2380; V = 12.18 \text{ FPS}$$

$$H = (0.15)(239)(2.30) \quad \frac{V^2}{2g} = 2.30$$

$$H = 8.25$$

$$\text{ELEV.} = 462.11 + 8.25 + 0.58 = 470.94$$

$$Q = 130,000 \text{ GPM}$$

$$Q = 290 \text{ CFS}$$

$$Q/2 = 145 \text{ CFS}$$

$$V = \frac{Q}{A} = \frac{145}{20} = 7.25 \text{ FPS}$$

$$\frac{V^2}{2g} = \frac{7.25^2}{64.4} = 0.816$$

IN 60" LINE

$$Q = 290 \text{ CFS}$$

$$A = 19.65 \text{ FT}^2$$

$$V = \frac{290}{19.65} = 14.75 \text{ FPS}$$

$$\frac{V^2}{2g} = \frac{14.75^2}{64.4} = 3.38'$$

THIS IS HIGHER THAN THE WEIR IN THE 105-DB LINE AND THEREFORE WILL NOT WORK

DECLASSIFIED

CHECK WITH AN ADDITIONAL 48" LINE FROM BOX #1 TO 107-D

APP. IN THIS CASE $\frac{Q_2}{Q_1} = \sqrt{\frac{(D_2/D_1)^5}{L_2/L_1}}$

$L_2 = L_1$ APP.

$\frac{Q_2}{Q_1} = \sqrt{\left(\frac{5}{4}\right)^5} = \sqrt{1.25^5} = \sqrt{3.05} = 1.75$

TOTAL FLOW EQUALS 130,000 GPM

$Q_2 = 1.75 Q_1$

$2.75 Q_1 = 130,000$

$Q_1 = 47,300$

$Q_2 = 82,700 \text{ GPM}$

LOSS BETWEEN BASIN AND BOX #1

$H = \frac{(82700^2)(1.28 + 12.58)}{(130000^2)} = 5.61$

HYDRAULIC GRADIENT ELEVATION AT BOX #1

$ELEV. = 448.25 + 5.61 = \underline{453.86}$

HYDRAULIC GRADIENT ELEVATION AT BOX #2

$ELEV. = 453.86 + 8.25 + 0.58 = 462.69$

HYDRAULIC GRADIENT ELEVATION AT DOWNCOMER VENA CONTRACTA

$\frac{L}{D} = \frac{247+16}{5.5} = 47.8$

$q = 22"-30" \text{ 1717 PPS} = \frac{29.0}{71.8}$

$H = (0.015)(71.8)(1.98) = 2.13$

VENA CONTRACTA DIP

$H_{vc} = \frac{3V^2}{2g} = (3)(1.98) = 5.93'$

$ELEV = 462.69 + 2.13 - 5.93 = 458.89$

$\& \text{ PIPE ELEV} = 458.00$

UNDER THIS CONDITION NO POCKET SHOULD FORM AND NO HYDRAULIC JUMP SHOULD EXIST. THE 105-D AND 105-B DOWNCOMERS ARE SIMILAR AND SINCE THE FLOW CONDITIONS HERE ARE BETTER THAN AT 105-B THE DOWNCOMER MODIFIED SHOULD HANDLE THE FLOW. THE ADDITION OF THE 48" LINE PROVIDES ADEQUATE CAP

DECLASSIFIED

BY G.H.B. DATE 1/6/60 SUBJECT 105-D DOWNCOMER SHEET NO. 20 OF 28
 CHKD. BY _____ DATE _____ REFLUENT SYSTEM JOB NO. DD 1121

CHECK FOR EMERGENCY CONDITION THAT EXISTS IF BOTH GATES AT THE 107-D BASIN ARE ACCIDENTALLY CLOSED INLET CHAMBER IS SEPARATED FROM BASINS BY TWO 4'x1' GATES

$$\text{BASIN ELEV.} = 449.83$$

LOSS VARIES INVERSELY AS THE SQUARE OF THE AREAS

$$H = \left[\frac{.656}{1} \right] \left[\frac{72^2}{32^2} \right] = 3.32'$$

ELEV. INLET CHAMBER

$$\text{ELEV.} = 449.83 + 3.32 = 453.15$$

THIS IS ROUGHLY THE ELEV. OF THE BY-PASS OUTLET TO SIMPLIFY CALCULATIONS USE BY-PASS OUTLET ELEV.

CALCULATE EQUIVALENT LENGTH OF 60" PIPE EXISTING 60" PIPE AND BY-PASS REPRESENT

ASSUME FLOW OF 100 CFS

BY PASS	{	1/2 OF ELBOW	=	20
		1/2 OF T	=	60
		14' OF BY-PASS	=	4
				84

$$h = (0.15)(84)(1.49) = 1.815$$

BY-PASS

$$\begin{aligned} Q &= 100 \text{ CFS} \\ A &= 10.40 \text{ ft}^2 \\ V &= 9.62 \text{ FPS} \\ \frac{V^2}{2g} &= 1.44 \end{aligned}$$

$$\begin{aligned} 60" \text{ PIPE } \left\{ \begin{aligned} 1/2 &= 147.8 & L &= 739; D = 5' \\ h &= (0.15)(147.8)(.402) = .89 \end{aligned} \right. \end{aligned}$$

$$\begin{aligned} 60" \text{ PIPE} \\ Q &= 100 \text{ CFS} \\ A &= 17.65 \\ V &= 5.09 \\ \frac{V^2}{2g} &= .402 \end{aligned}$$

$$\text{TOTAL LOSS} = 1.815 + .89 = 2.705$$

EQUIVALENT LENGTH OF 60" PIPE

$$L = \frac{(739)(2.705)}{.89} = 2245'$$

LENGTH OF 48" PIPE = 750' + 1 90° ELBOW

$$\text{EQUIV. LENGTH} = 750 + (12)(4) = 798'$$

CALCULATE DISCHARGE PER PIPE

$$\begin{aligned} D_2 &= 5 \\ L_2 &= 2245 \end{aligned}$$

$$\begin{aligned} D_1 &= 4 \\ L_1 &= 798 \end{aligned}$$

$$\frac{Q_2}{Q_1} = \sqrt{\frac{(A_1/D_1)^5}{L_2/L_1}} = \sqrt{\frac{(5/4)^5}{2245/798}} = \sqrt{\frac{1.085}{2.815}} = 1.042$$

DECLASSIFIED

BY G.H.13 DATE 1/6/60 SUBJECT 105-D DOWNCOMER
CHKD. BY _____ DATE _____ EFFLUENT SYSTEM

W-63531
Page 145
SHEET NO. 21 OF 28
JOB NO. D01121

$$Q_2 = 1.04 Q_1 \quad \text{SAY } Q_2 = Q_1 \\ \text{THEN } Q_1 = \frac{13000}{2} = 6500 \text{ GPM} = Q_1$$

HYDRAULIC GRADIENTS

AT BOX #1

CALCULATE LOSS BY CONSIDERING 48" LINE

$$h = [0.5 + (0.15)(1.95) + 1.0](2.07) \\ h = 9.30$$

$$\text{ELEV} = 454.75 + 9.30 = \underline{464.05}$$

$$\text{UNDER SIDE OF BOX COVER SLAB} = 462.37$$

$$Q = 65000 \text{ GPM}$$

$$Q = 145 \text{ CFS}$$

$$\text{At } 12.58$$

$$V = 11.52 \text{ FPS}$$

$$\frac{V^2}{2g} = 2.07$$

$$\frac{L}{D} = \frac{798}{4} = 199.5$$

AT BOX #2

$$\text{ELEV} = 464.05 + 8.25 + 0.58 = \underline{472.88}$$

$$\text{UNDER SIDE OF BOX COVER SLAB} = 466.00$$

AT VENA CONTRACTA

$$\text{ELEV.} = 472.88 + 2.13 + 5.73 = \underline{469.08}$$

ENERGY LEVEL AT BOTTOM OF DOWNCOMER (PG. 7)

$$\text{ELEV.} = 472.88 + 2.13 + 2.97 = 477.98$$

ABOVE BOTTOM OF DOWNCOMER

$$H = 477.98 - 455.29 = 22.69'$$

DOWNCOMER LOSS PER BAFFLE (PERFORATED)

DOWNCOMER IS SIMILAR TO 105-B DOWNCOMER
FROM PAGE 7 LOSS = 2.57'

THIS ANALYSIS INDICATES THE DOWNCOMER
WILL HANDLE THE FLOW ALTHOUGH BOXES #1 & 2
WILL BE SLIGHTLY PRESSURIZED AND SOME
EFFLUENT WILL ESCAPE AT THESE BOXES.
SINCE THIS IS AN EMERGENCY CONDITION THIS
IS CONSIDERED O.K.

DECLASSIFIED

BY G.H.B. DATE 1/4/60 SUBJECT 105-D DOWNCOMER
 CHKD. BY _____ DATE _____ * EFFLUENT SYSTEM

 SHEET NO. 22 OF 28
 JOB NO. DD 1121

DOWNCOMER WILL HANDLE FLOW WITH 107-D 60 GATE VALVES
 CLOSED IF AN ADDITIONAL 48" LINE IS INSTALLED FROM BOX #1 TO
 107 BASIN AND IF DOWNCOMER IS PERFORATED.

DECLASSIFIED

BY G.H.B. DATE 1/6/60 SUBJECT 10.5-D DOWNCOMER SHEET NO 25 OF 28
CHKD. BY _____ DATE _____ 8 EFFLUENT SYSTEM JOB NO. DD 112.1

CHECK EXISTING SYSTEM FOR 105000 GPM FLOW
WITH FLOW THROUGH BY-PASS AT 107-D BASIN.

$$Q = 95,000 + 10,000 = 105,000 \text{ GPM} = 234 \text{ GPM}$$

LOSSES ARE PROPORTIONAL TO Q^2 (SEE PG 20)

LOSS IN BY-PASS

$$h = (1.815) \left(\frac{234^2}{1000} \right) = 9.94$$

HYDRAULIC GRADIENT

AT BOX #1

$$h = (12.58) \left(\frac{234^2}{270} \right) = 8.19'$$

$$\text{ELEV.} = 454.75 + 9.94 + 8.19 = \underline{472.88}$$

AT BOX #2

$$h = (8.25 + 0.58) \left(\frac{234^2}{270} \right) = 5.74$$

$$\text{ELEV.} = 469.62 + 5.74 = \underline{478.62}$$

ENERGY GRADIENT AT BOTTOM OF DOWNCOMER

$$h = (2.13 + 2.97) \left(\frac{234^2}{270} \right) = 3.19'$$

$$\text{ELEV.} = 478.62 + 3.19 = 481.81$$

ABOVE BOTTOM OF DOWNCOMER

$$H = 481.81 - 455.29 = 26.52'$$

THIS IS ONLY 3.83' HIGHER IN THE DOWNCOMER
THAN THE CASE ANALYZED ON SHEET 22. SINCE
THE FLOW IS 25,000 GPM LESS THE DOWNCOMER
HAS ADEQUATE CAPACITY. THE TOPS OF BOXES #1 & 2
WILL BE UNDER 10' TO 12' OF HEAD HOWEVER,
SO EFFLUENT WILL ESCAPE THERE. SINCE THIS
IS AN EMERGENCY CONDITION IT IS CONSIDERED
SATISFACTORY.

DECLASSIFIED

BY GHB DATE 1/6/60 SUBJECT 105-D DOWNCOMER SHEET NO. 29 OF 28
CHKD. BY _____ DATE _____ \$ EFFLUENT SYSTEM JOB NO. DO 1121

CHECK EXISTING SYSTEM FOR 105000 GPM FLOW
(95000 + 10000) WITH 107 BASIN GATE VALVES OPEN
(NORMAL OPERATING CONDITION)

HYDRAULIC GRADIENT

AT BOX #1 (PG. 18)

$$h = (462.11 - 448.25) \left(\frac{234^2}{290^2} \right) = 9.04$$
$$ELEV. = 448.25 + 9.04 = \underline{457.29}$$

AT BOX #2

$$h = (470.94 - 448.25) \left(\frac{234^2}{290^2} \right) = 14.82$$
$$ELEV. = 448.25 + 14.82 = \underline{463.07}$$

THIS IS ONLY 1.43' BELOW THE WEIR IN THE
105-D CROSS OVER BOX AND IS ONLY A FEW INCHES
BELOW THE TOP OF THE STEEL LINER IN THE
105-D CROSSOVER BOX. THIS IS NOT ENOUGH
FACTOR OF SAFETY AND THE BOXES AND WEIR
SHOULD BE RAISED 3'-0" FOR THIS CONDITION.

SINCE RAISING BOXES WILL NOT SUFFICE
FOR THE 105000 + 10000 CONDITION THE
ADDITIONAL 48" LINE SHOULD BE CONSIDERED NECESSARY
FOR THIS CONDITION.

MODIFICATIONS NECESSARY

95000 GPM FLOW

1. REMOVE DOWNCOMER VENTS & PERFORATE BAFFLES.
2. VENT EFFLUENT LINE
3. RAISE CROSS OVER BOXES 3'-0"

105000 & 120000 GPM FLOW

1. SAME AS 1 & 2 ABOVE
2. ADD 48" LINE BETWEEN 107 BASIN & BOX #1

DECLASSIFIED

BY GHB DATE 1/6/60
CHKD. BY _____ DATE _____

SUBJECT 105-DR DOWNCOMER
EFFLUENT SYSTEM

SHEET NO. 25 OF 28
JOB NO. DD 1121

DECLASSIFIED

CHECK FOR 12000 GPM FLOW FROM 105-DR AND 10,000 GPM SHUT DOWN FLOW FROM 105-D ASSUME EQUAL FLOWS IN THE EFFLUENT LINES FROM 105-DR. UNDER THIS CONDITION THE NEAR LINE WILL BE CRITICAL SINCE IT MUST CARRY IN ADDITION THE 10,000 GPM SHUT DOWN FLOW FROM 105-D.

FLOW INTO BASIN OF NEAR LINE

$$Q = 60000 + 10000 = 70000 \text{ GPM} = 156.2 \text{ CFS.}$$

$$\text{BASIN W.S. ELEV.} = 450.00$$

LOSS IN GATE BETWEEN BASIN & DIST. CHAMBER.

$$Q = 0.62 A \sqrt{2gh}$$

$$156.2 = (0.62)(25) \sqrt{(64.4)(h)}$$

$$24400 = (240)(64.4)(h)$$

$$h = \frac{24400}{(240)(64.4)}$$

$$h = 1.58"$$

W.S. DIST. CHAMBER

$$\text{W.S.} = 450 + 1.58 = \underline{451.58}$$

W.S. AT CROSS OVER BOX

$$\frac{L}{D} = \frac{1534.33}{5} = 307$$

$$h = (0.15)(307)(.982) = 4.52$$

$$\text{W.S.} = 451.58 + 4.52 = \underline{456.10}$$

$$Q = 156.2 \text{ CFS}$$

$$A = 19.65 \text{ ft}^2$$

$$V = 7.95 \text{ FPS}$$

$$\frac{V^2}{2g} = .982'$$

ENERGY LEVEL AT BOTTOM OF DOWNCOMER

$$\frac{L}{D} = \frac{805 + 478.11 + 32}{5} = 263$$

$$\frac{L}{D} \text{ FOR } 2-45^\circ \text{ MITERS} = \underline{30}$$

$$293$$

$$h = [0.5 + (0.15)(293) + 1.0](.723)$$

$$h = 4.26$$

$$\text{ELEV.} = 456.10 + 4.26 = \underline{460.36}$$

$$Q = 134 \text{ CFS}$$

$$A = 19.65 \text{ ft}^2$$

$$V = 6.82 \text{ FPS}$$

$$\frac{V^2}{2g} = .723'$$

DECLASSIFIED

THIS IS APP. 4 FT. ABOVE BOTTOM OF DOWNCOMER. DOWNCOMER IS ADEQUATE TO HANDLE 60,000 GPM WITH THIS BACK PRESSURE. OTHER CONDITIONS WILL BE LESS SEVERE. THEREFOR, THE 105-DR SYSTEM IS ADEQUATE WITHOUT MODIFICATIONS.

BY G.H.B. DATE 1/6/60

SUBJECT 105-H DOWNCOMER

SHEET NO. 27 OF 28

CHKD. BY _____ DATE _____

\$ EFFLUENT SYSTEM

JOB NO. DD-1121

DECLASSIFIED

BY G.H.B. DATE 1/6/60 SUBJECT 105-H DOWNCOMER SHEET NO. 20 OF 28
CHKD. BY _____ DATE _____ # EFFLUENT LINE JOB NO. DO-1121

CHECK FOR 120000 GPM FLOW ASSUMING
EACH EFFLUENT LINE TAKES ONE HALF OF FLOW.

$$Q = 120000 \text{ GPM TOTAL}$$

$$Q = 60,000 \text{ GPM} = 134 \text{ CFS PER LINE}$$

$$\text{BASIN W.S. ELEV.} = 413.5$$

LOSS IN GATE BETWEEN BASIN & DISTRIBUTION CHAMBER

LOSS WILL VARY AS SQUARE OF FLOW (SEE PG 26)

$$h = (1.58) \left(\frac{134^2}{136.2} \right) = 1.16'$$

W.S. DIST. CHAMBER

$$\text{W.S.} = \underline{414.66}$$

ENERGY LEVEL AT BOTTOM OF DOWNCOMER

$$\frac{L}{D} = \frac{90 + 1945 + 210 + 180 + 90 + 25}{5} = 298$$

$$\frac{L}{D} \text{ FOR } 6 - 15^\circ \text{ MITERS (2-45^\circ \text{ ELBOWS}) } 18$$

$$\frac{L}{D} \text{ FOR } 4 - 22.50' \text{ MITERS (1-90^\circ \text{ ELBOW}) } 20$$

$$\frac{L}{D} \text{ FOR } 1 - 15^\circ \text{ MITER (1-15^\circ \text{ ELBOW}) } 3$$

$$\frac{L}{D} \text{ FOR } 5 - 15^\circ \text{ MITERS (1-75^\circ \text{ ELBOW}) } \underline{15}$$

$$354$$

$$h = [.5 + (0.15)^{.5} (354) + 1.0] [.723]$$

$$h = 4.92'$$

$$\text{ELEV.} = 414.66 + 4.92 = 419.58$$

THIS IS 5.58' ABOVE THE INVERT OF THE EFFLUENT
LINE AT THE BOTTOM OF THE DOWNCOMER. THE
DOWNCOMER IS ADEQUATE TO HANDLE 60,000 GPM
WITH THIS BACK PRESSURE. OTHER CONDITIONS
WILL BE LESS SEVERE. THEREFOR, THE 105-H SYSTEM
IS ADEQUATE WITHOUT MODIFICATIONS.

DECLASSIFIED

DATE

FILMED

8 / 10 / 94

END