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THROUGH-REACTOR FLOW CALCULATED FROM
HIGH TANK-HIGH VELOCITY FLUSH DATA

J. E. Morrissey

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THROUGH REACTOR FLOW CALCULATED FROM
HIGH TANK-HIGH VELOCITY FLUSH DATA

by

J. E. Morrissey
Process Engineering Unit
Process Technology Subsection
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

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THROUGH-REACTOR FLOW CALCULATED FROM
HIGH TANK-HIGH VELOCITY FLUSH DATA

I. INTRODUCTION

To satisfy reactor coolant supply criteria requires a knowledge of available emergency flow rates from secondary and last-ditch systems. This document presents a method for calculating high-tank flow contribution to the last-ditch coolant system from routine high tank-high velocity flush data. The measured flush flow is converted to equivalent through-reactor flow at 20 C and at the critical time of high-tank takeover from flywheel decay.

This document does not attempt to relate this equivalent flow to an assured emergency flow rate. A Technical Note¹ contains the bases for translating the calculated through-reactor flow to assured emergency flow and determining the reactor power levels the assured flow will support. There will be one exception to using the assured flow equation contained in reference 1. All factors except the F_c term, line corrosion factor, are to be obtained from the referenced Technical Note. The line corrosion factor to be used with the estimated through-reactor flow rate is contained in this report.

II. SUMMARY

This document discusses a method which was developed to calculate equivalent through-reactor flow from routine high tank-high velocity flush data. The method was developed to complement the referenced Technical Note for determining last-ditch coolant system adequacy. Also included are (a) current assessments of calculated through-reactor flows at B, D, and F reactors, and (b) sufficient information to facilitate conversion of future high-velocity flush data to equivalent through-reactor flow at B, D, and F reactors. While this method is currently applicable only at the B, D, and F reactors, it can be extended to include C, DR, and H reactors.

III. BACKGROUND AND QUALITATIVE DISCUSSION OF PROBLEMS

A knowledge of the available high-tank and export flow rate is required to determine the backup adequacy of the last-ditch coolant supply system. Process Standard - Water Plant, 190-B-070² requires the secondary and last-ditch systems be flow tested on a two-year schedule, or sooner, if a significant change is made to the reactor or water plant systems.

Historically, the "through-reactor drawdown" test is used to determine the high-tank contribution to the backup coolant supply. Such a test

¹Jones, S.S., Technical Note on Last-Ditch Cooling of the Small Hanford Reactors, HW-82406, June 1, 1964, (Secret).

²Process Standard - Water Plant, HW-27155 REV1, August, 1957, (Secret).

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requires production test authorization and consists of lowering riser pressure, during a reactor outage, until flow from the high tanks is automatically established. The rate at which the high-tank water level drops is measured with a mercury manometer. The flow rate is then calculated using these data and knowledge of the tank dimensions.

A large body of unpublished qualitative data exists on effects of corrosion in the high-tank discharge line. High velocity flush (HVF) data verify that discharge line corrosion significantly reduces the available emergency flow rate.

High-tank discharge lines at the six smaller reactors were chemically descaled in 1960-61. However, the cleaning resulted in only a temporary alleviation of the line corrosion problem and chemical inhibition was subsequently introduced by Design Change 905. The inhibitor was ineffective in arresting the corrosion rate, as indicated by HVF data, and it was necessary to recommend line descaling again at B, D, and F. The descaling was accomplished mechanically in March, 1964, March, 1963, and January, 1963, respectively. It is interesting to note that HVF flow at B remained relatively constant while sodium dichromate was kept in the lines. When it was replaced with sodium silicate, the flow rate decreased by approximately 12 per cent in nine months, thus prompting the recommendation for mechanical cleaning. HVF data recorded at D and F after mechanical cleaning again indicated rapid line corrosion with significant flow decreases from the clean pipe condition over relatively short time intervals, i.e., six months to 1-1/2 years. The data indicate that corrosion is a decreasing exponential function of the elapsed time since the last cleaning.

Since discharge line corrosion cannot be accurately predicted, it has become necessary to assess high-tank adequacy on a more frequent basis. There are several drawbacks to conducting through-reactor drawdown tests at an increased frequency. These are use of reactor outage time, a small nuclear safety risk, and the specific cost of planning and executing such a test. Obviously, a method for calculating equivalent through-reactor flow from HVF data would be advantageous. Actual through-reactor drawdown tests on the present two-year frequency would provide a convenient check on the accuracy of the calculated flow.

Presently HVF data are obtained at B, D, and F every two months under the mandatory provisions of Equipment Maintenance Standard 201.³

An acceptable calculational method would avoid the necessity of invoking conservative penalties for effects of line corrosion in lieu of more frequent through-reactor drawdown tests. Such penalties may, in some circumstances, limit reactor power below the levels attainable for bulk outlet temperature limited operation. Conservative penalties will con-

³Equipment Maintenance Standards, HW-73000, October, 1962.

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tinue to be assigned at C, DR, and H reactors until such a time as meaningful HVF data or through-reactor drawdown data are available.

IV. DEVELOPMENT OF THE METHOD

Basically, the HVF procedure at B, D, and F consists of completely opening a 12-inch flush valve in a bypass line downstream of the high-tank screen chest and flushing the discharge line at maximum velocity. The HVF flow rate is calculated from tank geometry and level-drop-versus-time data. The reader is referred to Equipment Maintenance Standard 201 for a detailed description of the HVF procedure.

Originally, the high-velocity flush was routinely performed to remove accumulated sludge and demonstrate that the high-tank screens would not become plugged during an emergency event. Since the flush velocity is approximately 50 per cent greater than the expected emergency flow velocity, debris not flushed out at the higher velocity are unlikely to be introduced into the piping system during an emergency event. Following line descaling and routine HVF, significant scale deposits have not been observed in the high-tank screen chests (except for the near tank at DR). Today, the HVF is primarily used to develop pressure drop-flow data on the discharge line. The HVF data are sufficiently sensitive to follow changes in flow and pressure drop with pipe surface conditions. For this reason, HVF techniques were chosen to provide interim data on line condition and predict the available through-reactor flow rate.

Consider the following simplified piping diagram.

FIGURE 1.

- Points:
- A = Water surface in high tank.
 - B = Pressure tap upstream of screen chest.
 - C = Pressure tap downstream of screen chest.
 - D = Top of riser.
 - E = Bypass flush valve.

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For through-reactor high-tank flow the following relationship exists:

$$P_T = \rho \frac{\Delta H_{AD}}{144} - \Delta P_{FAD} \quad (1)$$

Where: P_T = Top-of-riser pressure - psig.

ΔH_{AD} = Elevation of high-tank water surface above top-of-riser = feet.

ΔP_{FAD} = Frictional pressure drop from A to D - psi.

ρ = Density of water at local conditions - #/ft.³

$$\Delta P_{FAD} = \Delta P_{FAB} + \Delta P_{FBC} + \Delta P_{FCD} = K_{AD} G^{1.85} \quad (2)$$

Where: G = Flow ÷ 1000 - gpm

K = Proportionately constant dependent on system geometry and surface conditions.

$$\Delta P_{FAD} = (K_{AB} + K_{BC} + K_{CD}) G^{1.85} \quad (3)$$

Making the assumption that each high tank contributed one half the reactor flow $\left(\frac{G_R}{2}\right)$

$$\text{then: } \Delta P_{FAD} = (K_{AB} + K_{BC} + K_{CD}) \left(\frac{G_R}{2}\right)^{1.85} \quad (4)$$

Finally arriving at supply and demand equations:

$$\text{Supply} - P_T = \rho \frac{\Delta H_{AD}}{144} - (K_{AB} + K_{BC} + K_{CD}) \left(\frac{G_R}{2}\right)^{1.85} \quad (5)$$

$$\text{Demand} - P_T = \text{Function of } G_R = \text{function of } \frac{G_R}{2} \quad (6)$$

(Experimentally determined)

For the supply curve:

Known - ΔH_{AD} - from HW-72697⁴

K_{BC} - from experimental data.

K_{CD} - from experimental data and theoretical calculation.

$$K_{BC} + K_{CD} = K_{BD} \quad (7)$$

⁴Jones, S.S., J.E. Morrissey, and J.L. Manuel, Reactor Process Flow Technical Data, February 15, 1962, (Secret).

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Unknown - K_{AB} , resistance coefficient for frictional pressure drop in discharge line, can be evaluated from high velocity flush data.

A supply demand plot can be constructed from equation 5 as a function of K_{AB} , i.e., assume a value for K_{AB} , vary $G_R/2$ and calculate P_T .

FIGURE 2

Now it becomes necessary to evaluate K_{BD} and ΔH_{AD} for B, D, and F systems.

K_{BD} - Considerable experimental data exists for K_{BC} and K_{CD} in the Hanford literature and HVF files. K_{CD} can also be estimated by using the standard pipe line friction loss calculation using a friction factor 1.8 times the clean pipe value. The following values were arrived at by summing $K_{BC} + K_{CD}$ and taking velocity head into consideration. (Data from PT IP-582-I and Supplement A and area HVF files.)

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TABLE 1

Reactor High Tank	B		D		F	
	Near	Far	Near	Far	Near	Far
K _{BD} @ 10°C	.527	.497	.351	.516	.500	.490
@ 20°C	.488	.460	.325	.478	.463	.454

Assume these values will not change significantly with time unless the line is cleaned or the screen chest geometry is altered. The assumption may be justified by considering the decreasing exponential relationship of corrosion with time; i.e., this section of the line has never been cleaned and the present corrosion rate is probably negligible. This assumption may be checked each time an actual through-reactor drawdown test is conducted.

ΔH_{AD} - The values for ΔH_{AD} were arrived at using system elevation differences. (Elevation-feet above mean seal level.)

TABLE 2

Reactor High Tank	B		D		F	
	Near	Far	Near	Far	Near	Far
Water surface	619.3	627.3	621.8	622.8	569.3	565.3
Top of riser	505.7	505.7	503.7	503.7	450.5	450.5
ΔH_{AD} -feet	113.6	121.6	118.1	119.1	118.1	114.8
ΔH_{AD} -psi	49.2	52.6	51.1	51.6	51.4	49.7

The critical time for high-tank flow takeover from flywheel decay occurs when the water surface in the high tank has dropped about one foot. This document assumes the critical time of takeover occurs when the high tank check valve initially opens, i.e., full tanks. The error introduced with this assumption is well within the accuracy of this method.

Temperature Factor - A reference temperature of 20 C was chosen to (1) normalize the data, and (2) to provide a convenient method for evaluating change in line corrosion effects. All flow rates used in this document will be at 20 C except original HVF data. To convert a flow rate at T°C to 20°C use Figure 3 (in the appendix) and the following equation:¹

$$G @ 20^\circ = \frac{G_T}{F_T} \quad (8)$$

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K_{AB} - The value for K_{AB} (discharge line frictional pressure drop coefficient) is evaluated from HVF data, i.e., ΔH_{AB} , P_B , HVF flow (G_{HVF}) and water temperature.

Starting with the Bernoulli equation,

$$P_A + \rho \frac{H_A}{144} + \rho \frac{V_A^2}{288g} = P_B + \rho \frac{H_B}{144} + \rho \frac{V_B^2}{288g} + \Delta P_{FAB} \quad (9)$$

where: P_A and $V_A = 0$

$$\Delta P_{FAB} = \rho \left(\frac{H_A - H_B}{144} \right) - P_B - \rho \frac{V_B^2}{288g} = K_{AB} G_{HVF}^{1.85} \quad (10)$$

$$K_{AB} = \frac{\rho \Delta H_{AB}}{144} - P_B - \rho \frac{V_B^2}{288g} \quad (11)$$

$G_{HVF}^{1.85}$

and referred to 20°C:

$$K_{AB} @ 20^\circ C = \frac{\rho \Delta H_{AB}}{144} - P_B - \frac{\rho V_B^2}{288g} \quad (12)$$

$\left(\frac{G_{HVF}}{F_T} \right)^{1.85}$

The following steps are used to calculate equivalent through-reactor flow (at the critical time of high tank takeover and at 20°C) from the HVF data.

1. Construct a supply-demand plot at 20°C, as in Figure 2, for the high tank under consideration, from the data presented above, and the present reactor demand curve.
2. Calculate $K_{AB} @ 20^\circ C$ from HVF data using equation 12.
3. The intersection of the supply curve for the calculated $K_{AB} @ 20^\circ C$ and the reactor demand curve is the estimated flow and top-of-riser pressure for the tank under consideration.
4. Calculate a half-reactor flow from each high tank and sum to obtain total flow.

In practice the procedure can be simplified by constructing a cross-plot of K_{AB} versus $G_R/2$ (Locus of the intersections of the supply and demand curves at 20°C). This plot must be revised whenever there is a significant change in the reactor demand curve.

The appendix to this document contains the following information:

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1. Figure 3 - Temperature factor chart (F_T versus high-tank water temperature).
2. Figure 4 - Plot of G versus $G^{1.85}$.
3. Figure 5 - Plot of $\frac{\rho v^2}{288g}$ versus flow for 12-inch pipe.
4. Figures 6, 7, 8, 9, 10, and 11 - Supply-demand curves for near and far high tanks at B, D, and F reactors at 20°C.
5. Figures 12, 13, and 14 - Cross-plots of K_{AB} versus $\frac{G_R}{2}$ for near and far high tanks at B, D, and F reactors at 20°C.
6. Table 3 - Sample calculations of equivalent through-reactor flow at critical time of high tank takeover and 20°C for near and far tanks at B, D, and F reactors.
7. Table 4 - Tabular values for high tank supply curves at B, D, and F reactors at 20°C.

V. HVF DATA REQUIREMENTS

To perform the calculation to obtain equivalent flow and then to convert this to assured flow requires the following data:

1. High tank HVF flow rate (from manometric data - G_{HVF}).
2. Pressure upstream of the screen chest. (P_B).
3. High-tank water temperature.
4. Average high-tank water surface elevation above the 105, 0'0" level during the HVF. (ΔH_{AB}).
5. Elevation correction between the screen pressure gauge and 105, 0'0" level.

The 105, 0'0" level was arbitrarily chosen as the reference datum plane for convenience instead of the center-line of the high-tank discharge pipe.

This information is routinely available at B, D, and F. However, at C, DR, and H, neither instrumentation nor procedures are presently available which are capable of producing meaningful data.

VI. APPLICATION OF CALCULATED FLOW

The calculation method described herein is specifically designed to complement the Technical Note referenced earlier. The high-tank flow

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rate calculated by this method is equivalent to the flow that would be available to the reactor at the critical time of high-tank takeover and 20°C high-tank and reactor bulk-outlet water temperature. Using the nomenclature of the referenced Technical Note, the calculated flow is equivalent to a measured flow (G_m) in lieu of an actual through-reactor drawdown test. To arrive at assured emergency flow, this measured flow is corrected for low-flow measurement errors, line corrosion effects, emergency bulk outlet water temperature effects, and strainer plugging as listed in the referenced Technical Note via the equation¹ below:

$$G_{H_a} = \left(\frac{F_C F_S F_T}{1 + F_G} \right) G_{H_m}$$

where: G_{H_a} = assured reactor high-tank flow - 1000 gpm.

F_C = high-tank line corrosion factor, fraction of clean line flow.

F_S = high-tank strainer plugging factor, fraction of clean strainer flow.

F_T = emergency temperature factor, fraction of test temperature flow.

and $(1 + F_G)$ = low flow error factor, fraction increase in flow required to assure that the measured flow will be adequate; i.e., approximate correction for errors in the measurement of the flow from the high tanks on the last-ditch system.

G_{H_m} = measured through-reactor high-tank flow at test temperature - 1000 gpm.

This equation is to be used to arrive at assured flow; however, with one exception when using a through-reactor flow estimated from HVF data. The line corrosion factor, F_C , suggested in the Technical Note is not to be used with this method. Until such time as short-term line corrosion rates are better known, it is recommended that the estimated through-reactor flow rate (equivalent to G_{H_m}) be depreciated 1%/month for each month of time to the next HVF test. This value should be considered a minimum depreciation and should be increased if the HVF data suggests it is nonconservative. Thus, for the normal case with HVF's conducted on a routine two-month interval, the F_C , line corrosion factor, becomes 0.98.

This method can provide a convenient tool for developing short-term line corrosion correlations. Normalizing the HVF data to 20°C, allows a relative comparison of line frictional effects exclusive of temperature effects.

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VII. LIMITATIONS OF THE METHOD

Obviously, the inherent limitations are centered around the question of over-all accuracy of the calculated flow rate. The following qualitative comments are presented for consideration:

1. Since the rate of level drop and hence the total level drop for a HVF is approximately 50 per cent higher than a reactor test flow the fractional manometer measurement error for the former will be smaller than for the latter. Therefore, the accuracy of the HVF flow measurement should be greater than a through-reactor drawdown test.
2. A correlary to the above exists for the calculated value of K_{AB} , i.e., it should be at least as accurate as the through-reactor drawdown flow.
3. The screen chest pressure drop (K_{BC}) value is based on voluminous experimental data points at both high and low flows. The effect of K_{BC} is relatively small compared to K_{AB} and K_{CD} .
4. The value for K_{CD} has been determined from production test numerical results and verified by a theoretical calculation using a friction factor 1.8 times that of new pipe. It has been assumed that K_{CD} will not change significantly with time unless that portion of the line is descaled. (From downstream of the screen chest to the 36-inch process header.)
5. The real limitation to any calculation method is in the unknown accuracy associated with the low flow reactor demand curve. Until this critical assessment is made the only alternate method to determine over-all accuracy is through comparison of calculated to actual through-reactor test flows. One such comparison existed for F reactor in the fall of 1962. The calculated flow was 100 gpm higher than the test flow.

Until the accuracy of the low flow demand curve and the over-all accuracy of the calculated flow is assessed, a conservative error factor should be assigned for converting to assured flow for critical adequacy calculations; i.e., error curve without flow calibration, page 13 of reference 1. This is commonly referred to as high-low flow error factor.

VIII. SUGGESTED DEVELOPMENT PROGRAM

In order to establish this method as an accurate, reliable, and accepted tool, it is suggested that the following program be adopted:

1. Determine the accuracy of the low-flow reactor demand curve. Determine the best procedure for establishing the curve routinely.
2. Evaluate the over-all accuracy of the calculation method, incorporating error analysis and additional test data.

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3. Develop high-tank discharge line corrosion rate correlations based on HVF data and K_{AB} @ 20°C.
4. Cross check the accuracy of the calculated flow versus the actual through-reactor test flow during the bi-annual through-reactor tests.
5. Determine the precision of HVF data.
6. Develop similar method for C, DR, and H if applicable or practical.

IX. ACKNOWLEDGMENT

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Process Engineering Unit
Process Technology Subsection
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

JE Morrissey:md

X. APPENDIX

Production Test IP-576-AI, Dual Area Tripout Of B And C Reactor's Process Pumps was performed on July 20, 1964. Analysis of the B reactor high tank through reactor flow data and HVF data yielded the following results:

Breactor high tank flow rate at the critical takeover time and 20°C.

10,700 gpm	Calculated from results of PT IP-576-AI.
11,000 gpm	Calculated from Figure 12 of this document.
10,700 gpm	Calculated from supply curves in Figures 6 and 7 and the revised demand curve from the results of PT IP-576-AI.

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APPENDIX

TABLE 3
EXAMPLE CALCULATIONS

Equivalent through-reactor flow at critical takeover time and 20°C high-tank water temperature.

Test Data	R		D		F	
	Near	Far	Near	Far	Near	Far
Date of flush	4/1/64	4/1/64	4/10/64	4/10/64	5/3/64	5/3/64
$P_{AB}/144$ (psi)	60.6	64.1	62.3	63.1	63.6	61.9
P_B (psi)	7.3	16.6	10.0	10.0	10.0	11.0
P'_B @ 0'0" (psi)	8.6	16.9	12.4	12.0	11	12.0
HVF Flow (gpm)	8790	7950	8000	8550	7820	8370
$t_{1, \text{hightank}}$ (°C)	7.0	7.0	11.0	11.5	10.0	10.0
$t_{1, \text{reactor}}$ (°C)	~10	~10	~10	~10	~10	~10
<u>Calculated Flow</u>						
HVF Flow @ 20° (gpm)	9260	8380	8280	8830	8120	8700
$G_{HVF}^{1.85}$ @ 20°	61.5	51.0	50.0	56.2	48.2	55.0
$P_B^2/288g$ (psi)	4.2	3.4	3.5	4.0	3.4	3.8
K_{AB} @ 20°	.777	.858	.928	.839	1.021	.838
G_M @ 20° (gpm)	5660	5800	5670	5650	5280	5400
G_M @ 20°, total (gpm)	11460		11320		10680	

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TABLE 4
CALCULATED SUPPLY CURVES

Case	B			D		F	
	K _{AB}	K _{AD}		K _{AD}		K _{AD}	
		Near	Far	Near	Far	Near	Far
A	2.00	2.49	2.46	2.32	2.48	2.46	2.45
B	1.70	2.19	2.16	2.02	2.18	2.16	2.15
C	1.30	1.79	1.76	1.62	1.78	1.76	1.75
D	1.00	1.49	1.46	1.32	1.48	1.46	1.45
E	0.80	1.29	1.26	1.12	1.28	1.26	1.25
F	0.60	1.09	1.06	0.92	1.08	1.06	1.05
G	0.40	0.89	0.86	0.72	0.88	0.86	0.85

B NEAR

Flow	Case A	Case B	Case C	Case D	Case E	Case F	Case G
	Top-of-Riser Pressure - PT						
0	49.2	49.2	49.2	49.2	49.2	49.2	49.2
3000	30.3	32.6	35.6	37.8	39.4	40.9	42.4
4000	16.8	20.7	25.9	29.8	32.4	35.0	37.6
4500	8.9	13.7	20.2	25.1	28.3	31.6	34.8
5000	.3	6.3	14.1	20.0	23.9	27.8	31.8
5500		-2.1	7.3	14.3	19.0	23.7	28.4
6000			0	8.3	13.7	19.2	24.7
7000					2.2	9.4	15.8

B FAR

0	52.6	52.6	52.6	52.6	52.6	52.6	52.6
3000	34.0	36.2	39.3	41.5	43.0	44.6	46.1
4000	20.6	24.6	29.6	33.6	36.2	38.8	41.4
4500	12.8	17.6	23.9	29.0	32.2	35.4	38.7
5000	4.4	10.3	17.8	24.0	27.9	31.8	35.8
5500		2.1	11.0	18.4	23.1	27.8	32.5
6000			3.7	12.1	18.0	23.5	29.0
7000				-.7	6.6	13.9	21.2

D NEAR

0	51.1	51.1	51.1	51.1	51.1	51.1	51.1
3000	33.5	35.7	38.8	41.1	42.6	44.1	45.6
4000	20.9	24.8	30.0	33.9	36.5	39.1	41.7
4500	13.5	18.4	24.9	29.7	33.0	36.2	39.4
5000	5.6	11.5	19.4	25.2	29.1	33.1	37.0
5500		3.8	13.2	20.2	24.9	29.6	34.3
6000			6.5	14.8	20.3	25.8	31.3
7000				2.9	10.2	17.5	24.8

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TABLE 4 (Continued)

D FAR

<u>Flow</u>	<u>Case A</u>	<u>Case B</u> <u>Top-of-Riser</u>	<u>Case C</u> <u>Pressure</u>	<u>Case D</u> <u>- PT</u>	<u>Case E</u>	<u>Case F</u>	<u>Case G</u>
0	51.6	51.6	51.6	51.6	51.6	51.6	51.6
3000	32.8	35.0	38.1	40.4	41.9	43.4	44.9
4000	19.4	23.3	28.5	32.4	35.1	37.6	40.2
4500	11.4	16.3	22.8	27.6	30.9	34.1	37.4
5000	3.0	8.9	16.7	22.6	26.5	30.4	34.4
5500		0.6	10.0	17.0	21.6	26.3	31.0
6000			2.7	10.9	16.4	21.9	27.4
7000					4.9	12.2	19.5
<u>F NEAR</u>							
0	51.4	51.4	51.4	51.4	51.4	51.4	51.4
3000	32.7	35.0	38.0	40.3	41.8	43.3	44.9
4000	19.4	23.3	28.5	32.4	35.0	37.6	40.2
4500	11.6	16.4	22.9	27.7	31.0	34.2	37.5
5000	3.2	9.1	16.9	22.8	26.7	30.6	34.5
5500			10.3	17.2	21.9	26.6	31.3
6000			3.0	11.2	16.8	22.2	27.8
7000					5.4	12.7	20.0
<u>F FAR</u>							
0	49.7	49.7	49.7	49.7	49.7	49.7	49.7
3000	31.1	33.4	36.4	38.7	40.2	41.7	43.2
4000	17.9	21.7	26.9	30.9	33.5	36.1	38.7
4500	10.0	14.9	21.3	26.2	29.5	32.7	35.9
5000	1.7	7.6	15.4	21.3	25.2	29.1	33.0
5500			8.7	15.8	20.5	25.1	29.8
6000			1.6	9.8	15.3	20.8	26.3
7000					4.1	11.4	18.7

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FIGURE 6

B REACTOR
HIGH TANK
SUPPLY - DEMAND CURVES NEAR SIDE
PARAMETER: K_{AB} at 20°C

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FIGURE 7

B REACTOR
HIGH TANK
SUPPLY - DEMAND CURVES FAR SIDE
PARAMETER: K_{AB} at 20 °C

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FIGURE 8

D REACTOR
HIGH TANK
SUPPLY — DEMAND CURVES NEAR SIDE
PARAMETER: K_{AB} at 20°C

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FIGURE 9

D REACTOR
HIGH TANK
SUPPLY - DEMAND CURVES FAR SIDE
PARAMETER: K_{AB} at 20°C

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FIGURE 10

F REACTOR
HIGH TANK
SUPPLY—DEMAND CURVES NEAR SIDE
PARAMETER: K_{AB} at 20°C

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FIGURE 11

F REACTOR
HIGH TANK
SUPPLY — DEMAND CURVES FAR SIDE
PARAMETER: K_{AB} at 20°C

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