CALCULATION REVIEW AND APPROVAL
NUCLEAR POWER DEPARTMENT

Calculation #	N-91-069
Number of pages	12

Title of Calculation: Impact of Higher Capacity Recirculation System for the Electric Motor Driven AFW Pumps

- [X] Original calculation
- [ ] Revised calculation. Revision #______
- [ ] Superseding calculation. Supersedes calculation #______________

Modification #	Description:
88-099*B	Increased Aux Feed Pump Recirc Flow Capacity

Other References:

Prepared By: Curtis A. Castell   Date: 7/8/91

This calculation has been reviewed in accordance with QP 3-6. The review was accomplished by one or a combination of the following (as checked):

____ A review of a representative sample of repetitive calculca-tions

✓ A detailed review of the original calculation

____ A review of the calculation against a similar calculation previously performed

____ A review by an alternate, simplified or approximate method of calculation

Comments:

H/50

Reviewed By:	Date:	Approved By:	Date:
[signature]	7/9/91	[signature]	JUL 9, 1991

Form QP 3-6.1
Rev. 0

Purpose:

This calculation provides an estimate of the impact of the proposed higher capacity recirculation systems for the electric motor driven auxiliary feedwater pumps.

Assumptions:

1. The density of water will be assumed to be the nominal value of 62.4 lbm/cu. ft. Justification: This is a reasonable value for the standard density of water as given in many texts and reference 1 listed below. ✓

2. The acceleration of gravity will be assumed to be the nominal value of 32.2 ft/s^2. Justification: This is a reasonable value for the standard acceleration of gravity on the earth as given in many texts and reference 1 listed below. ✓

3. The nominal flow rate through one electric motor driven Auxiliary Feedwater Pump is 200 gpm. The recirculation line flow is about 80 gpm for the proposed system (Reference 12). Justification: The nominal flow rate is reasonable per assumption 5 and the recirculation line flows are reasonable for their intended design. ✓

4. The pressure at the discharge of T-24A and T-24B is assumed to be 1 psig. Justification: That pressure corresponds to a nominal level of 2.3 feet in the tanks. ✓

5. The electric motor driven pump nominal flow rate is 200 gpm. Justification: The discharge valve controllers are set to maintain the pump discharge pressure at 1200 psig. ✓

6. The feedline inside diameter is about 29 inches and the CST inside diameter is about 240 inches. Justification: These are reasonable values for these parameters. ✓

7. The conversion of gpm to flow velocity in a pipe in ft/s is 0.409x(flow in gpm)/(pipe ID in inches squared). Justification: This is a determined conversion factor. ✓

References:

1. Flow of Fluids through Valves, Fittings, and Pipe, Crane Technical Paper 410, 19th printing, 1980.

2. Drawing: Bechtel P-118, Aux. F.W. Pump Suction from Storage Tanks T-24A&B, Rev. 5.

3. Drawing: Bechtel P-117, Aux. F.W. Pump Suction from Storage Tanks T-24A&B, Rev. 4.

4. Drawing: Bechtel P-103, Emergency Feedwater Pumps to Main Feedwater Lines 4" & 3" DB-3, Rev. 6.

5. Drawing: Bechtel P-142, Emergency Feedwater from CTMT Pentration P-5 to Main Feedwater EB-9 EB-10 Inside (CTMT), Rev. 3.

6. Calculation N-90-029, Determination of Branch Resistance Coefficients in the AFW System, Rev. 0.

7. Calculation N-90-028, Auxiliary Feedwater Pump Flow-Head Characteristic Polynomials, Rev. 0.

8. Drawing Bechtel P-241, Emergency Feedwater from DB-3 into CTMT Penetration P-5 EB-10 Outside (CTMT), Rev. 4.

9. Drawing: Bechtel P-240, Emergency Feedwater from DB-3 into CTMT Penetration P-6 EB-10 Outside (CTMT), Rev. 4.

10. Drawing: Bechtel P-239, Emergency Feedwater from PENET P-5 to Main Feedwater System 3" EB-10, Rev 3.

11. Drawing: Bechtel P-242, Emergency Feedwater from Penet. P-6 to Main Feedwater System 3"-EB-10, Rev. 3.

12. Calculation N-91-063, Recirc line loss coefficient.

13. Letter dated March 17, 1989, from Robert B. Davidson (BW/IP International) to Hank Hoelscher (WE), Auxiliary Feedwater Pumps, (attached).

14. Calculation of K15A (attached).

15. Figure showing the AFW System nodalization (attached).

Calculation for Recirc. Only

Inputs

Density ρ := 62.4 (A1) ✓

Gravity g := 32.2 (A2) ✓

Friction Factors

f3 := 0.018	3 inch pipe	(R1)	✓
f4 := 0.017	4 inch pipe	(R1)	✓
f6 := 0.015	6 inch pipe	(R1)	✓
f8 := 0.014	8 inch pipe	(R1)	✓
f10 := 0.014	10 inch pipe	(R1)	✓

Elevations (Feet)

Z1 := 28.83	(R2)	✓
Z11 := 10.03	(R3)	✓
Z15 := 9.97	(R4)	✓
Z15A := 10.92	(R4)	✓

Pipe Diameter and K-factors (A3, R6, R12)

d1 := 10.42	K1 := 0.5 + 184·f10	K1 = 3	✓
d2 := 10.42	K2 := 0.5 + 180·f10	K2 = 3	✓
d3 := 10.42	K3 := 254·f10	K3 = 4	✓
d4 := 8.329	K4 := 0.043 + 28.4·f8	K4 = 0	✓
d11 := 4.26	K11 := 0.4 + 254·f4	K11 = 5	✓
d15A := 2.9	K15A := 136·f3	K15A = 2	✓
dRC := 1.939	KRC := 1891.6	KRC = 1892	✓
dcst := 240.			

Flow Rates (GPM) (A3)

Q1 := 46.4

Q2 := 46.4

Q3 := 92.8

Q4 := 92.8

Q11 := 92.8

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$Q15 := 92.8$

$Q15A := 92.8$

$QRC := 92.8$

Calculation

Velocity (FPS) (A7)

$v1 := 0.409 \cdot \frac{Q1}{d1^2}$ $v1 = 0$ ✓

$v2 := 0.409 \cdot \frac{Q2}{d2^2}$ $v2 = 0$ ✓

$v3 := 0.409 \cdot \frac{Q3}{d3^2}$ $v3 = 0$ ✓

$v11 := 0.409 \cdot \frac{Q11}{d11^2}$ $v11 = 2$ ✓

$v15 := 0.409 \cdot \frac{Q15}{d15A^2}$ $v15 = 5$ ✓

$v15A := 0.409 \cdot \frac{Q15A}{d15A^2}$ $v15A = 5$ ✓

$vRC := 0.409 \cdot \frac{QRC}{dRC^2}$ $vRC = 10$ ✓

$vcsta := 0.409 \cdot \frac{Q1}{dcst^2}$ $vcsta = 0$ ✓

$vcstb := 0.409 \cdot \frac{Q2}{dcst^2}$ $vcstb = 0$ ✓

Frictional Pressure Loss (PSID) (R1)

$C := 1.078 \cdot 10^{-4}$ ✓

$DP1 := C \cdot K1 \cdot \rho \cdot v1^2$ $DP1 = 0$ ✓

$DP2 := C \cdot K2 \cdot \rho \cdot v2^2$ $DP2 = 0$ ✓

$DP3 := C \cdot K3 \cdot \rho \cdot v3^2$ $DP3 = 0$ ✓

$DP11 := C \cdot K11 \cdot \rho \cdot v11^2$ $DP11 = 0$ ✓

$DP15A := C \cdot K15A \cdot \rho \cdot v15A^2$ $DP15A = 0$ ✓

$DPRC := C \cdot KRC \cdot \rho \cdot vRC^2$ $DPRC = 1297$ ✓

Pressure Equations (Bernoulli's Equation from Ref. 1)

$P1 := 1$ (A4) ✓

$P2 := 1$ (A4) ✓

$$P11 := P1 + \frac{\rho}{144} \cdot \left[Z1 - Z11 + \frac{vcsta^2}{2 \cdot g} - \frac{v11^2}{2 \cdot g} \right] - DP1 - DP3 - DP11 \qquad P11 = 9$$ ✓

Pump Head Equation (R7)

$$\delta P2 := -7.837 \cdot 10^{-9} \cdot Q11^4 + 1.020 \cdot 10^{-5} \cdot Q11^3 - 6.086 \cdot 10^{-3} \cdot Q11^2 + 0.218 \cdot Q11 + 1321$$ ✓

$\delta P2 = 1296$ $P15 := P11 + \delta P2$ ✓ $P15 = 1305$

$$P15A := P15 + \frac{\rho}{144} \cdot \left[Z15 - Z15A + \frac{v15^2}{2 \cdot g} - \frac{v15A^2}{2 \cdot g} \right] - DP15A \qquad P15A = 1305$$ ✓

$$Pexit := P15A + \frac{\rho}{144} \cdot \left[Z15A - Z1 + \frac{v15A^2}{2 \cdot g} - \frac{vcsta^2}{2 \cdot g} \right] - DPRC \qquad Pexit = 0$$ ✓

Calculation for 200gpm with Recirc Open. 6/12

Inputs

Density $\rho := 62.4$ (A1) ✓

Gravity $g := 32.2$ (A2) ✓

Friction Factors

$f3 := 0.018$	3 inch pipe	(R1)	✓
$f4 := 0.017$	4 inch pipe	(R1)	✓
$f6 := 0.015$	6 inch pipe	(R1)	✓
$f8 := 0.014$	8 inch pipe	(R1)	✓
$f10 := 0.014$	10 inch pipe	(R1)	✓

Elevations (Feet)

$Z1 := 28.83$	(R2)	✓
$Z11 := 10.03$	(R3)	✓
$Z15 := 9.97$	(R4)	✓
$Z15A := 10.92$	(R4)	✓

Pipe Diameter and K-factors (A3, R6, R12)

$d1 := 10.42$	$K1 := 0.5 + 184 \cdot f10$	$K1 = 3$	✓
$d2 := 10.42$	$K2 := 0.5 + 180 \cdot f10$	$K2 = 3$	✓
$d3 := 10.42$	$K3 := 254 \cdot f10$	$K3 = 4$	✓
$d4 := 8.329$	$K4 := 0.043 + 28.4 \cdot f8$	$K4 = 0$	✓
$d11 := 4.26$	$K11 := 0.4 + 254 \cdot f4$	$K11 = 5$	✓
$d15A := 2.9$	$K15A := 136 \cdot f3$	$K15A = 2$	✓
$dRC := 1.939$	$KRC := 1891.6$	$KRC = 1892$	✓
$dcst := 240.$			

Flow Rates (GPM) (A3)

$Q1 := 100$

$Q2 := 100$

$Q3 := 200$

$Q4 := 200$

$Q11 := 200$

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$Q15 := 200$

$Q15A := 200$

$QRC := 88.88$

Calculation

Velocity (FPS) (A7)

$v1 := 0.409 \cdot \frac{Q1}{d1^2}$ $v1 = 0$ ✓

$v2 := 0.409 \cdot \frac{Q2}{d2^2}$ $v2 = 0$ ✓

$v3 := 0.409 \cdot \frac{Q3}{d3^2}$ $v3 = 1$ ✓

$v11 := 0.409 \cdot \frac{Q11}{d11^2}$ $v11 = 5$ ✓

$v15 := 0.409 \cdot \frac{Q15}{d15A^2}$ $v15 = 10$ ✓

$v15A := 0.409 \cdot \frac{Q15A}{d15A^2}$ $v15A = 10$ ✓

$vRC := 0.409 \cdot \frac{QRC}{dRC^2}$ $vRC = 10$ ✓

$vcsta := 0.409 \cdot \frac{Q1}{dcst^2}$ $vcsta = 0$ ✓

$vcstb := 0.409 \cdot \frac{Q2}{dcst^2}$ $vcstb = 0$ ✓

Frictional Pressure Loss (PSID) (R1)

$C := 1.078 \cdot 10^{-4}$ ✓

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$DP1 := C \cdot K1 \cdot \rho \cdot v1^2$ $\quad DP1 = 0$ ✓

$DP2 := C \cdot K2 \cdot \rho \cdot v2^2$ $\quad DP2 = 0$ ✓

$DP3 := C \cdot K3 \cdot \rho \cdot v3^2$ $\quad DP3 = 0$ ✓

$DP11 := C \cdot K11 \cdot \rho \cdot v11^2$ $\quad DP11 = 1$ ✓

$DP15A := C \cdot K15A \cdot \rho \cdot v15A^2$ $\quad DP15A = 2$ ✓

$DPRC := C \cdot KRC \cdot \rho \cdot vRC^2$ $\quad DPRC = 1190$ ✓

Pressure Equations (Bernoulli's Equation from Ref. 1)

$P1 := 1$ (A4) ✓

$P2 := 1$ (A4) ✓

$$P11 := P1 + \frac{\rho}{144} \cdot \left[Z1 - Z11 + \frac{vcsta^2}{2 \cdot g} - \frac{v11^2}{2 \cdot g} \right] - DP1 - DP3 - DP11 \qquad P11 = 8$$ ✓

Pump Head Equation (R7)

$$\delta P2 := -7.837 \cdot 10^{-9} \cdot Q11^4 + 1.020 \cdot 10^{-5} \cdot Q11^3 - 6.086 \cdot 10^{-3} \cdot Q11^2 + 0.218 \cdot Q11 + 1321$$ ✓

$\delta P2 = 1190$ $\quad P15 := P11 + \delta P2$ ✓ $\quad P15 = 1199$

$$P15A := P15 + \frac{\rho}{144} \cdot \left[Z15 - Z15A + \frac{v15^2}{2 \cdot g} - \frac{v15A^2}{2 \cdot g} \right] - DP15A \qquad P15A = 1197$$ ✓

$$Pexit := P15A + \frac{\rho}{144} \cdot \left[Z15A - Z1 + \frac{v15A^2}{2 \cdot g} - \frac{vcsta^2}{2 \cdot g} \right] - DPRC \qquad Pexit = 0$$ ✓

Results:

With only the new recirculation line open:

Recirculation Line Flow Rate: 93 gpm ✓
Total Flow Rate: 93 gpm

With the new recirculation line open and the discharge flow control maintaining pump flow at 200 gpm:

Recirculation Line Flow Rate: 89 gpm ✓
Total Flow Rate: 200 gpm

Therefore, the balance 111 gpm could be supplied to the steam generator(s).

Conclusion:

This calculation shows that the proposed recirculation line will allow approximately 93 gpm flow when it is open. If the proposed recirculation line is open when the pump flow is being controlled to about 200 gpm, the recirculation line flow rate would be about 89 gpm. That would leave about 111 gpm to be supplied to the steam generator(s).

I cannot determine the significance of this situation on the PBNP FSAR accident analyses, because the failure of the recirculation system has not been evaluated. Also, the control system for the valve that controls the recirculation line is not safety grade or QA. Typically, current design criteria contained in NUREG-0800 (the standard review plan) require that all non-safety grade and non-QA equipment be assumed to fail to its worst-case condition (open for the recirculation valve) in addition to one limiting safety grade failure.

The limiting safety grade failure for the AFW system is typically a turbine driven AFW pump, because these pumps are the highest capacity. If auxiliary feedwater is actuated to one unit, then the electric motor driven pumps should still be able to provide sufficient flow to a unit without running out, even if the recirculation line valve fails open. It has been previously judged that the Auxiliary feedwater system flows may need to be corrected by operator action, but at least 5 minutes is allowable for these actions. (See evaluation for NCR N-91-035 and Calculation N-91-007).

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BW/IP

BW IP International, Inc.

Byron Jackson® Products
Pump Division

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Elgin Illinois 6012[illegible]

Telephone 312 741 0[illegible]
Telex RCA 258[illegible]
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Quotation

This quotation is made on the express condition that the terms below and on the reverse side are the exclusive terms and conditions of this transaction

17 March 1989

Wisconsin Electric Power Company
Point Beach Nuclear Plant
6610 Nuclear Road
Two Rivers, Wisconsin 54241

Attention: Mr. Hank Hoelscher

Subject: Auxiliary Feedwater Pumps
S/N's 681-S-1028/31

Dear Hank:

The minimum flow requirement as stated back in 1968 on these pumps is 30 gallons per minute. For our Engineering Dept. to calculate the minimum flow requirement by today's standards, we need a purchase order from Wisconsin Electric Power for $2,000.00 to complete this study.

Very truly yours,

BW/IP INTERNATIONAL, INC.
PUMP DIVISION

Robert B. Davidson
Regional Manager

RBD:ds (WISC.ELC)

CC: BW/IP International, Inc.
Mr. Fred Grondhuis - Elgin Sales

RECEIVED
MAR 20 1989
POINT BEACH

Determination of K15A

From Calc. N-90-029:

1. 90° ELL — $14 f_T$ ✓
2. 90° ELL — $14 f_T$ ✓
3. 90° ELL — $14 f_T$ ✓
4. 90° ELL — $14 f_T$ ✓

Total Fittings — $56 f_T$ ✓

Pipe length:

$(16'9'' - 9'11\tfrac{11}{16}'') + 6'7\tfrac{1}{4}'' + 2'9'' + (16'8'' - 10'11'')$ ✓

$= 16.75 - 9.97 + 6.60 + 2.75 + 16.67 - 10.92$ ✓

$= 21.88'$ ✓

Fittings

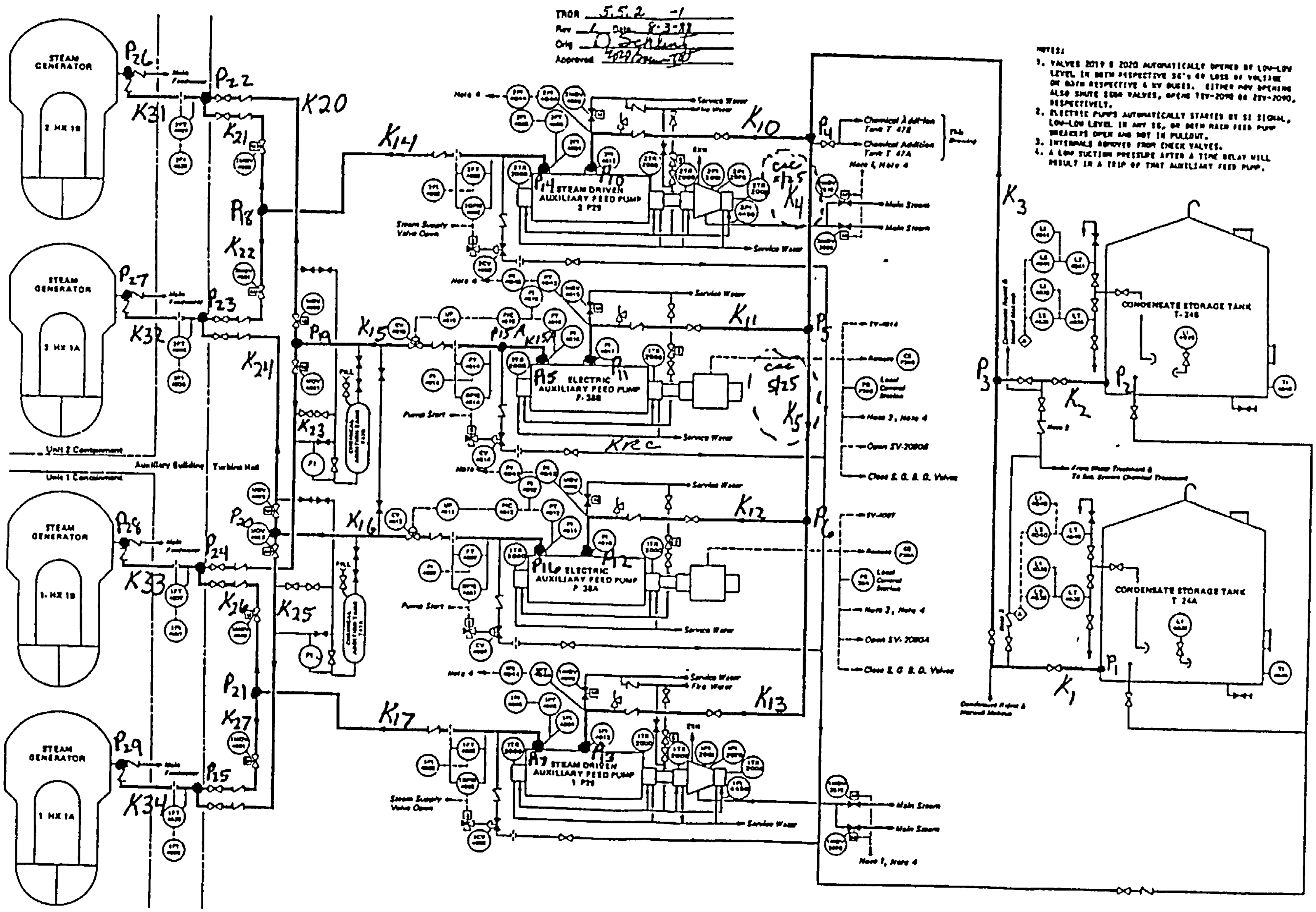
$4\tfrac{1}{2}'' + (3 \times 9'') = 31.5'' = 2.625$ ✓

Total:

$21.88' - 2.625' = 19.255'$ ✓

$K_{pipe} = f_T \frac{L}{D} = f_T \frac{19.255\ ft}{2.9''/12\ in/ft} = 79.7\ f_T$ ✓

Total loss coeff. $K15A = 56 f_T + 79.7 f_T \doteq 136 f_T$ (3'') ✓



FOR INFORMATION ONLY

AUXILIARY FEEDWATER SYSTEM
Figure 11.4.1

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