CALCULATION REVIEW AND APPROVAL
NUCLEAR POWER DEPARTMENT

Calculation #
N-91-063

Number of pages
~~10~~ 9 cac 7/2/91

Title of Calculation:
P38A & B Recirc Line System Characteristics

☒ Original calculation

☐ Revised calculation. Revision #______

☐ Superseding calculation. Supersedes calculation #__________

Modification #	Description:
88-099	AFW pump recirc line size increase.

Other References:
See attached.

Prepared By: Julia Pederson — Date: 6-24-91

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 calculcations

✓ 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:
As annotated on calc. cac 7/2/91

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Reviewed By:	Date:	Approved By:	Date:
CA Castell	7/2/91	A. L. Rem	7/2/91

Form QP 3-6.1
Rev. 0

Purpose:

The purpose of this calculation is to determine the system characteristics for the auxiliary feed pump mini-recirc system. This calc will address pumps P38A & B only.
In addition, this calc will determine the equivalent K (resistance coefficient) values for the recirc line to the CST.

References:

1. Byron Jackson Pump Curve T-30944 and T-30945 for pumps P38A & B respectively.

2. Crane Technical paper No. 410

3. Letter from Byron Jackson Pumps to WE dated August 7,1989 regarding required mini-recirc flows for the AFW pumps.

4. WE Dwg M-217 rev 4

5. Copes-Vulcan Dwg D-166085 rev 9
   Rockwell-Edwards Dwg C-464529 rev 5

6. Purchase Order No. 184514

7. Bechtel Dwgs: P-103 rev 7
   P-118 rev 5
   P-117 rev 5
   M-34 rev 8
   M-35 rev 6
   M-37 rev 6

Assumptions:

1. Calculation is based on the longest run of system piping which, by inspection is from the 2P29 aux feedwater pump.

Inputs:

TDH := 1192	psig	P38 head (psig) @ 200 gpm	✓
den := 62.4	lb/ft^3	Density of water	✓
Q := 70	gpm	Required mini recirc flow	✓

DISCHARGE LINE:

2" line info:

Schedule 80:

d280 := 1.939	in	Inside dia of 2" sch 80 pipe	✓

$K_{ent} := .5$ Recirc line pipe entrance ✓ 2/9

$CV_{chk} := 60$ Check valve flow coefficient (full) ✓

$CV_{cont} := 33$ Control valve flow coefficient (full) ✓

$f2 := .019$ Friction factor for 2" fully turbulent ✓

$K_{2glb} := 340 \cdot f2$ $K_{2glb} = 6.46$ 1500 #, 2" globe valve Ref 2 pg. A-27 ✓
Note: K is based on sch 160 pipe

$K_{290} := 14 \cdot f2$ 2" 90 degree elbow, Assumes $\frac{r}{d} = 1.5$ typical long radius ELL. cec 7/2/91 ✓

Determine flow meter orifice characteristics:

Typically, β should be in the range of 0.5 to 0.75

$d_o := 1.375$ Selected orifice diameter ✓

$\beta := \frac{d_o}{d280}$ $\beta = 0.709$ ✓

$RE := 50.6 \cdot \frac{Q \cdot den}{d280 \cdot 1.2}$ $RE = 9.499 \cdot 10^4$ Ref Crane Eqn 3-3 ✓

Re doesn't change much with the small Q-range used, so a fixed C is SAT. cec 7/2/91

$C := .705$ Ref Crane Pg A-20 ✓

2" schedule 40:

$d240 := 2.067$ in Inside dia of 2" sch 40 pipe ✓

3" schedule 10:

$d310 := 3.26$ in Inside dia of 3" sch 10 pipe ✓

$f3 := .018$ Friction factor for 3" fully turbulent ✓

$K_{3gate} := f3 \cdot 8$ 3" gate valve ✓

$K_{3chk} := f3 \cdot 50$ 3" check valve ✓

$K_{3x3r} := f3 \cdot 20$ 3x3 tee flow thru run ✓

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$K_{390}^{3x3r} := 14 \cdot f3$ — 3" 90 elbow ✓

3x2 reducer:

$\theta := 2 \cdot \operatorname{atan}\left[\frac{0.66}{3.5}\right]$ ✓

$\beta := \frac{d240}{d310}$ $\beta = 0.634$ ✓

$K_{3x2} := \frac{2.6 \cdot \left[\sin\left[\frac{\theta}{2}\right]\right] \cdot \left[1 - \beta^2\right]^2}{\beta^4}$ $K_{3x2} = 1.066$ enlargement ✓

4" schedule 10:

$d410 := 4.26 \ in$ — diameter of 4" sch 10 ✓

$f4 := .017$ — friction factor for 4" line ✓

$K_{490} := f4 \cdot 14$ — 4" 90 elbow ✓

4" schedule 80:

$d480 := 3.826 \ in$ — diameter of 4" sch 80 line ✓

6" schedule 10:

$d610 := 6.357 \ in$ — diameter of 6" sch 10 line ✓

$f6 := .015$ — friction factor for 6" line ✓

$K_{6x6r} := 20 \cdot f6$ — Flow thru tee 6x6 ✓

$K_{6x6b} := 60 \cdot f6$ — Flow thru branch tee 6x6 ✓

$K_{6gate} := 8 \cdot f6$ — 6" gate valve ✓

$K_{6chk} := f6 \cdot 50$ — 6" check valve ✓

$K_{690} := 14 \cdot f6$ — 6" 90 elbow ✓

$K_{exit} := 1$ Exit loss ✓

6x3 reducer:

$\theta := 2 \cdot atan\left[\frac{1.55}{5.5}\right]$ ✓

$\beta := \frac{d310}{d610}$ ✓

$K_{6x3} := 2.6 \cdot \left[\sin\left[\frac{\theta}{2}\right]\right] \cdot \left[1 - \beta^2\right]^2$ $K_{6x3} = 0.383$ enlargement ✓

6x4 reducer:

$\theta := 2 \cdot atan\left[\frac{1.05}{5.5}\right]$ ✓

$\beta := \frac{4.26}{d610}$ ✓

$K_{6x4} := \frac{.8 \cdot \left[\sin\left[\frac{\theta}{2}\right]\right] \cdot \left[1 - \beta^2\right]}{\beta^4}$ Contraction ✓

10" line info:

d1010 := 10.42 in — diameter of 10" sch 10 line ✓

f10 := .014 — friction factor for 10" line ✓

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$K_{10gate} := f10 \cdot 8$ — 10" gate valve ✓

$K_{1090} := f10 \cdot 14$ — 10" 90 elbow ✓

$K_{1045} := f10 \cdot 8$ — 10" 45 elbow ✓

$K_{10x10b} := f10 \cdot 60$ — 10x10 tee branch flow ✓

$K_{10x6b} := f6 \cdot 60$ — 10x6 tee branch flow ✓

Calculation:

pipe loss function:

$$DP(f,L,v,d) := .001294 \cdot f \cdot L \cdot den \cdot \frac{v^2}{d}$$ Ref Crane 410 eqn 3-5 ✓

velocity function:

$$v(d) := \frac{Q}{\left[\frac{\pi}{4 \cdot 144} \cdot d^2\right] \cdot 7.48 \cdot 60}$$ ✓

fitting loss function:

$$DPF(K,v) := .0001078 \cdot K \cdot den \cdot v^2$$ Ref Crane 410 eqn 3-14 ✓

equivalent resistance coefficient function:

$$K(dpt,d,q) := dpt \cdot \frac{d^4}{.00001799 \cdot den \cdot q^2}$$ Ref Crane 410 eqn 3-14 ✓

Calculate the pressure loss from the AFW pump discharge to the mini-recirc line tie-in:

piping:

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$v480 := v(d480)$ ✓

$dP_1 := DP(f4, 22, v480, d480)$ $\qquad dP_1 = 0.03$ ✓

fittings:

$K_{tot} := 3 \cdot K_{490}$ ✓

$dP_2 := DPF\left[K_{tot}, v480\right]$ $\qquad dP_2 = 0.018$ ✓

Calculate losses from the mini-recirc line entrance to globe valve:

pipe loss:

$v280 := v(d280)$ $\qquad v280 = 7.606$ ✓

$dP_3 := DP(f2, 10, v280, d280)$ $\qquad dP_3 = 0.458$ ✓

fittings:

$K_{tot} := K_{ent} + 1 \cdot K_{290}$ $\qquad K_{tot} = 0.766$ ✓

$dP_4 := DPF\left[K_{tot}, v280\right]$ $\qquad dP_4 = 0.298$ ✓

valves:

control valve:

$$dP_5 := \left[\frac{Q}{CV_{cont}}\right]^2$$ $\qquad dP_5 = 4.5$ ✓

check valve:

$$dP_6 := \left[\frac{Q}{CV_{chk}}\right]^2$$ $\qquad dP_6 = 1.361$ ✓

globe valve:

$dP_7 := DPF\left[K_{2glb}, v280\right]$ $\qquad dP = 2.514$ ✓

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$7 \quad \lfloor 2glb \rfloor \quad 7$

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restricting orifice:

$$dP_8 := 948 \cdot \left[\frac{Q}{70}\right]^2 \qquad dP_8 = 948$$

Flow meter orifice:

$$dP_9 := \left[\frac{Q}{236 \cdot d_o^{\,2} \cdot C}\right]^2 \cdot den \qquad dP_9 = 3.09$$

Calculate pressure loss from globe valve to 3x2 reducer:

piping:

$v240 := v(d240) \qquad v240 = 6.693$

$dP_{10} := DP(f2,26,v240,d240) \qquad dP_{10} = 0.865$

fittings:

$K_{tot} := 2 \cdot K_{290} + K_{3x2}$

$dP_{11} := DPF\left[K_{tot}, v240\right] \qquad dP_{11} = 0.482$

Calculate pressure loss from 3x2 reducer to 3x6 reducer:

piping:

$v310 := v(d310) \qquad v310 = 2.691$

$dP_{12} := DP(f3,157,v310,d310) \qquad dP_{12} = 0.507$

fittings/valves:

$K_{tot} := 7 \cdot K_{390} + K_{6x3} + 3 \cdot K_{3x3r} + K_{3gate} + K_{3chk}$

$dP_{13} := DPF[K_{tot}, v310]$ $dP_{13} = 0.208$ ✓

Calculate pressure loss from 3x6 reducer to condensate storage tank:

piping:

$v610 := v(d610)$ $v610 = 0.708$ ✓

$dP_{14} := DP(f6, 26, v610, d610)$ $dP_{14} = 0.002$ ✓

fittings/valves:

$K_{tot} := 2 \cdot K_{690} + K_{6x6b} + K_{6x6r} + K_{exit} + K_{6gate}$ ✓

$dP_{15} := DPF[K_{tot}, v610]$ $dP_{15} = 0.009$ ✓

Calculate suction piping pressure loss from condensate storage tank to 10x6 tee:

piping:

$v1010 := v(d1010)$ $v1010 = 0.263$ ✓

$dP_{16} := DP(f10, 156, v1010, d1010)$ $dP_{16} = 0.001$ ✓

fittings/valves:

$K_{tot} := 2 \cdot K_{10gate} + 6 \cdot K_{1090} + 3 \cdot K_{1045} + K_{ent} + 2 \cdot K_{10x10b} + K_{10x6b}$ ✓

$dP_{17} := DPF[K_{tot}, v1010]$ $dP_{17} = 0.002$ ✓

Calculate suction piping pressure loss from 10x6 tee to 4" 90 elbow:

piping:

$dP_{18} := DP(f6, 27, v610, d610)$ $dP_{18} = 0.003$ ✓

fittings/valves:

$K_{tot} := K_{6gate} + K_{6chk} + 4 \cdot K_{690} + K_{6x6b} + K_{6x4}$ ✓

$dP_{19} := DPF[K_{tot}, v610]$ $dP_{19} = 0.01$ ✓

Calculate suction piping pressure loss due to 4" 90 elbow:

fitting:

$v410 := v(d410)$ $v410 = 1.576$ ✓

$$dP_{20} := DPF\left[K_{490}, v410\right]$$ $$dP_{20} = 0.004$$ ✓ 9/9

Sum the dP for the system:

$\Sigma dP = 962.362$ psi ✓

Comparing this value to the pump curve would indicate that the pump is delivering ~~95~~ 360 gpm which is greater than the intial assumed flow rate of 70 gpm. Therfore, it is necessary to re-iterate by adjusting the flow rate until SYSTEM dP = Pump TDH.

Trial #	Q	System dP	Pump TDH	
1	70	2224 FT	3000 FT ✓	
2	82	3052 FT	2998 FT ✓	
3	80	2904 FT	2998 FT ✓	Acceptable

Calculate equivalent K values for the recirc line only based on 80 gpm:

$$K1 := K\left[dP_3 + dP_4 + dP_5 + dP_6 + dP_7 + dP_8 + dP_9, d280, 80\right]$$ $$K1 = 1.889 \cdot 10^3$$ ✓

$$K2 := K\left[dP_{10} + dP_{11}, d240, 80\right]$$ $$K2 = 3.42$$ ✓