Height of Discharge and Suction pipe Center Line from pump floor

$L_{CL} := 27in$

Wall Thickness

Pipe wall thickness:

$t_{wall} := 0.25in$

Flange Diameter

$D_{flange} := 26in$

Weir Floway pg IV-51

Barrel Pipe Diameter

$D_{C\_nom} := 36in$

Manifold Branching Coefficients

$K_{branch\_S} := \begin{pmatrix} 0.8 \\ 0.8 \\ 1.25 \\ 5 \end{pmatrix}$

K values for Branching flows come from: *Internal Flow Systems 2nd Ed.* Fig. 13.20

$K_{branch\_DM} := \begin{pmatrix} 5 \\ 2 \\ 0.6 \\ 0.2 \end{pmatrix}$

K values for Branching flows come from: *Internal Flow Systems 2nd Ed.* Fig. 13.8

$K_{branch\_M23} := \begin{pmatrix} -1.0 \\ 0 \\ 0.23 \\ 0.23 \end{pmatrix}$

K values for Branching flows come from: *Internal Flow Systems 2nd Ed.* Fig. 13.9

Pump Specific Losses

$h_{can} := 0.7ft$

Headloss from the suction pipe flange to the bell intake, for cans no more than 20 ft. long (Floway pg. IV-53)

Column friction loss for a

$h_{col} := 2.0\frac{ft}{100ft}$

19 in. dia. column with a 2-1/4 in. dia. shaft (Floway IV-32)

$h_{can\_ro} := 1.1ft$

Runout Headloss from the suction pipe flange to the bell intake, for cans no more than 20 ft. long (Floway pg. IV-53)

$h_{col\_ro} := 1.4\frac{ft}{100ft}$

Runout Column friction loss for a 19 in. dia. column with a 2-1/4 in. dia. shaft (Floway IV-32)

Pump Information

$NPSHr := 29.55ft$

Net Positive Suction Head required

Solution Methodology

The pump sizing will be based on a Conservation of Energy analysis of the system using the Bernoulli Equation.

$$h_{qin} - h_{qout} + \eta h_{pump} - h_{friction} =$$
$$(P/\rho g + V^2/2g + z)_{out} - (P/\rho g + V^2/2g + z)_{in}$$

This equation can be simplified because:
1. $h_{qin} = 0$, no energy is applied to the inlet of the system
2. $h_{qout} = 0$, no energy is applied against the exit of the system
3. $P_{in} = P_{out}$ Both inlet and exit are at atmospheric pressure
4. $V_{in} = 0$, the inlet velocity is the free surface of the forebay tank
5. $V_{out} = 0$, the outlet velocity is the free surface of the discharge tank

The simplified equation then is:

$$\eta h_{pump} - h_{friction} = z_{out} - z_{in}$$

The system will be broken into two parts: the gravity assisted suction side, and the pump through to the supply line piping. The gravity assisted suction side will give us our Net Positive Suction Head Available (NPSHa). Combining this with the pump head must then balance against the Total Dynamic Head (TDH) required by the conditions of service. This then is our Governing Equation:

$$NPSHa + \eta h_{pump} = TDH$$

Expanding the first and third terms will illustrate the full complexity of this calculation. (Cameron 19th Ed.)

$$NPSHa = h_{atm} - h_{vap} + h_{st} - h_{fs}$$

where (all distances are in feet):

h_{atm} = atmospheric pressure head.

h_{vap} = vapor pressure head of water at the operating temperature.

h_{st} = static height that the liquid supply level is above the centerline of the impeller eye. This is different than the static head which will be described below.

h_{fs} = friction losses on the suction side.

The summation of the suction and discharge friction losses will account for all minor losses in the system. Through symmetry many of these losses may be identical on both sides of the pump.

$$h_{fs} = h_{inlet} + h_{manifold} + h_{mitre} + h_{pipe} + h_{branch} + h_{BFV} + h_{expand} + h_{can}$$

$$h_{fd} = h_{column} + h_{dh} + h_{BFV} + h_{check} + h_{pipe} + h_{mitre} + h_{branch} + h_{manifold} + h_{Line}$$

The static head will also be calculated as a useful and intuitive tool in confirming the pump selection. The static head will be defined as:

$$h_{static} = z_{discharge} - z_{forebay}$$

This leads us to the formulation for our TDH:

$$TDH = h_{static} + h_{fs} + h_{fd}$$

Many of these heads will be determined from the velocity of the water in the pipe. Following a list of Physical Properties, our first step to solve for system losses therefore is to determine the flow through each pump and then determine the velocity in each diameter of pipe that will be used.

Constants and Physical Properties

Our list of physical constants and properties begins with acceleration due to gravity.

$g = 32.174\,\frac{ft}{s^2}$ gravity

We will need the specific volume of water at 68°F:

$\nu := 1.082 \cdot 10^{-5}\,\frac{ft^2}{s}$ White, *Fluid Mechanics* 6th Ed., Table A.1

We will also need the property of the density & vapor pressure of water at a 68°F.

$p_V := 2337Pa$ White, Fluid Mechanics 6th Ed., Table A.5

$p_V = 0.339\,psi$

$\rho := 1.937 \cdot \frac{slug}{ft^3}$ White, Fluid Mechanics 6th Ed., Table A.1

$\rho = 62.321\,\frac{lb}{ft^3}$

From the density of water and gravity we can now calculate the Specific Weight:

$\gamma := \rho \cdot g = 2.005 \times 10^3\,\frac{lb}{ft^2 \cdot s^2}$ Specific weight

Head losses due to friction will be governed by our estimate of the absolute roughness of the steel pipe:

$\varepsilon := 0.001ft$ USBR Design Standards No. 3 Chapter 11 pg 3

To find the system pump head required we will need to know what the atmospheric pressure is at the facility. To get this value we will use the following equation obtained from EngineeringToolBox.com:

$$P_{atm} := 101325Pa \cdot \left[1 - 2.25577 \cdot 10^{-5} \cdot \frac{1}{m} \cdot \left(z_{pump\_floor} \cdot \frac{0.3048m}{1ft}\right.\right.$$

$P_{atm} = 12.087\,psi$

$h_{vap} := \frac{p_V}{\rho \cdot g}$ Vapor pressure head