Annexure 6.9: Design of Air Vessel

DATA

Discharge through pipe line = 1.944 cumecs

Material of pipe line = Steel

Diameter of pipe line = 1550 mm

Thickness of pipe (ct) = 10 mm

Static Head = 120 mm

Length of pumping main = 18000 m

Total Head including friction
Head & other losses of 15 metre. } = 135 m

Design head of pumps. = 150 m

Atmospheric Head = 10 m

H_0 = Absolute Head = Total head + Atmospheric Head = 135 +10 =145 m

V_0 = Initial velocity $= \frac{1.994}{\left(\frac{\pi}{4}\right)(1.55)^2} = 1.03\ \mathrm{m/sec}$

C = Water Hammer Wave velocity,

$$= \frac{1425}{\sqrt{1+\frac{kd}{E_{ct}}}}$$

$$= \frac{1425}{\sqrt{1+[\frac{2.07x10^8}{2.1x10^{10}x0.01}]}} = 896.27\ m/s$$

Water Hammer Head $=\frac{cV_0}{g} = \frac{896.27 \times 1.03}{9.81}$

= 94.10 metres

Pipe Parameter $\rho = \frac{cV_0}{2gH_0}$

$= \frac{896.27 \times 1.03}{2 \times 9.81 \times 145}$

= 0.324

2ρ = 0.65

AIR VESSEL PARAMETER = $2C_0C/Q_0L$

Referring Chart f_0, k_c as 0.50 for limiting upsurge to 1.20 H_0 and down surge to 0.5 H_0

Air vessel parameter for 2ρ = 0.65 is calculated as follows:

From chart for 2ρ = $1.00 \times (2C_0C/Q_0L) = 10.50$

For 2ρ = 0.5, $2C_0C/Q_0L$ = 6.50

By interpolation for 2ρ = 0.65 and for k_c = 0.5

Air vessel parameter $2C_0C/Q_0L$ = 7.70

Volume of air C_0 = $\frac{7.7 \times 1.944 \times 18000}{2 \times 896.27}$

= 150.31 Cubic metres

Volume of Air Vessel =$C_0[H_0/H_{min}]^{1/1.20}$

= $150.31[(145)/0.5 \times (145)^{1/1.20}]$

= $150.31 \times (2)^{1/1.20}$

= 267.20 Cum

Increase the capacity by 20% to cater for upsurge of 1.20 H_0

= 267.20 × 1.2

= 320 m^3

WATER COLUMN SEPERATION LENGTH

The water column separation is calculated on the basis of the following formula:

$\square_1{}^2 - V_2{}^2 = (2g/L)\{(t_1 - t_2)\, V_1\, \{H + F\ (V_1{}^2/V_0)\}]$

H = Static Head, (Absolute Head)

F = Loss of head due to friction

V_1, V_2 = Velocities at instances t_1 and t_2.

(t_1-t_2) = Period between time intervals in seconds.

V_0 = Initial Velocity.

L = Length of pipeline

Initial velocity will come to rest over a time period after the stoppage of pumps. Assuming a time interval of 0.20 seconds and by using above formula, the subsequent velocities are calculated till the final velocity (V_n) is almost Zero. The water column separation length I is given by Laws =

lwcs Σ [V_1 + V_2 + ……… V_n] (t_2-t_1)

For the given diameter of pipe and for the calculated water column separation Length the volume of water required to be stored in Air vessel is calculated.

For Worked Example

$$(1.03)^2 - V_2{}^2 = 2 \times \frac{9.81}{18000}\,(0.20)(1.03)[145 + 15\frac{(1.03)^2}{1.03}]$$

$$(1.01)^2 - V_3{}^2 = 2 \times \frac{9.81}{18000}\,(0.20)(1.01)[145 + 15\frac{(1.03)^2}{1.01}]$$

Repeat n times till V_n = 0.01m /sec

Then $V_1+V_2+V_3+..............V_n$ (0.20) = say = 6.1 metres.

For a pipe of 1.55 per dia volume of water required to fill this separation length

$$\frac{\pi}{4}(1.55)^2(6.10) = 11.51\text{Cum}$$

FIXING THE SIZE OF VESSEL AND LEVELS OF WATER AND AIR IN AIRVESSEL CHAMBER

(i) Air And Water Volume

Air Vessel volume required = 320 Cum

If two vessels are provided volume of each vessel = 160 Cum

Provide 90 Cum of Air and 70 Cum of water in each vessel.

(ii) Determination Of Size of Air Vessel

Absolute Head at working head of pumps 150+ 10.35 160.35 metres.

Maximum upsurge permitted 160.35 × 1.2 = 192.42 metres

Pressure 19.25 kg/cm³

Using 25 mm thick MS Plate i.e., 22 mm+3mm for corrosion allowance

$$d = \frac{2f_t \times e \times t}{p}$$

f_t = Permissible tensile strength in steel plates = 1260 kgs/cm²

e = Weld efficiency say 0.9

t = Thickness in cms of plate = 2.2 cm

P =Pressure in kg/cm²

$= \frac{2 \times 1260 \times 1.90 \times 2.20}{19.25}$

= 259.20 cms

= Say 260 cms

Provide 2.60 m dia of vessel with a length L and two hemispherical ends.

Volume of (two hemispheres) spherical portion $=\frac{4}{3} \times \pi(1.3)^3 = 9.2$ Cum.

Total Volume of cylinder = 160 cum - 9.20 = 150.80 cum

Length of vessel of 2.6 m dia with volume 150.80 cum is = 28.40 metres

Provide 2 vessels each of 2.6 m dia and 28.40 m long with hemispherical ends.

(iii) Fixing of Levels of Water and Air in the Vessel

The levels are fixed by trial by assuming a depth and calculating volume in cylindrical and spherical portions,

(a) Normal Working Level

Volume of Air = 90 cum

Volume of Water = 70 cum

The normal working level is fixed by trial by assuming 1.15 metre of water by depth from bottom. Volume of water = 70.95 Cum which is more than required 70 Cum. Hence normal working level will be at 1.15 m from bottom of vessel.

(b) Upper Emergency Level

Air dissolves in water in the vessel. Assuming that 10% air dissolves in water the level of water rises by 10% of volume of air, i.e.:

Volume of water = 70 Cum + 10% of 90 Cum = 79 Cum.

The depth of water from bottom will be 1.35 m which gives volume of water as 79 Cum.

Hence upper emergency level will be 1.35 m from bottom of vessel.

(c) Lower Emergency Level

When pumps trip as per water column separation about 11.51 Cum of water is required to fill the pipeline. As calculated volume of water at a depth of 1.00 m from bottom of vessel = 56.43 Cum. Volume of water at normal working level is 71 Cum.

Quantity of water available is the difference between normal working level and lower emergency level.