FLUID MECHANICS D209 Q12 1996

(a)Describe the purpose and the operation of a surge shaft in a hydro-electric scheme.

(b) A water supply dam has a hydro-electric power station installed at its foot to use the compensation flow to the river downstream of 10 m^3/s. The intake in the reservoir and the pipe-line to the turbine are equivalent to a circular pipe of diameter 2 m, length 420 m and friction factor $f = 0.01$. The head difference between the water level in the reservoir and that in the tailrace is 80 m.

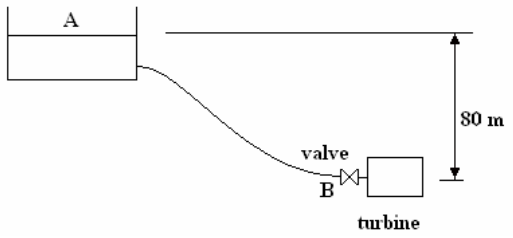
Show how the flow and pressure conditions following the opening and closing, respectively, of the turbine valves determine the design requirements which have to be met if no surge shaft is installed. Assume that, in the pipeline, the velocity of sound c is 1432 m/s.

(a) The surge shaft is to protect the high pressure tunnel and penstock from pressure surges due to sudden or rapid closure of the valves. The pressure is turned into head and causes the level in the surge tank to rise and absorb the energy.

$A = \pi D^2/4 = \pi \times 2^2/4 = 3.142\ m^2$
$u = Q/A = 10/ 3.142 = 3.18\ m/s$

Bernoulli

$h_A + z_A + u_A^2/2g = h_B + z_B + u_B^2/2g + \text{Losses}$
$0 + 80 + 0 = h_B + 0 + 3.18^2/2g + \text{Losses}$
$80 = h_B + 0.52 + \text{Losses}$



Pipe loss $= f Lu^2/2gd$
$h_f = 0.01 \times 420 \times 3.18^2/2g \times 2 = 1.082\ m$

$h_B = 80 - 0.52 - 1.082 = 78.4\ m \quad p = \rho gh = 998 \times 9.81 \times 78.4 = 0.767 \times 10^6\ Pa$

The following answers may be gleaned from the examiners report.

The pipe should be designed for twice the static head. The flow should be bypassed around the valve when closed as the water still needs to be removed from the reservoir.

If the design pressure is twice the static head then the pressure rise is equivalent to 80 when the valve is closed so $\Delta p = 80 \times 9.81 \times 998 = 783\ kPa$

GRADUAL CLOSURE

$\Delta p = 783 \times 10^3 = \rho uL/t = 998 \times 3.142 \times 420/t \quad t = 1.87\ s$

The examiner says allow 6 s for closure and 2 s for opening.

Clearly there is more to the solution than this