Hydrotechnical calculation for Outlet piping

Outlet pipe:
It is used to drain excess water from the dam, if necessary, to empty the dam. The outlet pipe is at the deepest point. The drain pipe they lead outside the dam. Or the drain pipe they lead directly into the base of the dam.
Each outlet has at least two valves: operational and revision. To achieve complete safety, an emergency valve is placed, which is permanently in the open position and is designed to quickly close the piping in the most critical cases. Trying to construct an operating valve is to achieve the best mechanical and hydraulic properties not only in the fully open position but also in all positions. Machine requirements are mainly: a simple construction of a fully secure valve control. Hydraulically, the water flow at all valve positions should be smooth and undisturbed with the least pressure drop, and to avoid cavitation phenomena and associated unpleasant shocks and shocks to make the shape of the outlet water stream contribute to the destruction of the energy flowing out of the water stream and achieved a practical watertight valve in the closed position.

Pipeline flow:
$Q = \mu F \sqrt{2 g h_0};\ d \leq d_p$

Q	pipeline flow	[m^3/s]
μ	output coefficient	[]
F	the flow area of the output hole	[m^2]
g	gravitational acceleration	[m/s^2]
h_0	rated net head (hydrostatic pressure)	[m]
d	diameter of the output hole	[m]
d_p	pipe diameter	[m]

Output coefficient:
$$\mu = \frac{1}{\sqrt{1 + \sum \xi}}$$

μ	output coefficient	[]
$\Sigma\ \xi$	sum of partial pressure losses	[]

The flow area of the output hole:
$$F = \frac{\pi d^2}{4}$$

F	the flow area of the output hole	[m^2]
d	diameter of the output hole	[m]

Sum of partial pressure losses:
It is the sum of all losses in the outlet, from the trash rack, in the inlet to the pipeline, the friction of water from the wall, the water passage through the valve etc.

Example 1:
We have to determine the capacity of the outlet steel pipe with the following parameters: rated net head (hydrostatic pressure) h_0 = 24m; diameter of the output hole (operational valve diameter) d = 2m; steel pipe length l = 22m; loss in trash rack ξ_1 = 0,1; loss in the inlet ξ_2 = 0,25; loss in the revision valve ξ_3 = 0,24; loss in operational valve ξ_4 = 0,67.

Loss of water friction on pipe walls:
$$\xi_5 = \lambda * \frac{l}{d} = 0{,}026 * \frac{22}{2} = 0{,}286[\,]$$

Sum of partial pressure losses:
$$\sum \xi = \xi_1 + \xi_2 + \xi_3 + \xi_4 + \xi_5 = 0{,}1 + 0{,}25 + 0{,}24 + 0{,}67 + 0{,}286 = 1{,}546[\,]$$

The flow area of the output hole:
$$F = \frac{\pi d^2}{4} = \frac{\pi 2^2}{4} = 3{,}142[m^2]$$

Output coefficient:
$$\mu = \frac{1}{\sqrt{1 + \sum \xi}} = \frac{1}{\sqrt{1 + 1{,}546}} = 0{,}627[\,]$$

Pipeline flow:
$$Q = \mu F \sqrt{2gh_0} = 0{,}627 * 3{,}142 * \sqrt{2 * 9{,}81 * 24} = 42{,}724[m^3/s]$$
$$d \le d_p; 2 \le 2 \rightarrow OK$$

Example 2:
We have to determine the capacity of the outlet steel pipe with the following parameters: rated net head (hydrostatic pressure) h_0 = 24m; diameter of the output hole (operational valve diameter) d = 2m; steel pipe length l = 22m; loss in trash rack ξ_1 = 0,1; loss in the inlet ξ_2 = 0,25; loss in the revision valve ξ_3 = 0,24; loss in operational valve, which is open to 50% stroke ξ_4 = 1,38.

Loss of water friction on pipe walls:
$$\xi_5 = \lambda * \frac{l}{d} = 0{,}026 * \frac{22}{2} = 0{,}286[\,]$$

Sum of partial pressure losses:
$$\sum \xi = \xi_1 + \xi_2 + \xi_3 + \xi_4 + \xi_5 = 0{,}1 + 0{,}25 + 0{,}24 + 1{,}38 + 0{,}286 = 2{,}256[\,]$$

The flow area of the output hole:
$$F = \frac{\pi d^2}{4} = \frac{\pi 2^2}{4} = 3{,}142[m^2]$$

Output coefficient:

$$\mu = \frac{1}{\sqrt{1+\sum \xi}} = \frac{1}{\sqrt{1+2{,}256}} = 0{,}554[\,]$$

Pipeline flow:

$$Q = \mu F\sqrt{2gh_0} = 0{,}554 * 3{,}142 * \sqrt{2 * 9{,}81 * 24} = 37{,}780[m^3/s]$$

$$d \le d_p; 2 \le 2 \rightarrow OK$$

Example 3:

We have to determine the capacity of the outlet steel pipe with the following parameters: rated net head (hydrostatic pressure) h_0 = 24m; diameter of the output hole (operational valve diameter) d = 2m; steel pipe length l = 22m and diameter d_p = 3m; loss in trash rack ξ_1 = 0,1; loss in the inlet ξ_2 = 0,25; loss in the revision valve ξ_3 = 0,24; loss in operational valve ξ_4 = 0,67. The revision and operating valve is located at the end of the outlet about diameter 2m. before the revision valve, there is a tapered pipe that has a loss ξ_5 = 0,15

Loss of water friction on pipe walls:

$$\xi_6 = \lambda * \frac{l}{d_p} = 0{,}026 * \frac{22}{3} = 0{,}191[\,]$$

Sum of partial pressure losses:

$$\sum \xi = \xi_1\left(\frac{d^2}{d_p^2}\right)^2 + \xi_2\left(\frac{d^2}{d_p^2}\right)^2 + \xi_3 + \xi_4 + \xi_5\left(\frac{d^2}{d_p^2}\right)^2 + \xi_6\left(\frac{d^2}{d_p^2}\right)^2$$
$$= 0{,}1\left(\frac{2^2}{3^2}\right)^2 + 0{,}25\left(\frac{2^2}{3^2}\right)^2 + 0{,}24 + 0{,}67 + 0{,}15\left(\frac{2^2}{3^2}\right)^2 + 0{,}191\left(\frac{2^2}{3^2}\right)^2$$
$$= 1{,}046[\,]$$

The flow area of the output hole:

$$F = \frac{\pi d^2}{4} = \frac{\pi 2^2}{4} = 3{,}142[m^2]$$

Output coefficient:

$$\mu = \frac{1}{\sqrt{1+\sum \xi}} = \frac{1}{\sqrt{1+1{,}046}} = 0{,}699[\,]$$

Pipeline flow:

$$Q = \mu F\sqrt{2gh_0} = 0{,}699 * 3{,}142 * \sqrt{2 * 9{,}81 * 24} = 47{,}654[m^3/s]$$

$$d \le d_p; 2 \le 3 \rightarrow OK$$

Literature:

Bohuslav Matocha: Strojírenství: Provozní uzávěry základových výpustí přehrad 1952
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