

REDUCTION OF ENERGY EXPENSES BY AIR RELEASE FROM PIPELINES

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This paper deals with analysis of energy losses related to large undissolved air pockets in pipelines for water transportation. An approximate method for estimation of the reduction energy expenses providing by air release valves is developed and introduced in the practice of the valve producing works A.R.I. (Israel).

Location and Size of Air Pockets

The air pockets may be located at picks of a pipeline, in descending stretches of it and at the points of the inclination changes^(1,4). The velocities in the pipelines are very often not sufficiently high for expelling of large air pockets and a great number of air release valves is used for this aim in the water supply systems^(1,5). The energy expenses reduction provided by the air valves may be estimated if the hydraulic resistance decrease due to the air pocket release is known. The extreme case, in which all cross-section of the descending pipeline stretch is filled by air and in which water flow is completely interrupted, was analyzed by Lescovich⁽¹⁾ (see scheme a, Fig. 1).

We shall analyze more common cases such as water flow in a descending stretch in which the upper part of the cross-section is filled by air (scheme b), and the case in which the air pocket is located near the pick of the pipeline (scheme c). The method for prediction of the actual sizes of the large air pockets has not yet been developed, and therefore, it is reasonable to find estimations of the losses for both cases represented by schemes b and c.

Losses Distributed Along Descending Stretch

The sum of hydraulic losses distributed along descending stretch (scheme b) are proportional to the gradient of the hydraulic head. This gradient may be estimated as in the case of the open steady flow of constant depth:

$$J_{of} = i = \sin\theta \quad (1)$$

where,

J_{of} = hydraulic head gradient for the open flow

θ = angle of the pipeline stretch inclination to horizontal

The air pocket may remain in the descending stretch, in the case in which velocity is lower than critical velocity, necessary for removing the pocket. If the air pockets are completely released through air valves, the gradient is:

(2)

where,

u = flow velocity

d = diameter of pipe orifice

c = Chezy's coefficient

and the ratio of the sum losses:

(3)

where,

h_{rof} = sum losses in the case of open flow

h_r = sum losses in the case of air pocket absence

The increase of the power which is necessary to provide flow rate through the stretch is:

$$\Delta N = Ag\rho_w u (h_{rof} - h_r) \quad (4)$$

where,

A = cross section of pipeline orifice

g = acceleration of gravity

ρ_w = density of water

Equations (3) and (4) are sufficient for an estimation of the possible power decrease providing by air release from the stretch. The relative power decrease (%) for the pump with efficiency coefficient η_p is:

(5)

Losses Related to the Air Pocket Location at the Pick of the Pipeline

An estimation of the head losses related to the air pocket at the pick of the pipeline (scheme c) may be obtained assuming that these losses appear mainly due to decrease of the water velocity after narrow cross-section 1-1. These hydraulic losses may be expressed in the form:

$$h_p = \zeta (u_n - u)^2 / 2g \quad (6)$$

where,

u_n = velocity in narrow cross-section

ζ = coefficient

The local head losses due to the sudden decrease of velocity may be calculated at $\zeta = 1$ (the upper estimation) and actual coefficient must be in interval:

$$0 < \zeta < 1$$

An estimation of the flow velocity u_n may be obtained assuming that the air pocket may increase narrowing the pipe cross-section to the moment when:

(7)

where,

u_c = critical flow velocity which is necessary for the removal of air pocket from pipeline orifice.

The relative power decrease (%) may be calculated as in the previous section:

(8)

An example of estimation of the relative power decrease, which can be obtained, providing air release from the pipeline (Fig. 1,a) follows.

Initial data: length of the descending stretch $l_d = 85$ m, $\theta = 5^\circ$ and internal pipe diameter $d = 1$ m (cross-sectional area $A = 0.785$ m²), Chezy's coefficient, $C = 56.67$ m^{1/2}/s, coefficient of the local energy losses $\zeta = 0.1$, velocity of water $u = 1.274$ m/s, power of the pump drive $N = 750$ kw and pump's efficiency $\eta = 0.85$, acceleration of gravity $g = 9.81$ m/s² and water density $\rho_w = 998$ kg/m³.

Hydraulic losses in this case: $h_r = J l_d = 4u^2 l_d / c^2 d = 0.172$ m, $i = \sin\theta = 0.0871$ and substituting the data in eq. (5) provides: $\delta_N = 11.1\%$ which is an estimation of the losses due to the long air pocket located in the upper part of the descending stretch.

An estimation of the losses due to the short air pocket located at the beginning of the descending stretch may be calculated using eq. (8): $\delta_N = 0.015\%$.

Using the calculated value of relative power decrease, time of pumps work and known energy prices, we can calculate energy expenses related to the large air pockets in the pipelines. Obtained equations enable to estimate the energy expenses reduction for water transportation through pipelines provided by air release valves. These estimations may be used for an effective selection and location of these valves during design phase of the pipeline project.

REFERENCES

1. Lescovich J.E. (1972) Locating and sizing of air release valves. *Journal of AWWA*, **64** (7), 457-461.
2. Tarshish M.S. (1996) Transients in a well pump-pipeline hydraulic system with air release valve. Proc. of 26th Israel Conference on Mechanical Engineering, 325-327.
3. Van Vuuren S.J. (1995) Valves to control air in pipeline design. *Water Management International*, 27-30.
4. Wisner P.E. et al. (1975) Removal of air from water lines by hydraulic means. *Journal of Hydraulic Division, ASCE*, 243-257.
5. Anon (1988) Water supply accessories. A.R.I., Kibbutz Kfar Haruv, Israel, 2-26.