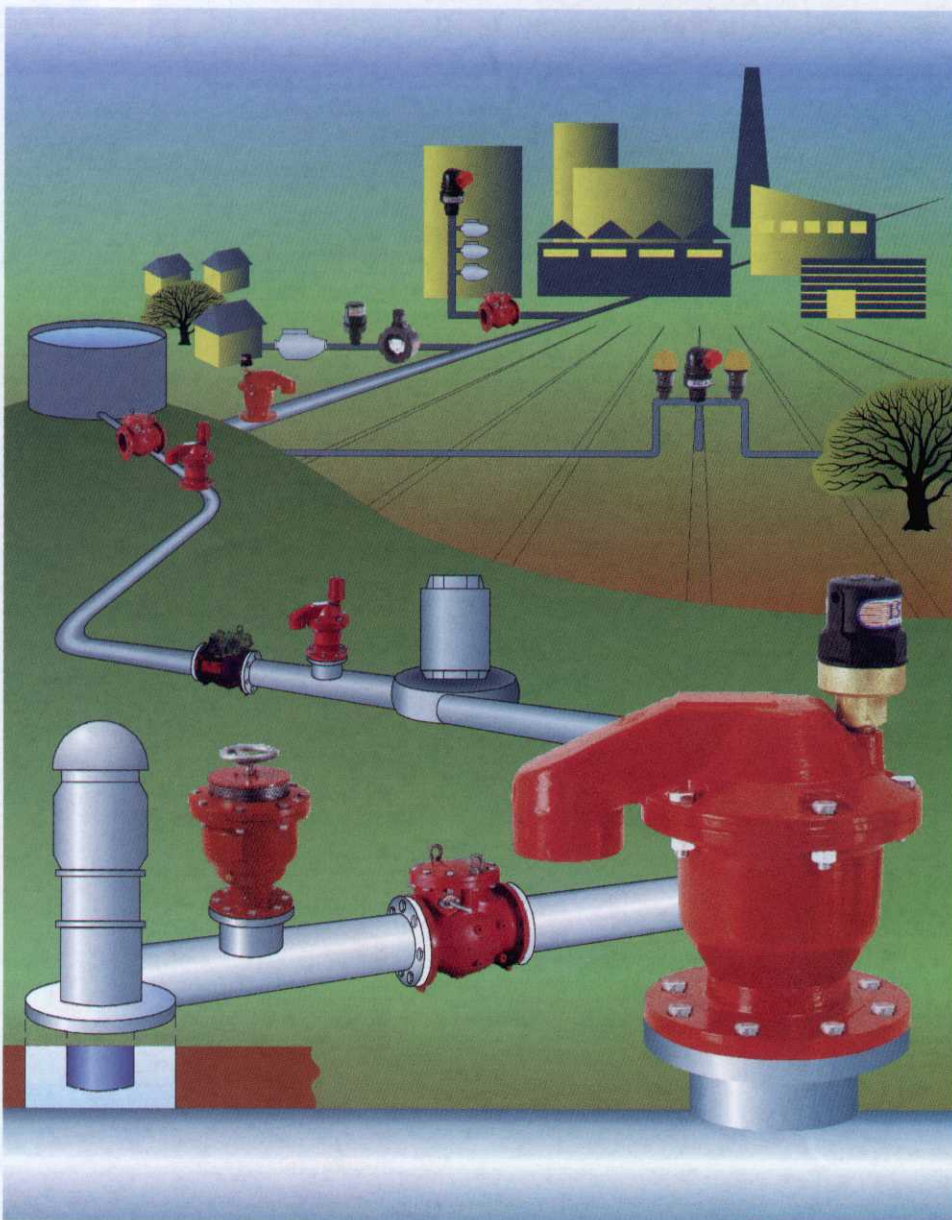# Pipeline air release
reduces energy demand

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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 in energy expenses provided by air release valves is developed and introduced in the practice of the valve manufacturer A.R.I. (Israel).

Location and Size of Air Pockets

The air pockets may be located at peaks of a pipeline, in descending stretches of it and at the points of inclination changes. The velocities in the pipelines are very often not sufficiently high for expelling large air pockets and a great number of air release valves are used for this purpose in water supply systems. 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 the whole cross-section of the descending pipeline stretch is filled by air (scheme a) and in which water flow is completely interrupted, was analyzed by Lescovich.

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 a peak 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) is proportional to the gradient of the hydraulic head. This gradient may be estimated in the case of the open steady flow of constant depth.

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

where J_{of} = hydraulic head gradient for the open flow
t = angle of the pipeline to horizontal

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

$$(2) \quad J = \frac{4u^2}{c^2 d}$$

where
u = flow velocity
d = diameter of pipe orifice
c = Chezy's coefficient

and the ratio of the sum of losses:

$$(3) \quad \frac{h_{rof}}{h_r} = \frac{J_{of}}{J} = \frac{idc^2}{4u^2}$$

where
h_{rof} = sum of losses in the case of open flow
h_r = sum of losses in the case of air pocket absence

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

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

where
A = cross-sectional area of pipeline orifice
g = acceleration of gravity
b_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 C_p is:

$$(5) \quad \delta_N = \frac{100\Delta N}{C_p N_p} = \frac{100 \, Agb_w \, uh_r}{C_p N_p} \left(\frac{idc^2}{4u^2} - 1 \right) \%$$

Losses related to the air pocket location at the peak of the pipeline

An estimation of the head losses related to the air pocket at the peak 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:

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

where
u_n = velocity in narrow cross-section
k = coefficient of hydraulic losses

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

$$0 < k < 1$$

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

$$(7) \quad u_n = u_c = \\ = SQRT \, (gd) \, (0.25 \times SQRTSint + 0.825)$$

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:

$$(8) \\ \delta_N = \frac{100\Delta N}{C_p N_p} = \frac{50Ab_w uk}{C_p N_p} \left[SQRT(gd) \text{----}> \right. \\ \left. (0.25 \times SQRT(sint) + 0.825) - u \right]^2 \%$$

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, t = 5° 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 k = 0.1, velocity of water u = 1.274 m/s, power of the pump drive N = 750 kw and pump's efficiency C_p = 0.85, acceleration of gravity g = 9.81 m/s² and water density b_w = 998 kg/m³.

Hydraulic losses in this case $h_r = Jl_d = 4u^2 l_d/c^2 d$ = 0.172 m, i = sin t = 0.0871 and substituting the data in eq. (5) provides: δ_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): δ_N = 0.015%.

Using the calculated value of relative power decrease, pumping duration and known energy prices, we can calculate energy expenses related to the large air pockets in the pipelines. Obtained equations enable us to estimate the energy cost saving 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.
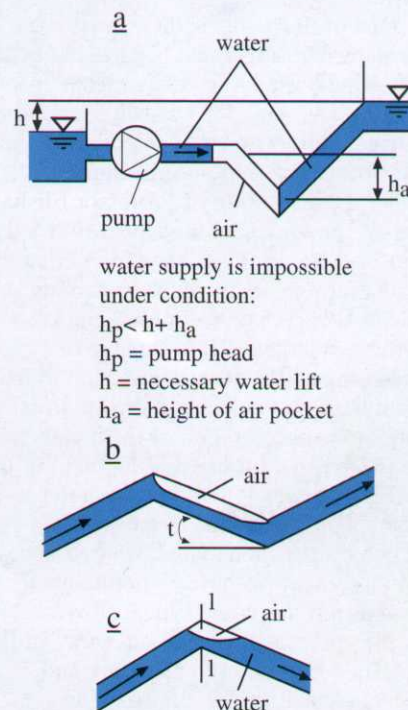

Fig. 1. Large air pockets in water supply pipeline

water supply is impossible under condition:
$h_p < h + h_a$
h_p = pump head
h = necessary water lift
h_a = height of air pocket

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