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Head of stock behind slice (head/jet and slice flow rate relationships)

Scope

The scope of this Technical Information Paper is to provide the relationship between head of stock behind the slice with either jet velocity or slice flow rate.

Safety precautions

No safety precautions have been specified for use with this technical information paper.

Content

Head and jet velocity

Jet velocity may be determined from the energy balance by measuring pressure between conditions at the pressure tap to those in the free jet.

For steady flow of an incompressible flow of uniform density and absence of shear stress work,

$$\left[\frac{p_1}{\gamma} + Ke_1 \times \frac{V_1^2}{2g} + z_1 \right] = \left[\frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 \right] + \Delta H_M + \Delta H_{L_{1-2}} \quad (1)$$

where:

- p = pressure, lb_f/ft^2 or N/m^2
- γ = specific weight of the fluid, lb_f/ft^3 or N/m^3
- Ke = kinetic energy flux correction factor (dimensionless)
- V = velocity, ft/s or m/s
- g = gravitational constant, equal to $9.81 \text{ m}/\text{s}^2$ or $32.17 \text{ ft}/\text{s}^2$
- z = elevation relative to a specified datum, ft or m
- ΔH_M = shaft work per unit weight of fluid flowing transmitted from system to the outside, $\text{ft} \cdot \text{lb}_f/\text{lb}_f$ or $\text{N} \cdot \text{m}/\text{N}$
- ΔH_L = loss of mechanical energy per unit weight of fluid flowing, called “headloss”, $\text{ft} \cdot \text{lb}_f/\text{lb}_f$ or $\text{N} \cdot \text{m}/\text{N}$
- Subscript 1 designates an upstream flow section.
- Subscript 2 designates a downstream flow section.

TIP Category: Automatically Periodically Reviewed (Five-year review)



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The derivation of this or a similar equation may be found in most basic fluid mechanics textbooks (e.g., see references 1, 2).

When the friction losses are negligible and there is no shaft work and if $Ke_1 = Ke_2 = 1$, Equation (1) becomes the one-dimensional Bernoulli equation, namely,

$$H = \frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 \quad (2)$$

where H is the total head. Taking the reference datum as the at the middle of the jet exiting from the headbox ($z_2 = 0$) and noting that gage pressure at section 2 is zero, an approximate relation for jet speed becomes

$$V_j = \sqrt{2gH} \quad (3)$$

where:

V_j = jet velocity
and H = total head upstream in the nozzle

or

$$V_j = K \sqrt{H} \quad (4)$$

where K is a constant, whose values are listed in Table 1 below. Note H is not just the pressure transmitter reading, but includes also velocity head and elevation head as well. For a first order estimation of jet velocity, the velocity head is often neglected, but the elevation head should be included. For more accurate and consistent jet velocity calculations, the velocity head should be included with adjustments for edge flow conditions (also see Note 5).

Table 1. Values of K

V	ft/min	ft/min	ft/min	m/min	m/min	m/min
H	in. H ₂ O	lb _f /in. ²	ft H ₂ O	m H ₂ O	mm Hg	kPa
K	138.9	731.0	481.3	265.7	31.0	84.9

Example 1

Estimate the jet velocity based on a headbox pond side manometer reading of 84.0 in. water column. The tap on the headbox pond side is located 4 inches above the centerline of the exiting jet.

If velocity head in the nozzle is neglected, then total head at the manometer tap, H , becomes

$$H = \frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = 84 + 0 + 4 \quad (\text{inches})$$

$$\begin{aligned} \text{Jet velocity} &= K \sqrt{H} \\ &= 138.9 \sqrt{88} \text{ ft/min} \\ &= 1303 \text{ ft/min} \end{aligned}$$