Technical Tips

Determination of Component Pressure Drops

Hays Fluid Controls provides information to allow the user to determine the pressure versus volumetric flow characteristics of our devices in two formats. The simplest and most prolific format is the Cv. Several device provided by Hays are not easily characterized by a Cv value are characterized by a loss factor. The purpose of this Tech Tip is to describe how to use these two factors and where each of these is applicable.

On strainer devices all data published by Hays is for a new, unclogged strainer. The variation in materials that clog a strainer makes it virtually impossible to predict pressure drops for clogged strainers. In system design it is recommended that a reasonable allowance be made for an additional restriction above that of the clean strainer.

The flow rate through a Mesurflo device can not be represented by a Cv or loss factor. The Mesurflo valve controls the flow through an active change in open area with pressure. In the operational range of a Mesurflo the flow is a constant. Neither Cv nor loss factor will represent this situation.

Cv

The literal definition of Cv is “The flow, in gallons per minute, of 60 °F water through the device at a 1 psi pressure drop across the device”. Sizing valves using a Cv value works very well for liquid flow in a single flow regime (Newtonian fluids in the laminar, transitional or turbulent region).

The definition of Cv above has been used for at least 50 years. This definition of Cv allows for very simple test equipment and procedures to determine the Cv for a device.

Any lab that had access to a means of controlling water flow, appropriate straight lengths of pipe with taps, a manometer (clear plastic tubing), a stopwatch and a calibrated volume (for example a 5 gallon bucket) could determine the Cv of a device with a reasonable level of accuracy. For exact highly repeatable values there are many standards defining a method of test for establishing this value (FCI, ISA, SEMASPEC amongst others have standards for this). All Hays published data is taken with a standard procedure utilizing lab quality equipment to ensure accurate results.

In the form of an equation for water flow (please refer to the end of this Tech Tip for symbols):

$$Q = C_V * \sqrt{\Delta P} \qquad (1)$$

For water at temperatures other than 60 °F or other fluids with similar viscosities:

$$Q = C_V * \sqrt{\Delta P * \left(\rho \middle/ \rho_w \right)} \quad (2) \quad \text{or} \quad \Delta P = \left(\rho_w \middle/ \rho \right) * \left(Q \middle/ C_V \right)^2 \quad (3)$$

As stated earlier this equation is accurate if the following conditions exist, the flow is of a Newtonian liquid, the flow rate falls in the turbulent flow regime and inlet and outlet tubes are of the same size. The data supplied by Hays is tested over the range of 0.5 to 9 ft/s in a schedule 40 pipe of the applicable inlet and outlet size. For all other cases a different correlation is required. A more detailed presentation of this topic is provided in the 2000 ASHRAE Handbook, Systems and Equipment Volume chapter 42 (chapter 41 in the 1996 volume).

Example 1:

A piping package is designed for a system that has a flow of 3 gpm of 50% ethylene-glycol/ 50% water at 40 °F, what is the contribution of the 2417 strainer to the pressure drop?

From the catalog the Cv for a ½" 2417 is 7.45. The density of the glycol-water solution is 67.47 lb/cu ft, the density of water at 60°F is 62.42 lb/cu ft, and the flow rate is given at 3 gpm. Therefore, equation (3) becomes:

$$\Delta P = \left(62.42 \middle/ 67.47 \right) * \left(3 \middle/ 7.45 \right)^2 = 0.15 \ \textit{psi}$$

Example 2:

A piping package is designed for a system that has a pressure of 0.5 psi available for the strainer when clean. The system uses a 50% ethylene-glycol/ 50% water at 40 °F, what is the flow rate that a 2417 strainer will allow at 0.25 psi?

From the catalog the Cv for a ½" 2417 is 7.45. The density of the glycol-water solution is 67.47 lb/cu ft, the density of water at 60°F is 62.42 lb/cu ft, and the flow rate is given at 3 gpm. Therefore, equation (2) becomes:

$$Q = 7.45 * \sqrt{0.25 * \left(62.42 \middle/ 67.47 \right)} = 3.58 \ \textit{gpm}$$

Loss Factor

The loss factor method of establishing the pressure – flow relationship allows a wider application than use of Cv values. This is used by Hays for hoses and pipes of varying length. For these the change in loss factor with length may be expressed as a linear expression of length. The equivalent value for Cv would be decreasing with length following a fairly complex equation.

The loss factor method is derived from the energy equation for steady one dimensional flow (reference chapter 2 of the ASHRAE Handbook Fundamentals).

$$\frac{P_i}{\rho} + g * z_i + \frac{1}{2} * V_i^2 = \frac{P_o}{\rho} + g * z_o + \frac{1}{2} * V_o^2 + \frac{k}{2} * V_X^2 \qquad (4)$$

where X is the reference for the smaller of the inlet or outlet fitting. Since V=Q/A and Z_0 and Z_1 for a typical HVAC device are almost identical, this equation is usually changed into

$$P_i - P_o = \Delta P = \frac{K * \rho * Q^2}{2 * A^2} \qquad (5)$$

The loss through a hose section complete with fittings is a combination of the pressure drops from the barb fittings at the inlet and outlet and the losses from the friction within the hose.

The losses due to the expansion and contraction through the inlet and outlet fittings are proportional to the area ratio of the inlet and outlet of the barb at the ends of the hose. Since the volumetric flow is conserved through the hose the loss factor for the two barbs may be expressed as:

$$K_{barb} = K_{\exp,inlet} + K_{cont,inlet} + K_{\exp,outlet} + K_{cont,outlet}$$

The losses through the hose may be expressed as:

$K_{hose} = \frac{f * L}{D}$ or $K_{hose} = C_1 * L$

Examination of the above terms will show that as diameter increases the Loss factor will decrease with diameter. This effect will be even more pronounced since the friction factor also decreases with increasing diameter.

Once again this may be combined with the loss factors from the barb as follows:

$$K_{hose} = K_{barb} + C_1 * L = C_2 + C_1 * L$$

The resulting expression for pressure drop through the hose will be:

$$\Delta P = \left(\frac{\rho * Q^2}{2 * A^2} \right) * \left(C_2 + C_1 * L \right) \qquad (6)$$

The Hays catalog provides a simplified version of this equation. Setting the following equivalencies:

$a = \frac{C_2 * \rho_w}{2 * A^2}$ (11) and $b = \frac{C_1 * \rho_w}{2 * A^2}$ (7)

Equation (8) then becomes:

$$\Delta P = Q^2 * \left(a + b * L \right) * \left({}^{\rho}\!/_{\rho_w} \right) \qquad (8)$$

While this form makes the constants a and b have dimensions it simplifies calculation sufficiently to warrant acceptance.

The data provided by Hays is based on test of hoses held straight. Pressure drop of the hose will increase when the hose is bent. There are several reasonably accurate correlations for the effect of bends on pipe and tubing pressure drops that provide effective K factors as a function of bend radius. These K factors may be added to those in the catalog once converted to the correct dimensions (via equation (6)).

Example 5:

A hose kit is designed for a system that has a flow of 3 gpm of 50% ethylene-glycol/ 50% water at 40 °F, what is the contribution of a ½”x24” hose to the pressure drop?

From the catalog the loss factor expression for the ½" hose is $\mathrm{K} = 0.00147 * \mathrm{L} + 0.0418$. *The hose is 24" long. The density of the glycol-water solution is 67.47 lb/cu ft, the density of water at 60°F is 62.42 lb/cu ft, and the flow rate is given at 3 gpm.*

Therefore, equation (13) becomes:

$$\Delta P = 3^2 * (0.00147 * 24 + 0.0418) * \left({}^{62.42}\!/_{67.47} \right) = 0.64\, psi$$

Note:
A small algebraic manipulation will yield an expression relating Cv to K for a hose as follows:
This provides a way to relate the two types of values. The loss factor is used within Hays since the result is that a larger value of K will yield a smaller flow rate at a given pressure (using two lengths of garden hose will reduce the flow out of a sprinkler). This format makes it easy to determine the pressure drop for any reasonable length of hose. Determination of a Cv value for a hose is cumbersome. The Cv value for a hose will go down as the length of the hose increases.

Symbology:

Symbol	**Description**	**Units**
Q	volumetric flow through device	gpm
Cv	flow coefficient for a device	gpm/sqrt(psi)
ΔP	pressure drop across the device	psi
ρ	density of the fluid flowing through the device	Lb/ft^3
ρ_w	density of water at 60 °F, 14.696 psia, approx. 62.42	Lb/ft^3
P_i	inlet pressure to the device	psi
z_i	height of the device inlet above a reference plane	Feet
G	acceleration due to gravity	ft/s^2
V_i	velocity at the inlet of the device	ft/s
P_o	pressure at the outlet of the device	psi
z_o	height of the device above a reference plane	feet
V_o	velocity at the outlet of the device	ft/s
V_x	velocity at the inlet to the device	ft/s
K	**total loss factor for a device**	**Dimensionless**
K_{barb}	**total loss factor for flowing through a hose barb**	**Dimensionless**
$K_{exp,\ inlet}$	**loss factor due to the expansion of fluid coming out of a hose barb on the inlet side of a device**	**Dimensionless**
$K_{cont,\ inlet}$	**loss factor due to the contraction of fluid coming out of a hose barb on the inlet side of a device**	**Dimensionless**
$K_{exp,\ outlet}$	**loss factor due to the expansion of fluid coming out of a hose barb on the outlet side of a device**	**Dimensionless**
$K_{cont,\ outlet}$	**loss factor due to the contraction of fluid coming out of a hose barb on the outlet side of a device**	**Dimensionless**
K_{hose}	**total loss factor due to all contractions and expansions in the inlet and outlet fittings of a hose barb**	**Dimensionless**
K_{eff}	**loss factor due to the expansion of fluid coming out of a hose barb on the outlet side of a device**	**Dimensionless**
f	**friction factor, based on internal surface of hose, most hoses exhibit "rough" surfaces driving the friction factor to a fairly constant value**	**Dimensionless**
L	**length of hose**	**Inches**
D	**inside diameter of hose**	**Inches**
C_1	**constant representing friction factor divided by diameter**	
C_2	**constant representing the impact of the expansion contraction losses of the barb at the inlet and outlet of the hose**	
A	**cross sectional area for device, for a hose this is the area of a schedule 40 pipe used for testing at the inlet of the hose**	**$Inches^2$**
a	**constant representing the hose losses that do not vary with length**	

b	**constant that represents the hose losses that vary with length**	

Cv and K Factor Summary:

Model 2405

Inlet	**Outlet**	**C_V**
½"	**½"**	**6.63**
¾"	**¾"**	**6.71**
¾"	½"	6.45
1"	1"	5.94
1"	¾"	6.02
1"	½"	6.04

Model 2406

Inlet	Outlet	C_V
½"	½"	6.23
¾"	½"	6.12
1"	½"	6.11

Model 2407

Inlet	Outlet	C_V
¾"	½"	8.52
¾"	¾"	14.37
¾"	1"	20.49
¾"	1¼"	21.16
1"	½"	8.10
1"	¾"	12.24
1"	1"	14.93
1"	1¼"	19.85
1¼"	½"	7.80
1¼"	¾"	12.67
1¼"	1"	15.10
1¼"	1¼"	14.85
1½"	¾"	11.98
1½"	1"	13.25
1½"	1¼"	15.07

Model 2417

Inlet	Outlet	C_V
½"	½"	7.45
¾"	¾"	5.09

Y Strainers

Inlet	Outlet	C_V
½"	½"	4.48
¾"	¾"	15.54
1"	1"	23.87
1¼"	1¼"	34.29
1½"	1½"	51.62

½" Hose

Length	**K**
12"	**5.93E-02**
18"	**6.81E-02**
24"	7.69E-02
36"	9.45E-02
48"	1.12E-01

K=0.00147*X+0.0418

where X is length of hose

¾" Hose

Length	K
12"	1.08E-02
18"	1.16E-02
24"	1.23E-02
36"	1.39E-02
48"	1.54E-02

K=0.00128*X+0.00925

where X is length of hose

1" Hose

Length	K
12"	3.66E-03
18"	3.67E-03
24"	3.69E-03
36"	3.71E-03
48"	3.74E-03

K=2.4*10-6*X+0.00363

where X is length of hose

1¼" Hose

Length	K
12"	7.44E-04
18"	7.74E-04
24"	8.04E-04
36"	8.64E-04

K=5*10-6*X+0.000684

where X is length of hose

1½" Hose

Length	K
12"	2.67E-04
18"	3.13E-04
24"	3.58E-04
36"	4.49E-04
48"	5.40E-04

K=7.57*10-6*X+0.000176

where X is length of hose