

## Theory

All manual balance valves on the market today have two functions, flow regulation by a valve or restrictor and flow measurement. The flow measurement function is used to adjust the position of the valve portion to provide the required flow at a given pressure. Many of the manual balance valves on the market today consist of a valve with an indicator showing position. This position is then compared to a chart to determine a value for the flow coefficient (CV) and the flow is determined based on this value. These valves do provide an ability to balance a system. They suffer from difficulty in use and higher than necessary system pressure drops. The Manual Balance valve simplifies the user's process by providing only a constant value for the CV and due to its design minimizes the pressure drop penalty on the system.

The Manual Balance valve is a Venturi style device. The pressure measurements across the Venturi do not represent the normal pressures measured in the system. The pressures measured across the Venturi are actually higher than the drop in pressure across the entire device. Since the power consumed in pumping is proportional to system pressure drop a Venturi style meter can help to reduce system operating costs.

The basis for the design of a venturi style meter is the drop in pressure that occurs when a fluid is accelerated. Mathematically the energy equation, sometimes referred to as Bernoulli's equation, expresses the relation between velocity and pressure as follows (including only the applicable terms):

$$\frac{P_1}{\rho} + \frac{1}{2}V_1^2 = \frac{P_2}{\rho} + \frac{1}{2}V_2^2 + \frac{k_{L1-2}}{2}V_2^2$$

Where:

$P_1$  is the pressure at station 1

$P_2$  is the pressure at station 2

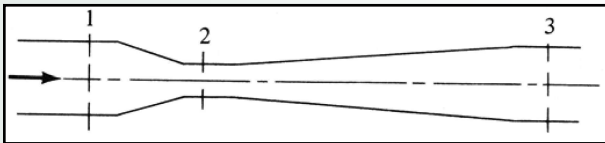
$\rho$  is the density of the fluid

$V_1$  is the velocity at station 1

$V_2$  is the velocity at station 2

$k_{L1-2}$  is the loss factor between station 1 and 2 (negligible for 1 to 2)

The cross section of a typical Venturi is shown below:



Applying the energy equation to this Venturi will give a great deal of insight. At the entrance, station 1 above, the fluid enters at a low velocity and high pressure. The upstream tap measures the fluid pressure at this location. The cross section is reduced to the minimum at section 2. Since there is less area for the flow the velocity of the flow at station 2 must be higher than at station 1. When this happens in order for the energy at station 2 to be the same as at station 1 the pressure must drop. The low pressure tap on a Venturi is placed at station 2. This lowering of the pressure provides a large pressure reading that can be converted to a flow rate. After the fluid passes through station 2 the cross section of the fluid passage is gradually increased such that no

separation of the flow from the sides of the passage will occur. This condition is held as long as possible. Station 3 represents the full diameter of the pipe. The energy equation may also be written between stations 2 and 3 as follows:

$$\frac{P_2}{\rho} + \frac{1}{2}V_2^2 = \frac{P_3}{\rho} + \frac{1}{2}V_3^2 + \frac{k_{L2-3}}{2}V_3^2$$

This time the fluid will start out in station 2 with a low pressure and high velocity. As the cross section opens up the velocity is reduced. As the velocity goes down the pressure increases to maintain a constant level of energy. The increase in pressure is referred to as pressure recovery. Pressure recovery only occurs when the angle of the expansion between stations 2 and 3 is 15° or less. For angle greater than 15° the loss factor,  $k_{L2-3}$ , is proportional to the diameter ratio raised to the fourth power.

It is a result of the existence of an expansion section that gives the Venturi a significantly lower impact on system pressure drop compared to competitive meters. An examination of most competitive meters will show that the end of the small cross section expands directly into a larger area imparting a major loss to the fluid stream.

## Application

Simplified versions of the equations in the theory section above are used for practical applications of the Venturi. The CV equation relates the flow through a device to the pressure drop. The equation is expressed as follows:

$$Q = C_v \sqrt{\Delta P}$$

Where:

$\Delta P$  is the pressure difference measured in psi

$Q$  is the flow rate of fluid in gpm

$C_v$  is the flow coefficient of the valve

Two values for  $C_v$  are available for the Venturi.

The Venturi  $C_v$  ( $C_{v, \text{Venturi}}$  or just  $C_v$ ) relates the flow through the valve to the pressure difference measured across the valve ports. This  $C_v$  is used in the field balancing a distribution to calculate flow.

The recovered  $C_v$  ( $C_{v, \text{Recovered}}$ ) is used to determine the impact on system pressure caused by having the Venturi in the line. There are no pressure ports at which this pressure can be measured except in a test lab. This value is used by an engineer to determine the pressure drop in a flow distribution system.

For the best accuracy it is recommended that the installation of a clean, smooth straight section of pipe upstream of the valve ten times the internal diameter and downstream for five internal diameters of the pipe be made. The Venturi will retain accuracy without the straight inlet and outlet sections provided that a smooth continuous flow of fluid is upstream of the valve.

## Use with fluids other than water or differing temperatures

The Venturi may be used with fluids other than water at temperatures between 33°F and 225°F. Fluids must be compatible with brass and EPDM to not damage the Venturi. To determine the flow of fluids other than water use this modified version of the CV equation:

$$Q = C_v \sqrt{\frac{\Delta P}{s_G}}$$

Where:

$\Delta P$  is the pressure difference measured in psi  
Q is the flow rate of fluid in gpm  
 $C_v$  is the flow coefficient of the valve  
 $s_G$  is the specific gravity of the fluid used at the condition during measurement

For example a 10015309 Venturi ( $C_v=0.56$ ) used with a 30% Propylene Glycol and Water mixture ( $s_G=1.048$ ) at 70 °F and a 0.95 psi pressure drop would have a flow rate as follows:

$$Q = C_v \sqrt{\frac{\Delta P}{s_G}} = 0.56 * \sqrt{\frac{0.95 \text{ (psi)}}{1.032}} = 0.537 \text{ (gpm)}$$

The Reynolds number of the Propylene Glycol mixture at is 1,732, within the range of usefulness of the venturi as indicated by the chart. Therefore, this application will retain the specified accuracy.

## Alternate forms of the CV equation

A careful examination of the flow curves provided for the Mesurmeter will indicate that the lines representing flow are not quite parallel. The equations presented in this Technical Tip represent an industry norm for HVAC applications. Much more involved correlations for the flow of fluid through venturi's nozzles and orifices are used in laboratories where time is significantly less important than accuracy. An intermediate equation that offers a slight improvement in accuracy without too much additional complication has been used to develop these charts. That equation is:

$$Q = Z \left( \frac{\Delta P}{s_G} \right)^x$$

Where:

$\Delta P$  is the pressure difference measured in psi  
Q is the flow rate of fluid in gpm  
Z is the flow constant of the valve  
x is the flow exponent of the valve  
 $s_G$  is the specific gravity of the fluid used

The flow constants and exponents for the Venturi series are provided in the chart at the end of this Technical Tip.

## Range of applicability of $C_v$ data provided

The Venturi has been tested over a wide range of conditions. It is recommended that extrapolation to flow regimes in which the Venturi has not been tested be avoided.