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Control Valve Coefficient Testing

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***Abstract*- Control valves are playing a vital role in modern manufacturing process industries around the world. Properly selected control valve increases the efficiency, safety, profitability and ecology. The most common final control element in the process control industries is the control valve. Control valve coefficient describes the relation between flow passage and pressure drop across valve (Flow Capacity). Control valve flow test rig was designed in order to calculate practically the flow coefficient (K_V) by standards ANSI/ISA-75.02-1996 and ANSI/ISA-75.01-2002. This flow test rig used to verify the designed K_V. It was necessary to t the K_V equation for incompressible fluids to proceed with flow sensor selection. It is also described the electronic instrumentation for measuring flow, temperature and pressure difference. This work describes the operation of flow test rig, to determine K_V of control valves with incompressible fluid under the regulations established by standards. The results obtained are much encouraging and the accuracy of control valve coefficient is ±1%.**

***Index Terms*- Control valve coefficient, K_V.**

I. INTRODUCTION

In any process line, the control valve is typically the final control part used for controlling the process [2]. The stem position of valve is controlled by actuators, which is operated by electric and pneumatic signals. There are different types of control valves which are used to control process according to set points. To achieve the flow rate variation, various types of plugs and seats can be used, since control valve coefficient depends on seat area. In the year 1944, Masoneilan [1] [13] introduced the concept of control valve coefficient typically for liquid flows. Within a very short span of time this concept was accepted universally for determining valve capacity. Control valve coefficient gives the flow capacity of control valve. The value of control valve coefficient depends on the difference in pressure across the valve and flow passing through it. Superior value of C_V, indicates the highest flow rate. Control valves with different sizes but identical C_V, have same flow capacity [1].

The C_V for liquid flow is calculated as, the flow of water through control valve in gpm at 60 °F (288.7 K) and differential pressure is 1 PSI [6.89 kpa]. The KV is flow of water through control valve in m3/hr with differential pressure of 1 Bar across the valve [9].

The control valve coefficient can also be confirmed practically for different valve openings by using international standards.

The control valve flow test rig is designed to measure control valve coefficient (K_V), for various valve sizes having linear and equal percentage flow characteristics. Test rig conceived in order to determine experimentally flow coefficient. Process fluid is water (incompressible fluid). Design considerations are according to ANSI/ISA 75.02-1996 standard. It is necessary to select sensors properly.

Flow sensor selected for this test rig is electromagnetic flow meter. Temperature sensor is RTD (PT – 100) and DPT for the differential pressure across the control valve. All parameters interfaced with PC through data logger. Butterfly valve used for upstream and downstream throttling valve to maintain specified pressure difference across the control valve.

The measurement of K_V values of the valves for various opening percentages. This used to determine flow characteristics.

In section II, the details of control valve are mentioned. Control valve coefficient test rig is demonstrated in section III. Head losses in pipes and control valve testing are presented in section IV & V respectively. The results are mentioned in section VI.

II. CONTROL VALVE

Process Industry contains various control loops which designed to control pressure, level, flow and temperature within set point to get quality product. [2]
To minimize the disturbances in process loop and effect of load variables. The process is controlled within a desired set point. When all measurement and comparison of process variables is over there is necessary final control element to implement control strategy according to controller [2].
The series of 100 is the standard globe control valve with pneumatic or electric actuator, fitted with a plug. Valve body designed appropriately. Seats are screwed [9].

Figure 1. Control valve

Control valve characteristics:

A flow characteristic gives the variation of flow with respect to valve opening from fully close to fully open. There are two types of control valve characteristics Inherent flow characteristics and installed flow characteristics. In inherent flow characteristics pressure drop is constant weather in installed flow characteristics pressure drop varies with respect to flow. Vale characteristics depends on design of valve plug [4].

Flow Coefficient

CV: The valve flow coefficient, is the number of U. S. gallons per minute of water passes through control valve with a pressure drop of one psi [4].

K_V: This is defined as the flow of water through a control Valve in m3/hr with a differential pressure of 1 Bar through the Valve [9].

$$Kv = \frac{Q}{31.6}\sqrt{\frac{\rho}{\Delta P}}$$

$C_V = 1.17\ K_V$

Q=Flow rate (m3/h)
ρ = Density of the liquid (1000 kg/m3)
ΔP=Pressure drop across control valve (Bar)

III. CONTROL VALVE COEFFICIENT TEST RIG

A test rig was developed to determine practically control valve flow coefficient K_V. The process fluid is incompressible. The set up established under stated standards ANSI/ISA 75.02-1996

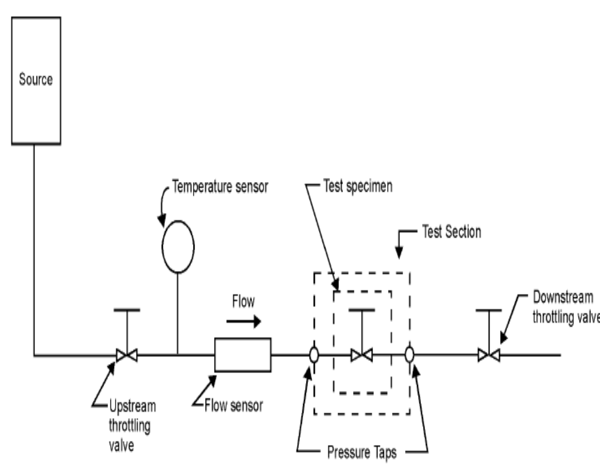

Figure 2. K_V Test Rig

Rather than experimentally measure K_V and calculate C_V, it is more straight forward to measure C_V directly. In order to assure uniformity and accuracy, the procedures for both measuring flow parameters and use in sizing are addressed by industrial standards. The currently accepted standards are sponsored by the Instrument Society of America (ISA) 75.02 in which measurement of C_V and related flow parameters is covered. The basic test system configuration is shown in Figure 2. Specifications, accuracies and tolerances are given for all hardware installation and data measurements such that coefficient can be calculated to an accuracy of approximately ±5 %. Fresh water at approximately 68° F circulated through the test valve at specified pressure differentials and inlet pressures. Flow rate, fluid temperature, inlet and differential pressure, valve travel and barometric pressure are all measured and recorded. This yields sufficient information to calculate the following sizing parameters.[7]

Flow measurement:
The flow sensor used was electromagnetic flow meter measuring instrument used was Magnetic flow meter. It gives average flow rate within an error not exceeding ±2% of the actual value. The resolution and reputability of the instrument shall be within ±0.5 %.

Pressure measurement:
DPT is used to measure differential pressure, error not exceeding ±2 % of actual value. Differential pressure transmitter used to measure differential pressure across the valve.

Figure3. Process Connection

Control Valve Coefficient Test Procedure:

1. Control Valve is installed without reducers. The flow velocity varies from 1 m/s to 3 m/s.
Deviation from standard requirements shall be recorded. ANSI/ISA-S75.02-1996

2. The variation of pressure is 1 to 2 bar.
3. Stem travel 0 % to 100 % to determine valve characteristics.

4. The following data shall be recorded:
- Valve travel is recorded.
- Pressure differential (Δp) across control valve measure by DPT
- Flow rate.
- Fluid inlet temperature
- Type and size of valve.
- Type of fluid [7].

Figure 4. Test Rig for control valve

IV. HEAD LOSSES IN PIPES

When velocity of flowing fluid changes. Either in magnitude or direction there is large scale turbulence generated in which a portion of the energy possessed by the flowing liquid is utilized which is ultimately dissipated as a heat and hence it is
Considered as loss. The change in magnitude of velocity of flow liquid due to change in crosses sectional area of the flow passage. The change in velocity of liquid may be either gradual or sudden and in both cases the energy is lost. But as compared with gradual change of velocity the loss of energy is much more when sudden changes of velocity takes place.[12]

1. Losses due to sudden enlargement
2. Losses due to sudden contraction.
3. Losses at the entrance of the pipe from large vessel.
4. Losses at exit from a pipe.
5. Losses due to obstructions in flow passage.
6. Losses due to gradual contraction and enlargement.
7. Losses in bends.
8. Losses in various pipe fittings.

Flow Velocity (m/s)	Pressure Drop (Bar)
1	0.015
2	0.039
3	0.075

Table 1: Pressure Loss for Line Size 100DN

V. CONTROL VALVE TESTING

After assembly of the control valve it under goes following testing.
1. Seat Leakage Testing.
2. Body Leakage Testing.

Seat leakage testing is done according to standard ANSI/FCI 70-2 as explained in Valve tested under leakage class IV.
Body leakage test done according to ANSI B 16.104. In this test valve is at full open state and water with high pressure through valve. Valve tested according to following pressure conditions. Table 2 shows the Body leakage testing details for materials WCB/WC6/WC9/WCC/P11/P12.

Class	150	300
Bar(PSI)	450(31)	1125(78)

Table 2: Body Leakage Testing

VI. RESULTS

Sr. No.	Flow Rate Q (m^3/hr)	Differential Pressure (Bar)	Control Valve Coefficient (Kv)
1	80.4375	1.399	68.05541
2	84.75	1.545	68.23204
3	60.375	0.792	67.89026
4	71.3437	1.084	68.57313
5	81	1.43	67.78443
6	66.1875	0.946	68.09941

Table 3. Result of K_V = 68

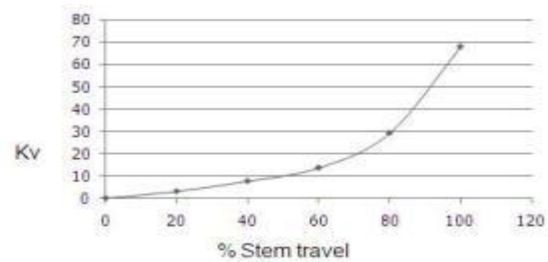

Figure 5. Equal Percentage Valve Characteristics for Kv=68

Sr. No.	Flow Rate Q (m^3/hr)	Differential Pressure (Bar)	Control Valve Coefficient (Kv)
1	94.59375	0.91	99.23267
2	100.5	1.03	99.09697
3	108.0938	1.151	100.8268
4	107	1.168	99.9167
5	115.125	1.323	100.1619
6	90.823	0.823	100.3127

Table 4. Result of K_V = 100

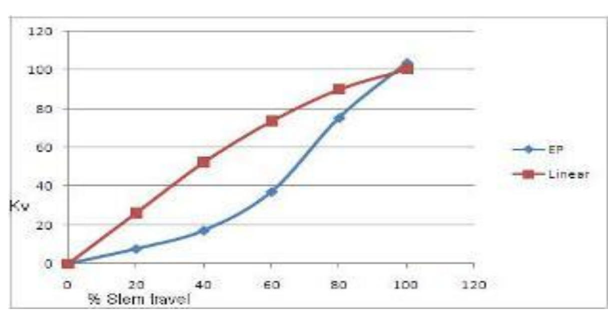

Figure 6. Equal Percentage and Linear Valve Characteristics for Kv=100

Sr. No.	Flow Rate Q (m^3/hr)	Differential Pressure (Bar)	Control Valve Coefficient (Kv)
1	63.28125	1.6	50.06428
2	58.3125	1.323	50.73348
3	37.6875	0.577	49.65035

Table.5 Result of K_V = 52 (Perforated Plug)

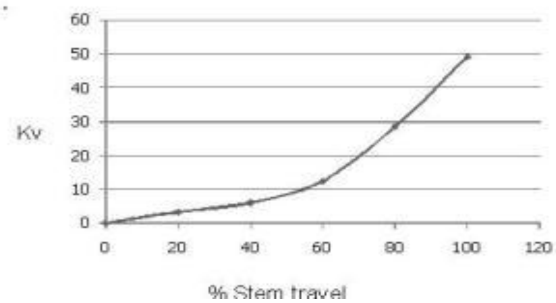

Figure 7. Equal Percentage Valve Characteristics for Kv=52(Perforated Plug)

VII. ACKNOWLEDGEMENT

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VIII. CONCLUSION

The flow capacity coefficient K_V was calculated practically by measuring flow rate and pressure difference across a valve and temperature measurements and verified against the designed

K_V. The accuracy of obtained control valve coefficient is ±1%. The measurement of Kv valve is at fully open position. In order to plot the characteristic curve, control valves tested with variable openings. For this testing the water flow rate is maximum 150 m3/hr with pressure up to 2 Bar, considering these ranges the control valve is tested.

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