CM3215 ChemE Transport Lab:

Characterization of a Pneumatic Control Valve

Pre-laboratory Assignment

Study and review the characterization of control valves (see Perry and Green, 2011). For more on control valves see Luyben and Luyben (1997, p75) and Stephanopoulos (1984, p253). Review ladder safety rules.

For the station you will be operating, obtain accurate calibration curves from the web archive (or from your previous lab results) for rotameter flow meter and the Honeywell DP meter. These calibration must be present in your laboratory notebook at the start of the lab; use complete referencing in your lab notebook for these calibration curves and for all information taken from the literature. Prepare data tables in your laboratory notebook for recording data. Prepare a safety section in your laboratory notebook detailing all safety issues associated with this laboratory. Search for "valve hysteresis" and write a description of this phenomena in your lab notebook.

Introduction

In a vast majority of chemical engineering processes the final control element is an automatic control valve, usually pneumatically actuated. Most control valves consist of a plug on the end of a stem that opens or closes an orifice opening as the stem is raised and lowered. The stem is attached to a diaphragm that is driven by instrument air pressure. The typical range of air pressure is 3 to 15 psig. The control valve *flow characteristic curve* is defined as the relationship between the flow through the valve and the valve position as the position is varied from 0% open to 100% open. There are two types of characteristics: *inherent* and *installed* flow characteristic. Inherent flow characteristic refers to the characteristic observed with constant pressure drop across the valve. Installed flow characteristic refers to the characteristic observed when the valve is in service with varying pressure drop and other changes in the system. We measure the installed flow characteristics of a pneumatic control valve.

Theory: See lecture.

Overall Objectives and Strategy: Evaluate the performance of FV-3 at your lab station and determine the trim of the valve. Address all other objectives as discussed in the assignment memo.

Experimental Procedure

Overall procedure:

1. Prepare the work station for isothermal water flow (see Procedure A in the appendix).
5 Set the ball valves to direct water flow through the pneumatic control valve FV-03.
6 Verify that the air-pressure regulator attached to the air line controlling FV-03 is set for no flow (see TA for instructions).
7 Set the flow through pneumatic control valve FV-03 to the desired rate (see Procedure B in the appendix).
8 Take data of Δp_{valve} across the control valve, water temperature, and flow rate on one or both flow meters.
9 Repeat steps 7 to 8 for different pneumatic valve settings—randomize your data trials. Take a total 25 data points of flow rate versus FV-03 stem position and controlling air pressure for flow rates spanning 0.9-3.8 *gpm* but do not exceed 90% on the rotameter. Take your data in such a way as to minimize systematic error. Remember that a true replicate is only obtained when you move away from an operating condition and subsequently return to that same operating condition. Note that approaching a valve position from above (a more open position) and from below (a more closed position) may not actually result in the same setting ("hysteresis").
10 Be sure to take all the data you need to address all your objectives as assigned in the Data Analysis section. There is

no excuse for not taking needed data. If in doubt about the need for a measurement or observation, note it in your notebook.

11 Shut down the station (see Shut Down procedure in the appendix).

Data Analysis

Determine the trim of the valve and address all objectives in the assignment memo from Dr. Morrison. See attached memo for instructions.

References

1. Luyben, Michael L. and William L. Luyben, *Essentials of Process Control*, McGraw-Hill, New York, 1997.
2. Morrison, Faith A, "Table of Analytical Functions," CM3215 Fundamentals of Chemical Engineering Laboratory, Department of Chemical Engineering, Michigan Technological University, Houghton, MI, www.chem.mtu.edu/~fmorriso/cm3215/AnalyticalFunctionsTable2.pdf, accessed 15Feb2011.
3. Perry, R.H. and D. W. Green, D.W., *Perry's Chemical Engineers' Handbook* 7th Edition (1997) Perry, R.H.; Green, D.W. (McGraw-Hill, New York, 1997). Online version available at: www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=48&VerticalID=0, accessed 24 Sept 2011.
4. Stephanopoulos, George, *Chemical Process Control: an Introduction to Theory and Practice*, Prentice-Hall, Englewood Cliffs, NJ, 1984.

Appendix: Procedures

Shut Down Procedure

1. Back off (loosen to close) the air pressure regulator until the regulator gauge shows zero pressure (0 psig) corresponding to no flow through FV-03. **Warning: do not loosen so far that the handle of the regulator comes off in your hand.**
2. Turn off pump P-01.
3. Close main air supply shut-off valve, AV-1.
4. Close valves WV-6 and WV-7.
5. Close valve WV-1.
6. Close WV-10 and drain T-02 by opening DV-02.
7. Dry off any wet surfaces with paper towels.
8. Turn off all the electronic devices and properly store them.
9. Turn off power to the Honeywell DP meter.

Procedure A: Preparation of the work station for isothermal water flow

1. Get an Omega DMM thermometer with a thermocouple and be ready to measure the temperature of water in T-02.
2. <u>When using the orifice meter for flow rate measurement</u>: Attach the leads for the Bourdon gauge (for high pressures) or Honeywell differential pressure meter (for up to 3.5 psi) to the pressure taps on either side of the orifice meter (FT-02) (red on high-pressure side, black on low-pressure side). Install a multi-meter to measure mA current signals from the DP meter.
3. <u>If tanks are not pre-filled</u>, fill tank T-02 as follows: make sure that Supply Tank (T-02) is empty and clean. If necessary, close the drain valve (DV-2). Close valve WV-11. Open water valve (WV-10) and fill T-02 with water. Once the tank is filled, a water control float valve will shut off water and keep water level constant.
4. Close valves WV-1, WV-2, and WV-3 and close needle valve WV-5.

5. Turn three-way valve WV-4 knob to direct the water flow through rotameter FI-01. Make sure that valves WV-11, WV-6, and WV-7 are closed. Adjust three-way valve WV-8 to direct water to tanks (not through the heat exchanger E-01). Turn three-way valve WV-9 knob to direct water to T-02.

Procedure B: Setting the flow through pneumatic control valve

1. Open the main air supply valve.
2. Adjust the stem position of FV-03 with the appropriate amount of air for the desired setting. To do this, adjust the position of the <u>*air pressure regulator*</u> that is installed in the air line to FV-03. **Note: air-pressure regulators are not "righty-tighty"; rather, when you right-hand advance regulators, more air flows.** Using a step ladder and the three point of contact rule, note the valve stem position for FV-03 (e.g. 5.5/8ths open). Note: The stem position of FV-03 is divided into 8 segments between 8/8ths closed and 0/8ths closed (Figure 1). Each notch corresponds to $1/8^{th}$ the distance. The longer notches are the ¼ markings
3. Allow the flow to stabilize for 1 minute and read the flow rate from the orifice meter and/or the rotameter. Measure pressure drop across the pneumatic control valve FV-03 with either the Honewell DP meter (low pressures) or the Bourdon gauge pair (high pressures), as appropriate. Note that two different pressure drops may be part of this experiment: the pressure drop across the orifice $\Delta p_{orifice}$ (gives flow rate after calibration) and Δp_{FV-03}, the pressure drop across FV-03 (to characterize the valve).
4. Record the pneumatic air pressure controlling FV-03.
5. Be sure to take all the data you need to address all the objectives in Dr. Morrison's memo (attached).

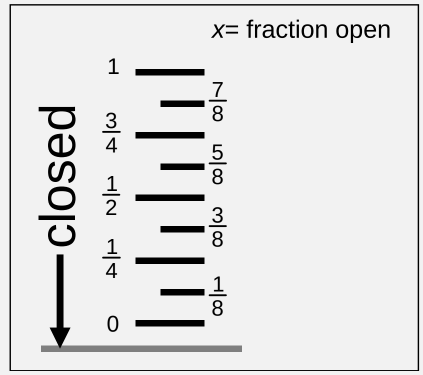

Figure 1: Schematic of the measuring scale on FV-03. The pointer moves up and down the scale depending on the fraction open of the valve.

Memo

To: CM3215 Lab groups

From: Dr. Faith Morrison

Subject: Characterize control valve FV-3 (Assignment 5)

Date: 17 February 2016

Please experimentally evaluate the performance of FV-3 at your lab station and determine the trim of the valve. Also, I need the following experimentally determined plots to support my funding request related to this valve (please make me look good).

1. Volumetric flow rate of water delivered (gpm) versus air pressure to operate pneumatic control valve FV-3 (in psi);
2. Valve stem position versus air pressure to operate FV-3 (in psi);
3. Valve flow coefficient C_v versus valve stem position x (fraction open) for FV-3;
4. Valve characteristic function $f(x)$ versus stem position x (fraction open).

You have two instruments that indicate volumetric flow rate, the orifice meter and the rotameter; for each data point, please use the more accurate one and justify your choice.

I have three final instructions:

- Use all available data on your graphs (do not average triplicates).
- Include a graph that supports your conclusion about the trim of the valve.
- Attach well organized raw data tables to your transmitted results.

I do not need a formal report; in fact I do not want too much text to read. Please get the plots and answers I have requested to me by Wednesday 2 March 2016, 2:05pm, in class. Thank you for your attention to this request.