CM3215

Fundamentals of Chemical Engineering Laboratory

Characterization of a Pneumatic Control Valve

Professor Faith Morrison

Department of Chemical Engineering
Michigan Technological University

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Lab: Characterization of a Pneumatic Control Valve

Note: There is no report due for this lab

Instead, there are some deliverables
(submit via memo of transmittal)

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Deliver your deliverables

Make what we ask for **easy to find**.

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.

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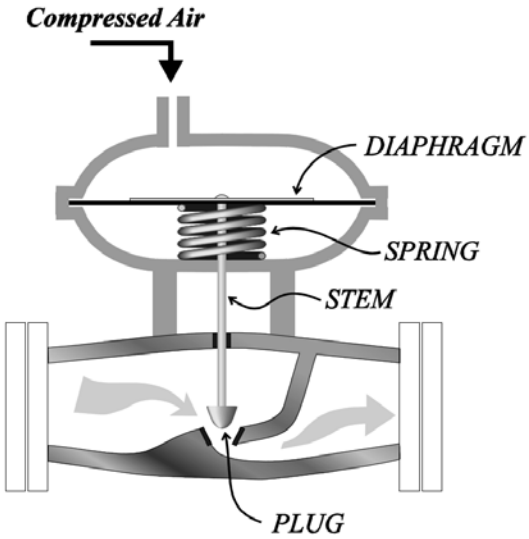
Design of a Pneumatic Control Valve

- Air-to-Close valve (AC)
- Design is fixed when manufactured
- On *failure* of instrument air, this valve will fail *open*
- Depending on safety considerations, choose air-to-close (AC; these fail open) or air-to-open (AO; these fail *closed*)



Courtesy of T. B. Co 2007

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The **valve flow coefficient** or sizing coefficient C_v is an experimentally determined quantity that allows engineers to compare flow capacities of valves of different sizes, types, and manufacturers.

$$C_V \equiv Q(gpm)\sqrt{\frac{SG}{\Delta p_{valve}(psi)}}$$

$$SG \equiv \frac{\rho(T)}{\rho_{water}(4^oC)}$$

Note: since this is an empirical correlation, **units are specified** and these units must be used

Values of valve flow coefficient C_V are provided by the manufacturer and can be used in determining pumping system head (assignment 5).

See: *Notes on Calculating Friction from Valve C_V*
http://www.chem.mtu.edu/~Efmorriso/cm3215/Cv_control_valves_2013.pdf

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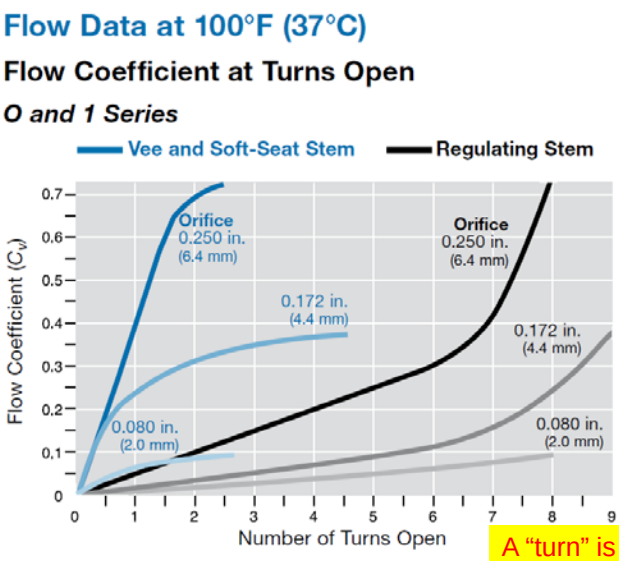
Example: Swagelok Integral Bonnet Needle Valves



A "turn" is 360° (full circle)

www.swagelok.com/downloads/webcatalogs/EN/MS-01-164.PDF

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To measure C_V(a function of valve position) for a given valve, we vary the valve position and measure both the friction-loss pressure drop across the valve and the flow rate through the valve.

$$C_v(x) \equiv \frac{Q(gpm)}{\sqrt{\frac{SG}{\Delta p_{valve}(psi)}}}$$

measure for FV03

Let x be the valve stem position;
when the valve is full open, $x=x_{max}$; usually $x_{max}=1$.

$$C_V(x) = C_V(x_{max}) f(x)$$
$$f(x) = \frac{C_V(x)}{C_V(x_{max})}$$

f(x) is the **valve characteristic function**

$$0 \le x \le x_{max} \quad \text{(usually } x_{max} \text{ is 1)}$$
$$0 \le f(x) \le 1$$

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Pneumatic Valve Position

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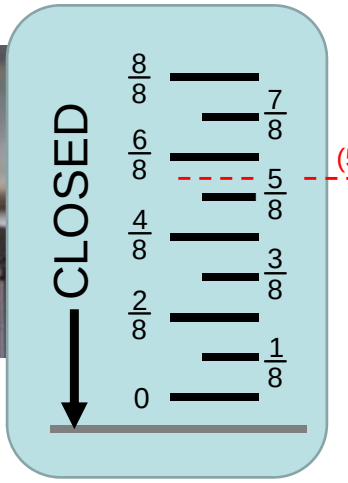
Note: The position of the valve stem is read from a set of notches based on 1/8th full scale per notch:

(compare to a 12 inch ruler)

x = fraction open



when the valve is full open, $x = x_{max}$; usually x_{max} is about 1 but it may be less.

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Valve Trim How a valve opens or closes depends on the design of the plug:

Valve Characteristic Function, $f(x)$

a)	Quick Opening:	$f(x) = 1 - e^{-\beta x}; (\beta > 20)$
b)	n^{th} Root:	$f(x) = x^{1/n}$
c)	Linear trim:	$f(x) = x$
d)	Equal percentage:	$f(x) = a^{1-x}$
e)	Hyperbolic:	$f(x) = [a - (a-1)x]^{-1}$

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Courtesy of T. B. Co 2007

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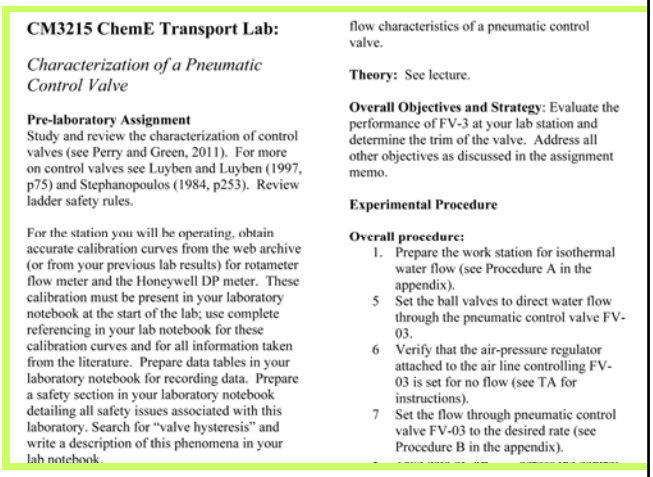
Lab: Characterization of a Pneumatic Control Valve

- Use air pressure to set a pneumatic control valve (water)
- Record valve stem position as a function of actuating air pressure
- Pump water through the valve and measure pressure drop across the valve and flow rate through the valve; record all needed data
- Calculate $C_V(x)$ and $f(x)$ for the pneumatic valve FV-03 and determine the trim of the valve; deliver all deliverables



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.

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).

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Prelab

- See Procedure on web for details of prelab
- Look up and describe "*Valve Hysteresis*"

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- *Deliver* your *deliverables*.
- Make it easy for me to find what I asked for.
- Do not write a report.
- Do not omit anything requested.

Be sure to take all the data you need to deliver your deliverables.

Memo

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How to Keep Figures at the Top of a Page in Word 2013

Faith A. Morrison (fmorriso@mtu.edu)
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29 September 2014

This is a brief document with one method of keeping Figures or Tables located at the top (or bottom) of a page. Without special measures, Microsoft Word will position these elements at positions on the page that do not conform to standard practice for report writing. Please send your feedback on these instructions and I will improve them.

The method employed here is to put the graphic (picture, figure, table) and its caption into a textbox and then position the textbox at the top or bottom of the page. The steps are listed below.

Inserting a Figure or Table

1. I recommend that you initially place all your figures and tables in order at the back of the report and only move them to their places within the text after you are done drafting the report. With

Figures/Tables to top or bottom in MS Word 2010

http://www.chem.mtu.edu/%7Efmorriso/cm3215/2012WordFigurePlacement.pdf

"*Top/Bottom*" rule is relaxed in the Appendix since there is no running text.

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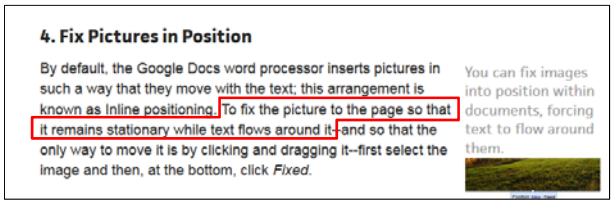
Figures/Tables to top or bottom in Google docs?



4. Fix Pictures in Position

By default, the Google Docs word processor inserts pictures in such a way that they move with the text; this arrangement is known as Inline positioning. To fix the picture to the page so that it remains stationary while text flows around it--and so that the only way to move it is by clicking and dragging it--first select the image and then, at the bottom, click *Fixed*.

You can fix images into position within documents, forcing text to flow around them.

http://www.pcworld.com/article/219060/20_google_docs_secrets.html

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