INST 180 (1-day Control Valves course)

Recommended schedule

(8:00 AM to 8:30 AM) – *Introduction and Quiz*

(8:30 AM to 9:30 AM) – *Control valve construction and types* – Questions 1 through 5

(9:30 AM to 9:45 AM) – **Break**

(9:45 AM to 10:30 AM) – *Pneumatic control devices* – Questions 6 through 9

(10:30 AM to 11:00 AM) – *Lab activity* – I/P transducer and 3-15 PSI control valve actuator

(11:00 AM to 12:00 PM) – **Lunch**

(12:00 PM to 1:00 PM) – *Valve positioners* – Questions 10 through 13

(1:00 PM to 1:30 PM) – *Lab activity* – Positioner demonstration

(1:30 PM to 1:45 PM) – **Break**

(1:45 PM to 2:15 PM) – *Motor-operated valves (MOVs)* – Questions 14 through 17

(2:15 PM to 3:00 PM) – *Cavitation and valve stiction* – Questions 20 through 23

(3:00 PM to 3:30 PM) – *Video: cavitation at Glen Canyon dam* – Questions 20 through 22

Video time index	Content
Start to 1:50	Intro and shots of MOV actuators in use
4:43 to 12:36	Cavitation damage in spillway
15:38 to 17:56	Adding air slots in spillway
24:20 to 25:18	Testing the new spillway

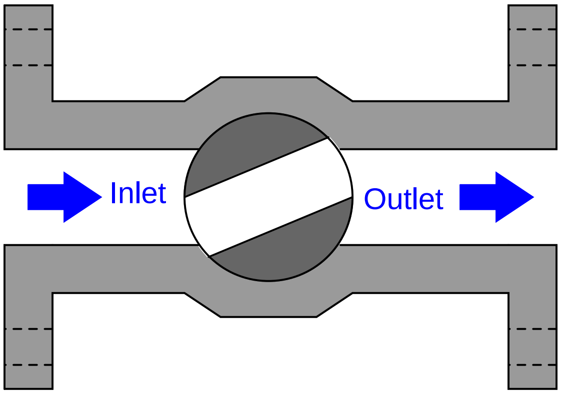
(3:30 PM to 3:45 PM) – **Break**

(3:45 PM to 4:30 PM) – *Quiz and Review*

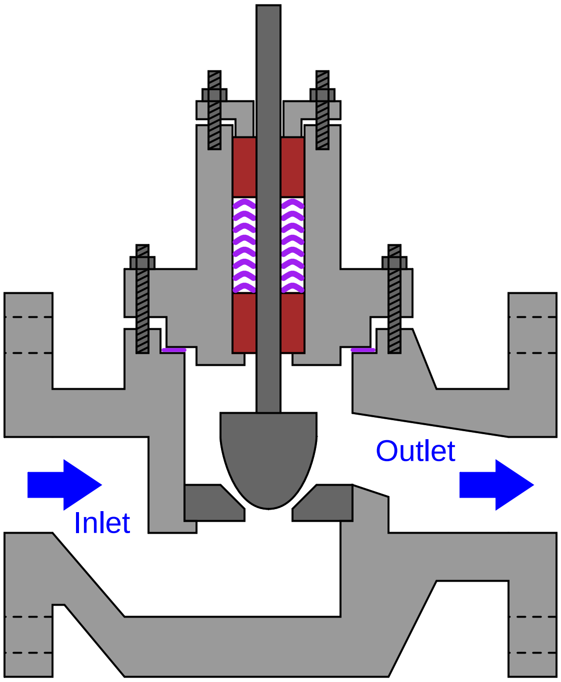
Question 1

Identify these different valve types from their respective diagrams:

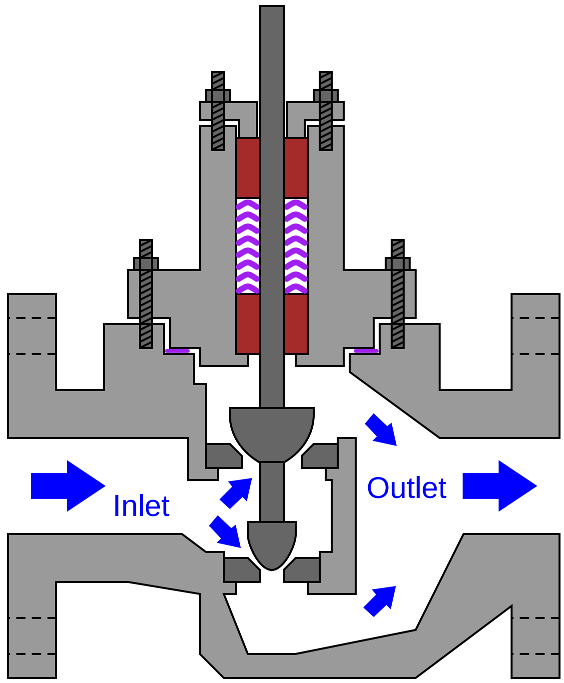
Valve #1:



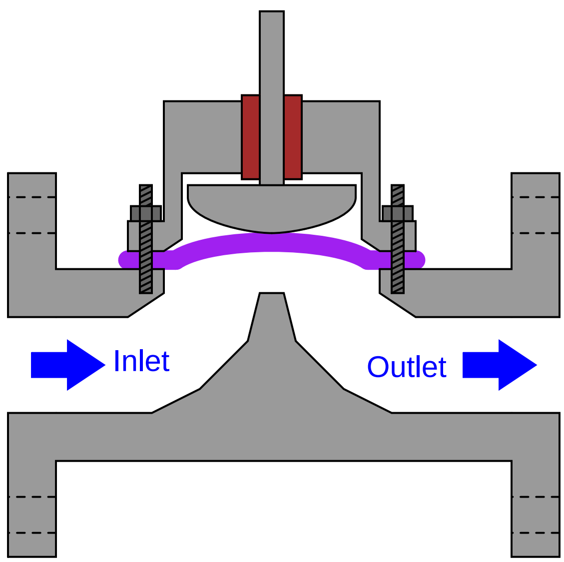
Valve #2:



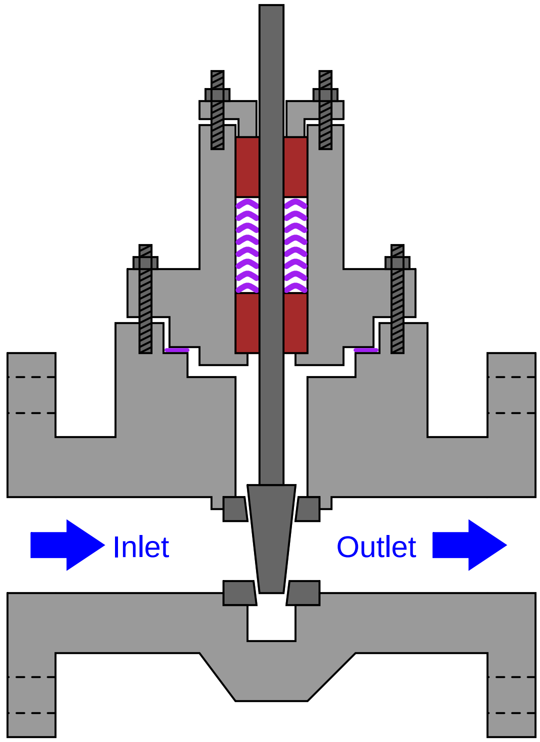
Valve #3:



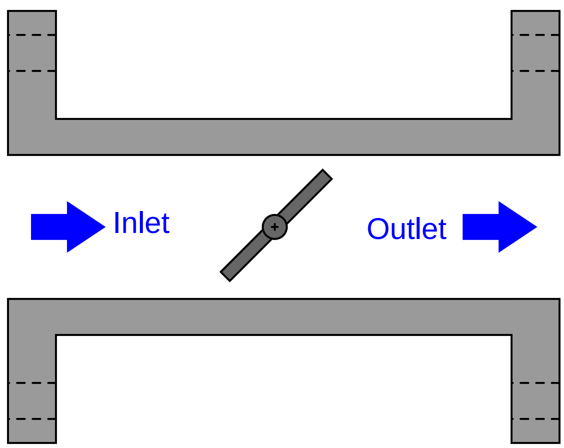
Valve #4:



Valve #5:



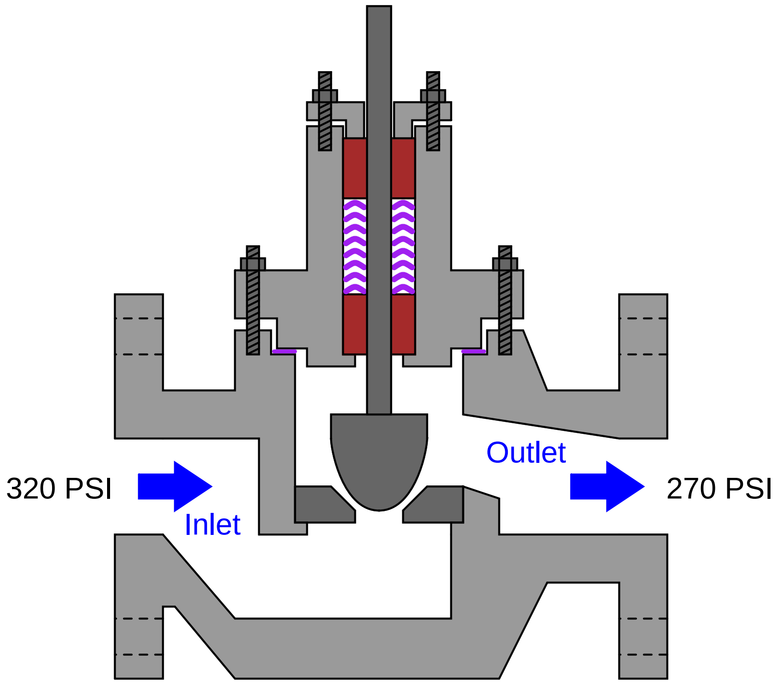
Valve #6:



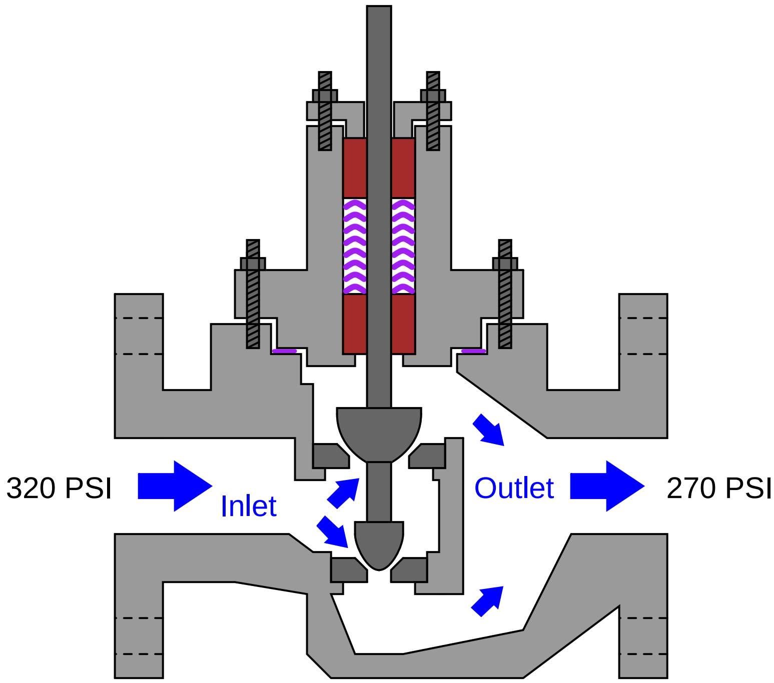
file i00770

Question 2

Suppose we had a single-ported globe valve such as this controlling fluid flow, with inlet and outlet pressures as shown in the illustration. If the plug has a cross-sectional area of 3 square inches, how much force will be exerted on the plug by the fluid? In which direction will this force be exerted?



Now suppose we replace the single-ported globe valve with a *double-ported* globe valve of similar operating characteristics. Given the same inlet and outlet pressures, how much (net) force will be exerted on the plugs by the fluid? Assume the upper plug has a cross-sectional area of 3 square inches, and the lower plug a cross-sectional area of 2 square inches:



Which of these two control valves will be easier to position (i.e. require less actuating force), all other factors being equal?

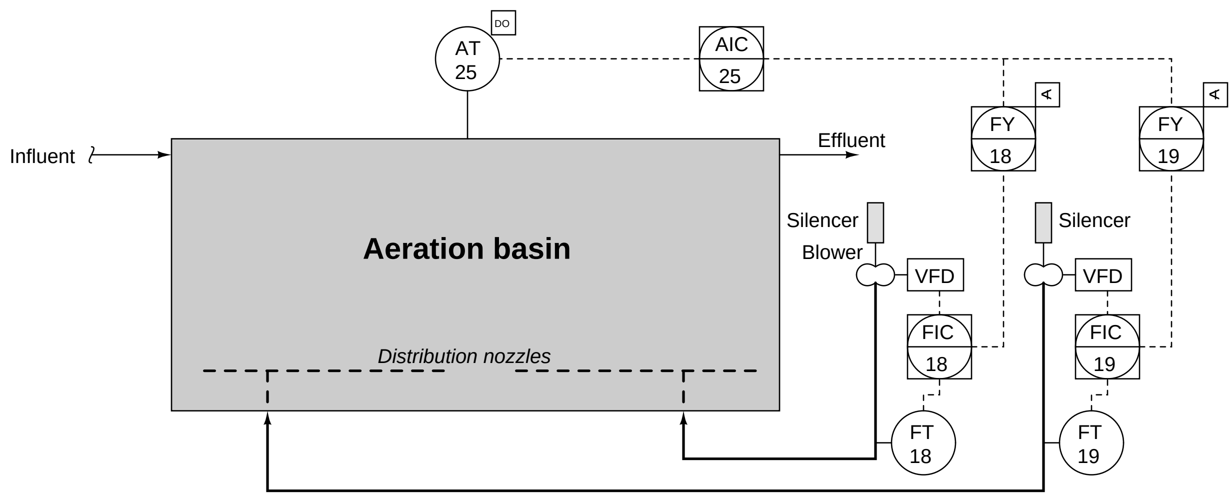
Suggestions for Socratic discussion

- For the valve requiring less actuating force, are there any disadvantages to the design? Clearly, lower actuating force is a good thing, so there must be some drawback to this design or else *all* control valves would be manufactured this way!
- Is the direction of flow arbitrary for this control valve, or is there a reason why the flow should be passing *up* past the plug rather than *down* past it?
- Does the packing of a double-ported control valve need to be different than the packing of a single-ported valve? Why or why not?

file i00772

Question 3

One of the major processes used to treat municipal wastewater is *aeration*, where the dissolved oxygen concentration of the wastewater is increased by bubbling air through the water in an *aeration basin*. A dissolved oxygen ("DO") analyzer measures the oxygen concentration in the wastewater, and a controller varies the speeds of blowers pumping air into the basins using AC motors powered through variable-frequency drives (VFDs) which allow the controllers' 4-20 mA output signals command the motors how fast to spin:



Identify the proper actions for each controller in this system, assuming direct-acting transmitters and VFDs that spin the motor at a faster speed with a greater 4-20 mA signal:

AIC-25 = *direct* or *reverse*? FIC-18 = *direct* or *reverse*? FIC-19 = *direct* or *reverse*?

Suppose an operator calls you to examine this system and determine why the dissolved oxygen value is not holding at setpoint. According to the operator, everything was working fine yesterday, and had been working fine for months. You go to the control room to view the display on the DCS, and you find these values:

Parameter	**AIC-25**	**FIC-18**	**FIC-19**
PV	41%	99%	2%
SP	75%	100%	100%
Output	100%	82%	100%

Identify *two* different faults, each one independently capable of accounting for all symptoms evident in this table.

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file i00776

Question 4

Read selected portions of the "Fisher Type 1098-EGR and 1098H-EGR Pilot-Operated Regulators" product bulletin (document 71.2:1098-EGR), and answer the following questions:

Page 4 shows excellent illustrations of the regulator body and actuator assemblies, as well as internal views of the pilot mechanism. Identify the type of valve trim used to throttle process fluid (stem-guided, cage-guided, port-guided), and also whether the valve body is *direct* or *reverse* acting. Additionally, explain how the valve plug position may be monitored while the regulator is in service.

The purpose of the *pilot* is to provide a *loading pressure* to the actuator of the 1098 pressure regulator. Page 6 explains how the pilot provides this loading pressure to the main actuator. Explain what this "loading pressure" does to the main regulator mechanism, and also how the regulator self-adjusts to changes in the downstream pipe pressure. Also, identify the fluid used to actuate the regulator – it is *not* instrument air!

What type of *stem packing* do you see used in this valve? Explain why you think the valve is designed in this way.

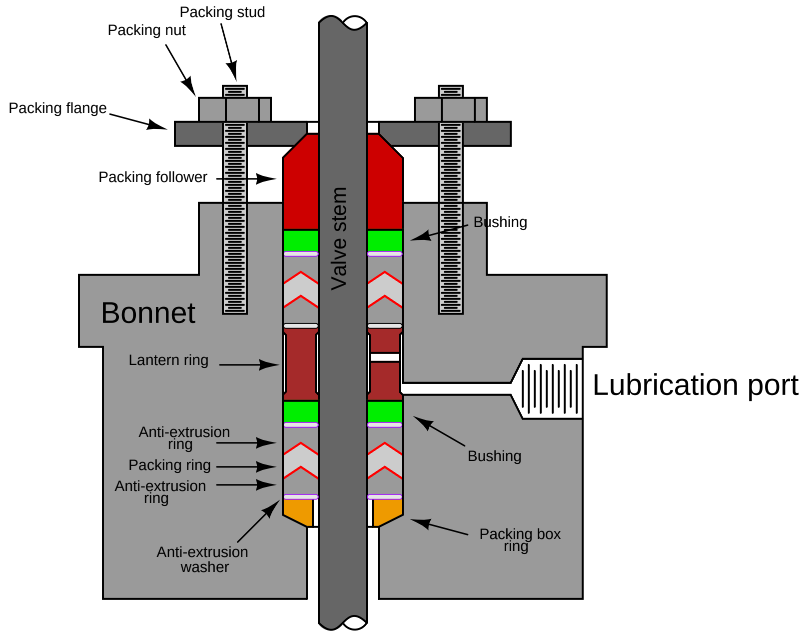
Suggestions for Socratic discussion

- A powerful problem-solving technique is performing a *thought experiment* where you mentally simulate the response of a system to some imagined set of conditions. Describe a useful "thought experiment" for this system, and how the results of that thought experiment are helpful to answering the question.
- Fisher's *Fundamentals of Gas Pressure Regulation* (Technical Monograph 27) by Floyd D. Jury gives a fairly comprehensive explanation of pressure regulators, including pilot-operated regulators. No photographs in this document, but a good amount of simple illustrations are provided. If you have lingering questions after reading the Fisher 1098 product bulletin, peruse this monograph.

  file i00783

Question 5

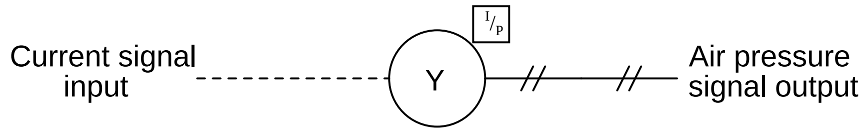
Examine this cut-away illustration of a control valve packing assembly, located inside the bonnet of the valve:



Explain the purpose of each labeled component within the packing assembly.
file i00879

Question 6

In instrumentation parlance, a *transducer* is a calibrated device used to convert one standardized signal into another standardized signal. One very common form of transducer is an *I/P transducer*, which converts an electric current signal into a pneumatic pressure signal:



The symbols shown above are standard for process and instrumentation diagrams (P&ID's), where an electric cable is shown as a dashed line, a pneumatic pipe or tube shown as a line with double hash-marks periodically drawn through it, and the instrument is a circle with letters (in this case, "Y", representing a signal relay, computing element, transducer, or converter).

The most popular range for electric current signals is 4 to 20 mA DC. The most common range for pneumatic (air pressure) signals is 3 to 15 PSI. Therefore, the most common type of I/P transducer has an input range of 4-20 mA and an output range of 3-15 PSI. Both of these ranges are there to represent some measured or manipulated quantity in an instrument system. That is, 0% of range will be represented by a 4 mA input signal to the I/P, and a 3 PSI output signal; 100% of range will be represented by a 20 mA input signal and a 15 PSI output signal; 50% range will be represented by a 12 mA input and a 9 PSI output.

Complete all the missing data in the following calibration table for this I/P transducer, and then describe how you were able to correlate the different percentages of range with specific current and pressure signal values:

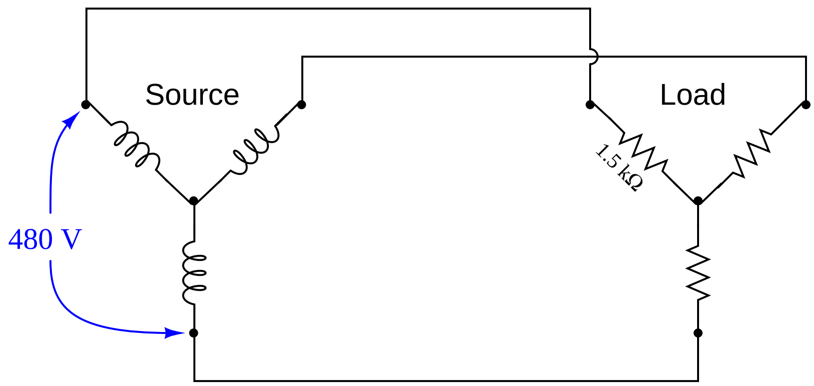
Input current (mA)	Percent of range (%)	Output pressure (PSI)
4	0	3
	10	
	20	
	25	
	30	
	40	
12	50	9
	60	
	70	
	75	
	80	
	90	
20	100	15

Challenge: build a computer spreadsheet that calculates all current and pressure values from given percentages.

file i00084

Question 7

Calculate the following parameters in this balanced 3-phase electrical power system:

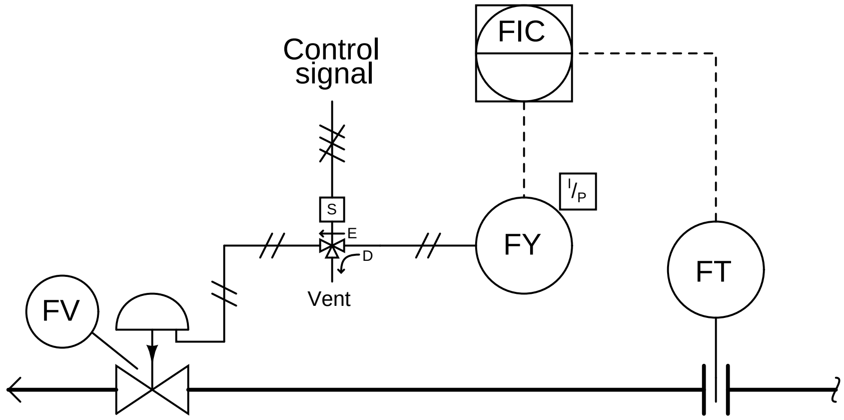


- $I_{line} =$
- $I_{phase(load)} =$

file i00915

Question 8

Explain what this electric solenoid valve will cause the pneumatically-actuated control valve to do when de-energized. What sort of fail-safe mode does this solenoid provide for the control valve that the valve would not otherwise exhibit on its own?



Also, based on how you know liquid flow controllers are typically tuned, how will the controller (FIC) react in automatic mode if the solenoid "trips"?

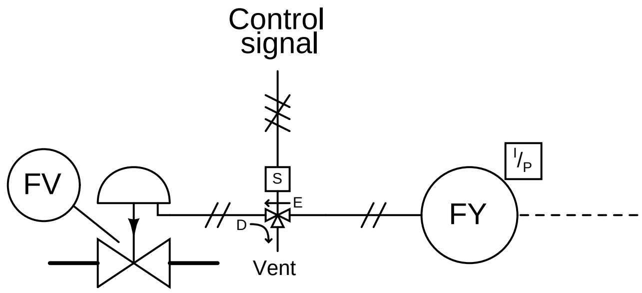
Suggestions for Socratic discussion

- What type of process is liquid flow: *self-regulating*, *integrating*, or *runaway*?
- Ideally, how should a liquid flow controller be tuned?

file i00917

Question 9

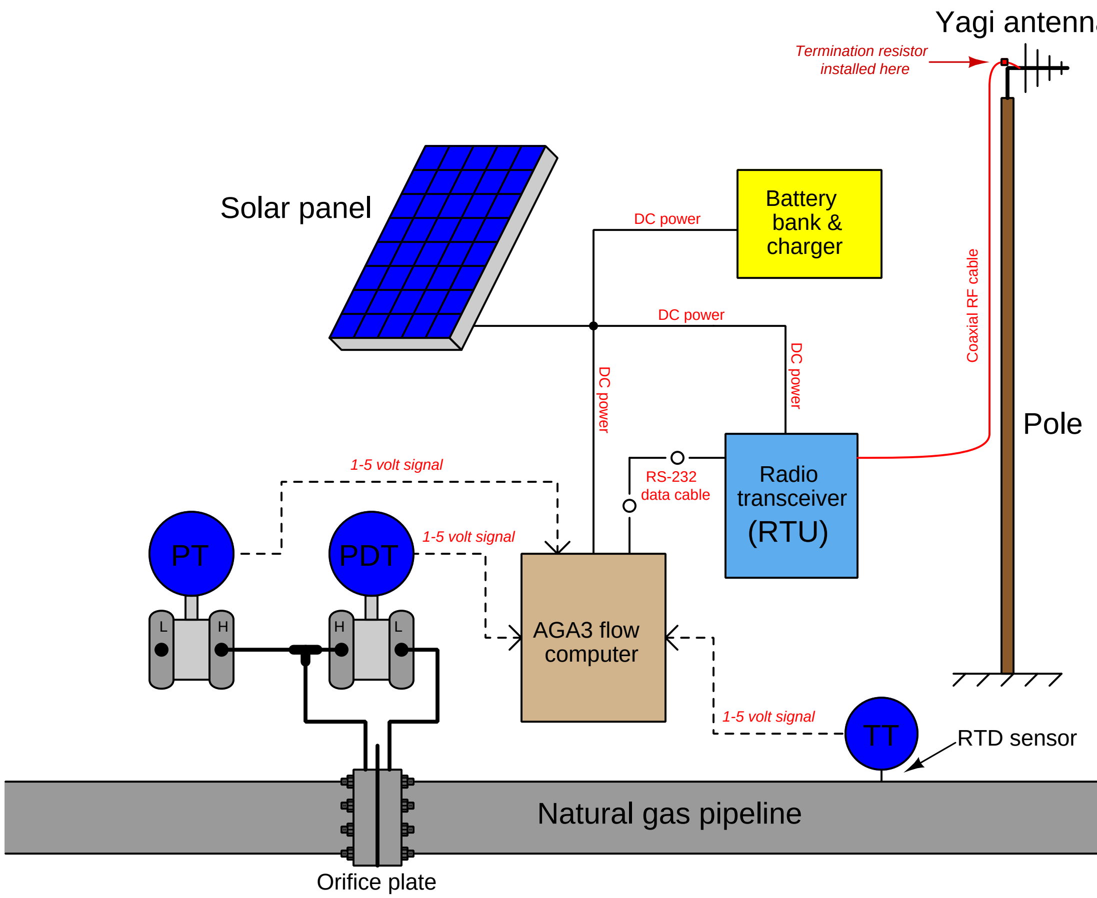
Explain what this electric solenoid valve will cause the pneumatically-actuated control valve to do when de-energized:



file i00918

Question 10

It is common practice to connect an antenna to a radio transceiver (transmitter/receiver) using a transmission line if the antenna must be located somewhere high up for good reception. In this particular example, a radio transceiver is used to communicate natural gas flow measurement data from a flow computer to some far-away location, as part of a SCADA system for the natural gas pipeline. The antenna is located at the top of a wooden pole for better signal strength than if it were located at ground level:



In this installation, the transmission line is a 20 foot length of 50 Ω coaxial cable. Knowing that reflected signals are bad in any transmission line system, the technician who installed this system also installed a 50 Ω *termination resistor* at the antenna-end of the cable, in parallel with the antenna.

Was the installation of this termination a good idea, or not? Explain your answer.

Suggestions for Socratic discussion

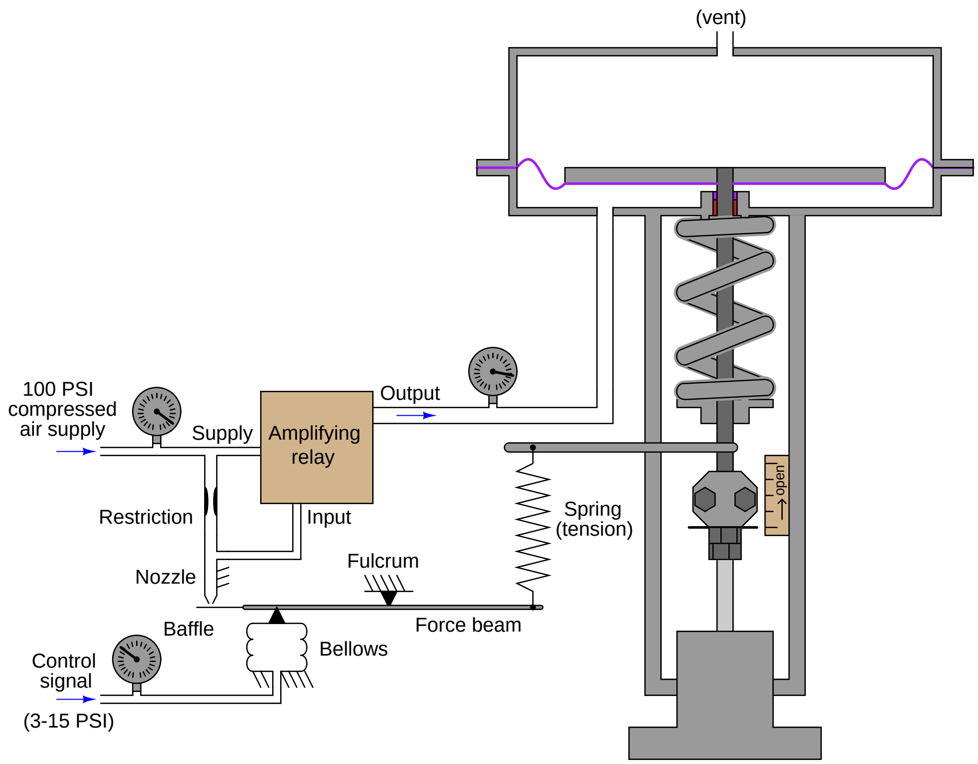
- Explain how a TDR could be used to check the transmission line for proper termination.
- For those who have studied gas flow measurement, what does *AGA3* mean, and why are there *three* process transmitters connected to the flow computer?
- Explain what a "SCADA" system is and what function it fulfills.
- It is quite common to find analog transmitters in solar-powered SCADA monitoring sites using *voltage* signal ranges rather than the *current* signals more commonly found in industrial (plant) applications. The reason for this is to reduce power consumption. Explain how the use of voltage signaling reduces power consumption compared to current signaling.

- Is this a true example of a "SCADA" node, or might it best be characterized as a *telemetry* node? Explain your answer.

file i01357

Question 11

This valve positioner system, shown in the fully-closed position, has a problem. When placed into service, the valve remains at 100% (full open) for *any* applied control signal value:



Looking at the gauges, you notice the supply gauge reads 95 PSI, the control signal gauge reads 4.3 PSI, and the output gauge reads 88 PSI.

Identify the likelihood of each specified fault for this valve positioner. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault could independently account for *all* measurements and symptoms.

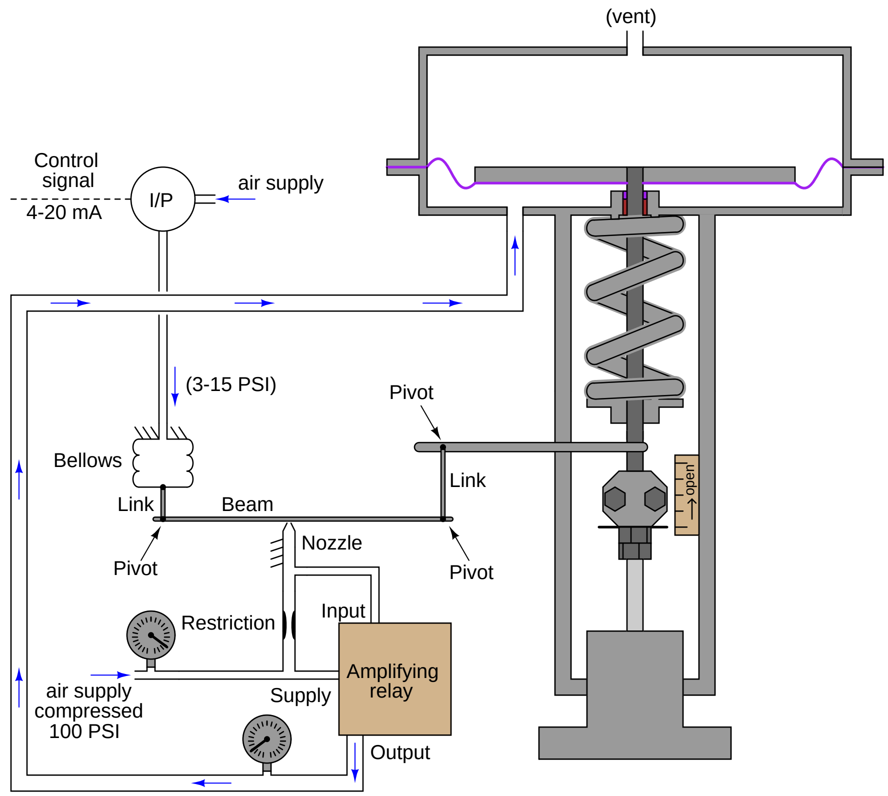
Fault	Possible	Impossible
Plugged restriction		
Plugged nozzle		
Broken spring		
Leak in bellows		
Leak in actuator diaphragm		
Air supply failure		

Finally, identify the *next* diagnostic test or measurement you would make on this system. Explain how the result(s) of this next test or measurement help further identify the location and/or nature of the fault.

file i01361

Question 12

This valve positioner system has a problem. The valve remains at 0% (fully closed) for *any* applied control signal value:



Looking at the gauges, you notice the supply gauge reads 75 PSI and the output gauge reads 0 PSI while the loop controller output is set at 100% in manual mode.

Identify the likelihood of each specified fault for this valve positioner. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault could independently account for *all* measurements and symptoms.

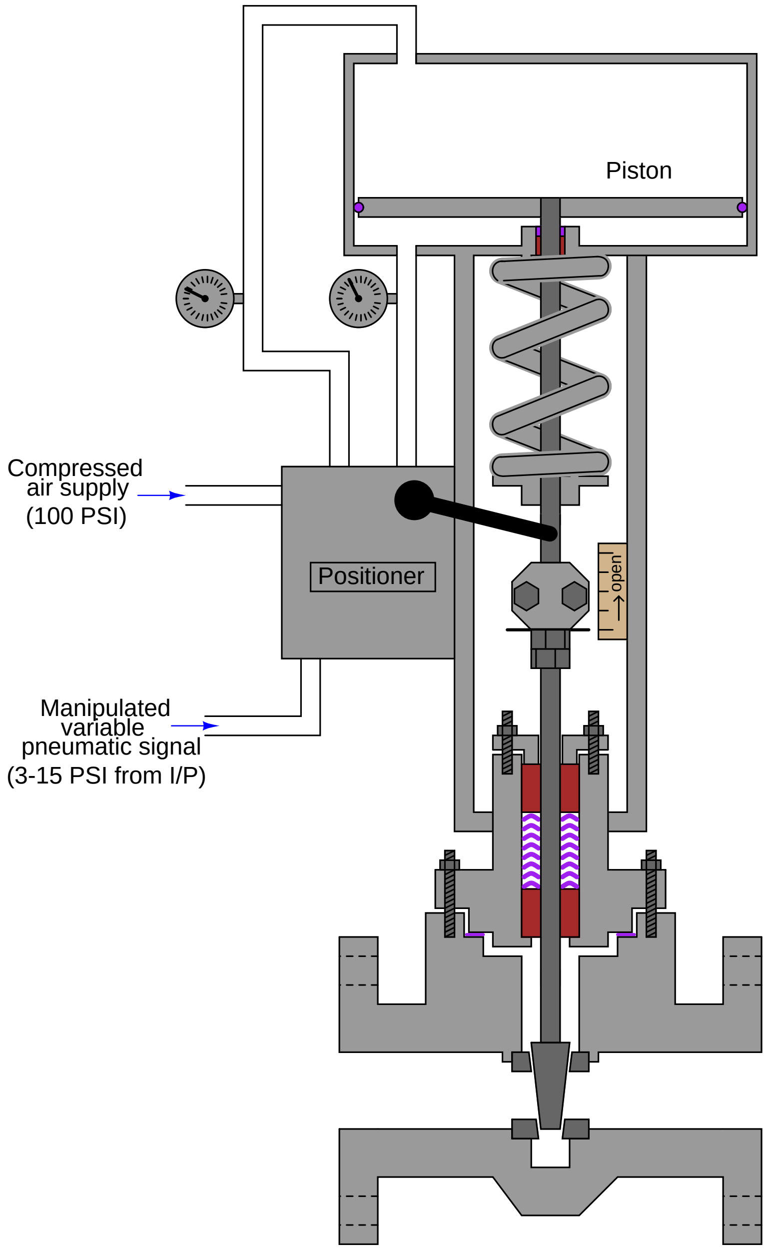
Fault	**Possible**	**Impossible**
Plugged restriction		
Plugged nozzle		
Broken link to valve stem		
Leak in bellows		
Leak in actuator diaphragm		
I/P output failed low		
I/P output failed high		
Positioner air supply failure		

Finally, identify the *next* diagnostic test or measurement you would make on this system. Explain how the result(s) of this next test or measurement help further identify the location and/or nature of the fault.

file i01362

Question 13

Identify the pressure readings one would expect to see on the two gauges of this positioner at the following pneumatic signal values, assuming proper signal-to-open calibration:



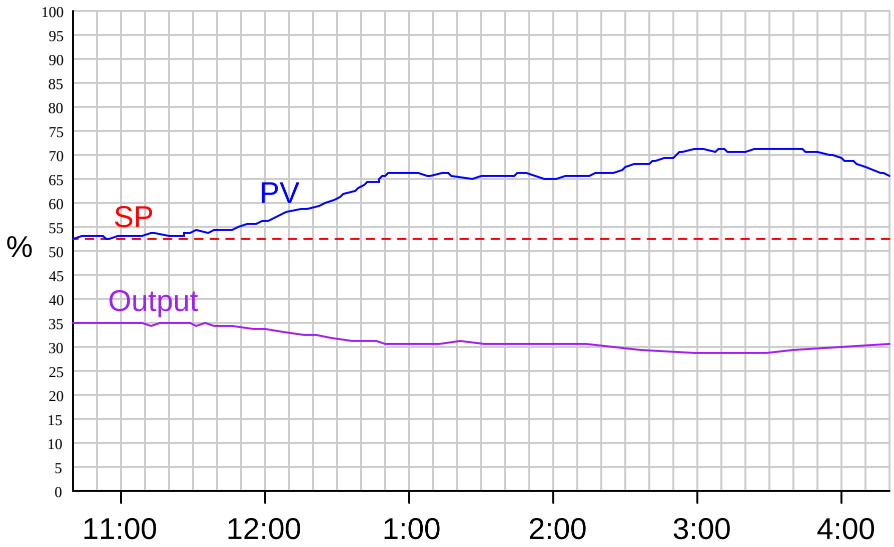
- Gauge readings at 0% (3 PSI) signal to the positioner
- Gauge readings at 50% (9 PSI) signal to the positioner
- Gauge readings at 100% (15 PSI) signal to the positioner

Finally, identify what these gauges would indicate if the valve were seized in the mid-open (50%) position due to excessive packing friction, assuming the pneumatic input signal was at 9.4 PSI.

file i01401

Question 14

Suppose you are summoned to diagnose a process control problem, and are shown this trend graph of the PV, SP, and Output for a particular loop:



We see the process variable clearly deviating from setpoint, which it should not do if the control system is doing its job as it should.

Determine the most likely cause of the problem, based on the data you see in this trend.

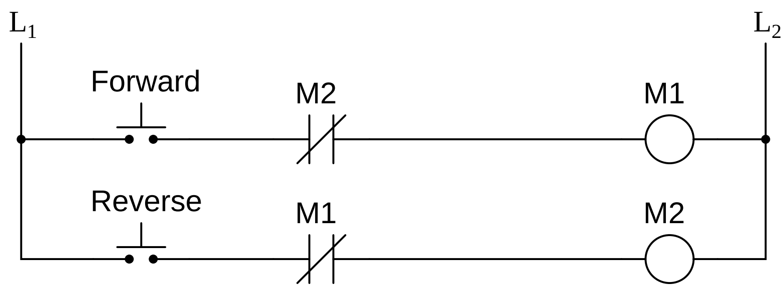
Suggestions for Socratic discussion

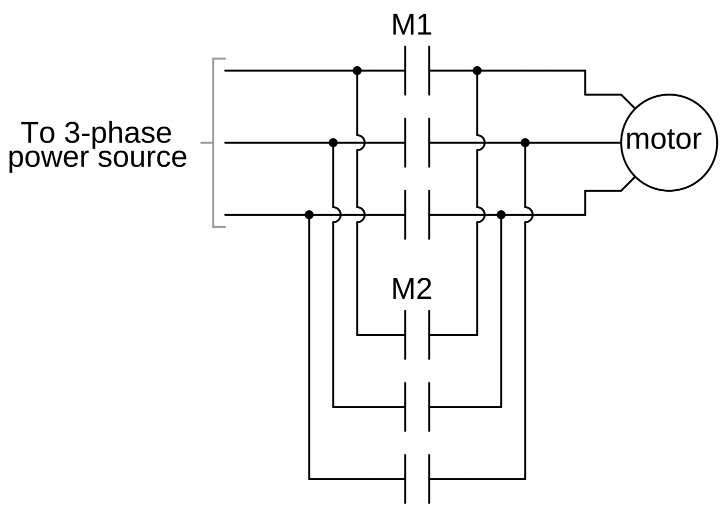
- Explain why viewing the *output* trend in addition to the PV trend is critically important to being able to diagnose the problem here.
- Examine this trend graph and explain how we can tell which mode (*automatic* or *manual*) the loop controller is in.
- Examine this trend graph and explain how we can tell which direction of action (*direct* or *reverse*) the loop controller is configured for.
- Identify as best you can the *proportional band* and *bias* values of this controller based on the data shown in the trend.
- Suppose the control valve in a process loop were to fail shut and thereby become unresponsive to the controller's output signal. How do you think this would affect the trend graph of PV, SP, and Output for the loop?
- Suppose the paper chart recorder displaying this trend graph were to fail in such a way that the PV pen drops all the way down to zero and becomes unresponsive to the transmitter's signal. Could an operator extrapolate the value of the PV just by examining the SP and Output trends? Explain why or why not.

file i01388

Question 15

The direction of rotation for a three-phase AC electric motor may be reversed by swapping any two of the three power conductor connections. With this in mind, explain how this reversing motor control circuit works:





In particular, what is the function of the two normally-closed "M" contacts (called *interlock* contacts) in the control circuit? What do you think might happen if those contacts were not there?

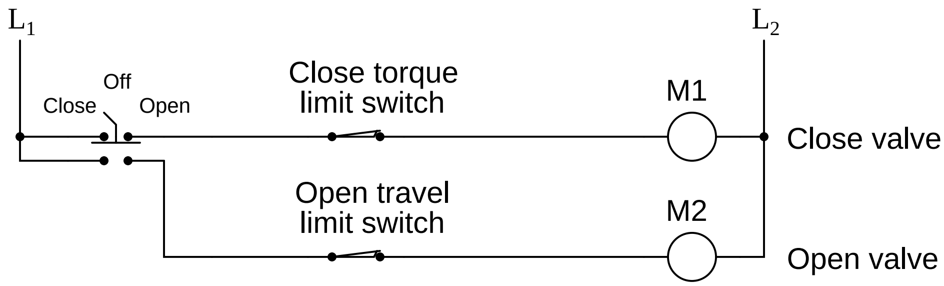
Suggestions for Socratic discussion

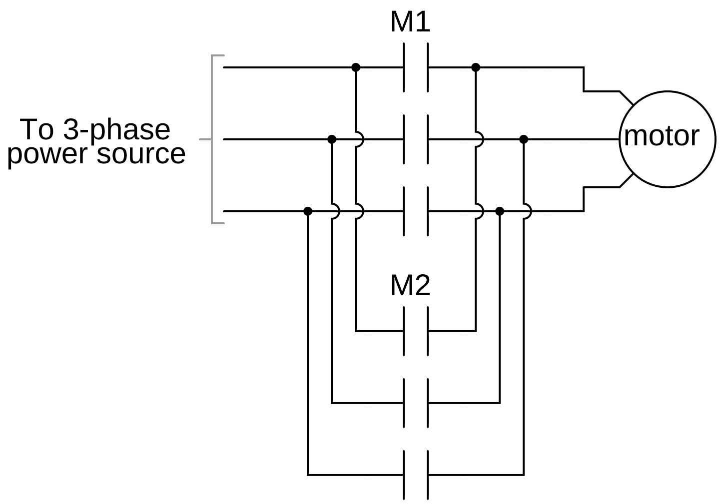
- Explain *why* reversing any two phase conductors supplying AC power to an induction motor will cause it to reverse direction.
- Explain what *arc flash* is, and how to protect yourself from it while working on high-voltage motor control circuits such as this one.
- Suppose an electrician tries to force the motor to spin in its forward direction by connecting a temporary jumper wire across relay coil M1. Will this accomplish the desired result? Explain why or why not, and also identify any potential safety hazards in doing this.
- Suppose an electrician tries to force the motor to spin in its forward direction by connecting a temporary jumper wire across the "Forward" pushbutton. Will this accomplish the desired result? Explain why or why not, and also identify any potential safety hazards in doing this.
- Suppose an electrician tries to force the motor to spin in its forward direction by connecting three temporary jumper wires across the M1 contacts. Will this accomplish the desired result? Explain why or why not, and also identify any potential safety hazards in doing this.

file i01391

Question 16

Explain how this motor control circuit works for an electrically-actuated gate valve. Note the use of a three-position switch with "Close," "Off," and "Open" positions:





Specifically, explain why the upper limit switch is designed to open when it detects a certain amount of motor torque, and why the lower limit switch is designed to open when it detects a certain distance of valve stem travel. It will help greatly to consider how a gate valve works when answering this question!

Suggestions for Socratic discussion

- Explain how to interpret the symbol used for the "Close/Off/Open" switch.
- Explain what *arc flash* is, and how to protect yourself from it while working on high-voltage motor control circuits such as this one.

file i01392

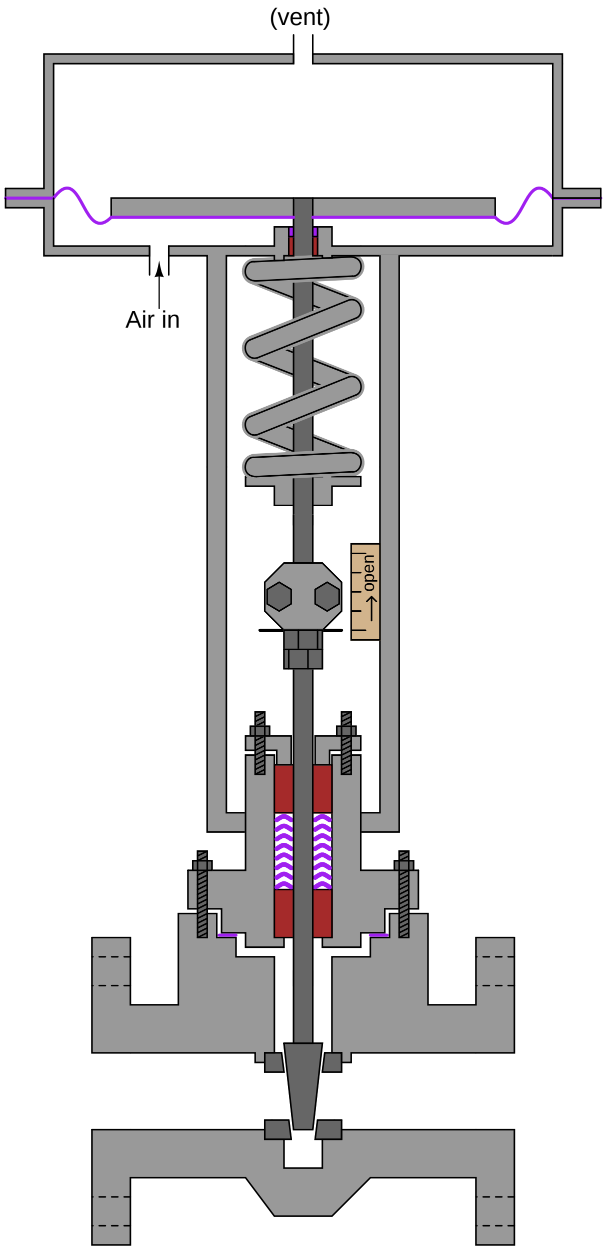
Question 17

Describe an *industrial application* for the calculus principle of *differentiation*, being sure to include actual numerical values as part of your example. Include graphs and diagrams if you find it helpful.

file i01393

Question 18

Examine this sliding stem valve and actuator assembly, and determine whether it is air-to-open or air-to-close. Also, determine what the valve will do (close, open, or stay in place) if the compressed air supply were to fail:



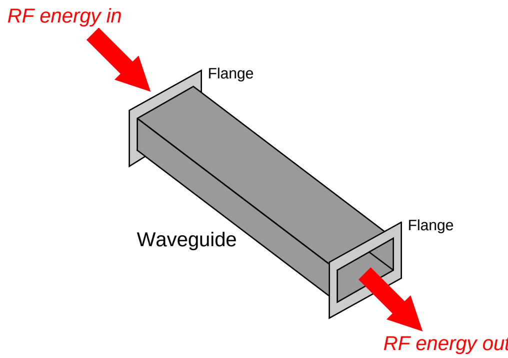
Suggestions for Socratic discussion

- Is this a *direct* or *reverse* acting actuator?
- Is this a *direct* or *reverse* acting valve body?
- Does the spring operate in a mode of *tension* or of *compression*?

file i00784

Question 19

In many microwave radio systems, hollow rectangular tubes known as *waveguides* are often used in lieu of cables to serve as transmission lines between the transceiver and the antenna. These hollow metal tubes acts as "pipes" to convey GHz-range electromagnetic waves with great efficiency, far exceeding the efficiency of coaxial cables:



The following table shows a comparison between RG-49/U waveguide and RG-9/U flexible cable:

Parameter	**RG-49/U waveguide**	**RG-9/U coaxial cable**
External dimensions	2 inch × 1 inch	0.420 inch diameter
Dielectric	air	polyethylene (plastic)
Weight	1.4 lb per foot	0.15 lb per foot
Attenuation at f = 5 GHz	0.011 dB per foot	0.23 dB per foot
Power rating	1.2 MW	66 W

Suppose an RG-49/U waveguide is used to transfer RF energy from a 300 watt radar transceiver to a dish antenna. Calculate the RF power (in watts) available at the antenna, assuming the waveguide is 8 feet long and that there are no other power losses between the transceiver and the antenna.

Now suppose that radar transceiver's power is increased to 800 watts. Calculate the RF power (in watts) available at the antenna, assuming the same waveguide length.

Now suppose that radar transceiver's power is increased to 3 kilowatts. Calculate the RF power (in watts) available at the antenna, assuming the same waveguide length.

Does the waveguide power loss remain constant as transmitter power increases, or does it change with the amount of transmitted power? How does the "lost" RF energy manifest itself through the waveguide (given that the Law of Energy Conservation tells us energy cannot be created or destroyed)?

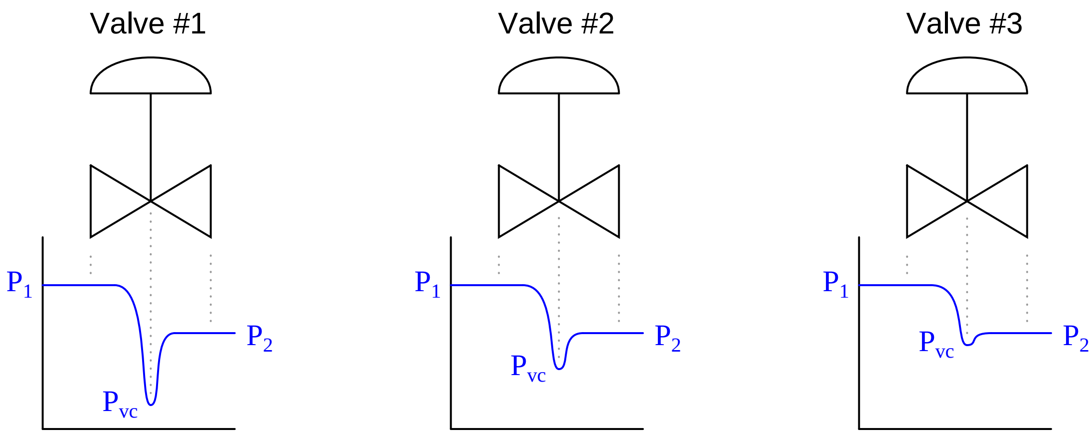
Suggestions for Socratic discussion

- Explain why the waveguide shown has such a greater power rating than the coaxial cable, based on their respective dB/foot loss ratings.
- Why aren't waveguides used for all GHz-frequency radio applications, given that their power losses are so much less than the losses exhibited by coaxial cable?
- For those who have studied level measurement technologies, explain how the concept of a *waveguide* relates to guided-wave radar (GWR) level transmitters.
- Is is possible for a waveguide to experience *reflected signals* as in the case of improperly terminated transmission line cables? Why or why not?

file i00791

Question 20

Examine the following graphs, plotting pressures along the fluid flow path within three different control valves:



As you can see from the graphs, the inlet pressures (P_1) and outlet pressures (P_2) are the same for each valve. That is, each of the three valves exhibits the same amount of permanent pressure drop. However, what happens inside each valve is quite different, an indicated by the different *vena contracta* pressures (P_{vc}).

When fluid enters a constricted portion of the valve, its velocity increases. A greater fluid velocity means the fluid molecules possess greater kinetic energy than before. In accordance with the Law of Energy Conservation, this increase in kinetic energy must be balanced by a corresponding loss in potential energy (fluid pressure) through the constriction. This is what accounts for the sudden decrease in pressure at the vena contracta point (the point of maximum constriction inside the valve).

After passing through the constriction, the fluid enters a wider portion of the valve and slows down. Molecular kinetic energy decreases while potential energy (pressure) increases. This is why pressure "recovers" downstream of the vena contracta. The difference between upstream and downstream pressures ($P_1 - P_2$) represents fluid energy lost in the throttling action of the valve.

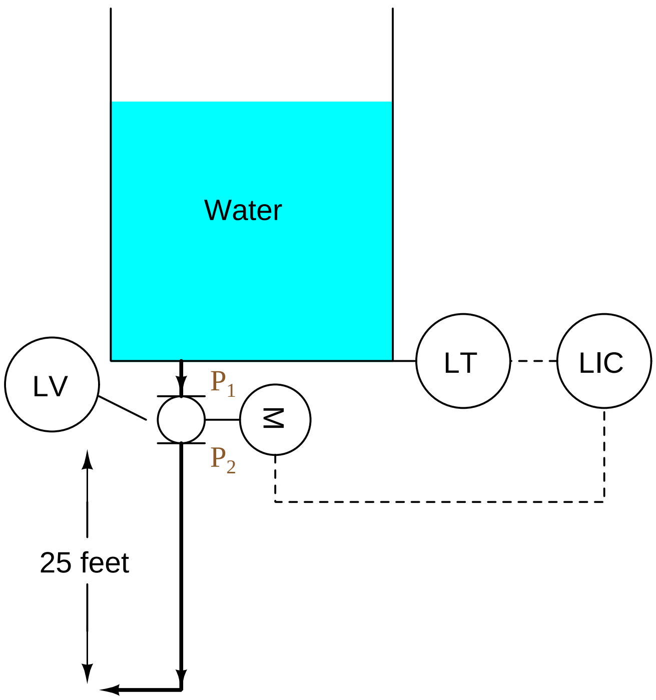
Determine which of the three valves has the greatest *pressure recovery*, and which of the three valves has the greatest *pressure recovery factor* (sometimes referred to as *pressure recovery coefficient*). Then, determine which of the three valves is more prone to cavitation in liquid service, all other factors being equal.

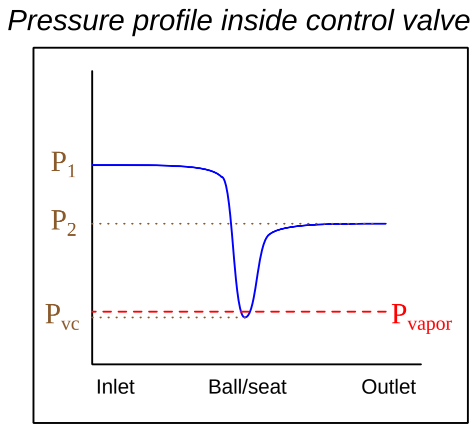
Finally, identify control valve types characterized by extremes of pressure recovery and pressure recovery factor.

file i01418

Question 21

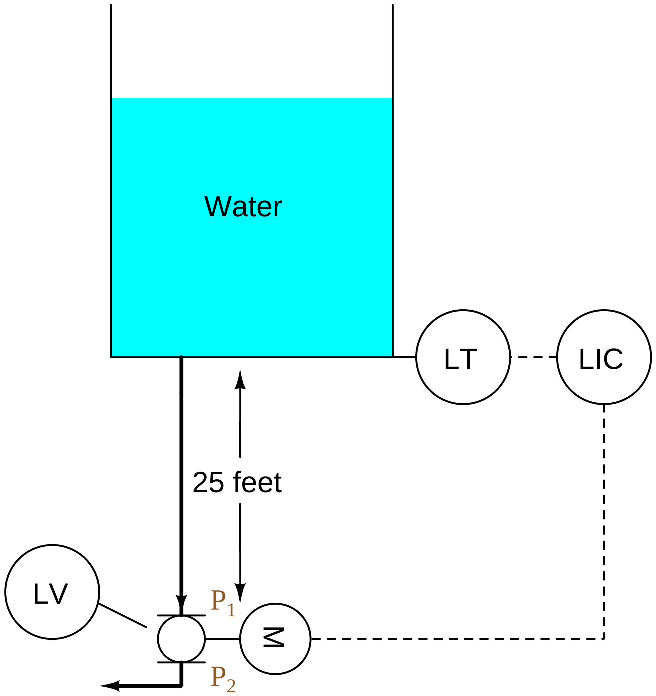
This level control valve cavitates when water flows through it. A pressure profile graph shows the valve's inlet pressure (P_1), outlet pressure (P_2), and vena contracta pressure (P_{vc}) superimposed on a dashed line showing the vapor pressure of the water:

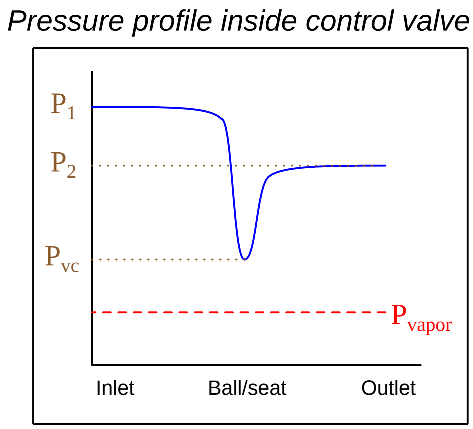




Explain why this valve cavitates, being sure to include data from the valve's pressure profile in your explanation.

Later, a process engineer decides to re-locate this same control valve to a lower position on the pipe. Now, even with the exact same flow rate going through the valve (Q) and the same pressure drop ($P_1 - P_2$), the valve no longer cavitates! A new pressure profile graph shows how all pressures at all points inside the control valve have changed as a result of the re-location:





Explain why the engineer's solution worked, being sure to include data from the valve's altered pressure profile in your explanation. Also, identify at least one *other* change that could have been made to this process to reduce or eliminate cavitation other than re-locating the valve.

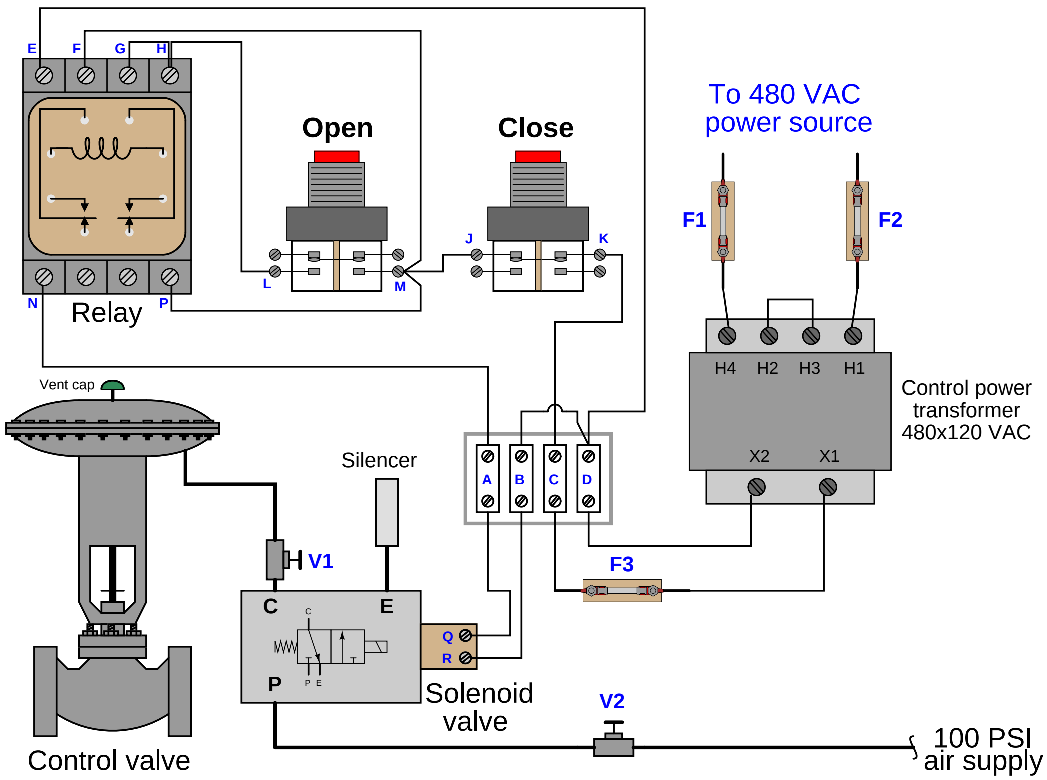
Suggestions for Socratic discussion

- Explain what the term "vapor pressure" means for a substance
- Would the engineer's solution have worked if water had been flowing the *other* direction through the valve (i.e. *up* into the vessel rather than *down* out of the vessel)? Why or why not?
- What type of control valve and actuator are used in this application?

file i01419

Question 22

Suppose this solenoid-controlled valve remains open all the time no matter which switch is pressed:



You measure 474 volts between terminals **H1** and **H4** on the transformer, and 118 volts between terminals **M** and **D**, with both pushbutton switches unpressed.

Identify the likelihood of each specified fault for this system. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault could independently account for *all* measurements and symptoms in this system. Also, identify one more possible fault not listed in the table.

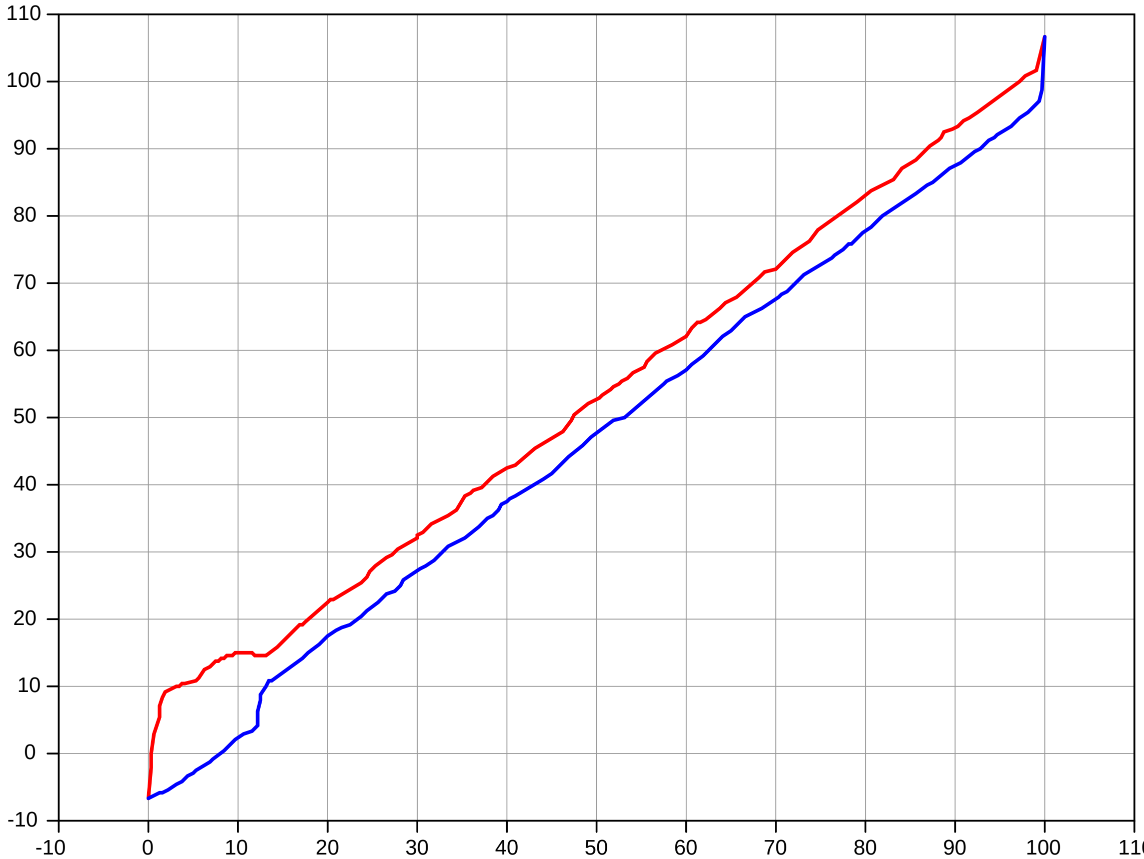
Fault	Possible	Impossible
Fuse F3 blown (failed open)		
Solenoid coil failed open		
"Open" switch contacts (L to M) failed open		
"Close" switch contacts (J to K) failed shorted		
Relay coil failed shorted		
Relay contact (G to P) failed shorted		
Relay contact (F to N) failed shorted		
Wire open between terminals K and D		
Valve V1 shut		
Valve V2 shut		

Finally, identify the *next* diagnostic test or measurement you would make on this system. Explain how the result(s) of this next test or measurement help further identify the location and/or nature of the fault.

file i01425

Question 23

While performing an "As-Found" analysis on a control valve equipped with a smart positioner, an instrument technician records this unusual valve signature:



What is your diagnosis of this valve signature? What physical problem(s) should the technician begin to look for when examining the valve?

Suggestions for Socratic discussion

- A useful problem-solving technique to apply to any scenario with a graph is to let the graph "tell you" what is happening step-by-step in time as you follow it from one extreme to the other. Try doing this: starting at the lower-left corner, following the upper (red) trace step by step as though you are re-playing the opening of the valve over time, interpreting the graph in terms of stem position and actuator pressure (applied force). Describe what the graph "tells" you as you follow it from one end to the other.

file i01424

Answer 1

Valve #1: Ball valve (rotary)

Valve #2: Single-ported globe valve (sliding stem)

Valve #3: Dual-ported globe valve (sliding stem)

Valve #4: Saunders valve (diaphragm)

Valve #5: Gate valve (sliding stem)

Valve #6: Butterfly valve (rotary)

Answer 2

For the single-ported valve, the force will be 150 lbs in the upward direction. For the double-ported valve, the force will be only 50 lbs in the upward direction.

Answer 3

Two points for AIC action, 1 point each for FIC actions. 3 points each for valid faults.

AIC-25 = **reverse** FIC-18 = **reverse** FIC-19 = **reverse**

The problem lies within the FIC-19 blower/nozzle system. Possibilities include:

- Plugged nozzle array
- Plugged silencer
- VFD power tripped (off)
- Blower failed (not blowing air)

Answer 4

The stem packing question is a "trick": there is no stem packing at all in this valve! The reason no packing is required is because any leakage past the stem will simply enter the diaphragm housing and then pass to the downstream side of the valve through the outlet pressure feedback tube, becoming part of the regulator's out-flow. These regulators normally operate in throttling mode, and tight shut-off is not critical.

Answer 5

Partial answer:

- Packing flange: transfers force from nuts to the packing follower
- Packing follower: transfers force from flange to the packing assembly
- Lubrication port: lubricant is pumped in here
- Lantern ring: allows even distribution of lubricant around the stem
- Packing box ring: provides a flat surface at the bottom of the assembly for the upper components to rest against

Answer 6

Input current (mA)	Percent of range (%)	Output pressure (PSI)
4	0	3
5.6	10	4.2
7.2	20	5.4
8	25	6
8.8	30	6.6
10.4	40	7.8
12	50	9
13.6	60	10.2
15.2	70	11.4
16	75	12
16.8	80	12.6
18.4	90	13.8
20	100	15

Follow-up question: explain the procedure for starting with a current value in milliamps and calculating the equivalent percentage.

Answer 7

- $I_{line} = 0.1848$ amps
- $I_{phase(load)} = 0.1848$ amps

Answer 8

Answer 9

When de-energized, the solenoid will cause the control valve to "fail" to its closed position.

Answer 10

There is absolutely no need for a termination resistor at the end of a transmission line terminating in an antenna.

Answer 11

A good diagnostic test here would be to pull the flapper away from the nozzle with your finger to see if the valve actuator returns to the "closed" (0%) position.

Answer 12

A good diagnostic test here would be to push the flapper toward the nozzle with your finger to see if the valve actuator tries to open.

Answer 13

- Gauge readings at 0% (3 PSI) signal to the positioner: *left-hand gauge saturated high (full pressure), right-hand gauge saturated low (0 PSI)*
- Gauge readings at 50% (9 PSI) signal to the positioner: *too little information to given to tell. We would have to know the valve's bench set pressure range as well as any other forces acting on the stem such as packing friction*
- Gauge readings at 100% (15 PSI) signal to the positioner: *left-hand gauge saturated low (0 PSI), right-hand gauge saturated high (full pressure)*

Answer 14

The problem is most likely the controller, but I will let you determine the nature of the problem!

Answer 15

The normally-closed contacts are referred to as *interlock* contacts, and they prevent simultaneous *forward* and *reverse* actuation of the motor.

Answer 16

When closing a gate valve, you want the gate to wedge firmly against the valve seat for tight shutoff. However, it does not matter as much whether or not the gate is fully withdrawn when the valve is wide open.

Answer 17

Any industrial example of rates-of-change (over time) or of relating one dependent variable's change to some other independent variable. Examples include but are not limited to:

- Flow measurement inferred from change in volume or mass over time
- Pipeline pressure rate-of-change detection
- Furnace temperature rate-of-change measurement
- "D" action in a PID controller

Award only half-credit if the example is not industrial in nature (calculating speed of a vehicle given its position over time). Award no credit if the example is not quantitative (i.e. if it lacks number values).

Answer 18

Answer 19

$P_{antenna}$ = 293.98 W at a transmitted power of 300 W.

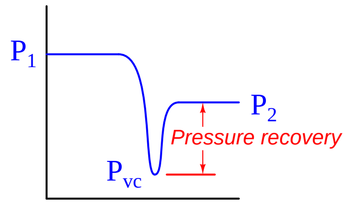
$P_{antenna}$ = 783.95 W at a transmitted power of 800 W.

$P_{antenna}$ = 2.9398 kW at a transmitted power of 3 kW.

Answer 20

Pressure recovery is the pressure difference between the outlet pressure (P_2) and vena contracta pressure (P_{vc}):

$$\text{Pressure recovery} = P_2 - P_{vc}$$



Pressure recovery factor is calculated by dividing the permanent pressure drop by the pressure drop from inlet (P_1) to the vena contracta (P_{vc}):

$$F_L = \sqrt{\frac{P_1 - P_2}{P_1 - P_{vc}}}$$

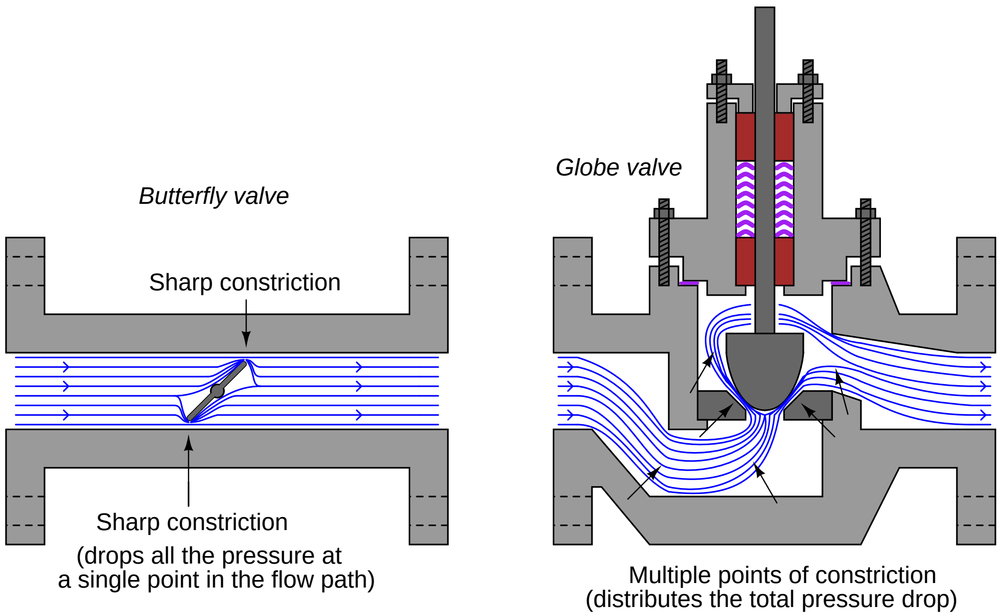
Based on this definition, valve #1 has the greatest pressure recovery and the lowest F_L, making it the most prone to cavitation. To avoid or reduce cavitation, it is best to use a control valve with low pressure recovery (a high F_L factor). Rotary valve designs such as ball, disk, and butterfly valves typically have greater pressure recovery (lower F_L figures) than globe valves, making them more prone to cavitation.

Ironically, control valves with low pressure recovery have high F_L values. Conversely, valves with high pressure recovery have low F_L values. To avoid or reduce cavitation, it is best to use a control valve with low pressure recovery (a large F_L factor). All other factors being equal (upstream and downstream pressures, flow rate, specific gravity, etc.), a valve with a large F_L will have a greater vena contracta pressure (P_{vc}) than a valve with a small F_L.

Rotary valve designs (ball, disk, butterfly, etc.) typically have greater pressure recovery (smaller F_L figures) than globe valves, making them more prone to cavitation. The reason for this greater pressure recovery is the relatively straight and wide flow path through a rotary valve body before and after the throttling element. Globe valves, with their more tortuous flow paths, drop more pressure along the whole valve body. As a result, the plug/seat opening in a globe valve does not have to do *all* the work of dropping process fluid pressure.

For the same total pressure drop ($P_1 - P_2$), a globe valve's trim will drop less pressure than a rotary valve's trim of comparable C_v. This results in a greater vena contracta pressure (P_{vc}) inside the globe valve, making is less prone to flashing and cavitation than a comparable rotary valve.

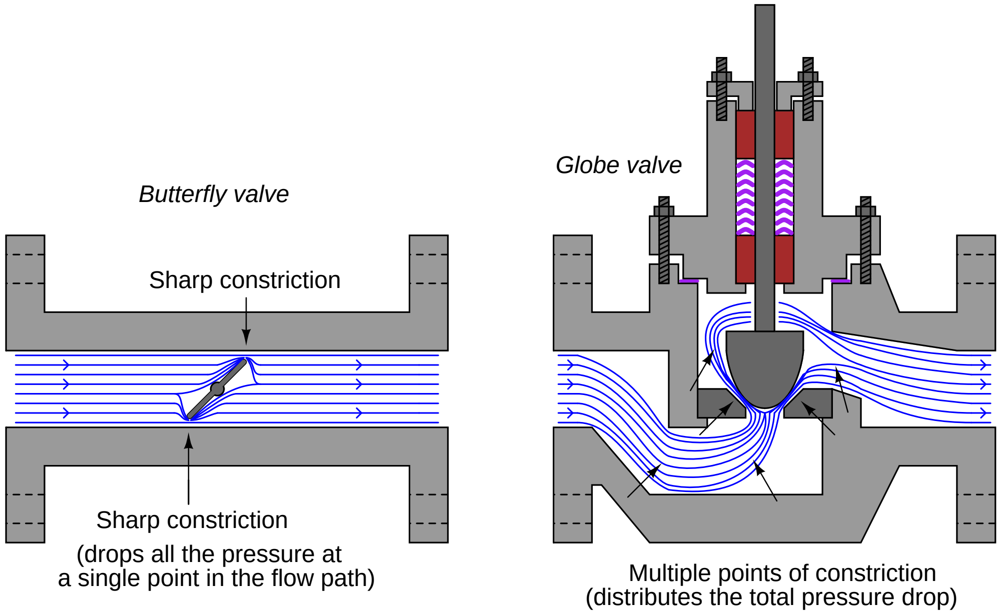
The following illustration shows the difference in flow paths between a butterfly valve and a globe valve. You can see here how the globe valve design does not rely on the plug/seat restriction to be the *only* point of pressure drop as is the case with the butterfly design:



F_L changes with valve stem position, just like C_v. For high-F_L valves such as globe valves, the amount of F_L change throughout the valve's travel is slight. For low-F_L valves such as butterfly valves, the amount of F_L change is much greater from fully open to fully shut.

Valve trim designed to reduce cavitation typically achieves very high (near-unity) F_L values. For Fisher's Cavitrol trim, the advertised F_L value for two-stage trim is 0.98, and for three-stage trim it is 0.99, which means P_{vc} is very nearly equal to P_2 (downstream).

Follow-up question: examine the following illustrations and then explain *why* rotary valve designs such as butterfly and ball valves tend to have lower F_L values than comparably-sized globe valves:



Answer 21

The new valve location raises absolute pressure at all points within the valve, ensuring the lowest pressure (P_{vc}) never drops below the water's vapor pressure. I will let you identify other solutions.

Answer 22

Fault	Possible	Impossible
Fuse F3 blown (failed open)		√
Solenoid coil failed open		√
"Open" switch contacts (L to M) failed open		√
"Close" switch contacts (J to K) failed shorted	√	
Relay coil failed shorted		√
Relay contact (G to P) failed shorted		√
Relay contact (F to N) failed shorted		√
Wire open between terminals K and D		√
Valve V1 shut	?	
Valve V2 shut		√

In order for a "shut" V1 to account for the control valve remaining open all the time, that hand valve would have had to be shut while the system was in a very particular condition! Simply shutting V1 under *any* condition(s) would not necessarily produce this effect.

A good "next test" would be to measure voltage between terminals Q and R on the solenoid.

Answer 23

This valve clearly experiences more friction as the plug nears the seat. If this is a cage-guided globe valve, I would suggest looking for interference between the piston and cage resulting from mis-alignment of the parts or poor machining. Another possibility is stem friction against the packing at that same (nearly-closed to closed) position.