

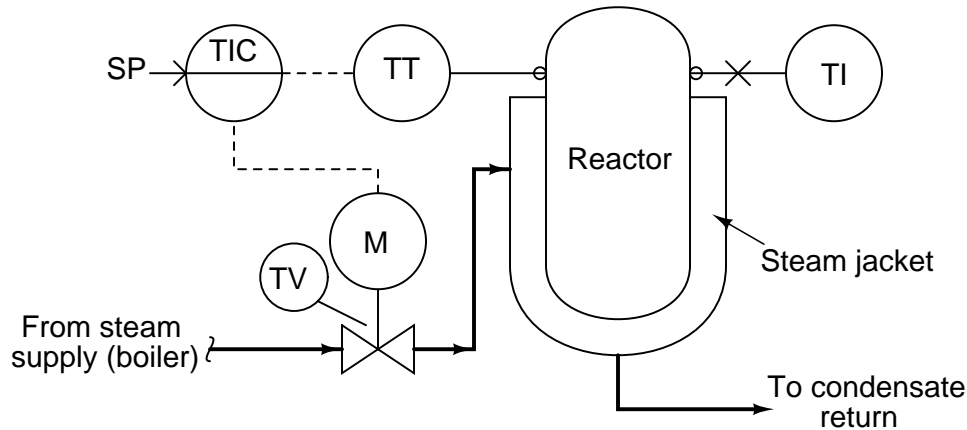
Troubleshooting problems in control system

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Questions

Question 1

Consider this control system, set up to maintain the temperature of a chemical reactor vessel at a constant (“setpoint”) value. The reactor’s source of heat is a steam “jacket” where hot steam is admitted through a motor-operated (M) control valve (TV) according to the temperature inside the reactor sensed by the temperature transmitter (TT):



You arrive at work one day to find the operator very upset. The last batch of product emptied from the reactor was out of spec, as though the temperature were too cold, yet the controller (TIC) displays the temperature to be right at setpoint where it should be: 175 °F.

Your first step is to go to the reactor and look at the temperature indicating gauge (TI) mounted near the same point as the temperature transmitter. It registers a temperature of only 137 °F.

From this information, determine what is the most likely source of the problem, and explain how you made that determination.

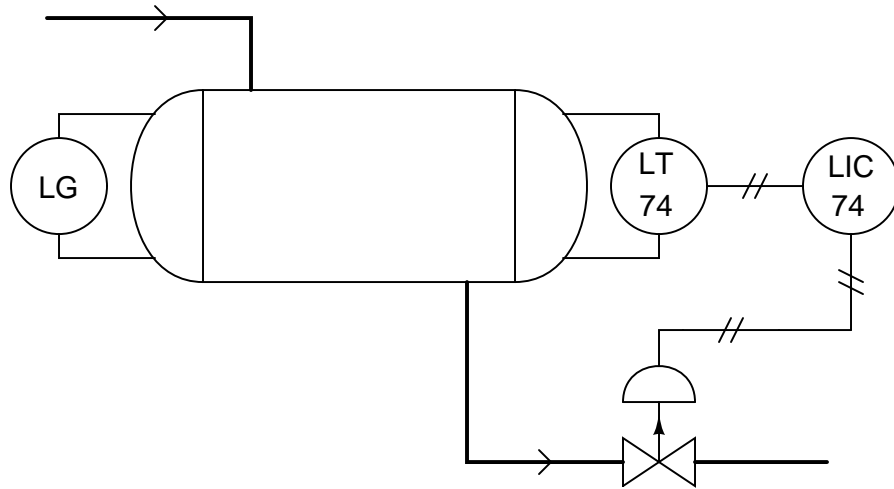
Suggestions for Socratic discussion

- Why was it a good decision to consult the temperature gauge (TI) on the reactor as a first diagnostic step?
- Suppose a fellow instrument technician were to suggest to you that the problem in this system could be a controller configured for the wrong action (e.g. direct action instead of reverse action). Do you think this is a plausible explanation for the symptoms reported here? Why or why not?
- Could the problem be that someone left the controller in *manual* mode rather than automatic mode as it should be? Explain why or why not.
- Based on the P&ID shown, are the instruments pneumatic or electronic?
- Given the fact that we know this reactor is steam-heated, is it possible to conclude that the chemical reaction taking place inside it is either endothermic (heat-absorbing) or exothermic (heat-releasing)?
- Safety shutdown systems often use a “two-out-of-three” (2oo3) voting algorithm to select the best measurement from three redundant transmitters. Explain how this same concept may be applied by the instrument technician in the course of troubleshooting the problem.

[file i00137](#)

Question 2

On the job, you are sent to troubleshoot a brand-new control system, consisting of a pneumatic liquid level transmitter connected to a pneumatic controller, which in turn drives a pneumatic control valve. The process vessel, piping, control valve, controller, and level transmitter are all brand-new: they even sport a fresh coat of paint.



According to the unit operator, this level control system has *never* worked. As she shows you, the liquid level inside the vessel is so low that the level gauge (LG) registers empty, yet the controller is commanding the valve 100% open, which of course continues to drain the vessel and prevent any liquid level from accumulating.

Being versed in process control theory, you decide to check how the controller is configured. Looking inside the controller case, you notice the controller is set for *direct* action: an increasing PV results in an increasing output signal (MV), which will move the air-to-close valve more toward the “closed” state.

Realizing how to fix the problem, you reach inside the controller and move a lever that switches it into *reverse* action mode.

Explain why this fixes the problem.

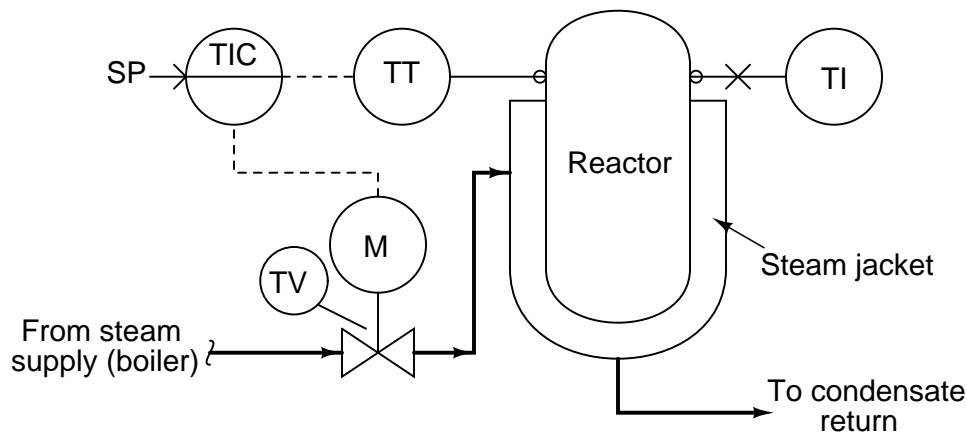
Suggestions for Socratic discussion

- Explain the significance of the “newness” of this process. How would your assumptions differ if you saw this process vessel was old and rusted instead of shiny-new?
- How do you suppose the controller got to be mis-configured in the first place?
- What would have to be different in this control system to permit a direct-acting controller instead of a reverse-acting controller?
- Suppose you did not discover the controller’s action set for direct action. If the controller had been left in manual mode instead of automatic mode, could this account for the problems exhibited by this system?

[file i00140](#)

Question 3

Consider this control system, set up to maintain the temperature of a chemical reactor vessel at a constant (“setpoint”) value. The reactor’s source of heat is a steam “jacket” where hot steam is admitted through a motor-operated (M) control valve (TV) according to the temperature inside the reactor sensed by the temperature transmitter (TT):



You arrive at work one day to find the operator very upset. The last batch of product emptied from the reactor was out of spec, and the temperature displayed by the indicating controller (TIC) shows it to be 197 °F. The setpoint is set at 175 °F, and the controller is in the automatic mode as it should be.

Your first step is to look at the indication on the controller showing the output signal going to the motor-actuated steam valve (TV). This output signal display (the “manipulated variable”) shows 0 %, which means “valve fully closed.”

Next, you decide to check the temperature shown at the temperature indicator (TI) located near the temperature transmitter (TT) on the reactor. There, you see a temperature indication of 195 °F.

From this information, determine what is the most likely source of the problem, and explain how you made that determination.

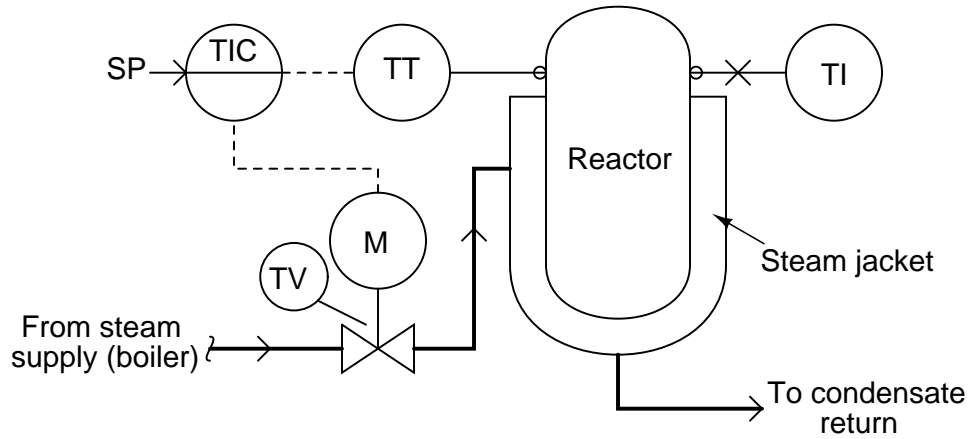
Suggestions for Socratic discussion

- Why is it important for us to know that the controller is in automatic mode? Would it make a difference if it were in manual mode instead?
- Explain why the first two diagnostic steps were to check the controller’s output display, then to check the TI on the reactor. What do each of these checks tell us about the nature of the problem?
- Suppose a fellow instrument technician were to suggest to you that the problem in this system could be a controller configured for the wrong action (e.g. direct action instead of reverse action). Do you think this is a plausible explanation for the symptoms reported here? Why or why not?

[file i00138](#)

Question 4

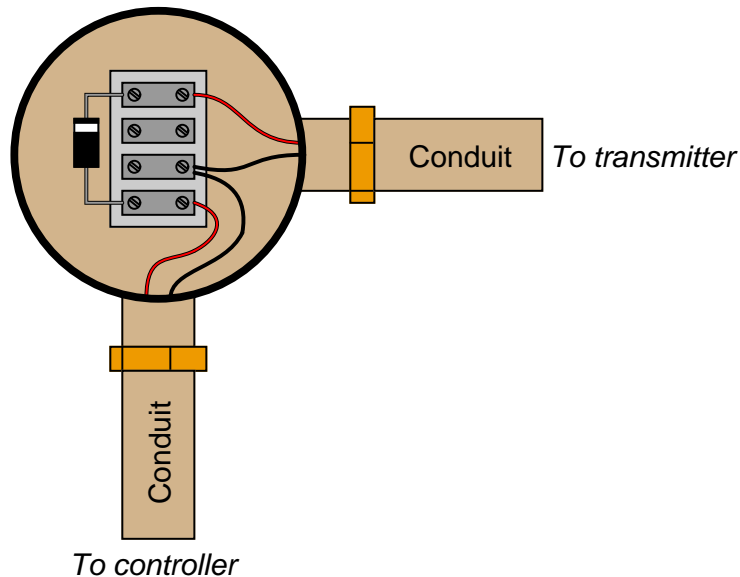
Consider this control system, set up to maintain the temperature of a chemical reactor vessel at a constant (“setpoint”) value. The reactor’s source of heat is a steam “jacket” where hot steam is admitted through a motor-operated (M) control valve (TV) according to the temperature inside the reactor sensed by the temperature transmitter (TT):



While doing some clean-up work near the reactor, you receive a frantic call from the operator on your two-way radio. He says that the controller (TIC) is registering a temperature of 186 °F, which is 11 degrees higher than the setpoint of 175 °F. A temperature this high could ruin the product inside the reactor. He wants you to check the temperature indicator on the side the reactor (TI) and let him know what it reads.

You look at the TI, and see that it registers a temperature of 172 °F, which is a bit too cold if anything, not too hot. You immediately report this to the operator using your radio, who then asks you to check out the system to see why he’s getting a false reading on the controller display.

Fortunately, you have your multimeter and tool set with you, so you proceed to the temperature transmitter to measure the milliamp signal it is outputting. Removing a cover from a round junction box on the conduit where the transmitter’s wires are routed, you see a terminal block inside with a 1N4001 rectifying diode placed in series with the circuit:



Setting your multimeter to measure milliamps, you connect the red and black test leads across the diode.

This shorts past the diode, forcing all the current to go through the meter instead of the diode, allowing you to “break in” to the 4-20 mA circuit without having to physically break a wire connection anywhere. Making a mental note to thank your instrumentation instructor later for showing you this trick, you see that your multimeter registers 15.683 mA.

Given a calibrated temperature transmitter range of 100 to 200 degrees F, determine what this current measurement tells you about the location of the problem in this temperature control loop, and explain how you made that determination.

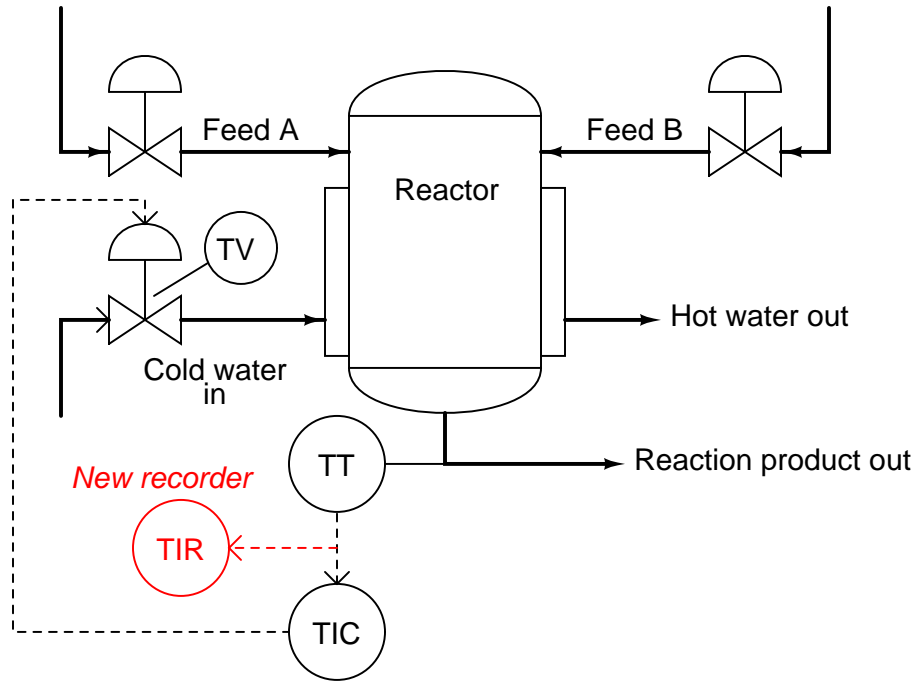
Suggestions for Socratic discussion

- Why is it important for technicians to be able to easily convert milliamp signal values into corresponding process variable (PV) values?
- How does the diode perform this useful function of allowing current measurement without breaking the circuit?
- Supposing there were no diode in this loop circuit, how would you suggest we measure the transmitter’s output current?
- Is it possible that the fault in this system could be something to do with the control valve? Why or why not?

[file i00139](#)

Question 5

In this process, two chemical streams are mixed together in a reactor vessel. The ensuing chemical reaction is exothermic (heat-producing) and must be cooled by a water cooling system to prevent overheating of the vessel and piping. A temperature transmitter (TT) senses the reaction product temperature and sends a 4-20 mA signal to a temperature indicating controller (TIC). The controller then sends a 4-20 mA control signal to the temperature valve (TV) to throttle cooling water flow:

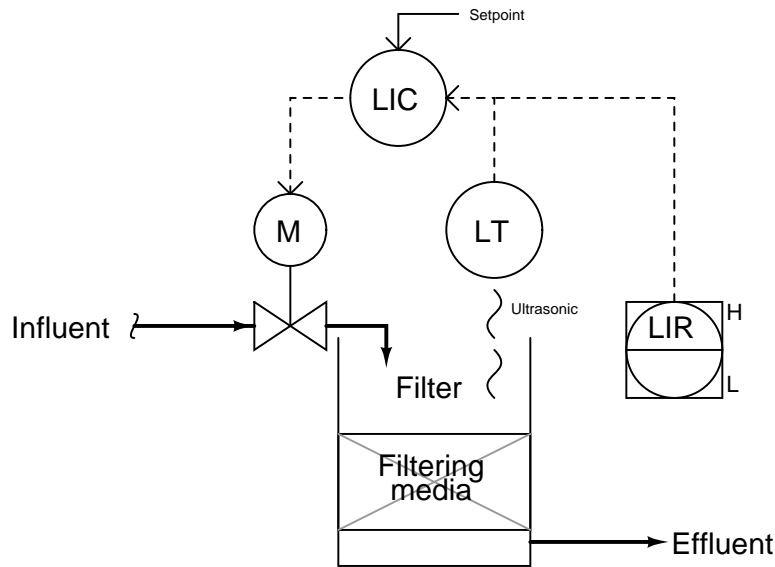


Suppose an instrument technician adds a temperature-indicating chart recorder (TIR) to the temperature transmitter circuit, necessitating the addition of a 250 ohm resistor to the 4-20 mA circuit to provide a 1-5 volt voltage signal which the recorder can read. Now the 4-20 mA temperature circuit has more resistance in it than it did before.

Describe in detail the effect this circuit modification will have on the performance of the cooling system.
file i02931

Question 6

This water filter level control system uses an ultrasonic level transmitter to sense the level of water in the filter, and a controller to drive a motor-actuated valve introducing raw water to be filtered:



Assuming a direct-acting level transmitter (increasing filter level = increasing signal), and a signal-to-open control valve (increasing controller output signal = wider open valve), determine whether the level controller needs to be configured for *direct-action* or *reverse-action*, and explain your reasoning. Annotate the diagram with “+” and “-” symbols next to the PV and SP controller inputs to show more explicitly the relationships between the controller inputs and output.

Next, determine the response of the controller to the following situations. In other words, determine what the controller’s output signal will do when this water level control system is affected in the following ways:

- A sudden increase in effluent flow rate (clean water demand)
- Level transmitter fails high (indicating 100% full water level)
- Control valve actuator fails, driving valve fully open (ignoring controller signal)

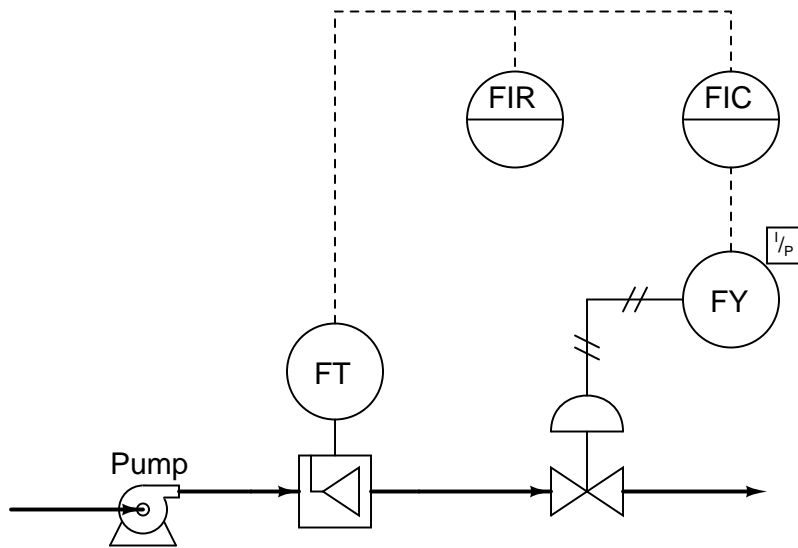
Suggestions for Socratic discussion

- Re-draw the diagram for this water filter level control system, replacing the controller (circle) with an op-amp symbol (triangle), determining the “+” and “-” input assignments on the opamp for PV and SP.
- Explain why level control is important in a water filter such as this.
- What do the “H” and “L” symbols near the LIR represent?

[file i02370](#)

Question 7

There is a problem somewhere in this liquid flow control system. The controller is in automatic mode, with a setpoint of 65%, yet the flow indicator and the flow controller both register 0.3%: (nearly) zero flow. A P&ID of the loop appears here:



Explain how you would begin troubleshooting this system, and what possible faults could account for the controller not being able to maintain liquid flow at setpoint.

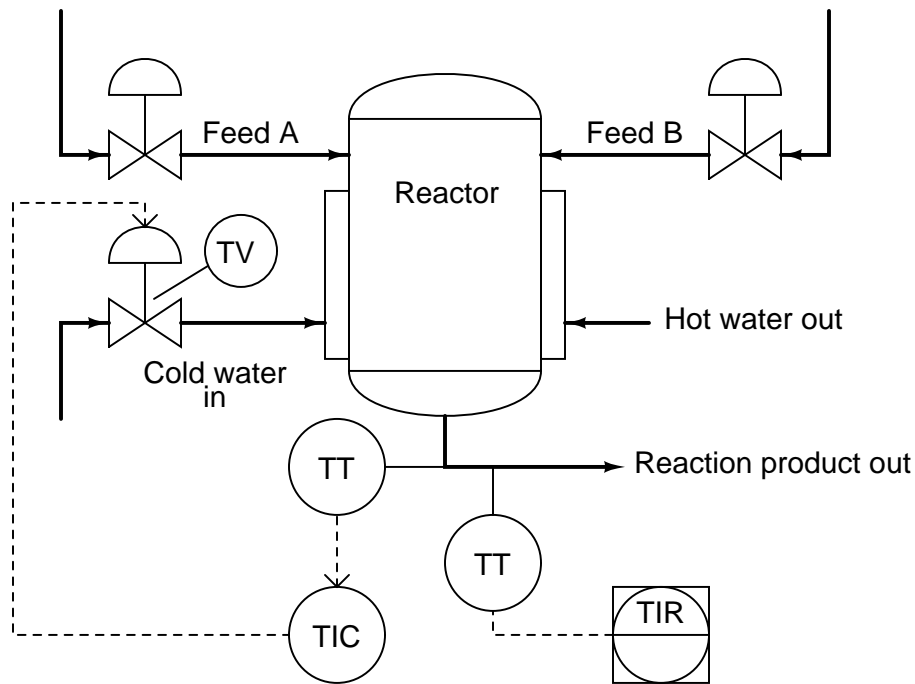
Suggestions for Socratic discussion

- Explain how you could divide this control system into distinct areas or zones which you may then begin to refer to when “dividing and conquering” the problem.

[file i02518](#)

Question 8

In this process, two chemical streams are mixed together in a reactor vessel. The ensuing chemical reaction is exothermic (heat-producing) and must be cooled by a water cooling system to prevent overheating of the vessel and piping. A temperature transmitter (TT) senses the reaction product temperature and sends a 4-20 mA signal to a temperature indicating controller (TIC). The controller then sends a 4-20 mA control signal to the temperature valve (TV) to throttle cooling water flow:

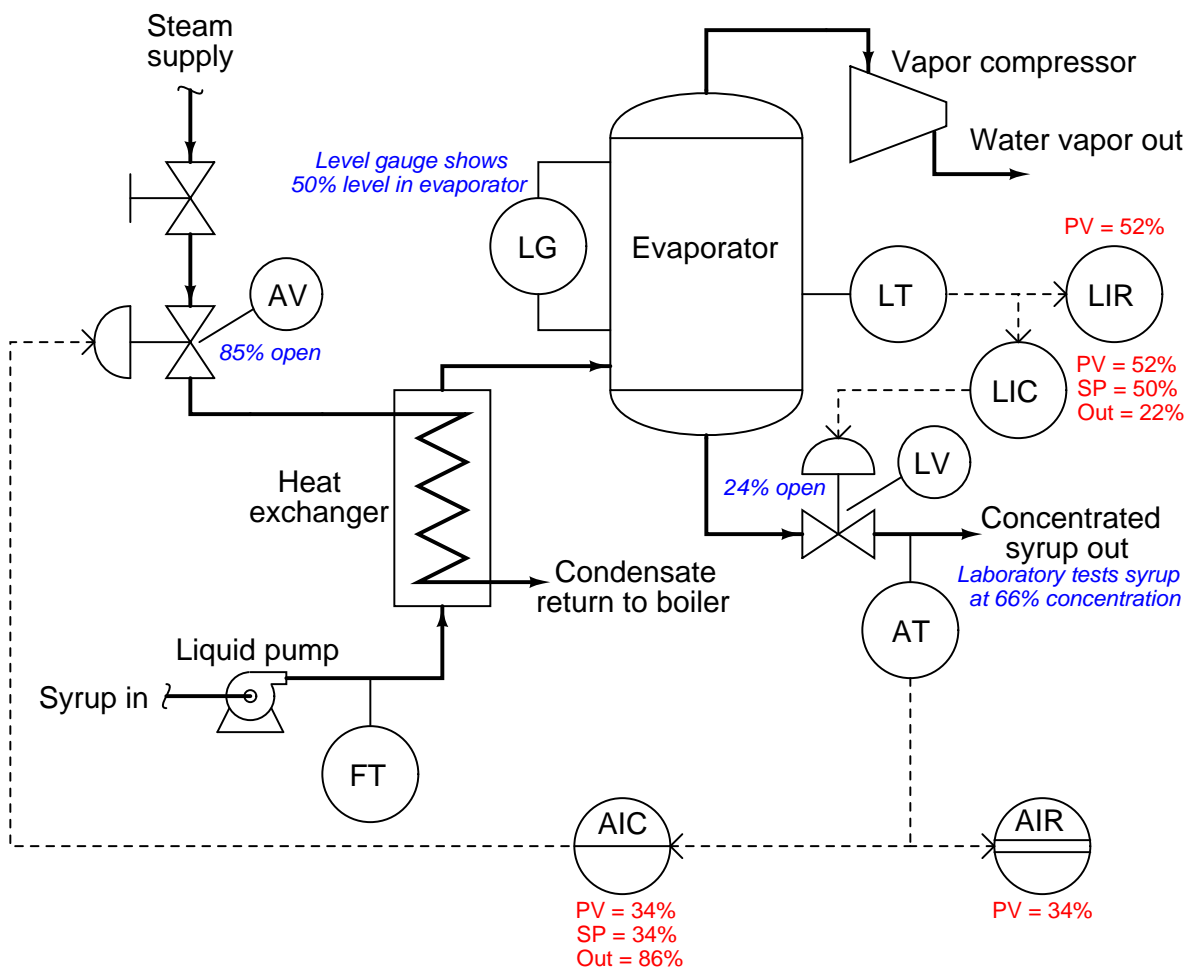


Suppose operators decide to increase production in this process reactor. This means the incoming feed flow rates will be increased, producing more heat.

Describe in detail how the cooling system will respond to this change in process operations.
[file i02933](#)

Question 9

In this process, maple syrup is heated as it passes through a steam heat exchanger, then enters an evaporator where the water boils off. The purpose of this is to raise the sugar concentration of the syrup, making it suitable for use as a food topping. A level control system (LT, LIR, LIC, and LV) maintains constant syrup level inside the evaporator, while an analytical control system (AT, AIR, AIC, and AV) monitors the sugar concentration of the syrup and adjusts steam flow to the heat exchanger accordingly.



Examine the live variable values shown in the above diagram, and then determine where any problems may exist in this syrup concentrating system.

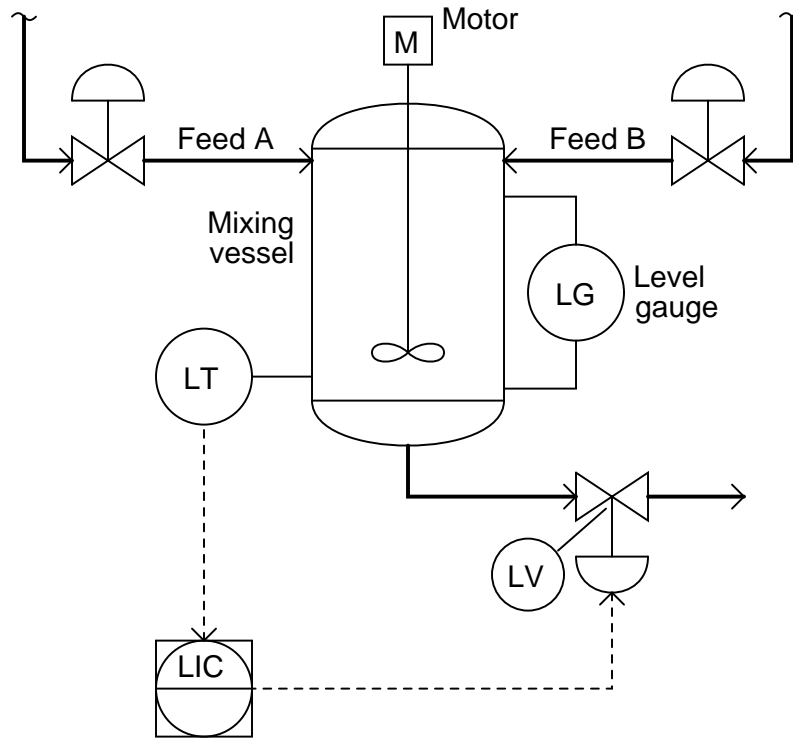
Suggestions for Socratic discussion

- A valuable principle to apply in a diagnostic scenario such as this is *correspondence*: identifying which variables correspond at different points within the system, and which do not. Apply this comparative test to the variables scenario shown in the diagram, and use the results to defend your answer of where the problem is located and what type of problem it is.

[file i02934](#)

Question 10

Examine this P&ID for a level control system in a vessel where two different fluids (Feed A and Feed B) are mixed together:

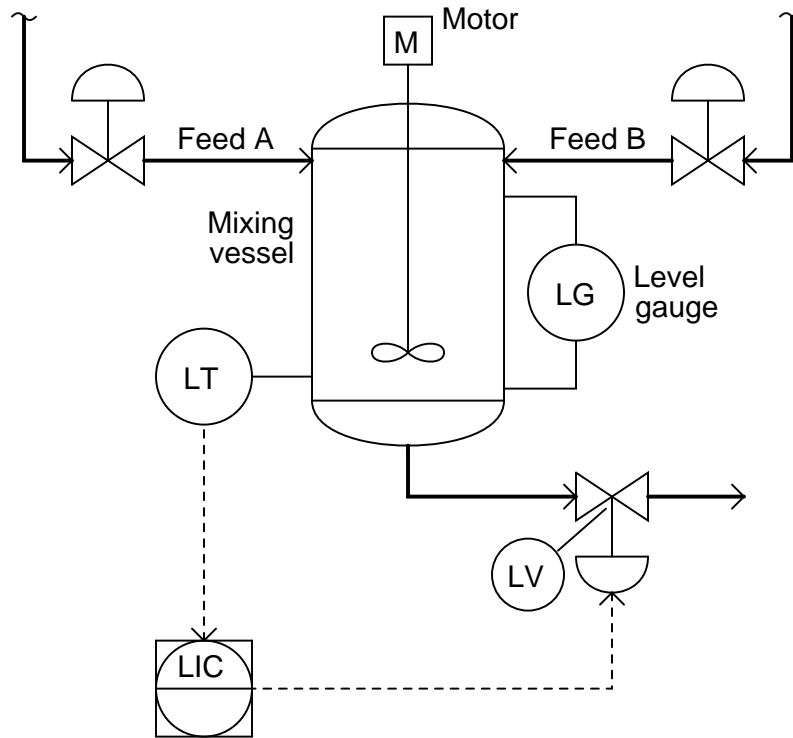


Determine the effect on the control system's regulation of liquid level inside the vessel if an instrument technician accidentally mis-calibrates the control valve such that it opens 2% more than it should (e.g. when the controller sends a 50% signal to the valve, it actually opens to 52% stem travel). Assume all other loop components are properly configured and that the controller is well-tuned.

file i04391

Question 11

Examine this P&ID for a level control system in a vessel where two different fluids (Feed A and Feed B) are mixed together:

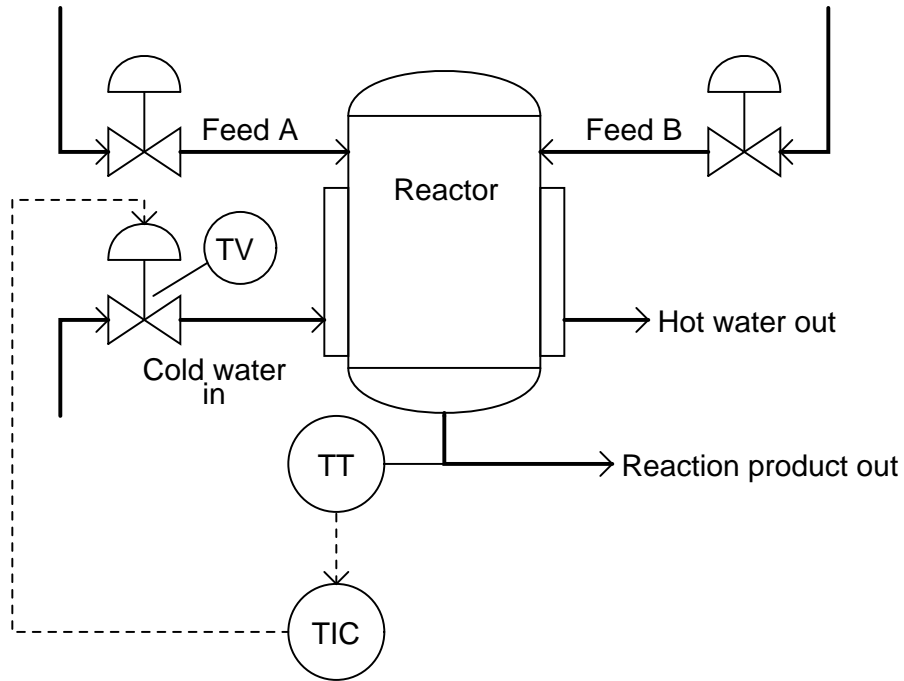


Determine the effect on the control system's regulation of liquid level inside the vessel if an instrument technician accidentally mis-configures the controller for the wrong type of action (e.g. direct action when it should be reverse, or vice-versa). Assume all other loop components are properly configured and that the controller is well-tuned.

file i04393

Question 12

In this process, two chemical streams are mixed together in a reactor vessel. The ensuing chemical reaction is exothermic (heat-producing) and must be cooled by a water cooling system to prevent overheating of the vessel and piping. A temperature transmitter (TT) senses the reaction product temperature and sends a 4-20 mA signal to a temperature indicating controller (TIC). The controller then sends a 4-20 mA control signal to the temperature valve (TV) to throttle cooling water flow:

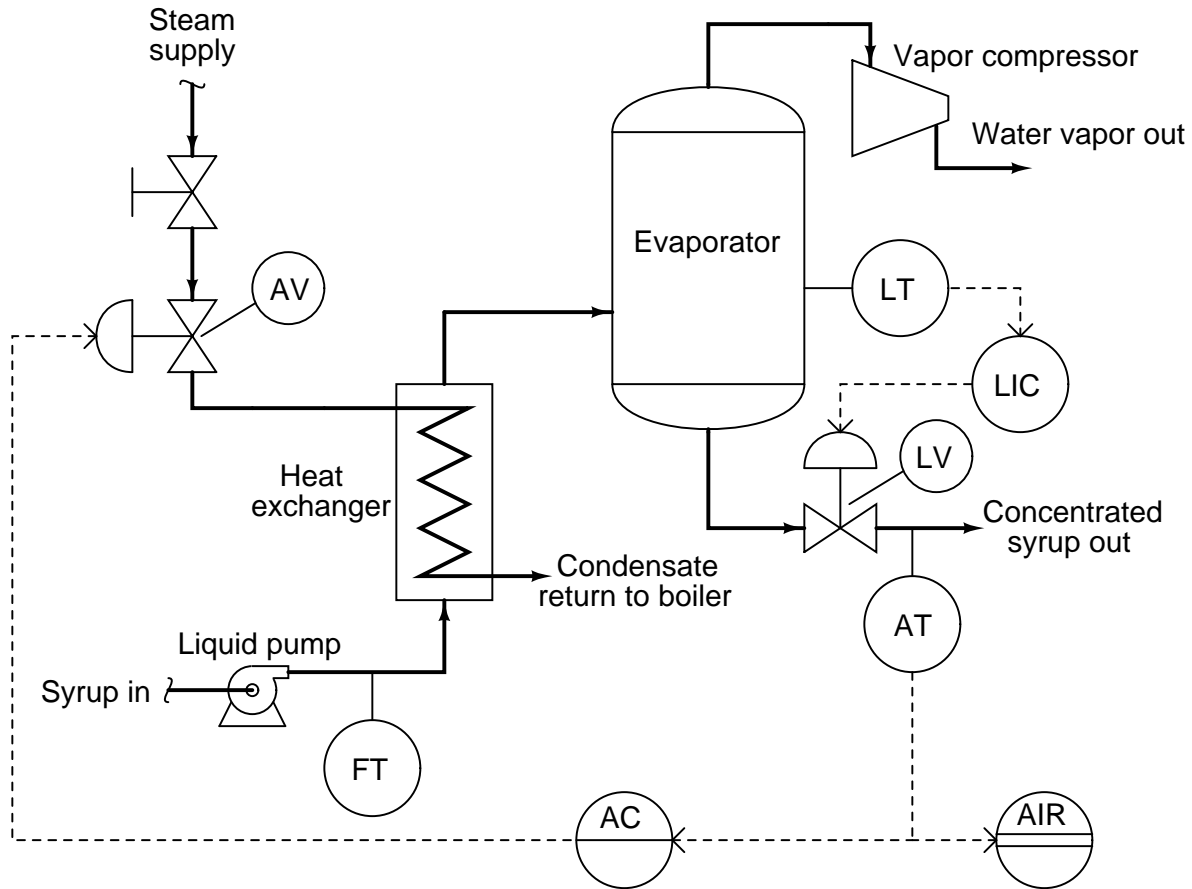


Suppose something fails in the control valve mechanism to make it incapable of opening further than 80%. From 0% to 80% position, however, the valve responds normally.

Describe in detail the effect this fault will have on the performance of the cooling system.
[file i02932](#)

Question 13

In this process, maple syrup is heated as it passes through a steam heat exchanger, then enters an evaporator where the water boils off. The purpose of this is to raise the sugar concentration of the syrup, making it suitable for use as a food topping. A level control system (LT, LIC, and LV) maintains constant syrup level inside the evaporator, while an analytical control system (AT, AIR, AC, and AV) monitors the sugar concentration of the syrup and adjusts steam flow to the heat exchanger accordingly.



Suppose the syrup analyzer (AT) suffers a sudden calibration problem, causing it to register too low (telling the analytical controller that the sugar concentration of the syrup is less than it actually is).

Describe in detail the effect this calibration error will have on the performance of the analytical control system.

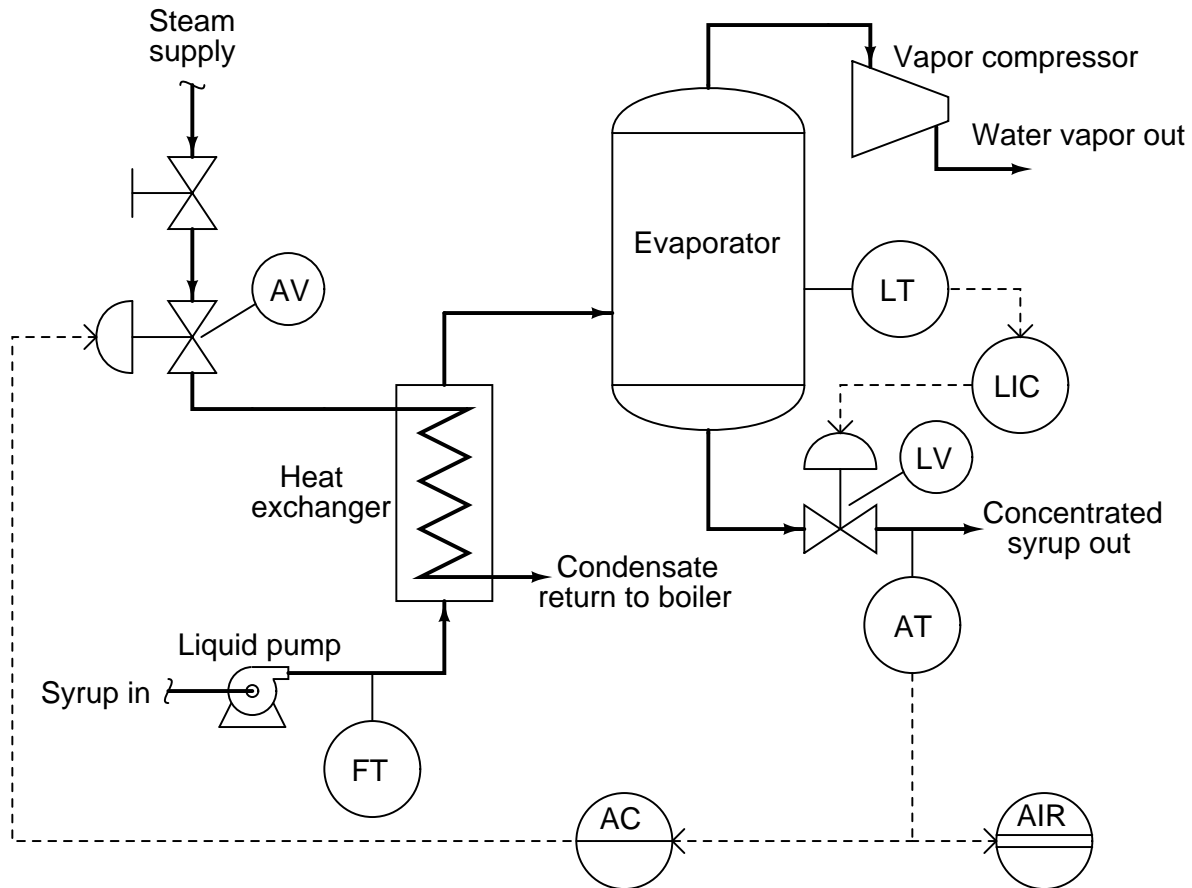
Suggestions for Socratic discussion

- What economic effect will this mis-calibration have on the process? In other words, does the process become more or less profitable as a result of this change?
- Suppose someone shuts the manual block valve on the steam line just a little bit, so that it is about 80% open instead of 100% open. How will this process change affect the control systems in this process?

[file i02936](#)

Question 14

In this process, maple syrup is heated as it passes through a steam heat exchanger, then enters an evaporator where the water boils off. The purpose of this is to raise the sugar concentration of the syrup, making it suitable for use as a food topping. A level control system (LT, LIC, and LV) maintains constant syrup level inside the evaporator, while an analytical control system (AT, AIR, AC, and AV) monitors the sugar concentration of the syrup and adjusts steam flow to the heat exchanger accordingly.



Suppose the steam tubes inside the heat exchanger become coated with residue from the raw maple syrup, making it more difficult for heat to transfer from the steam to the syrup. This makes the heat exchanger less efficient, which will undoubtedly affect the process.

Describe in detail the effect this heat exchanger problem will have on the performance of the analytical control system.

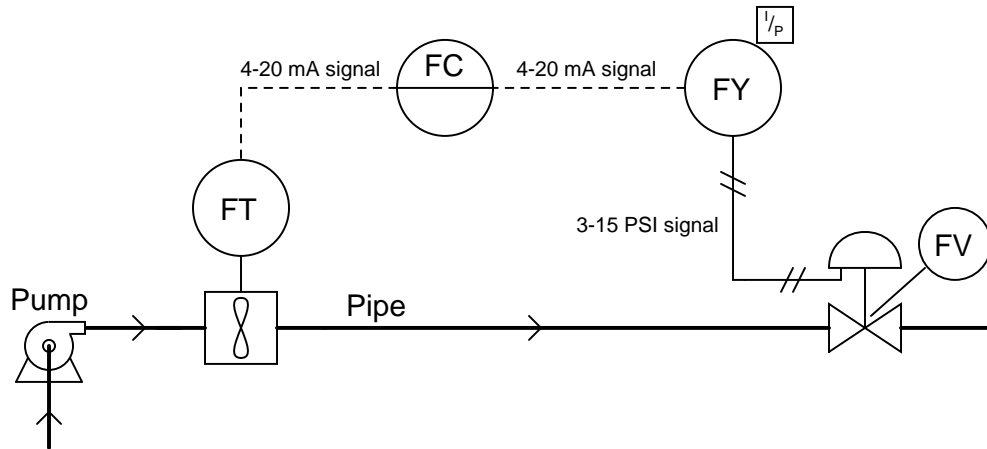
Suggestions for Socratic discussion

- Suppose the operations personnel of this maple syrup processing facility wished to have an *automatic* method for detecting heat exchanger fouling. What variable(s) could be measured in this process to indicate a fouled heat exchanger?
- What economic effect will this fouling have on the process? In other words, does the process become more or less profitable as a result of the heat exchanger fouling?

[file i02937](#)

Question 15

Pictured here is a P&ID (Process and Instrument Diagram) of a liquid flow control “loop,” consisting of a *flow transmitter* (FT) to sense liquid flow rate through the pipe and output an electronic signal corresponding to the flow, a *flow controller* (FC) to sense the flow signal and decide which way the control valve should move, a current-to-air (I/P) *transducer* (FY) to convert the controller’s electronic output signal into a variable air pressure, and an air-operated *flow control valve* (FV) to throttle the liquid flow:



The actions of each instrument are shown here:

- FT: increasing liquid flow = increasing current signal
- FC: increasing process variable (input) signal = decreasing output signal
- FY: increasing current input signal = increasing pneumatic output signal
- FV: increasing pneumatic signal = open more

Describe what will happen to all signals in this control loop with the controller in “automatic” mode (ready to compensate for any changes in flow rate by automatically moving the valve) if the pump were to suddenly spin faster and create more fluid pressure, causing an increase in flow rate.

Also describe what will happen to all signals in this control loop with the controller in “manual” mode (where the output signal remains set at whatever level the human operator sets it at) if the pump were to suddenly spin faster and create more fluid pressure, causing an increase in flow rate.

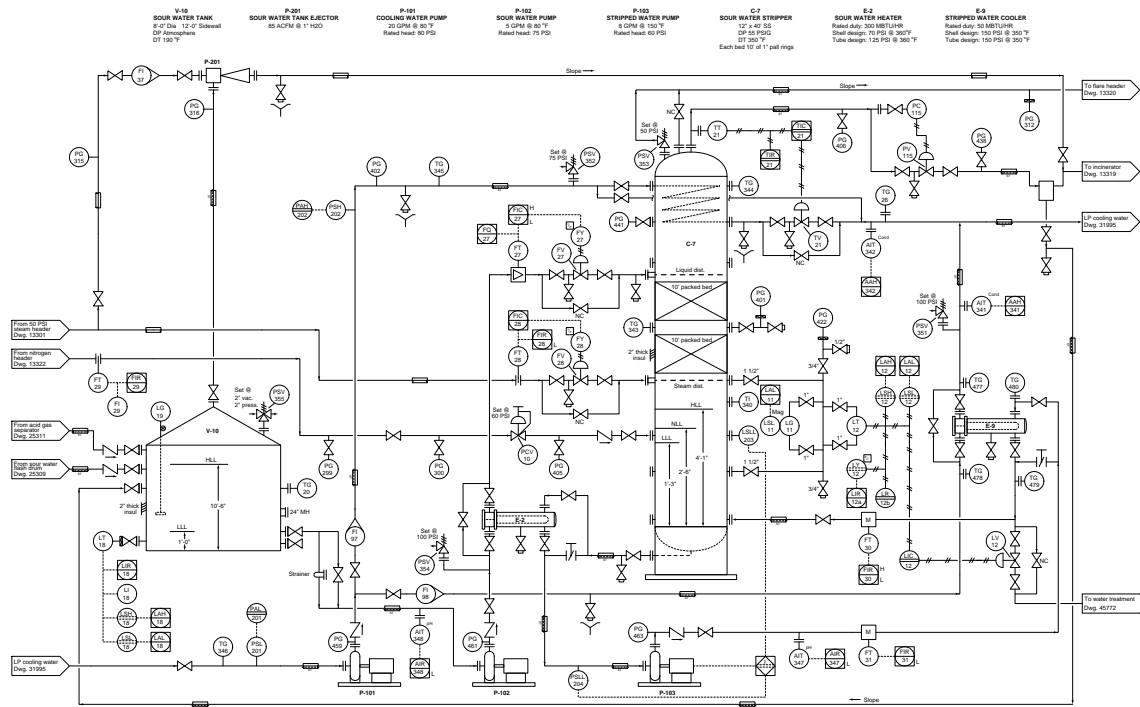
Suggestions for Socratic discussion

- Explain the practical benefit of having a “manual” mode in a process loop controller. When might we intentionally use manual mode in an operating process condition?

[file i00124](#)

Question 16

An operator reports a high level alarm (LAH-12) displayed at the control room for the last 13 hours of operation, in this sour water stripping tower unit (where sulfide-laden water is “stripped” of sulfur compounds by the addition of hot steam). Over that time period, the sightglass (level gauge LG-11) has shown the liquid level inside vessel C-406 drifting between 2 feet 5 inches and 2 feet 8 inches:



Identify the likelihood of each specified fault in this process. 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 process.

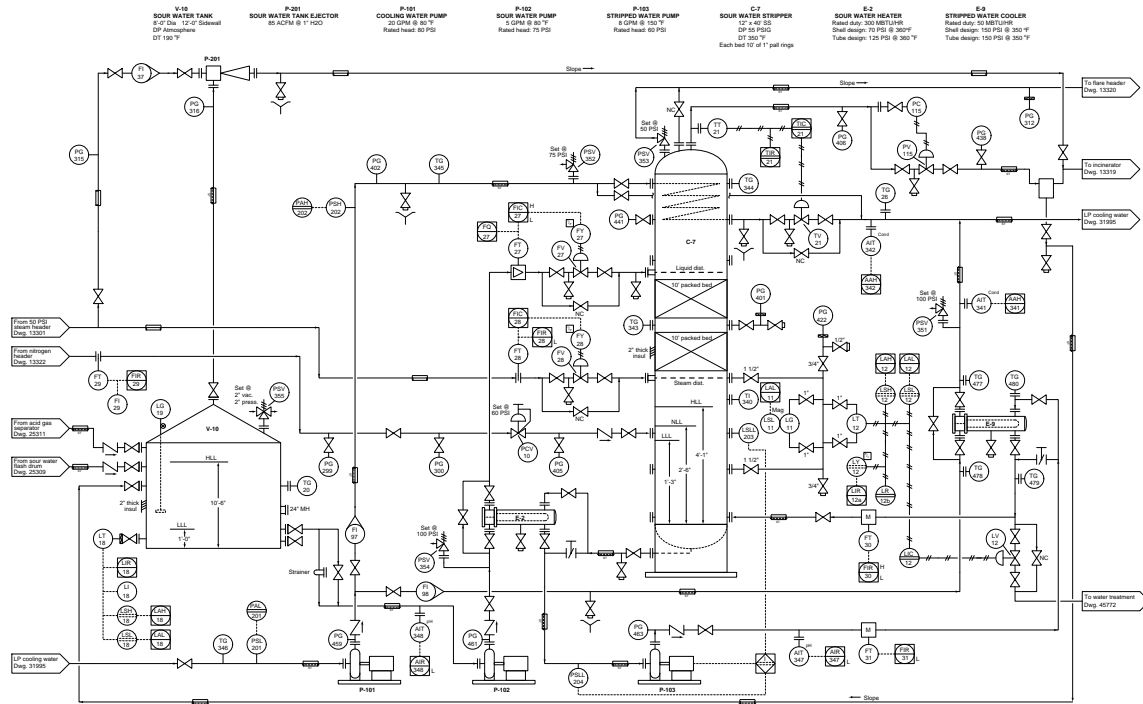
Fault	Possible	Impossible
LT-12 miscalibrated		
LG-11 block valve(s) shut		
LSH-12 switch failed		
LSL-12 switch failed		
Leak in tubing between LT-12 and LIC-12		
LIC-12 controller setpoint set too high		
LV-12 control valve failed open		
LV-12 control valve failed shut		

file i03540

Question 17

In this process, steam is introduced into “stripping” vessel C-7 to help remove volatile sulfur compounds from “sour” water. The temperature of the stripped gases exiting the tower’s top is controlled by a pneumatic temperature control loop. Unfortunately, this loop seems to have a problem.

Temperature indicating recorder TIR-21 registers 304 degrees Fahrenheit, while temperature indicating controller TIC-21 registers 285 degrees Fahrenheit. The calibrated range of TT-21 is 100 to 350 degrees Fahrenheit. A technician connects a test gauge to the pneumatic signal line and reads a pressure of 12.8 PSI:



Which instrument is faulty: the transmitter, the recorder, or the controller, or is it impossible to tell from what little information is given here?

[file i03541](#)

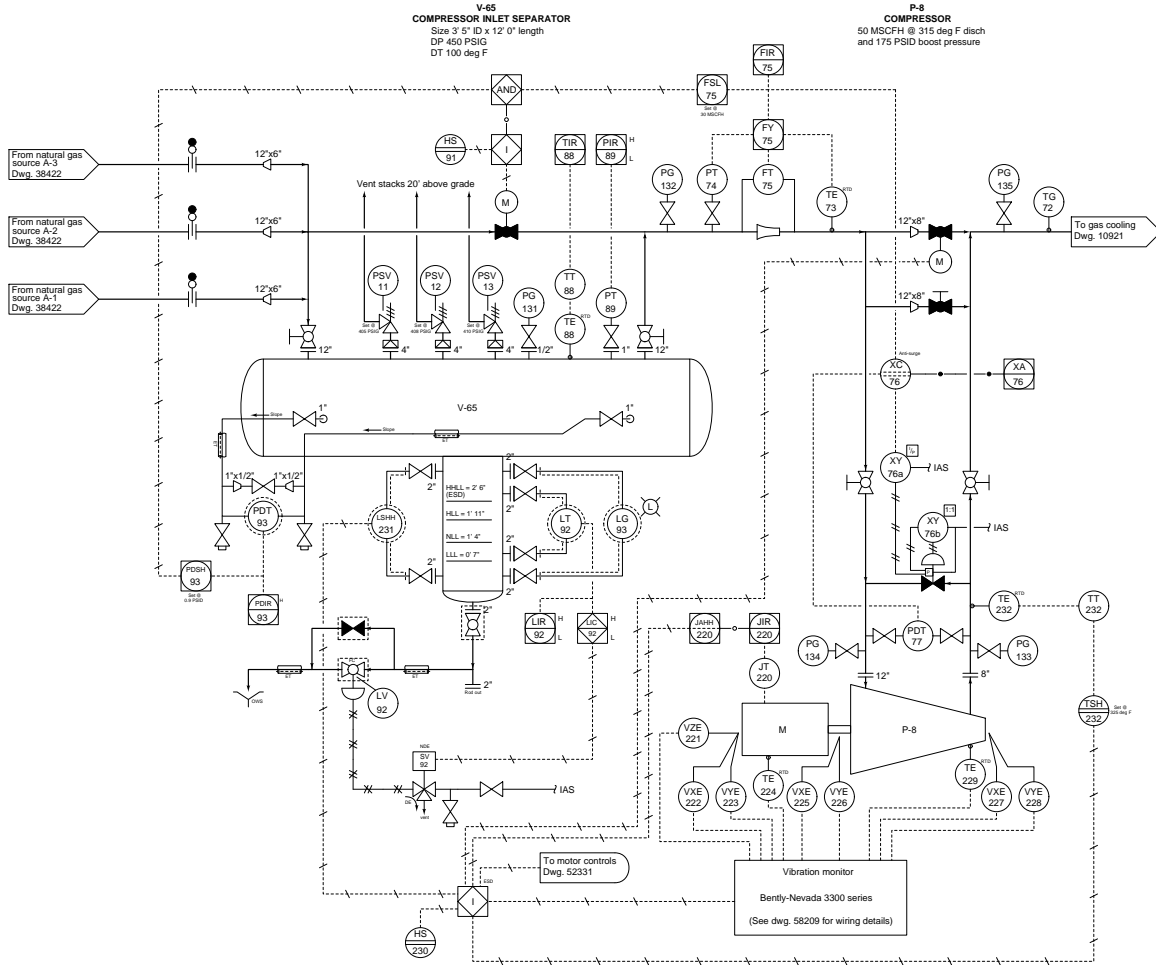
Identify the likelihood of each specified fault in this process. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault could independently account for *all* measurements and symptoms in this process.

Fault	Possible	Impossible
SV-115 leaking air		
PSL-105 failed		
PSL-114 failed		
PCV-39 pressure setpoint too low		
PCV-39 pressure setpoint too high		
PCV-40 pressure setpoint too low		
PCV-40 pressure setpoint too high		
ZS-38 failed		
Blind inserted in natural gas header		
Blind inserted in fuel gas header		

file i03500

Question 19

The compressor emergency shutdown system (ESD) has tripped the natural gas compressor off-line three times in the past 24 hours. Each time the operator goes to reset the compressor interlock, she notices the graphic display panel on the interlock system says “Separator boot high level” as the reason for the trip. After this last trip, operations decides to keep the compressor shut down for a few hours until your arrival to diagnose the problem. Your first diagnostic test is to look at the indicated boot level in the sightglass (LG-93). There, you see a liquid level appears to be normal:



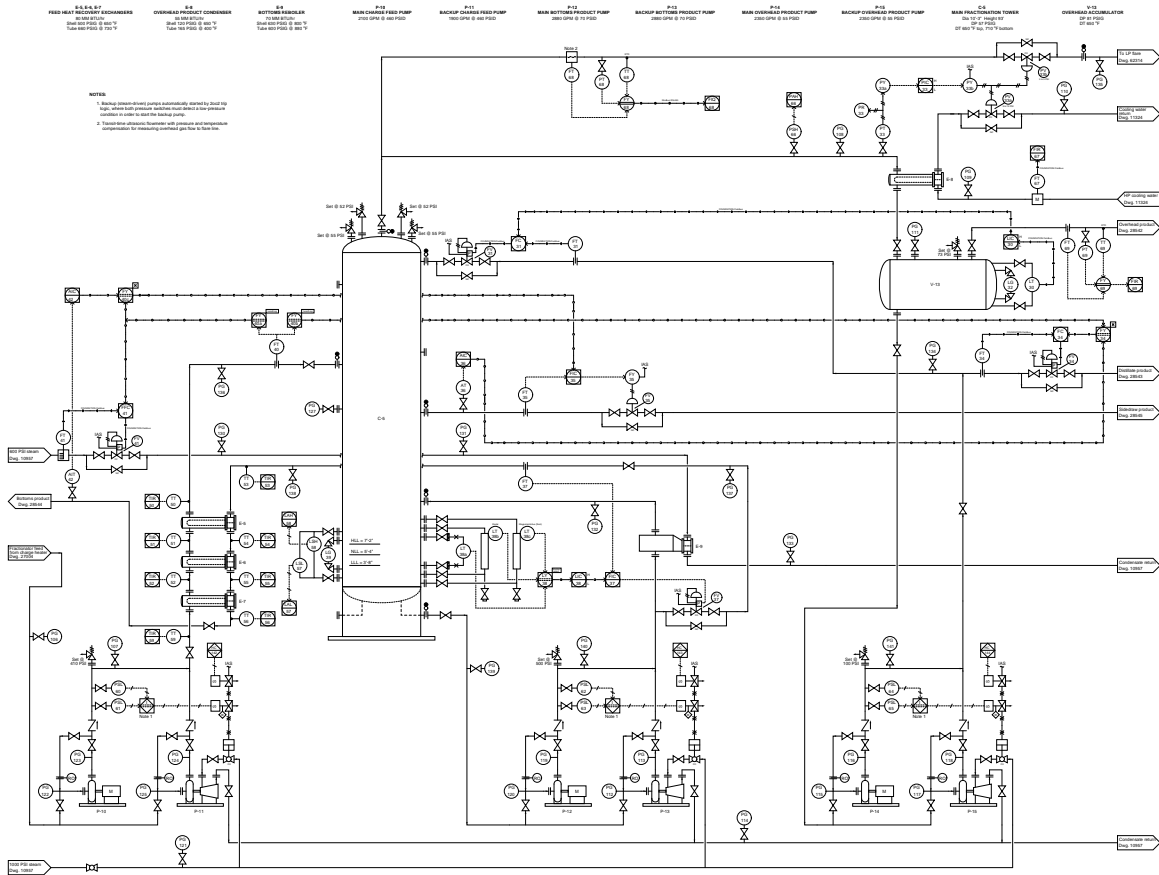
First, explain why this first diagnostic test was a good idea. Then, identify what would your *next* diagnostic test be.

Finally, comment on the decision by operations to leave the compressor shut down until your arrival. Do you think this was a good idea or a bad idea, from a diagnostic perspective? Why or why not?

[file i03502](#)

Question 20

The overhead pressure control system in this fractionator seems to have a problem. The controller (PIC-33) indicates the pressure being over setpoint by a substantial margin: the pressure reads 48 PSI while the setpoint is 37 PSI:



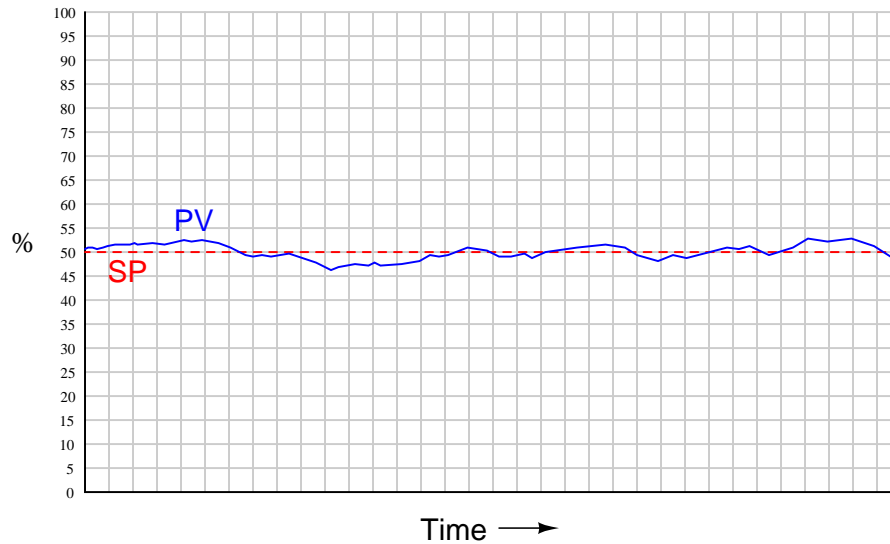
Identify the likelihood of each specified fault in this process. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault could independently account for *all* measurements and symptoms in this process.

Fault	Possible	Impossible
PT-33 calibration error		
PY-33a calibration error		
PY-33b calibration error		
PV-33b block valve closed		
PV-33b bypass valve open		
Instrument air supply to PY-33b failed		
Instrument air supply to FV-34 failed		

file i03533

Question 21

Inspecting the trends of PV and SP on a process chart recorder, you notice the poor quality of control:



The “wandering” of the process variable (PV) around setpoint may be due to excessive action on the part of the controller, or it may be due to load fluctuations in the process itself. In other words, the instability may be the fault of the controller reacting too aggressively, or it may be that the controller is not working aggressively enough to counter changes in process load.

Identify a simple method to determine which scenario is true. Hint: the way to check is as simple as pushing a single button, in most cases.

[file i01646](#)

Question 22

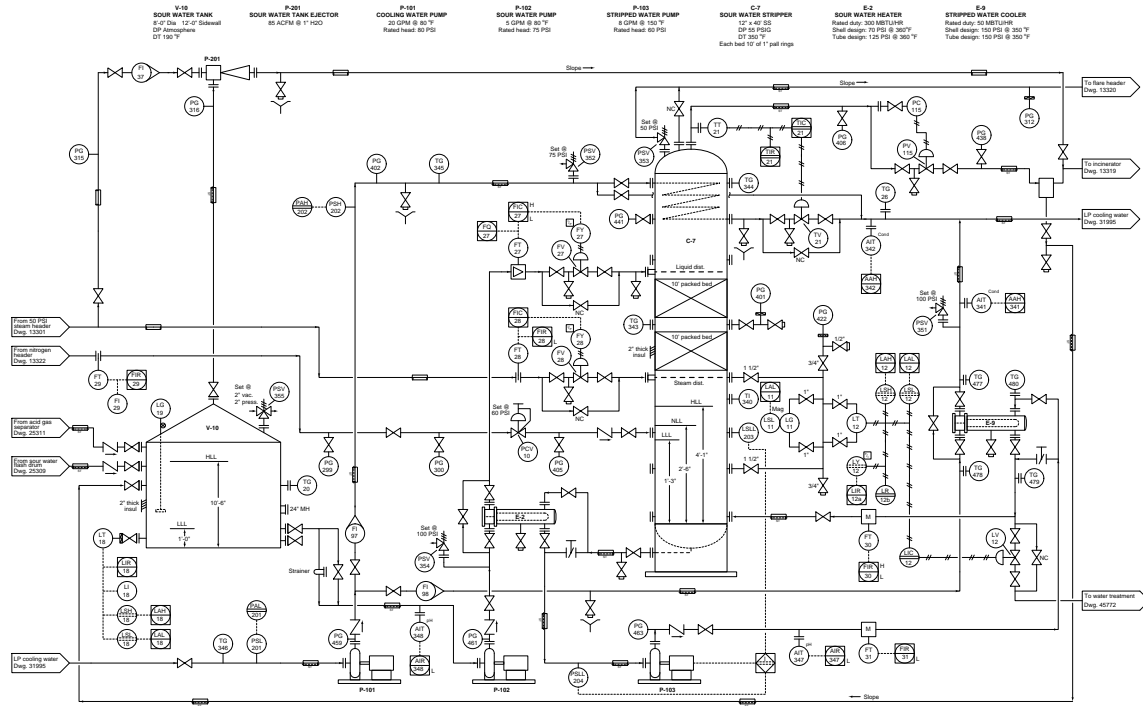
A very useful technique for testing process control loop response is to subject it to a “step-change” in controller output. In other words, the process is *perturbed* (the highly technical term for this is “bumped”) and the results recorded to learn more about its characteristics.

What practical concerns might surround “bumping” a process such as this? Remember, the process variable (PV) is a real physical measurement such as pressure, level, flow, temperature, pH, or any number of quantities. What precautions should you take prior to perturbing a process to check its response?

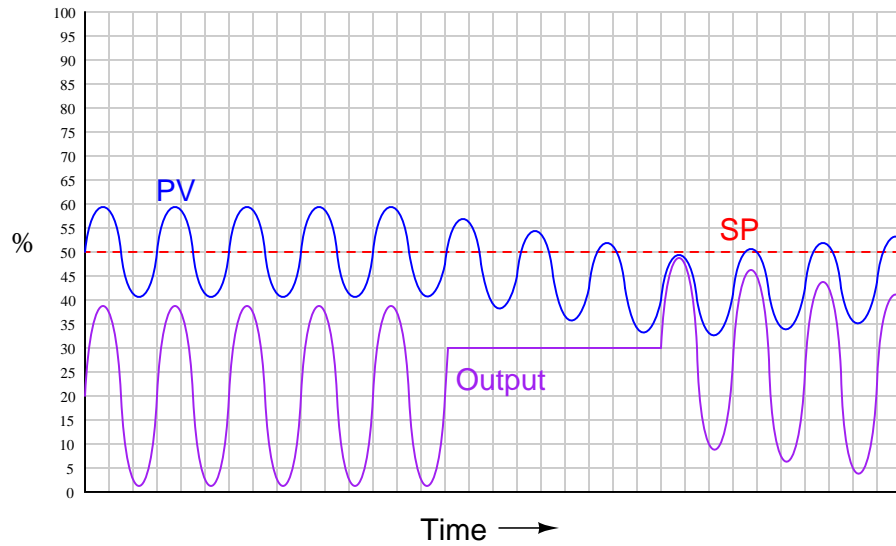
[file i01652](#)

Question 23

In this process, sulfur-laden water is “stripped” of sulfur compounds by the addition of hot steam. A level control system is supposed to maintain a constant level of liquid at the bottom of the stripping tower, but it seems to have a problem:



Here is what the trend recording from LR-12b looks like during the time an operator placed the controller in manual mode and then back to automatic mode:



A fellow technician tells you he thinks the controller is over-tuned (having too much gain). The operator, who just did the manual-mode test, disagrees. Based on the information seen in the trend, what do you think the source of the oscillation is, and how would you go about testing your hypothesis?

file i01902

Answers

Answer 1

Answer 2

Answer 3

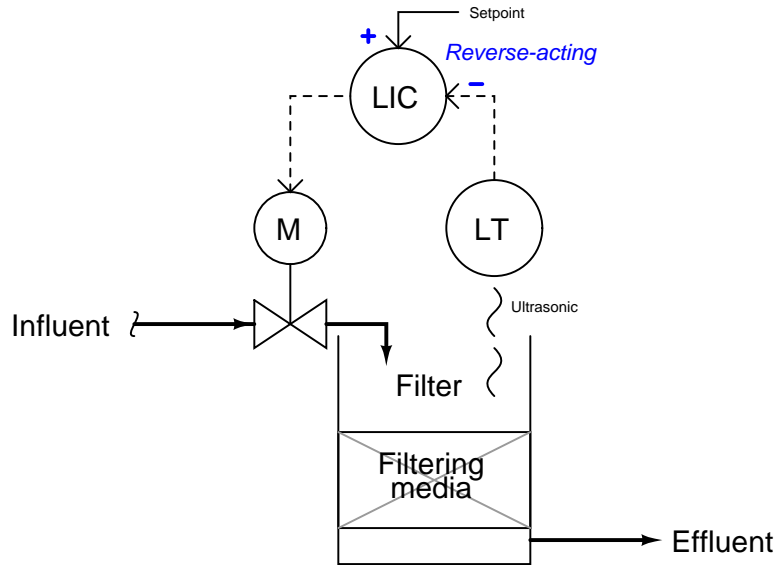
Answer 4

Answer 5

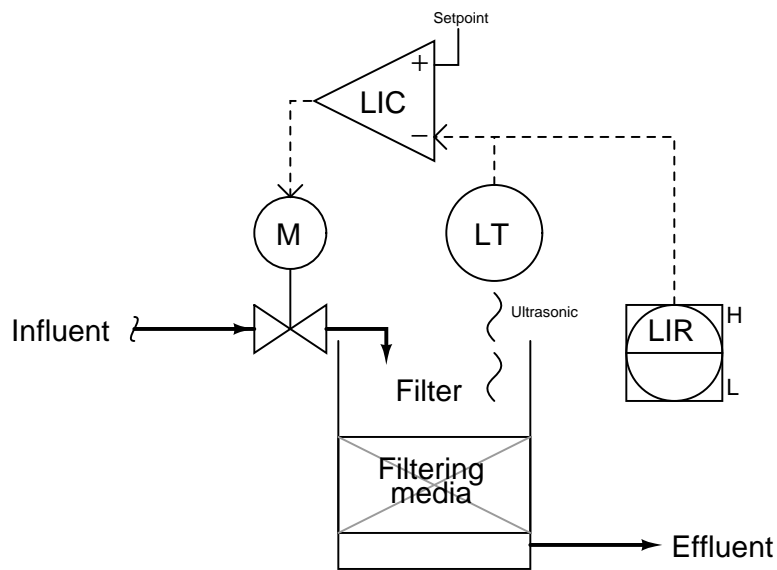
This circuit modification will have absolutely no effect on the performance of the system, as long as the loop-powered transmitter receives its minimum terminal voltage for proper operation.

Answer 6

This controller needs to be *reverse-acting*:



This re-drawing of the control system uses an opamp symbol in place of the ISA-standard circle used to represent a loop controller:



- A sudden increase in effluent flow rate (clean water demand): *controller output increases*
- Level transmitter fails high (indicating 100% full water level): *controller output decreases*
- Control valve actuator fails, driving valve fully open (ignoring controller signal): *controller output decreases*

Answer 7

One possible fault has to do with the control valve: perhaps something has happened to make it fail closed (loss of air supply, signal, etc.). Other possible problems include the following:

- Pump not running (no source of fluid power to motivate flow)
- Very poor controller tuning
- Wrong controller action
- Valve failed closed (loss of air supply, signal, etc.)
- Transmitter failed, showing no flow when in fact there is

A good “first test” for troubleshooting the loop is to check the controller output: is it trying to open up the valve?

Answer 8

The controller should still be able to maintain the process temperature at setpoint, but it will have to open the cooling water valve further than usual to do so.

Answer 9

The one glaring discrepancy we see here is between the laboratory’s measurement of syrup concentration and what the AIC and AIR indicate. Given that both the AIC and AIR agree with each other on PV value, we may conclude that the signal to both of these instruments corresponds to a 34% measurement. The problem is either the transmitter (AT) mis-measuring the syrup concentration, or else it is sensing the concentration okay but outputting the wrong 4-20 mA signal nonetheless, or else the laboratory made a measurement error of their own and incorrectly reported a syrup concentration that is too high.

We also see some minor discrepancies between controller output indications and actual valve stem positions, but these are small enough to ignore. Likewise, the discrepancy between the level gauge (LG) indication and the level controller/recorder indications is small enough that it does not pose a serious problem.

Answer 10

There will be **no adverse effect** resulting from this mis-calibration, unless the valve is unable to achieve a full-closed position when required. In such a case, the liquid level will **slowly fall below setpoint**.

Answer 11

The liquid mixing vessel will either **drain empty** or **overflow**, depending on which side of setpoint the process variable was on at the time of the mis-configuration.

Answer 12

There will be no effect on the performance of this cooling system, except in circumstances where the controller tries to open the valve further than 80%. In those cases, the process temperature will exceed setpoint.

Answer 13

The syrup’s sugar concentration will eventually become *excessive* as the analytical controller (AC) attempts to maintain setpoint.

Answer 14

The analytical control system should still be able to maintain sugar concentration at setpoint, unless the heat exchanger fouling is so extreme that even a wide-open steam valve does not heat the incoming syrup enough to sufficiently concentrate it.

Follow-up question: suppose the heat exchanger fouling really is this bad, but we cannot fix the heat exchanger with the tools we have available. What would you recommend the operator do to make this system produce on-spec syrup?

Answer 15

In automatic mode:

Process flow rate (increase) → FT output signal (increase milliamps) → FC output signal (decrease milliamps) → FY output signal (decrease PSI) → FV position (moves further closed, pinching off liquid flow).

In manual mode:

Process flow rate (increase) → FT output signal (increase milliamps) → FC output signal (remains steady) → FY output signal (remains steady) → FV position (holds position).

The important part of this question is the difference in response between “automatic” and “manual” controller modes. In automatic control mode, the controller takes action to bring the process back to setpoint. In manual control mode, the controller just lets the process drift and takes no action to stop it.

At first, having a “manual” mode in a control system seems pointless. However, giving human operators the ability to manually override the otherwise automatic actions of a control system is important for start-up, shut-down, and handling emergency (unusual) conditions in a process system.

Manual mode is also a very important diagnostic tool for instrument technicians and operators alike. Being able to “turn off the brain” of an automatic control system and watch process response to manual changes in manipulated variable (final control element) signals gives technical personnel opportunity to test for unusual control valve behavior, process quirks, and other behaviors in a system that can lead to poor automatic control.

Answer 16

Fault	Possible	Impossible
LT-12 miscalibrated		✓
LG-11 block valve(s) shut		✓
LSH-12 switch failed	✓	
LSL-12 switch failed		✓
Leak in tubing between LT-12 and LIC-12		✓
LIC-12 controller setpoint set too high		✓
LV-12 control valve failed open		✓
LV-12 control valve failed shut		✓

Answer 17

We know the indicating controller (TIC-21) must be miscalibrated, because the pneumatic signal pressure of 12.8 PSI agrees with the recorder’s indication of 304 degrees F.

Answer 18

Fault	Possible	Impossible
SV-115 leaking air		✓
PSL-105 failed		✓
PSL-114 failed		✓
PCV-39 pressure setpoint too low		✓
PCV-39 pressure setpoint too high		✓
PCV-40 pressure setpoint too low	✓	
PCV-40 pressure setpoint too high	✓	
ZS-38 failed		✓
Blind inserted in natural gas header		✓
Blind inserted in fuel gas header	✓	

Answer 19

Given the fact that the ESD system keeps indicating a high boot level, you know that it “thinks” the liquid level inside the boot is higher than it should be. The next logical step is to determine whether or not a high liquid level condition does indeed exist. If so, the trip is legitimate and there may be a problem with the liquid level control system. If not, the LSHH-231 or its associated wiring may have a fault that sends a false trip alarm to the ESD system.

However, the decision to leave the compressor idle for a few hours until your arrival was not a good one for diagnosis. If indeed there is a problem with excessive liquid collecting in the boot, this would only be evident during running operation. With the compressor idle and no new gas entering the separator vessel, there will be no new liquid collecting in the boot, which will give the boot level control system ample time to empty that liquid down to a normal level and make it appear as though there is no level problem. In other words, leaving the compressor idle for a few hours “erases” the evidence, making it more difficult to troubleshoot.

Aside from re-starting the compressor and watching it run, you could perform a test on the liquid level control system by simulating a high-level condition inside the boot (e.g. applying pressure to one side of LT-92) and observing how fast or slow the actual liquid drains out (as indicated by LG-93). If there is a problem with the level control valve LV-92 or its associated components, you should be able to tell in the form of a long (slow) drain time. The fact that the blind flange at the bottom of the boot drain line says “Rod out” on the P&ID suggests this line is prone to plugging with debris, which could explain a slow-draining condition and consequently the frequent high-level trips.

Answer 20

Fault	Possible	Impossible
PT-33 calibration error		✓
PY-33a calibration error		✓
PY-33b calibration error		✓
PV-33b block valve closed	✓	
PV-33b bypass valve open		✓
Instrument air supply to PY-33b failed		✓
Instrument air supply to FV-34 failed		✓

Answer 21

Place the controller in manual mode and observe the PV trend!

Answer 22

Some processes may not take well to “bumps,” especially large bumps. Imagine “bumping” the coolant flow to a nuclear reactor or the fuel flow to a large steam boiler: the results could be catastrophic! Not only is it a potential problem to exceed an operating limit (PV too high or too low) in a process, but it may be dangerous to exceed a certain *rate of change* over time.

Short of catastrophe, unacceptable variations in product quality may result from perturbations of the process. Again, these may be functions of absolute limit (PV too high or too low), and/or rates of change over time.

Remember, the purpose of regulatory control systems is to maintain the PV at or near setpoint. Any time the control system is disabled and the process purposely “bumped,” this purpose is defeated, if only momentarily. It is essential that operations personnel be consulted prior to manually perturbing a process, so that no safety or operating limit is exceeded in the tuning process.

Answer 23

This oscillation is clearly not the result of an over-tuned controller, because it persists even when the controller is in manual mode. The source must be coming from somewhere else in the process.

At this point in time, it would be a good thing to note the frequency of this oscillation, and begin searching for anything that could cause the level to go up and down at this frequency, or perhaps something that could “fool” level transmitter LT-12 into thinking the level is oscillating at this frequency. If the frequency is relatively high, local machine vibration could be the cause of it. This hypothesis makes a lot of sense, based on the fact that the controller’s action in automatic mode doesn’t seem to be correcting the oscillations at all: the oscillation amplitude seems to remain unchanged between automatic and manual modes. This is what we might expect from a vibration-induced oscillation, where the frequency of the oscillation is much faster than the liquid level can possibly change, and therefore faster than the level control system can physically compensate.