Oppgavesett Trykkmåling

Kompetansemål:

- idriftsette og optimalisere regulatorer basert på prosessbehov

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Oppgave 1

Hydrostatisk trykk og pascal's prinsipp

Oppgave 2

Identify and distinguish between *absolute* pressure, *gauge* pressure, and *differential* pressure. Give at least one example of each kind of pressure. Forklar forskjellen mellom absolutt trykk, relativt trykk og differanse trykk, gi også et eksempel på hver av dem.
file i00144

Oppgave 3

En dykker sin lufttak har et trykk på 300 bar før han går i vannet. Dykkeren dykkern den til en dybde på 20m. Her er trykket som som forårsakes av vekten til vannet 2bar, også kalt hydrostatisk trykk. Anta at mengden luft dykkern bruke på vei ned er å liten at den er uten betydning. Regn ut følgende trykk for tanken:

- absolutt trykk
- relativt trykk
- differansetrykk (i forhold til vannet utenfor tanken)

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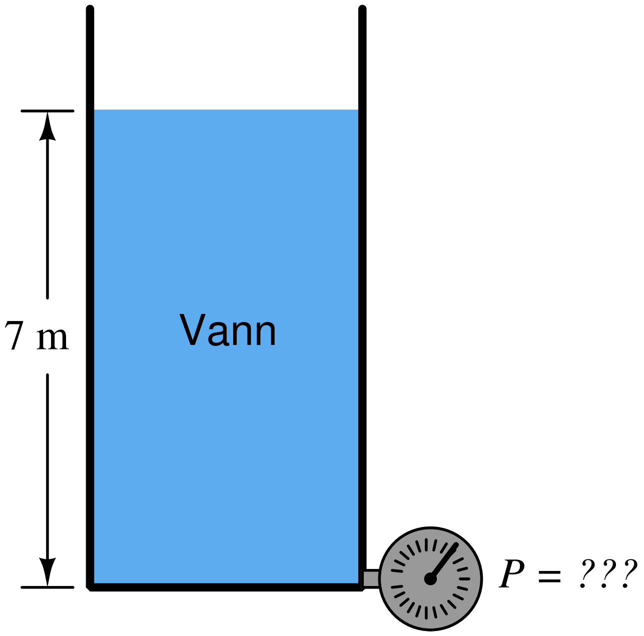
Oppgave 4

Use Bernoulli's equation to calculate the hydrostatic pressure at the bottom of this water storage tank:



Bernoulli's equation:

$$z_1 \rho g + \frac{v_1^2 \rho}{2} + P_1 = z_2 \rho g + \frac{v_2^2 \rho}{2} + P_2$$

Where,
$\rho = 1000 \text{kg/m}^3$ (for vann)
$g = 9.81 \text{ m/s}^2$

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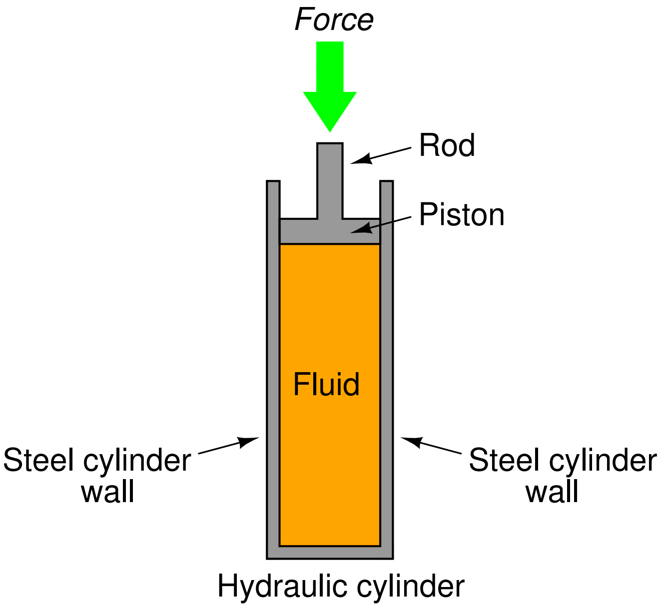
Oppgave 5

If force is exerted on the piston of this hydraulic cylinder, in what direction(s) will this force be transmitted to the cylinder walls? In other words, how does a fluid under pressure push against its surrounding container?



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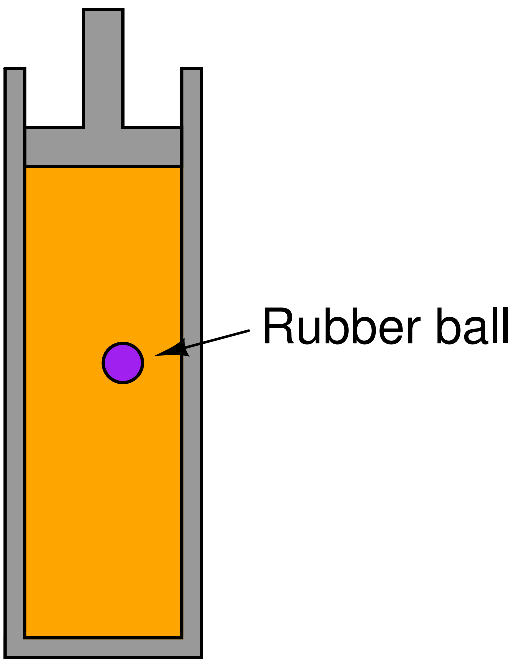
Oppgave 6

Suppose a small rubber ball is floating inside the fluid of a hydraulic cylinder as shown below. What will happen to the ball when a pushing force is exerted on the cylinder's rod? What will happen to the ball when a pulling force is exerted on the rod?



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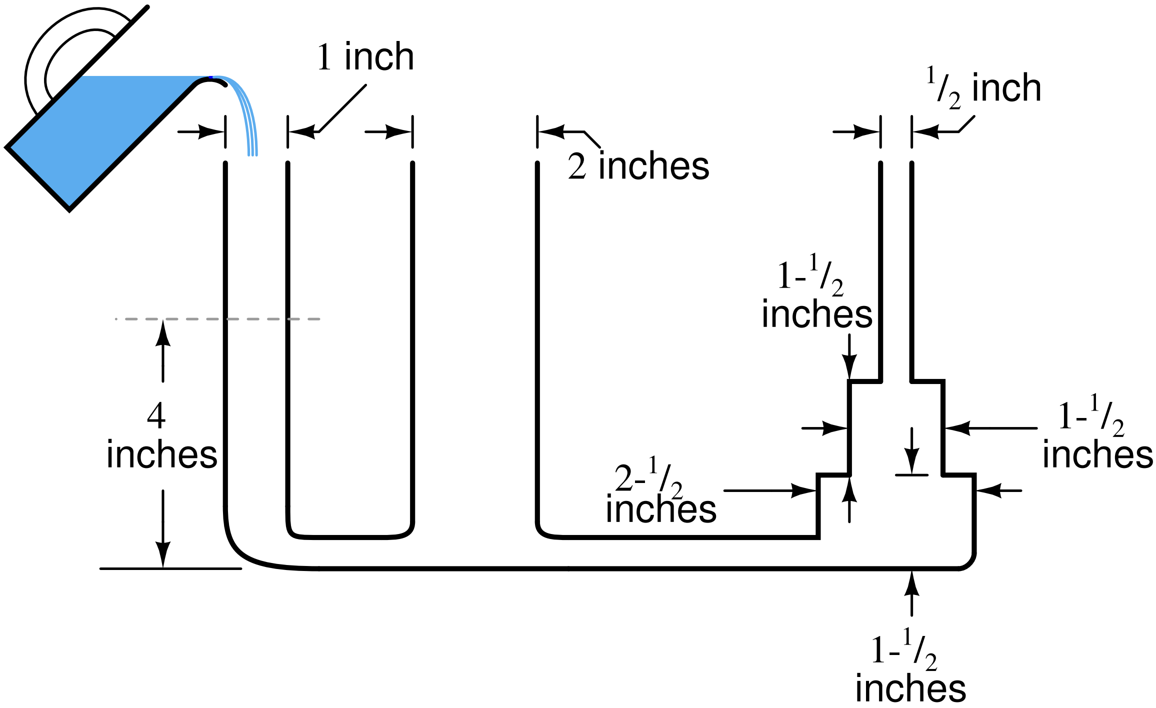
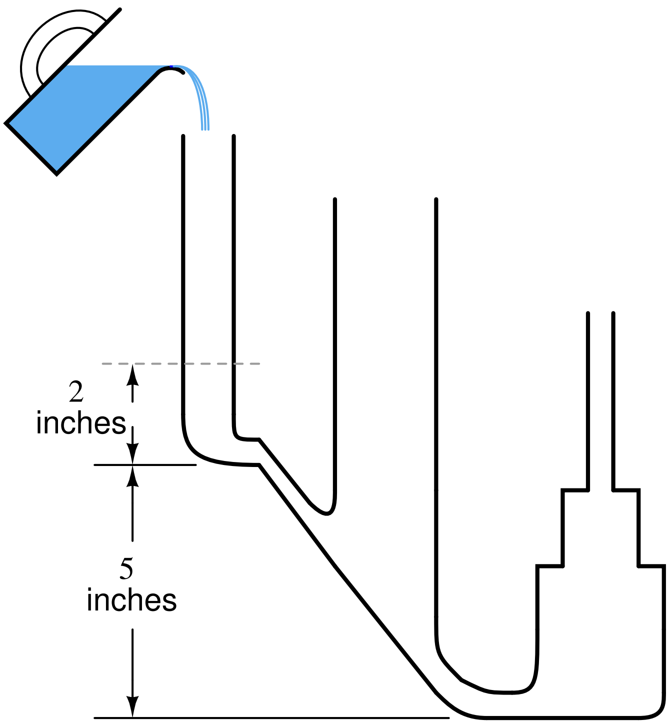
Oppgave 7

Suppose we were to steadily pour a liquid into the leftmost vertical tube until it reaches a mark four inches from the bottom. Given the diameters of the other tubes, how high will the liquid level settle in each when all columns are in a condition of equilibrium (no liquid *flowing* through any part of the system)?



Now consider the same set of vertical tubes (same diameters, same step heights) connected at the bottom by an *inclined* pipe. If we were to pour a liquid into the leftmost vertical tube until it reaches a mark two inches from its bottom, how high will the liquid level settle in each column when all columns are in a condition of equilibrium?



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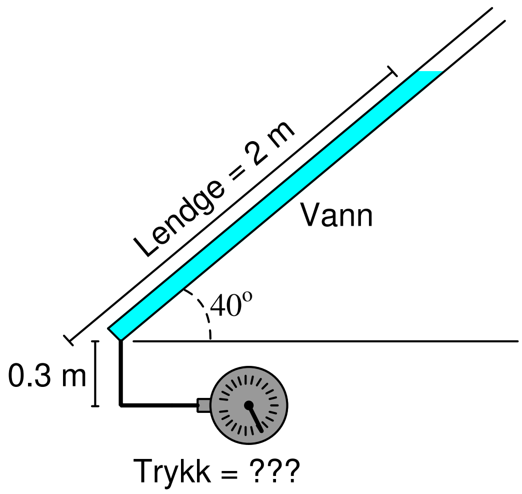
Oppgave 8

Et rør fylt med vann til 2 meter vinkles 40° fra horisontalplanet. Regn ut det hydrostatiske trykket som manometeret vil vise i Pascal.



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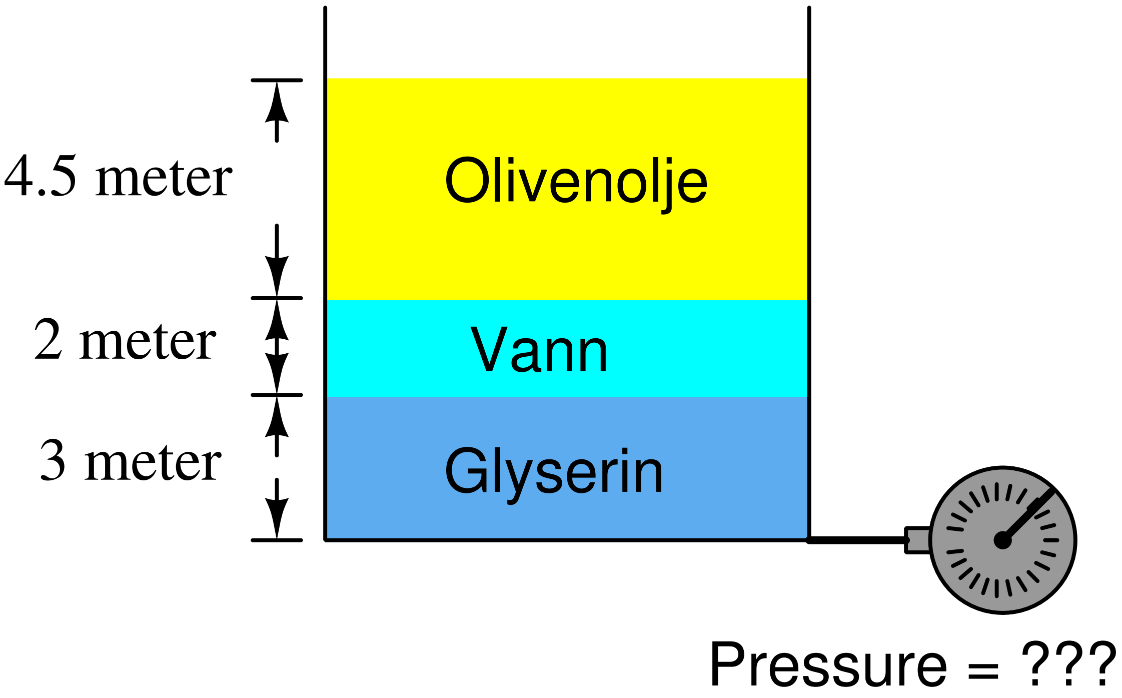
Oppgave 9

En tank inneholder tre ulike væsker med ulik massetethet. Regn ut trykket som manometeret i bunn av tanken vil vise i Pa og bar.

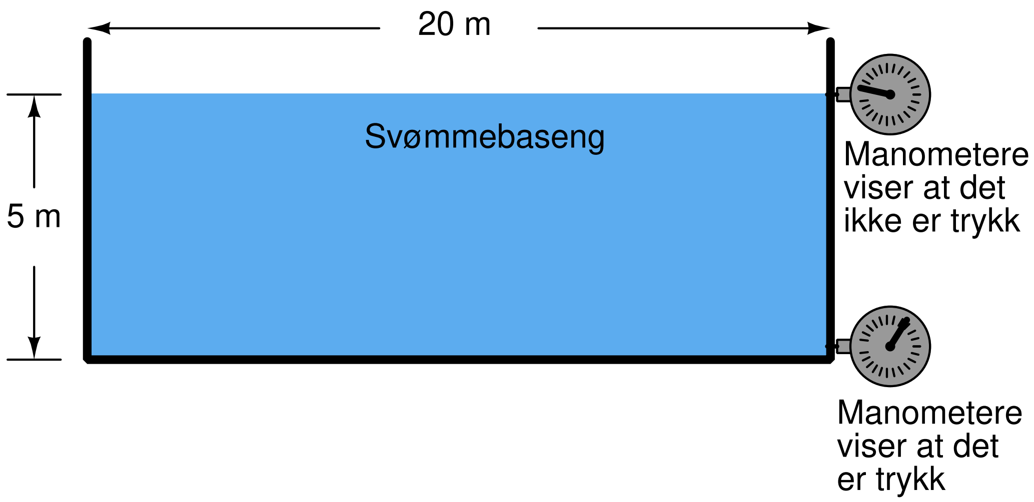


$\rho\ glyserin = 1260 kg/m^3$
$\rho\ olivenolje = 917 kg/m^3$

Calculate the total hydrostatic pressure at the bottom of the vessel, in units of PSI and kPa.
file i00235

Oppgave 10

Forklar hvordan den vertakale høyden av en væske kan genere et trykk, som i dette eksempelet:



Jo dypere du kommer i vannet jo mer trykk er det.

Husk at trykk er definert som kraft/areal

$$P = \frac{F}{A}$$

Regn ut den totale vekten av vannet i dette svømmebasenget. Basenget er rundt og har en diameter på 20m. Regn også ut trykket i bunn av basenget.

Vekten av vannet = ________ kg

Trykket i bunn av tanken = ________ Bar

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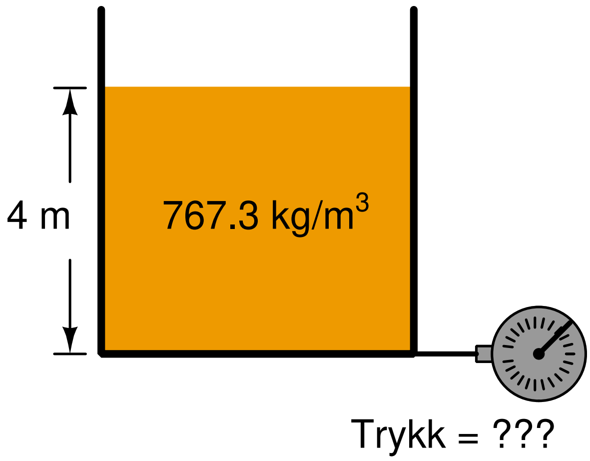
Oppgave 11

En tank som inneholder 4m med væske utgjør et hydrostatisk trykk på et manometer montert i bunn av tanken.



Regn ut det hydrostatiske trykket maometeres viser i kPa

$P =$ ________ kPa

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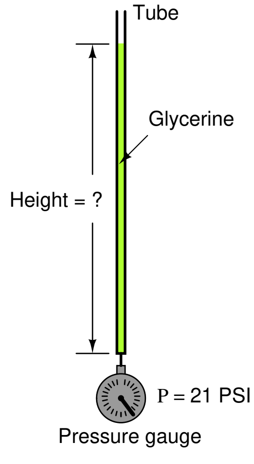
Oppgave 12

Regn ut høyden med glyserin ($\rho = 1259kg/m$) i et vertikalt rør om det er et hydrostatisk trykk på 1.5 Bar i bunn av røret:



Glyserin høyde = ________ meter

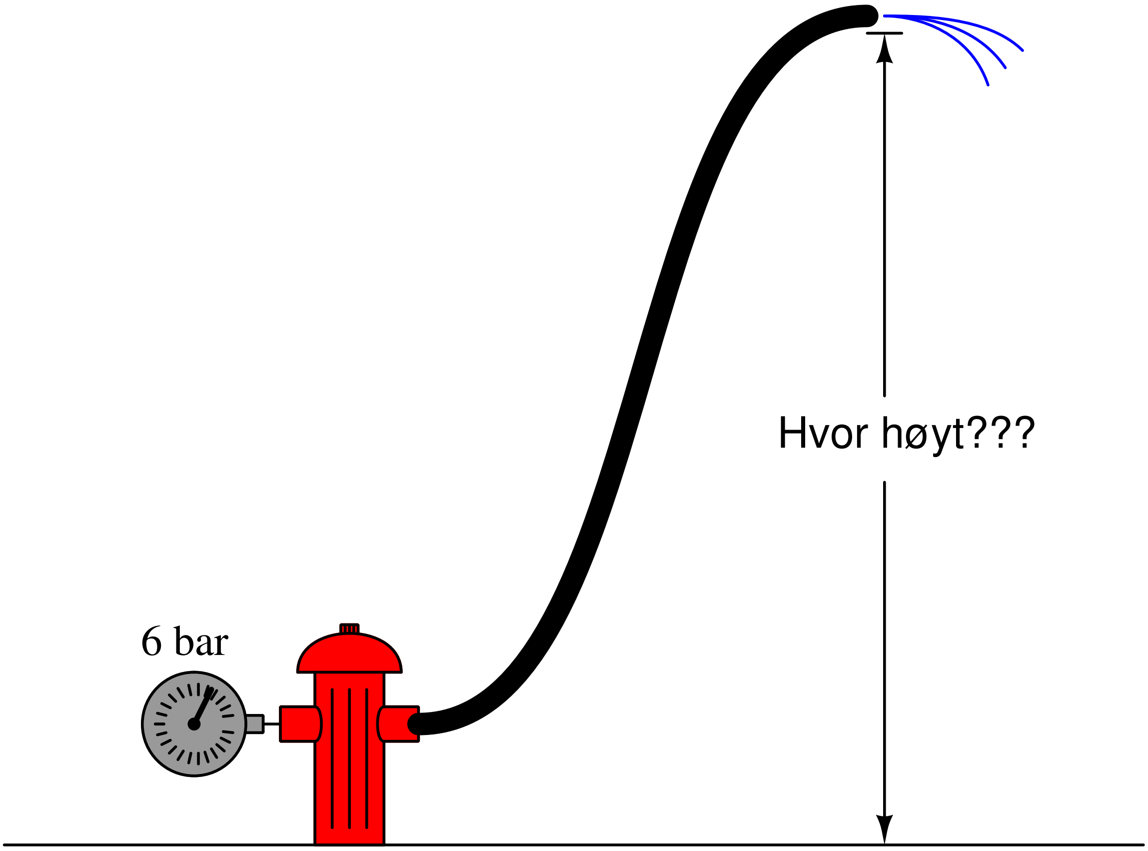
Regn også ut høyden med castor olje ($\rho = 961/m$) som skal til for å genere det samme hydrostatiske trykket:

Castor olje høyde = ________ meter

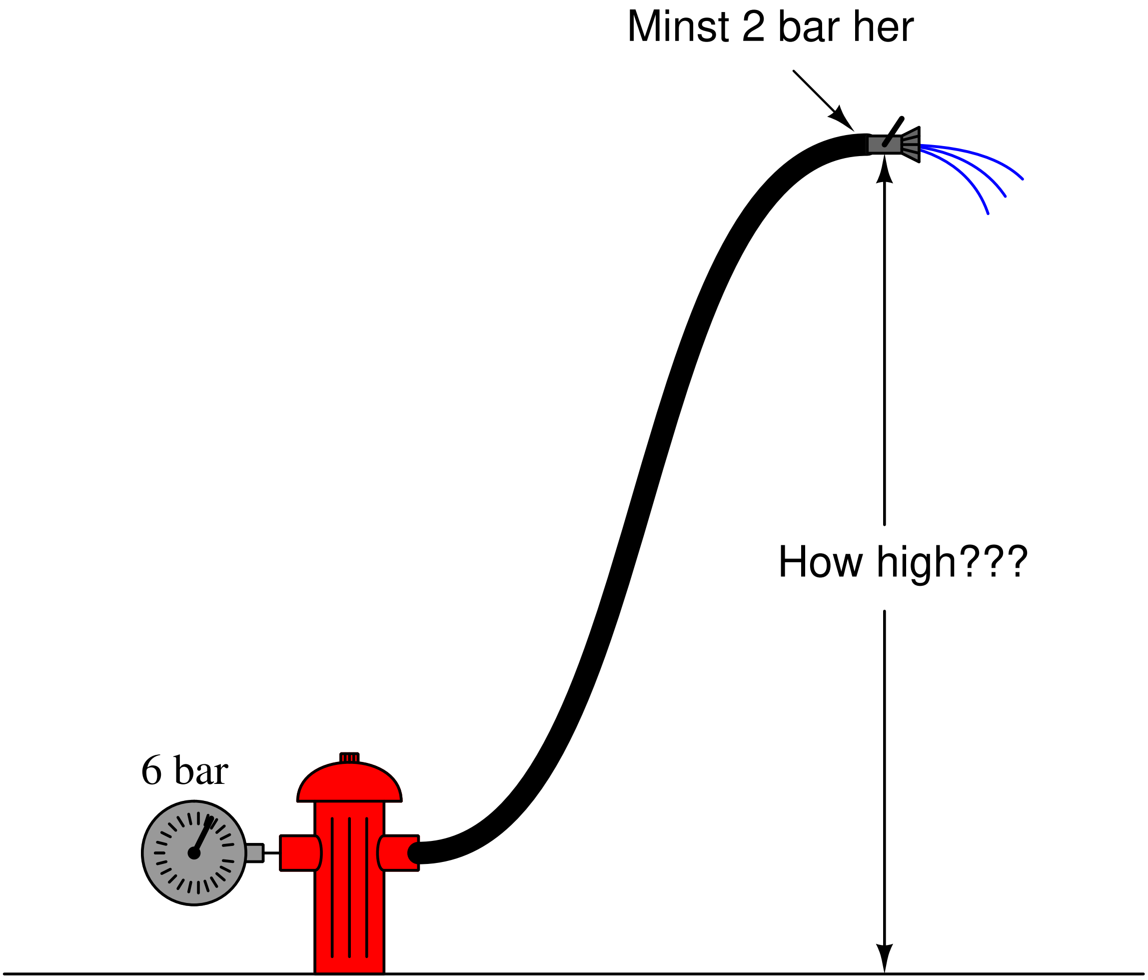
file i02951

Oppgave 13

Water pressure available at a fire hydrant is 6 bar. If a fire hose is connected to the hydrant and the hydrant valve opened, how high can the end of the hose be raised and still have water flow out the end?



Now, suppose that a spray nozzle attached to the end of the hose requires at least 2 bar of pressure at the coupling in order to create a proper spray of water. How high can the hose be raised then, and still have enough water pressure at the nozzle to allow for the fighting of a fire?



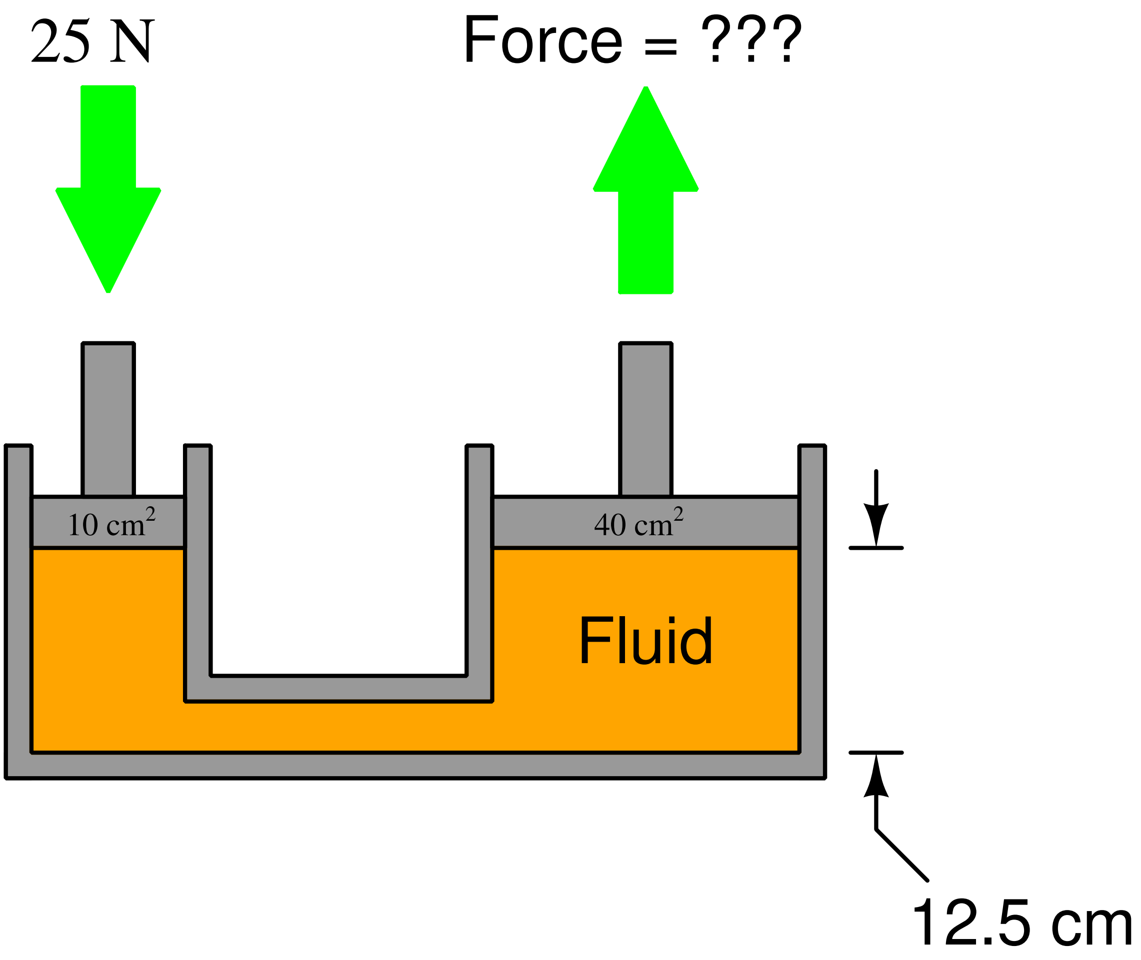
Suggestions for Socratic discussion

- How may firefighters ensure they are able to spray water high enough to put out tall building fires, if the hydrant pressure is insufficient?
- Describe a scenario with this fire hose that would illustrate *Pascal's Principle*.

file i00148

Oppgave 14

I dette hydrauliske systemet blir en kraft på 25 N tilført det minste stempelet. Hvor stor kraft vil det store stempele generere? Regn også ut trykket i fluidet.



Suggestions for Socratic discussion

- Identify which fundamental principles of science, technology, and/or math apply to each step of your solution to this problem. In other words, be prepared to explain the reason(s) "why" for every step of your solution, rather than merely describing those steps.
- Identify a practical application for a hydraulic system such as this.
- Does the pressure/force/area equation hold true for all piston positions, or only with the pistons in mid-stroke as shown in the illustration?
- Would it matter whether the fluid in this system was a liquid or a gas? Explain in detail how the system's behavior would differ (or not differ) depending on the type of fluid used.
- This mechanism seems to multiply the applied force. How can it do so without violating the Law of Energy Conservation (energy out cannot exceed energy in)?

- Demonstrate how to *estimate* numerical answers for this problem without using a calculator.

file i00150

Oppgave 15

A hydraulic system has two cylinders linked together with high-pressure tubing. The piston diameter of cylinder #1 is 3 inches, while the piston diameter of cylinder #2 is 4.5 inches. How much force will cylinder #1's piston exert if cylinder #2's piston is pushed with 200 pounds of force? How much fluid pressure will be within the hydraulic tube with 200 pounds of force applied to the piston of cylinder #2?

Also, determine which of the two pistons will travel furthest, and explain why this is so.

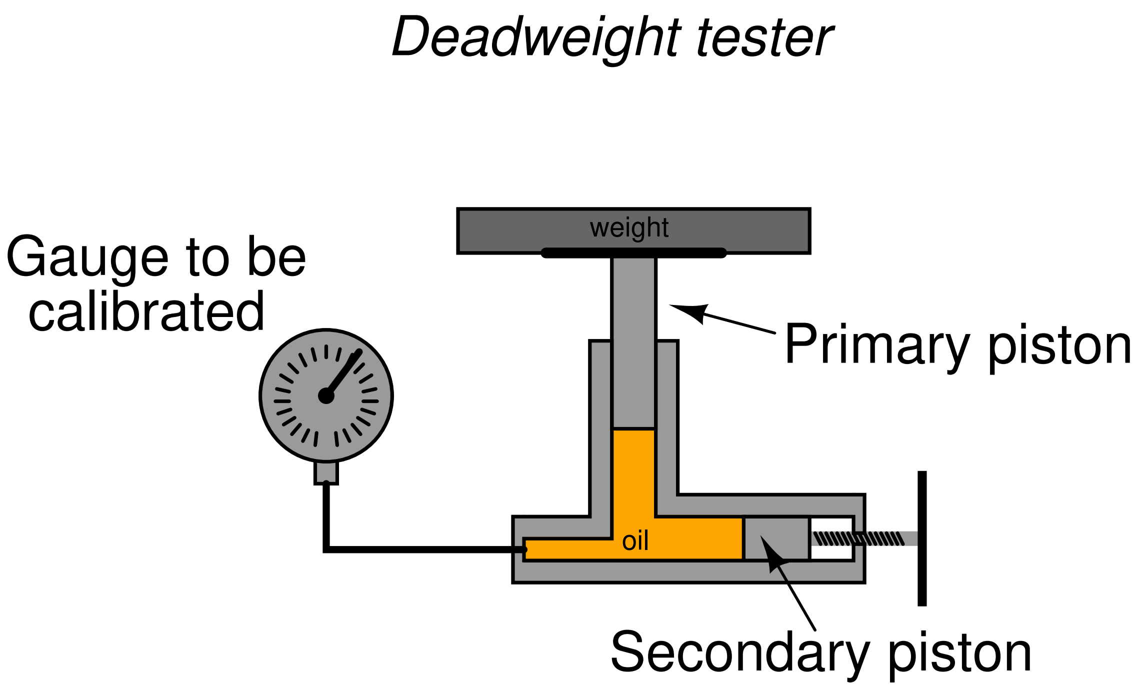
Suggestions for Socratic discussion

- A useful problem-solving technique is to sketch a simple diagram of the system you are asked to analyze. This is useful even when you already have some graphical representation of the problem given to you, as a simple sketch often reduces the complexity of the problem so that you can solve it more easily. Draw your own sketch showing how the given information in this problem inter-relates, and use this sketch to explain your solution.

file i00151

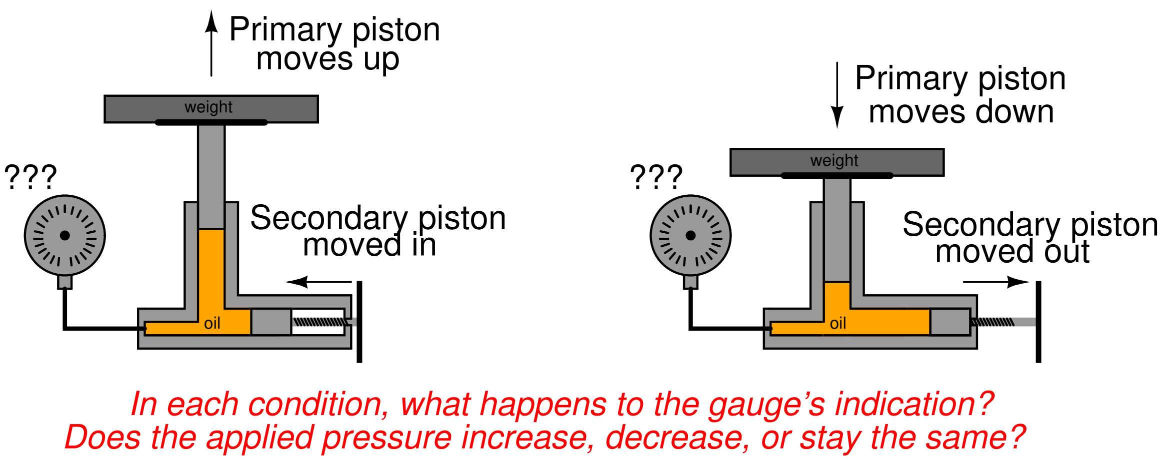
Oppgave 16

A pressure calibration device called a *deadweight tester* generates very precise pressures by means of calibrated weights placed on top of a hydraulic piston:



The secondary piston is moved in and out by turning a handle on a threaded rod. Its sole purpose is to displace enough oil to force the primary piston to rise from its resting position, so that it is entirely suspended by oil pressure. In that condition, the gauge will be subject to whatever pressure is proportional to the weights placed on top of the primary piston, and the area of the primary piston.

What will happen to the gauge's indication if the secondary piston is pushed in further? What will happen to the gauge's indication if the secondary piston is pulled out, but not so far that the primary piston comes down to its resting position? In other words, what effect does the secondary piston *position* have on pressure applied to the gauge?



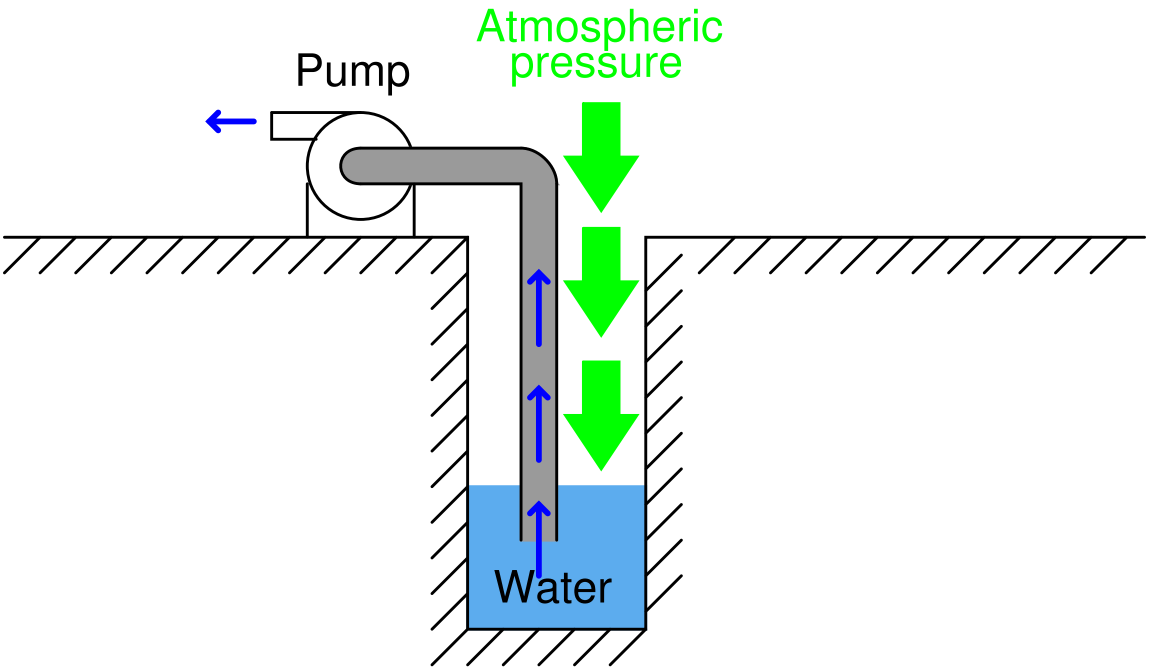
Suggestions for Socratic discussion

- Why are deadweight testers considered accurate *standards* for fluid pressure? What is it about their design and operation that makes them so accurate? Conversely, what aspects of their construction would have to change in order to corrupt their inherent accuracy?
- If a technician changes the type of fluid used in a deadweight tester (for example, from one type of oil to another), will its accuracy change?
- Identify some potential problems one might encounter when using a deadweight tester. What things, specifically, do you see that could go wrong with this device?

file i00153

Oppgave 17

A surface-mounted water pump pulls water out of a well by creating a vacuum, though it might be more technically accurate to say that the pump works by reducing pressure in the inlet pipe to a level less than atmospheric pressure, allowing atmospheric pressure to then push water from the well up the pump's inlet pipe:



Based on this description of pump operation, what is the theoretical maximum height that any pump can lift water out of a well, assuming the well is located at sea level?

Water wells located at altitudes other than sea level will have different theoretical maximum lifting heights (i.e. the farthest distance a surface-mounted pump may suck water out of the well). Research the average barometric pressure in Denver, Colorado (the "mile-high" city) and determine how far up a surface pump may draw water from a well in Denver.

Domestic water wells may be hundreds of feet deep. How can water be pumped out of wells this deep, given the height limitation of vacuum pumping?

Suggestions for Socratic discussion

- If the liquid in question was something other than water, would the maximum "lift" depth be different? Why or why not?

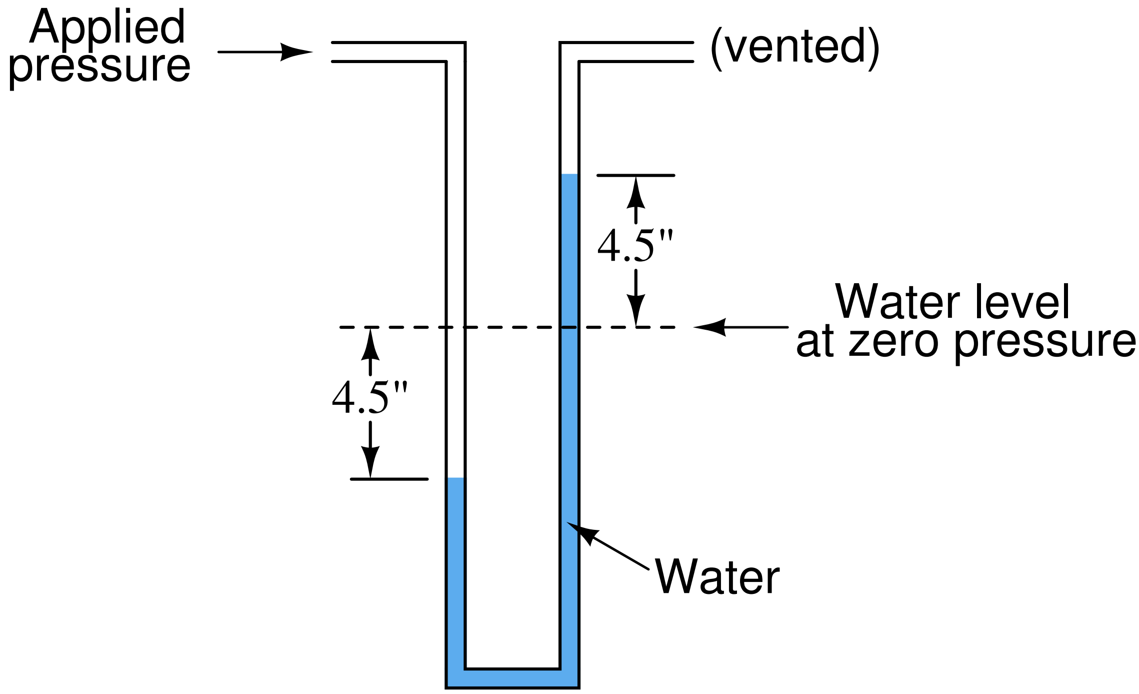
file i00147

Oppgave 18

Mekaniske instrumenter for måling av trykk

Oppgave 19

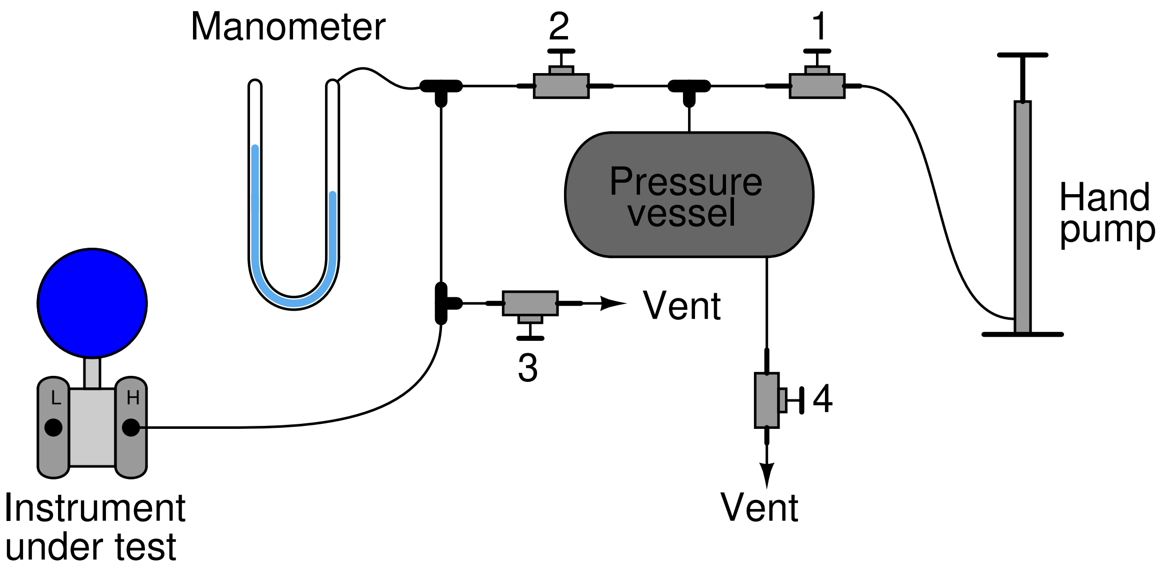
How much pressure is being applied to this U-tube water manometer, in units of "inches of water column" and "pounds per square inch"?



What would happen to the liquid levels if the water were replaced by an oil with a lesser *density*? Given the same applied pressure, would the distance between the two liquid columns be greater, less, or the same as shown in the above illustration?
file i00161

Oppgave 20

Determine what will happen at the following steps in the sequence (when prompted for a response) in this pressure transmitter calibration setup:

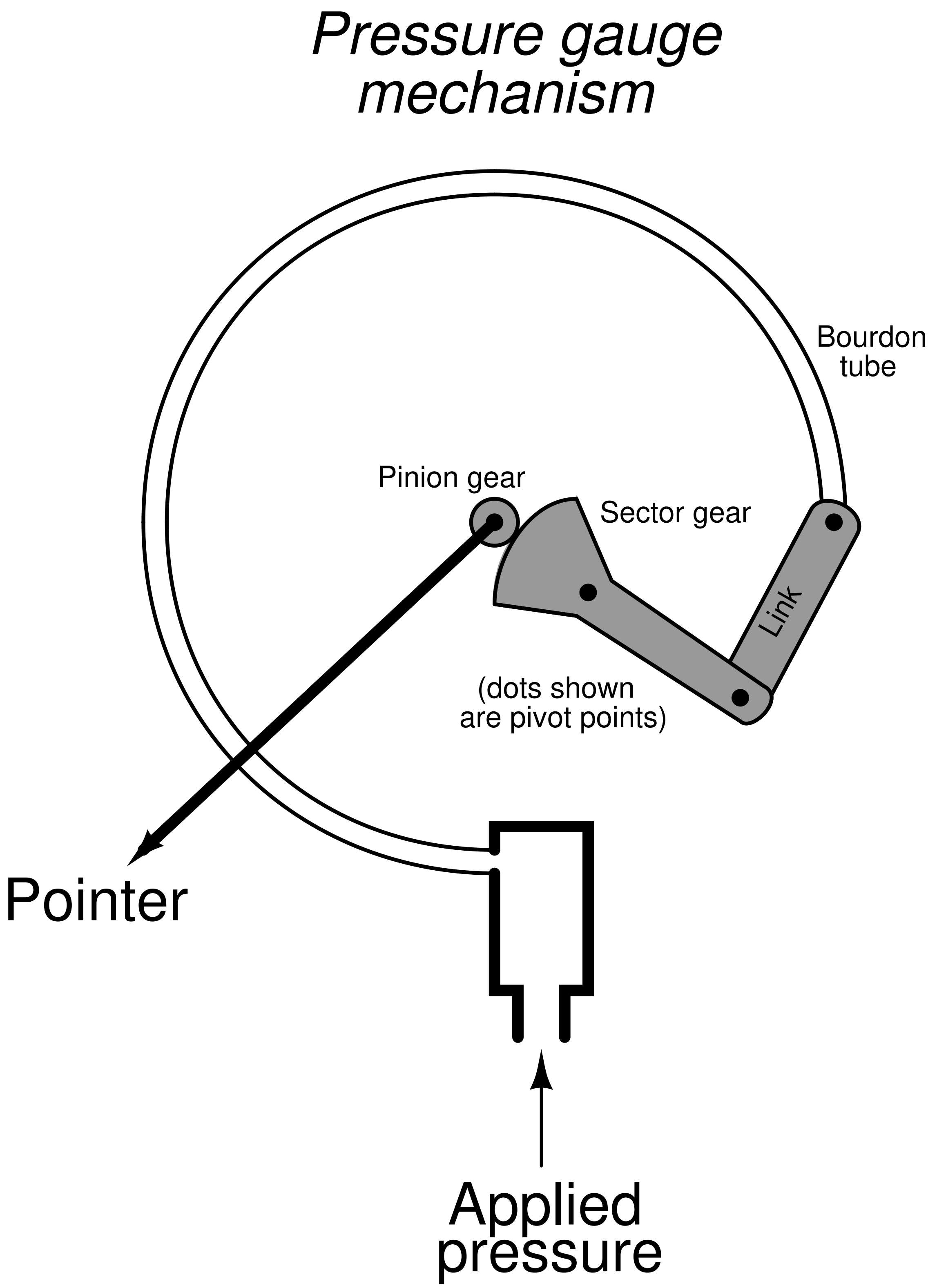


- **Step 1:** Open valves 1 and 2
- **Step 2:** Close valves 3 and 4
- **Step 3:** Operate hand pump until manometer registers maximum pressure
- **Step 4: (4 points)** Quickly open and close valve 4 – *does the manometer indication drop greatly, slightly, or not at all?*
- **Step 5:** Close valve 2
- **Step 6: (4 points)** Quickly open and close valve 4 – *does the manometer indication drop greatly, slightly, or not at all?*
- **Step 7:** Close valve 1
- **Step 8: (4 points)** Quickly open and close valve 3 – *does the manometer indication drop greatly, slightly, or not at all?*

file i00463

Oppgave 21

Shown here is a diagram of a standard pressure gauge, based on the pressure-sensing action of a hollow, C-shaped metal tube called a *bourdon tube*:



Using arrows, trace the motions of all moving components in this mechanism as an increasing pressure is applied to the fitting at the bottom of the bourdon tube.

Also, describe how the measurement span of this pressure gauge could be changed. In other words, what would have to be moved, adjusted, or altered in this mechanism in order to change the proportionality of applied pressure to pointer movement?

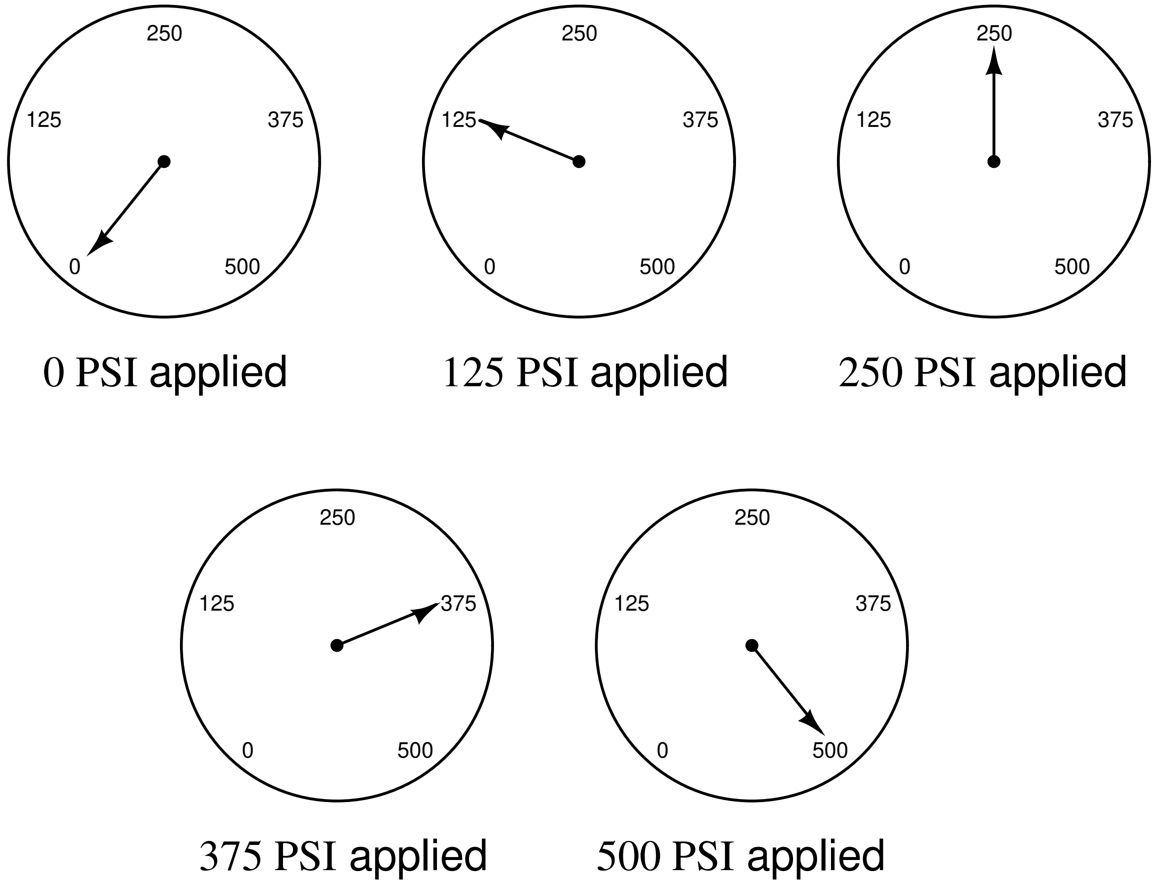
Suggestions for Socratic discussion

- Questions such as this tend to be challenging for people with limited experience working on mechanical devices. Identify some problem-solving strategies for a mechanically innocent student to apply to problems such as this.
- What sort of device(s) would you suggest using to apply a precisely known pressure to a gauge for calibration purposes?
- Suppose a pressure gauge is intended for service in a process measuring liquid pressure. Is it okay to calibrate this gauge on a test bench using compressed *air* instead of the liquid it will be exposed to in the field? Why or why not?

file i00173

Oppgave 22

A pressure gauge is supposed to accurately indicate applied pressure over its full calibrated range. In this example, a gauge with a range of 0 to 500 PSI is subjected to five different pressures along that range, and its response is accurate at all those points:



Describe, by drawing a set of five meter readings such as the set shown above, how a pressure gauge accurate at 0% and 100% of applied pressure – but with a *nonlinearity* problem between the LRV and URV points – might respond to the same five applied pressures.

Furthermore, describe how a bourdon tube pressure gauge instrument might be adjusted for linearity. In other words, how may a nonlinear pressure gauge be calibrated to become more linear?

Suggestions for Socratic discussion

- Explain how keeping both "As-Found" and "As-Left" calibration records on instruments such as this pressure gauge make it possible to track long-term calibration drift.
- Can a non-linearity error be corrected by adjusting the zero and/or span screws on an instrument? Why or why not?

file i00174

Oppgave 23

Kalibreringstabell for trykk

Oppgave 24

An electronic pressure transmitter has a calibrated range of 100 to 300 PSI, and its output signal range is 4 to 20 mA. Complete the following calibration table for a calibration tolerance of +/- 0.5% (of span), and be sure to show the equations used to calculate all the parameters given the percentage of span (x):

Input pressure applied (PSI)	Percent of span (%)	Output signal ideal (mA)	Output signal min. (mA)	Output signal max. (mA)
	0			
	10			
	25			
	50			
	75			
	90			
	100			

Equations used:

Input pressure =

Output signal (ideal) =

Output signal (min.) =

Output signal (max.) =

file i00013

Oppgave 25

Suppose you wish to calibrate a pneumatic pressure transmitter to an input range of 0 to 200 inches of water, with an output range of 3 to 15 PSI. Complete the following calibration table showing the test pressures to use and the allowable low/high output signals for a calibrated tolerance of +/- 0.5% (of span):

Input pressure applied (" W.C.)	Percent of span (%)	Output signal *ideal* (PSI)	Output signal *low* (PSI)	Output signal *high* (PSI)
	0			
	25			
	50			
	75			
	100			

Suppose this transmitter is installed as part of a complete pressure measurement system (transmitter plus remote indicator and associated components), and the entire measurement system has been calibrated within the specified tolerance (± 0.5%) from beginning to end. If the operator happens to read a process pressure of 153 inches W.C. at the indicator, how far off might the actual process pressure be from this indicated value?

Suggestions for Socratic discussion

- Demonstrate how to *estimate* numerical answers for this problem without using a calculator.

file i00227

Oppgave 26

Suppose you wish to calibrate an electronic pressure transmitter to an input range of -50 to 300 inches of water, with an output range of 4 to 20 mA. Complete the following calibration table showing the test pressures to use and the allowable low/high output signals for a calibrated tolerance of +/- 0.1% (of span). Assume you can only use positive test pressures (no vacuum), and be sure to designate which side the test pressure should be applied to (H = high ; L = low):

Input pressure applied (" W.C.)	Percent of span (%)	Output signal *ideal* (mA)	Output signal *low* (mA)	Output signal *high* (mA)
	0			
	25			
	50			
	75			
	100			

Suppose this transmitter is installed as part of a complete pressure measurement system (transmitter plus remote indicator and associated components), and the entire measurement system has been calibrated within the specified tolerance (± 0.1%) from beginning to end. If the operator happens to read a process pressure of 210 inches W.C. at the indicator, how far off might the actual process pressure be from this indicated value?

Suggestions for Socratic discussion

- Demonstrate how to *estimate* numerical answers for this problem without using a calculator.

file i00228

Oppgave 27

Suppose you are going to install a Rosemount model 1151 "Alphaline" (analog) differential pressure transmitter in a process, calibrated to a range of 0 to 100 inches W.C. The transmitter's model number shows the following specifications:

- Model = *1151DP*
- Pressure range code = *4*
- Output code = *E*
- Material code = *22*

Answer the following questions regarding this transmitter as it applies to the application you intend to install it in:

- Does this transmitter have sufficient turndown ("rangeability") for the application? Show your calculation to prove whether it does or not.

- Calculate the expected accuracy for this transmitter once installed, expressed in ± inches of water column.

- Calculate the six-month calibration stability of this transmitter after installation, expressed in ± inches of water column.

- Calculate the amount of total measurement error this transmitter may exhibit given an ambient temperature shift of 65 degrees Fahrenheit, expressed in ± inches of water column.

file i03477

Oppgave 28

Suppose you are calibrating a DP transmitter to go into service as a flow transmitter, measuring differential pressure generated by a segmental wedge flow element. This is a "smart" electronic transmitter with square-root characterization capability, which you decide to activate for this application.

Calculate the ideal current signal values at the following calibration pressures, assuming a calibrated range of 0 to 150 inches water column:

Input pressure (" W.C.)	Output current (mA)
0	
45	
75	
90	
110	
150	

Furthermore, suppose you performed an "As-Found" test on this DP transmitter and found it to respond as such:

Input pressure (" W.C.)	Output current (mA)
0	4.3
45	13.06
75	15.61
90	16.69
110	18.0
150	20.3

What type of calibration error is this (e.g. *zero* shift, *span* shift, or *nonlinearity*), and do you suspect it lies with the sensor or with the digital-to-analog converter? In other words, do you need to perform a *sensor trim* or an *output trim* on this instrument?

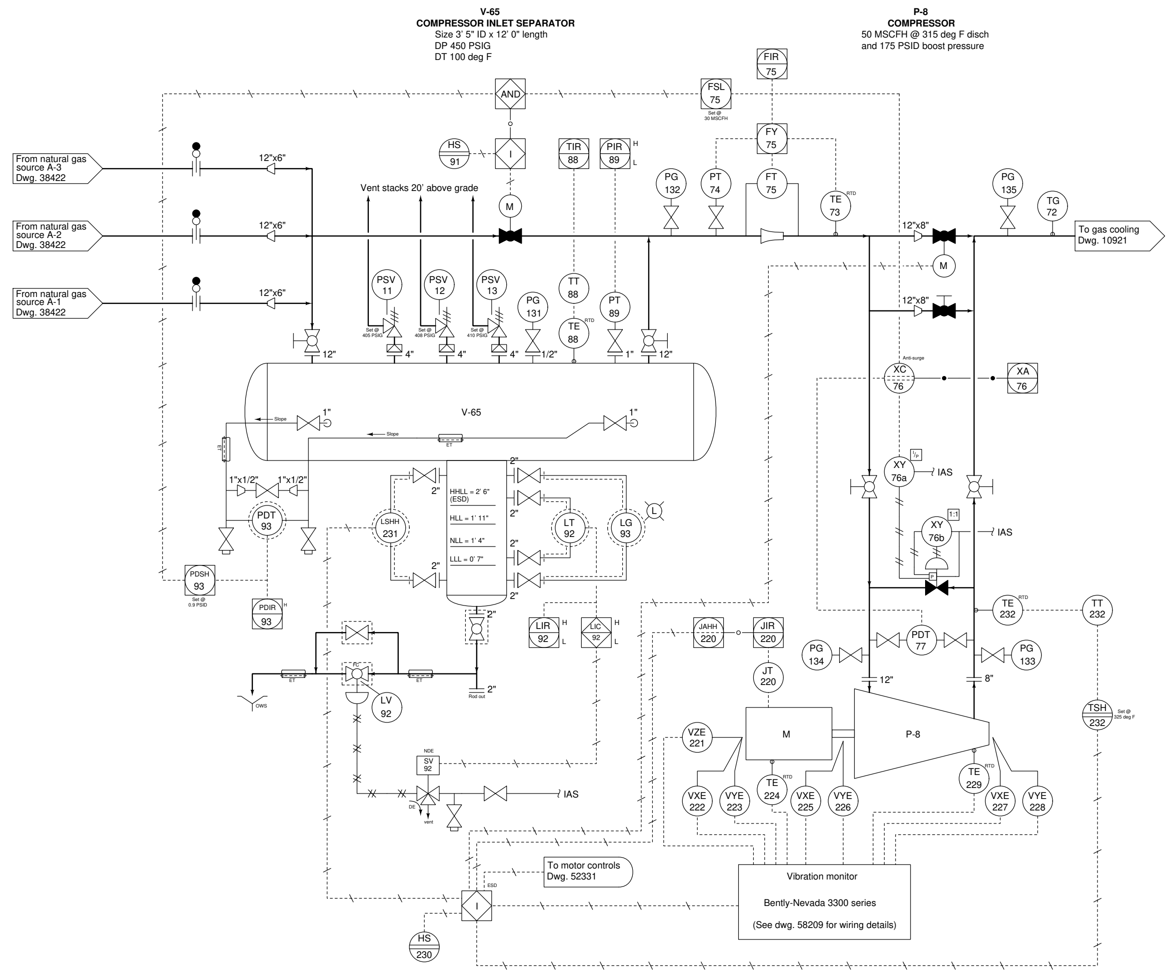
Suggestions for Socratic discussion

- Explain the difference between a *sensor trim* and an *output trim* in a "smart" transmitter.
- What tool(s) would you need to perform a sensor trim on a smart transmitter?
- What tool(s) would you need to perform an output trim on a smart transmitter?

file i04051

Oppgave 29

Pressure transmitter PT-89 on this natural gas separator vessel presently has a calibrated range of 0 to 400 PSIG. Operations personnel would like you to re-range this transmitter for 300 to 375 PSIG instead:



Answer the following questions about the task of re-ranging, explaining each of your answers:

- Does the new, requested range constitute a *zero* shift, a *span* shift, or both?
- If this is a "smart" (digital) transmitter, does it need to be *re-trimmed* as well as *re-ranged*?
- Will the control room indicator PIR-89 need to be *re-calibrated*, *re-ranged*, or both?
- Will the local pressure gauge PG-131 need to be *re-calibrated* as well?
- Will the pressure safety valves PSV-11, PSV-12, and/or PSV-13 need to be set for lower "lift" pressures?
- If the maximum (factory) range of this pressure transmitter is 0 to 750 PSI and the maximum turndown ratio for the required accuracy is 20:1, will it be able to meet

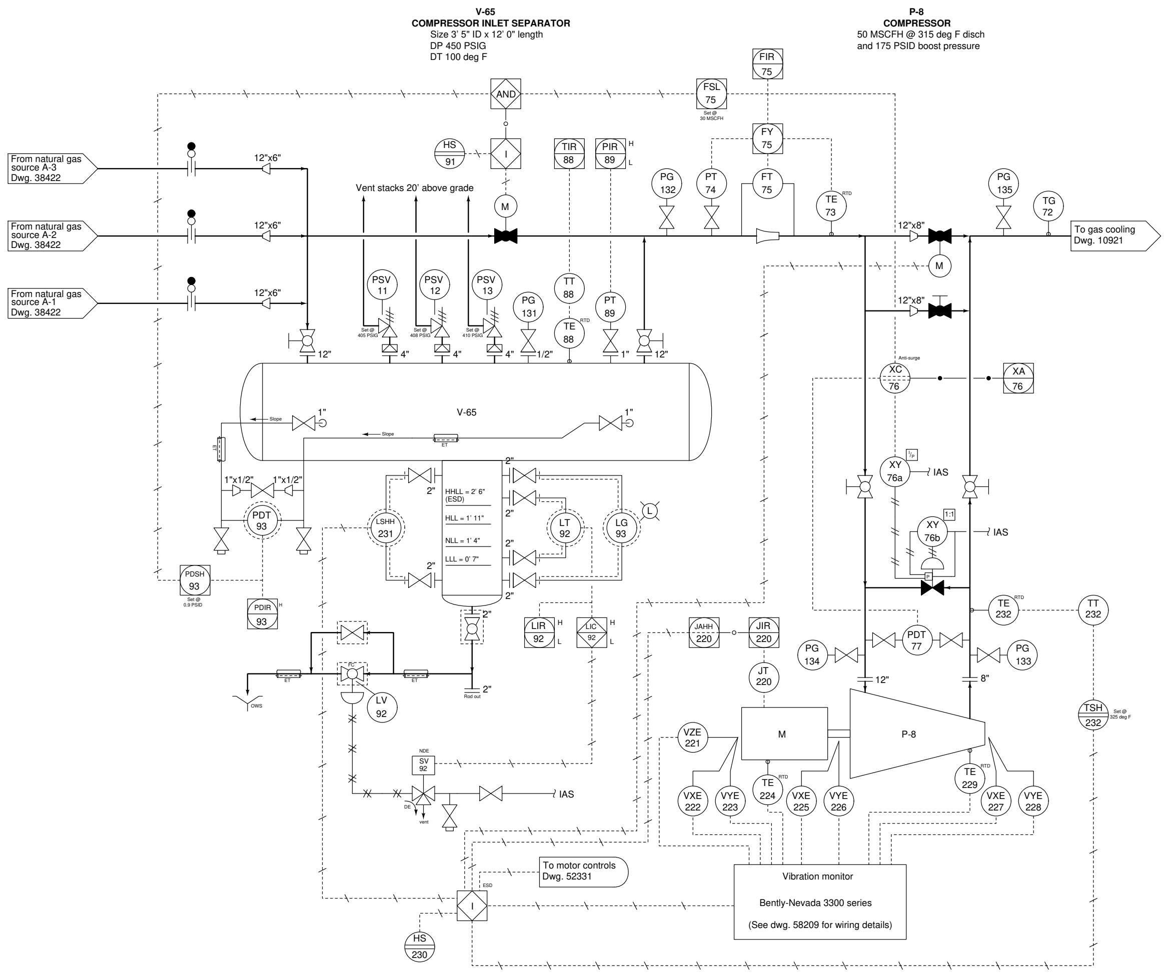
the new range? If not, what might you have to do in order to fulfill operations' request?

- Why do you suppose operations would like you to re-range this transmitter? In other words, what operational advantage(s) might be gained from doing so? Are there any potential disadvantages of having the new range versus the old?

file i03524

Oppgave 30

Pressure transmitter PT-89 on this natural gas separator vessel presently has a calibrated range of 0 to 400 PSIG. Operations personnel would like you to re-range this transmitter for 300 to 375 PSIG instead:



Answer the following questions about the task of re-ranging, explaining each of your answers:

- Does the new, requested range constitute a *zero* shift, a *span* shift, or both?
- If this is a "smart" (digital) transmitter, does it need to be *re-trimmed* as well as *re-ranged*?
- Will the control room indicator PIR-89 need to be *re-calibrated*, *re-ranged*, or both?
- Will the local pressure gauge PG-131 need to be *re-calibrated* as well?
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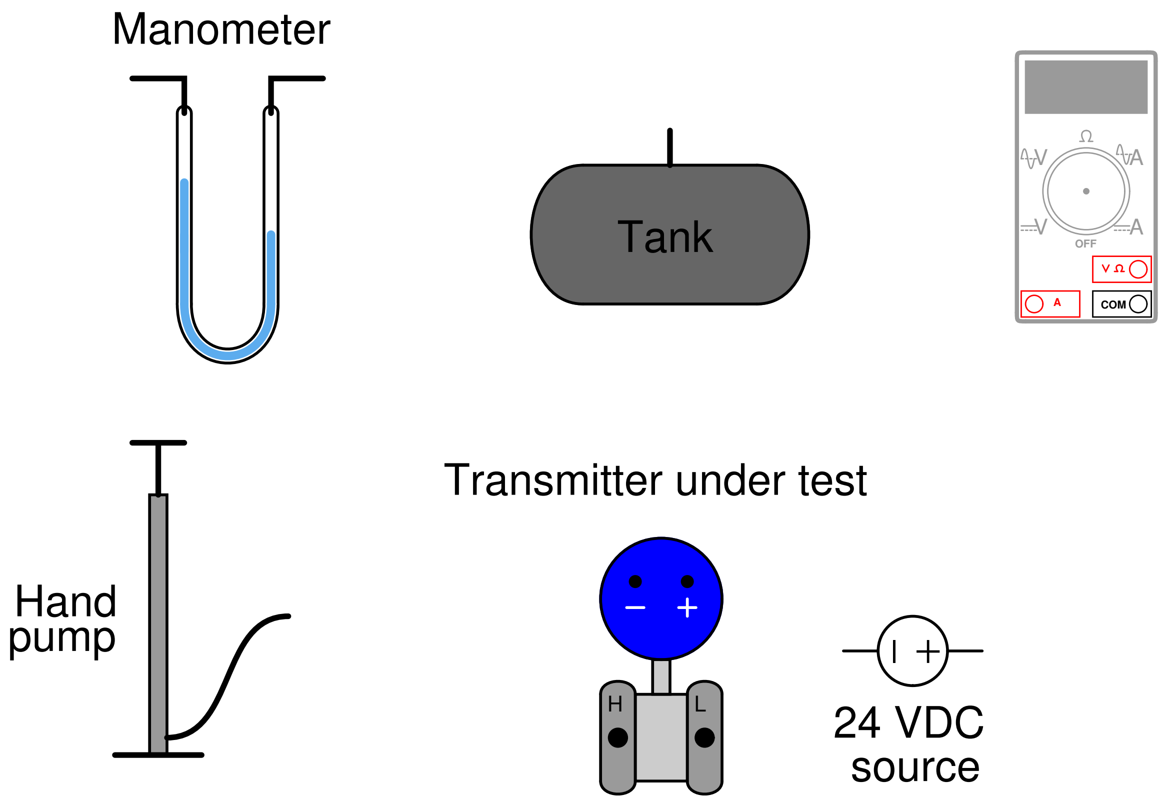
the new range? If not, what might you have to do in order to fulfill operations' request?

- Why do you suppose operations would like you to re-range this transmitter? In other words, what operational advantage(s) might be gained from doing so? Are there any potential disadvantages of having the new range versus the old?

file i03524

Oppgave 31

Sketch the necessary connecting tubes and wires to calibrate a DP transmitter to a low pressure range (somewhere in the range of a few inches of water), using a hand (bicycle-style) air pump as the pressure source and a U-tube manometer as a pressure standard. As pressure increases, the transmitter's output signal should increase as well:



file i00022

Oppgave 32

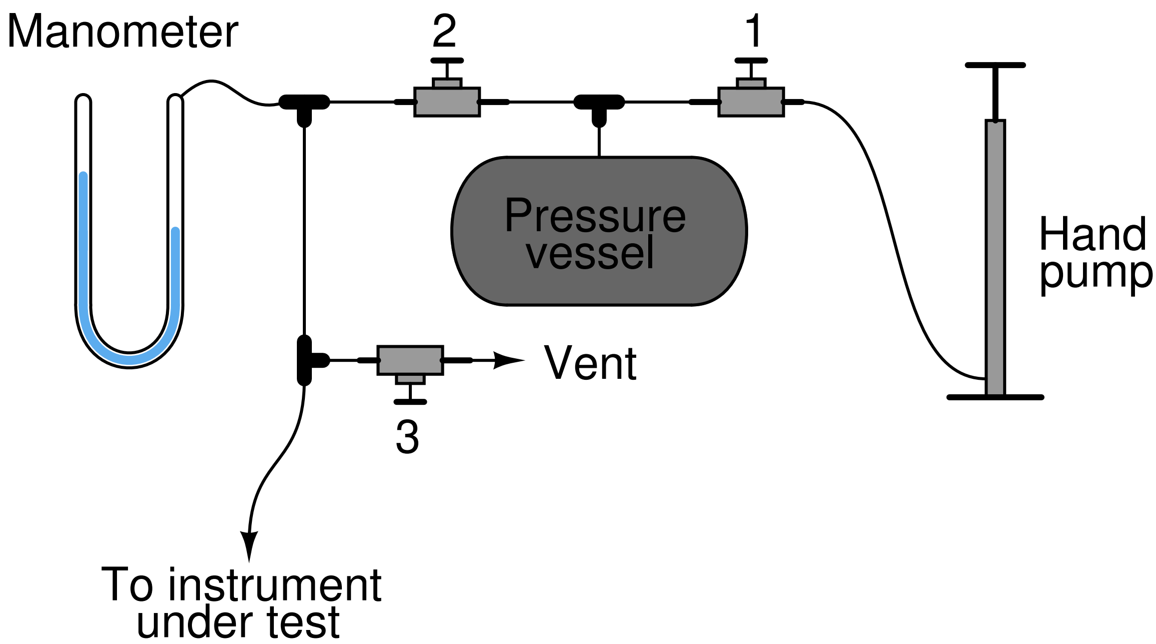
A very useful principle in physics is the *Ideal Gas Law*, so called because it relates pressure, volume, molecular quantity, and temperature of an ideal gas together in one neat mathematical expression:

$$PV = nRT$$

Where,
P = Absolute pressure (atmospheres)
V = Volume (liters)
n = Gas quantity (moles)
R = Universal gas constant (0.0821 L · atm / mol · K)
T = Absolute temperature (K)

Although this "law" is not perfectly accurate for real gases, especially at high pressures and/or near the point of liquefaction, it is quite accurate for air near ambient temperature and pressure.

One very practical application of this law is found in a method for generating low air pressures such as those easily measured by water- or oil-based manometers. Most mechanical air compressors generate pressures far exceeding the range of all but the largest manometers. Though it is possible to purchase precision pressure regulators for reducing such large pressures down to a level measurable by a manometer, these devices are expensive. An alternative is to generate the air pressure with a hand pump (such as a bicycle tire pump) connected to a relatively large pressure vessel:



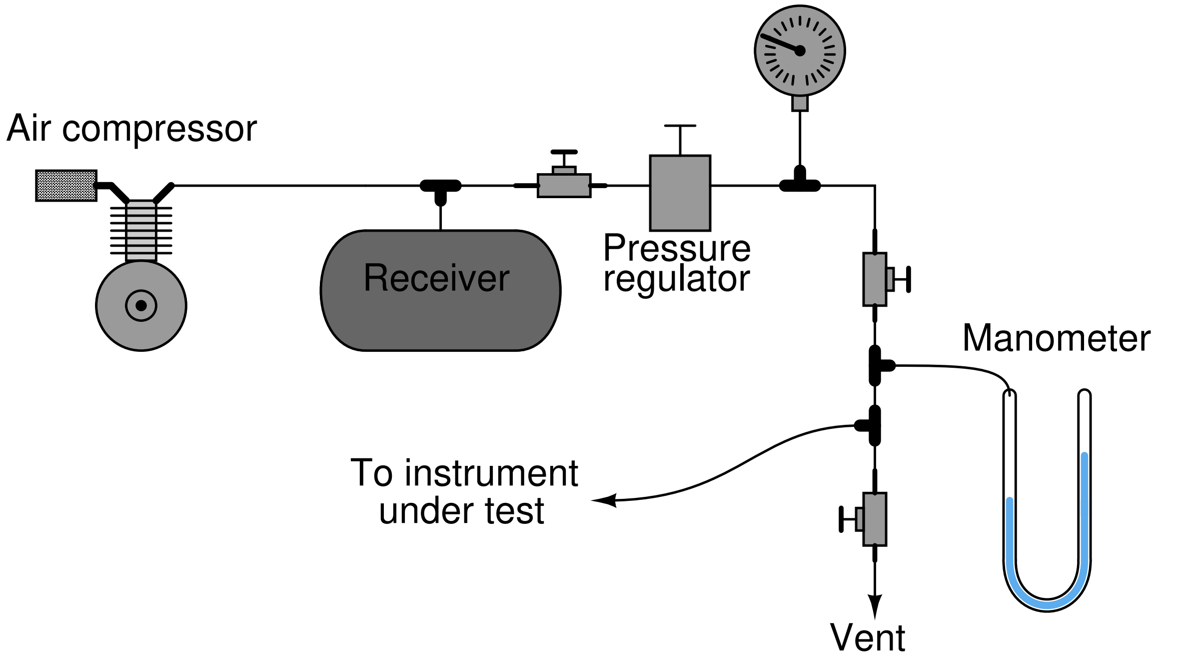
Without the volume of the pressure vessel connected to the tubing system, the air pressure would increase dramatically for each stroke of the air pump. With the pressure vessel connected, each pump stroke contributes a much smaller amount of additional pressure to the system. Use the Ideal Gas Law equation to explain why this is.

file i00286

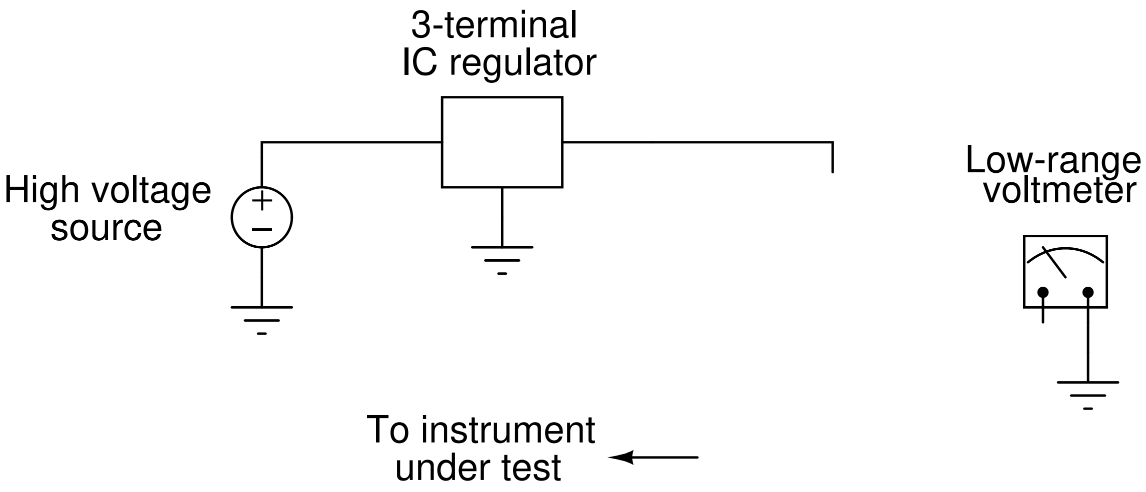
Oppgave 33

One challenge technicians face when calibrating low-pressure instruments is how to generate very low air pressures to simulate different low-pressure conditions for the pressure instrument under test. Measuring low pressures is no problem at all: very simple manometers will do the job quite nicely. Most mechanical air compressors, however, generate pressures far exceeding the range of most manometers. Though it is possible to purchase precision pressure regulators for reducing such large pressures down to a level measurable by a manometer, these devices are expensive.

A simple way to "divide" the pressure output of a standard pressure regulator from a few PSI to a few inches of water is to use a pair of small valves (preferably needle valves allowing for precise adjustment) to throttle the flow of compressed air and vent the regulator's output to atmosphere, then tap between those valves to obtain a reduced pressure:



Complete the following schematic diagram showing an electrical model for this pneumatic system, and then explain how it works:



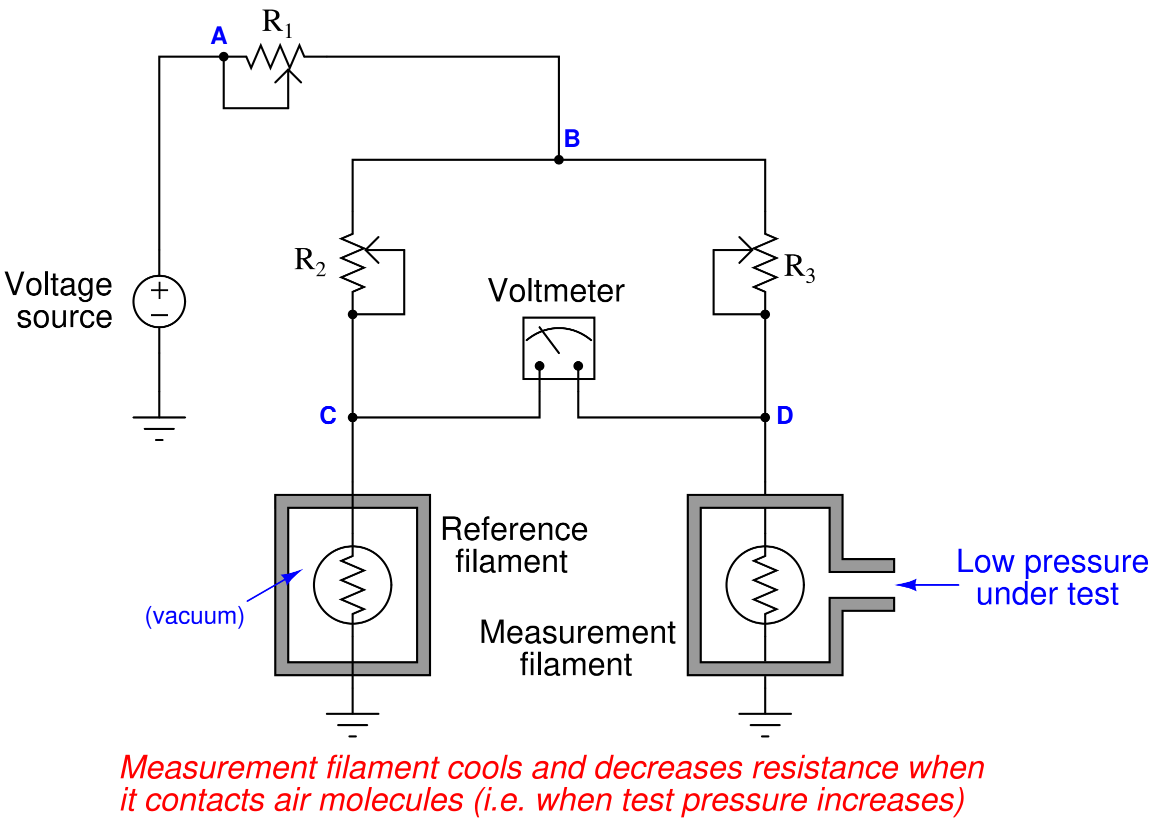
file i00287

Oppgave 34

Elektroniske måleelementer for trykk

Oppgave 35

A *Pirani gauge* is a special pressure instrument designed to measure very low pressures (i.e. hard vacuums). It uses two electrically heated filaments, one of which is dealed in a vacuum "reference" chamber, while the other is exposed to the process gas pressure under test. Gas molecules contacting the measurement filament causes it to cool and decrease resistance:



This Pirani gauge, however, has a problem. It registers a high pressure all the time, regardless of the strength of the vacuum connected to the measurement cell. A digital multimeter connected between test points **D** and ground registers 0 volts.

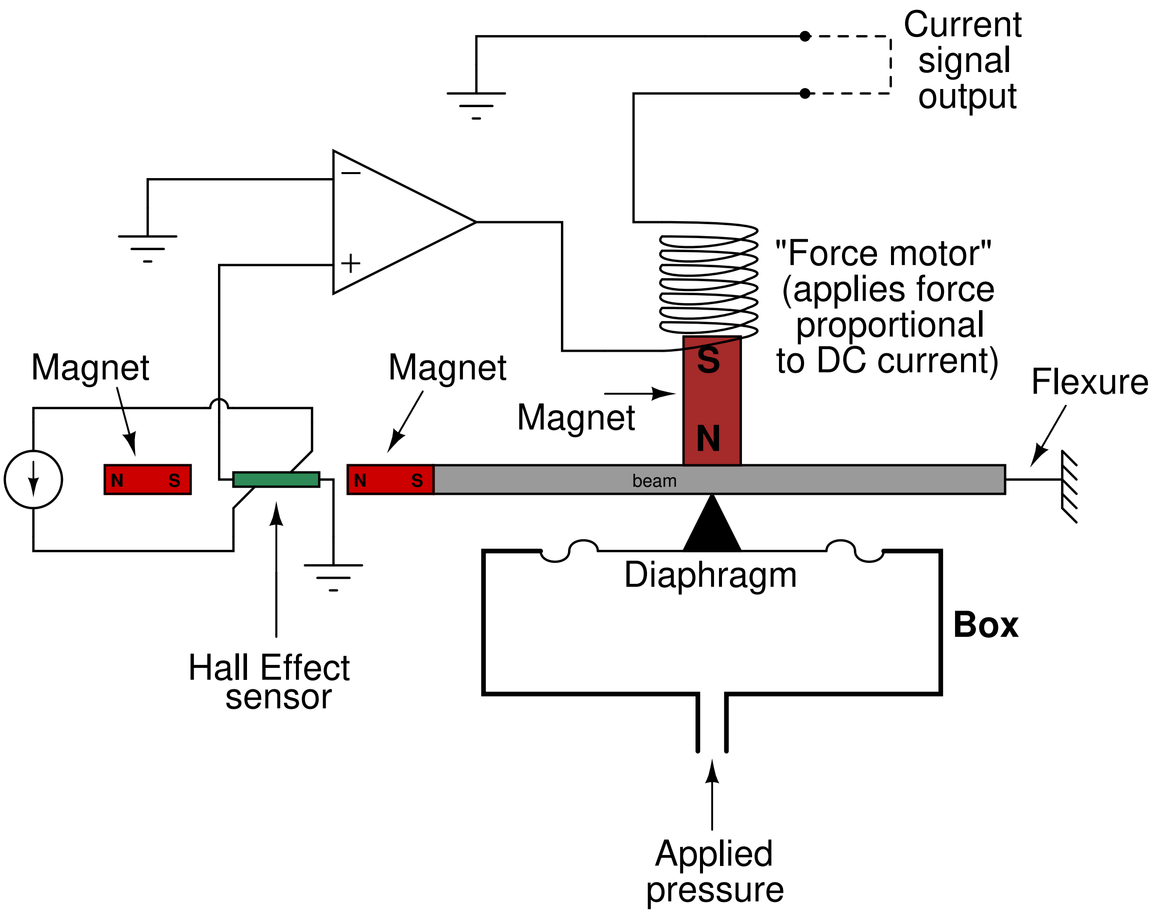
Identify the likelihood of each specified fault for this circuit. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault could independently account for *all* measurements and symptoms in this circuit.

Fault	**Possible**	**Impossible**
R_1 failed open		
R_1 failed shorted		
R_2 failed open		
R_2 failed shorted		
R_3 failed open		
R_3 failed shorted		
Reference filament burned out		
Measurement filament burned out		

file i00300

Oppgave 36

Shown here is a diagram for an *electronic* force-balance pressure transmitter:



Explain the following things in reference to this transmitter:

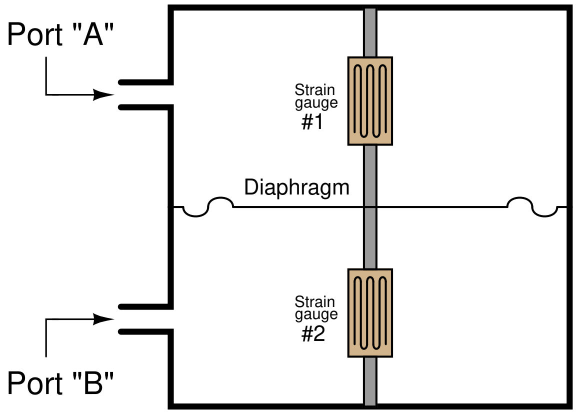
- What is a *flexure*?
- How is the opposing force generated?
- What does a *Hall Effect* sensor do?
- How is an imbalance of force detected?
- How would you incorporate a zero adjustment into this transmitter?
- How would you incorporate a span adjustment into this transmitter?

file i00207

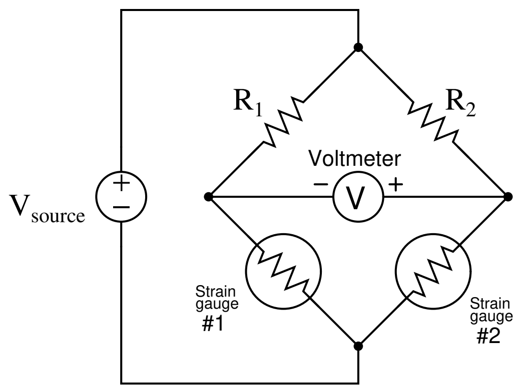
Oppgave 37

The following differential pressure sensor uses a matched pair of strain gauges. As the differential pressure increases, one strain gauge becomes compressed while the other becomes stretched. A voltmeter registers the bridge circuit's imbalance and displays it as a pressure measurement:

Pressure sensor illustration



Schematic diagram



Determine the following:

- Identify which port is the "high" pressure port
- Identify what the voltmeter will register if fixed resistor R_1 fails open
- Identify a component fault that would drive the voltmeter full upscale ("peg" positive)
- Identify another component fault that would drive the voltmeter full upscale ("peg" positive)

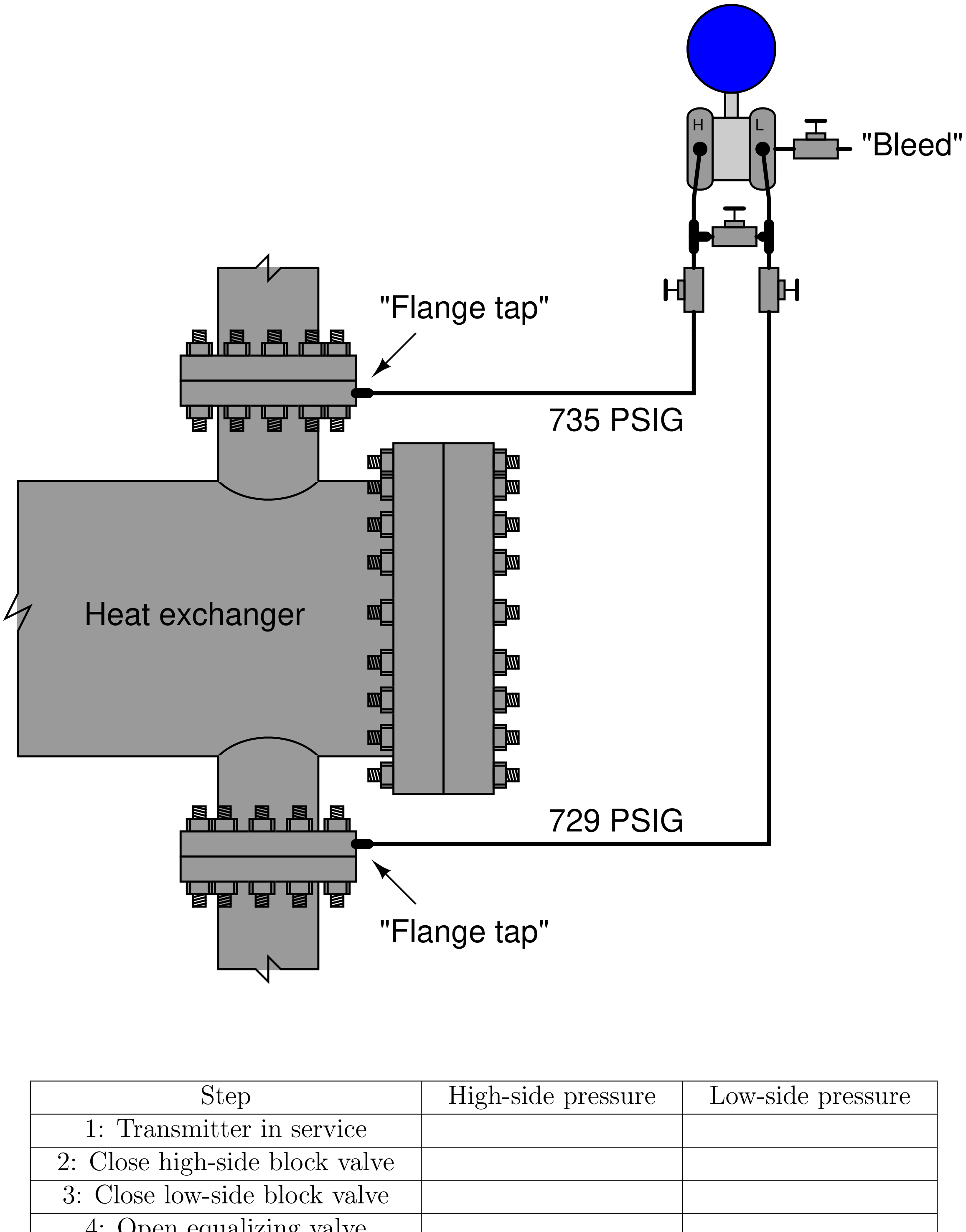
file i02944

Oppgave 38

Tilleggsutstyr

Oppgave 39

Determine the pressure at each port of the DP transmitter during an instrument technician's step-by-step valve isolation procedure. Assume the process fluid sensed by the transmitter is a gas and not a liquid:



Step	High-side pressure	Low-side pressure
1: Transmitter in service		
2: Close high-side block valve		
3: Close low-side block valve		
4: Open equalizing valve		
5: Open bleed valve		

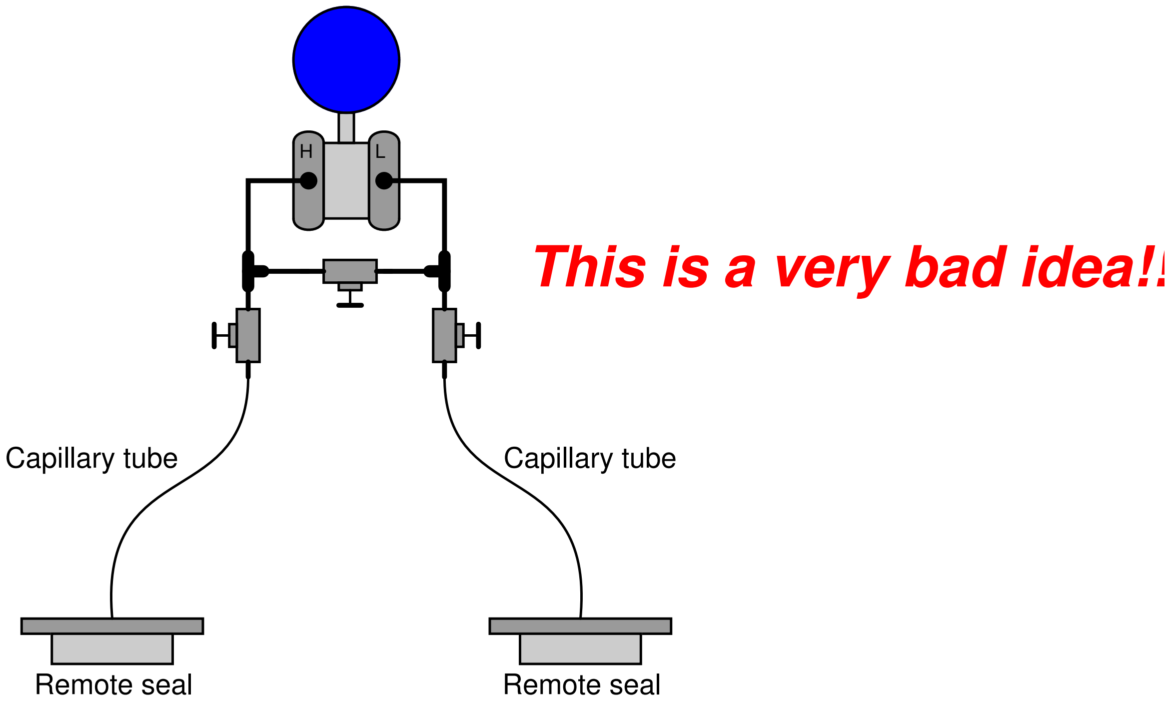
Based on the process pressures shown, identify the direction of process gas through this heat exchanger.

Also, identify what the technician needs to tell the process operator(s) prior to isolating the transmitter from this process.

file i00026

Oppgave 40

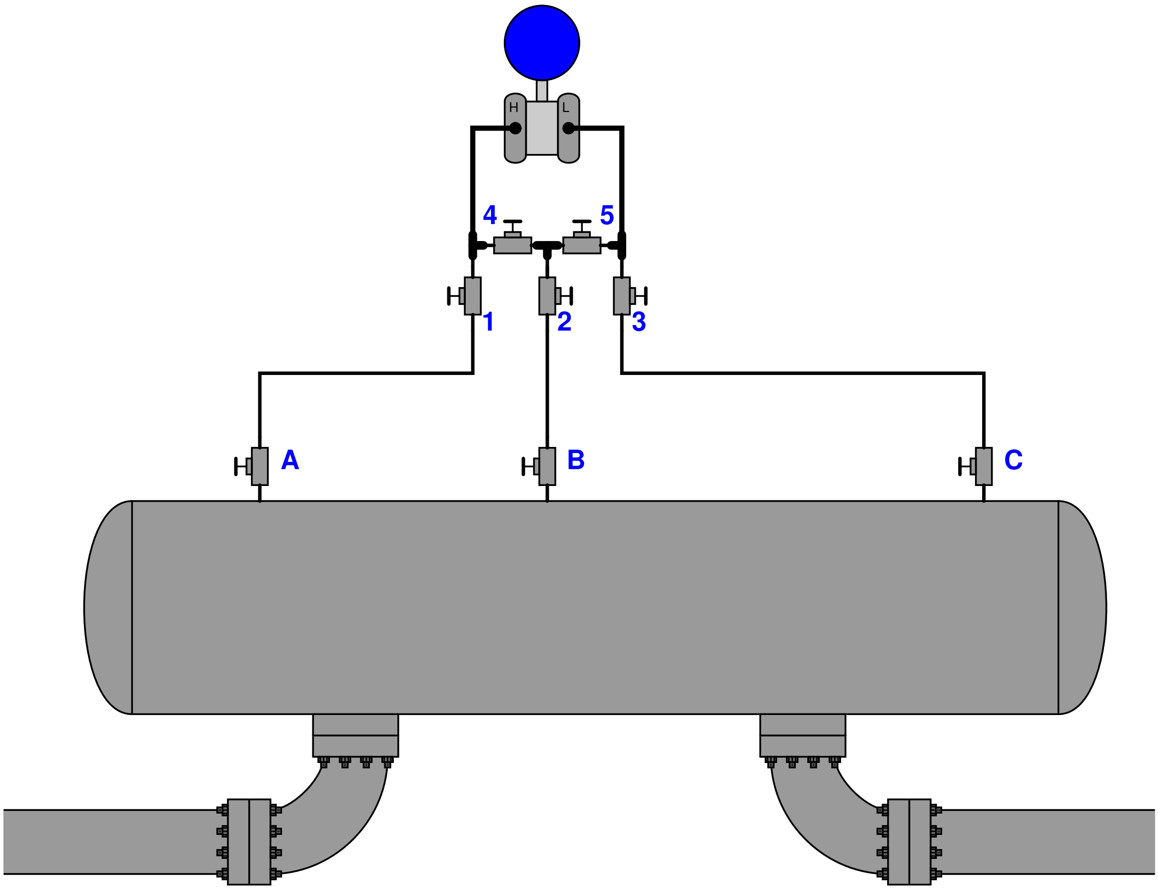
Explain why no one in their right mind would ever, *ever*, install a three-valve manifold on a DP transmitter with remote seals:



file i03460

Oppgave 41

An interesting application for a *5-valve manifold* is when a single DP transmitter needs to be able to measure differences in pressure between any two of three sample ports on a process vessel, such as in this example here:



Determine the necessary statuses for each of the valves in this system (e.g. *open* versus *shut*) in order to measure differential pressure between the specified ports on the process vessel:

Pressure	V_A	V_B	V_C	V_1	V_2	V_3	V_4	V_5
P_{AB}								
P_{BC}								
P_{AC}								

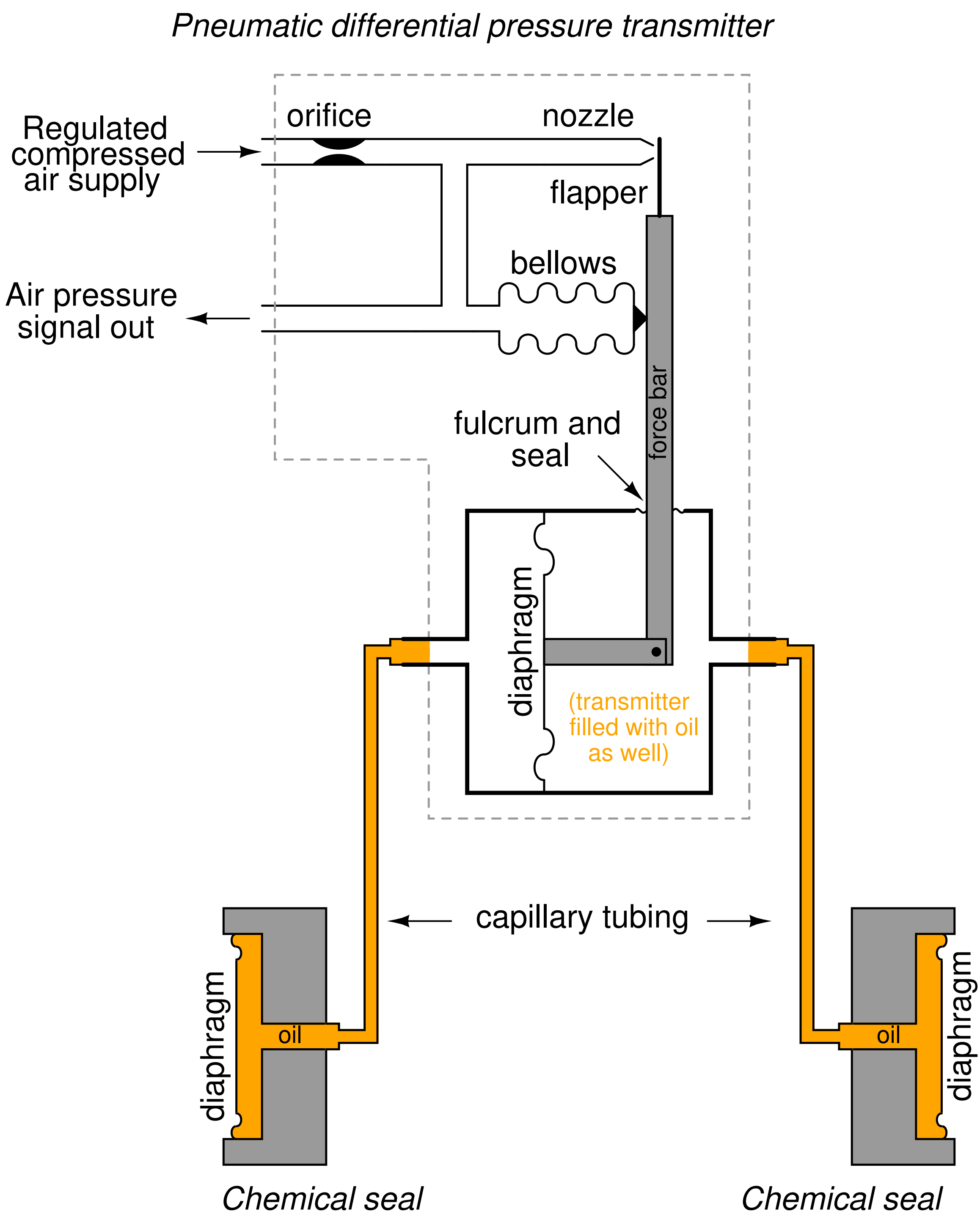
Suggestions for Socratic discussion

- For any of the giving valve "lineups," identify a good procedure for taking the transmitter out of service (i.e. which manifold valves to manipulate, in which order).
- Where in this impulse tubing system would you recommend installing a *bleed* fitting?

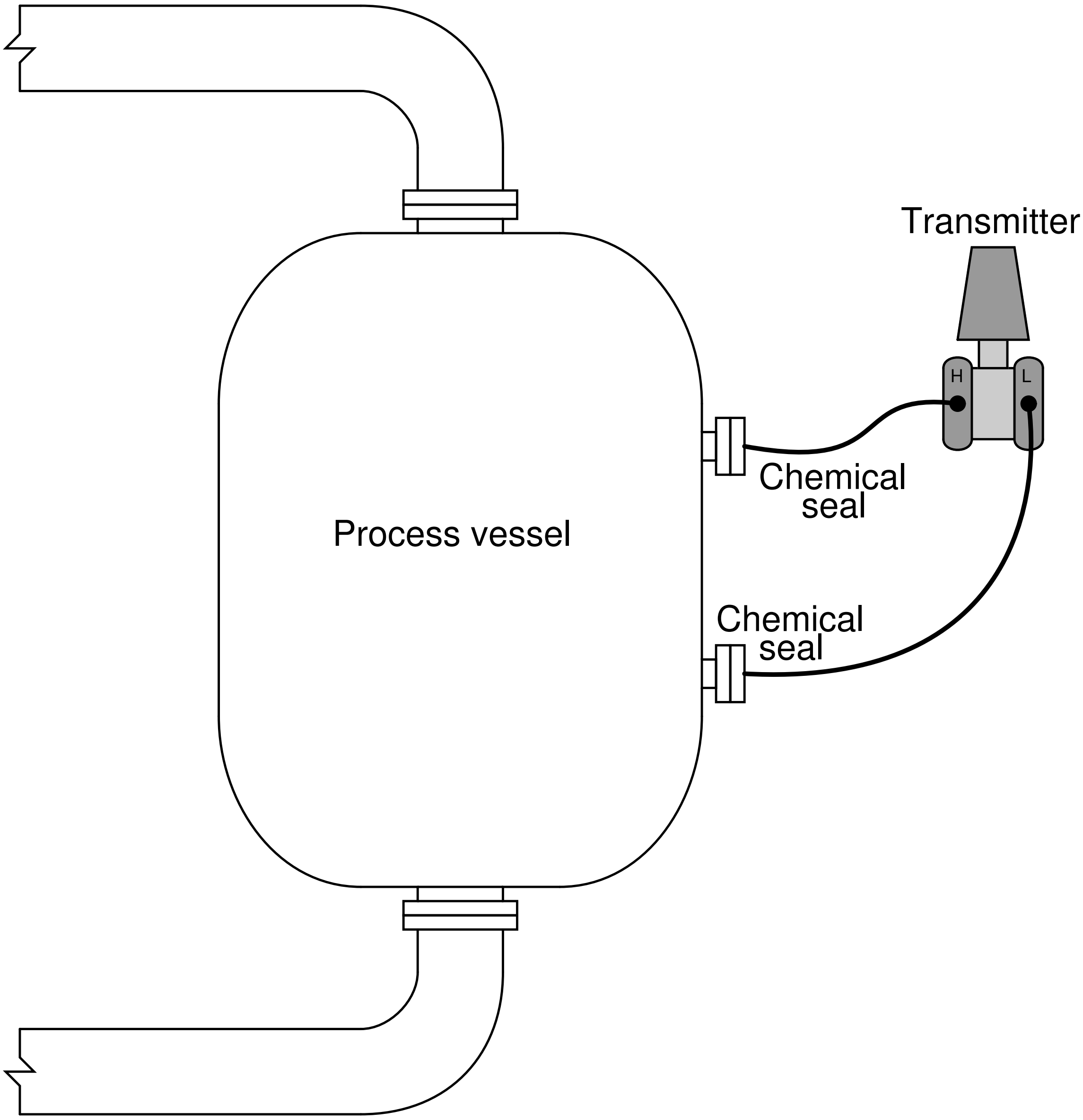
file i02576

Oppgave 42

Some pressure instruments come equipped with *chemical seals* consisting of diaphragm units connected to the instrument with small-bore "capillary" tubing filled with a liquid such as silicone oil:



These seals may then be connected to a process vessel to measure pressure, at some distance from the transmitter:



For what purpose(s) do these seals function? What advantage(s) do they lend to the instrument in measuring pressure?
file i00216

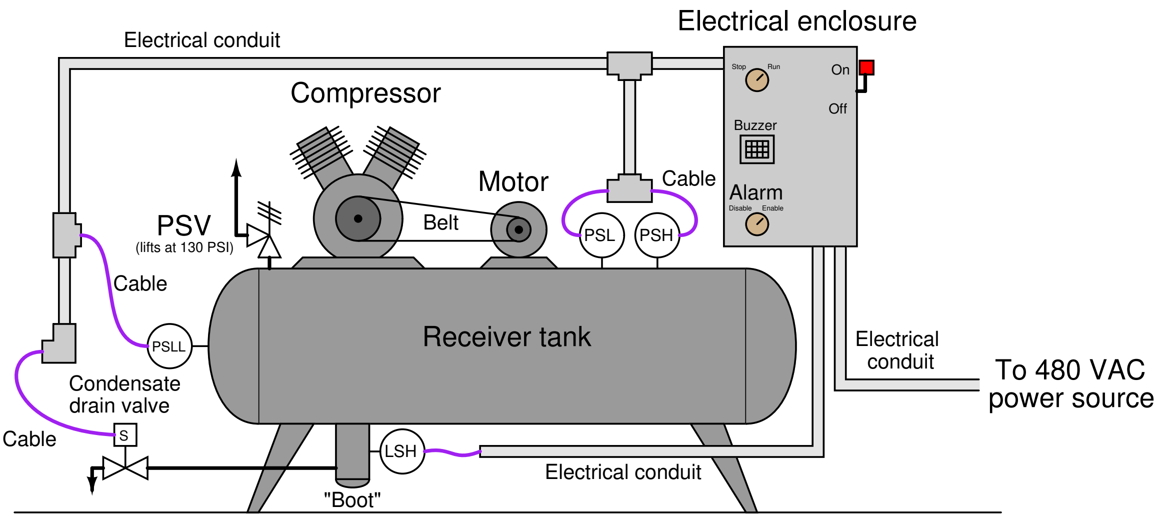
Oppgave 43

Why is *temperature* an important factor in pressure transmitters equipped with remote seals (sometimes called "chemical" seals)? Specifically, what temperature condition(s) could cause a differential pressure instrument with remote seals to experience measurement errors?

Also, describe what would happen to a pressure instrument equipped with remote seals if ever a leak developed in one of the capillary tubes.
file i00217

Oppgave 44

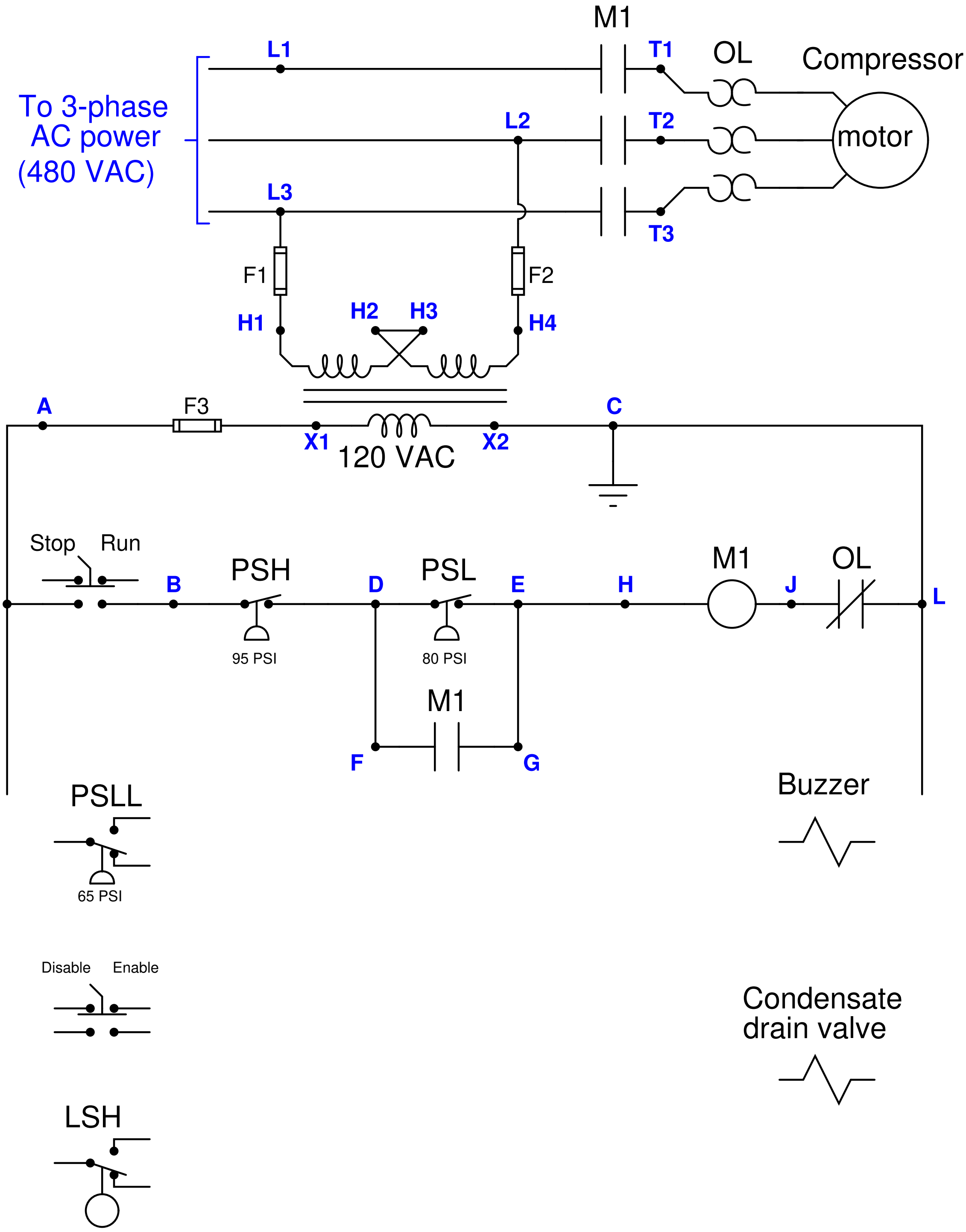
Electrically-powered air compressors are commonly used in many different industries for supplying clean, dry compressed air to machines, instrument systems, and pneumatic tools. A simple compressor system consists of a compressor which works much like a bicycle tire pump (drawing in air, then compressing it using pistons), an electric motor to turn the compressor mechanism via a V-belt, a "receiver tank" to receive the compressed air discharged by the compressor mechanism, and some miscellaneous components installed to control the pressure of the compressed air in the receiver tank and drain any condensed water vapor that enters the receiver:



Electromechanical relay circuitry located inside the electrical enclosure decides when to turn the compressor motor on and off based on the statuses of the high- and low-pressure control switches (PSH = high pressure switch ; PSL = low pressure switch).

Your task is two-fold. First, you must figure out how to wire a new low-low pressure alarm switch (PSLL, shown on the left-hand end of the receiver) so that an alarm buzzer will activate if ever the compressed air pressure falls too low. A newly-installed hand switch located on the front panel of the electrical enclosure must be wired with this PSLL switch in such a way that the buzzer cannot energize if the hand switch is in the "alarm disable" position. Second, you must figure out how to wire a new high-level switch (LSH, shown on the "boot" of the receiver tank) so that the condensate drain valve will energize automatically to open up and drain water out of the receiver boot when the level gets too high, and then automatically shut again when the water in the boot drops down to an acceptable level.

The following schematic diagram shows the basic motor control circuit for this air compressor, with the new switches, buzzer, and drain valve shown unwired:

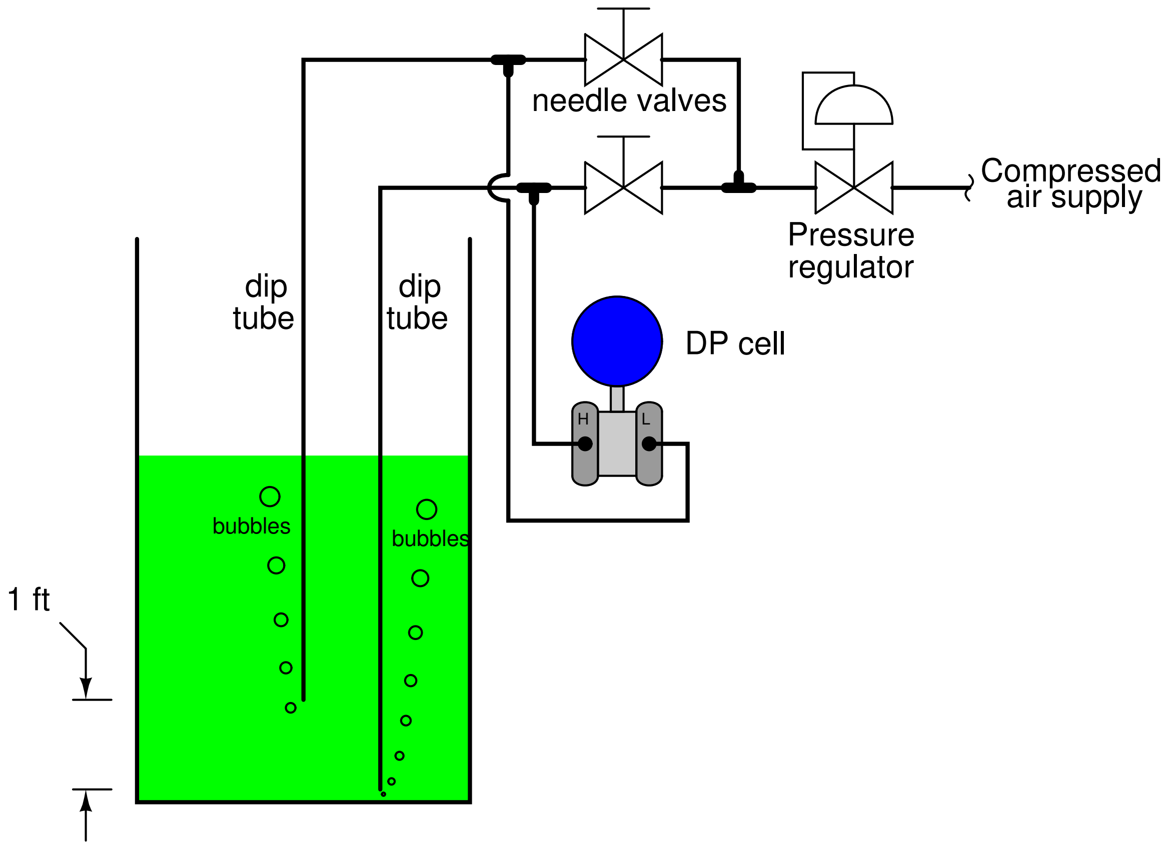


Complete this control circuit by sketching connecting wires between the new switches, buzzer, and drain valve solenoid. Remember that the way all switches are drawn in schematic diagrams is in their "normal" states as defined by the manufacturer: the *state of minimum stimulus* (when the switch is un-actuated). For pressure switches, this "normal" state occurs during a low pressure condition; for liquid level switches, this "normal" state occurs during a low-level (dry) condition. Note that each of the new process switches has SPDT contacts, allowing you to wire each one as normally-open (NO) or as normally-closed (NC) as you see fit.

file i02540

Oppgave 45

Explain how the following dip tube system measures the *density* of the liquid inside the vessel rather than the *level*. Assume the liquid level never drops below the upper dip tube, and that the difference in height between the two dip tubes is fixed at 12 inches (1 foot):



Furthermore, calculate the differential pressure sensed by the DP transmitter for a liquid with a density of 58 pounds per cubic foot.

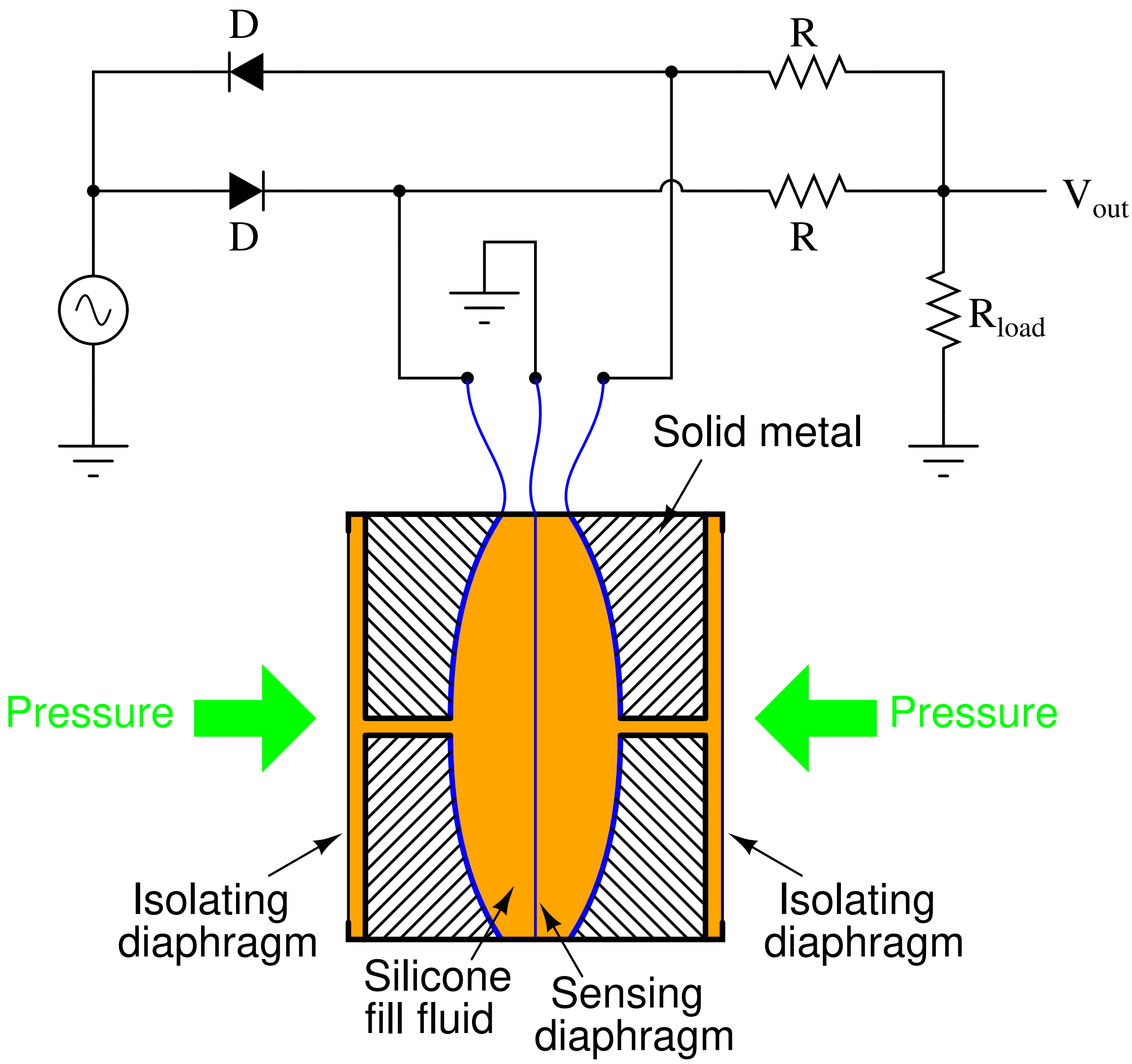
file i00264

Oppgave 46

DP-celle

Oppgave 47

An ingenious circuit used to generate an electrical voltage signal from a differential capacitance sensor is the *Twin-T diode circuit*, shown here connected to a Rosemount-style differential capacitance pressure sensor:

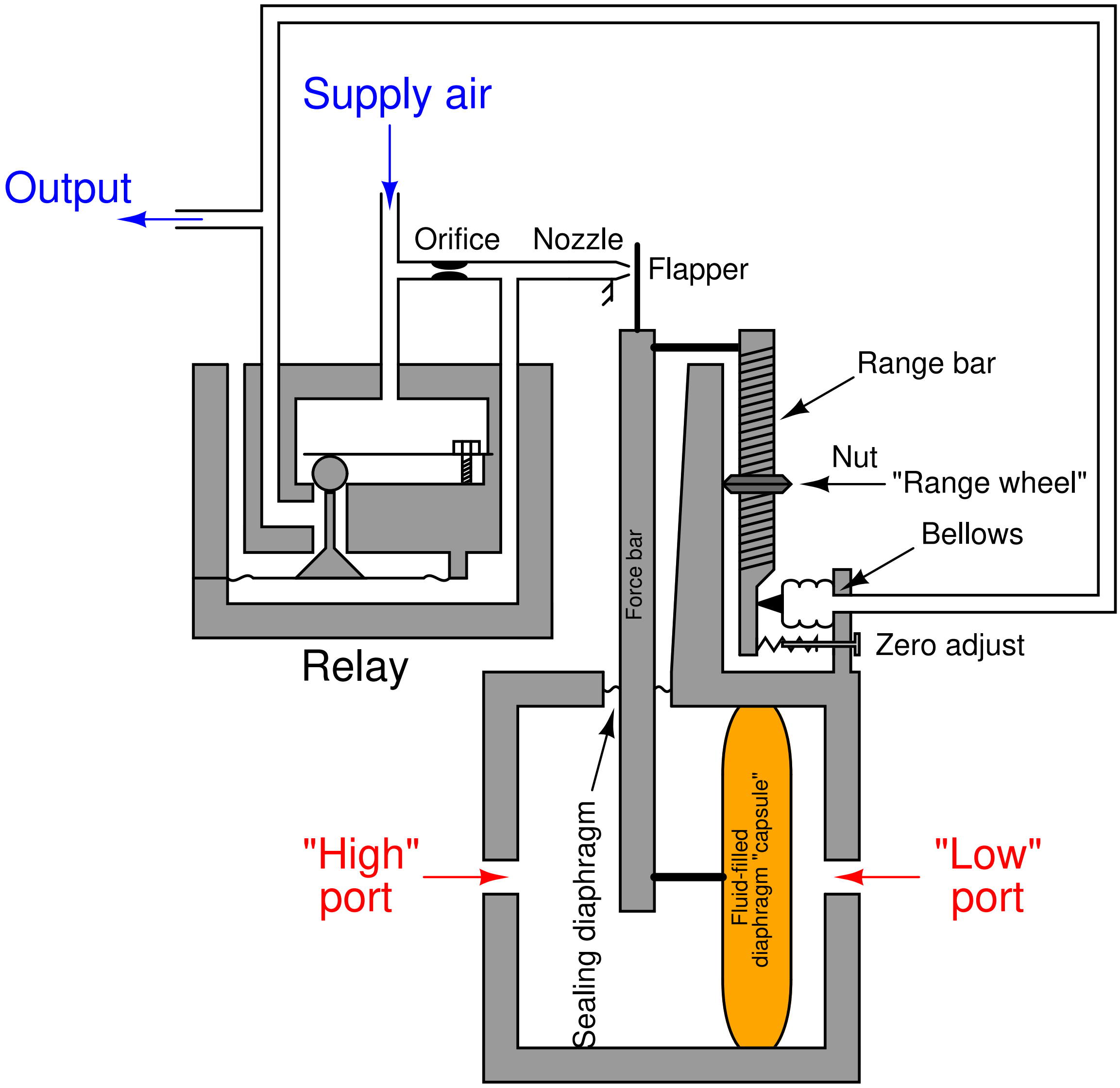


One capacitor is charged positive with respect to ground, while the other is charged negative with respect to ground, as the AC voltage source alternates positive and negative. While one capacitor of the pressure sensor is charging, the other is discharging through R_{load}, producing an output voltage (V_{out}).
If both capacitances are equal, the output voltage will alternate equally between positive and negative values, having a DC average value of zero. If one capacitance is larger than the other, it will store additional charge on its plates, causing it to sway the output voltage of the Twin-T circuit in the direction of its polarity. Thus, V_{out} becomes more positive as pressure increases on one side of the sensor, and more negative as pressure increases on the other side of the sensor.

Based on this explanation of the Twin-T circuit's operation, determine which side of the pictured differential capacitance sensor is the "High" pressure side, and which is the "Low" pressure side. Be sure to explain your reasoning!
file i00023

Oppgave 48

The following diagram is that of a pneumatic *moment-balance* differential pressure transmitter, similar to the Foxboro model 13A. The term "moment" refers to the physics principle of a force acting on a lever to produce a torque. "Moment-balance" is more appropriate than "force-balance" in this case because the device pits moment against moment, rather than force against force directly:



Describe this instrument's response to an increasing differential pressure (increasing pressure on the "High" side, and a steady pressure on the "Low" side; or a decreasing pressure on the "Low" side with a steady pressure on the "High" side), step by step.

Suggestions for Socratic discussion

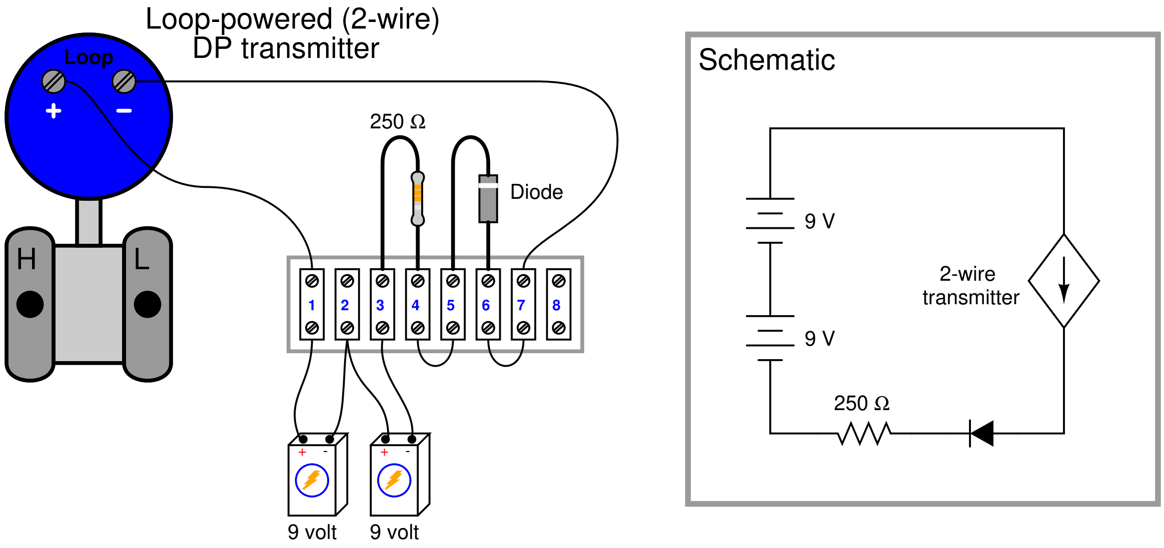
- Describe the purpose of the *sealing diaphragm* shown roughly mid-way along the length of the force bar.
- Identify how this instrument will respond to obstructions (blockages) in the following locations:

– Nozzle
– Vent (located on relay body)

file i00205

Oppgave 49

Connect a loop-powered differential pressure transmitter (with HART capability along with analog 4-20 mA output) to a DC voltage source, a 250 ohm resistor, and a diode as shown, using parts supplied by the instructor. You will need to bring your own multimeter for this experiment, but your instructor will supply the HART communicators. All electrical connections must be made using a terminal strip (no twisted wires, crimp splices, wire nuts, spring clips, or "alligator" clips permitted):



When you have your transmitter powered and functioning, answer the following questions:

- Trace the direction of current through this DC circuit (using conventional flow notation) and identify the polarity of the voltage across each component in accordance with that component's function as either an electrical *source* or an electrical *load*.

- Demonstrate how to measure the transmitter's output signal three different ways:
  - Breaking the circuit to directly measure current with a milliammeter (4-20 mA signal)
  - Connecting a milliammeter in parallel with the diode (4-20 mA signal)
  - How does an applied pressure (blowing into the plastic tube) to the "High" pressure port on the transmitter affect the electrical signal? How about an applied pressure to the "Low" pressure port?

- Explain how the differential pressure transmitter, with its "High" and "Low" pressure ports, can act either as a *direct-acting* or as a *reverse-acting* instrument.

- While measuring current (with the milliammeter shorting across the diode), temporarily short past the 250 ohm resistor with a jumper wire. How does this affect the circuit current, and why?

- Use the data-recording ("Min/Max") mode of your digital multimeter to capture the highest loop current signal value, as well as the lowest, explaining how this multimeter function might be diagnostically useful.

- Connect a HART communicator device in parallel with the transmitter, turn it on, and use it to access the transmitter's programmable parameters.

- Use a multimeter set to measure *AC* volts to detect HART communications in the circuit. What happens to the AC voltage measurement when the HART communicator is turned off? Is there any way to capture the peak HART signal values using your multimeter?

- Temporarily short past the resistor with a jumper wire and note whether or not this has any affect on the HART data communications.

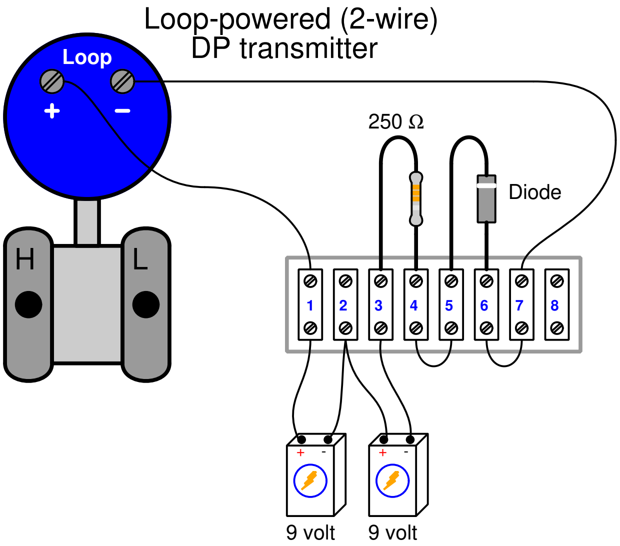
Suggestions for Socratic discussion

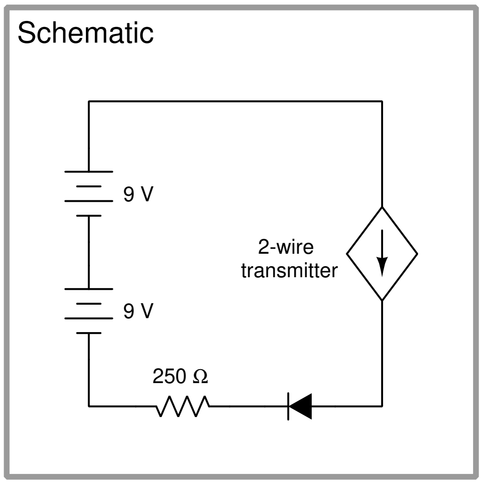
- How would the pressure transmitter respond if equal pressures were applied to *both* "H" and "L" ports?
- One of the basic rules electronics students learn when first using their multimeters is *never* connect an ammeter in *parallel* with anything, only in series. Explain why shorting across the diode is okay to do, and whether or not shorting across the resistor would be just as practical.

file i03877

Oppgave 50

Connect a loop-powered differential pressure transmitter (4-20 mA output) to a DC voltage source, a 250 ohm resistor, and a diode as shown, using parts supplied by the instructor. You will need to bring your multimeter as well as a 4-20 mA loop calibrator for this experiment! All electrical connections must be made using a terminal strip (no twisted wires, crimp splices, wire nuts, spring clips, or "alligator" clips permitted):





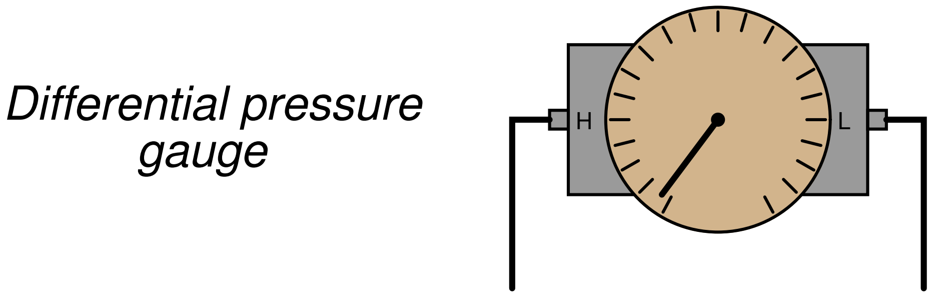
When you have your transmitter powered and functioning, answer the following questions:

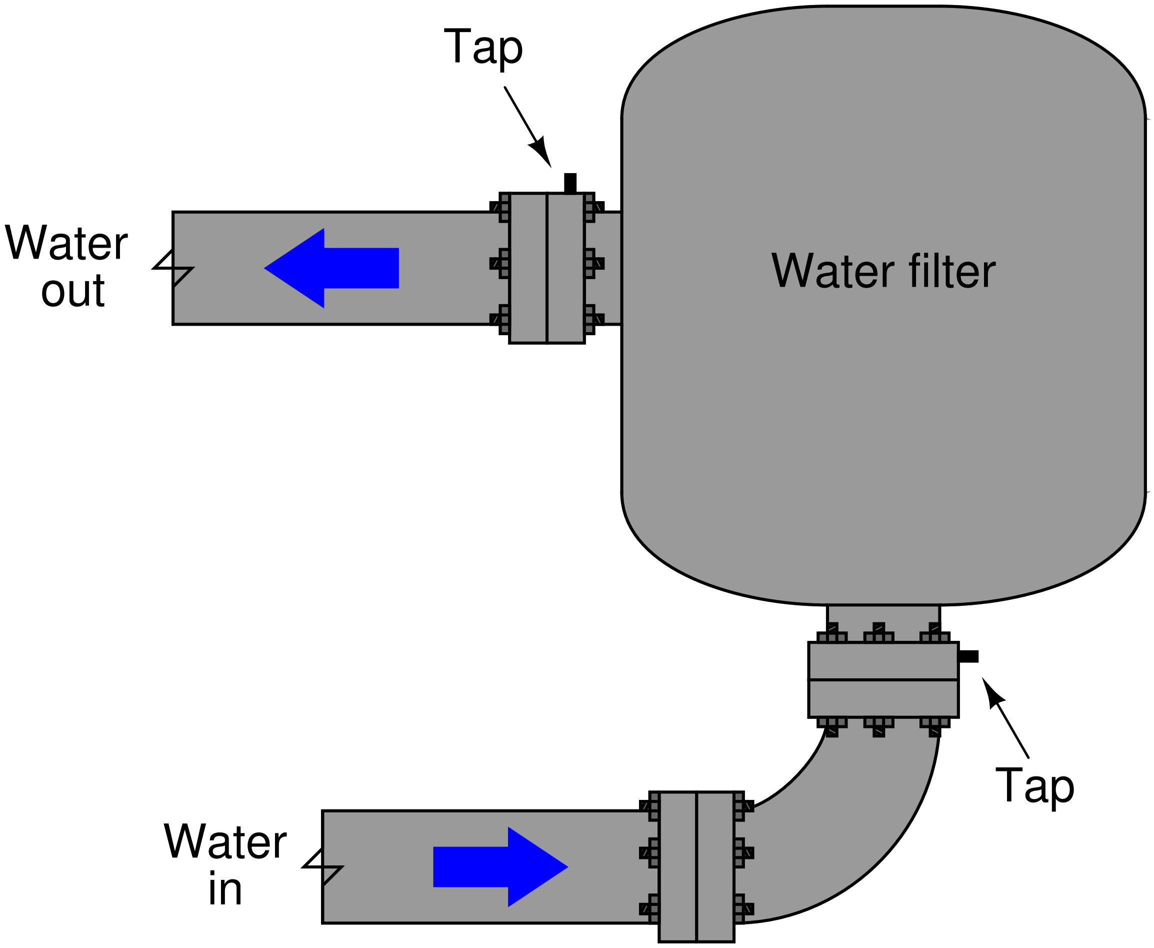
- Demonstrate how to measure the transmitter's signal using a voltmeter connected in parallel with the 250 ohm resistor. Leave the voltmeter connected for the duration of the experiment.
- Demonstrate how to use the loop calibrator in the "Measure" (or "Read") mode to measure the amount of current output by the transmitter. Compare the loop calibrator's current measurement against the voltmeter's voltage measurement.
- Remove the transmitter from the circuit and replace it with the loop calibrator, then demonstrate how to use the loop calibrator in the "Simulate" mode to mimic the operation of the transmitter. Compare the loop calibrator's current simulation value against the voltmeter's voltage measurement.
- Remove the batteries and the transmitter from the circuit and replace both with the loop calibrator, then demonstrate how to use the loop calibrator in the "Source" mode to supply current through the resistor and diode. Compare the loop calibrator's current source value against the voltmeter's voltage measurement.

file i03880

Oppgave 51

A large water filter occasionally plugs with debris, and operations wants to have a gauge indication of this plugging. Since plugging of the filter will result in greater differential pressure drop across it for any given amount of water flow through it, measuring pressure drop with a differential pressure gauge will provide a simple indication of filter plugging. Draw the connecting tubes between the differential pressure gauge and the filter (the two "taps" shown on the pipes are ready to connect to instrument tubing) so that the gauge registers positive pressure as the filter becomes plugged:





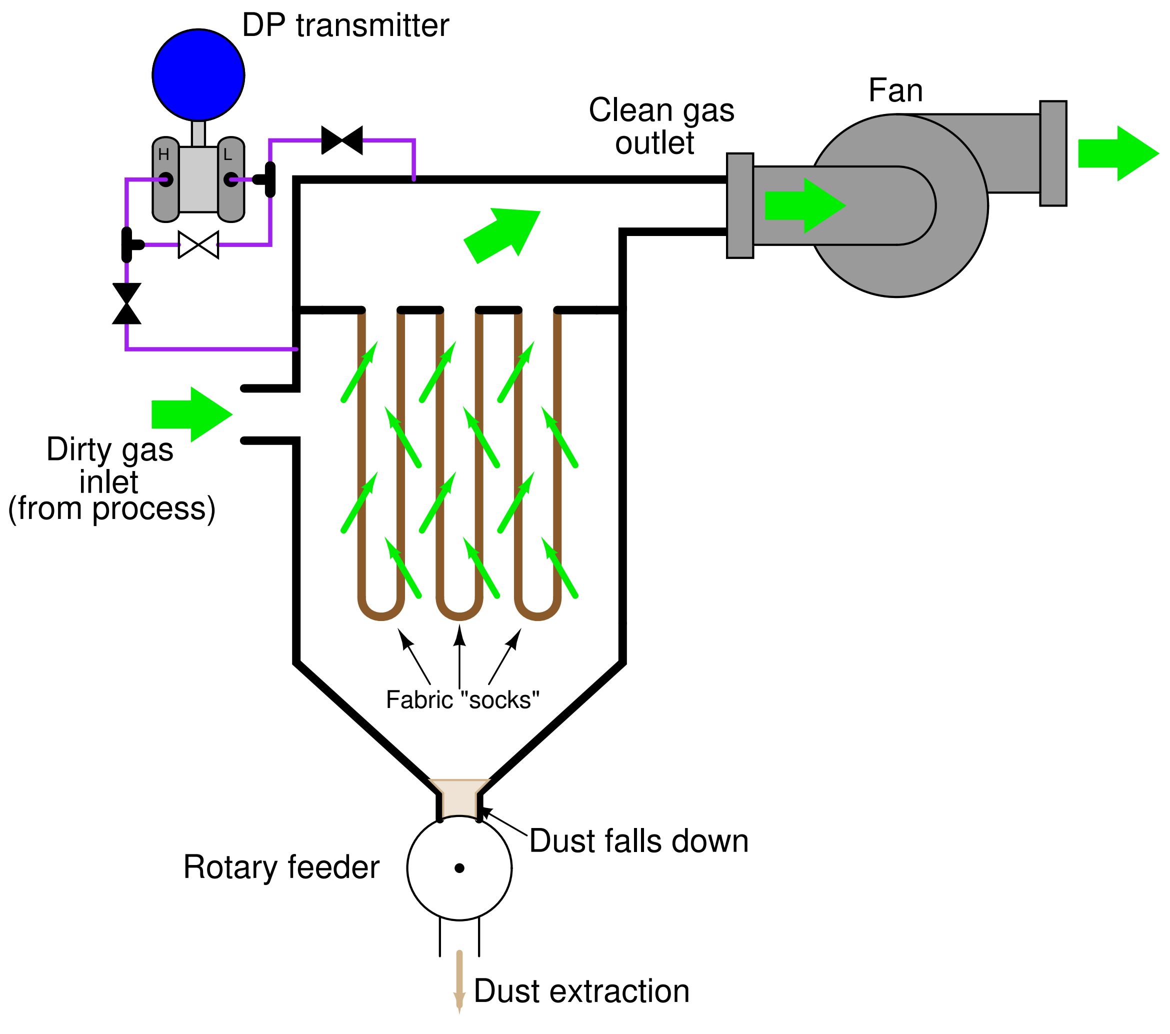
file i00215

Oppgave 52

Feilføking

Oppgave 53

Suppose a differential pressure transmitter is used to measure the pressure dropped across a *baghouse*, an assembly using multiple fabric "socks" to filter particulate material from a gas stream, like a large-scale vacuum cleaner. Gas passes through the socks, filtering out the particulate matter. The DP transmitter's pressure measurement serves to indicate how clogged the socks are:



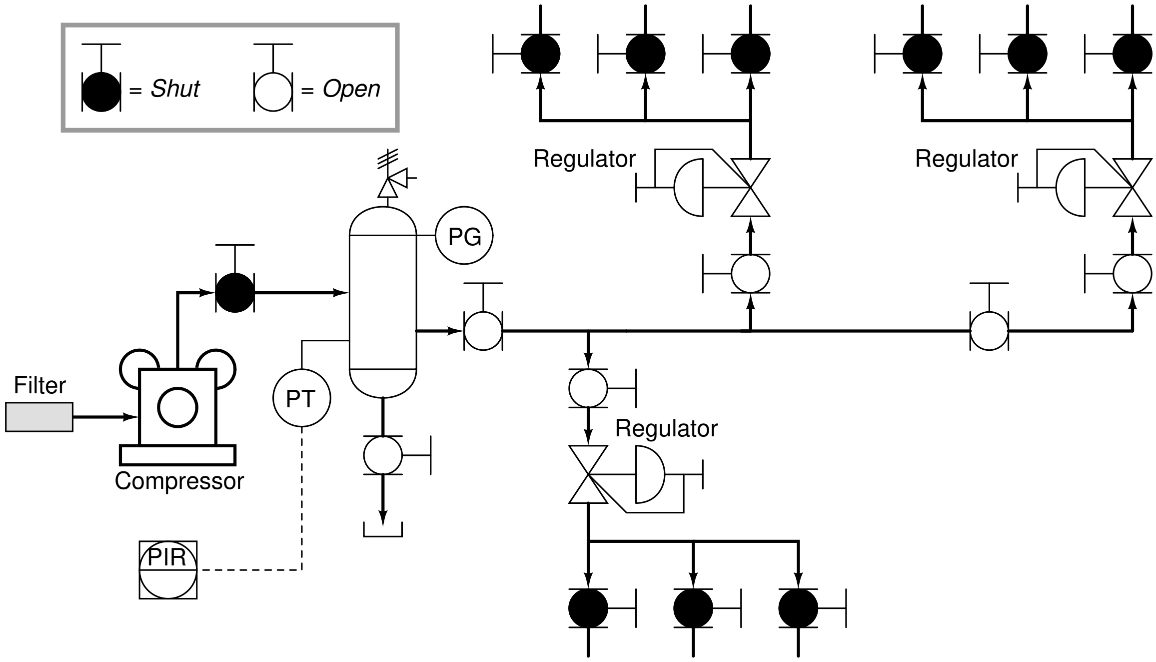
When the transmitter signal reaches a certain value (indicating clogged filter socks), a control system triggers either a mechanical shaker or a blast of gas from jets located near each sock shakes the dust from the outside area of each sock, the dust falling down into the narrow area below where it is extracted over time from the baghouse.

Suppose an instrument technician leaves the three valves in the positions shown (hollow = open ; solid = closed). What effect will this have on the socks over time as they perform their filtering job, assuming the control system continues to operate as designed?

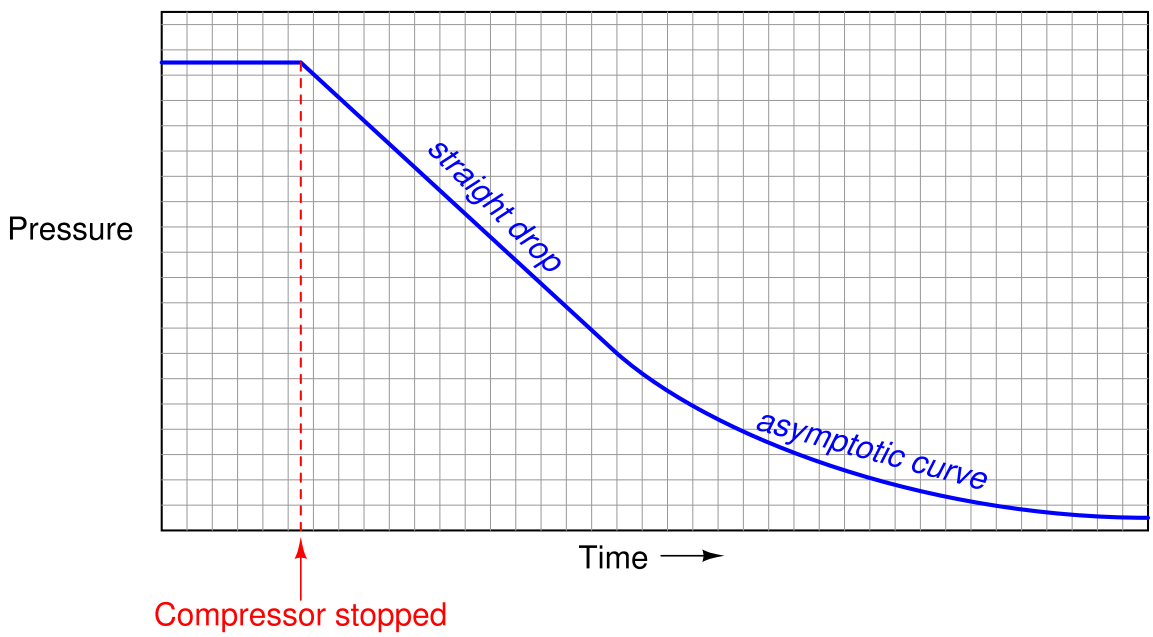
file i00021

Oppgave 54

A compressed air system has a leak, and you are part of a group of technicians asked to locate the leak. A pressure transmitter measuring receiver tank pressure is connected to a trend recorder, offering a way for you monitor tank pressure over time. Setting up for the leak test, one of the technicians on your team runs the compressor until the receiver tank gauge registers normal (full) pressure, then she shuts off the compressor and begins shutting off all the valves shown (dark) in this P&ID:



After waiting a few hours, you examine the trend of the receiver tank pressure, shown here:



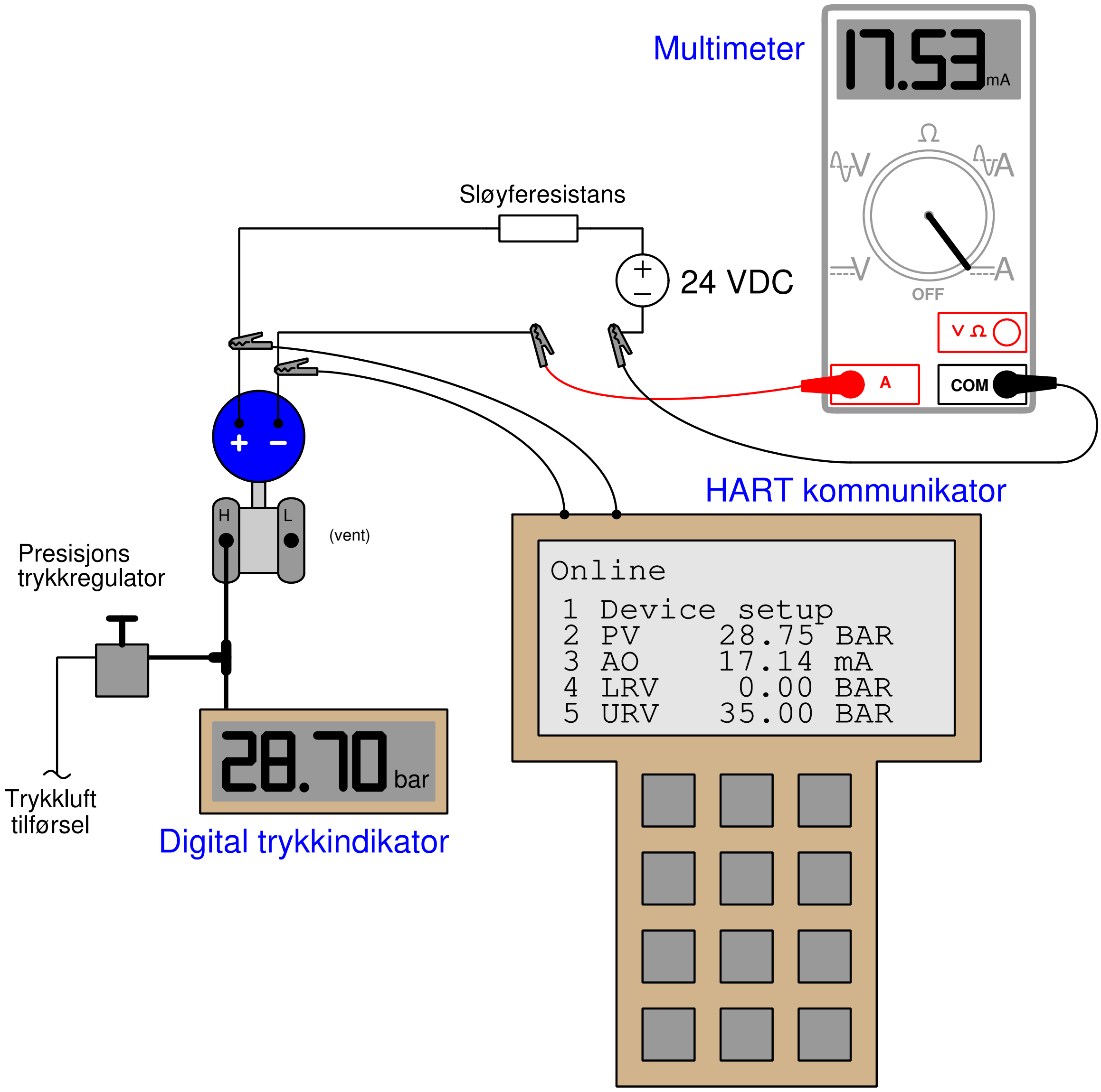
Another technician on your team sees this trend and exclaims, "Ah-Ha!! We know the leak is downstream of a pressure regulator, not upstream!" Puzzled by this, you ask your teammate to explain. "Look at the shape of the trend: a straight line sloping down, followed by a curve asymptotically approaching zero PSI. If the leak were upstream of a regulator, the whole downward trend would be asymptotic with no straight portions. If you take the Ideal Gas Law ($PV = nRT$) and express it as a differential equation over time ($\frac{dP}{dt}V = \frac{dn}{dt}RT$), you see that the rate of pressure fall ($\frac{dP}{dt}$) is proportional to the rate of air molecule leakage ($\frac{dn}{dt}$)."

Explain what your teammate is trying to say, in your own words. *Why* would the location of an air leak in this system make a difference in the *shape* of the trend? Furthermore, what would you do to isolate the location of the leak, now that you know it is downstream of a regulator?

file i01553

Oppgave 55

En SMART DP-celle er tatt ut av drift og tatt med for benkkalibrering. En automatikker kobler til et presisjons trykkmanometer og en luftkilde til High inngangen på DP-cellen, mens han måler strømutgangen med et multimeter.

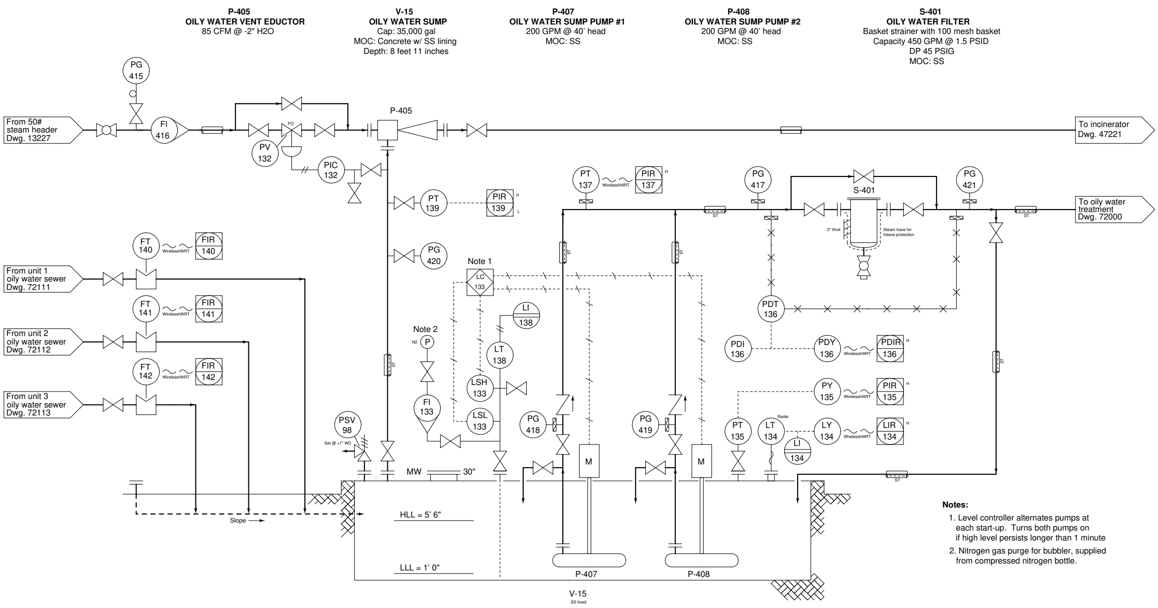


Regn ut avviket i % av måleområde for *sensor trim* og avviket i % av måleområde for *utgangstrim*. Forklar hvorfor en må ha en HART kommunikator for å kunne regne disse avvikene sepparat.

file i02033

Oppgave 56

An operator reports a series of false pressure alarms reported by pressure indicating recorder PIR-139 every few minutes. An instrument technician investigated this problem the previous day and declared it was most likely due to an electrical wiring fault between PT-139 and PIR-139 after measuring some intermittent high-current signals at the input terminals of PIR-139:



You are called to re-examine this system, because the other instrument technician didn't actually do anything to fix the problem. Your first test is to close the block (isolation) valve between PT-139 and the process pipe. After doing this, the mysterious pressure alarms cease. Later, you re-open that block valve and the pressure alarms resume.

Explain what the results of this simple test tell you about the nature and location of the fault. Does it confirm the first technician's diagnosis, or does it point to something else being wrong? Explain your answer in detail.

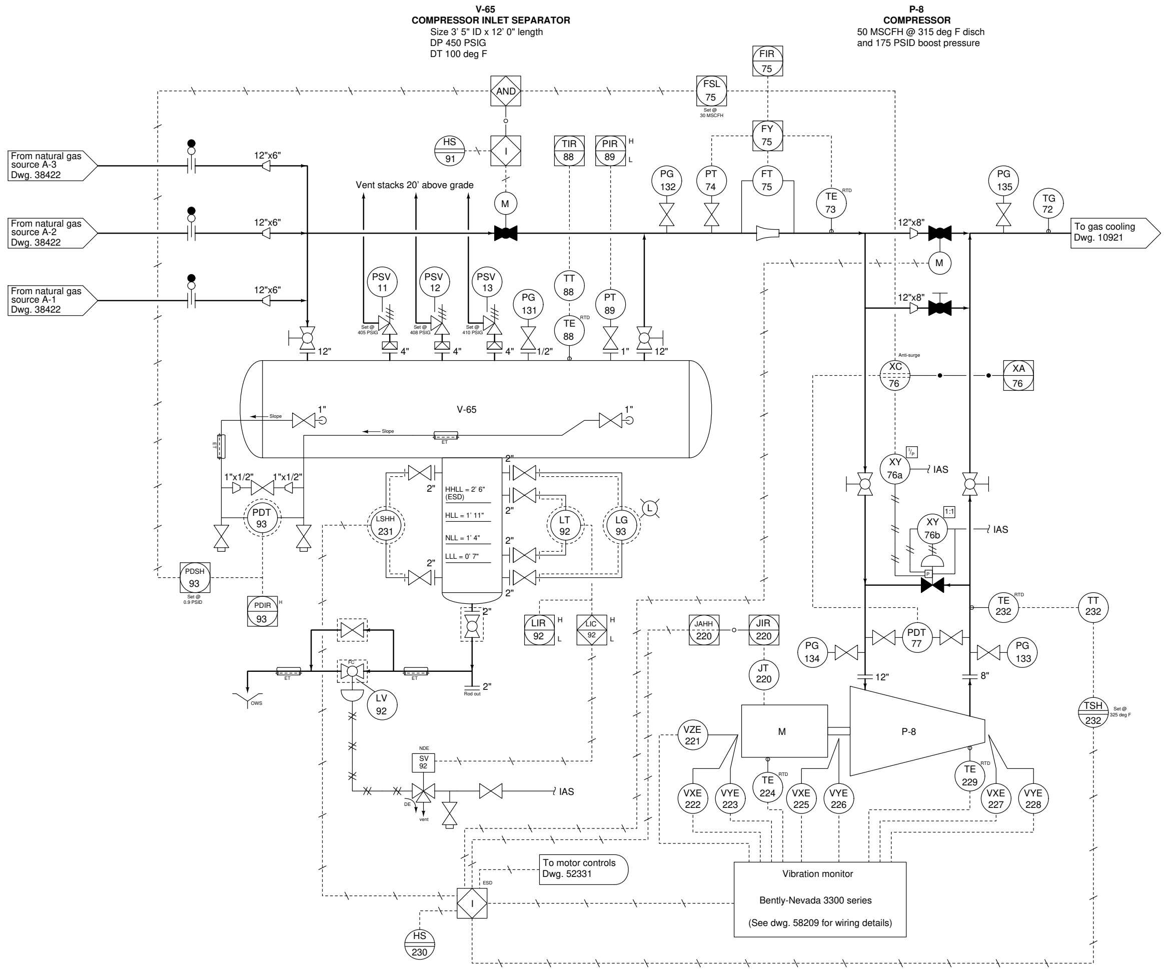
Suggestions for Socratic discussion

- One detail not described in the scenario is just how the first technician measured those intermittent high-current signals at PIR-139. Presumably it could have been done by continuously monitoring the display of a digital multimeter (DMM) long enough to see an alarm event occur. However, if the alarm events were infrequent enough, this could be a laborious task for someone to continuously watch a meter waiting to see the current change. Describe how you could use the *Min/Max* mode of a DMM instead to "automate" this task and free up the technician's time.

file i02553

Oppgave 57

The compressor automatically shut down last night, tripped by LSHH-231. The control system alarm log showed a high level alarm LIR-92 about 15 minutes prior to the shutdown:



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.

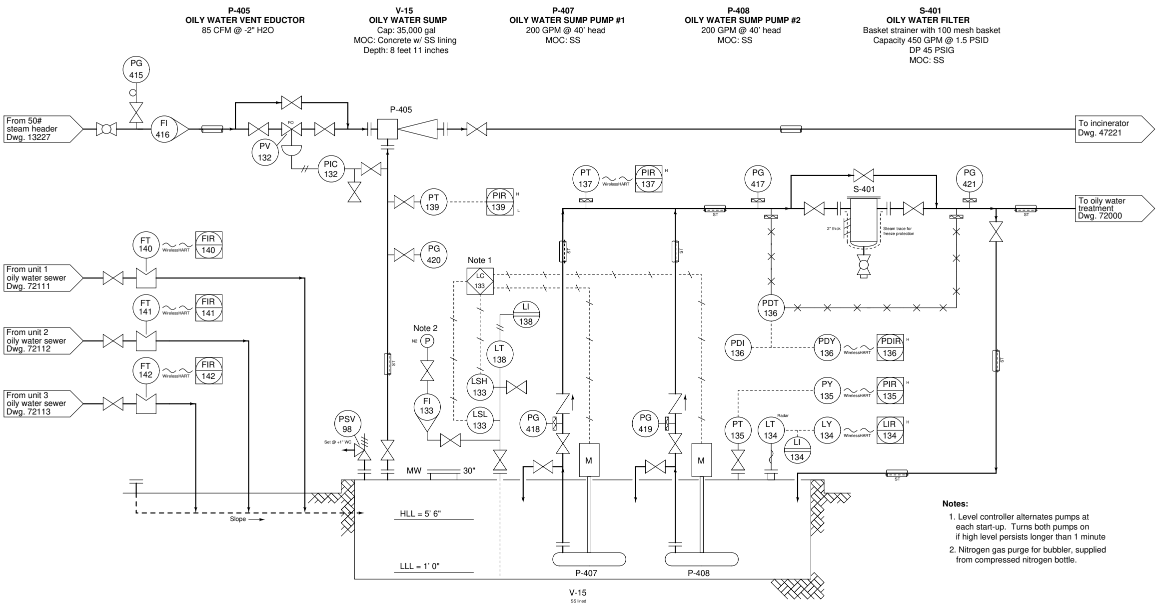
Fault	Possible	Impossible
2-inch line plugged at bottom of separator vessel		
LT-92 failed with high output signal		
Air supply to solenoid valve shut off		
Solenoid vent line plugged		
PSV-11 stuck open		
LSHH-231 failed with high output signal		

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 i03475

Oppgave 58

An operator reports a problem with the oily water filter instrumentation in this process: PDIR-136 indicates a differential pressure of 1.8 PSID, while PG-417 reads 12.5 PSI and PG-421 reads 11.3 PSI. Your first test is to check the indication of PIR-137, and you see that it reads 12.6 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
Upstream filter block valve partially shut		
Downstream filter block valve partially shut		
PDT-136 calibration error		
PT-137 calibration error		
PG-417 calibration error		
PG-421 calibration error		
Filter drain valve to sump left open		

Explain why the idea to check PIR-137 was a good first diagnostic test.

Suggestions for Socratic discussion

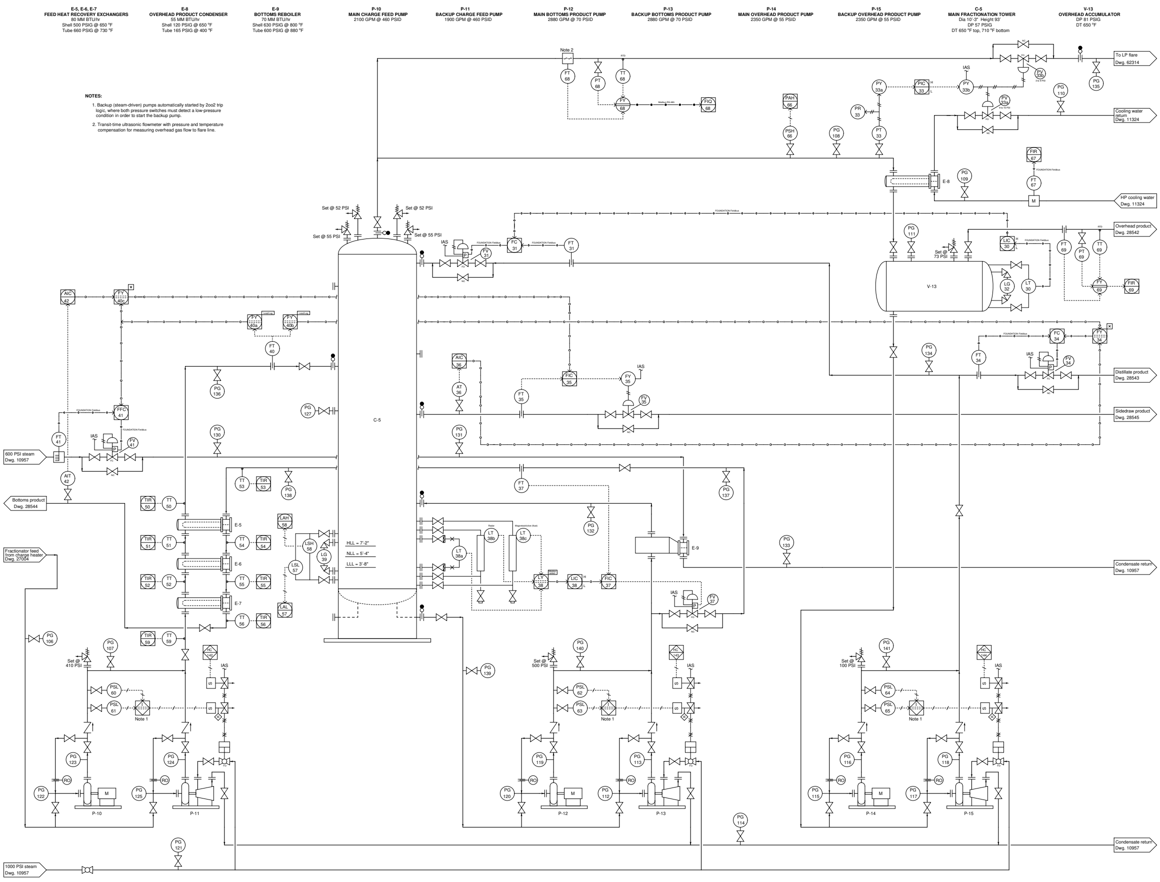
- Identify which fundamental principles of science, technology, and/or math apply to each step of your solution to this problem. In other words, be prepared to explain the reason(s) "why" for every step of your solution, rather than merely describing those steps.
- Identify the next diagnostic step you would take to isolate the problem in this system.

- Identify which port on each differential pressure indicator is the "high" and which is the "low", explaining your rationale.
- Estimate the amount of force applied to the 30-inch diameter manway cover on the sump by the −2 "WC vacuum produced by the eductor.

file i03511

Oppgave 59

An operator claims pressure gauge PG-108 is defective and needs to be replaced. This pressure gauge registers 50 PSI, while pressure controller PIC-33 and pressure recorder PR-33 both register the pressure as being equal to setpoint: 43 PSI. Before replacing this pressure gauge, however, you decide to do some diagnostic thinking to see if there might be other causes for the abnormally high reading at PG-108. The first thing you check is the position of control valve PV-33a, and you find its stem position to be at 35% open.



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
PG-108 calibration error		
PT-33 calibration error		
PIC-33 left in manual mode		
PY-33a calibration error		
PY-33b calibration error		

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.

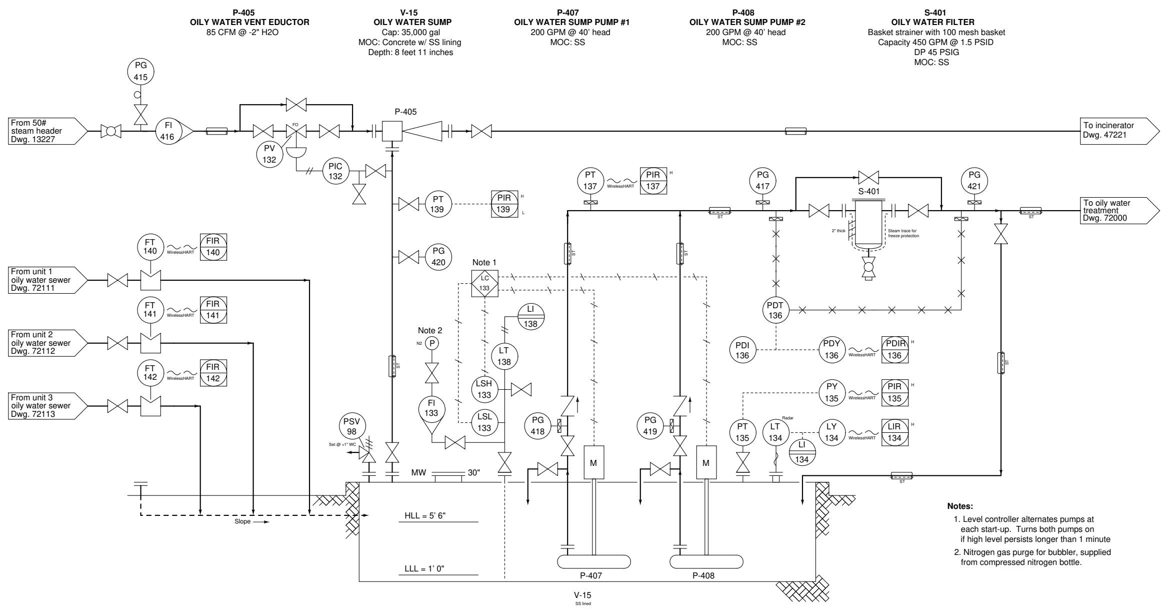
Suggestions for Socratic discussion

- Based on the information you have at this point, can you tell whether any suspected calibration error is due to a mis-adjustment of *zero* or of *span*? Explain why or why not.
- Is controller PIC-33 direct-acting or reverse-acting? How can you tell?
- Does control valve PV-33a throttle gas or liquid? How can you tell?
- Identify a typographical error in this P&ID.
- A useful diagnostic technique for identifying which instrument is miscalibrated is to compare the readings of multiple instruments (all sensing the same process variable) to see which one of them disagrees mostwith the others. May we apply this technique to the problem at hand? If so, which instrument readings should we compare? If not, explain why not.

file i03512

Oppgave 60

Suppose operators submitted a "trouble-call" to your instrument shop, claiming sump V-15 had an excessive liquid level inside of it (as indicated by LIR-134), and that the pump was not pumping that level down as it should:



Identify at least three possible faults, each one independently capable of accounting for the high sump level indication. Also, identify any diagnostic tests you could perform on this system to pinpoint the nature and location of the fault.

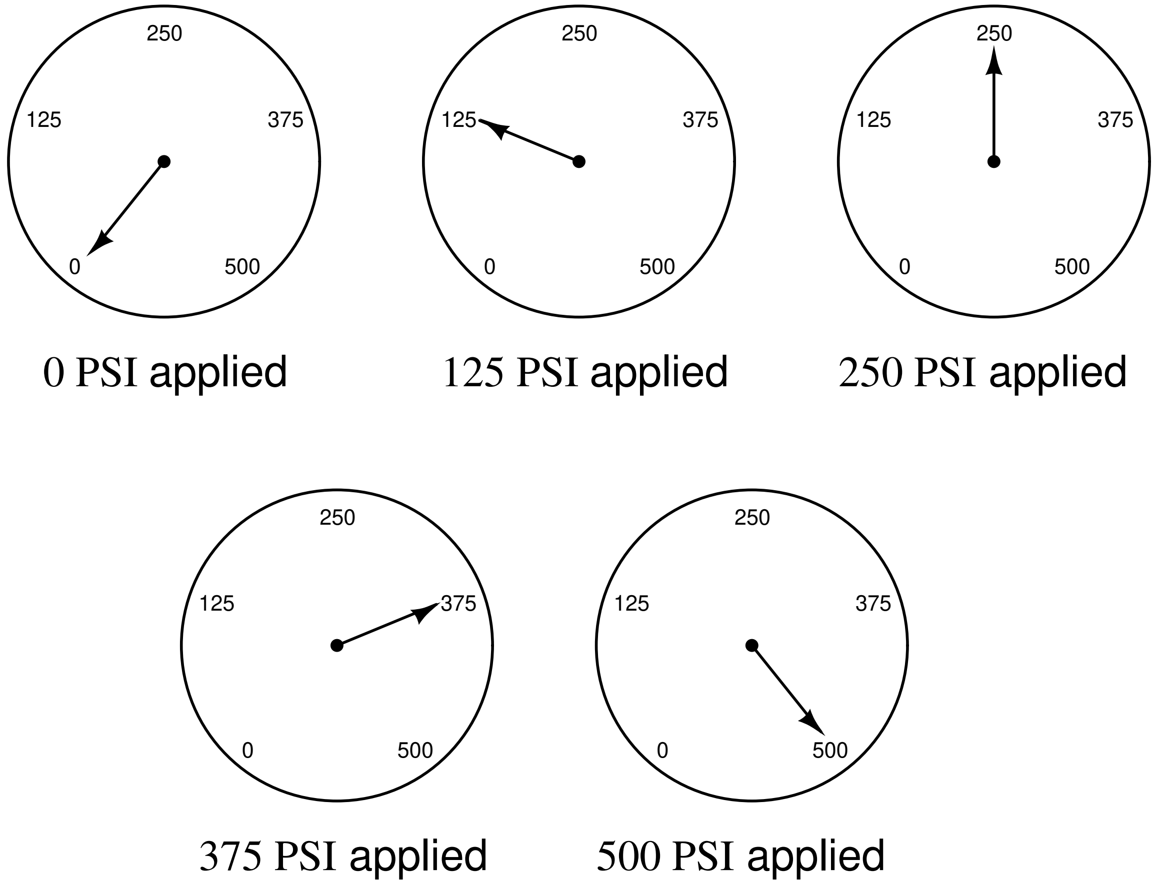
Suggestions for Socratic discussion

- Suppose this trouble-call came to you during a very cold winter day, when the outside temperature was well below freezing. How might this alter the list of potential faults?
- Explain the purpose for having *check valves* on the discharge lines of the two submersible sump pumps.
- Identify some of the different pressure-measurement accessory devices visible in this P&ID.

file i03513

Oppgave 61

A pressure gauge is supposed to accurately indicate applied pressure over its full calibrated range. In this example, a gauge with a range of 0 to 500 PSI is subjected to five different pressures along that range, and its response is accurate at all those points:



Describe, by drawing a set of five meter readings such as the set shown above, how a pressure gauge accurate at 0% and 100% of applied pressure – but with a *nonlinearity* problem between the LRV and URV points – might respond to the same five applied pressures.

Furthermore, describe how a bourdon tube pressure gauge instrument might be adjusted for linearity. In other words, how may a nonlinear pressure gauge be calibrated to become more linear?

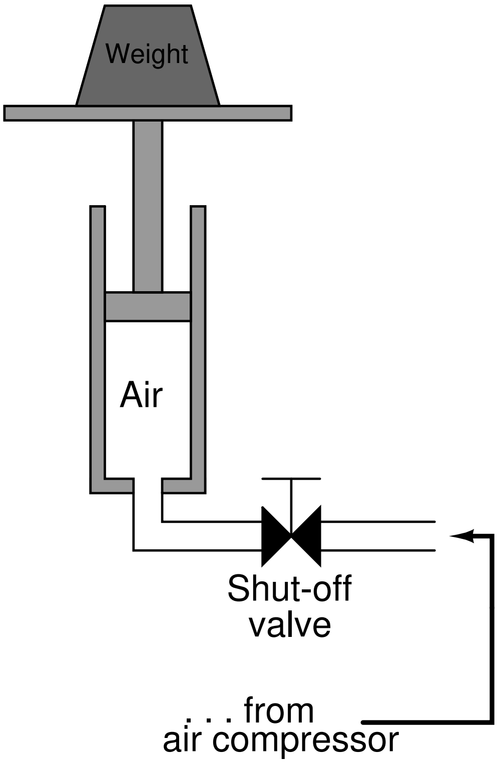
Suggestions for Socratic discussion

- Explain how keeping both "As-Found" and "As-Left" calibration records on instruments such as this pressure gauge make it possible to track long-term calibration drift.
- Can a non-linearity error be corrected by adjusting the zero and/or span screws on an instrument? Why or why not?

file i00174

Oppgave 62

Two pressure-actuated "lifts" are used to raise a heavy weight off the ground. One lift uses oil under pressure (from a hydraulic pump) while the other lift uses air under pressure (from an air compressor). Each lift is equipped with a shut-off valve on the line feeding fluid to the cylinder, so that the piston's motion may be halted:



What will happen if the weight were to fall off the lift platform after it had been raised up from ground level, in each case? Assume that the shut-off valve is closed (no fluid flow from pump or compressor into the cylinder) when this happens.

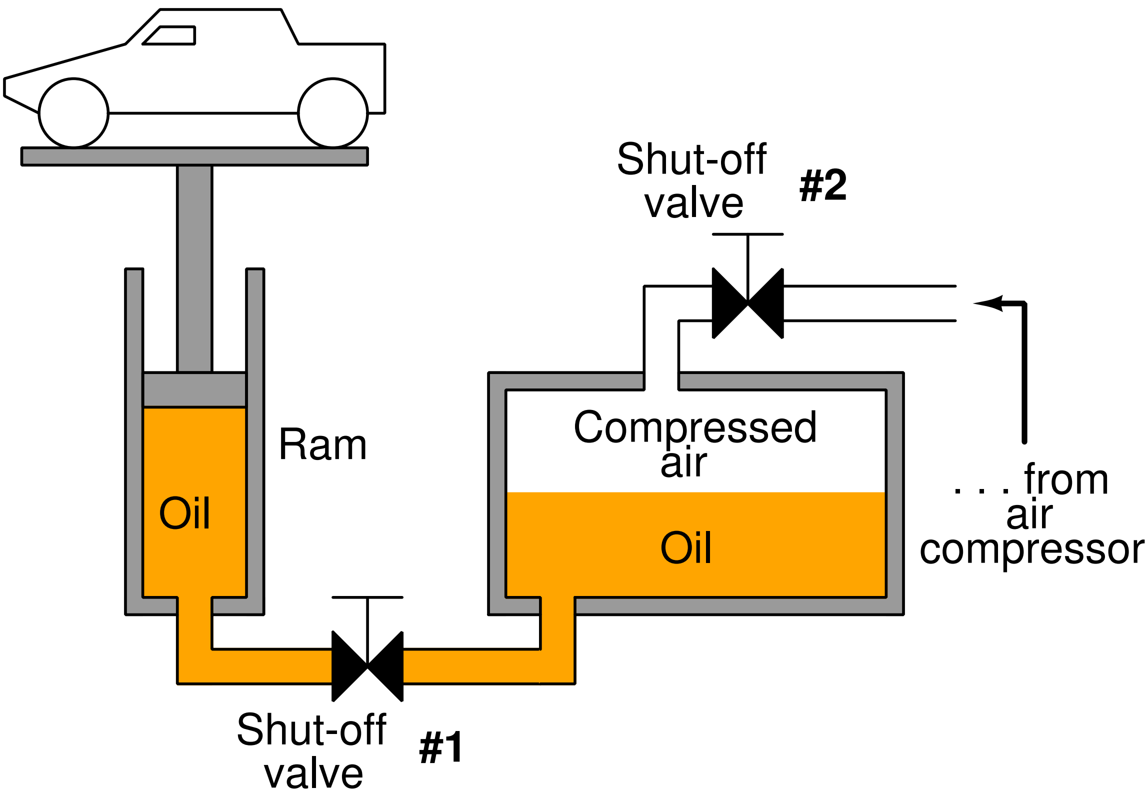
Suggestions for Socratic discussion

- What general lessons may we draw from this example regarding pressurized fluid safety?
- Does the calculation of piston force based on pressure ($F = PA$) change at all if the fluid in question is a *gas* rather than a *liquid*?

file i00750

Oppgave 63

Automobile lifts used in repair shops are often powered by an "oil under air" pressure system. Compressed air from the shop's compressor (used to power hand tools, pump up flat tires, clean parts, etc.) is readily available, and may be used as a source of pressure for a piston-and-cylinder lift machine. Using compressed air means that there need not be a separate hydraulic pump to impart pressure to the oil used in the cylinder:



Which shut-off valve would be the safer one to close for halting the platform's upward motion when lifting an automobile off the ground? Why?

If you were tasked with performing maintenance on this lift, how would you apply industry-standard "lock-out, tag-out" procedures to ensure a condition of *zero energy*? Where would you apply locks and tags, and in what positions should these safety devices be placed in before the locks and tags are set?

Suggestions for Socratic discussion

- Piston seals leak, and can even fail catastrophically. Describe the effect(s) of such a piston seal failure in this automotive lift, and also identify ways to make the system safe for the mechanic in the event of such a failure.
- Identify where any additional valves may be placed in this system in order to more easily facilitate locking it out in a zero energy condition.
- Is the size of the air/oil reservoir a factor in determining the lift's maximum weight capacity? Why or why not?
- Is the size of the ram's piston a factor in determining the lift's maximum weight capacity? Why or why not?

- Is the diameter of the air and/or oil piping a factor in determining the lift's maximum weight capacity? Why or why not?
- In a system where multiple devices need to be locked out for safety prior to maintenance, it is commonplace to use a *lock box* holding locks and keys for all these devices, then have maintenance people each place their own personal lock on the lid of this box so it cannot be opened. Explain how such a "lock-box" system works to keep everyone safe.

file i00751

Svar 1

Absolute pressure is the measurement of a pressure as compared to a pure vacuum. Atmospheric ("barometric") pressure, like the pressure figures reported by meteorologists, is an example of absolute pressure measurement.

Gauge pressure is the measurement of a pressure as compared to the pressure of Earth's atmosphere. The pressure indicated by a pressure gauge (like an oil pressure gauge for a car engine, or a tire pressure gauge) is an example of gauge pressure. When vented, such a gauge will register zero, even though there is still absolute pressure all around us due to Earth's atmosphere.

Differential pressure is the measurement of a difference between two different pressures. In essence, all pressure measurements are differential in nature: notice how *absolute* and *gauge* pressures are defined in terms of a comparison of one pressure against another!

Suffixes are sometimes appended to pressure units to distinguish between absolute (A), gauge (G), and differential (D) pressures. For example, you might see an absolute pressure represented as "150 PSIA", a gauge pressure as "35 PSIG", or a differential pressure as "86.5 PSID". If no such suffix is given, the pressure unit is assumed to be *gauge*.

Some units of pressure measurement are *always* absolute, never gauge or differential. These units include the *atmosphere* (14.7 PSIA), the *bar* (very close to 1 atmosphere – think of it as a "metric" atmosphere), and the *torr*, which is absolute millimeters of mercury column.

Svar 2

Absolute pressure = 2,014.7 PSIA. Gauge pressure = 2,000 PSIG. Differential pressure (between tank and water) = 1,978 PSID.

Gauge pressure is simple: it is the figure initially measured by the pressure gauge (2,000 PSIG). Again, we are assuming that the diver has not significantly decreased the tank's air pressure by consuming air from it as he or she descended to the specified depth. In reality, the pressure in the tank would have decreased a bit in supplying the diver with air to breathe during the descent time.

Absolute pressure is simply gauge pressure added to the pressure of Earth's atmosphere. Since the gauge pressure measured at the water's surface was (obviously) at sea level, and atmospheric pressure at sea level is approximately 14.7 PSIG, absolute air pressure inside the tank is 2,000 PSI + 14.7 PSI = 2,014.7 PSIG.

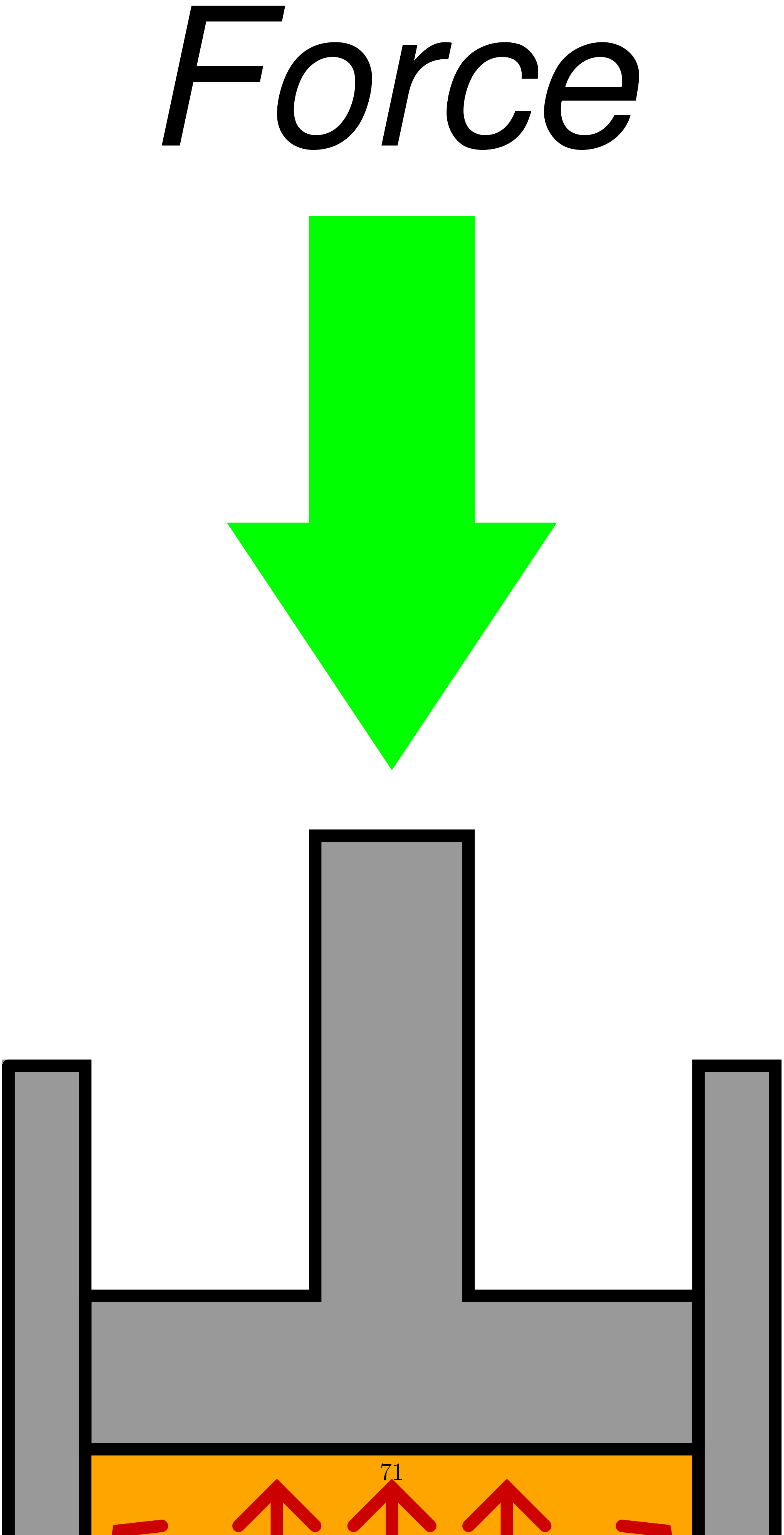
Differential pressure is simply the difference (subtraction) between the tank's gauge pressure of 2,000 PSI and the water's hydrostatic pressure (gauge) of 22 PSI. This is equal to 1,978 PSID. The same differential figure will be found even if atmospheric pressure is taken into consideration: the tank's absolute air pressure is 2,014.7 PSIA and the water's hydrostatic pressure is 36.7 PSIA (22 PSI + 14.7 PSI), resulting in a difference that is still 1,978 PSID. The key here in figuring differential pressure is to always keep pressure units the same: don't mix gauge and absolute pressures!

Svar 3

$P = 68670\text{Pa} = 0.6867$ Bar

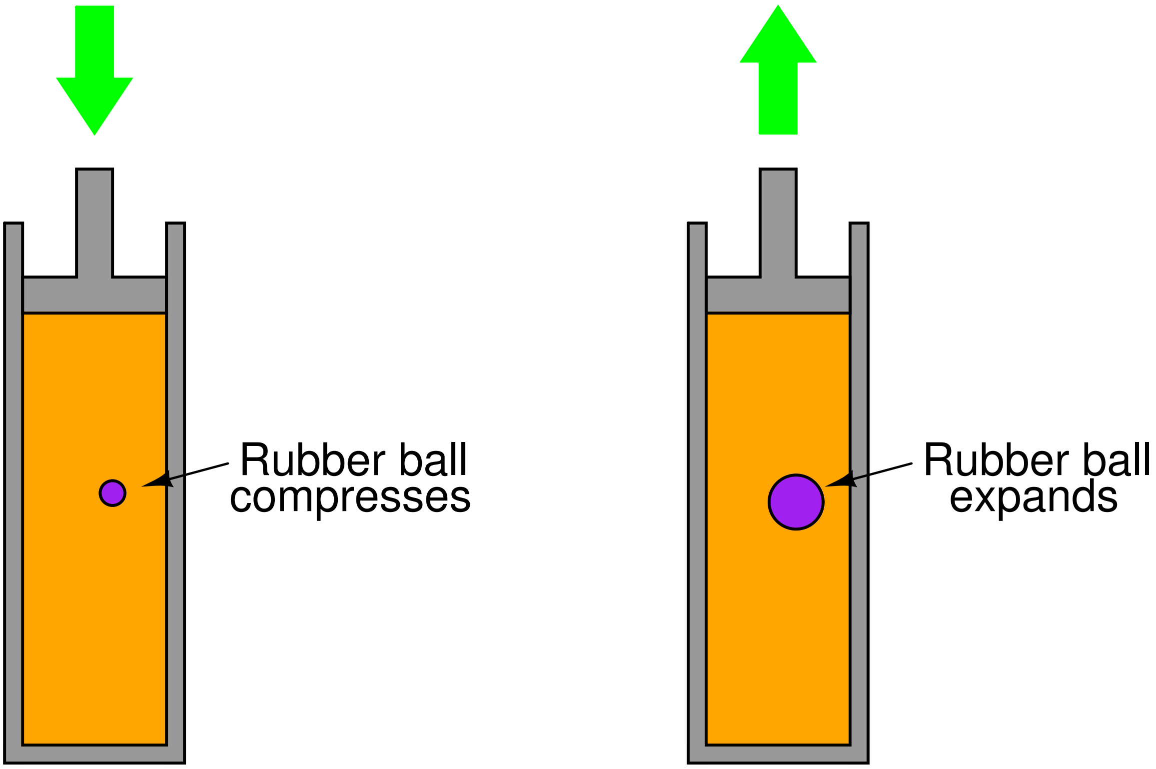
Svar 4

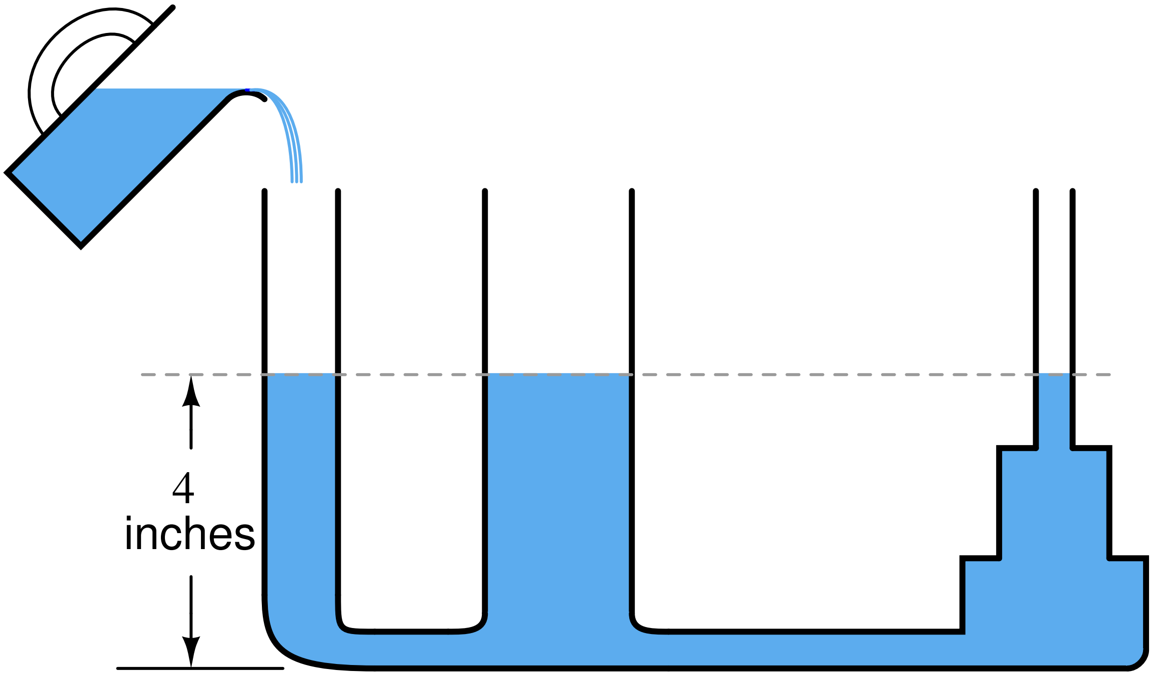
The fluid pressure will exert an outward force on the cylinder walls, like this:

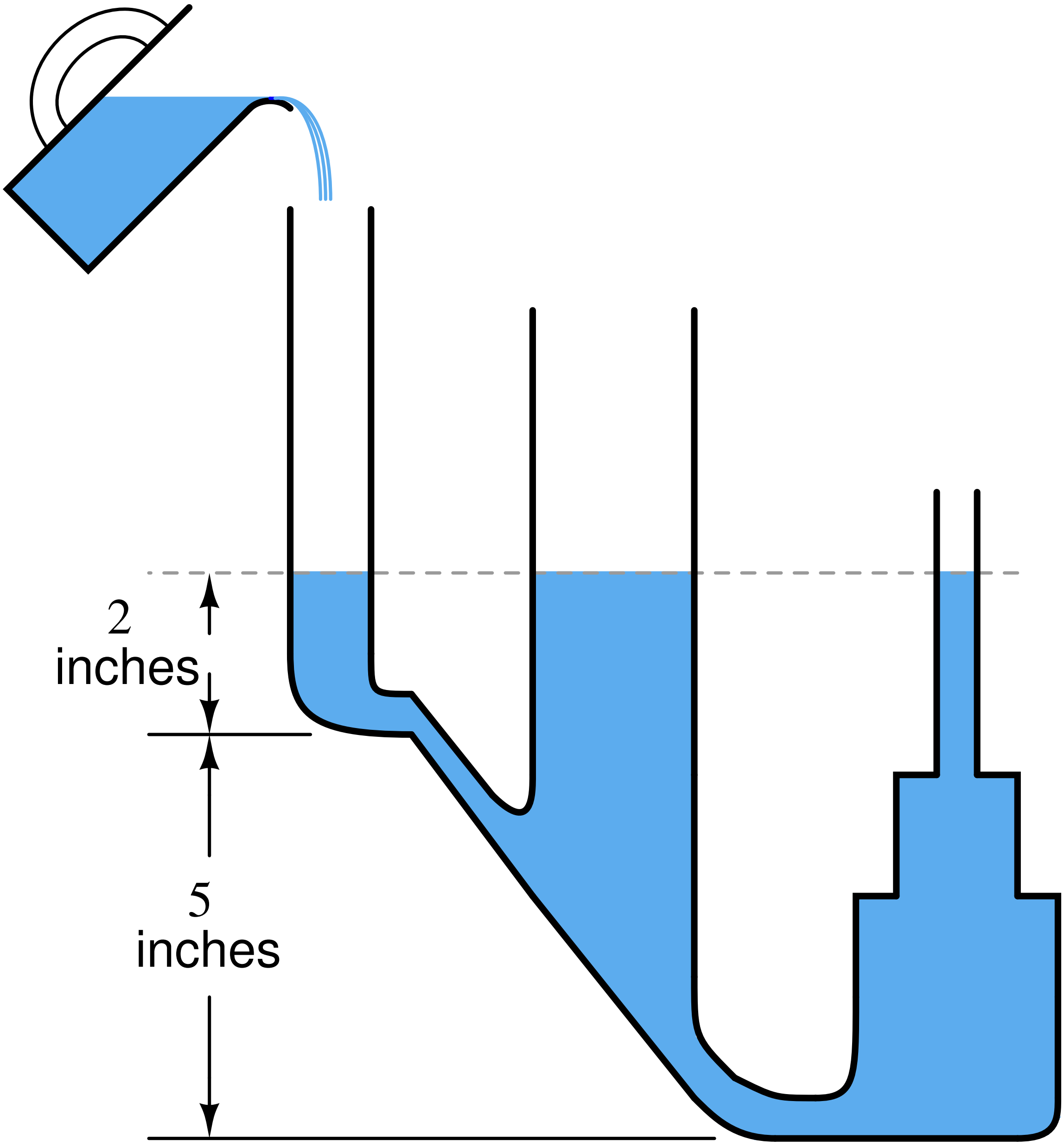

Force

Svar 5

A pushing force on the rod will compress the rubber ball to a smaller diameter. A pulling force will expand it to a larger diameter.




4
inches



Svar 7

Partial answer:

What matters here is the *vertical* height of the water column, not the angled length. Essentially, this is nothing more than a problem in trigonometry: to find the length of the side opposite the 40^o angle, given a hypotenuse of 10 feet (120 inches).
$= \Delta P = 17952 Pa$

Svar 8

$P = 97182 Pa$

Svar 9

Weight of water = <u>117,674</u> lbs

Area of circular pool bottom = 45,239 in^2

Pressure at bottom of pool = P = 2.601 lb/in^2 (PSI) = 72 inches of water column (" W.C.)

Svar 10

P = **<u>30.11</u>** kPa

Svar 11

Glycerine height = **<u>12.14</u>** meter

Castor oil height = **<u>15.91</u>** meter

Svar 12

With no nozzle on the end of the hose, the end may be raised a maximum of 184.54 feet. With a nozzle in place, the hose end may be raised only 115.33 feet.

Essentially, this is just another pressure unit conversion problem: in this case, PSI-to-feet of water column. 80 PSI is equivalent to 184.54 feet, so that is how high 80 PSI can force a column of water.
With a nozzle attached to the end of the hose, though, we are only allowed to "drop" 50 feet of hydrostatic pressure, in order to leave 30 PSI remaining at the nozzle coupling for proper operation. 50 PSI is equivalent to 115.33 feet, so this is how high we may raise the hose end with a nozzle on it.
It must be understood that the first calculation is not a very practical one. 80 PSI of pressure at the hydrant will *just* push water 184.54 feet high. If the hose were 190 feet and poised vertically, there would be a column of water inside 184.54 feet tall, with no water at all coming out the end. If the hose end were brought exactly to a height of 184.54 feet, water would be right at the lip of the hose, not even trickling out. Obviously, some pressure is needed at the hose end in order to push water out onto a fire, so the *practical*, no-hose height for 80 PSI will be somewhat lower than 184.54 feet.
The hose-with-nozzle scenario is more realistic, because an actual figure for minimum hose-end pressure is given for us to incorporate into our calculations.

Svar 13

Force at large piston = 100 pounds. I'll let you calculate the fluid pressure on your own, as well as explain the relationship of Pascal's Principle to this system.

Svar 14

The fluid pressure will be 12.575 PSI, and cylinder #1's piston force will be 88.889 pounds.

Piston #1 will travel further than piston #2.

Svar 15

Ideally, the secondary piston's position will have *no effect* on the oil pressure sent to the gauge. Consequently, the gauge indication should not change.

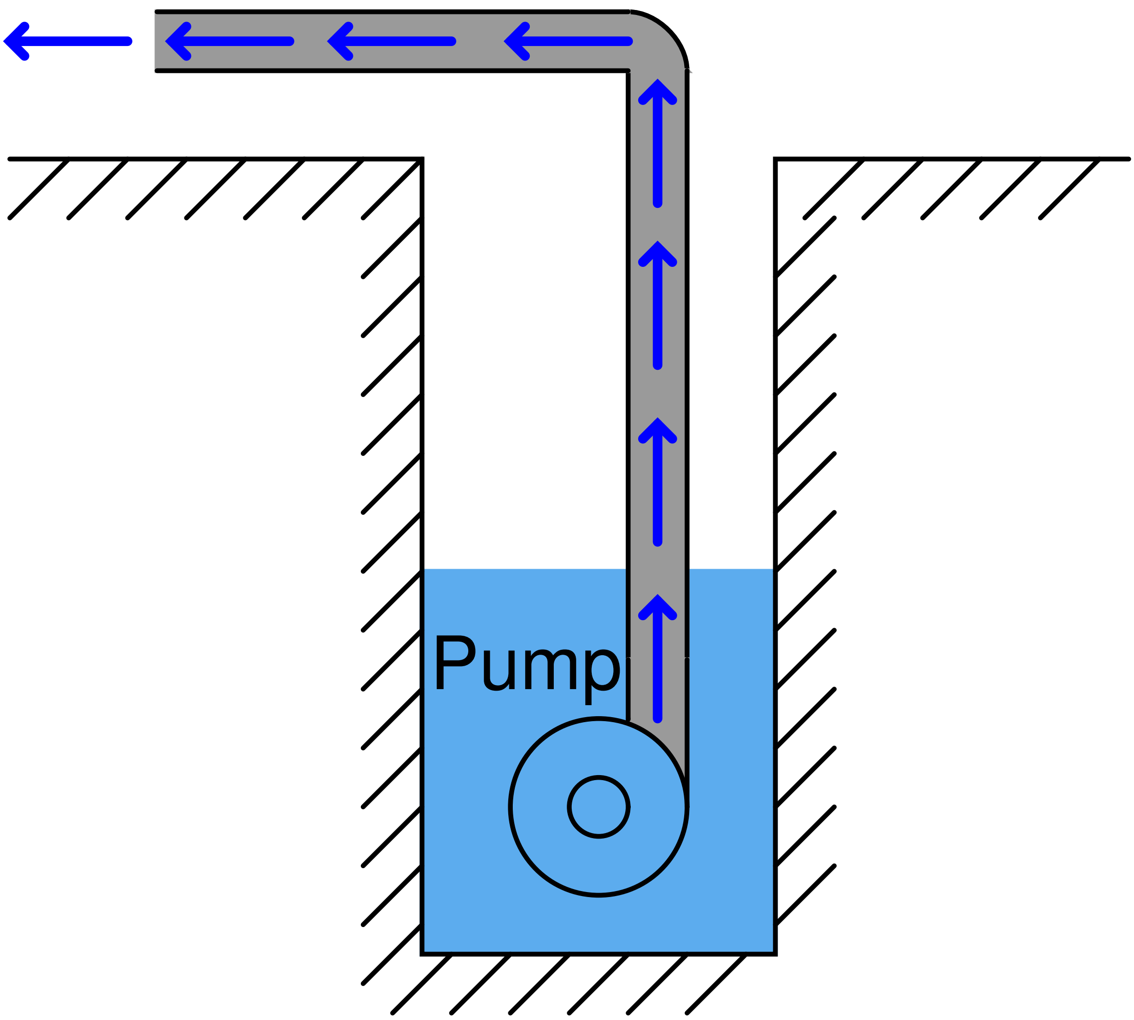
Svar 16

406.9 inches, which is a little bit less than 34 feet. For this amount of "lift height," the pump would have to create a near-perfect vacuum in the inlet pipe. To calculate this figure, convert 14.7 PSIA into inches of water column absolute (14.7 PSIA)(27.68 "W.C. / PSI).

Since this kind of water pump works by creating a vacuum (reducing the inlet pressure to something less than 14.7 PSIA), it is inherently limited in lift height. Since atmospheric pressure is always 14.7 PSIA (on Earth, anyway), this kind of pump simply cannot suck water any higher than this amount of pressure expressed in inches or feet of water.

The average barometric pressure in Denver is 24.63 inches of mercury absolute (12.097 PSIA). This equates to a water-lifting height of 334.9 inches, or 27.9 feet.

Submersible pumps overcome this limit by creating a *positive pressure* rather than a *vacuum*. The pumping action is therefore not limited by the relatively low pressure of Earth's atmosphere, but only by the capacity and design of the pump itself:



Svar 17

Applied pressure = 9 "W.C., which is equal to 0.32514 PSI.

For the same applied pressure, the distance between the two liquid columns will be *greater* than with water. In other words, for a pressure of 9" W.C., there will be *more* than 9 inches of vertical distance separating the two liquid columns.

Essentially, manometers work on the principle of balanced pressures: the applied gas pressure forces the liquid columns to shift height. When they do so, they generate a hydrostatic pressure proportional to their differential height. When this hydrostatic pressure equals the applied pressure, the liquid columns stop moving and a condition of equilibrium is reached.

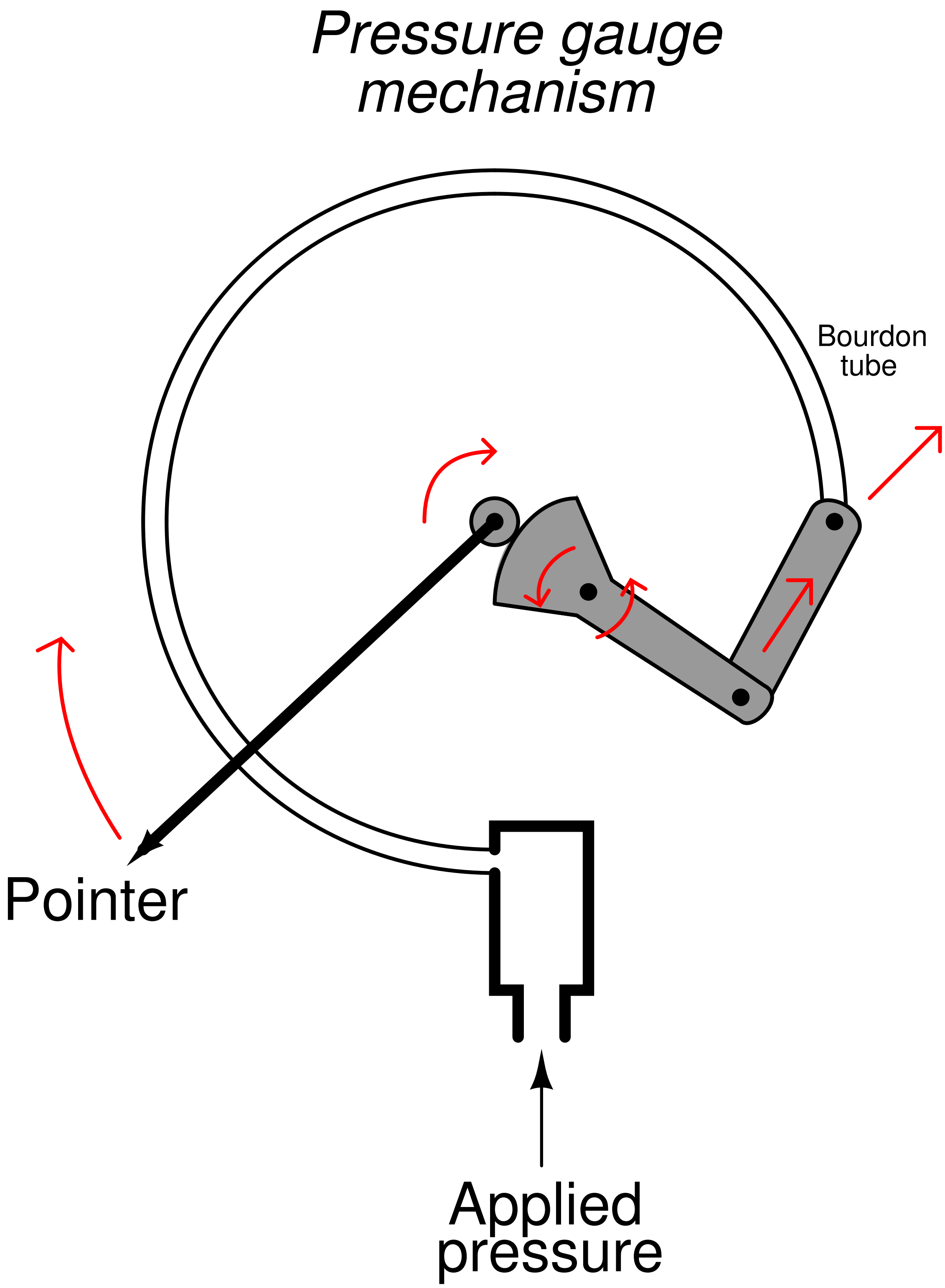
If a lighter fluid such as oil is used instead of water, a greater height will have to be developed to generate the same amount of hydrostatic pressure to oppose the applied gas pressure and reach equilibrium. Conversely, if a heavier (denser) liquid such as mercury were to be used, a much smaller vertical height would develop between the two columns for the same pressure.

Svar 18

- **Step 4:** Quickly open and close valve 4 – manometer indication drops **slightly**
- **Step 6:** Quickly open and close valve 4 – manometer indication **does not drop** at all
- **Step 8:** Quickly open and close valve 3 – manometer indication drops **greatly**

Svar 19

The parts in this gauge mechanism would move as such:



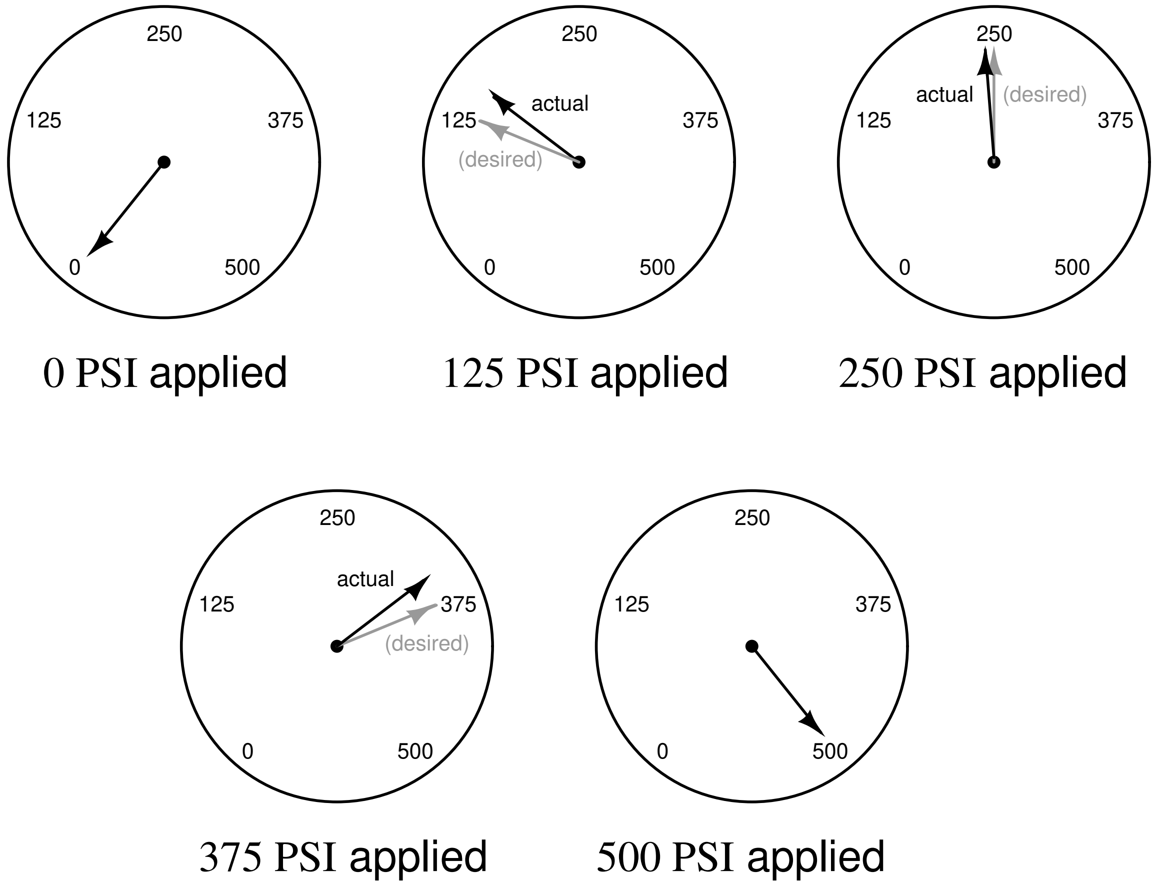
Possible things to change to make this pressure-measuring mechanism more sensitive:

- Decrease the spring rate ("stiffness") of the bourdon tube
- Shorted the arm of the sector gear (the portion to the right of the pivot, joining with the link)

- Increase the sector gear radius
- Decrease the pinion gear radius

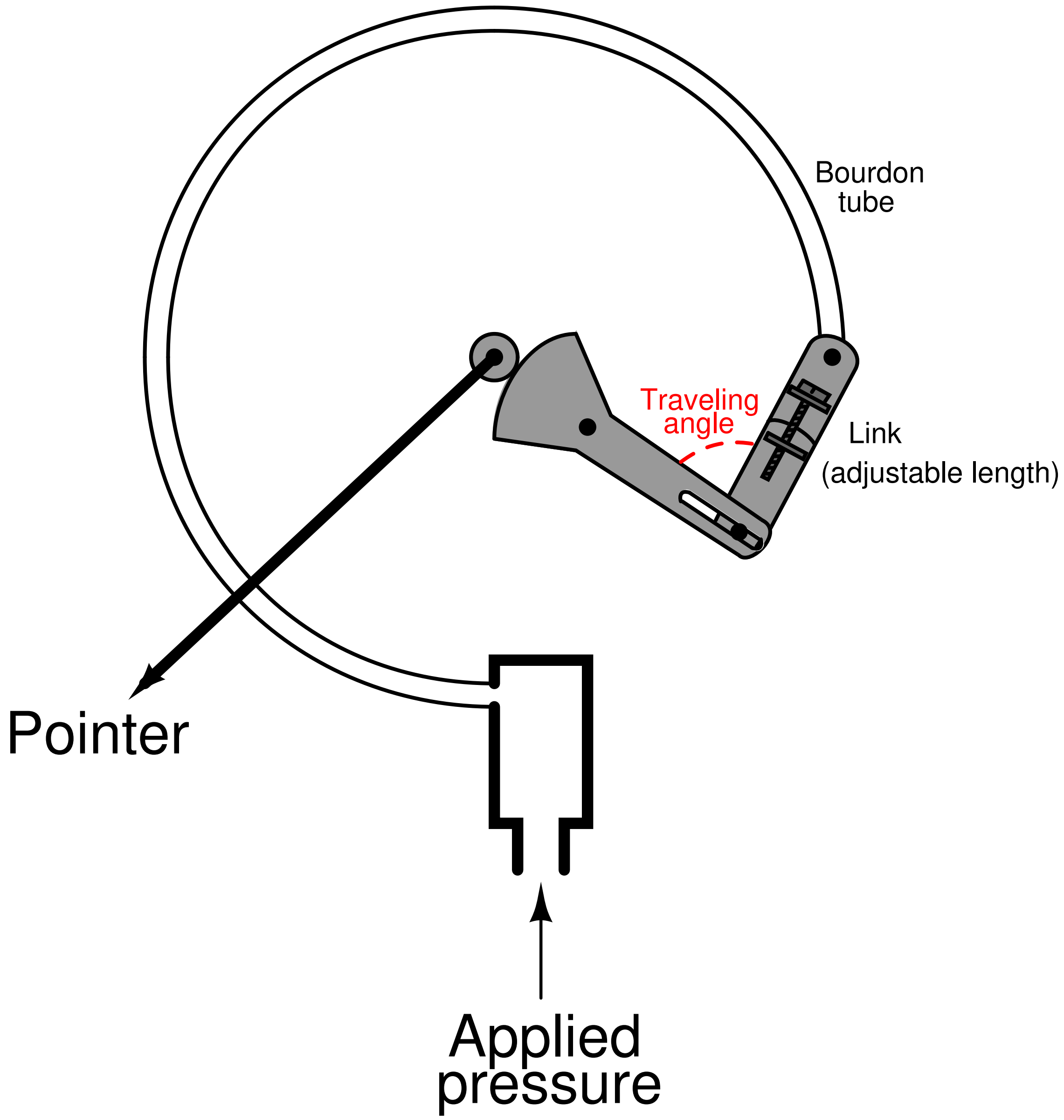
Svar 20

Here is one example of how a pressure gauge might respond in a non-linear fashion to the same five applied pressures, while still being accurate at the LRV and URV points:



Here, the gauge reads high at the 25% point (125 PSI), slightly low at the 50% point (250 PSI), and low at the 75% point (375 PSI), while still accurate at 0% (0 PSI) and 100% (500 PSI).

Any adjustment that affects the *traveling angle* of the mechanism will have an effect on linearity. Some (high-quality) pressure gauge mechanisms are equipped with an adjustable-length link to facilitate changes to this angle:



It is sage advice to *leave all angle adjustment(s) untouched* until all possible zero and span adjustments have been made to the instrument. Usually, it is possible to get a nonlinear instrument to read within specified tolerance in a 5-point calibration just by adjusting the zero and span adjustments.

In many mechanical instruments, a simple linearity alignment is to apply a 50% input signal and check for link/lever perpendicularity (that all links and levers intersect at 90^o angles to each other).

Svar 21

This is a graded question – no answers or hints given!

Svar 22

Input pressure applied (PSI)	Percent of span (%)	Output signal *ideal* (PSI)	Output signal *low* (PSI)	Output signal *high* (PSI)
0	0	3	2.94	3.06
50	25	6	5.94	6.06
100	50	9	8.94	9.06
150	75	12	11.94	12.06
200	100	15	14.94	15.06

Given the tolerance of ± 0.5% of the 200" span (± 1"), the actual process pressure could be as low as 152 "W.C. or as high as 154 "W.C.

Svar 23

Input pressure applied (" W.C.)	Percent of span (%)	Output signal *ideal* (mA)	Output signal *low* (mA)	Output signal *high* (mA)
50 L	0	4	3.984	4.016
37.5 H	25	8	7.984	8.016
125 H	50	12	11.984	12.016
212.5 H	75	16	15.984	16.016
350 H	100	20	19.984	20.016

Given the tolerance of ± 0.1% of the 350" span (± 0.35"), the actual process pressure could be as low as 209.65 "W.C. or as high as 210.35 "W.C.

Svar 24

This is a graded question – no answers or hints given!

Svar 25

Partial answer:

Input pressure (" W.C.)	Output current (mA)
0	
45	12.76
75	
90	
110	17.70
150	20

Svar 26

Svar 27

Svar 28

This is a graded question – no answers or hints given!

Svar 29

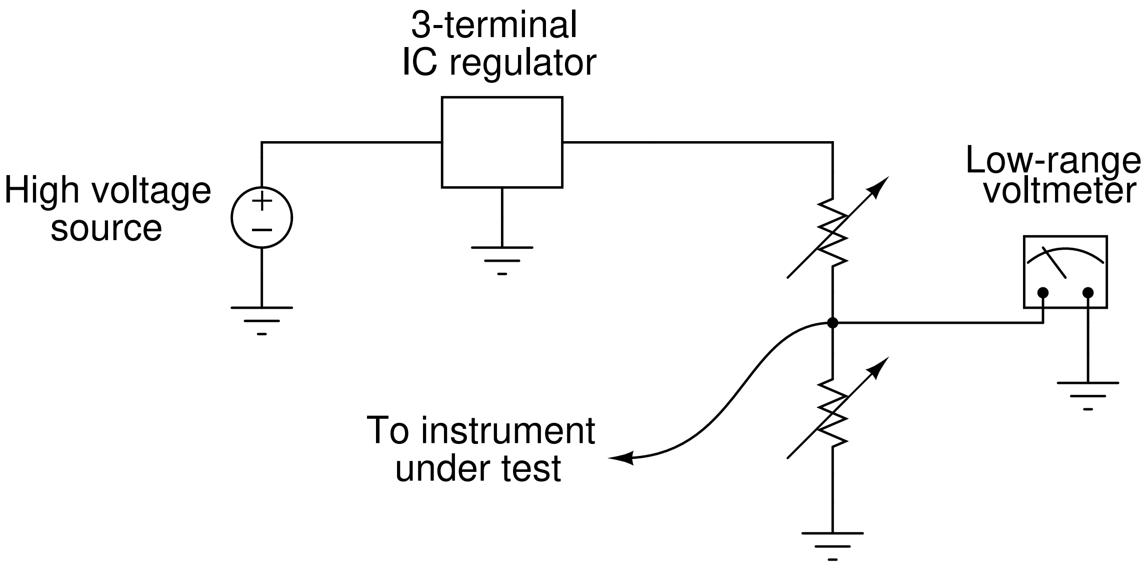
Actuating the hand pump introduces more air molecules to the system (n). Assuming temperature (T) remains constant, the air pressure (P) will increase in inverse proportion to the volume (V) of the pressure vessel for each additional stroke of the pump.

Follow-up question: If we wished the pressure to increase *less* for every stroke of the pump, would we want a smaller pressure vessel or a larger pressure vessel? Explain your answer.

Challenge question: suppose a technician follows these steps in using this system.

- Close valve 2, open valves 1 and 3
- Pump several strokes' worth of air into the pressure vessel
- Close valves 1 and 3
- *Slowly* open valve 2 until manometer registers desired pressure, then close

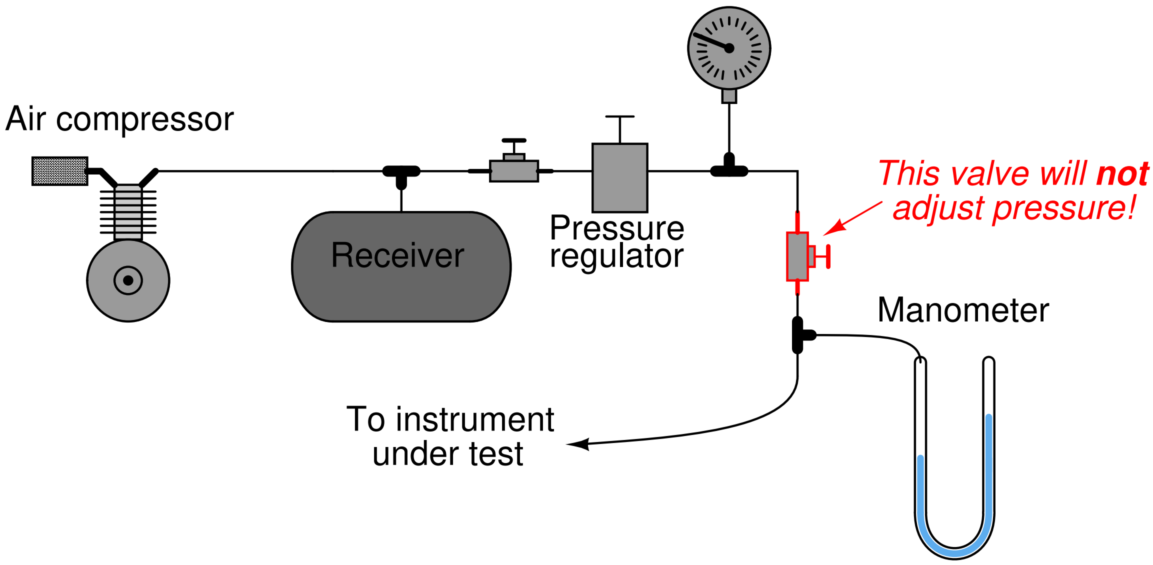
Is the air pressure going to the instrument under test greater than, less than, or equal to the air pressure in the vessel?



I'll leave the explanation to you!

Follow-up question #1: explain what you could do with one or both of the two needle valves to *increase* the amount of pressure sent to the instrument under test.

Follow-up question #2: explain why placing a valve in "series" with the regulator's output will *not* adjust pressure to the instrument under test or the manometer.



Svar 31

Fault	Possible	Impossible
R_1 failed open		$\surd$
R_1 failed shorted		$\surd$
R_2 failed open		$\surd$
R_2 failed shorted		$\surd$
R_3 failed open	$\surd$	
R_3 failed shorted		$\surd$
Reference filament burned out		$\surd$
Measurement filament burned out		$\surd$

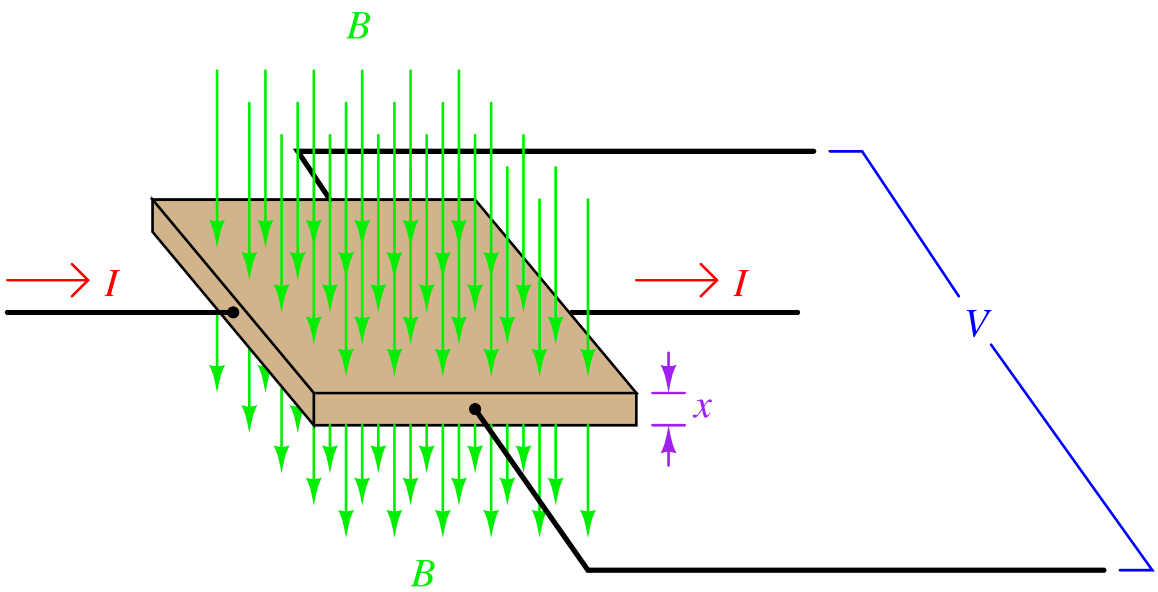
Svar 32

Partial answer:

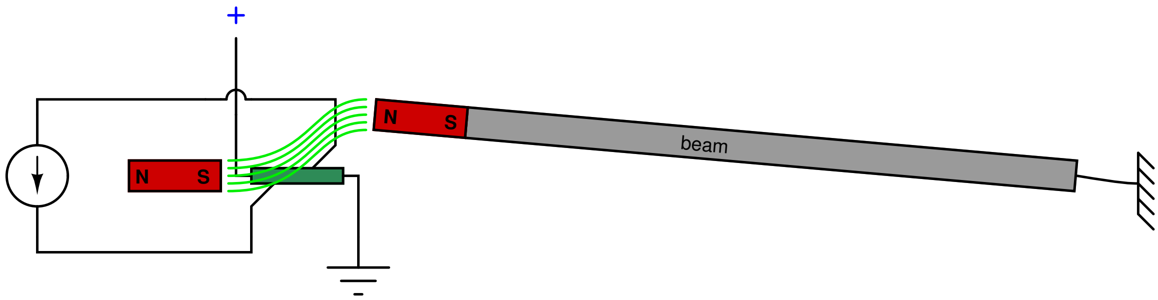
A *flexure* is a thin strip of springy material, usually spring steel, designed to act as a frictionless fulcrum and/or a pivoting link. Unlike bearings, flexures are usually not able to handle a lot of angular motion.

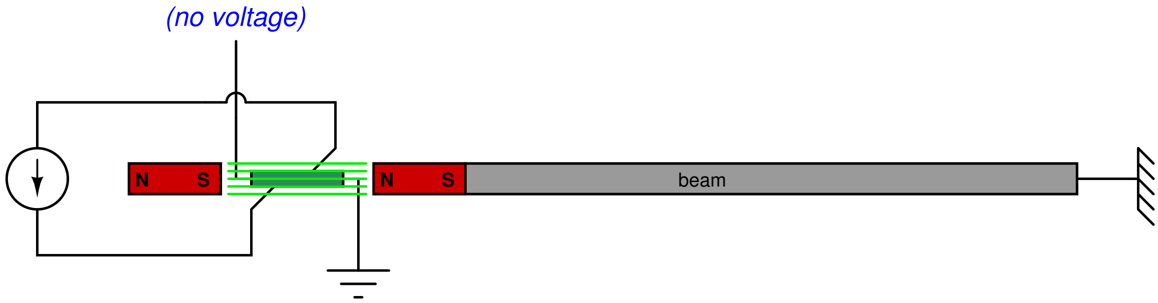
Hall Effect sensors are used to detect magnetic fields. They generate a DC voltage proportional to the magnitude and polarity of an applied magnetic field and the magnitude and direction of a perpendicular DC current:

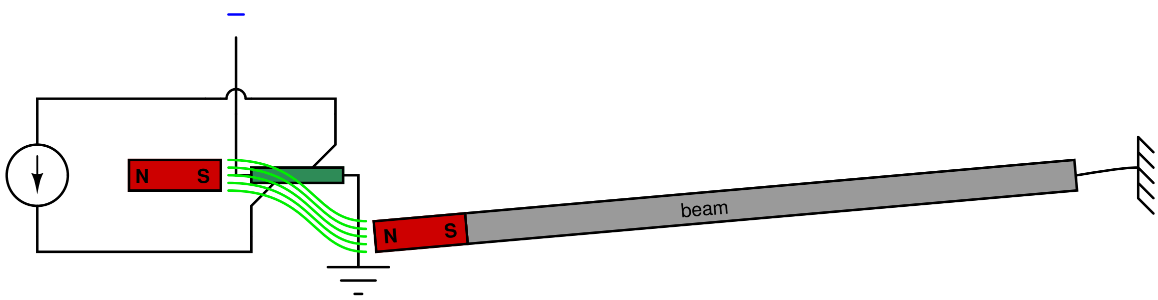
$$V_{Hall} = K\frac{IB}{x}$$



The operation of the Hall Effect sensor may not be clear to all readers. It is oriented such that the magnetic field is parallel to the Hall Voltage axis and not perpendicular to it, when the beam is exactly level. When the beam tips up or down, however, the magnetic flux lines passing from the "North" tip of the beam's magnet to the "South" tip of the stationary magnet to the left of the Hall Effect sensor will angle, passing through the Hall Effect sensor with a definite direction, either up or down, depending on which way the beam tips:







Thus, any output voltage from the Hall Effect sensor indicates an out-of-balance condition between the diaphragm and force motor.

Svar 33

- Which port is the "high" pressure port: **Port "B"**
- What will happen if fixed resistor R_1 fails open: **Voltmeter will drive fully upscale ("peg" positive)**
- Identify a component fault that would drive the voltmeter full upscale ("peg" positive):
-
- Strain gauge #1 fails shorted
-
- Strain gauge #2 fails open
-
- R_1 fails open
-
- R_2 fails shorted

Svar 34

This is a graded question – no answers or hints given!

Svar 35

If the equalizing valve is ever opened, it could shuttle fill fluid from one remote seal to the other, imbalancing the system. This would make the transmitter read less differential pressure than there actually was applied between the remote seals. The problem would be difficult to correct without dismantling the system entirely and re-packing the seals and capillary tubes with fill fluid.

Svar 36

Svar 37

Remote, chemical seals provide a means for pressure transmitters to measure the pressure of extremely corrosive process fluids. The only portions of the instrument in contact with the process fluid are the seal elements themselves: their housings and diaphragms. The capillary tubing connecting the seals to the transmitter contain only clean oil, as does the transmitter itself.

Now you're probably wondering, "What's the point of using a remote diaphragm to contact the process fluid? If the fluid were too corrosive for the transmitter, wouldn't it be too corrosive for the remote seal diaphragm as well? And if a remote seal can be made to withstand the corrosive effects of the fluid, then why not a regular transmitter?"

For one, pressure transmitters (especially the motion-balance kind) are limited in the kinds materials their pressure elements may be constructed of. The pressure element (bellows, diaphragm, bourdon tube) must be made of a material with good elastic properties, and that usually means a fairly narrow range of metals. The seal diaphragms, on the other hand, are designed to be "slack." That is, they are not supposed to provide any spring resistance to motion, but be limp and transfer all the process pressure to the transmitter's sensing element. Because they need not function as spring elements, their elastic properties are not as critical as for the transmitter's sensing element, and this allows a wider range of materials with different corrosion resistances. In some cases, the remote diaphragm may be non-metallic, and thus have corrosion resistance properties very different from that of a metal.

Even if the seal diaphragms are metallic, like the transmitter's sensing element, there is still good reason to use chemical seals in some applications. With a normal pressure transmitter mounted remotely from the process vessel, some kind of tubing will be necessary to transfer fluid pressure to it from the vessel. The range of available materials for instrument tubing is far more limited than the range of materials for seal diaphragms or even transmitter sensing elements. It may be that even the best instrument tubing cannot tolerate the corrosive effects of the process fluid, but a seal diaphragm made of some exotic metal alloy can. Using remote seals and capillary tubes filled with nice, clean oil neatly solves the problem, containing the process fluid within the seals and not allowing it to enter the tubing.

Another, entirely different, reason for using remote seals is in food processing, where no "pockets" are allowed in the fluid system due to the need for regular disinfection and decontamination. Standard ΔP transmitter capsule assemblies and impulse tubing would create cavities for bacteria to collect and grow in nutrient-rich fluid. Remote seals present a flat surface to the process fluid, transmitting the pressure to the fill fluid where bacteria cannot enter.

A similar reason for using remote seals is to avoid plugging. With standard "impulse" tubes connecting a process vessel or pipe to a transmitter, there exists the possibility of sediment or debris plugging the tubes. However, flush-mounted remote seals provide no place for sediment or debris to collect.

Svar 38

Increased temperature causes the fill liquid in the capillary tube to expand, thus creating a pressure at the transmitter's sensing element independent of the process fluid pressure being measured.

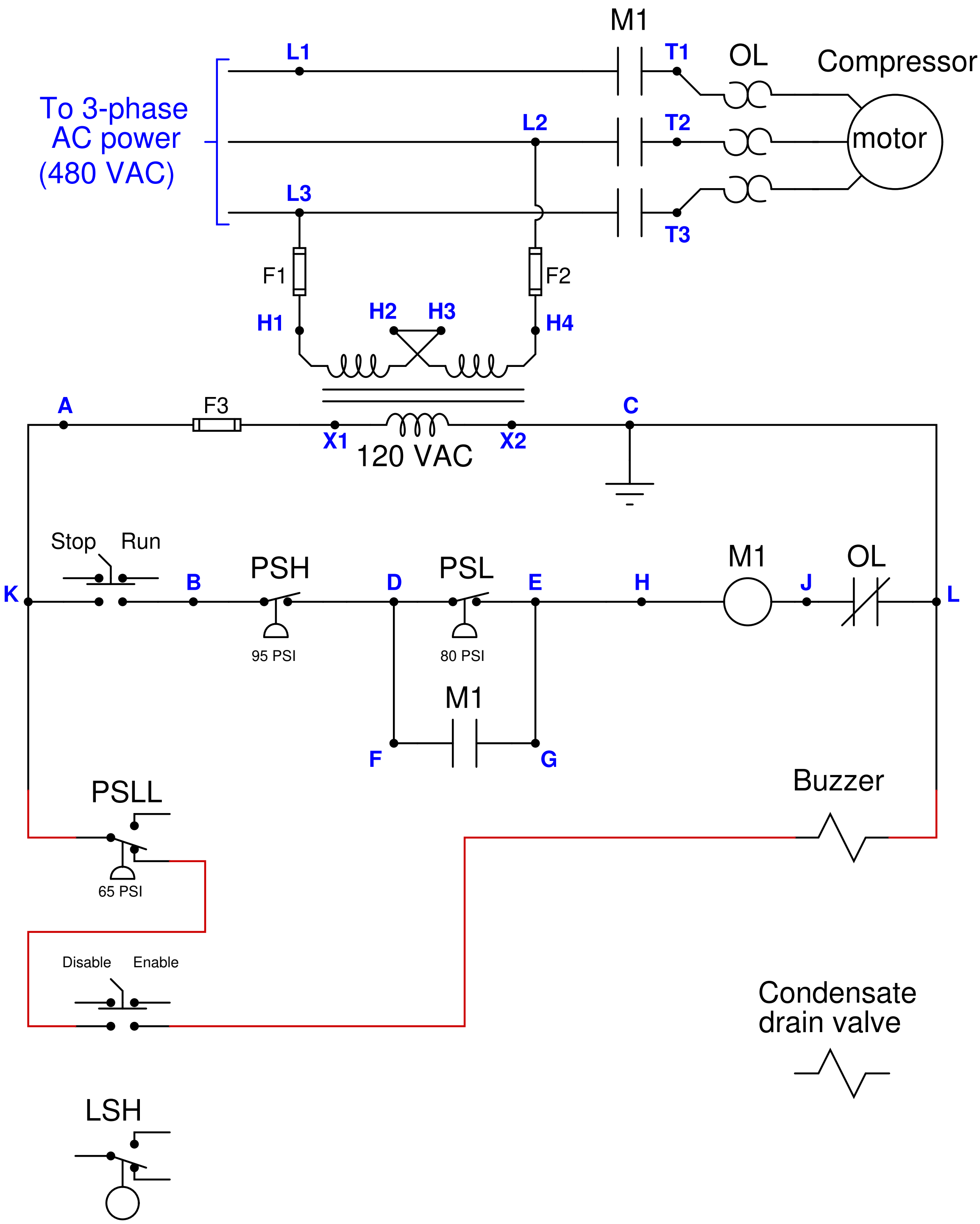
If the seal-equipped transmitter is differential in nature, and the temperatures of both seal units and capillary tubes are equal, then any temperature-induced pressures will cancel out at the transmitter, and there will be no problem. However, if the temperature of one seal or capillary is greater than the other, there will be a *differential* pressure induced by temperature that the transmitter will detect and interpret as process fluid differential pressure.

Remote seal/capillary systems must be completely gas-free (nothing but liquid inside) in order to work. If even a small air or other gas bubble works its way in to the fill fluid between the remote seal diaphragm and the instrument sensing element, the fill fluid will be compressible, meaning that the seal diaphragm will displace a greater volume of fill fluid than the instrument's sensing element. Thus, the instrument may not "see" the entire amount of process pressure change applied to the seal diaphragm, and its measurement accuracy will be compromised.

In summary, leaks in a remote seal system have *very detrimental effects* on instrument accuracy. If ever such a system develops a leak, the whole instrument must be replaced. Even if you could patch the leak, you would have to "pack" the seal unit, capillary tubing, and transmitter pressure housing with new fill liquid under a strong vacuum to "pull" any dissolved gas bubbles out of the liquid. Needless to say, the facilities required for such an operation are typically not available in a plant instrument shop, thus rendering the instrument unrepairable by you.

Svar 39

Partial answer: (this is just one possible solution to the wiring of the pressure switch):



Svar 40

This is a graded question – no answers or hints given!

Svar 41

This is a graded question – no answers or hints given!

Svar 42

As the differential pressure increases ("high" side pressure increases relative to "low" side pressure):

- Diaphragm "capsule" is forced to the right.
- Force bar rotates counter-clockwise about the sealing diaphragm, which acts as a fulcrum for the force bar.
- Flapper approaches nozzle.
- Nozzle backpressure increases.
- Increased nozzle backpressure presses up on relay diaphragm.
- Inside relay, the ball-shaped supply valve opens and the cone-shaped vent valve closes.
- Relay output pressure increases (more than the nozzle backpressure increase, due to amplification).
- This output pressure is sent to the bellows, which presses to the left at the range bar's lower end.
- Range bar rotates clockwise about the "range wheel" (movable fulcrum nut).
- Top of range bar moves to the right, pulling against the force bar to move the flapper away from the nozzle.
- System reaches equilibrium, where force exerted by the bellows against the range bar balances force exerted by diaphragm capsule against the force bar.

End result: output pressure equals some proportion (multiple or fraction) of differential pressure across diaphragm capsule.

Svar 43

Fluke brand multimeters all have a "Min/Max" mode useful for recording measurements over long spans of time. This is an incredibly valuable yet under-utilized diagnostic tool, because it allows the technician to detect certain intermittent conditions by connecting the meter, leaving it alone to record data, then checking later to see whether a particular event occurred in the interim.

Svar 44

Svar 45

Svar 46

This is a graded question – no answers or hints given!

Svar 47

This is a graded question – no answers or hints given!

Svar 48

Svar 49

Svar 50

Fault	Possible	Impossible
2-inch line plugged at bottom of separator vessel	√	
LT-92 failed with high output signal		√
Air supply to solenoid valve shut off	√	
Solenoid vent line plugged		√
PSV-11 stuck open		√
LSHH-231 failed with high output signal		√

Svar 51

Partial answer:

Fault	Possible	Impossible
Upstream filter block valve partially shut		
Downstream filter block valve partially shut		√
PDT-136 calibration error		
PT-137 calibration error		
PG-417 calibration error		√
PG-421 calibration error		
Filter drain valve to sump left open		√

Svar 52

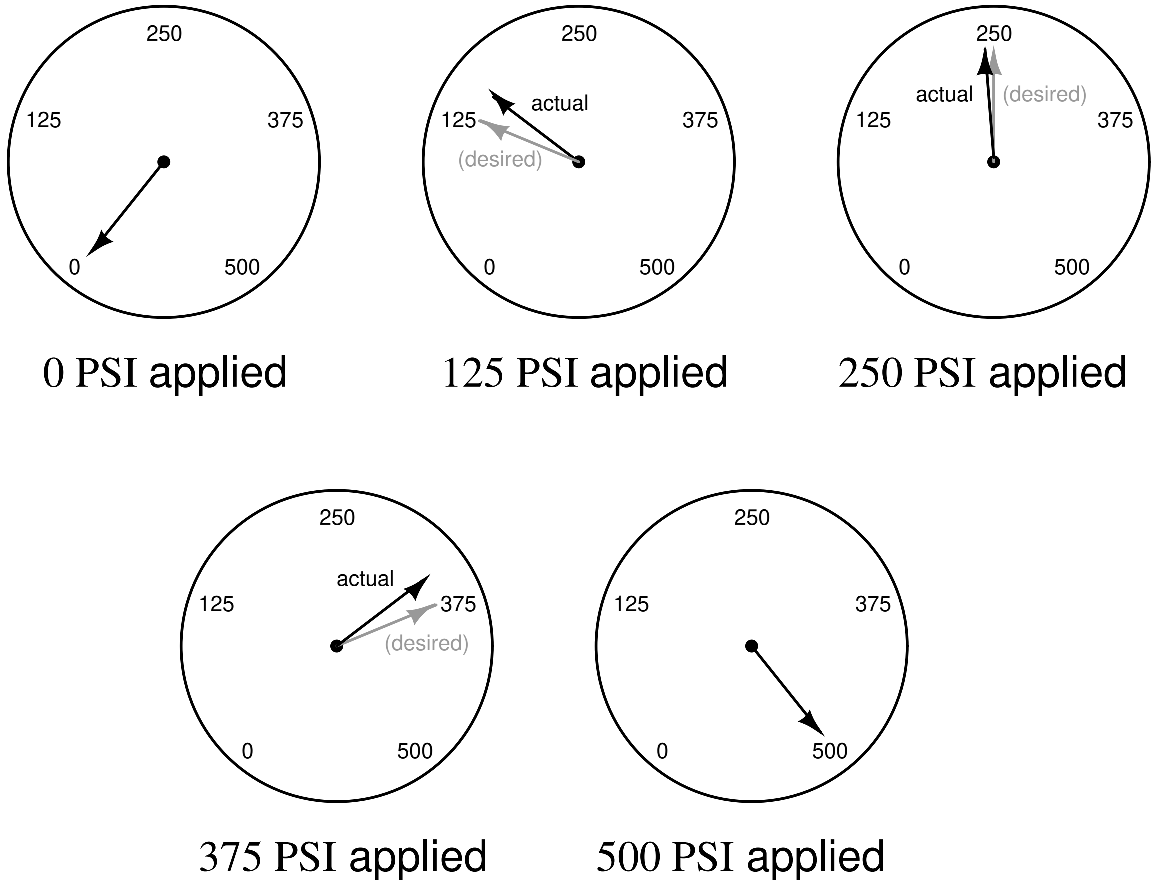
Partial answer:

Fault	Possible	Impossible
PG-108 calibration error		
PT-33 calibration error	√	
PIC-33 left in manual mode		
PY-33a calibration error		
PY-33b calibration error		

Svar 53

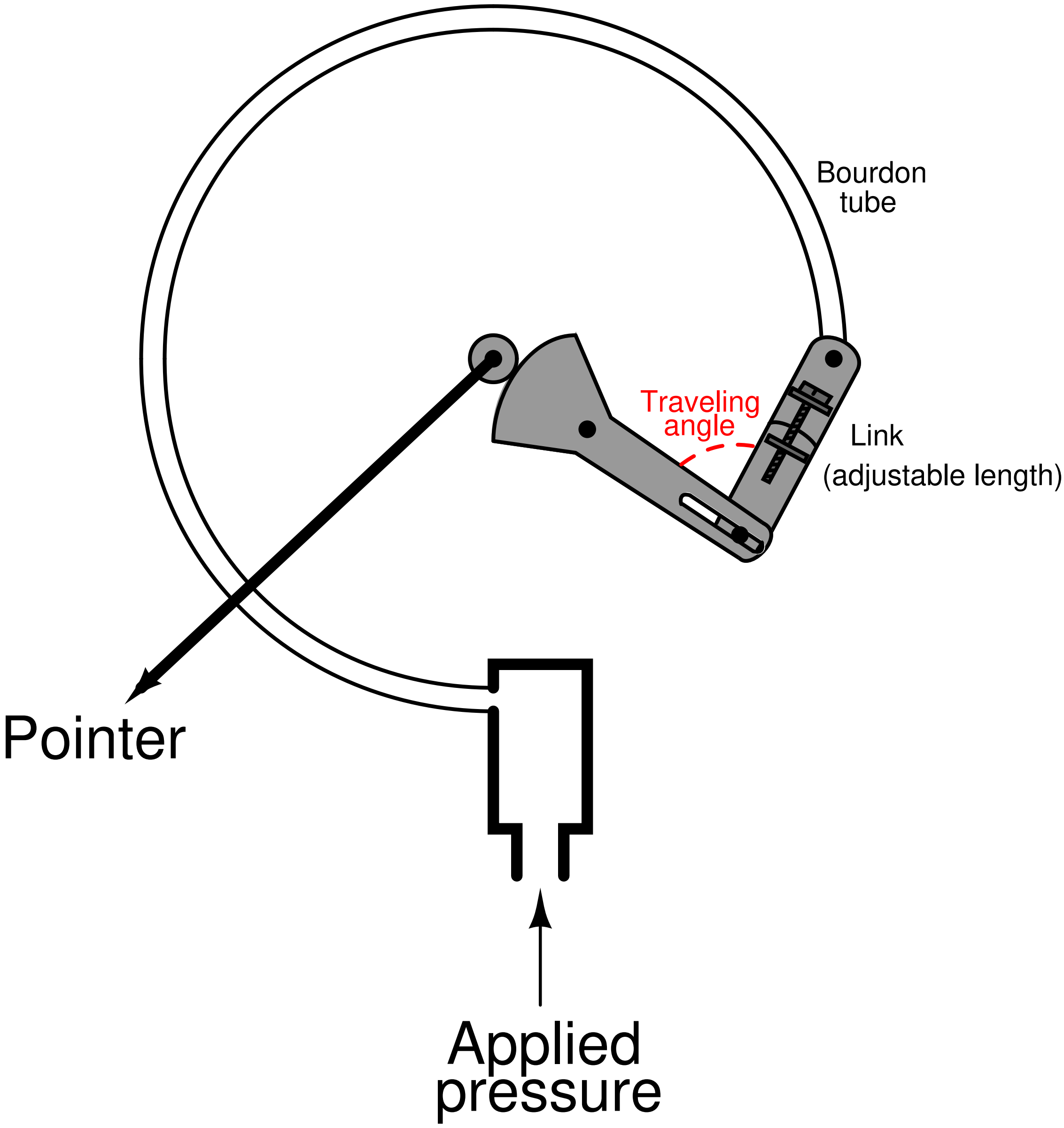
Svar 54

Here is one example of how a pressure gauge might respond in a non-linear fashion to the same five applied pressures, while still being accurate at the LRV and URV points:



Here, the gauge reads high at the 25% point (125 PSI), slightly low at the 50% point (250 PSI), and low at the 75% point (375 PSI), while still accurate at 0% (0 PSI) and 100% (500 PSI).

Any adjustment that affects the *traveling angle* of the mechanism will have an effect on linearity. Some (high-quality) pressure gauge mechanisms are equipped with an adjustable-length link to facilitate changes to this angle:

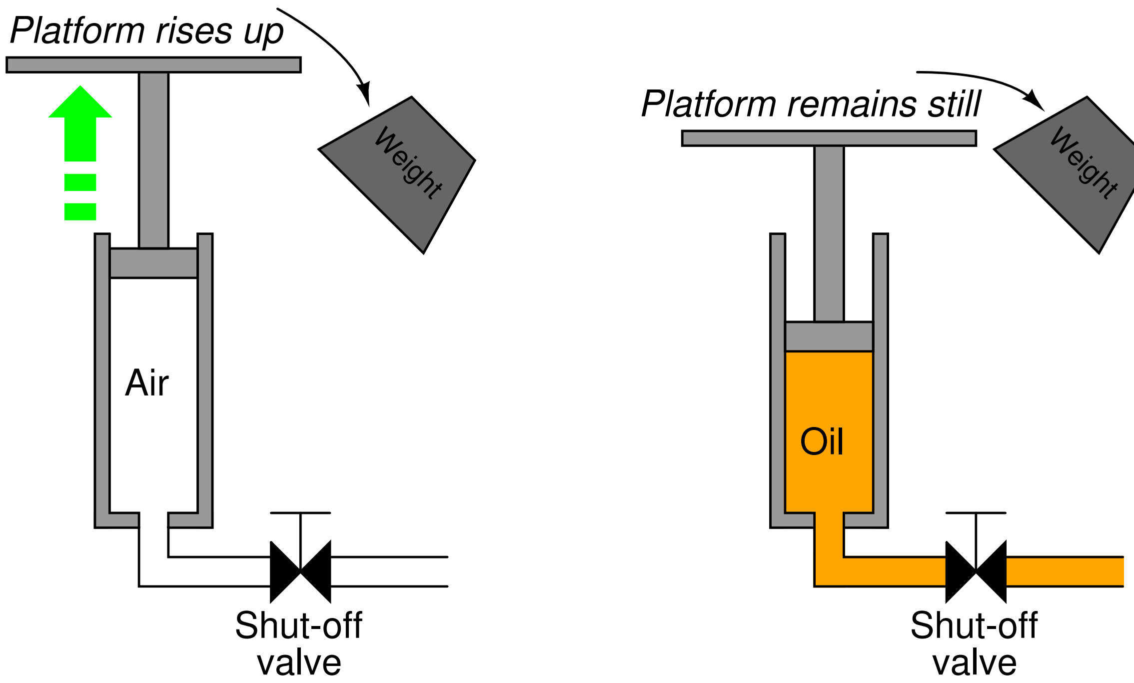


It is sage advice to *leave all angle adjustment(s) untouched* until all possible zero and span adjustments have been made to the instrument. Usually, it is possible to get a nonlinear instrument to read within specified tolerance in a 5-point calibration just by adjusting the zero and span adjustments.

In many mechanical instruments, a simple linearity alignment is to apply a 50% input signal and check for link/lever perpendicularity (that all links and levers intersect at 90^o angles to each other).

Svar 55

If the weight falls off the oil-actuated lift, the piston will hold its original position. If the weight falls off the air-actuated lift, the piston will rise substantially (perhaps even ejecting from the cylinder!) due to expansion of the air:



Svar 56

Shut-off valve #1 (the oil valve) would be the safer one to close for halting the platform's vertical motion.