Strømningsmålling

Kompetansemål:

- montere, konfigurere, kalibrere og idriftsettelse digitale og analoge målesystemer
- måle fysiske størrelser i automatiserte anlegg

Oppgaver

Oppgave 1

Suppose a turbine flowmeter used to measure the flow of natural gas has a "K factor" equal to 37.2 pulses per Sl (standard liter). Calculate the following:

The total amount of gas volume passed through the flowmeter after a digital counter circuit records 2,594,620 pulses.

The flow rate through the meter (i SLM) with the pulse signal having a frequency of 94 Hz.

The amount of time required (in units of hours and minutes) to accumulate 525,000 pulses (on a digital counter circuit) give a steady flow rate of 170 SLM.

Suppose someone entered the wrong K factor value into the digital electronic transmitter connected to the turbine meter's pickup coil. Would this cause a *zero shift*, a *span shift*, a *linearity error*, or a *hysteresis error*? Explain your reasoning.

Suggestions for Socratic discussion

- The label "Standard Cubic Feet" means one cubic foot of volume with the gas at room temperature and atmospheric (sea-level) pressure. Explain why we might use the unit of "Standard Cubic Feet" to express the flow of a gas through a pipe rather than simple "Cubic Feet".
- What advantages does a turbine meter have for measuring natural gas flow that make it well-suited for this application?
- Explain what would be necessary to make a turbine flowmeter register the true *mass flow rate* of the fluid rather than just the volumetric flow rate.
- Demonstrate how to *estimate* numerical answers for this problem without using a calculator.

file i04057

Oppgave 2

Turbine flow meters are almost self-explanatory in their operation. Compare and contrast the turbine flow meter against the standard orifice plate flow meter as a flow-measuring device. What are some of the advantages of turbine meters over orifice plates? Are there any significant disadvantages?
Also, compare signal linearity between the two flow measurement technologies: we know that orifice plates require square-root characterization to obtain a linear response to flow rate. Is the same true for turbine meters? Why or why not?
file i00497

Oppgave 3

A turbine flowmeter measuring cooling water for a large power generator uses an electronic circuit to convert its pickup coil pulses into a 4-20 mA analog current signal. The "K factor" for the turbine element is 99 pulses per liter, and the 4-20 mA analog output is ranged from 0 to 500 l/m flow. Complete the following table of values for this transmitter, assuming perfect calibration (no error). Be sure to show your work!

Measured flow (l/m)	Pickup signal frequency (Hz)	Percent of output span (%)	Output signal (mA)
250			
412			
	305		
	780		
		63	
		49	
			10
			16

Suggestions for Socratic discussion

- Demonstrate how to *estimate* numerical answers for this problem without using a calculator.
- Suppose you were asked to check the accuracy of the frequency-to-current converter circuit for this flowmeter. What sort of test equipment would you use, and how could you perform the test with the flowmeter still installed in the cooling water pipe?
- Could the pulse output of the pickup coil be used directly as a flow signal, or is the converter circuit absolutely necessary?
- Explain how a PLC could be used to *totalize* the water flow through this flowmeter, to provide total usage values at the end of each day.

file i00101

Oppgave 4

Read pages 2-2 through 2-18 of the "Rosemount Series 8700 Magnetic Flowmeter Flowtubes" reference manual (publication 00809-0100-4727 Revision DA), and answer the following questions:

Identify the minimum upstream and downstream straight-pipe runs necessary for reliable flow measurement using one of these magnetic flowmeters.

Two cables connect the remotely-mounted transmitter ("head") unit to the flowtube. Identify the purpose of each cable; specifically, what each one connects to inside the flowtube.

Identify the proper direction of process liquid flow when the flowtube is mounted vertically or at an angle, and explain why this is the preferred direction.

Suggestions for Socratic discussion

- Explain why it is important to not run cables from two different magnetic flow transmitters to their respective flowtube assemblies through the same electrical conduit.
- Explain why cable termination procedures must be strictly adhered to, including not stripping back the cable shield more than half an inch, and also bonding the shield conductors (only) to the flowtube case.
- Comment on the flange bolt torquing sequences shown on page 2-7. Are these sequences arbitrary, or is there some general principle we should recognize here?

file i04066

Oppgave 5

Magnetic flowmeters exhibit special advantages and disadvantages when compared to other flow-measuring technologies. For each of the following strengths and weaknesses, explain *why* it is this way for a magnetic flowmeter:

Strengths:

- Short upstream/downstream straight-pipe requirements: 5 up and 3 down (typically)
- Output is linearly related to volumetric flow rate – no square root characterization required
- Good rangeability
- Bidirectional measurement possible

Weaknesses:

- Does not work with nonconducting fluids
- Excellent electrical grounding of the flowmeter is *essential*
- Coating of electrodes may affect performance
- Needs to be installed in pipe with electrodes horizontal, never vertical

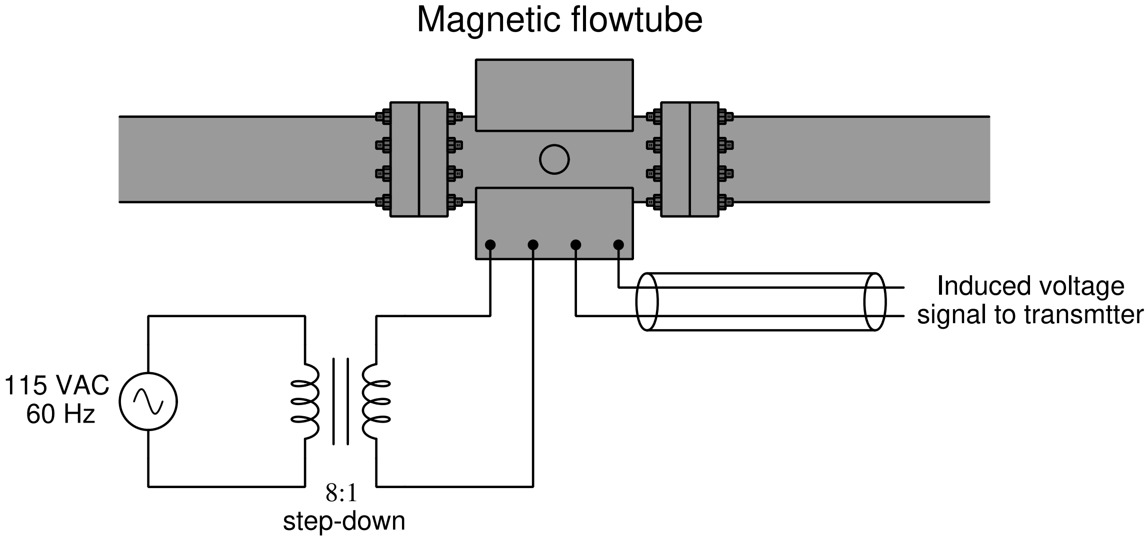
Suppose a magflow meter is operating with a partially-filled pipe, with both electrodes still fully contacting the liquid. Will this operating condition cause a *zero shift*, a *span shift*, a *linearity error*, or a *hysteresis error*? Explain your reasoning.

Suppose the flowstream through a magflow meter contains some non-conductive solids in addition to conductive liquid. Will this affect the accuracy or reliability of the flowmeter? Explain why or why not.

file i00525

Oppgave 6

The field coil of this AC magnetic flowmeter is energized by 60 Hz line AC power, the coil exhibiting a known quantity of inductance as well as wire resistance:



The *magnitude* of the induced voltage signal is a function of the field coil's magnetic flux density (B), the velocity of the fluid moving through the flowtube (v), and the diameter of the flowtube (d). The *phase angle* of the induced voltage signal will be the same as the phase angle of the current through the field coil, relative to the source voltage.

Calculate the magnitude and phase angle of the induced voltage signal, given the following parameters:

- Flowtube diameter = 14 centimeters
- Magnetic flux density = 1.0 millitesla, RMS
- Field coil resistance = 11 ohms
- Field coil inductance = 4.1 millihenrys
- Fluid velocity = 6.3 meters per second

file i00045

Oppgave 7

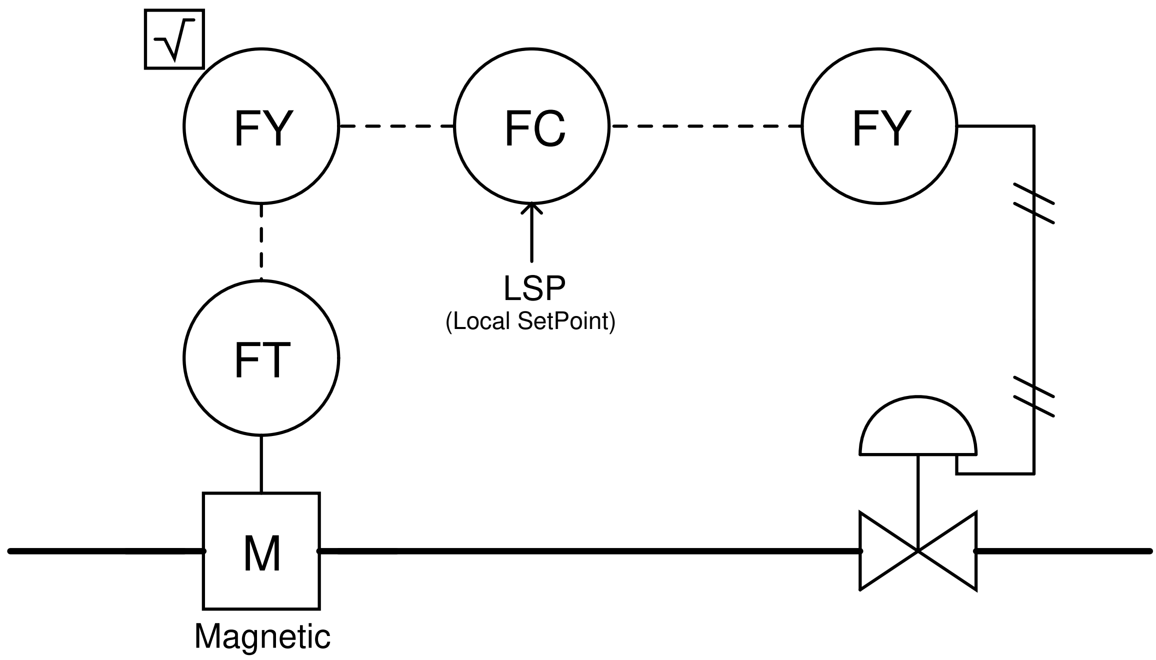
Magnetic flowmeters only function when measuring the flow of *electrically conductive* fluids. First, explain why electrical conductivity is an essential property of the fluid. Second, identify common fluids that *cannot* be detected by a magnetic flowmeter. Third, determine whether slight changes in conductivity have any effect on the accuracy of a magnetic flowmeter (e.g. if the conductivity of the fluid decreased by a factor of two, would the output voltage similarly decrease by the same factor?).
file i00523

Oppgave 8

Explain the difference(s) between an *AC* magnetic flowmeter and a *DC* magnetic flowmeter. Also, describe why there are two types (i.e. what advantages do each type of magnetic flowmeter enjoy?)
file i00524

Oppgave 9

The following flow control system (as built) refuses to maintain process flow at a steady setpoint. It seems "sluggish" to respond to changes at high flow rates, and control at low flow rates is very erratic (rapid cycling in the measured flow). From the control scheme shown here, can you determine the problem?



file i00526

Oppgave 10

Suppose a vortex flowmeter is used to measure the flow rate of fuel oil into a large combustion boiler. The vortex meter has a "K factor" equal to 10.344 pulses per liter. Calculate the following:

The sensor frequency at a fuel oil flow rate of 8510 liter per hour.

The total amount of fuel consumed by the boiler after a digital counter circuit records 800,000 pulses.

The fuel oil flow rate (in liter per minute) at a sensor frequency of 35 Hz.

Suppose someone entered the wrong K factor value into the digital electronic transmitter connected to the vortex meter's sensor. Would this cause a *zero shift*, a *span shift*, a *linearity error*, or a *hysteresis error*? Explain your reasoning.

Suggestions for Socratic discussion

- Identify how we could set up this vortex flowmeter to record the total amount of fuel oil consumed by the boiler every 24 hours, and then log those values in records for operator reference.
- Explain how you could use simple test equipment to measure the frequency of the signal output by the vortex shedding sensor while the flowmeter was in operation. Note: some vortex flowmeters provide test points for you to connect electronic test equipment directly to the sensor inside the pipe!
- If the temperature of the fuel oil were to increase slightly, would it affect the vortex flowmeter's measurement accuracy? Explain why or why not.
- Explain what would be necessary to make a vortex flowmeter register the true *mass flow rate* of the fluid rather than just the volumetric flow rate.
- Demonstrate how to *estimate* numerical answers for this problem without using a calculator.

file i04059

Oppgave 11

Read pages 2-3 through 2-5 of the "Rosemount Model 8800C and Model 8800A Smart Vortex Flowmeter" reference manual (publication 00809-0100-4003 Revision JA), and answer the following questions:

Explain why a vertical pipe orientation is preferred for this type of flowmeter, identifying the proper direction(s) of flow for different process fluids.

Figure 2-2 shows preferred mounting positions for hot pipes – explain why these positions are preferred to other alternative positions.

Identify the minimum upstream and downstream straight-pipe lengths for this flowmeter.

Figure 2-9 on page 2-12 shows the bolt-tightening sequence recommended for flange-mounted flowmeter installations. Examine each of the sequences shown, and explain why the sequence of bolt-tightening matters. Hint: the exact same principle is involved when tightening lug nuts on a car wheel, and it is called *cross-torquing*.

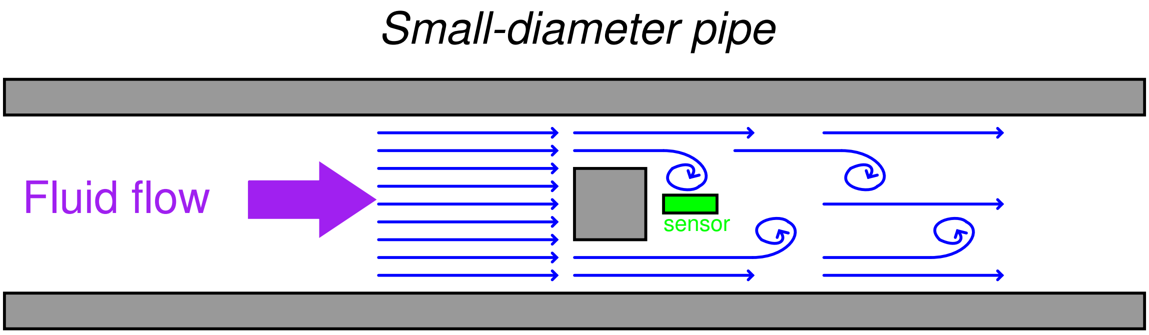
Suggestions for Socratic discussion

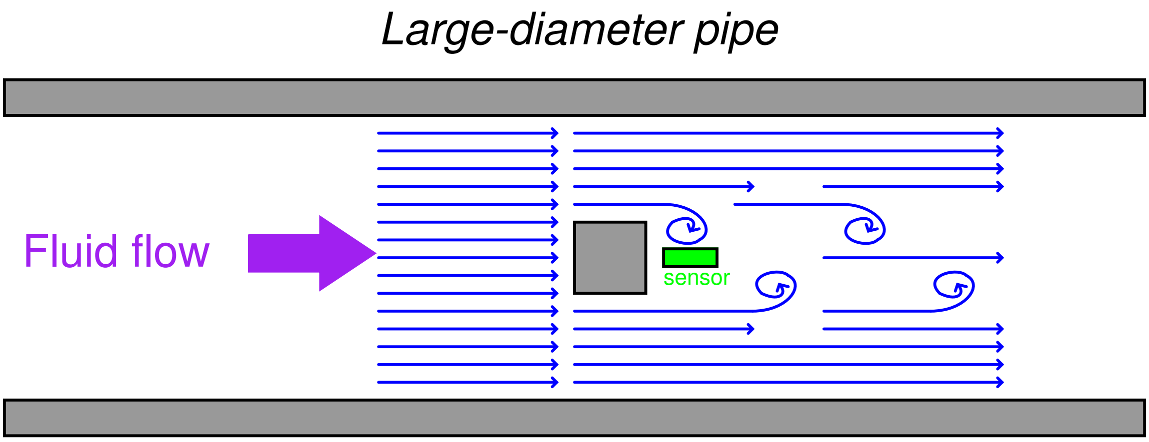
- Explain why the manual recommends you "install valves downstream of the meter when possible".
- This manual mentions the option of pressure and temperature compensation for the vortex flowmeter. Explain why one might choose to apply this type of compensation in a specific process application. Also, explain why compensating pressure and temperature sensors should be located downstream of the vortex flowmeter rather than upstream.
- Suppose you needed to "cross-torque" the bolts on a machine component, but did not have a manual to specify which bolts to torque in what order. Explain how you could apply a general cross-torquing procedure to *any* multi-bolt application.
- Suppose you were asked to build a circuit to interpret the pulse output from this model of vortex flowmeter, blinking an LED on and off with the pulse frequency. Sketch this circuit, being sure to note which screw terminals on the flowmeter to connect your circuit to.

file i04063

Oppgave 12

Suppose two water pipes of different diameter both have blunt objects ("bluff bodies") in the paths of their respective water flows. A pressure sensor device located near each of the bluff bodies measures the frequency of the vortices produced:



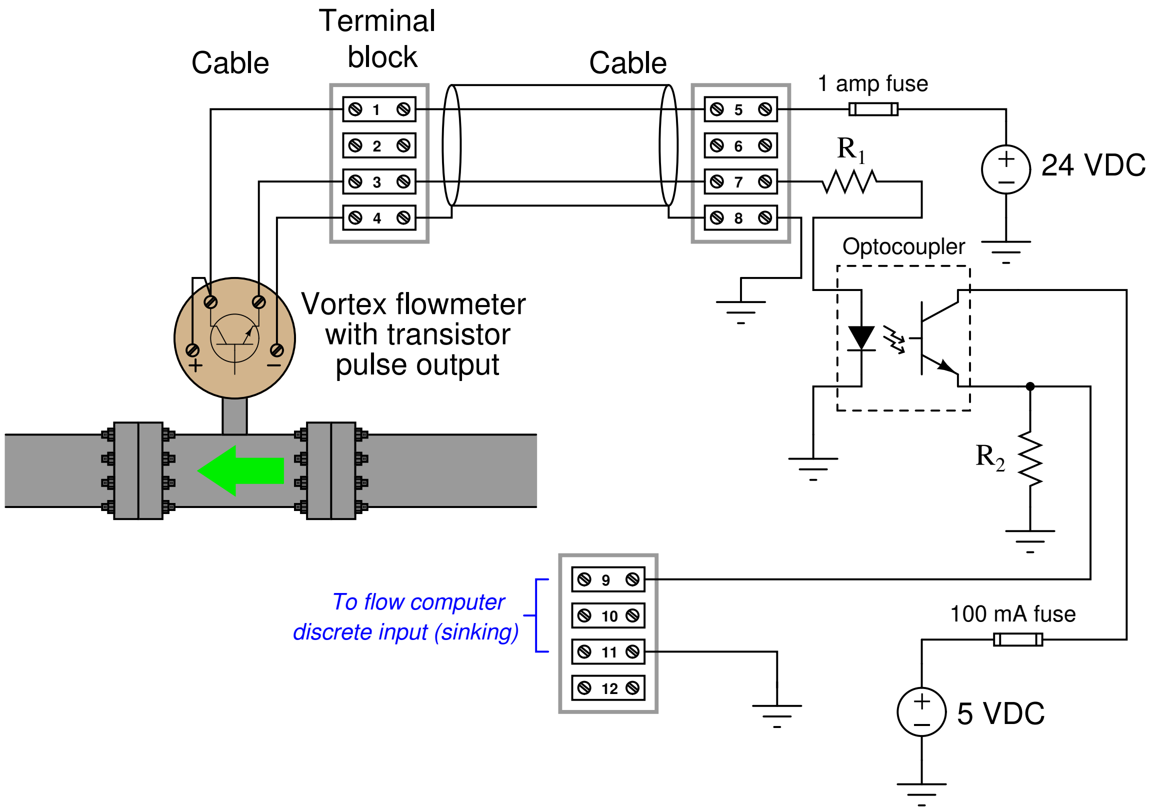


If the bluff bodies in both pipes have the same physical dimensions, and the vortex shedding frequencies are the same in both scenarios, which pipe carries a greater volumetric flow rate of water? Or, do they carry the same amount of flow? Why or why not??

file i00495

Oppgave 13

Contractors install this vortex flowmeter, equipped with a pulse output (1 pulse per 25 gallons), to totalize flow through a pipe:



Unfortunately, the flow computer connected to this circuit is not registering any accumulated flow, even though an operator has verified flow through the pipe at approximately 370 gallons per minute. Your first step is to disconnect the flow computer input from this circuit (so it is wired exactly as shown) then to take your DC voltmeter and measure voltage between terminals 1 and 4: there, your meter registers 23.1 volts DC. Your next step is to measure DC voltage across the collector and emitter terminals of the optocoupler's transistor: there your meter 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_2 failed open		
R_1 failed shorted		
R_2 failed shorted		
1 amp fuse blown		
100 milliamp fuse blown		
24 VDC source dead		
5 VDC source dead		

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.

<u>file i00053</u>

Oppgave 14

Compare and contrast the vortex-shedding flow meter against the standard orifice plate flow meter. What are some of the advantages of vortex meters over orifice plates? Are there any significant disadvantages?

Also, compare signal linearity between the two flow measurement technologies: we know that orifice plates require square-root characterization to obtain a linear response to flow rate. Is the same true for vortex meters? Why or why not?

file i00494

Oppgave 15

Research the necessary upstream and downstream straight-pipe requirements for vortex and turbine meters, and identify how these requirements compare against the typical requirements of orifice plates. For review's sake, why do we need a certain minimum length of straight pipe length upstream and downstream of a flow-measuring device?

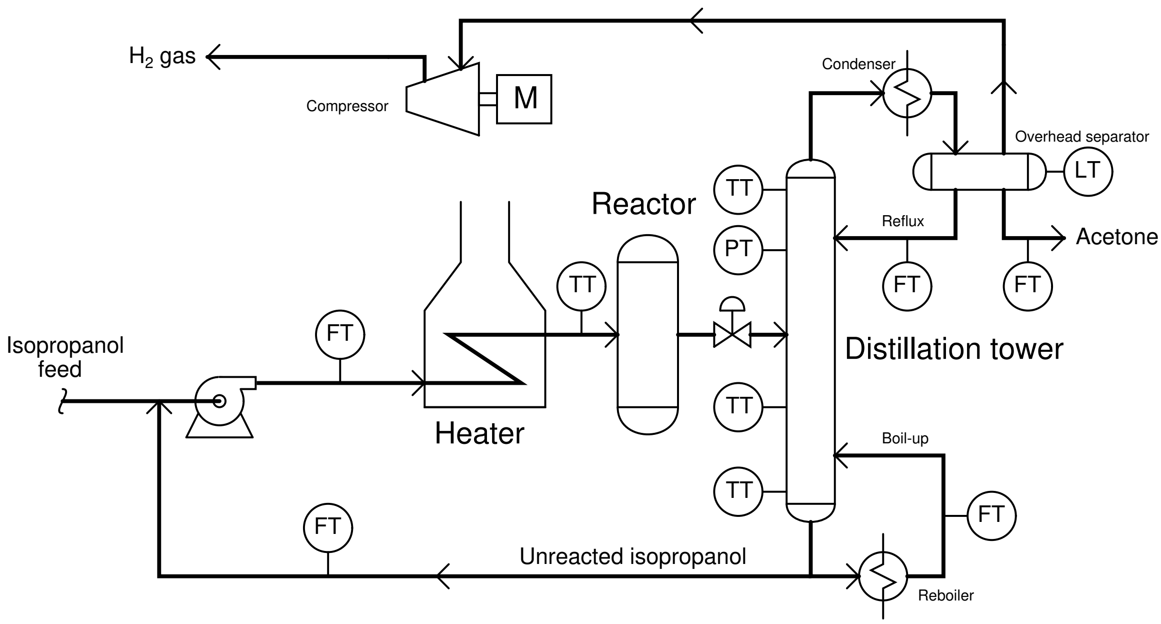
file i00501

Oppgave 16

Acetone – a valuable industrial solvent (chemical formula C_3H_6O) – may be manufactured from isopropyl alcohol (chemical formula C_3H_8O) in a chemical reaction that breaks two atoms of hydrogen away from each molecule of alcohol, leaving acetone and hydrogen gas (H_2) as byproducts:

$$C_3H_8O \rightarrow C_3H_6O + H_2$$

A simplified flow diagram for this process is shown here:



Suppose the decision is made to use a vortex flowmeter to measure acetone reflux flow into the distillation tower. This particular vortex flowmeter has a minimum Reynolds number value of 10,000 as specified by the manufacturer. Calculate the minimum flow rate of acetone at 20 ^{o}C this vortex meter will be able to measure given a schedule-40 pipe size of DN40 (ID=40.94). Assume a density of 790 kg/m^3 and an absolute viscosity of 36 mPa s for acetone at this temperature.

Suggestions for Socratic discussion

- Why would you as a technician (not an engineer) need to know anything about *minimum flow cutoff* for a vortex flowmeter? Identify a practical scenario where this knowledge might become important for you to do your job.
- Explain what the *Reynolds number* of a flowing fluid means in your own words. Specifically, what effects are manifest from different Reynolds number values?
- What is the purpose of a *distillation tower* in this particular process and how does it work?
- If you are familiar with distillation tower operation, identify which sunstance has the lower boiling point: acetone or isopropyl alcohol.

file i04060

Oppgave 17

Read selected portions of the "Daniel Ultrasonic Gas Flowmeter" manual for the 3400 series SeniorSonic and JuniorSonic flowmeters (part number 3-9000-740 Revision H), and answer the following questions:

Read page 3-22 and identify the minimum straight-pipe lengths upstream and downstream required for proper operation of the flowmeter.

Read page 3-22 and identify how closely the diameter of the meter flowtube must match the inside diameter of the pipe it connects to.

Read page 3-22 and identify how closely a temperature-sensing probe (i.e. thermowell with RTD) may be installed to the meter flowtube, and which side (upstream or downstream) it should be on.

Read pages 5-1 through 5-5 and identify the operating principle (Doppler or transit-time) used in both the SeniorSonic and JuniorSonic gas flowmeters.

Suggestions for Socratic discussion

- Why should the Senior flowmeter be installed with chords oriented horizontally?
- Why should the Junior flowmeter be installed with chords 45 degrees off vertical?
- How many paths (chords) are used in the Senior versus the Junior models?
- How does the general design of the Senior model differ from that of the Junior model?

file i04070

Oppgave 18

Transit-time ("counterpropagation") ultrasonic flowmeters infer the flow rate of a gas or a liquid by measuring the time it takes for sound waves to travel both upstream and downstream through a moving fluid:

$$Q = k \frac{t_{up} - t_{down}}{(t_{up})(t_{down})}$$

Where,
Q = Volumetric flow rate
k = Constant of proportionality
t_{up} = Time for sound pulse to travel upstream (against the flow)
t_{down} = Time for sound pulse to travel downstream (with the flow)

Perform a "thought experiment" where the fluid inside an ultrasonic flowmeter is standing still, and demonstrate how this equation gives a value of zero for Q.

Suggestions for Socratic discussion

- A strong emphasis is placed on performing "thought experiments" in this course. Explain why this is. What practical benefits might students realize from regular mental exercises such as this?
- Perform a thought experiment demonstrating how the speed of sound is irrelevant for this type of flowmeter, based on an analysis of the formula shown above. Use the substitutions $t_{up} = \frac{L}{c-v}$ and $t_{down} = \frac{L}{c+v}$ to define travel time in terms of path length (L), fluid velocity (v), and speed of sound (c).

file i04071

Oppgave 19

Ultrasonic flowmeters exhibit special advantages and disadvantages when compared to other flow-measuring technologies. For each of the following strengths and weaknesses, explain *why* it is this way for an ultrasonic flowmeter:

Strengths:

- May be attached to the *outside* of a pipe
- Relatively inexpensive on large pipes
- Work on liquids, gases, and some vapors
- Output is linearly related to volumetric flow rate – no square root characterization required
- Good rangeability
- Bidirectional measurement possible

Weaknesses:

- Calibration varies with speed of sound in fluid for some types (which?)
- Efficiently coupling sensors to pipe can be challenging
- May require long straight-pipe lengths to condition flow
- May suffer false readings from sound waves "ringing around the pipe" instead of going through the fluid

file i00529

Oppgave 20

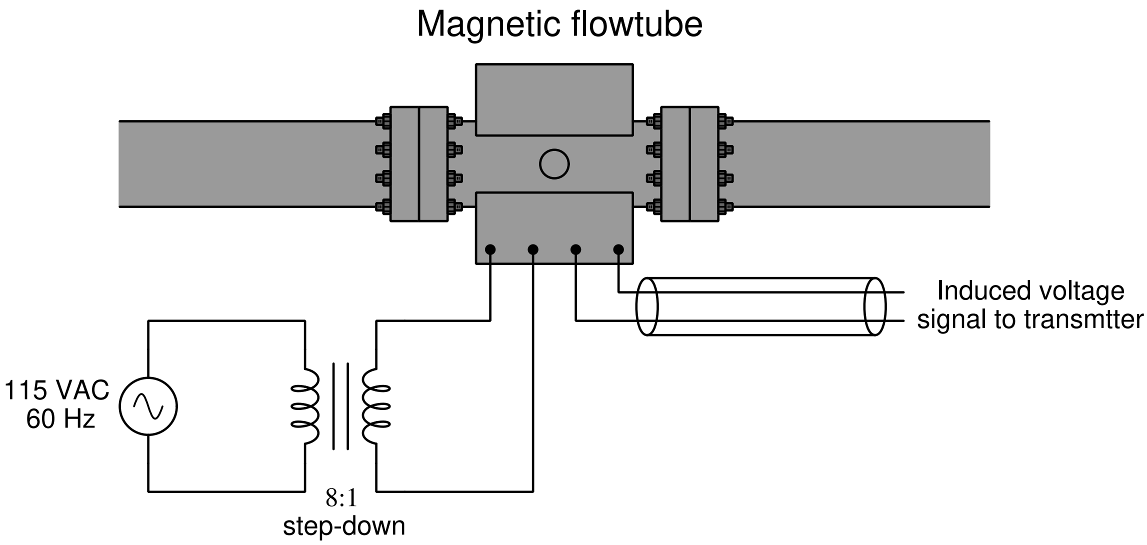
Noen dyr bruker ekkolokasjon for å finne veien i mørket. Ubåter bruker sonar til det samme. Forklar hvordan dette prinsippet kan brukes til å akustisk måle avstanden til et objekt. Hvordan kan vi bruke dette til å måle hastigheten til et objekt?
file i00528

Oppgave 21

Describe the operational principles of two types of *ultrasonic* flowmeter technologies: *Doppler* and *transit-time*. What physical properties of the fluid stream affect an ultrasonic flowmeter's calibration?
file i00527

Oppgave 22

The field coil of this AC magnetic flowmeter is energized by 60 Hz line AC power, the coil exhibiting a known quantity of inductance as well as wire resistance:



The *magnitude* of the induced voltage signal is a function of the field coil's magnetic flux density (B), the velocity of the fluid moving through the flowtube (v), and the diameter of the flowtube (d). The *phase angle* of the induced voltage signal will be the same as the phase angle of the current through the field coil, relative to the source voltage.

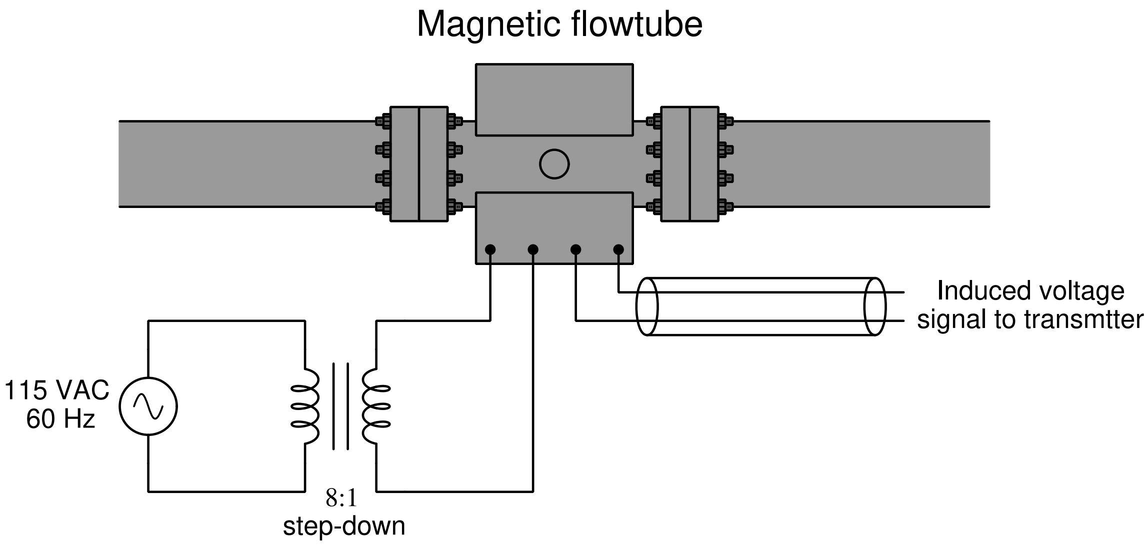
Calculate the magnitude and phase angle of the induced voltage signal, given the following parameters:

- Flowtube diameter = 14 centimeters
- Magnetic flux density = 1.0 millitesla, RMS
- Field coil resistance = 11 ohms
- Field coil inductance = 4.1 millihenrys
- Fluid velocity = 6.3 meters per second

file i00045

Oppgave 23

The field coil of this AC magnetic flowmeter is energized by 60 Hz line AC power, the coil exhibiting a known quantity of inductance as well as wire resistance:



The *magnitude* of the induced voltage signal is a function of the field coil's magnetic flux density (B), the velocity of the fluid moving through the flowtube (v), and the diameter of the flowtube (d). The *phase angle* of the induced voltage signal will be the same as the phase angle of the current through the field coil, relative to the source voltage.

Calculate the magnitude and phase angle of the induced voltage signal, given the following parameters:

- Flowtube diameter = 14 centimeters
- Magnetic flux density = 1.0 millitesla, RMS
- Field coil resistance = 11 ohms
- Field coil inductance = 4.1 millihenrys
- Fluid velocity = 6.3 meters per second

file i00045

Oppgave 24

The two major types of ultrasonic flowmeters work best in different fluid streams. One type "prefers" a clean fluid stream, while the other "prefers" a flow stream containing particulate matter or bubbles. Identify which ultrasonic flowmeter type is best suited to which type of flow stream, and explain why.

file i00530

Oppgave 25

Refer to pages 4 and 5 of the "Micro Motion 'ELITE' Coriolis Flow and Density Meters" product datasheet (publication PS-00374 Revision L), and answer the following questions:

Compare the turndown performance of a Coriolis flowmeter against that of a typical orifice plate flowmeter, and identify which one has better performance. Explain *why* one has better performance than the other.

Examine the graph of accuracy versus flow rate on page 4 and explain the meaning of the "turndown ratio" limits shown on the graph (e.g. 100:1, 20:1, 2:1). Explain what *turndown* means for any measuring instrument.

Select an appropriate model of flowmeter for measuring the flow rate of water up to 25 GPM.

Select an appropriate model of flowmeter for measuring the flow rate of natural gas up to 400 SCFM (at a line pressure of 500 PSI).

Suggestions for Socratic discussion

- Page 10 contains tables showing the effect of process temperature and process pressure on measurement accuracy, both for flow rate and for density. Explain why changes in process pressure and/or process temperature would have this effect on a Coriolis flowmeter.
- Pages 17 through 22 show illustrations of these Coriolis flowmeters. For each of the given drawings, identify where the two vibrating tubes are located, and what shape those tubes take.

file i04076

Oppgave 26

Suppose we are measuring the flow rate of a liquid using a Coriolis flowmeter, and the volumetric flow rate of the liquid increases (with liquid density remaining the same). Will the amplitude of the meter tubes' "undulating" motion increase, decrease, or remain the same given this change in flow? Will the meter tubes' resonant frequency of vibration increase, decrease, or remain the same? Explain your answers.

Now suppose we are using the same Coriolis flowmeter to measure liquid flow, but this time the liquid's density becomes greater (i.e. the liquid becomes denser) with no change in volumetric flow. Again, qualitatively identify the change in undulation amplitude, and also in resonant frequency, for the flowmeter's metal tubes, and explain your answers.

Finally, suppose the flow through this Coriolis meter stops completely. How will changes in fluid density affect the tubes' motion, given a condition of zero flow? Again, explain your answers.

Suggestions for Socratic discussion

- A strong emphasis is placed on performing "thought experiments" in this course. Explain why this is. What practical benefits might students realize from regular mental exercises such as this?

file i00728

Oppgave 27

Suppose both a thermal mass flowmeter and a Coriolis mass flowmeter monitor gas flow going through the exact same pipe. Normally, the gas flowing through this pipe is pure helium (specific heat $c = 1.24$ cal/g-K), and the thermal mass flowmeter has been calibrated for helium gas. Then one fine day an operator places a few shutoff valves in the wrong positions and sends hydrogen gas (specific heat = 3.41 cal/g-K) down the line instead of helium.
Not knowing that the wrong gas is now flowing through this pipe, the operator adjusts a manual flow control valve to stabilize the flow rate at its normal value, looking at the thermal mass flowmeter's indication as the process variable.

First, explain why the two flowmeters no longer agree with each other (assuming they registered in perfect agreement while sensing the flow of helium gas).

Second, identify whether the Coriolis flowmeter registers *more* mass flow than the thermal flowmeter or *less* mass flow than the thermal flowmeter.

Finally, identify which of the two flowmeters (if any!) still registers the true mass flow rate with hydrogen going down the line instead of helium.

Suggestions for Socratic discussion

- Explain what *specific heat* means, and give a practical example from everyday life.
- What does this "thought experiment" tell us about Coriolis versus thermal mass flowmeters in general? Which of these flowmeter types do you think costs less?
- Thermal mass flow measurement is used almost universally for intake air flow measurement on automobile engines with electronic controls. Do you think the same type of problem exists in this application that we saw in our "thought experiment"?
- Suppose the gas composition does not change (i.e. it is still pure helium), but the line pressure increases. How will each of these mass flowmeters respond to this one process condition change?
- Suppose the thermal mass flowmeter were replaced with an orifice plate and DP sensor. Would this solve the problem of discrepancies between flowmeters resulting from fluid composition changes? Explain why or why not.

file i04080

Svar

Svar 1

Partial answer:

The amount of time required to accumulate 525,000 pulses (on a digital counter circuit) give a steady flow rate of 170 SLM = **1 hour, 23 minutes**

Svar 2

- **Advantages of turbine meters over orifice plates**
- Very high accuracy
- Linear output requires no square-root characterization
- Better rangeability due to linear response to flow
- **Advantages of orifice plates over turbine meters**
- Typically cheaper
- Cleanliness of flow stream not as critical
- Turbine may become bound if viscous or fibrous solids are present in the flow stream
- Less wear over time (no bearings to wear out)

Svar 3

Measured flow (l/m)	Pickup signal frequency (Hz)	Percent of output span (%)	Output signal (mA)
250	412.5	50	12
412	679.8	82.4	17.18
184.8	305	36.97	9.915
472.7	780	94.55	19.13
315	519.8	63	14.08
245	404.3	49	11.84
187.5	309.4	37.5	10
375	618.8	75	16

$$Q = kf$$

Where,
f = Frequency in Hertz (pulses per second)
k = Calibration factor in liter per pulse
Q = Volumetric flow rate in liter per second

$$Q = \frac{kf}{60}$$

Where,
f = Frequency in Hertz (pulses per second)
k = Calibration factor in pulses per gallon
Q = Volumetric flow rate in gallons per minute

Svar 4

Svar 5

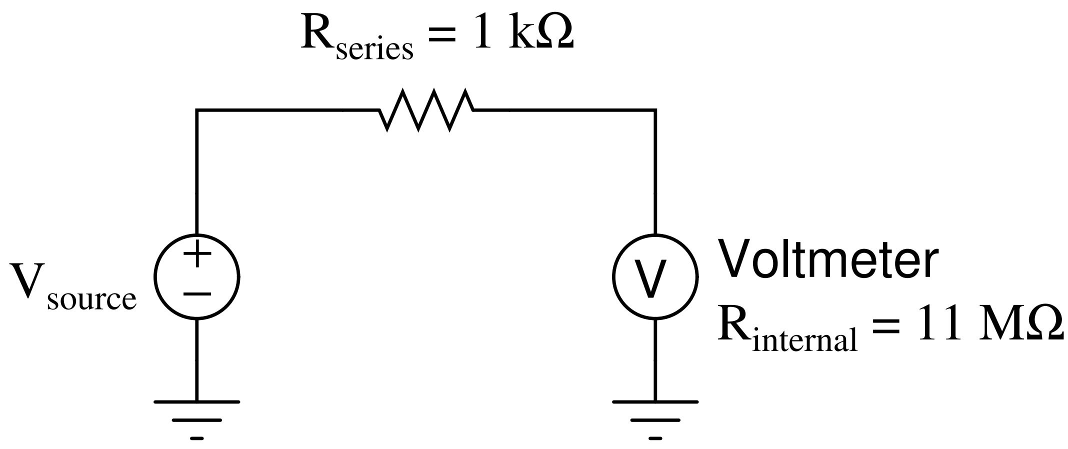
Svar 6

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

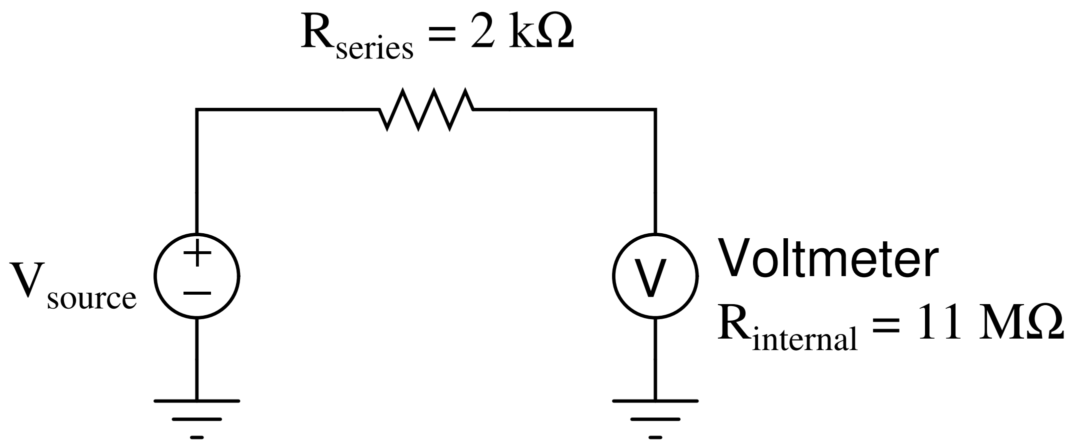
Svar 7

Answer to second question: most oils and concentrated alcohols have very low conductivity and thus cannot be measured by a magnetic flowmeter. Gases and vapors suffer the same problem.

In answer to the third question, I offer the following electrical "thought experiment." Consider the effect of doubling the series resistance in this circuit:



Does the voltmeter accurately measure V_{source} ?



Does the voltmeter accurately measure V_{source} ?

Svar 8

"AC" flowmeters indeed use alternating current to energize their field windings, but "DC" meters do not use steady direct current. Rather, "DC" flowmeters use *pulsed* magnetic fields, sometimes of consistent polarity and other times with reversing polarity (making them "alternating" after all!).
Dual-frequency magflow meters attempt to capitalize on the best features of both DC and AC techniques, by employing specialized pulse waveforms.

DC magflow meters enjoy good rejection of "noise" voltages, while AC magflow meters typically exhibit faster response times.

Svar 9

Since the output of a magnetic flowmeter is linear with regard to flow, there is no need for square root extraction, as indicated by the first "FY" device in the loop. Square-rooting the flow signal will only cause problems if there is no need to do so!

Svar 10

Partial answer:

The total amount of fuel consumed by the boiler after a digital counter circuit records 800,000 pulses = **77,339.5 liter**

Svar 11

Svar 12

The large pipe carries a greater volumetric rate of water flow than the small pipe.

Since the vortex shedding frequency is proportional to the fluid *velocity*, we know that the flow velocities in both cases must be the same (given identical bluff body geometries). However, since the larger pipe has a greater cross-sectional area, an identical velocity equates to a greater *volume* rate of water moving past the bluff body and sensor.

Svar 13

Svar 14

- **Advantages of vortex meters over orifice plates**
- Immune to changes in fluid density (and therefore temperature and pressure as well)
- Linear output requires no square-root characterization
- Better rangeability due to linear flow response (at least down to the "cut off" point)
- **Advantages of orifice plates over vortex meters**
- Cheaper for very large pipe sizes
- Orifice plates may be more tolerant of low-frequency pipe vibrations
- Some orifice plates may measure bidirectional flow
- Able to sense flow down to zero (vortex flowmeters will "cut off" at some low flow rate)

Low-flow cutoff is a problem unique to vortex flowmeters. At low flow rates, the Reynolds number drops below the turbulent threshold, at which point fluid viscosity prevents vortices from shedding. The vortex street simply ceases to exist at any flow rate below this critical point, meaning the flowmeter's output goes to zero at any flow rate below the cutoff point.

Svar 15

Vortex meter and turbine meter both: 15 to 50 pipe diameters upstream; 5 pipe diameters downstream.

Svar 16

$$Re = \frac{Dv\rho}{\mu} \Rightarrow v = \frac{Re\mu}{D\rho} = \frac{10000 \cdot 36mPas}{40.94mm \cdot 790kg/m = 0.099m/s}$$

$$Q = Av = \pi(\frac{40.95mm}{2}) \cdot 0.099m/s = 0.13l/s = 7.81l/m$$

Svar 17

Svar 18

Svar 19

Svar 20

The time elapsed between the generation of an acoustic pulse and the reception of its echo (reflected off the solid object) is directly proportional to the distance between the pulse source and the object. *Velocity* is simply the first derivative of distance with respect to time ($v = \frac{dx}{dt}$).

Svar 21

Flow stream velocity may be measured via the use of sound waves transmitted and received through the liquid. One sonic technology, called *Doppler*, infers velocity by the change in sound frequency between the transmitted sound wave and the received sound wave.
Another sonic flowmeter technology, called *transit-time*, measures liquid velocity by measuring the difference between upstream and downstream velocities of sound waves transmitted through the fluid.
Doppler flowmeter calibration depends on the speed of sound through the process fluid. Transit-time flowmeter calibration does not. Ultrasonic flowmeters are not suitable for multiphase (vapor/liquid mixed) flows, and thus the pipe must be completely full of liquid (no gas pockets) or completely full of gas (no puddles or streams of liquid) in order to function properly.

Svar 22

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

Svar 23

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

Svar 24

Transit-time = clean flow streams ; Doppler = flow streams containing particulate and/or bubbles.

Svar 25

Svar 26

Increased volumetric flow rate with constant density: the undulating motion of the tubes will *increase* in amplitude due to the greater inertial forces, but the resonant frequency of the tubes will *remain the same* because the tubes' mass has not changed.

Increased density with constant volumetric flow rate: the undulating motion of the tubes will *increase* in amplitude due to the greater inertial forces resulting from an increased mass flow rate, and the resonant frequency of the tubes will *decrease* due to increased tube mass.

Changes in fluid density at zero flow: there will be no undulating motion, because there will be no Coriolis force with zero flow. The tubes' resonant frequency, however, will vary inversely with fluid density. One practical caveat is that there will need to be *some* flow in order to push a new fluid of different density into the flowmeter's vibrating tubes, in order to sense that new density.

Svar 27