Skills for Life!

Jubail Technical Institute

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Department of Electrical and Electronics Skills

STUDENT HANDBOOK

Instruments Principles & Calibration and Maintenance

INCT 1426

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Prepared by

Industrial Instrumentation and Control Skills Team

Instruments Principles & Calibration

INCT 1426

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Lesson 1: SI Fundamental units & Derived Units

All systems of weights and measures, metric and non-metric are linked through a network of international agreements supporting the International System of Units. The International System is called the SI units.

The SI units are classified into FUNDAMENTAL units and DERIVED units.

1.1 SI Fundamental Units*:*

Base quantity	Name	Symbol
Length	Meter	m
Mass	kilogram	kg
Time	Second	s
Electric Current	ampere	A
Thermodynamic Temperature	Kelvin	K
Amount of substance	Mole	mol
luminous intensity	candela	cd

1.2 SI Derived Units:

These units are defined algebraically in terms fundamental units. For example, the SI unit of force, the Newton, is defined to be the force that accelerates a mass of one kilogram at the rate of one meter per second. This means the one Newton is equal to one kilogram meter per second squared, so the algebraic relationship is N = $kg \cdot m/s^2$.

Derived quantity	**Units**	**Symbol**
Frequency	Hertz	Hz
Force	newton	N
Energy	Joule	J
Power	Watt	W
Pressure, Stress	pascal	Pa
Electric charge	coulomb	C
Electric potential difference	Volt	V
Electric resistance	Ohm	Ω
Electric capacitance	Farad	F
inductance	Henry	H
Electric conductance	siemens	S
Thermodynamic temperature	degree Celsius	°C

1.3 SI Prefixes:

The following SI prefixes can be used to prefix any of the above units to produce a multiple or submultiples of the original unit.

10^n	Prefix	Symbol	Decimal equivalent
10^9	giga	G	1 000 000 000
10^6	mega	M	1 000 000
10^3	kilo	k	1 000
10^0	none	none	1
10^{-3}	milli	m	0.001
10^{-6}	micro	μ	0.000 001
10^{-9}	nano	n	0.000 000 001
10-^{12}	pico	p	0.000 000 000 001

1.4 Errors

The different types of error that needs to be minimize to achieve optimal results.

1. Mistakes:

   These are also called 'human error'. Mistakes are caused by carelessness, casualness and fallibility. ie an error made in recording and calculating the final measurement. Generally, good measurement practices will minimize mistakes.

2. Compensating (random):

   These errors are due to the nature of the measured variable, inconstant environmental conditions and limitations in the instrument. The technician does not have control over these conditions and has to find other ways to take the measurement.

3. Systematic errors:

   Systematic errors are caused by faulty equipment. To minimize this error, the measuring equipment has to be maintained and checked periodically.

4. Sampling errors:

   Sampling errors are those which relate to the sample to be measured. If the sample is taken with a probability-based approach, the measurement might not be as expected. Take the measurement from the purist possible sample.

A measurement or estimate is said to be accurate when the total error is small. The small error cannot be defined as it depends on the value to be measured. For example, the speedometer of a car does not have to be 100 percent accurate. When the meter reads 80 km/h, the actual speed could be anywhere between 81 – 79 km/h. That range, however, is acceptable for the driver in order for him not to get a speeding ticket.

Exercise:

Mention a recent experience where you had an error in a measurement. How would you classify that error? Is there a way to control and minimize that error?

....

....

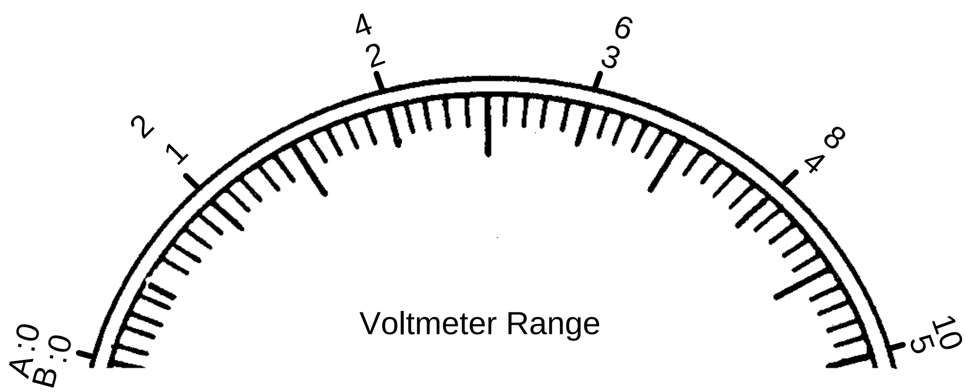
1.5 Terminology:

Every subject has its own terminology. In instrumentation engineering, there are several terms one must be acquainted to understand the subject.
Here is a summary of these terms:

1- Range	2- Span	3- Error	4- Accuracy
5- Precision	6- Resolution	7- Sensitivity	8- Linearity

1.6.1 Range:

The range is the maximum and the minimum values that a instrument can measure. For example, if a thermometer has a minimum temperature measurement of 0 and a maximum of 100, the range of the device would be 0 – 100 degrees Celsius. It does not have the ability to measure beyond these two extremes.



1.6.2 Span:

The algebraic difference between the Minimum and Maximum range values.
In the example above:

The voltmeter range A = 0 – 10. The span = 10

The voltmeter range B = 0 – 5. The span = 5

1.6.3 Error:

The difference between the true value and the measured one is called Error. It can be stated as:

$$e = Y_T - Y_M$$

Where e = Absolute error

Y_T = True value

Y_m = Measured value

It is usually expressed as a percentage:

$$\% \text{ Error} = \frac{|YT - YM| \times 100}{|YT|}$$

Example 1: The true value of a pressure gauge is 180kPa, but the measuring gauge shows 150kPa. What is the percent error?

$$\% \text{ Error} = \frac{180 - 150}{180}$$

$$= 16.7\%$$

1.6.4 Accuracy:

It is defined as the closeness with which a reading approaches the real value of the measured variable.

The closer the reading of a measurement to the true (real), value the more accurate the instrument is.

The accuracy of a measuring system is determined by calibration under known operating conditions and is expressed as being plus or minus certain figure.

$$\% \text{ Accuracy} = 100\% - \text{Percent error}$$

In example 1:

$$\% \text{ Accuracy} = 100\% - 16.7\%$$

$$= 83.3\%.$$

1.6. 5 Precision:

It the closeness with which individual measurements is distributed about their mean value.

A precise measurement may not necessarily be an accurate one.

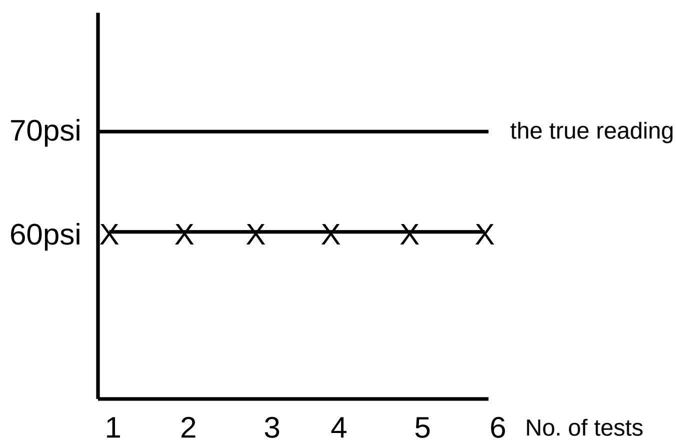
$$\text{Precision} = 1 - \frac{X_{nth} - X_{nn}}{X_n}$$

Where X_{nth} = value of the nth measurement

X_n = the average of a set n measurement

You must distinguish between precision and accuracy. A precise measurement may not be an accurate one.

The following graph illustrates the difference between precision and accuracy:



The transducer is not accurate (measuring 60 psi instead of 70 psi) but it has a high precision since its measurements, differ from the actual value by nearly the same amount every time.

Example 2: From the following experiment results calculate the precision of the third measurement.

No. of tests	Measurement values (psi)
1	30
2	35
3	40
4	38

The Average Value X_n $= \dfrac{30+35+40+38}{4} = 33.75$

Precision = $1 - \dfrac{|\,40 - 33.75\,|}{33.75}$

= 1 - 0.118

= 0.881

1.6.6. Resolution:

It can be defined as the smallest change of input to an instrument, which can be measured by the output. Other words it is the smallest division of the reading scale. For example a car speedometer is subdivided into 20km/h. This means that when the needle is between the scale markings we cannot estimate speed more accurately than to the nearest 5km/h. This figure of 5km/h therefore represents the resolution of the speedometer.

Example 3: A voltmeter has a range of 0 – 200 V with a resolution of 2%. What is the smallest change that can be measured?

The smallest change that can be measured = $\frac{2}{100} \times 200 = 4V$

1.6.7. Sensitivity:
Is the ratio of change in output to the corresponding change in the input.

$$S = \frac{\text{Change in output}}{\text{Corresponding Change in input}}$$

Example 4: The table below shows a set of readings was obtained by a sensor. What is the sensitivity of the transducer?

I/P °C	O/P mv
5	4
10	8
15	12
20	16
25	20
30	24

$$\text{Sensitivity} = \frac{\Delta O/P}{\Delta I/P} = \frac{20-8}{25-10} = 0.8\,mV/{}^\circ C$$

1.6.8 Linearity:

Should the relationship of an output results are plotted against the corresponding values of the input we get a straight line. Therefore if data measured on the output of a system for corresponding inputs can fit into a straight line when it is said the system is linear.

1.6.9. Calibration:

Calibration can be defined as the process for determination (by measurement or comparison with a standard) of the correct value of each scale reading on measuring instrument.

Lesson 2: Temperature Measurement & Calibration

Definition:

Temperature is a measure of the hotness or coldness of a material. It is measured in many different units, but the centigrade scale is often used.

The table below shows mostly known variables and their temperature in different scales.

Particulars	**Kelvin °K**	**Celsius °C**	**Fahrenheit °F**
Absolute zero	0	-273	-459.67
Freezing point of water	273	0	32
Average human body	310	36.8	98.2
Boiling point of water	373	100	212

Conversion between Units:

Kelvin to **C**elsius

°C = °K – 273

Celsius to **K**elvin

°K = °C + 273

Fahrenheit to **C**elsius

°C = (°F – 32) / 1.8

Celsius to **F**ahrenheit

°F = °C x 1.8 + 32

2.1 The Dry-Block Calibrator:

The Dry-Block Calibrators are used to calibrate probes. They can be used as portable or bench top instruments..

There are many calibrators in the market. The one in the workshop is the Fluke 514 Dry-Block Calibrator. It uses a precession, platinum RTD as a sensor and a controller to control the temperature at the desired set point that we need.

Communication with the 514 calibrator can be done easily through the buttons on the front panel.

2.1.1 Specifications:

Power	115 VAC (± 10%), 50/60 Hz, 230 VAC (± 10%), 350 W
Ambient Temperature	5 °C to 50 °C (40 °F to 120 °F)
Operating Range	-25 °C to +140 °C (-13 °F to +284 °F) At 23.3 °C (74 °F) ambient
Resolution	0.01 °C or 0.01 °F
Control Stability	±0.02 °C (0.04 °F)
Safety	Over voltage (installation) Category II, Pollution Degree 2 per IEC1010-1
Computer Interface	RS-232 (IEEE optional)
Fault Protection	Sensor burnout protection, over-temperature cut-out, and electrical fuses

2.1.2 The Front Panel:

1. Control Indicator:

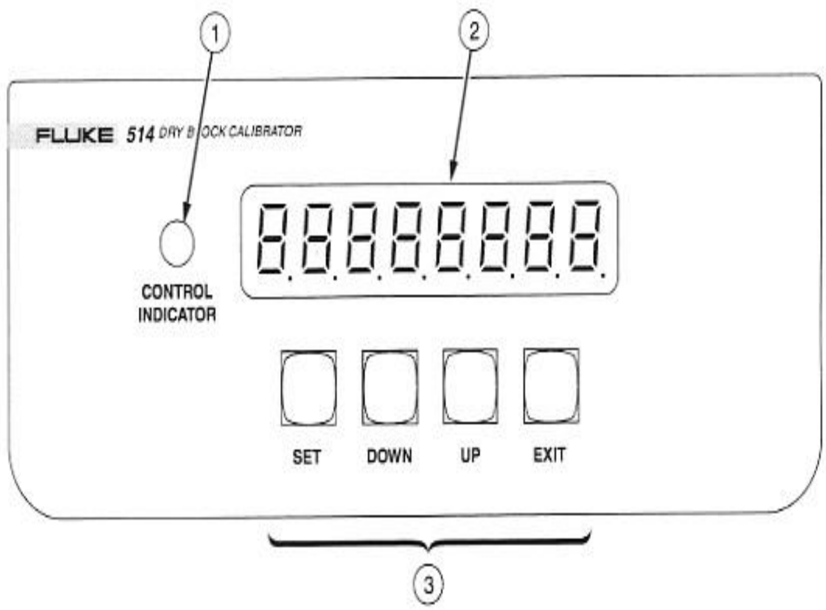
The control indicator is a two-color LED. The indicator shows the ratio of heating to cooling. When it is red, the calibrator is heating and when it is green, the calibrator is cooling. When the LED is flashing, then the temperature is being held constant.

2. Controller Display:

The digital display shows the set-points, actual temperatures, and various calibrator functions and settings.

3. Control Keypad:

The dry-block calibrator in the workshop has push buttons at the front. This is called the front panel. The push-button switches are used to control whatever is available in the calibrator (set-point, scan rate…etc).



2.1.3 Cooling System:

The calibrator has a fan inside it that runs continuously to cool the calibrator down during operation. The area around the calibrator must be clear to allow adequate ventilation.

2.2 Using the Dry-Block Calibrator:

2.2.1 Objectives:

- To get familiar with using the dry block calibrator to heat or cool probes.

2.2.2 Equipment:

- A dry-block calibrator
- A temperature probe or insert

2.2.3 Procedure:

- Connect the calibrator to a 110VAC or 220VAC output socket
- Turn the calibrator on by toggling the power switch at the back
- After a while you should see the display showing a number similar to this:

20.00 C	Well temperature in degrees *Celsius*

This display is for the actual temperature inside the thermowells, the letter on the right shows whether the measurement is in Celsius or in Fahrenheit.

- Setting the temperature involves: (1) selecting the set-point memory and (2) adjusting the set-point value.
- Select a set-point memory by first pressing "SET". The number of the set point memory currently being used is shown at the left of the display, followed by the current set-point value.

2. 50.0	Set-point memory 2 (50.0 °C) currently

Go to set-point memory number 3, then press "SET".

- Next step is when you want to change this set-point value, this is done

New set-point value

through the "UP" and " C - 10.0

memory location to -10 degrees Celsius. Then, you can press "SET" to confirm the value or "EXIT" to cancel it. We want to set the value; so, press "SET".

- Next, set the temperature scale units. The scale can be set to either Celsius (°C) or Fahrenheit (°F). The units are used to display the well temperature and set-points.

Un = C	Scale units currently selected

  Press "UP" and "DOWN" to change this value. For now, set it to C (Celsius). Press "SET".

- Now you have the choice to enable or disable the scan rate. The scan rate is the rate of change of the temperature. This rate of change is measured in degrees per minute. Therefore, if you set the new temperature to 50°C and the scan rate to 10. then, the it will take one minute to change the temperature from let's say 20° to 30° and so on. If the scan rate is set to "OFF", then the calibrator will heat or cool at the maximum possible speed (rate). Press "UP" or "DOWN" and set the scan rate to "On". Then, press "SET".

ScAn=On	Scan function on

- If you have set the scan function to "On", you will have to set the scan rate. You can set the scan rate from 0.1 °C/min to 100 °C/min. Use the

Scan rate set to 3 °C/min

- "UP" and "DOWN" keys to set the scan rate to 7 °C/min. Then press "SET".

- Now you have finished setting the dry-block calibrator. Observe what happens. Test the temperature with the temperature probe and write down your observations.

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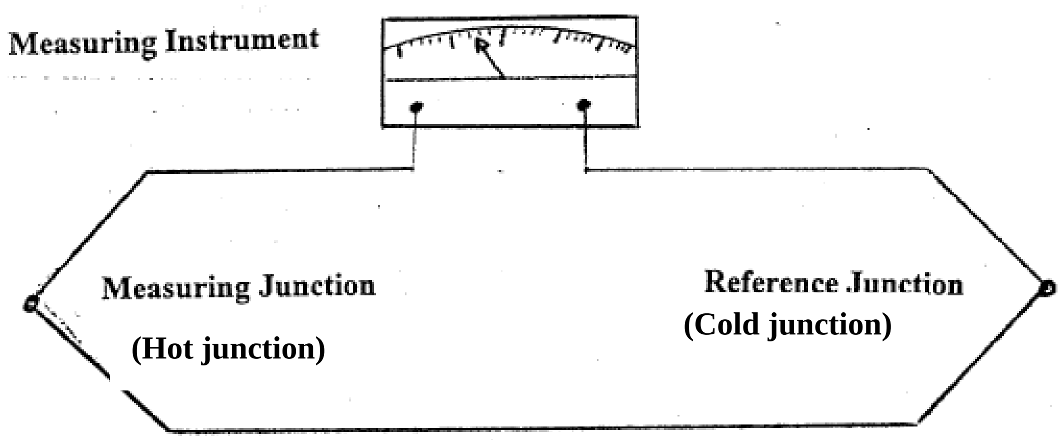
Exercise1: Testing & Measurement of Temperature Using Thermocouple

1.1 Objectives:

- Test different types of thermocouples
- Use standard conversion tables to determine Temperature / Voltage relationship.

Introduction:

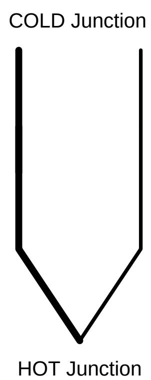
A thermocouple is a temperature-sensing device that generates an electrical voltage when heated. Basically, it consists of two wires made from different metals.
At one end of the thermocouple, the wires are joined together(*hot junction.)*.At the other end (*cold junction),* the wires are connected to



Simple thermocouple circuit

a voltmeter, which measures very small voltage when the hot junction is heated. This phenomenon is known as the *seebeck effect.*

The picture below shows typical thermocouples used in the field.



The thermocouple generates a voltage at its cold junction. So, how can we convert this voltage into degrees Celsius or Fahrenheit?

There is a table for every type of thermocouple that lists the milli-volt outputs of the thermocouple and their equivalent Celsius degrees. You can find the table for the type J thermocouple at the end of this book.

Thermocouples have a color code that defines which terminal are positive and which are negative. This is different from type to type. The table below shows 3 types of thermocouples and some useful information that you might need to know.

TC type	Materials used	Color code	Measurement range
Type J	Iron/ Constantan	White +ve Red -ve	>0 to 750°C
Type K	Chromel/Alumel	Yellow +ve Red -ve	>0 to 1250°C
Type T	Copper/Constantan	Blue +ve Red -ve	>0 to 350°C

1.2 Testing Thermocouple:

1.2.1 Objective:

To be able to test a thermocouple

To be able to take and interpret the voltage readings of a thermocouple

1.2.3Equipment List:

- J and K type thermocouples
- Thermometers

- Dry-block calibrator
- Process Calibrator.

1.2.4 Procedure:

1. Obtain two different types (J and K) of thermocouple.

2. Connect each of the thermocouple to a digital voltmeter.

3. Using a glass tube mercury thermometer, measure the ambient temperature and record it.

4. Insert the thermocouple in to the dry block calibrator and set the temperature you want to measure.

5. Record in the tables below, temperatures and their corresponding DC voltage output of the thermocouple. Then record the temperature using thermocouple table.

No of tests	Temperature (ºC)	At ambient temp. mV	J /Ktype (mV)	(ambient temp. mV) + (J/K type mV)	Temperature (ºC) using thermo. Table
1	30				
2	35				
3	40				
4	45				
5	50				
6	55				
7	60				
8	65				
9	70				

6. Turn OFF and disconnect the dry-block calibrator.

Questions:

1. Write down two applications where thermocouple can be used.

1. furnaces
2. computer components

2. In your opinion, what types of errors could take place when measuring temperatures?

1. wrong multimeter connections
2. not waiting for temperature to stablize
3. inaccurate multimeter
4. inaccurate thermocouple
5. using a large thermowell
6. ambient temperature could have changed

Exercise 2: Calibration of Thermocouple Temperature. Transmitter.

2.1 OBJECTIVES:

- To study the operation of RS 363-0222 Thermocouple Temperature transmitter.
- To study the applications of Thermocouple Temperature transmitter.
- To practice the calibration procedure of Thermocouple Temperature Transmitter.

2.2Equipment List:

- RS 363-0222 Thermocouple transmitter.
- 24 DCV power supply.
- FLUKE 714 Thermocouple calibrator.
- Digital multimeter.
- Wires and screw drivers.

2.3Introduction:

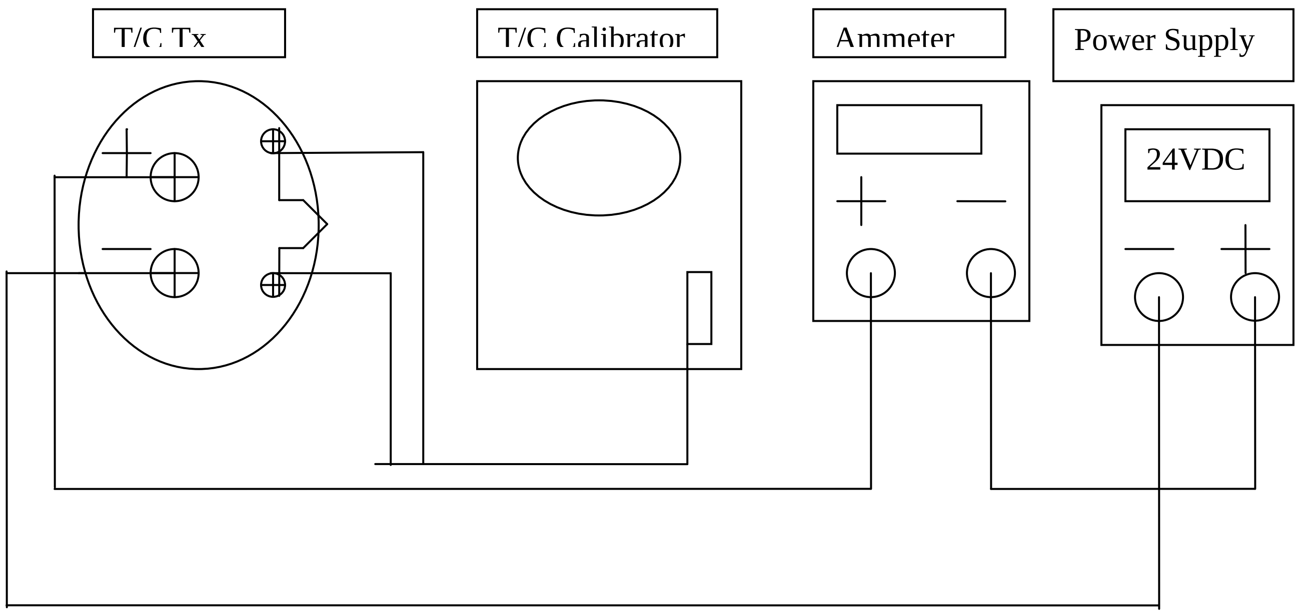
The RS temperature Transmitter (shown above) measures the temperarture detected by ‘K’ thermocouple sensor. 2 wires of thermocouple are connected to Transmitter input terminal. The mill volt change is then converted to a 4 to 20 mA. This measurement signal is transmitted on the same two wires that supply power to the transmitter electronics.

2.4 Calibration Method

Use test equipment that is at least three times as accurate as the desired accuracy of the transmitter.

Calibration is performed by simulating the miillivolt of ‘K’ Type Thermocouple . This is done by connecting the FLUKE 714 Thermocouple calibrator to input terminals.

Set up equipment as shown below:



2.5 How to calibrate transmitter

1. Make the connections as shown in the above figure.
2. Keep the Fluke thermocouple calibrator in OUTPUT mode by pressing the out Button.
3. Using the thermocouple Type Button to get ‘K” type on Display.
4. Select unit as Degree Centigrade.
5. Switch on the 24VDC Power supply.
6. With Increase /decrease Button Keep temperature display at 0 °C
7. Read the current on multimeter. It should be 4mA. If not ,then adjust the Z pot on transmitter to get 4mA out put.
8. On Fluke thermocouple calibrator increase the temperature slowly to 1000°C and read the current on multimeter. It should be 20mA. If

not please adjust the ‘S ‘pot on the transmitter to get the full range current of 20 mA.

9. Repeat the step 6. through 8, till you get the proper current out put.
10. Change the temperature on Fluke thermocouple calibrator in steps of 250°C from 0 °C as shown in Table and Record the current Reading.

Sr. No.	Applied temperature from Fluke Simulator	mA output from Transmitter	Standard Output in mA	% error
1	0°C		4	
2	250°C		8	
3	500°C		12	
4	750°C		16	
5	1000°C		20	
6	750°C		16	
7	500°C		12	
8	250°C		8	
9	0°C		4	

Lesson 3: Study of Pneumatic Temperature Transmitter

3.1 Objectives:

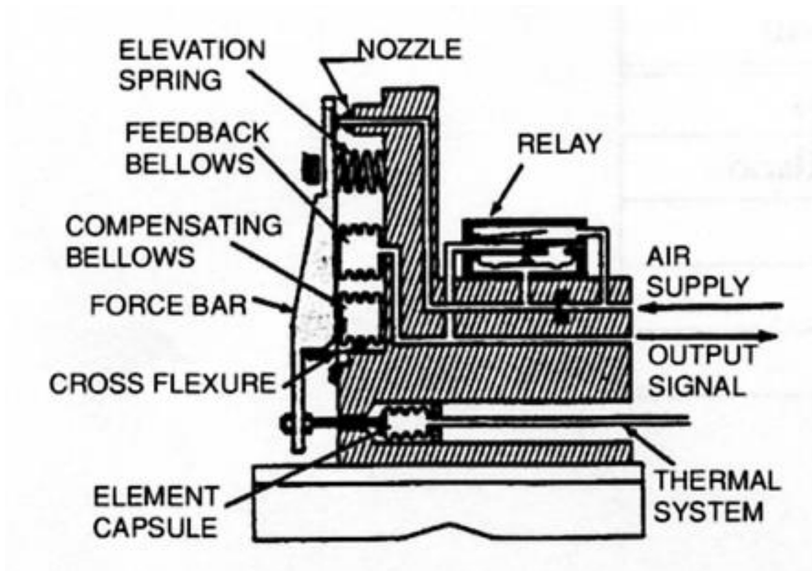
- To study the operation of FOXBORO 12A pneumatic temperature transmitter.

3.2 Equipment List:

- FOXBORO 12A pneumatic temperature transmitter.
- Air pressure supply.
- Pressure gauge 0-30 psi.
- Spanners.
- Screw drivers.
- Plastic tubing connectors.

3.3 Introduction:

The 12A series Temperature Transmitter is a force-balance instrument that continuously measures the temperature and transmits it as a proportional 3 to 15 psi air pressure output signal.



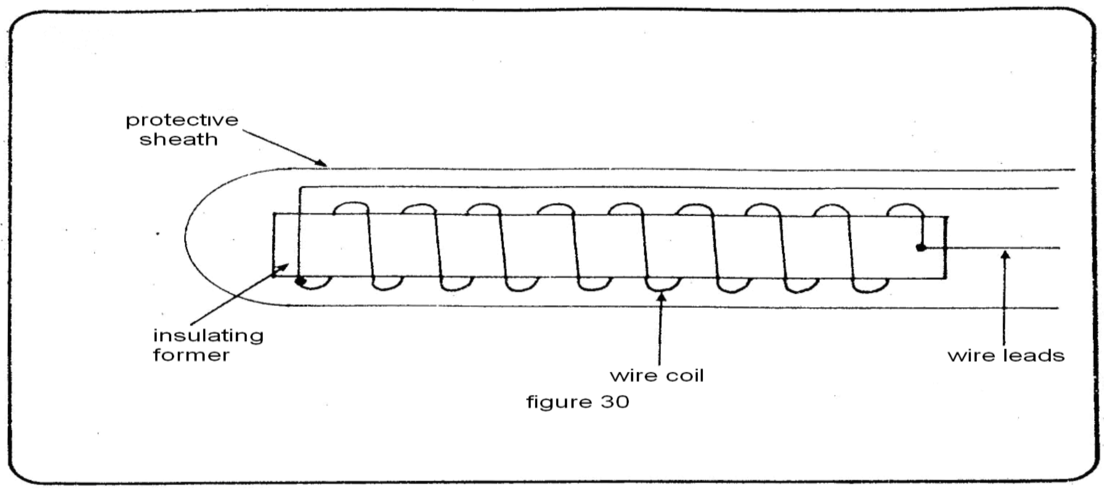
See the Figure above any change in the sensor temperature of the gas-filled thermal element causes a change in the gas pressure and, therefore, a change in the force being applied to the bottom of the force bar. The force bar pivots about a cross-flexure, and any motion of the force bar causes a change in the clearance between the nozzle and the top of the force bar. This produces a change in the output pressure from the relay to the feedback bellows, until the force exerted by the bellows balances the force exerted by the thermal system.

Two additional forces act on the force bar. The elevation spring is used to elevate or suppress the zero of the transmitter, and the compensating bellows is used to compensate for ambient temperature and atmospheric pressure variations.

The output pressure, which establishes the force balance, is the transmitted pneumatic signal. This pressure is proportional to the force exerted by the thermal system and, therefore, is proportional to the measured temperature. The signal is transmitted to a pneumatic receiver to record, indicate, and/or control.

Exercise 3: Testing & Measurement of Temperature using RTD

RTDs are temperature sensors, they work on the principle that when metal is heated up, its resistance increases. They are usually made of a wire wound around an insulator as shown in the figure below. They are favored for their high precision and resolution.



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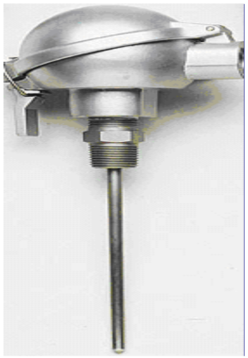
RTD Transmitters convert the resistance measurement to an analog current

3.1 Testing the RTD



3.1.1 Objective:

- To be able to test a RTD
- To be able to take and interpret the resistance readings of a RTD

3.1.2 Equipment List:

- Dry-Block Calibrator
- RTD
- Multimeter and connection leads
- Thermometer

3.1.3 Procedure:

- The RTD which you will be using in this lab session is the FOXBORO type DB Nickel.
- Disconnect the RTD wires from the transmitter.
- Using a mercury tube type thermometer, measure the ambient temperature,

Ambient temp: = ________________________

Using a digital ohmmeter, measure the resistance between the White-and- White wires and Red-and-Red wires. For the ambient temperature, obtain the expected resistance values from the RTD table provided with the RTD.

- Plug in and turn on the dry-block calibrator
- Set the temperature of the calibrator as shown in the table below, observe the Convert of this voltage to degrees Celsius and write down your results.

Temperature Setpoint	**RTD resistance measured**	**RTD resistance Std**
25		
50		
75		
100		

If it is possible to measure temperature using a thermometer, why do we need all this conversion?

……The RTD can send the temperature reading to a remote location…………...

Can the RTD be calibrated?

……No…………………………………………………………………………...

From the results in the table what do you conclude in terms of how good or how bad the instrument is and why did you make this judgment?

……………………………………………………………………………………

. The measurements are close to the true value, therefore the RTD is accurate.

Exercise 4: Calibration of RTD Temperature Transmitter

4.1 OBJECTIVES:

- To study the operation of RS 363-0216 RTD Temperature transmitter.
- To study the applications of RTD Temperature transmitter.
- To practice the calibration procedure of RTD Temperature Transmitter.

4.2 Equipment List:

- RS 363-0216 RTD transmitter.
- 24 DCV power supply.
- FLUKE 712 RTD calibrator.
- Digital multimeter
- Wires and screw drivers.

Introduction:

The RS temperature Transmitter (shown above) measures the temperature applied to the RTD sensor. 3 wire RTD terminals are connected to Transmitter input terminals. The resistance change is then converted to a 4 to 20 mA. This measurement signal is transmitted the same two wires that supply power to the transmitter electronics..

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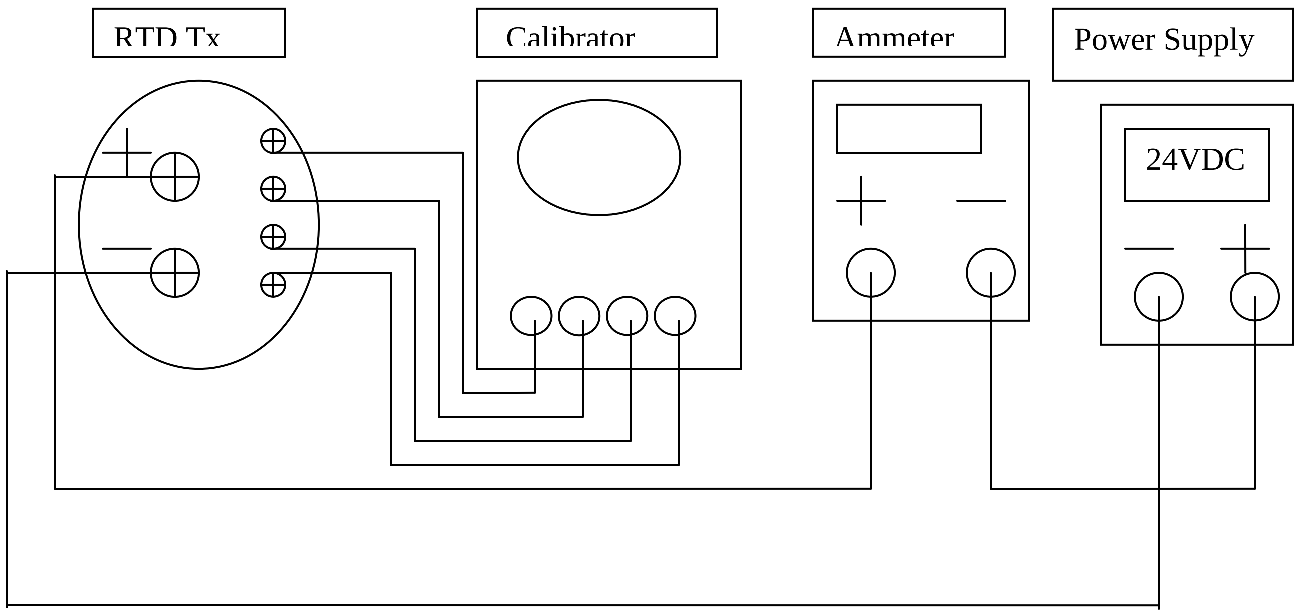
4.3 Calibration Method

Use test equipment that is at least three times as accurate as the desired accuracy of the transmitter.

Calibration is performed by simulating the Resistance of PT-100 RTD. This is done by connecting the FLUKE 712 RTD calibrator to input terminals.

Set up equipment as shown below:



1. Make the connections as shown in the above figure.
2. Keep the Fluke RTD calibrator in OUTPUT mode by pressing the out Button.
3. Using the RTD Type Button get PT-100 on Display.
4. Select unit as Degree Centigrade.
5. Switch on the 24VDC Power supply.
6. With Increase /decrease Button Keep temperature display at 0 °C
7. Read the current on multimeter. It should be 4ma. If not adjust the Z pot on transmitter to get 4mA out put.
8. On Fluke RTD calibrator increase the temperature slowly to 100°C and read the current on multimeter. It should be 20mA. If not please

adjust the ‘S ‘pot on the transmitter to get the full range current of 20 mA.

9. Repeat the step 6. through 8, till you get the proper current out put.
10. Change the temperature on Fluke RTD calibrator in steps of 25°C from 0 °C as shown in Table and Record the current Reading.

Sr. No.	Applied temperature from Fluke Simulator	mA output from Transmitter	Standard Out put in mA	error
1	0°C		4	
2	25°C		8	
3	50°C		12	
4	75°C		16	
5	100°C		20	
6	75°C		16	
7	50°C		12	
8	25°C		8	
9	0°C		4	

Lesson 4: Pressure Measurement & Calibration

Definition:

Pressure is defined as the force applied over a unit area, and can be expressed in the following formula:

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

Where P = Pressure measured in Pascal (Pa)

F = Force measured in Newton (N)

A = Area measured in m^2

Note:

- In pressure measurements, the English system is still being used. Pressure sometimes is expressed in pounds per square inch and is shortened to psi or lb/in^2.
- There is another older unit being used called the bar. 1 bar is equivalent to 14.7psi, or 1ookPa.

4.1 Types of Pressure Measurements:

There are four types of pressure measurement:

1) Atmospheric Pressure:

Although we do not feel it, we are subjected to the pressure of earth's atmosphere. We use sea level as a common reference point, where the air exerts a pressure of 14.7 psi.

2) Gauge Pressure:

Gauge pressure uses atmospheric pressure as the starting point for all measurements. If, for example, a gauge showing 50 psi, this means 50 psi more than atmospheric pressure. Most pressure measurement are taken as Gauge Pressure, abbreviated psig.

3) Absolute Pressure:

Absolute pressure scales use absolute zero as its starting point. Absolute pressure is the complete absence of pressure including atmospheric pressure. Absolute pressure is shortened as psia.

Absolute pressure = gauge pressure + atmospheric pressure

Absolute pressure = gauge pressure + 14.7 psi

In other words, to find absolute pressure, add 14.7 psi to a pressure gauge reading.

4) Vacuum Pressure:

This pressure is measured below atmospheric pressure. It is gauge pressure that is less than atmospheric.

Vacuum pressure is expressed in inches (or mm) of mercury.

Hg is the symbol for mercury.

4.2 Methods of pressure measurements:

There are several methods used to measure pressure in industry.

1) Manometer
2) Bourdon tube
3) Diaphragm
4) Bellows
5) Piezoresistive effect

4.2.1 Manometer:

The basic manometer consists of a uniform glass tube, bent in the shape of a letter U. It is partly filled with a liquid (usually mercury) and both ends are left open to atmosphere as shown in figure 17.

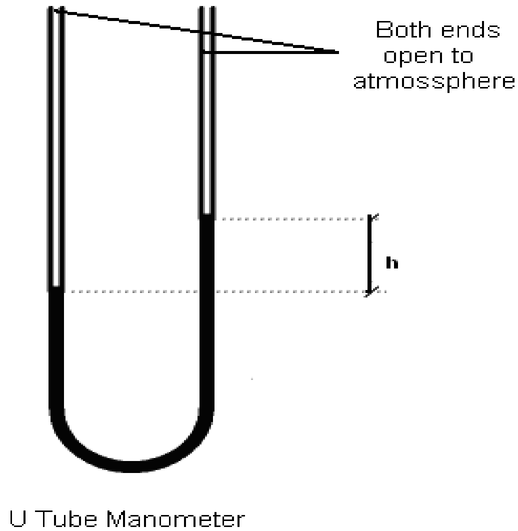


Figure 17

4.2.2 Basic Manometer

The simple U-tube manometer is very cheap and quite accurate and is used to compare a pressure with atmospheric pressure. In figure 18a below both end of the manometer are open to the atmosphere and so the height of the mercury in both sides of the manometer are the same.

In figure (18b), one end is connected to 20 psi input, and the other side is left open. Since the input pressure is more than the atmospheric pressure, the mercury level has risen to the side of the open end.

In figure (18c), the input pressure is less than atmospheric. Therefore the atmospheric pressure raises the mercury level in the 8-psi side.

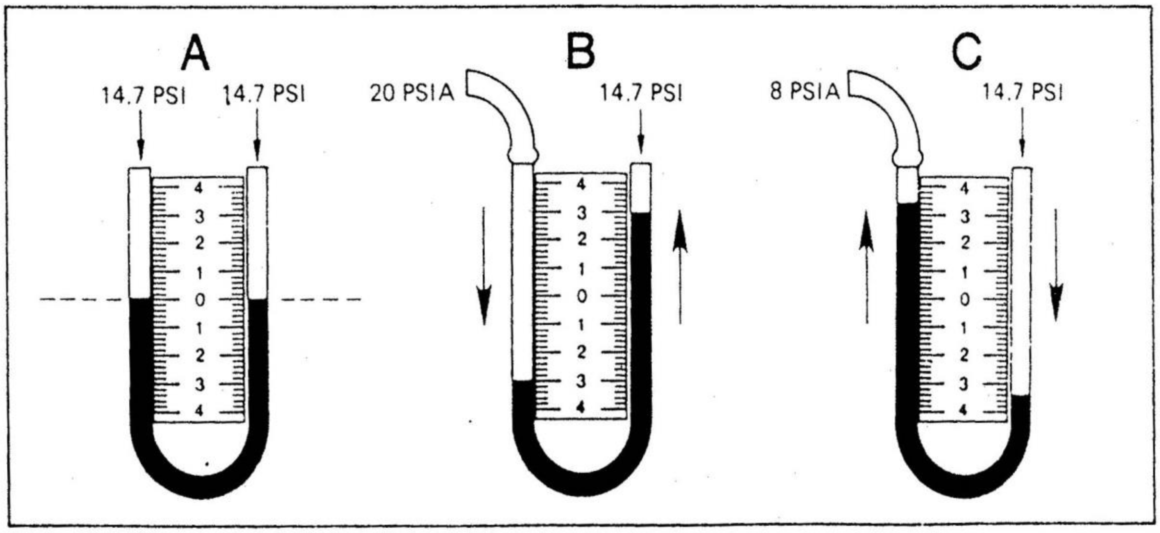


Figure. 18

Manometer can also measure the difference between to working pressures. If one pressure is connected to one end of the manometer and the other pressure is connected to the other side, the difference in the height of the mercury in the two sides is the differential pressure.

Differential pressure is the difference between two different pressures.

4.2.3 Bourdon Tube:

The bourdon tube is a flat oval shaped tube that is bent to form part of a circle. The bourdon tube is a pressure-sensing device. It changes its shape (stretches out) when pressure is applied to it. The movement of the tube is almost proportional with the applied pressure. The total movement of the free end is very small, about 3/8 of an inch. The figure19. shows the Bourdon tube as part of a pressure gauge. The tip of the tube is connected to a gear mechanism, lever and a pointer. When pressure is applied to the gauge, the Bourdon tube moves. This movement causes the gear mechanism to change the position of the pointer on the scale.

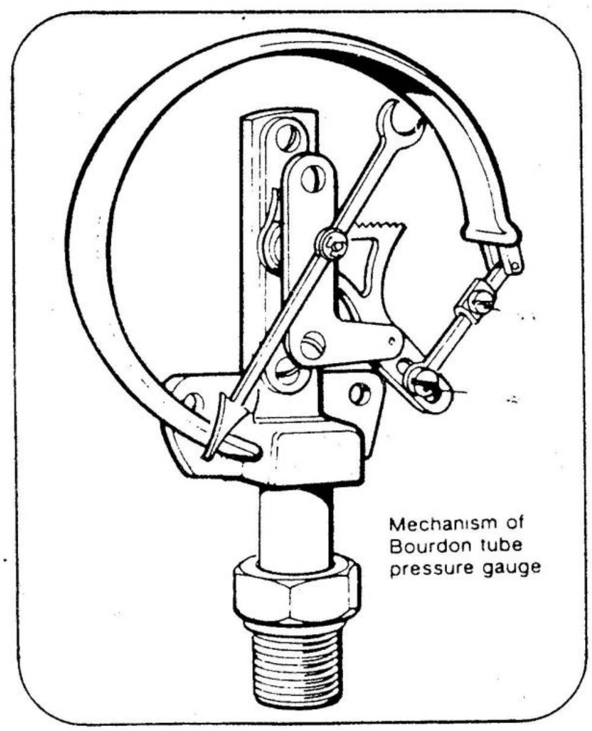
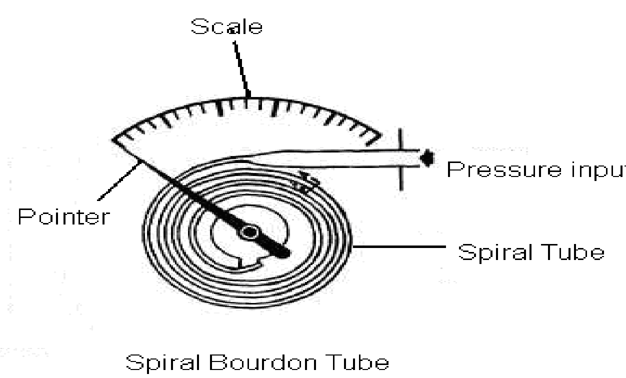


Figure 19

Where greater sensitivity is required, the Bourdon tube may be constructed in the form of a Spiral or Helix. The schematic for Spherical and Helical bourdon tube is shown in figure 20.



4.2.4. The strain gauge and Piezoresistive Effect:

A strain gauge is a device which experience a change of electrical resistance when it is strained. The basic strain gauge consists o f a long wire folded to fit a small area and is mounted on a flexible backing sheet, like paper. If the gauge is firmly stuck to the surface of a more rigid body such as a diaphragm plate, then a change in deflection of the diaphragm will cause an identical fractional change of the stain gauge dimensions and therefore change its resistance.
The typical schematic of strain guage is shown in figure 23.

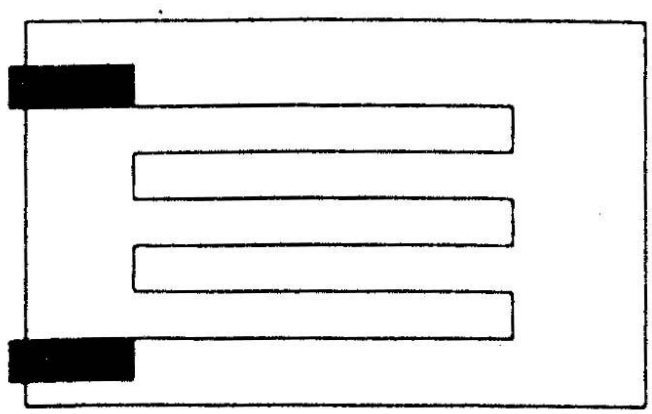
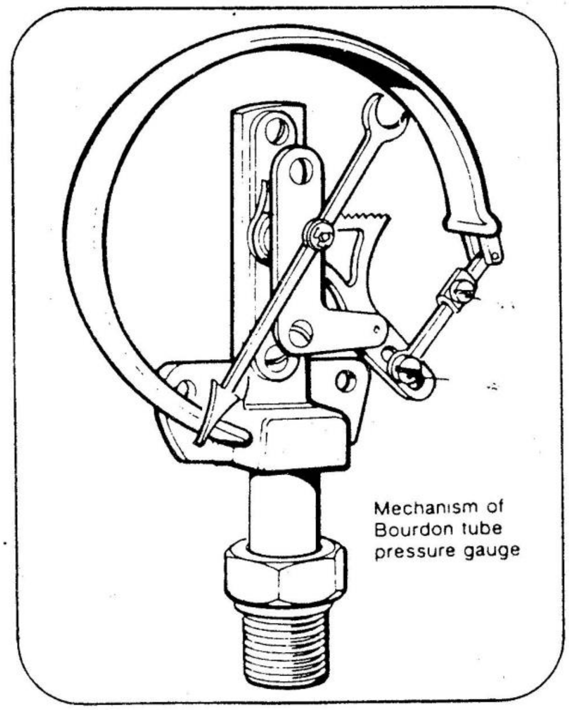


Figure 23

Exercise 5: Pressure Measuring Instruments

5.1 Introduction:



Pressure-sensing instruments usually produce motion in response to a change in pressure .In pressure gauges, the pressure produced causes the needle (pointer) to move. The movement of the needle is proportional to the pressure being exerted.
The main parts of a pressure gauge are the Bourden tube.
It consists of an elastic tube which has been flattened to elliptical cross section and bent into " C "shape with a span of about 270Cº. Bourden tubes increase as pressure applied. They are quite rugged, but too much pressure may cause deformation to the element.
Pressure is applied simultaneously to the test gauge and the gauge under test and a comparison is made between the two.

5.2 Pressure Gauge.

5.2.1Objectives:

- Use pressure gauges to measure pressure
- Carry out a comparison testing
- Assess accuracy, precision and resolution

5.2.2 Equipment List:

- Two Pressure gauges
- Regulated air supply
- Assorted tubing and fittings

5.2.3 Procedure:

1. Note the pressure gauge reading when not connected to the air supply line.

   Is there a zero error?

   Yes No

   If yes, what is the reading?……………….

2. Set the air pressure to zero psi
3. Connect the pressure gauge to the 0 – 30 psi line. Adjust the pressure to the values listed below in the table and record your readings.

True value Pressure in (psi) of bench gauge	Measured value Pressure (psi) of gauge under test	Error = T V - MV	% error = $\frac{\text{Error}}{\text{T V}}$ x 100
30 psi			
25 psi			
20 psi			
15 psi			
10 psi			

4. Set the true pressure value to the values shown below. Using the gauge under test, measure each true value five times and record them in the table below:

True value	1	2	3	4	5
30 psi					
25 psi					
20 psi					
15 psi					

5. Take a second pressure gauge and note the reading when is not connected to the air supply.

Is there a zero error?

Yes No

What does this gauge read?

6. Set the true pressure value to the values shown in the table below. Using the second gauge, measure the true value five times and record these measurements.

True value	1	2	3	4	5
30 psi					
25 psi					
20 psi					
15 psi					

7. Take one of the pressure gauges, which does not have zero error and connect it to the air supply.

8. Set the air supply to 70 psi as shown on the bench gauge and check the indication on your gauge under test.

9. Increase the pressure to 160 psi and then back to 70 psi. Record the reading in the table below.

10. Reduce the pressure to zero psi and then back to 70 psi. Record this reading in the table below.

11. Repeat 2 and 3 five times, at each step record the indication of the bench gauge and the gauge under test.

No of readings for 70 psi	Test gauge measurement	% Error
1		
2		
3		
4		
5		

12. using the above table, construct a graph of actual values against test gauge values.

Questions:

1. In step no 3, was the percentage error more at 30 psi or at 10 psi?

2. In step no 4, did the pressure gauge have good precision? State your reasons.

3. In step no 5, was the second pressure gauge accurate?

4. In step no 6, did the pressure gauge have good precision?

5. What is the pressure per division on the scale of the second pressure gauge?

6. What is the resolution of your pressure gauges?

Exercise 6: Calibration of Differential Pressure Transmitter

6.1 Objectives:

- To study the principle of operation of FOXBORO l3A differential pressure transmitter.
- To study the applications of the transmitter.
- To practice the installation of the transmitter for different applications.
- To practice the calibrations procedure of the FOXBORO 13A transmitter.

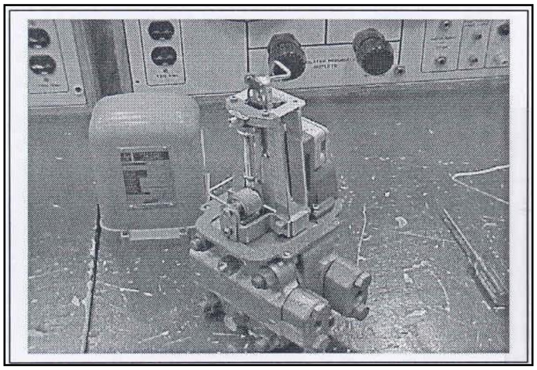
6.2 Equipment List:

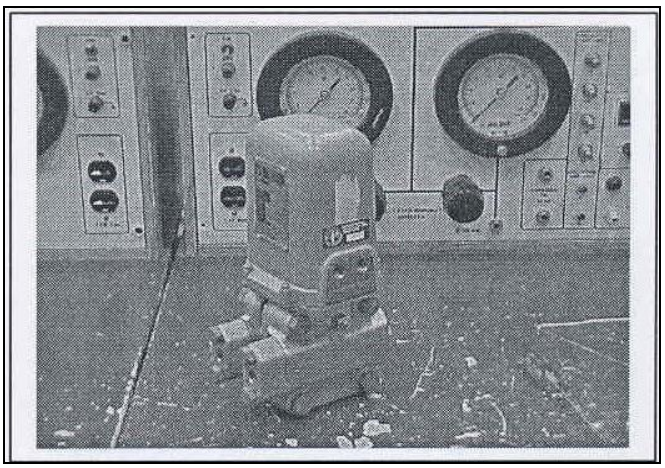
- FOXBORO 13A dip transmitter
- Regulated air pressure supply
- Pressure gage 0-psi.
- Plastic tubing and connectors.

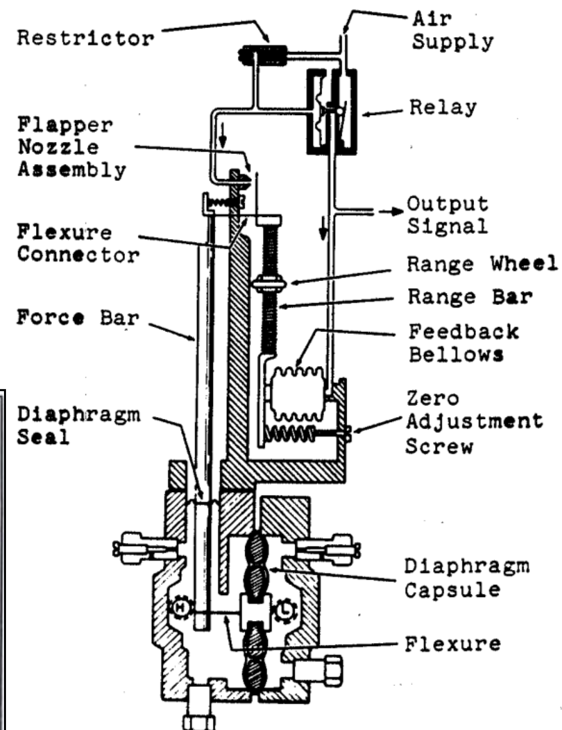
6.3 Introduction:

The 13A series differential pressure transmitter is a pneumatic force-balance instrument that measures differential pressure and transmits a proportional pneumatic output signal. The transmitter is used in flow, liquid level, and other differential pressure applications.
The high and low pressures are connected to opposite sides of a twin-diaphragm capsule. The force on the capsule is transmitted through the flexure to the lower end of the force bar. The diaphragm seal serves both as a fulcrum for the force bar and as a seal for the pressure chamber. The force is transmitted through the flexure connector to the range bar which pivots on the range adjustment wheel.

Any movement of the range bar causes a minute change in the clearance between the flapper and the nozzle. This produces a change in output pressure from the relay to the feedback bellows until the force in the feedback bellows balances the force on the diaphragm capsule.







6.4 Procedure:

<u>Flexure Locknut adjustment:</u>

Make this adjustment if capsule was removed or if flexure locknut was loosened. Flexure locknut holds a force bar and the diaphragm capsule inside the transmitter.

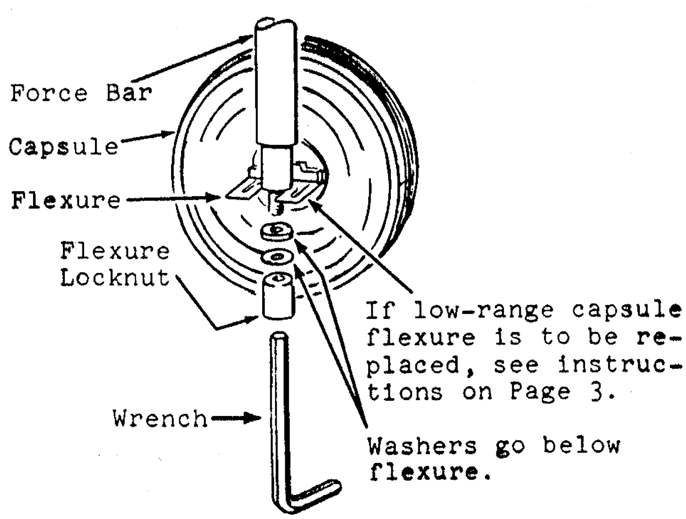
1. Set up equipment as shown in the figure below.
2. Remove the bottom drain plug and loosen flexure locknut with a Y4 inch hex- key wrench.

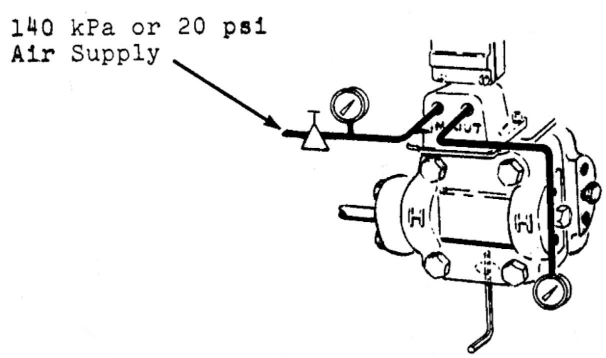
3. With no differential on capsule, adjust zero screw so that output pressure is 20 kpa or 3 psi.
4. Carefully tighten flexure locknut so output pressure does not change by more than 2.7 kpa or 0.4 psi.

If output pressure is not within these limits, loosen locknut and do step 2 again and carefully retighten the locknut.

If output pressure is still not within limits, it indicates that index marks on capsule and body are not aligned. Correct by repositioning capsule. (refer to replace diaphragm capsule section).

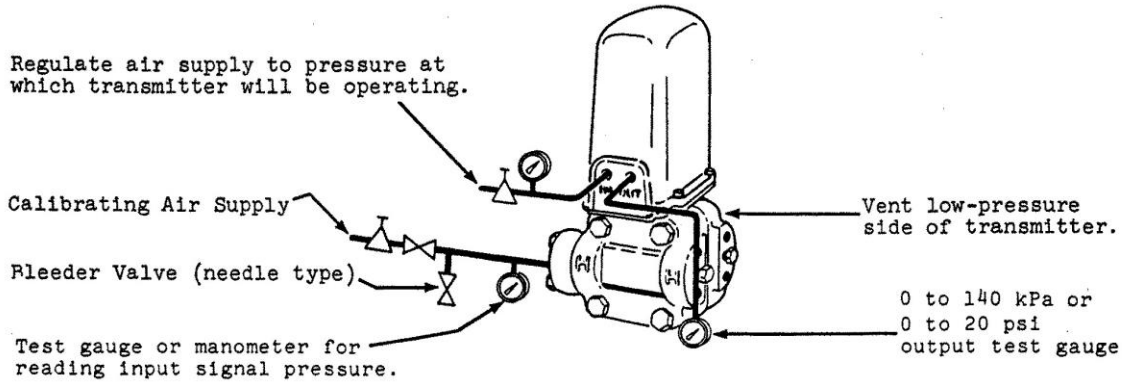
5. When output pressure is within limits with the locknut tightened, replace the bottom plug.
6. Calibrate transmitter.



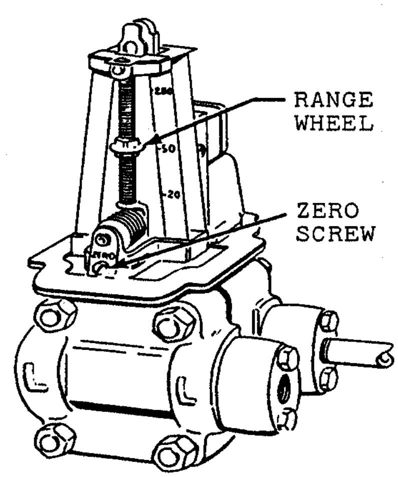


Bench Calibration Procedure:

The figure below shows the piping needed for bench calibration.



1. Set up the calibration equipment as shown in the figure.
2. If diaphragm capsule was removed or if flexure locknut was loosened, adjust locknut (refer to Flexure Locknut Adjustment above).
3. Position range wheel at desired span. Tighten locknut under wheel.
4. With no pressure differential on transmitter, adjust zero screw so that the output is 20 kpa or 3 psi.



5. Apply calibrating pressure equivalent to the upper range value (62 kpa). Output reading should be 100 kpa or 15 psi.

   If output reading is not correct, adjust range wheel until reading is correct. (Note: raising range wheel will lower output reading). Tighten range wheel locknut after each adjustment.

6. Repeat steps 4 and 5 until both outputs are within desired accuracy without adjustment. Check that range wheel locknut is securely tightened.

OUTPUT RANGE	20 to 100 kpa 3 to 15 psi
AIR SUPPLY	120 to 150 kpa or 18 to 22 psi
CAPSULE CODE: M	Span limit ?p:5 to 62 kpa
CAPSULE CODE: H	Span limit ?p: 50 to 210 kpa

6.5 Maintenance of Differential Pressure Transmitter

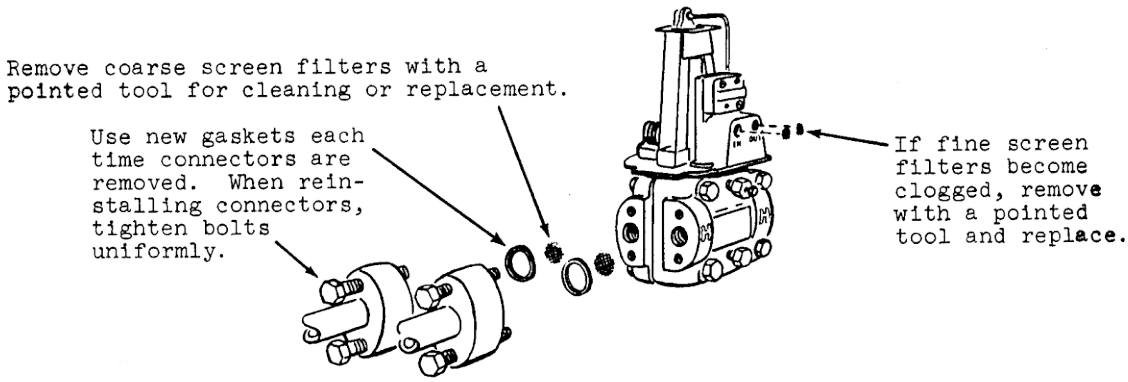
To Clean Nozzle Assembly:

Note: An accumulation *of* dirt at the flapper nozzle may cause a zero shift.

1. Clean nozzle with 0.76 mm diameter wire, compressed air, or suitable solvent. Wipe nozzle assembly to clean.
2. Replace the nozzle assembly.

To Clean or Replace Screen Filters:

1. Uniformly unscrew bolts for the differential input filters cover. Use new gasket each time connectors are removed.
2. Clean or replace the differential input filters.
3. Reinstall the filters, new gasket, and the cover.
4. If fine screen filters become clogged, with pointed tool and replace. (Note do not remove the fine screen filters in this experiment).



To Clean Restrictor:

Note: A plugged restrictor will cause low output pressure.

1. Unscrew restrictor from top of relay base. (Note: On some models restrictor is located either under relay or not side of relay base)
2. Clean with a 0.127 rom diameter wire and fix back

.

To Replace Relay:

1. Remove the two larger screws and pry off the relay. A new gasket must be supplied with each replacement relay.

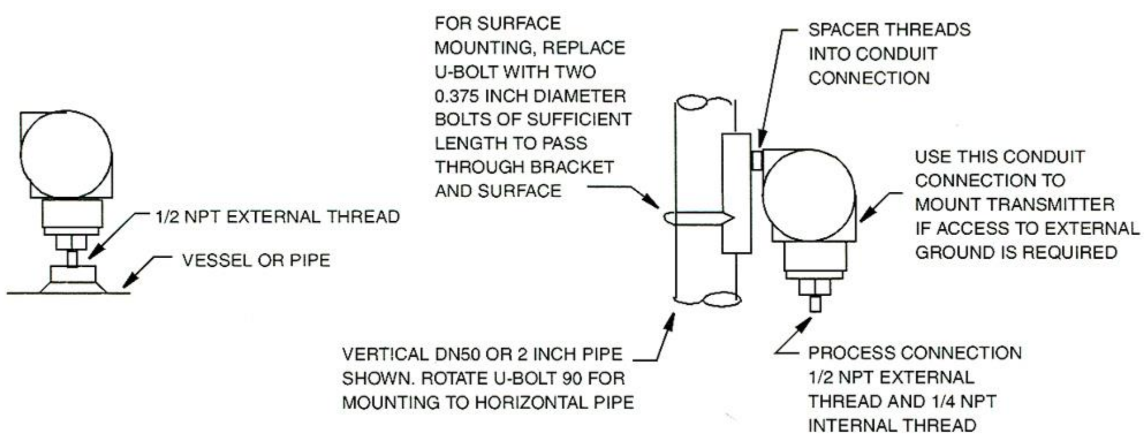
Lesson 5: SIGNAL CONVERTERS

5.1 Standard Installation and Mounting of Pneumatic to Current Converter

5.1.1 Installation and Mounting

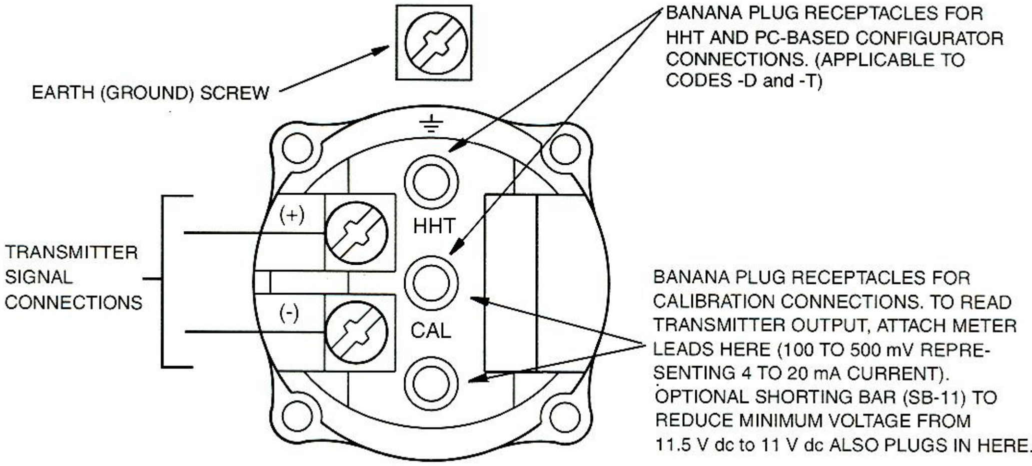
The P/I converter can be mounted directly to the process pipe if the pipe is strong enough to hold the converter.

Or it can be mounted using the mounting set (U-bolt and mounting bracket) to a pipe. If the transmitter is to be mounted to a wall, the U-bolt can be replaced by regular 0.375 inch diameter bolts.



Identification of Field Terminals

For a transmitter with a 4 to 20 mA output signal the field terminals are shown below.



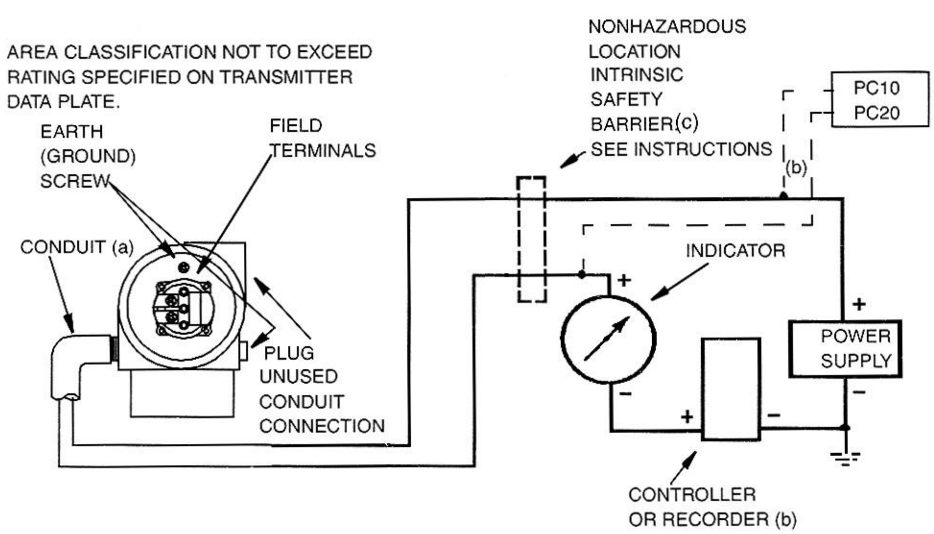
The transmitter signal connections are used for both supplying the transmitter with power and getting the 4 to 20 mA signal.

The HHT plugs are used to connect the instrument with a Hand Held Terminal (HHT) for better configuring and calibrating of the transmitter.

The CAL connectors are used to test the transmitter's output without taking the supply leads out. A voltage signal is produced in the CAL connectors, where 100 mV represents 4 mA and 500 mV represents 20 mA.

Loop Wiring

The figure below shows the the connections needed to wire the instrument to a Process.



Experiment 7: Calibration of Pneumatic to Current Converter

7.1 Objectives:

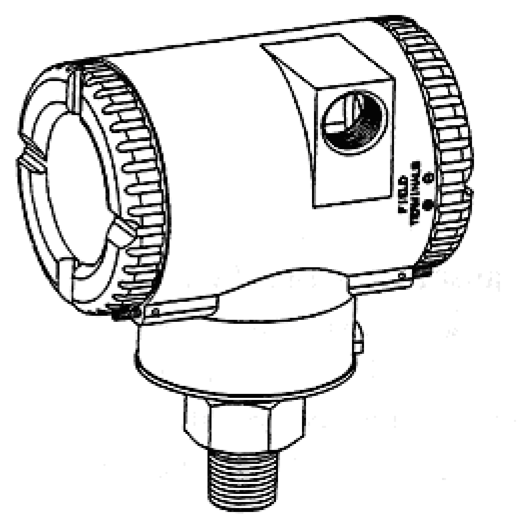
- To study the operation of FOXBORO IPI10-A21F pneumatic to current converter.

- To study the applications of the converter.

- To practice the calibration procedure of the pneumatic to current converter.

7.2 Equipment List:

- FOXBORO IPI10-A21F converter.
- 24 DCV power supply.
- Air pressure supply.
- Pressure gauge 0-30 psi.
- Digital multimeter
- Plastic tubing connectors.
- Wires and screw drivers.
- Spanners.

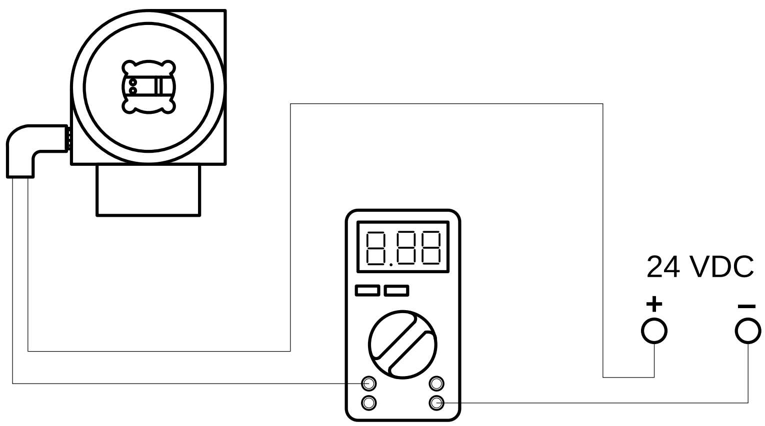


7.3 Introduction:

The pneumatic to current (P/I) converter accept a pneumatic signal from 3 to 15 psi and produce proportional electrical output signal ranging from 4mA to 20mA.
The intelligent pneumatic to current converter measures pressure by applying the pressure to a silicon strain gauge micro sensor. This micro sensor converts the pressure to a change in resistance, and the resistance change is converted to a 4 to 20 mA signal proportional to the pressure. This measurement signal is transmitted to remote receivers over the same two wires that supply power to the transmitter.

The most common application of the converter is to receive a pneumatic signal from a pneumatic instrument and convert it to an electrical signal to control and electrical instrument such as motorized valve or send the signal to DCS.

7.4 PROCEDURE:



1. Set up equipment as shown in the figure above.
2. Turn the power supply and make sure the screen on the converter is on.
3. On the screen of the converter Press *NEXT* **CALP** will appear
4. Press *ENTER* CAL ATO will appear.
5. Set the Input Pressure to zero PSI the Press *ENTER* ATODONE will appear
6. Press *NEXT* CAL LRV will appear then set the Input Pressure to the lower range (3 PSI) then press *ENTER* LRVDONE will appear.
7. Press *NEXT* CAL URV will appear then set the Input Pressure to the upper range (15 PSI) then press *ENTER* URVDONE will appear.
8. Press *NEXT* ADJ 4MA will appear.
9. Press *ENTER* then check the output current if its exactly at 4 mA or press *ENTER* to adjust the output to 4 mA exactly.
10. After the adjustment, press *NEXT* ADJ 20 mA will appear.
11. Press *ENTER* to check the output current wither it is at 20 mA exactly or press *ENTER* to adjust it to 20 MA exactly.

12. After the adjustment press *NEXT* **CANCEL** will appear if you want to cancel the calibration you did press *ENTER* or go to *NEXT.*
13. SAVE will appear press *ENTER* to save the calibration settings.
14. Now the calibration is completed. Fill the table below:

No of tests	Input pressure (psi)	Output current (mA)	Std Current (mA)	% Error
1				
2				
3				
4				
5				

7.5 CALIBRATION DIAGRAM FOR THE P/I CONVERTER

CAL AT0: Calibrates the transducer when the input is at 0 psi

CAL LRV: Calibrates the transducer wher the input is at the Lower Range Value.

CAL URV: Calibrates the transducer wher the input is at the Upper Range Value.

ADJ 4mA: Allows to adjust the output current if it is not accurately at 4mA.

A 4mA▲ ▲: Increases the lower range output by large increments.

A 4mA▼ ▼: Decreases the lower range output by large decrements.

A 4mA▲: Increases the lower range outp by small increments.

A 4mA▼: Decreases the lower range output by small decrements.

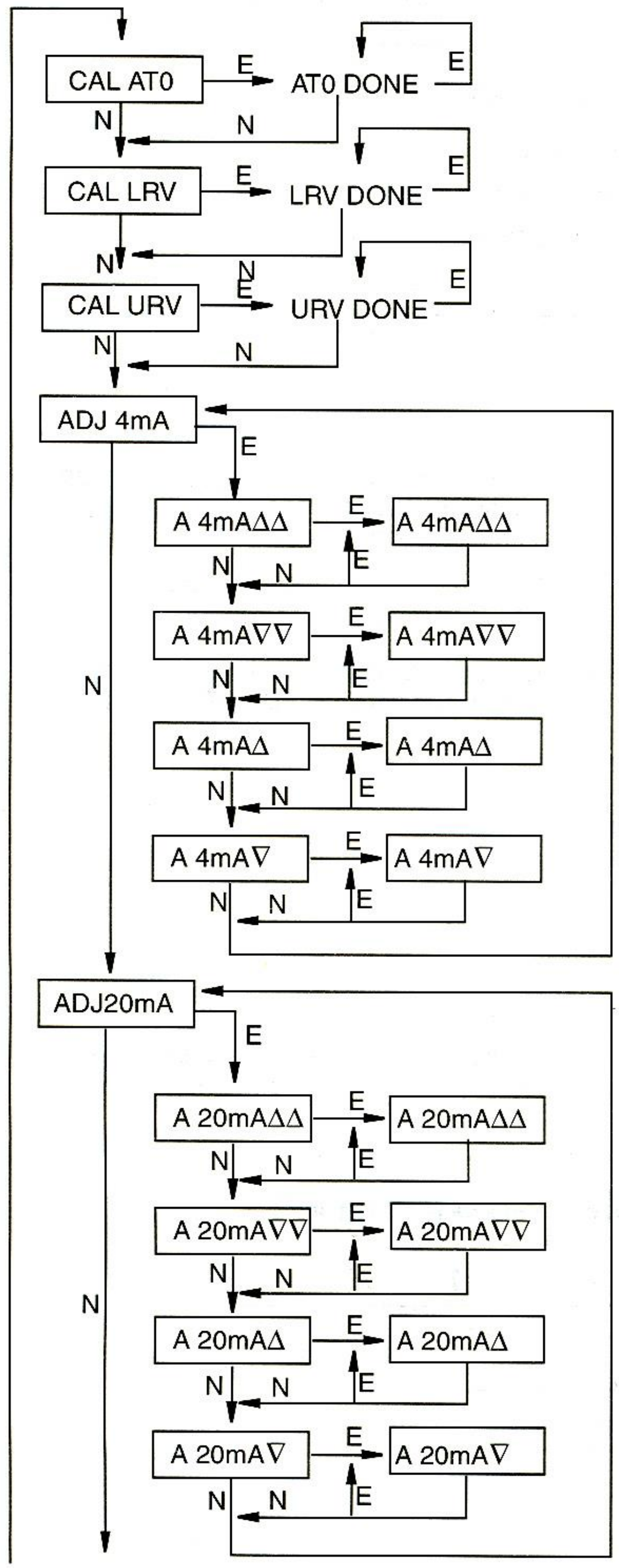
ADJ20mA: Allows to adjust the output current if it is not accurately at 20mA.

A 20mA▲ ▲: Increases the upper range output by large increments.

A 20mA▼ ▼: Decreases the upper range output by large decrements.

A 20mA▲: Increases the upper range output by small increments.

A 20mA▼: Decreases the upper range output by small decrements.



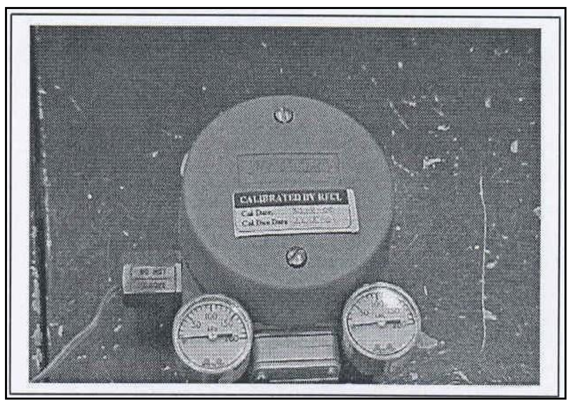
Experiment 8: Calibration of Current to Pneumatic (I/P) Converter

8.1 Objectives:

- To study the principle of operation of FOXBORO E69F current-to-pneumatic signal converter.
- To study the applications of the converter.
- To practice the installation of the converter for different applications.
- To practice the calibration procedure of the current-to-pneumatic converter.

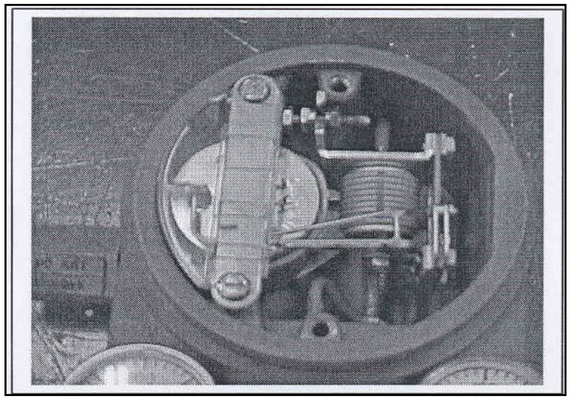
8.2 Equipment List:

- FOXBORO E69F converter.
- Digital calibrator.
- Air pressure supply.
- Pressure gauge 0-30 psi.
- Digital multimeter
- Plastic tubing connectors.



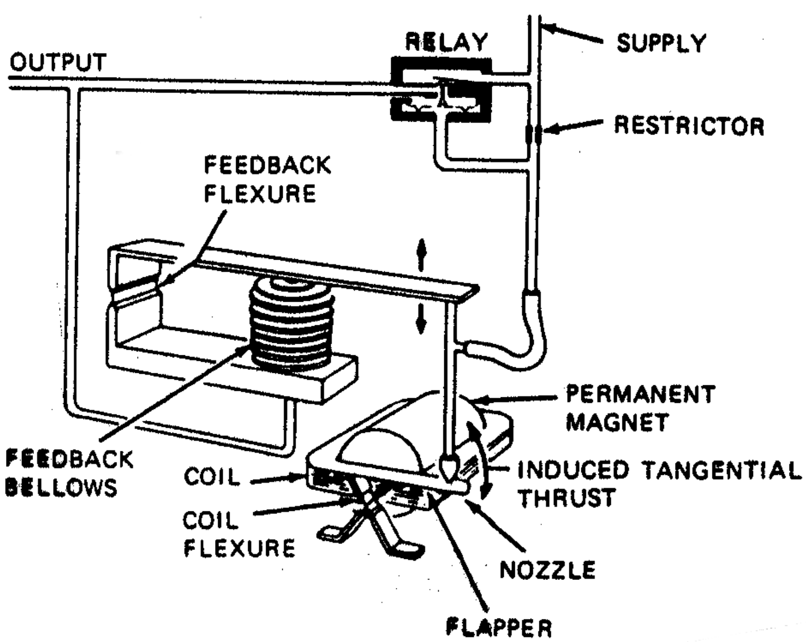
8.3 Introduction:

The E69F current-to-pneumatic signal converter is a field mounted instrument that transforms a dc milliampere input signal to a proportional pneumatic output signal. This output signal will be used to operate another instrument in a process.



A dc mill ampere input signal is converted to a proportional pneumatic output signal in the following manner. A coil positioned in the field of a permanent magnet reacts to the current by producing a tangential thrust proportional to the input signal flowing through it. The thrust varies the gap between a flapper and a nozzle. This causes a change in the output pressure of the relay, which is also the converter output pressure.

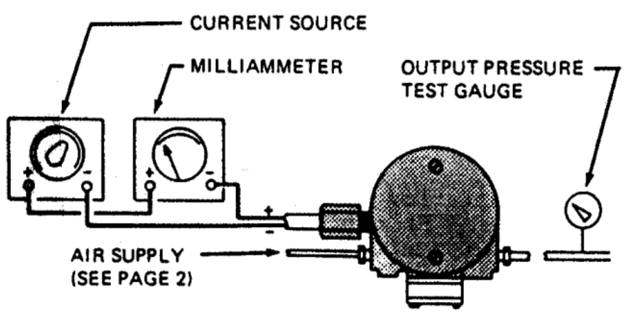
This pressure is fed to a feedback bellows which exerts a force on a feedback flexure to move the nozzle and establish a throttling relationship between the flapper and the nozzle.



INPUT	4 to 20 mA
OUTPUT	20 to 100 kpa or 3 to 15 psi
SUPPLY PRESSURE	140 KPA OR 20 PSI

8.4 Procedure:

The figure below shows the equipment set-up for calibration procedure.



Calibration Procedure:

Set up equipment as shown in Figure

1. Apply 12 mA (50%) input to converter, output should read 60 kpa or 9 psi.

   If reading is not correct, adjust zero screw (see Fig.) to get the correct output.

2. Apply 20 mA (100%) input to converter, output should read 15 psi.

   If the error is greater than 2%, go to step 4.

   If the error is less than 2%, go to step 5.

4a. Loosen 5/16 in bellows locknut. Note reference line on bellows. Rotate bellows so that reference line moves toward motor to decrease span or away from motor to increase span until the error is within 2%. Tighten bellows locknut.

4b. Repeat steps 2 and 3.

5. (Read Caution below) See Fig.3. Loosen the 5/16 inch span locknut (***see caution below***) and turn the 5/16 inch span adjustment nut a proportional

amount needed from step 3 based on the following 1/6 of a turn (point to point) will correct the error by 0.5%.

CAUTION:	The span locknut must be loosened prior to span adjustment. Do not force nuts against each other to make small span changes. Forcing nuts together could result in stripping of threads. Do not over tighten span locknut when locking in lace as threads could become stripped.

6. Disregard output changes that occur when span adjustment is made. Tighten span locknut.
7. Apply 12 mA (50%) input to converter and adjust output (zero screw) to 60 kpa or 9 psi (50%).
8. Apply 20 mA (100%) input and check output for 100 kpa or 15 psi (100%). If output is not correct. Repeat steps 5 through 7.
9. Apply 4 mA (0%) and check output for 20 kpa or 3 psi (0%). If necessary, readjust zero screw for correct output.
10. Apply 100% input and check output. If output is not correct, repeat steps 5 and 8 until both 0% and 100% outputs are correct.

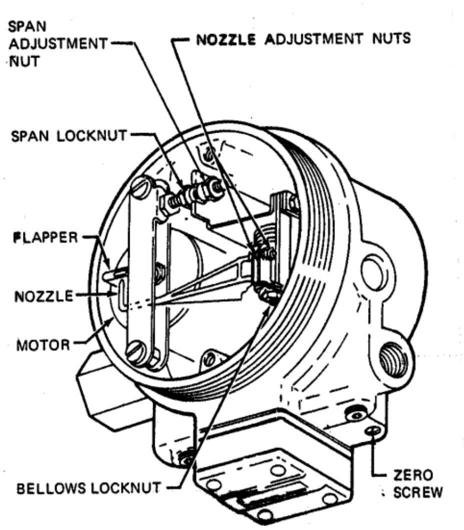


Fig. 5a

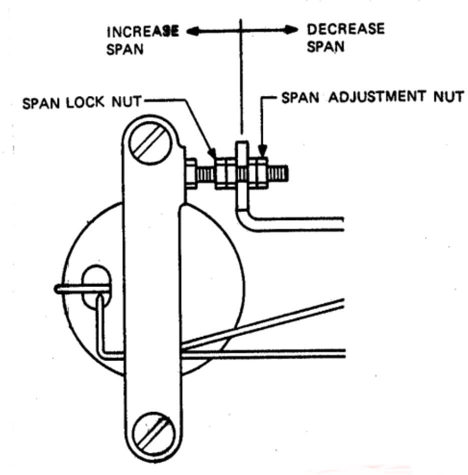
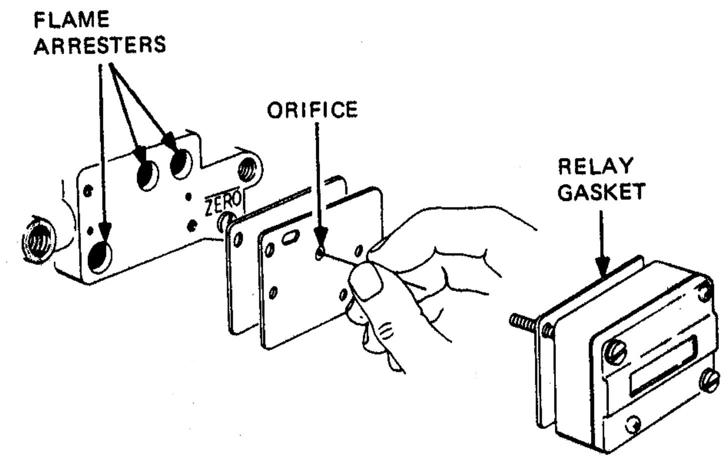


Fig. 5

Relay Maintenance: (See the figure below)

1. Remove the two large screws and pry off relay. A new gasket is supplied with each replacement relay.
2. To clean restrictor, insert 0.1 mm wire through the orifice as shown below.
3. Reinstall the relay.



Questions:

1. Write down two applications where I/P converter can be used .

Experiment 9: Calibration of Electronic Current to Pneumatic (I/P) Converter

9.1Objectives:

- To study the operation of FISHER-ROSEMOUNT 3311 current-to-pneumatic signal transducer.
- To study the applications of the transducer.
- To practice the calibration procedure of the current-to-pneumatic transducer.

9.2 Equipment List:

- FISHER-ROSEMOUNT 3311 transducer.
- Digital calibrator.
- Air pressure supply.
- Pressure gauge 0-30 psi.
- Digital multimeter.
- Plastic tubing connectors.

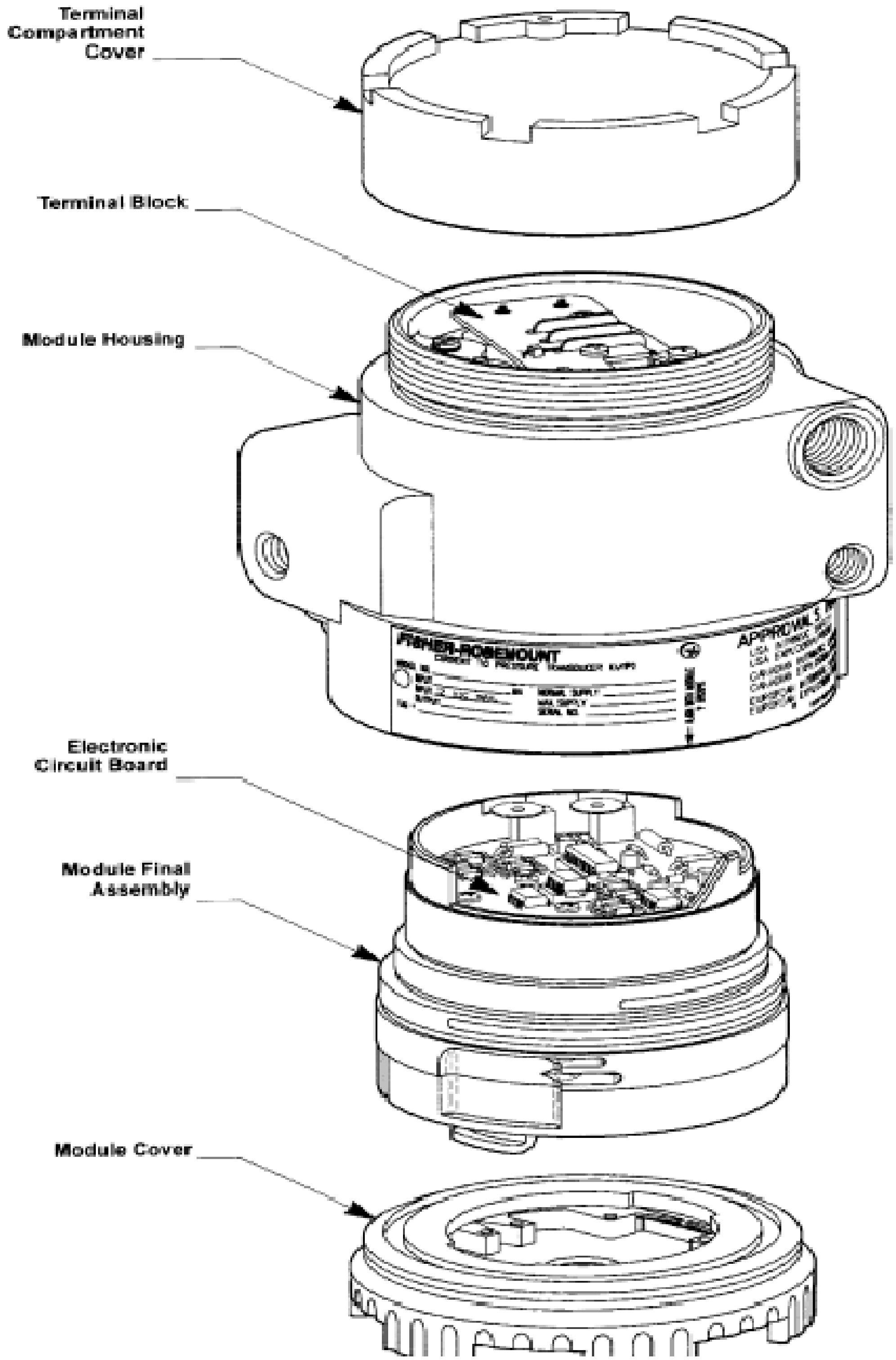
Introduction:

The Current-to-Pressure (I/P) Transducer accepts an electrical input signal and produces a proportional pneumatic output. Typically, 4-20 mA is converted to 3-15 psi (0.2-1.0 kg/cm"). Models are available in direct or reverse action and field-selectable full or split range inputs.

The most common application of the transducer is to receive an electrical signal from a controller and produce a pneumatic output for operating a control valve actuator or positioner. The transducer may also be used to transduce a signal for a pneumatic receiving instrument.

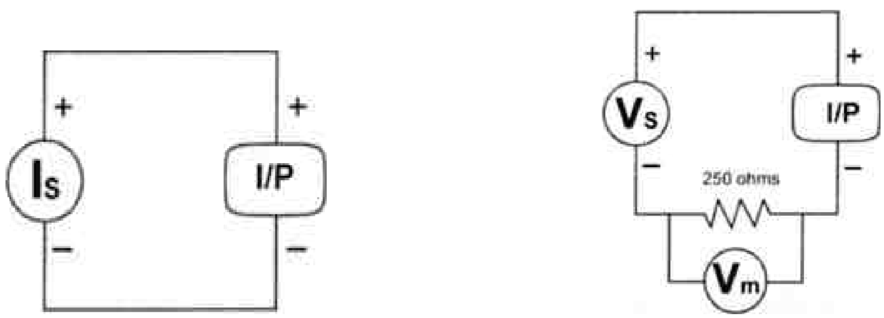
The Model 3311 is an electronic I/P transducer. It has a single electronic circuit board, as shown in Figure 1. The circuit contains a solid-state pressure sensor that monitors output pressure and is part of an electronic feedback network. The self-correcting ability provided by the sensor/circuit combination allows the transducer to produce a very stable and responsive output signal.

All active mechanical and electrical components are incorporated into a single, field-replaceable module called the module final assembly, shown in Figure 1.. The module final assembly is easily removed by unscrewing the module cover. Its design minimizes parts and reduces the time required for repair and troubleshooting.
The terminal compartment and module compartment are separated
by a sealed compartment wall. The dual compartment housing protects the electronics.


Terminal Compartment Cover
Terminal Block
Module Housing
FISHER-ROSEMOUNT
APPROVALS
Electronic Circuit Board
Module Final Assembly
Module Cover

9.3 Procedure:

Calibration of the Model 3311 requires either an accurate current generator or an accurate voltage generator with a precision 250-ohm, ½ watt resistor. The Figure below shows how to connect either device.



Calibration also requires a precision output indicator and a minimum non surging air supply of 3 SCT'M at 20psi for standard performance units. For multi range performance units, the air supply must he at least 3psi greater than the maximum calibrated output pressure, up to 35 psi maximum. For ease of calibration, the output load volume, including the output tubing and output indicator, should be a minimum of 2 cubic inches.

Before calibration, it is necessary to determine the type of input (full or split range), and the type of output action (direct or reverse). The unit supports the following input/output combination: Standard performance full range input, direct action.

- Multirange performance full range input, direct action.
- Standard performance split range input, direct action.

Standard performance full range input, direct action:

Use the following procedure to achieve a standard 3-15 psi (0.2 to 1.0 kg/cm^2) output span for a 4-20 mA input signal:

1. Remove the module final assembly from the housing..
2. Confirm that the unit is direct acting. A green electronic circuit board identifies direct-acting units.
3. Position the range jumper in the “Hi” position which is located in the circuit board jumper positions.
4. Replace the module final assembly in the housing.
5. Connect the air supply to the air supply port.
6. Connect a precision output indicator (pressure gauge) to the output signal port.
7. Make sure that the output gauge port has an output gauge or a threaded plug installed. A threaded plug is provided for I/P units shipped without output gauges.
8. Remove the terminal compartment cover.
9. Connect the current source (or voltage source) positive lead (+) to the terminal block positive (+) and the current source (250-ohm resistor lead) negative lead (-) to the terminal block negative (-). Refer to Figure above.
10. Apply a 4.0 mA (V_m = 1.0 V) signal, and adjust the zero screw to achieve a 3.0 psi output. The output will increase with clockwise rotation of the zero screw.
11. Apply a 20.0 mA (V_m = 5.0 V) signal, and adjust the span screw to achieve a 15.0 psi output. The output will increase with clockwise rotation of the span screw.
12. Repeat Steps 10 and 11 to verify and complete the calibration.

Multirange performance full range input, direct action:

Use the following procedure with a multirange performance unit to achieve the desired direct action output span for a 4-20 mA input signal:

1. Perform steps 1 through 9 of the calibration procedure for **Standard Performance: Full Range Input, Direct Action**.
2. Apply a 4.0 mA (V_m = 1.0 V) signal, and adjust the zero screw to achieve the desired lower psi limit of the output range. The lower limit must be between 0.5 psi (0.03 kg/cm^2) and 9.0 psi (0.6 kg/cm^2). The output will increase with clockwise rotation of the zero screw.
3. Apply a 20.0 mA (V_m = 5.0 V) signal, and adjust the span screw to achieve the desired upper psi limit of the output range. The span must be at least 6.0 psi (0.4 kg/cm^2). The maximum upper limit is 30.0 psi (2.0 kg/cm^2). The output will increase with clockwise rotation of the span screw.
4. Repeat steps 2 and 3 to verify and complete the calibration.

Standard performance split range input, direct action

Use the following calibration procedure to produce a 3-15 psi (0.2-1.0 kg/cm^2) output span for a 4-12 mA input signal:

1. Perform steps 1 through 9 of the calibration procedure for Standard Performance: Full Range Input, Direct Action .
2. Apply an input of 4.0 mA (V_m = 1.0 V), and adjust the zero screw to achieve an output of 3.0 psi (0.2 kg/cm^2).
3. Apply an input of 12.0 mA (V_m = 3.0 V), and adjust the span screw to achieve an output of 15.0 psi (1.0 kg/cm^2).
4. Repeat steps 2 and 3 to verify and complete the calibration.

Use the following calibration procedure to produce a 3-15 psi (0.2-1.0 kg/cm^2) output span for a 12-20 mA input signal

1. Perform steps 1 through 9 of the calibration procedure for Standard Performance: Full Range Input, Direct Action.
2. Apply an input of 4.0 mA (V_m = 1.0 V), and adjust the zero screw to achieve an output of 3.0 psi (0.2 kg/cm^2).
3. Apply an input of 12.0 mA (V_m = 3.0 V), and adjust the span screw to achieve an output of 15.0 psi (1.0 kg/cm^2).
4. Maintain the input of 12.0 mA (V_m = 3.0 V), and adjust the zero screw to achieve an output of 3.0 psi (0.2 kg/cm^2). The unit may not turn down this low; if it does not, go to step 7.
5. If the output reaches 3.0 psi (0.2 kg/cm^2) in Step 4, apply an input of 20.0 mA (V_m = 5.0 V) and note the error (the actual reading versus 15.0 psi). Adjust the span screw to overcorrect the error by a factor of two. For example, if the reading was 14.95 psi (0.9 kg/cm^2), adjust the span screw to achieve an output of 15.05 psi (1.1 kg/cm^2).
6. Repeat steps 4 and 5 to verify and complete the calibration.
7. Turn off the air supply. Remove the module final assembly from the housing. Place the range jumper in the "Lo" position, which is located in the circuit board jumper positions. Turn on the air supply.
8. Apply an input of 12.0 mA (V_m = 3.0 V), and adjust the zero screw to achieve an output of 3.0 psi (0.2 kg/cm^2).
9. Apply an input of 20.0 mA (V_m - 5.0 V), and note the error (the actual reading versus 15.0 psi). Adjust the span screw to overcorrect the error by a factor of two. For example, if the reading was 14.95 psi (0.9 kg/cm^2), adjust the span screw to achieve an output of 15.05 psi (1.1 kg/cm^2).
10. Repeat steps 8 and 9 to verify and complete the calibration.

Input current (mA)	Output Pressure (psi)	Standard O/P	% Error
4			
8			
12			
16			
20			

Review Questions:

1) From what you observed in the readings above, explain whether the device is working fine or not.

……………………………………………………………………………………………

2) What do you comment on linearity?

……………………………………………………………………………………………

3) What will be the effect on linearity when following reverse step (20ma – 4ma).

……………………………………………………………………………………………

4) Can this calibrator +ve and –ve terminals can be interchanged.

……………………………………………………………………………………………

Lesson 6: Flow Measurement and Calibration

6.1 Introduction:

Flow is the term used to describe the quantity of fluid or material passing a given point.. The physical properties of fluids in flow metering are pressure, density, velocity and viscosity.

a) Velocity:

The velocity of a flowing fluid is its speed in the direction of flow. When the average velocity is slow, the flow is laminar. This means that the fluid flows in layers with the fastest moving layers toward the center and the slowest moving layers on' the outer edges of the stream. As the velocity increases, the flow become turbulent. The layers disappear, and the velocity across the stream is more uniform. The figure 30a shows the difference between laminar and turbulent flow.

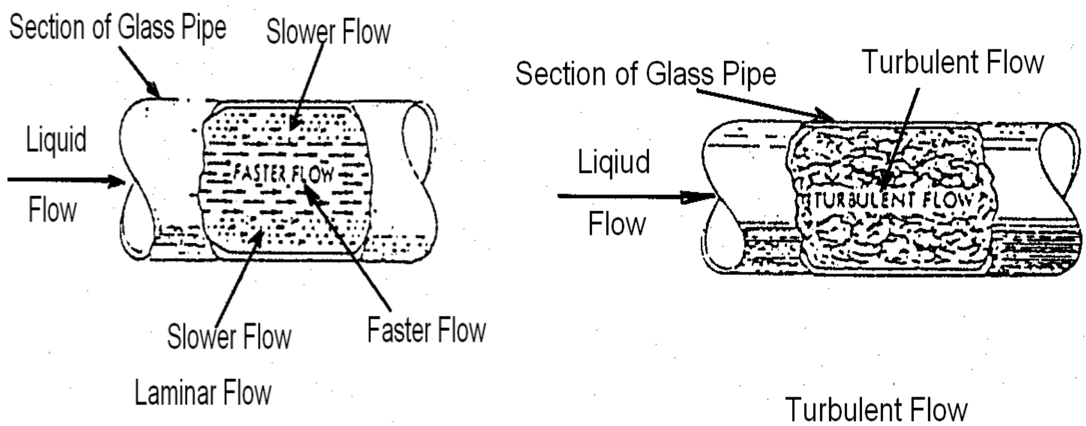


Figure 30a

b) Viscosity:

The viscosity of a fluid refers to its physical resistance to flow. Oil is more viscous than water and water is more viscous than gasoline.

Where the quantities are identified in the figure. The SI unit for viscosity is called poise (P) .

c) Flow Measurement:

To measure the flow in industrial applications, devices and instruments are required. There are a number of devices used to measure the rate of flow of fluid. In this chapter I we will look at different basic instruments and methods used in flow measurement.

Primary devices:

The flow rate of fluid in a pipe is related to the difference in pressure across a restriction inside the pipe. Forcing the fluid through a reduced area causes the pressure on the upstream side of the restriction to .be greater than the pressure on the downstream side as seen from figure 31.

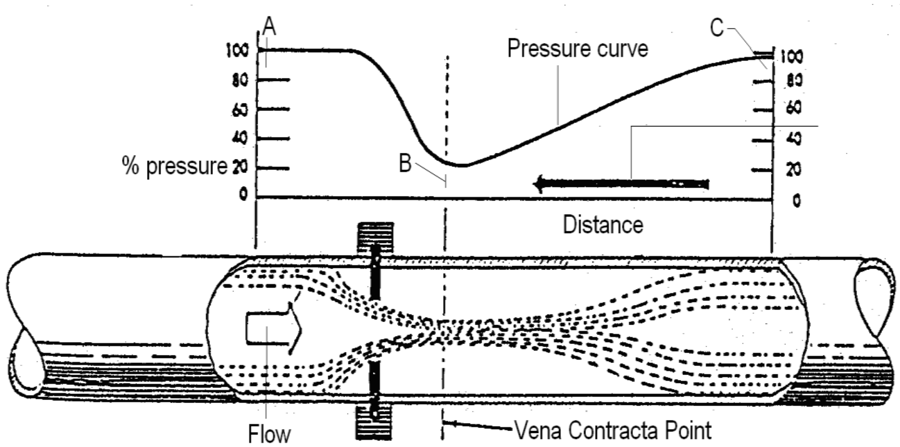


Figure 31

The purpose of the primary measuring ORIFICE PLATE devices is to create a difference in pressure in a flowing fluid (or gas). A secondary device, such as manometer, or other differential pressure measuring instrument, is installed to measure this pressure to determine the velocity or volume flow rate of the fluid As shown in figure 32.

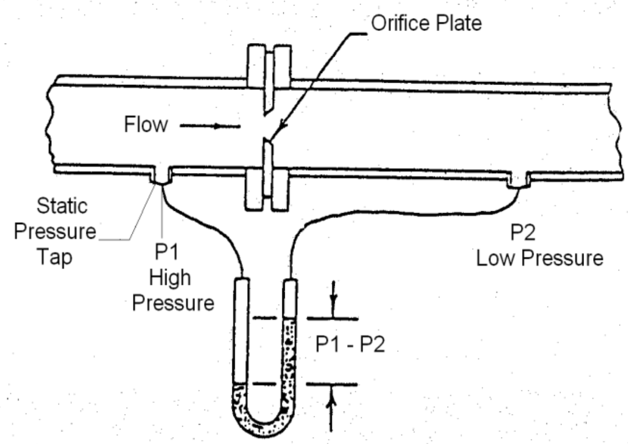


Figure 32

6.2. Orifice plate:

The simplest primary device perhaps is the orifice plate. An orifice plate is a thin, circular disk metal plate with a hole in it. The shape and location of the hole depends on the type of orifice and I application. Different types of orifice plate are shown in figure 33.

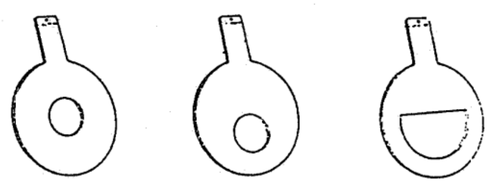


Figure 33

It is placed within the pipe carrying the fluid. A pressure is built up in front of the disk as the fluid moves toward it. As the fluid moves through the opening, the pressure behind the plate is reduced. A typical orifice installation is shown In the figure 34.

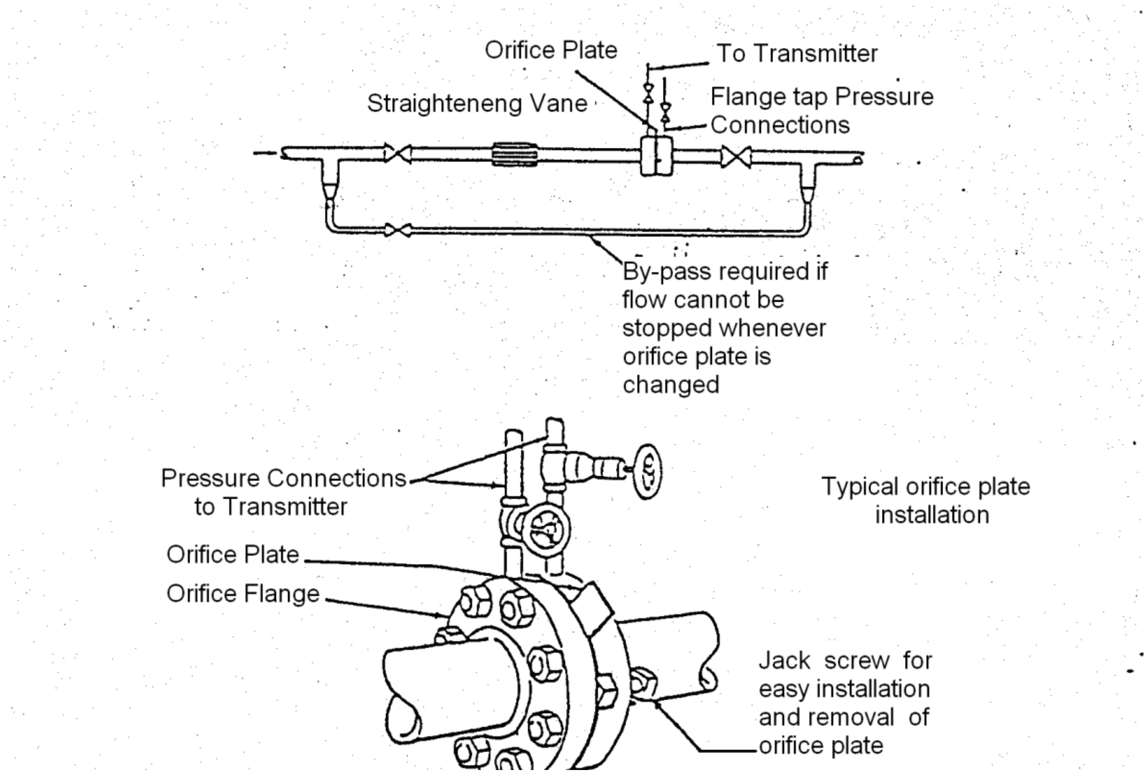


Figure 34

To obtain the pressure developed in the upstream and in the downstream; it is required to install taps in the pipe on both sides of the plate. The location of the taps is critical and varies from one application to another and manufacturer recommendations must be followed.

Types of orifice plates:

As already shown in figure 33, the orifice is usually made of stainless steel but other materials, such as, nickel, steel, glass, plastic and other materials are used.

Concentric:

A conventional orifice plate consists of a thin circular plate containing a concentric hole. The most popular orifice plate is the sharp-edged concentric plate. The upstream of the plate usually is polished While the edge of the orifice bore must be square and sharp, a 45 degree chamber or bevel on the down stream side is permissible if the plate must be made thicker to resist warping excessive pressure. The quadrant-edge orifice plate is for measuring very viscous fluid and is seldom used. Its upstream edge is round, not sharp.

Eccentric and Segmental:

Fluids often carry solids in suspension. When these fine particles settle out of the flow, they can cause errors. As they fall to the bottom of the pipe, its area becomes smaller and it is no longer perfectly round. An eccentric hole that is bored off-center, usually tangent to the bottom of the flow line, will often   overcome this problem. The fluid velocity simply sweeps the solids through the orifice.

When solids are very heavy, it may help to use a segmental bore.
Weep hole in orifice plate:

Orifice plate that are to handle-liquids containing small amounts of dissolved air should contain a small vent hole bored at the top (usually called sweep hole) to permit the air to pass through the plate. Without this hole large errors can exist in measuring differential pressure.
Orifice plates for use with steam should have a similar hole drilled at the bottom to drain any condensed steam.

6.3 Venturi tube:

Figure 35 represents a basic venture tube; it is another primary device the venturi tube produces a large differential pressure with a minimum permanent pressure loss. It has higher advantage of being able to measure flows containing suspended solids. Its cost is high when compared to orifice plate.

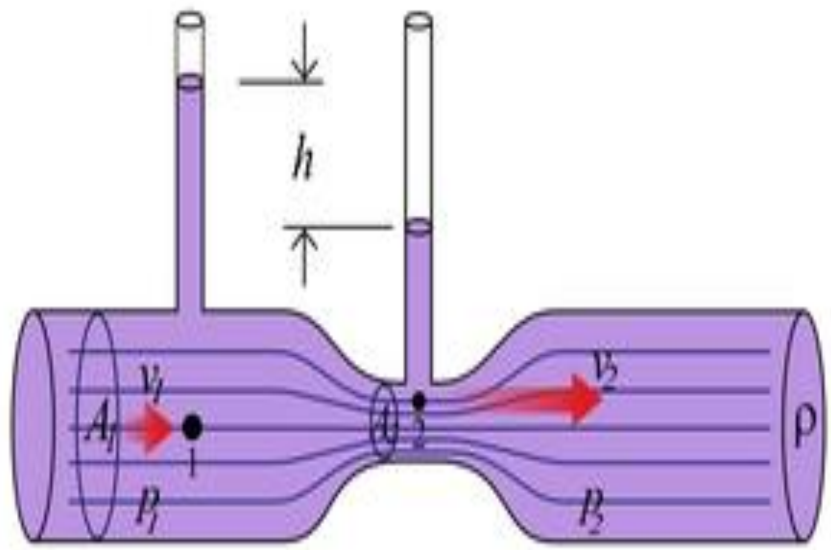


Figure 35

The pressure at "1" is higher than at "2" because the fluid speed at "1" is lower than at "2".

The limiting case of the Venturi effect is choked flow,

Exercise 10: Testing Flow Measurement using Venture & Orifice

Orifice Plate:

10.1 Objectives:

- To see the effect of installing an orifice plate in a process flow.
- To be able to measure flow using the orifice plate.

10.2 Equipment List:

The flow process station trainer

- A multimeter
- Connection leads
- Connection tubes

10.3 Procedure:

- Connect the d/p transmitter to the 24VDC power supply.
- Set the multimeter to DC current measurement and connect it in series to the transmitter.
- Turn on the main power switch
- Make some flow by turning the pump on for medium speed (say 25 Hz). Then vent the tubes connected to the transmitter. Any air left will cause a faulty reading, so this step is important
- Press the STOP button to stop the pump. Observe the reading of the multimeter.

  I = ___________________

- Change the speed of the pump so that the rotameter reaches its maximum value (10 gpm). What is the value that you off of the d/p transmitter?
- I = ___________________

  Is the transmitter working properly?. How do you know?

  ………………………………………………………………………………

Venturi tube:

10.4 Objectives:

- To be able to measure flow using the venturi tube.

10.5 Equipment List:

The flow process station trainer

- A multimeter
- Connection leads
- Connection tubes

10.6 Procedure:

- Remove the orifice plate from last experiment.
- Replace the orifice plate with a venturi tube.
- Connect the d/p transmitter to the 24VDC power supply.
- Set the multimeter to DC current measurement and connect it in series to the transmitter.
- Turn on the main power switch.
- Make some flow by increasing the speed of the pump to medium speed (say 25 Hz). Then vent the tubes connected to the transmitter. Any air left will cause a faulty reading, so this step is important
- Press the STOP button to stop the pump. Observe the reading of the multimeter.

  I = ___________________

  Change the speed of the pump so that the rotameter reaches its maximum value (10 gpm). What is the value that you off of the d/p transmitter?

  I= ___________________

- Is the transmitter working properly? If not, why didn't you get good readings?

  ……………………………………………………………………………

  ……………………………………………………………………………

Lesson 7: Level Measurement and Calibration

The most important factor to consider when measuring level is whether the tank is open to atmosphere or closed.

The simplest method to measure level is by use of a sight glass tube. This tube is fitted near the tank and gives an indication of to where the fluid has reached in terms of height. The figure below on the left shows how the sight glass meter is used and on the right is a picture of some industrial sight glass tubes.

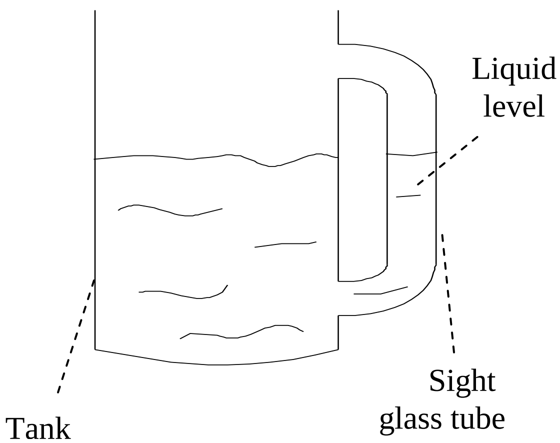


Figure 36

Although the sight glass method is old, it gives a visual direct indication of the level of fluid inside a tank. The sight glass tube however cannot be used for viscous fluids as it would be difficult for the fluid to enter and move freely inside the tube. The other disadvantage is that no signal (electrical or pneumatic) can be sent through the sight glass tube.

7.1 Float sensors:

Float sensors are used mostly in houses but you can find some of them in the industries. When the level of a tank rises, the buoyancy of the float sensor will lift it up. The float is then connected by a mechanism to a level sensing element. Float sensors are often used as switches so that when a certain level is reached the float will change over a switch.

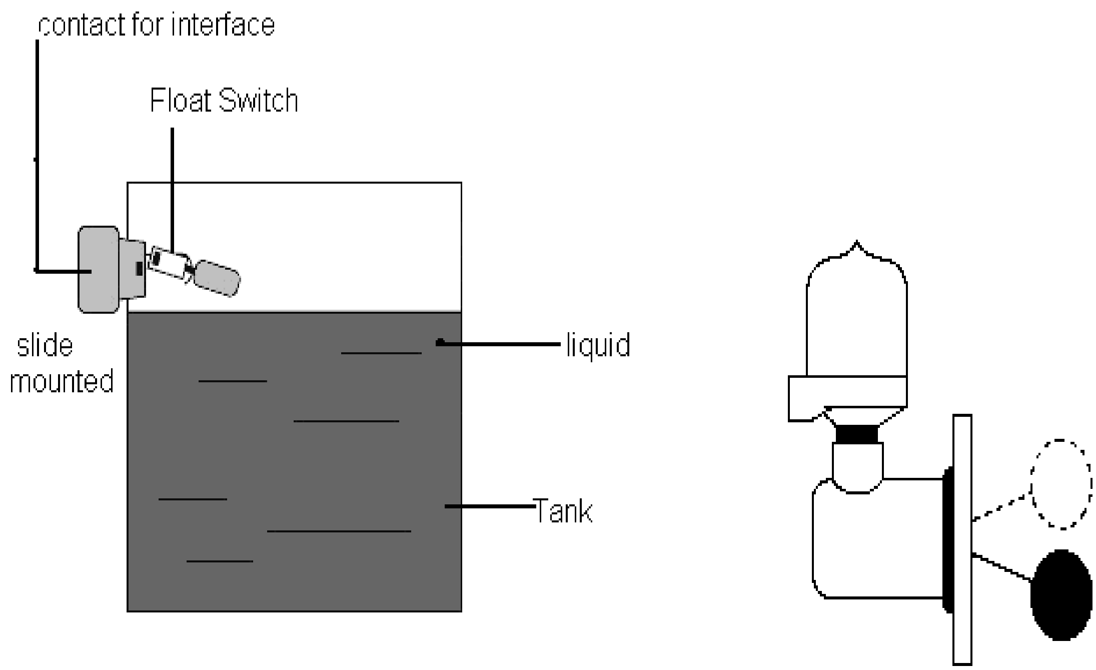
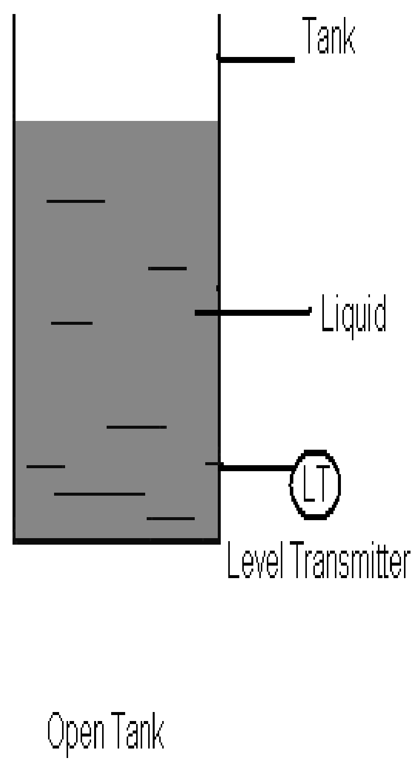


Figure 35.

7.2 Pressure-Level Instruments:

As level increases, there will be more material applied to the bottom of the tank. This material has weight in the form of pressure. Therefore, a pressure measuring instrument can be connected at the bottom of the tank and this pressure is then converted to a level signal. More pressure means more material exist and therefore the level in the tank has increased.

Measuring pressure in closed tanks is different from in open tanks. Lets assume that we are using the d/p transmitter to measure pressure. The high side will be connected to the bottom of the tank and the low side can be open to atmosphere. But when a closed tank is used, the space above the level might have some gases that exert additional pressure to the process. Therefore, the low side of the transmitter must be connected to the top of the tank in order to compare it with the high side that contains only liquid as shown in the figures.



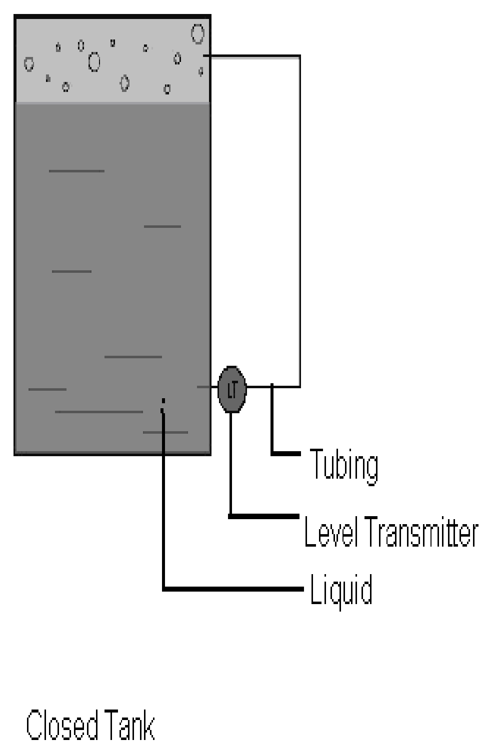


Figure 36

7.3 Ultrasonic and Radar Waves:

New to the level measuring technology is the ultrasonic and radar waves transmitter-receiver combination. The transmitter is mounted at the top and it transmits waves onto the fluid. The transmitted signals gets reflected by the fluid and the receiver receives it. The time taken between transmitting and receiving the signal is measured and as the level increases, the time will decrease because the waves get reflected quickly. By measuring time, we can calibrate the transmitter so it gives 0 to 100% of span when certain time is obtained.

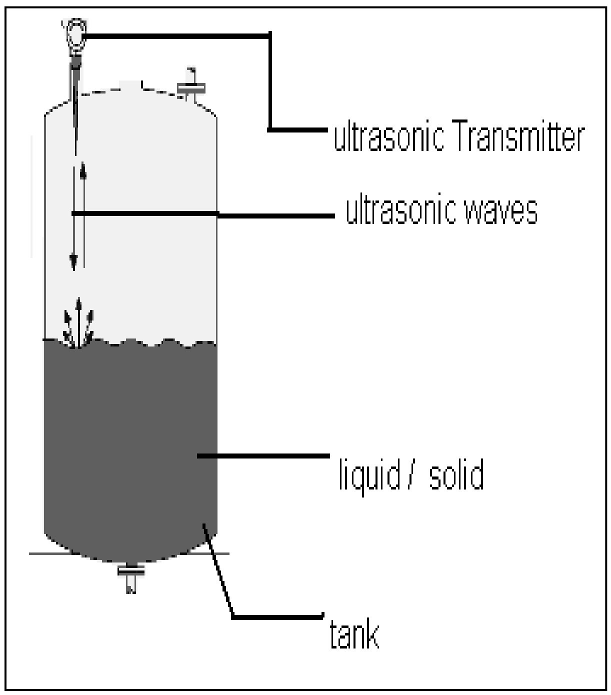


Figure 37

Exercise 11: level Measurement using Differential Pressure Transmitter

11.1 Objectives:

- To learn how to use the d/p transmitter to measure level in tanks

11.2 Equipment List:

- Level process station
- Multimeter
- Connection leads
- Connection tubes

11.3 Procedure:

- Connect the d/p transmitter to the 24VDC power supply.
- Set the multimeter to DC current measurement and connect it in series with the transmitter.
- Turn on the main power switch.
- Turn on the pump by pressing the “pump” button. Then vent the tubes connected to the transmitter. Any air left will cause a faulty reading, so this step is important
- Stop the pump by pressing the "pump" button again. Observe the reading of the multimeter.

  I=____________________

- Turn on the pump until the level in the tank reaches 25 cm. observe and record the reading of the multimeter

  I= ____________________

Review exercise:

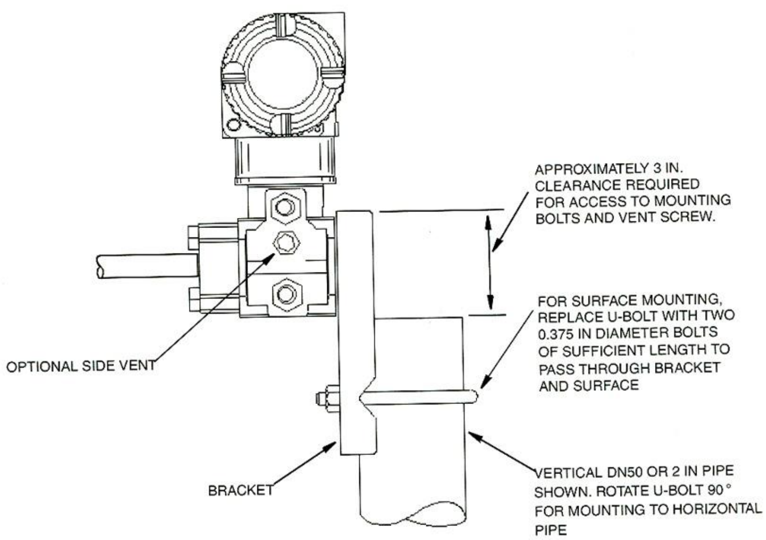
- At what range is the transmitter set?
  ………………………………………………………………………………………..
- What are some advantages and limitations of this level measuring methods can you think of?………………………………………………………………………………………

Lesson 8: Smart Transmitters

8.1 Standard Installation and Mounting of Intelligent Differential Pressure Transmitter

8.1.1 Installation and Mounting

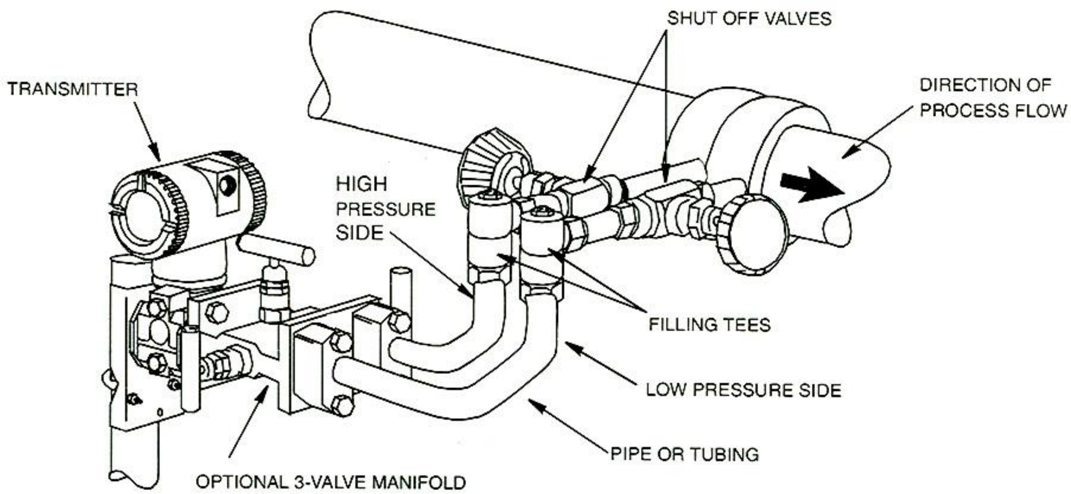
The Electronic dp Transmitter can be mounted using the mounting bracket to a wall or a pipe.



Be sure to leave at least 3 inches of clearance for access to mounting bolts and back connections.

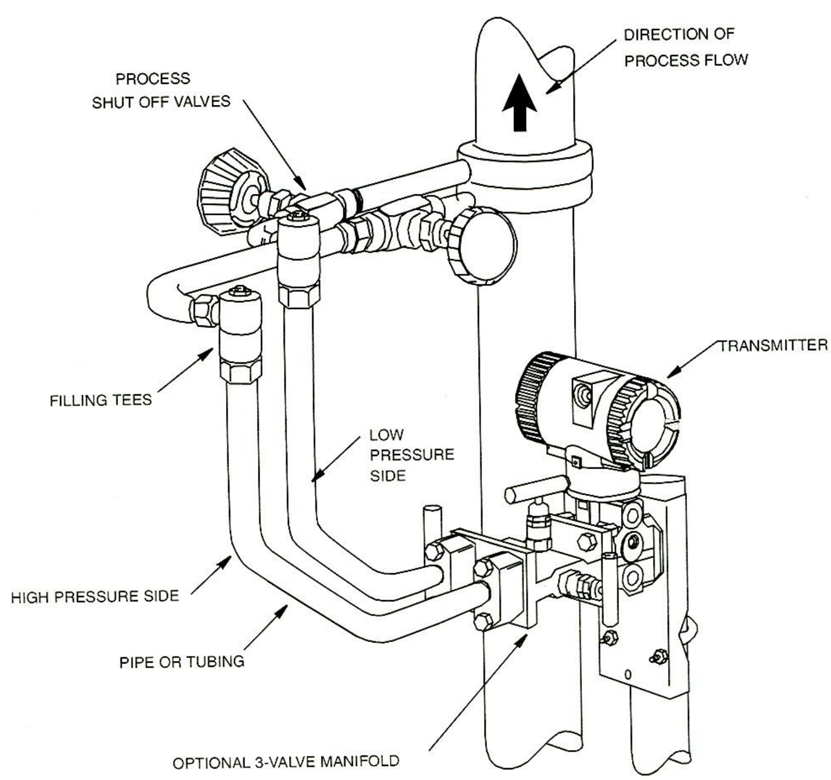
8.1.2 Installation of Flow Measurement Piping

The figure below shows the typical installation when the transmitter is used for flow



The figure above shows the transmitter piping connections when the flow is horizontal.

Notice the 3-valve manifold. This is used to safely isolate the transmitter from the process and for putting it back in the process.



For isolating the instrument from the process:

1. Open the equalizer valve
2. Slowly shut both the low and high pressure sides simultaneously
3. Open the vent valves to drain what is left from the process fluid
4. Take the transmitter out by removing all the bolts that connects it to the process

For putting the instrument back in process, reverse the steps mentioned earlier.

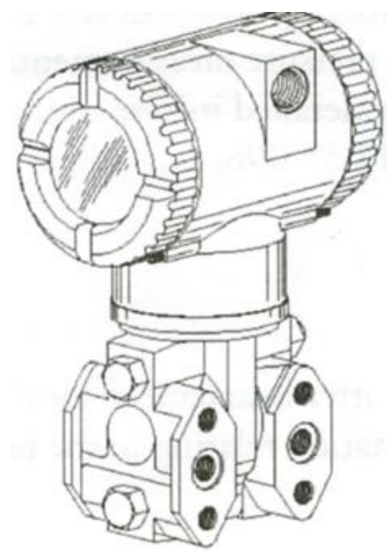
Exercise 12: Calibration of Intelligent Differential Pressure Transmitter

14.1 Objectives:

- To study the operation of FOXBORO 1DP10 intelligent differential pressure transmitter.
- To study the applications of the transmitter.
- To practice the calibration procedure of the intelligent differential pressure transmitter.

12.2Equipment List:

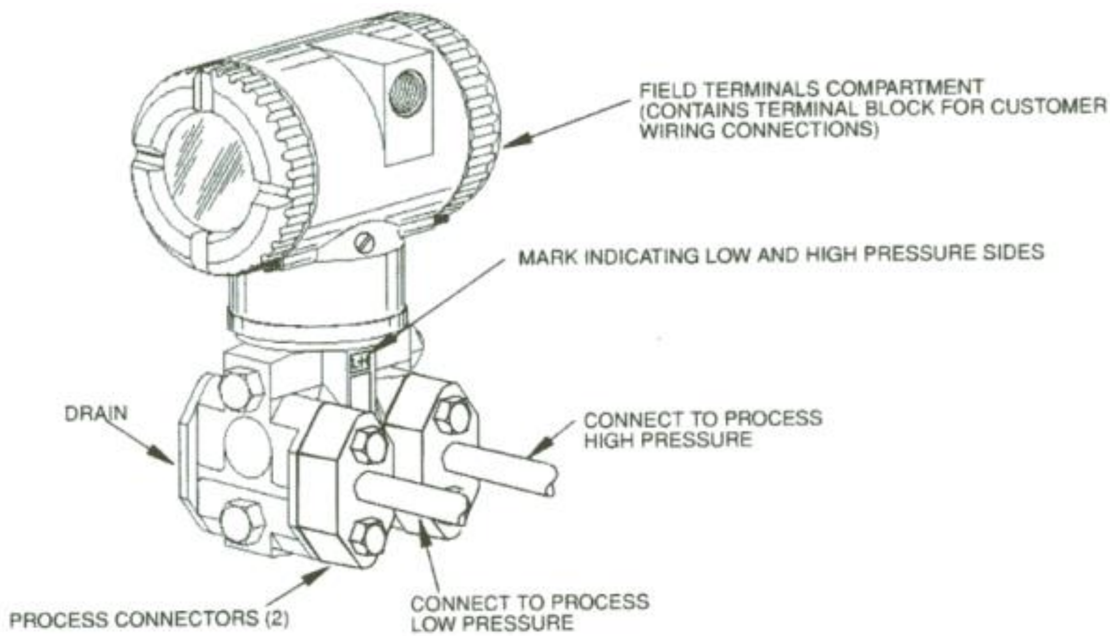
- FOXBORO 1DP10 d/p transmitter.
- 24 DCV power supply.
- Air pressure supply.
- Pressure gauge 0-30 psi.
- Digital multimeter
- Plastic tubing connectors.
- Wires and screw drivers.
- Spanners.



12.3Introduction:

The IDP10 Intelligent Differential Pressure Transmitter (shown in figure below) measures the difference between two pressures applied to opposite sides of a silicon strain gauge microsensor within the sensor assembly. This microsensor converts differential pressure to a change in resistance. The resistance change is then converted to a 4 to 20 mA or digital signal proportional to differential pressure or to the square root of differential pressure. This measurement signal is transmitted to remote receivers over the same two wires that supply power to the transmitter electronics. These wires also carry two-way data signals between the transmitter and remote communication devices.

.



12.4 Procedure:

There are two types of Calibration procedure adopt in industry

i) Field Calibration
ii) Lab Calibration or Bench Calibration

12.4.1 Field Calibration

Normally in industry during commissioning period and shutdown it is require to calibrate the transmitter in the field. For this purpose there is no need to disconnect the transmitter from the process pipe just disconnect impulse tubing and connect these tubes to hand held pneumatic pump.

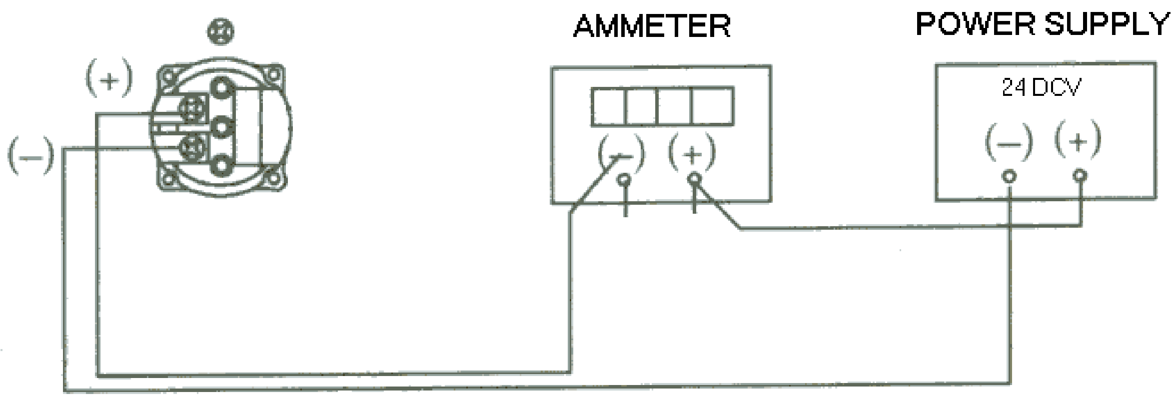
12.4.2 Lab Calibration or Bench Calibration

Transmitter must be disconnected from process pipe and bring it to calibration lab for calibration. In lab Bench pneumatic or hydraulic pump are used to calibrate.

Calibration Method

Use test equipment that is at least three times as accurate as the desired accuracy of the transmitter.
Calibration is performed by simulating the process differential pressure. This is done by applying a pressure equal to the differential pressure to one side of the transmitter and venting the other side of the transmitter.

Note:- Calibrating source gauge is in psi
Set up equipment as shown below:



How to change the measuring unit of transmitter

Press next two times then press configuration, press enter then again press next 8times you will see M-EGU press enter then press U then again press enter. Now by using next button you can select your desired unit (in our case psi) then press enter. Then again press next button 7times then press save to save your changes.

How to re-range the transmitter

Press next to go in calibration mode then press enter then again press next go in rerange mode press enter to go in MIURV(upper range value) enter upper range. Then press next to go in M1LRV(Lower range value) enter lower range. Then press enter and save your setting.

How to calibrate transmitter

By pressing next go in calibration mode LRV. Apply lower range value through pressure source press enter and wait for some time then go to URV apply upper range value enter save the results.

Example 1

Calibrate differential pressure transmitter to 0-5psi

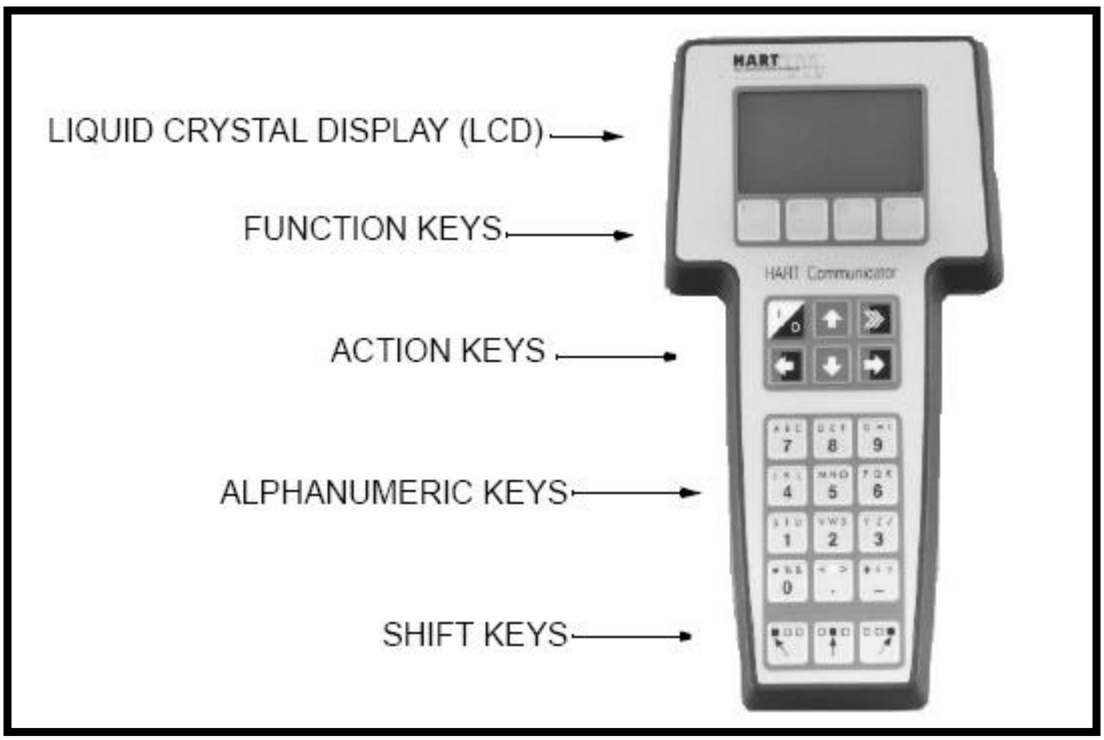
Sr. No.	Applied pressure	mA output	Calibrating source gauge	% error
1				
2				
3				
4				
5				
6				
7				
8				
9				

Exercise13: Configuring Smart Transmitter Using HHT

13.1 Hart Communicator

The HART (Highway Addressable Remote Transducer) Communicator is a hand-held interface that provides a common communication link to all HART-compatible, microprocessor-based instruments.

HART Communicator interfaces with any HART-compatible device from any wiring termination point using a 4–20 mA loop, provided a minimum load resistance of 250 ohms is present between the Communicator and the power supply. .



HART COMMUNICATOR.

13.2 HART COMMUNICATOR CONNECTIONS

HART Communicator can interface with a transmitter from the control room, the instrument site, or any wiring termination point in the loop through the rear connection panel (Figure 2-2).To interface, connect the HART Communicator with the appropriate connectors in parallel with the instrument or load resistor. All connections are non-polarized.

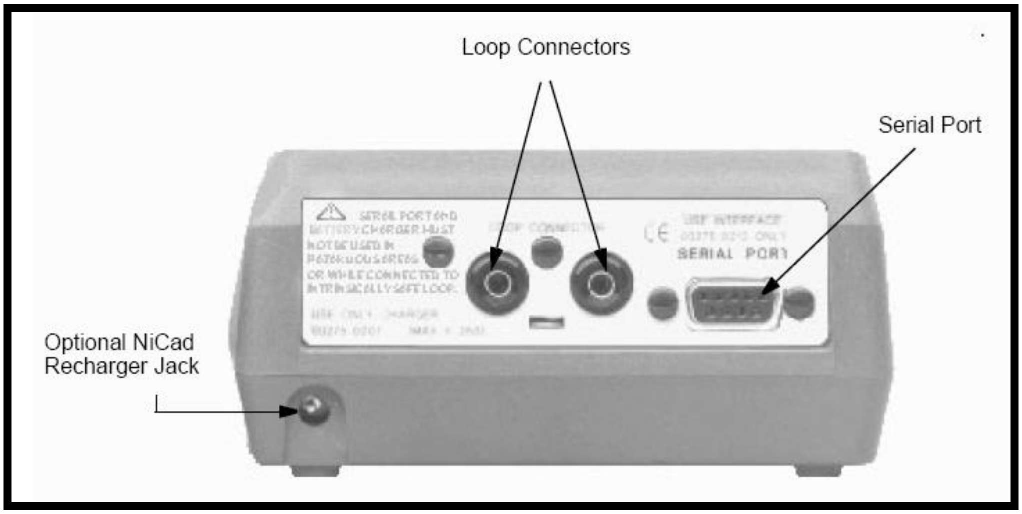
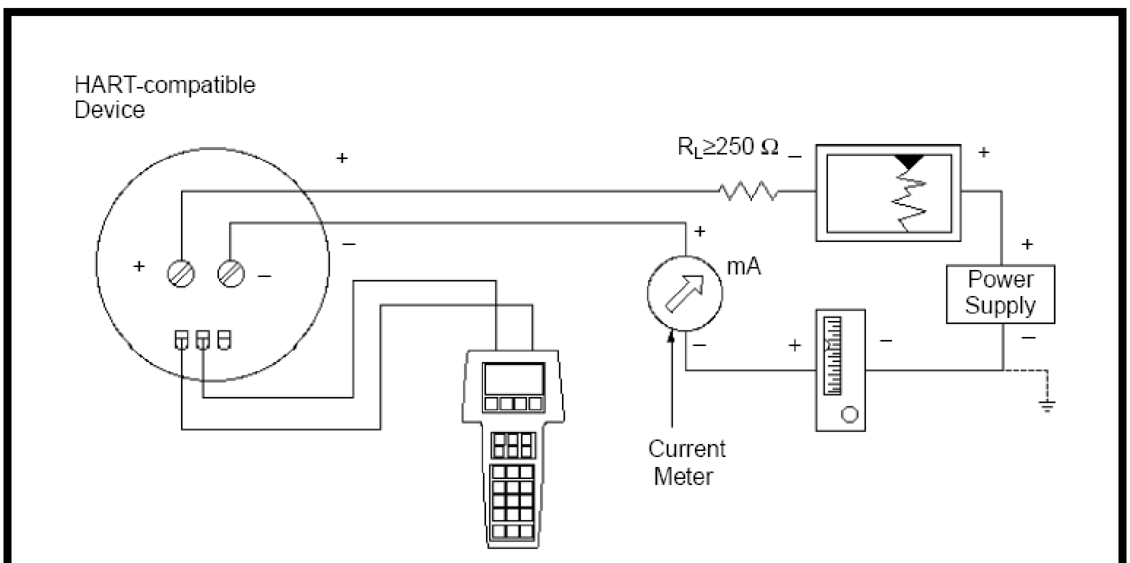


Fig: Rear connection Panel

NOTE: For the HART Communicator to function properly, a minimum of 250 Ohms resistance must be present in the loop. The HART communicator does not measure loop current directly.

Figure **:** illustrate typical wiring connections between the HART Communicator and any compatible device.

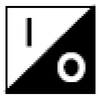


Connecting the HART Communicator to the Loop.

13.3 THE ACTION KEYS

The action keys are the six blue, white, and black keys located above the alphanumeric keys. The function of each key is described as Follows:

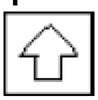
On/Off Key



Use this key to power up and power off the HART Communicator.

.

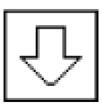
Up Arrow Key



Use this key to move the cursor up through a menu or list of options.

.

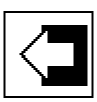
Down Arrow Key



Use this key to move the cursor down through a menu or list of options.

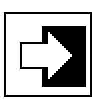
.

Left Arrow and Previous Menu Key



Use this dual-function key to move the cursor to the left or back to the previous menu.

Right Arrow and Select Key



Use this dual-function key to move the cursor to the right or to select a menu option.

Hot Key

Use this key to quickly access important, user-defined options when connected to a HART-compatible device.

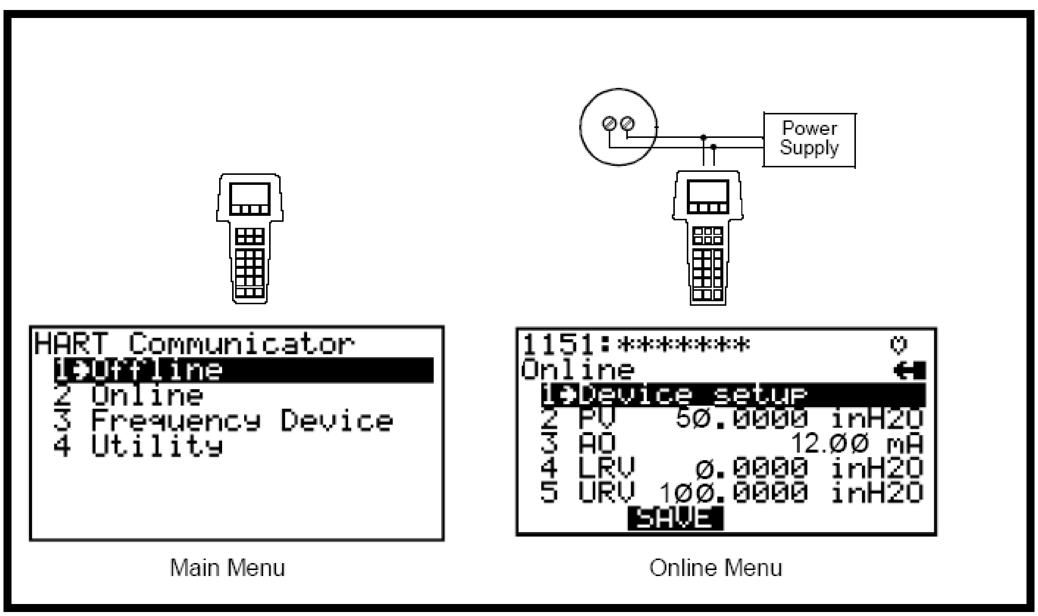
13.4 ALPHANUMERIC AND SHIFT KEYS

The 12 alphanumeric keys perform two functions — the fast selection of menu options and data entry. Three shift keys enable use of the upper row of characters on each alphanumeric key.

Hart communicator alphanumeric and Shift keys

13.5 Getting to Know The Hart Communicator

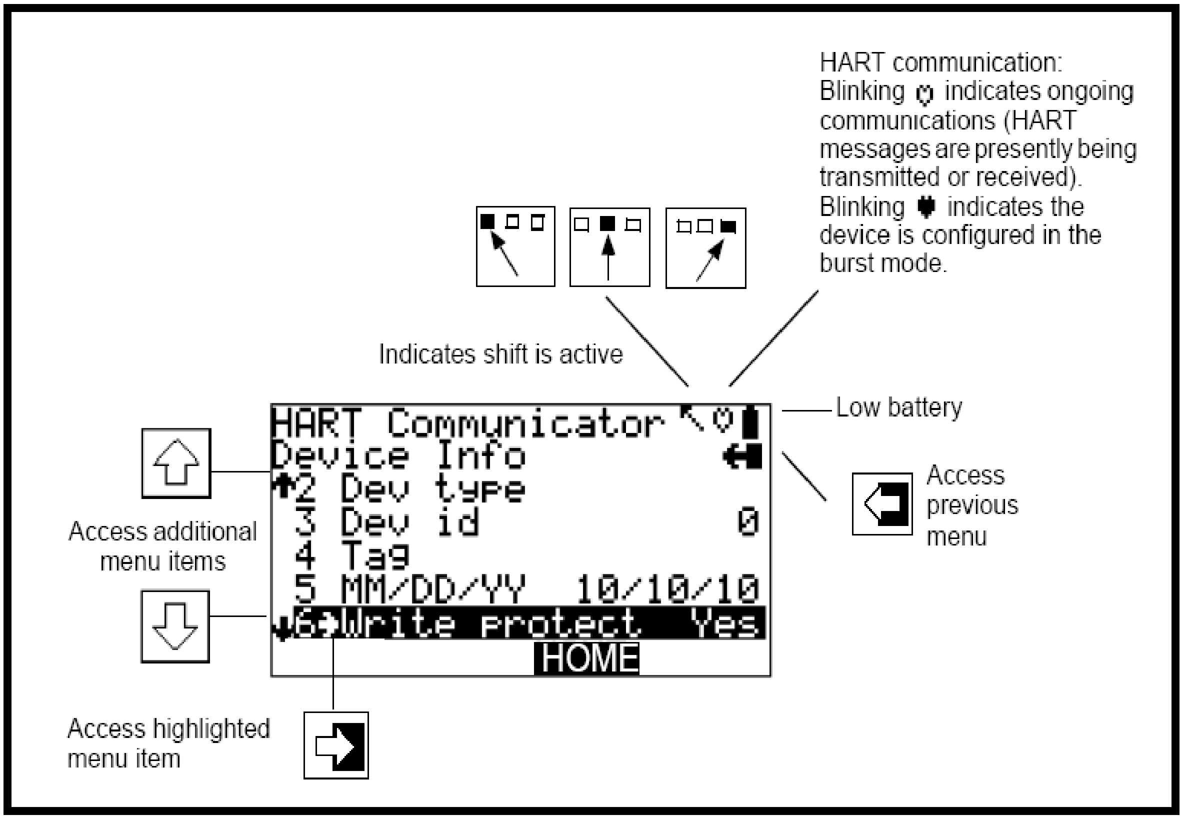
The HART Communicator is generally used in two environments — offline (not connected to a device) and online (connected to a device). The first menu displayed when you power up the Communicator is different for offline and online.
See **Figure**



Powering up online or offline

13.6 Soft Icons

The HART Communicator menus display icons that represent specific keys on the keypad. Figure shows examples of these



Menu icons and associated keys.

Example: Configuring the Smart Transmitter from Offline Menu and downloading the program to Transmitter and Testing Transmitter by Bench Calibration

13.7.1 Objective : To Configure the Smart Transmitter with Hand Held Communicator and down Loading the Configuration to Transmitter.

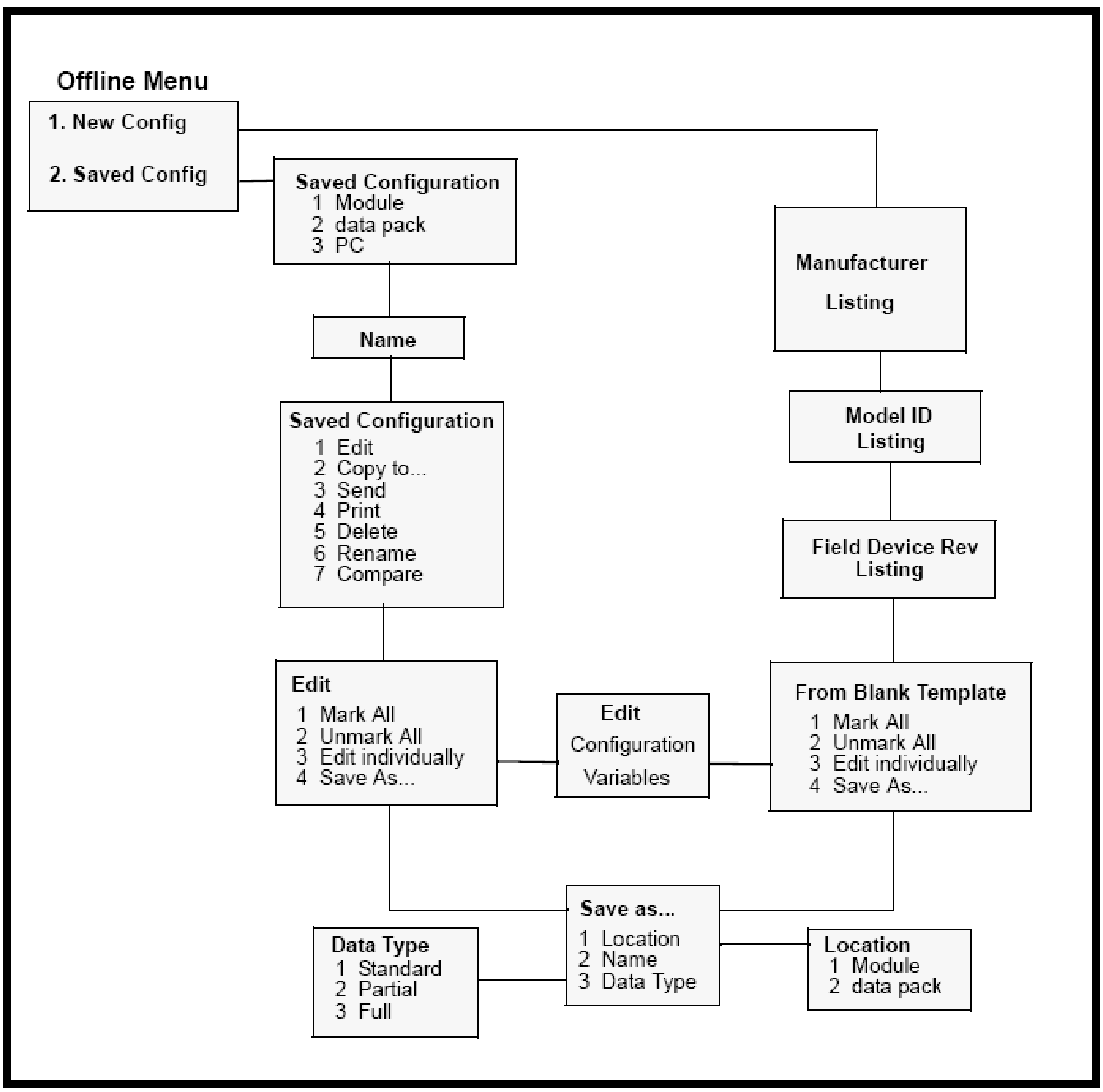
13.7.2 Equipment List:

- Hart Communicator

- Multimeter
- Connection leads
- Connection tubes
- Rose Mount Smart Transmitter.

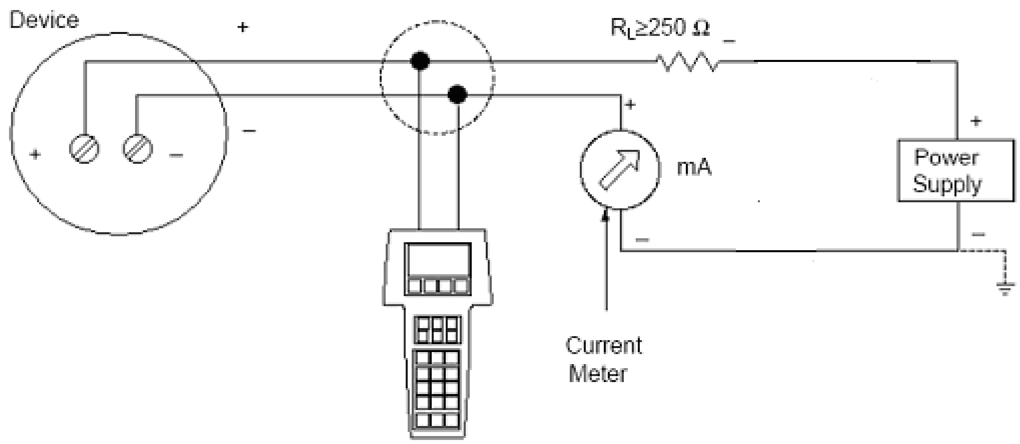
13.7.3. Procedure:

1. Note down the manufacturer name plate details available on Rose mount smart pressure Transmitter.
2. Turn ON the Communicator.
3. Follow the Offline Menu Tree given below to enter the details about Tag, Range, and Engineering Units. Calibration Range is 0- 10 PSI.
4. After Entering the data save the configuration with save soft key button.



Offline Menu Tree

After Configuration Make the connections as shown in the figure below and down load the program from Communicator with the Help of Send Soft Key.



- Connect the smart transmitter to the 24VDC power supply.
- Set the multimeter to DC current measurement and connect it in series with the transmitter.
- Switch on the Hart Communicator and down load the Configuration to Smart Transmitter with the help of Send soft Key.
- After down loading, connect the Pressure source to Smart Transmitter to complete the bench calibration as shown in the following Table.

No of tests	Input pressure (psi)	Output current (mA)	Std o/p	% Error
1	0			
2	2.5			
3	5			
4	7.5			
5	10			

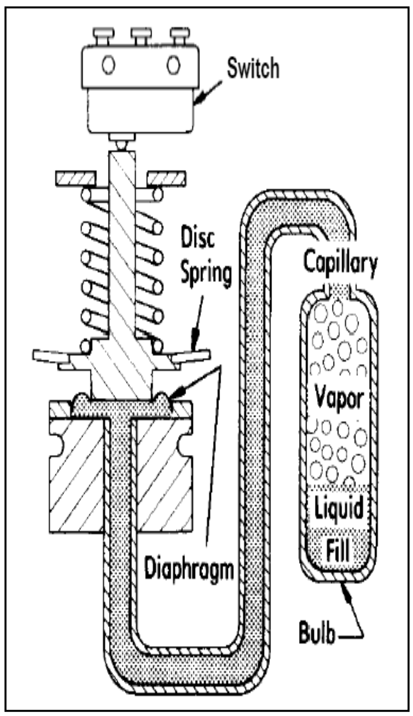
Lesson 9: Other Instruments and Transducers

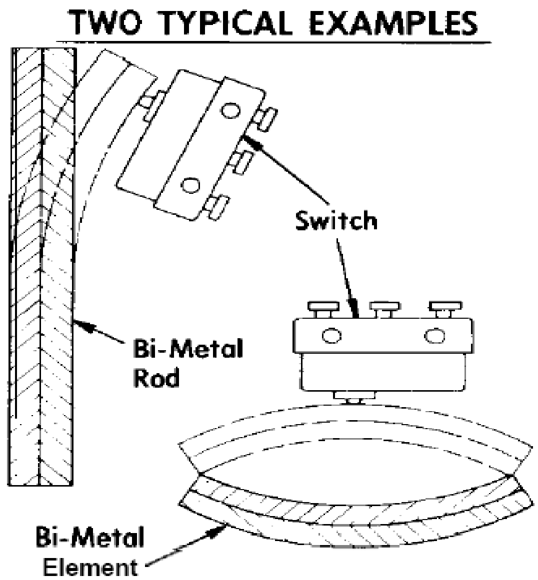
9.1 Temperature Switch:

Temperature switches come in different measuring techniques, namely:

1. Vapor Pressure Technique
2. Bi-metal Technique
3. Liquid Fill Technique

Vapor Pressure Switch





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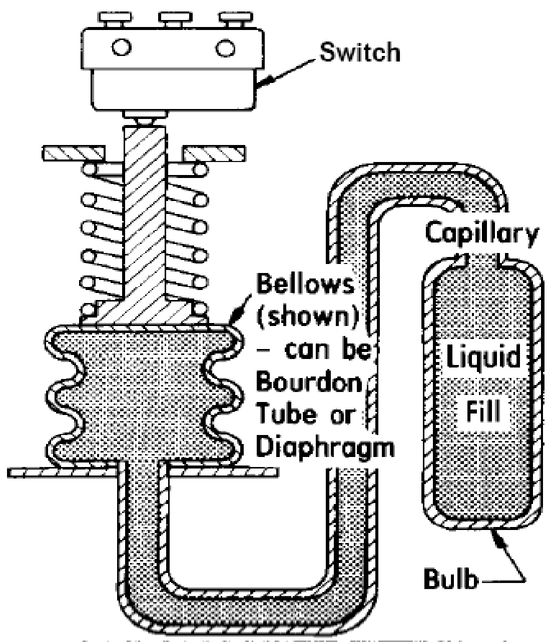
Bi-Metal Technique Switch



Liquid Fill Technique Switch

Exercise 14: Testing of Temperature Switches

16.1 Objectives: To be able to use and test a temperature switch

14.2 Equipment List:

Sr No	Name	Qty
1	Dry-block Calibrator	1
2	Temperature switch	1
3	Multimeter	1
4	Connection leads	1

14.3 Procedure:

As shown in figure 41,

- Open the cover of the temperature switch and locate the NO contact.
- Connect the contact with wires to the multimeter and set the multimeter to "continuity test."

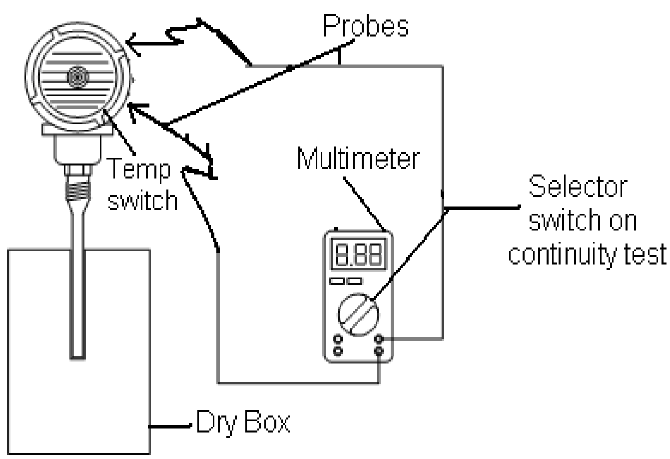


Figure 41

- You have to know at what temperature does the switch change-over.

Change-over temperature = ………………………………

- Insert the temperature switch into the dry-block calibrator.
- Plug in and turn on the dry-block calibrator.
- Set the temperature to the set point temperature that you have recorded
- What happens to the NO switch?

  ……………………………………………………………………………………

- Can the temperature switch be used to control certain processes?

  ……………………………………………………………………………………

- What are some applications of the temperature switch?

  ……………………………………………………………………………………

Exercise 15: Testing of Pressure Switches.

15.1 Objectives:

- Upon completion of this experiment, you will be able to:
- Use a pressure switch in industrial applications.

15.2 Introduction:

The pressure switch is often used as part of an automatic control systems to provide interlocks, alarm or protective trips. Generally, a pressure switch is simply a pressure gauge with electrical contacts and no indicator.

Note> The Honeywell L404A pressure switch contains a glass container, which has two electrical contacts, one at each end.

The main scale setting and the differential setting determine the operational range of this pressure switch

The upper range value = main scale setting

The lower range value = main scale setting – differential setting

15.3 Equipment:

Sr No	Name	Qty.
1	Regulated air supply	1
2	Pressure switch (Honeywell L404A)	1
3	Two lamps.	1
4	Multimeter	1
5	Assorted tubing and fittings	-

15.4 Procedure:

Set the regulated pressure supply at the bench to zero psi.

Connect the pressure switch tubing to the pressure switch

Set the main scale and the differential scale to the desired values. Record them below.

Main setting	Differential setting

Using the multimeter, measure the resistance across the following points

5- write down your result in the table below**.**

Contact	Resistance Ω	Contact open / closed
Red - White		
Red - Blue		

6- While monitoring the resistance between the contacts, increase the air pressure and record the value of the pressure at the point where the resistance changes.

Pressure value =

7- Using the multimeter, measure the resistance across the contacts

Contact	Resistance Ω	Contact Open / closed
Red – White		
Red – Blue		

While measuring either of these resistances, decrease the air pressure and record the pressure at the point the resistance value changes

Pressure value =

Examine the following values:

Main scale setting point =

Differential setting point =

The value recorded in step 5 =

The value recorded in step 7 =

Set the bench power supply to 12 V

Set the main scale set point to 25 psi and the differential setting to 10 psi.

Connect the pressure tubing to the pressure switch and increase the pressure to approximately 25 psi.

What happens to the lamp? Write your answer below

…………………………………………………………………………………………….

…………………………………………………………………………………………….

…………………………………………………………………………………………….

13. Now decrease the pressure and observe at what value of pressure the lamp change state.

Pressure =

Review Questions:

1.Write down two applications where this pressure switch can be used.

…………………………………………………………………………………………….

2. What is the value of the differential gap for practical purposes?

…………………………………………………………………………………………….

Exercise 16: Testing Of Limit Switches

16.1 Objectives:

- To be able to use and test a limit switch

16.2 Equipment List:

Sr No	Name	Qty.
1	Limit switch	1
2	Multimeter	1

16.3 Procedure:

- Open the cover of the limit switch and locate the NO contact.
- Connect the contact with wires to the multimeter and set the multimeter to "continuity test."

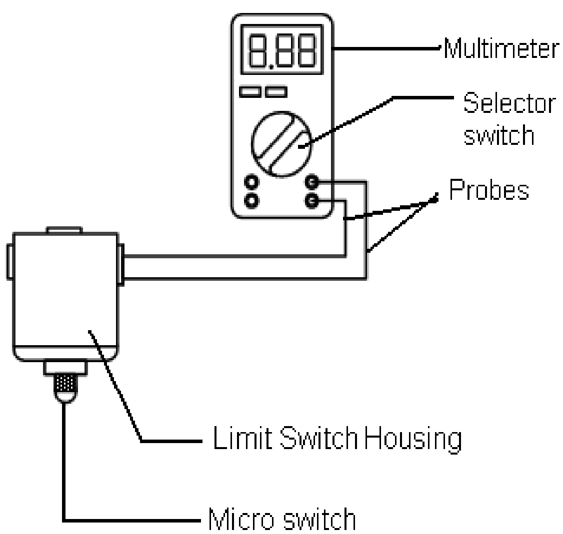


Figure 42

- Push the wheel of the limit switch towards its body. What do you notice?

  ……………………………………………………………………………………….

- What happens to the NC switch?

  ……………………………………………………………………………….

- Where do you see this action useful?

  ……………………………………………………………………………….

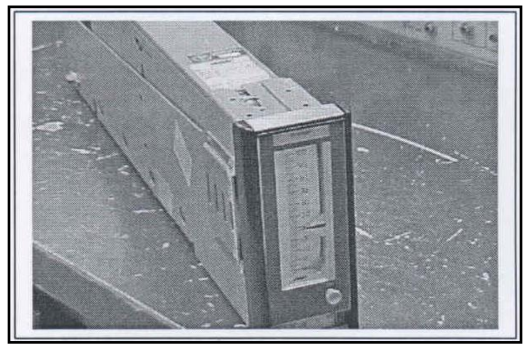
Experiment 17: Hands-on Operation using Pneumatic Controller

17.1 Objectives:

- The operation of the pneumatic process controller.
- Observe the controller response

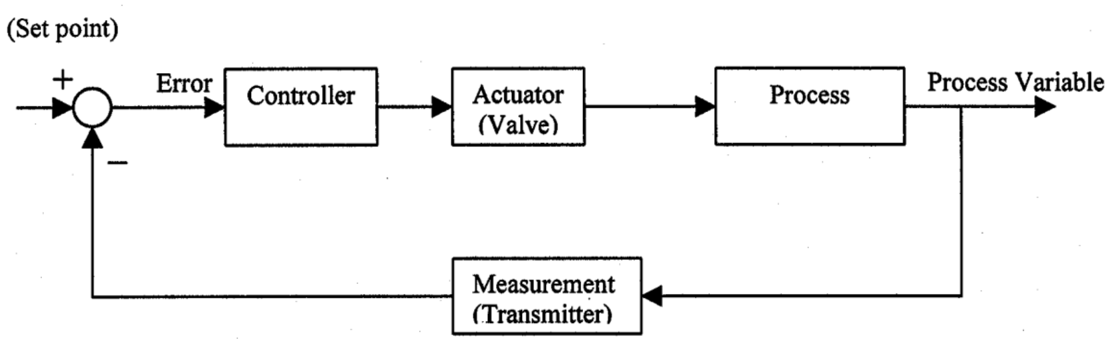
17.2 Equipment List:

- OXBORO pneumatic process controller.
- Regulated air pressure supply.
- Pressure gauge 0-30 psi.
- Plastic tubing and connectors.



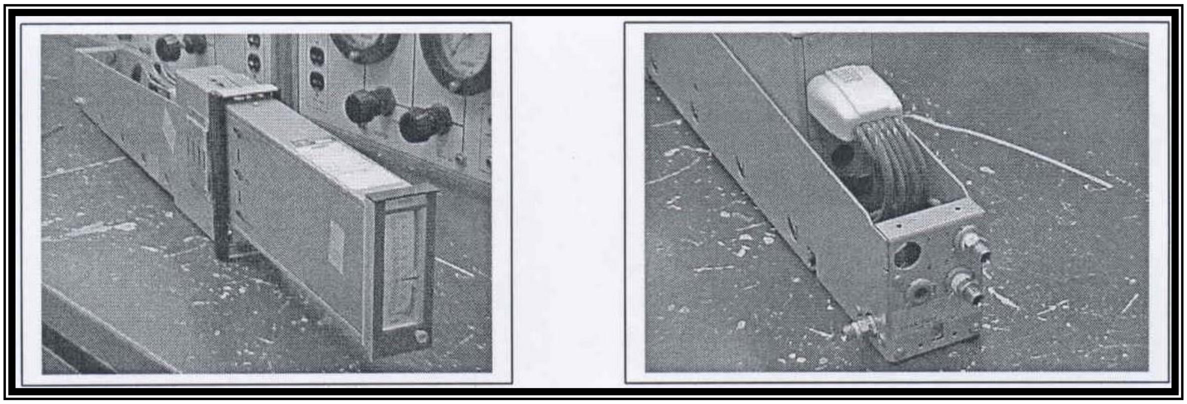
17.3 Introduction:

Process controllers play the major part of any control system. The controller must be selected to perform as it is expected by the system. Some control systems require on/off control and some others require continuous control. Most of the process industries use the continuous control in their control systems.. A block diagram example show below, can explain how the controller can be used.

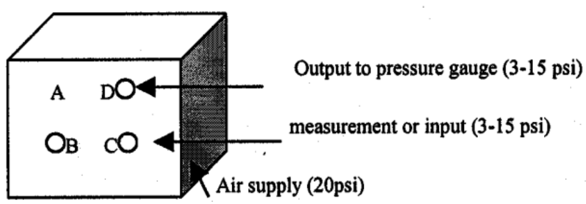


17.4 Procedure:

Make the connection shown below. Check that the output is connected to a pressure gauge and the measurement input is taken from the regulated air supply.



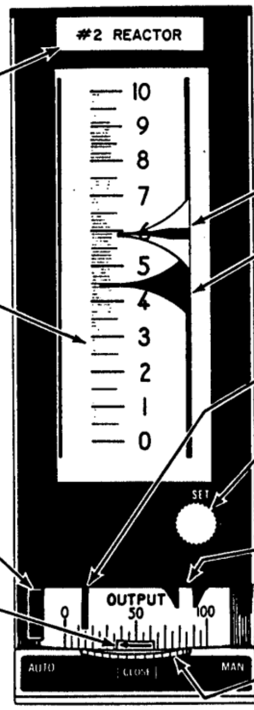
Rear of the Shelf



Observe the response of the controller by varying the measurement input.
To change the response of the controller Adjust the Proportional, Reset and Derivative switches of Controller .

— OPERATION —

Components on Front of Instrument



Instrument Identification

Marked as specified in sales order. With optional alarm lights, nameplate is back-lighted when alarm goes on.

Set Point Measurement Dial

Dial is graduated as specified in sales order.

Transfer Switch

To switch between automatic and manual control (see details on Page 4).

Final Operator Direction Label

Arrow indicates direction to turn wheel to close final operator. (Arrow can be positioned to face either direction.)

Set Point Index

Measurement Pointer

Output Pointer

Set Point Adjustment Knob

Knob can be locked in place with optional set screw on side.

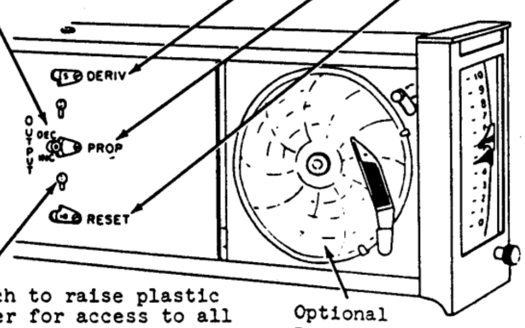
Memory Pointers

Pointers are adjustable so that a desired output or a desired output range is indicated.

Manual Output Adjustment Wheel

Components at Instrument Control Panel

To expose control panel, withdraw controller part way (see Page 4).



Reversing Switch

Output increases with either increasing (INC) or decreasing (DEC) input.

Derivative Adjustment, 0.01-50 minutes

Proportional Band Adjustment, 5-500%

Reset Adjustment, 0.01-50 minutes

Latch to raise plastic cover for access to all adjustments shown.

Optional Recorder

To Effectively Eliminate Reset and/or Derivative Actions

Turn reset adjustment to MAX position. Reset time = approx. 200 min.

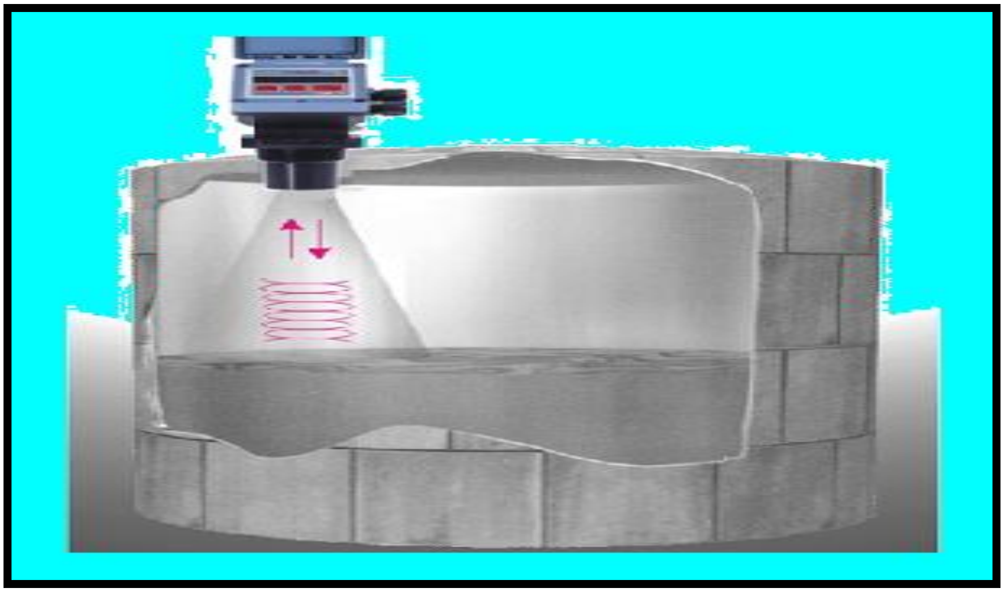
Turn derivative adjustment to 0.01 minutes.

Do not use setting in black area.

Lesson 10: Ultra-sonic Level and Flow sensor

10.1 Ultrasonic Level Measurement

Determination of liquid level by the use of ultrasonic implies the transmission and reception of sound waves Figure 2.16. Ultrasonic sound waves are above the range of frequencies audible by the human ear (20,000 Hz).

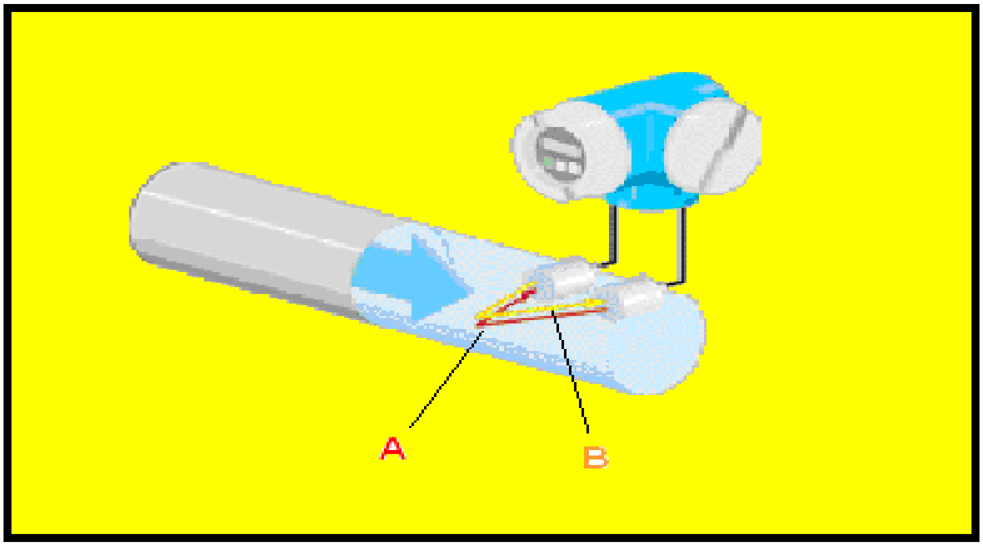


Ultrasonic Level sensor installed on closed Tank.

10.2 Ultrasonic Flow Measurement

Ultrasonic flowmeters operate on the principle of measuring the velocity of sound as it passes through the fluid flowing in a pipe. The most common approach to this application is described below and is shown in Fig.

Piezoelectric crystals (barium titanate or lead zirconate titanate) are used as transmitters to send acoustic signals through the fluid flowing through the pipe to receivers that are also piezoelectric crystals. The fluid flows through the pipe at a velocity, v.



Ultrasonic Flow sensor installation on pipe surface

Ultrasonic flow meters are normally installed on the outside of liquid filled pipes, so the measuring element is non intrusive and will not induce a pressure drop or disturbance in the process stream.

.

However, the instrument can be readily attached to the outside of existing pipes without shutdown.

\

RTD, Pt100 -Temperature VS. Resistance -Table

°C	Ohm Ω	°C	Ohm Ω	°C	Ohm Ω	°C	Ohm Ω
±0	100.00	+62	124.01	124	147.56	+186	170.68
+2	100.78	64	124.77	126	148.32	188	171.42
4	101.56	66	125.54	128	149.07	190	172.16
6	102.34	68	156.30	130	149.82	192	172.90
8	103.12	70	127.07	132	150.57	194	173.63
10	103.90	72	127.83	134	151.32	196	174.37
12	104.68	74	128.60	136	152.07	198	175.10
14	105.46	76	129.36	138	152.82	200	175.84
16	106.23	78	130.13	140	153.57		
18	107.01	80	130.89	142	154.32		
20	107.79	82	131.65	144	155.07		
22	108.57	84	132.41	146	155.82		
24	109.34	86	133.18	148	156.57		
26	110.12	88	133.94	150	157.32		
28	110.89	90	134.70	152	158.07		
30	111.67	92	135.46	154	158.81		
32	112.44	94	136.22	156	159.56		
34	113.22	96	136.98	158	160.30		
36	113.99	98	137.74	160	161.05		
38	114.77	100	138.50	162	161.79		
40	115.54	102	139.26	164	162.53		
42	116.31	104	140.01	166	163.28		
44	117.08	106	140.77	168	164.02		
46	117.86	108	141.52	170	164.76		
48	118.63	110	142.28	172	165.50		
50	119.40	112	143.04	174	166.24		
52	120.17	114	143.79	176	166.99		
54	120.94	116	144.55	178	167.73		
56	121.70	118	145.30	180	168.47		
58	122.47	120	146.06	182	169.21		
60	123.24	122	146.81	184	169.95		

TABLE 7 ***Type J Thermocouple*** — *thermoelectric voltage as a function of temperature (°C); reference junctions at 0 °C*

J °C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
						Thermoelectric Voltage in Millivolts						
-210	-8.095											-210
-200	-7.890	-7.912	-7.934	-7.955	-7.976	-7.996	-8.017	-8.037	-8.057	-8.076	-8.095	-200
-190	-7.659	-7.683	-7.707	-7.731	-7.755	-7.778	-7.801	-7.824	-7.846	-7.868	-7.890	-190
-180	-7.403	-7.429	-7.456	-7.482	-7.508	-7.534	-7.559	-7.585	-7.610	-7.634	-7.659	-180
-170	-7.123	-7.152	-7.181	-7.209	-7.237	-7.265	-7.293	-7.321	-7.348	-7.376	-7.403	-170
-160	-6.821	-6.853	-6.883	-6.914	-6.944	-6.975	-7.005	-7.035	-7.064	-7.094	-7.123	-160
-150	-6.500	-6.533	-6.566	-6.598	-6.631	-6.663	-6.695	-6.727	-6.759	-6.790	-6.821	-150
-140	-6.159	-6.194	-6.229	-6.263	-6.298	-6.332	-6.366	-6.400	-6.433	-6.467	-6.500	-140
-130	-5.801	-5.838	-5.874	-5.910	-5.946	-5.982	-6.018	-6.054	-6.089	-6.124	-6.159	-130
-120	-5.426	-5.465	-5.503	-5.541	-5.578	-5.616	-5.653	-5.690	-5.727	-5.764	-5.801	-120
-110	-5.037	-5.076	-5.116	-5.155	-5.194	-5.233	-5.272	-5.311	-5.350	-5.388	-5.426	-110
-100	-4.633	-4.674	-4.714	-4.755	-4.796	-4.836	-4.877	-4.917	-4.957	-4.997	-5.037	-100
-90	-4.215	-4.257	-4.300	-4.342	-4.384	-4.425	-4.467	-4.509	-4.550	-4.591	-4.633	-90
-80	-3.786	-3.829	-3.872	-3.916	-3.959	-4.002	-4.045	-4.088	-4.130	-4.173	-4.215	-80
-70	-3.344	-3.389	-3.434	-3.478	-3.522	-3.566	-3.610	-3.654	-3.698	-3.742	-3.786	-70
-60	-2.893	-2.938	-2.984	-3.029	-3.075	-3.120	-3.165	-3.210	-3.255	-3.300	-3.344	-60
-50	-2.431	-2.478	-2.524	-2.571	-2.617	-2.663	-2.709	-2.755	-2.801	-2.847	-2.893	-50
-40	-1.961	-2.008	-2.055	-2.103	-2.150	-2.197	-2.244	-2.291	-2.338	-2.385	-2.431	-40
-30	-1.482	-1.530	-1.578	-1.626	-1.674	-1.722	-1.770	-1.818	-1.865	-1.913	-1.961	-30
-20	-0.995	-1.044	-1.093	-1.142	-1.190	-1.239	-1.288	-1.336	-1.385	-1.433	-1.482	-20
-10	-0.501	-0.550	-0.600	-0.650	-0.699	-0.749	-0.798	-0.847	-0.896	-0.946	-0.995	-10
0	0.000	-0.050	-0.101	-0.151	-0.201	-0.251	-0.301	-0.351	-0.401	-0.451	-0.501	0
0	0.000	0.050	0.101	0.151	0.202	0.253	0.303	0.354	0.405	0.456	0.507	0
10	0.507	0.558	0.609	0.660	0.711	0.762	0.814	0.865	0.916	0.968	1.019	10
20	1.019	1.071	1.122	1.174	1.226	1.277	1.329	1.381	1.433	1.485	1.537	20
30	1.537	1.589	1.641	1.693	1.745	1.797	1.849	1.902	1.954	2.006	2.059	30
40	2.059	2.111	2.164	2.216	2.269	2.322	2.374	2.427	2.480	2.532	2.585	40
50	2.585	2.638	2.691	2.744	2.797	2.850	2.903	2.956	3.009	3.062	3.116	50
60	3.116	3.169	3.222	3.275	3.329	3.382	3.436	3.489	3.543	3.596	3.650	60
70	3.650	3.703	3.757	3.810	3.864	3.918	3.971	4.025	4.079	4.133	4.187	70
80	4.187	4.240	4.294	4.348	4.402	4.456	4.510	4.564	4.618	4.672	4.726	80
90	4.726	4.781	4.835	4.889	4.943	4.997	5.052	5.106	5.160	5.215	5.269	90
100	5.269	5.323	5.378	5.432	5.487	5.541	5.595	5.650	5.705	5.759	5.814	100
110	5.814	5.868	5.923	5.977	6.032	6.087	6.141	6.196	6.251	6.306	6.360	110
120	6.360	6.415	6.470	6.525	6.579	6.634	6.689	6.744	6.799	6.854	6.909	120
130	6.909	6.964	7.019	7.074	7.129	7.184	7.239	7.294	7.349	7.404	7.459	130
140	7.459	7.514	7.569	7.624	7.679	7.734	7.789	7.844	7.900	7.955	8.010	140
150	8.010	8.065	8.120	8.175	8.231	8.286	8.341	8.396	8.452	8.507	8.562	150
160	8.562	8.618	8.673	8.728	8.783	8.839	8.894	8.949	9.005	9.060	9.115	160
170	9.115	9.171	9.226	9.282	9.337	9.392	9.448	9.503	9.559	9.614	9.669	170
180	9.669	9.725	9.780	9.836	9.891	9.947	10.002	10.057	10.113	10.168	10.224	180
190	10.224	10.279	10.335	10.390	10.446	10.501	10.557	10.612	10.668	10.723	10.779	190
200	10.779	10.834	10.890	10.945	11.001	11.056	11.112	11.167	11.223	11.278	11.334	200
210	11.334	11.389	11.445	11.501	11.556	11.612	11.667	11.723	11.778	11.834	11.889	210
220	11.889	11.945	12.000	12.056	12.111	12.167	12.222	12.278	12.334	12.389	12.445	220
230	12.445	12.500	12.556	12.611	12.667	12.722	12.778	12.833	12.889	12.944	13.000	230
240	13.000	13.056	13.111	13.167	13.222	13.278	13.333	13.389	13.444	13.500	13.555	240
°C	0	1	2	3	4	5	6	7	8	9	10	°C

K°C

TABLE 9 ***Type K Thermocouple*** — *thermoelectric voltage as a function of temperature (°C); reference junctions at 0 °C*

Thermoelectric Voltage in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10	°C
-270	-6.458											-270
-260	-6.411	-6.444	-6.446	-6.448	-6.450	-6.452	-6.453	-6.455	-6.456	-6.457	-6.458	-260
-250	-6.404	-6.408	-6.413	-6.417	-6.421	-6.425	-6.429	-6.432	-6.435	-6.438	-6.441	-250
-240	-6.344	-6.351	-6.358	-6.364	-6.370	-6.377	-6.382	-6.388	-6.393	-6.399	-6.404	-240
-230	-6.262	-6.271	-6.280	-6.289	-6.297	-6.306	-6.314	-6.322	-6.329	-6.337	-6.344	-230
-220	-6.158	-6.170	-6.181	-6.192	-6.202	-6.213	-6.223	-6.233	-6.243	-6.252	-6.262	-220
-210	-6.035	-6.048	-6.061	-6.074	-6.087	-6.099	-6.111	-6.123	-6.135	-6.147	-6.158	-210
-200	-5.891	-5.907	-5.922	-5.936	-5.951	-5.965	-5.980	-5.994	-6.007	-6.021	-6.035	-200
-190	-5.730	-5.747	-5.763	-5.780	-5.797	-5.813	-5.829	-5.845	-5.861	-5.876	-5.891	-190
-180	-5.550	-5.569	-5.588	-5.606	-5.624	-5.642	-5.660	-5.678	-5.695	-5.713	-5.730	-180
-170	-5.354	-5.374	-5.395	-5.415	-5.435	-5.454	-5.474	-5.493	-5.512	-5.531	-5.550	-170
-160	-5.141	-5.163	-5.185	-5.207	-5.228	-5.250	-5.271	-5.292	-5.313	-5.333	-5.354	-160
-150	-4.913	-4.936	-4.960	-4.983	-5.006	-5.029	-5.052	-5.074	-5.097	-5.119	-5.141	-150
-140	-4.669	-4.694	-4.719	-4.744	-4.768	-4.793	-4.817	-4.841	-4.865	-4.889	-4.913	-140
-130	-4.411	-4.437	-4.463	-4.490	-4.516	-4.542	-4.567	-4.593	-4.618	-4.644	-4.669	-130
-120	-4.138	-4.166	-4.194	-4.221	-4.249	-4.276	-4.303	-4.330	-4.357	-4.384	-4.411	-120
-110	-3.852	-3.882	-3.911	-3.939	-3.968	-3.997	-4.025	-4.054	-4.082	-4.110	-4.138	-110
-100	-3.554	-3.584	-3.614	-3.645	-3.675	-3.705	-3.734	-3.764	-3.794	-3.823	-3.852	-100
-90	-3.243	-3.274	-3.306	-3.337	-3.368	-3.400	-3.431	-3.462	-3.492	-3.523	-3.554	-90
-80	-2.920	-2.953	-2.986	-3.018	-3.050	-3.083	-3.115	-3.147	-3.179	-3.211	-3.243	-80
-70	-2.587	-2.620	-2.654	-2.688	-2.721	-2.755	-2.788	-2.821	-2.854	-2.887	-2.920	-70
-60	-2.243	-2.278	-2.312	-2.347	-2.382	-2.416	-2.450	-2.485	-2.519	-2.553	-2.587	-60
-50	-1.889	-1.925	-1.961	-1.996	-2.032	-2.067	-2.103	-2.138	-2.173	-2.208	-2.243	-50
-40	-1.527	-1.564	-1.600	-1.637	-1.673	-1.709	-1.745	-1.782	-1.818	-1.854	-1.889	-40
-30	-1.156	-1.194	-1.231	-1.268	-1.305	-1.343	-1.380	-1.417	-1.453	-1.490	-1.527	-30
-20	-0.778	-0.816	-0.854	-0.892	-0.930	-0.968	-1.006	-1.043	-1.081	-1.119	-1.156	-20
-10	-0.392	-0.431	-0.470	-0.508	-0.547	-0.586	-0.624	-0.663	-0.701	-0.739	-0.778	-10
0	0.000	-0.039	-0.079	-0.118	-0.157	-0.197	-0.236	-0.275	-0.314	-0.353	-0.392	0
0	0.000	0.039	0.079	0.119	0.158	0.198	0.238	0.277	0.317	0.357	0.397	0
10	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.718	0.758	0.798	10
20	0.798	0.838	0.879	0.919	0.960	1.000	1.041	1.081	1.122	1.163	1.203	20
30	1.203	1.244	1.285	1.326	1.366	1.407	1.448	1.489	1.530	1.571	1.612	30
40	1.612	1.653	1.694	1.735	1.776	1.817	1.858	1.899	1.941	1.982	2.023	40
50	2.023	2.064	2.106	2.147	2.188	2.230	2.271	2.312	2.354	2.395	2.436	50
60	2.436	2.478	2.519	2.561	2.602	2.644	2.685	2.727	2.768	2.810	2.851	60
70	2.851	2.893	2.934	2.976	3.017	3.059	3.100	3.142	3.184	3.225	3.267	70
80	3.267	3.308	3.350	3.391	3.433	3.474	3.516	3.557	3.599	3.640	3.682	80
90	3.682	3.723	3.765	3.806	3.848	3.889	3.931	3.972	4.013	4.055	4.096	90
100	4.096	4.138	4.179	4.220	4.262	4.303	4.344	4.385	4.427	4.468	4.509	100
110	4.509	4.550	4.591	4.633	4.674	4.715	4.756	4.797	4.838	4.879	4.920	110
120	4.920	4.961	5.002	5.043	5.084	5.124	5.165	5.206	5.247	5.288	5.328	120
130	5.328	5.369	5.410	5.450	5.491	5.532	5.572	5.613	5.653	5.694	5.735	130
140	5.735	5.775	5.815	5.856	5.896	5.937	5.977	6.017	6.058	6.098	6.138	140
150	6.138	6.179	6.219	6.259	6.299	6.339	6.380	6.420	6.460	6.500	6.540	150
160	6.540	6.580	6.620	6.660	6.701	6.741	6.781	6.821	6.861	6.901	6.941	160
170	6.941	6.981	7.021	7.060	7.100	7.140	7.180	7.220	7.260	7.300	7.340	170
180	7.340	7.380	7.420	7.460	7.500	7.540	7.579	7.619	7.659	7.699	7.739	180
190	7.739	7.779	7.819	7.859	7.899	7.939	7.979	8.019	8.059	8.099	8.138	190
°C	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**°C**