Industrial Electrical/Electronic Control Technology

Level-III

Based on October, 2023 Curriculum Version 2



MODULE TITLE : Installing Instrumentation and Control Devices

MODULE CODE: EIS IEC3 M04 1023

Nominal Duration 100hrs

Prepared by: Ministry of Labor and Skill

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Table of contents

Acknowledgment

Ministry of Labor and Skills wish to extend thanks and appreciation to the many representatives of TVT instructors and respective industry experts who donated their time and expertise to the development of this Teaching, Training and Learning Materials (TTLM).

Acronym

OSH---------- Occupational safety and health

OHSR--------- Occupational Health and Safety Regulation

PFD ----------Process Flow Diagrams

PFD----------Process flow diagram

LVDT---------- Linear Variable Differential Transformer)

LDR---------- The Light Dependant Resistor

Introduction to the Module

Install instrumentation and control device , Install instrumentation and control device modules is designed to meet the industry requirements under the Instrument and control to performing maintenance, troubleshooting and repair works on instrument and control device including diagnose and rectify fault in instrument and control device: Carry out Install instrumentation and control device

This module covers the units:

- Installation work plan and preparation
- instrumentation and control devices installation
- Instrumentation and control devices installation test

Learning Objective of the Module

- Plan and prepare Installation work
- Install instrument and control devices
- Test install instrument and control devices

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the “LAP test” giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

Unit one:- Installation work plan and preparation

This unit is developed to provide you the necessary information regarding the following content coverage and topics.

- OH&S policies and procedure for installation
- Work instructions read and interpretation
- Tools, equipment ,material & testing devices

This unit will also assist to attain the learning outcomes stated in the cover page .Specifically ,upon completion of this learning guide, you will be able to:-

- Plan, prepare and observe OH&S policies and procedure for installation
- Reade and interpret Work instructions
- Tools, Material, equipment and testing devices

1.1 OHS policies and procedure for installation

Planning is **preparing** a sequence of action steps to achieve some specific goal. If a person does it effectively, they can reduce much the necessary time and effort of achieving the goal.

An organization's occupational health and safety policy is a statement of principles and general rules that serve as guides for action. The health and safety policy should have the same importance as the other policies of the organization.

Occupational safety and health (OSH) is generally defined as the science of the anticipation, recognition, evaluation and control of hazards arising in or from the workplace that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment.

Occupational Health and Safety or workplace health and safety, is about preventing work injury, illness and disease. It is the responsibility of all workers to identify potential hazards in the workplace and prevent injury.

OHS guidelines

Regulatory Practices issues OHS Guidelines to help with the application and interpretation of sections of the **Occupational Health and Safety Regulation ("OHSR")** and with divisions of the **Workers Compensation Act**s that relate to health and safety. Guideline is a statement by which to determine a course of action. Guidelines may be issued by and used by any organization (governmental or private) to make the actions of its employees or divisions more predictable, and presumably of higher quality. A guideline is similar to a rule. Occupational Health and Safety (OH&S) policy is a statement of principles and general rules that serve as guides for action. Senior management must be committed to ensuring that the policy is carried out with no exceptions. The health and safety policy should have the same importance as the other policies of the organization.

The policy statement can be brief, but it should mention:

- Management's commitment to protect the safety and health of employees.
- The objectives of the program.
- The organization's basic health and safety philosophy.

- Who is accountable for occupational health and safety programs?
- The general responsibilities of all employees.
- That health and safety shall not be sacrificed for expediency.
- That unacceptable performance of health and safety duties will not be tolerated.

The objective of this issuance is to protect every workingman against the dangers of injury, sickness or death through safe and healthful working conditions, thereby assuring the conservation of valuable manpower resources and the prevention of loss or damage to lives and properties, consistent with national development goals and with the State's commitment for the total development of every worker as a complete human being.

Occupational safety and health, including compliance with the OSH requirements pursuant to national laws and regulations, are the responsibility and duty of the employer. The employer should show strong leadership and commitment to OSH activities in the organization, and make appropriate arrangements for the establishment of an OSH management system. The system should contain the main elements of policy, organizing, planning and implementation, evaluation and action for improvement, as shown in figure bellow

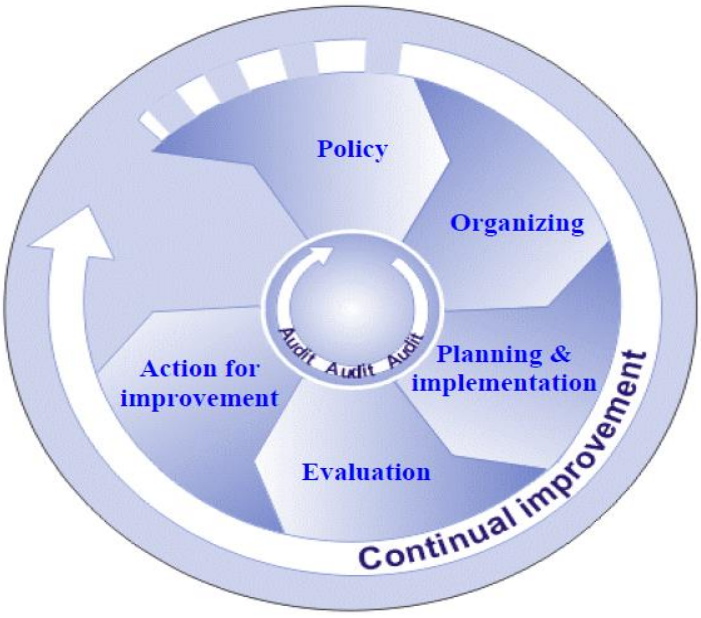


Figure1.1. Planning and implementing policies

The Occupational Health and Safety Regulations (OHS Regulations) build on the OHS Act. They set out how to fulfill duties and obligations, and particular processes that support the OHS Act. For example, they include requirements for:

- safe operation of major hazard facilities and mines
- training for high risk work
- managing and removing asbestos
- licenses for specific activities

Your responsibilities

You must also comply with the legislation. You have responsibilities to:

- protect your own Health and Safety and that of your co-workers;
- not initiate or participate in the harassment of another worker; and
- Co-operate with your supervisor and anyone else with duties under the legislation.

Your rights

The legislation gives your three rights:

- The right to know the hazards at work and how to control them;
- The right to participate in Occupational Health and Safety; and the right to refuse work which you believe to be unusually dangerous.

You may not be punished for using these rights. An employer can be required to legally justify any action taken against a worker who is active in Health and Safety.

If you are inexperienced, you must receive an orientation which includes;

- What to do in a fire or other emergency;
- First aid facilities;
- Prohibited or restricted areas;
- Workplace hazards; and
- Any other information you should know.

You must also be supervised closely by a competent supervisor.

Committees Have Duties To:

- Regularly inspect the workplace;
- Conduct accident investigations;
- Deal with the Health and Safety concerns of employees;
- Investigate refusals to work;Your right to refuse

You have the right to refuse to do work which you believe is unusually dangerous. The unusual danger may be to you or to anyone else. An unusual danger could include such things as:

- a danger which is not normal for your occupation or the job;
- a danger under which you would not normally carry out your job; and/or
- a situation for which you are not properly trained, equipped or experienced.

Preparing Installation

Engineering Diagrams are vital for an understanding of a process to chemical. engineers, of equipment to mechanical engineers, of electrical circuits to electrical engineers, and so on. These diagrams are prepared in many ways to suit the specific requirements. Block Flow Diagrams (BFD), Process Flow Diagrams (PFD), Piping and Instrumentation Diagrams (P&ID) are basic requirements of process engineering and are prepared before attempting any detailing. When any chemical manufacturing project is conceived, immediate information is sought on the requirements of raw materials and utilities. This information can be calculated using the Laws of Conservation of Mass and Energy. Process engineers are involved in the preparation of both these types of diagrams. Let us look at P&ID in detail:

P&ID is a schematic illustration of the functional relationship of piping, instrumentation, and system equipment components. It shows all the piping including the physical sequence of **branches, fittings, equipment, instrumentation and control interlocks**. In this type of diagram, the information is included .

1.2 Work instructions interpretation

What do work instructions for measuring instruments include?A work instruction for measuring instruments typically starts with a brief description of the instrument and its purpose. It then further specifies the technical calibration conditions. Calibration conditions might include information about the environment the instrument should be in, how the instrument is supposed to be set up and how to accurately perform the measurement. Setting up the instrument includes cleaning it and calibrating it to zero setting. The last parts outline the treatment of results and possible information on periodic measurements or auditing.

The work instruction content for measuring instruments would look something like this:

1. Description and purpose of the measuring instrument
2. Technical specifications
3. environment
4. setting up the instrument
5. measurement procedure
6. Interpretation of the results

Do not forget to include information about how to leave the instrument after usage. The person after you will expect a clean and properly left tool, calibrated back to zero setting, so he/she doesn't spend extra minutes doing what is supposed to be your work. To sum up, you need to think about three main things when preparing work instructions for measuring instruments: how to prepare the instrument, how to use it and what to do with it after you're done measuring. For a better visual on how such work instructions should look like, have a look at an example.

Work Instructions For Material Handling

Did you know that one of the most common injuries in the workplace are back and spine injuries, with one of the main reasons for them being material handling? The improper treatment and storing of materials or performing related operations often results in costly injuries and should be specifically addressed in work instructions. Whether moving materials manually or mechanically, your employees should be aware of potential risks

with the task at hand and know the strategies to minimize the danger. On the other side, employers are responsible for ensuring safety and focus on creating effective work instructions for material handling.

What is material handling?

Material handling includes any good moving within a storage area. These actions are loading, unloading, palletizing, de-palletizing, etc. It is either manual, semi-automated or manual, depending on the involvement of employees. The more manual the task, the higher the risk.

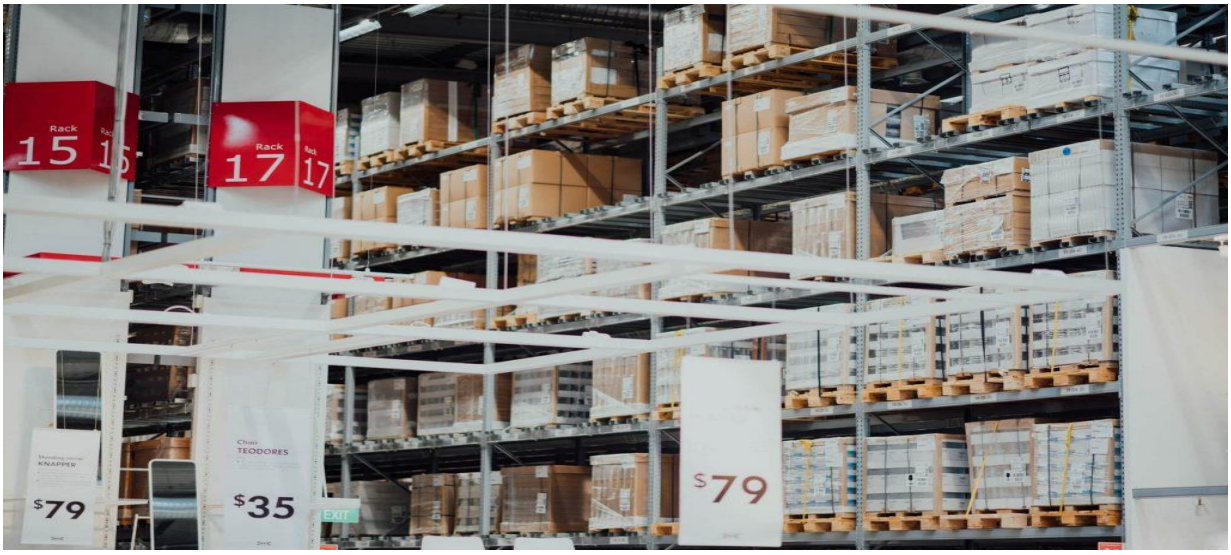


Fig 1.2-Material handling

How to structure your work instructions for material handling?

The underlying theme throughout your material handling work instructions should be on taking actions to prevent accidents. If you don't know where to start, an idea is, to begin with the basics and later narrow it down to specific operations.

In the introductory part, focus on providing an understanding of what the risks in handling are and what precautions should employees take to prevent them. Address at least the following topics:

- What should your employees know before moving, handling, and storing materials?
- What are the potential hazards?
- Which precautions should your employees follow?
- How to report an injury?

Here you can also add the topics of ergonomics as a study of how the work environment should be adapted to the employees and the importance of training for material handling.

Important safety measures

Continue with listing important safety measures regarding material handling. Make sure you list all operations that include goods handling and further specify the precautions for each. You can divide this part into more sections, focusing on manual and automated handling separately.

If you're discussing manual material handlings, your work instructions should include basic principles on what to do and what to avoid when moving materials manually. Provide the rules for manual material handling (a full list can be found here):

- keep the correct posture; keep lifts close to your body and avoid bending over;
- avoid sudden lift movements;
- never lift from a sitting position or twist your spine while lifting;
- ask your coworkers to help you if you see lifting an object is a two-person job;
- don't overestimate your capabilities.

If, on the other hand, handling requires the help of machinery (e.g. cranes, industrial trucks, conveyors,…), you should provide instructions on how to operate the loaded machines. Here is an example of safety measures employees should consider while using cranes:

- always check what you're lifting and how much it weighs;
- inspect the crane's load chart to prevent it being overloaded;

- plan lifts before the actual operation;
- daily inspect the critical parts of a crane.

It is difficult to fit all information your material handling work instructions should focus on into a blog post, that's why we provide you with two examples from OSHA and the University of Saskatchewan. We're sure they'll give you a clear idea of how a good work instruction for material handling should look like.

Write standardized work instructions for lean manufacturing in 5 easy steps

If you wish to succeed in your lean manufacturing documentation, consider 3 questions before writing it: who performs the task? When do they perform the task? And how do they perform it? Answers will provide you with inputs for further design of lean standardized work instructions.

Do you already have the answers to the questions in mind? Great. Now follow the 5 steps to create standardized work instructions in lean manufacturing:

Observe work

Start with an observation of a task you wish to standardize. You can design a process study sheet in Excel and print it to help you with notes. When collecting details, be sure to use correct real times, stay focused and don't guess what the workers are doing.

Understand the throughput of the process

Understand cycle times, inputs and outputs and the capabilities of how many parts per period can be delivered, so understand the throughput. Focus on takt time and line balancing. You can do some simple calculations for the two, provided you have the information on the length and number of products produced in a process.

Define the task steps

By using a standard work chart document, define the exact sequence of the steps, needed to perform a certain task. You can add images, charts and tables to visualize it. Also, don't forget to include the information on whether the process succeeded or failed.

Document the standard in-process inventory

Keep in mind that lean manufacturing's goal is to minimize it. Think about the requirements for the inventory at the beginning and end of the process and how much stock will the semi-products create in between the steps.

Create a combination table

Join the steps and create a comprehensive image of the process. The most common combination table is a Gantt chart. It allows you to see how much time does each step take, who is responsible for it and which steps need to be completed to move on to the next ones. This is usually done by the project office and includes real-time dates of the tasks. SWI tasks following the lean manufacturing Kaizen approach need to be updated regularly, to ensure the best quality and consistency. Designing standardized work instructions in lean manufacturing by following the 5 steps will result in the work will be done faster, problems solved quicker, waste reduced and costs lowered

1.3 **Tools, equipment, material and testing devices**

- Material

1 Wires and Cables

2 Pipes/tubes & Fittings

3 Sealing materials

- **Necessary tools**

You will need the following tools:

- Cutter- Calipers and gauges
- Shaper- Screw drivers(assorted)
- Drill- Soldering iron/gun
- Threading tools(assorted- Wrenches hexagonal or Allen key

- Tapper- Water level tri-square
- File- Measuring tap
-

➢ **Equipment/testing devices**

- Communication equipment (e.g., 2-way radio, cell phone)
- Fastening equipment
- Multi-meters
- Insulation tester or (Megger)
- Calibrators

Self-Check 1	Written Test

1.2 Self check

Part I. say true or false

1.OHS is a science that control hazards in a work place

2.OHSpolicy is a statement of principle and a general rule that serve as a guide for action

3.One of the standard work instruction is obserb work

4. **Define the task steps is not a step of work instruction**

5. Work instruction tasks not following the lean manufacturing Kaizen

Part II. Choose the best answer.

1. Which one of the following safety equipment?
   A. Measuring instrument B. Hand tool
   C. Glave D. All of the above
2. Which one is true for material handling procedure.
   A. Manual B. semi automated C.Fully automated D.A& B
3. From the following which is important safety for Material handling.
   A. Avoid sudden lift movements;
   B. Never lift from a sitting position or twist your spine while lifting;
   C. Ask your coworkers to help you if you see lifting an object is a two-person job
   D. All
4. Which one is used to prepare installation for instrument

A.BFD B.PFD C.P & ID D. None

5. work instruction content for measuring instruments include
   A. Description and purpose of the measuring instrument
   B. B. Technical specifications C. setting up the instrument
   C. D. measurement procedure E. All

Unit Two: Instrumentation and control devices Installation

This unit is developed to provide you the necessary information regarding the following content coverage and topics

- Instrumentation and process control devices
- instrumentation and control standards
- Instrumentation and control device installation

This unit will also assist to attain the learning outcomes stated in the cover page .Specifically ,upon completion of this learning guide, you will be able to:-

- Understand instrumentation and process control devices
- Follow instrumentation and control standards
- Install instrumentation and control device

2.1 Instrumentation and process control devices

- **Basic concept of instrumentation and control devices**

➢ **Instrumentation definition**

Instrumentation is the art of measuring, monitoring and controlling of the value of some plant parameter, pressure, flow, level, temperature etc… and supplying a signal that is proportional to the measured parameter.

Instrumentation is the design and use of an electrical system to collect and process physically meaningful data

Industrial control and automation are meaningless without a proper instrumentation scheme. Therefore, technological advancement requires advancement in both instrumentation and control.

Industrial processes to be handled by measurement and instrumentation can vary widely from simple to complex processes

Elements of instrumentation

Measuring device (to get information about the system and to control that system); to get information the following processes are must,

- Introduction: A basic instrument system consists of three elements:

➢ Sensor Or Input Device

➢ Signal Processor

- Receiver Or Output Device

Input devices but you can never separate it from the rest of the system as in many cases they are all integral (e.g. a mechanical pressure gauge incorporates all of these elements. All instrumentation systems can be generally described by the block diagram of figure below. Here the system consists of three different parts: the sensor, the processes, and the display/storage. **Signal Conditioning**



Fig 2. 1 A block diagram of Instrumentation system

- **Instrumentation engineering** is the engineering specialization focused on the principle and operation of measuring instruments that are used in design and configuration of automated systems in electrical, pneumatic domains etc.
- **Instrumentation technologists, technicians** and mechanics specialize in troubleshooting and repairing and maintenance of instruments and instrumentation systems.

Introduction Of Transducer

Transducers

- A transducer is a device that convert one form of energy to other form. It converts the measurand to a usable electrical signal.
- In other word it is a device that is capable of converting the physical quantity into a proportional electrical quantity such as voltage or current.

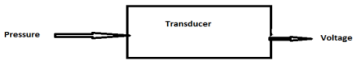


Fig 2.2 **Transducers**

Sensors

Sensor is used for an element which produces a signal relating to the quantity being measured Example: Resistance Temperature Element/(RTD), the quantity being

measured is temperature and the sensor transforms and input of temperature into a change in resistance.

Sensor is used for an input device that provides a usable output in response to a specified physical input. For example, a thermocouple is a sensor that converts a temperature difference into an electrical output. The term transducer is generally used to refer to a device that converts a signal from one form to a different physical form. Thus sensors are often transducers, but also other devices can be transducers, such as a motor that converts an electrical input into rotation.

• Transducer is often used in place of the term sensor. They are elements that when subject

to some physical change experience a related change.

• Sensors are transducers.

• A measurement may use transducers, in addition to the sensor, in other parts of the system to convert signals in one form to another form.

• A **transducer** is a device that converts one type of energy to another. Energy types include (but are not limited to) electrical, mechanical, electromagnetic (including light), chemical,

acoustic or thermal energy. While the term transducer commonly implies the use of a sensor/detector, any device which converts energy can be considered a transducer. Transducers are widely used in measuring instruments.

• Transducer means **converts.**

- Transducer contains two parts that are closely related to each other i.e. the sensing element and transduction element.
- The sensing element is called as the sensor. It is device producing measurable response to change in physical conditions.
- The transduction element convert the sensor output to suitable electrical form.

Classification Of Transducers

The transducers can be classified as:

I. Active and passive transducers.
II. Analog and digital transducers.
III. On the basis of transduction principle used.

IV. Primary and secondary transducer

V. Transducers and inverse transducers.

Active and passive transducers

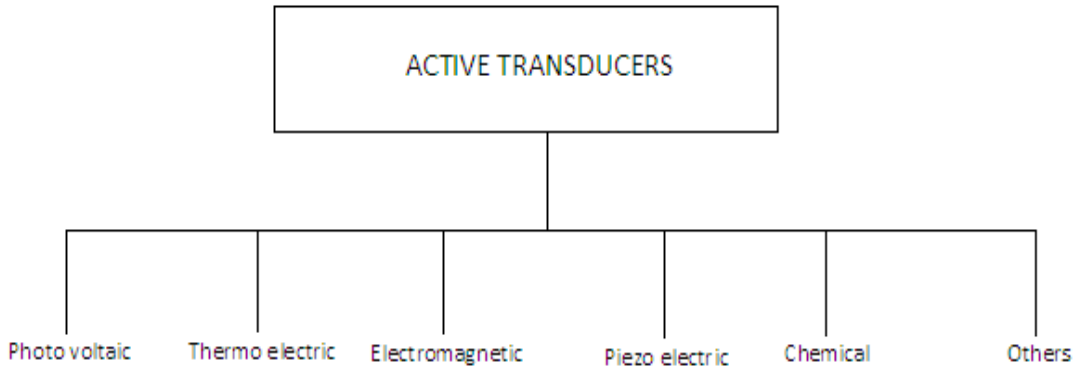
A. Active transducers

These transducers do not need any external source of power for their operation. Therefore they are also called as self generating type transducers.

The active transducer are self generating devices which operate under the energy conversion principle.

As the output of active transducers we get an equivalent electrical output signal e.g. temperature or strain to electric potential, without any external source of energy being used

Classification of Active Transducers



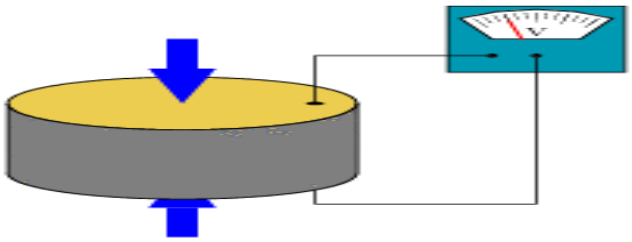


Fig2.3 Piezo Electric Transducer

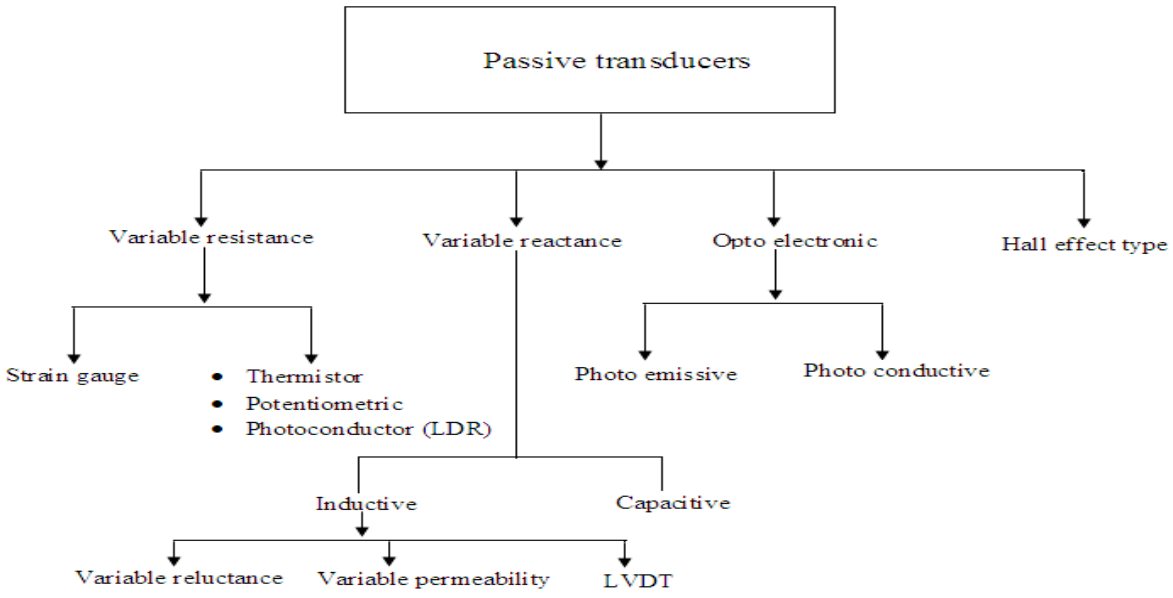
B. Passive Transducers

I. These transducers need external source of power for their operation. So they are not self generating type transducers.

II. A DC power supply or an audio frequency generator is used as an external power source.

These transducers produce the output signal in the form of variation in resistance, capacitance, inductance or some other electrical parameter in response to the quantity to be measured

Classification of Passive Transducers



III. Analog and digital transducers.

A. Analog instrument:-Analog instrument are used to measure Electrical and non electrical quantity

Eg. Voltage ,current, resistance,Power,Pressure etc

- Analog Instruments have a pointer and Scale.T he pointer and scale are used to indicate their

Value



Fig2.4.Analog Instrument

B. Digital Instrument:- Digital instruments also used to measure Electrical and non electrical quantity

- Digital instruments their value Display in the form of a number

Eg. Voltage ,current, resistance, Power, Pressure etc

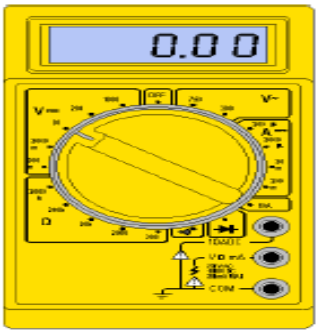


Fig2.5.Digital Instrument

- **Signal Conditioning**

Signal Conditioning - a front-end preprocessing,which generally includes functions such as

signal amplification, filtering, electrical isolation, and multiplexing. In addition, many transducers require excitation currents or voltages, bridge completion, linearization, or high amplification for proper and accurate operation.

Transducers

Transducers are devices that convert one type of physical phenomenon, such as temperature, strain, pressure, or light, into another. The most common transducers convert physical quantities to electrical quantities, such as voltage or resistance. Transducer characteristics define many of the signal conditioning requirements of a DAQ system. Table 1 summarizes the basic characteristics and signal conditioning requirements of some common transducers.

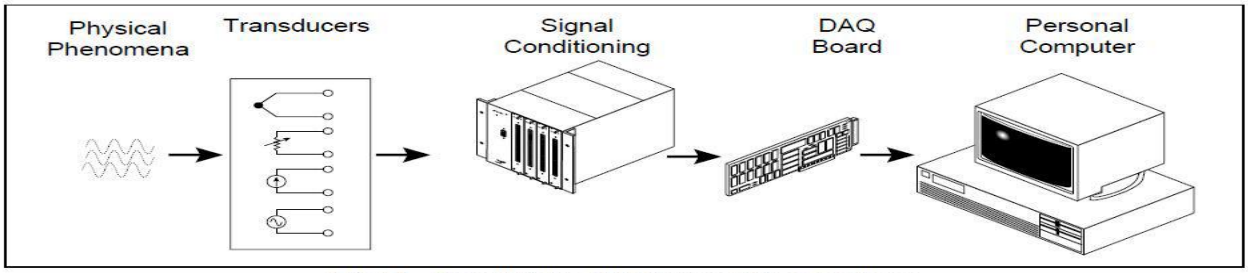


Figure 1. A General PC-Based DAQ System with Signal Conditioning

Fig 2.6 Signal condition procedure

Signal Conditioning Devices

Charge amplifiers, lock-in amplifiers, power amplifiers, switching amplifiers, linear amplifiers, tracking filters, low-pass filters,high-pass filters, and notch filters are some of the signal-conditioning devices used in mechatronic systems.

2.2 Instrumentation and control standards

- **Istrument Code and Standard**

Below are some of the major organizations that individually contribute hundreds, some even thousands, of codes or standards across all disciplines and multiple industries.

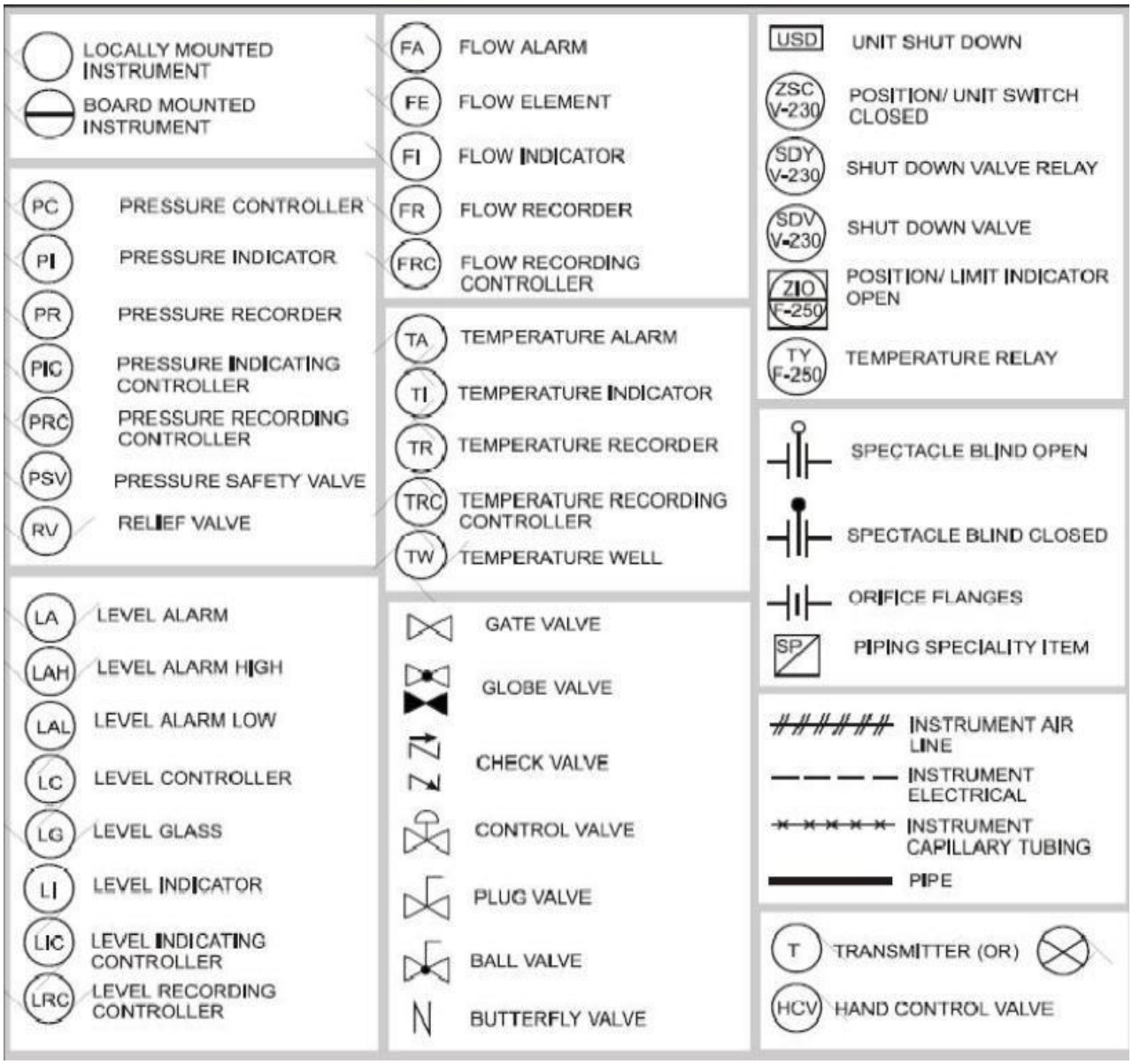
Abbreviation	Organization
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials (ASTM International)
DIN	Deutsches Institut für Normung
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers

ISA	International Society of Automation formerly Instrument Society of America
ISO	International Organization for Standardization
NFPA	National Fire Protection Association
SAE	Society of Automobile Engineers (SAE International)

Industry Standards

Your career path and the industry you work in is going to determine which codes and standards are relevant for you, but there are a few that are difficult to avoid no matter what industry you serve.Below is a partial list of standards that have been particularly useful in my career.

bbreviation	**Code/Standard**
BPVC	Boiler and Pressure Vessel Code
B31.1	Pressure Piping Code – Power Piping
B31.2	Pressure Piping Code – Fuel Gas Piping
B31.3	Pressure Piping Code – Process Piping
ISA-5.1	Instrumentation Symbols and Identification
ISA-5.4	Instrument Loop Digrams
ISA-101.01	Human Machine Interfaces for Process Automation Systems
NFPA 70	National Electric Code
NFPA 79	Electrical Standard for Industrial Machinery
NFPA 85	Boiler and Combustion Systems Hazards Code
NFPA 86	Standard for Ovens and Furnaces



Process flow diagram(PFDs) shows the major interconnectons of process vessels and equipment, but omits details such as instrument signal lines and auxilary instruments.

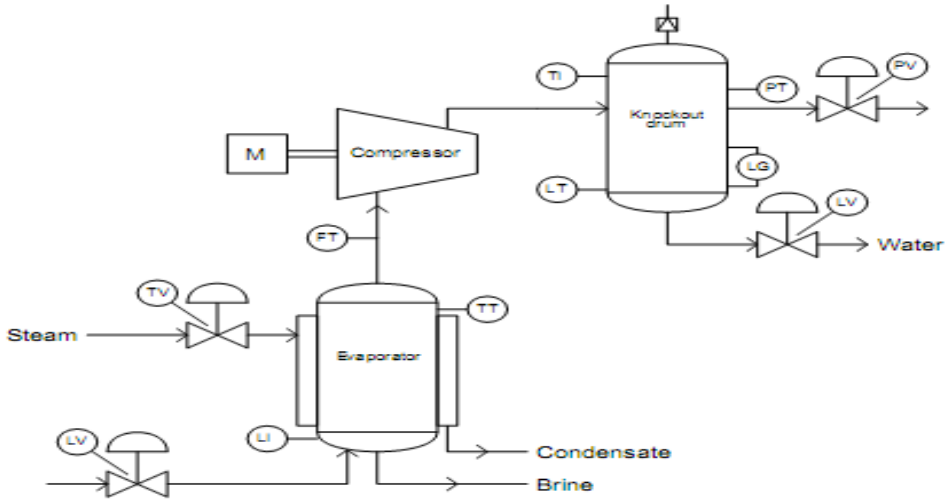


Fig2.6 process flow diagram

Pipingand instrumentation diagram(P&IDs)shows the layout of all relevent process vessels, pipes and machinery, but with instrument superimposed on the diagram showing what gets measured and what gets controlled. Here, one can view the flow of the process as well as the flow of information between instrumentmeasuring and controlling the process.

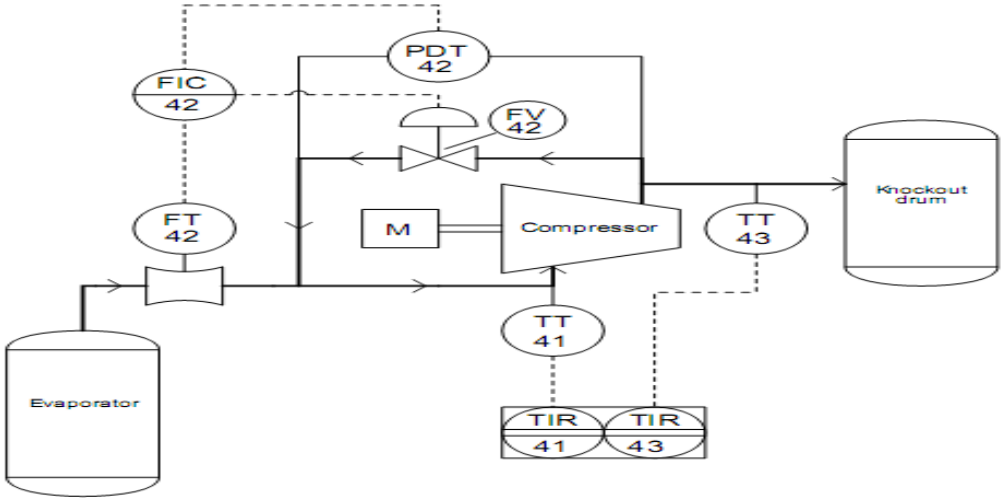


Fig 2.7 process flow diagram

SAMA diagrams is Acronym Standing for Scientific Apparatus Makers Association, referring to a unique form of diagram used primary in the power generation industryto document control strategies. Thesediagram focus on the flow of information with in a control system rather than on the processpiping, or instrument interconnections (wiring, tubes, etc). the general flow of a SAMAdiagrams istop-to-bottom,with the process sensinginstrument(transmiter located at top and the final control element(valve or variable-speed motorlocated at bottom.no attempt is made to arrange symbol in aSAMA diagrams to correlate with actual equipment layout:These diagrams are all about the algorithms used to make control decisions, and nothing more.A sampleSAMA diagrams appers here, showing a flow transmiter (FT sending process variable signal to a PID controller, which then sends a manuplated variable signal to a flow control valve(FCV)

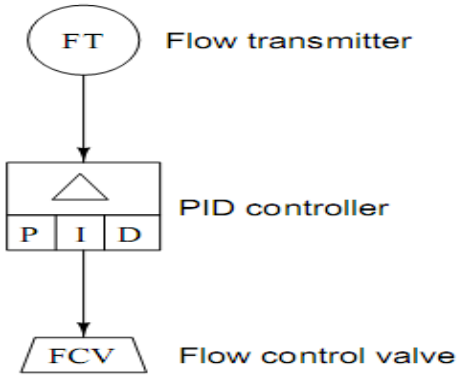


Fig 2.8 **Sama diagram**

2.3 Instrumentation and control device installation

- **Basic terms of measurement technique**

Let us start again with the definition of electrical measurements. Apart from the term “measurements” also other terms are in use, for example “scientific instrumentation” (or just instrumentation) and “metrology”. The scientific instrumentation is often used as a synonym of measurements, and the metrology is assumed as a science about measurements. Thus, the measurements will be treated narrower, as a technique or engineering of measurements.

There are various explanations of the term “measurements”. We can expand the definition presented in Chapter 1 as: The measurement is a cognitive process of gathering the information from the physical world. In this process a value of a quantity is determined (in defined time and conditions) by comparison it (with known uncertainty) with the standard reference value.

- **Application of measuring instruments**
  - A. Indicate
  - B. Record
  - C. Comparison
  - D. Integrated

Indicating instruments measure the electrical quantity with the help of a pointer and calibrated scale. Recording instruments use an ink pen continuously rotated on the drum to record the readings on a graph paper. Indicating instruments require an observer to monitor the changes in the quantity under measurement. Examples of comparison measurement instruments include dial indicators , test indicators , and optical comparators. Integrated type instrument is used to do two function i.e it reads the value again it perform mathematical operation

- **characteristics of instrument**

A. Static characteristics of instruments

The static characteristics of measuring instruments are concerned only with the steady state reading that the instruments settle down to, such as the accuracy, Precision and the reaction to ambient temperature changes are further considerations. These attributes are collectively known as the static characteristics of instruments, and are given in the data sheet for a particular instrument. The various static characteristics are defined in the following paragraphs.

Accuracy of an instrument is a measure of how close the output reading of the Instrument is to the correct value.

Precision is a term that describes an instrument’s degree of freedom from random errors.

Tolerance is a term that is closely related to accuracy and defines the maximum Error that is to be expected in some value. When used correctly,

tolerancedescribesthemaximumdeviationofamanufacturedcomponentfromsome specified value

Range or span of an instrument defines the minimum and maximum values of a quantity that the instrument is designed to measure.

B. Dynamic characteristics of instruments

This is considered when the instrument is used to measure conditions varying with time.

Sensitivity of measurement is a measure of the change in instrument output that occurs when the quantity being measured changes by a given amount. Thus, sensitivity is the ratio: scale deflection value of measure and producing deflection

Linearity it is normally desirable that the output reading of an instrument is linearly proportional to the quantity being measured.

Zero Drift describes the effect where the zero reading of an instrument is modified by a change in ambient conditions.

Resolution is showing a particular output reading, there is a lower limit on the magnitude of the change in the input measured quantity that produce an observable change in the instrument output.

C. Mathematical calculation

Unit conversions

The following subsections give sets of physically equal quantities, which may be used to create unity fractions for unit conversion problems. Note that only those quantities shown in the same line (separated by=symbols) are truly equal to each other, not quantities appearing indifferent lines!

Conversion formulae for temperature

$^{o}F = (^{o}C)\ (9/5)+32$

$^{o}C = (^{o}F - 32)(5/9)$

$^{o}R = {}^{o}F + 459.67$

$K = {}^{o}C + 273.15$

Conversion factors for distance

1inch (in) =2.540000 centimeter (cm)

1foot (ft.) = 12 inches (in)

1yard (yd.) = 3feet (ft.) 1 mile (mi) = 5280 feet (ft.)

Conversion factors for volume

1gallon (gal) =231.0cubic inches (in3) = 4 quarts (qt) = 8pints (pt.) =128 fluid ounces (fl. oz.) =3.785 4 liters (l) 1milliliter (ml) =1cubic centimeter (cm3)

Conversion factors for velocity

1mile per hour (mi/h) =88 feet per minute (ft./m) =1.46667feet per second (ft./s) =1.60934 kilometer per hour (km/h) =0.44704 meter per second (m/s)

Conversion factors for mass

1pound (lb.) = 0.45359 kilogram (kg) =0.031081slugs

Conversion factors for force

1pound-force (lb. f) = 4.44822 newton (N)

Conversion factors for area

1acre = 43560 square feet (ft2) = 4840 square yards (yd2) = 4046.86 square meters (m2)

Conversion factors for pressure (either all gauges or all absolute)

1pound per square inch (PSI) =2.03603inches of mercury (in. Hg) = 27.6807 inches of water (in. W. C.) = 6.894757 kilo-Pascal (kPa)

Conversion factors for pressure (absolute pressure units only)

1atmosphere (Atm) =14.7pounds per square inch absolute (PSIA) = 760 millimeters of mercury absolute (mm HgA) = 760 torr (torr) =1.01325 bar (bar)

Conversion factors for energy or work

1British thermal unit (Btu) = 251.996 calories (cal) = 1055.06 joules (J) =1055.06watt-seconds (W-s) = 0.293071 watt-hour (W-hr) =1.05506x1010 ergs (erg) =778.169 foot-pound-force (ft-lbf)

Conversion factors for power

1 horse power (hp 550ft-lbf/s) =745.7watts (W) =2544.43British thermal units per hour (Btu/hr) =0.0760181boiler horse power (hp boiler)

Properties of water

- Freezing point at sea level = $32^{o}F = 0^{o}C$
- Boiling point at sea level = $212^{o}F=100^{o}C$

- Density of water at 4oC =1000kg/m3 =1g/cm3=1kg/liter=62.428lb/ft3=1.951slugs/ft3
- Specific heat of water at 14oC = 1.00002 calories/g.^{o}C =1BTU/lb.^{o}F = 4.1869 joules/g. ^{o}C
- Specific heat of ice 0.5calories/g.^{o}C
- Specific heat of steam 0.48calories/g.^{o}C
- Absolute viscosity of water at 20^{o}C = 1.0019 centipoise (cp) = 0.0010019 Pascal-seconds (Pa.s) Surface tension of water (in contact with air) at18oC =73.05 dynes/cm
- PH of pure water at 25^{o}C=7.0(pH scale = 0 to14)

A fluid is any substance having the ability to flow: to freely change shape and move under the influence of a motivating force. Fluid motion may be analyzed on a microscopic level, treating each fluid molecule as an individual projectile body.

Pressure (p): how much force (F) is distributed across how much area (A). P= (F/A) in the metric system, the standard unit of pressure is the Pascal (Pa), defined as one Newton (N) of force per square meter (m2) of area. In the English system of measurement, the standard unit of pressure is the PSI: pounds (lb.) of force per square inch (in2) of area. Pressure is often expressed. In units of kilo-Pascal (kPa) when metric units are used because one Pascal is a rather low pressure in most engineering applications.

2.3.1 Instrument in process Industry

Things in Industry that we commonly measure are:

1. Temperature Transducers

A. Thermocouples

When two wires with dissimilar electrical properties are joined at both ends and one junction is made hot and the other cold, a small electric current is produced proportional to the difference in the temperature. See beck discovered this effect. It is true no matter how the ends are joined so the cold end may be joined at a sensitive millivolt meter. The hot junction forms the sensor end.

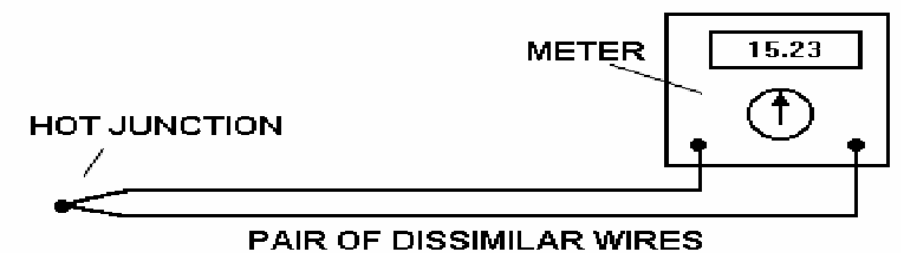


Fig 2.9 Thermocouples Transducer

The picture shows a typical industrial probe with a flexible Extension and stand ard plug



Fig 2.9 Thermocouole

Thermocouples come in several forms. They may be wires insulated from each other with plastic or glass fiber materials. For high temperature work, the wire pairs are put inside a tube with mineral insulation. For industrial uses the sensor comes in a metal enclosure such as stainless steel.

Types of Thermocouples:

Type J 0 to 800oC	Type R/S 0 to 1600oC
Type B 500 to 1800oC	Type K 0 to 1200oC
Type N 0 to 1200oC	Type T -199 to 250oC
Type L 0 to 800oC	Type E 0 to 600oC

B. Thermistor

A special type of resistance sensor is called a Thermistor. They are made from a small piece of semi-conductor material. The material is special because the resistance changes a lot for a small change in temperature and so can be made into a small sensor and it costs less than platinum wire. The temperature range is limited. They are only used for a typical range of - 20 to 120oC and are commonly used in small hand held thermometers for everyday use.

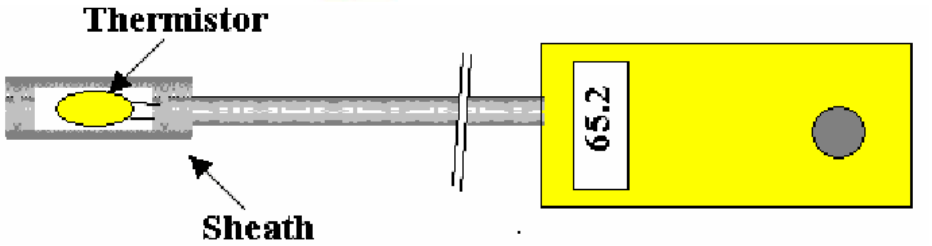


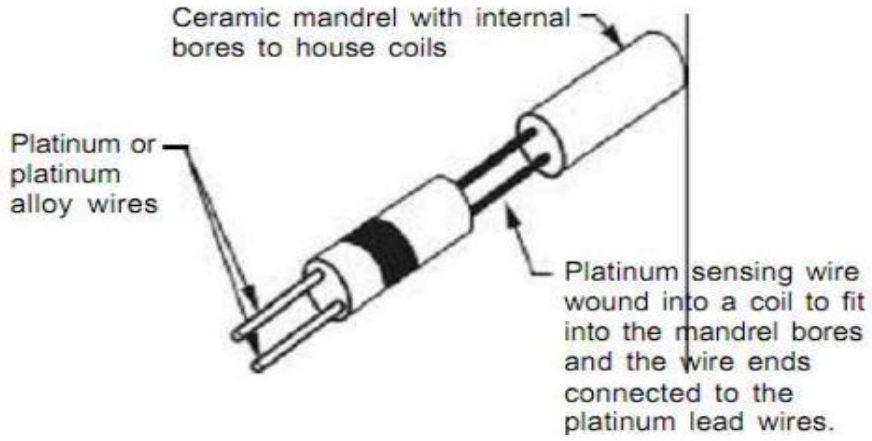
Fig 2.10.Thermistor

C. RTD (Resistance Temp. Detector)

A resistance temperature detector (RTD) operates on the principle that electrical resistance of metal changes as its temperature changes. The resistance of the sensing element increases as the temperature rises. There are two basic RTD designs

1. Wire wound **2. Thin film**

Wire wound design is a platinum sensing wire wound into a coil and housed in a ceramic mandrel to protect the coil. The thin film design consists of platinum deposited on a ceramic substrate and trimmed to achieve the desired alpha the construction is then covered with glass and epoxy to protect platinum film. Thin films are manufactured much in the same way as computer chips.



The metal that is employed in a RTD must change resistance with respect to temperature and provide stability and a high output. The three metals that best exhibit these characteristics are:

Platinum:

It can withstand oxidation and is effective over a range of –200 to + 850^0 C. The four basic ohm values of 100, 200.500 and 1000 give the user different degrees of sensitivity within the sensor.

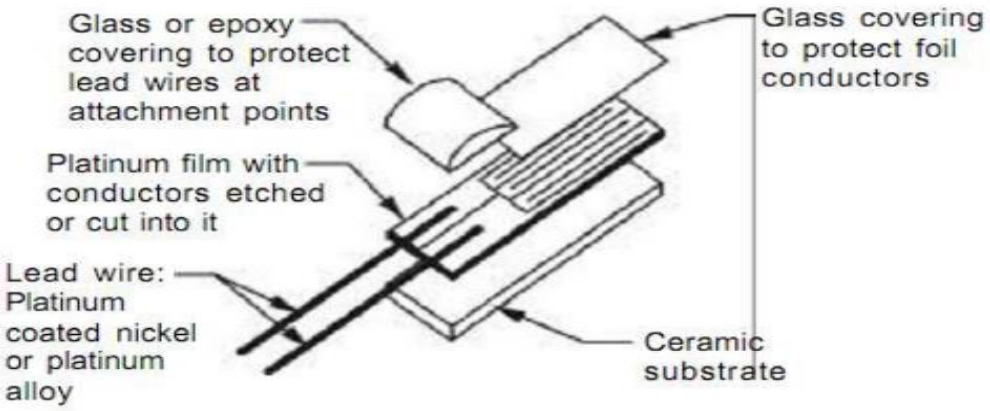
Copper:

The greatest strength of this metal is its low cost. Copper performs poorly in oxidizing atmospheres and has a low output and thus an inability to perform in narrow measuring spans.

Nickel:

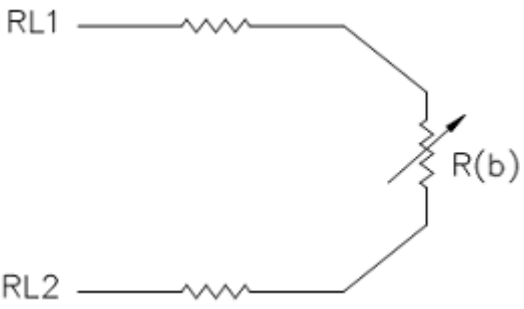
This metal is a good compromise between copper and platinum. It has a higher output and is slightly less expensive than platinum. It is extremely nonlinear above 300 degrees C

Film type sensing elements are made from a metal coated substrate which has a resistance pattern cut into it. This pattern acts as a long, flat, skinny conductor, which provides the electrical resistance. Lead wires are bonded to the metal coated substrate and are held in place using a bead of epoxy or glass.

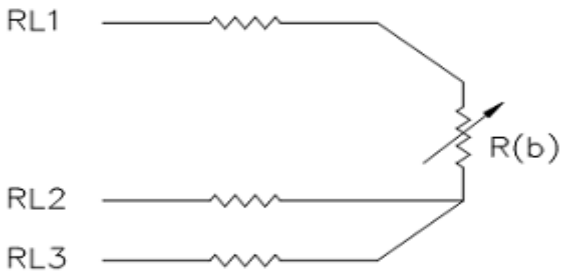


RTDs are available in two-, three-, and four-wire configurations. The number of lead wires directly affects such factors as accuracy, stability, installation budget and distance between sensor and receiver.

2-wire construction is the least accurate of the 3 types sincethere is no way of eliminating the lead wire resistance from the sensor measurement. 2-wire RTD's are mostly used with short lead wiresor where close accuracy is not required.

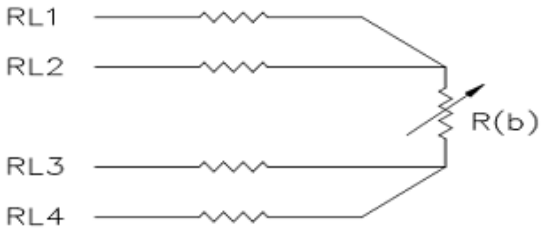


3-wire construction is most commonly used in industrial applications where the third wire provides a method for removing the average lead wire resistance from the sensor measurement. When long distances exist between the sensor and measurement/control instrument, significant savings can be made in using a three-wire cable instead of a four-wire cable.



4-wire construction is used primarily in the laboratory where close accuracy is required. In a 4 wire RTD the actual resistance of the lead wires can be determined and removed from the sensor measurement.

The 4-wire circuit is a true 4-wire bridge, which works by using wires 1 & 4 to power the circuit and wires 2 & 3 to read. This true bridge method will compensate for any differences in lead wire resistances



D. Bi-metal temperature sensors

This type temperature gauge employs the principle of solid expansion and it consists of a bimetal strip. In response to the temperature change, the bimetal expands and helical bimetal rotates at its free ends.

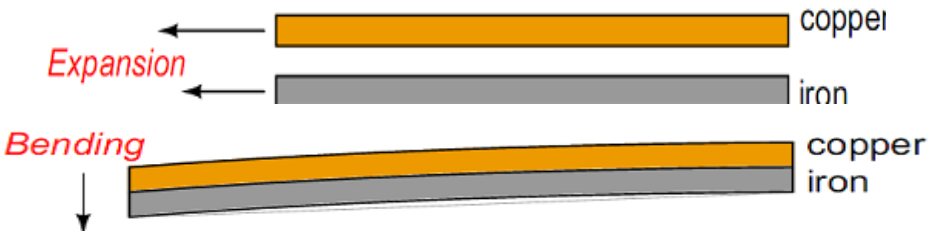


Fig 2.11 Bi-metal Strip sensors

E. Mercury type thermometer:

It is one of the most versatile and widely used devices in industrial temperature measurements. The entire assembly of bulb, capillary, and gauge is calibrated directly on the basis of pressure change changes corresponding to temperature.



Fig 2.12 Mercury type thermometer

2. Pressure Transducers

Pressure sensors either convert the pressure into mechanical movement or into an electrical output. Complete gauges not only sense the pressure but indicate them on a dial or scale. Mechanical movement is produced with the following elements.

- Bourdon Tube.
- Spring and Piston.
- Bellows and capsules.
- Diaphragm.

A. Bourdon Tube

The Bourdon tube is a hollow tube with an elliptical cross section. When a pressure difference exists between the inside and outside, the tube tends to straighten out and the end moves. The movement is usually coupled to a needle on a dial to make a complete gauge. It can also be connected to a secondary device such as an air nozzle to control air pressure or to a suitable transducer to convert it into an electric signal. This type can be used for measuring pressure difference.

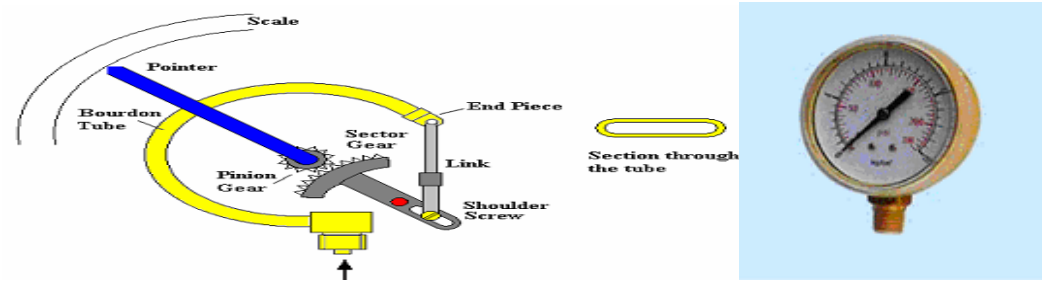


Fig 2.13 Bourdon Tube

B. Piston Type

The pressure acts directly on the piston and compresses the spring. The position of the piston is directly related to the pressure. A window in the outer case allows the pressure to be indicated. This type is usually used in hydraulics where the ability to withstand shock, vibration and sudden pressure changes is needed (shock proof gauge). The piston movement maybe connected to a secondary device to convert movement into an electrical signal.

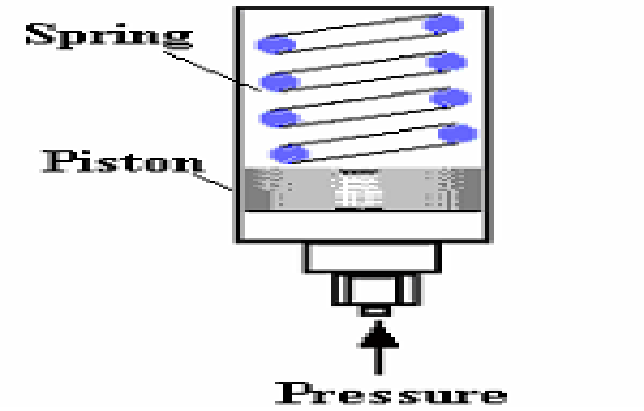


Fig 2.14. Piston Type

C. Capsules and Bellows

A bellows is made of several capsules. These are hollow flattened structures made from thin metal plate. When pressurized the bellows expand and produce mechanical movement. If the bellows is encapsulated inside an outer container, then the movement is proportional to the difference between the pressures on the inside and outside. Bellows and single capsules are used in many instruments. They are very useful for measuring small pressures

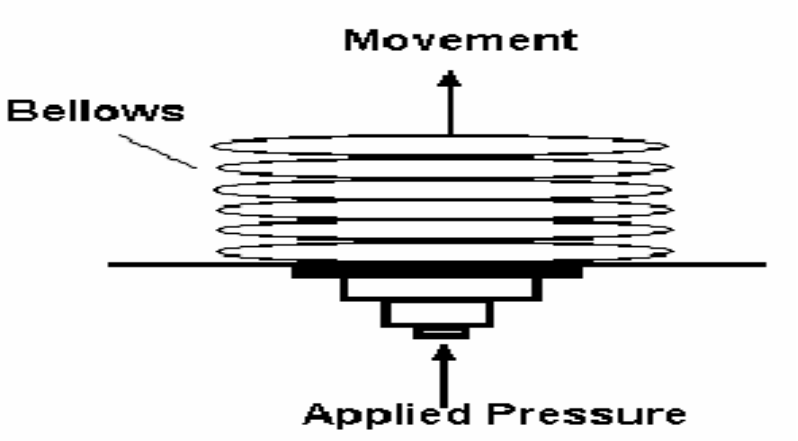


Fig 2.15 Bellows

D. Diaphragms

These are similar in principle to the capsule but the diaphragm is usually very thin and perhaps made of rubber. The diaphragm expands when very small pressures are applied. The movement is transmitted to a pointer on a dial through a fine mechanical linkage.

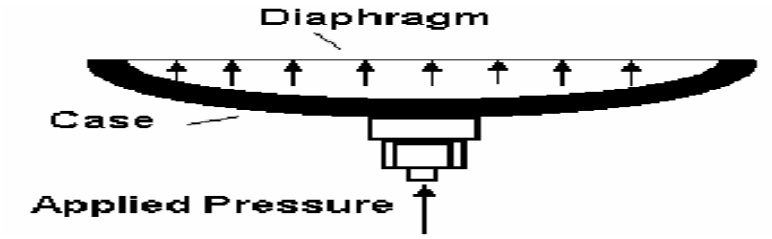


Fig 2.16 Capsules

E. Electrical Pressure Transducers

There are various ways of converting the mechanical movement of the preceding types into an electric signal. The following are types that directly produce an electric signal.

- Strain Gauge types.
- Piezo electric types.
- Other electric effects.

➢ **Strain Gauge Types**

The principles of electric strain gauges are covered later. Strain gauges are small elements that are fixed to a surface that is strained. The change in length of the element produces changes in the electrical resistance. This is processed and converted into a voltage. A typical pressure transducer would contain a metal diaphragm which bends under pressure.



Fig 2.17 **Strain Gauge**

- **Other Electric Effects**

Other electric effects commonly used in transducers are Capacitive and Inductive. In these cases, the pressure produces a change in the capacitance or inductance of an electronic component in the transducer. Both these effects are commonly used in an electronic oscillator and one way they may be used is to change the frequency of the oscillation. The frequency may be converted into a voltage representing the pressure

- **Differential capacitance sensors**

Another common electrical pressure sensor design works on the principle of differential capacitance. In this design, the sensing element is a taut metal diaphragm located equidistant between two stationary metal surfaces, forming a complementary pair of capacitances. An electrically insulating full fluid (usually a liquid silicone compound) transfers motion from the isolating diaphragms to the sensing diaphragm, and also doubles as an effective dielectric for the two capacitors:

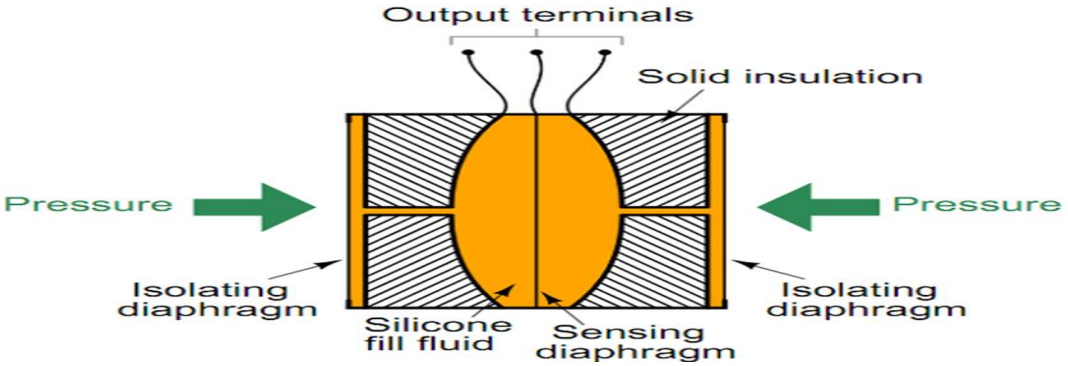


Fig 2.19 **Differential capacitance sensors**

Any difference of pressure across the cell will cause the diaphragm to °ex in the direction of least pressure. Since capacitance between conductors is inversely proportional to the

distance separating them, this causes capacitance on the low-pressure side to increase and capacitance on the high- pressure side to decrease:

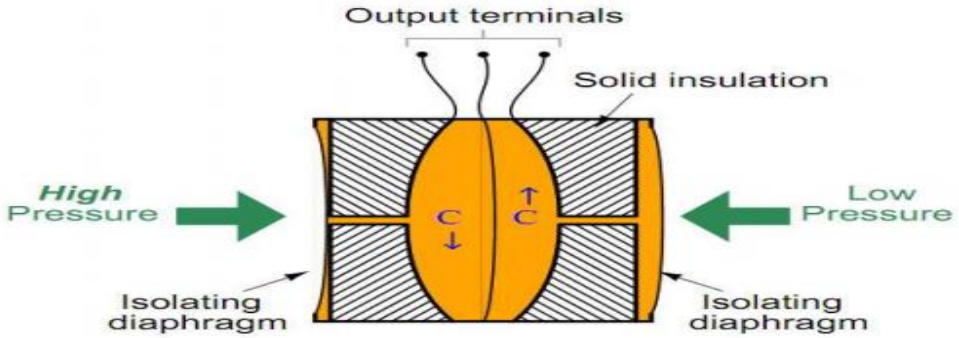


Fig 2.19 **Differential capacitance**

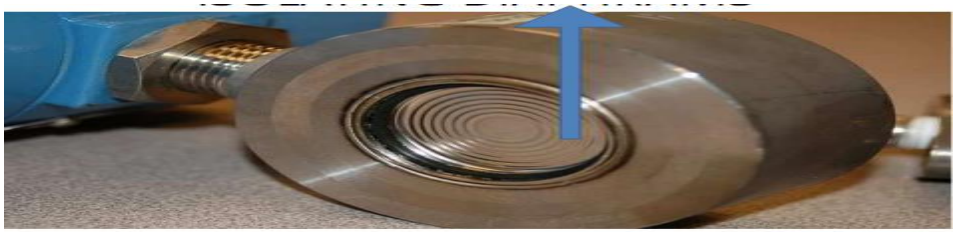
A capacitance detector circuit connected to this cell uses a high-frequency AC excitation signal to measure the different in capacitance between the two halves, translating that into a DC signal which ultimately becomes the signal output by the instrument representing pressure. These pressure sensors are highly accurate, stable, and rugged. The solid frame bounds the motion of the two isolating diaphragms such that the sensing diaphragm cannot move past its elastic limit.This gives the differential capacitance excellent resistance to overpressure damage. For Example we can see the Rosemount transmitter as below:



Fig 2.20 Dismounting Of the Transmitter



Fig 2.21 Close up Photography of Isolating Diaphragm's



3. Flow Meters

There are many hundreds of types of flow meters depending on the make and application. They may be classified roughly as follows.

- Positive Displacement Types• Inferential Types
- Variable Area Types• Differential Pressure Types

A. Positive Displacement Types

These types have a mechanical element that makes the shaft of the meter rotate once for an exact known quantity of fluid. The quantity of fluid hence depends on the number of revolutions of the meter shaft and the flow rate depends upon the speed of rotation. Both the revolutions and speed may be measured with mechanical or electronic devices. Some of the most common listed below.

- Rotary piston type
- Vane type.
- Lobe type or meshing rotor
- Reciprocating piston type
- Fluted spiral gear.

B. Inferential Type Meters

The flow of the fluid is inferred from some effect produced by the flow. Usually this is a rotor which is made to spin and the speed of the rotor is sensed mechanically or electronically. The main types are:

- Turbine rotor types
- Rotary shunt types
- Rotating vane types•
- Helical turbine types

- **Turbine Type**

The turbine type shown has an axial rotor which is made to spin by the fluid and the speed represents the flow rate. This may be sensed electrically by coupling the shaft to a small electric tachometer. Often this consists of a magnetic slug on the rotor which generates a pulse of electricity each time it passes the sensor.

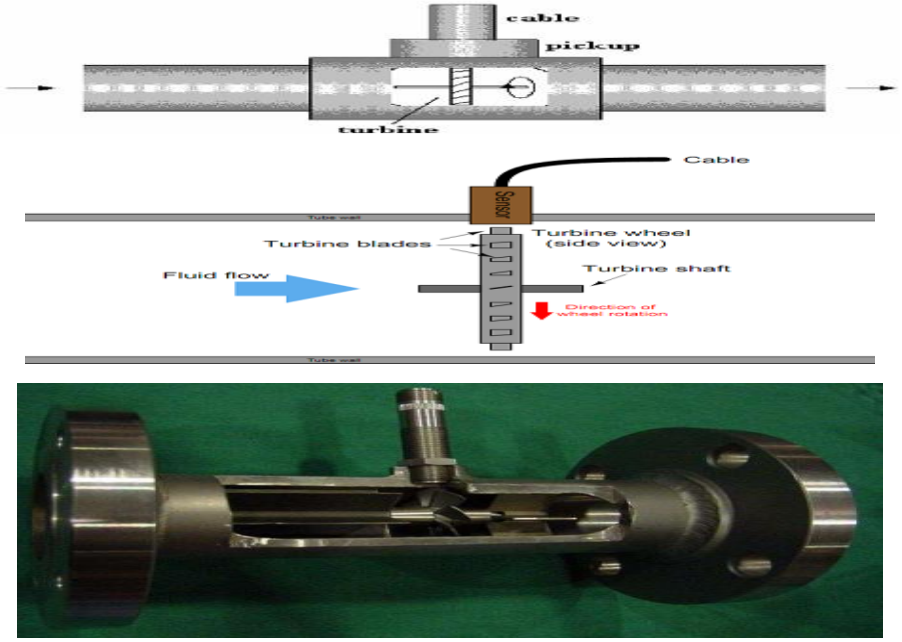


Fig 2.22 Turbine type flow meter

- **Rotating Vane Type**

The jet of fluid spins around the rotating vane and the speed of the rotor are measured mechanically or electronically.

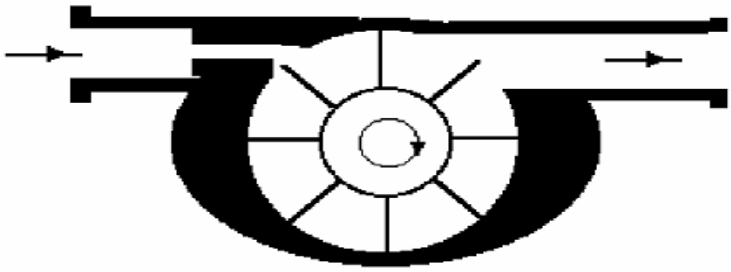


Fig 2.23 Rotating Vane flow meter

C. Variable Area Types

There are two main types of this meter

- Float type (Rota meter)
- Tapered plug type.

➢ **Float Type**

The float is inside a tapered tube. The fluid flows through the annular gap around the edge of the float. The restriction causes a pressure drop over the float and the pressure forces the float upwards. Because the tube is tapered, the restriction is decreased as the float moves up. Eventually a level is reached where the restriction is just right to produce a pressure force that counteracts the weight of the float. The level of the float indicates the flow rate. If the flow changes the float moves up or down to find a new balance position.

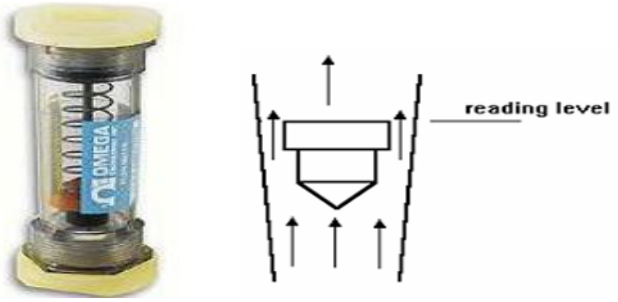


Fig 2.23 Float type flow meter

➢ **Tapered Plug Type:**

In this meter, a tapered plug is aligned inside a hole or orifice. A spring holds it in place. The flow is restricted as it passes through the gap and a force is produced which moves the plug. Because it is tapered the restriction changes and the plug takes up a position where the pressure force just balances the spring force. The movement of the plug is transmitted with a magnet to an indicator on the outside.



Fig 2.24 Tapered Plug flow meter

D. Differential Pressure

- **Flow Meters**

These are a range of meters that convert flow rate into a differential pressure. The important types conform to BS1042 and are

- Orifice Meters.
- Venturi Meters
- Nozzle Meters
- Pitot Tubes.

The diagram shows a cross section through the four types of d.p. meters.

Orifice Plate

Of all the pressure-based flow elements in existence, the most common is the orifice plate. This is simply a metal plate with a hole in the middle for fluid to flow through. Orifice plates are typically sandwiched between two flanges of a pipe joint, allowing for easy installation and removal:

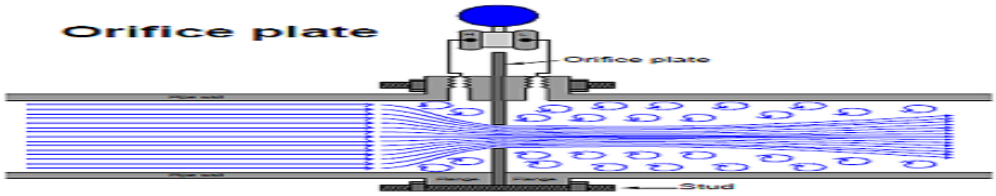
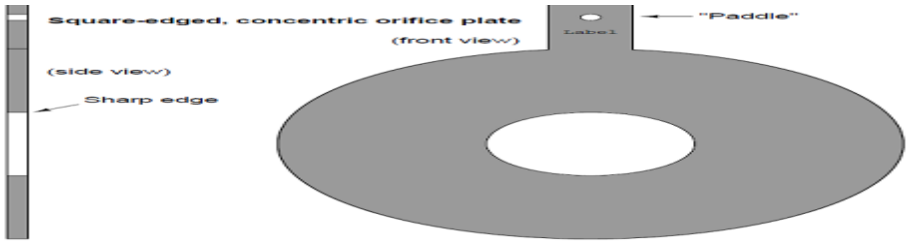


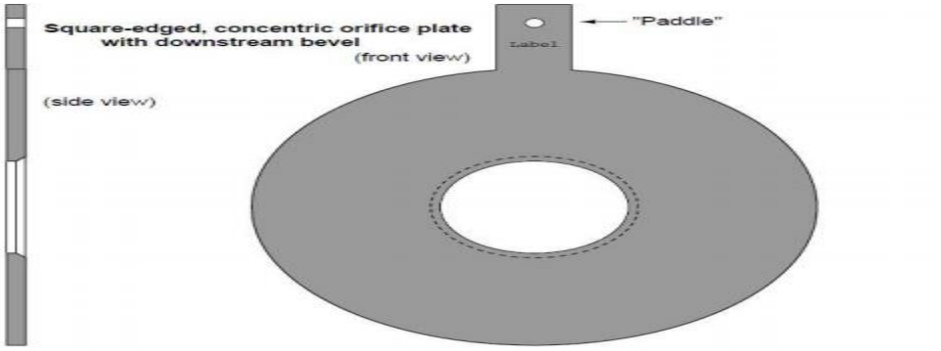
Fig 2.25 Orifice Plate

The point where the fluid flow profile constricts to a minimum cross-sectional area after flowing through the orifice is called the vena contract, and it is the area of minimum fluid pressure. The vena contract corresponds to the narrow throat of a venturi tube. The simplest design of orifice plate is the square-edged, concentric orifice. This type of orifice plate is manufactured by machining a precise, straight hole in the middle of a thin metal plate.Lookingat a side view of a square-edged concentric orifice plate reveals sharp edges (90^{o} corners) at the hole:



Square-edged orifice plates may be installed in either direction, since the orifice plate \appears “exactly the same from either direction of fluid approach. In fact, this allows square-edged orifice plates to be used for measuring bidirectional flow rates (where the fluid flow direction reverses itself from time to time). A text label printed on the \paddle" of any orifice plate customarily identifies the upstream side of that plate, but in the case of the square- edged orifice plate it does not matter.

The purpose of having a square edge on the hole in an orifice plate is to minimize contact with the fast-moving moving fluid stream going through the hole. Ideally, this edge will be knife-sharp. If the orifice plate is relatively thick (1/8 or an inch or more), it may be necessary to bevel the downstream side of the hole to further minimize contact with the fluid stream:



Looking at the side-view of this orifice plate, the intended direction of flow is left-to-right, with the sharp edge facing the incoming fluid stream and the bevel providing a non-contact outlet for the fluid. Beveled orifice plates are obviously unidirectional, and must be installed with the paddle text facing upstream.

Other square-edged orifice plates exist to address conditions where gas bubbles or solid particles may be present in liquid flows, or where liquid droplets or solid particles may be present in gas flows. The first of this type is called the eccentric orifice plate, where the hole is located off center to allow the undesired portions of the fluid to pass through the orifice rather than build up on the upstream face:

For gas flows, the hole should be offset downward, so that any liquid droplets or solid particles may easily pass through. For liquid flows, the hole should be offset upward to allow gas bubbles to pass through and offset downward to allow heavy solids to pass through.

The second offcenterorifice plate type is called the segmental orifice plate, where the hole is not circular but rather just a segment of a concentric circle:

As with the eccentric orifice plate design, the segmental hole should be offset downward in gas flow applications and either upward or downward in liquid flow applications depending on the type of undesired material(s) in the flow stream.

For relatively low flow rates, an alternative arrangement is the integral orifice plate. This is where a small orifice plate is physically attached to the differential pressure-sensing element so that no impulse lines are needed. A photograph of an integral orifice plate and transmitter is shown here:

Flow Nozzle: Another variation on the venturi theme is called a flow nozzle, designed to be clamped between the faces of two pipe flanges in a manner similar to an orifice plate. The goal here is to achieve simplicity of installation approximating that of an orifice plate while improving performance (less permanent pressure loss) over orifice plates**:**

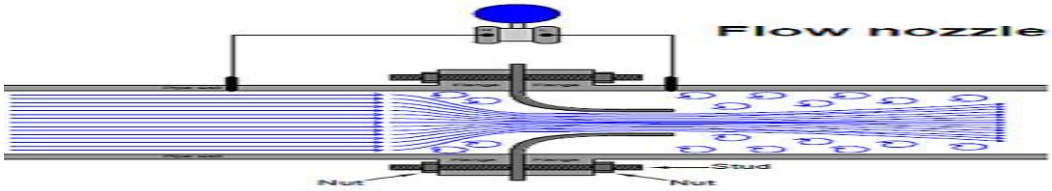


Fig 2.26 Flow nozzle

Pitot tube

Other pressure-based flow elements exist as alternatives to the orifice plate. The Pitot tube, for example, senses pressure as the fluid stagnates (comes to a complete stop) against the open endof a forward-facing tube. A short coming of the classic single-tube Pitot assembly is sensitivity to fluid velocity at just one point in the pipe, so a more common form of Pitot tube seen in industry is the averaging Pitot tube consisting of several stagnation holes sensing velocity at multiple points across the width of the flow**:**

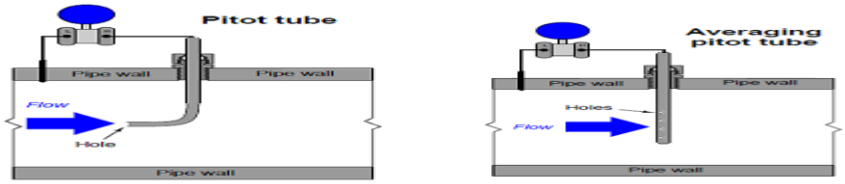
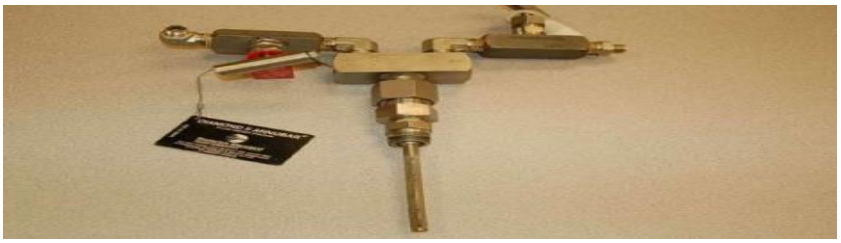
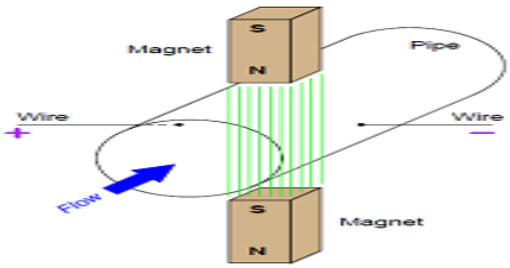


Fig 2.27 Pitot tube



E. Magnetic Flow meters

When an electrical conductor moves perpendicular to a magnetic field, a voltage is induced in that conductor perpendicular to both the magnetic flux lines and the direction of motion. This phenomenon is known as electromagnetic induction, and it is the basic principle upon which all electro-mechanical generators operate. In a generator mechanism, the conductor in question is typically a coil (or set of coils) made of copper wire. However, there is no reasonthe conductor must be made of copper wire. Any electrically conductive substance in motion is sufficient to electromagnetically induce a voltage, even if that substance is aliquid(or a gas). Consider water flowing through a pipe, witha magnetic field passing perpendicularly through the pipe:



The direction of liquid flow cuts perpendicularly through the lines of magnetic flux, generating a voltage along an axis perpendicular to both. Metal electrodes opposite each other in the pipe wall intercept this voltage, making it readable to an electronic circuit.

A voltage induced by the linear motion of a conductor through a magnetic field is called motional EMF, the magnitude of which is predicted by the following formula (assuming perfect perpendicularity between the direction of velocity, the orientation of the magnetic flux lines, and the Axis of voltage measurement):

$E=Blv$

Where,

E = Motional EMF (volts)

l = Length of conductor passing through the magnetic field (meters)

v = Velocity of conductor

B = Magnetic flux density (Tesla) (meters per second)

4. Level Measurements

- Level gauges
- Float
- Differential pressure transmitter
- Compensated leg system
- Displacement
- Ultrasonic level transmitter
- Radar level transmitter

A.Level gauges (sight glasses)

The level gauge or sight glass is to liquid level measurement as manometers are to pressure measurement: a very simple and effective technology for direct visual indication of process level. In its simplest form, a level gauge is nothing more than aclear tube through which process liquid may be seen. The followingphotograph shows a simple example of a sight glass:



A functional diagram of a sight glass shows how it visually represents the level of liquid inside a vessel such as a storage tank:

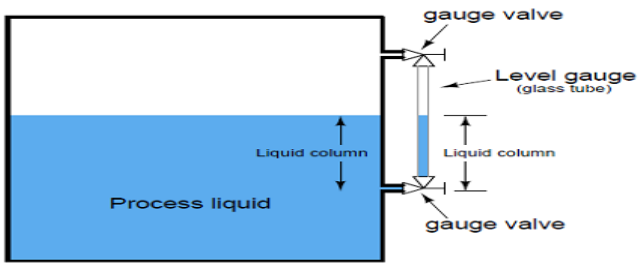


Fig 2.28 Level gauges (sight glasses)

B. Float

Perhaps the simplest form of solid or liquid level measurement is with a float: a device that rides on the surface of the fluid or solid within the storage vessel.

Floats may be used for manual \gauging" of level, as illustrated here:

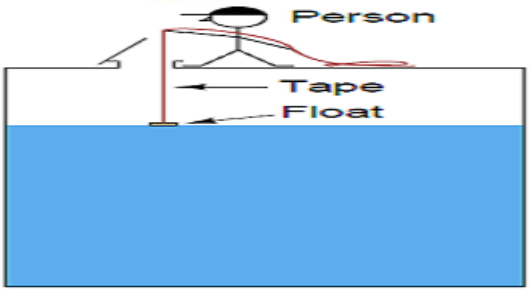


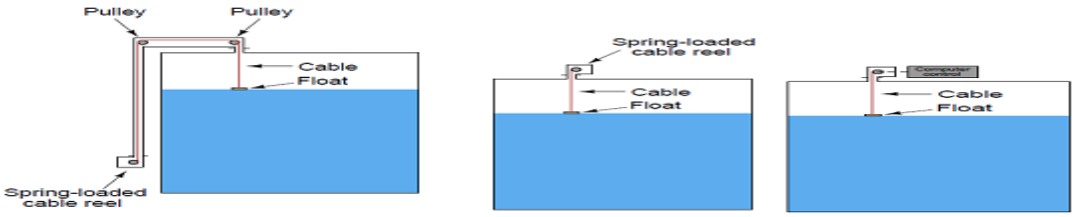
Fig 2.29 Float type level measurement

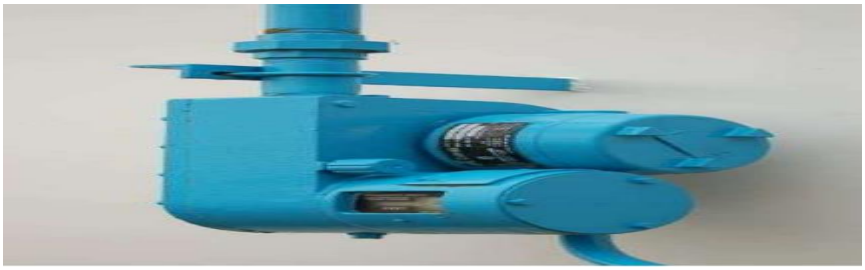
A person lowers a float down into a storage vessel using a flexible measuring tape, until the tape goes slack due to the float coming to rest on the material surface. At that point, the person notes the length indicated on the tape (reading off the lip of the vessel access hole).

Obviously, this method of level measurement is tedious and may pose risk to the person conducting the measurement. If the vessel is pressurized, this method is simply not applicable.

If we automate the person's function using a small winch controlled by a computer {having the computer automatically lower the °oat down to the material surface and measure the amount of cable played out at each measurement cycle {we may achieve better results without human intervention. Such a level gauge may be enclosed in such a way to allow pressurization of the vessel, too:

A simpler version of this technique uses a spring-reel to constantly tension the cable holding the float, so that the float continuously rides on the surface of the liquid in the vessel:





A variation on the theme of float level measurement is to place a small float inside the tube of a

Sight glass-style level gauge

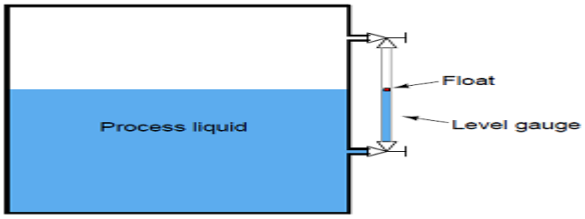


Fig 2.30 Sight glass-style level gauge

D. Differential Pressure transmitter

Differential pressure transmitters are the most common pressure-sensing device used in this capacity to infer liquid level within a vessel. In the hypothetical case of the oil vessel just considered, the transmitter would connect to the vessel in this manner (with the high side toward the process and the low side vented to atmosphere):

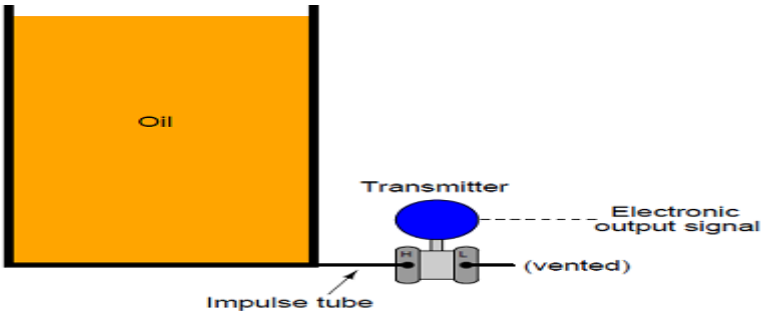


Fig 2.31 Differential Pressure Transmitter

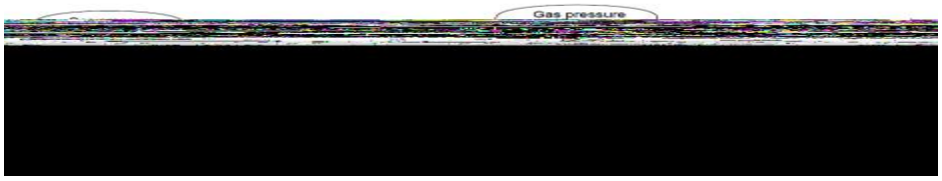
Connected as such, the differential pressure transmitter functions as a gauge pressure transmitter, responding to hydrostatic pressure exceeding ambient (atmospheric) pressure. As liquid level increases, the hydrostatic pressure applied to the \high" side of the differential pressure transmitter also increases, driving the transmitter's output signal higher.

Some pressure-sensing instruments are built specifically for hydrostatic measurement of liquid level in vessels, doing away with impulse tubing altogether in favor of a special kind of sealing diaphragm that protrudes slightly into the vessel through a flanged pipe entry (commonly called a nozzle). A photograph of such a level transmitters shown here:



A. Compensated leg systems

The simple and direct relationship between liquid height in a vessel and pressure at the bottom of that vessel is ruined if another source of pressure exists inside the vessel other than hydrostatic (elevation head). This is virtually guaranteed to be the case if the vessel in question is unvented. Any gas or vapor pressure accumulation in an enclosed vessel will add to the hydrostatic pressure at the bottom, causing any pressure-sensinginstrument to falselyregistera high level:



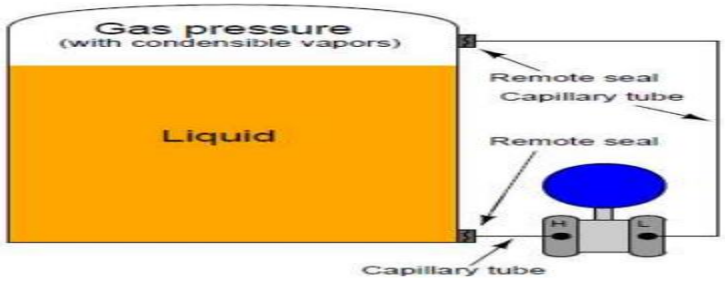


Fig 2.32 Compensated leg systems

B. Displacement

Displacer level instruments exploit Archimedes' Principle to detect liquid level by continuously measuring the weight of a rod immersed in the process liquid. As liquid level increases, the displacer rod experiences a greater buoyant force, making it appear lighter to the sensing instrument, which interprets the loss of weight as an increase in level and transmits a proportional output signal. In practice a displacer level instrument usually takes the following form.

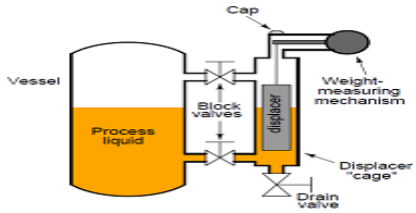




Fig 2.33 Displacement type level measurement

D. **Ultrasonic level measurement**

Ultrasonic level instruments measure the distance from the transmitter (located at some high point) to the surface of a process material located further below. The time-of-flight for a sound pulse indicates this distance, and is interpreted by the transmitter electronics as process level. These transmitters may output a signal corresponding either to the fullness of the vessel (fill age) or the amount of empty space remaining at the top of a vessel (ullage).

Fill age= Total height –Ullage

Ullage= Total height –Fill age

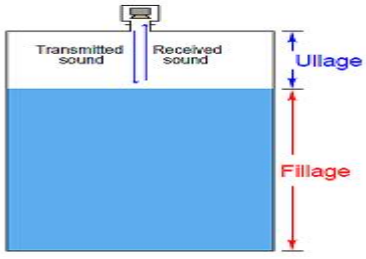




Fig 2.34 Ultrasonic level measurement

F. Level measurement

Radar level instruments measure the distance from the transmitter (located at some high point) to the surface of a process material located further below in much the same way as

ultrasonic transmitters. The fundamental difference between a radar instrument and an ultrasonic instrument is the use of radio waves instead of sound waves. Radio waves are electromagnetic in nature (comprised of alternating electric and magnetic fields), and very high frequency (in the microwave frequency range {GHz). Sound waves are mechanical vibrations (transmitted from molecule to molecule in a fluid or solid substance) and of much lower frequency (tens or hundreds of kilohertz {still too high for a human being to detect as a tone) than radio waves.

Some radar level instruments use waveguide \probes" to guide the radio waves into the process liquid while others send radio waves out through open space to reflect of the process material. The instruments using waveguides are called guided-wave radar instruments, whereas the radar instruments relying on open space for signal propagation are called non-contact radar. The differences between these two varieties of radar instruments is shown in the following illustration:

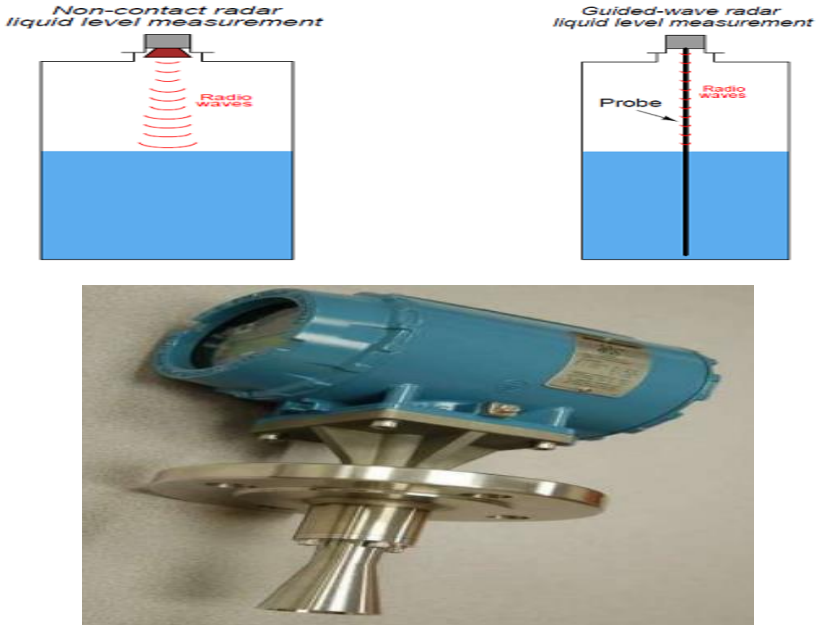


Fig 2.35 Radar type level measurement

6. Load Measurements (Strain Gauge)

- **STRAIN GAUGE:-**It is used to measure the load of an object

- The strain gauge is a passive, resistive transducer which converts the mechanical elongation and compression into a resistance change.
- This change in resistance takes place due to variation in length and cross sectional area of the gauge wire, when an external force acts on it.

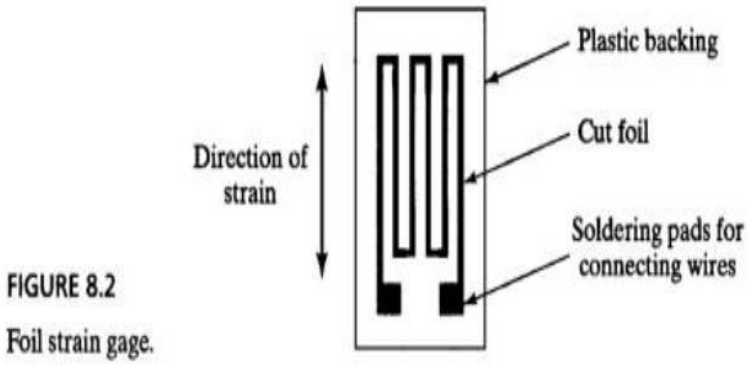


FIGURE 8.2
Foil strain gage.

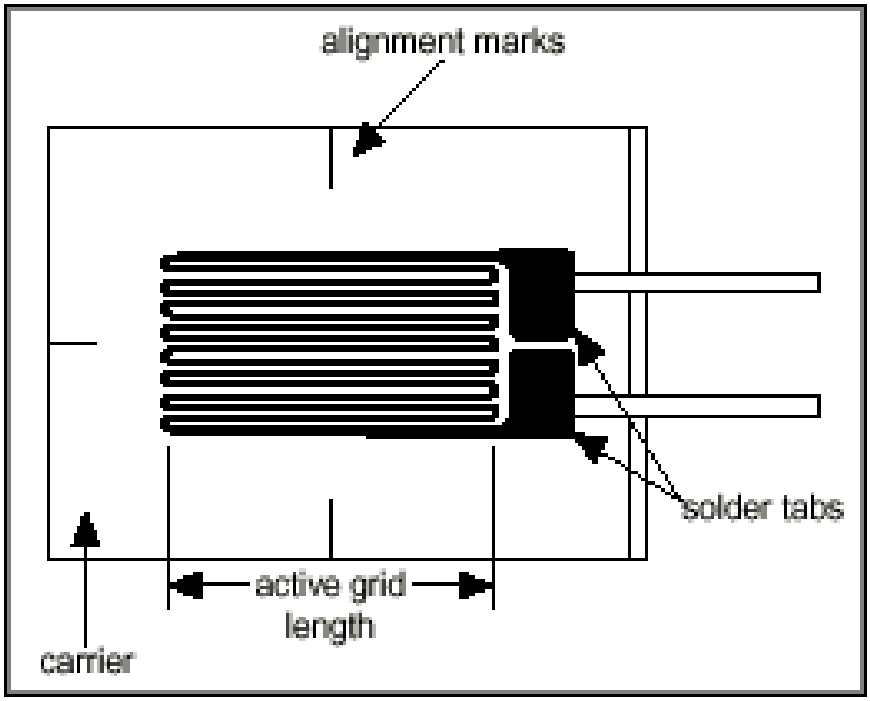


Fig2.36.Bonded strain Gauge

Types Of Strain Gauge

- There are Two Common type of strain gauge these are
  - **Wire gauge**
  - **Semiconductor gauge**

I. Wire gauge

A. Unbonded

B. Bonded

C. Foil type

A. Unbonded Strain Gauge

- An unbonded meter strain gauge is shown in fig
- This gauge consist of a wire stretched between two point in an insulating medium such as air. The wires may be made of various copper, nickel, crome nickle or nickle iron alloys.
- In fig the element is connected via a rod to diaphragm which is used for sensing the pressure. The wire are tensioned to avoid buckling when they experience the compressive force.
- The unbounded meter wire gauges used almost exclusively in transducer application employ preloaded resistance wire connected in Wheatstone bridge as shown in fig.
- At initial preload the strain and resistance of the four arms are nominally equal with the result the output voltage of the bridge is equal to zero.
- Application of pressure produces a small displacement , the displacement increases a tension in two wire and decreases it in the other two thereby increase the resistance of two wire which are in tension and decreasing the resistance of the remaining two wire .
- This causes an unbalance of the bridge producing an output voltage which is proportional to the input displacement and hence to the applied pressure .

B. Bonded Strain Gauge

- The bonded metal wire strain gauge are used for both stress analysis and for construction of transducer.
- A resistance wire strain gauge consist of a grid of fine resistance wire. The grid is cemented to carrier which may be a thin sheet of paper bakelite or teflon.

- The wire is covered on top with a thin sheet of material so as to prevent it from any mechanical demage.
- The carrier is bonded with an adhesive material to the specimen which permit a good transfer of strain from carrier to grid of wires.

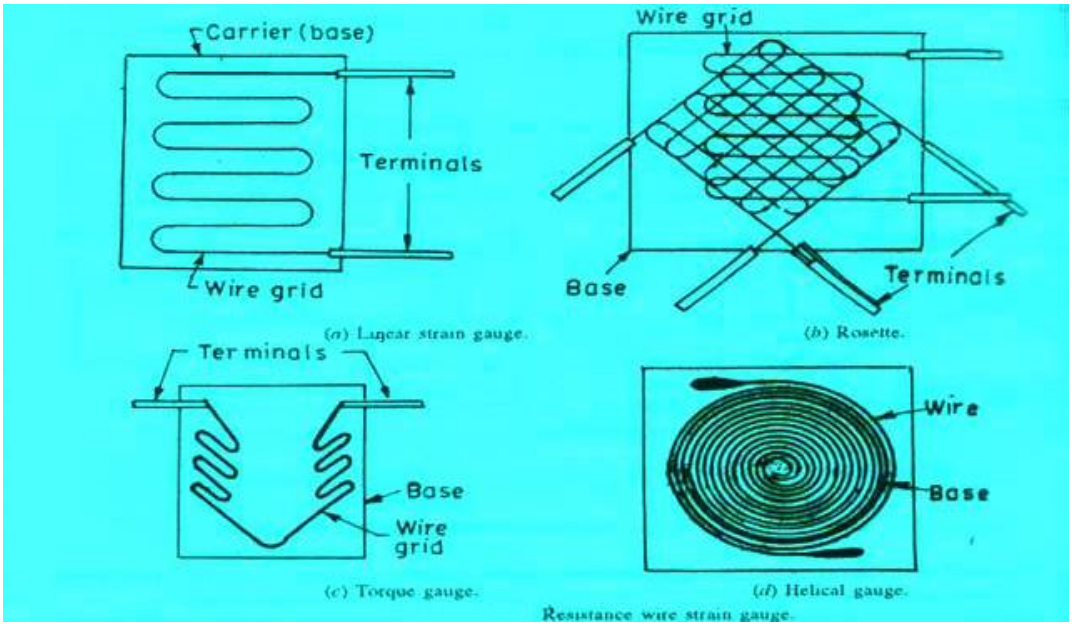


Fig2.28 Bonded Strain Gauge

C. **Bonded Metal Foil Strain Gauge**

- It consist of following parts:
  1. Base (carrier) Materials: several types of base material are used to support the wires. Impregnated paper is used for room temp. applications.
  2. Adhesive: The adhesive acts as bonding materials. Like other bonding operation, successful strain gauge bonding depends upon careful surface preparation and use of the correct bonding agent.

In order that the strain be faithfully transferred on to the strain gauge, the bond has to be formed between the surface to be strained and the plastic backing material on which the gauge is mounted.

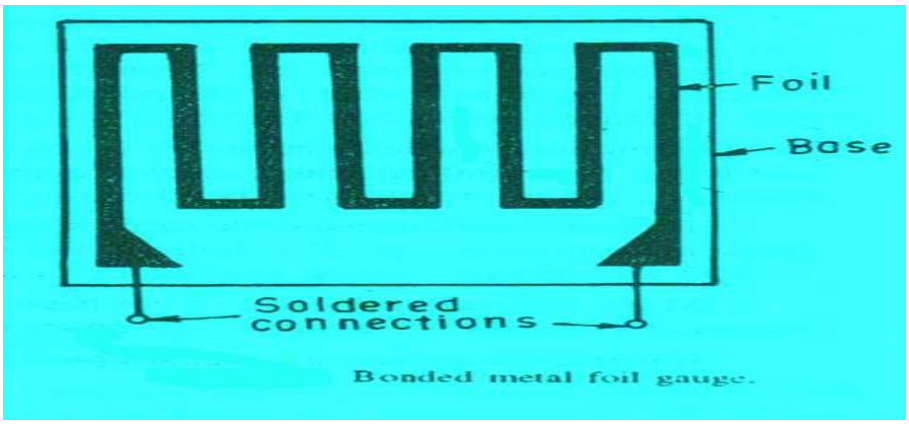


Fig 2.29 Bonded Metal Foil Strain Gauge

It is important that the adhesive should be suited to this backing and adhesive material should be quick drying type and also insensitive to moisture.

3. Leads: The leads should be of such materials which have low and stable resistivity and also a low resistance temperature coefficient
    - This class of strain gauge is only an extension of the bonded metal wire strain gauges.
    - The bonded metal wire starin gauge have been completely superseded by bonded metal foil strain gauges.
    - Metal foil strain gauge use identical material to wire strain gauge and are used for most general purpose stress analysis application and for many transducers.

➢ Semiconductor Gauge

- Semiconductor gauge are used in application where a high gauge factor is desired. A high gauge factor means relatively higher change in resistance that can be measured with good accuracy.
- The resistance of the semiconductor gauge change as strain is applied to it. The semiconductor gauge depends for their action upon the piezo-resistive effect i.e. change in value of resistance due to change in resistivity.

Silicon and germanium are used as resistive material for semiconductor gauges

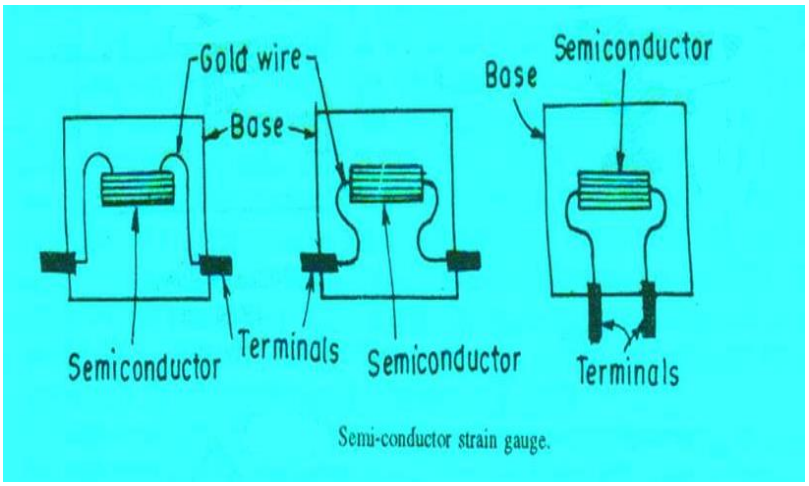


Fig2.30 Semiconductor Gauge

6. Resistive transducers/ Measurements

Resistive transducers :-Resistive transducers are those transducers in which the resistance change due to the change in some physical phenomenon.

- The resistance of a metal conductor is expressed by a simple equation.
- $R = \rho L/A$
- Where R = resistance of conductor in Ω

L = length of conductor in m

A = cross sectional area of conductor in m^2

ρ = resistivity of conductor material in Ω-m.

Potentiometer and Linear Variable Differential Transformer(LVDT) are good example of Resistive transducer

7. Potentiometer

- The potentiometer are used for voltage division. They consist of a resistive element provided with a sliding contact. The sliding contact is called as wiper.
- The contact motion may be linear or rotational or combination of the two. The combinational potentiometer have their resistive element in helix form and are called helipots.
- Fig shows a linear pot and a rotary pot

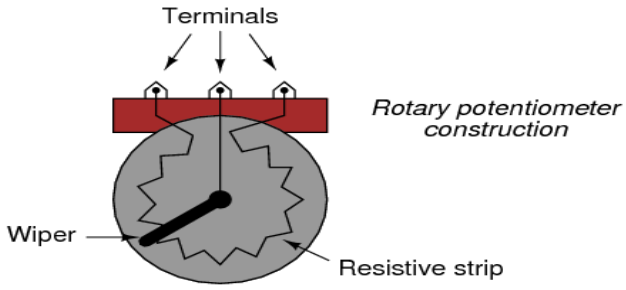


Fig2. 40 Rotary type of POT

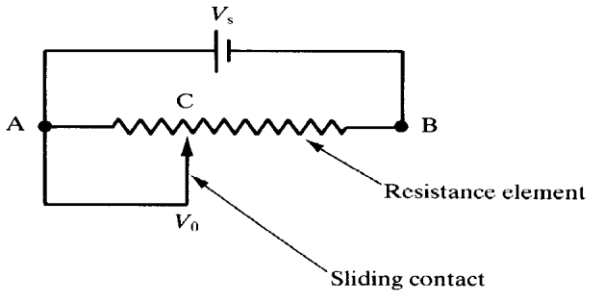


Fig2.41. Linear type of POT

II. Linear Variable Differential Transformer(LVDT)

- AN LVDT transducer comprises a coil former on to which three coils are wound.
- The primary coil is excited with an AC current, the secondary coils are wound such that when a ferrite core is in the central linear position, an equal voltage is induced in to each coil.
- The secondary are connected in opposite so that in the central position the outputs of the secondary cancels each other out.

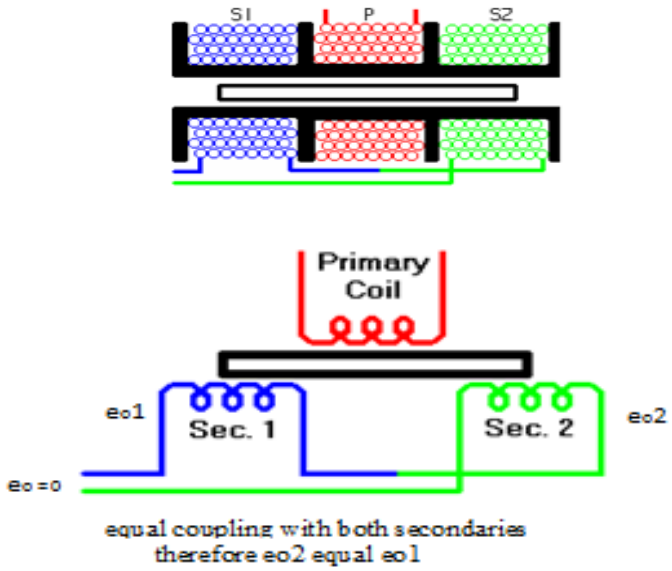


Fig2.42. LVDT

- The excitation is applied to the primary winding and the armature assists the induction of current in to secondary coils.

- When the core is exactly at the center of the coil then the flux linked to both the secondary winding will be equal. Due to equal flux linkage the secondary induced voltages (eo1 & eo2) are equal but they have opposite polarities. Output voltage eo is therefore zero. This position is called “null position

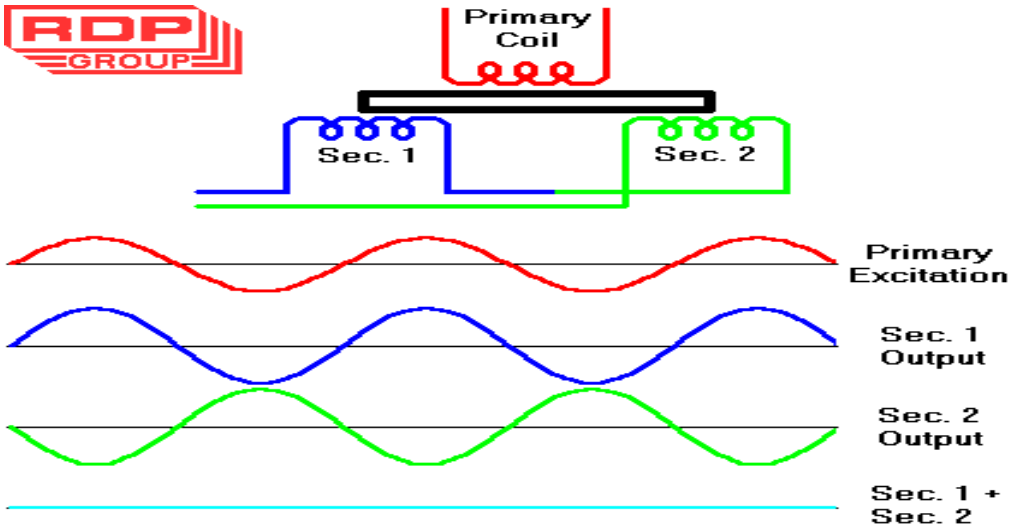


Fig2.43 LVDT

- Now if the core is displaced from its null position toward sec1 then flux linked to sec1 increases and flux linked to sec2 decreases. Therefore eo1 > eo2 and the output voltage of LVDT eo will be positive
- Similarly if the core is displaced toward sec2 then the eo2 > eo1 and the output voltage of LVDT eo will be negative.

8 .Photo transducers

The **Photo transducers or** light sensor is a passive devices that convert this "light energy" whether visible or in the infrared parts of the spectrum into an electrical signal output. Light sensors are more commonly known as "Photoelectric Devices" or "Photo Sensors" because the convert light energy (photons) into electricity (electrons).

Common Type of photo transducers or photo sensors are the following

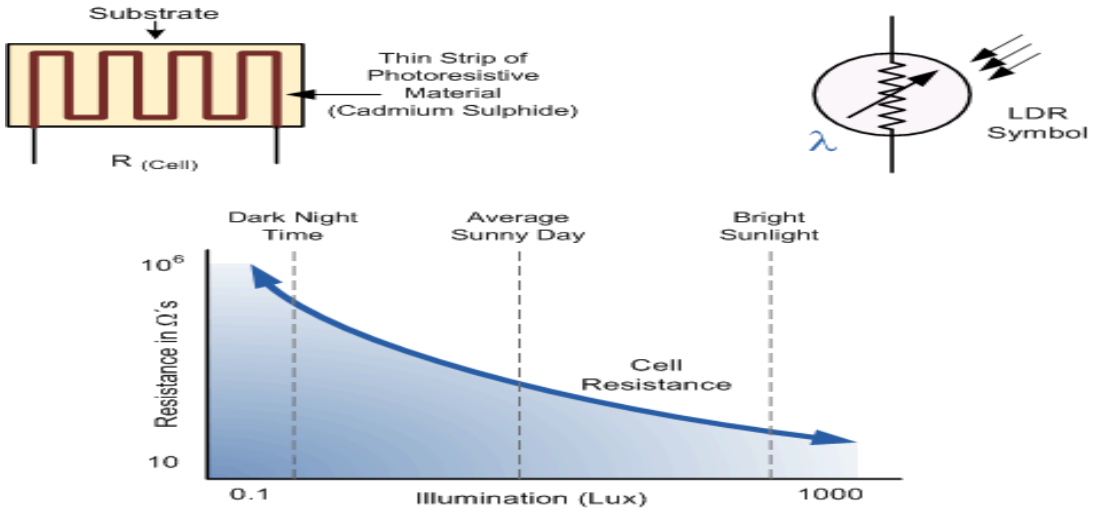
D. The Light Dependant Resistor(LDR)

A **Photoconductive** light sensor does not produce electricity but simply changes its physical properties when subjected to light energy. The most common type of photoconductive device is the Photoresistor which changes its electrical resistance in response to changes in the light intensity. Photoresistors are Semiconductor devices that use light energy to control the flow of electrons, and hence the current flowing through them. The commonly used Photoconductive Cell is called the **Light Dependant Resistor** or **LDR**.

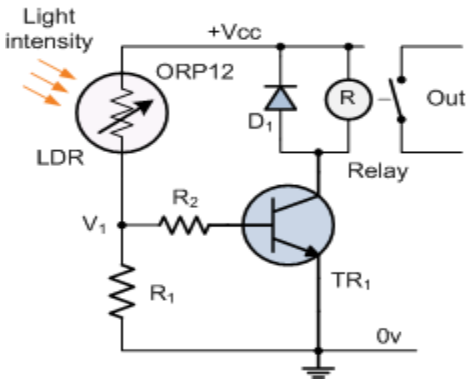


Fig2. 44 Light Dependant Resistor

As its name implies, the **Light Dependant Resistor** (LDR) is made from a piece of exposed semiconductor material such as cadmium sulphide that changes its electrical resistance from several thousand Ohms in the dark to only a few hundred Ohms when light falls upon it by creating hole-electron pairs in the material. The net effect is an improvement in its conductivity with a decrease in resistance for an increase in illumination. Also, photoresistive cells have a long response time requiring many seconds to respond to a change in the light intensity



One simple use of a Light Dependant Resistor, is as a light sensitive switch as shown below.



This basic light sensor circuit is of a relay output light activated switch. A potential divider circuit is formed between the photoresistor, LDR and the resistor R1. When no light is present ie in darkness, the resistance of the LDR is very high in the Megaohms range so zero base bias is applied to the transistor TR1 and the relay is de-energised or "OFF".

As the light level increases the resistance of the LDR starts to decrease causing the base bias voltage at V1 to rise. At some point determined by the potential divider network formed with resistor R1, the base bias voltage is high enough to turn the transistor TR1 "ON" and thus activate the relay which inturn is used to control some external circuitry.

As the light level falls back to darkness again the resistance of the LDR increases causing the base voltage of the transistor to decrease, turning the transistor and relay "OFF" at a fixed light level determined again by the potential divider network.

By replacing the fixed resistor R1 with a potentiometer VR1, the point at which the relay turns "ON" or "OFF" can be pre-set to a particular light level. This type of simple circuit shown above has a fairly low sensitivity and its switching point may not be consistent due to variations in either temperature or the supply voltage. A more sensitive precision light activated circuit can be easily made by incorporating the LDR into a "Wheatstone Bridge" arrangement and replacing the transistor with an Operational Amplifier as shown.

B.The Photodiode

Photojunction Devices are basically PN-Junction light sensors or detectors made from silicon semiconductor PN-junctions which are sensitive to light and which can detect both visible light and infrared light levels. Photo-junction devices are specifically made for sensing light and this class of photoelectric light sensors include the Photodiode and the Phototransistor

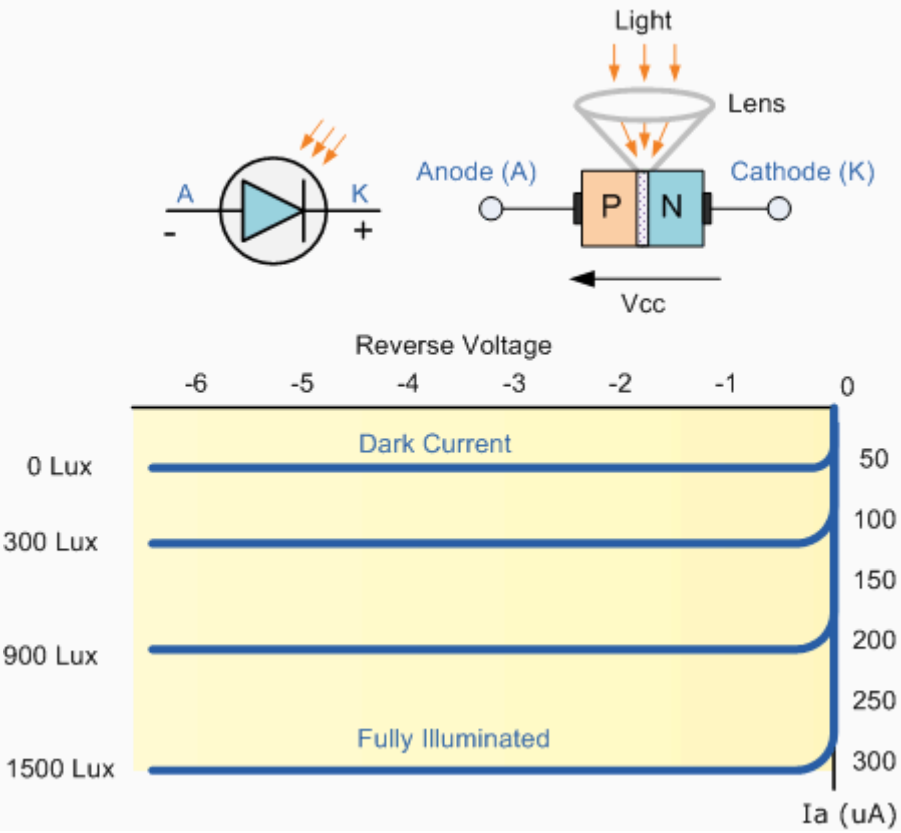


Fig2.45Photodiode

This characteristic can be a problem for diodes with transparent or glass bead bodies such as the 1N4148 signal diode. LED's can also be used as photodiodes as they can both emit and detect light from their junction. All PN-junctions are light sensitive and can be used in a photo-conductive unbiased voltage mode with the PN-junction of the

photodiode always "Reverse Biased" so that only the diodes leakage or dark current can flow.

Photo-diode Construction and Characteristics



When used as a light sensor, a photodiodes dark current (0 lux) is about 10uA for geranium and 1uA for silicon type diodes. When light falls upon the junction more hole/electron pairs are formed and the leakage current increases. This leakage current increases as the illumination of the junction increases. Thus, the photodiodes current is directly proportional to light intensity falling onto the PN-junction. One main advantage of photodiodes when used as light sensors is their fast response to changes in the light levels, but one disadvantage of this type of photodevice is the relatively small current flow even when fully lit.

Photodiodes are very versatile light sensors that can turn its current flow both "ON" and "OFF" in nanoseconds and are commonly used in cameras, light meters, CD and DVD-ROM drives, TV remote controls, scanners, fax machines and copiers etc, and when integrated into operational amplifier circuits as infrared spectrum detectors for fibre optic communications, burglar alarm motion detection circuits and numerous imaging, laser scanning and positioning systems etc.

E. Phototransistor

An alternative photo-junction device to the photodiode is the **Phototransistor** which is basically a photodiode with amplification. The Phototransistor light sensor has its collector-base PN-junction reverse biased exposing it to the radiant light source. Phototransistors operate the same as the photodiode except that they can provide current gain and are much more sensitive than the photodiode with currents are 50 to 100 times greater than that of the standard photodiode and any normal transistor can be easily converted into a phototransistor light sensor by connecting a photodiode between the collector and base.

Phototransistors consist mainly of a bipolar NPN Transistor with its large base region electrically unconnected, although some phototransistors allow a base connection to control the sensitivity, and which uses photons of light to generate a base current which in turn causes a collector to emitter current to flow. Most phototransistors are NPN types whose outer casing is either transparent or has a clear lens to focus the light onto the base junction for increased sensitivity

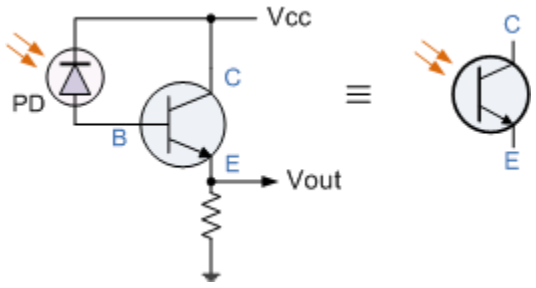
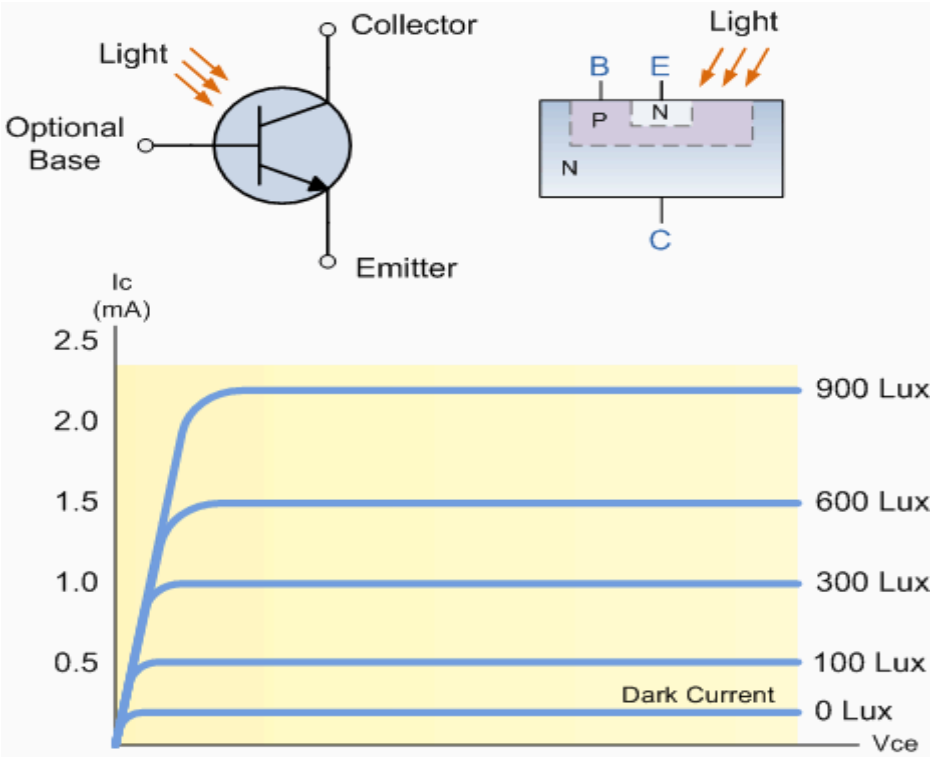


Fig2.46 Phototransistor

Photo-transistor Construction and Characteristics



D . Photodarlington

Photodarlington transistors use a second bipolar NPN transistor to provide additional amplification or when higher sensitivity of a photodetector is required due to low light levels or selective sensitivity, but its response is slower than that of an ordinary NPN phototransistor.

Photo darlington devices consist of a normal phototransistor whose emitter output is coupled to the base of a larger bipolar NPN transistor. Because a darlington transistor

configuration gives a current gain equal to a product of the current gains of two individual transistors, a photodarlington device produces a very sensitive detector.

Typical applications of **Phototransistors** light sensors are in opto-isolators, slotted opto switches, light beam sensors, fibre optics and TV type remote controls, etc. Infrared filters are sometimes required when detecting visible light..

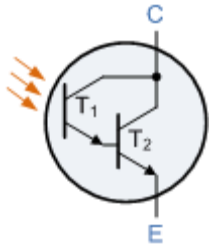


Fig2.47 **Photo-darlington**

9. Photovoltaic Cells.

The most common type of photovoltaic light sensor is the **Solar Cell**. Solar cells convert light energy directly into DC electrical energy in the form of a voltage or current to a resistive load such as a light, battery or motor. Then photovoltaic cells are similar to a battery because they supply DC power. Unlike the other photo devices above which use light intensity even from a torch to operate, photvoltaic cells work best using the suns radiant energy. Solar cells are used in many different types of applications to offer an alternative power source from conventional batteries, such as in calculators, satellites and now in homes offering a form of renewable power.

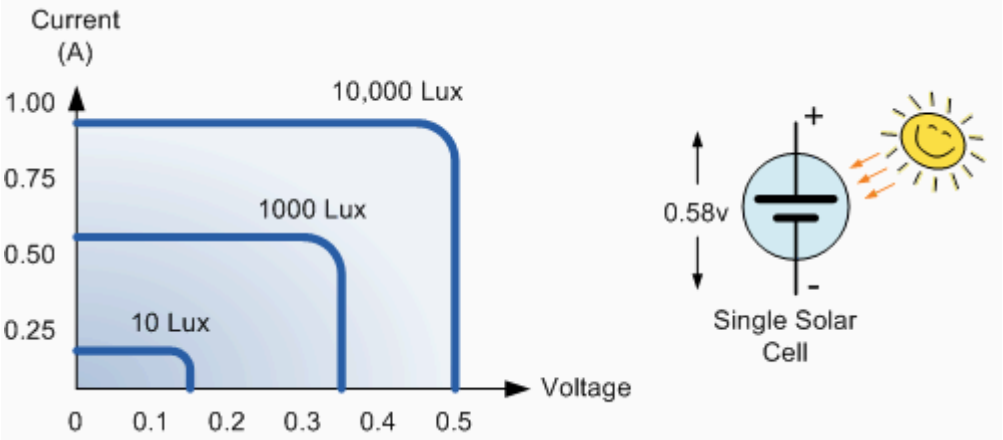


Fig2.48Photovoltaic Cell

Photovoltaic cells are made from single crystal silicon PN junctions, the same as photodiodes with a very large light sensitive region but are used without the reverse bias. They have the same characteristics as a very large photodiode when in the dark. When illuminated the light energy causes electrons to flow through the PN junction and an individual solar cell can generate an open circuit voltage of about 0.58v (580mV). Solar cells have a "Positive" and a "Negative" side just like a battery.

Individual solar cells can be connected together in series to form solar panels which increases the output voltage or connected together in parallel to increase the available current. Commercially available solar panels are rated in Watts, which is the product of the output voltage and current (Volts times Amps) when fully lit.

Characteristics of a typical Photovoltaic Solar Cell.



The amount of available current from a solar cell depends upon the light intensity, the size of the celland its efficiency which is generally very low at around 15 to 20%. To increase the overall efficiency of the cell commercially available solar cells use polycrystalline silicon or amorphous silicon, which have no crystalline structure, and can generate currents of between 20 to 40mA per cm^2. Other materials used include Gallium Arsenide, Copper Indium Diselenide and Cadmium Telluride. These different materials each have a different spectrum band response, and so can be "tuned" to produce an output voltage at different wavelengths of light.

Self-Check 2	Written Test

I.Say True or False

1.Inorder to measure highest temperature range Thermocouple is preferable

2.Burdon tube is used to measure Level

3.LVDT is to measure load

4.Float type level measurement is direct measurement

5.Energy meter is a type of integrated type measurement

Test 1:- Choose the best answer from the given alternatives

1.Which one of the following is not used to measure Temperature.

A. Thermocouple B. Potentiometer C. Thermistor D.RTD

2.From the following which one is used to as pressure transducer

A. Diaphragm B. Capsule C. Burdon tube D.All

3.which temperature measurement not need to touch

A .Radiation /Infrared pyrometer B. Mercury in glass thermometer C .Thermo couple

D.Thermistor

4.which temperature measurement is preferable to measure Higher Temperature.

A. Termistor B.RTD C. Termocouple D. None

5. Orifice plate & Pitot Tube are a type of _____Transducer

A. Level B. Pressure C .Flow D.All

6.Tachometer meter is

A. Indicating instrument B.Recording instrument C.Integtating instrument D.A&B

7.LVDT is a

A.Velocity transducer B.Displacement transducer C.Pressure transducer D.acceleration transducer

8. which Level measurement not need to touch.

A. Float gauge B. Displacement C.Ultrasonic level measurement D. All

9.Thermo couple are used for the measurement of

A. Temperature B. Pressure C.Voltage D. Flow

10.Which one is a type of transducer do not required external power supply

A. Potentiometer B. Photovoltaic C.LVDT D.all

11.By what principle operate a potentiometer

A. Change in resistance B. Change in induced EMF C. Change in position D. None

12.From the following g which one is not a pressure Transducers

A. Manometer B. Thermometer C.Bellow D.Diaphragm

13.In a float gauge type level measurement

A. Direct measurement B.Ultrasonic type C.Electrical type D.A&C .

14. _____a type of Strain Gauge that are used to measure small load & it is more sensitivity

A. Semiconductor gauge B. Unbonded C. Bonded D.All

15. . LEDs are

A. Photodiode B.LDR C. Phototransistor D. All

Operation sheet 2:- **Instrumentation and control devices installation**

Operation title:-Temperature measurement

Purpose: Temperature measurement of liquid using Thermocouple.

Instruction:- Follow the the given step measure the temperature of water with different temperature range . You have given 40 minute for the task and you are expected to write the answer on the given paper

Steps in doing the task

Step 1.prepare a Thermocouple



Fig. Teromcouple

Step 2.Choose the Electrical Multimeter that have a Temperature selector



Fig. Multimeter

Step 3.Insert the above type thermocouple terminal into the multimeter.

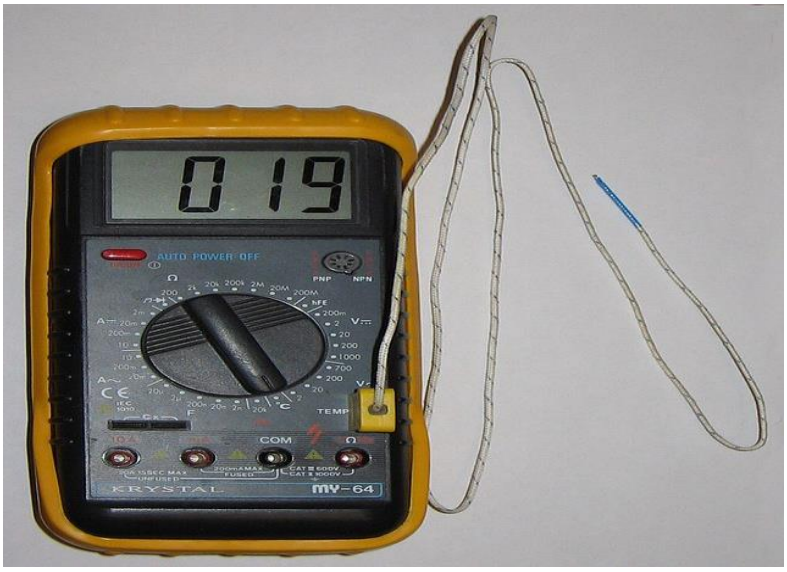


Fig.Multimeter with thermocouple

Step 4.The Multimeter change to temperature selector

Step 5.Insert the sensor terminal of thermocouple into water and record the value

Step 6. Insert the sensor terminal of thermocouple into Boiled water and record the value

Step 7. Insert the sensor terminal of thermocouple into Ice and record the value

Lap Test-2

Instruction :-Given the necessary tools and materials you are expected to perform the following tasks within 1 hour.

Task 1:- Temperature measurement of a liquid using Thermocouple

Unit Three: Inspect the complete work

This unit is developed to provide you the necessary information regarding the following content coverage and topics

- Installed devices inspection
- work completion procedure
- Test all complete termination

This unit will also assist to attain the learning outcomes stated in the cover page .Specifically ,upon completion of this learning guide, you will be able to:-

- Inspect installed devices for completeness before formal functioning
- Notify work completion according to procedure
- Conduct of testing all completed termination / connections of wiring

3.1 Installed devices inspection

Instrument Equipment Testing, Inspection and Maintenance Implementing an ambient air monitoring network, with the various types of equipment needed, is no easy
task. Through appropriate testing, inspection and maintenance programs, monitoring organizations can be assured that equipment is capable of operating at acceptable performance levels. Every piece of equipment has an expected life span, and its use should be discontinued if its performance quality ceases to meet appropriate standards. For amortization purposes, EPA estimates a 7 year lifespan for most monitoring instruments and a somewhat longer lifespan for more permanent types of equipment (instrument racks, monitoring shelters etc.). This means that funds for replacing capital equipment are provided in resource allocations and monitoring organizations should make the best use of equipment replacement resources. Monitoring organizations may be able to prolong the life of equipment but in doing so they may run the risk of additional downtime, more upkeep and a greater chance of data invalidation, while losing out on newer technologies, better sensitivity/stability and the opportunities for better information management technologies.

Due to the many types of equipment that can be used in an ambient air monitoring program, this section provides general guidance on testing, inspection, and maintenance procedures for broad categories of equipment only. In most cases, equipment manufacturers include inspection and maintenance information in the operating manuals. The role of monitoring organizations, in developing a quality system, is to address the scheduling and documentation of routine testing, inspection, and maintenance.

Detailed maintenance documents should be available for each monitoring site. Elements incorporated into testing, inspection and maintenance documents include:

- equipment lists - by organization and station;
- spare equipment/parts lists - by equipment, including suppliers;
- inspection/maintenance frequency - by equipment;
- testing frequency and source of the test concentrations or equipment;

- equipment replacement schedules;
- sources of repair - by equipment;
- service agreements that are in place; and
- monthly check sheets and entry forms for documenting testing, inspections and maintenance

performed.

3.2 work completion procedure

3.2.1 Installation report and records

The final step is to produce an installation report and records document. This document should summarize the results, outcomes, and achievements of the installation project. It should also provide the evidence and documentation of the installation process, such as the installation logs, checklists, test results, verification reports, calibration certificates, and warranty documents. The installation report and records document helps you to demonstrate the completion and compliance of the installation project and to provide the client or stakeholder with the necessary information and support for the operation and maintenance of the installed equipment.

Why documentation and reporting are important

Documentation and reporting are essential for any equipment installation project, as they help to communicate and collaborate with the client or stakeholder, monitor and control the progress and performance of the installation project, identify and resolve any issues or problems that may arise, ensure quality and compliance with relevant standards and regulations, and provide evidence and documentation for future reference and audit. Proper documentation and reporting is not only a requirement but also a best practice for equipment installation projects, allowing you to ensure success and satisfaction.

3.3 Teste all completed termination

3.3.1 Terminations/Connections at Field Instruments & Junction Boxes

- Connections at Field Instruments: All connections at the field instrument shall be made on screw type terminal blocks. Wire nuts and spring type terminals shall not be used. Instruments with integral terminal blocks shall be connected directly to the field cable.
- The outer jacket of shielded twisted single pair/triad cables shall be left intact up to the point of termination. Drain wires and mylar shields on shielded cables shall be cut and insulated with heat shrink sleeve at the field instrument unless otherwise specified by the instrument manufacturer.
- All Cable entries to field Junction Boxes shall be through the bottom.
- Conduit and Cable sealing shall be as per SAES-J-902 section 6. Cable gland being used shall be selected as per the "Cable Gland Selection Table".
- Twisted, multi-pair/triad cables shall be cut to the appropriate length to minimize looping and flexing of the cable within the junction box.
- For twisted shielded single pair/triad cables the outer jacket shall be left intact up to the point-of-termination (approximately three to four inches from terminal blocks). The shield drain wire shall be insulated from jacket end to Approximately, one inch of heat shrink tubing shall be applied over the jacket end.
- For individually shielded twisted multi-pair/triad cables each pair/triad shall be heat shrink sleeve insulated from the cable-jacket-end up to the point-of-termination to keep the foil shielding intact and free from accidental grounds.
- The shield drain wire shall be insulated from foil end to terminal. Approximately, two inches of heat shrink tubing shall be applied over the jacket end.
- All spare pairs/triads of a multi-pair/triad cable shall be terminated at both the field junction box and the marshaling cabinet. Drain wires for spare shielded pairs/triads shall also be individually terminated at these locations.
- Each cable or group of cables carrying similar signals shall contain a minimum of 20% spare pairs or triads.

- Cable shields must have a single, continuous path to ground. Special grounding terminals in intimate contact with the DIN Rail, jumper bars or preformed jumper combs designed for the selected terminal blocks shall be used to consolidate shield drain wires for connection to ground. Ground loops and floating shields shall be avoided. Shield drain wires shall not be daisy-chained to the ground connection.

Self-Check 3	Written Test

I. Say True or False

1. Inspection and Maintenance decrease the expected life span of an instrument.
2. In most cases, equipment manufacturers include inspection and maintenance information in the operating manuals
3. The role of monitoring organizations, in developing a quality system, is to address the scheduling and documentation of routine testing, inspection, and maintenance.
4. Equipment replacement schedules is under testing, inspection and maintenance program
5. Evidence and documentation of the installation process is not under installation report and records document

II. Choose the best answer

1. Elements incorporated into testing, inspection and maintenance documents include:
   A..Equipment lists
   B. Spare equipment/parts lists
   C .Inspection/maintenance frequency D. All
2. Evidence and documentation of the installation process include
   A. installation logs B checklists C. test results D. All
3. which inspection instrument used to measure temperature
   A.RTD B.Capsul C.Diaphragm D. Strain Gauge

4.which inspection instrument is not used to measure pressure

A.RTD B.Capsul C.Diaphragm D. Strain Gauge

5. which inspection instrument is not used to measure Level

A.RTD B.Capsul C.Sight glass D. Strain Gauge

Operation sheet 3.1:- **Inspect the complete work**

Operation title:-Inspect pressure measurement of a Compressor

Purpose: Replace defective pressure measurement of a compressor.

Instruction:- Follow the the given step Assemble and Disassemble the defective pressure measurement of a compressor **.** You have given 50 minute for the task and you are expected to write the answer on the given paper

Steps in doing the task

Step1.First unfasten (unlock) the screw of pressure measurement from a using Allenkey, socket wrench.

Step 2.Second unfasten (unlock) pressure measurement using Allenkey, socket wrench

Step 3.Check and identify the type of pressure sensor i.e burdontube, capsule, diaphragm, Bellows etc.

Step 4.If possible repair if not prepare a new one

Step 5..Install the new pressure pressure measurement on the compressor

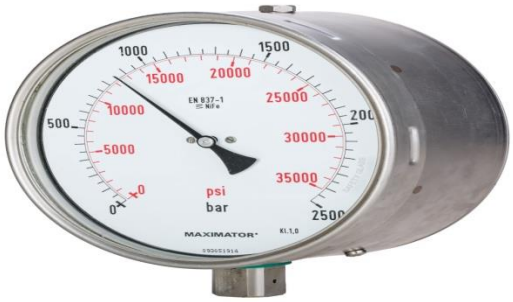


Fig. Pressure measurement

6.Calibrate the installed pressure measurement

7.Inspect the installed pressure measurement by giving the power to the compressor

Lap Test:-2

Instruction :-Given the necessary tools and materials you are expected to perform the following tasks within 1 hour.

Task 1:- Replace defective pressure measurement of a compressor

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