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SECTION-1

CHAPTER-1
DEFINITIONS

ATTITUDE - The relative orientation of a vehicles or object represented by its angles of inclination to three orthogonal reference axis.
CLASS I AREA CLASSIFICATION

Areas are classified as Division 1 or Division 2 locations, or not classified, in accordance with the expectation of the presence of explosive or ignitable mixtures.

Division 1 locations may contain hazardous mixtures under normal operating conditions.

Division 2 locations are those in which the atmosphere is normally non-hazardous but may become hazardous due to equipment failures, failure of ventilating systems, etc.

Locations not classified as Division 1 or Division 2 may be called non-hazardous areas.

COMMUNICATION LINK - Computer control is a device in which control and / or display action are generated for use by other system devices. When used with other control devices on the communication link the computer normally performs or functions in a hierarchical relationship to the other control devices.
CORRECTIVE MAINTENANCE is an activity that is not normal in the operation of the equipment and which requires access to the interior. Such activities are expected to be performed by qualified personnel who are aware of the hazards involved.

CREEP - A change in output occurring over a specific time period while the measurand and all Environmental conditions are held constant.

CURRENT-TO-PRESSURE TRANSDUCER - A device which receives an analog electrical signal and convert it to a corresponding air pressure.

DEW POINT, TEMPERATURE.
The temperature, referred to a specific pressure, at which water vapour condenses.

DISPLACEMENT - The change in position of a body or point with respect to a reference point.

DISTRIBUTED CONTROL SYSTEM - That class of instrumentation (input/output devices, control devices and operator interface devices) which in addition to executing the stated control functions also permits transmission of control, measurement, and operating information to and from a single or a plurality of user specified locations, connected by a communication link.

DRIFT - An undesired change in output over a period of time, which change is not a function of the Measurand.

ELECTROMAGNETIC - Converting a change of Measurand into an output induced in a conductor by a change in magnetic flux, in the absence of Excitation.

FLOW RATE - The time rate of motion of a fluid, usually contained in a pipe or dust, expressed as fluid quantity per unit time.

HERMETICALLY SEALED DEVICE is a device which is sealed against the entrance of an external atmosphere and in which the seal is made by fusion of glass of metal.

HYSTRESIS - The maximum difference in output, at any Measurand value within the specified Range, when value is approached first with increasing and then with decreasing Measurand.

IGNITION-CAPABLE EQUIPMENT AND WIRING is the equipment and wiring which in its normal operating condition releases sufficient electrical or thermal energy to cause ignition of a specific hazardous atmosphere, under normal operating conditions.

INDUCTIVE - Converting a change of Measurand into a change of the self-inductance of a single coil.

INTRINSICALLY SAFE EQUIPMENT AND WIRING is the equipment and wiring which is incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture.

IONIZING - Converting a change of Measurand into a change in ionization current, such as through a gas between two electrodes.

LOWER LIMIT - The pneumatic signal corresponding to the minimum value of the transmitted input.

MICROMETER.
A metric measure with a value of 10^{-6} metres or 0.000001 metre, (previously referred to as "micron").

NON-INCENDIVE EQUIPMENT AND WIRING is the equipment and wiring which in its normal operating condition would not ignite a specific hazardous atmosphere. The circuits may include sliding or make-and-break contacts releasing insufficient energy to cause ignition.

OPERATIONAL MAINTENANCE is any maintenance activity, other than corrective maintenance, intended to be performed by the operator and which is required in order to serve the equipment's intended purpose.

PARTS PER MILLION (PPM).
Represents parts per million and should be given on a weight basis. The abbreviation shall be ppm (w/w). If inconvenient to present data on a weight basis (w/w) it may be given in a volume basis; (v/v) must be stated after the term ppm, e.g., 5ppm (v/v) or 7 ppm (w/w).

PHOTOCONDUCTIVE - Converting a change of Measurand into a change in the voltage generated when a junction between certain dissimilar materials is illuminated.

PIEZOELELCTRIC - Converting a change of Measurand into a change in the electrostatic charge or voltage generated by certain materials when mechanically stressed.

PNEUMATIC CONTROLLER - A pneumatic controller is a device which compares the value of a variable quantity or condition to a selected reference and operates by pneumatic means to correct or limit the deviation.

POSITION is the spatial location of a body or point with respect to a reference point.

POTENTIOMETERIC - Converting a change of Measurand into a voltage ratio change by a change in the position of a movable contact on a resistance element across which excitation is applied to the coil(s).

PURGING CLASSIFICATIONS
Type Z Purging. Covers purging requirements adequate to reduce the classification of the area within an enclosure from Division 2 (normally non-hazardous) to non-hazardous.
Type Y Purging. Covers purging requirements adequate to reduce the classification of the area within an enclosure from Division 1 (hazardous) to Division 2 (normally non-hazardous).
Type X Purging. Covers purging requirements adequate to reduce the classification of the area within an enclosure from Division 1 (hazardous) to non-hazardous.

RANGE - The Measurand values, over which a Transducer is intended to measure, specified by their upper and lower limits.

RANGES OF PNEUMATIC PRESSURE TRANSMISSION SIGNALS.
80 k Pa (12 psi) span (preferred). The operating pressure range for the 80 kPa operating pressure span shall be 20 kPa (3 psi) to 100 kPa (15 psi).
160 kPa (24 psi) span. The operating pressure range for the 160 kPa operating pressure span shall be 40 kPa (6 psi) to 200 kPa (30 psi).

RELATIVE HUMIDITY.
The ratio of the amount of water vapour contained in the air at a given temperature and pressure to the maximum amount it could contain at the same temperature and pressure under saturated conditions.

REPEATABILITY - The ability of a Transducer to reproduce output readings when the same Measurand value is applied to it consecutively, under the same conditions, and in the same direction.

Repeatability is expressed as the maximum difference between output readings; it is expressed as "within _________ percent of Full Scale Output". Two Calibration Cycles are used to determine Repeatability unless otherwise specified.

RESOLUTION - The magnitude of output step changes as the Measurand is continuously varied the range.It is specified as Average and Maximum Resolution; it is usually expressed in percent of Full Scale Output.

SUPPLY PRESSURE LIMITS
80 kPa (12 psi) span. A minimum of 130 kPa (19 psi) and a maximum of 150 kPa (22 psi).
160 kPa (24 psi) span. A minimum of 260 kPa (38 psi) and a maximum of 300 kPa (44 psi).

SEALED DEVICE is a device which is so constructed that it cannot be opened during normal operational conditions or operational maintenance ; it has a free internal volume less than 100 cm^3 (6.1 in^3) and is sealed to restrict entry of an external atmosphere. It may contain normally arcing parts or internal hot surfaces.

SENSITIVITY - The ratio of the change in Transducer Output to a change in the value of the Measurand.

SINGLE GROUND REFERENCE POINT is a single grounding point to which all grounding conductors of any single intrinsically safe system are connected. It may be used as the ground reference for more than one intrinsically safe system.

SUPERVISORY SET POINT CONTROL SYSTEM - The generation of set point and/or control information by a computer control system for use by shared control, shared display or other regulatory control devices.

THERMOELECTRIC - Converting a change of Measurand into a change in emf generated by a temperature difference between the junctions of two selected dissimilar materials.

THRESHOLD - The smallest change in the Measurand that will result in a measurable change in Transducer Output.

CHAPTER-2
ELECTRICAL HAZARDS

Explosive Gas - Air Mixture:
A mixture of flammable gas or vapour with air under atmospheric conditions in which, combustion spreads throughout the unconsumed mixture.

Flammable material:
A gas, vapour, liquid, dust or solid that can react continuously with atmospheric oxygen and that may therefore sustain fire or explosion when such reaction is initiated by a suitable spark, flame or hot surface.

Flash Point:
The lowest temperature at which sufficient vapour is given off from a flammable material to form an explosive gas-air mixture.

Hazardous Area:
An area in which explosive gas-air mixtures are, or may be expected to be present in quantities such as to require special precautions for the construction and use of instruments and electrical apparatus.

Ignition Temperature:
The lowest temperature of a flammable gas vapour at which ignition occurs.

Non - Hazardous Area:
An area in which explosive gas-air mixtures are not expected to be present so that special precautions for the construction and use of instruments and electrical apparatus are not required.

FACTORS DECIDING EXPLOSION HAZARD
Three separate factors define the possibility of an explosion hazard. They are :

i) Area Classification i.e. Zones/Divisions (Probability of the gas being present);
ii) Gas classification i.e. Gas Group (type of gas);
iii)Temperature classification i.e. Ignition Temperature.

Area Classification
The purpose of sub-dividing (or classifying) the hazardous area into zones/divisions is to indicate the probability of a hazardous mixture of gas and air being present. The object is to permit the safe use of electrical equipment of balancing the risk of the gas being present with the precautions being taken.

CLASSIFICATION BASED ON EUROPEAN / AMERICAN STANDARD
Depending upon the possibility of being a continuous presence of the explosive gas mixture or its being present occasionally for a short while, the area has been divided into various divisions/zones, as shown in Table - 1.

TABLE-I AREA CLASIFICATION BASED ON EUROPEAN/AMERICAN STANDARD

Area Classification	European Standard (IEC)	American standard (NEC)
An area in which an explosive gas-air mixture is continuously present or present for long periods.	Zone 0	Division 0
An area in which an explosive gas-air mixture is likely to occur under normal operating conditions.	Zone 1	Division 1
An area in which an explosive gas-air mixture is not likely to occur, and if it does, it will exist only for a short time.	Zone 2	Division 2

GAS CLASSIFICATION

The minimum energy required for an electrical spark, in the event of short circuit, to ignite an explosive atmosphere varies considerably with the gases concerned.

Gases are classified into groups (Table-II) according to their ease of ignition be electrical sparks. The ignition energy (allowed into a hazardous area) necessary to ignite the explosive gases is carefully defined based on the results if the tests on specialized Spark Test apparatus.

Equipment certified for use in gas group II C can be used in any other groups like II A or II B, but equipment certified for groups like II A cannot be used in Group II B.

TABLE -II GAS GROUPING

	Gas Groups according to	
Typical Representative Gas	**European Standard (IEC)**	**American Standard (NEC)**
Methane	I	D
Propane	II A	D
Ethylene	II B	C
Hydrogen	II C	B
Acetylene	II C	A

Temperature Classification:

Gas-air mixtures can be ignited by hot surface of the electrical equipment in hazardous area. Hence the maximum surface temperature reached even under fault condition should not exceed the gas ignition temperature. The European Standard (EN 50014) classifies the apparatus for use in the hazardous area based upon the maximum permissible surface temperature which the equipment may attain, and it is assigned a 'T' rating. The higher the 'T' rating of the apparatus, the lower the maximum surface temperature and better / safe it is. The classification according to the European / American Standards is given in Table - III.

All temperature classifications, unless otherwise specified, are assessed with reference to a maximum ambient temperature of 40º C. If the equipment is to be used at an ambient temperature higher than this, then its temperature classification should be reassessed.

It should be recognised that the number of the temperature classified is in the reverse direction from that which most people expect. The higher the temperature classification number, the lower the maximum surface temperature of the equipment, and greater the number of gases and vapours with which the equipment can be safely used.

TABLE-III TEMPERATURE CLASSIFICATION

Maximum Surface Temperature (ºC)	**IEC(ES)**	**NEC(AS)**
450 and above	T1	T1
300	T2	T2
280	T2	T2A
250	T2	T2B
230	T2	T2C
200	T3	T3
180	T3	T3A
65	T3	T3B
160	T3	T3C
175	T4	T4
120	T4	T4A
100	T5	T5
85	T6	T6

PROTECTION METHODS:

TYPE	SYMBOL	ALLOWED TO BE USED IN
Explosion - proofing	Ex 'd'	Zone 1 or 2
Powder filling	Ex 'q'	Zone 2
Pressurization	Ex 'p'	Zone 1 or 2
Oi immersi on	Ex 'o'	Zone 2
Increase safety	Ex 'e'	Zone 1 or 2
Intrinsic safety	Ex 'ia' & 'ib'	Zone 0*, 1 or 2

STANDARDS FOR METHODS OF PROTECTION:

Type	BS 53445	IEC Standard 79	Cenelec Standard EN 50	BS 5501 Part
Explosion-proofing	None	None	028	8
Powder filling	9	5	017	4
Pressurization	5	2	016	3
Oil immersion	9	6	015	2
Increased safety	6	7	019	6
Intrinsic safety	4	11	020 (apparatus) 034 (systems)	7

CHAPTER-3
CABLES

Various Standards used for cables : -

1. IS - 694 - For unarmoured cables.
2. IS - 1554 - General construction, colour coding, Number printing, sheath thickness etc.
3. IS - 3975 - Armouring
4. IS - 8130 - Conductor
5. IS - 5831 - Insulation, sheath material etc.
6. ASTM - D - 2863 - Oxygen Index
7. ASTM - D - 2843 - Smoke density
8. IEC - 754 - Acid gas generation
9. IEEE - 383)
   IEC - 332) Flammability Tests.
   SS - 4241475)
10. IS - 9968 - Elastomer
11. IS - 10418 - Packing

CLASSIFICATION OF INSULATING MATERIALS (BASED ON IS : 1271)

The recognized classes of insulating materials and the temperatures assigned to them are as follows :

Class	**Temperature**
Y	90° C
A	105 ° C
E	120 ° C
B	130 ° C
F H	155° C 180° C
C	above180° C

Insulation may be grouped into the following recognized classes :

Class Y insulation consists of materials or combinations of materials, such as cotton, silk and paper without impregnation. Other materials or combinations of materials may be included in this class, If by experience or accepted tests they can be shown to be capable of operation at Class Y temperatures.

Class A insulation consists of materials or combinations of materials, such as cotton, silk and paper when suitably impregnated or coated or when immersed in a dielectric liquid such as oil. Other materials or combinations of materials may be included in this class, if by experience or accepted tests they can be shown to be capable of operation at Class A temperatures.

Class E insulation consists of materials or combinations of materials which by experience or accepted tests can be shown to be capable of operation at Class E temperatures (materials possessing a degree of thermal stability allowing them to be operated at a temperature 15 Centigrade degrees higher than Class A materials).

Class F insulation consists of materials or combinations of materials, such as mica, glass fibre, asbestos, etc. With suitable bonding substances such as appropriate silicone resins. Other materials or combinations of materials may be included in this class. If by experience of accepted tests they can be shown to be capable of operation at Class H temperatures.

Class C insulation consists of materials or combinations of materials such as mica, porcelain glass and quartz with or without an inorganic binder. Other materials or combinations of materials may be included in this class. If by experience of accepted tests they can be shown to be capable of operation at temperatures above the Class H limit. Specific materials or combinations of materials in this class will have a temperature limit which is dependent upon their physical, chemical and electrical properties.

TYPE OF CABLES

PVC :-
It is nothing but Polyvinyl Chloride material. This has a good electrical properties but poor flammability properties. The temperature rating is only 70°C. This is called TYPE- A compound as per IS-5831.This material very easily burns and also generates quite lot amount of smoke and toxic gases.

HRPVC :-
This term describes a Heat Resistant PVC material. This has comparatively good electrical properties. This material has a temperature rating of 85°C. This material is called TYPE - C compound as per IS-5831.

FLAME RETARDANT PROPERTIES :-
1. They must be difficult to ignite or burn.
2. If it catches fire, it must propagate less quickly.
3. They must evolve less smoke on burning.
4. They must emit less corrosive or toxic gases on burning.

FRLS PVC :-
This term describes a Flame Retardant Low Smoke PVC material. This has comparatively low electrical properties and mechanical properties but very good flammability properties. This also has an operating temperature of 85°C. 1.6 times costlier.

FRLSLH Compound : -
This term means a Flame Retardant Low Smoke and Low Halogen compound. This has very good flammable properties. However, the temperature rating is only 85°C. 3 to 4 times costlier.

ELASTOMER : -
The term elastomer or elastomeric compound describes a flame retardant material of rubber base. This material has very good flammable properties but has slightly inferior mechanical properties.

PTFE : -
This means Poly Tetra Flouro Ethelene compound. This has a very good mechanical, electrical and flammable properties. This will meet the Voltage grade with comparatively less thickness of insulation. It is 6 times costlier than HRPVC.

Significance of flame retardant properties are apparent.

1. It will not catch fire easily.

2. Flame/fire will not be propagated to a longer distances and hence the systems/subsystems/co-systems are saved.
3. In case of fire, less emission of toxic gases means that safety to the operating personnel and less corrosive to the atmosphere/components/equipments located in the zone.

OTHER FLAMMABILITY PROPERTIES : -

1. Oxygen Index
It is a measure of ignition of material at ambient temperature. Typical value is 29. The standard governing this property is ASTM-D-2863.

2. Temperature Index

It is, in contrast to the oxygen index, a measure of ignition of material in atmospheric air at elevated temperatures. Typical value is 250°C. The standard governing this property is ASTM-D-2863.

3. Smoke Density

It is a measure of amount of smoke emission by burning of the material. Typical value is 60%. This means that there will be 60% smoke and 40% light transmittance. The standard governing this property is ASTM-D-2843.

4. Toxic gas generation

It is a measure of amount of toxic or acid gases generated while burning the cable. Typical value of 20%. The standard governing this property is IEC-754.

There are many other properties and tests, the cable has to pass through for it to be qualified as a FRLS cable. The testing methods and acceptable values/norms are dictated in the standards IEEE-383 and SS-4241475.

VARIOUS OTHER PARAMETERS GOVERNED BY IS

1. Conductor --> IS-8130

2. Insulation --> IS-5831 for PVC and IS-6380 for rubber.

3. Inner sheath and Outer sheath --> IS-5831.

4. Armour --> IS-3975.

5. For all general parameters like insulation thickness, inner sheath and outer sheath thickness, type of inner sheath (Taped or extruded), cores colour coding/number printing, order of cores and type of armouring, it is referred to IS-1554.

CHAPTER-4
COMMUNICATION PROTOCOLS

1. RS-232-C and RS-449

The interface between the computer or terminal and the modem is an example of a Physical layer protocol. It must specify in detail the mechanical, electrical, functional, and procedural interface.

The mechanical specification for a 25 pin connector is 47.04 ± .13 mm wide (screw center to screw center), with all the other dimensions equally well specified. The top row has pins numbered 1 to 13 (left to right); the bottom row has pins numbered 14 to 25 (also left to right).

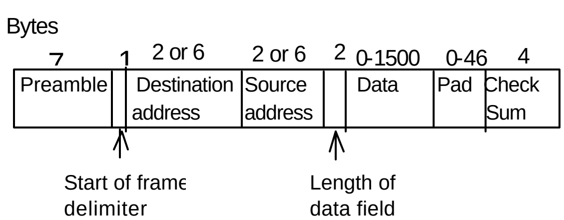
The electrical specification for RS-232-C is that a voltage more negative than -3 volts is a binary 1 and a voltage more positive than +4 volts is a binary 0. Data rates up to 20 kbps are permitted as are cables up to 15 meters.

The functional specification tells which circuits are connected to each of the 25 pins, and what they mean. Figure shows 9 pins that are nearly always implemented. The remaining ones are frequently omitted. When the terminal or computer is powered up, it asserts (i.e., sets to a logical 1) Data Terminal Ready (pin 20). When the modem is powered up it asserts Data set Ready (pin 6). When the modem detects a carrier on the telephone line , it asserts Carrier Detect (pin 8). Request to Send (pin 4) indicates that the terminal wants to send data. Clear to send (pin 5) means that the modem is prepared to accept data. Data is transmitted on the Transmit circuit (pin 2) and received on the Receive circuit (pin 3).

Other circuits are provided for selecting the data rate, testing the modem, clocking the data, detecting ringing signals, and sending data in the reverse direction on a secondary channel. They are hardly ever used in practice.

The procedural specification is the protocol, that is, the legal sequence of events. The protocol is based on action-reaction pair's. When the terminal asserts Request to Send, for example, the modem replies with Clear to Send, if it is able to accept data. Similar action-reaction pairs exist for other circuits as well.

RS-232-C has been around for years. Gradually, the limitation of the data rate to not more than 20 kbps and the 15 meter maximum cable length have become increasingly annoying.



The new standard, called RS-449, is actually three standards in one. The mechanical, functional, and procedural interfaces are given in RS-449, but the electrical interface is given by two different standards , RS 423A and RS 422A . However this requires a 37 pin connector and 9 pin (optional) connector.

IEEE 802

IEEE has produced several standards for LANs. The standards collectively known as IEEE 802 include :

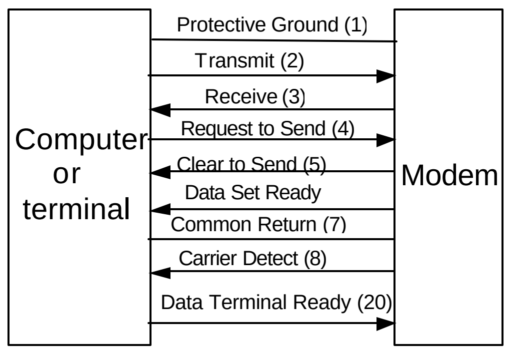
1) CSMA/CD
2) Token bus &
3) Token Ring

The various standards differ at the physical layer and the MAC sub layer but are compatible at the data link layer.

IEEE 802.3.

In the LAN protocol 1-persistent CSMA /CD, when a station wants to transmit, it listens to the cable. If the cable is busy the station waits until it goes idle, otherwise it transmits immediately. If 2 or more station simultaneously begin transmitting on an idle cable, they will collide. All colliding stations then terminate their transmission, wait a random time and repeat the whole process all over again.
The IEEE 802.3 standard is for this 1-persistent CSMA/CD LAN protocol.
The 802.3 standard describes a whole family of 1-persistent CSMA/CD systems, running at speeds from 1 to 10 Mbps on various media. The term ‘Ethernet’ is used to refer to a specific product that implements 802.3.

Configuration



1) A Transceiver is clamped securely on to the cable so that its tap makes contact with the inner core.

2) The transceiver handles carrier detection and collision detection.

3) When a collision is detected the transceiver puts a special invalid signal on the cables to ensure that all transceivers also realise that a collision has occurred.

4) A transceiver cable connects the transceiver to an interface board inside the computer.

5) The interface board contains a controller chip that transmit frames to and receives frames from the transceiver.

6) The controller is responsible for assembling the data into the proper format, as well as computing check sums on outgoing frames and verifying them on incoming frames.
The maximum cable length permitted by IEEE 802.3 is 500 meters.

The frame structure is as follows:-

1) Each frame starts with a preamble of 7 bytes containing a bit pattern of 10101010 which produces a square wave to allow the receivers clock to synchronize with the sender’s.

2) Next the ‘start of frame byte’ containing 10101011 to denote the start of the frame itself.

3) The frame contains the destination and source address. The standard allows 2 byte and 6 byte addresses, but the parameters defined for the 10 Mbps based and the standard uses only the 6 byte addresses.

4) The higher order bit of the destination address is 0 for ordinary addresses and 1 for group addresses. When a frame is sent to a group address all the station in the group receive it. Sending to a group of station is called multicast.

5) The length field tells how many bytes are present in the data field from a minimum of 0 to a maximum of 1500. To make easier to distinguish valid frames from garbage 802.3 states that valid frames must be at least 64 bytes long.

6) If the data position of a frame is less than 46 bytes the pad field is used to fill out the frame to the min. size.

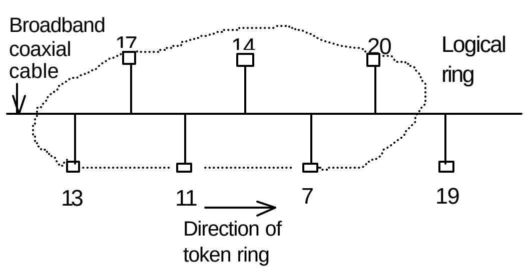
7) The final field is the checksum. It is effectively a 32 bit hash code of the data. If some data bits are erroneously received, the checksum will almost certainly be wrong and the error will be detected.

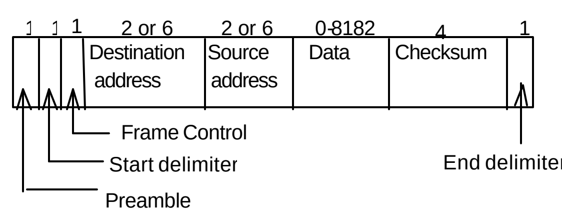
Disadvantages of IEEE 802.3

1) Due to the probabilistic MAC protocol, a station might have to wait arbitrarily long to send a frame.

2) 802.3 frames do not have priorities making them unsuitable for real time systems in which important frames should not be held up waiting for unimportant frames.

IEEE 802.4
A simple system in which each station takes its turn to send a frame can be used, but a break in the ring cable would bring the whole network down. So a new standard IEEE 802.4 was adopted which is known as the Token bus.





Physically the token bus is a linear or tree-shaped cable onto which the stations are attached. Logically, the stations are organized into a ring with each station knowing the address of the station to its “left” and “right”. When the logical ring is initialized, the highest numbered station may send the first frame. After it is done, it passes permission to its immediate neighbour by sending the neighbour a special control frame called a token. The token propagates around the logical ring, with only the token holder is being permitted to transmit frames. Since only one station at a time holds the token, collisions do not occur.

An important point to realize is that the physical order in which the stations are connected to the cable is not important. Since the cable is inherently a broadcast medium, each station receives each frame, discarding those not addressed to it. When a station passes the token, it sends a token frame specifically addressed to is logical neighbour in the ring, irrespective of where that station is physically located on the cable For the physical layer, the token bus uses the 75Ω broadband coaxial cable used for cable television. Speeds of 1,5 and 10 Mbps are possible. This physical layer is totally incompatible with 802.3 and a lot more complicated.

Bus Frame Format.

1) The 802.4 bus frame format is different from the 802.3 frame format. The preamble is used to synchronize the receiver's clock and it may be as short as 1 byte.

2) The starting delimiter and ending delimiter fields are used to mark the frame boundaries. Both these fields contain analog encoding of symbols other than 0's and 1's so that they cannot occur incidentally in the user data. As a result no length field is needed.

3) The frame control field is used to distinguish the data frame from the control frame. The token frame used to pass the token from station to station and frames relating to adding and deleting stations from the logical ring and some of the control frames.

4) The checksum is used to detect transmission errors.

2. HART PROTOCOL
Highway Accessible Remote Transducer

The HART protocol operator using FSK (frequency shift keying), which is based on BELL 202 communication standard.

The digital signal is made up from two frequencies 2 & 2.2 KHz representing bits '1' & '0', respectively. Sine waves of these frequencies are super imposed on the DC analog signal cables to give simultaneous analog and digital communications since average value of FSK signal always zero, 4-20 mA signal is not affected.

This producer genuine, simultaneous communication with a response time for approx. 500 ms for each field device, without interrupting any analog signal timing that might be taking place.

Upto two motor devices may be connected to each HART loop. The primary one is generally a management system or a PC and the secondary one can be a hand held terminal or laptop computer. A standard hand held terminal (called HART communicator is available to make field operations as uniform as possible further networking options are provided by gateways. HART follows the basic open system interconnections (OSI) reference model developed by ISO. The OSI model provides the structure and elements of a communication system. The HART protocol uses a reduced OSI model, implementing only layer 'Physical', 'Link' & 'Application',

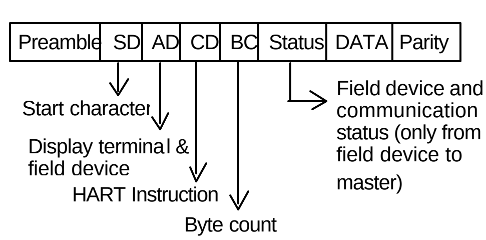
Layer 1, the physical layer, operates on FSK principle,
Data transfer rate - 1200 bits/sec
Logic '0' frequency - 2200 Hz
Logic '1' frequency - 1200 Hz

For short distances, unshielded 0.2 mm^2 2 win lines are suitable. For longer distances (upto 1500 m), single, shielded bundle of 0.2 sq.mm twisted pairs can be used. Beyond this upto 3000m can be covered using single, shielded, twisted 0.5 mm^2 pairs. A total resistance of between 230 Ω and 1100 Ω must be available in the communication circuit.

Layer 2, link layer, establisher the format for a HART message. HART is a master/slave protocol. All the communication activities originate from a master e.g. a display terminal. This addresses a field device(slave), which interprets the command and sends a response.

A specific size of operand is required to enable the field device to carry out the HART instruction.

Structure of message



Layer 2, improves transmission reliabilities by adding the parity character derived from all the preceding characters. Each character also receives a bit for add parity.

The individual characters are :
1 start bit, 8 data bits, 1 bit for odd parity and 1 stop bit.

Layer 7, the application layer, brings the HART instruction set into play. The master sends messages with request for specific values, actual values and any other data or parameters available from the device. The response message provides the master with status instruction and data from the slave.

To make interaction between HART compatible devices an efficient on possible, classes of conformation has been established for master and classes of command for slaves. For slave devices, logically uniform communication is provided by following command sets,

1) Universal commands :- Understood by all field devices.
2) Common practise commands : - Provide functions which can be carried out by many, though not all, field devices together, these commands comprise a library of most common field device functions.
3) Device - specific commands: Provide functions which are restricted to an individual device, permitting special features to be incorporated that are accessible by all users.

Operating conditions

The HART standard requires level-3 resistance to interference in the lives in accordance with IEC-801-3 and -4. This satisfier the general requirement for noise resistance.

Connecting or disconnecting a user, or even breakdown of communication does not interfere with transmission between the other units.

For intrinsically sage application, barrier or isolators must be able to transmit the BELL 202 frequencies in both directions.

Technical data

Type of timing - FSK (BELL 202)

TR - 1.2 K 0 bit 2.2 K 1 bit 1.2 K

Signal structure 1 start bit, 8 data bit, 1 odd parity, 1 stop Transfer rate for simple variables approx. 2/sec max. no. of units in bus mode, with a central power supply - 15.
Max. Variable specifications : Max. no. of variable per field unit (one modern) - 256.
Max. No. of variables / message - 4
Max. No. of master systems - 2

Physical layer : Error rate destination circuit 10^{-5} bit.

Link layer : Recognizes all groups of upto 3 corrupt bits and practically all longer and multiplier groups.

Application layer :- Communication station transmitted in a response message.

The following rule determines max. Line length for a particular application can be taken from the restrictions governing the signal.

$$L = \frac{65 \times 10^6}{R.C} - \frac{C + 10}{150}$$

where l is length (M), R is the resistance (r) of the local plus internal resistance from the barrier / isolator, C is the line capacity (pf/m), and Cf is the max. Internal capacitance for smart field units (pf).

Chapter - 5

PAINTING PROCEDURE

The finished panel surfaces shall be free from all waves, bellies and other imperfections. Surface preparation shall be by power tool cleaning after degreasing and rinsing.

The primer shall be epoxy zinc chromate paint of yellow colour. Two coats of primer shall be applied on both exterior and interior surface. The primer should be sprayed and not brushed. The interval of drying timer shall be 12 hours. The extent of primer coating after two coats shall be around 60 microns.

The exterior painting shall be of poly urethene paint light grey shade 631 semiglossy finish and applied by spraying. 2 coats of painting shall be done with an interval of 12 hours for drying. The finish coat paint which comes in 2 packs i.e. paint & hardener shall be mixed in proper ratio as advised by paint manufacturer (indicated in the paint container test/certificate). The poly urethene paint coating shall have enough abrasive resistance.

Suggested paint manufacturers are M/s. Berger, Asian Paints. Shalminar, Bombay Paints, CDC, Jenson & Nicholson.

SELECTION OF DIFFERENT TYPES OF TEMPERATURE SENSORS

	Platinum Resistance Thermometer	**Thermocouple**	**Thermistor**
Sensor	Platinum-wire wound or flat-film resistor	Thermo element, two dissimilar metals/ alloys	Ceramic (metal oxides)
Accuracy (typical values)	0.1 to 1.0°C	0.5 to 5.0°C	0.1 to 1.5°C
Long term Stability	Excellent	Variable, Prone to aging	Good
Temperature range	-200 to 650°C	-200 to 1750°C	-100 to 300°C
Thermal response	Wire wound-slow Film-faster 1-50 sec. typical	Exposed tip-fast Sheathed-slower 0.1 to 10 sec. typical	Generally fast 0.05 to 2.5 sec. typical
Excitation	constant current required	None	None
Characteristics	PTC resistance	Thermo voltage	NTC resistance
Linearity	Fairly linear	Most types non-linear	Exponential
Lead resistance effect	3&4 wire-low 2 wire -high	Short cable runs satisfactory	Low
Electrical “pick-up”	Rarely susceptible	Susceptible	Not susceptible
Interface	Bridge 2,3 or 4 wire	Potentiometric input. Cold junction compensation required	2 wire resistance
Output characteristics	0.4Ω / °C approx.	From 10μ V/ °C to 40μV/°C depending on type	-4%/ °C
Extension Leads	Copper	Compensating cable	Copper
Cost	Wire wound - more expensive Film - cheaper	Relatively low cost	Inexpensive to moderate

THERMOCOUPLE SHEATH MATERIALS

Sheath Material	**Maximum Continuous Temperature**	**Notes**	**Applications**
Refractory Oxide, recrystallised, e.g. Alumina (Impervious)	1750°C	Good choice for rare metal thermocouple. Good resistance to chemical attack. Mechanically strong but severe thermal shock should be avoided	Forging iron & steel. Incinerators, carburizing and hardening in heat treatment. Continuous furnaces. Glass Lehrs.

Silicone Carbide (Porous)	1500° C	Good level of protection even in severe conditions. Good resistance to reasonable levels of thermal shock. Mechanically strong when thick wall is specified but becomes brittle when aged. Unsuitable for oxidising atmosphere but resists fluxes.	Forging iron & steel. Incinerators Billet heating, slab heating, butt welding. Soaking pits ceramic dryers.
Impervious Mullite	1600° C	Good choice for rare metal thermocouples under severe conditions. Resists Sulphurous and carbonaceous atmosphere/ Thermal shock should be avoided.	Forging iron & steel. Incinerators, heat treatment. Glass flues. Continuous furnaces.
Mild steel (cold drawn seamless)	600° C	Good physical protection but prone to rapid corrosion.	Annealing up to 500° C. Hardening pre-heaters. Baking ovens.
Stainless steel 25 / 20	1150° C	Resists corrosion even at elevated temperature. Can be used in Sulphurous atmospheres.	Heat treatment annealing, flues, much chemical process. Vitreous enamelling. Corrosion resistant alternative to mild steel.
Inconel 600/800*	1200°	Nickel-Chromium -Iron alloy which extends the properties of stainless steel 25/20 to higher operating temperatures. Excellent in Sulphur free atmospheres; superior corrosive resistance at higher temperatures. Good mechanical strength.	Annealing,carburizing, hardening. Iron & steel hot blast. Open hearth flue &stack. Waste heat boilers. Billet heating, slab heating. Continuous furnaces. Vitreous enamelling. Glass flues & checkers. Gas super heaters. Incinerators up to 1000°C. Highly sulphurous atmospheres should be avoided above 800°C Soaking pits. Cement exit flues & Kilns.
Chrome Iron	1100°C	Suitable for every adverse environments. Good strength. Resists severely corrosive and sulphurous atmospheres.	Annealing,carburizing, hardening. Iron & steel hot blast.

Insulation Material	**Usable Range**	**Application Notes**
PVC	-10°C to 105°C	Good general purpose insulation for "light" environments. Waterproof and very flexible.
PTFE	-75°C to 250 / 300°C	Resistant to oils, acids, other adverse agents and fluids. Good mechanical strength and flexibility.
Glass fibre (varnished)	-60°C to 350 / 400°C	Good temperature range but will not prevent ingress of fluids. Fairly flexible but does not provide good mechanical protection.
High temperature glass fibre	-60°C to 700°C	Will withstand temperature range upto 700°C but will not prevent ingress of fluids. Fairly flexible; not good protection against physical disturbance
Ceramic Fibre	0 to 1000°C	Will withstand high temperature, upto 1000°C. Will not protect against fluids or physical disturbance
Glass fibre (varnished stainless steel overbraid)	-60°C to 350 / 400°C	Good resistance to physical disturbance and high temperature (up to 400°C). Will not prevent ingress of fluids.

No.	SWG		B & S (AWG)	
0	**Inches**	**mm**	**Inches**	**mm**
1	0.324	8.23	0.3249	8.25
2	0.300	7.62	0.2893	7.35
3	0.276	7.01	0.2576	6.54
4	0.252	6.40	0.2294	5.83
5	0.232	5.89	0.2043	5.19
6	0.212	5.38	0.1819	4.62
7	0.192	4.88	0.1620	4.11
8	0.176	4.47	0.1443	3.667
9	0.160	4.06	0.1285	3.26
10	0.144	3.66	0.1144	2.91
11	0.128	3.25	0.1019	2.59
12	0.116	2.95	0.0907	2.30
13	0.104	2.64	0.0808	2.05
14	0.092	2.34	0.0720	1.83
15	0.080	2.03	0.0641	1.63
16	0.072	1.83	0.0571	1.45
17	0.064	1.63	0.0508	1.29
18	0.056	1.42	0.0453	1.15
19	0.048	1.22	0.0403	1.02
20	0.040	1.02	0.0359	0.912
21	0.036	0.914	0.0320	0.813
22	0.032	0.813	0.0285	0.724
23	0.028	0.711	0.0253	0.643
24	0.024	0.610	0.0226	0.574
25	0.022	0.559	0.0201	0.511
26	0.020	0.508	0.0179	0.455
27	0.018	0.457	0.0159	0.404
28	0.0164	0.417	0.0142	0.361
29	0.0148	0.376	0.0126	0.320
30	0.0136	0.345	0.0113	0.287
31	0.0124	0.315	0.0100	0.254
32	0.0116	0.295	0.0089	0.226
33	0.0108	0.274	0.0080	0.203
34	0.0100	0.254	0.0071	0.180
35	0.0092	0.234	0.0063	0.160
36	0.0084	0.213	0.0056	0.1423
37	0.0076	0.193	0.0050	0.127
38	0.0068	0.173	0.0045	0.114
39	0.0060	0.152	0.0040	0.102
40	0.0052	0.132	0.0035	0.089
41	0.0048	0.122	0.0031	0.079
42	0.0044	0.112	0.0028	0.071
43	0.0040	0.102	0.0025	0.064
44	0.0036	0.091	0.0022	0.056
45	0.0032	0.081	0.0020	0.051
46	0.0028	0.071	0.0018	0.046
47	0.0024	0.061	-	-
48	0.0020	0.051	-	-
50	0.0016	0.041	-	-
51	0.0012	0.030	-	-
52	0.0010	0.025	-	-

T tera 10^{12}	da deca	10 nana 10^{-9}
G giga 10^{9}	d deci 10^{-1}	p pico 10^{-12}
M mega 10^{4}	c centi 10^{-2}	f femto 10^{-16}
k kila 10^{3}	m milli 10^{-3}	a atto 10^{-18}
h hecto 10^{2}	µ micro 10^{-4}	

CONVERSION TABLE -1

1 inch = 25.4 millimetres 1 yard = 0.9144 metres						
	mm	**cm**	**mt**	**Inches**	**Feet**	**Yards**
1 mm	1	0.1	0.001	0.0393701	0.00328084	0.00109361
1cm	10	1	0.01	0.393701	0.0328084	0.0109361
1 mt	1000	100	1	39.3701	3.28084	1.09361
1 inch	25.4	2.54	0.0254	1	0.083333	0.0277778
1 ft	304.8	30.48	0.3048	12	1	0.333333
1 yard	914.4	91.44	0.9144	36	3	1

	Metres	Km	Feet	Furlongs	Miles	Nauticalmiles
1 mt	1	0.001	3.28084	0.0049709	0.00032137	0.00053961
1 km.	1000	1	3280.84	4.97097	0.62137	0.53961
1 ft	0.3048	0.0003048	1	0.0015152	0.00018939	0.00016474
1 furlong	201.168	0.201168	660	1	0.125	0.108553
1 mile	1609.344	1.609344	5280	8	1	0.86842
1nautical mile	1853.18	1.85318	6080	9.21212	1.15152	1

	T° K	0 ° C	t ° F	r° R
Degrees Kelvin ° K	T	0+273.15	5/9(t+459.67)	5/9 r
Degrees Celsius ° C	T-273.15	0	5/9 (t-32)	5/9(r-491.67)
Degrees Fahrenheit° F	9/5 T-459.67	9/5 (0+32)	t	r - 459.67
Degrees Rankine ° R	9/5 T	9/5 (0+491.67)	t + 459.67	r

1 square mile = 640 acres = 258.999 hectares.
1 acre = 4 roods = 10 square chains = 4840 square yards.
1 square chain = 16 square perches (square rods) = 484 square yards = 404.686 metres.
100 square millimetres = 1 square centimetre 100 square metres = 1 are
100 square centimetres = 1 square decimetre 100 ares = 1 hectare
100 square decimetres = 1 square metre 100 hectares = 1 square kilometres.

	SQ. mm	SQ. cm	SQ. m	SQ. inches	SQ. ft	SQ. yards
1SQ. mm		1	0.01	0.000001	0.00155	0.00000107689
1SQ. cm	100	1	0.0001	0.15500	0.0010763	0.0001196
1SQ. m	1000000	10000	1	1550	10.7639	0.0001196
1Sq.inch	645.16	6.4516	0.0006451	1	0.0069444	0.0007716
1SQ. ft	92903	929.03	0.092903	144	1	0.111111
1SQ.yard	836127	836.12	0.836127	1296	9	1

Diameter of Thickness in Inches and Millimetres								
No.	**Standard wire gauge**	**Birmingham gauge**	**American Brown & Sharpe's gauge**		**Steel wire gauge**			
	S. W. G.	**B. W. G.**	**A. W. G.**		**Stl. W. G.**			
	in	**mm**	**in**	**mm**	**in**	**mm**	**in**	**mm**
15/0	-	-	1,000	25.40	-	-	-	-
14/0	-	-	0.9583	24.34	-	-	-	-
13/0	-	-	0.9167	23.28	-	-	-	-
12/0	-	-	0.8750	22.22	-	-	-	-
11/0	-	-	0.8333	21.17	-	-	-	-
10/0	-	-	0.7917	20.11	-	-	-	-
9/0	-	-	0.7500	19.05	-	-	-	-
8/0	-	-	0.7083	17.99	-	-	-	-
7/0	0.500	12.700	0.6666	16.93	-	-	0.4900	12.45
6/0	0.464	11.786	0.6250	15.88	-	-	0.4615	11.72
5/0	0.432	10.973	0.5883	14.94	-	-	0.4305	10.93
4/0	0.400	10.160	0.5416	13.76	0.4600	11.68	0.3938	10.00
3/0	0.372	9.449	0.5000	12.70	0.4096	10.40	0.3625	9.208
2/0	0.348	8.839	0.4452	11.31	0.3648	9.2656	0.3310	8.407
0	0.324	8.230	0.3964	10.07	0.3249	8.252	0.3065	7.785
1	0.300	7.620	0.3532	8.971	0.2893	7.348	0.283	7.188
2	0.276	7.010	0.3147	7.993	0.2576	6.544	0.2625	6.668
3	0.252	6.401	0.2804	7.122	0.2294	5.827	0.2437	6.190
4	0.232	5.893	0.2500	6.350	0.2043	5.189	0.2253	5.723
5	0.212	5.385	0.2225	5.652	0.1819	4.621	0.2070	5.258
6	0.192	4.877	0.1981	5.032	0.1620	4.115	0.1920	4.877
7	0.176	4.470	0.1764	4.481	0.1443	3.665	0.1770	4.496
8	0.160	4.064	0.1570	3.988	0.1285	3.264	0.1620	4.115
9	0.144	3.658	0.1398	3.551	0.1144	2.906	0.1483	3.767
10	0.128	3.251	0.1250	3.175	0.1019	2.588	0.1350	3.429
11	0.116	2.946	0.1113	2.827	0.0907	2.30	0.1205	3.680
12	0.104	2.642	0.0991	2.517	0.0808	2.05	0.1055	2.680
13	0.092	2.337	0.0882	2.240	0.0720	1.83	0.0915	2.324
14	0.080	2.032	0.0785	1.994	0.0641	1.63	0.0800	2.032
15	0.072	1.829	0.0699	1.775	0.0571	1.45	0.0720	1.829

16	0.064	1.626	0.0625	1.588	0.0508	1.29	0.0625	1.588
17	0.056	1.422	0.0556	1.412	0.0453	1.15	0.0540	1.372
18	0.048	1.219	0.0495	1.257	0.0403	1.02	0.0475	1.207
19	0.040	1.016	0.0440	1.118	0.0359	0.91	0.0410	1.041
20	0.036	0.914	0.0392	0.9957	0.0320	0.813	0.0348	0.8839

CONVERSION FACTORS

Length :	
1 inch	25.4 millimetres (mm)
1 foot	304.8 mm
1 yard	0.9144 metre (m)
1 mile	1.609 kilometre (km)
1 mm	0.039 inch
1 m	1.094 yard
1 km	0.621 mile
1 mil	0.0254 mm
1 micron	0.001 mm

Area :	
1 $inch^2$	645.16 square millimeters (mm^2)
1 $foot^2$	0.093 square metre (m^2)
1 $yard^2$	0.836 m^2
1 mm^2	0.002 $inch^2$
1 m^2	1.196 $yard^2$
1 $inch^2$	12.73240 circular mils (circ mils)
1 circ mil	0.00050671 mm^2
1 acre	4046.86 m^2

Volume :	
1 $inch^3$ 1 $foot^3$	16387.1 mm^3 0.0283 m^3
1 cm^3	0.061 $inch^3$
1 m^3	35.315 $foot^3$
1 $inch^3$	0.01639 litres
1 gallon	4.546 litres
1 litre	0.22 gallons

Weight :	
1 lb	0.454 kg
1 ton	1016 kg
1 kg	2.205 lbs

Density :	
1 $lb/inch^3$	2.768×10^4 kg/m^3 27.68 gm/cm^3 or gm/ml
1 lb/ft^3	16.019 kg/m^3 0.016 gm/cm^3 or gm/ml
1 kg/m^3	0.0624 lb/ft^3
1 $tonne/m^3$	62.43 lb/ft^3

Force :	
1 lbf (pound force)	4.448 newtons (N)
1 pdl (poundal)	0.138255 N
1 N	0.255 lbf 0.102 kg
1 kgf	9.80665 kg m/s^2 9.80665 N

Pressure :	
1 $lbf/inch^2$	6.895 KN/m^2
1 KN/m^2	0.145 $lbf/inch^2$
1 MN/m^2	0.102 kg/mm^2
1 Pa (pascal)	1 N/m^2
1 pz (pieze)	1 K Pa
1 torr	133.322 Pa
1 dyn/cm^2	0.1 Pa
1 bar	10^5 Pa 1.01972 kgf/cm^2
1 bar	14.5 psi 0.986923 atm 750.062 torr

Linear velocity (speed) :	
1 ft/sec	0.3048 m/s
1 mile/hr	0.477 m/s 1.609 km/h
1 m/s	3.281 ft/sec 2.237 mile/hr
1 km/hr	0.621 mile/hr

Angular velocity :	
1 rad/s	0.159155 rev/s
1 rev/s	360 degree/s

Power :	
1 Hp	745.70 Watts 33000 foot pounds per minute 550 foot pounds per second
1 KW	1.34 Hp

Energy :	
1 ft. lbf	1.356 joules (J)
1 KWHr	3.60 Mega joules (MJ)
1 joule	0.738 ft lbf 9.478×10^{-4} Btu
1 MJ	0.278 KWHr

Magnetic :	
Lines per square centimetre (gauss)	0.155 Liner per square inch
Oersted	0.4947 Ampere turns per inch
Watts per kg	2.2046 watts per pound
Lines per square centimetre (gauss)	10^4 webers per square metre

TABLE 1

BRITISH STANDARD WIRE GAUGE (SWG)

Gauge No.	Diameter	Sectional area	Nominal weight of copper wires
	mm	sq. mm	Kg/Km
7/0	12.70	126.709	1126.17
6/0	11.76	109.097	969.85
5/0	10.97	94.580	840.68
4/0	10.16	81.097	720.75
3/0	9.449	70.129	623.38
2/0	8.839	61.368	545.53
0	8.230	53.193	472.88
1	7.620	45.606	405.42
2	7.010	38.600	343.15
3	1.401	32.181	286.06
4	5.893	27.271	242.46
5	5.385	22.774	202.45
6	4.877	18.677	166.05
7	4.47	15.697	139.54
8	4.064	12.974	115.32
9	3.658	10.510	93.41
10	3.251	8.3032	73.81
11	2.946	6.8193	60.61
12	2.642	5.4806	48.72
13	2.337	4.2890	38.13
14	2.032	3.2432	28.83
15	1.829	2.6271	23.35
16	1.626	2.0755	18.45
17	1.422	1.5890	14.13
18	1.219	1.1677	10.38
19	1.016	0.81097	7.207
20	0.9144	0.65677	5.838
21	0.8128	0.51884	4.613
22	0.7112	0.39729	3.531

23	0.6096	0.29187	2.595
24	0.5588	0.24523	2.180
25	0.508	0.20271	1.801
26	0.4572	0.16419	1.459
27	0.4166	0.13626	1.212
28	0.3759	0.11097	0.9867
29	0.3454	0.09374	0.8332
30	0.3150	0.07794	0.6926
31	0.2946	0.06819	0.6061
32	0.2743	0.05910	0.5255
33	0.2540	0.05067	0.4505
34	0.2337	0.04289	0.3813
35	0.2134	0.03575	0.3179
36	0.193	0.02926	0.2601
37	0.1727	0.02343	0.2083
38	0.1524	0.01824	0.1622
39	0.1321	0.01370	0.1218
40	0.1219	0.01168	0.1038
41	0.1118	0.009813	0.08721
42	0.1016	0.008110	0.07207
43	0.09144	0.006568	0.05838
44	0.08128	0.005188	0.04613
45	0.07112	0.003973	0.03531
46	0.06096	0.002919	0.02595
47	0.05080	0.002027	0.01802
48	0.04064	0.001297	0.01153
49	0.03048	0.0007297	0.006486
50	0.02540	0.0005067	0.004505

TABLE 2
BROWN & SHARP'S GAUGE (A.W.G)

Gauge No.	Diameter	Sectional area	Nominal weight of copper wires
	mm	sq. mm	Kg/Km
6/0	14.73	170.454	1515.36
5/0	13.11	134.912	1199.38
4/0	11.68	107.219	953.18
3/0	10.41	85.177	757.23
2/0	9.271	67.505	600.13
0	8.255	53.521	475.80
1	7.341	42.321	376.23
2	6.553	33.728	299.85
3	5.817	26.572	236.23
4	5.182	21.087	187.46
5	4.623	16.784	149.21
6	4.115	13.298	118.22
7	3.658	10.507	93.41
8	3.251	8.3018	73.81
9	2.896	5.5850	58.54
10	2.591	5.2717	46.87
11	2.311	4.1960	37.36
12	2.057	3.3245	29.55
13	1.829	2.6267	23.35
14	1.626	2.0754	18.45
15	1.448	1.6463	14.64
16	1.295	1.3179	11.72
17	1.143	1.0260	9.122
18	1.016	0.81070	7.207
19	0.9144	0.65670	5.838
20	0.8128	0.51886	4.613
21	0.7239	0.41157	3.659
22	0.6426	0.32434	2.883
23	0.5740	0.25880	2.301
24	0.51505	0.20471	1.820
25	0.4547	0.16235	1.443
26	0.4039	0.12810	1.139
27	0.3607	0.10217	0.9083
28	0.3200	0.08044	0.7151
29	0.2870	0.06470	0.5752
30	0.2540	0.05067	0.4505
31	0.2261	0.04014	0.3563
32	0.2007	0.03161	0.2811

33	0.1803	0.02555	0.2271
34	0.1600	0.02011	0.1788
35	0.1422	0.01589	0.1413
36	0.1270	0.01267	0.1126
37	0.1118	0.009810	0.08721
38	0.1016	0.008107	0.07207
39	0.08890	0.006207	0.05518
40	0.07874	0.004870	0.04329

SECTION-2

CHAPTER-1

NEMA STANDARDS

TABLE - 1 :- Comparison of IEC (Metric) Preferred output Ratings and NEMA Standard Horsepower Ratings.

IEC Preferred ratings, KW	Equivalent horsepower, rounded	NEMA standard horsepower
0.06	0.080	1/12
0.09	0.121	1/8
0.12	0.161	1/6
0.18	0.241	1/4
0.25	0.335	1/3
0.37	0.496	1/2
0.55	0.737	3/4
0.75	1.005	1
1.1	1.475	1.5
2.2	2.95	2
3	4.02	3
3.7	4.96	5
4	5.36	7.5
5.5 7.5	7.37 10	10 15
11	15	20
15	20	25
18.5	25	30
22	29	40
30	40	50
37	50	60
45	60	75
55	74	100
75	101	125
90	121	
147	150	
132	177	175
150	201	200
160	214	
185	248	250
200 220	268 295	 300

TABLE 2 : Comparison of the International System of Units (Metric) and American Customary System Units.

Quantity	**International System of Units (metric)**	**American customary Units**
Linear measure	Millimetre	Inch
Angular measure	Degree	Degree
Mass	Kilogram	Pound
Force Torque	Newton Newton meter	Pound-force Pound-force foot
Power	Kilowatt	Horsepower

OUTPUT EQUATION :

$$\text{kW output} = \frac{T \times N}{K \times 1000}$$

where T = torque

N = speed, r/min

K = 9.549 if torque is in Newton meters

= 7.043 if torque is in pound - force feet

conversion of torque :

1. Pound-force feet to Newton meters
   Newton meters = 1.356 x pound-force feet
2. Newton meters to pound-force feet
   Pound-force feet = 0.7376 x Newton meters

Conversion of horsepower :

In American customary units, $\text{Horsepower} = \frac{\text{kW}}{0.7457}$

In metric units, $\text{Horsepower} = \frac{\text{kW}}{0.7355}$

MOTOR RATINGS

The NEMA rating of a motor consists of the output of that machine along with any other characteristics assigned to it by the manufacturer. These characteristics include, but are not limited to speed, voltage, current, and service factor.

TABLE 3: MOTOR ENCLOSURES

Types	Characteristics
	OPEN
Drip-proof (ODP)	Will not allow dripping liquids or solids to enter the motor when falling on the motor at an angle not greater than 15° from vertical.
Splash-proof	A splash-proof motor is similar to a drip-proof motor, except it is constructed to exclude liquids and solids falling on it any angle not more than 100° from the vertical.
Guarded	Motor openings are limited in size. Openings giving access to live or rotating parts do not permit the passage of a rod 3/4 in (2 cm) in diameter and are at less 4 in (10 cm) away from those parts.
Semi guarded	Top half of the motor with limited-size openings as defined under Guarded type.
Externally ventilated	Motor cooled by air circulated by a separate motor-driven blower. Normally used on large low-speed motors where rotor fans cannot move sufficient air to properly cool the motor.
Pipe ventilated	Motor end shields are constructed to accept pipe or ducts to supply ventilating air. Air can be supplied from a source remote from the motor, if necessary, to supply clean air for cooling.
Weather protected, type 1	Ventilating passages minimise entrance of rain, snow, and airborne particles. Passages are less than 3/4 in (2 cm) in diameter.
Weather protected, type 2	Motors have, in addition to t type 1, passages to discharge high-velocity particles blown into the motor.

	TOTALLY ENCLOSED
Fans-cooled (TEFC)	Cooled by external integral fan mounted on the motor shaft.
Explosion - proof	Enclosed motor which withstands internal gas explosion and prevents ignition of external gas.
Dust-ignition-proof	Excludes ignitable amount of dust and amount of dust that would degrade performance.
Waterproof	Excludes liquids and airborne solids except around shaft.
Pipe-ventilated	Openings accept air inlet and /or exit ducts or pipe for air cooling.
Water-cooled	Cooled by circulating water.
Water-air-cooled	Cooled by water-cooled air.
Air-to-air cooled	Cooled by air-cooled air.
TEFC guarded	Fan cooled and guarded by limited size openings.
There are two other classes of protection for both open and totally enclosed motors :	
Encapsulated windings	Machine having random windings filled with resin.
Sealed windings	Machine with form wound coils with wiring and connections sealed against contaminants.

VOLTAGE AND FREQUENCY:

The standard voltages for FHP dc motors, universal motors, and 60-Hz have standard voltages of 115 [15 hp (11 kW) and smaller], 230, 460, 575, 2300, 4000, 4600, and 6600 V.

Motors must operate successfully under running conditions within the limits specified for voltage and frequency variation by the NEMA operating-service conditions. Successful operation within the variations specified, however, does not necessarily mean what the motor will be able to start and accelerate the load to which it is applied.

Service Conditions:

Usual environmental service conditions are defined by NEMA as :

1. Ambient temperatures in the range of 32 to 105°.F (0 to 40℃) or, when water cooling is used, in the range of 50 to 105°F(10 to 40°C).
2. Barometric pressure corresponding to an altitude not exceeding 1000 m
3. Installation on a rigid mounting surface.
4. Installation in areas or supplementary with ventilation.

Usual operating service conditions are :

1. Voltage variation up to 6 percent of rated voltage for universal motors and 10 percent of rated voltage for ac and dc motors.
2. Frequency variation not more than 5 percent above or below rated frequency.
3. Combined voltage and frequency variation not more than 10 percent above or below the rated voltage and frequency.
4. V-belt drive, flat-belt, chain, and gear drivers, in accordance with NEMA standards.

Locked - Rotor kVA

Every AC motors (except three-phase wound-rotor types) rated 1/20 hp and larger has a better designation for locked-rotor kVA per horsepower (Table 4). It is calculated as follows :

TABLE 4 Locked - Rotor kVA/hp Code Designations

Code letter	Locked-rotor kVA/hp	Code letter	Locked-rotor kVA/hp
A	0 - 3.15	L	9.0 - 10.0
B	3.15 - 3.55	M	10.0 - 11.2
C	3.55 - 4.0	N	11.2 - 12.5
D	4.0 - 4.5	P	12.5 - 14.0

E	4.5 - 5.0	R	14.0 - 16.0
F	5.0 - 5.6	S	16.0 - 18.0
G	5.6 - 6.3	T	18.0 - 20.0
H	6.3 - 7.1	U	20.0 - 22.4
J	7.1 - 8.0	V	22.4 and up
K	8.0 - 9.0		

Service Factor
NEMA service factor is a multiplier which indicates what percent higher than the name plate horse power can be accommodated continuously, at rated voltage and frequency without injurious overheating (i.e., exceeding NEMA allowable temperature rise for given insulation systems).

Types of motor Starters
IEC Starter Ratings. Utilization categories are used with IEC devices to define the typical duty cycle for a starter or contactor. The IEC utilization categories are :

AC1 Non inductive or slightly inductive loads
AC2 Starting of slip-ring motors
AC3 Starting of squirrel-cage motors and switching off only after the motor is up to speed [make at load running amperes (LRA), break at full - load amperes (FLA)]
AC4 Starting of squirrel - cage motors with inching and plugging duty; rapid start/stop (make and break are LRA)
AC11 Auxiliary (control) circuits

TABLE 5 : Motor Starter Sizes.(As per NEMA STD)

Single - phase horsepower		Three - Phase horsepower			
115 V	230 V	200 V	230 V	460-575 V	Starter Size *
1/3 1	1 2	1 1/3 3	1 1/2 3	2 5	00 0
2	3	7 1/3	7 1/3	10	1
3	5	10	10	10	1p, 1 3/4
3	7 1/2	10	15	25	2
		15	20	30	2 1/2
		25	30	50	3
		30	40	75	3 1/2
		40	50	100	4
		50	75	150	4 1/2
		75	100	200	5
		150	200	400	6

Electrical Enclosure Types and specifications

Electrical enclosures should be selected and specified according to NEMA Standard Publication No. 250.

Type 1. Indoor use primarily to provide a degree of protection against contact with the enclosed equipment in locations where unusual service conditions do not exist.

Type 3. Outdoor use primarily to provide a degree of protection against windblown dust, rain, and sleet and to resist damage by the formation of ice on the enclosure.

Type 3R. Outdoor use primarily to provide a degree of protection against wind blown dust rain, splashing water, and hose-directed water and to resist damage by the formation of ice on the enclosure.

Type 4 .Indoor or outdoor use primarily to provide a degree of protection against wind blown dust and rain, splashing water, and hose -directed water and to resist damage by the formation of ice on the enclosure.

Type 4X. Indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water, and hose -directed water and to resist damage by the formation of ice on the enclosure.

Type 6. Indoor or outdoor use primarily to provide a degree of protection against the entry of water during occasional temporary submersion at a limited depth.

Type 6P. Indoor or outdoor use primarily to provide a degree of protection against the entry of water during prolonged submersion at a limited depth.

Type 7. Indoor use in locations classified as Class I, Groups A, B, C or D, as defined in the National Electrical Code.

Type 9. Indoor use in locations classified as Class II, Groups E or G, as defined in the National Electrical Code.

Type 12. Indoor use primarily to provide a degree of protection against dust, falling dirt and dripping non corrosive liquids.

Type 13. Indoor use primarily to provide a degree of protection against dust, spraying of water, oil , and non corrosive coolant.

CHAPTER-2
VOLTAGE DROP

Voltage drops are calculated by using the formula:
$V = b\ (p1\ L/S \cos\phi + \lambda\ L\ \sin\phi)\ I_s$ where
v - voltage drop
b - factor equal to 1 for three phase circuits and equal to 2 for single phase circuits.

p1- resistivity of the conductors in normal duty taken as being equal to the resistivity at the normal duty temperature, i.e., 1.25 times the resistivity at 20° C,, giving 0.0225 $\Omega mm^2/m$ for copper and 0.036 $\Omega mm^2/m$ for aluminium.

L= Length of cabling conduits in metres
S = cross-section of conductors in mm^2
$\cos\phi$ = Power Factor: if the exact figure is not available, the PF is taken as being 0.8 ($\sin\phi$ - 0.6)

λ = linear reactance of conductors, taken as being equal to 0.08 mΩ/m if the exact figure is not available.

I_s- current in use in A.

The higher the current, the b igger the voltage drop will be. The voltage drop should therefore be calculated for the starting current to see if this is suitable for the application. If the most important criterion is the locked rotor torque (or the acceleration time), the voltage drop will have to be limited to 3% maximum. The relative voltage drop (in%) is equal to :

$DV = 100\ V / V_0$

V_0 voltage between each phase and neutral

<u>Various allowable voltage drop levels in power cable of motor circuit :</u>

1.0 UDHE Specification for SPIC Project
Specification reference UAN 66-6133-700, Clause No. 6.0 sheet E-3/Page 3/3
* Voltage drop in cables between MCC & Motor terminals shall be restricted to the following limits while sizing the cables.
Under full load : 3% of 415 V
Under starting load : 10% of 415 V(DOL starter)

2.0 Unchahar T.P.S., 2 x 210 MW, Unit 3 & 4 Specification:
Cable sizing (Unchahar page 1227/Vol.II, Part-I, Section-VII, Clause 5.02.02)
* Power cable shall be sized on the following consideration.
* (b) Voltage drop : The maximum allowable voltage drop during normal running from 415V MCC to load shall not exceed 3% of 415V under full load condition.

3.0 Engineer’s Reference book, Page 13/30 cable
* Typical requirement in the IEE (Institution of Electrical Engineers, UK) is that, the voltage drop in the cable run should be such that the total drop in the circuit of which the cable forms a part does not exceed 2.5% of nominal voltage.

4.0 Kirloskar Electric: (Refer Page No. 59)
* The voltage drop will have to be limited to 3% of maximum.

5.0 Incab: (Page No. 104 of Incab’s Cables & Tables)
* Voltage drop does not exceed 2.5% of nominal voltage.

6.0 The Indian Electricity Rules, 1956 (Refer Page Nos. 23, 232, 233 & 234)
* In motor circuits, the voltage drop from the consumer’s terminal shall not under full load conditions, exceed 7.5% of the declared or nominal voltage.

7.0 Asia Brown Boveri limited (ABB): (Refer ABB Motors - HT Motors - Technical Catalogue - Page No. 28 - Voltage drop along the cable.

* Induction motors draw heavy currents during starting, resulting in considerable voltage drop along the cable. If other loads are connected in parallel to the motors, the voltage drop along the common feeder causes operational problems to these associated loads. Larger the starting current and longer the common feeder, larger will be the voltage drop. In view of this while specifying the motors or cables, it is estimate the right combination of starting current and cable size, alternatively, it is important to know voltage drop for an installation when starting/locking of motors occurs such that the maximum voltage drop is less than 3%.

CHAPTER-3
<u>**MCC (Motor Control Centre)**</u>

Based on the type of motor to be controlled, the MCC is classified as,

(i) HT Switchgear MCC(For controlling HT motors)
(ii) LTMCC (For controlling LT motors)
MCC, by definition, is the electrical equipment containing switching devices & controlling devices for controlling the operation of number of motors in a centralised locations.

The MCC is further classified based on the following criteria.

1) Based on operational fronts

- Single front MCC
- Double front MCC

2) Based on Module type
- Non-draw out type
- Draw Out type

The MCC contains the following

(i) Bus Bar Chamber - To accumulate main Bus Bars.
(ii) Cable alloy - For termination of external cables.
(iii) Base channel - For free standing & supporting
(iv) Modules - For accelerating starter components.

In the draw out MCC, the starter modules can be pulled out to the following positions.

1) Service position - Both Power and Control Circuit get power supply.
2) Test Position - Only control circuit get supply for testing the modules without energising the motor.
3) Isolated position - Both power & control circuit supplies are cut-off & any maintenance work can be carried out.

INSULATION CLASS

Class F allows for temperature rises of 105°K (by the resistance variation method) over 40° C ambient and maximum temperatures of 155°C at the hot spots in the machine (of IEC 85 and IEC 34-1).

Complete impregnation with tropicalised varnish of thermal class 155°C gives protection against attacks from the environment, such as 90% relative humidity. For special constructions the winding is of class H and impregnated with special varnishes which enable it to operate in conditions of high temperatures with relative air humidity of up to 100%.

Temperature rise (T*) and maximum temperature at hot spots (T_{max}) for insulation classes (IEC 34-1).

INSULATION CLASS	T*	T_{max}
Class B	80°K	130°C
Class F	105°K	155°C
Class H	125°K	180°C

* Measured using the winding resistance variation method.

RATED POWER IN RELATION TO FRAME SIZE AND SPEED

415VOLTS,50Hz,50° AMBIENT, 10-5-10 VARIATION				
FRAME	**2 POLE**	**4 POLE**	**6 POLE**	**8 POLE**
PM 63	0.12	0,12	-	-
PM 63	0,18	0.18	-	-
PM 63	0.25	-	-	-
PM 71	0.37	0.25	-	-
PM 71	0.55	0.37	-	-
PM 80	0.75	0.55	0.37	-
PM 80	1.10	0.75	0.55	-
PM 90 S	1.50	1.10	0.75	0.37
PM 90 L	2.20	1.50	1.10	0.55

PM 100 L	3.70	2.20	1.50	0.75 & 1.10
PM 112 M PM 132 S	- 5.50	3.70 5.50	2.2 5.50	1.5 5.50
PM 132 S	7.50	-	-	-
PM 132 M	-	7.50	5.50	-
PM 160 M	11.0	11.0	7.50	3.70
PM 160 M	15.00	-	-	5.50
PM 160 L	18.50	15.00	11.00	7.50

CHAPTER-4
RELAYS

Mechanical Relays vs. Solid state Relays:

Solid state Relays are chosen for their long life span as well as their fast actuation time. Their primary drawback is their "Off-State" leakage current which can, in high impedance digital circuits, leave a device continually on, or in analog circuits significant errors.

Mechanical Relays are chosen for their versatility. 'Normally Open" and "Normally Closed" contacts as well as multi-pole configurations and dry circuit contacts are available. They have no "Off-State" leakage current. Their drawbacks are slower switching time, shorter life span, and in some instance electrical noise both in the coil and contact circuits.

CHAPTER-5
CIRCUIT BREAKERS

Circuit Breaker is a device capable of opening the Power line feeders of an electrical system manually or automatically. It opens the circuit automatically at some predetermined value of o/c or fault circuit without damage to the mechanism or the circuit carrying portions of the device. The arrangement allows the user to close the circuit breaker even after repeated operations and be provided with the same level of protection. The circuit breaker therefore provides the same function as a line fuse with the exception that it is reusable after it opens the circuit.

The primary consideration in selecting circuit breaker is that it can be set to trip at proper value of o/c, and that it possesses a high enough interrupting rating to perform its function without being damaged. The NEC lists the max. ratings or settings for ac-motor branch protection is being 700% of FLC of magnetic CB. 250% for DC motors up to 50 HP and 150% for DC motors above 50 HP.

Thermal magnetic trip type circuit breaker has two separate parts. It has thermal trip unit which will open the circuit on o/c condition exists for a period of time. It also has a magnetic trip unit which will open the circuit instantly at a much higher value of current. Regardless of the application, thermal trip point should be such that it will protect the power lines or power bus from drawing excessive currents over a period of time which will cause abnormal heating of these conductors. The magnetic portion of the CB should provide immediate removal from the line during short circuit or ground fault conditions.

Magnetic trip or instances CBs are generally used wherever circuit protection against short circuit and ground faults is the only consideration. For motor control circuits, the instantaneous breaker, when used, should be selected such that it will allow the *inrush* current to pass without tripping but will open the circuit at some value in excess of this current.

Low voltage contactor for motor control

The contactor is a central device of all control systems. It is the component in the controller which opens and closes the circuit from the energy source to the apparatus under control. L.V. contactors operates at 600V ,maximum.

Motors draw high inrush currents during starting which range to approx. 600% of FLMC. The contactor must therefore be capable of closing on and carrying these higher currents without experiencing abnormal degradation. It must also be capable of interrupting these same magnitude of currents. NEMA standards provide these factors by establishing max. Operating conditions of six times FLMC for ac motors and 4 times FLMC for DC motors used in conjunction with reduced voltage starters and 10 times FLMC for dc across-the-line full voltage starters.

Normally when a controller is to be used for plugging or inching, the contactor must be derated. This precaution is necessary to accommodate the additional heating which results from these frequent inrush current surges.

Motor O / L protection : -

The purpose of O/L protection is to protect the motor during the normal course of its operation and to prevent it from operating beyond its full load capacity during both starting and running. Whenever motor is subjected to such conditions, its normal life is reduced.
The motor must be taken off line before the current produces enough heat to cause damage to the motor.

BIMETAL O/L RELAY :-

BOL have a bimetal which is either connected in series with a motor current carrying conductor & heated directly or is heated by a heater element in series with the motor conductor. Overload current of the motor causes dissimilar metal elements to wrap to a point where contacts mounted on them will open the motor circuit.

Time-current characteristics (tripping time vs. current) at 40°C ambient shall be given in log scale, the tripping time in seconds the circuit in multiples of ultimate trip circuit. The relay should not trip while the FLMC flows thro' the heating element. The relay has an inverse time characteristics, which means that the higher the O/L is, the faster relay trips.

THERMAL OVERLOAD RELAYS:

The relay operates on the differential system of protection provided by the double slide mechanism. Under single phasing and unbalanced conditions, the two slides of the relay undergo differential deflection. One slide senses the movement of the bimetal that has deflected the maximum while the other slide senses the minimum deflection. The slides are linked in such a way that the difference in movements of the two slides is amplified for actuation of the micro switch. This leads to accelerated tripping under single phasing.

CHAPTER – 6

TIMERS

TIME DELAY RELAY

Timers are ideally suited for machine tools, sequence controls and other applications, where quickly adjustable and dependable time delays are required between related operations. They reset as fast as 0.02 seconds and are perfect for high speed operations.

Design Principle / system operation

The relays operate on a recalculating air principle - the rate of air travel through the timing orifice determine the duration of timing cycle. The system operation can be explained in three steps.

Reset position

The magnet, cavity spring and atmospheric pressure hold the diaphragm in complete contact with the sealing surface.

Timing stroke

Operating force draws the centre of the diaphragm upward, displacing air on the spring cavity. Air circulates through perforations at the outer edge of the diaphragm, through the metering orifice and into the timing cavity. When sufficient air enters the timed contacts transfer.

Resetting stroke

Force applied by the magnet defeats the atmosphere seal holding the outer position of the diaphragm against the sealing surface. Air re-circulates from the taking cavity through the perforations and back into the spring cavity. On completion of the stroke the diaphragm reset position is re-established.

The repeat accuracy of a time delay relay as per IS 5831 (Part 1) - 1973 is one-half of the variation between the maximum and minimum observed operating times at any particular setting, divided by the mean of all the observed operating times and the quotient multiplied by 100 and expressed in terms of plus or minus percentage.

Notes :

1. ON DELAY TIMER :- The change over of contacts take place with delay on energisation of timer coil.
2. OFF DELAY TIMER :- The change over of contacts is instantaneous on energisation of timer coil and change over of contacts take place with delay on de-energisation on timer coil.
3. Timer with instantaneous Contact Block :-

DELAY ON ENERGISATION (ON DELAY) :
Timing delay period commences when time delay relay receives supply. The output relay energises at the end of the time.

INTERVAL TIMER:
On energisation of time delay relay, output relay changes the state for the time set. After completion of set time output relay de-energises. By switching off supply, the time delay relay gets de-energised and is ready for the next cycle of operation.

DELAY ON DE-ENERGISATION (OFF DELAY) :
Timer is energised and relay is in OFF condition. When control input is given through control contacts, relay is energised. Delay period commences when control input is removed. At the end of set time, relay is de-energised and load is disconnected.

CYCLIC INSTANT :
On energisation, relay output is ON and OFF repeatedly to the set time. Cycle starts with relay in energised condition. By removing supply, the relay gets reset.
CYCLIC DELAYED :
On energisation the relay is alternatively OFF and ON repeatedly to the set time. The cycle starts with a pause time. Timer is reset when supply to the relay is switched off.

SECTION-3

COMBUSTION THEORY

The three essential components of combustion are fuel, oxygen, and heat. Stochiometric combustion is defined as having just the right amount of oxygen and fuel mixture so the most heat is released. In most fossil, the chemical elements that react with oxygen to release heat are carbon and hydrogen.

Stochiometric reaction for pure carbon, oxygen, and the hydrogen are as follows:

$C + O_2 \rightarrow CO_2 + 14,093$ BTU / lb.
$H_2 + 1/2\ O_2 \rightarrow H_2O + 61,100$ BTU / lb.

Need for air instead of pure oxygen:

Air contains about 21% oxygen and 79% nitrogen by volume, and is readily available. Pure oxygen must be processed, and on most applications the cost to process oxygen outweighs the benefit of increased Combustion control. One cubic foot of methane (at standard temperature and pressure) will burn completely with 9.52 cubic feet of air as shown below:

$$CH_4 + 2O_2 + 7.53N_2 \rightarrow CO_2 + 2H_2O + 7.53N_2 + 1,013 \text{ BTU / FT.}$$

The ratio of 9.53 cubic feet of air to one cubic foot of methane is known as the stochiometric air/fuel ratio. The heat released when the fuel burns is known as the heat of combustion. Table 1-1 and Table 1-2 list the stochiometric air/fuel ratios and heats of combustion for several common fuels.

Table 1-1 -- COMBUSTION RANGES FOR SELECTED GASEOUS FUELS

Fuel	**Stochiometric air/fuel ratio(ft^3 air/ft^3 fuel)**	**Heat of combustion (btu/ft^3)**
Hydrogen (h_2)	2.38	325
Carbon monoxide (co)	2.38	322
Methane (ch_4)	9.53	1013
Propane (c_3h_8)	23.82	2590
Natural gas	9.4 - 11.0	950 - 1150
Coke oven gas	3.5 - 5.5	400 - 600

TABLE 1-2 -- COMBUSTION RANGES FOR SELECTED SOLID AND LIQUID FUELS

Fuel	Stochiometric air/fuel ratio (ft^3 air/lb. Fuel)	Heat of combustion (btu /lb)
Carbon (c)	150	14,093
Sulphur (s)	56	3,983
No. 2 oil	180 - 195	18,500 - 19,800
No. 6 oil	170 - 185	17,500 - 19,000
Bituminous coal	120 - 140	12,000 - 14,000

The importance of excess air:

Flue gas heat loss is the single largest energy loss in a combustion process. It is impossible to eliminate all flue gas heat loss because the products of combustion are heated by the combustion process. But flue gas heat loss can be minimised by reducing the amount of excess air supplied to the burner.

Since the oxygen in the flue gas is directly related to the amount of excess air supplied, an oxygen flue gas analyser is the best way to effectively measure and control the amount of excess air in the flue gas and the associated heat loss. Zirconium oxide O_2 flue gas analysers are the preferred combustion control analysis method.

For combustion efficiency, you never want to operate a burner with less air than is required for stoichiometric combustion. Not only does this result in a smoking stack, but it significantly reduces the total energy released in the combustion process due to unburned fuel.

If a burner is operated with a deficiency of air, or the air and the fuel are mixed improperly, all the fuel will not burn. As a result, carbon monoxide and hydrogen will appear in the products of combustion. Carbon monoxide (CO) and hydrogen (H_2), collectively referred to as combustibles, results from incomplete combustion. When insufficient excess air is available, the amount of combustibles in the flue gas increases dramatically.

In practice, some trace levels of unburned fuel appear in the flue gas stream even with some amount of excess air due to poor mixing of fuel and air at the burner or burner conditions . As a result, combustion processes are not operated at the stoichiometric point. Instead, combustion processes are operated with sufficient excess air to keep the amount of combustibles minimised. Combustibles levels of a few hundred parts per million (ppm) in the flue gas have an insignificant effect on efficiency.

"COMBUSTION EFFICIENCY is maximised when the correct amount of excess air is supplied so the sum of energy losses from both unburned fuel Loss and flue gas heat loss is minimised." By measuring the concentration of oxygen and combustibles, both unburned fuel loss and flue gas heat loss can be minimised. Combined oxygen and combustibles analysers enable both measurements to be made at a single sample point. From this, the supply of excess air can be controlled on a continuous basis, minimising heat loss and unburned fuel loss, and therefore ensuring the most efficient operation of a boiler.

OXYGEN MEASUREMENT

Oxygen concentration in flue gas is an excellent indicator of excess air in the flue gas. The existing technologies used to measure excess air in flue gas are the zirconium cell, and the wet electrochemical cell. Zirconium oxide analysers indicate net oxygen; that is, the oxygen remaining after burning with whatever free combustibles are present around the hot zirconium oxide cell. Paramagnetic and wet electrochemical cell oxygen analysers measure gross oxygen. For combustion efficiency applications, the difference between net and gross measurements are small since combustibles are generally in the ppm range, while oxygen is usually in the present range.

Difference may also occur between the technologies because zirconium oxide analysers can measure oxygen on a wet basis where the flue gas contains water vapour. The other measuring techniques all require cool, dry samples, and measure on a dry basis. For example, assume you have a flue gas containing 5% O_2, 10% H_2O, balance nitrogen (85%). If the water (H_2O) is removed from the sample to make a dry reading, oxygen would read as 5.5% O_2 (5% of 100% vs. 5% of 90%).

COMBUSTIBLE MEASUREMENTS

Incomplete combustion results in combustibles, consisting of hydrogen (h_2) and carbon monoxide (CO), in the flue gas. More than a few 100 ppm of combustibles results in wasted fuel, soot formation, and reduced heat transfer efficiency. In addition, high concentration of combustibles create an environmental concern and a potentially explosive condition.

The three prevalent methods for on-line monitoring of combustibles in flue gas are with catalytic element, wet electrochemical cell, and non-dispersive infrared absorption. However, wet electrochemical cells and infrared technologies measure only co.

Catalytic combustibles detector

A catalytic combustibles detector provides the required accuracy to maximize combustion efficiency, and is sensitive to both hydrogen and carbon monoxide. Also, a catalytic combustible detector can be packaged with an oxygen analyser, eliminating the need for a separate analyser to measure combustibles and these combustible detectors can work in high temperature areas where CO infrared analysers cannot.

Infrared carbon monoxide measurement

Carbon monoxide is one of many gases that absorb infrared energy at specific, discrete wavelengths. If a beam of infrared light is passed through a gas sample containing CO and if the emerging energy is measured with a spectrophotometer, significantly less energy will be detected for wavelengths between 4.5 and 4.7 microns than if CO were not present. The amount of energy absorbed is a measure of the CO in accordance with beer's law:

$$\log (i/i_o) = -\alpha\ c\ l$$

Where i_o is the intensity of the infrared light at a specific wavelength (λ) entering the sample; i is the intensity leaving the sample, α is the absorption coefficient for co at wavelength λ, c is the concentration of co in the sample; and l is the path length of the infra red light beam through the sample. By holding the path length, i as constant, the ratio i/i_o becomes a direct measurement of the CO concentration.

CHAPTER-2

Temperature sensors

Thermocouples essentially comprise a thermo element (a junction of two specified dissimilar metals) and an appropriate two wire extension lead. A thermocouple operates on the basis of the Junction located in the process producing a small voltage which increases with temperature. It does so, on a reasonably stable and repeatable basis.

Resistance thermometers utilise a precision resistor, the ohms value of which increases with temperature (in the case of a positive temperature coefficient). Such variations are very stable and precisely repeatable.

Thermistors are an alternative group of temperature sensors which display a large value of temperature coefficient of resistance (usually negative, sometimes positive). They are providing high sensitivity over a limited range.

Temperature is one of the most measured of the physical quantities. As such measuring it correctly, is of vital importance. Critical factors such as process and reaction rates, raw material usage, and product specifications, yield and quality, can all be affected by the precision and frequency with which temperature is measured.

There are various types of thermocouple sensor available which in combination cover the range -250ºC to 3,000ºc C. Resistance thermometer technology handles a more restricted range of -200º C to 1000ºc C. Thermocouples are generally characterised as rugged and versatile, whilst resistance thermometers permit better measurement accuracy and stability.

An important characteristic of both sensor technologies, and the main reason for their particular value to industry and science, is that their outputs are in the form of electrical signals. Such signals can be readily transmitted, switched, displayed and further processed by other equipment.

Temperature scales

The definition of temperature owes its existence to a long line of famous scientists Planck, Nyquist, Stefan - Boltzmann, Carnot, and Kelvin.

Temperature is defined principally in terms of the kelvin. One kelvin unit is 1/273.16 of the thermodynamic temperature of the triple point of water. Most of us, however, prefer to think in terms of degrees Celsius. And, since the incremental units are the same, but with an offset of -273.25 degrees, the triple point of water in degrees Celsius is 0.01ºC an ideal metric interval.

THERMOCOUPLES

SEEBECK EFFFECT

If there is a temperature gradient in an electrical conductor, the energy(heat) flow is associated with an electron flow along the conductor, and an electromotive force(emf) is then generated in that region. Both the size and direction of the emf are dependent on the size and direction of the temperature difference along with the Conductor length.

Material types

In general, these are divided into two main categories - rare metal types (typically, platinum vs platinum rhodium) and base metal types (such as nickel chromium vs nickel aluminium and iron vs copper nickel (constant)). Platinum - based thermocouples tend to be the most stable, but they're also the most expensive. They have a useful temperature range from ambient to around 2,000℃- and, short term, much greater (-270℃ to 3,000℃). The range for the base metal types is more restricted, typically from 0 to 1,200ºC, although again wider for non-continuous exposure. However, signal outputs for rare metal types are small compared with those from base metal types.

Thermocouple selection

For a selection of a particular thermocouple type for a sensing application, physical conditions, duration of exposure, sensor lifetime and accuracy all have to be considered.

3.15 IEC: (BS 4937 part 30: 1993 soon to be replaced by BSEN 60584.3) colour codes and tolerances - extension and compensating cable

Tolerance is defined as the maximum additional deviation inμv caused by the introduction of the extension or compensating cable into a circuit. The letter 'x' after the thermocouple type indicates extension cable, while 'c' denotes compensating cable.

RTD MATERIALS

They include copper, gold, nickel, platinum and silver. Of these, copper, gold and silver have inherently low electrical resistivity values, making them less suitable for resistance thermometry - although copper does exhibit an almost linear resistance relationship against temperature.

RTD SELF - HEATING EFFECTS

In order to measure the resistance of a platinum resistance thermometer, an electric current has to be passed through the sensor. However, ironically, in doing so the passage of the current produces a heating effect-and the temperature of the thermometer element is raised slightly above the equilibrium of the surroundings it is trying to measure. This is known as self-heating. By making thermal contact between the sensor wire and sheath as good as possible and similarly ensuring good contact of the sheath with the outside surroundings, the effect is minimised.

Interference :-

SERIES MODE

Series mode interference is usually caused by the unequal coupling of signal lines within the local magnetic fields. A low pass filter can be used for the higher frequency components although this may be a little expensive for many temperature applications.

COMMON MODE

Moving on to common mode, which is caused, for example, by electromagnetic or static coupling of a field onto signal lines, or by dissimilar earth potentials, errors can be reduced by the use of a differential input with a very high impedance so that the measurement circuit is effectively floating.

Isolation amplifiers can also be harnessed, or guard systems used.
EXTENSION CABLES:

Extension cables use wires of nominally the same conductors as the thermocouple itself, which thus inherently possess similar thermo power characteristics, and present no connection problems. Miss-match errors arising from high connecting box temperatures are likely to be relatively small. These cables are less costly than thermocouple wire, although not cheap, and are usually produced in a convenient form for carrying over long-distances-typically as flexible wiring or multi-core cables. They are recommended for best accuracy.

COMPENSATING CABLES:

Compensating cables, on the other hand, are less precise, but cheaper. They are different, relatively low cost alloy conductor materials whose net thermocouples in question, but which do not match them as faithfully as do extension cables. Thus, the combination develops similar outputs to those of the thermocouple, but the operating temperature range has to be restricted to keep miss-match errors acceptably small.

THERMOWELL:

Thermowells are closed end re-entrant protection tubes into which temperature sensing elements can be inserted - and come in all shapes and sizes.

The internal diameter of the thermowell is usually such that the sensor can be easily inserted, but no longer - to minimise the air gap, and thus maximise the thermal response and the atmospheric protection. This can also be achieved by the incorporation of a reduced bore at the tip of the thermowell to accommodate the sensing element or insert assembly.

Materials range from BRASS (350°C), through MILD STEEL (550° C) but are more typically STAINLESS STEEL (800° C), INCONEL 600 (1,100° C) or INCOLOY 800 (1,100° C) used in the applications.

Thermocouple types & ranges

International type designation	**Conductor material**	**Temperature range (°c)**
R	Pt - 13% rh (+) Pt (-)	0 to + 1600
S	Pt - 10% rh (+) Pt (-)	0 to +1500
B	Pt - 30% rh (+) Pt - 6% rh (-)	+100 to +1600
K	Ni - cr(+) Ni - al (-)	0 to +1100
T	Cu (+) Cu - ni (-)	-185 to +300
J	fe (+) cu - ni (-)	+20 to +700
E	ni - cr (+) cu - ni (-)	0 to +800
N	ni - cr - si (+) ni - si (-)	0 to +1250

BASE METAL THERMOCOUPLE EXTENSION & COMPENSATING WIRES & CABLES

THERMOCOUPLE WIRE

Twin, single conductor, having a temperature/e.m.f. relationship to the appropriate standard over the complete temperature range.

EXTENSION CABLE

Twin, stranded conductors for connection between thermocouple and instrument (or external reference junction), of the same materials as the thermocouple, and having the same e.m.f./temperature characteristics over a limited temperature range.

<u>Connection of thermocouples to measuring instruments</u>

Ordinary copper wires should never be used, as the error will equal to the difference in temperature between the connecting point of the thermocouple and the instrument (or external junction).

Extension or compensating wire or cable must be employed, and it is essential that the same polarity is maintained. If the polarity is reversed, the e rror is equal to twice the temperature difference between the connecting point of the thermocouple and the instrument (or external reference junction).

For maximum accuracy, extension cables should be used, and the terminals and connectors should be of thermocouple materials to maintain continuity.

Single or multi-strand ?

The choice is mainly determined by the application (e.g. Termination considerations and internal diameter of associated sheath). Generally, single strand wires are used for hot junctions, and multi strand for extensions of the thermocouple as being more flexible. The greater the effective conductor diameter, the lower the value of thermocouple loop resistance; an important consideration with long cable runs.

<u>CHAPTER-3</u>
4-20 mA SIGNAL TRANSMISSION

ISA-S50.1 STANDARD

Three types of current loop control are defined in ISA-50.1; each comprises a power supply, transmitter, and receiver. The systems are designated type 2,3 or 4, depending on whether the transmitter is a two, three, or four-wire.

Type 2 transmitters draw power and transmit signals over the same pair of wires. Type 3 transmitters draw power from one wire and drive the signal on a second, with a common return for both. The type 4 draws power from two wires, and provides the signal over another two.

In addition to categorization by type (2,3, or 4), transmitters are categorised in three classes (l, h, and u). The class letter suffix defines the value of external load resistance to which the transmitter must be able to deliver rated current at a minimum specified supply voltage. Receiver contains a resistor to convert the transmitted current into a voltage in accordance with ohm's law. A class 2l transmitter, for example, must be capable of delivering the rated current (20 mA) into an external load resistance of at least 300 ohms when powered by a minimum supply voltage of 23V.

Advantages and disadvantages

Advantages:

* 4 - 20 mA systems are low in cost and easy to apply.
* Wire quality requirements for shielding and ohm drop are minimal.
* The standard is widely accepted, with many vendors able to supply hardware.
* Current required for the live zero can be used to power the remote transducer.
* Electrically isolated transmitters can be distributed throughout the plant and powered from one supply.

Disadvantages.

* Signal response is slow in long runs, primarily because of interconductor inductance and capacitance.
* Receiving electronics must have provision for negating the live zero.
* Troubleshooting large loops can be difficult.
* Non decimal (16 mA) signal span makes calculations more difficult.
* In larger systems where a backup system supplies power during interruptions, multiple current loops consume additional power.

CHAPTER-4
CHEMICAL SEAL

Chemical seals or diaphragm protectors can be provided with the most pressure sensors. These components serve the following functions :

1) They keep the process fluid from freezing, gelling, or settling out due to temperature changes;
2) They prevent poisonous, noxio us, or corrosive process materials from entering the pressure sensor; and
3) They prevent slurries or viscous polymers from entering and thereby plugging the detector element. In the following discussion, several chemical seal designs are described. All are filled with non compressible liquids which transmit the process pressure to the protected pressure element.

Filling fluids are selected to provide low thermal expansion, low viscosity, and no danger of process contamination in case diaphragm rapture. Table A lists some of the filling fluids, their applicable temperature ranges, and their thermal expansion coefficients. One of the popular filling fluids is a 70% to 30% mixture of glycerine and water used between 30°F and 300°F (-1 to 149°C). For lower temperatures ethyl alcohol, kerosene, toluene, or silicon oils are used in the -50°F to 100°F (25 to 816°C). The casketing materials are plastics or Teflon up to 400°F (205° C), while on high temperature services metallic gaskets or special volumetric elements are used.

Table –A:Temperature ranges and thermal expansion characteristics of chemical seal filling fluids:

Filling fluid	**Deg. F**	**Deg. C**	**Expansion coefficient (sg/deg. F)**
Toluene	-40 to +200	-40 to +93	0.00063
Dow corning silicone (dc -200)	-30 to +300	-34 to +148	0.00075
Kerosene	-30 to +350	-34 to +177	0.00051
Hooker chemical fluorlube (fs - 5)	-20 to +300	-29 to +148	0.00049
Dibutyl phthalate	+20 to +300	-7 to +148	0.00080
22% Na - 78%K	+20 to +1400	-7 to +760	
70% GLYCERINE, 30% WATER	+30 to +300	-1 to +148	0.00051

CHAPTER-5
FLUE GAS ANALYSERS

Typical flue gas measurements

- SO_2 0-3000 PPM
- NO 100-700 PPM
- NO_2 0-100 PPM
- CO 0-50 PPM
- CO_2 12-20%
- SO_3 0-100 PPM
- O_2 1-5%
- PARTICULATE 150MG/M^3

Measurement criteria

1. Safety
2. Compliance
3. Maintenance
4. Efficiency

OXYGEN MEASUREMENT

Technology

1. Paramagnetic
2. Polarographic
3. Zirconium oxide

Application

* combustion control

CARBON MONOXIDE MEASUREMENT

Technology

1. Non dispersive - infra red
2. Catalytic bead
3. Thermal conductivity

APPLICATION

* Air pollution, combustion control
* Safety monitoring.

CARBON DIOXIDE MEASUREMENT

Technology

1. Non dispersive - infra red
2. Thermal conductivity

Application

* Air pollution

THERMAL CONDUCTIVITY:

Consider two different gas in equal cylindrical enclosures. If a heating element is inserted, the rate of thermal conduction between element and container wall will be inversely proportional to the density of gas.

As the absolute temperature increases, the lighter molecules move even more quickly. The thermal conductivity also depends upon the temperature too :

$$k1 = k0 \{(b+273)/(b+t)\} \times \{(t^{3/2}/273)\}$$

Where

k1 = thermal conductivity at ab. temp t.

k0 = thermal conductivity at ref. temp t.

b = constant for the substance.

CHEMI LUMINES CENTM ETHOD:

This method is based upon the principle that nitric oxide (NO) reacts with ozone (O_3) to give nitrogen dioxides (NO_2), oxygen (O_2) and about 10% electronically excited NO_2. The transition of electronically excited NO_2 to its normal state NO_2 gives a light emission lamda between 590-2750 nm.

$NO + O_3 \rightarrow NO_2 + O_2 + H_{LAMDA}$

The intensity of this emission is proportional to the mass flow rate.

Polarographic analysis

Electrolysis current is proportional to the concentration of electrolysis material. Only a small fraction of the sample material is electrolysed and the current generated is limited by the rate of chemical diffusion through an electrolytic gel. This technique is used to detect O_2 .

Process analysis

A process analysis system is an assembly of equipments which measures chemical compression and provides a visual or written indication of the variables measured.

A process analysis sampling system includes all equipments containing the process sample, including necessary accessories inclusive of the analyser itself.

A sampling system consists of filters, regulators, valves, flow meters, condensers, gauges and other pneumatic & hydraulic components.

A sampling system does :

1.To take a sample representative of the flowing process stream.
2.To transport the sample to the analyser.
3.To condition it to be compatible with the analyser.
4.To transport it from the analyser to the designed point of rejection.

A well designed sampling system optimises accuracy and other performance factors with the cost of equipment, installation, operation and maintenance.

Factors to be considered

Nature of process stream

A. Composition
(i) Condensables
(ii) Ccorrosivity
(iii) Foreign material such as dirt, bubbles, etc.

B. Pressure
C. Temperature
D. Location
E. Size, type & orientation of duct
F. Type of connection
G. Number of streams.

Nature of analyser

A. Flow required
B. Temperature of operation
C. Components to be measured.
D. Location relative to sample point.
E. Speed of response.
F. Interfering components
G. Method of calibration.

B.AVAILABLE UTILITIES :

(i) Electricity
(ii) Steam
(iii) Water
(iv) Air
(v) Sample return point.
(vi) Waste rejecter.

Filters

* Edge type filters
* Depth type filters

Phase separating devices

1. Liquid remaining separators
2. Gas removing separators
3. Liquid, solid and gas solid separators.

CONDUCTIVITY

Conductivity measurement determines the chemical strength of various solutions. Conductance is the ability of a solution (or solid) to conduct an electric current. Its reciprocal is resistance.

Conductance = 1 / Resistance

Unit of measurement for conductance: mho or siemens

Since the conductivity of solution is low, micro siemens (µs) is commonly used. By measuring conductance, we measure the total ionic concentration. The solutions most suited to conductivity measurement are electrolytic solutions, such as salts, acids, or bases in water.

Conductivity measurement

To measure conductivity, a sensor containing two electrodes connected to the positive (+) and negative (-) terminals of a voltage source is immersed in the solution.The current that follows in this circuit is initially a function of the applied voltage and the resistance of the solution. With solution resistance obtained, the chemical concentration can be determined by comparing to current valves previously obtained at known concentration.

Interference factors

1. Electro chemical effects :

Sometimes gas formed at one electrode would effect current measurement. To reduce this electro chemical effect(formation of a gas, electroplating and chemical reaction in the solution etc.,) Alternating current is used along with appropriate circuitry.

2 . Temperature compensation :

In solutions, electric current is carried by moving particles (ions). The movability of the ions is directly proportional to temperature. Hence the temperature of the solution is measured and compensation for temperature change to be included in the circuitry.

3 . Probe constant of the scanner :

The volume of solution between two electrodes plays an important role in measuring resistance or conductance.

The set volume between electrodes is defined by the “probe constant” ie., the distance between the two electrodes divided by the area of each electrode. The basic probe constant of 1.0 is defined as two 1 cm^2 electrodes separated by a distance of 1 cm.

Generally speaking solutions with extremely high conductivity require a sensor with a probe constant greater than 1.0

Conductivity = conductance x probe constant
= (1/resistance) x (length/area)
= siemens / cm.

CHAPTER-6

pH

pH is defined as

$$pH = -\log_{10}(h^+)$$

pH is a dimensionless quantity and lies on a scale from 0-14.

Pure water is aid to be neutral and lies exactly mid scale.

It should be noted that a movement of 1 ph corresponds to a 10 fold increase (or decrease) in concentration.

In industrial situations, one measures the difference in ph values between the measured and reference solutions via the equation is,

$$pH - pH\ std = \frac{\text{emf measured cell} - \text{emf std cell}}{\text{constant x abs. Temperature}}$$

$$pH = pH\ std + \frac{\text{emf measured cell} - \text{emf known}}{\text{constant x abs. Temperature}}$$

$$= c1 + \frac{\text{emf measured cell} - c2}{c3}$$

c1,c2 & c3 are constants.

Measurement of ph is accomplished by means of an electrode which develops a potential that is directly related to the hydrogen ion concentrated of the solution in which the electrode is immersed. A second electrode is necessary to complete the electrical circuit and to serve as a constant reference potential against which the potential of the glass electrode can be compared. This electrode is called the reference electrode.

CHAPTER-7

FLOW METERS

Types of flow meters :

1. Concentric
   a) square edge
   b) quadrant edge
2. Segmental
3. Eccentric

Definitions

(I) REYNOLDS NO : (re)

It is the ratio of internal forces to viscous forces.

When re is low.

1. Viscous force predominates
2. Flow is laminar.

When re is high

1. Internal forces predominates
2. Flow is turbulent.

Formula for Reynolds number

$Re = 4q_m / p\ m1d$

Where q_m = mass flow rate

m1 = dynamic viscosity

= u x r

U = kinetic viscosity

R = density

D = diameter of pipe.

Formula for Reynolds no
Re = u1 d / u

Where
u1 = axial velocity
d = diameter of pipe
u = kinetic viscosity

CO-EFFICIENT DISCHARGE (C_d):

It is the ratio between actual & theoretical discharge. For best results C_d should be between 0.92 and 0.97.

$$c_d = q_m (1-b^4)^{1/2} c/ (p /4)d^2 (2hr)^{1/2}$$

Where
q_m = mass flow rate
b = dia. of orifice / dia. of pipe
r = density of fluid
h = differential pressure.

CONCENTRIC SQUARE EDGE OF ORIFICE:

1. It is normally used when re > 10,000
2. Not recommended for highly viscous liquids.
3. At low values of re, c_d may change as high as 30%.
4. Used for line of 2" (80mm) & larger pipes.
5. B should be between 0.2 - 0.75.

QUADRANT EDGE

1. Measures accurately with below 10,000 and down to 500.
2. Normally used for viscous fluids or viscosity is unknown.

VENT HOLE OR DRAWN HOLE:

1. Used for liquid with entrained gas or vapour.
2. Prevents accumulation of gas ahead of orifice plate.
3. It is 10% or less the dia. of orifice & isolated at top of plate.
4. Placed inside and tangent to a concentric circle onthe plate having a diameter the same as the pipes.

For gas with entrained liquid droplets, vent hole is provided at bottom. The provision of vent holes is often considered as disadvantage, because it can result an error in flow measurement.

CHAPTER-8
Vibration monitoring systems

Critical rotating machinery on power plants must be equipped with instrumentation and monitoring systems capable of protecting the machinery.

Bearings of turbine-generators, boiler feed pumps, fans, fan motors are to be maintained in order to achieve the following.

- Continuity of operation
- Economic operation for long term
- Preservation of invested capital

- Environmental safety.

The above can be fulfilled only if

- The condition of machinery and its components are continually monitored
- Irregularities in operational condition are detected early and when reaching a dangerous condition, the machine is immediately shut down. Monitoring of mechanical vibrations as an indicator for machine condition and shock impulses as an indicator for bearing condition have both proven to be affective.

DISPLACEMENT SENSORS

Eddy current probes are non-contact sensors primarily used to measure shaft vibration, shaft/rotor position and clearance. Also referred to as displacement probes, eddy current probes are typically applied on machines utilizing sleeve / journal bearings. They have excellent frequency response with no lower frequency limit and can also be used to provide a trigger input for phase-related measurements.

VELOCITY SENSORS:

Velocity sensors are used for low to medium frequency measurements. They are useful for vibration monitoring and balancing operations on rotating machinery. As compared to accelerometers, velocity sensors have lower sensitivity to high frequency vibrations. The mechanical design of the velocity sensor; an iron core moving within a coil in a limited magnetic field, no clipping of the generated signal occurs, but smooth saturation.

ACCELEROMETERS

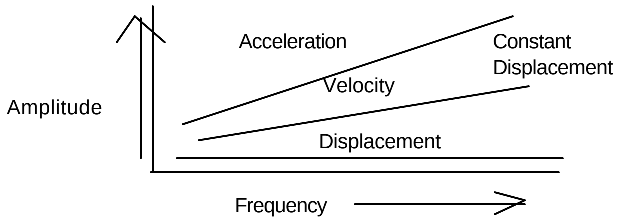
Piezoelectric accelerometers having a constant signal over a wide frequency range, up to 20 kHz for a given mechanical acceleration level, are very useful for all types of vibration measurements.

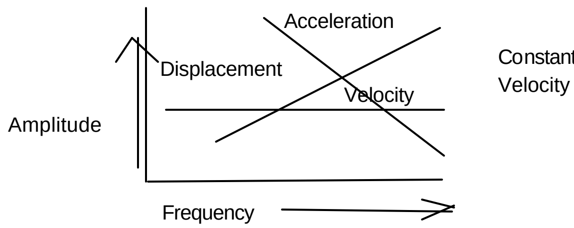
Characteristics	**Coil& management velocity sensor**	**Piezoelectric velocity sensor**
Flat frequency response 20 -1,500 Hz 2 - 5,000 Hz	 Yes No	 Yes No
Phase fidelity 2-5,000 Hz	 Acceptable	 Excellent
Reduced noise at Higher frequencies	No	Yes
Linearity	Good	Good
Mounting in any orientation	Sensor dependent	Yes
Temperature limitation	> +707°F(+375°C)	+248°F(+120°C)
EMI resistance	Acceptable	Excellent
Mechanical durability	Good	Excellent

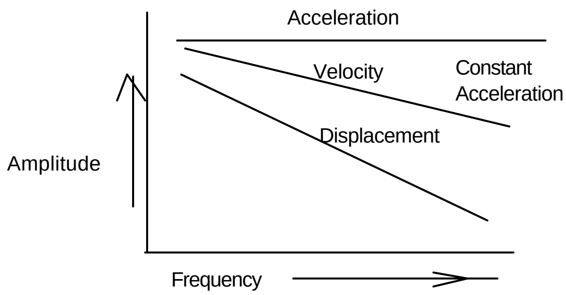
PIEZOELECTRIC SENSORS

Accelerometers operate on the piezoelectric principal: a crystal generates a low voltage or charge when stressed during compression. Motion in the axial direction stresses the crystal due to the inertial force of the mass and produces a signal proportional to acceleration of that mass. This small acceleration signal can be amplified for acceleration measurements or converted (electrically integrated) within the sensor into a velocity or displacement signal. This is commonly referred as the icp (integrated circuit piezoelectric) type of sensor. The piezoelectric velocity sensor is more rugged than a coil and magnet sensor, has a wide frequency range, and can perform accurate phase measurements.

The two basic piezoelectric materials used in vibration sensors today are synthetic piezoelectric ceramics and quartz.

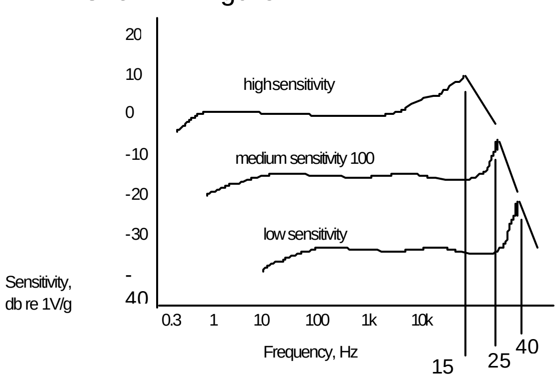






PRIAMARY SENSOR CONS IDERATIONS”

Two of the main parameters of a piezoelectric sensor are sensitivity and frequency range. In general most high frequency sensors have low sensitivities and, conversely, most high sensitivity sensors have low frequency ranges. The dependence of inertia on mass governs this relationship. As the mass increases, the sensitivity is also increased, however, the usable frequency range is reduced since the sensor more quickly approaches its resonance frequency as shown in figure.



<u>CHAPTER-9</u>
<u>SIGNAL ISOLATORS</u>

Traditional methods of protection in hazardous area can be separated into several categories: segregation, mechanical, containment and energy limiting. Segregation and containment methods address the first two conditions, oxygen and fuel, while mechanical and energy limiting address the third condition, the ignition source. These methods may be used in combination to eliminate the risk of an explosion.

Segregation methods

Segregation describes the process of evacuating the hazardous atmosphere and replacing it with an alternative substance. Protection methods in the segregation category include oil immersion, pressurization, powder-filling, and/or encapsulation. With oil immersion, the possible source of ignition is isolated from the explosive atmosphere by being submerged in oil. An example of this method is a power line transformer. Pressurization reduces the fuel content to below ignitable levels by diluting the atmosphere with an inert gas under pressure. Powder-filling involves filling the apparatus enclosure with fine grained material, such as glass embedding the apparatus in a thermal setting substance, such as an epoxy or potting compound.

Mechanical methods

Mechanical methods remove the possibility of an explosion by eliminating the ignition source and limiting the energy being emitted. For example, an increased safety solution - which is a type of mechanical protection - eliminates spark generation and current leakage paths, while non-incentive solutions minimize high temperatures under normal conditions.

Containment

Explosion proofing is the most popular method of containment in North America. This involves "containing" the flame or explosion rather than eliminating it. Explosion proofing physically isolates the spark or temperature source from the hazardous atmosphere.

Energy limitation

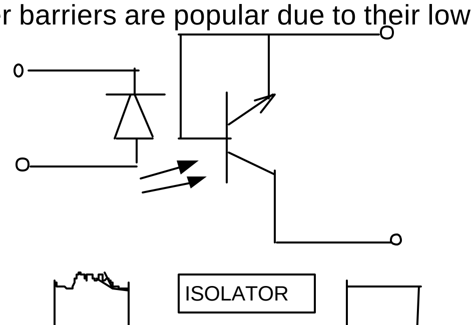
The fundamental principle of this technique is energy limitation, in which the inherent energy of an electrical circuit is restricted to such low levels that any spark occurring does not contain sufficient energy to ignite an explosive mixture. In addition, IS restricts the amount of energy so that high temperatures, which are also capable of igniting an explosive mixture, do not exist.

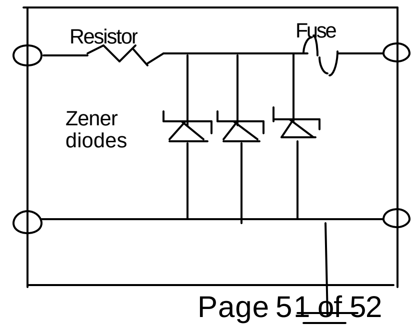
<u>Zener isolation:</u>

One of the simplest ways to protect hazardous area instrumentation through intrinsic safety is to use a zener diode barrier mounted between the safe area control equipment and the hazardous area instrumentation. The resistor limits current to the hazardous area, and the fuse opens if current is excessive. By diverting excess energy to a safety ground, the zener diodes ensure hazardous voltages are also not presented to the hazardous area.

Advantages :-

Zener barriers are popular due to their low initial cost.





Disadvantages:

1) There is major obstacle to address if zener barriers are used for retrofit application. It is essential that zener barriers be bonded (grounded) to a potential equalizing system to prevent fault currents from entering the hazardous area.

2) Another disadvantage of zener barriers is that they provide no inherent isolation for noise and disturbances. In addition, due to the necessary impedance inserted in the signal path for zener barriers, they cannot be applied to, or may substantially hinder the performance of, some signal types.

OPTICAL ISOLATION:

Any unwanted voltage is filtered by LED & light sensitive transistor circuit so that output signal is exactly as input signal .

GALVANIC ISOLATION:

With this technology there is no conductive path from the safe area to the hazardous area, and no common ground path for hazardous energy either. All signals are passed across the isolation path while maintaining data integrity.