INSTRUMENT MECHANIC

NSQF LEVEL - 4

2nd Year

TRADE THEORY

Sector: ELECTRONICS & HARDWARE

(As per revised syllabus July 2022 - 1200 Hrs)

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

Sector : **Electronics & Hardware**

Duration : **2 Years**

Trade : **Instrument Mechanic - 2nd Year - Trade Theory - NSQF Level - 4 (Revised 2022)**

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2022 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of comprising various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Instrument Mechanic - 2nd Year - Trade Theory - NSQF Level - 4 (Revised 2022) in Electronics & Hardware Sector under** under Annual pattern. The NSQF Level - 4 (Revised 2022) Trade Practical will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Director General, Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

ATUL KUMAR TIWARI, *I.A.S*
Secretary
Ministry of Skill Development & Entrepreneurship,
Government of India.

June 2023
New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of Federal Republic of Germany. The prime objective of this Institute is to develop and provide instructional materials for various trades as per the prescribed syllabi under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade practical book consists of series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

In order to perform the skills in a productive manner instructional videos are embedded in QR code of the exercise in this instructional material so as to integrate the skill learning with the procedural practical steps given in the exercise. The instructional videos will improve the quality of standard on practical training and will motivate the trainees to focus and perform the skill seamlessly.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

Chennai - 600 032 **EXECUTIVE DIRECTOR**

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisation to bring out this IMP **(Trade Theory)** for the trade of **Instrument Mechanic** under the **Electronics & Hardware** Sector for ITIs.

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Shri. Harish Menon	-	Senior Instructor Govt ITI, Kalamassery
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NIMI records its appreciation of the Data Entry, CAD, DTP Operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks, the invaluable efforts rendered by all other staff who have contributed for the development of this Instructional Material.

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

INTRODUCTION

TRADE PRACTICAL

The trade practical manual is intented to be used in practical workshop. It consists of a series of practical exercises to be completed by the trainees during the course of the **Instrument Mechanic** trade supplemented and supported by instructions/ informations to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF LEVEL - 4 (Revised 2022) syllabus are covered.

This manual is divided into eighteen modules.

Module 1	**Basic Specifications of Instruments**
Module 2	**Measurement of Motion**
Module 3	**Measurement of Pressure**
Module 4	**Measurement of Flow**
Module 5	**Measurement of Solid Flow**
Module 6	**Measurement of Level**
Module 7	**Measurement of Temperature I**
Module 8	**Measurement of Temperature II**
Module 9	**Recorders**
Module 10	**Final Control Elements**
Module 11	**Controllers**
Module 12	**Controllers modes and Turning**
Module 13	**Programmable Logic Controllers**
Module 14	**Digital Control System and Networking**
Module 15	**Fundamentals of SCADA & DCS**
Module 16	**Basic of Hydraulics**
Module 17	**Basic of Pneumatics**
Module 18	**Analytical Instruments**

The skill training in the shop floor is planned through a series of practical exercises centred around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI looks forward to the suggestions from the experienced training faculty for improving the manual.

TRADE THEORY

The manual of trade theory consists of theoretical information for the Course of the **Instrument Mechanic 2nd** Year- NSQF LEVEL - 4 (Revised 2022) in Electronics & Hardware. The contents are sequenced according to the practical exercise contained in NSQF LEVEL - 4 (Revised 2022) syllabus on TradeTheory attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

The trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indications about the corresponding practical exercises are given in every sheet of this manual.

It will be preferable to teach/learn the trade theory connected to each exercise at least one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not for the purpose of self learning and should be considered as supplementary to class room instruction.

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

Sl.No.	Learning Outcome	Exercise No.
1	Identify the parameters of measurement systems. Identify, select, test, wire & Execute the operation of different process sensors by selecting appropriate signal conditioning for stress, strain, load displacement and Thickness. **ELE/N9408**	**2.1.161-174**
2	Select, Installs, services and calibrate instruments for motion, speed, position, acceleration, vibration & record the data. **ELE/N9419**	**2.2.175-180**
3	Identify different unit of pressure, terms and operation of basic instruments. Perform maintenance, Servicing calibration and installation of field pressure gauges, switches, electronic pressure indicators and transmitters for absolute, atmospheric, gauge, vacuum and differential pressure measurement. **ELE/N9420**	**2.3.181-205**
4	Recognize the fundamental of fluid flow, terms, different unit of flow, read specification of flow meters. And fluid pump. Perform the maintenance, Servicing and calibration and installation of variable DP flow meters / head flow meters, variable area flow meters, positive displacement eters, Electronic type flow meters and mass flow meters for fluids flow measurement. **ELE/N9421**	**2.4.206-227**
5	Identify, operate, maintain, troubleshoot and calibrate the devices for solid flow measuring system & verify the result within standard. **ELE/N9422**	**2.5.228-232**
6	Identify, select, wire & Execute the operation of different types of level instruments use for liquid level and solid level. Carry out maintenance, Servicing, calibration and Installation. **ELE/N9423**	**2.6.233-251**
7	List out different unit of temperature, terms and read specification of temperature instruments.Perform measurement, maintenance, Servicing and calibration of Bimetallic and filled system thermometers &thermo switches.**ELE/N9424**	**2.7.252-255**
8	Identify, select, evaluate performance, install, service and calibrate temperature Indicators, Transmitters (RTD'S, Thermistors and Thermocouples types) various type of pyrometers and instruments for humidity. **ELE/N9425**	**2.8.256-266**
9	Identify, select, Operate, maintain, Service and calibrate different types of recorders. **ELE/N9426**	**2.9.267-273**
10	Identify different types of Final control elements and role. Identify different valve body, constructional feature, Dismantle, inspect parts, replace parts, recondition, check, and resetting of control valves with actuators, convertors & positioners. Install and test the performance. **ELE/N9427**	**2.10.274-294**
11	Identify fundamental of automatic control system and various functional elements in control loop. Identify, select, Install, wire, configure, test the performance, maintain, and service various types of ON-OFF and PID controllers (electronic and pneumatic).	**2.11.295-305**
12	Tune controller mode and evaluate performance of control loops as per specification and system application **ELE/N9428**	**2.12.306&307**
13	Identify modules of PLC, its function, Wire and connect the digital I/OS field devices to the I/O odule of PLC, install Software, Hardware and configure plc for operation. Write and execute simple logic and real application programs. **ELE/N9429**	**2.13.308 - 321**
14	Operate, maintain, service, configure, install, WIRE and test HART transmitters /devices (I/O). And Net-working system for instrumentation. **ELE/N9430**	**2.14.322 - 329**
15	Identify the different modules of DCS, function, Wire and connect I/OS field devices to the I/O Modules, install Software, Hardware and configure DCS for operation with HMI. Write and execute DCS AND SCADA programs FOR real application. **ELE/N9431**	**2.15.330 - 338**
16	Identify, check constructional Feature and function of hydraulic pump, and hydraulic power system, accumulator, hydraulic hoses and fitting, Hydraulic components. Build AND test hydraulic control circuit. **ELE/N9432**	**2.16.339 - 349**
17	Lay out construction feature, operate, maintain of air compressor, air Distribution system, pneumatic associate components, piping, tubing and fitting. Build and test pneumatic control circuit. **ELE/N9433**	**2.17.350 - 362**
18	Identify constructional feature, operate, maintain, service and calibrate of Analytical instruments. **ELE/N9434**	**2.18.363 - 368**

SYLLABUS FOR INSTRUMENT MECHANIC

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) With Indicative Hours	Professional Knowledge (Trade Theory)
Professional Skill 68 Hrs. Professional Knowledge 18 Hrs.	Identify the parameters of measurement systems.Identify, select, test, wire & Execute the operation of different process sensors by selecting appropriate signal conditioning for stress, strain, load displacement and Thickness.ELE/ N9408	161. Finding the range, span and accuracy of instrument (example- ammeter, voltmeter etc. (04 Hrs.) 162. Test the voltmeter/ ammeter using std. voltage/ current source for total range. Check the dead zone, repeatability, reproducibility, drift, Dead band, backlash, hysteresis. (05 Hrs.) 163. Identify the strain gauge type, cantilever or load cell specification. (04 Hrs.) 164. Check the strain gauge using ohm meter / multimeter. (03 Hrs.) 165. Measure the load using strain gauge instrument. [using half (two), quarter(one), full (four) strain gauges on bridge]. (06 Hrs.) 166. Determine the sensitivity, liner range of strain gauge measurement. (06 Hrs.) 167. Make null balance and gain adjustment. Calibrate strain gauge instrument by adjusting zero and span. (05 Hrs.) 168. Identifying the various parts of LVDT. Study the specification of LVDT like range, exiting frequency, voltage, sensitivity etc. (05 Hrs.) 169. Identifying the coils in LVDT. Verifying the connection of secondary coils. Testing the LVDT coils using multimeter. (05 Hrs.) 170. Verify the LVDT characteristics by changing the displacement. (05 Hrs.) 171. Determine the liner range and sensitivity, resolution of LVDT. (05 Hrs.) 172. Measure the phase difference of LVDT secondary coils on CRO. (05 Hrs.) 173. Calibrate the LVDT by adjusting zero and span. (05 Hrs.) 174. Test and calibrate displacement meter, accelerometer and thickness instruments. (05 Hrs.)	Scope and necessity of instrumentation. Fundamentals of measurement systems- functional block diagram of measurement system. Calibration and calibration standards– basic standards, secondary standards, working standards. Fundamental units - The metric system, Base& supplementary units, Derived Units, Multiplying factors and standards of length, mass, time & frequency. Temperature & electrical units. Instrument characteristics Static characteristics– accuracy, precision, sensitivity, resolutiondead zone, repeatability,reproducibility, drift, Dead band,backlash, hysteresis. Dynamic characteristics–speed response, fidelity, lag. Error deviation, true value, data. Types of errors- systematic, random& illegitimate error. Certainty/uncertainty, validity Of result. Measuring system Response. Introduction, amplitude responses, Phase response, Delay, rise time &slew rate. Damping & its importance. Statistical analysis – arithmetic mean, deviation from the mean average deviation, standard deviation. Stress &Strain Measurement. Introduction to Strain gauges, types of strain gauges and differences. Applications of strain gauges, load cells. LVDT, RVDT, advantages and limitations. (18 hrs.)

Professional Skill 36 Hrs. Professional Knowledge 10 Hrs.	Select, Installs, services and calibrate instruments for motion, speed, position, acceleration, vibration & record the data. ELE/ N9419	175. Measure the vibration of motor/ machine. (06 Hrs.) 176. Servicing and maintenance vibrometers & accelerometer. (06 Hrs.) 177. Measure the speed of motor. (06 Hrs.) 178. Identify different parts, its function &Operation of eddy current, type AC and DC tachometer. (06 Hrs.) 179. Servicing and maintenance of mechanical and electrical tachometer. (06 Hrs.) 180. Identify different parts/section, its function &Operation and use Stroboscope and find motion of object. (06 Hrs.)	Measurement of motion, velocity / vibrometers and acceleration. Difference between tachometer and speedometers. Types of tachometers-Eddy current type, AC and DC tachometer. Stroboscope and its applications. seismic instrument.(10 Hrs.)
Professional Skill 120 Hrs. Professional Knowledge 35 Hrs.	Identify different unit of pressure, terms and operation of basic instruments. Perform maintenance, Servicing calibration and installation of field pressure gauges, switches, electronic pressure indicators and transmitters for absolute, atmospheric, gauge, vacuum and differential pressure measurement. ELE/ N9420	181. Measure the atmospheric pressure using barometer. (03 Hrs.) 182. Identify specification and construction of each manometer and find their range, scale type, resolution, type of liquid using, tube material, isolation valve types, fitting types and sizes, zero adjustment and spirit bubbler etc. (05 Hrs.) 183. Measure the differential pressure, gauge pressure and vacuum pressure using U tube manometer. (05 Hrs.) 184 Dismantle and assemble the manometer. Cleaning the glass tube, aligning the gravity balances etc. (05 Hrs.)	Principle of Pressure in Liquids & Gases. Properties of matter Principles of liquid pressure, units of pressure Liquids pressure and volume, density and specific gravity. Factors affecting liquid **Principle of Pressure in** Liquids & Gases. Properties of matter Principles of liquid pressure, units of pressure Liquids pressure and volume, density and specific gravity. Factors affecting liquid pres- sure. Pressure relation with volume, temperature and flow. Units of pressure and unit conversions. Types of pressure: absolute, gauge, atmospheric and vacuum pressures and their relationships. Barometers, manometers types and applications.(07 Hrs.)pres- sure. Pressure relation with volume, temperature and flow. Units of pressure and unit conversions. Types of pressure: absolute, gauge, atmospheric and vacuum pressures and their relationships. Barometers, manometers types and applications. (07 Hrs.)
		185. Dismantle and assemble the pressure gauge (bourdon tube, diaphragm type), Identify the various parts like sensing element, link, liver, pinion gear, hair spring, pointer size shape material, sensor material etc. (06 Hrs.)	Types of pressure sensing elements-bourdon tube, diaphragms, capsules, and bellows. Eachontypes, shapes, material used for various applications, ranges advantages and limitations. Pressure switches types and applications.(07 Hrs.)

		186. Measurement of gauge pressure and vacuum pressure using bourdon tube / diaphragm gauge. (04 Hrs.) 187. Measurement of differential pressure using diaphragm/ capsule gauge. (04 Hrs.) 188. Identify specifications of pressure switch – range, differential pressure span, contact types, contacts current rating, number of contacts etc. (05 Hrs.) 189 Dismantle and assemble the pressure switch – identify the various parts- sensing elements, control spring, pressure and differential pressure adjustment screws, shaft arrangement pivoting, contacts relay operation and change of contacts. Type of material using for various parts etc. (05 Hrs.) 190. Connect and operate the pressure switch with load at various pressure and differential pressure settings. Make adjust the errors screws. (05 Hrs.)	
		191 Identify the basic specifications of pressure indictor/ transmitter (electronic) like range, resolution, size of display, type of sensor (symbol), sealed type, number scales, connection type, tap threading size and type-(male, female NPT/SAE), body material, mounting type (back or bottom) etc. (05 Hrs.) 192. Test and operating the pressure transmitter with supply, milli ammeter, pressure source (pneumatic/ hydraulic). Finding the resolution, accuracy etc. (05 Hrs.) 193. Familiar with pressure calibrator controls and settings. (03 Hrs.) 194. Calibrating the pressure gauge using standard meter/ pressure calibrator. (05 Hrs.) 195. Measuring gauge, vacuum and differential pressure using DP transmitter. (05 Hrs.) 196. Calibrating the DP transmitter using standard meter / pressure calibrator. (05 Hrs.)	Electrical pressure transducers. Method of conversion, primary and secondary pressure transducers. Potentiometric pr. Transducers, Capacitive pr. transducers, reluctance-servo pressure transducers, strain gauge pressure transducers, piezo electric pressure transducer. Differentials pressure transducers.(07 Hrs.)

		197. Measuring low pressure/ vacuum using McLeod gauge. (05 Hrs.) 198. Test & calibrate of Pressure gauges, indicators, transmitters with Dead weight Tester. (05 Hrs.) 199. Test & calibrate of Pressure gauges, indicators, transmitters with comparator Tester. (05 Hrs.)	Low Pressure Measurement. Vacuum, gauges, thermal conductivity gauges, pirani gauges, thermocouple gauges, slack diaphragm. Ionization gauge, McLeod gauge, capacitance manometers. Method of pressure instrument calibration. Dead weight tester and comparators/manifolds. (07 Hrs.)
		200. Installation of pressure gauge in pipeline with safety valve and pig tail /siphon etc. measuring pressure in flow line. (05 Hrs.) 201. Installation and testing of pressure switch and pressure relief valve with compressor. (05 Hrs.) 202. Installation and testing of pressure switch with solenoid and alarm in process line. (05 Hrs.) 203. Fault finding in pressure gauge. (05 Hrs.) 204. Simple fault finding in pressure transmitter. (05 Hrs.) 205. Fault finding in pressure process line. (05 Hrs.)	Pressure Instrument Installation and Servicing. Elements of pressure transmitters, Installation components, pressure taps, Isolation valve, instrument piping, connections and fittings blow down valve, instrument valve, pulsation damper, diaphragm seal, pressure transmitter, Installation, procedure, locating and mounting, piping, electrical wiring placing into service, guidelines for periodic maintenance, troubles shooting and repair, instrument shop safety.(07 Hrs.)
Professional Skill 88 Hrs. Professional Knowledge 27 Hrs.	Recognize the fundamental of fluid flow, terms, different unit of flow, read specification of flow meters. And fluid pump. Perform the maintenance, Servicing and calibration and installation of variable DP flow meters / head flow meters, variable area flow meters, positive displacement meters, Electronic type flow meters and mass flow meters for fluids flow measurement. ELE/N9421	206. Measurement of pressure in flow line with different flow rates. (04 Hrs.) 207. Measurement of flow rate using fixed volume tank. (04 Hrs.) 208. Operating fluid pump and observing the pressure at input and output. verifying flow variation by adjusting bypass line. (04 Hrs.) 209. Measurement of DP of venturi and orifice using manometer. (04 Hrs.) 210. Measurement of DP using DP gauge. (04 Hrs.) 211. Adjusting the valves of manifold and observing the changes in DP gauge. (04 Hrs.) 212. Calibrating the pneumatic DP transmitter for flow rate measurement. (04 Hrs.) 213. Calibration electronic DP transmitter for flow rate. Verifying the square root relation and linear relation of DP. (04 Hrs.)	Properties of Fluid Flow. Basic properties of fluids, fluids in motion, getting fluids to flow, units of flow rate and quantity flow, factors affecting flow rate, Reynolds number, relation between flow rate and pressure, area, quantity Typesof flow meters –head type, variable area type, quantitative flow meters. Mass flow meters. Head type of flow meters: working principle, types-venturi tube, orifice plates and its shapes. Pitot tube, flow nozzles, constructions, tapings, advantages, limitations, applications, materials used for various flows. Types of secondary devices used to measure for flow rates. Open channel flow meters-principle of open channel flow, weirs, notches and flumes. Various shapes and their applications, maintenance, Variable area type flow meter-

		214. Installing a head type flow meter with venturi or orifice, manifold and DP, milli ammeter or indicator, supply. Measuring flow rate in line. (04 Hrs.) 215. Calibrating head type flow meter with standard volumetric tank. (04 Hrs.) 216. Dismantling, checking, overhauling and calibration of D. (04 Hrs.)P. cell/ transmitter. (Pneumatic & electronic). (04 Hrs.) 217. Identify and carry out preventive maintenance. (04 Hrs.) 218. Study of construction of weirs, notches and flumes their shape and connections and use. (04 Hrs.) 219. Install and testing of Rota meters in flow line. Vertical alignment. (04 Hrs.) 220. Measurement of flow rate and calibrating rotameter. (04 Hrs.) 221. Dismantle, identify different parts, its function, AND operation of various types of positive displacement meters. (04 Hrs.) 222. Installation, testing and calibrating quantitative flow meter. (04 Hrs.) 223. Dismantle and assemble quantitative flow meters like Oscillating piston type, Rotating vane meter, Lobed impeller and oval flow meter. (04 Hrs.) 224. Identify and carry out preventive maintenance of positive displacement flow meters. (04 Hrs.) 225. Installation, testing and calibration of turbine flow meter. (04 Hrs.) 226. Installation, testing and calibration of vortex flow meter. (04 Hrs.) 227. Installation, testing and calibration of ultrasonic flow meter. (04 Hrs.)	Rota meter, constructions, working principle, applications. Various shapes of float, type of materials used for body and float. Factors affecting rotameter performance, measuring gas and liquid flow. Positive Displacement. Meters. Advantages and disadvantages of positive displacement meters, piston meter, oscillating piston meter, rotating vane meter, notating disk meter, lobed impeller and oval flow meter, calibrating positive displacement meters. Target flow meters, turbine flow meter, magnetic flow meters, vertex flow meter. Construction, working principle, advantages and disadvantage, applications. Carioles mass flow meter, thermal flow meters and summary basics of ultrasonic flow meters. The Doppler hit method. The beam deflection method, frequency difference method.(27 hrs.)
Professional Skill 29 Hrs. Professional Knowledge 09 Hrs.	Identify, operate, maintain, trouble-shoot and calibrate the devices for solid flow measuring system & verify the result within standard. ELE/N9422	228. Installation, testing and calibration of mass flow meter. (05 Hrs.) 229. Measuring semi solid liquid flow rate using flow meter.(06 Hrs.) 230. Calibrating and adjustment of flow meter for solid flow.(06 Hrs.) 231. Identify and carry out maintenance& preventive maintenance of solid flow measuring system. (06 Hrs.) 232. Service and calibrate solid flow meter. (06 Hrs.)	Metering the flow of solid particles. Measuring volumetric and mass flow rate of solids, volumetric solids flow meter, mass flow meter for solids, belt type solid meters belt type solid meters belt speed sensing and signal processing, slurries, constant weight feeders. (09 Hrs.)

Professional Skill 68 Hrs. Professional Knowledge 20 Hrs.	Identify, select, wire & Execute the operation of different types of level instruments use for liquid level and solid level. Carry out maintenance, Servicing, calibration and Installation. ELE/N9423	233. Measurement of liquid level using stick gauge and converting liquid level into volume and mass (using specific gravity). (04 Hrs.) 234. Study the construction and operation of various types of sight glasses. (04 Hrs.) 235. Installation, testing and calibration of liquid level indicator. (04 Hrs.) 236. Cleaning the glass tube and operating the isolation valves, calibrating zero adjustments. (04 Hrs.) 237. Calibrating and Measuring the liquid level using float type, displacer type level systems. (04 Hrs.) 238. Measuring the liquid level of open and close tank using pressure / DP gauge. Converting liquid height into pressure using liquid density. (04 Hrs.) 239. Calibrating DP transmitter for liquid level measurement.Adjusting square root to linear scale display (04 Hrs) 240. Installation, testing and calibration of liquid level indicator. (04 Hrs.) 241. Service and calibrate different types level indicators and transmitters. (04 Hrs.) 242. Identify and carry out maintenance& preventive maintenance of above level indicators and transmitters. (04 Hrs.) 243. Construct and operate conductivity probe Level indicator. (04 Hrs.) 244. Construction and operation of capacitance probes indicating transmitters and sonic level detector. (04 Hrs.) 245. Install and test capacitance probes indicating transmitters and sonic level detector. (04 Hrs.) 246. Service and calibrate capacitance probes indicating transmitters and sonic level detector. (04 Hrs.)	Principles of level measurement. Types of level measurements-solid and liquid, volume and mass, mechanical and electrical type. Surface sensing gauges, storage tank gauges, sight glasses, magnetic gauges, buoyancy, displacement gauges. Factors need to consider for open and closed channel level measurements level switches, mercury level switches in high pressure tank, level detectors, magnetic reed switches. Pressure head instruments. Hydrostatic pressure, specific gravity,pressurized fluids, pressure head instrumentation, air bellows, U- tube manometers, air purge systems, liquid purge systems, force balance diaphragm system. Electrical method conductivity and capacitance method for measuring the liquid level, capacitance probes, zero and span adjustments, sonic level detectors, point level detection. Solid level measurement Using weight to determine level, sonicsolid level measurement with microwaves, using capacitance probes to measure solid level, diaphragm switches, nuclear gauges, microwave solid level detectors. (20 hrs.)
		247. Study the construction, operation and use of load cell technique to determine solid level in vessel. (04 Hrs.) 248. Study the construction, operation and use of different types of solid level switches. (02 Hrs.)	

		249. Study the construction, and operation of capacitance probes transmitters, microwave level detector / gauges. (02 Hrs.) 250. Install and test various types of solid level indicating transmitters and sonic level detector. (04 Hrs.) 251. Service and calibrate various types of solid level indicating transmitters and sonic level detector. (04 Hrs.) 252. Study the construction, operation and use of temperature-controlled oil bath/furnace for low and high temperature. (03 Hrs.) 253. Dismantling identify different parts, its function, adjustment, assemble and operation of Bimetallic and fluid filled (liquid, gas and vapour) system thermometers & thermo switches. (10 Hrs.)	
Professional Skill 29 Hrs. Professional Knowledge 09 Hrs.	List out different unit of temperature, terms and read specification of temperature instruments. Performmeasurement, maintenance, Servicing and calibration of Bimetallic and filled system thermometers &thermo switches. ELE/N9424	254. Install and test various types of thermometers and switches. (08 Hrs.) 255. Service and calibrate arious types of thermometers and switches. (08 Hrs.)	Temperature measurement. Temperature, heat, specific heat, changing physical state Fahrenheit and Celsius temperature scales Rankin and Kelvin scales, calibration of temperature scales primary and secondary standards. Industrial application of temperature measuring instruments with compensating link & precautions to be taken. Bimetallic and fluid filled temperature instruments. Bimetallic thermometers, liquid-in-glass thermometers, filled system thermometers, thermometer bulbs, capillary & bourdon tube, temperature transmitters for filled system, advantages & disadvantages of filled systems. (09 Hrs.)
Professional Skill 29 Hrs. Professional Knowledge 09 Hrs.	Identify, select, evaluate perfor mance, install, service and calibrate temperature Indicators, Transmitters (RTD'S,	256. Verify the characteristics of different types of RTD's, and Thermistors. (02 Hrs.) 257. Study circuit operation of signal conditioner for RTD's, and Thermistors. (02 Hrs.)	Electrical temperature instrument. Resistance thermometer, how it works, RTD bridge circuits, lead wire error, RTD elements. (03 Hrs.)

	Thermistors and Thermocouples types) various type of pyrometers and instruments for humidity. ELE/N9425	258. Install and test various types of two and three wire RTD transmitters. (03 Hrs.) 259. Service and calibrate various types of RTD transmitters using temperature calibrator or resistors. (03 Hrs.)	
		260. Verify the characteristics of different types of Thermo couples. (02 Hrs.) 261. Study circuit operation of signal conditioner for Thermocouples based indicator and transmitters. (02 Hrs.) 262. Install and test various types of Thermocouples based indicator and transmitters. (03 Hrs.) 263. Service and calibrate various types of Thermo couples based indicator and transmitters using temperature calibrator or milli volt source. (03 Hrs.)	protecting wells for RTD, advantages and disadvantages of RTDs, thermistors, thermocouples, Ex-tension wires, compensating for changes in reference junction temperature, construction of thermocouple junction, types of thermocouple, advantages and disadvantages ofthermocouples. (03 Hrs.)
		264. Measure high temperature using Optical and Radiation pyrometer. (03 Hrs.) 265. \Measure the relative humidity using humidity sensors. (03 Hrs.) 266. Measure the various points like motor, drilling point, hill person temperature etc. using thermal imager. (03 Hrs.)	Pyrometry. Molecular activity and electromagnetic radiation, defining pyrometry, effects of emittance, effects temperature, wavelength and radiated energy, pyrometers and wavelengths, using of optical and radiation pyrometer, Measurement of humidity. Thermal imagers. (03 Hrs.)
Professional Skill 29 Hrs. Professional Knowledge 09 Hrs.	Identify, select, Operate, maintain, Service and calibrate different types of recorders. ELE/N9426	267. Practice recording of variable signal. (05 Hrs.) 268. Study the construction, operation and use of circular chart recorder for temperature or pressure or mV or mA. (03 Hrs.) 269. Study the construction, operation and use strip chart recorder-pneumatic and electronic recorders. (03 Hrs.) 270. Calibrating electronic recorder. (04 Hrs.) 271. Calibrating pneumatic recorder. (04 Hrs.) 272. Overhaul, check, fault find, repair, test of pneumatic, electronic recorders. (single point &multipoint). (06 Hrs) 273. Study of paperless LCD/LED recorder. (04 Hrs.)	Recorders. Introduction to recorders, Construction, working principle, various parts installation and use of pneumatic and electronic recorders. Strip-chart, circular chart. (09 Hrs.)

Professional Skill 29 Hrs. Professional Knowledge 09 Hrs.	Identify different types of Final controlelements and role.Identify different valve body, constructional feature,Dismantle, inspect parts, replace parts, recondition, check, and resetting of control valves with actuators, convertors & positioners. Install and test the performance. ELE/N9427	274. Installation and testing valve actuator (pneumatic) with control valve. (02 Hrs.) 275. Calibrating valve positioner with control valve. (01 Hr.) 276. Calibrating current to pressure converter. (01 Hr.) 277. Calibrating voltage to current converter. (01 Hr.) 278. Installation and testing electro pneumatic positioner with control valve. (02 Hrs.) 279. Calibratingelectro pneumatic positioners with control valve. (01 Hr.) 280. Dismantle, fault finding, repair, clean, reassemble and test of actuators and positioners. (02 Hrs.)	Final control elements in process loops. Final control elements, actuators, load set Point compensation, feedback loops, control variables, effects of disturbances on performance, parts of final control sub-system, control signal, electric control signals,fluidic control signals, Pneumatic and Hydraulic Actuators.Pneumatic principles, effects of changing pressure, pressure /volume/ temperature relationship, effects of changing temp. Pneumatic actuators, diaphragm actuator, spring and springless actuators, direct and reverse acting actuator, piston actuator, positioner, Electrical actuators and their advantages. (03 Hrs.)
		281. Record specification of linear, equal, percentage quick opening control valves. (01 Hr.) 282. Record the characteristic of control valves. (01 Hr.) 283. Remove and install control valves with service line. (01 Hr.) 284. Dismantling, reconditioning, checking, replacing parts and resetting of control valves. (02 Hrs.) 285. Carry out maintenance of control valves. (01 Hr.) 286. Identifying the proximity switch and study the specifications, constructions, No.of contacts etc. (01 Hr.) 287. Installation and testing micro and limit switches with the load. Verifying its function. (01 Hr.) 288. Installation and testing capacitance or inductive proxy with the load (buzzer/ indicator etc). testing its function. (01 Hr.) 289. Installation and testing, adjusting the range of IR or ultrasonic proxy with load. (01 Hr.) 290. Installation of proxy with relay and operating high current load (like motor or AC lamp etc. (01 Hr.)	Control valves. Control valves functions and components, types' of control valves, based on valve flow characteristics-liner, equal percentage, quick opening valves, globe valves, cage valves, butterfly valves, ball valves, sliding gate valves, diaphragm valves, split body valves,capacitive, inductive type valve, proximity switch, IR switch, micro switch, limit switch, other control valves, control valve mechanical considerations, selecting control valves, valve positioner.(03 Hrs.)
		291. Operate of, sequential. (01 Hr.) Control and block valves. (02 Hrs.) 292. Operate of electromechanical and solid-state relay. (02 Hrs.)	Control elements applications. Feedwater control system works, sequential. valve control, control and block valves, applying relays in final control

		293. Service & test and use electromechanical and solid-state relay. (02 Hrs.) 294. Design and test sequential. Logic operation using relay. (01 Hr.)	elements, relay logic in operation, automatic valve control,controllers and activators, turbine control System, throttle and governor valves and activators.Introduction of internal parts of different types of control valves. (03 Hrs.)
Professional Skill 29 Hrs. Professional Knowledge 09 Hrs.	Identify fundamental of automatic control system and various functional elements in control loop. Identify, select, Install, wire, configure, test the performance, maintain, and service various types of ON-OFF and PID controllers (electronic and pneumatic). ELE/N9428	295. Install, wire up and test the control operation. (03 Hrs.) 296. Study construction & operation of ON-OFF Electronic and pneumatic Controllers. (02 Hrs.) 297. Service and maintenance of ON-OFF Electronic and pneumatic Controllers. (03 Hrs.) 298. Install, wire up, test and monitor the performance of control operation using ON- OFF Electronic and pneumatic Controllers. (03 Hrs.) 299. Practical on PID controller trainer on various process parameters. (03 Hrs.)	Introduction to controllers. Basic block diagram of control systems. Advantages Process variable and set point, analog controllers, digital controllers, control angles and limits, control loop measuring Pv, amplifying signals final control elements, current proportioning. Hunting & its effect on the product. Types of controller and their operation. Types of controller, range limit of controllers. (05 Hrs.)
		300. Study construction & operation of PID Electronic / DIGITAL Controllers. (02 Hrs.) 301. Service and maintenance of PID Electronic/ DIGITAL Controllers. (03 Hrs.) 302. Install, wire up, Configure, test the control operation using PID Electronic / DIGITAL Controllers. (03 Hrs.) 303. Verify the steady state and transient responses of PID Electronic / DIGITAL Controllers in P, PI, PD, PID. (02 Hrs.) 304. Install, connect pneumatic signal, align and test the control operation using PID pneumatic Controllers. (03 Hrs.) 305. Verify the steady state and transient responses of PID pneumatic Controllers in P, PI, PD, PID. (02 Hrs.)	ON/OFF controllers, direct and reverse acting controllers proportional controllers, automatic/manual split control, pneumatic control. Adaptive, limiting and batch control, ratio control system, feed forward, feedback control systems and cascade control system. Comparison between pneumatic and electronic control systems. Basic knowledge on communication protocol.(04 Hrs.)
Professional Skill 29 Hrs. Professional Knowledge 09 Hrs	Tune controller mode and evaluate performance of control loops as per specification and system application ELE/ N9428	306. Perform the control operation in manual and automatic mode. (15 Hrs.) 307. Set "optimum setting for unit process in PID Controller (Electronic and pneumatic). (14 Hrs.)	Controller models and tuning. Controller tuning, setting, controller modes, proportional mode, off-set, integral mode, reset mode, derivative mode(rate),single, mode controller, two mode controller, three mode controllers, tuning the control loop, step-change- response method. (09 Hrs.)

Professional Skill 58 Hrs. Professional Knowledge 14 Hrs.	Identify modules of PLC, its function, Wire and connect the digital I/OS field devices to the I/O Module of PLC, install Software, Hardware and configure plc for operation. Write and execute simple logic and real application programs. ELE/N9429	308. Wire and connect the digital I/OS field devices to the I/O Module of PLC. (04 Hrs.) 309. Install PLC Programming software and establish communication with PC and PLC. (04 Hrs.) 310. Hardware configuration and Prepare the input and output addresses for each slot. (04 Hrs.) 311. Prepare and download ladder programs for various switching Gates. (04 Hrs.)	Introduction to programmable controllers. History of programmable controllers, general characteristics of programmable controllers, some limitation of PLCs, method of developing PLC programming. (04 Hrs.)
		312. Write and execute program logic control operation. (04 Hrs.) 313. Develop programs using arithmetic, / data copy operation and execute. (04 Hrs.) 314. Write and execute program on sequence control using timers and counters. (04 Hrs.) 315. Develop programs using shift bit operation. (04 Hrs.) 316. Interface analog o/p module of plc with actuator, relay. (04 Hrs.)	Input/output devices. Definition of input /output devices, I/O interface, input modules, output modules, input devices encoders, output devices, the opto-isolators, safety. (04 Hrs.)
		317. Prepare programs based on on-delay and off-delay timers making on and off of a single LED taking one input and one output. (04 Hrs.) 318. Two LEDs on and off using pushbutton as an input. first LED on for 3 sec and off for 2 sec, and second Led on for 2 sec and off for 3 sec for continuous cycle till stop is pressed. (04 Hrs.) 319. Sequencer task using three LEDs as output and two input pushbuttons one as input (NO) for start and other for stop (NO). (04 Hrs.) 320. Configuring the project using analog input and output instructions and implement a on off closed loop control for the given process. (05 Hrs.) 321. Development of ladder logic for various tasks related to timers and counter based industrial applications. (05 Hrs.)	Processing and programming functions. The processor unit, the memory, memory organization, ladder diagrams, data logger, most used programming symbols, start, stop, station example, other programming symbol timers and counters, data manipulation instructions, alternate PLC symbols. (06 Hrs.)

Professional Skill 58 Hrs. Professional Knowledge 14 Hrs.	Operate, maintain, service, configure, install, WIRE and test HART transmitters / devices (I/O). And Net-working system for instrumentation. ELE/N9430	322. Installing & Operating HART transmitters/devices (I/O). (10 Hrs.) 323. Creating tag, measuring the parameter, configuring the parameter values in Hart transmitter using communicator. (10 Hrs.) 324. Preparation network cables and connectors. Testing network cables. (07 Hrs.)	Digital control systems: need of smart devices, HART transmitters futures, advantages, applications. Working method of HART devices, HART protocol. HART communicators and PC based HART device configuration. Steps in calibration of HART devices. Communication.(04 Hrs.)
		325. Preparation of network cables - serial (RS232/485 standards or equivalent) and Ethernet. (07 Hrs.) 326. Connect network connectivity hardware and check for its functioning. (07 Hrs.) 327. Dismantle and assemble the desktop computer system. (07 Hrs.) 328. Study the operation of Pulse Code Modulation and Demodulation. (03 Hrs.) 329. Connect any one data output of the decade counter to the Data Inputs of the FSK Modulator and measure output waveform. (07 Hrs.)	Networking: types of networks used in digital instrument systems. LAN, WAN, Ethernet. Point to point and multi networking. Ring, delta, star connections. Redundant Net. TCP/IP addresses and descriptions. Types of Cable categories (CAT), and their descriptions. Various types of Cable connectors. Advantages and disadvantages of co-axial cable and fiber optic cables. Various tools used in networking- wire cutter, crimp tool, memory blade holder, memory blade cartridge, cable strip tool with blade cassettes. Terminators and extra connectors, taps, calibration tool etc. fundamentals: modulation and demodulation, signal to noise ratio, digital communication basics-PWM, PCM, FSK. (10 Hrs.)
Professional Skill 58 Hrs. Professional Knowledge 14 Hrs.	Identify the different modules of DCS, function, Wire and connect I/OS field devices to the I/O Modules, install Software, Hardware and configure DCS for operation with HMI. Write and execute DCS AND SCADA programs FOR real application. ELE/ N9431	330. Wire and connect the I/O Module of DCS to field signals. (06 Hrs.) 331. Install DCS Programming software and establish communication with PC and DCS. (06 Hrs.) 332. Set the communication between DCS and SCADA System. (06 Hrs.) 333. Concept of Tag/Points Generation. (06 Hrs.) 334. Attaching points to the display Element. (06 Hrs.)	Fundamentals of SCADA and DCS. History of DCS development. Basic architecture, description advantages and disadvantages, applications. Terminology- RTU (remote transmitting unit, central monitoring station, types of communications, field instruments and types. (04 Hrs.)
		335. Practice HMI, operator panel and touch panel operation and related software. (10 Hrs.) 336. Set up and configure HMI with PLC. (06 Hrs.) 337. Animate objects on a HMI screen to monitor motor status. (06 Hrs.) 338. Use security features to do tag logging and command execution. (06 Hrs.)	Field bus: futures, advantages, architecture, basic block diagram, working. Work station, Human Machine Interface (HMI). Controller (with basic types), filed bus interfacing modules, gateway, network manager, I/O modules, field bus devices (I/0), remote transmission panel (RTP), Ethernet. Electronic device description language (EDDL) and device description (DD).

			Field bus power supply and its function. Introduction of digital and multi drop communication protocol Vendors.Futures-library, call up, various visualized futures, Reports (alarms, events), history, trading etc. (10 Hrs.)
Professional Skill 29 Hrs. Professional Knowledge 09 Hrs.	Identify,check constructional Feature and function of hydraulic pump, and hydraulic power system, accumulator, hydraulic hoses and fitting, Hydraulic components. Build AND test hydraulic control circuit. ELE/N9432	339. Practice symbolic representation of Hydraulic components. (02 Hrs.) 340. Familiar with hydraulic hoses and fitting. (02 Hrs.) 341. Feature and function of hydraulic pump and hydraulic power system. (02 Hrs.) 342. Feature and function of hydraulic accumulator. (02 Hrs.) 343. Service and test different types of valves. (03 Hrs.)	Basic Hydraulics: Principles of Hydraulics. Fluid power and hydraulics, force, weight and mass, pressure, work, power, energy, incompressibility and non-diffusion, hydrostatic pressure, Pascal'slaw, transmission of fluid power, fluid flow in pipes, Bernoulli's principle, the effect of heat on liquids. A typical hydraulic power system. Hydraulic Fluids. Functions of Hydraulic fluids, physical properties, viscosity, viscosity index, viscosity and pressure, power point, fluid selection, component protections, chemical properties, system contamination, water, dissolve air, foaming, corrosion and rusting, types of hydraulic fluids. (05 Hrs.)
		344. Design hydraulic circuit for double acting cylinder actuation. (03 Hrs.) 345. Design hydraulic circuit using Pilot operated check valve. (03 Hrs.) 346. Design hydraulic circuit using Pressure reducing Valve. (03 Hrs.) 347. Design hydraulic circuit Using Pressure relief & Pressure regulating valve. (03 Hrs.) 348. Design hydraulic Pressure sequencing circuit. (03 Hrs.) 349. Design hydraulic circuit using Pressure compensated flow control. (03 Hrs.)	Directional control valves. Directional control valve classification, review of two way valves, 'globe, gauge, plug, needle, ball, automatic two way valves, check valves, pilot operated check valves, spool valves, three ways pool valves, controlling hydraulic motors, NO and NC valves, holding valves, four and five way valves, rotary spool valves, schematic symbols, flow ratings, accessories. (04 Hrs.)
Professional Skill 29 Hrs. Professional Knowledge 09 Hrs.	Lay out construction feature, operate, maintain of air compressor, air Distribution system, pneumatic associate components, piping, tubing and fitting. Build and test pneumatic control circuit. ELE/N9433	350. Study construction operation and use of air compressor. (02 Hrs.) 351. Operation and use of air filters, regulators and lubricator. (02 Hrs.) 352. Practice and use of Pneumatic Piping, tubing and fitting. (Metallic and non-metallic). (02 Hrs.)	Pneumatic principles, mass, pressure, work and energy, compressibility, law of pneumatics, transmission of pneumatic fluid power, pneumatic leverage,air properties, airflow in pipelines, viscosity of air pressure, Bernoulli's law, components of pneumatic power system. Primary air treatment. Air treatment, preliminary filtering, relative. Humidity, effects of moisture, water removal, dew point, moisture separators, oil

			scrubbers, air dryers, (deliquescent and absorption type) air receivers. Secondary air treatment. Methods of treatment, Contaminate separation, contaminate filtrationand filter classification and rating, types of media surface filters, depth filters, absorption filters, Lubricating theair. (06 Hrs.)
		353. Set up a system to provide Pneumatic (air) supply of 20 psi output from the available compressor. (02 Hrs.) 354. Build a pneumatic circuit of a single acting cylinder being controlled by 3 way 2 position directional control valves. (03 Hrs.) 355. Build a pneumatic circuit of a double acting cylinder being controlled by 5 way 2 position directional control valves. (03 Hrs.) 356. Build a pneumatic AND, OR circuit by 3 way 2 position directional control valves to operate double acting cylinder. (03 Hrs.) 357. Build a pneumatic circuit of a pilot controlled double acting cylinder of being controlled by 3 way 2 position directional control valves and 5 way 2 positions valve. (02 Hrs.) 358. Build a pneumatic circuit to test logical latch circuit by 5 way 2 position, 3 way 2 valve direction control valves. (02 Hrs.) 359. Build a pneumatic circuit to control oscillation of piston by pilot operated 5 way 2 position, 3 way 2 direction control valves. (02 Hrs.) 360. Cutting the metallic tube as per dimensions using tube cutter. (02 Hrs.) 361. Bending the tube in to 900and 450 using pipe bending tools. (02 Hrs.) 362. Installation of simple piping diagram. (02 Hrs.)	Piping houses and fittings. Requirement of piping, airflow, piping dimensions and safety factors, piping connections, compressed air piping applications, metallic tubing, tubing bending and tube fitting, tube installation, nonmetallic tube houses, hose fittings and coupling, hose installation.(03 Hrs.)
Professional Skill 25 Hrs. Professional Knowledge 09 Hrs.	Identify constructional feature, operate, maintain, service and calibrate of Analy tical instruments. ELE/N9434	363. Operation of pH meter conductivity meter and dissolved oxygen Meter. (04 Hrs.) 364. Wire up pH meter electrode to pH meter. (04 Hrs.) 365. Calibrate pH meter using buffer solution. (04 Hrs.) 366. Determination of pH (by pH meter). (04 Hrs.) 367. Wire up conductivity meter to electrode and find the electrolytic conductivity of solution. (04 Hrs.) 368. Service and maintenance of conductivity meter & Dissolved oxygen meter. (05 Hrs.)	Analytical instruments. Exposure to basic analytical instruments. Types of electrodes used for PH measurements. Relation of PH and mV. PH indicator and controllers. Conductivity meters. Dissolved gen meter. (09 Hrs.)

Characteristics of instrument

Objectives: At the end of this exercise you shall be able to
- **describe the scope and necessary of instrumentation**
- **explain the purpose of tools**
- **explain the fundamentals of measurement system**
- **describe fundamental units of measure system**
- **describe static and dynamic characterizes of instrument.**

Scope and necessity of instrumentation

Instrumentation is one of the branches of engineering. Which deals with measurement and control of the process variables. It also deals with the design and implementation of systems with the numerous amount of processes involved accurate instrumentation is required to make operation run smoothly.

Pressure flow level temperature and more inaccurate reading can lead to personal injuries

Control and instrumentation engineers are responsible for designing developing installing managing and maintaining equipment which is used to monitor and control engineering systems. Machinery and process.

Fundamental Methods of Measurement System

Objectives: At the end of this lesson you shall be able to
- **state the fundamental methods of measurement.**

Measurement The collection of information about the state or change of state of variables is called measurement

A measuring instrument exists to provide information about the physical value of some variable being measured

The act or process of measurement produces it's result but items be reliable.

Fundamental methods of measurement

Measurement is usually done by some kind of comparison.

There are two methods of measurement

1 Direct comparison with a primary or a secondary standard.

2 Indirect comparison with a calibrated system.

Direct comparison

It is one of the method of measurement in which the measured (input) is directly compared with the standard.

It is less common method of measurement where greater accuracy is required.

Eg . Measuring length using steel rule.

Indirect comparison

The measure and (input) is converted into an analogous form in order to make the desired information intelligible..

It is very common in practice.

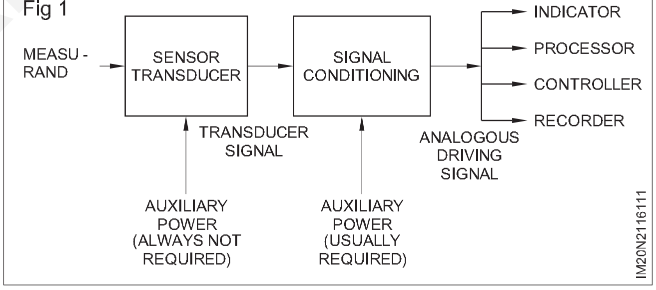
Eg. Measuring temperature using RTD.

Functional block diagram of Measurement system

Generalized measuring system

Any measuring system may have any one or any combination or all of the following stages as shown in Fig 1.

Fig 1



First stage – Sensor stage or detector transducing stage.

Second stage – Signal conditioning stage or intermediate stage

Third stage – Read out stage or display stage or terminating stage.

End stage consists of a basic element or elements to perform its required function.

1 First stage or Sensor stage

The main function of the first stage is to sense or detect the measured. It should be insensitive to every other possible input.

2 Second stage or signal conditioning stage

It modifies the transduced signal compatible or suitable for third stage.

3 Third stage or read out stage

It provides the information in a form comprehensible to human senses or to a controller

Stages of the general measurement system

First stage (Sensor Transducer)	Second stage (Signal conditioning)	Third stage (Read out)
It senses the input And provides analogous Output EG. Measuring Pressure using pressure gauge.	It modifies the transduced Signal compatible or suitable for third stage	It provides the information in a form comprehensible To human senses or to Controller.

Calibration: It may be defined, in general, as the process for determination, by measurement or comparison with a standard, of the correct value of each scale reading on a meter or other measuring instrument;

Calibration standards

Calibration standards are devices that are compare against less accurate device to verified instrument

Basic standard

Basic standard are unaltered standards which are used over for a longer period of lime and do not reflect conditions.

Secondary standard

Secondary standard are used to calibrate analytical equipment and analytical method.

Working standard

The working standards are the principal tools of a measurement laboratory. They are used to check and calibrate general laboratory instruments for accuracy and performance or to perform comparison measurements in industrial applications. The working standards may be less accurate and less expensive.

Unit – Classification of unit system

Unit

A unit is defined as a standard or fixed quantity of one kind used to measure other quantities of the same kind.

Classification

Fundamental units and derived units are the two classifications.

Fundamental units

Units of basic quantities of length, mass and time.

Derived units

Units which are derived from basic units and bear a constant relationship with the fundamental units EG. Area , volume, pressure, force etc.

Systems of units

- F P S system is the British system in which the basic units of length, mas and time are foot, pound and second respectively.
- C G S system is the metric system in which the basic units of length, mass and time are centimeter, gram and seconds respectively.
- M K S system is another metric system in which the basic units of length, mass and time are meter, kilogram and second respectively.
- S I units are referred to as Systems international units which is again of metric and the basic units their names and symbols are as follows.

Fundamental units and derived units are the two classifications of units.

Length,mass and time are the fundamental units in all the systems (i.e) F. P.S,C.G.S,M.K.S AND S.I. systems.

Example

Length: What is the length of copper wire in the roll, if the roll of copper wire weighs 8kg, the dia of wire is 0.9 cm and the density is 8.9 gm/cm3?

Solution

Mass of copper wire in the roll = 8kg (or) 8000 grams

DIa of copper wire in the roll = 0.9cm

Density of copper section of copper wire

$$\frac{\pi d^2}{4} = \frac{\pi \times (0.9^2)}{4} = 0.636cm^2$$

Volume of copper wire

$$= \frac{\text{Mass of copper wire}}{\text{Density of copper wire}} = \frac{8000\text{grams}}{8.9\text{ gm/cm}^3} = 898.88\text{cm}^3$$

Length of copper wire

$$= \frac{\text{Volume of copper wire}}{\text{Area of crosssection of copper wire}} = \frac{898.88\text{cm}^3}{0.636\text{cm}^2}$$

Length of copper wire = 1413cm.

Time: The S.I unit of time, the second, is another base units of S.I it is defined as the time interval occupied by a number of cycles of radiation from the calcium atom. The second is the same quantity in the S.I in the British and in the U.S systems of units.

Fundamental units of F.P.S,C.G.S,M.K.S and S.I

S no	Basic quantity	British units		Metric units				International units	
		F.P.S	**Symbol**	**C.G.S**	**Symbol**	**M.K.S**	**Symbol**	**S.I unit**	**Symbol**
1	Length	Foot	ft	centimeter	cm	Metre	m	Metre	m
2	Mass	Pound	lb	Gram	g	kilogram	kg	Kilogram	Kg
3	Time	Second	s	Second	s	Second	s	Second	s
4	Current	Ampere	A	Ampere	A	Ampere	A	Ampere	A
5	Temprature	Fahren-heit	^{o}F	Centigrade	^{0}C	Centi-grade	^{0}C	Kelvin	K
6	Light intensity	Candela	Cd	Candela	Cd	Candela	Cd	Candela	Cd

Derived units of F.P.S,C.G.S,M.K.S and SI system

S.No	Physical quantity	British units		Metric units				International units	
		FPS	Symbol	CGS	Symbol	MKS	Symbol	SI Units	Symbol
1	Area	Square foot	ft^2	Square centimetre	cm^2	Square metre	m^2	Square metre	m^2
2	Volume	Cubic foot	ft^3	Cubic centimetre	cm^3	Cubic metre	m^3	Cubic metre	m^3
3	Density	Pound per cubic foot	lb/ft^3	Gram per cubic centimetre	g/cm^3	Kilogram per cubic metre	kg/m^3	Kilogram per cubic metre	Kg/m^3
4	Speed	Foot per second	ft/s	Centimetre per second	cm/sec	Metre per second	m/sec	Metre per second	m/sec
5	Velocity (linear)	Foot per second	ft/s	Centimetre per second	cm/sec	Metre per second	m/sec	Metre per second	m/sec
6	Acceleration	Foot per square second	ft/s^2	Centimetre per square second	cm/sec^2	Metre per square second	m/sec^2	Metre per square second	m/sec^2
7	Retardation	Foot per square Second	ft/s^2	Centimetre per square second	cm/sec^2	Metre per square second	m/sec^2	Metre square second	m/sec^2
8	Angular velocity	Degree per second	Deg/sec	Radian per second	rad/sec	Radian per second	rad/sec	Radian per second	rad/sec
9	Mass	Pound (slug)	lb	Gram	g	Kilogram	kg	Kilogram	kg
10	Weight	Pound	lb	Gram	g	Kilogram weight	kg	Newton	N
11	Force	Pounds	lbf	dyne	dyn	Kilogram force	kgf	Newton	$N(kgm/sec^2)$
12	Power	Foot pound per second	ft.lb/sec	Gram.centimetre/sec	g.cm/ sec	kilogram metre per second	kg.m/ sec	-	-
		Horse power	hp	Erg per second		watt	W	watt	W(J/sec)
13	Pressure,Stress	Pound per square inch	lb/in^2	Gram per square centimetre	g/cm^2	Kilogram per square metre	kg/m^2	Newton per square metre	N/m^2
14	Energy, Work	Foot.pound	ft.lb	Gram centimetre	g.cm	Kilogram metre	kg.m	joule	J(Nm)
15	Heat	British thermal unit	Btu	calorie	Cal	joule	J	joule	J(Nm)
16	Torque	Pound force foot	lbf.ft	Newton millimetre	N mm	Kilogram metre	kg.m	Newton metre	Nm
17	Temperature	Degree Fahrenheit	°F	Degree Centigrade	°C	Kelvin	K	Kelvin	K
18	Specific heat	BTU per pound degree fahrenheit	Btu/lb°F	Calorie per gram degree Celsius	Cal/g°C	Joule per kilogram kelvin	J/(kgK)	Joule per kilogram kelvin	J/(kgK)

S.No	Physical quantity	British units		Metric units				International units	
		FPS	Symbol	CGS	Symbol	MKS	Symbol	SI Units	Symbol
19	Frequency	Cycle per second	1/s	Hertz	Hz	Hertz	Hz	Hertz	Hz
20	Moment of inertia	Pound force foot square second	$lbf.ft.s^2$	Gram square centimetre	$g.cm^2$	Kilogram square metre	$kg.m^2$	Kilogram per square metre	$Kg.m^2$
21	Momentum	Pound second	lb.s	Gram centimetre per second	g.cm/sec	Kilogram metre per second	kg.m/sec	Kilogram metre per second	Kg.m/ sec
22	Moment of force	Pounds foot	lbs/ft	Gram centimetre	g.cm	Kilogram metre	kg.m	Newton metre	Nm
23	Angle	degree	deg	degree	deg	degree	deg	Radian	rad
24	Specific volume	Cubic foot per pound	ft^3/lbs	Cubic centimetre per gram	Cm^3/g	Cubic metre per kilogram	m^3/kg	Cubic metre per kilogram	m^3/kg
25	Specific resistance	Ohm foot	Ω ft	Ohm centimetre	Ω cm	Ohm meter	Ω m	Ohm meter	Ω m
26	Specific weight	Pound per cubic foot	lbf/ft^3	Gram per cubic centimetre	g/cm^3	Kilogram per cubic metre	kg/m^3	Newton per cubic metre	N/m^3
27	Fuel consumption	Miles per gallon	m/gal	Centimetre per cubic centimetre	cm/cm^3	Kilometre per litre	km/l	Metre per cubic metre	m/m^3
28	Dynamic viscosity	Pound force per square foot	lbf/ft^2	Centi poise	cP	pascal second	$P_{a.s}$	pascal second	$P_{a.s}$
29	Surface tension	Poundal per foot	pdl/ft	dyne per centimetre	dyn/cm	Newton per metre	N/m	Newton per metre	N/m
30	Entropy	British thermal unit per degree Fahrenheit	$Btu/^0F$	Calorie per degree centigrade	$Cal/^0c$	Joule per kelvin	J/K	Joule per kelvin	J/K
31	Electric current	Columb per second	C/s	Biot	Bi	Ampere	A	Ampere	A
32	Electric voltage	Volt	V	Volt	V	Volt	V	Volt	V
33	Electric resistance	Ohm	Ω	Ohm	Ω	Ohm	Ω	Ohm	Ω, (V/A)
34	Electric conductance	Mho, Siemens	℧,s	Mho	℧,s	Siemens	s	Siemens	s
35	Light intensity	Candela	Cd	Candela	Cd	Candela	Cd	Candela	Cd
36	Specific gravity	No unit	-	No unit	-	No unit	-	No unit	-

Units and abbreviations

Quantity	Units	Abbreviation of unit
Calorific value	kilojoules per kilogram	kJ/kg
Specific fuel consumption	kilogram per hour per newton	kg/hr/N
Length	millimetre, metre, kilometre	mm, m, km
Mass	kilogram, gram	kg, g
Time	seconds, minutes, hours	s, min, h
Speed	centimetre per second, metre per second kilometre per hour, miles per hour	cm/s, m/s km/h, mph
Acceleration	metre-per-square second	m/s^2
Force	newtons, kilonewtons	N,kN
Moment	newton-metres	Nm
Work	joules	J
Power	horsepower, watts, kilowatts	Hp, W, kW
Pressure	newton per square metre kilonewton per square metre	N/m^2 kN/m^2
Angle	radian	rad
Angular speed	radians per second radians-per-square second revolutions per minute revolutions per second	rad/s rad/s^2 Rpm rev/s

Decimal multiples and parts of unit

Decimal power	Value	Prefixes	Symbol	Stands for
10^{12}	1000000000000	tera	T	billion times
10^{9}	1000000000	giga	G	thousand milliotimes
10^{6}	1000000	mega	M	million times
10^{3}	1000	kilo	K	thousand times
10^{2}	100	hecto	h	hundred times
10^{1}	10.10^{1}	deca	da	ten times
10^{-1}	$0.1\ 10^{-1}$	deci	d	tenth
10^{-2}	0.01	centi	c	hundreth
10^{-3}	0.001	milli	m	thousandth
10^{-6}	0.000001	micro	µ	millionth
10^{-9}	0.000000001	nano	n	thousand millionth
10^{-12}	0.000000000001	pico	p	billionth

SI units and the British units:

Quantity	SI unit British unit	British unit SI unit
Length	1 m = 3.281 ft 1 km = 0.621 mile	1 ft = 0.3048 m 1 mile = 1.609 km
Speed	1 m/s = 3.281 ft/s 1 km/h = 0.621 mph	1 ft/s = 0.305 m/s 1 mph = 1.61 km/h
Acceleration	1 m/s^2 = 3.281 ft/s^2	1 ft/s^2 = 0.305 m/s^2
Mass	1 kg = 2.205 lb	1 lb = 0.454 kg
Force	1 N = 0.225 lbf	1 lbf = 4.448 N (1 million newtons)
Torque	1 Nm = 0.738 lbf ft	1 lbf ft = 1.355 Nm
Pressure	1 N/m^2 = 0.000145 lbf/in^2 1 Pa = 1 N/m^2 1 bar = 14.5038 lbf/in^2	1 lbf/in^2 = 6.896 kN/m^2 1 lbf/in^2 = 6.895 kN/m^2
Energy, work	1 J = 0.738 ft lbf 1 J = 0.239 calorie 1 kJ = 0.948 Btu (1 therm = 100 000 Btu) 1 kJ = 0.526 CHU	1 ft lbf = 1.355 J 1 calorie = 4.186 J 1 Btu = 1.055 kJ 1 CHU = 1.9 kJ
Power	1 kW = 1.34 hp	1 hp = 0.7457 kW
Fuel consumption	1km/L = 2.82 mile/gallon	1 mpg = 0.354 km/L
Specific fuel consumption	1 kg/kWh = 1.65 lb/bhp h 1 litre/kWh=1.575 pt/bhp h	1 lb/bhp h = 0.606 kg/kWh 1 pt/bhp h = 0.631 litre/kWh
Calorific value	1 kJ/kg = 0.43 Btu/lb 1 kJ/kg = 0.239 CHU/lb	1 Btu/lb = 2.326 kJ/kg 1 CHU/lb = 4.188 kJ/kg

Multiplying factors can also be used in relation to standard unit measurement such as length, mass, time and frequency

For example

To calculate the open of a square you would multiply the length of one side by itself. Area = side x side (or) A = S2

To calculate the volume of box you would multiply the length width, and height = volume x width x height (or) v= 1wl

To standard unit of length is = meter (m)

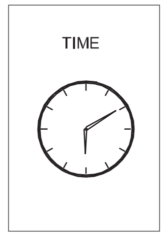
Standard unit of mass is = Kilogram (K)

Standard unit of time is = second (S)

Standard unit of frequency is Hertz (H)

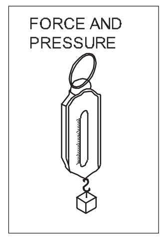
TIME

T	Time or time interval	s	Second	s
nu	Rotational frequency	l/min	Reciprocal second	l/s
u,v,w,c	Velocity speed	m/min	Metre per second	m/s
ω	Angular velocity	rad/s	Radian per second	rad/s
g	Acceleration of freefall	m/s^2	Metre per second squared	m/s^2
a	Acceleration	m/s^2	Metre per second squared	m/s^2
	Retardation	m/s^2	Metre per second squared	m/s^2



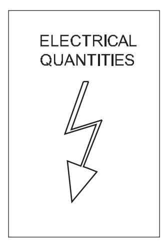
FORCE AND PRESSURE

F	Force	kgf	Newton (1kgf = 9.80665N)	N
G(P,W)	Weight	kgf	Newton	N
γ	Specific weight	kgf/m^3	Newton per cubic metre	N/m^3
M	Moment of force (force x distance)	kgf.m	Newton metre	N.m
p	Pressure (force/ area)	kgf/cm^2	pascal, Newton per square metre	Pa,N/m^2
p	Normal stress	kgf/mm^2	bar (1 bar = 10 N/m)	
τ p	Shear stress	kgf/mm^2	bar	
E	Modulus of elasticity	kgf/mm^2	Newton per square metre	N/m^2
G	Shear modulus	kgf/mm^2	Newton per square metre	N/m^2
μ	Co-efficient of friction	No Unit		



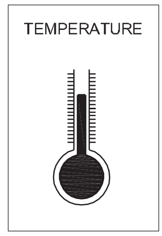
ELECTRICAL QUANTITIES

V	Electric potential	V	Volt	V(W/A)
E	Electromotive force	V	Volt	V(W/A)
I	Electric current	A	Ampere	A
R	Electric resistance	Ω	Ohm	Ω (V/A)
e	Specific resistance	Ω m	Ohm metre	Vm/A
G	Conductance	Ω^{-1}	Siemens	S



TEMPERATURE

Scale	Freezing point	Boiling point
Centigrade (˚C)	0°C	100°C
Faranheit (°F)	32°F	212°F
Kelvin (K)	273K	373K
Reaumur (°R)	0°R	80°R



$$\frac{°R}{80} = \frac{°C}{100} = \frac{K-273}{100} = \frac{°F-32}{180}$$

Instruments characterizes

Static characterizes

1 Static characterizes

2 Dynamic characterizes

Accuracy: It may be defined as the ability of a device or a system to respond to a true value of a measured variable under reference conditions. In actual practice, accuracy is generally and necessarily expressed as the limit of error of a measuring device or system under certain operating conditions that may or may not be specified.

Precision: Precision is defined as measured between one or more measured values to each other.

Sensitivity: The term sensitivity is sometimes used to describe the maximum change in an input signal that will not initiate a response on the output

Resolution: It is the least incremental value of input or output that can be detected, caused, or otherwise discriminated by the measuring device. It is often used as an expression of observer error in reading. That is, the resolution of a scale or chart is the minimum error that must be assumed to exist, that can be attributed exclusively to the observation. This is generally considered to be about one-fifth of the smallest scale division. If these least incremental values are considered small, this would be termed fine resolution if they are considered large, this would be termed coarse resolution.

Dead zone: It is the largest range of values of a measured variable to which the instrument does not respond. This is sometimes called dead spot and hysteresis. Dead zone usually occurs with friction in an indication or recording instrument, more often in the latter.

Backlash: Backlash or mechanical hysteresis is defined as that lost motion of free play which inherent in mechanical elements, such as gears, linkages, or other mechanical-transmission devices that are not rigidly connected.

True value: It is the error – free value of the measured variable. It is given as

True value = Instrument reading – Static error.

Repeatability: The repeatability of a measuring device may be defined as the closeness of agreement among a number of consecutive measurements of the output for the same value of the input, under the same operating conditions, approaching the measurement from the same direction, and for full-range traverses.

Reproducibility: The reproducibility of an instrument is the closeness of agreement among repeated measurements of the output for the same value of input, made under the same operating conditions over a period of time, approaching drift, i.e. the instrument calibration does not gradually shift over a long period of time such as a week, a month, or even a year.

Drift: It is an undesired change or a gradual variation in output over period of time that is unrelated to changes in output, operating conditions, or load this term most often applies to changes that occur after a specified warm-up period. A long-term calibration drift usually occurs because of the ageing of component parts.

Sensitivity: It can be defined as the ratio of a cange in output to the change in input which causes it, at steady - state conditions.The ratio must be expressed in the units of measurement of output and input.

Dead band: Dead band of input values in the domain of a transfer functions in a control system or signal processing system. Where the output is zero (0)

Hysteresis: It can be electrical and mechanical system lag between input and an output difference hysteresis

Dynamic Characteristics

Speed of response: It is the rapidity with which an instrument responds to changes in the measured quantity.

Fidelity: It is the degree to which an instrument indicates the changes in measured variable without dynamic error.

Lag: It is retardation or delay in the response of an instrument to changes in the measured quantity.

Error It is the difference between the true value of a quantity changing with time and the value indicated by the instrument, if no static error is assumed.

Deviation: It is the departure of a given reading from the arithmetic mean of the group of readings. If the deviation of the first reading, is called d2 and so on then the deviations from the mean can be expressed as

True value: True value is the error free value of the measured variable it is give as

True= Instrument reading- Stat error

Data: Data can be define as a systematic record of particular quantity is a collection of fact and figures to be used specific purpose at work.

Types of error

Objectives: At the end of this lesson you shall be able to
- **describe types of error.**

They are three types of errors

i Gross error or mistake

ii Systemic error

iii Random (or) accidental error

i Gross error

This class of error mainly convers human mistake in reading instrument and recording and checking measured result mistake normally experiment.

ii Systemic error

These types of errors, sometimes referred to as bias, influence all measurements of a quantity alike. A constant uniform deviation of the operating point of an instrument is known as a systematic error. There are two types of systematic errors:

ii a Environmental error

Environmental error due to area surrounding tempera line effect, magnetic field, pressure effected of instrument

ii b Observational error

Thus an error on account of parallax error. Highly accurate meter provided error

iii Random error

The happening or disturbances about which we are uniped together and called Random or residual error

iv Illegitimate errors

Illegitimate errors involve making gross mistakes in the experimental setup, in taking or recording data or in calculating results, for example making wrong assumptions or using wrong units etc.

Analysis of Measurement System

Objectives: At the end of this lesson you shall be able to
- **describe uncertainty in measuring system**
- **describe measures system response**
- **describe statistical analysis**
- **describe uncertainty.**

Certainty

Once a measurement is taken, the next step is to know how certain we are in that measurement the certainly of a single measurement is zero.

Uncertainty

Uncertainty measures the range of possible values within which the true value of the measurement lies

- Validity of result

The quality or state of being valid such as a the state of being acceptable according to the law the validity of the conrract is being quentimed

- The Measuring system Response

Amplitude response

Since the frequency response is a complex-valued function, it has a magnitude and phase angle for each frequency. The magnitude of the frequency response is called the amplitude response (or magnitude frequency response), and it gives the filter gain at each frequency.

Phase response

In signal processing phase response is the relationship between the phase of a sinusolidal input and output signal passing through any device that accepts input and producer an output signal.

Delay-time

Delay time is a broad term encompassing the complexities of construction projects and contractors that lead to delays. Delays can be costly and are best avoided, but some circumstances such as unexpected and unavoidable.

Rise time

Rise time is the time taken for a signal to cross a specified lower voltage threshold followed by a specified upper voltage threshold. This is an important parameter in both digital and analog systems. In digital systems it describes how long a signal spends in the intermediate state between two valid logic levels.

Slew rate

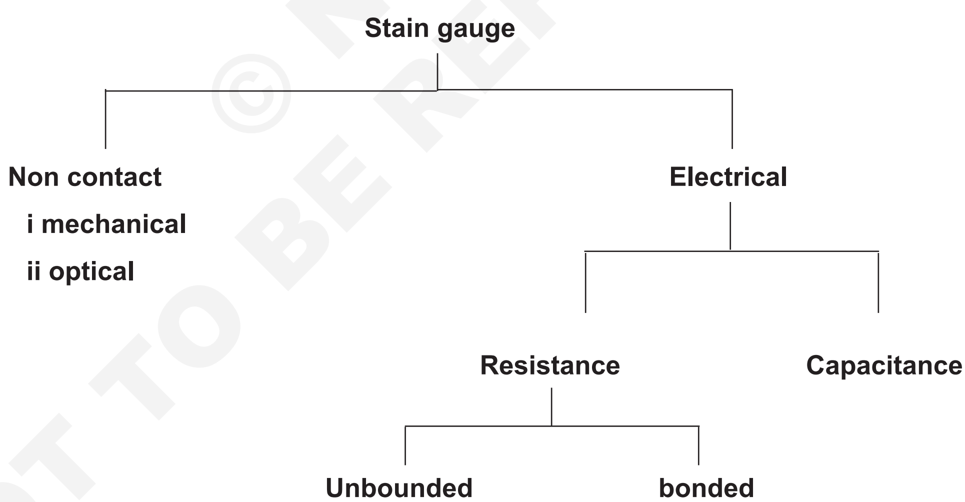
In electronic slew rate is defined at the change of voltage or current or any other electrical quantity per unit of time.

Damping important

Damping, in physics restraining of vibrainm monium, such as mechanical oscillations, noise, alternatively electric currents, by dissipation of energy. Damping is of primary importance in commonly vibrainm response complained under conditions of Sheedy state reasonable and stamary random excitation. Dampty also play a crucial role in fixing me border line between stability and instabuility.

Introduction to strain gauges

Objectives: At the end of this lesson you shall be able to
- **explain different types of strain gauges and its applications.**



Measurement Strain

The most commonly used instrument to measure strain are electrical strain gauge

$$\text{Strain} = \frac{\text{Change dimension}}{\text{Original dimension}}$$

No Strain units

1 Force

2 Torque

3 Weight

4 Level

5 Pressure

6 Strength

7 Displacement

8 Vibration

Stress Measurements

Stress is defined as force per unit area within materials that arises from externally applied forces, uneven heating, or permanent deformation and that permits an accurate description and prediction of elastic, plastic, and fluid behavior.

Stress is given by the following formula:

Kg/cm F/A

Strain Measurements

Strain is a non-dimensional value that represent that change of length of a material relative to its initial length since the changes of length are usually very small the standard fractional prefixes of the SI system are used for strain micrometer per meter (llm/m=106 m/m=ppm) is generally used.

Stain gauge

A stain gauge work on the principle of electrical conductance and its dependence's on the conductors there are four types of stain gauge

i Wire(Resistance)Strain gauge

ii Thin flim stain gauge

iii Foil stain gauge

iv Semiconductor stain gauge

Resistance Strain Gauge

Strain gauge is a positive-type resistance transducer which converts a mechanical displacement into a change of resistance. It is the most commonly used transducer for the measurement of displacement.

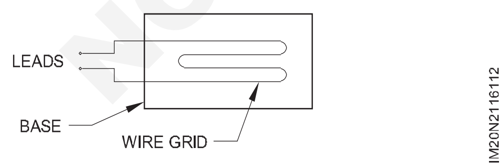
The resistance gauge is essentially a fine wire which changes its resistance, when mechanically strained, due to physical effects. Its length and cross sectional area vary and a change of electrical resistivity also occurs. The strain gauge is mounted to the measured surface so that it elongates or contracts with that surface. This deformation of the sensing materials causes it to undergo a change in resistance.

Types Basically, there are two types of strain gauges:

i Bonded strain gauge ii Unbonded Strain gauge

Bonded Strain Gauge In bonded strain gauges, a grid of fine wire is cemented to a thin paper sheet or very thin Bakelite sheet, and covered with a protective sheet of paper or thin Bakelite. The paper sheet is bonded with an adhesive material to the structure under study. The most useful form of bonded strain gauge is shown in Fig 1.

Fig 1



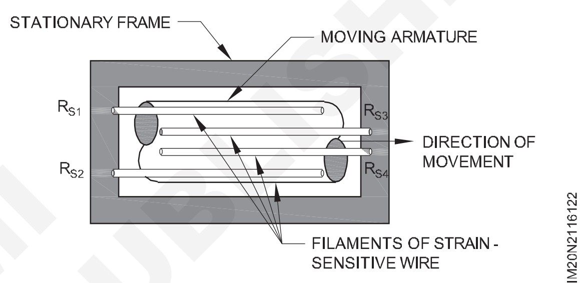
When the surface to which the strain gauge is bonded is disturbed because of an applied force (or load), the strain gauge is also strained. The resistance of the wire changes on account of change in length and diameter of the wire.

The size of the grid varies with the application they can be as small as 3mmX3mm square. Usually they are larger, but seldom more than 2.5 cm long and 1.25 cm wide.

The strain gauge is useful only for measuring very small displacements (strains). However, larger displacements can be measured by bonding the gauge to a flexible element such as a thin cantilever beam and applying the unknown displacement to the end of the beam.

Unbonded Strain Gauge The unbonded strain gauge consists of a stationary frame and an armature that is supported in the center of the frame, as shown i8n fig. The armature can move only in one direction and its travel in that direction is limited by four filaments of strain-sensitive wire wound between rigid insulators that are mounted on the frame and on the armature. The filaments are of equal length and arranged as shown in Fig 2.

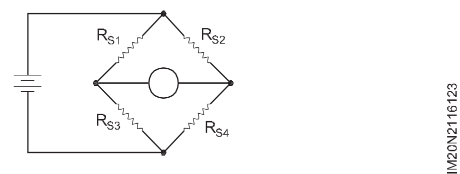
Fig 2



When an external force is applied to the strain gauge, the armature moves in the direction indicated in the filaments Rs1 and Rs2 increase in length, whereas the filaments Rs3 and Rs4 decrease in length. The resistance change of the four filaments is proportional to their change in length, and this change can be

Measured with a Wheatstone bridge, as shown in Fig 3. The unbalance current indicated by the galvanometer is calibrated in terms of the magnitude of displacement of the armature. A linkage pin can be attached to the armature in order to measure displacement directly.

Fig 3



A change in temperature causes a change in resistance of the filament. Therefore temperature compensation must be provided. In some cases a dummy filament (identical to the active filament) is cemented to a piece of the same material as the active filaments so as to assume the same temperature. The dummy gauges (filaments) and active gauges are placed in adjacent legs of a Wheatstone bridge. Thus any change in temperature affects the two gauges equally and, therefore, there are no errors caused by change in resistance due to temperature.

The unbonded strain gauge transducer can be constructed in a variety of configurations, depending on the required use. They are mainly used in force and pressure transducers and accelerometers.

Load cell

Load cells are commonly used to measure weight in an industrial environment. They can be installed on hoppers, reactors, etc., to control their weight capacity, which is often of critical importance for an industrial products.

Strain Gauge load Cell The strain gauge load cell is an electro-mechanical

Construction Strain gauge load cell is constructed of wire grids (known as strain gauges) bonded to precisely machined supporting columns, as shown is Fig 2. These grids are connected electrically to form a balanced Wheatstone bridge, as shown in Fig 3. Additional compensation resistors are added to the circuit for maintaining the accuracy of the bridge over a wide range of temperatures.

Working: The principle of operation of the strain gauge load cell depends upon the deflection of the column. When a force (or load) to be measured is applied to the supporting column as shown in Fig 4, the column is compressed causing the wires in the grids bonded to sides X1 and Y1 to decrease in length and increase in cross sectional area, thus decreasing their electrical resistance. The grids bonded to sides X2 and Y2 are virtually unaffected by the compression of the column. These grids are attached to the column to minimize errors due to temperature variations. When the column is stressed in tension, the measuring grid wires, (Strain gauges) are lengthened and their resistance is increased. The change in resistance of the strain gauges causes the Wheatstone bridge, which is directly proportional to the force (or load) applied to the column, to become unbalanced, thus providing a linear output voltage signal with respect to the force.

In Fig 3, the resistance Rmc is used to compensate for the temperature dependence of the modulus of elasticity of the load-sensing column, because any change in the modulus of elasticity will give a different strain and thus a different output signal, even though the force is the same. The resistance Rtc is used to compensate for the slightly different temperature coefficients of resistance of the four strain gauges. Sometimes two additional non-temperature-sensitive resisters Rss and Ris are used. The Rss is adjusted to standardize the sensitivity for a nominal input excitation to a desired value, and Ris used to adjust the input resistance to a desired value.

Advantages Following are the advantages of strain gauge load cells:

i They are small and compact in size.

ii They are well suited for measurements where an electrical output signal is desired.

iii They can measure upto the rated capacity, with deflections in the range 0.125 to 0.25

iv They respond rapidly to load variations.

v They are relatively maintenance free and, if hermetically sealed, may be installed in practically any environment.

vi They are inexpensive.

Strain gauge 4S7AGE

Pressure measurement using strain gauge: Strain gauge is a passive pressure transducer. The electrical resistance of the strain gauge element changes when it contracts or stretches.

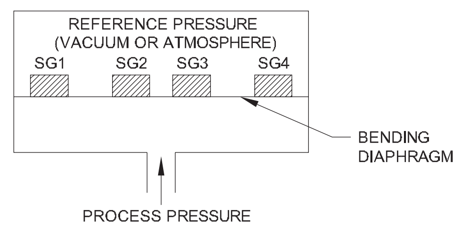
Principle

The measured process strain gauge If inserted through bellows or diaphragm, the strain gauge contracts or wakes up. This deformation causes its length and diameter to change, resulting in a change in electrical resistance Occurs. The voltage is obtained using a Wheatstone bridge. This output voltage is taken as a measure of pressure.

Construction

Four strain gauges SG1, SG2, SG3 and SG4 are attached to a flexible diaphragm as shown in Fig 4 SG2 and SG3 strain gauges are closely attached to the middle of the diaphragm. SG1 and SG4 strain gauges are attached to the diaphragm. A diaphragm placed in a closed chamber divides the chamber into two parts. A hole is provided on both sides of the chamber to give reference pressure and process pressure. Since the strain gauges are all placed in one place, the temperature changes affects all strain ganges equally.

Fig 4



DIAPHRAGM TYPE STRAIN GAUGE PRESSURE TRANSDUCER

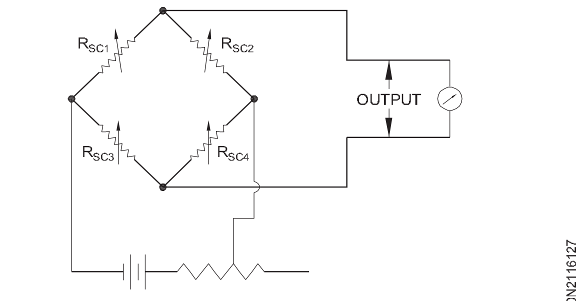
IM20N2116126

Working

When no pressure is applied, the diaphragm is in neutral position. So all resistances of wheatstone bridge are equal so bridge balance. Will be in position. As the process pressure is applied, the diaphragm flexes. This causes the strain gauges placed in the middle of the diaphragm to be compressed. Strain gauges placed on the edge also stretch. So the resistance of SG2 and SG3 strain gauges decreases and the resistance of SG1 and SG4 strain gauges increases and affects the balance of the bridge. Hence the current in the bridge circuit changes and the galvanometer deflects. The deflection of the galvanometer gives the output.

Used to measure pressure from 15 Kpa to 350 Mpa

Fig 5



STRAIN GAUGE BRIDGE CIRCUIT

Advantage

1 Small size easy to fit

2 Have good frequency response

3 No damage due to stray (External) magnetic field

4 Temperature commensalism not user.

5 High Stability and more

6 Over range capacity

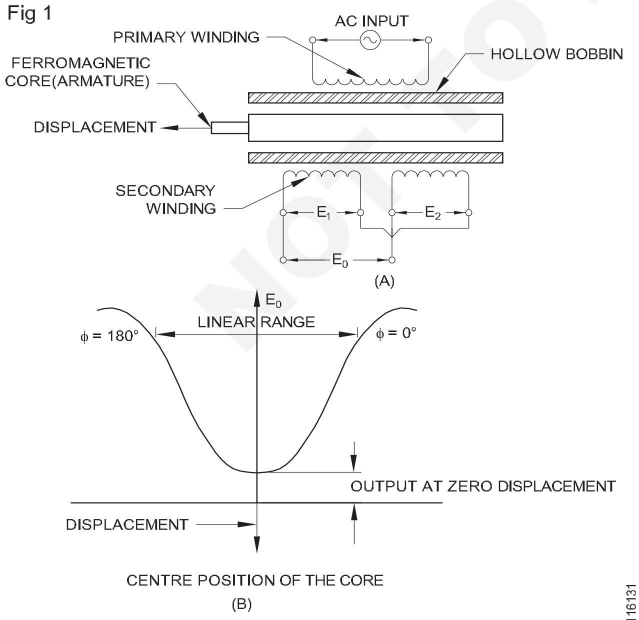
Measurement of Displacement

Objectives: At the end of this lesson you shall be able to
- **explain about LVDT**
- **explain about RVDT.**

Linear Variable-Differential Transformer (LVDT): It is the most widely used inductive transducer to translate linear motion into electrical signal.

Construction A differential transformer consists of a primary winding and two secondary windings. The windings are arranged concentrically and next to each other. They are wound over a hollow bobbin which is usually of a non-magnetic and insulating material, as shown in Fig 1. A ferromagnetic force core (armature) in the shape of a rod or cylinder is attached to the transducer sensing shaft. The core slides freely within the hollow portion of the bobbin. As a.c. excitation is applied across the primary winding and the movable core varies the coupling between it and the two secondary windings. When the core is in the centre position, the coupling to the secondary coils is equal. As the core moves away from the centre position, the coupling to one secondary becomes more and hence its output voltage increases, while the coupling and the output voltage of the other secondar windings are connected in series opposition as shown in Fig 1

Fig 1



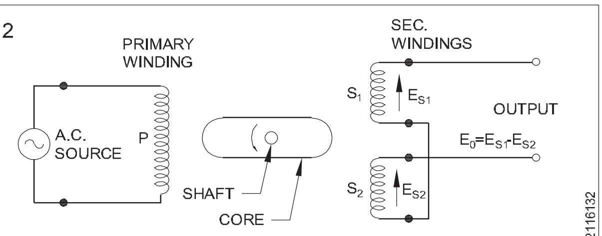
LVDT (A) SCHEMATIC DIAGRAM OF LVDT (B) VARIATION OF OUTPUT VOLTAGE WITH CORE BE POSITION

Working Any physical displacement of the core causes the voltage of one secondary winding to increase while simultaneously, reducing the voltage in the other secondary winding. The difference of the two voltages appears across the output terminals of the transducer and gives a measure of the physical position of the core and hence the displacement.

When the core is in the neutral or zero position, voltages induced in the secondary windings are equal and opposite and the net output is negligible. As the core is moved in one direction from the null position, the differential voltage, i.e. the difference of the secondary voltages, will increase while maintaining an in phase relationship with the voltages, will increase while maintain an inphse relationship with the voltage from the input source. In the other direction from the null position. The differential voltage will again increase but will be 180°.

And direction of movement of the core and hence of displacement may be determined. Variation of output voltage with core position is shown in Fig 2

Fig 2



ROTARY VARIABLE DIFFERENTIAL TRANSFORMER (RVDT)

Following are the advantages of LVDT:

i The output voltage of these transducers is practically linear for displacements upto 5mm.

ii They have infinite resolution.

iii These transducers possess a high sensitivity.

iv These transducers can usually tolerate a high degree of shock and vibration without any adverse effects.

v They are simple, light in weight, and easy to align and maintain.

vi These transducers have low hysteresis and hence repeatability is excellent under all conditions.

Disadvantages Following are the disadvantages of LVDT:

i Relatively large displacements are required for appreciable differential output.

RVDT: A variation of linear variable differential transformer (LVDT) may be used to sense angular displacement.

This is the Rotary Variable Differential Transformer (RVDT). The circuit of a RVDT is shown in fig . It is similar to the LVDT except that its core is cam shaped and may be rotated between the windings by means of a shaft.

The operation of a RVDT is similar to that of an LVDT. At the null position of the core, the output voltages of secondary windings S1 and S2 are equal and in opposition. Therefore, the net output is zero. Any angular displacement from the null position will result in a differential voltage output. The greater this angular displacement, the greater will be the differential output. Hence the response of the transducer is linear.

Clockwise rotation produces an increasing voltage of a secondary winding of one phase while counter clock-wise rotation produces an increasing voltage of opposite phase. Hence, the amount of angular displacement and it direction may be ascertained from the magnitude and phase of the output voltage of the transducer.

Rotary variable differential transformer (RVDT)

Advantages of RVDT: High Accuracy: RVDTs are known for their high precision and accuracy in measuring angular displacement. They can provide reliable and repeatable measurements, making them suitable for applications that require precise position sensing.

Wide Measurement Range: RVDTs can typically measure angular displacements ranging from a few degrees to several revolutions, depending on the specific model. This versatility allows them to be used in various applications with different angular motion requirements.

Good Linearity: RVDTs often exhibit excellent linearity, meaning the output is directly proportional to the input angular displacement. This linearity simplifies the calibration process and enhances measurement accuracy.

Rugged and Durable: RVDTs are constructed to withstand harsh environments, including high temperatures, vibrations, and mechanical shocks. They are often made from robust materials and designed to be resistant to dust, moisture, and other contaminants, making them suitable for demanding industrial applications.

Electrical Isolation: RVDTs provide electrical isolation between the input and output, ensuring that the measured signal is not affected by electrical noise or ground loops. This isolation helps maintain measurement accuracy and signal integrity.

Limitations of RVDT: RVDTs may have limited resolution compared to some other position sensors. The resolution is dependent on factors such as the number of windings and the overall design of the specific RVDT. If high-resolution measurements are required, other sensor technologies may be more suitable.

Relatively Large Size: RVDTs can be physically larger compared to some other types of position sensors. This can be a limitation when space is limited or when a compact design is necessary

Mechanical Wear: Like any mechanical device, RVDTs are subject to wear and tear over time, especially if exposed to extreme conditions or excessive use. Regular maintenance and calibration may be required to ensure accurate and reliable measurements.

Limited Angular Range: While RVDTs offer a wide measurement range, they may not be suitable for applications that require continuous rotation or very large angular displacements. In such cases, alternative sensing technologies, such as encoders, may be more appropriate. It's important to note that the specific advantages and limitations of an RVDT can vary depending on the manufacturer, model, and intended application. It is always recommended to consult the manufacturer's specifications and guidelines for accurate information regarding a particular RVDT sensor.

Measurement of motion

Objectives: At the end of this exercise you shall be able to
- **explain vibrometers & accelerometers**
- **explain different types of tachometer**
- **explain stroboscope & its applications.**

Motion

The action or process of motion or of changing place or position. Motion in described in term of displacement, distance, velum, acceleration time and speed

Velocity

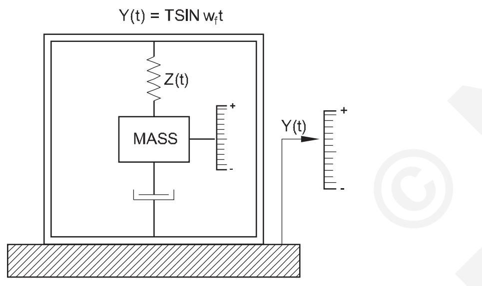
The rate of change of distance it is the rate of change of displacement speed of an object moving can never the negative. The velocity of a moving object can be zero.

Acceleration

Acceleration rate at which velocity changes with time, in terms of both speed and direction. A paint on an object moving in a straight line is accelerated.

Vibrometer (Fig 1)

Fig 1



In vibration analysis of mechanical system, it is required to measure the displacement. Velocity and acceleration component of system. An Instrument which used to measure three parameters is referred an vibration meaning instrument. The major required of a seismic instrument to indicate an output which represent an input such as the displacement amplitude, velocity or acceleration of vibrating system closed a possible. The frequency range of vibrometer depends upon several factor such as damping natural frequency etc.

Applications

The Instrument is used to record building vibration also used for measuring vibration of hug structure railway, bridges etc.

SEISMIC Accelerometer

A schematic diagram of a seismic transducer is shown in Fig 4 It is called a seismic accelerometer also. The mass is connected through a parallel spring and damper arrangement to a housing frame. The housing frame is connected to the source of vibrations whose characteristics are to be measured. The mass has the tendency to remain fixed in its spatial position so that the vibrational motion is registered as a relative displacement between mass and housing frame. This displacement is sensed and indicated by an appropriate transducer.

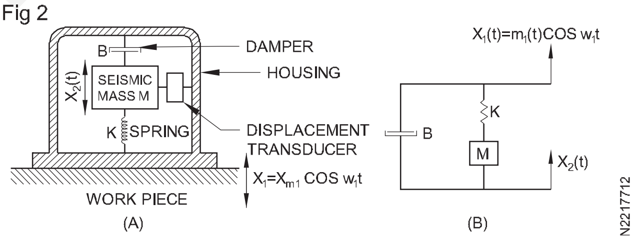
The seismic transducer may be used in two different modes:

- Displacement mode
- Acceleration mode.

The mode to be selected depends upon the proper selection of mass, spring and damper combinations. In general, a large mass and a soft spring are suited for displacement mode measurements, while a relatively small mass and a stiff spring are used for acceleration mode measurements.

A typical piezo-electric accelerometer is shown in Fig 2 The piezo- electric crystal is spring loaded with seismic mass in contact with the crystal. When subjected to an acceleration, the seismic mass stresses the crystal to a force F= Ma, resulting in a voltage generated across the crystal. The force generates an output voltage which is proportional to the acceleration.

Fig 2



PIEZO-ELECTRIC TYPE ACCELEROMETER

Salient Feature

Some of the features of piezo-electric accelerometers are:

i The instrument is quite small in size and has a small weight (Typically about 25X10-3 kg).

ii The natural frequency is very high. It may be as high as 100 kHz and therefore the accelerometer is useful for high frequency applications. They can be used for any vibration and shock applications.

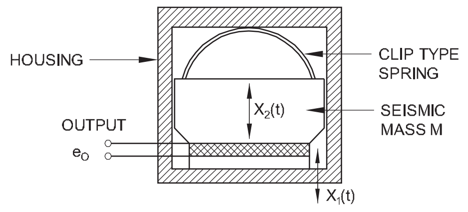
The primary elements of importance in shock measurements are that the device should have a natural frequency which is greater than 1 kHz and a range typically greater than 500g (i.e g = 9.81 m/s2). The only accelerometer that can usually satisfy these requirements is the piezo-electric type.

iii The crystal is a source with a high output impedance and in order to avoid loading effect, a voltage monitoring source of a high input impedance should be used.

Electrical impedance matching between transducer and readout circuitry is usually a critical matter requiring a very careful design consideration.

iv These accelerometers are useful for high input frequencies and their response is poor at low frequencies. Therefore, they should not be used for applications where the input frequency is lower than 10 Hz.

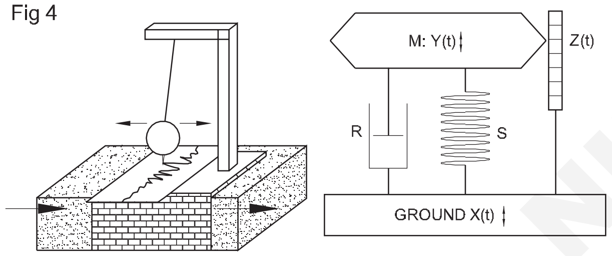
Fig 3



PIEZO-ELECTRIC TYPE ACCELEROMETER

Seismic Instrument (Fig 4)

Fig 4



SIMPLE SEISMOGRAPH

A simple seismometer, sensitive to up-down motions of the Earth, is like a weight hanging from a spring, both suspended from a frame that moves along with any motion detected. The relative motion between the weight (called the mass) and the frame provides a measurement of the vertical ground motion. A rotating drum is attached to the frame and a pen is attached to the weight, thus recording any ground motion in a seismogram.

Any movement from the ground moves the frame. The mass tends not to move because of its inertia, and by measuring the movement between the frame and the mass, the motion of the ground can be determined.

Early seismometers used optical levers or mechanical linkages to amplify the small motions involved, recording on soot-covered paper or photographic paper. Modern instruments use electronics. In some systems, the mass is held nearly motionless relative to the frame by an electronic negative feedback loop. The motion of the mass relative to the frame is measured, and the feedback loop applies a magnetic or electrostatic force to keep the mass nearly motionless. The voltage needed to produce this force is the output of the seismometer, which is recorded digitally.

Measurement of Speed

In industrial processes, speed as a variable refers to the revolutions per minute of some piece of rotating equipment. Speed is scalar quantity equal to the magnitude of velocity. There are various methods of measurement, of which tachometers are the most frequently used device. They are used for the measurement of angular speed, usually in revolutions per minute (rpm), although they can be calibrated in many other meaningful unit's dependents upon application, such as feet per minute, miles per hour, yards per minute, or even in terms of production units per unit time. There are two types of tachometers.

Mechanical tachometers employ only mechanical parts and mechanical movements for the measurement of speed. The three types of mechanical tachometers are:

i Revolution counters

ii Centrifugal-force tachometers

iii Resonance tachometers

Electrical tachometers consist of a transducer which converts the rotational speed into an electrical signal, coupled with a recorder or an indicator to indicate the measured value of speed. The electrical signal may be either an analog signal which can be used for analog indication, or pulses which can be digitally counted in terms of revolutions in a unit's time. Following are the different types of electrical tachometers:

i Eddy-current or magnetic drag-type tachometers

ii Electric generator tachometers, either a.c or d.c

iii Contactless tachometers

iv Frequency tachometers

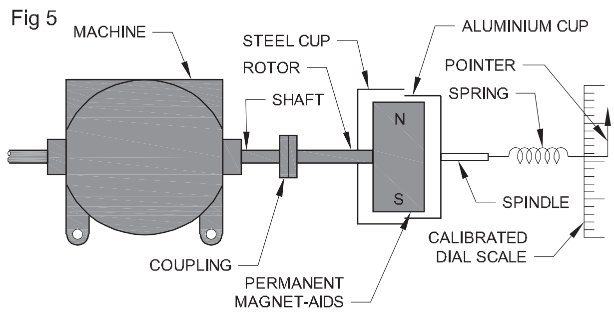
v Ignition-type tachometers

vi Stroboscopic tachometers

Some of the mechanical and electrical tachometers are described in detail.

Magnetic drag (or Eddy-current) Tachometer (Fig 5)

Fig 5



MAGNETIC-DRAG TYPE TACHOMETER

In the magnetic-drag type of tachometer, a transducer produces an analog signal in the form of a continuous drag due to eddy currents induced in an aluminum cup. The induced current is proportional to speed.

Construction and working

It consists of a rotor which is coupled to the rotor shaft of the machine whose speed is to be measured. A permanent magnet is attached to the rotor which rotates within an aluminum cup along with the rotor. A spindle is attached to the aluminum cup, to which a pointer is fixed a shown in Fig 5. A hairspring is fixed to the spindle, which provides necessary controlling torque. At no revolutions, it positions the pointer at zero on the calibrated scale.

As the magnet rotates within the aluminum cup along with the shaft of the machine, eddy currents are induced in the cup which result in a torque or drag that tends to turn (or deflect) the cup against the spring. The deflection of the cup is proportional to the induced emf, which in turn is proportional to the speed of the shaft. The deflection is indicated by the pointer which moves on a calibrated dial scale.

These types of tachometers are commonly used in automobiles which measure the angular speed of the wheel. In the case of the car wheel, the angular speed is converted into a linear speed in kilometers per hour (or miles per hour).

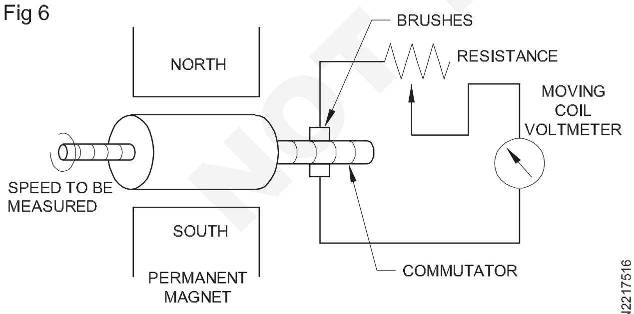
In some of the applications, such as in aircraft engines. Mechanical coupling of the magnet is replaced by an electric drive consisting of a three phase synchronous generator driven by the machine shaft under test, and connected

In other applications, such as for measuring locomotive speed, the permanent magnet is kept stationary and a soft-iron rotor produces a revolving magnetic field.

In industrial applications, the magnetic drag-disk torque is converted to a transmission signal by a pneumatic force balance system, the output pressure of which is directly proportional to the speed of rotation. In this case, speeds up to 12000 rpm can be measured.

D.C. Tachometer: It consists of a permanent magnet to provide the magnetic flux, an output winding placed on the rotor (known as armature), as shown in Fig 6.

Fig 6

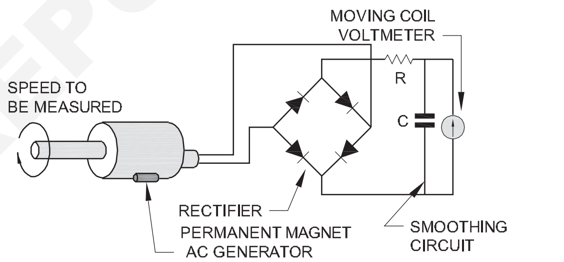


DC TACHOMETER GENERATOR

When the rotor is stationary, there is no relative motion between magnetic field and winding, and the output voltage is zero. As rotor speed increases, the relative motion between magnetic field and winding is sinusoidal and whose magnitude is proportional to the rotor speed. A commutator and brushes are fixed to the rotor to convert the a.c voltage in the windings to a d.c. output voltage, in the same manner as the d.c. generator. With this types of tachometer, speed in the range of 10 to 5000 rpm may measured

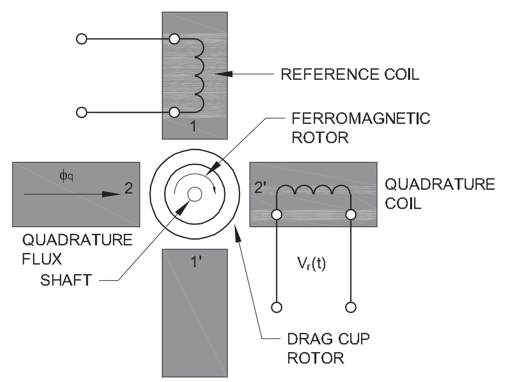
A.C Tachometer: It is similar to a two-phase induction motor. It consists of a primary winding that is placed mechanically at 90 to the secondary, and a rotor, as shown in Fig 7. When the rotor is stationary and the primary winding is excited by an a.c. input voltage, the induced voltage in the secondary is zero due to the relative positions of the two windings being placed 90 to each other. As the rotor is turned, a voltage is induced in the secondary winding whose magnitude is proportional to the rotor speed. Since the output signal is a voltage, a high input resistance is connected with the readout instrument to give the near-zero current flow in the secondary winding, as shown in Fig 8. Any current flow in the output winding will cause a voltage drop which will be subtracted from the true measured voltage and thus give the error in speed measurement. With this type of tachometer, speed in the range of 500 to 10000 rpm may measure.

Fig 7



A.C TACHOMETER GENERATOR

Fig 8



Difference between Tachometer and Speed meter

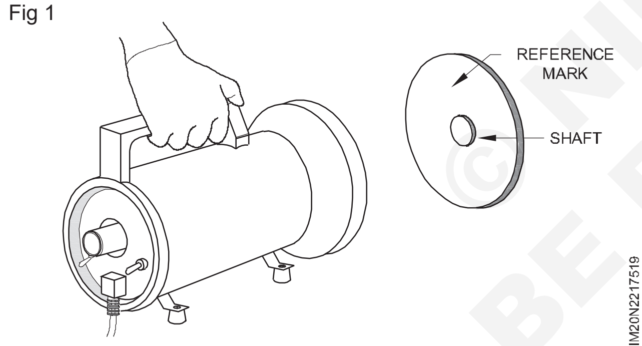
S.No	Tachometer	Speed meter
1	Tachometer measures speed of engine	Speed meter measure speed of vehicle
2	Unit of tachometer revolute Per minute (RPM)	Unit of speed measure is KM/hour or miles/hour
3	Tachometer measures Rotational Speed	Speed meter measure linear speed

Stroboscope

Stroboscope is an instrument that works on the phenomenon of stroboscopic effect. It creates a stop motion effect of a rotating object by flashing a high intensity light on it. This appearance of a moving object to be stationery can be used to study rotating. Oscillating (or) vibrating objects.

Hence a strobe scope instrument can be used for the measurement of rotational speed or rotary motion (rpm) of a motor or any rotating object. Rotational speed and ranging between 600 to 20000 rpm can be measured with the help of stroboscope. The variable frequency flashing light in strobe scope is called strobostron. (Fig 1)

Fig 1



A variable frequency oscillator is used to control the flashing frequency of the light. Measurement of the above figure shows the rotational speed using the stroboscope velocity of a shaft in order to measure the angular or any rotating body a disc with masking Is mounted to the rotating shaft (or) body whose angular velocity is to be measured. The stroboscope is adjusted such that the light flashes directly on the reference marking on the rotating body.

The frequency of these flashes is varied and adjusted by means of a frequency adjusted by means of a frequency adjustment know until the reference marks on the rotating disc appear to the stationary.

This occurs when the frequency of the flash lamp is equal to the speedo rotation of the reference marks found the disc and hence the shaft. Thus the frequency of the flashing light of a strobe scope gives the angular velocity (or) speed when calibrated in terms of speed.

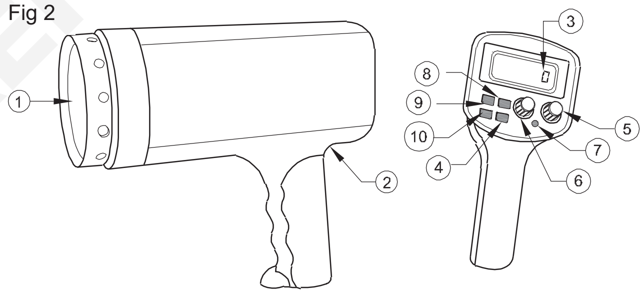
Applications:

1 It is a portable and manually operated device used to measure periodic (or rotary motions.

2 it is used to measure speed

3 it is very convenient to use for a spot check on machinery speed and for laboratory work. (Fig 2)

Fig 2



1 - FLASH TUBE (XENON LAMP)
2 - POWER SWTICH
3 - DISPLAY
4 - RANGE SWTICH
5 - COARSE (FLASHING RAT ADJUSTING KNOB)
6 - FINE (FLASHING RATE ADJUSTING KNOB)
7 - JACK FOR EXTERNAL TRIGGERING SIGNAL
8 - INTERNAL/EXTERNAL TRIGGERING BUTTON
9 - X2 BUTTON FOR FAST CHECK
10 - /2 BUTTON FOR FAST CHECK

Measurement of pressure

Objectives: At the end of this exercise you shall be able to
- **explain the principles of pressure in liquid and gases**
- **describe the pressure relation with volume density, specific gravity, temperature and liquid flow.**
- **describe the units of pressure and unit conversions**
- **explain the types of pressure**
- **explain barometer and types of manometers.**

Principles of pressure in liquid & gases Properties of matter. Am characteristic that can be measure such as an objects density mass volume, length , mallecbilim , hardness, temperature noise are considered properties of matter.

Principle of liquid applied perpendicular to the surface is the an object per unit area over which that force is distributed in the liquid of the vessel. The force used to calculated the pressure must act etc right angle to face this force is called pressure. It denotes the letter of P.

Properties of Pressure

1 The pressure in liquid increase with increase in depth

2 The pressure at a point increase with the density of the liquid

3 The pressure is same in all directions about a point in liquid at rest

4 Upward pressure at a point in a liquid is equal to downward pressure

Concept of pressure

Continuous physics force exerted on or against an object by something in contact with it.

Definition

Pressure is an expression of exerted on a surface per unit area i.e., the force applied is perpendicular to the surface of object per unit area.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{\text{Newton}}{\text{s.q.meter}} = p = \frac{F}{A} \text{N/M}^2$$

As the amount of gas increases assuming the volume of chamber and the temperature remain constant the pressure increases.

Unit: Standard unit and also the S.I. unit of pressure is pascal (Pa) and Metric unit of pressure is bar.

1 Pascal is defined as a force of one newton per square meter.

i. e. 1 Pascal = 1 N/m^2

1 Bar = 105 N/m^2

Pressure units in different systems

British unit FPS	Pounds per square inch	lb./in2
Metric units CGS	Gram per square centimeter	g/cm2
MKS	Kilogram per square metre	Kg/m2
International	Newton per square metre Circuit SI	N/m2

Pascal, s Law

A French scientist, Pascal stated that the pressure applied at any points liquid, at the rest is transmitted equally in all directions. This is known as Pascal law

Applications of Pascal s law

Pascal s law is applied in many devices like the siphon, hydraulic press, hydraulic lift, brahma press, air compressor, rotary pump and hydraulic brake. These hydraulic machines are based on the principle of transmission of pressure in liquids.

Volume of a solid volume: It is measure of the amount of space that a substance or a diesel takes up. The basic SI unit of a volume is the cubic water (cm3), but smaller volumes may be measured in (cm3) , and liquids way be measured in liters (2) or milliners

$$\text{Volume} = \text{Massdensity}$$

The Formula for calculating value

Volume of a liquid

A submerged object displaces a volume of liquid equal to the volume of the objects one millitre of water has a volume of 1 cm3 cubic millimeter)

Volume of a gas

The volume of a gas is defined as the space occupied by the gaseous particles at standard temperature and pressure conditions. It is denoted as , v, the SI unit of volume is liters denoted as L. a mole of gas has a volume of 24m3 (or) 2400 cm3 at rooms temperature.

Density and specific gravity

Density is defined as mass per unit volume. It has the SI unit kg m-3 or kg/m3 and is an absolute quantity .

Specific gravity is the ratio of a materials, s density with that of water at 4° c

It is therefore a relative quantity with no units.

Factors affecting liquid pressure

Properties of gases

1 Charle's law

First law or law of volume

At the constant pressure the volume (V) of a given mass of gas is directly proportional its absolute temperature (T)

$$v \alpha T : \frac{V}{T} = K(\text{KConstant})$$

Second law or law of pressure

At constant volume the pressure (P) of given mass of gas is directly propportional to its absolute temperature (T)

$$p \alpha t : \frac{p}{T} = K(K - \text{constant})$$

2 Boyle 's gas equation

At constant temperature the volume (V) Of a given mass of gas is inversely proportional to its pressure. (P)

$$V \quad \alpha \quad \frac{1}{p} ;\ PV = K(K - \text{constant})$$

3 Perfect gas equation

Since boyle's law and charle's law can be not be applied independently due to changes in changes in pressure , volume and temperature a combined law called ' gas equation' has been formulated . Gas equation is relating to pressure, volume and temperature of perfect gas which obeys both the boyle 's law and charle 's law. A gas which obeys boyle 's and charle 's law is called ideal gas.

As per boyle 's law

$$V \alpha \frac{1}{p} \qquad P v = k(\text{constant}) P_1V_1 = P_2V_2 = K$$

As per cahrle 's law

$$V \alpha T \qquad \frac{V}{T} = K(\text{Constant}) \frac{v_1`}{T_1} = \frac{V_2}{T_2} = K$$

Combining the above two laws,

$$\frac{p_1V_1}{T_1} = \frac{P_2V_2}{T_2} = R(R = \text{gasConstant})$$

$$\frac{PV}{T} = r$$

If mass of the gas is m, then

$$PV = RT$$

$$P = \text{Pressure}(KN/m^2)$$

$$V = \text{Volume}(m^3)$$

$$m = \text{Mass(kg)}$$

$$R = \text{gasconstant(kgf.m/kg/k)}$$

$$T = \text{absolutetemperture(K)}$$

Gas constant R= 29. 27kgf.m/kg/k

= 287 joule /kg /k

True gas and its properties

1 It has mass and volume. So, it has weight

2 It can be compressed or expanded into a container

3 It is invisible.

4 General gas law

Boyle 's Charles 's and gay- lussac 's laws can be combined to obtain the general law is given by

$$\frac{PV}{T} = \text{Constant(o r)}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3} = \dots\dots\dots \frac{P_nV_n}{T_n}$$

In the perfect gas law, the P and T represents absolute pressure and absolute temperature (in °K) respectively).

Pressure relationship

Atmospheric pressure: The air surrounding the earth exerts a pressure on the earth's surface. The pressure prevelling directly on the earth's surface is known as atmospheric pressure.

F=Q/T

Unit of pressure

Pressure may be measured in either british (fps). Or Metric (also called In british units. Pressure is measured in pounds (of force) per square area). In metric (or SI) units, it is measured in newtons (of force) Per sq of area).

(a) High Pressure

1 Newton per square metre (1N/m2) = One pascal (1pa)

1 atmospheric pressure (1 atm) = 14.696. psi = 101.325k pa)

(b) Low Pressure

1 millibar = 100 duyne /cm2 = 14.5x 10 -3 psi

1 micron = 10 -6 Hg = 19.34x10-6 psi

1 torr = 1mm Hg = 1000 microns = 19.34x10-3 psi

(c) Vaccum Pressure

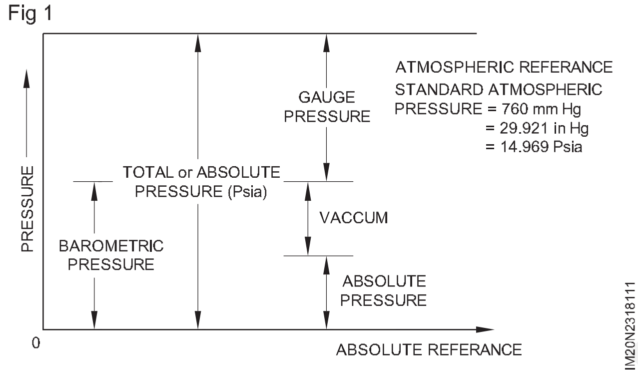
Units : mm Hg , cm Hg

1n H20 mm water column

Pressure Conservation Table

To Convert from	To Torr	Multiply by
mm Hg		1
Inches Hg		25.4
Inches of water		1.87
Feet of water		22.39
Atmospheres		760
Psia		51.7
Kilopascal		7.5
Microns		0.001
To Convert to	From Torr	Divided by

Fig 1



Pressure Relationship

Atmosphereric pressure: The air surrounding the earth exerts a pressure on the earth 's surface. The pressure prevailing directly on the earth's surface is known as atmospheric pressure, as shown in Fig 1.

The atmosphere pressure is also referred to as reference pressure. Normally it considers the sea level as its reference points.

The atmosphere pressure may be calculated from the fundamental principle a barometer which states that the barometer reads pressure due to the height of mercury (Hg) in the tube and is weight.

Atmospheric pressure = p g h

Where (rho) p= Density of Hg = 13600 kg/m3

g = Acceleration due to gravity = 9.81 m/s2

and

h = height of Hg column = 760 mm of Hg at Normal sea level

Substituting the above valves in equation, we get

Atmospheric pressure = 13660x 9.81.0.76

= 1,01,396 M/m2

= 1,013 bar

But for easy and simple calculation, we take the atmosphere pressure as 1 bar.

1 **Absolute pressure:** absolute pressure is defined as the pressure which is measured with reference in absolute vacuum pressure.

2 **Gauge pressure:** it is defined as the pressure which is measured with the help of a pressure measuring instrument in which the atmosphere pressure is taken a datum. The atmosphere pressure on the scale is marked a zero

3 **vacuum Pressure:** It is defined as the pressure below the atmospheric pressure.

Mathematically:

I.Absolute pressure = Atmosphere pressure + gauge Pressure

$$P_{ab} = P_{atm} + p_g$$

IIAbsolute pressure = Atmosphere pressure – vacuum pressure

$$P_{ab} = P_{atm} - P_{vacc}$$

IIIVacuum pressure = Atmospheric pressure – absolute Pressure

1 Atmospheric Pressure = 76 cm of mercury = 33.91 ft of

= 76x 13.6gm/cm2

= 76x 13.6x 10-3 kg. /cm2

= 76x 13.6x 10 -3 x 9.8 N/cm2

= 10.13 bar

= 1013 mbar (1 bar = 1000 m bar)

1 Pascal = 1 n/m2

1 bar = 105 Pascal = 105 = 10 n/cm2

1 bar = 0.986923 atmosphere

1 millibar = 0.01 n/cm2 = 10-2 N/cm2

1 atmosphere pressure (FPS) = 14.7 pound / inch2 (psi)

1 atmosphere pressure (Metric) = 1.0336 kg /cm2

1 atmosphere pressure (Metric) = 1.014 x 106 dyne/ cm2

Effects of altitude on atmospheric pressure

Atmospheric pressure changes according to altitude a tabulation is shown here with variations.

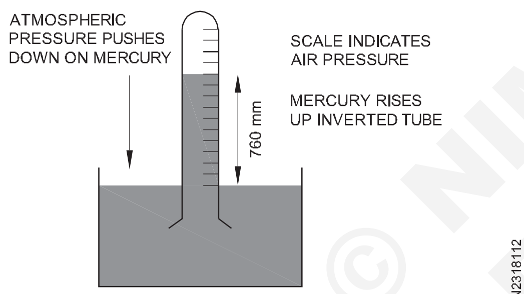
For every 11 meter above sea level drop in air pressure is shown 1.3m bar

For every 100 ft above sea level drop in air pressure is 1"Hg (mecrcury)

S.No.	Place	Unit of pressure	Mercury column	Inch units
1	Sea level	1013 m bar	750mm	14.7psi
2	520 metres above sea level	951.5.m bar	700 mm	13.7 psi

Since manometers inherently measure the pressure difference between the two ends of the liquid column, if one end is at zero absolute pressure, then the difference in height of the liquid from the zero reference indicates the absolute pressure. This is the principle of the barometer, as shown in Fig 2 Its readings are generally in millimeters of mercury (mm Hg). With a barometer, high vacuums are not measured.

Fig 2



BAROMETER

Applications

1It is the simple method to measure

2It is used to measure the atmospheric pressure.

Aneroid Barometer

It is an instrument used for measuring atmospheric pressure. As is name suggesting, it is liquid less barometer unlike fortins barometer.

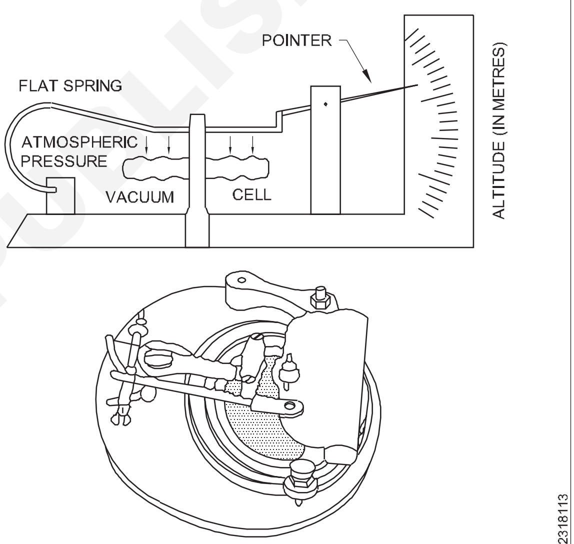
In this type a completely evacuated pressure capsule is linked to a pointer mechanism.

As atmosphere pressure changes the capsule expands or compressed, then the motion of the capsule is transmitted through a link and lever (having a high multiplication factor) to a pointer which indicates over a scale.

This scale is calibrated in terms of atmospheric pressure in absolute units (above absolute zero pressure in the capsule) or in terms of height above sea – level in meters or feet. : The pressure of atmospheric is balanced by a spring.

For measurement of altitude Aneroid barometer is calibrated to read zero altitude (height) at sea – level. Now the maximum atmospheric pressure acts on the evacuated capsule. As this barometer is taken higher and higher the atmospheric pressure decreases and the pointer moves to indicates the altitude as shown in Fig 3.

Fig 3



ANEROID BAROMETER

Range

Used to measure atmospheric pressure below or above the sea level i.e 760 mm of Hg.

Uses

- Altitude measurement in aircrafts.
- Household or laboratory use for atmospheric pressure measurement.
- Absolute pressure measurement.

Material (capsule)

Phosphor – bronze

Berryllium – copper

Manometers

The manometers are the simplest measuring instrument used for gauge pressure (low – range pressure) measurements, by balancing the pressure against the weight of a column of liquid. The action of all manometers depends on the effects of pressure exerted by a fluid at a depth. The different types of manometers are discussed below Pressure in simple words is described as the physical force exerted on an object.

In this article, let us learn how fluid pressure is measured with respect to earth 's atmosphere using a device known as a manometer.

Fluid pressure is given by the following equation:

P= pgh

Where,

P is the fluid pressure

ρ is the density of the fluid

g is the acceleration due to gravity

h is the depth

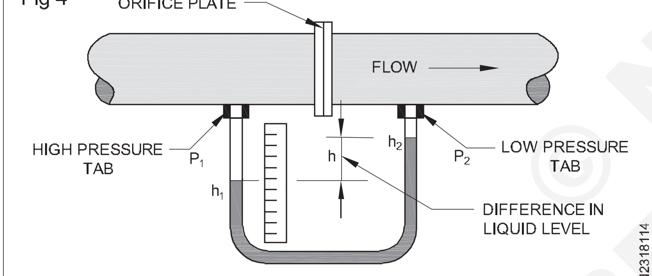
Manometer and classification of manometers

Manometer is a device that measures the fluid pressure. Based on various criteria, manometers are classified into different types. They are:

1 U- tube Manometer (Figs 4 & 5)

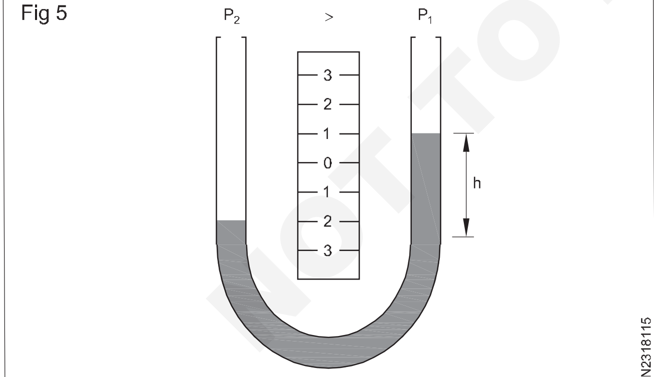
2 Enlarged leg Manometer

Fig 4



U - TUBE MANOMETER

Fig 5



U - TUBE MANOMETER

3 Well type Manometer (Fig 6)

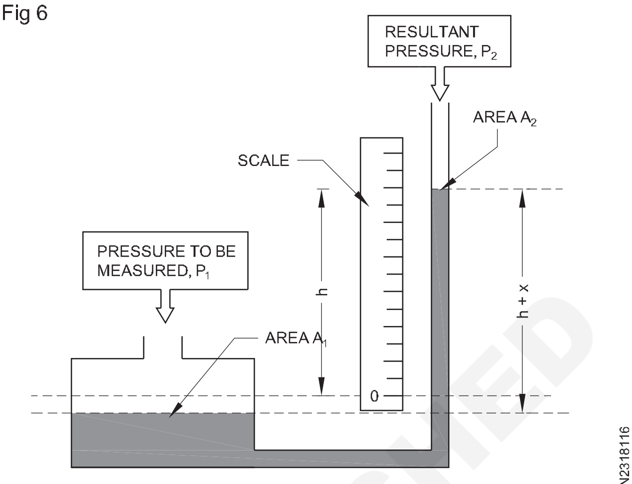
4 Inclined tube Manometer (Fig 7)

U- tube Manometer Principle

The principle of the manometer is that the pressure to be measured is applied to side of the tube producing a movement of liquid, as shown in figure above. It can be seen that the level of the filling liquid in the leg where the pressure is applied, i.e. the left leg of the tube, has dropped, while that in the right hand leg as risen. A scale is fitted between the tubes to enable us to measure this

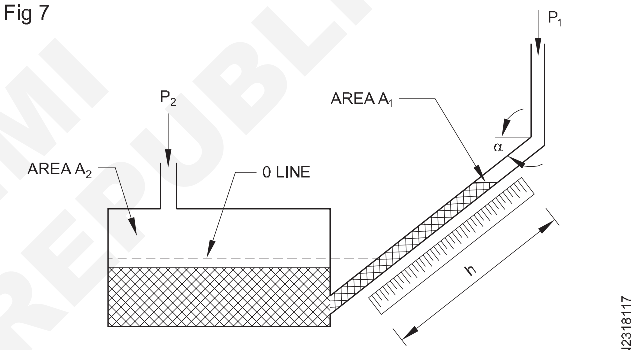
The Applied Pressure = P x g x h

Fig 6



WELL TYPE MANOMETER

Fig 7



INCLINED TUBE MANOMETER

Construction: It consist of a transparent (glass) tube constructed in the form if an elongated U and is partially filled with a liquid, most commonly water or mercury. Water and mercury are used because their specific weights for various temperatures are known exactly and they do not stick to the tube. One end of the tube is connected to one pressure tap and the other end is connected to the other pressure tap, or it may be left open to the atmosphere. The U - tube manometer is known in fig 1

Working: When there is a pressure difference between the two ends of the tube, the liquid level goes down on one side to the other indicates the difference in pressure. From Fig. 12.2 the differential pressure ($P_1 - P_2$) is obtained by the relation:

$$(P_1 - P_2) = (\rho - \rho_1)(h_1 - h_2)\,g$$

$$P = (\rho - \rho_1)\,gh$$

Where ρ = density of fluid in U – tube

ρ_1 = density of fluid whose pressure is being measured h = ($h_1 - h_2$) , difference in fluid levels

g = acceleration due to gravity

When a manometer is used to measure low pressures then water is used as the liquid, and when it is used to measure high pressures then mercury is used as the liquid , Mercury is almost 14 times as heavy as water. Therefore, the difference in levels in a mercury – filled manometer is about 1/14 what it would be if water were in the tube.

Well Type Manometer

Well – type manometer is a variation of the U – tube manometer in which one of the leg is replaced by a large meter well as shown in Fig 6. The purpose of this is to the variation of level in the well of negligible magni as compared to that in the tube. The head can be then as compared to that in the tube. The head can then has directly on a single (along the tube) instead ding the two readings as in the U- tube manometer the different pressure can be calculated, as below.

$$P_1 = (1 + \frac{A_1}{A_2})\ hxd$$

Inclined type manometer

The inclined tube manometer or slant manometer is an enlarged leg manometer with its measuring leg inclined to the vertical axis by some angle. The angle of inclination is of the order of 10n is of the order of 10° The inclination is done to expand the scale and thereby to increase the sensitivity.

The inclined manometer is used to measure very small pressure difference (in hundredth of an inch of water). The manometer is tipped so that the liquid moves distance through the tube as it rises. In Fig 7 an inclined manometer is shown. The distance y that the liquid moves through the tube greater than the distance x that the liquid.

Where:

P2 = Pressure applied to the large diameter / high pressure

P1 = Pressure applied to small diameter (low pressure)

A2 = Area of the well

A1 = Area of the tube

D = Density of manometer liquid.

H = Head of the manometer liquid.

Sensitivity

If the area of the well is 500 or more times larger than the area of the vertical leg, then the error in neglecting the area term is negligible. This gives the manometer its sensitivity.

The head relation for a properly designed well – manometer is then P2 – P1 = h x d,

When the vertical scale is placed so as read zero when pressure differential is zero. Negative pressure (vacuum) relative to atmospheric pressure can be measured by connecting the tube to the vacuum source and keeping the well open to atmosphere.

The areas of both the limbs can be changed to provide for change of ranges.

Range – 159 mm to 3000 mm of liquid

Use

a Used to measure the high pressure

b Used to calibrate the high pressure instruments like standard gauge etc.

Application of manometer

1 It is used to measure the pressure of the fluids using mechanical properties of fluids.

2 It is used to measure vacuum.

3 It is used to used to measure leaks in pipelines

4 It is used to for calibration of motor.

5 It is used to measured liquid level present in a tank.

6 It is used to measured differential pressure.

Pressure sensing elements

Objectives: At the end of this exercise you shall be able to
- **explain pressure sensing elements**
- **explain types, materials and use of board on the tube pressure gauges.**
- **explain the types and use of pressure switches.**

Elastic pressure transducers

This type of pressure transducers uses elastic primary sensing elements such as the bourdon tube, bellows and diaphragm.

Bourdon tube: Bourdon tube acts as the primary sensing element. It senses the input quantity (Pressure) there are three types of bourdon tube.

1 'C' type

2 'Spiral' type

3 'Helical' type

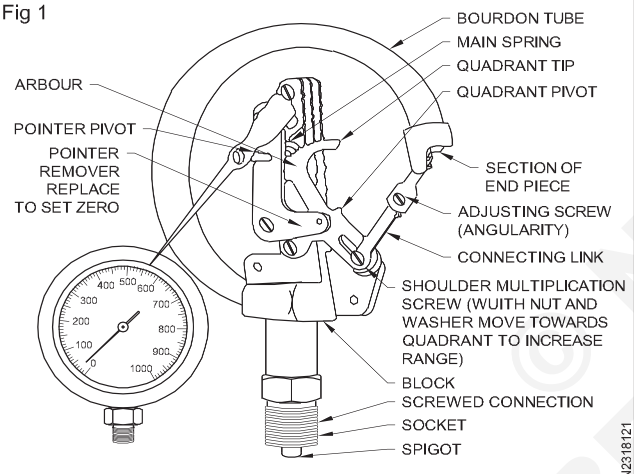
Type Bourdon Tube Pressure Gauge

Objectives: At the end of this exercise you shall be able to
- **explain the work principle of 'C' type bourdon – Tube pressure gauge.**
- **state the specifications of p 'c' type bourdon gauge.**
- **state the uses of 'c'**
- **explain precautions in its use.**

Most commonly used types of pressure gauge is the on tube pressure gauge because of its simplicity versatility.

Bourdon tube pressure gauge consist of a thin walled oval section bent in a circular arc. It is supported brass socket. The free end of the tube is sealed called as tip. The tip is connected by a link to the which operates a pointer and the other end of is open for the application of the pressure to be. The internal pressure tends to straighten out. The resultant movement of the free end of the use the sector gears the sector through the link in the lock wise direction. The pointer, which is fixed on shaft moves in the clockwise over a in scale as shown in Fig 1.

Fig 1



BOURDON TUBE PRESSURE GAUGE

Chosen for the tube depends upon the nature of and the thickness of material depends on range.

Common errors and adjustment of errors

Bourdon tube pressure gauge

Zero error

Gauge shown wrong reading at zero of the scale or error is equal at all major divisions it is called zero error example the 0 – 5 kg/cm^2 and 3 kg/ cm^2 1.2 kg/ cm^2, 2kg/ cm^2 to 2.2 kg/ cm^2 and 3 kg/ cm^2 32kg/ cm^2 etc. It shows 0.2 kg/ cm^2 more which is due zero error.

The zero error can be adjusted by taking out the pointer and refaxing at one major division at zero. It means shifting its position with respect to pinion.

Multiplication error

If the error is goes on increasing it is said to be multiplication error. For example if the gauge is 0.5 kg/ cm^2 .

For 1 kg/ cm^2 it shows 1.2 kg/ cm^2 , for 2 kg/ cm^2 it shows 2.3 kg/ cm^2 and for 3 kg/ cm^2 it shows 3.4 kg/ cm^2. The error is goes on increasing at each point. In bourdon tube pressure gauge the actual travel of the pointer is non - linear and parallel due to compound stresses developed in it. However for a small travel of the tip this can be considered to be linear and parallel to the axis of the link. The small linear tip movement is matched with a rotational pointer movement . This is known as 'Multiplication' and can be adjusted by adjusting the length of the lever. Decreasing the lever length increases the range.

Angularity error

If the error in increasing or decreasing after the mid scale it is known as angularity error. When the linear motion of the tip is converted to a circular motion with a link, lever and pinion attachment a one to one correspondence between them may not occur and a distortion results. This is known as 'Angularity' and can be adjusted by adjusting link length. Increasing the link length increases the reading which is directly proportional.

Backlash error

This error is due to wear and tear pinion and sector teeths. When the reading of the gauge do not match for decreasing and increasing pressure this error is called backlash or hypothesis error. It can be eliminated by adjusting hair spring.

Material

Tube: Phosphor, Bronze, Beryllium copper brass and steel alloy

Sector & pinion: Bronze, stainless steel, PVC & Teflon hair spring :Phosphor bronze

Spiral type Bourdon 's Tube Pressure Gauge

Objectives: At the end of this exercise you shall be able to
- **explain the working principle of spiral type bourdon gauge**
- **state the specifications of spiral bourdon gauge**
- **state the use of spiral bourdon gauge.**

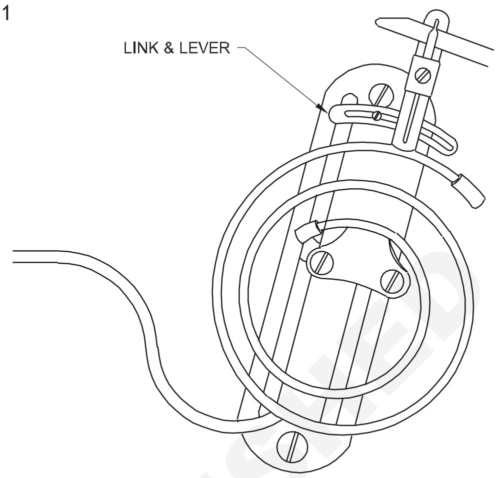
The linear tip movement of 'C' type bourdon tube is about 4 mm (max.mm). When have utilize this linear movement for the circular movement (270°) of the pointer over the scale. This is done by the using various links. Sector gear and pinion. These are liable to create zero, multiplication and angularity errors. By increasing the number of turns (of 270°sections) as in spiral and helical bourdon tubes, an enlarged movement of the free end of the tube is obtained and the need for further magnifying movement is avoided. In this way, the need for sectors and pinions are avoided. Thus, the backlash error of gears (Worn – out due to vibration and constant use) is also eliminated.

The tip movement in a spiral bourdon tube will be the sum of the tip movements of all the 270° sections of 'C" tube that the spiral tube consists of. Thus the magnified movement can be directly used for indicating. It is shown in Fig 1.

Materials used for a construction of spiral bourdon tube

Phosphor bronze, Beryllium Copper, Brass etc

Fig 1



SPIRAL TYPE BOURDON'S GAUGE

Uses

- Indicating instruments
- Recording instruments
- Pressure Transducers

Helical Type Bourdon 's Tube Pressure Gauge

Objectives: At the end of this exercise you shall be able to
- **explain the Construction and working of helical type bourdon gauge**
- **state the specifications of helical type bourdon gauge**
- **state the uses spiral bourdon gauge**
- **state the advantage and limitations of helical type bourdon gauge.**

Introduction

The helical sensor produces an even greater motion of the free end than spiral element.

Construction

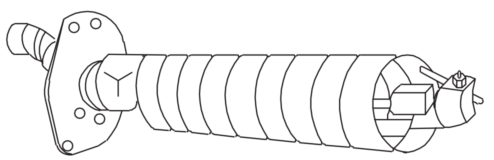
The Fig 1 shows the construction of helical button gauge.

Helical bourdon tube is essentially series of 'C" type bourdon tubes joined end of end each at different place one after the other. The materials commonly used for making helical bourdon tube are bronze berrylium copper nickel alloy stainless step 1 etc.

Working

When pressure is applied this helical tends to uncoil and produces greater movement of the free end requiring no mechanical amplification. This increases the sensitivity and accuracy of the instrument.

Fig 1



HELIX

Uses

It is used to measure fluid pressure with good accuracy. It is used to measure pressure ranging from 0 – 200 Kpa up to 0 to 550 M.Pa. Helical coils can also used as the element in different pressure sensors if one of the pressure is acting on the outside surface and the other on the inside of the coil. Helical element are mainly used in transmitters and records with pneumatic or electronic equipment.

Advantages

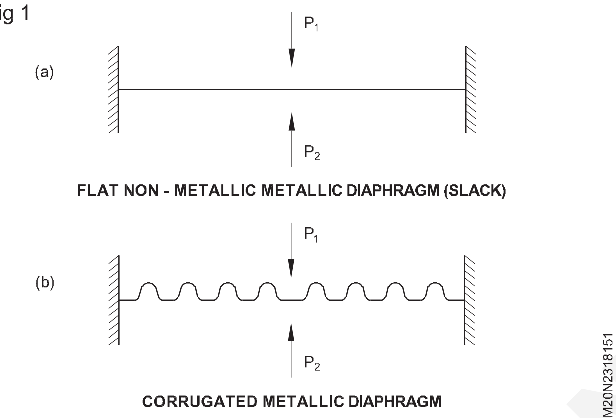
It does not require any magnification unit. It can be used for pressure measurement on continuously fluctuating services.

Diaphragm Gauge

Objectives: At the end of this exercise you shall be able to
- **explain the working principle of diaphragm gauge and its sensitivity**
- **state the specifications of diaphragm gauge**
- **state the uses of diaphragm gauge**
- **state the use of liquid seal.**

The motion of the diaphragm can be transferred by a suitable linkage to make it an indicating device to measure pressure. The diaphragms can be in the form of flat: corrugated, or dish plates and the choice depends on the strength and amount of deflection desired. In high precision instruments the diaphragms are generally used in pairs, front and back, to form an elastic capsule. Two classes of diaphragm are – (1) slack or non – metallic diaphragm. Fig 1 a & b

Fig 1



Slack diaphragms are made from rubber, Teflon, leather, impregnated cloth, neoprene, the metallic diaphragm, pressure element employs a thin flexible diaphragm, made from material like brass, bronze, flexible diaphragm made from material like brass, bronze SS. The force of the pressure against the effective area of the diaphragm causes a deflection of the diaphragm. The motion of the diaphragm operates an indicating or recording type instrument. Diaphragm gauges are very widely used in measuring instruments.

The construction of non- metallic (slack) diaphragm and metallic diaphragm and metallic diaphragm (Spring) gauges are shown Fig 2 & 3.

Ranges

1 Metallic (corrugated) 10mm of water to 3.5 kg/cm2

2 Non – metallic – vacuum to 250 of water gauge.

Uses

1 Non – metallic diaphragm gauges are used for draft gauges- indicating , recording and controlling instruments.

2 Metallic diaphragm gauges are used for low and high pressure gauges and liquid seals.

Fig 2

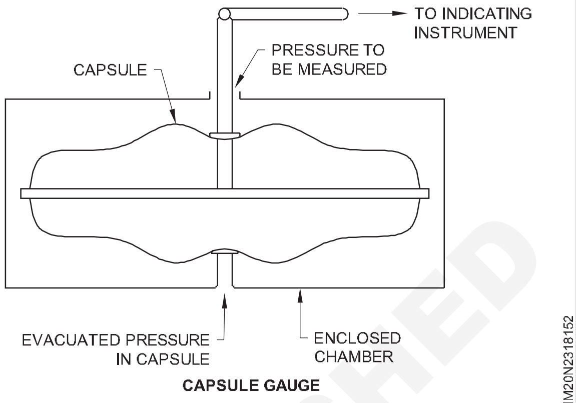
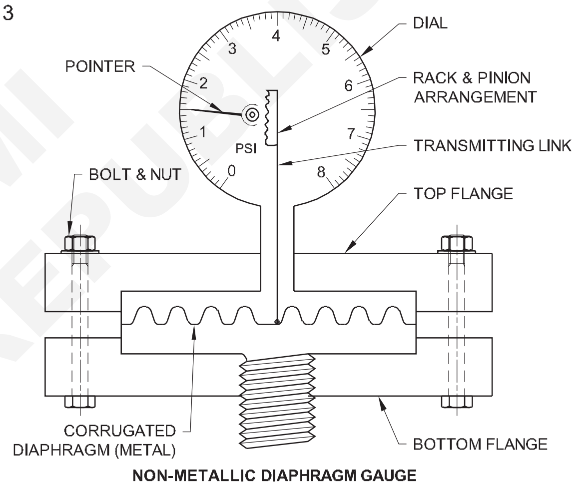
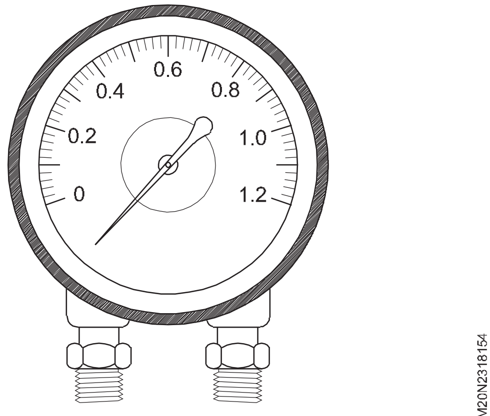


Fig 3



Different type pressure gauge (Fig 4)

Fig 4



Different pressure gauges is an object that acts as an essential visual indicator of the difference of pressure between two pressure points of one pipe system. Most commonly, differential pressure gauges are used within industrial process systems, such as those installed in chemical plants, petrochemical plants, power plants and refineries. Different pressure gauges have many uses, including but not limited to liquid flow, liquid levels, and efficiency of filtration. You should be careful not to confuse differential pressure.

- In Fig – 5 is the construction of differential pressure gauge.
- In this case two infects are represented as pressure P, and pressure P2
- One end is connected with high pressure and another end is connected with low pressure and it is measured the different pressure.
- The applications of differential pressure gauge is given in Fig 6 and 7

Fig 5

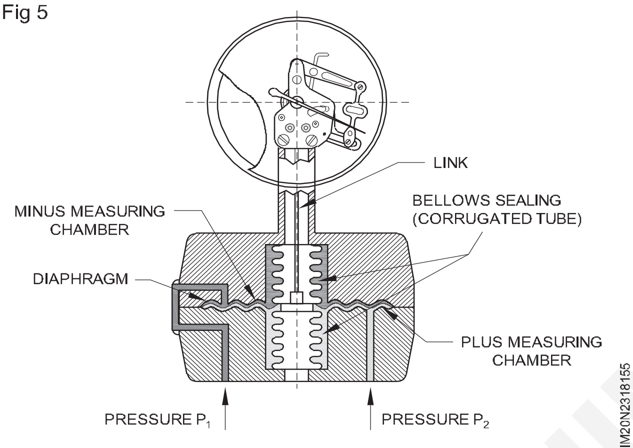


Fig 6

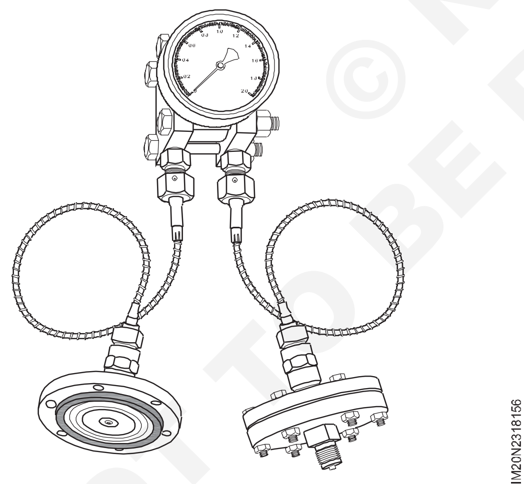
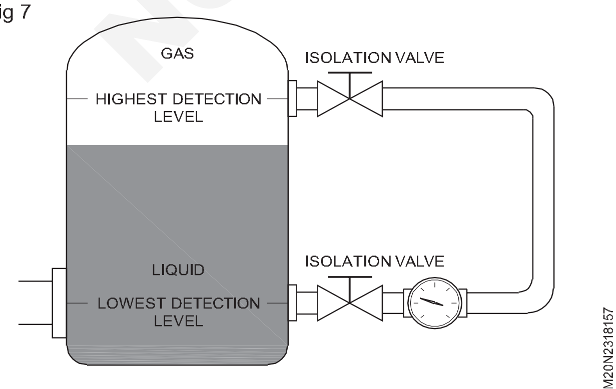


Fig 7



Different pressure gauges, on the other hand, are more effective at reading liquid level within a tank because they read two different points simultaneously. Not only this, but different pressure gauges specifically measure the difference in gas pressure compared to overall pressure, which allows users to translate the results into a reading of a true liquid level.

Differential pressure inflow

The flow of pressure inside a pipe is of equal importance. Again, differential pressure gauges are critical in determining such inflow rates before and after a diameter- reducing item is inserted. The items that could be used to reduce the diameter of a pipe include orifice plates, flow nozzles, or ventures.

Bellows pressure gauge

The bellows are made of an alloy which is ductile, has high strength and retains its properties over long use i,e. has very little hysteresis effect. They are used in two forms, In one arrangement, pressure is applied to one side of the bellows and the resulting deflection is counter balance by a spring as shown in Fig 8. This arrangement indicates the gauge pressure.

In another differential arrangement, the differential pressure is also indicated. In this device, one pressure is applied to the inside of one sealed bellow while the other pressure is applied to the inside of another sealed bellow, as shown in Fig 9. by suitable linkage and calibration of the scale, the pressure difference is indicated by a pointer on the scale.

Spring – opposed bellow elements as shown in (Fig 8) are very sensitive and are quite useful in working signaling, ad tripping devices because of the considerable amount of movement for a given change in pressure . It is made of a metallic bellows enclosed in a shell which is connected to pressure source. Pressure acting on the outside of the bellows compress the bellows and moves its free end against the opposing force of the spring .A rod resting on the bellows transmits the motion to pointer. Phosphor bronze is the commonly used material for bellows and the springs are of carefully heat treated metal.

For larger static pressures (up to 2000 psig) and larger differential pressures (up to 50 psi) , bellows of differential gauges are extensively used.

Advantages:

1 It is the simplest structure

2 It is adaptable for absolute and differential pressure

3 It is good in the low to – moderate pressure range.

Disadvantages Following are the disadvantages of bellows:

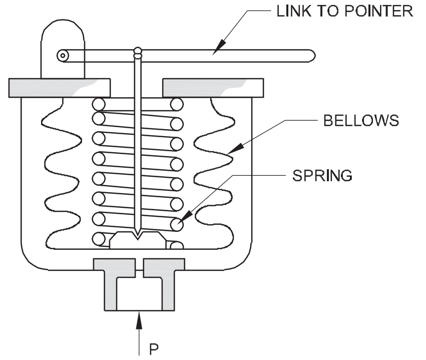
1 It needs ambient temperature compensation

2 It is unsuitable for high pressures.

3 The availability of metals and work – hardening of some of them is limited.

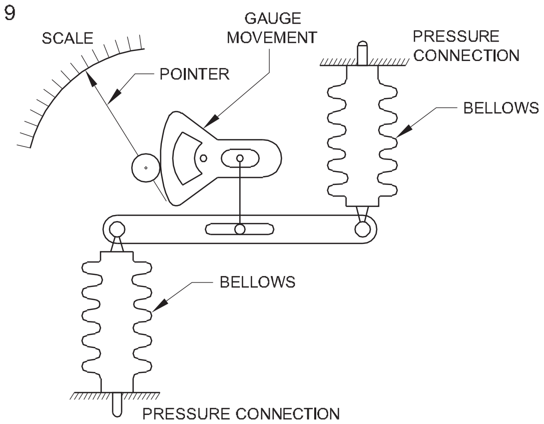
4 It is unsuitable for zero and the stiffness (Therefore, it is used only in conjuction with (in parallel with) a reliable spring a appreciably higher stiffness for accurate characterization).

Fig 8



BELLOWS PRESSURE ELEMENT

Fig 9



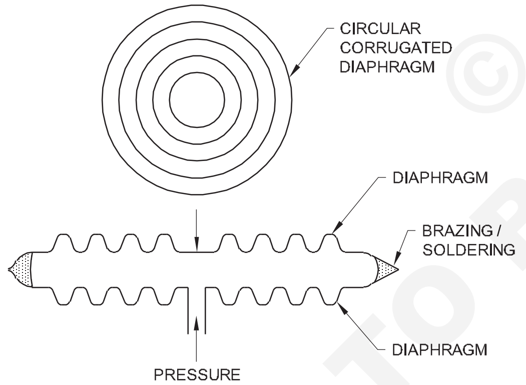
DIFFERENTIAL BELLOWS GUAGE

Capsule gauge

Objectives: At the end of this exercise you shall be able to
- **explain the working principles of capsule gauge and its sensitivity**
- **state the specifications of capsule gauge.**
- **state uses of capsule gauge.**

Two circular diaphragms are brazed or soldered together to form a capsule. These capsules may be used as single or stacked depending on the pressure range to be measured. (Fig 1)

Fig 1



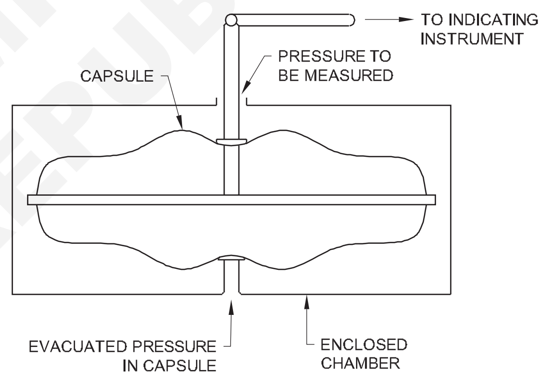
CAPSULE

The deflection of a pressure capsule depends on

- Range of the capsule varies as the fourth power of the diameter
- Thickness of the materials
- Elasticity of the material
- Design of the capsule (shape and number of corrugations)

In capsules deflection and pressure relationship is linear. The capsules should be made of a material which will maintain its accuracy after long use. Phosphor bronze capsules should not be used, where chemical corrosion and wide temperature variations are expected. The construction of capsule gauge is shown in Fig 2.

Fig 2



CAPSULE GAUGE

Materials

Phosphor – bronze, stainless steel, Ni – SPAN C (nickel alloy)

Ranges

- Phosphor bronze capsules – 0 to 125 mm water to 0 to 2 kg/ cm^2
- Stainless steel capsules – 0 to 200 mm water to 0 to 3.5 kg/ cm^2
- Ni – SPANC capsules – 0 to 100 mm of water to 0 to 2 kg/ cm2

Uses

- Low pressure measurement
- Differential pressure measurement
- Photoshor bronze- for general application
- Stainless steel - for corrosive applicaition
- Ni SPANC - for temperature variations from 10°C to 65 °C

Materials used for variations applications

Standard materials used for pressure gauge stainless steel (or copper alloy)

Ceramic and metallic diaphragms are used for pressure gauges

Bellow pressure gauge generally made of stainless steel, Inconel , brass, beryl ling copper , or phosphor bronge, stainless steel is a preferred choice for its corrosion resistant properties.

C- Type Bourdon tube pressure gauge

Advantage and disadvantages of bourdon tube pressure gauges.

Advantages

1 The results of the bourdon tube is accurate

2 Simple in construction.

3 Cost is law

4 Easy to install

5 High repeatability

Disadvantages

1 They are subjected to hysteresis

2 Sensitive to shocks and vibrations

3 Not a precision instrument

4 Speed of response is less.

Pressure switch

A pressure switch is a form of switch that operates an electrical contact. When a certain set fluid pressure has been reached on its input. The switch may be designed to make contact either on pressure raise or pressure fail.

Main parts of the pressure switch shown in Fig 4

1 Switching element

2 Set point adjusting nut

3 Calibrating scale

4 Piston assembly

5 Pressure range spring

6 O' ring seal

7 Diaphragm

8 Pressure parts

Types of pressure switches (Fig 3)

1 Electro mechanical switch

2 Diaphragm switch

3 Bourdon tube switch

4 Diaphragm piston switch

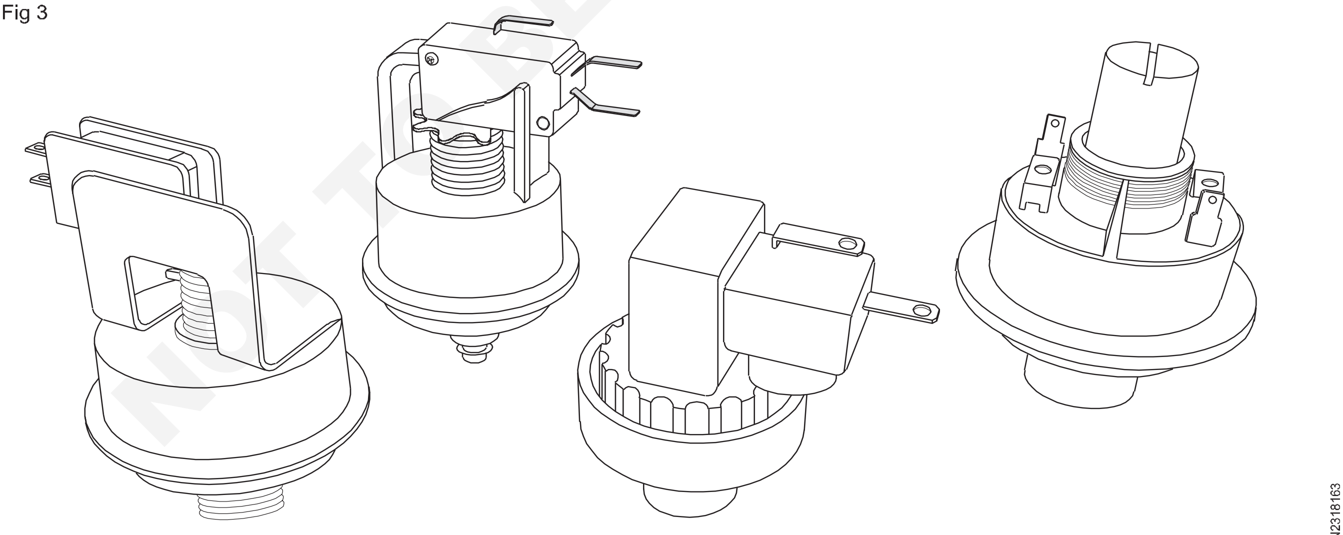
5 Piston switch

6 Solid state pressure switch

Uses

- Low Pressures measurement
- Differential pressure measurement
- Phosphor bronze – for general application
- Stainless steel – for corrosive application
- Ni – SPANC – for temperature variations from 10° C to 65°C.

Fig 3

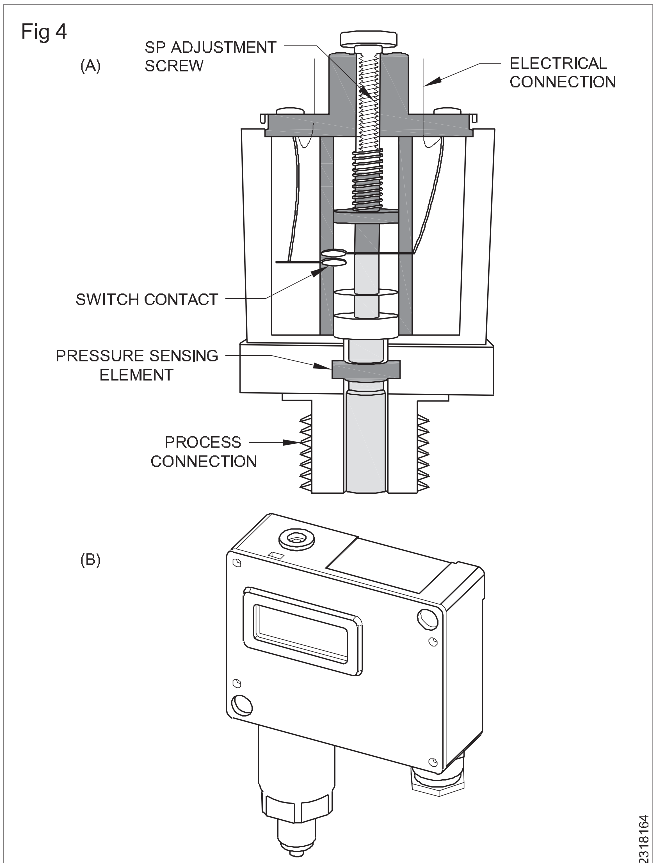


PRESSURE SWITCHES

Working principle

A typical switch has a piston with one side subjected to the fluid pressure. The other side is usually in atmosphere pressure. The force exerted by the fluid pressure is countered by force from a preloaded spring. The surface area in contact with the fluid and the spring constant is carefully designed so that the piston only moves when a certain pressure is reached. The spring is pre – compressed by the set point screw. The set point screw is adjusted to set the activated pressure higher or lower.

Fig 4

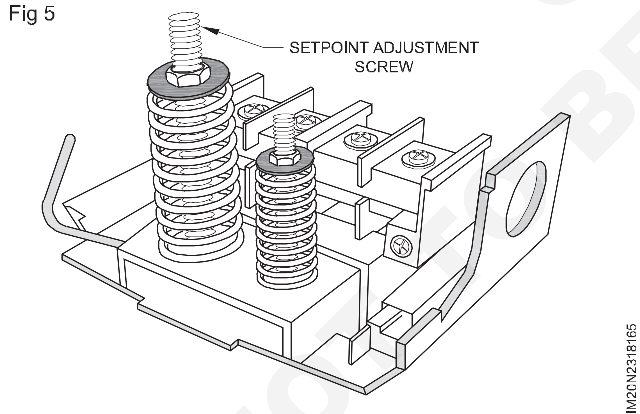


PARTS OF A PRESSURE SWITCH

Set point adjustment screw

Integrated with the spring is the set point adjustment screw. The set point adjustment screw is used to increases or decrease the activation pressure. (Fig 5)

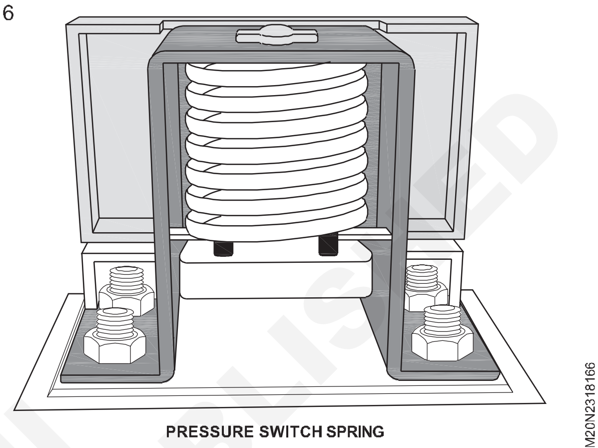
Fig 5



Pressure sensing element:

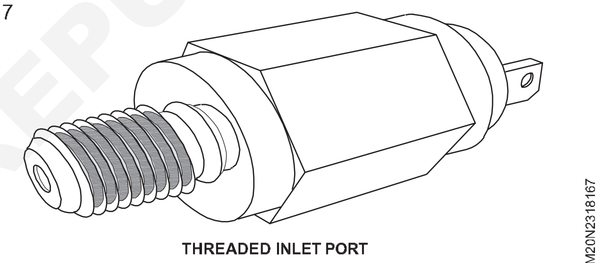
Mechanical pressure switches are classified according to their pressure sensing element .This is the main part of the switch that mechanically actuates the switch from the pressure of the fluid. The area of the piston or diaphragm on the fluid side is designed to transfer sufficient force from the expected fluid pressure. The larger the area. The larger the actuating force and spring force required , Note that only a small force is needed to actuate the switch . much of the pressure is countered by the spring. (Figs 6, 7 & 8)

Fig 6



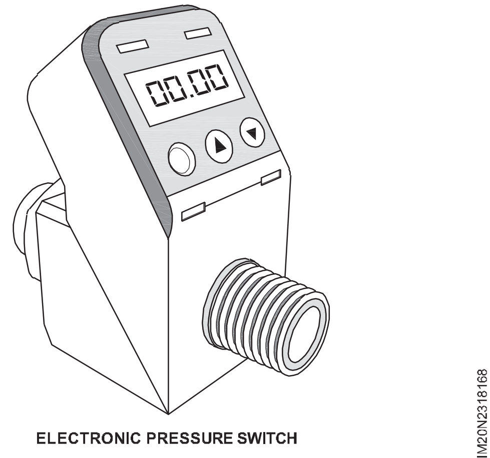
PRESSURE SWITCH SPRING

Fig 7



THREADED INLET PORT

Fig 8



ELECTRONIC PRESSURE SWITCH

Electrical Pressure Transducers

Objectives: At the end of this exercise you shall be able to
- **explain the electrical pressure transducers and the method of conversation**
- **explain the strain gauge pressure transducers**
- **explain the piezo electric pressure transducers**

Electrical Pressure transducers

A transducer is a device which converts one form of energy into another from of energy 'However, in the filed of electrical instrumentation, 'a transducer is defined as a device which converts a physical quantity , a physical condition, or mechanical output into an electrical Signal'

Most of the methods of converting mechanical output into an electrical signal work equally well for the below, the diaphragm and the bourdon tube.

In this conversion, a Mechanical motion is first converted is converted into a change in electrical resistance and then the change is resistance is converted into a change in electrical current or voltage.

Generally ,an electrical pressure transducer consists of three elements:

1 Pressure sensing element such as a below, a diaphragm or a bourdon tube.

2 Primary conversion element, e,g. resistance or a voltage.

3 Secondary conversion element

Following are the different types of commonly used electrical pressure transducers.

Types of electrical pressure transducers.

1 Capacitive pressure transduced

2 Potention metric pressure transduced

3 Reluctance servo pressure transducer

4 Strain gauge pressure transducer

5 Piezo electric pressure transducer

6 Different pressure transducer.

Capacitive pressure transducers

Basic principle: The principle of operation of capacitive pressure transducers is based upon the familiar capacitance equation of the parallel plate capacitor i.e

$$c = \frac{E_0 E_r A}{d} \text{ Farad}$$

Where, C = the capacitance of a capacitor in farad

A = area of each plate in m2

d = distance between the two plates in m

E0 = 8.854 x 10 -1^2 farad /m^2

Er = dielectric constant (relative per miltivity)

Thus, capacitance of a capacitor varies when

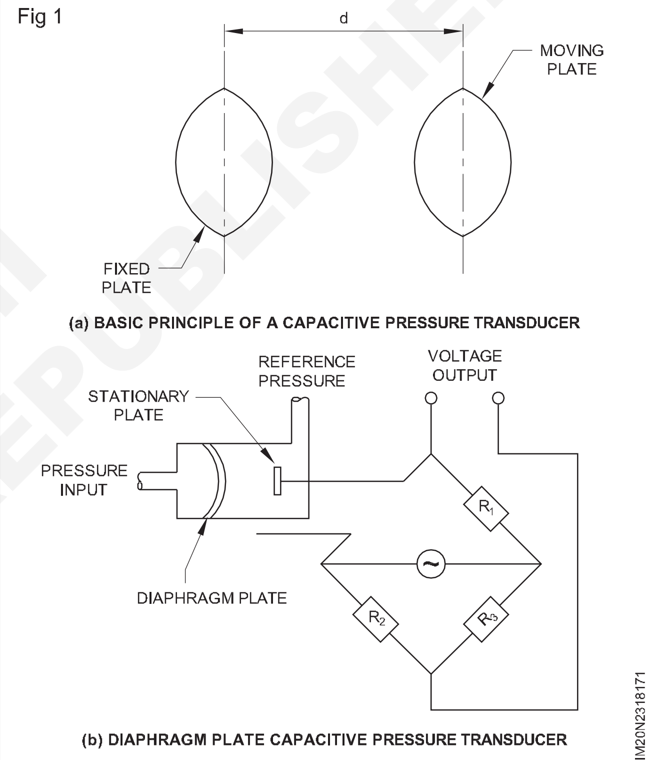
The area A of the plate is changed

The distance d between the two plates is changed

The dielectric constant E , is changed now, from the above, equation, the capacitance of a parallel plate capacitor is inversely proportional to the spacing between

Capacitive pressure transducer (Fig 1)

Fig 1



(a) BASIC PRINCIPLE OF A CAPACITIVE PRESSURE TRANSDUCER

(b) DIAPHRAGM PLATE CAPACITIVE PRESSURE TRANSDUCER

Construction and working : It consists of a fixed plate and a movable plate which is free to move as the pressure applied changes . According to the changes in pressure the movable plate also changes its position, due to which the distance d is changed with increase in pressure, the distance d becomes less, due to which the capacitance C is inversly proportional to d. C is Increased with decrease in pressure, the distance d increase and thus capacitance C is decreased this change in capacitance can be calibrated to measured the change in pressure.

In place of a movable plate a diaphragm may be used as shown in Fig 1 which expands and contracts due tom change in pressure. The diaphragm plate acts as a movable plate of a capacitor. A fixed plate is replaced near the diaphragm. These plates form a parallel plate capacitor which is connected as one of the arms of a bridge , as shown in Fig 1.Any change in pressure causes a change in distance between the diaphragm and fixed plate, which unbalances the bridge. The voltage output of the bridge corresponds to the pressure applied to the diaphragm plate.

Advantages

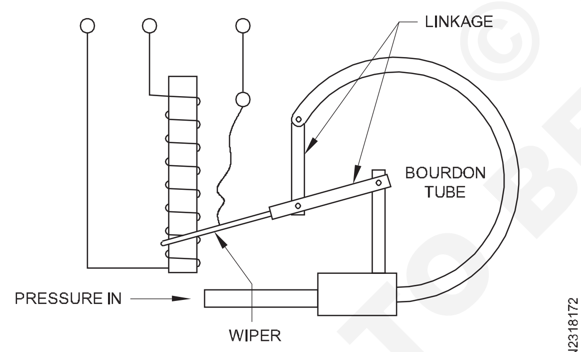
- It gives rapid response to changes in pressure. Response time as short as ten milli seconds are possible.
- It can withstand a lot of variation and shock ,as in a hard landings by an unmanned space craft on the surface of a planet.
- It is extremely sensitive.
- It is has good frequency response . it can measure both static and dynamic changes.

Disadvantage

- The metallic part of the capacitor must be insulated from each other. In general , the frames must be earthed.
- The performance of a capacitive transducer is severely affected by changes in temperature.
- The sensitivity of a capacitance transducer is adversely affected by changes in temperature.
- Errors may be caused by erratic and distorted signals.

Potentiometric pressure transducers (Fig 2)

Fig 2



POTENTIOMETRIC PRESSURE TRANSDUCER

This type of pressure , there is a potentiometer (basically a variable resistance) which is made by winding resistance wire around an insulated cylinder. A moveable electrical contact, called a wiper, sides along the cylinder , touching the wire at one point on each turn. The position of the wiper determines how much wire, and therefore, how much resistance , is between the end of the wire and the wiper. A mechanical linkage from the pressure sensing element (such as bellows , a diaphragm ,and the bourdon tube) controls the position of the wiper on the potentiometer. Some potentiometers are made curved so that the wiper can pivot in circular motion rather than moving along a straight 0line. The position of the wiper determines the resistance of the potentiometer , which in turn determines the pressure Fig shows a diagram of a potentiometric pressure transducer in which the sensing element is a bourdon tube. An increase in pressure makes the bourdon tube straighten out partially. This motion causes the linkage to move the wiper across the winding on the potentiometer, As the wiper moves, it increases the resistance between terminals A and C, which is equivalent to the pressure sensed by the bourdon tube.

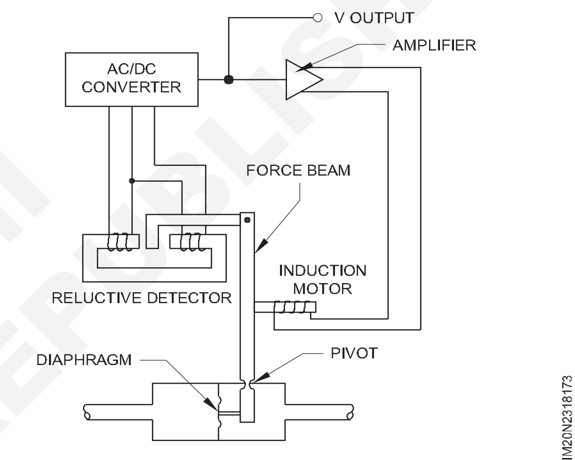
Advantages

Potentiometric pressure transducers are widely used in industry for the following reasons.

- The resistance can be easily converted into a standard voltage or current reasons.
- These pressure transducers are simpler and less expensive than other type of transducers.
- They are easy to design to meet special requirements in specific applications.

Servo pressure transducers (Fig 3)

Fig 3



Servo pressure transducers: A servo pressure transducer is also called a 'force balance pressure transducer'. It producers an electrical signal proportional to the pressure. The principle of the servo pressure transducer is used in many industrial differential pressure cells. Figure shows the construction of a servo pressure transducer

Working principle: An increase in pressure P1 over P2 (Fig1) flexes the diameter phragm and moves the short end of the force beam pivots, and the long and end moves a magnetic materials in the reluctive detector. The signal from the reluctive detector is converted from a.c power, and sent to an amplifier. The amplifier responds by activating an inductive motor that moves the force beam back towards its original position. Very little flexing ever occurs in the diaphragm, even over the entire range of the instrument .As a result, the diaphragm lasts a long time.

Servo pressure transducers are available in a multitude of pressure ranges. The devices are generally used for measurement of pressure below 500 psi.

They do not respond to high frequency ocillations.

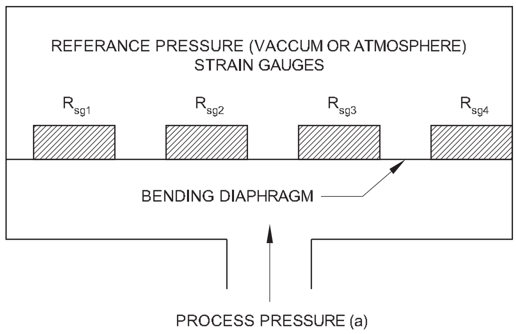
Other servo pressure instrument use capacitive detectors, and some use a bourdon tube as the sensing element.

Construction and working

Strain gauge is a passive resistance transducer whose electrical resistance changes when it is stretched to a pressure sensing diaphragm.

Basic principle: the strain gauge is a fine wire which changes its resistance when mechanically strained, due to physical effects. A strain gauge may be attached to the diaphragm so that when the diaphragm flexes due to the process pressure applied on it, the strain gauge stretches or compresses. This deformation of the strain gauge causes the variation in its length and cross – sectional area due to which its resistance also changes, as shown in Fig 4

Fig 4



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Construction and working: Figure shows a bridge circuit with four strain gauges , R_{sg1} ,R_{sg2}, R_{sg3}, R_{sg4} . Two strain gauges, R_{sg1} , Rsg4 are mounted so that increasing pressure increases their resistance . Strain gauges R_{sg2} and R_{sg3}, , are mounted so that increasing pressure decrease their resistance . A change in temperature affects all the four strain gauges in the same way, resulting in no change in the pressure indication.

a Strain gauge transducer with diaphragm element

b Strain gauge bridge circuit (Fig 5)

At balance, when is no pressure , no current flows through the galvanometer G, and hence there will be no deflection in the galvanometer. As soon as the pressure is applied, the strain gauge stretches or compresses accordingly and the bridge circuit is unbalanced due to the change in resistance of the strain gauges. Thus , current flows in the galvanometer , which is measured by the deflection of a the galvanometer. These changes affect the output of the bridge circuit, which indicates a change in measured pressure . Now , this change in output voltage may be calibrated for the pressure change.

Advantages

Following are the advantage of strain gauge pressure transducers.

1 They are small and easy to install

2 They have good accuracy

3 They are available for wide range of measurements (from vacuum to 200,000 psig).

4 They possess good stability.

5 They have high output signal strength.

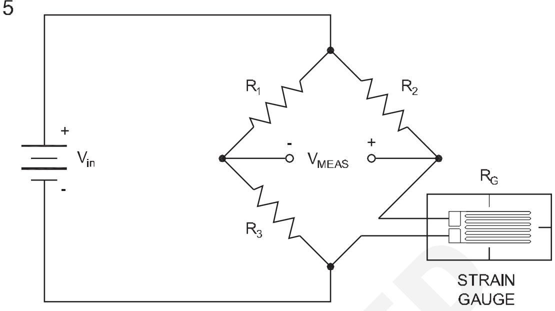
6 They have high over rage capacity.

7 They are simple to maintain.

8 They contain no moving parts.

Strain gauge bridge circuit (Fig 5)

Fig 5



STRAIN GAUGE BRIDGE CIRCUIT

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Disadvantages

Following are the disadvantages of strain gauge pressure transducers:

1 Their cost is moderate to high (could be offset by reduced installation costs).

2 Electrical readout is necessary in these transducers.

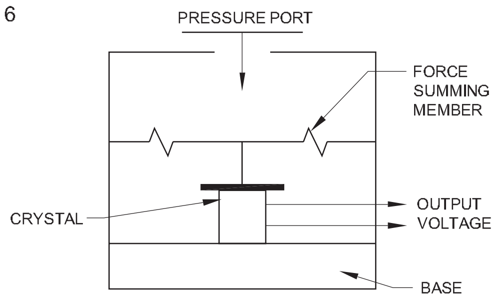
3 They require constant voltage supply.

4 They require temperature compensation due to problems presented by temperature variations.

Piezo electric pressure transducer (Fig 6)

Devices until the piezo electric characteristics of crystalline and ceramic materials (such as quartz) rate an electrical signal.

Fig 6



PIEZO - ELECTRIC TRANSDUCER

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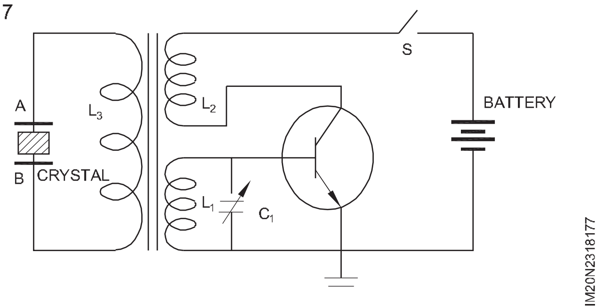
Principle : such transducers depend upon the principle when pressure is applied on piezo electric crystal such as (quartz), an electrical charge is generated are about 40 crystalline materials that, when subject to squeeze generate an electric charge some of piezo electric materials are barium titanate sintered crystal of quartz tourmaline, and Rochelle salts, lead titanate etc a piezo electric pressure transducer.

Construction and working : It consists of a diaphragm by which pressure is transmitted to the piezo electric crystal. Y 1 This crystal generates an electrical signal which is amplifier . A second piezo electric crystal y 2 is included to compensate for any acceleration of the device during use. This

Fig 7

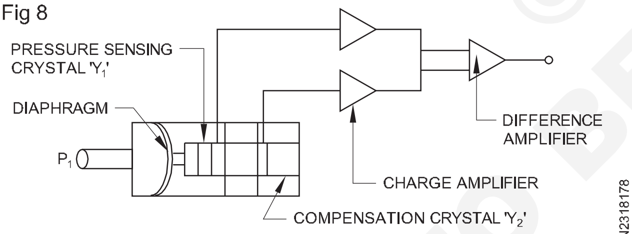


compensation is needed because rapid acceleration of the transducer creates additional pressure on the piezo electrical crystal . Vibration is a major source of high rapidly changing acceleration.

Signals from the compensation crystal, are amplified by a second charge amplifier. A different amplifier is used which subtracts pressure alone, all effects of acceleration are removed.

Piezo electric pressure transducers (Fig 8) are used to measured very high pressures that change very rapidly. For example , the pressure inside the cylinder of a gas thousands of pounds per square inch. Similar pressure changes occur in compressors, rocket motors, etc. It is impossible for ordinary pressure transducers to measure such great pressure changes over such short time periods. They do not respond fast enough. But piezo electric materials produce an electrical voltage when, they are squeezed suddenly. The voltage disappears when the pressure stops changing.

Fig 8



PIEZOELECTRIC PRESSURE TRANSDUCER

Piezo electric pressure transducers may be used to measure over ranges up to 0-50,000 psi. however, piezo electric transducers cannot measure steady pressures . They respond only to changing pressures.

Advantages

The advantages of piezoelectric pressure transducers are:

1 The transducer needs no external power and is therefore transducers self – generating (active type)

2 It has a very good high – frequency response.

Disadvantages

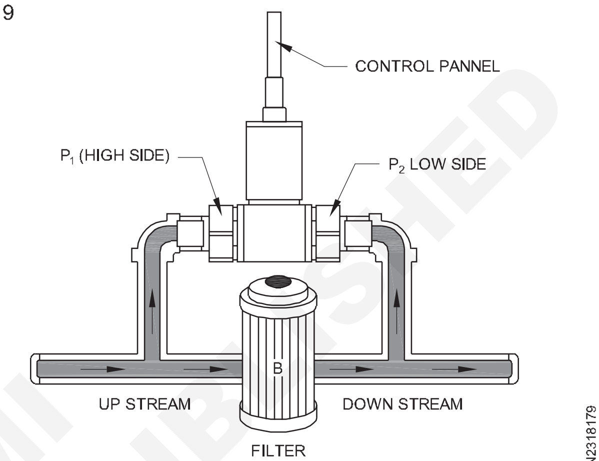
The disadvantage of piezoelectric pressure transducers are:

1 This type of transducer cannot measure static pressures.

2 The output of the traducer in affected by changes in temperature them fore temperature compensatory derives have to be used.

Differential pressure transducers (Fig 9)

Fig 9



DIFFERENTIAL PRESSURE TRANSDUCERS

1 Different pressure transducers measure the difference in pressure between two points, typically refined to as P 1 P 2 or high side to low side.

2 A differential pressure transducer is a great choice the continuously monitoring the condition of a fitter within a system.

3 By using a differential pressure transducers, an operator has a live view via the pressure transducers output signal, of the condition of the fitter.

4 This eliminates the need to repeatability shutdown the system for inspection.

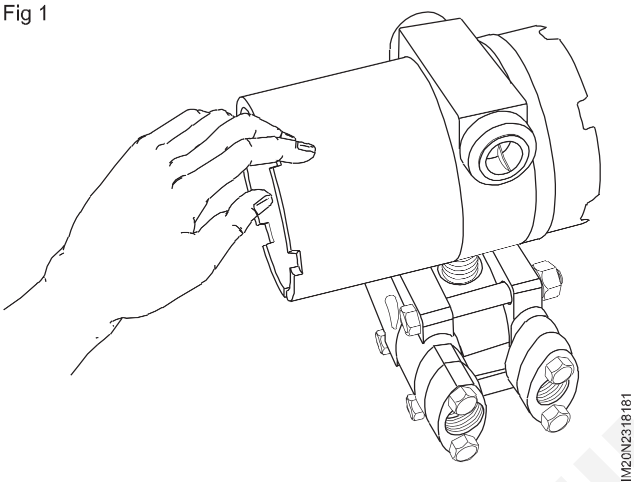
5 Using a different pressure transducer is recommended over two individual pressure transducers, because it eliminates potential compound in accuracies and need to calculate difference between two transducers.

Basics of Differential pressure transmitters

Objectives: At the end of this exercise you shall be able to
- **Explain construction and operation of DPT**
- **Explain installation of DP**
- **Explain pressure calibrators / Comparators**

One of the most common, and most useful, pressure measuring instruments in industry is the differential pressure transmitter. (Fig 1) This device senses the difference in pressure between two ports and outputs a signal representing that pressure in relation to a calibrated range.

Fig 1



Differential pressure transmitter may be based on any of the previously discussed pressure-sending technologies, so this section focuses on application rather than theory.

DP transmitter construction and behavior

Differential pressure transmitters constructed for industrial measurement applications typically consist of a strong (forged metal) body housing the sensing element(s), topped by a compartment housing the mechanical and /or Electronic components necessary to translate the sensed pressure into a standard instrumentation signal (e.g 3-15 PSI, 4-20mA, digital fieldbus codes)

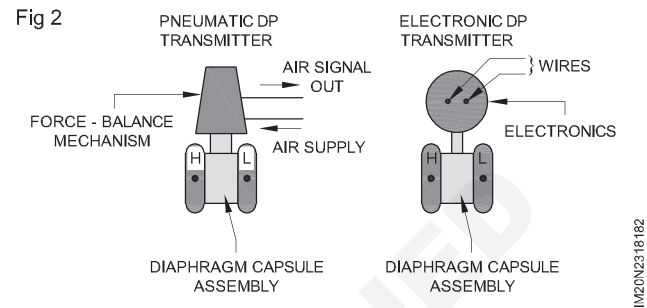
In differential pressure transmitters the pressure-sensing element is housed in the bottom half of the device (the colored, round, cast-aluminum structure). Fig 3

Regardless of make or model, every differential pressure ("DP"," d/p", or ΔP) transmitter has two pressure ports to sense different process fluid pressures.

What these labels represent is the effect any increasing fluid pressure applied to that port will have on the direction of the output signal's change.

The most common sensing element used by modern DP transmitter is the diaphragm. One side of this diaphragm receives process fluid pressure from the "high" port, while the other receives process fluid pressure from the "low" port as shown in Fig 2

Fig 2



Any difference of pressure between the two ports causes the diaphragm to flex from its normal resting (center) position. This flexing is then translated into an output signal by any number of different technologies, depending on the manufacturer and model of the transmitter:

The concept of differential pressure instrument port labeling is very similar to the "inverting" and "noninverting" labels applied to operational amplifier input terminals:

The "+" and "_" symbols do not imply polarity of the input voltage(s); i.e. it is not as though the "+" input must be more positive than the "_" input. These symbols merely represent the different direction each input tends to drive the output signal.

An increasing potential applied to the "+" input drive the opamp's positive, while an increasing potential applied to the "_" input drives the opamp's output negative. Phrasing this in terms common to closed-loop control systems, we could say that the "+" input is direct-acting while the "_" input is reverse-acting.

Similarly, the "HY" and "L" labels on a DP transmitter's ports do not imply magnitude of input pressures; i.e. it is not as though the 'H' port's pressure must be greater than the "L" ports pressure.

The most common sensing element used by modern DP transmitter is the diaphragm. One side of this diaphragm receives process fluid pressure from the "high" port, while the other receives process fluid pressure from the "low" port.

Any difference of pressure between the two ports causes the diaphragm to flex from its normal resting (center) position. This flexing is then translated into an output signal by any number of different technologies, depending on the manufacturer and model of the transmitter:

Fig 3

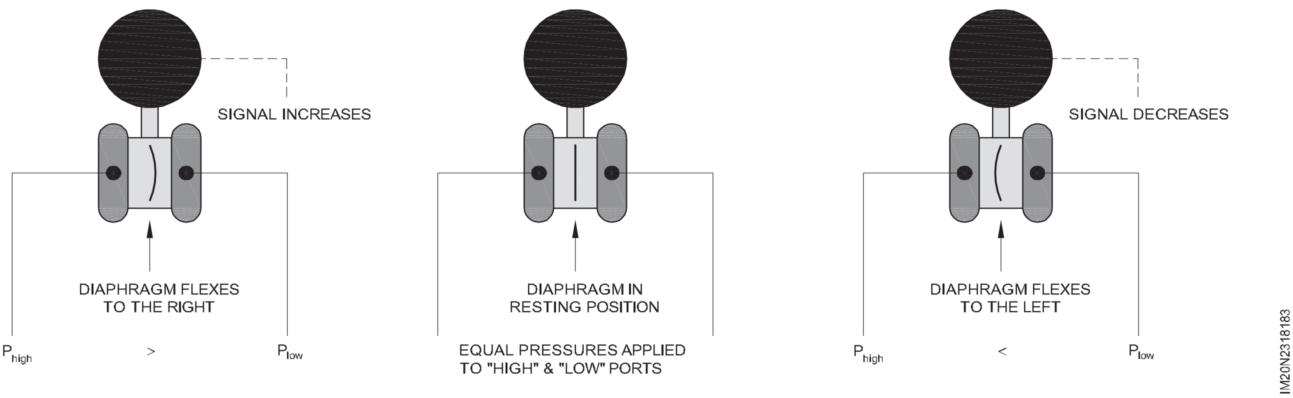
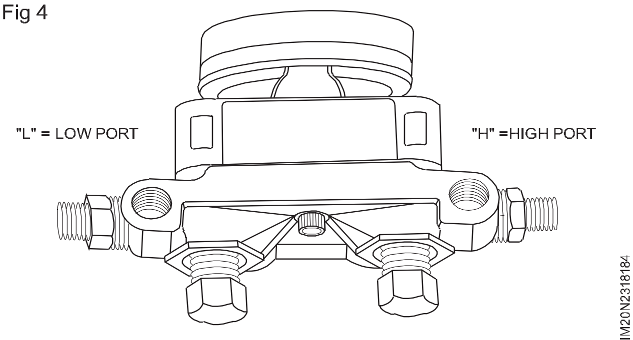


Fig 4

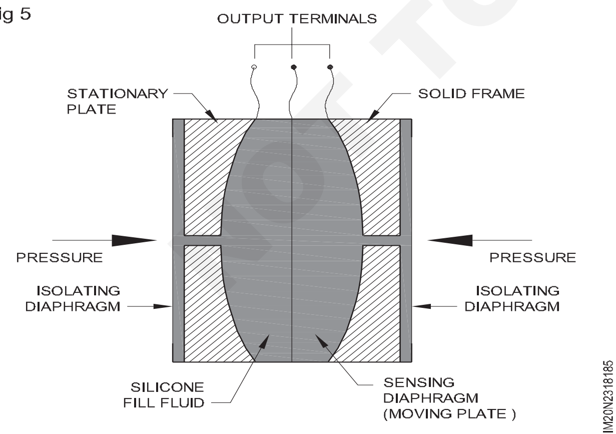


Differential Pressure Transmitter Working Principle

Another common electrical pressure sensor design works on the principle of differential capacitance. In this design, the sensing element is a taut metal diaphragm located equidistant between two stationary metal surfaces, comprising three plates for a complementary pair of capacitors. An electrically insulating fill fluid (usually a liquid silicone compound) transfers motion from the isolating diaphragms to the sensing diaphragm, and also doubles as an effective dielectric for the two capacitors: Fig 2

By removing four bolts from the transmitter, we are able to remove two flanges from the pressure capsule, exposing the isolating diaphragms to plain view: Fig 5

Fig 5

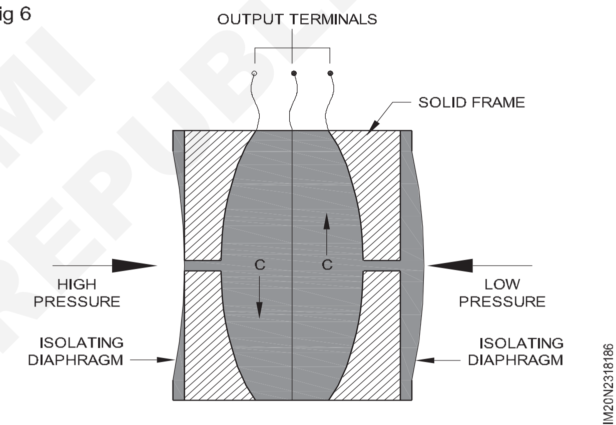


Any difference of pressure across the cell causes the diaphragm to fixe in the direction of least pressure.

The sensing diaphragm is a precision-manufactured spring element, fig 2 meaning that its displacement is a predictable function of applied force. The applied force in this case only be a function of differential pressure acting against the surface area of the diaphragm in accordance with the standard force-pressure- area equation F = PA.

In this case, we have two forces caused by two fluid pressure working against each other, so our force-pressure- area equation may be rewritten to describe resultant force as a function of differential pressure. (Fig 6)

Fig 6



The diaphragms secondary function as one plate of two capacitors provides a convenient method for measuring displacement. Since capacitance between conductors is inversely proportional to the distance separating them, capacitance on the low-pressure side willincrease while capacitance on the high- pressure side will decrease.

A capacitance detector circuit fig 3 connected to this cell uses a high-frequency AC excitation signal measure the different in capacitance between the two halves, translating that into a DC signal which

As the illustration shows, the higher- pressure isolating diaphragm gets pushed toward the metal frame, transferring its motion to the sensing diaphragm via the fill fluid. If too much pressure is applied to that side, the isolating diaphragms to transfer process fluid pressure to a single sensing diaphragm through an internal “fill fluid”- is that the solid frame bounds the motion of the two isolating diaphragms such that neither one is able to force the sensing diaphragm past its elastic limit.

Low pressure measurements

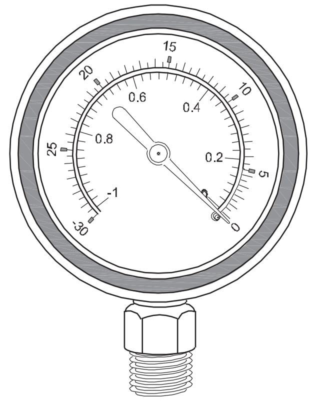
Objectives: At the end of this exercise you shall be able to
- **describe the low pressure measurements**
- **describe the vacuum and vacuum gauge**
- **explain the thermal conductivity gauge**
- **explain Mc Lead gauge**
- **explain capacitance manometer.**

Low pressure range are typically from Q/ in H_2O (0.004PSI) full scale up to 25 in H_2O (0.903 PSI) full scale. The pressure sensors used to make these measurements are very sensitive and over pressure can adversely affect accuracy or, in extreme caresses, damage the unit below 1 mm of by reading of pressure is called low pressure.

1 mm of Hg = 1 torr

1 micron = (10-3 torr) 0.0001 torr

Fig 1

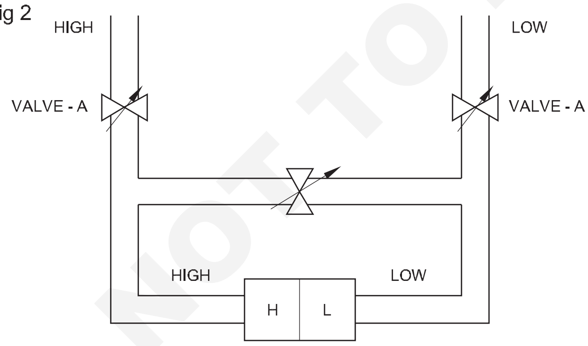


VACCUM GUADE

Vacuum gauges (Fig 2)

These are also of Bourdon tube gauge where the tube attempts to contract under vacuum thus recording vacuum of the engine in mm Hg (millimeters of mercury)

Fig 2



DIFFERENTIAL PRESSURE SENSOR

> **A reading of 760 mm Hg is prefect vacuum (zero absolute pressure)**
>
> **A zero of say 300 mm Hg means to say that 300 mm of vacuum is equivalent to (760-300) milli Hg absolute pressure.**

Vacuum gauges are often used by service mechanics to find out the mechanical condition of the engine and whether valves, ignition timing and carburetor setting are correct and carry out fine adjustments to obtain the best performance of the engine.

Thermal – conductivity Gauge

Thermal-conductivity gauge measure pressure by measuring the changes in the ability of a gas to conduct heat. The ability of a material to carry heat by conduction is called “Thermal-conductivity”. The conductivity of a gas does not change when the pressure changes, until the pressure drops blow about one torr, As the pressure continues to drop, the conductivity of the gas decreases and the gas loses its ability to conduct hrat. Thus, at low pressure, the conductivity of a gas has a direct relationship to its pressure. The relationship between changes in conductivity and changes in pressure work over a pressure range from about 10-4 torr up to about 10-2 torr. It’s used for the absolute pressure (very low pressure) measurement.

Basic Operating Principles: A pressure gauge based on changes in Thermal conductivity

Is made by enclosing a wire filament in a chamber connected connected to the pressure source. When voltage is applied to the filament, electricity flows, making it hot. The rising temperature increases the resistance of the filament. The filament then reaches an ‘equilibrium temperature’, the temperature at which heat is produced in the filament as fast as it is removed. Heat id removed by both radiation and conduction. Convection is so slight that it can be ignored.

The voltage applied to the filament is held constant any change in pressure causes a change in conductivity of the gas surrounding the filament. The change in conductivity changes the equilibrium temperature of the filament, which in turn causes the change in the resistance. Therefore, the change in resistance is used to indicate the pressure change.

An increase in conductivity (due to an increase in pressure) increases the flow of Heat away from the filament decreating the temperature of the filaments. A Decreading pressure) increases the filament temperature.

There are two types of thermal conducting gauges

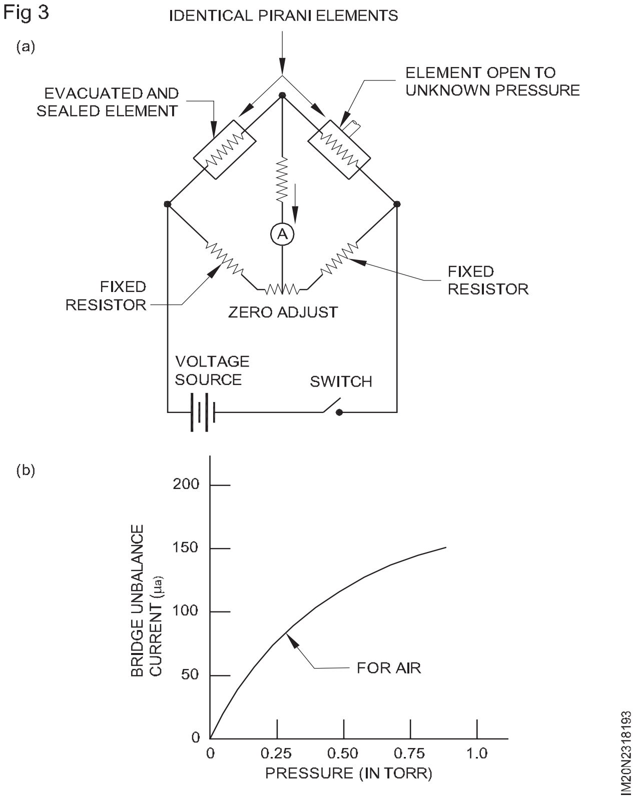
1 pirani gauge (a & b)

2 Thermo couple gauge.

1 **Pirani gauge:** It consists of two wire filaments. One filament serves as a reference and is sealed in an evacuated glass, while the other filament is kept in

a container connected to the source of pressure. These two filaments are connected in a bridge circuit as shown in Fig 3.

Fig 3



Operating Principle: If the resistance of the two pirani elements are equal, no current flow through the ammeter. This current flow indicates a change in pressure of the gas being measured. A curve between the bridge unbalance current (μ a) and the pressure (torr) is shown in fig. Pirani gauges are used for the pressure range about 10-5 to 1 torr.

Because gases differ in heat conductivity, the gauge must be calibrated for the gas being measured. Users must follow the manufacturers calibrating procedure carefully for accurate pressure readings.

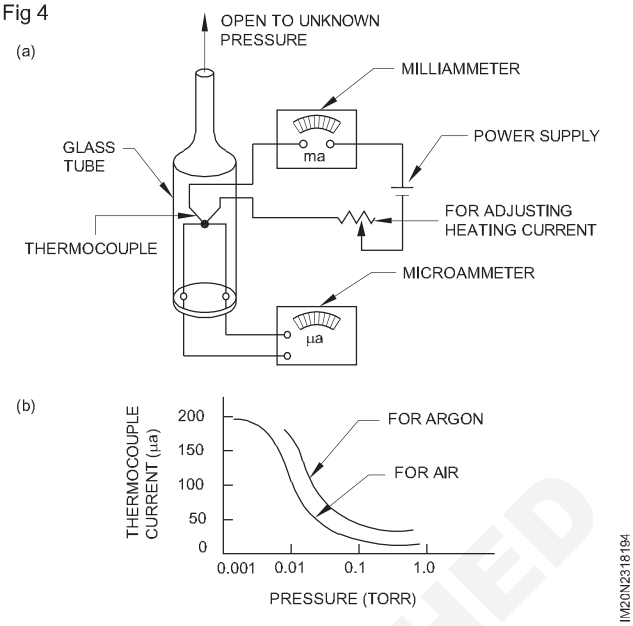
2 **Thermocouple gauge:** The thermocouple gauge works on the same basic principle as the pirani gauge. The only difference is that the filament temperature is measured by a thermocouple. Fig 4a shows a diagram of a temperature gauge. It requires careful calibration, but once calibration it is as accurate as the pirani gauge. A curve between temperature current (μ a) and pressure (torr) is shown in Fig 4b

Thermocouple gauges are used for the pressure range from about 10-4 to 1 torr.

Disadvantages of Thermal Conductivity Gauges:

Both the pirani gauge and thermocouple gauge are easily damaged by organic vapours. The filaments can become coated with a deposit of decomposed vapours,which alters the wave.

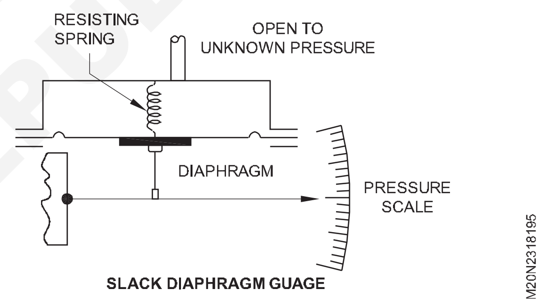
Fig 4



Stack Diaphragm gauge (Fig 5)

A slack diaphragm gauge with a weak spring and a large area can be used over pressure ranges as low as 0.01-0.40mm Hg(torr). It is possible to achieve accuracies of 1-2%.

Fig 5



Advantages: Following are the advantages of diaphragm elements:

1 Their cost is moderate

2 They process high over range characteristics

3 They are adaptable to absolute and differential pressure measurement.

4 They have good linearity.

5 They are available in several materials for good corrosion resistance.

6 They are small in size.

7 They are adaptable to slurry services.

Disadvantages: Following are the disadvantages of diaphragm elements:

1 They lack good vibration and shock resistance

2 They are difficult to repair

3 They are limited to relatively low pressure.

Ionization gauges

An ionization gauge measures the density of a gas. The operating principle of the ionization gauge follows Boyle's las, i.e. at constant temperature, the ratio of pressure of two gases is equal to the ratio of their two densities, i.e

Where p= measured pressure

P1= initial pressure

$$\frac{p}{P1} = \frac{p}{p_1}$$

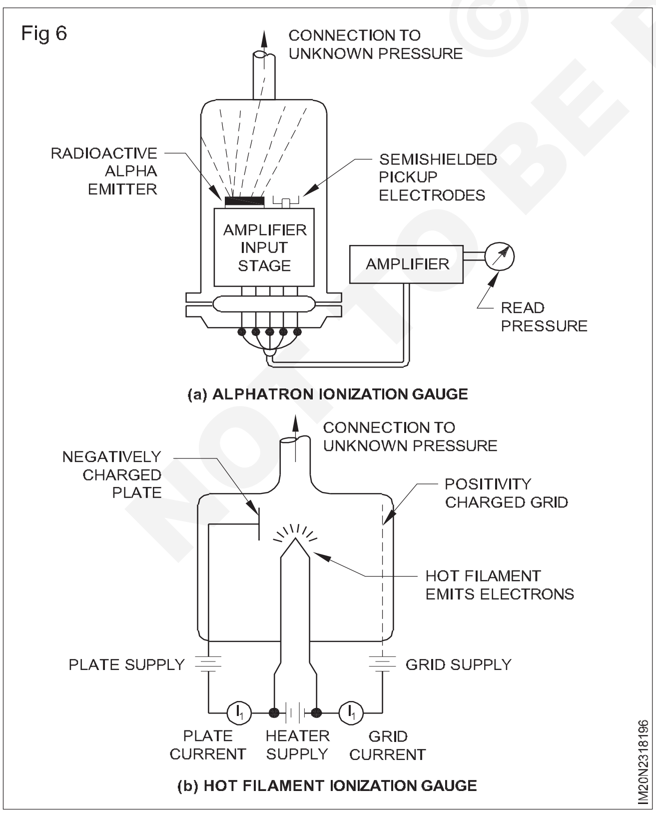
ρ = measured density

$\rho 1$ = initial density.

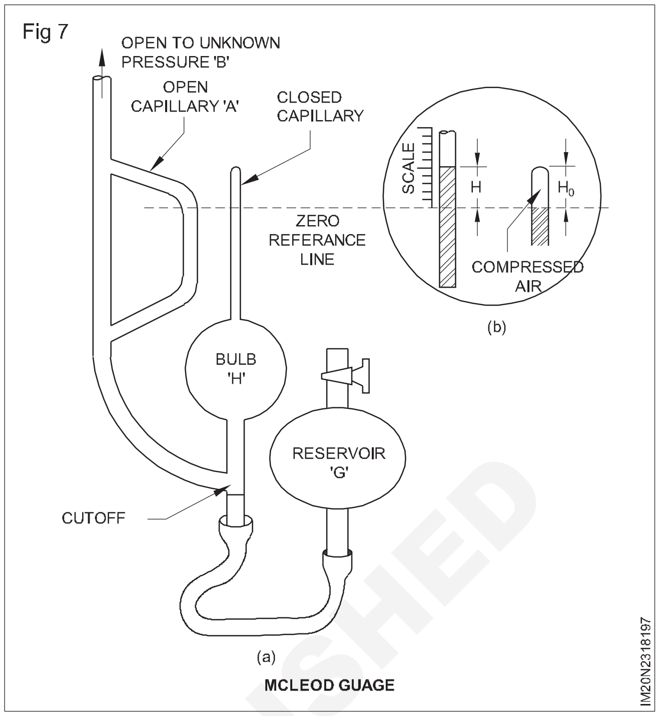
This instrument consists of a chamber in which some of the gas molecules are changed to positively charged icons. These ions are attracted towards a negatively charged plate and deliver their charge, which creates an electric current.

There are two methods used to produces gas ions. In the first method, a stream of alpha (α) particles are produced from a radioactive source. An ionization gauge using alpha radiation is known as an " Alphatron Gauge" shown Fig 6a.

In the second method, a stream of electrons, produced from a red-hot filament are attracted towards a positively charged grid of wire. Any positively charged ions produced due to collision of electrons with gas molecules are attracted towards the negatively charged plate. A hot filament Ionization gauge which works on this principle is shown in Fig 6 b.



McLeod Gauge (Fig 7)



The McLeod gauge is used for measure low pressure down to one hundred thousands of an inch of mercurycor 10m bar down to 10-3m bar). The McLeod gauge amplifies pressure by compressing a gas into a small volume. The pressure of the compressed gas is then measured with mercury manometer Fig shows a diagram of McLeod gauge.

Construction and working

A McLeod gauge is connected to the unknown gas whose pressure measurement is required.

The gas enters the gauge through B and fills the tubes down to the level of the mercury reservoir. The pressure is equal throughout the tubes and the bulb mercury is pumped up from the reservoir G. As the mercury rises above the cut-off it traps gas inside the bulb. The mercury is then pumped higher in the gauge until all the gas in the bulb is compressed into the closely capillary tube.

The compression of gas in the closed capillary tube makes the pressure of the trapped gas higher than the measured pressure. This pressure difference causes a difference in the mercury levels in the two tubes. The difference in height is used to calculate the pressure.

The volume of the bulb can be made quite large and the zero reference line on the closed capillary tube can be placed near the top of the tube. Thus, a large volume of gas can be compressed into a very small volume. This compression multiple the pressure many times. The pressure can be calculated by using the following equation:

$P = KH\ H_0\ (1 - KH)$

Where P= measured pressure

K = a constant, determine by the geometry of the gauge

H= difference in heights of the two mercury columns

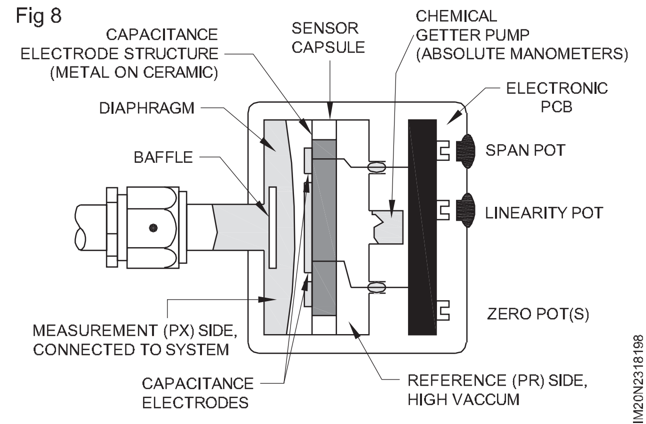
H0 = height of the top of the closed capillary tube above the line marked on the tube.

The McLeod gauge is a very accurate pressure – measuring device and often serves as a standard for calibrating other low – pressure measuring device and often serves as a standard for calibrating other low – pressure gauges. It can be designed to measure pressure as low as 0.05 microns(0.00005 torr.)

Capacitance manometer (Fig 8)

- Capacitive manometer is a pressure gauge used in the rough and high vacuum gauge.
- Capacitive manometers are extremely accurate, typically 1% of scale.
- It is a capable of measuring the absolute pressure or relative pressure depending on the gauge model used.

Fig 8



- Capacitive maintenance operates in the range from atmospheric pressure to about 16-5 torr.
- They are absolute gauges because any gas at the same.

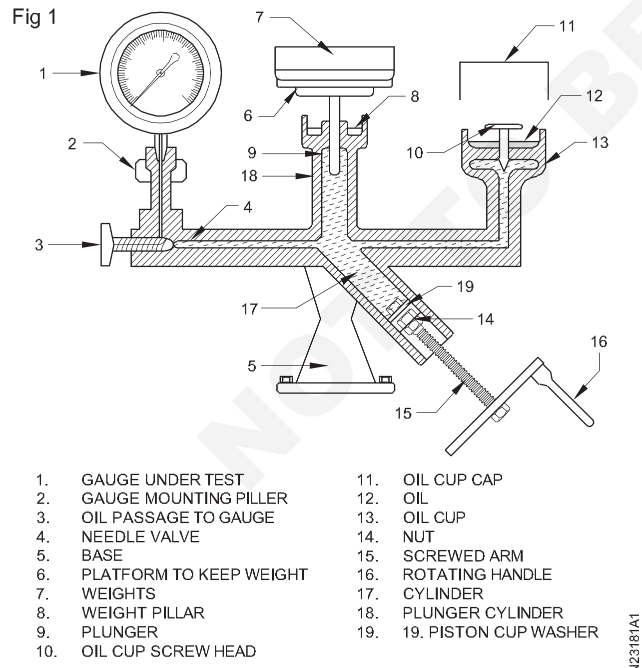
Method of pressure calibration dead weight tester

Objectives: At the end of this lesson you shall be able to
- **explain the construction of dead weight tester**
- **explain the operating of dead weight tester**
- **calibrating the given bourdon tube pressure gauge.**

Introduction

The dead weight tester Fig 1 is the standard pressure calibrator for calibrating pressure gauge. The working fluid in dead weight tester is oil.

Fig 1



DEAD WEIGHT TESTER

Parts

1 Gauge under test

2 Gauge mounting pillar

3 Oil passage to gauge

4 Needle valve

5 Base

6 Platform to keep weights

7 weights

8 weight pillar

9 plunger

10 oil cup screw head

11 oil cup cap

12 oil

13 Oil cap

14 Nut

15 Screwed arm

16 Rotating handle

17 Cylinder

18 Plunger cylinder

19 piston cap washer.

Construction and Operation of Dead weight tester

The instrument works on hydraulic pressure transmitting principle. It has a three pillars (1) Oil cup pillar, (2) Weight platform pillar (3) Test gauge mounting pillar.

The oil cup pillar has an oil cap with needle valve to control oil. The weight platform pillar consists of plunger and cylinder. The weights are kept on platform. The gauge mounting pillar has a another needle valve to control the oil pressure. Different adopters are used to mount the gauge on pillar. The above three pillars are connected to a screwed piston pump, which sucks the oil from oil cap and pushes it to gauge and platform pillars to develop pressure.

Operation

Mount the pressure gauge to be tested on gauge pillar with suitable adopter. Open the oil cap needle valve. Then close the oil cup valve and open needle valve mounted on test gauge pillar. Turn the piston clockwise direction to push the oil in plunger cylinder and gauge mounting pillar. By this action the pressure is developed in plunger cylinder which pushes the plunger by lifting the weights kept on platform, simultaneously the pressure will also act on pressure gauge which indicated the valve.

The pressure gauge reading is compared with the weights kept on weight platform.

Note

The floating plunger is most important part of the tester and must be handled carefully. Its displacement must be limited to one cm. If the handle is rotated continuously, the floating plunger may get damaged and locked. Hence care should be taken to limit the displacement of plunger to above value.

Advantages

1 To calibrate the wide range of pressure gauge

2 By using weight & piston cylinder construction to change the fluid pressure.

3 It is easy to use and operate.

Disadvantages

1 In between the piston and cylinder the striction value is not accuracy

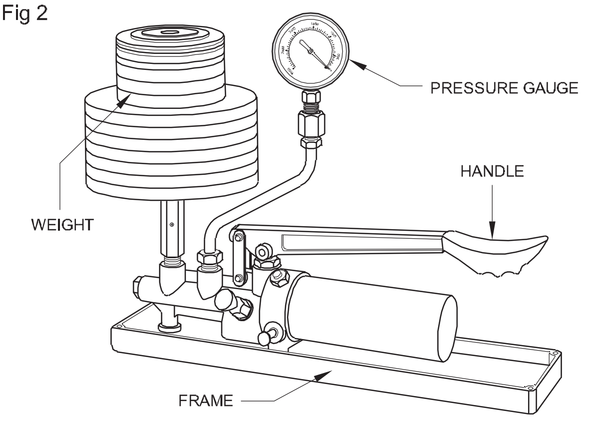
2 The value of ‘g’ is differ depending upon the place. So the value is not accurate.

Pressure Calibrators (Fig 2)

In fig shows the construction of pressure calibrator

Pressure calibrator is lightweight and easy to use. They can generate pressure up to 1000 bar and are well-suited for calibrator of pressure transmitters, pressure calibrator transducers, pressure switch and pressure gauges. The system offers optional adjustable over pressure protection, fine control and a unique selector switch to move from priming to high pressure generation.

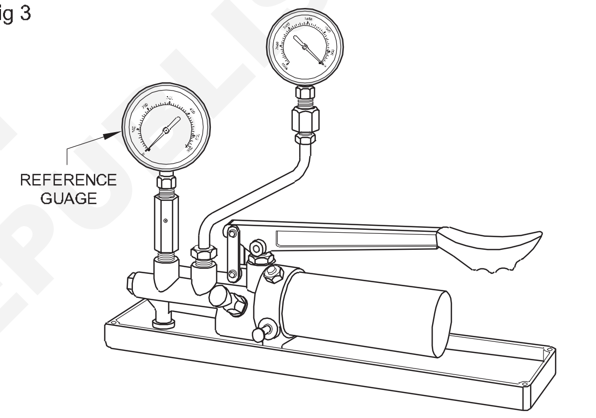
Fig 2



Comparator (Fig 3)

Bothe dead weight tester and comparator similar in construction and operation. There is only one difference. Comparator checks and compares the accuracy of a pressure gauge against. Reference gauge is also called as a test gauge.

Fig 3



Principle of working

The operating principle of comparator is a simple form of comparison. Pressure produced by the pump is equally distributed to the test gauge and to a device being calibrated or checked. The reading of the test gauge serves as the reference to which other device readings are compared against

Selection of the test gauge range is the determining factor in establishing the precision to which a comparison check is to be made. Proper selection of the test gauge range must be made to minimize the amount of the unit error. Therefore, it is important to select a test gauge that has a full scale range equal to or only slightly in excess of the pressure value to be measured.

Operation:

1 Select a test gauge that is adequate for the pressure range desired.

2 Fit the test gauge in place specified.

3 Assemble gauge to be tested to the straight pipe extension. Seal the connection by tightening nul.

4 Pumping to the desired test pressure. Open the release valve to vent the pressure.

5 Prior to taking readings, both gauges should be finger tapped lightly at the center of the gauge face, to eliminate any movement friction.

6 Note the pressure readings on the test gauge and the gauge to be tested. If the pressure indicated on the gauge under test is not equal to the pressures of the test gauge, the gauge being tested requires calibration.

7 Open release valve slowly until pressure returns to zero. Do not loosen any connections until pressure in the gauge tester has reached zero, as indicated on the test gauge.

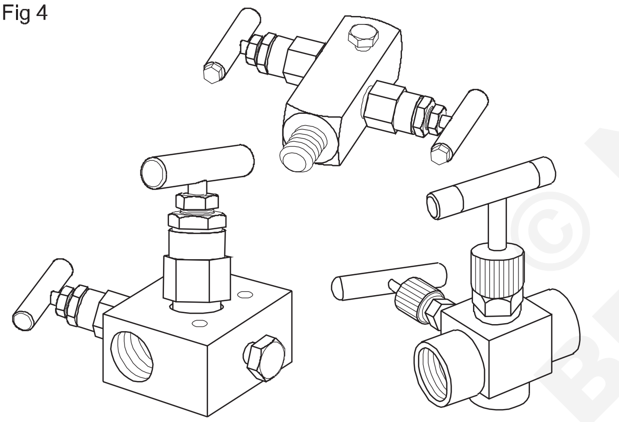
8 Unseal the gauge that has been tested by unscrewing the nut.

9 Remove the test gauge in the same manner as the Gauge under test

Caution: Do not pump handle to pressures greater than the pressure range of the gauges connected to the test pump, as this may damage the gauges.

Manifold valve (Fig 4)

Fig 4



2 WAY MANIFOLD VALVE

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The manifold valves are the types of the valves or equipment that are mostly used for the formation of the single system by combining two or more hydraulic systems or the valves. The system further form and work as a single unit but they possess separate opening for each valves and the valve chamber is common for the connection.

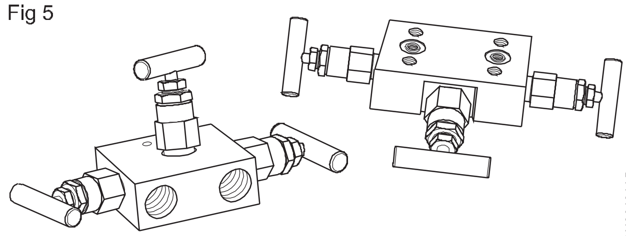
These valves are mostly used by the industries or the places where there is a need of the fluid controlling or the regulating system. It plays a major role in such case by improving the overall efficiency of the system and by reducing the overall cost of the system. (Fig 5)

Applications

The most common application or the uses of the manifold valves are

For the regulating the fluid flows the place they are used. These valves wherever they are used, it provides the leakage proof applications.

Fig 5



3 WAY MANIFOLD VALVE

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It can work very well at the places where there are cases of the high temperature and the pressures. They can fit easily in the small places and does not occupy more places.

The two or more systems can be easily connected by using single manifold valves.

Very easy in operation and does not have any complex mechanism for operation.

Easily replaceable in case of any failure.

These 2-way manifold valves are providing very tight packaging and do not cause the issue like a leak or spill at the places whenever used.

Because of their astonishing benefits these types of the Manifold valves are demanded in the national and international market

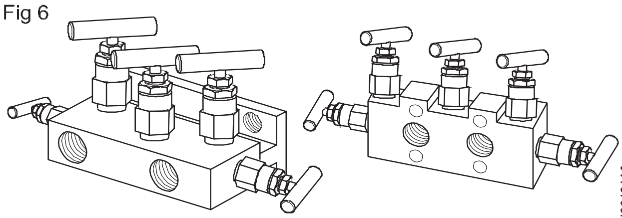
Pressure Transmitter Manifolds

The following illustration shows the three valves comprising a three valve manifold (within the doored-line box), as well as a fourth valve called a “bleed” valve used to vent trapped fluid pressure atmosphere.

Note: The standard 3 – valve manifold, for instance, does not provide a bleed valve-only block equalizing valves.

While this illustration shown the three valves as separate device, connected together and to the transmitter, by tubing three- valve manifolds are more commonly manufactured as monolithic devices: the three valves cast together.

Fig 6



5 WAY MANIIFOLD VALVE

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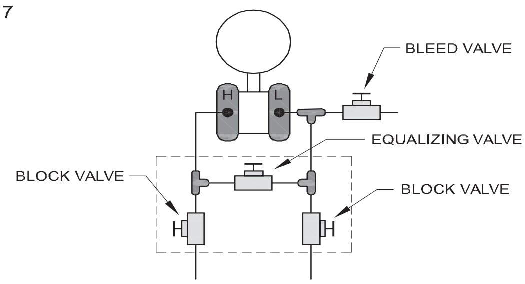
Fig 7



IMPULSE LINES TO PROCESS

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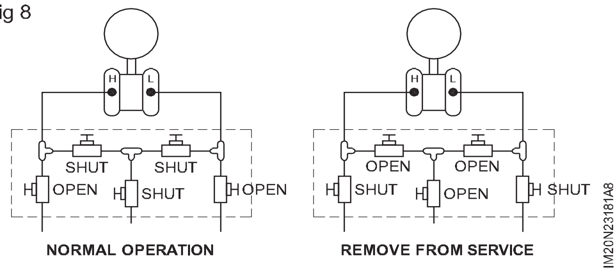


Fig 8

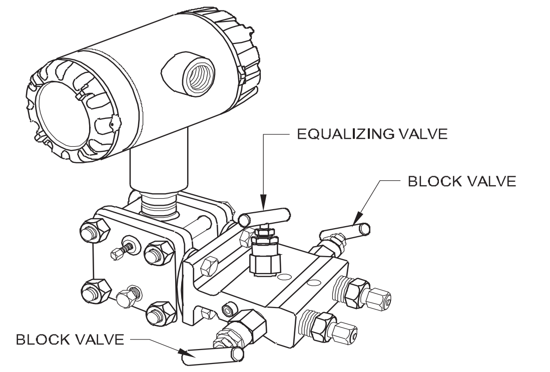


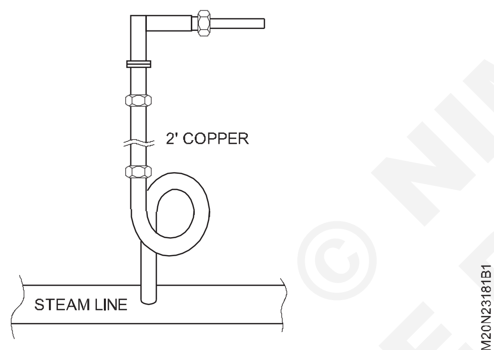
Fig 9

Pressure instrument installation

Objectives: At the end of this exercise you shall be able to
- **explain pigtail/siphon.**
- **explain reasons for breakdowns in pressure gauges**
- **explain isolation valve, instrument valve, diaphragm seal is pulsation**
- **explain guidelines of periodical maintenance of pressure measure instrument**
- **explain maintenance of pressure instruments**

Pigtail/Siphon (Fig 1)

Fig 1



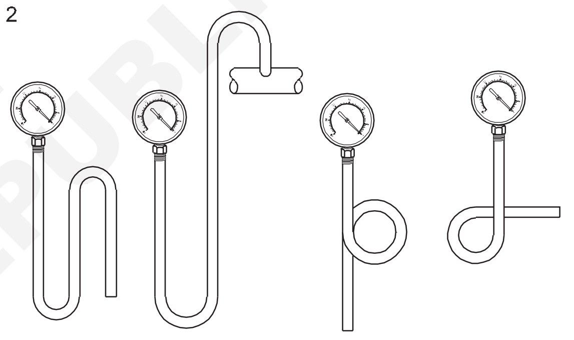
Pigtail on steam pressure gauge

The pigtail was invented to prevent the internal parts of stream pressure gauge, particularly the materials of the responsive elements and of any fusible joints, form being subjected to high steam temperatures steam pressure gauges are highly sensitive instruments, that, if not properly cared for, can be easily damaged or destroyed.

To ensure steam pressure gauges are highly reliable, it is essential to use steam gauge pigtail, which will damage to the gauge from direct exposure to high steam pressure.

The pigtail allows steam to change phase from a gas into liquid by dissipating the latent heat energy of steam and allowing the steam to condense, thus providing a loop seal liquid. The loop seal of liquid prevents the transfer of the heat energy form the steam to the gauge. the pigtail loop also protects the gauge from any pressure surges in the system. (Fig 2)

Fig 2



Types of siphons

Coil siphon: vertical and horizontal installation

The pressure medium forms a condensate and is collected inside the coil or pigtail portion of the siphon. The condensate prevents the hot media from coming into direct contact with the pressure instrument. When the siphon is first installed, it should be filled with water or any other suitable separating liquid.

Figure 3 and Fig 4 show the different configurations that can be used. The typical installation is the vertical installation with the isolation valve located near the pressure gauge.

Reason for breakdowns in pressure gauges

1 Mechanical vibration

Solutions for gauges experiencing mechanical vibration

For most situations, a liquid-filled case is the most convenient and cost –effective way to protect pressure gauge form vibration. The glycerin or silicone-oil case fill acts a damper to slow down the movement. It also lubricates the pinion and segment gears, thereby reducing wear and prolonging the life of a gauge.

Fig 3

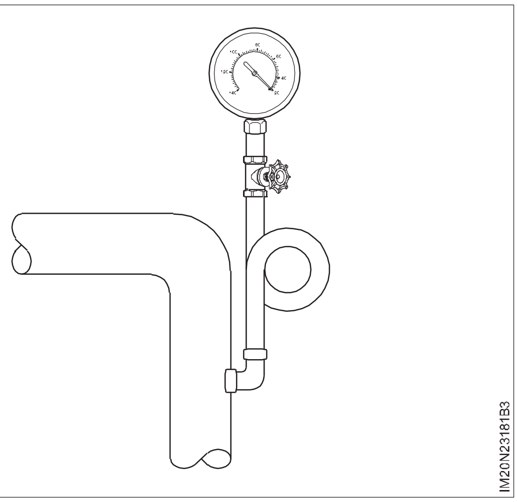
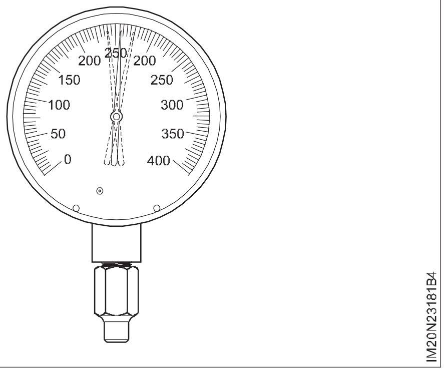


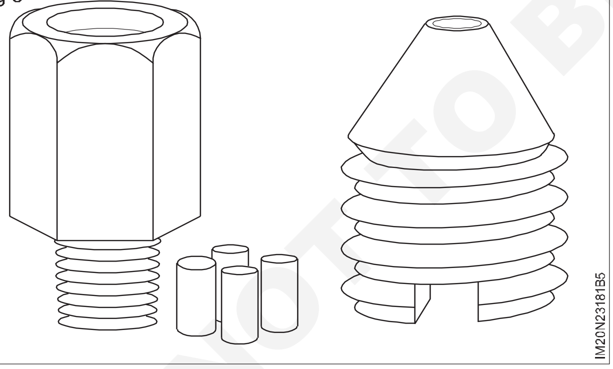
Fig 4



A second solution is to move the gauge away from the source of the vibration. How? Use a diaphragm seal with capillary connection. A diaphragm seal can be mounted. Practically anywhere in the application, and the line allows for remote reading.

2 Pulsation (Fig 5)

Fig 5



Pointer flutter

Vibration refers to regulator oscillation of mechanical parts. Pulsation, on the other hand, is regular instances of rapid pressure increases and decreases of the media.

Visible signs of pulsation

- Pointer flutter
- Loose or broken pointer in extreme cases.

Solution for gauges experiencing pulsation

As with mechanical vibration, a liquid – filled case is an easy solution. So valves and protective device like a socket restrictor. This small device has a small orifice to restrict and slow down the pressure if the media before encounters the gauge. Restrictors, as cost-effective and easy to install. Several gauges for compressed gas regulators, come standard with a restrictor already threaded into the bore.

For more extreme pulsation, use a snubber Fig 6 or needle valve. Snubbers function like restrictors but come in more material choices, orificd sizes and psi ratings, snubbers are also less prone to clogging and are more adjustable in the field, thanks interchangeable pistons or adjustment screws. Needle valves aslo throttle the media thereby reducing the impact of pulsations. These pulsations dampeners are commonly found in jump discharged and boiler house applications.

3 Extreme temperature

Different gauge have different tolerance for extreme temperatures. We look at both ambient temperatures, such as what is found in the arctic or around a furnace, and the temperature of the process media.

Visible signs or extreme temperature

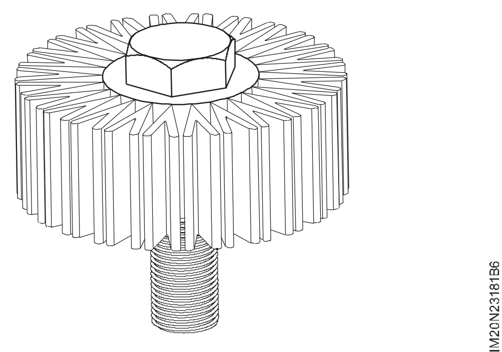
Dial and /or liquid fill is discolored, usually yellow, orange, brown, or black.

Dial, case or window is melted – usually because the media is too hot.

Risk posed by extreme temperature

- Difficult in obtaining an accurate reading
- Loss of accuracy functionally
- Pressure system failure.

Fig 6



Solution for gauges in extreme temperatures

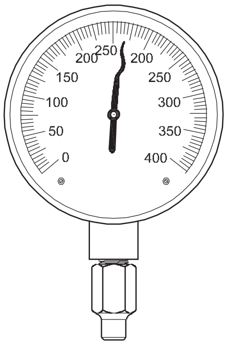
A diaphragm seal with capillary allows pressure measurement to occur away from extreme ambient or media temperatures. Pigtail, coil, and mini (rod and cap siphons use the same principle to dissipate heat.

Glycerin is the typical fill fluid for pressure gauges. For extremely hot or cold ambient temperatures, silicone till is the better choice as it will not discolor in heat over time freeze in sub-zero environments.

4 Pressure spikes

Spikes occur when the pressure sharply increases and then suddenly drops. This condition can cause all ports of problems for gauges not designed for this condition.

Fig 7



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Visible signs of pressure spikes

- Bent pointer, like a fishtail or fish hook, from hitting the stop pin too often
- Nicked or broken pointer from hitting the stop pin too hard
- Broken stop pin

Risk posed by pressure spikes

- Increased wear on movement and components
- Loss of accuracy functionally
- Split bourdon tube, leading to released media
- Pressure system failure

Solution for gauges experiencing pressure spikes

As with pulsation, good solution for dampening the effect of pressure spikes are to use a liquid-filled gague and /or accessories like resistors, snubbers, needle valves, or diaphragm seal with capillary. Another way to prevent damaged pointers and internals is to replace the gauge with one that has a higher pressure range. A good rule of thumb is to choose a gauge that is two times the expected pressure maximum. So, if process typically reaches 500 psi, use one that goes up to 1;000 psi.

For grater reassurance that a gauge never exceeds a certain maximum, attach an overpressure protector to the instrument. This unique option allows the user to changing the maximum pressure setting. If the pressure ever reaches that value, the protectors spring loaded piston valve will automatically close, preventing the gauge from experiencing the spike. And when the system pressure drops approximately 25% below pre-set maximum, the valve with automatically reopen.

5 Overpressure

This situation is very similar to pressure spikes,but occurs when the gauge regularly measures pressures gear or at the maximum range. We typically see this condition in water/waste water treatment and gas lines.

Overpressure can cause the Bourdon tube to deform and split. This is major problem because a rupture allows caustic media, such as the hydrofluoric (HF) acid in alkylation units, to escape. In pharmaceutical manufacturing, a rupture event ruins very expensive product and leads to shutting down the line, quarantining the product,and re-sterilizing the process.

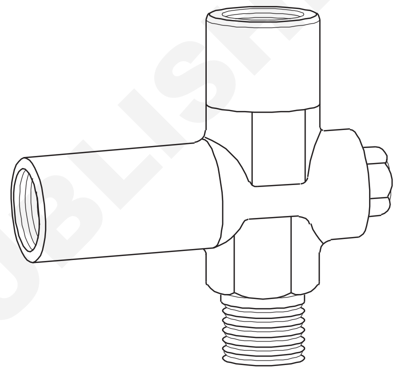
Visible signs of overpressure

- Pointer buried against stop pin
- Pointer dislodges stop pin

Risks posed by overpressure

- Increased wear on movement and components.
- Loss of accuracy/functionality
- Split bourdon tube, leading to released media
- Pressure system failure

Fig 8



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Solution for gauges experiencing overpressure

As overpressure is similar to pressure spikes, so is the fix: use a gauge with a higher pressure range, and attach an overpressure protector.

6 Corrosion

Corroded pressure gauge

Many industries work with harsh chemicals: chemicals hydrofluoric acid in refineries, flocculants and chlorine wastewater treatment, chlorinated gases in fiber optic production, aslo so on.

Visible sign of corrosion

- Discoloration and deterioration of the gauge case, pointer, connection and dial

Risk posed by corrosion.

- Loss off accuracy/ functionality
- Pressure system failure

Solution for gauges in corrosive environments

Isolate the gauge from harsh chemicals by using diaphragm seal made of the appropriate corrosion resistance materials.

7 Clogging

Clogging is an issue for paper plants, waste water plants, pharmaceuticals, and other industries, as slurry sulpy , viscous, and high-particulate media can gum up the system.

Visible sign of clogging

- Gauge at or near zero when the system is operating

Risks posed by clogging

- Loss of accuracy /functionally
- Possibility of overpressure

Solutions for gauges measuring clogging media

Again, use a diaphragm seal to separate the gauge from the challenging media. An excellent solution is WIKA's All welded system (AWS), an assembly comprising an XSEL industrial process gauge permanently welded to a bell- shaped diaphragm seal.

As the AWS still has a small orifice that the media can enter, customers can opt for versions with a flushing port. This component allows operators to clear away media either when clogging occurs or during regular maintenance.

Another solution is WIKA's INLINE TM diaphragm seals, which has smooth walls for full flow – through. By eliminating dead spaces, there's no risk of media buildup.

8 Mishandling /abuse

Gauges look sturdy, especially the larger process gauges, but they are not designed to b e handles or metholds! During site visits, we often see evidence of gauge mistreatment. Operators might grap on to a gauge as they move around process skids on wheels, or steps on them as they climb scaffolding. Not only is his practice unsafe, it increases the chances of gauge damage and failure.

Visible signs of mishandling/abuse

- Cracked case
- Broken window
- Loss of case filling
- Crooked or bent gauge and / or process connection

Risks posed by mishandling/abuse

- Loss of functionality

Solutions for gauge mishandling/abuse

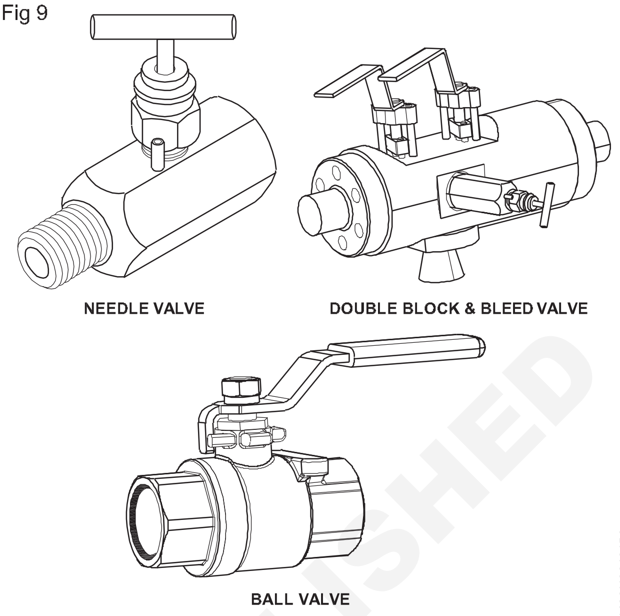
Training is the best prevention. Employees should be aware of the dangers of mishandling gauges. They should also know how to properly connect gauges. For example, hen threading the gauge onto the process some people tighten it by hand, which risks torqueing the case.

Risks posed by mechanical vibration

- Wear and tear of internal components
- Loss of accuracy /functionality
- Pressure system failure

Isolation valve (Fig 9)

Fig 9



An isolation valve is a valve in a fluid handling system that stops the flow of process media to a given location, usually for maintenance or safety purpose. They can also be used to provide flow logic (selecting one flow path versus another), not because of the type of the valve itself. Therefore, many different types of valves can be classified as solation valves.

Process plant practice

Isolation valves can be in the normally open position(NO) or normally closed (NC). Normally open valves are located between pressure vessels, pumps, compressors, tanks, pressure sensors, liquid level measurement instrumentation and other components and allow fluids to flow between components, or to be connected to sensors. The controlled closure of open valves enables the isolation of plant components for testing or maintenance of equipment, or allows flow of fluid to specific flow paths. Normally closed valves are used to connect fluids and process components to other systems only when required. Vent and drain valves are examples of normally closed valves which are only opened when required to depressurize (vent) or drain fluids from a system.

Instrument valves

Instrument valves, instrumentation – Needle, ball and manifold valves range includes needle valves, ball valves, manifold valves, safety valves, gauge valves, block and bleed valves.

Valves are used in requests wherever instrumentation measurement follows. Valves are used for separation venting, block & bleed stagnant pressure, complete pressure, gauge pressure, differential pressure, differential pressure. Liquid level & instrument lines.

Valve end connections are NPT female & NPT male. Also different threading such as BSP male – female, BSPP/BSPT male – female can be manufactured.

Valves are for starting or stopping flow, regulating or throttling flow, preventing back flow or relieving and regulating pressure in fluid or gaseous handling applications.

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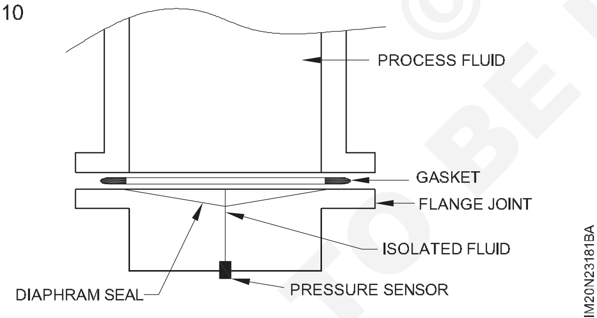
Valves are for starting or stopping flow, regulating or throttling flow, back flow or relieving and regulating pressure in fluid or gaseous handling applications.

Block and bleed type gauge valves performs block and bleed function and gives more control then multi-port valves. One side there is process flow line and other side their pressure gauge. Plug is also attached for bleeding function.

Diaphragm seal (Fig 10)

Fig 10



A diaphragm seal is a flexible membrane that seals and isolates an enclosure. The flexible nature of this seal allows pressure effects to cross the barrier but no the material being contained.

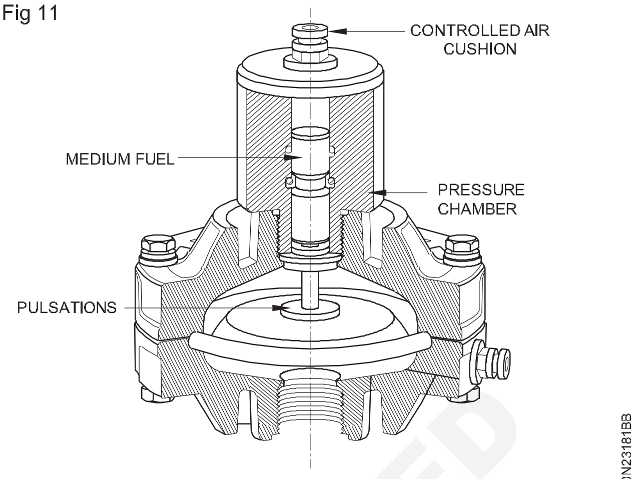
Common uses for diaphragm seals are to protect pressure sensors from the fluid whose pressure is being measured.

Since diaphragm seals need to be highly flexible, elastomers, are commonly used, and include a wide variety of both general purpose and specialty rubbers. Elastomers are limited to low pressure applications and those that are chemically compatible with the various plastics and rubbers used.

Installation components

Pulsation damper (Fig 11)

Fig 11



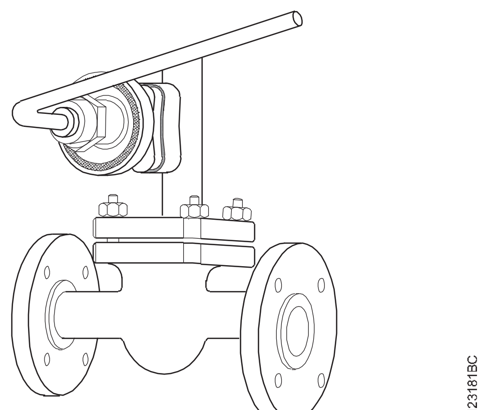
PULSATION DAMPER

Pulsation dampers are designed to observe the excess pressure by up to 80% to prevent and list. Pulsation dampers are designed to either be pressurized by a compressed carline or via the same air connection to an air operated diaphragm pump to use pressure to counteract and limit the effect of over pressure.

Pulsation dampers regular's little maintenance and are often fit and forget. They should be fitted as close to the outlet of the pump as possible.

Blow down valve (Fig 12)

Fig 12



BLOW DOWN VALVE

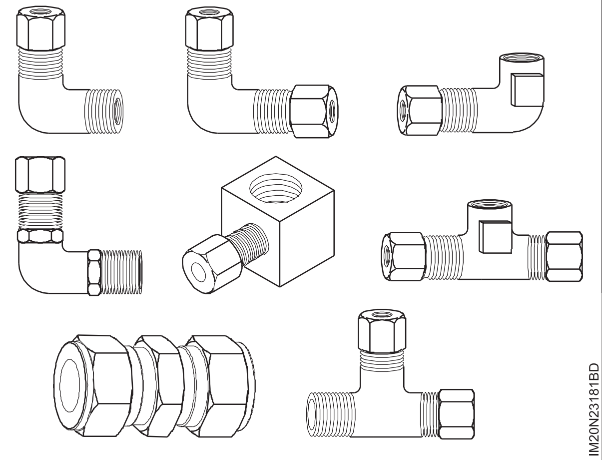
Blow down valves are useful in fossil fuel fired boilers for continuous or intermittent use to drain dissolved solids from the boiler water. These valves are fitted on the drain lines of the boilers.

Generally, only one blow down valve is used in boilers, however the use of multiple blowdown valves in a boiler on the design and purpose of the boiler.

Tube fittings

The fittings and designs to connect fitting to equipment parts, and to connect pipe and hose fittings firmly without leakages. Some of the different fittings used with pneumatic systems are shown in Fig 13

Fig 13



Fittings are designed to prevent air leaks at connections and protect the tube against.

Metal tube fittings

Tube bending

Metal tubing is earlier to install than pipe because it requires fewer connections. Most of the necessary changes in direction are made by bending me tube care must be used when bending tubing because once it in bent, it cannot be straightened. Bending tools are used to bend the tube to the probe radium. Fig 2 shows the be radius for different size of tubes.

Tube fittings:

The fittings are designed to connect tubing to equipment parts and be connect pipe and lose fittings firmly without leakage. Some of the different fittings used with pneumatic systems are shown in fig 1.

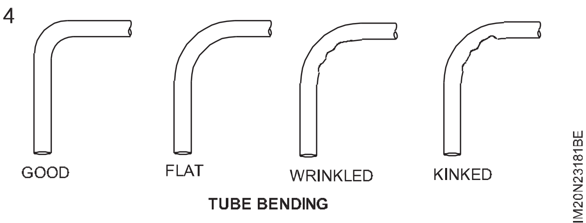
Fittings are designed to prevent air leaks at connections and to protect the tube against damage.

Tube installation:

The general procedure and precautions installing tubing.

1 select tubing and fittings for flow, pressure and service requirements
2 from line with minimum numbers of bends.
3 protect the lines from accidental damage
4 avoid connections in straighteners
5 tubing assemblies should have installed and removable without bending or damaging the tube. (Fig 14)

Fig 14



Tube OD nominal (in.)	Minimum bend radius R (in.)
3/8	1 1/4
7/16	1 1/4
1/2	1 1/4
5/8	1 1/2
3/4	1 3/4
7/8	2
1	3
1 1/8	3 1/2
1 1/4	1 3/4
1 3/8	5
1 1/2	5

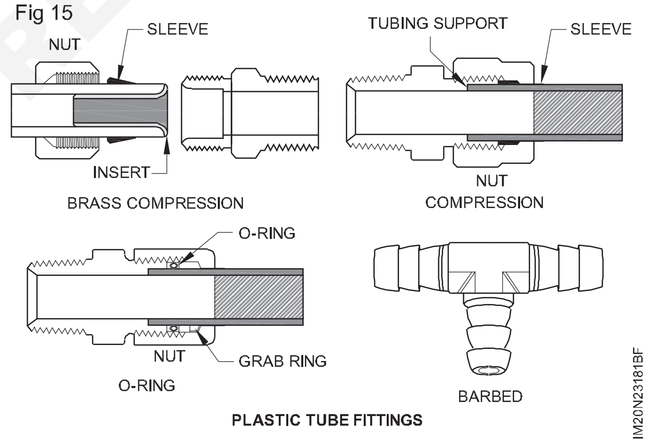
Nonmetallic tubing

Non- metallic or plastic tubing can be made of poly. Ethylene, poly, propylene, or poly vinyl chloride the plastic tubing in limited to working pressure below 100 psi and to temperature below 190°F plastic tube fittings aslo shown in Fig 4.

Advantages

1 in resistant to chemical attack.
2 If until not corrode
3 It is available in colors
4 It is excellent for pilot control lines

Fig 15



Maintenance And repair of pressure Measuring instruments

Maintenance of pressure instruments is very necessary for their proper working and accurate reading. It also improves the life and reliability of the instruments.

1 Periodic Maintenance (PM)

Generally, instructions for the periodic maintenance of an instrument are given in

the manual supplied by the manufacturers, which explains how and when to ser- vice the instrument. Individual plants or industries also prepare their guidelines for periodic maintenance.

Periodic maintenance of pressure instruments generally includes the following three things:

(a) Visual Inspection Any leaks or damage in piping and wiring of the instrument can be examined visually and small corrections may be done during that period. But correction should be done without interrupting the plant operation and without causing safety hazards.

(b) Blowdown and Venting Clogging of lines is a major cause of instrument failure, but it can be prevented by periodic blowdown. The blowdown procedure removes dirt and foreign materials from an instrument line before it becomes plugged. By venting gas trapped in a liquid-filled line, gas buildup can be avoided, which also causes faulty pressure readings. Instrument valves must be closed before blowdown and venting so that it keeps dirt out of the instrument. After blowdown and venting, the instrument valve must be reopened.

(c) Cleaning and Lubrication Instruments with mechanical linkages undergo wear and misalignment. Dirt may clog the linkages, causing the mechanism to stick. Checking linkages periodically reveals problems before they are serious enough to interfere with instrument operation.

The mechanical linkage should operate smoothly. If repair or adjustments are not needed, simple cleaning and lubrication of the instrument must be done according to the manufacturers specifications...

Care of the Instrument

The following steps should be taken for pressure-measuring instruments:

(i) Liquid-filled manometers must be levelled, the liquid and the chambers must be kept at a reasonably constant temperature, and errors must not be introduced in the connecting pipes. Proper allowance must be made for the pres- sure due to liquids in the pipes where liquid enters the manometer.

(ii) Owing to the very large variation in design and construction of instruments, it is always necessary to consult the manufacturer's recommendations for installation, servicing and maintenance.

(iii) All pressure gauges should be mounted correctly, protected from heat, corrosion, and vibration.

(iv) The zero of the instrument should be checked daily, or weekly, depending upon the variation found, and it should be corrected if this is found necessary. (v) The calibration should be checked every 3,6 or 12 months, depending upon the use and the accuracy expected.

(vi) If the instrument contains mercury, the mercury chamber should be checked every six months and the mercury should be cleaned or replaced if necessary.

Troubleshooting

Troubleshooting helps in quickly finding instrument failure. The first important step in troubleshooting is to observe the instrument in operation, and write down its symptoms. The instrument manufacturer's troubleshooting chart should be used as a guide for observing key symptoms. Table 12.3 shows a typical trouble- shooting chart for locating a problem in a faulty pressure transmitter. Table 12.4 is an orientation table for pressure detectors.

Troubleshooting Chart

Symptom	Possible Causes	Corrective Action
Low output or zero output	Power supply loop wiring	Check output of power supply.
		Check for shorts and multiple ground
		Check polarity of connections.
		Check loop impedance.
	Pressure piping	Check that pressure connection is correct.
		Check for leaks or blockage.
		Check that blocking valves are fully open.
		Check for entrapped gas in liquid lines and for liquid in dry lines.
		Check for sediment in transmitter process flanges.
	Transmitter electronic connections,	Check for shorts in sensor leads.
		Make sure bayonet connectors are clean and check the sensor connection

Symptom	Possible Causes	Corrective Action
	Transmitter electronic failure.	Determine faulty amplifier assembly by trying spare assembly. Replace faulty amplifier assembly.
High output	Sensing element	Refer to “checkout of sensing element.”
	test diode failure.	Replace test diode or jumper test terminals. Check output of power supply.
	Power supply.	Check for leaks or blockage.
	Pressure piping.	Check for entrapped gas in liquid lines and for liquid in dry lines.
		Check for sediment in transmitter process flanges. c Make sure bayonet connectors are clean and check the sensor connections.
	Transmitter electronic connections.	Make sure bayonet connectors are clean and check the sensor connections.
	Transmitter electronic failure.	Determine faulty amplifier assembly by trying spare assembly. Replace faulty amplifier assembly.
Erratic output	Sensing element	Refer to “checkout of the sensing element”.
	loop wiring	Check for intermittent shorts, open circuits, and multiple grounds.
	Pressure piping	Check for entrapped gas in liquid lines and for liquid in dry lines.
	Transmitter electronic connections.	Check for intermittent shorts, open circuits.
	Transmitter electronic failure	Make sure that bayonet connections are clean ic and check the sensor connections. Determine faulty amplifier assembly, by trying spare assembly. Replace faulty amplifier assembly.
		Observe mechanical linkages; check for dirt, binding, excessive wear, misalignment. For dirt, clean and lubricate as per manufacturer’s instructions.
When moving final components in linkage through entire range manually or by applied pressure output signal responds to mechanical motion.	Indicates mechanical problem	For binding realign mechanical parts. For wear, replace as needed sensor (Bourdon tube, bellows, diaphragm, etc.). Perform calibration.
No output response to me chanical motion	Indicates electrical problems.	Replace electrical or electronic subassemblies. Perform calibration.

Preventive maintenance of pressure instruments

Objectives: At the end of this lesson you shall be able to
- **Explain proper usage of pressure gauges**
- **Explain the safety measures taken to maintain gauges**
- **State preventive measures to be taken to avoid damage to the devices.**

Safety instructions:

Before installing and using any type of gauge, it is important to study and understand the various information given in the manual to ensure appropriate usage of pressure gauge. Improper application can lead to instrument failure and damage. There is also possibility of injury to the person operating the pressure gauges.

1 Pressure gauges that are mechanically defective can cause injuries or give rise to process faults. Suitable precautions should be taken to avoid this. Mechanically defective gauges should be repaired or replaced immediately.

2 Separate regulations apply to service with hazardous media such as oxygen, acetylene, combustible substances, toxic substances

3 And to service in refrigeration plant, compressors and the like.

4 Before disassembling the pressure gauge the impulse ducts between the pressure gauge and the system have to be locked and relieved from pressure.

5 The standard nominal pressure rating and the permissible operating temperature of the gasket should be observed for all process connections.

6 De-installed pressure gauges can contain dangerous media residues. Adequate safety precautions must be taken when de-installing or transporting these instruments.

Maintenance of pressure gauges

Generally, instruction for periodic maintenance of an instrument is given in the manual supplied by the manufacturer. It explains how and when to service the device. Individual plants or industries also prepare their guidelines for periodic maintenance. For proper maintenance and usage of pressure gauges the followings points should be considered and understood.

Select a pressure gauge with a full-scale pressure range of approximately twice the normal operating pressure. For Bourdon tube gauges, the maximum operating pressure should not exceed 75% of the full-scale range. In case the pressure gauge dial has a black triangle at end scale this means the operating pressure could be raised up to 90% of full scale for fluctuating pressures and up to 100% of full scale for steady pressure. If the pressure exceeds this specified range, the over pressure may damage the sensing element of the gauge.

Flow measurement

Objectives: At the end of this exercise you shall be able to
- **describe the properties of flow measurement**
- **explain the units of flow measurement**
- **describe the reynolds number**
- **explain the relationship between the pressure, area, volume.**

Introduction

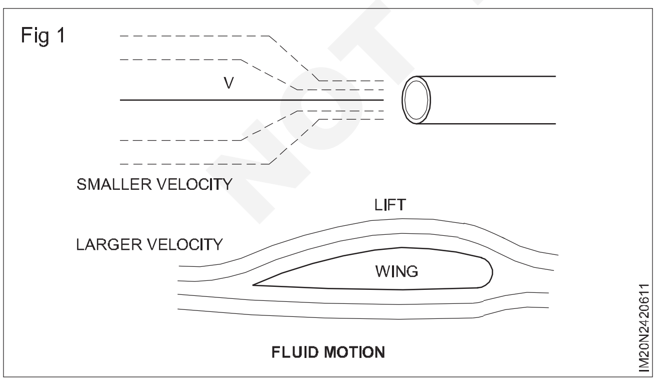
Measurement of flow rate and quantity is the oldest of all measurements of process variables in the field of instrumentation. It is made for determining the proportions and the amount of materials flowing in or out of a process. For the purpose of cost accounting, such measurement is often required to be made for steam, water and gas services. Without flow measurements, plant material balancing, quality control and even the operation or any continues process would be almost impossible.

Properties of Fluid

Flow patterns in a fluid (gas or liquid) depend on three factors: the characteristics of the fluid, the speed of flow, and the shape of the solid surface. Three characteristics of the fluid are of special importance: viscosity, density and compressibility.

- Density
- Viscosity
- Temperature
- Pressure
- Specific Volume
- Specific Weight
- Specific gravity
- Surface Tension

Fluid Motion (Fig 1)



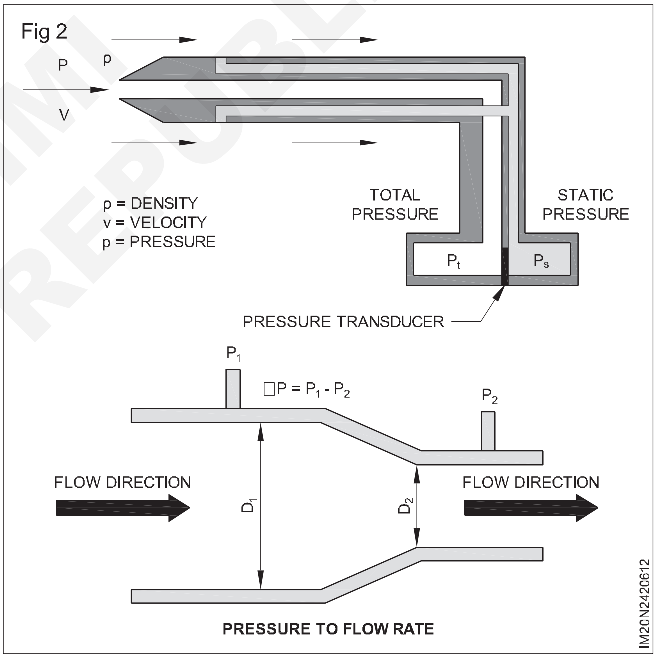
When a fluid, either a liquid or a gas, is set in motion, different parts of the fluid move with different velocities. For example, if a jar of water is tilted so that the water starts flowing out, the top layer of the water moves over the lower part.

Flow rate and Quantity

Flow rate Qis defined to be the volume V flowing past a point in time t or Q= v/t where 'v' is the Volume and 't' is the time.

The SI unit of discharge Q is m^3 / S-

Pressure to flow rate (Fig 2)

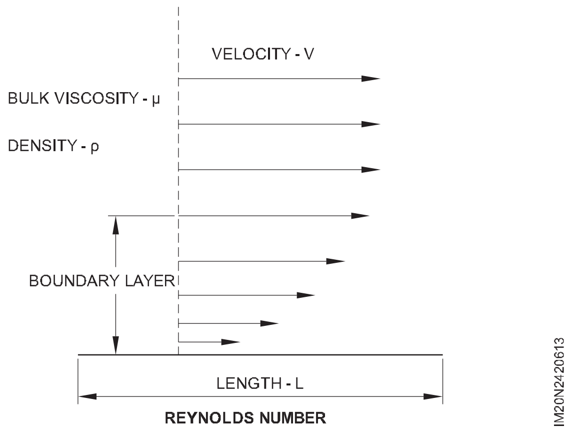


This relationship can be expressed by the equation F = Q/t. Fluid flow requires a pressure gradient (ΔP) between two points such that flow is directly proportional to the pressure differential. Higher pressure differences will drive greater flow rates. The pressure gradient establishes the direction of flow.

Reynold's Number (Fig 3)

The Reynolds number helps predict flow patterns in different fluid flow situations. At low Reynolds numbers, flows tend to be dominated by Laminar flow, while at high Reynolds numbers flows tend to be turbulent.

Fig 3



Formula

$$Re = \frac{\rho u L}{\mu}$$

Re = Reynold number

= Density of the fluid

u = flow speed

L = Characteristic Linear dimension r2

μ = Dynamatic Viscosity of the fluid

Reynold number = Re

$$Re = ratio = \frac{\text{Inertia Force}}{\text{Viscous Force}}$$

$$Re = \frac{\rho V\, dv/dx}{\mu d^2V/dx^2}$$

$$Re = \frac{\rho v\, V/L}{\mu V/L^2}$$

$$\text{Kinetic Viscosity} - V = \frac{\mu}{\rho}$$

$$Re = \frac{\rho v L}{\mu}$$

Reynolds Number is dimensions

$$Re = \frac{VL}{V}$$

Ref = Reynolds Number per foot

$$Ref = \frac{V}{V}$$

Newtonian Fluid Reynolds Number (Re) Formula

μ = Fluid dynamic viscosity in kg / (m.s)

p = fluid density in kg / m3

V = fluid velocity in m / s

D = pipe diameter in m

$$Re = \frac{\rho VD}{\mu}$$

Factors affecting flow rate

- A variety of factors such as fill Volume, Temperature, Pump position and storage times affect the flow rate accuracies of Elastomeric Pumps.
- From the Basic relationship we deduce that factors affecting flow rate comprises average velocity of the flow and cross sectional area of the pipe.
- Apart from these other factors which can influences liquid flow are :-
  - i Liquid's velocity
  - ii Density
  - iii Friction of the liquid in content with the pipe.

Units of Flow

Flow is the volume of fluid that passes in a unit of time. Flow is measured is units of cubic feet per second (cfs), gallons per minute (gpm) cubic meters per second (cms)

The SI unit is cubic meters per second (m^3 / s)

SI unit = m^3 / s

Common symbols Q, V

Relation between flow rate and Pressure Area, Quantity, Velocity

1 Bernoulli's equation states mathematically that if a fluid is flowing through a tube and the tube diameter decreases, then the velocity of the fluid increases, the pressure decreases, and the mass flow (and therefore volumetric flow) remains constant so long as the air density is constant.

2 The Velocity is higher where the area is smaller, **Pressure and Velocity are inversely related,** according to Bernoulli's principle in order to determine the Flow Rate represented as Q, we must define both the volume V and the point in time it is flowing past represented by t, or **Q =V/t**. Additionally Flow rate and velocity are related by the equation Q = Av where A is the cross – sectional area of flow and v is its average velocity.

3 This relationship can be expressed by the equation F = . Fluid flow requires a pressure gradient (ΔP) between two points such that flow is directly proportional to the pressure differential. Higher pressure differences will drive greater flow rates.

Getting Fluids to Flows

- There are basically two ways to make fluid flow through a pipe.
- One way is to fill the pipe, so the flow is down fill, in which case gravitational kinetic energy.
- The second way is to make the pressure at one end of the pipe larger than the pressure at the other end.

Types of flow meters

Objectives: At the end of this exercise you shall be able to
- **explain the methods of flow measurement**
- **explain the principle of head pipe flow meter**
- **explain mercury principle, construction advantages, disadvantages and uses of venture tube**
- **explain the orifice plate, pilot tube, flow nozzle, open channel flow meter**
- **explain differential pressure transmitter**
- **explain preventive maintenance of differential pressure transmitter.**

Methods of Flow Management

Flow measurement is the qualification of bulk fluid movement. Flow can be measured in a variety of ways. The common types of flowmeters with industrial applications are listed below :

- Obstruction type (differential pressure or variable area)
- Inferential (turbine type)
- Electromagnetic
- Positive=displacement flowmeters, which accumulate a fixed volume of fluid and then count the number of times the volume is filled to measure flow.
- Fluid dynamic (vortex shedding)
- Anemometer
- Ultrasonic
- Mass flowmeter (Coriolis force).

Flow measurement methods other than positive-displacement flowmeters rely on forces produced by the flowing stream as it overcomes a known constriction, to indirectly calculate flow. Flow may be measured by measuring the velocity of fluid over a known area. For very large flows, tracer methods may be used to deduce the flow rate from the change in concentration of a dye or radioisotope.

Types of Flow meters

The first is the primary element, which is in contact with the fluid, resulting in some form of interaction may be that of imparting motion to the primary element; the fluid may be accelerated etc.

The second or secondary element translates the interaction between fluid and primary element into a signal that can be converted into volume, weights or rates of flow and indicates or records the resulted.

Inferential (Rate Meters)

Inferential Flow Measurements

In the inferential type of flow measuring methods, the flow rate is inferred from a characteristic effect of a related phenomenon. A classic example of an inferential measurement is a human body running fever, resulting from a serious sickness or disability, in which the rise in body temperature (fever) is not the cause of sickness but a characteristic phenomenon resulting from the ailment.

The following are the inferential type of flow measuring methods:

i Variable head or different meters

ii Variable area meters

iii Magnetic meters

iv Turbine meters

v Target meters

vi Thermal flowmeters

vii Vortex meters

viii Ultrasonic flowmeters

Head Type Flow Meter Variable Head Type Flow Meter

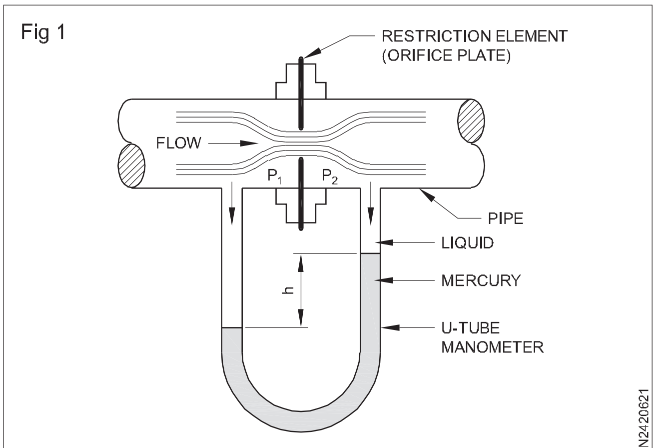
Variable Head or Differential Flowmeters (Fig 1)

This is one of the oldest and most widely used methods of industrial flow measurement. It measures volume rather than mass flow rates, but mass rates can be calculated or computed easily by knowing or sensing temperatures and pressures.

Basic Operating Principle

Variable head flowmeters operate on the principle that a restriction (or obstruction) in the line (or pipe) of a flowing fluid, introduced by the orifice plate or venture tube or elbow, produces a differential pressure across the restriction element which is proportional to the flow rate. The proportionality is not a linear one but has a square root of the differential pressure. This relationship in that the flow rate is proportional to the square root of the differential pressure.

Fig 1



DIFFERENTIAL PRESSURE FLOWMETER

This relationship was derived from Bernoulli's theorem which states that in a flowing stream, the sum of the pressure head, the velocity head and the elevation head at one point is equal to their sum at another point removed in the direction of flow from the first point plus the loss due to friction between the two points.

Advantage of Differential Flowmeters

- Its cost is relatively low especially for large lines.
- It offers the widest applicational coverage of any type of meter.
- It is accurate (with accuracy of about ±1/4 to ± 2%) and reliable.
- It can be easily removed without shutting down the process.
- It is adaptable to any pipe size and flow rate.

Disadvantage and Limitations

The disadvantages and limitations of a differential flowmeter are :

- There is relatively high permanent pressure loss in it.
- It is difficult to use for slurry services.
- It exhibits a square root relationship between head and flow rate, rather than linear characteristics, which limits the usable flow range ability to a 3 :1to 5: 1 range.
- Connecting pipings sometimes present a problem, such as freezing, condensation, etc.
- Low flow rates are not easily measured with these meters, except through the use of integral orifice devices where in-line mounting is required.
- Its accuracy is dependent on many fixed fluid characteristics such as temperature, pressure, specific gravity, compressibility, etc.
- It is difficult to measure pulsating flow with this type of meter.

Parts of a Differential Flowmeter

A differential flowmeter basically consists of two parts : i) Primary elements and (ii) Secondary elements.

The parts of the meter used to restrict the fluid flow in the pipe line in order to produce a differential pressure are known as primary elements. They are : i) orifice plates, ii) venture tubes, iii) flow nozzles iv) pilot tubes, v) weir and notes vi) flume.

Secondary elements are those which measure the differential pressures produced by the primary elements and convert them to usable forces or signals. Various secondary elements are : i) manometer, ii) bellow meter, iii) force balance meters and iv) ring balance meters

The various types of primary elements are described below.

Orifice Plates (Fig 2)

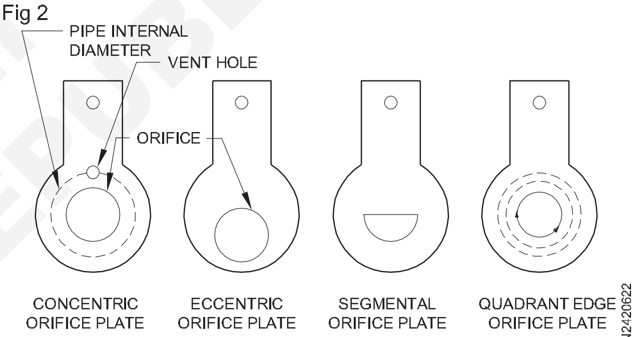
Orifice plates, as shown in Fig 2 are the simplest and cheapest form of primary elements and are used more frequently than all other types. An orifice plate is inserted in the line and the differential Pressure across it is measured. There are four types of orifice plates which are listed below :

- Concentric orifice plate
- Eccentric orifice plate
- Segmental orifice plate
- Quadrant edge orifice plate

Concentric orifice plate

It is most widely used. It is usually made of stainless steel and its thickness varies from 3.175 to 12.70 mm (1/8 to ½ in.), depending on pipe line size and flow velocity. It has a circular hole (orifice) in the middle, and is installed in the pipe line with the hole concentric to the pipe. It is also made from other materials such as nickel, monel, phosphor bronze, etc. to withstand the corrosive effects of the fluid. The plate thickness at the orifice edge should not exceed any of the following :

Fig 2



ORIFICE PLATES

D /50

d/8

(D-d)/8

Where D = the pipe internal diameter

d = the orifice diameter or bore

Eccentric Orifice Plate

It is similar to the concentric plate except for the offset hole which is bored tangential to a circle, concentric with the pipe and of a diameter equal to 98% of that of the pipe. Location of the bore prevents damming of solid materials or foreign particles and makes it useful for measuring fluids containing solids, oils containing water and wet stream. The eccentric orifice plate is used where liquid fluid contains a relatively high percentage of dissolved gases, and is installed with the bore tangential to the lower surface of the pipe when the fluid is a gas.

Segmental Orifice Plate

This orifice plate is used for the same type of services as the eccentric orifice plate. It has a hole which is a segment of a circle, the diameter of which is customarily 98% of the pipe diameter. It is installed with the dam horizontal and with the curved section of the opening coincident with the lower surface of the pipe.

Quadrant Edge Orifice Plate

This type of orifice plate is used for flows such as heavy crudes, syrups and slurries, and viscous flows. It is constructed in such a way that the edge is rounded to form a quarter-circle. The plate has a concentric opening with a rounded upstream edge rather than the sharp, square edge normally used. It may be used when the line Reynolds numbers range from 100,000 or above, down to 3,000 to 5,000 (depending upon beta ratio) with a coefficient accuracy of approximately 0.5%

Sometimes, orifice plates are provided with an additional small hole for the passage of condensates and gates, as shown in Fig 11.2. This hole located at the bottom when gases are measured, to allow the condensate to pass in order to

Advantages of Orifice Plates

The advantages of orifice plates are :

- Its cots is low.
- They can be used in a wide range of pipe sizes (3.175 to 18211.8mm).
- They can be used with differential pressure devices.
- They are well-known and have predictable characteristics.
- They are available in many materials.

Disadvantages and Limitations of Orifice Plates

- They causes relatively high permanent pressure loss.
- They tend to clog, thus reducing use in slurry services.
- They have square root characteristics.
- Their accuracy is dependent on care during installation
- They have changing characteristics because of erosion, corrosion and scaling.

Application:

1 Eccentric orifice plate is and for measuring flow rates of fluids containing solids, oils, containing water and wet stream.

2 Quadrant edge plates are used for heavy crudes, syrups and slurries, and viscous flows have Reynolds number below 10,000

Venturi tubes (Fig 3)

A venture tube is used where permanent pressure loss is prime importance, and where maximum accuracy is desired in the measurement of high viscous fluids. It consists of i) a straight inlet section of the same diameter as the pipe in which the high pressure tap is located, ii) a converging conical inlet section in which the cross-section of the stream decreases and the velocity head and decrease of pressure head, iii) a cylindrical throat which provides for the low pressure tap location of the decreased pressure in an area where flow velocity is neither increasing nor decreasing, and (iv) a diverging recovery cone in which velocity decreases and the decreased velocity head is recovered as pressure head, as shown in Fig 3. The Pressure taps are located one-quarter to one-half pipe diameter up-stream of the inlet cone and at the middle of the throat section.

The venturi tube can be used to handle a fluid which is handled by an orifice plate and fluids that contain some solids, because these venture tubes contain no sharp corners and do not project into the fluid stream. It can be also used to handle slurries and dirty liquids that build up around other primary elements, if the pressure taps are protected from plugging.

The venturi tubes are usually made of cast iron or steel, and built in several form such as i) long-form or classic venture tube, ii) short-form where the outlet cone is shortened, iii) an eccentric form to minimize the buildup of heavy materials and a (iv) rectangular form used in air duct-work. Figure shows the different types of venture tubes.

Venturi tubes are available in sizes from 100 mm to 813 mm with a flow coefficient value of 0.984 for all diameter ratios, and beta ratios between 0.3 and 0.75. its overall accuracy ranges from ±1/4 to ±3%. Venturi coefficient is less affected by a decreasing Reynolds number.

Advantages

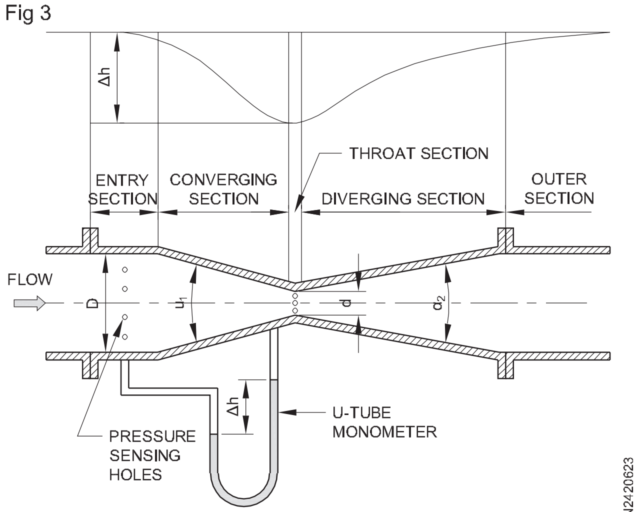
The advantages of a venture tube are :

- It causes low permanent pressure loss.
- It is widely used for high flow rates
- It is available in very large pipe sized.
- It has well-known characteristics.
- It is more accurate over wide flow ranges than orifice plates or nozzles.
- It can be used at low and high beta ratios.

Disadvantages

The disadvantages of a venture tubes are :

- Its cost is high
- It is generally not useful below 76.2 mm pipe size.
- It is more difficulty to inspect due to its construction.
- It has the limitation of a lower Reynolds number 150,000, (some data is however available down to a Reynolds number of 50,000 in some sizes).



PRESSURE MEASUREMENT USING VENTURIMETER

Applications of Venturimeter

1 Used in engine carburetors (Automobile sector) to measure airflow.

2 Used in process Industries (Processed power piping Industries) to measure and control process flow.

3 In the medical Industries, blood flow in the arteries is measured by venturi meters.

4 Used for measurement of flow of water and fluids used in industrial processes, industrial wastes, gases suspended particles, slurries and dirty liquids.

Flow nozzles

Objectives: Sat the end of this lesson you shall be able to
- **describe the uses of nozzles**
- **explain the advantages and disadvantages of nozzles.**

Flow Nozzles (Figs 1&2)

The flow nozzles are used for flow measurements at high fluid velocities and are more rugged and more resistant to erosion than the sharp edged orifice plate. Basically, there are two types of flow nozzles, the long – radius flow nozzles and the I.S.A. (International Federation of the National Standardizing Associations) flow nozzle. A flow nozzle consists of a convergent inlet whose shape is a quarter ellipse, and a cylindrical throat as shown in fig Differential pressure measurement taps are normally located one pipe diameter upstream and one – half diameter downstream from the inlet faces of the nozzle. For a given diameter and a given diameter and a given differential pressure, it allows measurement of flow rates almost 65% more than that of the Orifice plate.

Flow nozzles are manufactured commonly from materials such as stainless or chrome – moly steel. They are made commercially in various configurations, viz flange type, holding ring type, and throat type.

Flow nozzles should be used at Reynolds numbers of 50,000 or above. However, data is available for Reynolds number down to 6,000; so it is possible to use nozzles with more viscous fluids. Flow nozzles have very high co-efficient of discharge, typically 0.99 or greater, and a wide range of beta ratios of 0.2 to 0.8.

Advantages

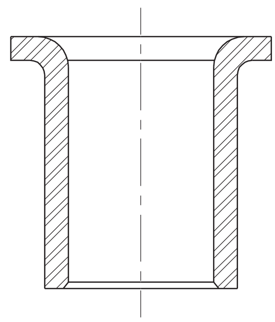
Following are the advantages of a flow nozzle :

- Its permanent pressure loss is lower than that for an Orifice plate.
- It is available in numerous materials.
- It is useful for fluids containing solids that settle.
- It is widely accepted for high – pressure and temperature steam flow.

Disadvantages

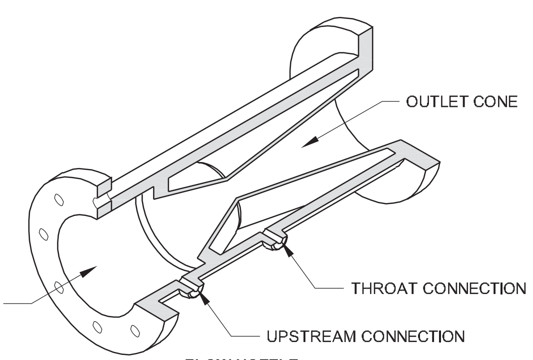
Following are the disadvantages of a flow nozzle

Fig 1



FLOW NOZZLES

Fig 2



FLOW NOZZLE

- Its cost is higher than Orifice plate
- It is limited to moderate pipe sizes
- It requires more maintenance (it is necessary to remove a section or pipe to inspect or install it).

Applications

- It can be used for high pressure temperature steam flow.
- It can be used to measure high fluid rates.
- To create jets and streams at high pressures.

Pilot Tube (Fig 3)

Pilot tubes are used mainly for the measurement of fluid velocity. The operating principle of a pilot tube is based on the fact that when a solid body is kept centrally and stationary in a pipe line with a fluid streaming down, the velocity of the fluid starts diminishing due to the presence of the body till it is reduced to zero directly in front of the body. This point is known as the stagnation point.

As the kinetic head (pressure) is lost by the liquid, it gains a static head. Thus, by measuring the difference between pressure at normal flow line and that at stagnation point, the fluid velocity is determined.

A pilot tube consists of a tube with an impact opening of 3.125 to 6.35 mm which is placed directly in the line of flow, and a static opening at 900 from the impact opening, as shown in Fig 3. The differential pressure across these taps is proportional to the velocity of the fluid. The measurement of quantity rate is calculated from the ratio of average velocity to the velocity at the point of measurement. For an accurate measurement, the pilot tube is moved across the entire diameter of the pipe to measure the velocity at several points and then the true average velocity is calculated. The accuracy of a pilot tube may range from ±1/2 to ±5%.

Pilot tubes are rarely used in process streams but are used occasionally in utility streams where high accuracy is not necessary.

Advantages

The advantages of pilot tubes are :

1 These tubes have no process loss.

2 They are economical to install.

3 Some types can be easily removed from the pipe line.

Disadvantages

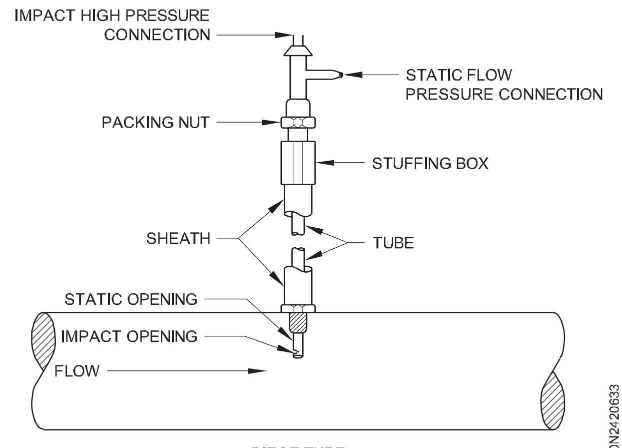
The disadvantages of the pilot tubes are :

1 These tubes have poor accuracy

2 They are unsuitable for dirty or slurry fluids.

3 They are sensitive to upstream disturbance.

Fig 3



PITOT TUBE

Open Channel Flow Meter

The common method of measuring flow through an open channel is to measure the height or HEAD of the liquid as it passes over an obstruction (a flume or weir) in the channel.

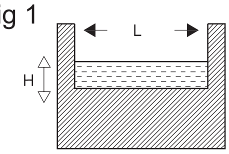
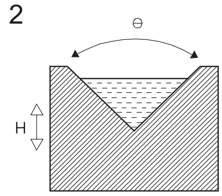
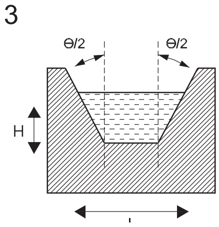
A weir is a concrete or masonry structure which is constructed across the open channel (such as a river) to change its water flow characteristics. Weirs are constructed as an obstruction to flow of water. Theses are commonly used to measure the volumetric rate of water flow, prevent flooding and make rivers navigable.

Types of Weirs

Weirs are classified according to :

1 Types of Weirs based on Shape of the Opening

- Rectangular weir
- Triangular weir
- Trapezoidal (Cippoletti) weir

	Types of weir	Diagram
a	Rectangular	Fig 1 
b	Triangular	Fig 2 
c	Trapezoidal	Fig 3 

Rectangular weir

- It is a standard shape of weir. The top edge of weir may be sharp crested or narrow crested.
- It is generally suitable for larger flowing channels.

Triangular weir

- The shape of the weir is actually reverse triangular like V. So, it is also called V-notch weir.
- This type of weirs are well suitable for measuring discharge over small flows with greater accuracy.

Trapezoidal weir

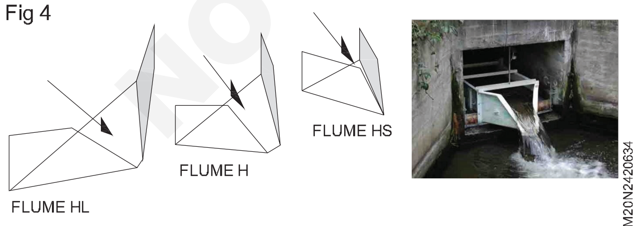
- Trapezoidal weir is also called as Cippoletti weir. This is rapezoidal in shape and is the modification of rectangular weir with slightly higher capacity for same crest strength.
- The sides are inclined outwards with a slope 1:4 (horizontal : vertical)
- In cippoletti weir both sides are having equal slope. So we, can divide the trapezoid into rectangle and triangle portions. So, Total discharge over trapezoidal weir Q = discharge over rectangular weir + discharge over triangular weir.

Flumes (Fig 4)

A flume is a stabilized channel section for measuring the flow. They are less inclined than weirs which make them well suited for runoff measurement. They require a very low head loss for operation. Examples of flumes are Parshall flume, H-flume, cut-throat flume, long-throated flume and venturing flume, They can be a “flat-bottom” type. In the case of a flat-bottom flume, the shape of the side walls creates a contraction of the flow of liquid (ex. Cut-throat flume). They can also combine vertical and side contractions (ex. Parshall flume).

Flumes work according to the venture principle by reducing the flow area, velocity increases and water depth changes. A flume usually has three section : a converging section, throat section and diverging section. Sizes vary according to the type and shape of flume. For practical purposes, to determine the absolute flow of a flume, the calibration curves supplied by the manufacturer should be used.

Fig 4



1 HS-Flumes : Of this ‘small’ category H-flume, the flow depth is restricted to 30 cm and is capable to measure flow ranging between 0.005 to 23 l/s.

2 HS-Flumes : Of this ‘normal’ category H-flume. In this case the maximum flow depth are 1.4m and this is able to measure flow ranging from 0.01 l/s to 2400 l/s.

3 HL-Flumes : This is largest H-flume among the three categories. Though in this case also, the maximum flow depth is 1.4m, the HL-flume is wider than the normal H-flume and hence the accuracy is lesser. The use of this type of flume is only recommended if the anticipated discharge exceeds the capacity of the normal H-flume. The HL= flume is able to handle flow rate as high as 3300 l/s.

Advantages

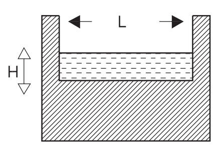
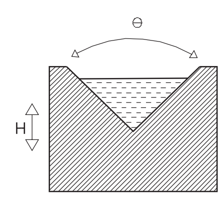
- Minimal drop in pressure.
- Enables measurement in a large range of flow.
- The flow-rate in flumes is usually high enough to prevent sedimentation; they are therefore self-cleaning.
- Provides a reliable measurement in free flow and submerged flow conditions.

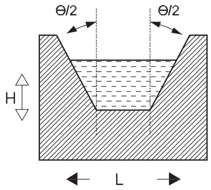
Disadvantages

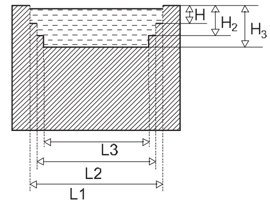
- Installation is usually expensive.
- Installation requires extremely careful work.
- Requires a secure watertight base.
- Flow at the entrance must be evenly distributed, with little turbulence, to produce accurate measurements.

Notches

A notch may be defined as an obstruction over which the flow of liquid occurs. As the depth of flow above the base of the notch is related to the discharge, the notch forms a useful measuring device. In case of measuring tank or reservoir, the opening is provided at the side of the tank such that the liquid surface in the tank below the top edge of the opening. In fact, this is a large opening which has no upper edge, so that it has a variable area depending upon the level of the free surface.

	Types of notches	**Diagram**
a	Rectangular	Fig 1 
b	Triangular	Fig 2 

c	Trapezoidal	Fig 3 

d	Stepped	Fig 4 

Variable-area flowmeters

Objectives: At the end of this exercise you shall be able to
- **describe principle of variable area flow meter**
- **briefly explain the construction and the usage of rotameter**
- **explain different shapes and materials of floats used in rotameter**
- **describe the factors affecting rotameter.**

A'variable area meter" measures fluid flow by allowing the cross sectional area of the device to vary in response to the flow, causing some measurable effect that indicates the rate. A rotameter is an example of a variable area meter, where a weighted "float" rises in a tapered tube as the flow rate increases; the float stops rising when area between float and tube is large enough that the weight of the float is balanced by the drag of fluid flow. A kind of rotameter used for medical gases is the Thorpe tube flowmeter. Floats are made in many different shapes, with spheres and spherical ellipses being the most common. Some are designed to spin visibly in the fluid stream to aid the user in determining whether the float is stuck or not. Rotameters are available for a wide range of liquids but are most commonly used with water or air. They can be made to reliably measure flow down to 1% accuracy.

Another type is a variable area orifice, where a spring-loaded tapered plunger is deflected by flow through an orifice. The displacement can be related to the flow rate.

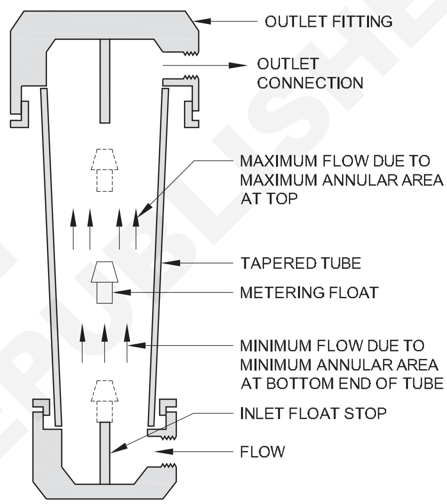
Variable Area Flowmeters

In the differential – head flowmeters described above, the flow restriction is of fixed size and the pressure differential across it changes with the flow rate; whereas in the variable area flow meters, the size of the restriction is adjusted by an amount necessary to keep the pressure differential constant when the flow rate changes, and the amount of adjustment required is proportional to the flow rate. Basically there are two types of variable – area flowmeters : forms an annular orifice.

The tube is mounted vertically with the small end at the bottom. The fluid to be measured enters the tube from the bottom and passes upward around the float, and exit at the top.

When there is no flow through the rotameter Fig 1, the float rests at the bottom of the metering tube where the maximum diameter of the float is approximately the same as the bore of the tube. When fluid enters the metering tube, the float moves up, and the flow area of the annular orifice increases. The pressure differential

Fig 1



ROTAMETER

IM20N2420641

across the annular orifice is proportional to the square of its flow area and to the square of the flow rate. The float is pushed upward until the lifting force produced by the pressure differential across its upper and lower surface is equal to the weight of the float. If the flow rate rises, the pressure differential and hence the lifting force increases temporarily, and the float then rises, widening the annular orifice until the force caused by the pressure differential remains constant and the area of the annular orifice (i.e free area between float and inside wall of the tube) to which the float moves, changes in proportion to the flow rate. Any decreases in flow rate causes the float to drop to a lower position. Every float position corresponds to one particular flow rate for a fluid of a given density and viscosity. A calibration scale printed on the tube or near it, provides a direct indication of flow rate.

The tube materials of rotameter may be of glass or metal. The glass metering tubes are commonly used for relatively low pressure and temperature services of non-hazardous fluids such as water and air.

Inside the metal tube, a different technique for indication is necessary such as magnetic or electrical, in which the linear motion of the float is converted into a rotary motion for the movement of a pointer on a calibrated scale.

Since the majority of fluid applications of rotameters arte for low viscosity fluids, corrections must be provided for the changes in fluid density or specific weight. These corrections are specially important for gas flows where changes in operating temperatures and pressures cause significant changes in the specific weight of the flowing medium.

In addition to flow rate indication at the point of measurement, rotameters can be equipped with additional functions such as alarm, pneumatic or electric transmission recording, controlling or totalizing. The accuracy of rotameters is from ±0.5% of rate to ±10% of full scale depending upon size, type and calibration.

Rotameters can directly measure flows as high as 4000 gpm (920 leter/hr). Higher flow rates can be economically handled using the bypass-type rotameter which consists of an orifice plate located in the main line and sized to take a standard pressure drop at maximum flow.

Advantages

The advantages of a rotameter are :

- Its cost is relatively low.
- Rotameters have good rangeability.
- It is good for metering small flows.
- It is easily equipped with alarm switches, or transmitting devices.
- It handles wide variety of corrosives.
- Viscosity – immune floats are available in rotameters.
- It can be used in some light slurry services.
- It has low pressure drop requirement.

Disadvantages

The disadvantages of a rotameter are :

- The glass tube type is easily subject to breakage.
- It must be mounted vertically.
- It is not good in pulsating services.
- Rotameters are generally limited to small pipes sizes (unless bypass-type rotameter is used)
- Rotameters are limited to relatively low temperature.
- The accuracy of rotameters is fair (about ±1/2 to ±10%).
- It requires in-line mounting (except bypass –type)

Types of Floats (Fig 2)

Materials of Rotameter

1 Stainless steel

2 Glass

Factors Affecting Rotameter

1 Fluid Density

2 Fluid Types

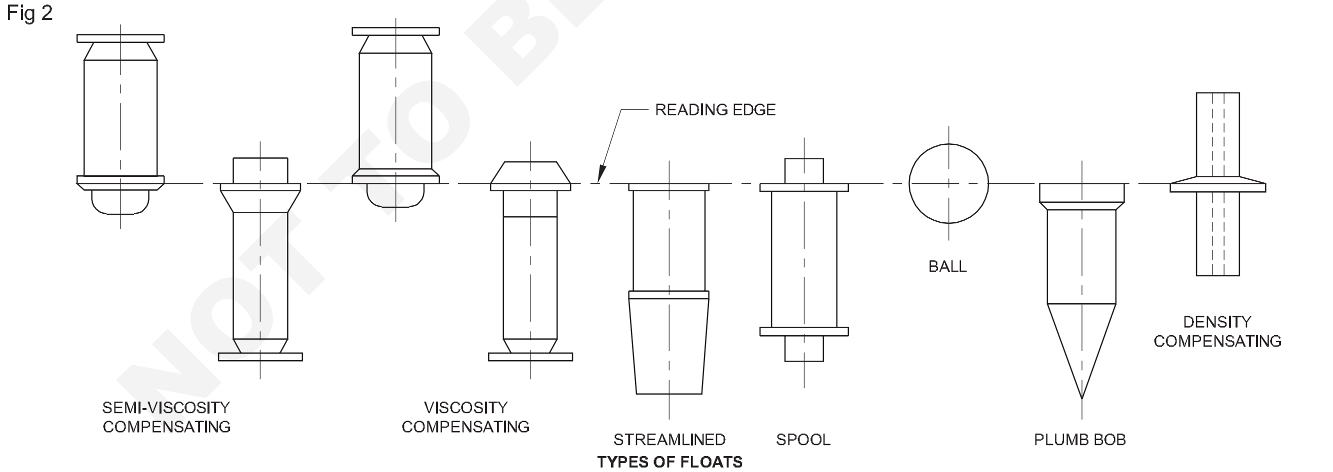
3 Fluid Viscosity

4 Maximum Flow Rate

5 Operate and measure Temperature and Pressure

6 Materials of Construction.

Fig 2



TYPES OF FLOATS

Nutatic disc flow meter working principle, applications, advantages and disadvantages

Objectives: At the end of this exercise you shall be able to
- **describe different types of positive displacement**
- **explain nutating disc flow meter**
- **explain oscillating piston type flow meter**
- **explain cylinder and piston type**
- **explain rotating vane flow meter**
- **explain lobed impeller type flow meter**
- **explain oval type flow meter**
- **describe calibration method of positive displacement meter**
- **describe the preventive maintenance of positive displacement meter.**

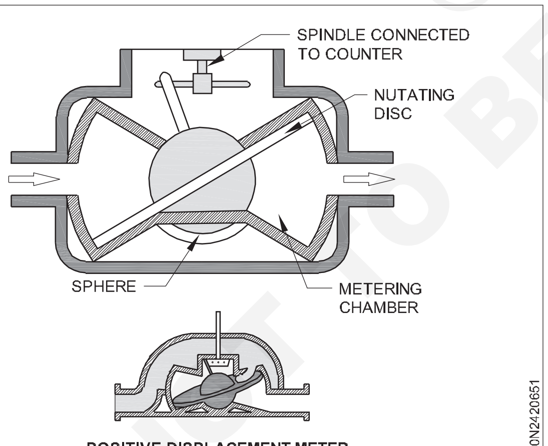
Positive Displacement Meters (Fig 1)

Positive displacements meters are essentially flow quantity meters. They are most widely used for the applications where the highest degree of accuracy and good repeatability are required. These devices work on the principle that as the liquid flows through the meter, it separates the flow of liquid into separate known volumetric increments which are counted and totaled. The sum of the increments gives the measurement of the total volume of liquid passes through the meter.

Positive displacement meters may be divided into following categories :

- Nutating disc type
- Oscillating piston type
- Rotating vane type
- Reciprocating piston type
- Lobed impeller type

Fig 1



POSITIVE DISPLACEMENT METER

Nutatic Disc Flow Meter working principle Applications

Advantages and Disadvantages

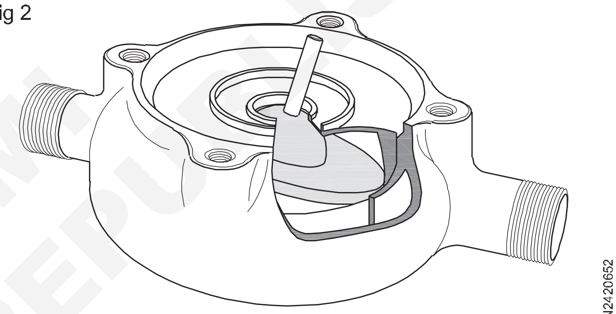
Positive displacement type flow meter

Design / construction of nutating disc flow meter

Above figure 1 shows the schematic diagram of nutating disc meter. It consists of a precision machined chamber, a center ball, movable disc and counter mechanism. The disc is integral to the ball / sphere mounted inside the chamber. A small pin is fastened to the ball to convert nutating motion / eccentric spinning motion of the ball into rotary motion of the shaft. The disc is pivoted at the geometric center, and it is allowed to nutate or wobble in a specially designed chamber. The controlled clearance between the disc and chamber ensured the proper sealing and minimum leakage.

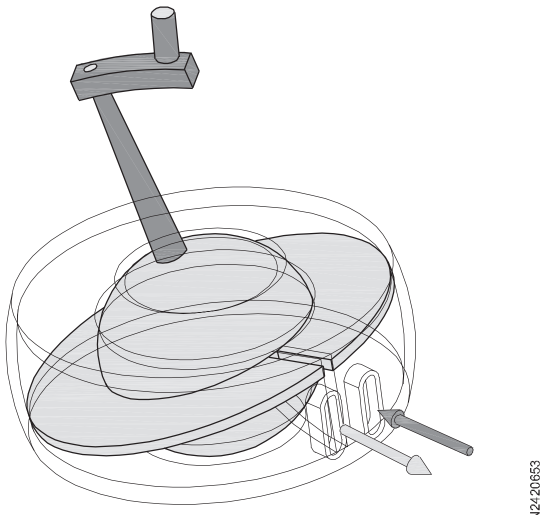
How nutating disc flow meter work (Figs 2&3)

Fig 2



NUTATING DISC FLOW METER WORK

Fig 3



NUTATING DISC ENGINE

The disc divides the chamber into two equal volume. In above Fig 2 water enters at the left side of the eccentrically mounted disc. The liquid pressure sets the disc in motion, results in the quantity of liquid that enters left side of the chamber will be rolled out thorough the outlet. When the disc and ball wobble it generate a cone with the apex at geometric center, this motion is getting translate into a rotary motion of shaft by the pin fastened to the ball. The movement of the disc is then transmitted by the cam and gear train to the totalizer or pulse transmitter. Each complete cycle of nutation of the disc will be counted by the counter mechanism which can be directly calibrated in terms of volume of liquid received or discharges. Each revolution of disc indicates the passage of fixed volume of fluid.

A variety of secondary accessories, which perform additional functions, can be added to this fundamental mechanism. For example, Count resetting device.

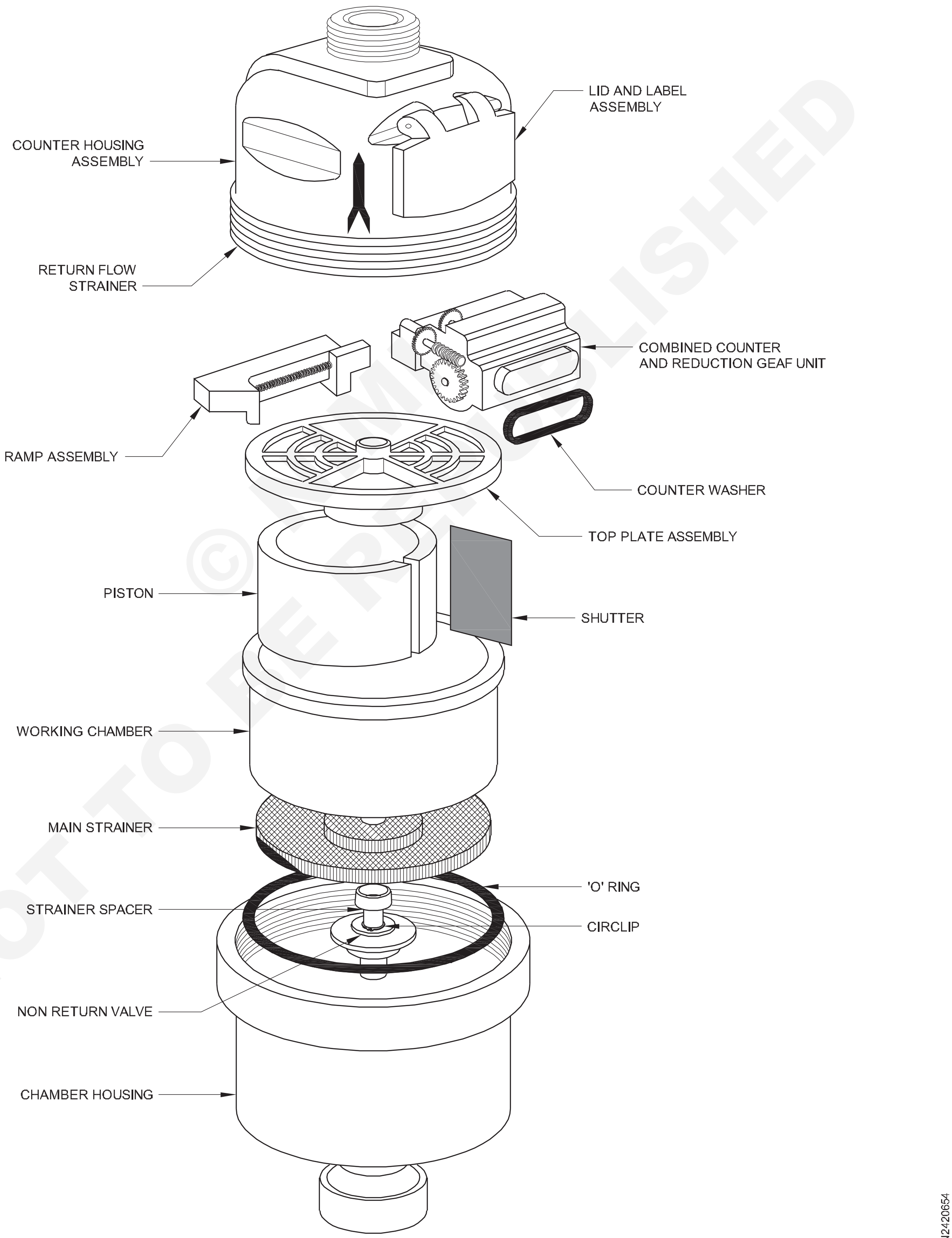
Read : Oscillating piston flow meter working, advantages and disadvantages

- Differential Pressure flow meter

Applications nutating disc flow meter

Nutating disc meter one of the common flow meter, it is used extensively in residential water services measurement, and also it can be used in many industrial applications. It can be used in automatic batching of liquid. (Fig 4)

Fig 4



OSCILLATING PISTON TYPE FLOW METER

Advantages and Disadvantages of nutating disc flow meter

Advantages

1 Relatively low cost

2 Less affected by the velocity profile in downstream and upstream.

3 The nutating-disc is durable, minimum maintenance.

4 High accuracy, repeatability. (Accuracy is about ± 1%)

5 Low-pressure drop.

6 Eliminate the requirement of straight upstream and downstream piping.

7 Applicable to automatic liquid batching System

8 No of materials are available for construction

Disadvantages

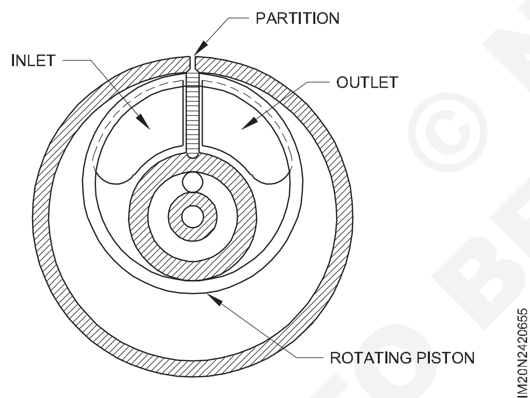
1 Performance may have affected by suspended solid particle. (The strain of suitable mesh size is used to avoid this problem)

2 It is limited to pipe size and capacity.

3 Only clean fluids can be measured

4 Accuracy is affected by the viscosity of fluids flow through them.

Fig 5



Oscillating Piston Type Flow Meter

Principle

This oscillating piston type flow meter comes under the category of positive displacement type meter. This meter traps a known volume of fluid and allow it to pass from meter inlet to outlet. Then the number of trapped volumes passing through the meter is counted to obtain the total flow. The term displacement means that the fluid flowing through the meter replaces (displaces) the volume of fluid that has flown through the meter immediately before. No volume of fluids is counted twice. The reading in the meter changes in direct proportion to the volume of fluid passing through it.

Construction

This meter consists of a main body made of cast brass. Inside a chamber houding, working chamber is kept alongwith main strainer, strainer spaces, oring circlip non return valve as shown in Fig 4.

The working chamber consists of the piston shutter and top plate, the spindle which has a pinion drive, the counter mechanism and the total flow recorder.

The counter mechanisms are of two types, one clock type and another digital numbered. Both the mechanisms are driven by the train of gears moved by the piston.

Working chamber or the bottom head with cylinder has a cut way for the water to enter and leave. The piston moves inside the chamber. The internal construction of chamber with inlet, outlet partition and rotating piston is shown in Fig 5

The diameter of the hard rubber piston is considerably smaller than that of the cylinder (measuring chamber).

The cylinder is normally made of bronze. It is such a way made, so that the piston fits off – center and can oscillate around the inner wall. The outer and inner wall of the cylinder is separated by a partition. The piston is slotted, so that, it fits around the partition without binding. The partition keeps the piston rotating.

When fluid enters the meter through the inlet port, the piston oscillates around the wall of the cylinder, as the piston revolves once the contents of the measuring chamber enter more thorugh the meter and discharge at the outlet port. The different positions of piston is shown in the Fig 6.

Each time, the piston completes a path around the wall of the cylinder, the center part of the piston makes one revolution around the fixed center part of the cylinder.

Each revolution corresponds to the movements of a fixed volume of water through the meter.

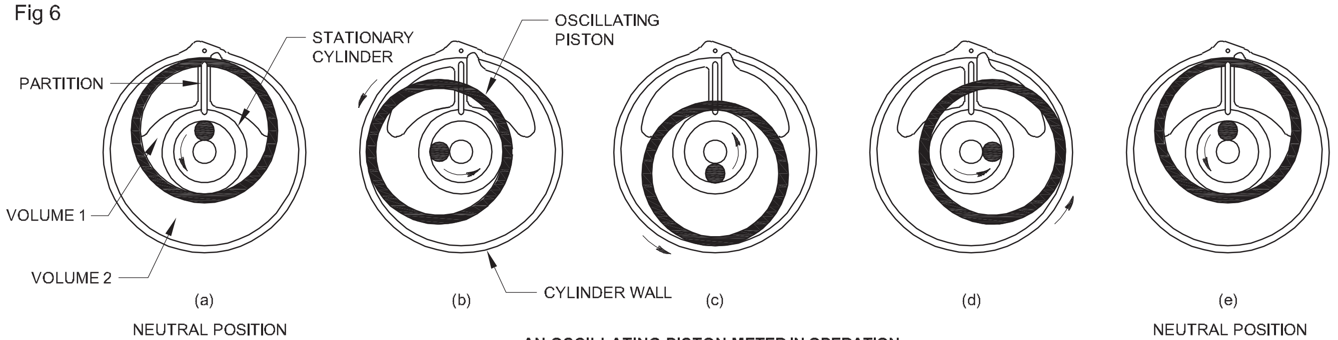
Therefore, if you count the revolutions made by the piston center post, you can find the amount of fluid flowing through the meter.

Oscillating piston meters are accurate, precise and have a wide flow range. The meters are also ideal for measuring low rates of flow. They require no power supply and need only simple maintenance.

The disadvantages of this meters are expensive, limited throughout size and liable for corrosion. In addition they can be damaged by excessive flow, are often difficult to install. They are usually suitable for clean liquids. Generally, these meters are used to measure cold water and can also be used for other clean liquids. They are available in size of 15, 25, 50mm diameters.

Good preventive maintenance requires a regularly scheduled inspection and lost program, visual inspection for leaks, damaged pipes.

Fig 6



AN OSCILLATING PISTON METER IN OPERATION

Reciprocating piston type flowmeter

Objectives: At the end of this lesson you shall be able to
- **explain the parts and functions of reciprocating piston type flowmeter**
- **describe the advantages and disadvantages.**

Reciprocating piston meters:

The reciprocating piston meter is the oldest of the positive displacement meters. It is widely used in petroleum industry. It is very similar in construction to a reciprocating steam engine piston and cylinder. It consists of a cast iron cylinder sitted with a piston. Two slide values are attached at the inlet and outlet ports. The Fluid to be measured enters through the inlet forcing the piston to the left position. At this point, an external leakage causes both slide valves to move and thus the liquid enters the left cylinder forcing the piston to its extreme right position. When the cylinder becomes full, the slide valves again move and the cycle is repeated. The external arm of the slide valve drives a counter which provides a total of the fluid quantity that has passes through the meter. Instead of one piston, a number of pistons operating on a centre crank are generally incorporated with this type of meter.

Reciprocating pump meters are available in many forms such as multipiston meters, double – acting piston meters, rotary valves, and horizontal slide valves. The accuracy of these meters are from ±0.2 ±0.3%

Advantages

The advantages of reciprocating piston meters are :

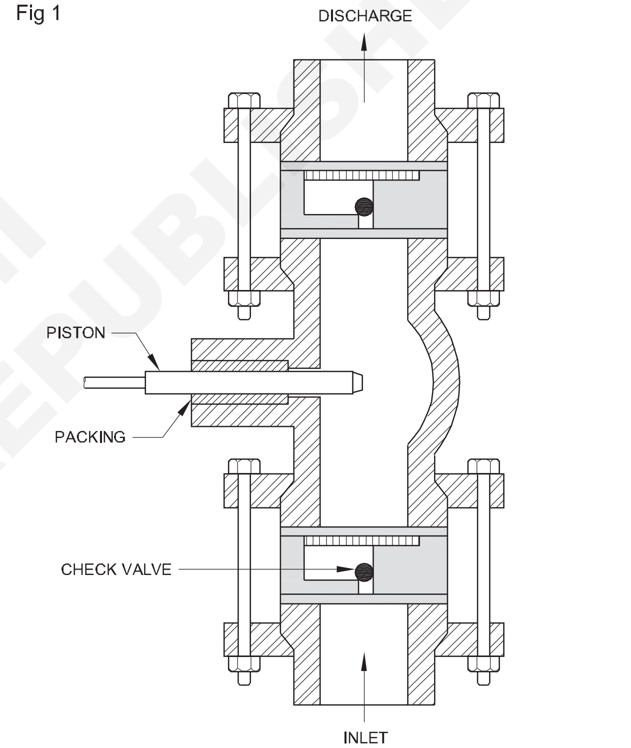
- Its accuracy is high
- Construction materials are not limited in reciprocating piston meters.

Limitations

The limitations of reciprocating piston meters are :

- Their cost is relatively high.
- They are subject to leakage
- Problems are created by dirty fluids
- It requires high maintenance cost
- It is restricted to moderate flow rates
- It produces pulsating flow when used for liquid measurement.

Fig 1

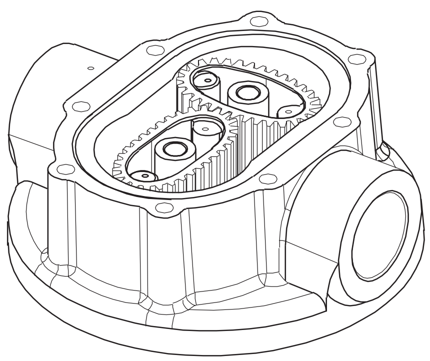


RECIPROCATING PISTON PUMB FLOW METER

Oval type of flow meter

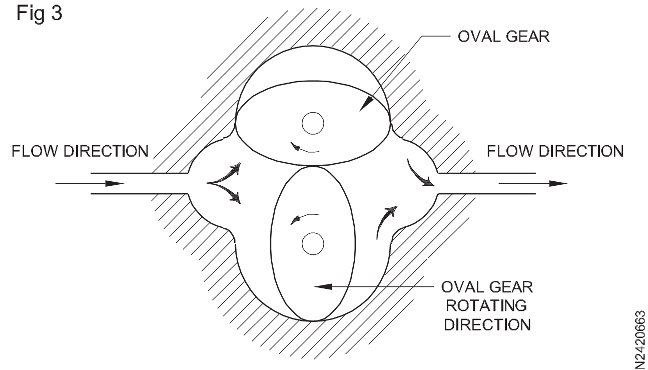
An oval gear meter (Figs 2 &3) is a positive displacement meter that uses two or more oblong gears configured to rotate at right angles to one another, forming a T shape. Such a meter has two sides, which can be called A and B. No fluid passes through the center of the meter, where the teeth of the two gears always mesh. On one side of the meter (A), the teeth of the gears close off the fluid flow because the elongated gear on side A is protruding into the measurement chamber, while on the other side of the meter (B), a cavity holds a fixed volume of fluid in a measurement chamber on side B to be released into the outlet port. Meanwhile, fluid entering the inlet port will be driven into the measurement chamber of side A, which is now open. The teeth on side B will now close off the fluid from entering side B. This cycle continues as the gears rotate and fluid is metered through alternating measurement chambers. Permanent magnets in the rotating gears can transmit a signal to an electric reed switch or current transducer for flow measurement. Though claims for high performance are made, they are generally not as precise as the sliding vane design.

Fig 2



OVAL TYPE FLOW METER

Fig 3



OVAL TYPE FLOW METER

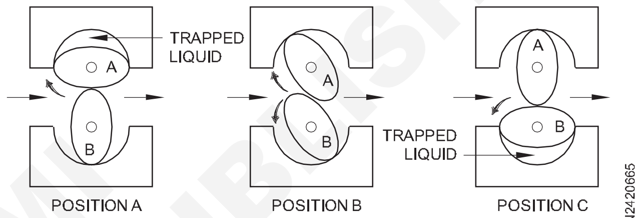
Gear meter (Fig 4)

Gear meter differ from oval gear meters in that the measurement chambers are made up of the gaps between the teeth of the gears. These openings divide upto the fluid stream and as the gears rotate away the inlet port, the meter's inner wall closes off the chamber to hold the fixed amount of fluid. The outlet port is located in the area where the gears area coming back together. The fluid is forced out of the meter as th gear teeth mesh and reduce the available pockets to nearly zero volume.

Oval gear flow meters – operating principle (Fig 5)

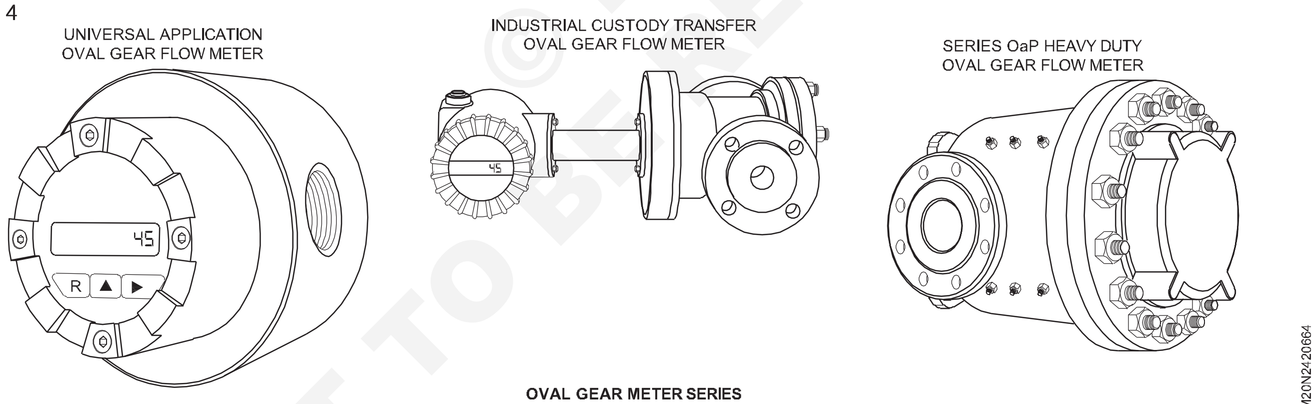
The measuring element of an oval gear meter consists of two toothed precision oval wheels which are driven by the fluid passing thorough the unit. The number of revolutions is an exact measure of the volume.

Fig 5



OVAL GEAR FLOW METERS

Fig 4



OVAL GEAR METER SERIES

Maintenance and recalibration requirements are minimal because of the lack of moving parts. Often, the gear meter is selected over the Coriolis because of its accuracy and longevity in harsh environments where the Coriolis is susceptible to interference changes and general wear.

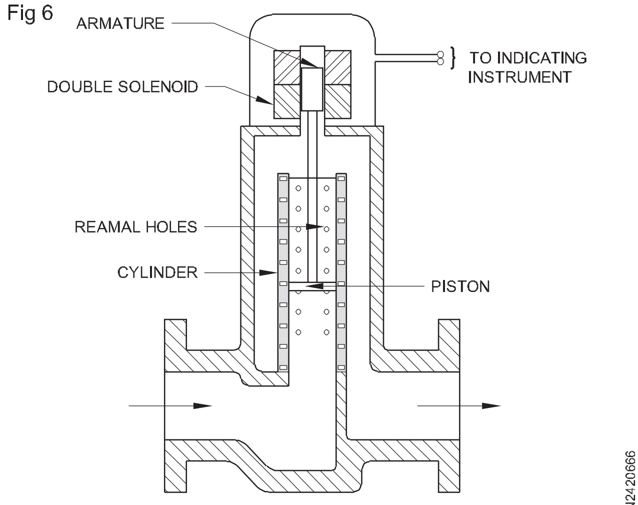
Cylinder and piston type flowmeters (Fig 6)

The cylinder and piston type variable area flowmeter is most oftenly used for measuring flow of fuel oils, tar. Chemicals liquors, and other such high viscosity fluids. Its operating principle is similar to rotameters, it consists of a cylinder and a piston fitted into it.

When fluid enters the cylinder, the piston exerts a constant downward force, and the difference in pressures between the two sides of the piston places the piston in a particular position. As the downstream flow is increased, the pressure on the load side of the piston is reduced. The increased differential pressure then forces the piston up, thereby increasing the area of the openings through which the fluid can flow until the pressure differential is again balanced. The linear movement of the piston in the cylinder is sensed by a linear variable differential transformer (LVDT) which converts this linear motion into voltage signal which is proportional to the flow rate.

These types of meters arte used for high viscosity fluids materials which are corrosive or might clog lines, and materials whose flow coefficients are not well known.

Fig 6



CYLINDER AND PISTON TYPE METER

Advantages

The advantages of cylinder and piston type flowmeter are:

- It is good for high viscosity fluids.
- It has good accuracy.
- The range of such instruments can have wide variations.
- It can be designed to use flow rates of the order of 0.08 cc/min where variable-head meters are not suitable.

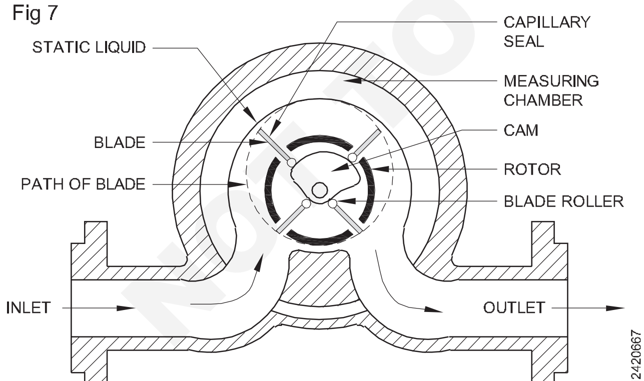
Disadvantages

The disadvantages of cylinder and piston type flowmeter are :

- Its cost is relatively high.
- It has limited size range (about 25 to 100mm).

Rotating vane meters (Fig 7)

Fig 7



ROTATING VANE METER

The rotating vane meter is most widely used in the petroleum industry and is used for such services as gasoline and crude oil metering. It consists of a cylindrical rotor that revolves on ball bearings around a central shaft and stationery cam, as shown in Fig 7. As liquid flows against an extended blade, the resulting rotation of the rotor and the action of the cam cause the blades to act as cam followers, creating measuring chambers that accurately measures fluid thorough-put. Capillary actions of the metered fluid effectively seals the blades to form the measuring cavities.

These types of meters are quite accurate and are available in sizes upto 400 mm. It has a normal accuracy of ±0.1%, an accuracy of ±0.05% has been achieved in the larger meters. These meters are built from a variety of materials of construction, and can be used for fairly high temperature and pressure services whose upper limits are approximately 1770 C and 1000 psig (6.9 MPa) respectively. These meters can be used to measure the flow ranges from a few gallons per minute of low viscosity clean liquids to 17,500 gallons per minute (66.5) liters/minute).

Advantages

The advantages of rotating vane meter are :

- It allows low pressure loss.
- It is applicable to a wide variety of gas and liquid fluids including viscous materials.
- It has relatively high temperature and pressure ratings.
- It is available in numerous construction materials.
- It has a good accuracy.

Disadvantages

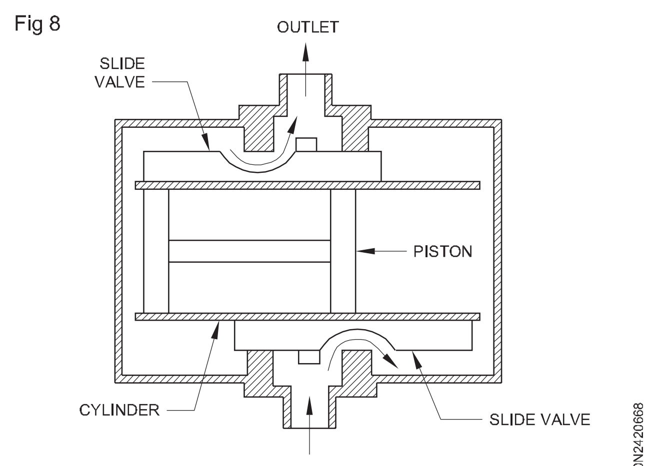
The disadvantages of rotating vane meter are :

- It is susceptible to damage from entrained vapours and dirty fluids.
- Its accuracy decreases at low flow rates.

Reciprocating piston meters

The reciprocating piston meter is the oldest of the positive displacement meters, it is widely used in petroleum industry. It is very similar in construction to a reciprocating steam engine piston and cylinder. It consists of a cast iron cylinder fitted with a piston, as shown in Fig.8 Two slide valves are attached at the inlet and outlet ports. The fluid to be measured enters through the inlet forcing the piston to the left until the cylinder is full and piston is in its extreme left positions. At this point, an external leakage causes both slide valves to move and thus the liquid enters the left cylinder forcing the piston to its extreme right position. When the cylinder becomes full, the slide valves again move and the cycle is repeated. The external arm of the slide valves drives a counter which provides a total of the fluid quantity that has passed through the meter. Instead one piston, a number of pistons operating on a centre crank are generally incorporated with this type of meter.

Reciprocating pump meters are available in many forms such as multi-piston meters, double-acting piston meters, rotary valves, and horizontally slide valves. The accuracy of these meters are from ±0.2 to ±0.3%.



RECIPROCATING PISTON METER

Advantages

The advantages of reciprocating piston meters are :

- Its accuracy is high
- Construction materials are not limited in reciprocating piston meters.

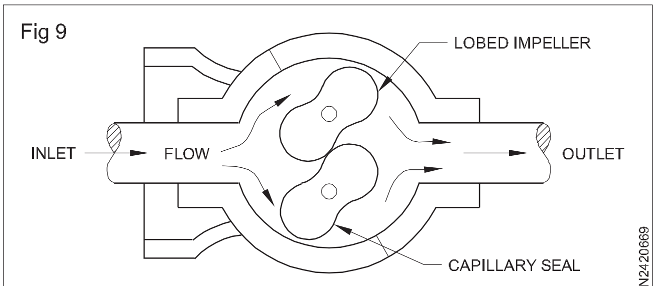
Limitations

The limitations of reciprocating piston meters are :

- Their cost is relatively high.
- They are subject to leakage.
- Problems are created by dirty fluids.
- It requires high maintenance cost.
- It is restricted to moderate flow rates.
- It produces pulsating flow when used for liquid measurement.

Lobed impeller meter (Fig 9)

A register is attached to one of the impellers through a gear train mechanism. The fluid to be measured is trapped in the between the lobes and is passes from inlet to outlet.



LOBED IMPELLER METER

A recent addition to this general type of meter is one using oval geared rotors in place of the lobed rotors. In place of the lobed rotors. These meters may be used for either liquid or gases, and are normally built for services in pipe sizes from 50 to 610 mm, and their maximum capacities ramges from I to 17,500 gpm (or 3.8 to 66,500 litres / minute). The accuracy of these meters ranges from ±0.1 to ± 0.5%^.

Advantages

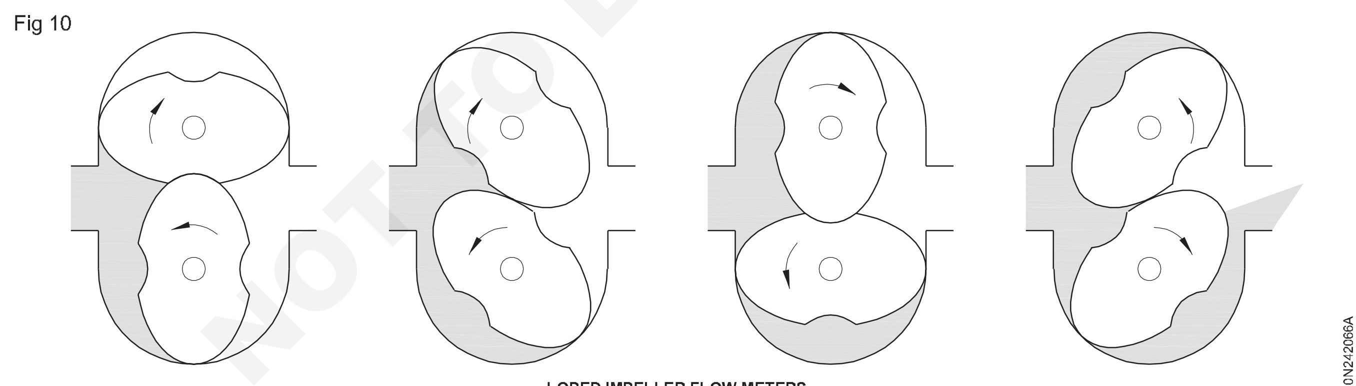
The advantages of lobed impeller meter are :

- It is increasingly accurate at higher flows where leakage or slip is decreased.
- It can be used for corrosive services.
- It has a good capacity range.

Limitations

The Limitations of lobed impeller meter are :

- Its cost is relatively high.
- It requires frequent maintenance of rotating parts.



LOPED IMPELLER FLOW METERS

Calibration of positive displacement flow meter

Flow meter calibration is the process of comparing the pre-set scale or metering of a flow meter to a standard scale of measurement and adjusting its metering to conform to the standard. Calibration is an essential aspect of instrumentation in a broad range of industries that require high-accuracy measurements with a negligence percentage of error e.g. in oil & Gas, Petrochemical, and manufacturing.

Flow meters are calibrated by comparing and adjusting their metering to correspond with a predefined standard. Flow meter manufacturers typically calibrate their products in-house after production or send them to an independent calibration facility for adjustment.

Rate refers to the speed at which a process fluid is moving through pipelines, orifices or vessels at a given time. Control and instrumentation engineers measure this value to monitor and regulate the speed and efficiency of industrial flow processes and devices.

Ideally, test devices must be 'reset' from time to time to prevent having inaccurate readings. For example, a bathroom scale that indicates 10lbs when nobody is standing on it needs to be recalibrated to indicate an initial zero value.

In industrial settings, flow meters are periodically calibrated to ensure that measurements are accurate allowing operations to process in a safe and timely manner.

Positive displacement calibration types :

- Master Meter Calibration
- Gravimetric Calibration
- Piston Prover Calibration

Master meter calibration procedures

Master meter calibration compares the measurements of a flow meter under test to that of a calibrated flow meter or 'master' flow meter operating at the desired flow standard and adjusts its calibration accordingly. The master flow meter is usually a device whose calibration is set to a national or international standard.

To perform Master meter calibration :

- Place the master meter in series with the flow meter under test.
- Compare the readings of the master flow meter and flow meter using a measured volume of liquid.
- Calibrated the flowmeter under test to conform with the master flow meter calibration.

Gravimetric calibration procedures

Gravimetric calibration is one of the most accurate and cost-effective volumetric and mass flow meter calibration procedures. The gravimetric method is ideal for liquid flowmeter calibration in oil, water purification and petrochemical industries.

To perform a gravimetric calibration :

- Place an aliquot (small portion) of process fluid in a test meter and weight it for a precise amount of time while it flows 60 seconds.
- Use a calibrated scale to obtain an accurate measurement of the weight of test fluid.
- After the test period is completed, divert the test fluid into a discharge container.
- Obtain the flow rate of the aliquot by dividing its volumetric weight by the test duration.
- Compare calculated flow rate to the flow rate of the flow meter and adjust it to the measured flow rate.

Piston prover calibration procedures

In the piston prover flow meter calibration procedure, a known volume of fluid is forced through a flow meter under test. The piston prover is a cylindrical device with a known internal diameter.

The piston prover contains a piston which produces volumetric flow by positive displacement. The piston prover method is ideal for ultrasonic flow meter calibration, fuel flow meter calibration, and turbine flow meter calibration to a high degree of accuracy.

Preventive maintenance of positive displacement flow Meter

1 Leave flushing fluid in the lines overnight or during extended off-times. This keeps internals wet, prevents residual fluids from drying, and facilities startups.

2 Follow the Maintenance Guide instructions when opening and cleaning a flow meter. During cleaning, separate the gears from the shafts. On carbide bearings, clean inside the center of the gear bearing and on the outer surface of the shafts at the point where the gear rotates on the shaft. Apply a suitable lubricating fluid before closing the flow meter. After tightening the bolts, a short squirt of shop air will briefly spin the gears, which should be easily audible.

3 Install and maintain filters. Install the recommended filter to eliminate potential plugging. Should plugging occur, the flow meter will still pass fluid but with no signal output.

4 Check electrical compatibility between the flow meter's output signal and the input of the PLC. If signals are not being detected at startup, first check wiring and electrical compatibility.

5 Verify reliable grounding of electrical parts, as per installation guidelines. A dedicated power supply is recommended. Voltage spikes on shared power lines, negligent grounding and sloppy wiring will likely produce erratic readings and chronic maintenance.

6 Don't allow Air into the flow meter. Always keep the flow meter internally wet.

7 When allow meter is removed from the line during maintenance, clean the internals immediately, Lubricate the gears, and cap the fluid ports.

8 When installing the pickup sensor, turn it lightly to a hand tight torque.

9 A calibration factor (k factor) is used with the flow meter, which is valid for most fluids except water or equivalent viscosities.

Target Flowmeter

Objectives: At the end of this exercise you shall be able to
- **explain the construction working principle advantages and disadvantages and uses of target flow meter**
- **explain the construction working principle advantages and disadvantages and uses of turbine flow meter**
- **explain the construction working principle advantages and disadvantages and uses of magnetic flow meter**
- **explain the construction working principle advantages and disadvantages and uses of vortex flow meter.**

Target flowmeters

The target meter measures flow by measuring the force on a target (or disc), centered in the pipe angles to the direction of fluid flow. The fluid flow develops a force on the target which is proportional to the square of the flow.

The target meter consists of a target (or disc) which is mounted on a force bar (or beam) passing through a flexible seal, and is positioned in the centre of and perpendicular to the flowing stream, as shown in Fig 1. The device may be installed directly in the flow line, thus eliminating the need for pressure-tap connections. The flowing fluid while passing through the pipe, develops a force on the target which is proportional to velocity head (the square of the flow). The force bar transmits this force to a force transducer (either electronic or pneumatic) to measure the force which is proportional to the square of the flow. The relationship between the flow rate and force is expressed by the equation.

$$Q = K\sqrt{F}$$

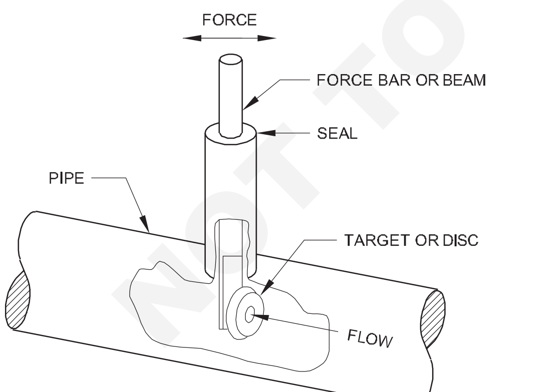
Where, Q = flow rate

K = a known coefficient

F = force

The target meters are available in sizes from 12.5 to 203 mm pipe diameter, and an accuracy of about ±1/2% with proper calibration. The targets (or discs) are available with diameters of 0.6 to 0.8 times pipe diameter.

Fig 1



TARGET METER

Target meters are applied in a number of fields for measurement of liquids, vapours and gases. They are especially useful for measuring heavy viscous, dirty or corrosive fluids. The force-balance type (i.e. target type) can handle pressures upto 1,500 psig and temperatures to 3980 C, and the strain gauge type (i.e. drag body type) can handle pressures upto 5,000 psig and temperature to 3150 C.

Advantages

The advantages of target flowmeters are :

- They are useful for difficult measurements such as slurries, polymer-bearing and sediment –bearing materials corrosive mixtures, etc.
- They provide good accuracy when calibrated for specific streams.
- Their repeatability is good.
- They are good for relatively high temperatures and pressures.

Disadvantages

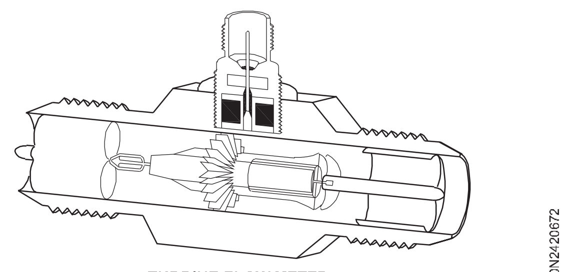
The disadvantages of the target flowmeters are :

- In-line mounting required in these flowmeters.
- They have a limited calibration data.
- In case of target flowmeters no-flow conditions must exist for zeroing the scale.

Turbine flow meter

The turbine flowmeter is used for the measurement of liquid, gas and very low flow rates. It works on the basic principle of turbine. It consists of a multi-bladed rotor (turbine wheel) which is mounted at right angles to the axis of the flowing liquid, as shown in Fig 2. The rotor is supported by ball or sleeve bearings on a shaft which is retained in the flowmeter housing by a shaft-support sections. The rotor is free to rotate about its axis.

Fig 2



TURBINE FLOW METER

The flowing fluid impinges on the turbine blades (rotor). Imparting a force to the blade surface which causes the rotation of the rotor. The speed of the rotor is directly proportional to the fluid velocity, and hence to volumetric flow rate when it is at a steady rotational speed. The speed of rotation is monitored in most of the meters by a magnetic –pickup coil, which is fitted to the outside of the meter housing. The magnetic-pickup coil consists of a permanent magnet with coil windings which is mounted in close proximity to the rotor but internal to the fluid channel. As each rotor blade passes the magnetic-pickup coil, it generates a volt-age pulse which is a measure of the flow rate, and the total number of pulses give a measure of the total flow.

The electrical voltage pulses can be totaled; subtracted and manipulated by digital techniques so that a zero error characteristics of digital handling is provided from the pulse generator to the final read out. The K factor (i.e. the number of pulses generated per gallon of flow) is given as,

Where, K = pulses per volume unit

$$K = \frac{T_k f}{Q}$$

Tk = a time constant in min.

Q = a volumetric flow rate in gpm.

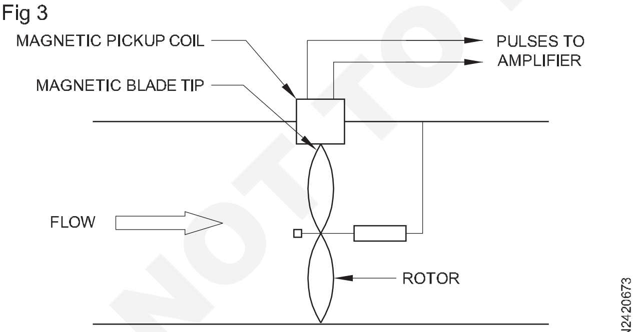
f = frequency in Hz

The turbine flow meters provide very accurate flow measurement over wide flow range. The accuracy range is from ±1/4 to ±1/2%, and the repeatability is excellent, ranging from ±0.25% to as good as ±0.02%. the rangeability of turbine meters are generally considered to be between 10 : 1 and 20 : 1, however, in low flow ranges, it is often less than 10 : 1. The military type turbine meters have achieved rangeabilities greater than 100 : 1. The turbine meters are available in sizes ranging from 6.35 to 60 mm and liquid flow ranges from 0.1 to over 50,000 gallons per minute.

The turbine meters are widely used for military applications. They are particularly useful in blending systems for the petroleum industry. They are effective in aerospace and airborne applications for energy-fuel and cryogenic (liquid oxygen and nitrogen) flow measurements.

Turbine Flow Meters (Fig 3)

Fig 3



TURBINE FLOW METERS

Advantages

The advantages of turbine flowmeter are :

- Its accuracy is good.
- It provides excellent repeatability and rangeability.
- It allows fairly low pressure drop.
- It is easy to install and maintain.
- It gives good temperature and pressure ratings.
- It can be compensated for viscosity variations.

Disadvantages

The disadvantages of turbine flowmeter are :

- Its cost is high.

Electrical method for measurements flow

Magnetic flowmeter (Figs 4&5)

This type of meter use Faradays law of electromagnetic induction for making flow measurement. Faradays law states that when a conductor cuts the magnetic lines of force a voltage is induced in the conductor of many liquids are very good conductors. The magnetic flowmeter has magnet coils, meter electrode, Laminated iron core, meter pipe section, and insulating pipe liner. These meters are built with flanged end fittings. Inset types are also used. The magnetic coils are placed on alternate sides of pipe section. These magnets produce magnetic field perpendicular to the flow of liquid through the pipe. A pair of electrodes are placed at right angles both to the magnetic field and a x d of pipe. As liquid passes through pipe, magnetic lines of force are cut and emf is induced. This voltage is conducted by the electrodes to a separate converter that converts voltage into control signals.

E = CBLV

or

Where, E = INDUCED VOLTAGE IN VOLTS

$$V = \frac{E}{CBL}$$

C = dimensional constant

B = magnetic field in weber/m2

L = length of conductor (fluid) m

V= velocity of the conductor (fluid) in m/s

The equation of continuity to convert a velocity measurement to volumetric flow rate is given as

Q = VA

Where, Q = volumetric flow rate

V = fluid velocity

A = cross-sectional area of the flowmeter

Now, putting the value of V from Eq. (11.7) the volumetric flow rate can be written as,

$$Q = \frac{EA}{CBL}$$

Since, for given size of flowmeter A,C,B, and L become constants, the Q can be written as,

Q = KE

Where, K = $\frac{A}{CBL}$ = a constant

Therefore, the induced voltage is directly proportional and linear with volumetric flow rate.

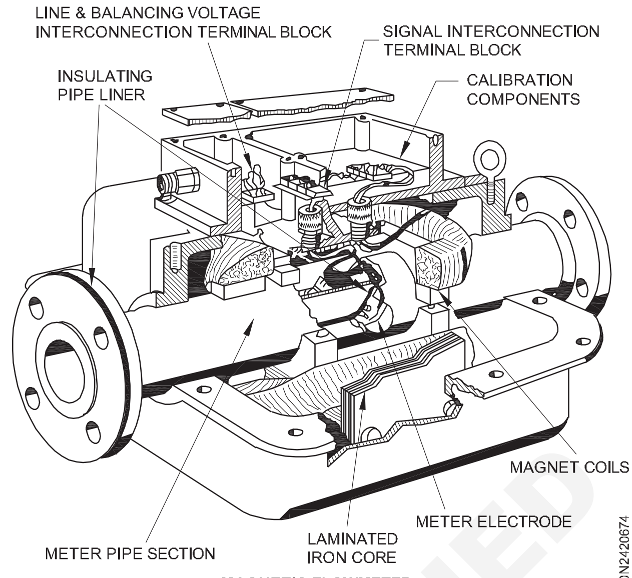
Construction and Working

The magnetic flowmeter consists of an electrically insulted or non-conducting pipe such as fiber glass, with a pair of electrodes mounted opposite to each other and flush with the inside walls of its pipe and with magnetic coil mounted around the pipe so that a magnetic field is generated in a plane mutually perpendicular to the axis of the flowmeter body and to the plane of the electrodes. If a metal pipe is used, an electrically insulting liner is provided to the inside of the pipe.

Magnet coils, thus inducing the voltage in the liquid which is detected by the pair of electrodes mounted in the pipe wall. The amplitude of the induced voltage is proportional to the velocity of the flowing liquid. The magnetic coils may energized either by AC or DC voltage, but the recent development is the pulsed DC-type in which the magnetic coils are periodically energized.

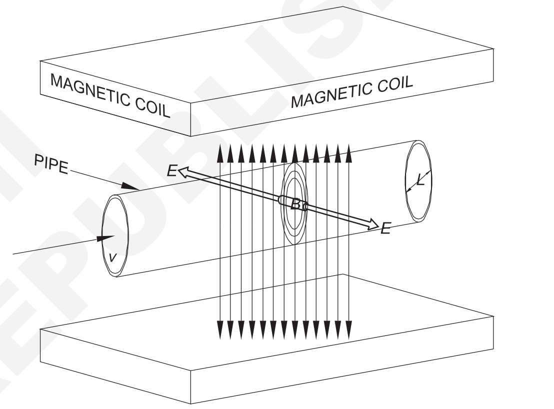
Magnetic meters are available in sized from 2.54 to 2540 mm in diameter, with an accuracy range ±1/2 to ±2%. The rangeability of such meters may be 30 : 1

Fig 4



MAGNETIC FLOWMETER

Fig 5



Vortex flow meter

Objectives : At the end of this lesson you shall be able to
- **understand the function of vortex meter**
- **describe features of vortex meter.**

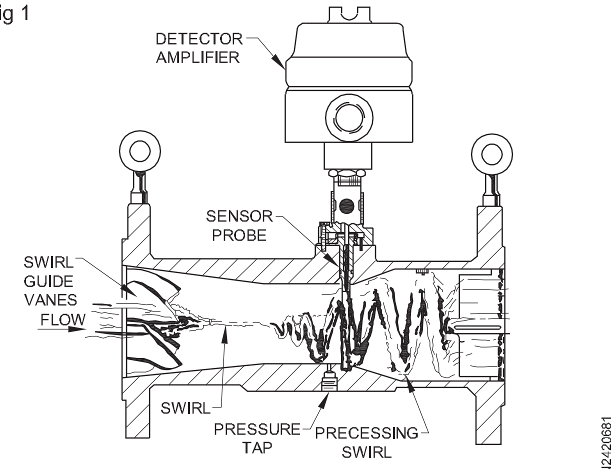
The vortex flowmeter has a complex machined body with swirl Guide vanes at the entrance and sensor body. The detector amplifier is fitted outside the body. It has also got a flow straightener fitted at the meter outlet. (Fig 1)

The fixed swirl inducing helical vane at the entrance produces spinning or swirling motion of the fluid.

The inner part of the meter is like a Venturi type flowmeter. It's diameter decreases after the swirl vanes and increases after the sensor probe. This will cause the fluid at accelerate but will the axis of rotation still on the centerline of the meter, the swirling fluid then enters the enlarges part of the meter which causes the axis of fluid rotation to change from straight to helical path. The resulting spiraling vortex is known as vortex precession.

The velocity of the meter is higher than the fluid. Incidentally as each vortex passes through the sensor there is a change in the local fluid velocity. The change

Fig 1



CONSTRUCTION OF A TYPICAL VORTEX PRECESSION (SWIRL) METER in the velocity is proportional to volumetric flow rate and can be detected by piezo electric thermistor sensors.

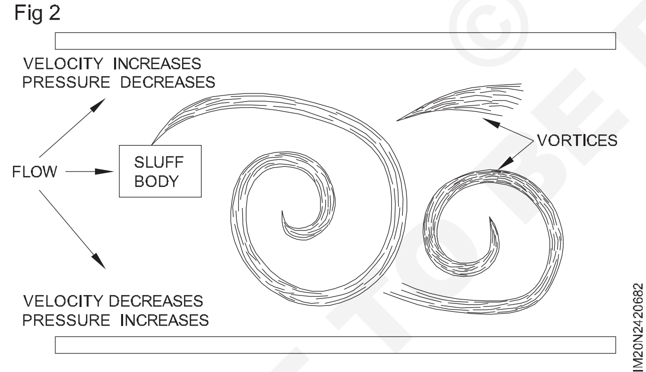
This vortex meter provides a linear digital or analog output signal without the use of separate transmitters or converters. Meter accuracy is good. The meter does not have any moving or wearing components, thus has good reliability and less maintenance. It also has less installation cost.

It cannot be used for less than 12 mm dia and meters above 30 mm have limited application due to high cost. The internal components requires complex machining which makes the meter more costlier.

Vortex shedding flowmeters

The operation of the vortex shedding flowmeter is based on the phenomenon known as vortex shedding which occurs when a gas or liquid flows around non-stream lined (or blunt) object known as sluff body. When a fluid flows past an obstacle, boundary layers of slow moving fluid are formed along the outer surfaces of the obstacle and the flow is unable to follow contours of the obstacle on its downstream side. Thus the flow layers are separates from the surface of the object, and a low pressure area is formed behind the object which causes the separated layers to get detached from the main stream of the fluid and roll themselves into eddies or vortices in the low pressure area, as shown in Fig 2. Each eddy on vortex first grows and gets detached or shed from alternate sides of the object. The frequency at which the vortices are formed is directly proportional to the fluid velocity.

Fig 2



As a vortex is shed from one side of the sluff body the fluid velocity on that side increases and the pressure decreases, and at the same tome the velocity on the opposite side decreases and pressure increases, thus causing a net pressure change across the sluff body. As the next vortex is shed from the opposite side of the sluff body, the entire effect is reversed.

Advantages

The Advantages of vortex flowmeters are :

- It has very low pressure drop.
- It has good response speed.

Disadvantages

The advantages of vortex flowmeters are :

- Their cost is high.
- They are not available over 200 mm size.
- Their upper temperature limit is 2040C.
- They require in-line mounting.

Installation of Vortex Flow Meter (Figs 3to5)

Fig 3

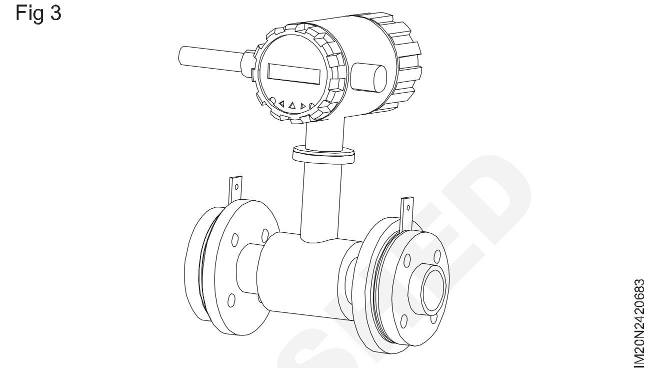


Fig 4

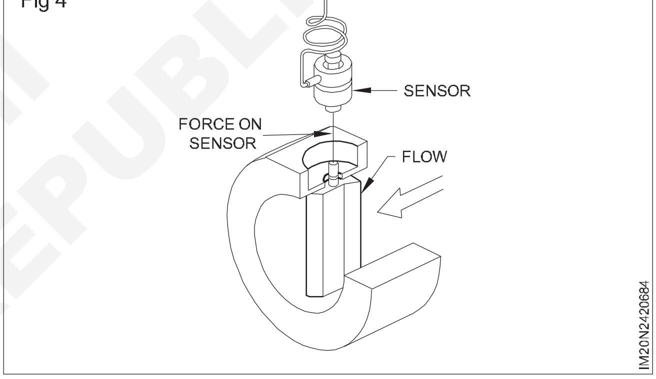
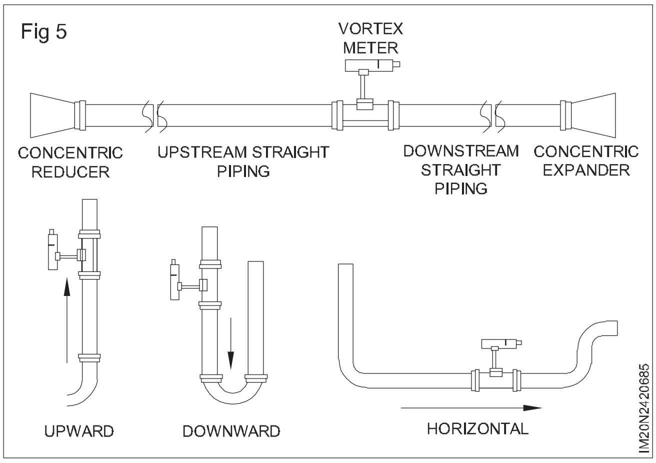


Fig 5



1 The flow meter must be in the correct orientation with water flowing in the direction of the arrow on the flow meter body.

2 Flow meter must be installed horizontally with the dial facing upward.

3 Two-wire cable is required.

4 The general rule is that 0.5 mm wire is good for a run of upto 240V.

5 Each Flow meter has an adapter to allow connection to irrigation system.

6 Flow meters are installed between the master valve and zone vales.

7 To avoid false alerts, there should be no water taps or other uncontrolled water use on the downstream side of the flowmeter.

8 The pipe carrying water away from the meter needs to be 5 times the width of the pipe.

Advanced flow meters

Objectives: At the end of this exercise you shall be able to
- **explain briefly coriolis mass flowmeter**
- **explain briefly thermal mass flowmeter**
- **explain briefly ultrasonic flowmeter.**

Coriolis mass flow meter working principle

Mass flow meters are the types of flow meters which are mainly employed in mass-related processes such as chemical reactions, heat transfer, etc. In all these processes, accurate measurement of flow is the prerequisite.

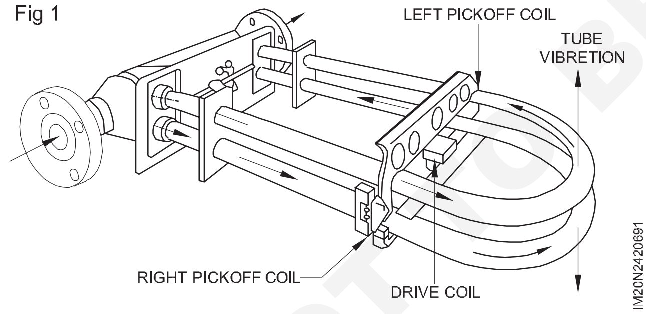
There are numerous types of mass flow meters available in the industry. However, the most widely used type is the Coriolis meter. Another type available is thermal type mass flow meters

Coriolis mass flow meter

A Coriolis meter works on Coriolis Effect, hence it is named so. Coriolis meters are considered to be true mass meters since they tend to measure the mass rate of flow directly while other flow meter technologies measure volumetric flow.

Since mass does not change, no adjustments are needed for varying fluid characteristics. Hence, a Coriolis ,meter operates in linear fashion. These types of meters exist in variety of design.(Fig 1)

Fig 1



The most common type of unit includes

1 a U-shaped flow tube

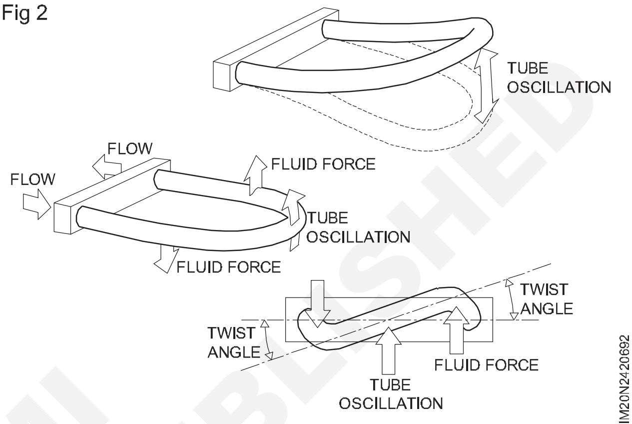
2 a sensor assembly

3 an electronics unit

In this meter unit, the liquid passes through a U-shaped tube which vibrates in an angular harmonic oscillation. Coriolis forces will then deform the tube and a further vibration component gets added to the already oscillating tube. This added vibration element results in a phase shift or twist in few parts of the tubes.(Fig 2)

This resulting phase shift which is directly proportional to the liquid mass flow rate is measured with the help of sensors. This measured information is further transferred to the electronics unit where it gets transformed to a voltage proportional to mass flow rate. A Coriolis meter is shown in the figure 2 below:

Fig 2



Principal of operation

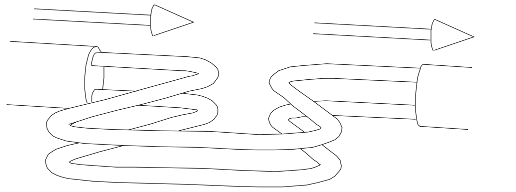
The flow is guided into the U-shaped tube. When an oscillating excitation force is applied to the tube causing it to vibrate, the fluid flowing through the tube will induce a rotation or twist to the because of the Coriolis acceleration acting in opposite directions on either side of the applied force.

For example, when the tube is moving upward during the first half of a cycle, the fluid flowing into the meter resists being forced up by pushing down on the tube. On the opposite side, the liquid flowing out of the meter resists having its vertical motion decreased by pushing up on the tube.

This action causes the tube to twist. When the tube is moving downward during the second half of the vibration cycle, it twists in the opposite direction.

An advantage of Coriolis flow meters is that it measures the mass flow rate directly which eliminates the need to compensate for changing temperature, viscosity and pressure conditions. (Fig 3)

Fig 3



Advantages of Coriolis Meters

1 Coriolis flow meter is capable of measuring a wide range of fluids that are often incompatible when other flow measurement devices. The operation of the flow meter is independent with other flow measurement devices. The operation of the flow meter is independent of Reynolds number; extremely vicious fluids can also be measured. A Coriolis flow meter can measure the flow rate of Newtonian fluid, all types non-Newtonian fluids, and slurries. Compressed gases and cryogenic liquids can also be measured by some designs.

2 Coriolis flow meters provide a direct mass flow measurement without the addition of external measurement instruments. While the volumetric flow rate of the fluid will vary with changes in density, the mass flow rate of fluid is independent of density changes.

Disadvantages of Coriolis Meters

1 Coriolis flow meters are not available for large pipelines. The largest Coriolis flow meter that is currently available has a maximum flow rating of 25,000 Ib/min (11,340 kg/min), and is equipped with 6 in. (15 cm) flanges. When larger flow rates must be measured, two or more flow meters mounted in parallel are required.

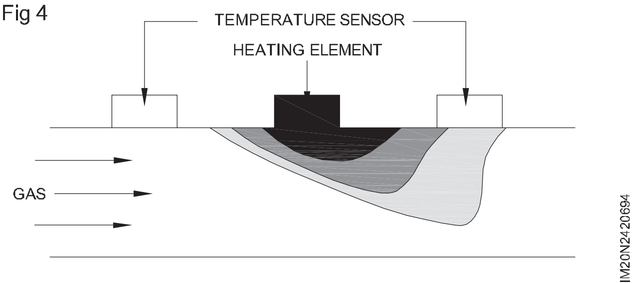
2 Some flow meter designs require extremely high fluid velocities in order to achieve a significant amount of time or phase difference between the flow detector signals. This can result in extremely high pressure drops across the flow meter.

Thermal mass flowmeters

Thermal mass flowmeters (Fig 4) generally use combinations of heated elements and temperature sensors to measure the differences between static and flowing heat transfer to a fluid and infer its flow with a knowledge of the fluid's specific heat and density. The fluid temperature is also measured and compensated for. If the density and specific heat characteristics of the fluid are constant, the meter can provide a direct mass flow readout, and does not need any additional pressure temperature compensation over their specified range.

Technological progress has allowed the manufacture of thermal mass flowmeters on a microscope scale as MEMS sensors; these flow devices can be used to measure flow rates in the range of Nano liters or micro liters per minute.

Fig 4



Thermal mass flowmeter (also called thermal dispersion or thermal displacement flowmeter) technology is used for compressed air, nitrogen, helium, argon, oxygen and natural gas. In fact, most gases can be measured as long as they are fairly clean and non-corrosive. For more aggressive gases, the meter may be made out of special alloys (e.g. Hastelloy), and pre-drying the gas also helps to minimize corrosion.

Thermal Flowmeters

Thermal flowmeters are very popular for the measurement of unsteady flow of gases, and can be used to measure flow rate in terms of mass, which is very desirable feature, especially on gas service. There are two types of thermal flowmeters:

Heat Transfer Flowmeters

This type of flowmeter measures the rise in temperature of the fluid after a known amount of heat has been added to it. Its theory is based upon the specific heat equation which is given as.

$$Q = WC_P(T_2 - T_1)$$

or

$$W = \frac{Q}{C_P(T_2 - T_1)}$$

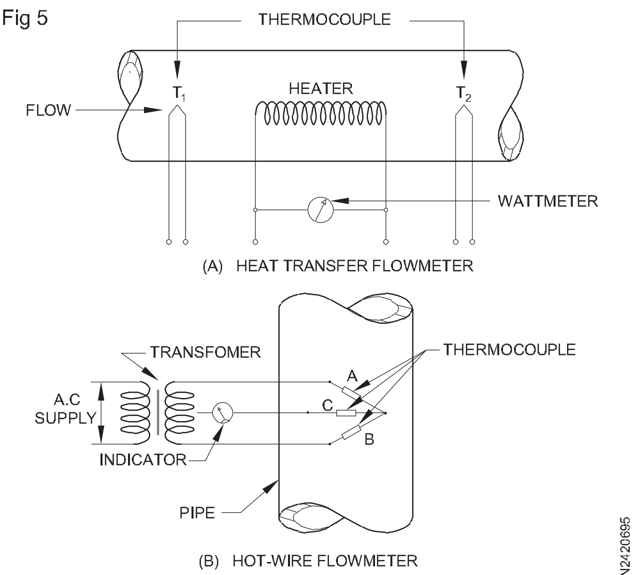
Where Q = heat transfer

W = mass flow rate of fluid

C_P = specific heat equation

A schematic diagram of a heat transfer flowmeter is shown in Fig 5, which consists of an electric immersion heater for the heating of flowing fluid. Two thermocouples (or resistance thermometers) T1 and T2 are placed at each side of the heater as in Fig 5a. The thermocouple T1 measures the temperature of fluid before it is heated, while the thermocouple T2 measures the temperature so after. The power supply to the heater equals the

Fig 5



THERMAL FLOWMETERS

heat transferred to the fluid, i.e. Q and is measured by a wattmeter. Thus by measuring the valves of Q, T1 and T2 the flow rate w of liquid is determined from the Eq.(11.14).

This type of flowmeter has disadvantages in that the temperature sensor and the heater are directly placed into the fluid stream, and thus, they are easily damaged by corrosion and erosion. Furthermore, large input power is required to measure high flow rates. These disadvantages are overcome by mounting the heater, and upstream and downstream temperature sensors (T1 and T2) on the outside of the piping. But it results in a non-linear response.

Hot-Wire Flowmeters

This type of flowmeters measures the effect of the flowing fluid on a hot body. A hot-wire flowmeter consists of two thermocouples, A and B, connected in series to form a thermopile. A third thermocouple C is placed in the output circuit of the thermopile, as shown in Fig 5b. the thermopile is heated by passing an alternating current to it. The alternating current does not pass through the third thermocouple and it is therefore not electrically heated. The whole assembly is placed into the fluid (usually gas) stream whose flow rate is to be determined. The fluid (gas) cools the heated thermopile by convection, and since the input power to the thermopile is held constant, the thermopile attains an equilibrium temperature and produces an emf that is a function of the temperature oif the gas, velocity of the gas, and its density, specific heat, and thermal conductivity. The third thermocouple (unheated) attains the ambient temperature of the gas, generating an emf that is proportional.

Ultrasonic Flowmeters

In ultrasonic flowmeters, the measurement of flow rate is determined by the variation in parameters of ultrasonic oscillations. There are two types of ultrasonic flowmeters currently in use :

Time Difference Type

These devices measure flow by measuring the time taken for ultrasonic wave to transverse a pipe section, both with and against the flow of liquid within the pipe. It consists of two transducers, A and B, inserted into a pipe line, and working both as transmitter and receiver, as shown in Fig 6a. The ultrasonic waves are transmitted from transducer A to transducer B and via versa. An electronic oscillator is connected to supply ultrasonic waves alternately to A and B which is working as transmitter through a changeover switch, when the detector is connected simultaneously to B or A which is working as receiver. The detector measures the transit time from upstream to downstream transducers and vice versa.

The time TAB for ultrasonic wave to travel from transducer A to transducer B is given by the expression :

$$T_{AB} = \frac{L}{(C + V\cos\theta)}$$

And, the time (T_{AB}) to travel from B to A is given as,

θ = angle of path with respect to the pipe axis

V= velocity of fluid in pipe

The time difference between and can be calculates as,

$$\Delta T = T_{AB} - T_{BA} = \frac{2LV\cos\theta}{C}$$

or

$$V = \frac{\Delta TC}{2L\cos\theta}$$

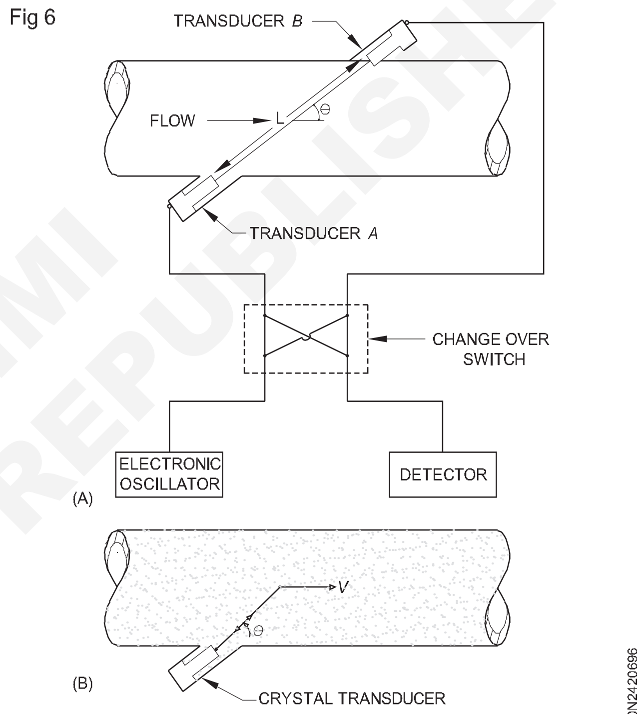


Fig 6

ULTRASONIC FLOWMETER

Since, this type of flowmeter relies upon an ultrasonic signal traversing across the pipe, the liquid must be relatively free of solids and air bubbles.

Doppler Flowmeters

In Doppler flowmeter, an ultrasonic wave is projected at an angle through the pipe wall into the liquid by a transmitting crystal in a transducer mounted outside the pipe, as shown in Fig 6b. Part of the ultrasonic wave is reflected by bubbles or particles in the liquid and is returned through the pipe wall to a receiving crystal. Since the reflectors (bubbles) are travelling at the fluid velocity, the frequency of the reflected wave is shifted according to the Dopple principle. The Velocity of the fluid is given by the equation:

$$V = \frac{\Delta f C_t}{2 f_0 \cos\theta} = \Delta f K$$

Where Δf = difference between transmitted and received frequency

C_t = velocity of sound in the transducer

f_0 = frequency of transmission

θ = angle of transmitter and receiver crystal with respect to the pipe axis.

K = constant

Advantages of Ultrasonic Flowmeters

The advantages of ultrasonic flowmeters are :

- It does not impose additional resistance to the flow or disturb the flow pattern as the trasnducers are inserted in the wall of pipe.
- Its velocity / output relationship is linear.
- It has no moving parts.
- Its repeatability is in the order of 0.01%.

Measuring bulk solids on a conveyor

Objectives: At the end of this lessons you shall be able to
- **explain conveyor belt method for solid flow measurement**
- **explain weight feeder method for solid flow measurement**
- **maintenance of solid flow meters.**

Conveyor belts are often used to move materials in mining and other applications, and a measurement of the amount of material conveyed is a key control parameter

Many industrial operations need to make mass flow measurements of dry bulk solid materials on conveyor belts, and on screw and chain conveyors (Figure 1) Typical industrial applications include moving materials at mine sites, paper mills, and power plants, as well as bulk material blending. Loading and unloading of trucks, barges, and railcars to and from plants are also popular applications Mass flow measurements of these bulk solids are required for two main reasons, control and material transfer

In control applications, the amount of material fed to a downstream process is regulated Mass flow is measured and sent to an automation system, which can then speed up or slow down the conveyor to control the amount of material being delivered to a downstream process, such as ore into a crusher at a mine or wood chips into a digester at a paper mill. Alternately, the measurement can be used as a set point to control other processes, such as the feed of a secondary materials in blending system.

control the amount of material being delivered to a downstream process, such as ore into a crusher at a mine or wood chips into a digester at a paper mill. Alternately, the measurement can be used as a setpoint to control other processes, such as the feed of a secondary material in a blending system

In material transfer applications, the mass flow must be measured to ascertain the amount of material being transferred from one place to another, such as from a process plant to a truck or from a coal bin to a kiln.

Two common ways of making these mass flow measurements are radiation-based instrument and belt conveyor load cells. The Table compares these two technologies, and the text below describes each in detail

Radiation-based, principle of operation

A radiation-based sensor consists of a sealed radioactive source in a source holder and a scintillation detector. The source and detector are mounted on opposite sides of the conveyor (belt, screw, drag chain, or vibrating). In some applications, the source is mounted above and the detector is mounted below, while in other applications the detector is mounted above and the source below

In either case, a fan-shaped collimated beam of radiation is transmitted from the source through the process material and the conveyor to the detector (Figure 2).

As radiation passes through matter, its field strength weakens. As the loading of the material, or total mass per square foot on the belt or screw conveyor changes, the amount of radiation reaching the detector changes. The greater the loading or mass on the belt, the lower the radiation field at the detector Conversely, the lower the loading or mass on the belt, the higher the radiation field at the detector. The amount of radiation seen at the detector is thus proportional to the amount of material on the conveyor, and is translated into an output signal from the detector

Radiation-Based, Application Advice

A Cesium-137 or Cobalt-60 isotope emits gamma rays, which are focused by a source holder, and then attenuated when penetrating the material and the conveyor belt. A polyvinyl toluene or other type of scintillator detector mounted on the other side of the conveyor belt receives the radiation, the strength of which is proportional to the amount of material on the belt.

Radiation from the source holder is a random emission of gamma rays produced as the isotope decays to a stable state. Radiation-based weight measurement works best with consistent medium to heavy loads, but can lose accuracy with very light loading and thin layers of material due to the randomness of the gamma ray emission. Conveyor widths from about .5 to 3 m can be accommodated, with wider belts better suited to measurement with load cells.

It’s typical for radiation-based detector electronics to include a discrete or an analog input for input of a tachometer signal, which is required to determine the speed of the material being conveyed on variable speed belts. This signal allows the electronics to make an accurate measurement of total tonnage that has passed the scale. The discrete input typically accepts a frequency output from the tachometer.

Alternately, the analog input can accept a 4...20 mA current signal from the tachometer

This measuring principle has proven to be reliable in even the most extreme process conditions because it performs non-contact measurement through the conveyor belt. As noted, integrated electronics are typically built into the instrument to compensate for additional variables such as belt or screw speed, and to use these factors to convert the measurement into a total weight or a weight-per-time period output

As shown in the table, this method of measurement is more expensive up front, but provides an extremely stable measurement with little required maintenance Radiation-based measurement is not affected by the levels of vibration typically found in conveying applications, or by high temperatures up to 60°C. Measurement precision is about ±1%, and is independent of process material effects such as dust, corrosion, and spillage

Installation is relatively simple as the instrument is usually supplied with a frame, which mounts directly to the conveyor. The instrument can be relocated if required with minimal effort, and can be mounted on inclined conveyors without affecting measurement.

Most radiation-based instruments feature a variety of outputs suitable for direct connection to plant automation systems. Typical output options include 4...20 mA with or without HART, Profibus PA, or Foundation Fieldbus.

Radiation-based systems provide a non-mechanical and solid state measurement, greatly reducing required maintenance, which is their chief advantage over belt conveyor load cells.

Belt conveyor load cells, principle of operation

A belt conveyor load cell system replaces a short section of the support mechanism of the belt, often one or more sets of idler rollers. This support roller is mounted on load cells, so the weight of the dry bulk material on the belt is measured (Fig 1)

This load cell weight measurement is then integrated with the belt speed to compute the mass flow of material moving on the bell, after deducting the mass of the belt itself. Belt conveyor load cell systems generally include the electronics to perform this calculation in the form of a weight instrument

A belt conveyor load cell system is normally mounted in a well-supported straight section of belt, with no vertical or sideways curvature permitted, and as close to level as is practical. The weighed support must be aligned vertically and horizontally with the adjacent supports to avoid tensile forces in the belt, as these can skew the measurement.

A special type flow meter suited for powdered or granular solids is the weigh feeder. One of the most common weigh feeder designs consists of a conveyor belt with a section supported by rollers coupled to one or more load cells, such that a fixed length of the belt is continuously weighed:

Weigh feeder method for solid flow measurement

The load cell measures the weight of a fixed-length belt section, yielding a figure of material weight per linear distance on the belt. A tachometer (speed sensor) measures the speed of the belt. The product of these two variables is the mass flow rate of solid material "through" the weigh feeder.

Where.

W= Mass flow rate (e.g. pounds per second)

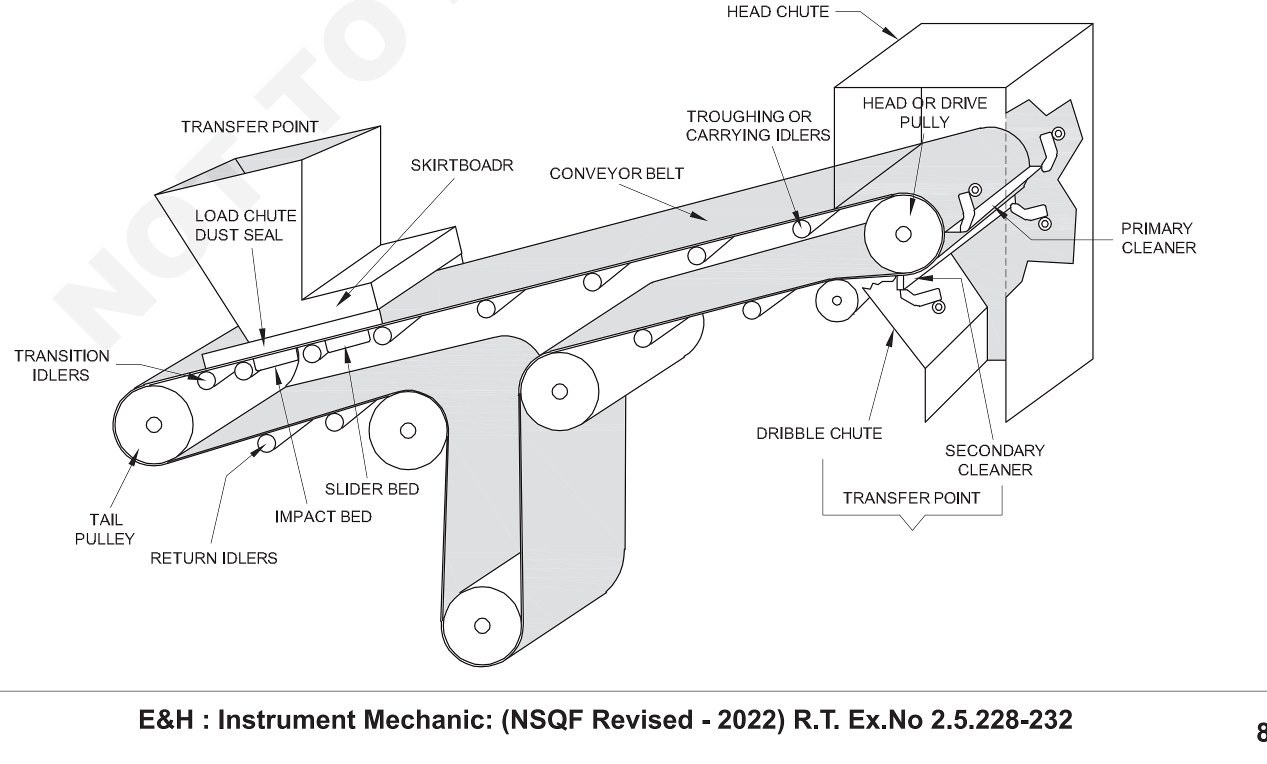
F = Force of gravity acting on the weighed belt section (e.g., pounds)

V = Belt speed (e.g., feet per second)

D = Length of weighed belt section (e.g. feet)

A small weigh feeder (about two feet in length) is shown in the following photograph, the weigh feeder being used to feed powdered soda ash into water at a municipal filtration plant to neutralize pH:

Fig 1



As shown in fig 1 the middle of the belt's span (hidden from view) is a set of rollers supporting the weight of the belt and of the soda ash piled on the belt. This load cell array provides a measurement of pounds material per foot of belt length (lb/ft).

The speed sensor measures belt speed in feet per minute (ft/min). This measurement, when multiplied by the pounds-per-foot measurement sensed by the load cells, translates into a mass flow rate (W) in units of pounds per minute (lb/min). A simple unit conversion (x60) expresses the mass flow rate in units of pounds per hour (lb/h).

The reason for this discrepancy is that the camera's snapshot of the weigh feeder display screen happened to capture an image where the values were not simultaneous. Weigh feeders often exhibit fluctuations in belt loading during normal operation, leading to fluctuations in calculated mass flow rate.

Sometimes these fluctuations in measured and calculated variables do not coincide on the display screen, given the latency inherent to the mass flow calculation (delaying the flow rate value until after the belt loading has been measured and displayed).

Preventive maintenance with flow meters

Flow Preventative Maintenance Service includes:

- Extensive Diagnostics
- Configuration Check
- Output Check
- Meter Verification
- Reporting
- Visual Inspection
- Zero Stability Verification
- Density Check
- Calibration

We have a special service to capture the valuable information from the Smart Meter Verification integrity check.

Maintenance represents a key issue for many organisations due to the ongoing digitisation of production processes. Maintenance can be broadly defined as all aspects relating to the effective performance of mass flow meters and controllers. Maintenance may consist of corrective maintenance - maintenance conducted when needed, e.g. after contamination - or preventive maintenance, where instruments are periodically returned for servicing or calibration. Today's instruments are increasingly future-proof and 'intelligent. In addition to the rise of condition-based maintenance, we are also seeing a shift towards predictive maintenance, which helps reduce unscheduled downtime and wastage. Regulations are also having a growing impact on maintenance, with numerous markets introducing more and more instrument maintenance requirements.

The importance of effective maintenance

The maintenance of mass flow instruments is of crucial importance customers. The flow instruments have a highly robust design and are resistant to wear under normal circumstances. Instruments are increasingly being utilised under extreme process conditions. Effective maintenance can reduce the likelihood of sudden failures under such circumstances. Unexpected downtime triggers direct costs in terms of the extra hours that staff need to check and recommission the instrument. Moreover, this downtime also has a negative impact in terms of short-term yields or production quality and potential long- term reputational damage.

The aspect of maintenance plays a considerable role in Industry 4.0. Following the invention of the steam engine, mass production driven by electric engines and far-reaching automation, we are currently in the midst of the fourth industrial revolution. The current revolution is characterised by the application and exchange of data through high-speed network connections, yielding more efficient and intelligent production techniques. This development is also referred to as 'smart industry. Among other motivating factors, Industry 4.0 is driven by the desire to reduce the cost of ownership.

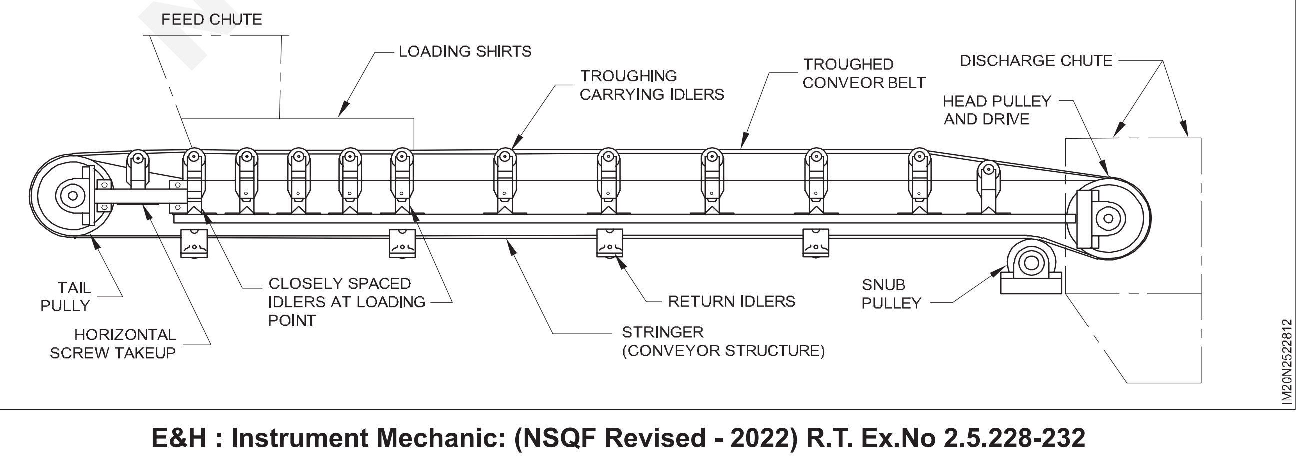
Maintenance through the years

Corrective maintenance

The corrective maintenance was still the industry standard. Most mass flow meter and controllers were still analogue and did not have any diagnostic parameters. Any instruments in need of maintenance were either shipped to Bronkhorst or serviced by a visiting technician. This method was extremely costly and time-consuming due to the lengthy downtimes involved.

The company's worldwide service network was later restructured, and currently comprises 20 G50s (Global Service Offices, authorised service departments around the world) and a 24/7 help desk. Spare parts were kept in stock in order to ensure rapid service.

Fig 2



Metering the flow of solid particles typically involves controlling the rate at which the particles are dispensed or transported. There are various methods and devices used for this purpose, depending on the specific application and requirements. Here are a few common approaches:

Gravity Flow: In simple systems, solid particles can be metered by relying on gravity flow. By controlling the size and geometry of an opening or chute, the rate of particle flow can be regulated. This method is often used in basic applications where accuracy is not critical.

Screw Feeders: Screw feeders consist of a rotating screw within a tube or trough. As the screw rotates, it conveys and meters the solid particles along the length of the screw. By adjusting the rotational speed or pitch of the screw, the flow rate can be controlled with higher accuracy than gravity flow.

Vibratory Feeders: Vibratory feeders use vibrations to move and meter solid particles. The particles are transported along a trough or tube that vibrates, causing the particles to move forward. The frequency and amplitude of the vibrations can be adjusted to regulate the flow rate.

Belt Conveyors: Belt conveyors are commonly used for metering bulk solid particles over longer distances. By adjusting the speed of the conveyor belt, the flow rate can be controlled. Additionally, specialized belt designs, such as weigh belt feeders, can provide more precise metering by incorporating weighing mechanisms. **Rotary Valves:** Rotary valves are often employed for metering solid particles in pneumatic conveying systems or in situations where a controlled discharge is required. These valves consist of a rotating rotor with pockets or vanes that alternately allow or block the flow of particles.

Metering Hoppers: Metering hoppers are vessels designed with specific geometries and openings to regulate the flow of solid particles. They can incorporate features such as baffles, adjustable gates, or mechanical devices to control the discharge rate. Metering hoppers are commonly used in industries such as food processing and pharmaceuticals. It's important to note that the selection of the appropriate method for metering solid particles depends on factors such as particle properties (size, shape, flowability), required accuracy, flow rate, and process conditions. Consulting with experts in the field or specialized equipment manufacturers can help determine the best approach for a specific application. The volumetric and mass flow rates of solids can be measured using various techniques and equipment, depending on the specific characteristics of the solid material and the application.

Here are some commonly used methods

Volumetric Flow Rate Measurement

Belt Conveyors: By measuring the belt speed and the cross-sectional area of the material on the conveyor, you can calculate the volumetric flow rate. Vibrating Conveyors: The amplitude and frequency of the vibrations can be used to estimate the volume of material being transported.

Bucket Conveyors: By counting the number of buckets passing a point per unit time and knowing the bucket volume, you can determine the volumetric flow rate.

Screw Conveyors: Measuring the rotational speed of the screw and the cross-sectional area of the material can provide the volumetric flow rate.

Mass Flow Rate Measurement: Weighing Systems: Using load cells or weighing scales beneath the conveyor or in a hopper, the weight of the material passing through can be measured over a specific time period to determine the mass flow rate.

Impact Flow Meters: These devices utilize the impact force of the material hitting a plate or sensor to calculate the mass flow rate.

Gamma Ray Density Measurement: By measuring the density of the material using gamma ray absorption techniques, the mass flow rate can be determined. It's important to note that the choice of method depends on factors such as the nature of the solid material, its particle size, flow characteristics, and the required accuracy of the measurements. Additionally, calibration and validation of the measurement equipment are essential to ensure accurate and reliable results.

Principles of level measurement

Objectives: At the end of this lessons you shall be able to
- **explain the importance of liquid level measurement**
- **explain the types of level measurement**
- **define volume, mass, density and specific gravity**
- **describe stick gauge, surface sensity guage, storage tank guage to measure liquid level**

Importance of level measurement

The main reason for measuring level is to keep track of inventery interms of volume and weight.

The industry has increased its demands on control of inventery.

Level measurement is one key component in a tank gauging, system irreliable and accurate inventery control.

Principle of level measurement

Solvent, chemical, steam, liquid and power plant, a large proportion of water is required – hence it is considered very important to accurately measure the water level in factory. In some industries it is necessary to measure the solid level.

Types of level measurement . solid and liquid

1 liquid level measurement

2 solid level measurement

Solid level

In solids, particles are tightly or closely packed.

The gaps between the particles are tiny and hence it is tough to compress them.

Solid has a fixed shape and volume.

Due to its rigid nature, particles in solid can only vibrate about their mean position and cannot move.

Force of attraction between particles is adamant.

The rate of diffusion in solids is very low.

An example of solids: solid ice, sugar, rock, wood, etc.

Liquid level

In a liquid state of matter, particles are less tightly packed as compared to solids.

Liquids take the shape of the container in which they are kept.

Liquid are difficult to compress as particles have less space between them to move.

Liquids have fixed volume but no fixed shape.

The rate of diffusion in liquids is higher than that of solids.

Force of attraction between the particles is weaker than solids.

Example of a liquid state of matter: water, milk, blood, coffee, etc.

Volume

Volume is a scalar quantity expressing the amount of three dimensional space enclosed by a closed surface. For example, the space that a substance (solid, liquid, gas, , or plasma) or 3D shape occupies or contains. Volume is often quantified numerically using the SI derived unit, the cubic metre.

Mass

In physics mass is the most basic property of matter and it is one of the fundamental quantities mass is defined as the amount of matter present in a body. The sl unit of mass is the the kilogram(kg). the formula of mass can be written as:

Density

The density pen unit volume unit area or unit length. (a) the mass of substance per unit volume. (b) the distribution of a quantity (mass, electricity, energy) per unit usually of space

P=m/v

P=density of matter(kg/m3)

M= mass of the object(kg)

V= volume of object.m3

Specific gravity

Specific gravity or relative gravity is a dimensionless quantity that is defined as the ratio of the density of a substance of the density of was at a specified temperature and pressure

Specific gravity = density of the / density of water = p_{obje} / p_{H2O}

What is the mass of 2 liters aceton?

Zacerton density – 78.46kg/m2

1 liter = 0.001 cubic meter

Liter to converted cubic meter

2 liter aceton – 0.002m3

P=m/v

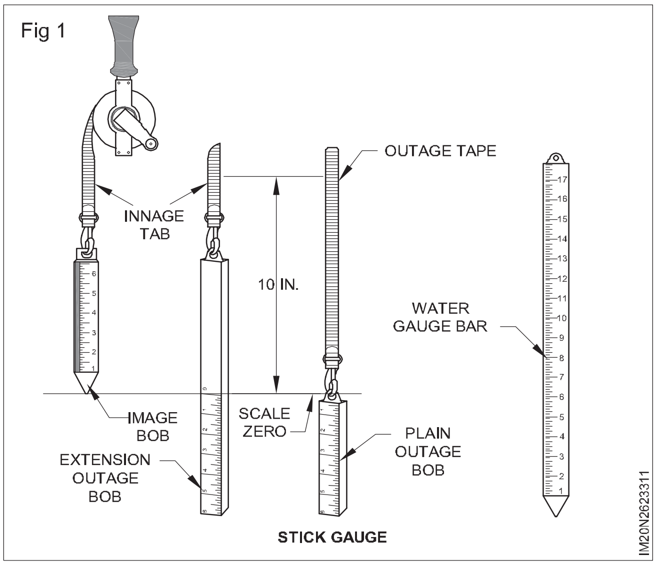
M=pXv

= 784.6kg / m3 x 0.002m3

M2 1.57kg = 1570 grms

Stick guages (Fig 1)

Fig 1



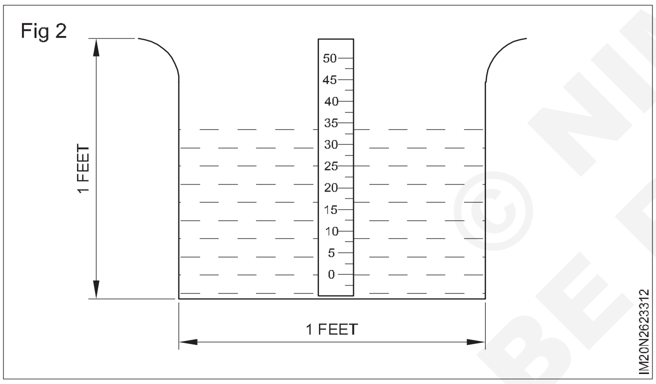
1 feet length

1 feet width

1 feet height

The feel of filled with water tank capacity value 28.2 litter. (Fig 2)

Fig 2



A stick guage is very simple method used to measure height of liquid. When a horizontal tank is filled with liquid. Shown in figure. The measurement marked stick gauge. Should be placed vertically position touch the bottom of tank then the liquid should be sticiking the top the scale reading.

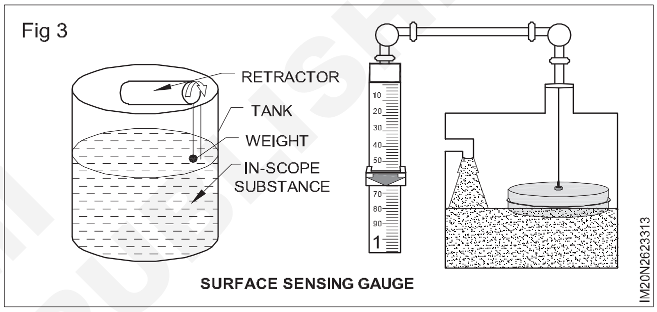
Every time take measurement after stick guage cleaning with cloth

Surface sensing guage (Fig 3)

In surfaces detector level gauges, a 'plumb line' weight is lowered from the sensor unit, which is fixed to the top of the tank, until the weight makes contact with the surfaces of the contained material

The material is then retracted into the sensor unit whist the line is measured. The resulting measurement is then used to calculate the level of material present in the tank surface level gaugesservo-operated float gauges that provide continuousmeasurement, surface detectors are periodic measurement systems the most commonly reported problem with surface detectorlevelmeasurement systems is that the plumb weight can be jammed in the sensor unit. Similarly to float-operated wire-guided systems, this method's components are prone to accelerated wear because of

Fig 3



continuos movement of the float on the liquid surface, which applies continuous movement on the mechanical components.

Storage tank guage (Fig 3)

Tank gauging is measurement of liquid in large storage tanks with the purpose of quantifying the volume and mass of the product and tanks. The oil and gas industry generally uses static volumentric accessments of the tank. This measurement is an absolutely reliable and accurate system for liquid level measurement

Types of level measurement

Objectives: At the end of this lessons you shall be able to
- **explain right glass and its types**
- **describe that type level indicator**
- **describe magnetic guage method of level measurement**
- **explain dispaner level sensor**
- **factors need no consider for open and closed channel level measurement**

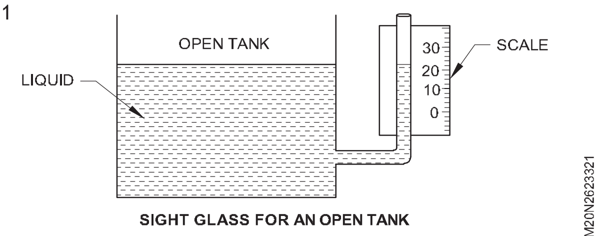
Sight glass

A sight glass (also called a guage glass) is another method of liquid level measurement. It is used for the continuous indication of liquid level within a tank or vessel.

Construction and working

A sight glass instrument consists of a graduated tube of toughened glass which is connected to the interior of the tank at the bottom in whch the water level is connected to the tank at the bottom in which the water level is required. Fig1 shows a simple sight glass for

Fig 1



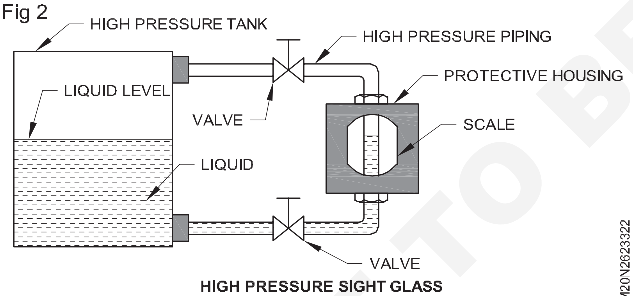
SIGHT GLASS FOR AN OPEN TANK

an open tank in which the liquid level in the sight glass matches the level of liquid in the tank. As the level

Of liquid in the tank rise and falls, the level in the sight glass also rises and falls accordingly. Thus, by measuring the level in the sight glass, the level of liquid in the tank is measured. In sight glass, it is not necessary to use the same liquid as in the tank. Any other desired liquid also can be used.

When it is desired to measure a liquid level with the liquid under pressure or vaccum, the sught glass must be connected to the tank at the top as well as at the bottom, otherwise the pressure difference between the tank and the sight glass would cause false reading. In this case, the glass tube is enclosed in a protective housing, and two valves are provided for isolating the gauge from the tank in case of breakage of the sight glass. The smaller valve at the bottom is provided for blowing out the guage for cleaning purposes. Fig 2 shows a high pressure sight glass in which measurement is made by reading the position of the liquid level on the calibrated scale. This type of sight glass in high pressure tanks is used with appropriate safety precautions. The glass in high pressure tanks is used with appropriate safety precautions. The glass tube must have a small inside diameter and a thick wall.

Fig 2



HIGH PRESSURE SIGHT GLASS

Ranges

The standard practice is not to go in for a glass tube of more than 900 mm length in case the height of the tank is more than 900 mm, two or more sight glass level gauges are provided at different levels. This type of gauges is made to withstand pressures of 350 psi of steam pressure at 252°c (or 500 °F), or 1000 psi liquid

Advantages

Following are the advantages of sight glass level instrument:

1 direct reading is possible

2 special designs are available for use upto 316°c and 10,000 psi.

3 glassless designs are available in numerous materials for corrosion resistance.

Disadvantages

The disadvantages of the sight glass instrument are:

1 It is read only where the tank is located, which is not always convenient.

2 Since sight glasses are located on the outside of the tanks, the liquid in the sight glass may freeze in cold weather even though the liquid inside the tank does not , and thus, it may cause error in the reading.

3 Heavy, viscous liquids or liquids containing material which fall out of solution and clog the tube cannot be measured satisfactorily by a sight glass.

4 Overlapping gauges are needed for long level spans.

5 Accuracy and readability depend on the cleanliness of glass and fluid.

Types of level guage: (sight glass)

There are commonly 3 types of level gauges used:

1 Reflex level guage

2 Transparent level guage

3 Magnetic type level guage

Reflex level guage:

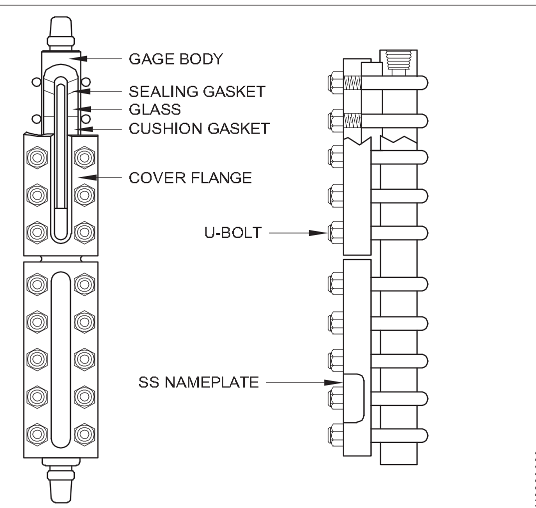
Reflex glass level gauges working principle is based on the light refraction and reflection laws.

Reflex glass level gauges use glasses having the face fitted towards the the chamber shaped to have prismatic grooves with section angle of 90°. When in operation, the chamber is filled with liquid in the lower part and gases or vapors in the upper part.

LIQUID ZONE:

This zone appears dark when the guage is in operation the light ray's incident on the external face of the glass are quite perpendicular to said face and, therefore, not deviated by the glass. These rays reach the glass/liquid interface with an inclination of approx.. 45°.

Fig3



REFLEX LEVEL GAGUGE

Therefore the rays incident within the critical angle are refracted within the liquid and, since the internal walls of the guage chamber are not reflecting, the rays cannot be seen from the outside. In fact the zone will appear dark, nearly blac, to the observer.

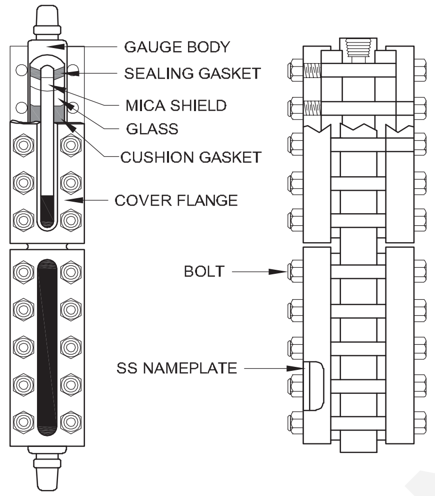
Advantage

Reflex glass level guage can be used in most of the fluid application

Transparent level guge:

Transparent level gauges are always fitted with two plate transparent glasses between which the fluid is contained. The fluid level is indicated as the result of the different transparency of the two media.

Fig 4



TRANSPARENRT LEVEL GAUGE

To protect glass surfaces from corrosive action of the process fluid, transparent level gauges can be fitted with Mica shields. The transparent level guage is particularly recommended for applications where the glass needs to be protected from corrosive fluids and high temperature.

Applications:

- In corrosive fluid.
- The observation of interface
- The observation of the liquid color
- For steam with an operating pressure > 20 bar
- If repeated thermal shocks comes

Mica sheet use in transparent level guage: Mica sheet are widely used in visual liquid level to protect the glass surface from the corrosive effects of hot alkaline or acidic solutions. Mica shields are also commonly used in steam water applications to prevent etching and the weaking of the glass.

Buoyancy principal

A body at rest in a fluid is acted upon by a force pushing upward called the buoyant force which is equal no me weight of the fluid that the body displaces.

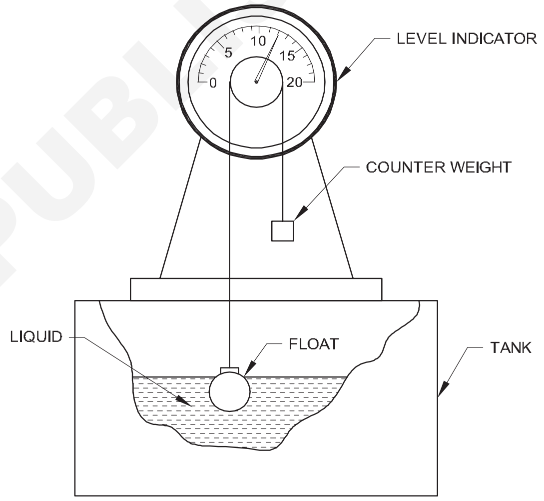
Float-type level indicator (Buoyancy)

Float operated level indicator is used to measure liquid levels in a tank in which a float rests on the surface of liquid and follows the changing level of liquid. The movement of the float is transmitted to a pointer through a suitable mechanism which indicates the level on a calibrated scale. Various types of floats are used such as hollow metal spheres, cylindrical-shaped floats and disc-shaped floats.

Construction and Working

Fig 5 shows the simplest form of float operated mechanism for the continuous liquid level measurement. In this case, the movement of the float is transmitted to the pointer by stainless steel or phosphor-bronze flexible cable wound around a pul- ley, and the pointer indicates liquid level in the tank. The float is made of corrosion resisting material (such as stainless steel) and rests on liq- uid level surface between two grids to avoid error due to turbulence. With this type of instrument, liquid 1 level from 1/2ft. (152 mm) to 60, ft.(1.52 m) can be easily measured.

Fig 5



FLOAT-OPERATED LIQUID LEVEL INDICATOR

Advantages

Float type level indicators offer the following advantages:

1 It is possible to read the liquid levels in a tank from the ground level even if the tank is kept below the ground level.

2 Its cost is low and has reliable designs.

3 It operates over a large temperature range.

4 There is a choice of corrosion-resistant materials to make these.

Disadvantages

1 They are normally limted to moderate pressures

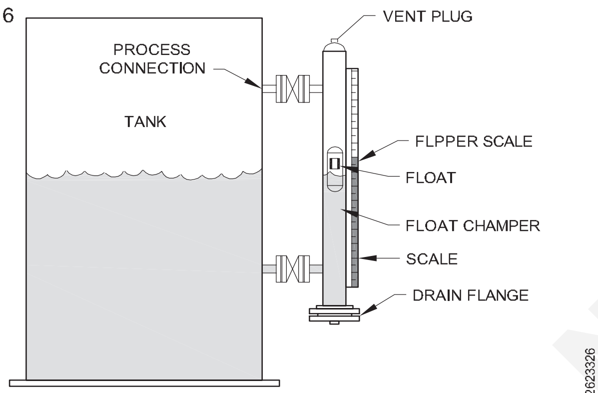
2 They are tailored to tank geometry.

Magnetic float level indicator or Magnetic guage (Fig 6 & Fig 7)

Magnetic level indicator is that the measuring instrument shares the same the same fluid-as the vessel. The level indicator is attached to the vessel and connects directly with the fluid to be measured. Within the chamber is a float with a magnet assembly inside. This float rests on the fluid's surface. As the fluid level rises or falls, so does the float. As the float moves up or down, the magnet assembly rotates a series of bi-color magnetic flags or flaps, changing the visual indicators mounted just outside the chamber from one color to the other.

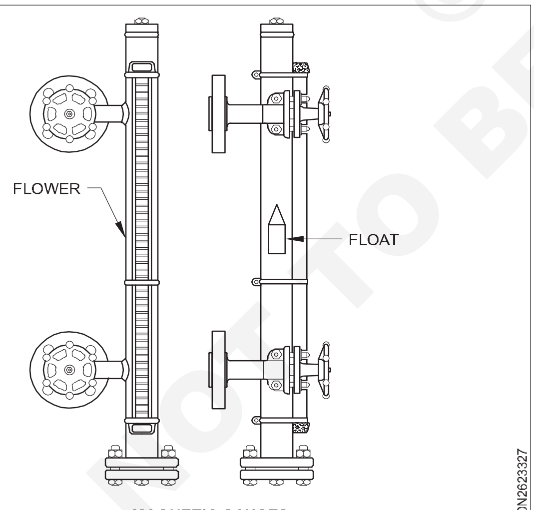
Since the magnetic level indicator (fig 1 & 2) working principles relies on the interaction between magnets, these level measuring instruments do not need a power source. They are also virtually maintenance-free. An additional advantage: the indicator's magnetic force can affect optional switches or transmitters mounted outside of the chamber. The colored flags are easy to see, even from a distance, and are paired with a scale for precise readings. As for any level instrumentation, the size and material of the float are chosen according to the media, temperature, pressure, and density of the process media.

Fig 6



MAGNECTIC FLOAT LEVEL INDICATOR

Fig 7



MAGNETIC GAUGES

Advantages

- Continuos and easy monitoring
- Sealing construction
- Requested length and connection manufacturing
- Ability to work in different densities
- Manufacturing according to various installation types
- Long life time
- Easy maintenance
- Up to 6 meters can be manufactured in one piece.
- Works up to 160°C in PN 10/16/25/40(Opt.) pressure class
- Self-cleaning feature of the system with up-and-down movement of the float

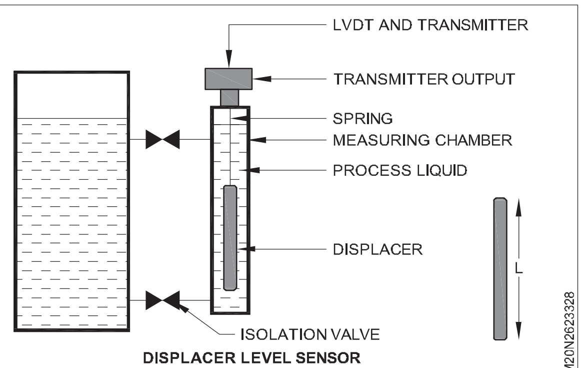
Application Areas

- All steam and hot water boilers
- Waste water systems
- Filling and unloading containers
- All chemical and petroleum products
- Oil boilers
- Diesel fuel tanks and generator sets
- Submarine, helicopter and ship fuel tanks

Displacer Level Sensor

Displacer level sensor use Archimedes' Principle to detect liquid level by continuously measuring the weight of a displacer rod immersed in the process liquid. The displacer is cylindrical in shape with a constant cross-sectional area and made long or short as required. Standard heights range from 14 inches to 120 inches. As liquid level increases, the displacer rod experiences a greater buoyant force, making it appear lighter to the sensing instrument, which interprets the loss of weight as an increase in level and transmits a proportional output signal Although the basic theory of operation has been outlined above, in a practical displacer level sensor, the construction is engineered to achieve the desired measurement objective with sophisticated electronic circuitry.

Fig 8



DISPLACER LEVEL SENSOR

In these types of displacer level sensors, the displacer is attached to a spring which restricts its movement for each increment of buoyancy (i.e. level change) A transmitter incorporating a Linear Variable Differential Transformer (LVDT) is used to track the rise and fall of the displacer rod as liquid level changes. Sophisticated electronics is then used to process the voltage signal from the LDVT into a 4-20mA output signal.

Factor need to consider for open and closed channel level measurement

- Factors considered for open talk
- It should be normal water tank

- Liquid which is not affected by environment
- Liquid which is not reacted by chemicals.

Factors considered for closed tanks

- Liquid which is riskly flammable
- Liquids which is corrosive
- Costly liquids live crude oil and cooling oils.

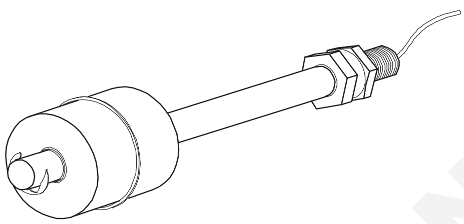
Principles of level measurement Using Level Switches

Objectives: At the end of this lessons you shall be able to
- **describe about level switch**
- **explain mercury switch in high pressure tank**
- **explain level detectors?**
- **describe about magnetic need switches.**

Level Switch (Fig 1)

A level switch is an electrical or mechanical method for measuring the level of a liquid, powder, or granule material. It is designed to activate an alarm if the material level in a container passes a predetermined height or depth. When a level switch detects that a tank is full, it is referred to as full or upper limit detection. If the level of the material drops, indicating that the tank is nearly empty, the switch will also provide an alert, which is referred to as empty or low level detection.

Fig 1

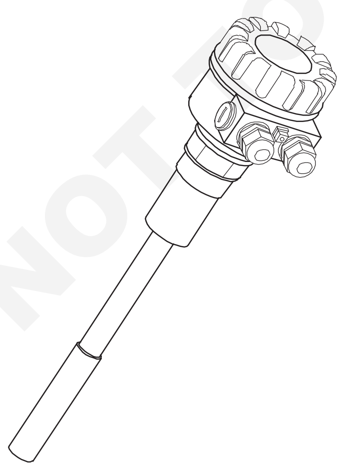


LEVEL SWITCH

IM20N2623331

Level switches are an essential part of production operations and are used in harsh conditions where there are extremes in temperature, pressure, and vibrations. The diversity of level switches makes them applicable to any conditions for measuring a wide array of products. Their accuracy, reliability, and durability are a necessity for the efficiency of industrial applications. (Fig 2)

Fig 2



A VIBRATING ROD LEVEL SENSOR

IM20N2623332

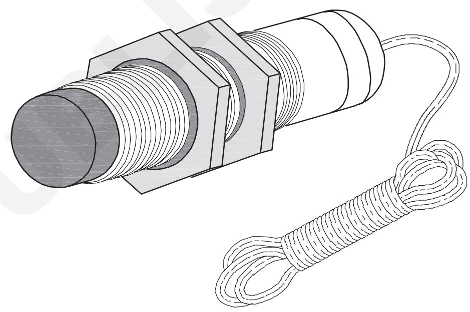
Road level switch

Road level switches have a stainless steel rod that vibrates or oscillates at a specific frequency and is powered by an electronic circuit

Inductive Level Switches

Inductive level switches are non-contact switches that respond to a targeted material when the material comes within the sensing field. An oscillator resonant circuit uses an open core coil to produce a concentrated high frequency electromagnetic field that comes from the surface of the sensor. If a material enters the target area, eddy (Fig 3)

Fig 3



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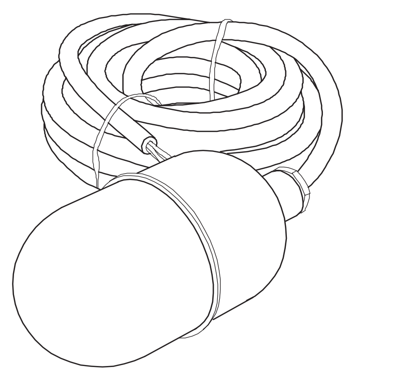
Mercury level switches

A sealed glass tube containing a minimal amount of liquid mercury and two unconnected electrodes that produce module electricity flow when the tube is 5 page moved past a certain angle so 167 that the liquid metal pools in between the electrodes, making a complete circuit. Once back in the original position, the current stops instantly. (Fig 4)

Fig 4



MERCURY LEVEL SWITCHES

IM20N2623334

Float switch

A float switch detects the level of a liquid in a tank. Based on the water level it will open or close an electrical circuit generally used to pump water in or out the tank

Photo electric proximity sensor

These Sensors in front of the Sensor S reflected from detect them objects directly by the detecting own gansmitted light an object's surface.

Optical level sensor

The object to be dectected reflects or blocks the light bear sent by an emitting diode.

capacitive sensor

A capacitives device that sensor is an Electonic can detect solid or targets without physical Contact Liquid

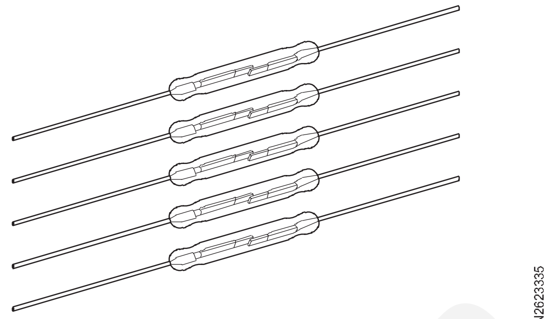
Tuning fork sensor

The frequency Media in which in air the fork frequency drop changes depending on the it is vibrato Immersed when at their natural frequency drop.

Magnetic reed switch

Magnetic red Switch is used to Control flow of Electricity. If the contact of magnetic reed is open electricity cannot flow. if the magnetic reed switch is closed Electricity Can flow. (Fig 5)

Fig 5



MAGNETIC REED SWITCH

Pressure head instruments

Objectives: At the end of this lessons you shall be able to
- **explain mystratic pressure types**
- **define specific gravity, density**
- **describe pressurized fluids**
- **explain air bellus method of level measurement**
- **explain air purse system of level measurement**
- **explain liquid purse system of level measurement**
- **explain ferue balance diaphragm system of level measurement.**

Hydrostatic pressure type

A liquid in a tank at rest exerts a force on the walls of the tank. This foreca Id at rest, is known as "hydrostatic pressure", and is proportional to the depth for height) of liquid in the tank. Hydrostatic liquid level measurement are listed below.

1 Pressure gauge method

2 Air bellows

3 Air punge system

4 Liquid purge system

Pressure gauge method

This is the simplest method used for liquid level measurement in an open tank Hydrostatic pressure of any liquid in an open tank is given by the equation:

$P=p \times h \times S_g$ or,

$h=P/p \times S_g$

where, P= pressure in psi or N/m^2

p= the water density

S_g= specific gravity

h= height of liquid (often called head) in inch or metre.

Hydrostatic pressure of a liquid in a close tank or vessel is given by the equation:

$P=(p \times h \times S_g)$+ external pressure on liquid

(7.3) Therefore, the pressure measured at the bottom of tank containing a liquid of known density and specific gravity is directly proportional to the height or level of liquid in the tank. This principle is utilized in pressure gauge instru ment for liquid level measurement.

Construction and Working

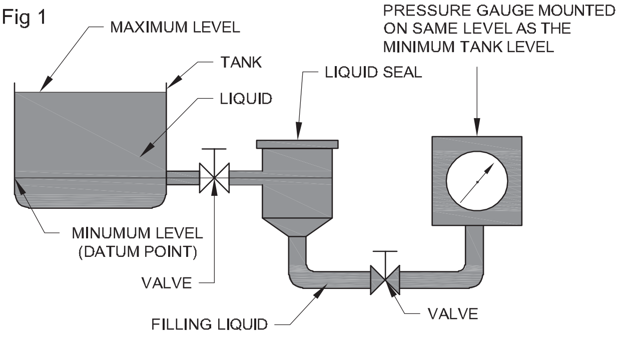
The pressure gauge level indicator consists of a pressure gauge connected at the lowest level of the tank. The level at which the pressure gauge is fitted. is known as the reference level and the static pressure measured by the rauge is a measure of the height of liquid column above the reference level and hance the liquid level. A liquid seal is connected with the piping on the tank including a shut-off valve while measuring corrosive or highly viscous liquids. This liquid seal consists of a fluid with which the measuring system s filled. This filling liquid transmits the pressure head of the measured liquid. The free surface of the filling liquid is kept in indirect contact with the measured liquid. These two liquids must not mix or react chemically, open tank pressure indicator for measuring liquid level. (Fig 1)

The location of the pressure gauge should be chosen carefully, since any fference in elevation above or below the lowest level of the tank will affect reading.)

Disadvantages

The instrument must be mounted at same level as the minimum level in the k. This is often inconvenient, as a tank may be located at certain height ove the control room. In this case, the level indicator in the control room ould show an error equivalent to the height of the tank from the control room.

Fig 1

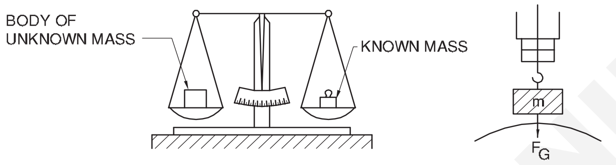


OPEN TANK PRESSURE INDICATOR

Weight Density and Specific gravity (Fig 2)

It is now seen that the mass of a substance is measured by its weight only without any reference to volume. But if equal weights of lead & aluminium, are compared the volume of lead is much smaller than volume of aluminium. So we can now say that lead is more dense than aluminium.. i.e In other words the density of lead is greater than aluminium.

Fig 2

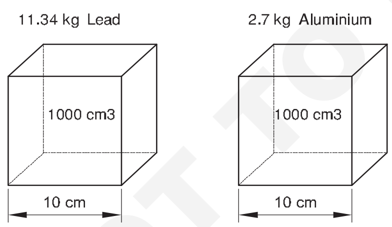


COMPARISON BETWEEN MASS & WEIGHT

The relation of mass and volume is called density. (Fig 3)

The density expresses the mass of volume E.g. 1 dm3 of water has the mass of 1kg-thus the density of 1kg/dm3

Fig 3 DENSITY



COMPARISON

Unit

The density is measured as below

Solids	gm/cc	Liquids	gm/cc
Aluminum	2.7	Water	1.00
Lead	11.34	Petrol	0.71
Cast iron	6.8 to 7.8	Oxygon	1.43
Steel	7.75 to 8.05	Diesel Oil	0.83

MKS/SI=Kg/m3, CGS-1 gm/cm3 FPS-lbs/c ft

The specific gravity of a substance is also called its relative density.

$$\text{Specific gravity (or) Relative density} = \frac{\text{Density of the substance}}{\text{Density of the water at 4 °C}}$$

$$= \frac{\text{Mass of any volume of a substance}}{\text{Mass of an equal volume of water ate 4° C}}$$

Formula

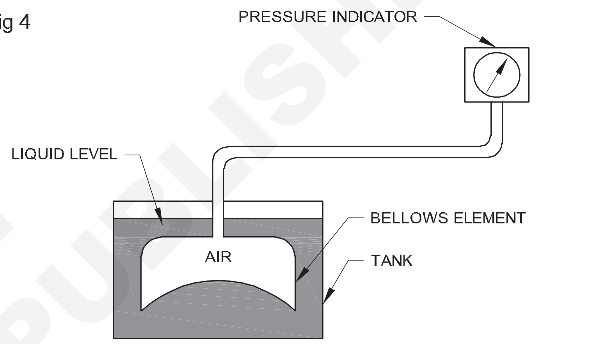
Pressurized fluid

Pressurized fluid such as Subcritical water pressurized aqueous tonic liquids. Can be wed for the production of phytochemicals from a variety biomasses.

Air Bellows

Air bellows are used for liquid level measurement where air indicator cannot be conveniently located at the specified datum line. Fig 4 Illustrates the principle of the air bellows.

Fig 4



FLEXBILE AIR BELLOWS

Construction and Working

Air bellows consists of the bellows element which is connected by the tubing with the pressure indicator. Air is scaled in the cavity above the bellows and inside the tubing to the pressure indicator. When the tank is empty, the sealed air is uncompressed and corresponds to zero on the pressure indicator. As the tank is filled with liquid, the head of liquid in the tank flexes the bellows, which com- presses the air above the bellows. The compression of sealed air is transmitted to the indicator which is callibrated in terms of the tank liquid level. Air bellows may be constructed for various applications and ranges. Fig shows an industrial application of air bellows, in which a closed box air bellows is connected to the process fluid tank via a seal, for liquid level measurement. Here, liquid seals are used while measuring corrosion or viscous liquids level.

Manometers

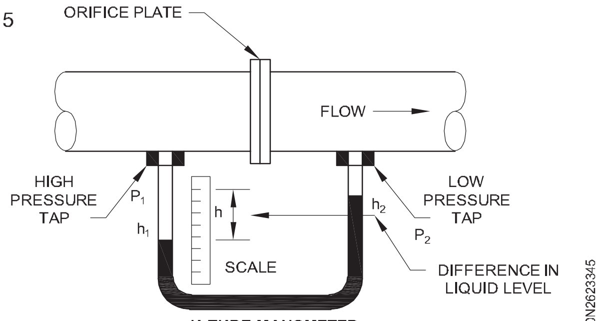
The manometer is the simplest measuring instrument used for gauge pressure range pressure) measurements, by balancing the pressure against the right of a column of liquid. The action of all manometers depends on the ect of pressure exerted by a faid at a depth. The different types of ma- meters are discussed below.

U-tube Manometer

The U-tube is the simplest form of manometer and is used for experimental in laboratories. By suitable choice of liquids, a wide range of pressure can be recorded

Construction It consists of a transparent (glass) tube constructed in the form of an elongated U and is partially filled with a liquid, most commonly water or mercury. Water and mercury are used because their specific weights various temperatures are known exactly and they do not stick to the tube. One end of the tube is connected to one pressure tap and the other end is connected to the other pressure tap, or it may be left open to the atmosphere. The U-tube manometer is shown in Fig 5.

Fig 5



U-TUBE MANOMETER

Working When there is a pressure difference between the two ends tube, the liquid level goes down on one side of the tube and up on the other side. The difference in liquid levels from one side to the other indicates the difference in pressure. From Fig. 9.2 the differential pressure (P-P obtained by the relation:

$(P_1 - P_2)= (P-P_1)\ (h_1-h_2)g$

$P= (p-p_1)gh$

or

where

p=density of fluid in U-tube

p_1= density of fluid whose pressure is being measured

h= (h_1-h_2), difference in fluid levels

g= acceleration due to gravity

When a manometer is used to measure low pressures then water is used the liquid, and when it is used to measure high pressures then mercury p used as the liquid. Mercury is almost 14 times as heavy as water. Therefor the difference in levels in a mercury-filled manometer is about 1/14 of wha it would be if water were in the tube.

Limitations In the U-tube manometer, the application of pressure cause the liquid in one leg to go down while that in the other leg goes up, so there is no fixed reference. This tends to make the measurement of the height more difficult than it would be if one surface could be maintained at some fixed level.

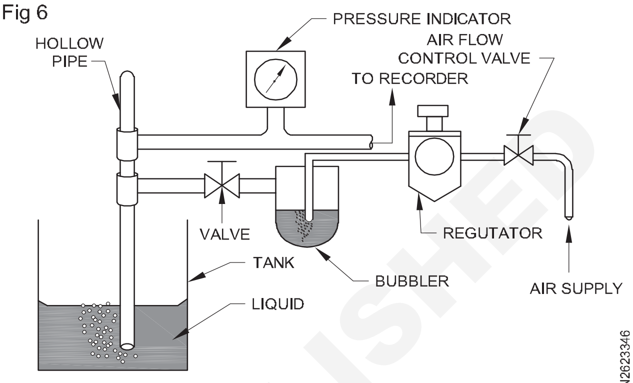
Air Purge System

Air purge (also known as bubbler tube) system is one of the most popular hydrostatic pressure type of liquid level measuring system which is suitable any liquid as shown in Fig 6.

Construction

An air purge system consists of a hollow tube (known as bubbler tube) inserted in the liquid of the tank. Tow connections are made with the bubbler tube, one to the regulated air supply and the other to a pressure gauge, calibrated in terms of liquid level. A bubbler is connected in the air supply line which serves simply as a visual check to the flow of the supply air. A level recorder may be connected with the pressure gauge to keep the continuous record of liquid level as shown in Fig. 6.

Fig 6



AIR PURGE SYSTEM

Working

When there is no liquid in the tank or the liquid level in the tank is below the bottom end of the bubble tube, the air flows out of the bottom of the bubble be and the pressure gauge indicates zero. In other words, there is no back pressure because the air escapes to the atmosphere. As the liquid level in the tank increases, the air flow is restricted by the depth of liquid and the air pressure acting against liquid head appears as back pressure to the pressure gauge. This back pressure causes the pointer to move on a scale, calibrated terms of liquid level. The full range of head pressure can be registered as bel by keeping the air pressure fed to the tube, slightly above the maximum head pressure in the tank. The range of the device is determined by the length of the tube. Because air is continuously bubbling from the bottom of is said to be purged. The common purging fluid is air, but, if air reacts with the tank fluid or is absorbed, different gases (like carbon or nitrogen) are chosen depending on liquid properties.

Advantages

Following are the advantages of air purge system:

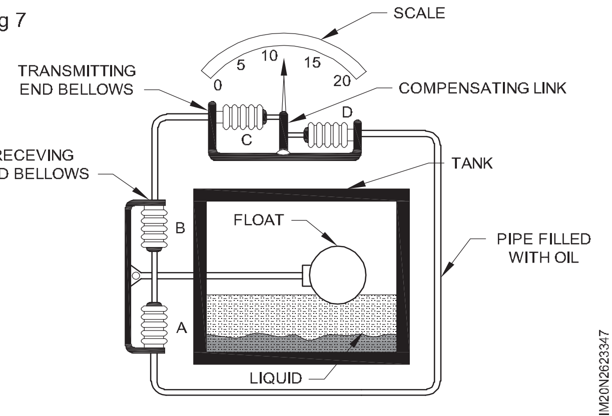
i In this system, the pressure gauge can be placed above or tank level and can be kept as far away as 500 ft (12.7m) from the tank below the with the help of piping.

ii This type of device is well-suited for measuring the level of corrosive or abrasive liquids.

Liquid purge system

When an air purge system is unsuitable, because air bubbling through liquid may, interfere with its crystalization, liquid purge system is used. The

Fig 7



construction and working of liquid purge system is the same as an air purge system, the only difference is that in place of air, water or light mineral oil used as the purge liquid. The nature of the purging liquid must be such that the introduction of small quantities of it into the plant will not, affect product on process should be free flowing and not vaporize at the temperature of the pipe line. The purging liquid may be either soluble or in soluble in the vessel liquid. The rate of flow of the purging liquid is normally adjusted to about gallon/hour. The supply liquid pressure determined by the range of liquid level to the monitored.

Fore Balance diaphragm method of level measurement Fig 7 consist of A bellows elements two in the transmitter Side (C18D) and two in me receiver Side (A&B) that are fixed in the outer ends Bellows & Cana, D are hydraulic Connected popes through pipes with an oil, where the float moves up or down according to change in level position is transmitted by a lower arm to the bellows assembly A-B. When the level rises. 8 is compressed and A expands, thus causing oil in the pipe low from 8 to C. and from D to A. The bellows are balanced so that the movement at the transmitter end is reproduced in reverse mode at the receive end, e. C expands and D is compressed as the fiquid level rises: The we bellows C and D action the compensating link pivoted on the pointer, in e same directions and will rotate the pointer in proportion to the level value. Any change in ambient temperature affects both the bellows, i.e. both pand or contract. Therefore level transmission at the pointer, is affected With hype instrument level transmission up to 2017 6 35mm) can be achieved

Advantages

Float type level indicators offer the following advantages:

1 It is possible to read the liquid levels in a tank from the ground level even if the tank is kept below the ground level.

2 Its cost is low and has reliable designs.

3 It operates over a large temperature range.

4 There is a choice of corrosion-resistant materials to make these.

Disadvantages

Following are the disadvantages of float type level indicators:

1 They are normally limited to moderate pressures.

2 They are tailored to tank geometry.

Advance level Measuring Instruments

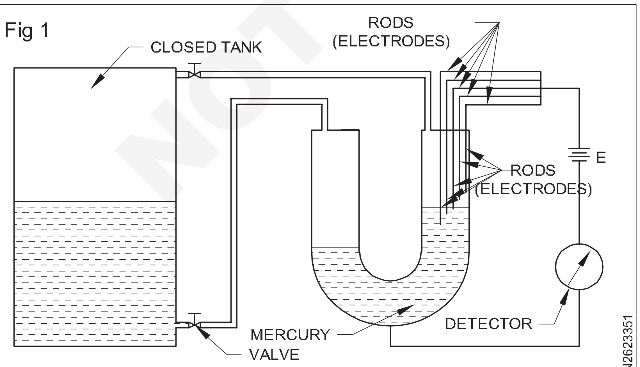
Objectives: At the end of this lessons you shall be able to

- **explain conditioning and capacitance method of level measurement**
- **explain zero and span adjustments of capacitance probe method of level measurement**
- **explain ultrasonic level detector measurement for Level**
- **explain radiation level deter.**

Conductivity and capacitive method

i Measurements of level using change in conductance (Fig 1)

Fig 1



LEVEL CHANGE MEASUREMENT USING CHANGE IN CONDENCE

Measurement of level using change in conductance in this method, due to the pressure at the bottom of the tank, the level of the mercury filled in a system such as a Utube manometer connected to it varies. The level is measured by changing the resistance (conductance) of an electrical circuit using these variables. Construction

At the bottom of the tank, a U-tube-like structure partially filled with mercuy is connected through a tube Another limb of the U tube is attached to the top of the static pressure tank. Conductive conductors of different lengths are connected to an external resistance and mounted in a U-tube. A constant voltage source is connected to the wires through the ammeter eie galvanometer. Mercury is perfect over wires when falling the circuit is gradual

Working

When the water level in the tank rises. Pressure builds up at the bottom. This causes the mercury level in the U-tub limb to rise and touch the wires: Thus, the wires along with the resistance are connected in parallel and increase the circuit current A reading is obtained from the detector

As the tank level decreases, the level of mercury also decreases leaving a few wires alone. Due to this, the resistance increases (conductance decreases) and the current flowing in the circuit decreases. The deflection of the detector varies with the current detector reading wake liquid level calibrated.

Measurement of level using change in capacitance

Capacitance level indicator

Objectives: At the end of this lesson you shall be able to
- **explain the principle and working of capacitance level indicator**
- **describe the advantages and disadvantages of capacitance level indicator.**

This instrument is based on the principle of capacitance equation given by

$C=K\frac{A}{D}$

C = capacitance in farad, K = dielectric constant

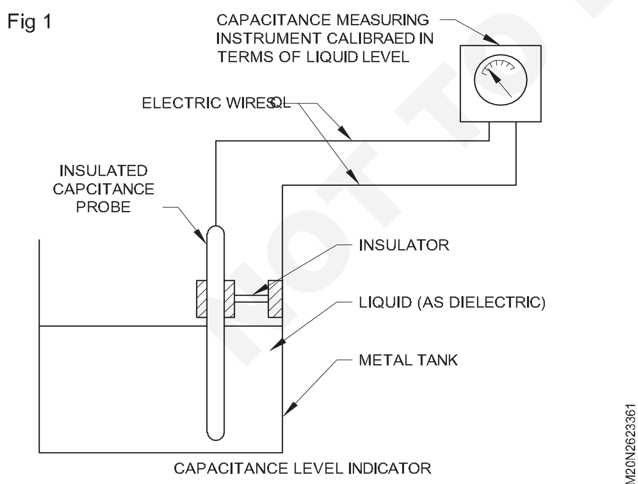
A=Area of plate in m2 D-Distance between two plates in mm. In this A and D are constant. The capacitance will vary as per the liquid level. This principle is utilised in the capacitance level indicator. (Fig 1)

The capacitance level indicator consists of an insulated capacitance probe, firmly fixed closed and parallel to the wall of the tank. The capacitance probe and the wall of the tank is connected to a meter or instrument calibrated in terms of liquid level

If the level of the tank increases the capacitance increases, when the tank level decreases the capacitance also decreases. The increase or the decrease in liquid level is measured and displayed on the indicator calibrated interms of liquid level. It has got great advantages ie these instrument are very sensitive and useful in small system. There are no moving parts thus it requires less maintenance. It is also suitable for remote and continuous indication.

Probe materials for most conceive fluids are available and good use for slurries. The main advantages of capacitance level indicator, is its performance will be severely affected by dirt and contaminants

Fig 1



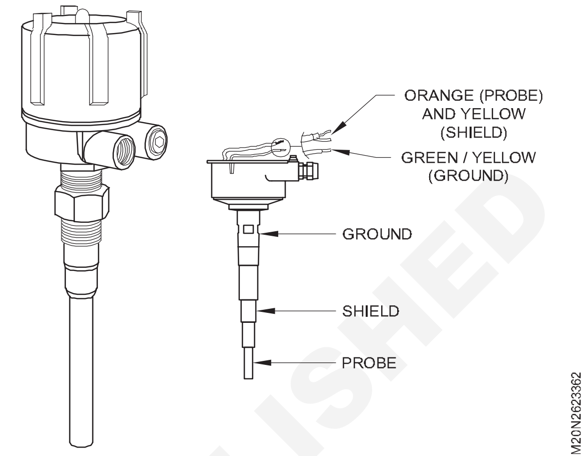
CAPACITANCE LEVEL INDICATOR

Capacitance Probe

Less than 5 Ohm must be present between:

- Orange wire and probe
- Yellow wire and shield

Fig 2



- Green/yellow wire and ground

More than 1 MΩ resistance must be present between:

- Orange and yellow wires
- Orange and green/yellow wires

If other values are present, the wiring of the probe is incorrect defective.

capacitive probe measurement is based on the capacitance change of a capacitor. The probe and the tank wall form a capacitor whose capacitance is dependent on the amount of product in the tank: An empty tank has a lower, a filled tank a higher capacitance

zero and span adjustment of expectance type Connect level transmitter

1 connect the level transmitter in the (tank).

2 check whether transmitter shows zero reading by connecting with multimeter otherwise release the pressure.

   (if the transmitter is smart

3 connect multimeter to the level transmitter

4 put multimeter to ma range

5 Fill the corresponding liquid in correct density and note down the readings. Fill liquid at 25%, 50%, 75% and 100% in both ascending and descending orders and note down the reading

6 check for errors if there is zero and span adjustment should be done.

7 For zero calibration drain the liquid and check the multimeter if it is not 0 then go to sensor trim option in the HART then go to zero trim sensor Set at zero.

8 For span calibration: fill 100% and wait for some time then go to sensor trim and select span trim and set for span

9 After doing zero and span trimming again check the reading at 0% 25% 50% 75% and 100%

In case of non smart capacitance type transmitter

10 Connect a multimeter and rotate the zero pot and stop when multimeter shows 4ma.

11 Fill the chamber to maximum liquid level and rotate the span screw to 20ma.

12 Repeat these steps and check all readings.

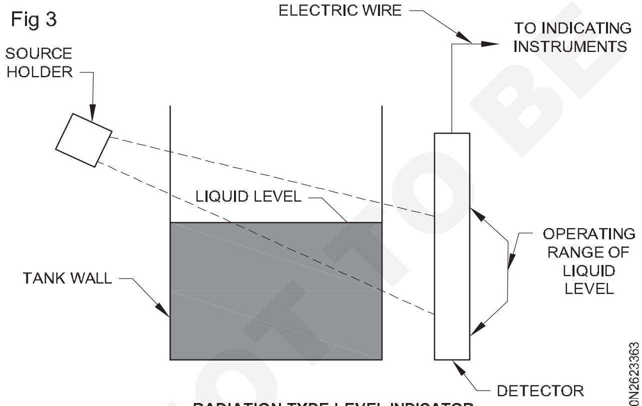
Radiation Level Detector (Fig 3)

Radiation level detectors are used where other electrical methods would not survive. Also, the most common reason for using a radiation level detector is that it does not need to come in contact with the liquid being measured.

Construction and Working

Figure shows a radiation level detector. It consists of gamma rays source holder on one side of the tank and a gamma detector on the other side of the tank. The gamma rays from the source are directed towards the detector in a thin band of radiation. When the gamma rays penetrate the thick wall of the tank, its energy level afterwards is greatly reduced. The radiation received at the gamma detector is inversely proportional to the thickness of the tank walls and the medium between the radiation source and the detector. That is the thicker the medium between source and detector, the less radiation received by the detector and vice versa.

Fig 3



RADIATION TYPE LEVEL INDICATOR

When the tank is empty, the gamma rays pass only through the two tank walls and the air or vapour in the empty tank. When liquid enters the tank and its level rises, the radiation beam passes through a path in the liquid, u well as the tank walls. The liquid in the tank reduces the radiation received by the detector. The amount of radiation received is inversely proportional the amount of liquid between the radiation source and the detector. The difference in the amount of radiation received by the detector, corresponds the liquid level in the tank. Thus, when liquid level rises, the amount of

Advantages

Following are the advantages of radiation level indicators:

i There is no physical contact with the liquid.

ii They are suitable for molten metals as well as (corrosive, abrasive, highly viscous, adherent).

iii They are useful at very high temperatures/pressures.

iv They have good accuracy and response.

v They have no moving parts.

Disadvantages

Following are the disadvantages of radiation level indicators:

i The reading is affected by density change of liquid.

ii Radiation source holders may be heavy.

iii Their cost is relatively high

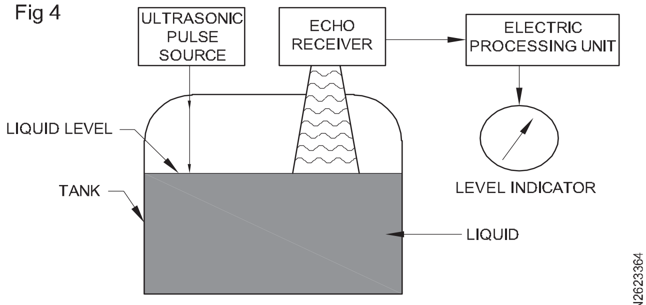
Ultrasonic Level Detectors (Fig 4)

Working and Construction

Ultrasonic level detectors operate either by the absorption of acoustic energy as it travels from source to receiver or by the attenuation (frequency change of a vibrating diaphragm face, oscillating at 35 to 40 KHz. It operates by generating an ultrasonic pulse and measuring the time it takes for the eche return. When an ultrasonic transmitter is mounted at the top of the tank, pulse travels in air at a speed of 331 meter/second at 0 °C. The time of travel is an indication of the depth of the vapour space above the liquid in the tank If an ultrasonic transmitter is mounted on the bottom of the tank, the times of travel reflects the depth of liquid in the tank and the speed of travel is a function of what that liquid is. In case of water at 25 "C. an ultrasonic pulse travels at the speed of 1,496 meters/second. Figure illustrates the work of an ultrasonic level detector.

Temperature compensation is essential in ultrasonic level measurement because the velocity of sound is proportional to the square root of temperature and, in case of air, it changes by about 0.6 meter/second for per change in temperature. The speed of travel rises with temperature, and amounts to about 0.18% per "C.

Fig 4



ULTRASONIC LEVEL DETECTOR

In order to measure the time of travel of the echo of an ultrasonic pulse is essential that some of the sonic energy be reflected. Liquids and s with large and hard particles are good reflectors. Loose dirt have poor flecting characteristics as they tend to absorb the sonic pulse. Since the reflecting surface be flat If the same Sonic Pulse is reflected from a sloping surface

echo will not be directed back to the source and the round-trip travel time will not accurately reflect the vertical distance Irregular surfaces result in diffuse reflection where only small portions of the total echo travels vertically back to the source.

Ultrasonic level measuring devices can be used for both continuous and point measurements. The point measuring ultrasonic detectors are used for measurement of gas/liquid, liquid/liquid, or gas/solid interfaces.

Advantages

Following are the advantages of ultrasonic level detectors:

i Ultrasonic level detectors are non-contact type measurement techniques.

They have the ability to measure level without making physical contact with the process material

ii They have no moving parts.

ii The reliability of the reading is unaffected by changes in the composition, density, moisture content, electrical conductivity, or dielectric constant of the process fluid.

Disadvantages

Following are the disadvantages of ultrasonic level detector:

1 An ultrasonic transmitter is subject to many interferences, which affect the strength of the echo it receives. The echo can be weak due to dispersion (which reduces sound intensity by the square of distance) and absorption (which in dry air reduces its energy level).

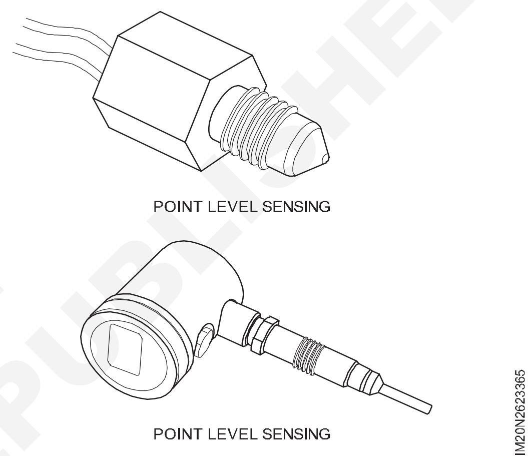
2 Temperature compensation is essential in ultrasonic level measurement

3 The dirt, irregular and slope surfaces affect the accuracy of the measurement,

Point level detection in liquids (Fig 5)

A tuning fork sensor oscillates at its resonant frequency. The drive works piezoelectrically. The oscillating frequency changes as the fork enters the medium. The chnage is analyzed and translated into a switching signal.

Fig 5



Solid level measurement

Objectives: At the end of this lessons you shall be able to
- **explain solid level measurement unit weight**
- **explain diaphragm switch in solid level measurement**
- **explain nuelear gauge method for measurement**
- **explain briefly microlevel solid detector method for level measurement**
- **describe different type of switches in solid level measurement**

Using weight to determine solid level

The water tank is placed one of the gauges. As the level increases the pressure exerted on the gauge increases, this makes the strain gauge shrink and to reduce resistance

The weight of the tank is shown in the load.

Level of the fluid = volume of fluid / surface area here volume of the fluid = weight of fluid / density of the fluid

The weight of the fluid = weight of vessel with fluid – weight of the vessel.

Weight of the vessel is known and the weight of the vessel with fluid is what we measured using load cell.

Solid level measurement with microwaves

There are two types of radar level the radar instrument work by transmitting high frequency. Electromagnetic radiation (GHz) and synchronizing the transit time with the level instruments. However, radar has an advantage over ultrasound because of the inherent sound limitations. Sound waves are a form of mechanical energy that uses the molecules in the atmosphere causes the speed of sound to vary. For example, vapors are atypical cause of error ultrasonic level measurements because they change the speed and the force of propagation there are two types of radar level instruments: non-contact and guided wave (as show in figure).

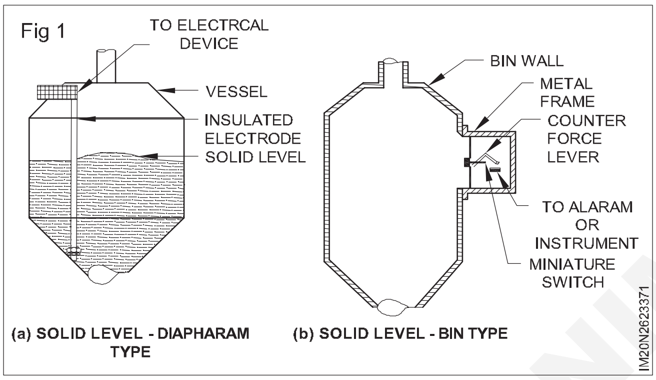
Level measurement

Bin type electrical capacitance method

To give the level of solids in a tank methods. are handled. In which electrical many. The capacitance method is one.

Construction

An insulator in the system is fig 1 permanently in an insulated long wire tank fitted. This wire is capacitance with measuring electrical circuit or bridge circuit is connected. The tank is electrically grounded the electrical capacitance between the working solid and wires varies with the level of the solid so the wire and terminals are taken from the tank and together with an electrical circuit the level of solids can be measured by connecting for continuous indication or recording use this method. Alarm and control also used. Density of the solid and temperature affects the measurement

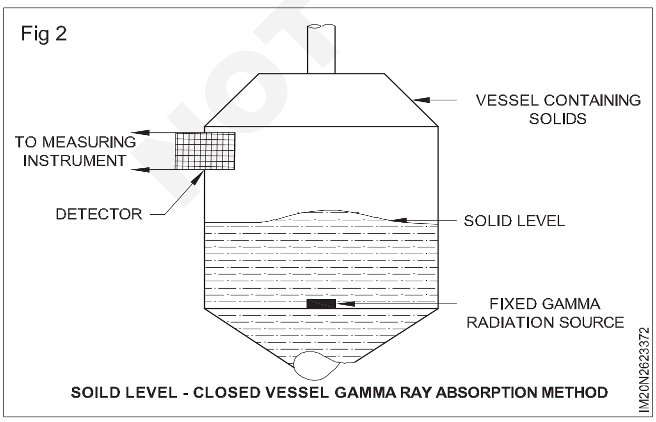


Diaphragm method

This gauge is used to measure the level of a solid at a point. High and low set pointa.com (two units of measure to be used want several diaphragm should be used to measure the level at several points in the tank.

Construction

A diaphragm is as shown in fig 2 attached to metal frame. Diaphragm is attached to the tank to tank to touch the solid. A counter force lever is connected to the diaphragm. This lever is electrical a switch is connected which trips the circuit



Working

As the level rises and touches the diaphragm, the pressure in the solid creates forces on the diaphragm thus the lever moves and the electrical switching trips a switch can be used to activate an alarm or conveyor system this device can also be used at high pressure however, it cannot be used at high temperatures.

Nuclear gauge level measurement solids

Nuclear level measurement technology has been applied effectively to measure liquid and solids for more than 30 years the basic method of measuring the nuclear level is the sending of radiation through the level is the sending of radiation transferred radiation is measured using a detector

Level measurement in lost vessels gamma ray absorption method

The level of solids in the tank isa measured using gamma ray absorption method

Construction

A source of the finished tank gamma is placed at the bottom. Of the tank the upper part gamma ray detector is placed. Detector's output is connected to the display circuit

Working

The gamma rays from the source absorbs. The detector gives output according to the power of gamma rays received. Solids in the tank absorb gamma rays. The amount absorbed varies with the height or level of the solid. So as the level increases, the output of the detector decreases. Continuous indication or alarm circuits can be acticated with this output. The instrument high pressure and can be used in temps. Also know the height it can be used to measure the density of fluidised bed measured

levels, helath, safety, licensing, or product contamination concerns are minimal.

i Presebce if dust, mist, and nonmetalic foam has negligible effect on the accuracy of the measurement.

ii By using thick windows microwave leve detectors can withstand heavy abrasion on solids service and isolates the sensor from hazardous and toxic liquids on high-pressure service.

Disadvantage

The beam-breaker type microwave level sensor is more expensive as it requires two devices to install along with separate windows on metal surface.

Microwave level switches

Working and construction

Microwave level detectors use electromagnetic radio waves, typically in either the microwave X- band around 10GHz or the microwave K- band around 24 GHz, for the level measurement. Wave length can be calculated by dividing the wavelength in a vacuum by the square root of the window materials dielectric constant.

Microwaves do not pass through metal walls, but they do pass through fiber glass or plastic tank walls and through windows of plastic, ceramic, or glass that are installed in metal vessel walls. As long as the window material has a relatively low dialectic constant (e.g. less than 4.0) and as long as thickness is close to an even multiple of a half wavelength, attenuation is minimal.

Side-mounted microwave level detectors (switches) are used on hard-to-handle solid, liquid-solids interface, and liquid-liquid interface applications top-mounted microwaves level detectors are used for continuous level measurement on liquid applications using radar technique.

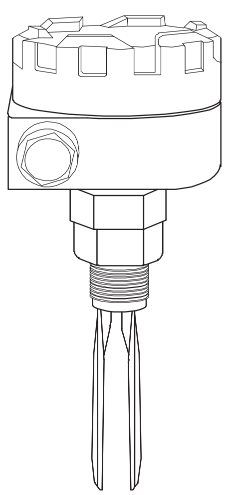
There are various microwave level switches that are used for liquid or liquid level measurements such as

- Reflection level switches
- Beam-breaker level switches

Vibrating fork switches

Working principle

Fig 3



The vibrating fork type level sensor works on the principle of tuning forks. There is a piezo ceramic crystals located inside the fork assembly. This frequency is continuously monitored by the internal electronic circuitry

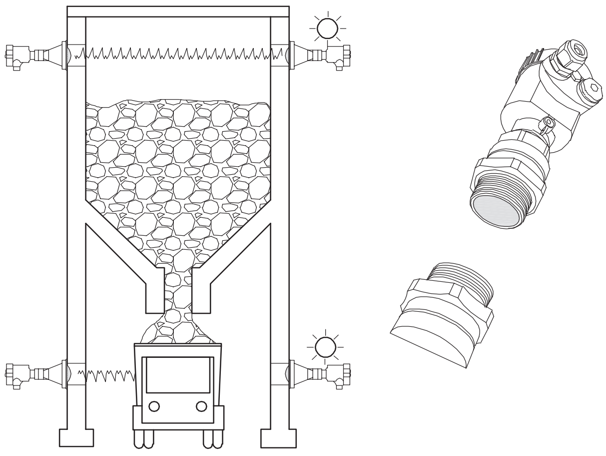
When the fork comes in contact with liquids/solid material, the frequency slightly changes, and this changes, and this change in frequency is sensed by the electronic circuit which in turn send out a signal. This signal is processed to give out as a relay output either N.O or N.C signal which in turn indicates level signal either low or high depends on.

The working principle of laser sensors

The working principle of all laser sensors are based on the triangulation principle. Some laser sensors are designed and manufactured for metal and polished objects and some for completely dark objects.

Laser sensor is widely used in industrial and agricultural production, national defines and military, medical and health, scientific research, and other aspects and applications.

Fig 4



The sensor consists of a laser, optical parts, and photoelectric devices used to convert the measured physical parameters such as length, flow, speed, etc. into optical signals, and then use a photoelectric converter to convert the optical signals into electrical signals output

Microwave level detector

Microwave Barrier Switch detects the upper and lower limits of silo, hopper, etc... The microwave system enables non-contact detection and easy maintenance.

Further the mounting positions can be easily decided because detection works when the accumulation of material blocks the straight line between transmitter and receiver.

Principle

Microwaves can pass through walls made of insulators with low permittivity, such as plastics, glasses, died bricks, woods and ceramics

The microwave barrier switch can detect the presence or non-presence of materials inside containers made of low permittivity materials without making any contact with the actual materials inside.

The absorption of microwaves is used for the supervision of limit values in microwave barriers. The microwave emitter and receiver form a radiation barrier. A narrow beam runs through the tank on the level which is to be monitored.

As soon as the medium enters the radiation area, the microwave signal is damped so that only a small part reaches the receiver. This is recognized and used for triggering the switching signal.

Advantages

- Adjustable sensitivity
- Flush mounted, non-contact measurement
- No wear and tear or maintenance with long service life
- Easy installation and commissioning

Temperature

Objectives: At the end of this lesson you shall be able to
- **define heat and specific heat**
- **explain effects heat**
- **explain temperature scales**
- **explain furnace and oil bath**
- **write precautions to be followed while measuring temperature.**

Temperature Measurement

Temperature: The Temperature of a substance is a measure of the hotness, coldness, of that substance. It is the thermal state of a body or a substance which determines whether it will give heat tends to flow from a body at a higher temperature to a body at temperature, just as water flows from higher to lower levels.

The terms, heat and temperature, are closely related. Temperature may be defined as "degree of heat" but heat related quantitatively by the second law of thermodynamics, which states that heat flows, of its own accord, from a body at a higher temperature to a body at a lower temperature. It is therefore important to remembers that a temperature measurements two bodies in intimate contact are at the same temperature only. If there is no heat flow between them.

Heat

Heat is a form of energy. Heat is also work because energy is the ability to do work. Heat is produced by pressure, friction and chemical changes.

Effects of heat

1 Raises the temperature
2 Increase volume
3 Changes state
4 Brings about chemical action
5. Changes physical properties

Units of heat

There are 5 units to measure heat

1 Calorie
2 Kilocalorie
3 British thermal unit
4 Centigrade heat unit
5 Joule

Calorie definition: The calorie was defined as the amount of heat required at a pressure of 1 standard atmosphere to raise the temperature of 1 gram of water 1° Celsius.

Kilocalorie

The heat required to raise the temperature to 1 kg water by 1° Celsius is 1 Kilocalorie.

British thermal unit: the amount of heat needed to raise 1 pound of water at maximum density trough 1 degree Fahrenheit

Centigrade heat unit: It is the amount of heat required to raise the temperature of one pound of water by one Celsius degree. It is equal to 1.8 BTU or 1.899 Joules.

Joule: SI unit of heat is joule

1 calorie = 4.2 Jo

1 Kilo calorie= 4.2 K J

Specific heat: The quantity of heat required to raise the temperature of one gram of a substance by one Celsius degree. The units of specific heat are usually calories or joules per gram per Celsius degree. For example, the specific heat of water is 1 calorie (or 4.186 joules) per gram per Celsius degree.

Fahrenheit and Centigrade (Celsius) temperature scales

The Fahrenheit scale, abbreviated °F, was intruded in about 1709 by a German philosopher Fahrenheit, and centigrade (Celsius) scale, abbreviated °C, was introduced in about 1742 by a Swedish astronomer and professor, Celsius. These scales are based on the fact that that the melting of ice and the boiling of water occur at certain fixed temperature, at standard atmospheric pressure (14.7 psi).

On the Fahrenheit temperature scale, the melting point of ice is designed at 32°F and the boiling point at 212° F. On the centigrade and Centigrade temperature scale, the melting point of ice designated at 0°C and the boiling point at 100°C. Between the two fixed points, the Fahrenheit scale is divided into 180 equal divisions and the centigrade scale into 100 equal divisions. Since both scales are linear, temperatures can be easily converted from one from one to the other, using the following equation.

$$\frac{°C}{100} = \frac{°F - 32}{180}$$

Kelvin and Rankine temperature scales

The kelvin scale, abbreviated as o K, was introduced in about 1848, by Lord Kelvin, 1824 – 1927. On the kelvin temperature scale, the ice-point is 273.15 °K and the steam-point 373.015°K. The kelvin scale, is also divided into 100 equal divisions. The centigrade(0°C) can be converted into kelvin (°K) by using the equation:

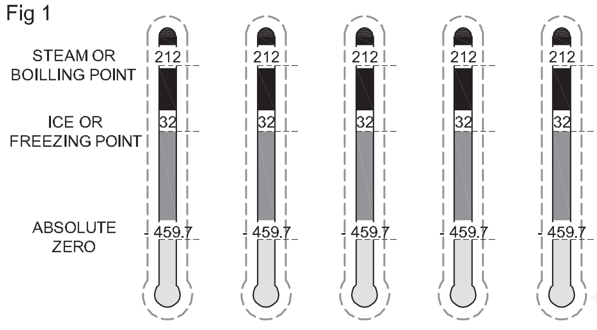
$$^{\circ}K = 0^{\circ}C + 273.15$$

the Rankine scale is abbreviated as °R. On the Rankine scale, the ice-point is 491.7°R and the steam point is 671.7°R. The Rankine scale. Like the Fahrenheit scale is also divided into 180 equal division temperature in Fahrenheit (OF)can be converted into Rankine (°R) using the equation

$$^{\circ}R = ^{\circ}F + 459.69$$

Both the ranking and kelvin in temperature scales are called absolute scale because they use absolute zero as one of their reference point. (Fig 1)

Fig 1



RANGES OF DIFFERENT TEMPREATURE SCALES

Relation between four scales of temperature

$$\frac{C}{100} = \frac{F-32}{180} = \frac{R}{80} = \frac{K-273}{100}$$

Primary standard

1 178 – 90 – international temperature scale (1990)

2 SPRY – standard platinum resistance (thermometer) and Its – 90 constant standards in which primary are provided.

Secondary standard

A standard platinum resistance thermometer commonly used temperature calibration purpose series 300, series A, B, D, E thermos levels

Standards of measurement of temperature controlled oil bath Fig (2&3)

Fig 2

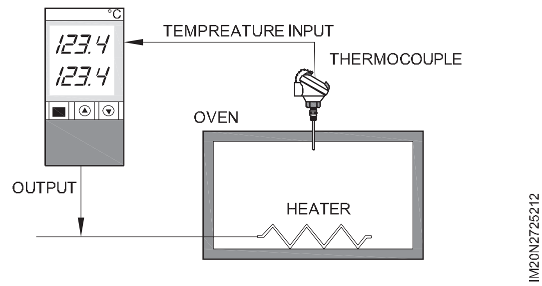
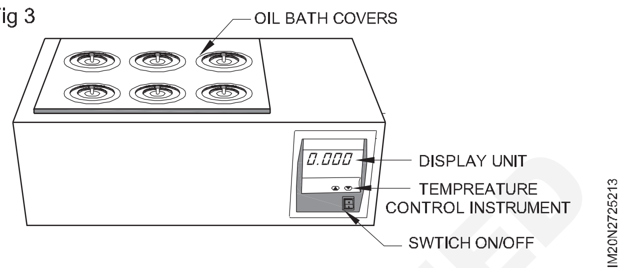


Fig 3



A controller monitors the actual temperature in oil bath while measuring the oil bath temperature. It is below the set temperature it sends a signal to heater. The heater in to raise the set point temperature again to use mineral oil and silicon oil.

A temperature controller is device used to control temperature that measure the set point compares it. The temperature transducer are used to determine how much heat is required to bring process temperature to the desired valve.

An important function of temperature thermocouple measure compared to set point constant temperature maintain to monitor the heater how to long time operated.

Use of oil bath

Used to chemical reaction provide more uniform heat compared to other.

Temperature controlled furnace

The furnace produces heating system it is produced 400°C degrees, temperature heat.

Furnace different type design, and function, temperature, different fuel, and they differ as to the mode of introduction of combustion air heat is generated by the industrial sector by mixing air or oxygen fuel or from electrical energy.

Types of thermometers

Objectives: At the end of this exercise you shall be able to
- **explain bimetallic thermometer**
- **explain liquid in glass thermometer and gas thermometer**
- **explain filled system thermometer and its advantages disadvantages**
- **explain about thermo switch, construction and working principle**

Methods of temperature measurement

They are classifies as follows

1 Explain thermometers.

2 Filled system thermometer.

3 Electrical temperature instruments.

4 Pyrometers

Expansion thermometers

There thermometer are classified according to the nature of substance which expands.

i Expansion of solids.

  a bimetallic thermometers.

ii Expansion of solids

  a liquid in glass thermometers.

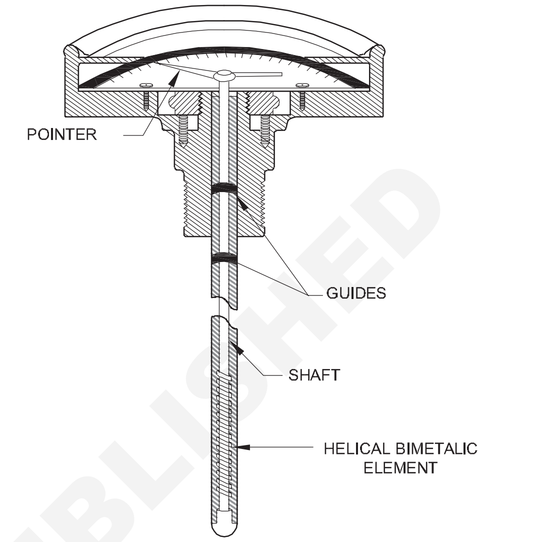
  b liquid in metal thermometers.

iii Expansion to gases.

  a Gas thermometers.

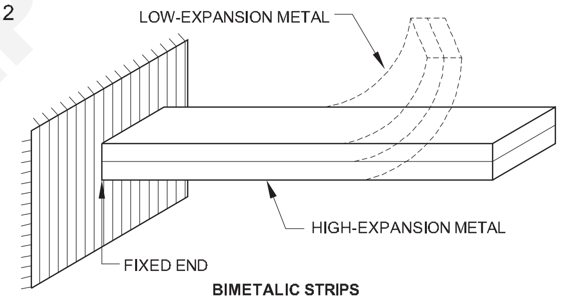
Bimetallic thermometer (Fig 1&2)

Fig 1



THERMOMETER WITH HELICAL BIMETALLIC ELEMENT

Fig 2



BIMETALIC STRIPS

Bimetal thermometer

Objectives: At the end of this lesson you shall be able to
- **explain the principle of bimetallic thermometer**
- **describe the types and uses of bimetallic thermometer.**

The expansion of two solid metals namely Brass and invar is utilised in type of instruments. Due to change in temperature brass expand quickly and the invar's expansion is negligible, thus making a change in position. The movement of the bimetallic strip is utilised to deflect a pointer over a calibrated scale. The deflection is small if the strip is short and is large if the strip is long. (Fig 2)

A longer strip can be obtained by making it as spiral; helix or multi- helix. The helical bimetallic element's one end is fixed at the bottom instrument body made of steel tube. At the other end a shaft is fixed which is free to move the guides. The pointer moves over the dial which is fitted with shaft which will rotate in the bearing of the instrument body. The instruments can work up to 540o C. the cost is low, easy to instal and maintain. They are tough and cannot be broken and have good accuracy. The main disadvantage is that they are limited to local mounting, only indicating available.

Bimetallic thermometers are inexpensive relatively rugged and easy to need. They are also reasonably accurate it handled carefully. They are available for the temperature range from -103 to 1004°F (-75 to 540°C).

Advantages: Following are the advantages of bimetallic thermometers:

i Their cost is low.

ii They are tough, and cannot easily be broken.

iii They have good accuracy relative to cost.

iv They have fairly wide temperature range.

Disadvantages: Following are the disadvantages of bimetallic thermometers:

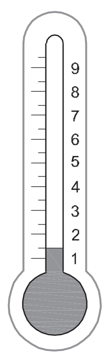
- i They are limited to local mounting.
- ii Only indicating type id available.
- iii There is always a possibility of calibration change due to rough handling.
- iv Their accuracy is not as high as glass stem thermometers.

Liquid in glass thermometer

The liquid-in-glass thermometer is one of the simplest temperature measuring device, widely used in both laboratory and industry. Its operation is based on the fact that liquid expand as the temperature rises. In this type of thermometer, the expansion causes the liquid to rise in the tube, indicating the temperature.

The simplest form of the liquid-in –glass thermometer is shown in Fig 1. It consists of a small-bore glass tube with a thin-wall glass bulb and part at its lower end. The liquid that fills the bulb and part of the tube is usually mercury. As heat is transferred trough the well and metal stem and into the mercury, the mercury, the mercury expands, pushing the column of mercury expands, pushing the column of mercury higher in the capillary above which indicates the temperature.

Fig 1



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LIQUID IN - GLASS THERMOMETER

The liquid- in- glass thermometer is commonly used for the temperature range of -18.4 to 608oF (-120 to 320°C).But when mercury is used as liquid , it freezes at -38.2 oF (-39°C). thus, for measuring very low temperatures, alcohol is used as liquid. For measuring high temperatures, the thermometers glass stem above the mercury can be charged with nitrogen at pressure of 30 to 300psi. This helps in preventing the mercury from evaporating or boiling. Even with the nitrogen, liquid-in-glass thermometers are usually limited to temperatures below 1100°F (600°C) temperature higher than 600°C can affect the glass and cause permanent changes in the accuracy of the instrument.

The liquid-in-glass thermometers have got certain disadvantages also. They are fragile and not easily adapted to automatic recording or transmission of temperature data. This limits their use in modern industries. They can be difficult to real also. In the mercury-in-glass thermometer, a large error may be introduced by changes in the size of the bulb due to ageing.

The industrial mercury-in –glass thermometer is used in applications such as open tanks containing liquids, cooking kettles, certain molten metal baths, steam lines, pipe lines for fluid flow, and air ducts. It should not be employed when rapidly fluctuating temperatures are to be measured with high accuracy.

Uses

1 Open tank

2 Cooking kettle

3 Molden metal boths

4 Stem line

5 Pipe line for fluid flow.

Disadvantages

1 Record method size in difficult to read

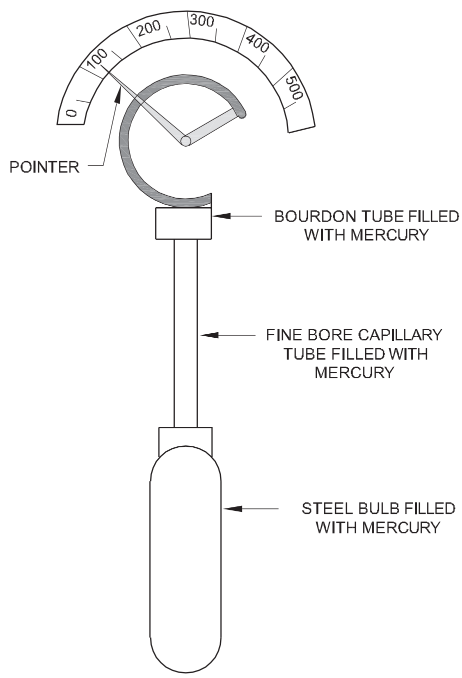
2 Even small change in blub capacity will cause more error.

3 Easily broken glass thermometer

Liquid -in- metal thermometer

The distinct disadvantages of liquid-in-glass thermometers are overcome in liquid-in- metal thermometers. A liquid-in-metal thermometer is shown in Fig 2 in which mercury has been used as liquid and the metal is steel. This mercury-in-steel thermometer works on exactly the same principle as the liquid-in – glass thermometer. The glass bulb is replaced by a steel bulb and the glass capillary tube by one of stainless steel. Mercury is used as liquid in the system. As mercury in the system is not visible, a bourdon tube, the bulb and the capillary tube are completely filled with mercury, usually at a higher pressure.

Fig 2



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MERCURY-IN-STEEL THERMOMETER

When the temperature to be measured rises, the mercury in the bulb expands more than the bulb so that some mercury is driven through the capillary tube into the bourdon tube. As the temperature continues to rise, increasing amounts of mercy will be driven into the bourdon tube, causing it to bend. One end of the bourdon tube is fixed, while the motion of the pointer which moves on a calibrated temperature scale.

The bourdon tube and thermometer bulb may have a variety of forms, depending upon the use to which they are put the thermometer bulb is also placed in a protective pocket where the gas or liquid whose temperature is being measured is at a pressure other than atmospheric in this case the pocket prevent the blub being subjected to this pressure and also enable the blub to be changed without shutting down the plant. The capillary tube used in the mercury-in-steel thermometer is usually made from stainless steel, as mercury will amalgamate with other metals. Changes of temperature affect the capillary and the mercury it contains, and hence the thermometer reading. But if the capillary tube of an appreciable length is used, it is necessary to compensate for the effects due to changes in the temperature in the neighborhood of the tube.

Generally, mercury is used as a liquid. But it has its limitations, particularly at the lower end of the temperature scale. For this and other reasons, other liquids are lower end of the temperature scale. For this and other reasons, other liquids-in- metal thermometers, with their usual temperature ranges, are given below in table 1

Table 1 Temperature ranges of liquid used in liquid-in-metal thermometers

Liquid	**Temperature range in °F**	**Equivalent scale in °C**
Mercury	- 38 to +1200	-39 to + 650
Xylene	- 40 to + 750	-40 to + 400
Alcohol	- 50 to + 300	- 46 to + 150
Either	+ 70 to + 195	+ 20 to + 90
Other organic liquids	-125 to + 500	- 87 to + 260

Gas thermometers

The operation of gas thermometers depends upon the Ideal Gas law which states that the volume of a gas increases with temperature, if the pressure is maintained constant; and the pressure increases with temperature, if the volume is maintained constant. Therefore, if a certain volume of inert gas is enclosed in a bulb, capillary and Bourdon tube, and most of the gas in the bulb, then the pressure indicated by the Bourdon tube may be calibrated in terms of the temperature of the bulb.

Nitrogen is the favourite fill for a gas-filled thermometer because it is almost inert and inexpensive. It does react somewhat with the steel bulb material at temperatures exceeding 427°C, and it does act less like a perfect gas at extremely low temperatures. Under these conditions helium should be used. Different ranges are obtained by selecting the correct filling pressure.

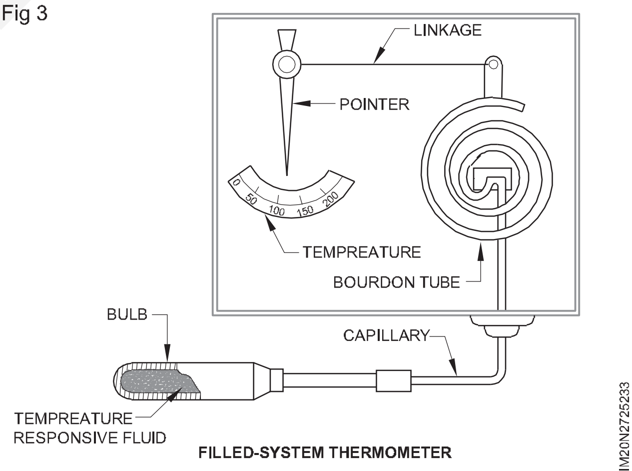
An advantage of the gas-filled thermometer is that the gas in the bulb has a low thermal capacity than a similar quantity of liquid, so that the response of the thermometer to temperature changes will be more rapid than that for a liquid-filled system with a bulb of the same size and shape.

Filled system termometers

Fig 3 shows basic components of a filled-system thermometer. It consists of a Bourdon tube, a capillary tube, and a thermometer bulb all interconnected as shown. The entire system is sealed after filling with an appropriate

Liquid (know as filling liquid) at a pressure at the normal ambient temperature the common liquid that are used are mercury ethyl alcohol xylene and toluene. when in the use the thermometer blub is installed inside. the substance to be measured. This causes the filling liquid inside the bulb to heat or cool until it temperature matches the temperature of the measured substance. This change in temperature causes the filling liquid to expand or contract and thus the Bourdon tube moves. With increase in temperature (heating) the liquid expands and this expansion forces the Bourdon tube to uncoil. With decrease in temperature (cooling) the liquid contracts and it forces the Bourdon tube to coil more tightly. The movement of the Bourdon tube may be used to drive a pointer for indicating temperature (Fig or to drive the pen on a strip-chart.

Fig 3



Basically, there are four types of filled system thermometers:

i Gas-filled thermometers (which is already described in this chapter as gas thermometer) Class-3

ii Liquid-filled thermometers - Class-1

iii Mercury-filled thermometers - Class-5

iv Vapour -pressure thermometers class-2

The advantages and disadvantages of filled system thermometers

Advantages

The advantages of filled-system thermometers are:

i They have a rugged construction.

ii They require low maintenance.

iii In filled-system thermometers there is no need for electric power since they are self-sufficient.

iv The point of display can be located at a considerable distance from the point of measurement.

v They possess satisfactory time response sensitivity and accuracy for most industrial applications.

vi Their cost is low.

vii They deliver enough power to drive not only a pointer or recording pen but also a controller mechanism.

viii Three (or more) separate systems can be put in a single instrument case.

ix The capillary allows considerable separation between the point of measurement and the point of temperature indication. Although the system length is limited to 75 m, applications up to 120 m are in successful operation. It is frequently more economical to employ transmitters for signal transmission beyond 30 m.

Disadvantages

The disadvantages of filled-system thermometers are:

i They need a large bulb for the sake of accuracy.

ii The entire system usually has to be replaced in case of failure.

iii Their accuracy, sensitivity, and temperature span is much lower compared to electrical temperature instruments.

iv Maximum spans are not as narrow as in the bimetallic thermometer or electrical systems.

v They have limited maximum temperature compared to some electrical measuring systems.

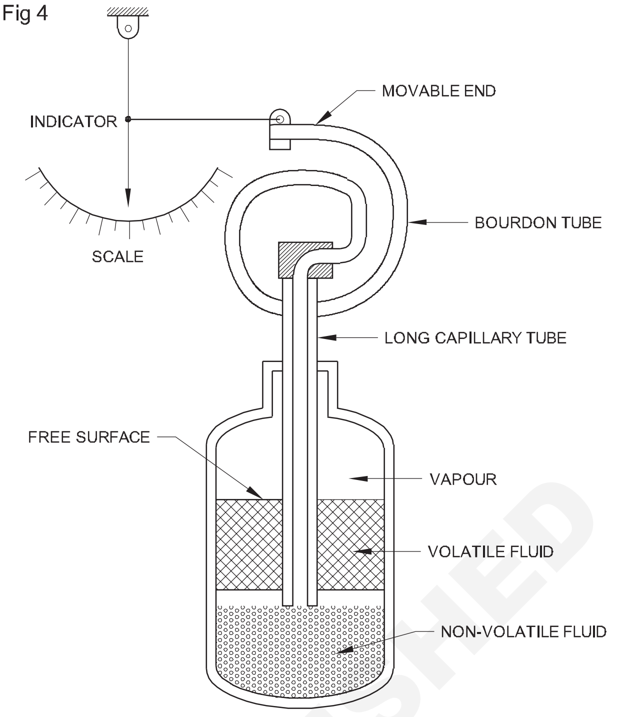
vi Thermal system, being under pressure, cannot be broken without destroying the calibration.

vii Separation of me measuring element and bourdon of more than 75m. Generally, is not recommended in these thermometers.

Vapour pressure thermometer

If consists of a partially filled bulb is used as the sensing element to measure the temperature when bulb senses the temperature vapour will be formed above the liquid will be formed above the liquid level inside bulb. (Fig 4)

Fig 4

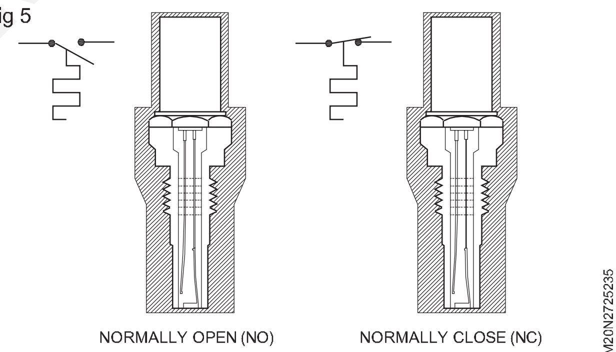


VAPOUR PRESSURE THERMOMETER

Thermo switch

A Mechanical device that is used to monitor and control the temperature in manufacturing and industrial processes by turning ON & OFF switch contacts once a fixed temperature range is reached is known as a temperature switch. This switch is a small and cost- effective solution to measure temperature. The temperature switch symbol is shown below. (Fig 5)

Fig 5

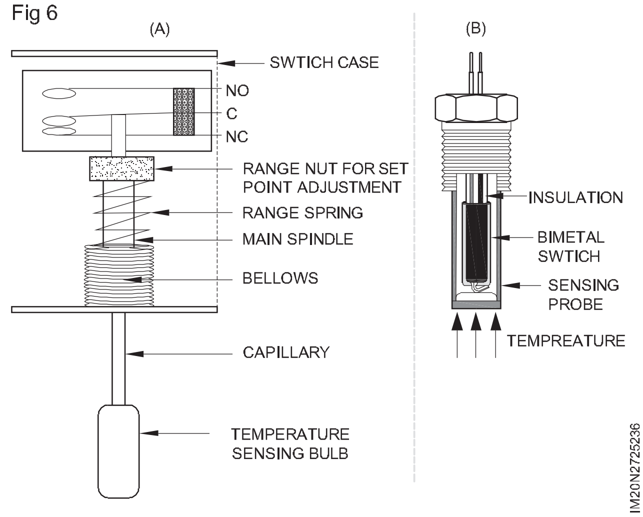


Thermo switch construction (Fig 6)

Construction (thermo switch)

The different components used in this switch mainly include switch case, range nut. range spring main spindle, bollows, capillary, and temperature sensing bulb. The construction diagram of the temperature switch is a shown in Fig 6 A & B.

Fig 6



Construction

As shown in the above diagram, the fluid within the temperature sensing bulb responds to variations in temperature. Once temperature increases, the pressure within the bellows increases. So the increase in the temperature sensing bulb will compress the bellows & moves the spindle up until the force of spring as well pressure of bellows are in equilibrium. The spindle movement is moved toward the switch & causes ON & OFF action based on the set point of the switch

Working Principle

The working of a temperature switch mainly depends on the variations of temperature taking place within an enclosed space The function of a temperature switch is to trigger when changes in temperature occur.

Once the sensing probe in this switch detects an increase in temperature, then it opens the electric contacts Similarly, if the switch detects a decrease in temperature then electrical contacts will be closed. So these variations In temperature can be used to activate a switching mechanis.

These switches are categorized into two types

1 Mechanical temperature switches

2 Electronics temperature switches.

Mechanical Temperature Switches

Mechanical temperature switches are available in two types bimetallic and liquid expansion temperature s which are used for measuring or detecting the change in temperature.

Bimetallic Temperature Switch

The bimetallic temperature switch or bimetallic thermometer uses the bimetallic strip, which is used to change the temperature into mechanical displacement Here, the bimetallic stop mainly uses the principle of metal expansion on heating. So when the temperature changes then the volume of metal will be changed Bimetallic The temperature coefficient of each and every metal is different, so it shows the main relationship between the change within the metal's.

Liquid Expansion Thermometer

The liquid filled temperature switch or liquid-filled expansion thermometer includes a brass bulb that is filled with a gas or chemical fluid it includes a fluid-filled bulb system. So at the thermometer bulb, a large amount of fluid is kept which has the maximum sensitivity. This enclosed fluid will expand once the bulb gets heated. So this liquid expansion will increase the fluid pressure within the bulb. The increase in fluid pressure will result in the activation of the pressure switch which is connected to the bulb.

Temperature Transmitter

Objectives: At the end of this exercise you shall be able to
- **explain temperature transmitter and its advantages and features**
- **explain construction, working and advantages and disadvantages of RTD**
- **explain RTD temperature transmitter**
- **explain protecting well of RTD**
- **explain thermistor**
- **explain signal conditioning arcuate of RTD and thermistor.**

Temperature transmitter

Temperature Transmitters on big installations or where a wide variety of different measurements are being made with a wide range of instrumentation, it is more usual to transfer the signal from the measurement point to the control area by means of temperature transmitters. This has the great advantage of allowing standardization of the readout equipment. Also in the case of electrical transmission (by say 4-20 mA signal), the measurement is much less liable to degradation from electrical interference. Also, the use of temperature transmitters allows the choice of measurement technique to be unencumbered by considerations of length of run to the readout location.

The choice of electrical or pneumatic transmission is usually dictated by over- all plant policy rather than the needs of particular measurement, in this case the temperature. However, where the requirement is for electrical temperature measurement for accuracy or other considerations the transmission will also need to be electrical

A temperature transmitter converts the thermocouple or RTD signal to a 4- 20 mA output signal and is the ideal solution for many remote temperature measurement applications. 4-20ma transmitters have definite advantages over conventional temperature measuring devices, but must be selected with caution in order to avoid “ground loop problems. (Fig1)

Use of temperature transmitters

In many cases, the temperature of a remote process must be monitored. Common temperature sensing devices such as thermocouples and RTD’s produce very small “signals.” These sensors can be connected to a two-wire transmitter that will amplify and condition the small signal. Once conditioned to a usable level, this signal can be transmitted through ordinary copper wire and used to drive other equipment such as meters, data loggers, chart recorders, computers or controllers.

Compact M12 RTD Transmitters (Fig 2)

This unique probe is ideal for areas with space limitations where traditional head connections are too large to fit. The M12 thread design offers a secure Industrial connection.

Fig 1

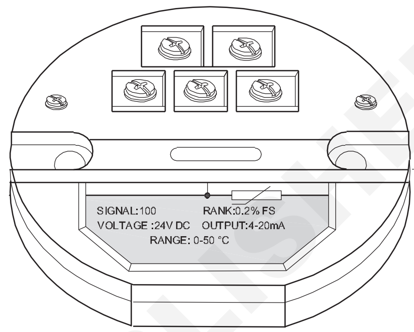
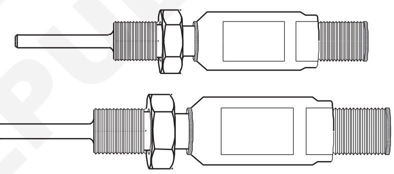


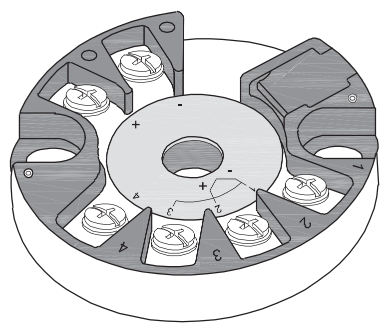
Fig 2



Smart Temperature Transmitters (Fig 3)

This smart head transmitter that accepts thermocouple temperature sensors and converts sensor output over a configured range to a standard industrial (4 to 20 mA) transmission signal.

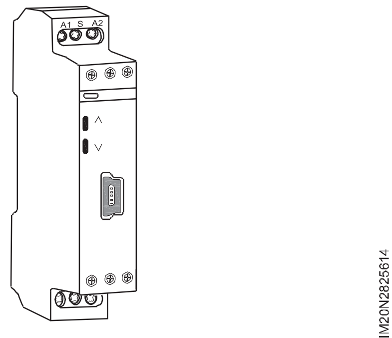
Fig 3



DIN Rail Temperature Transmitter (Fig 4)

The TXDIN1600 Series is a new generation DIN rail mounted temperature transmitter. It has been designed to accept most common process and temperature sensor inputs and provide the user with a standard two wire 4 to 20 mA output signal. Isolation is provided between input and output and all temperature ranges are linear to temperature.

Fig 4



Schematic circuit of a temperature transmitter (Fig 5)

As shown in Above Temperature Transmitter circuit, if we measure temperature using. Temperature sensor the following four activities and important.

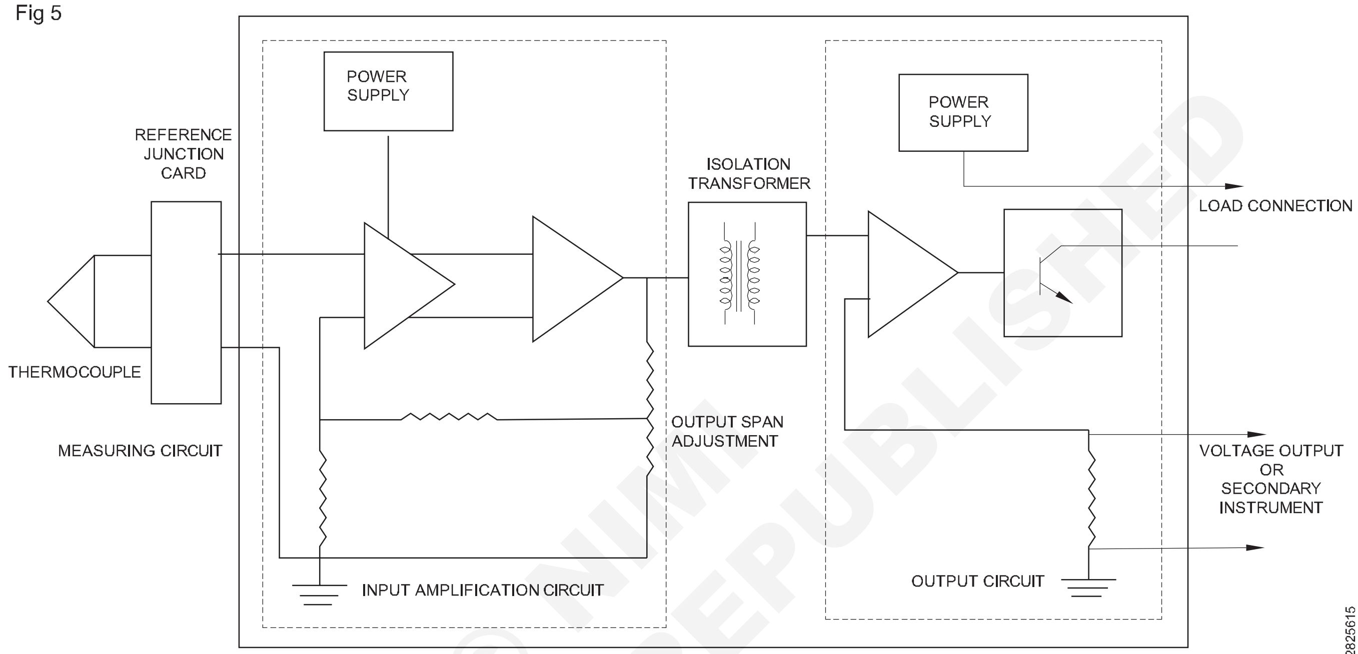
1 Amplification of sensor output

2 To transmit secondary instruments for displaying output

3 To be protect sensor from over range measurement

4 To control Circuit through feedback.

Fig 5



SCHEMATIC CIRCUIT OF A TEMOREATURE TRANSMITTER

Temperature Transmitter section

1 Measuring Circuit

2 Input amplification Circuit

3 Isolation Circuit

4 Output Circuit.

Measuring Circuit: In this circuit thermo couple is used as sensor.

Input amplification circuit: the output from measuring circuit is given to amplification circuit. sensor output is amplified by Amplifier and noise is removed by filter circuit. In this section span and Range adjustment are done.

Isolation circuit: To isolate output circuit and load circuit from measuring and amplification circuit Isolation Transformer Connected. This circuit protects load and output circuit from over range.

Output circuit: Signal from the output circuit is again amplified. In this section, transistor and thermistors Controlled circuits output circuit connected to load circuit and secondary instrument.

Working principle: The electrical output of temperature sensor is amplified by amplifier of Circuit and transmit to isolation transformer required Range is received, through span adjustment resister. The amplifier signal from transformer secondary is given to output circuit and again amplified here to give on off consist to load circuit through thyristor and transistor banned electronic circuit. Power is given the load circuits through switching circuit calibrated secondary instrument with Temperature is connected to measure the output.

Advantages of temperature transmitters

Transmitters offer numerous advantages over the more traditional ways o measuring temperature.

1 AC power is not needed at the remote location to operate a two wire transmitter.

Since transmitters are powered by a low level 4-20 mA output current signal, no additional power has to be supplied at the remote location In addition, the usual 24 Vdc signal necessary for operation is standard in plants that have large amounts of Instrumentation.

2 Electrical noise and signal degradation are not a problem for two-wire transmitter users.

The transmitter's current output signal lends itself to a high immunity when it comes to ambient electrical noise. Any noise that does appear in the output current is usually eliminated by the common-mode rejection of the receiving device. In addition, the current output sig will not change (diminish) with distance as most voltage signals do.

3 Wire costs drop significantly when using transmitters.

Low voltage signals produced by thermocouples almost always require the use of shielded cable when they are sent any significant distance. Ambient electrical noise from arcing electrical relays, motors and a power lines can raise havoc with these signals that are transmitted an unshielded cable. In addition, expensive, heavy gage wire is oft installed in applications that call for long cable runs (since it reduces errors from signal voltage drops caused by line resistance).

Features of the temperature transmitter

Transmitters provide a two-wire output with the same wiring used for power and output. The load resistance is connected in series with a dc power supply, and the current drawn from the supply is a 4-20 mA or output signal which is proportional to the input signal.

Two-wire transmission permits remote mounting of the transmitter near the sensor to minimize the effects of noise and signal degradation to which low level sensor outputs are susceptible.

A rugged metal enclosure, suitable for field mounting, offers environmental protection and screw terminal input and output connections. This enclosure may be either surface or standard relay track mounted.

Most temperature transmitters are linearized to the voltage signal produced by the thermocouple or RTD, although there are new models now available that are linearized to the actual temperature.

The temperature transmitters convert the thermocouple or RTD signal to a 4-20 mA output signal. Some models will convert to an RS-232C output. Transmitters are available with dip switch selection for several thermocouple types per model, as well as thermocouple and RTD selection on a single model. RTD or thermocouple transmitters are available in either isolating or non-isolating models, and they also feature output ranging adjustments with Zero and span adjustments over so to loo% of the sensor range.

Schematic circuit of a temperature transmitter

The advantages and disadvantages of filled system thermometers

Advantages: The advantages of filled-system thermometers are:

i They have a rugged construction.

ii They require low maintenance.

iii In filled-system thermometers there is no need for electric power since they are self-sufficient.

iv The point of display can be located at a considerable distance from the point of measurement.

v They possess satisfactory time response sensitivity and accuracy for most industrial applications.

vi Their cost is low.

vii They deliver enough power to drive not only a pointer or recording pen but also a controller mechanism.

viii Three (or more) separate systems can be put in a single instrument case.

ix The capillary allows considerable separation between the point of measurement and the point of temperature indication. Although the system length is limited to 75 m, applications up to 120 m are in successful operation. It is frequently more economical to employ transmitters for signal transmission beyond 30 m.

Disadvantages: The disadvantages of filled-system thermometers are:

i They need a large bulb for the sake of accuracy.

ii The entire system usually has to be replaced in case of failure.

iii Their accuracy, sensitivity, and temperature span is much lower compared to electrical temperature instruments.

iv Maximum spans are not as narrow as in the bimetallic thermometer or electrical systems.

v They have limited maximum temperature compared to some electrical measuring systems.

Electrical temperature instruments

There are three types of electrical temperature instruments which are generally used in industries.

i Resistance thermometer

ii Thermocouple

iii Thermistor

Resistance Thermometer

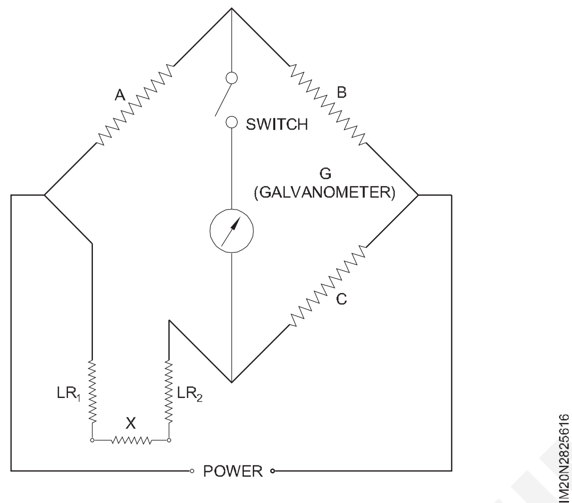
The resistance of certain metals changes with temperature change. Resistance thermometer utilizes this characteristic. With the increase of temperature, the electrical resistance of certain metals increases in direct proportion to the rise of temperature. Therefore, if the electrical resistance of a wire of known and calibrated material is measured, the temperature of the wire can be determined. Platinum, copper and nickel are generally used in resistance thermometers.

In this type of thermometer, a temperature sensitive resistance element is fabricated in a suitable form to insert in the medium whose temperature is to be measured, and is connected by leads to a whetstone bridge as shown in Fig 6. The bridge consists of a sensing element resistance X having high temperature coefficient and resistances A, B and C whose ohmic values do not alter with change of temperature. LR, and LR, are the lead wire resistances of the sensing element. The principle of wheat-stone bridge states that in balanced condition (when no current, flows through galvanometer), the ratio of resistances is given by:

$$\frac{A}{B} = \frac{\left(X + LR_1 + LR_2\right)}{C} \quad (13.4)$$

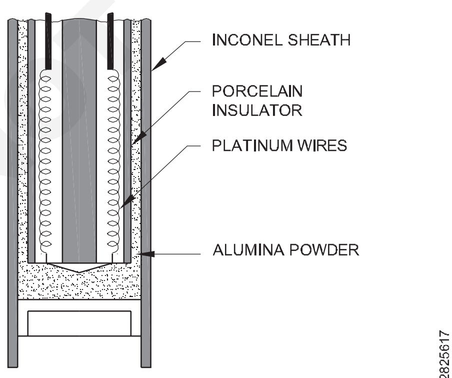
Now when resistance X changes, the wheat-stone bridge becomes un- balanced and thus galvanometer will give deflection which can be calibrated to give suitable temperature scale.

Fig 6



Resistance elements are generally long, spring like wires enclosed in a metal sheath. The construction of practical resistance thermometer is shown in Fig 7. The resistance element is surrounded by a porcelain insulator which prevents short circuit between wire and the metal sheath. Two leads are attached to each side of the platinum wire. When this instrument is placed in a liquid or a gas medium whose temperature is to be measured, the sheath quickly reaches the temperature of the medium. This change in temperature causes the platinum wire inside the sheath to heat or cool, resulting in a proportional change in the wire's resistance. This change in resistance can be directly calibrated to indicate the temperature.

Fig 7



A RESISTANCE THERMOMETER

The conductors used for resistance thermometer are platinum, nickel of various purities, 70 per cent nickel/30 per cent iron (Balco) and copper, listed in order of decreasing temperature range capability. These conductors are all avail- able as fine wire for sensor winding. Platinum is also available as a deposited film sensor, and nickel and Balco are available in foil-type sensors. A comparison chart of various resistance temperature detectors (RTD) or sensors, is given in Table 13.5.

Advantages: Following are the advantages of resistance thermometers

- i They possess high accuracy of measurement.
- ii They have a wide temperature range from -200 to 650°C.
- iii They are small in size.
- iv They are fast in response.
- v They have good reproducibility.
- vi They have shown stable and accurate performance over many years.

Disadvantages: Following are the disadvantages of resistance thermometers

- i Their cost is high.
- ii They need a bridge circuit, power supply.
- iii They show inaccuracy resulting from the current flowing through the bridge circuit and thereby heating the resistance element.
- iv They produce mechanical abuse o vibration.
- v They have larger bulb size than thermocouples.

RTD Bridge circuit

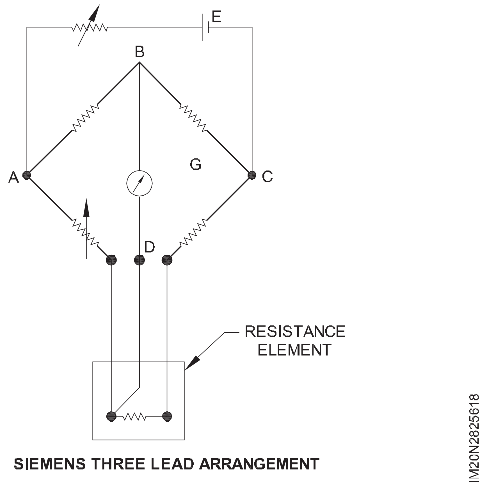
The self-heating produced in RTDs due to flow of current alters the temperature of the element. The importance one must assign to this effect depends upon the thermal communication between the RTD and the medium whose temperature is to be measured. For measurement of temperature of a block of metal the communication is good, while for an air temperature measurement the communication is poor. In still air the error due to self-heating is about 0.3°C per milliwatt.

One of the primary sources in the measurement of resistance of RTDs is the effect of leads which connect the resistance element of the thermometer to the bridge circuit. Several arrangements may be used to correct this effect. These are:

1 **Three Lead Arrangement:** Fig 3 shows the Siemen's three lead arrangement. This is simplest type of correction. At balance conditions the centre lead carrie's no current, and the effect of other He leads is cancelled out.

2 **Double Slide Wire Bridge:** A double slide wire bridge is shown in Fig 8. It has two slide wire resistors S_1, and S_2, which are tied together so that the fraction of S_1, in series with resistance R_2, is equal to fraction of S_2, in series with resistance R_2. This fraction is defined as f. There are three equal leads from the resistance element of thermometer to the bridge. The resistance of each lead is R_L

Fig 8



SIEMENS THREE LEAD ARRANGEMENT

∴ At balance we have:

$$\frac{R_t + R_L}{fS_2 + R_3 + R_L} = \frac{R_1 + S_1 - fS_1}{fS_1 + R_2 + S_2 - fS_2}$$

If the right hand side of the above expression is unity, the resistance of thermometer element is $R_t = f S_1 + R_3$. This relationship is independent of the resistance of leads.

The above condition is achieved when:

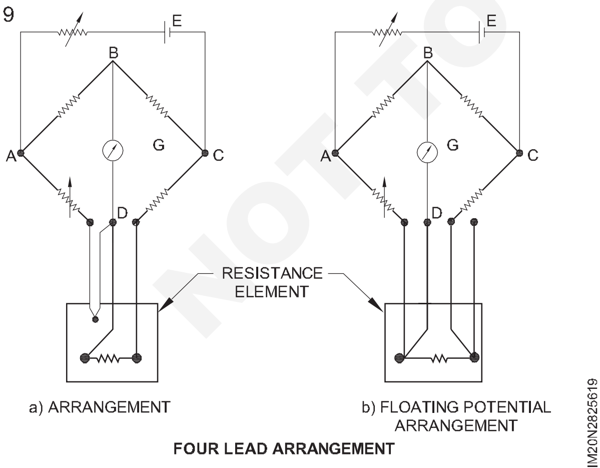
$$R_1 + S_1 - f S_1 = f S_1 + R_2 + S_2 - f S_2$$

This is an identity when: $R_1 - R_2 = S_1 = 0.5 S_2$

The bridge is designed using these values.

3 **Four Lead Arrangement:** The Callender four lead arrangement shown in Fig 9 solves the problem of lead resistances by inserting two lead wires in the adjustable arm of the bridge so that the effect of lead wires on the resistance thermometer is cancelled out. This arrangement is quite useful when thermometers are used in both AD and DC to provide an output proportional to temperature differential between the two thermometers.

Fig 9



FOUR LEAD ARRANGEMENT

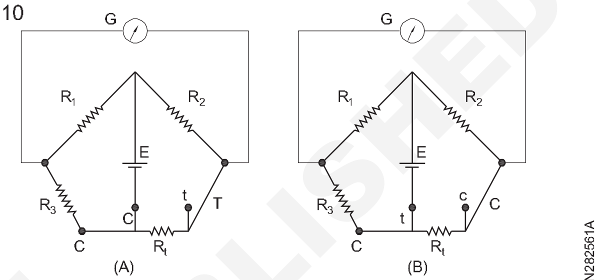
Four Lead Arrangement

The floating-potential arrangement in Fig. 8 the come as the Siemens' connection, but an extra lead is inserted. This extra lead may be used to check the equality of lead resistance. The thermometer reading may be taken in the position shown, followed by additional readings with the two right and left leads interchanged, respectively. Through this interchange procedure the best average reading may be obtained and the lead error minimized.

In applications, where the highest degree of accuracy is required, the four lead method is used. Such a system is used with a platinum resistance thermometer employed as a laboratory standard for calibration purposes. In this method, two circuit arrangements are used. They are shown in Fig 9. In fact, both the arrangements are required for measurement purposes. First a measurement is made using circuit of Fig 10a and then a second reading is taken by using circuit of Fig 10b. The average of the two readings is taken to give the correct result.

Four lead method for connection of resistance thermometer.

Fig 10



FOUR LEAD METHOD FOR CONNECTION OF RESISTANCE THERMOMETER

For circuit of Fig 10 (a), we have: $R_a + C = R_t + T$ …(i)

For circuit of Fig 10b, we have: $R_b + T = R_1 + C$ …(ii)

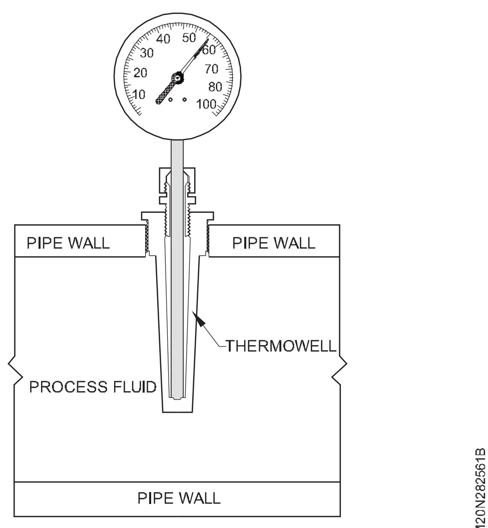
∴ From (i) and (ii) we get: $R_t\ (R_a + R_b)/2$

It is evident that this method should be used only when accuracy of the highest order is desired since the method is both time consuming and inconvenient.

It should be noted that two separate leads are connected directly to each end of the resistance winding. These are leads C and c on one side and T and r on the other side.

RTD protecting wells (Fig 11)

Fig 11



Protecting wells are available in stainless steel carbon street, Inconel or cast iron and they are used for temperature up to 1100°C.

It should be connected to the corresponding length of lead wire connected to RTD.

Resistance Temperature Detector

RTD (Resistance Temperature Detector) a metal which changes at electrical resistance when temperature changes.

The most common metal used for precision resistance measurements is platinum. platinum is chosen because it is noble metal which is stable, corrosion resistant, does not oxidize readily, and is easily workable into thin wire.

Copper also used as an RTD Because of its resistance value, RTD's copper are low in ohms Value and accurate measurements of the resistance when used as an RTD.

Because Copper wire changes resistance with Temperature and it is used to connect the RTD to the transmitter, lead length between the RTD and 2 wire transmitter must be taken into consideration.

RTD Sensor

Three versions of RTD's compensate for lead length between the RTD and the transmitter.

The signal from the RTD's is typically developed by having a constant current flow through the RTD and the voltage across the RTD is measured to determine the resistance of the RTD. (Figs 12&13)

Resistance = voltage / current.

Fig 12

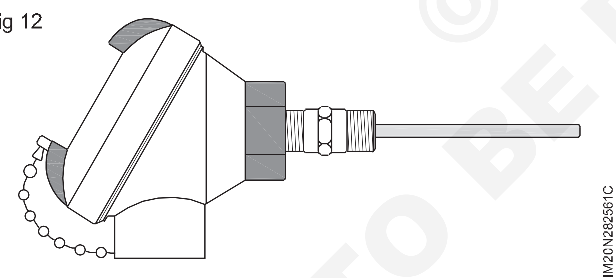
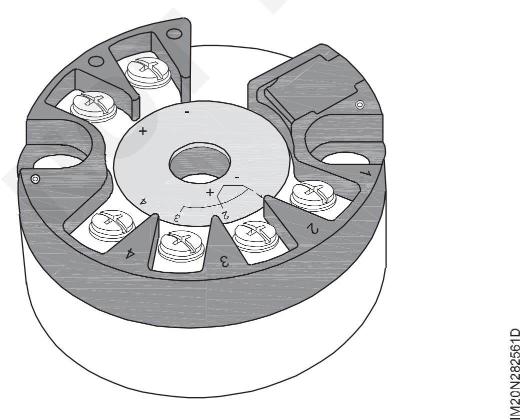


Fig 13



RTD temperature transmitters convert the RTD resistance measurement to a current signal, eliminating the problems inherent in RTD signal transmission via lead resistance Errors in RTD circuits (especially two and three wire RTDs) are often caused by the added resistance of the lead wire between the sensor and the instrument.

Transmitter input, specifications, user interfaces, features, sensor connections, and environment are all important parameters to consider when searching for RTD temperature transmitters.

Transmitter input specifications to take into consideration when selecting RTD temperature transmitters include reference materials, reference resistance, other inputs. and sensed temperature.

The transmitter is mounted on the Head of the temperature Sensor & converts it into a linear current loop signal of 4 to 20mA DC, capable of driving a load of up to 600 Ohms. The instrument operates in two-wire configuration.

2 wire RTD Transmitter

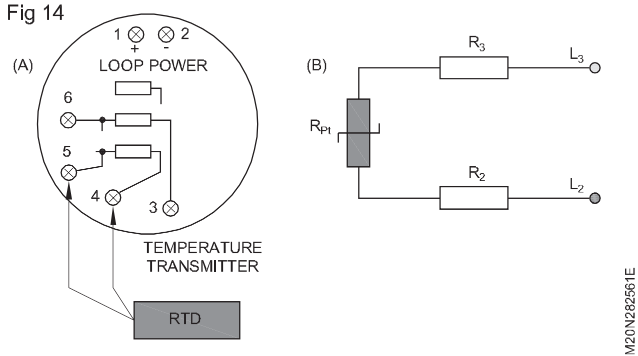
$R_{Pt}\ 100 = R_{pt} + R_2 + R_3$

- Rpt is Resistance of RTD
- R2 is Resistance of first lead wire (Extension cable used to connect RTD)
- R3 is Resistance of first lead wire (Extension cable used to connect RTD)

Note: L2 & L3 are extension cable leads

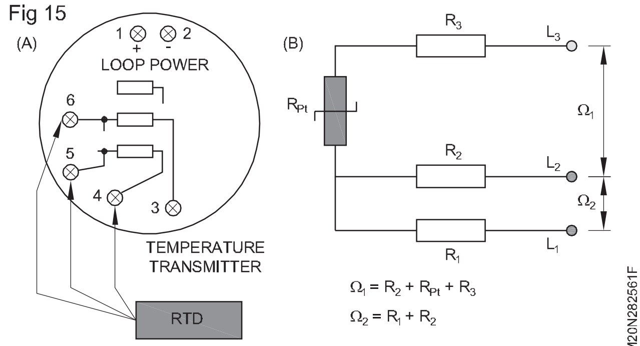
The wire resistances R2 and R3 are included in the measured value. Wire resistance can be cancelled by calibration, but just at one specific temperature of the wire (often room temperature). (Fig 14)

Fig 14



3 wire RTD Transmitter (Fig 15)

Fig 15



R_{Pt} 100 = $R_{pt} + R_2 + R_3$

- Rpt is Resistance of RTD
- R1 is Resistance of first lead wire (Extension cable used to connect RTD)
- R2 is Resistance of first lead wire (Extension cable used to connect RTD)
- R3 is Resistance of second lead wire (Extension cable used to connect RTD)
- L1, L2 & L3 are extension cable leads.
- Ω1 is the total resistance between lead wires L2 & L3
- Ω2 is the total resistance between lead wires L1 & L2

Note: If and only if the wire resistance R1 and R3 are equal you measure the true Pt100 resistance. Keep all the wire resistances R1, R2 and R3 equal.

Thermistors

(Fig 16) and (Fig 17) thermistor or thermal resistance means that the resistance changes with temperature

Fig 16

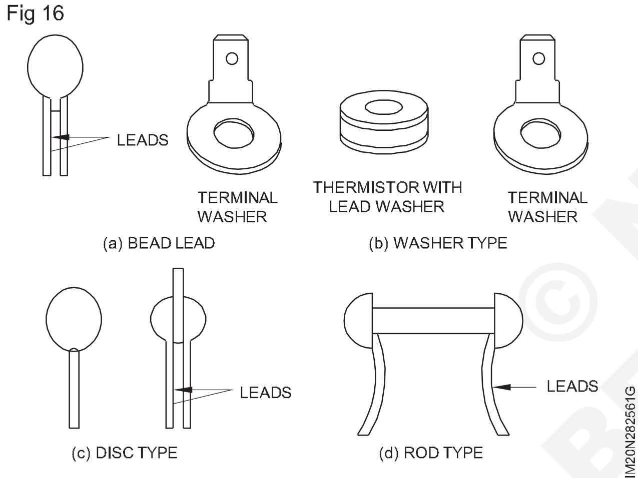
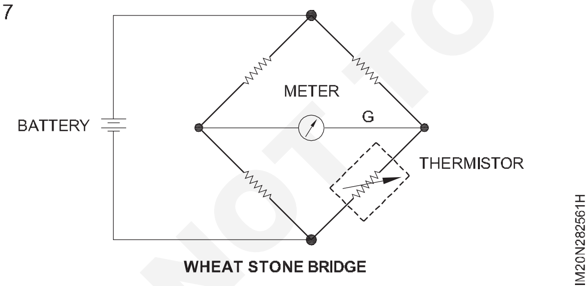


Fig 17



They are two types

1 Positive temperature coefficient thermistor (PTC)

2 Negative temperature coefficient thermistor (NTC)

PTC – thermistor

The temperature increases, The thermistor increases in resistance. This type of thermistor made barium, titanate, material.

MTC - Thermistor

Which resistance of thermistor decreases as the temperature increases. This type of Thermistor is made manasenese , Nickel, cobalt, iron, oxide ect.

Construction of thermistor

Thermistor made Iron, Nickle, Cobalt oxide ect. Thermistor different shapes and size available.

1 Bead type

2 Rod type

3 Probe type

4 Disc type

5 Washer type.

1 Beed thermistor

Small thermistor are Made in bead form. They grange Riven These are given 0-5mm to 25mm in diameter Flaps Coating provided.

2 Probe thermistor

Bead thermistor available glass coating. Provided they are called probe thermistor This 2-5mm in diameter. The glass probes are used to measure the temperature of fluid.

3 DISC thermistor

It is cylindrical flat in shape during. manufacturing thermistor material become flattens. when are pressed under high pressure. Thermistor are available diameter ranging from 2.5 mm. to 25mm to it is controlled the temperature

4 Washer type thermistor

This type of disc thermistor thermites. there is a hole in the middle. It is helpful to mount this hole thermistor on the bolt.

5 Rod type thermistor

This type of thermistor avail to length and cylindrical, from 10.5 to 50mm and diameter. These given high resistance even at low temperature

Temperature measurement using thermistor

A thermistor can be used to measure the temperature at a placed the thermistor should be placed at the place where the temperature. is to be measured. As Shown in picture a series circuit should be bettercy and melli ammelen.

The thermistor changes according to the Small change is temperature. As the resistance changes with temperature the current in the also changes. temperature can be measured directly by calibrating the micro meter against temperature

Thermo couple

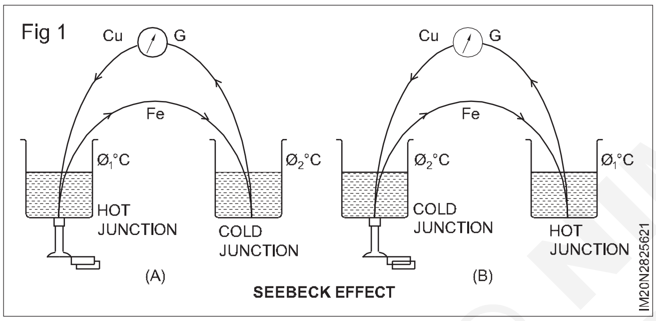
Objectives: At the end of this exercise you shall be able to
- **explain principle of thermos couple**
- **describe thermos couple and its advantages and disadvantages**
- **explain lead wire compensation in thermos couple**
- **explain signal conditioning circuit of thermos couple.**

Thermo couple

A thermo couple is an Electrical device consisting two dissimilar electrical conductor forming an A Thermocouple produces a temperature dependent voltage a result of the see back effect. and this voltage can be interpreted to measure temperature

Seebeck effect

The Seebeck effect Fig 1 occurs ends of a when the thermocouple are at different temperature, which result in electricity flowing from the hot metal to the cold metal to the cold metal in the Pelties effect temperature difference is Created the Junctions when Electrical between current flows across the terminals.

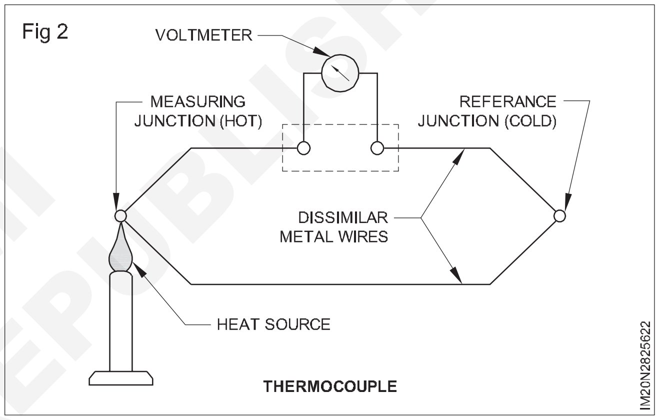


SEEBECK EFFECT

Thermocouples

The working principle of a thermocouple depends on the thermo-electric effect. two dissimilar metals are joined together so as to form a closed circuit, there will be two junctions where they meet each other. If one of these junctions is heated then, a current flows in the circuit which can be detected by a galvanometer, The amount of the current produced depends on the difference in temperature between the two junctions and on the characteristics of the two metals. This w first observed by Seebeck in 1821 and is known as Seebeck effect. Instrument which record the variations in current flow are calibrated in terms of temperature and are know as thermocouple pyrometer Fig 1 shown a thermo couple made from two different kind metal. The wires are joined at the ends which from two at Junction measuring Junction and a reference junction heating the measuring junction produces a voltage, greater then the voltage.

Across the reference junction. The difference between two voltages is measured and voltmeter reading is converted to its corresponding temperatures. This con- version table is generally supplied by the thermocouple manufacturers. There are various types of thermocouples which are used in industries, viz. copper constantan, iron constantan, chromel alumel, platinum rhodium and chromel-constantan. A practical thermocouple used in industries, is shown in Fig 2. It consists of a protective well and head across the measuring junction to avoid damages in pressurized systems or when measuring corrosive fluids. The measuring junction of the thermocouple is connected to the voltmeter and reference junction with extension wires. Extension wires are also known as compensating leads. The characteristics of compensating wire must be similar to those of the thermocouple wires it joins, otherwise, the voltage generated at the connections will be large enough to affect the instruments' accuracy. The voltmeter reads the difference between the measuring and reference junctions' voltages which can be calibrated to give temperature reading.



THERMOCOUPLE

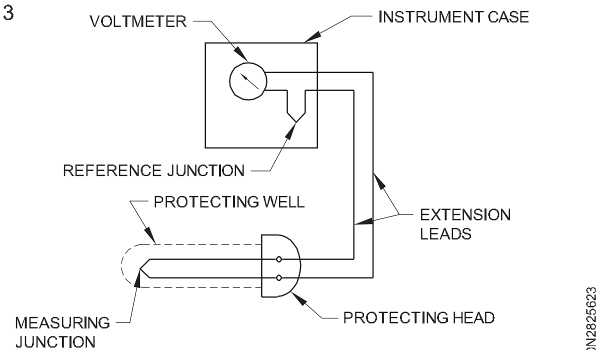
To protect thermocouples from harmful atmospheres, corrosive fluids, mechanical damage; to support the thermocouples or to permit entry into a pressurized system, protecting tubes or wells are supplied. These tend to reduce the speed of response of the thermocouple, so small-mass thin-wall or needle-type installations are supplied where feasible. Disposable-tip thermocouples are sup plied in furnace applications.

Thermocouples are not limited to single point measurement. They can be connected in parallel to provide the average temperature in a system. They can also be used to measure the difference between two temperatures. A single thermocouple can be utilized by two separate measuring instruments, with proper precautions.

Based on the possible combinations of metals, there are large numbers of thermocouples available.

An emf chart for various thermocouples with free ends at 0°C is given in the Fig 3. Thermocouple tables are given in Tables 13.7 and 13.8 for Iron-constantan thermocouple and platinum Vs. platinum plus 13% rhodium thermocouple respectively, for the calibration of the instruments. The thermocouple tables are based upon the reference junction temperature of 0°C, therefore, a direct conversion from the tables can be made only when an ice bath is used at the reference Junction.

Fig 3



A PRACTICAL THERMOCOUPLE

If it is not possible to maintain the reference junction temperature at 0°C, a correction factor must be applied to the millivolt values.

Advantages

1 They are inexpensive

2 They are simpler to use than resistance thermometer

3 There are need of a bridge circuit

4 They have extremely wide temperature range from -270 to 2800°C

5 They are good accuracy.

6 They are reproducibility

Disadvantages

1 They required much of an amplifier for many applications

2 They need expensive accessories for control application

3 They hold chances of stray voltage pickup.

4 Their temperature voltage relation nonlinear.

5 Temperature spans are not as narrow by filled System or resistance thermometer.

Lead Wire Compensation: In many applications it is desirable to place the reference junction at a point far removed from the measurement junction. The extension lead wires from the thermocouple leads to the meter are, therefore very long and are usually not at the same temperature throughout their length. This causes errors, which can be avoided by using extension lead wires made of the same materials as the thermocouple wires. T of the most commonly used thermocouples, iron-constantan and copper-constantan, normally use extension lead wires of the same material and therefore there are no errors caused by the use of these lead wires. However, the use of extension lead wires made of the same material as the thermocouples may not be possible in many cases due to cost and other considerations. Under these circumstances materials are chosen such that the relationship between emf and temperature is the same or almost the same as that for thermocouple wires. These wires are then called compensating leads.

Types of Thermocouples

Thermocouple Types

Two Dissimilar metals used to create a thermocouple can be of varied types.

Different metals exhibit different properties, and the hot junction formed between these two metal wires defines the thermocouple.

To yield better results, scientists and researches have standardized some metal combinations and segregated them as thermocouple types. Primarily there are eight types of thermocouples: E,J,N,K,R,T, and S type.

E – Type Thermocouple

Chromel and Constantan are the alloys that form an E-type thermocouple. The temperature range is between 0 to 870 °C. this thermocouple does not focus on the oxidation in the atmosphere and can be used in an inert environment.

J- Type Thermocouple

J type of thermocouple is formed with Iron and Constantan. 0 to 760 °C is its temperature range. Owing to the low-temperature range of the thermocouple, its life span reduces in high temperatures. J types thermocouple is best suited for vacuum and inert environment.

K – Type Thermocouple

Chromel and Alumel form a K-Type thermocouple. The temperature range is between 95 and 1260 °C. the neutral or oxidizing environment is best suited for these types of the thermocouple, it's the mst linear thermocouple.

R- Type Thermocouple

A combination of Platinum (13 % Rhodium) and Platinum forms R type thermocouple. The temperature range is between 870 to 1450 °C . it is costlier than S type thermocouple as it contains a higher percentage of Rhodium.

S – Type Thermocouple

It is a combination of Platinum (10 % Rhodium) and Platinum. The temperature range is between 980 to 1450 C. S type thermocouple is used in applications involving very high temperatures.

Type Thermocouple

It is formed with Copper and Constantan. The temperature range is between -200 to 370 °C. This type of thermocouple is suitable for the inert atmosphere as well as the vacuum. They are widely used as they generally resist decomposition even in a moist environment.

Advantages or benefits of the thermocouples

- Very wide temperature range abour -20 °C to + 250 °C
- Fast response time
- They are a simple construction
- Low initial cost

- Durable
- Easy to read has a clear screen and good scale
- Quick response for any temperature changes
- Precision accuracy in temperature measurement
- It is not easily broken good durability
- Good to be used temperature variation measurement with below 1 cm distance range
- Available in small sheath sizes
- Not required bridge circuit
- Good accuracy
- Does not required bridge circuit
- Good reproducibility
- Does not required bridge circuit
- Good reproducibility
- High – speed response
- They are rugged
- They are a self- power active device

Disadvantages of drawhack of the thermocouple

- Not as stable as RTD
- Recalibration is difficult
- More susceptible to RFI/EMI
- They are nonlinear
- It is used for only temperature measurement only
- They have a low output voltage
- Less sensitivity
- They require a reference for operation, since stray voltage pick up is possible
- As output voltage is very small so it needs amplification
- Decreased accuracy comparing to RTD
- Difficult to verify
- Require expensive TC wire from the sensor to recording device
- The cold junction and lead compensation is essential

RTD VS Thermocouple

Resistance temperature detector and thermocouple are both Temperature Measuring Instruments but are different in many ways.

A **Temperature measuring range:** The RTDs have a low measuring range, whereas thermocouples can be used for high temperature, such as up to 1800 °C.

B **Accuracy:** RTDs are known to have relatively higher accuracy than a thermocouple at lower temperatures.

C **Sensitivity:** RTDs are more sensitive and react faster to any temperature change than thermocouples due to the presence of cold junction compensation in thermocouples.

D **Drift:** The design of RTD sensor allows it to produce stable readings for a longer duration of time. RTD sensor drift is smaller when compared to Thermocouples.

E **Cost:** RTD sensors are more expensive than thermocouples , but installation and maintenance expenditure on thermocouples can make them more costly in the long term.

Temperature range of different thermocouple

Thermocouple Type	**Temperature range (°C)**				
	Short term use	**Continuous use**	**Class 1 Tolerance**	**Class 2 Tolerance**	**Class 3 Tolerance**
Type E	-40 to 900	0 to 800	-40 to 800	-40 to 900	-40 to 904
Type J	-180 to 800	0 to 750	-40 to 750	-40 to 750	N/A
Type K	-180 to 1300	0 to 1100	-40 to 1000	-40 to 1200	-180 to 1300
Type M	-270 to 1300	0 to 1100	-40 to 1000	-40 to 1200	-270 to 1304
Type R	-50 to 1700	0 to 1600	0 to 1600	0 to 1600	N/A
Type S	-50 to 1750	0 to 1600	0 to 1600	0 to 1600	N/A
Type T	-250 to 400	- 185 to 300	-40 to 350	-40 to 350	-250 to 404
Type B	0 to 1820	200 to 1700	N/A	600 to 1700	4 to 1820

Temperature VS Resistance Table Resistance @ 0°C

Temperature Range

-320 to 1562°F

-200 to 850°C

Accuracy:

Grade A Tolerance = ±[0.13+0.0017*|t|] °C

Grade B tolerance = ±[0.25+ 0.0042 *|t|] °C

Recommended Applications:

Where higher accuracy is needed in general purpose and industrial application.

Temp	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
-200	18.520									
-190	22.826	22.397	21.967	21.538	21.108	20.677	20.247	19.815	19.384	18.952
-180	27.096	26.671	26.245	25.819	25.392	24.965	24.538	24.110	23.682	23.254
-170	31.335	30.913	30.490	30.067	29.643	29.220	28.796	28.371	27.947	27.522
-160	35.543	35.124	34.704	34.284	33.864	33.443	33.022	32.601	32.179	31.757
-150	39.723	39.306	38.889	38.472	38.055	37.637	37.219	36.800	36.382	35.963
-140	43.876	43.462	43.048	42.633	42.218	41.803	41.388	40.972	40.556	40.140
-130	48.005	47.593	47.181	46.769	46.356	45.944	45.531	45.118	44.704	44.290
-120	52.110	51.700	51.291	50.881	50.471	50.060	49.650	49.239	48.828	48.416
-110	56.193	55.786	55.378	54.970	54.562	54.154	53.746	53.337	52.928	52.519
-100	60.256	59.850	59.445	59.039	58.633	58.227	57.821	57.414	57.007	56.600
-90	64.300	63.896	63.492	63.088	62.684	62.280	61.876	61.471	61.066	60.661
-80	68.325	67.924	67.522	67.120	66.717	66.315	65.912	65.509	65.106	64.703
-70	72.335	71.934	71.534	71.134	70.733	70.332	69.931	69.530	69.129	68.727
-60	76.328	75.929	75.530	75.132	74.732	74.333	73.934	73.534	73.134	72.735
-50	80.306	79.909	79.512	79.114	78.717	78.319	77.921	77.523	77.125	76.726
-40	84.271	83.875	83.479	83.083	82.687	82.290	81.894	81.497	81.100	80.703
-30	88.222	87.827	87.433	87.038	86.643	86.248	85.853	85.457	85.062	84.666
-20	92.160	91.767	91.373	90.980	90.586	90.192	89.799	89.404	89.010	88.616
-10	96.086	95.694	95.302	94.909	94.517	94.124	93.732	93.339	92.946	92.553
0	100.000	99.609	99.218	98.827	98.436	98.044	97.653	97.261	96.870	96.478
Temp	0	1	2	3	4	5	6	7	8	9
0	100.000	100.391	100.781	101.172	101.562	101.953	102.343	102.733	103.123	103.513
10	103.903	104.292	104.682	105.071	105.460	105.849	106.238	106.627	107.016	107.405
20	107.794	108.182	108.570	108.959	109.347	109.735	110.123	110.510	110.898	111.286
30	111.673	112.060	112.447	112.835	113.221	113.608	113.995	114.382	114.768	115.155
40	115.541	115.927	116.313	116.699	117.085	117.470	117.856	118.241	118.627	119.012
50	119.397	119.782	120.167	120.552	120.936	121.321	121.705	122.090	122.474	122.858
60	123.242	123.626	124.009	124.393	124.777	125.160	125.543	125.926	126.309	126.692
70	127.075	127.458	127.840	128.223	128.605	128.987	129.370	129.752	130.133	130.515
80	130.897	131.278	131.660	132.041	132.422	132.803	133.184	133.565	133.946	134.326
90	134.707	135.087	135.468	135.848	136.228	136.608	136.987	137.367	137.747	138.126
100	138.505	138.885	139.264	139.643	140.022	140.400	140.779	141.158	141.536	141.914
110	142.293	142.671	143.049	143.426	143.804	144.182	144.559	144.937	145.314	145.691
120	146.068	146.445	146.822	147.198	147.575	147.951	148.328	148.704	149.080	149.456
130	149.832	150.208	150.583	150.959	151.334	151.710	152.085	152.460	152.835	153.210
140	153.584	153.959	154.333	154.708	155.082	155.456	155.830	156.204	156.578	156.952

150	157.325	157.699	158.072	158.445	158.818	159.191	159.564	159.937	160.309	160.682
160	161.054	161.427	161.799	162.171	162.543	162.915	163.286	163.658	164.030	164.401
170	164.772	165.143	165.514	165.885	166.256	166.627	166.997	167.368	167.738	168.108
180	168.478	168.848	169.218	169.588	169.958	170.327	170.696	171.066	171.435	171.804
190	172.173	172.542	172.910	173.279	173.648	174.016	174.384	174.752	175.120	175.488
200	175.856	176.224	176.591	176.959	177.326	177.693	178.060	178.427	178.794	179.161
210	179.528	179.894	180.260	180.627	180.993	181.359	181.725	182.091	182.456	182.822
220	183.188	183.553	183.918	184.283	184.648	185.013	185.378	185.743	186.107	186.472
230	186.836	187.200	187.564	187.928	188.292	188.656	189.019	189.383	189.746	190.110
240	190.473	190.836	191.199	191.562	191.924	192.287	192.649	193.012	193.374	193.736
250	194.098	194.460	194.822	195.183	195.545	195.906	196.268	196.629	196.990	197.351
260	197.712	198.073	198.433	198.794	199.154	199.514	199.875	200.235	200.595	200.954
270	201.314	201.674	202.033	202.393	202.752	203.111	203.470	203.829	204.188	204.546
280	204.905	205.263	205.622	205.980	206.338	206.696	207.054	207.411	207.769	208.127
290	208.484	208.841	209.198	209.555	209.912	210.269	210.626	210.982	211.339	211.695
300	212.052	212.408	212.764	213.120	213.475	213.831	214.187	214.542	214.897	215.252
310	215.608	215.962	216.317	216.672	217.027	217.381	217.736	218.090	218.444	218.798
320	219.152	219.506	219.860	220.213	220.567	220.920	221.273	221.626	221.979	222.332
330	222.685	223.038	223.390	223.743	224.095	224.447	224.799	225.151	225.503	225.855
340	226.206	226.558	226.909	227.260	227.612	227.963	228.314	228.664	229.015	229.366
350	229.716	230.066	230.417	230.767	231.117	231.467	231.816	232.166	232.516	232.865
360	233.214	233.564	233.913	234.262	234.610	234.959	235.308	235.656	236.005	236.353
370	236.701	237.049	237.397	237.745	238.093	238.440	238.788	239.135	239.482	239.829
380	240.176	240.523	240.870	241.217	241.563	241.910	242.256	242.602	242.948	243.294
390	243.640	243.986	244.331	244.677	245.022	245.367	245.713	246.058	246.403	246.747
400	247.092	247.437	247.781	248.125	248.470	248.814	249.158	249.502	249.845	250.189
410	250.533	250.876	251.219	251.562	251.906	252.248	252.591	252.934	253.277	253.619
420	253.962	254.304	254.646	254.988	255.330	255.672	256.013	256.355	256.696	257.038
430	257.379	257.720	258.061	258.402	258.743	259.083	259.424	259.764	260.105	260.445
440	260.785	261.125	261.465	261.804	262.144	262.483	262.823	263.162	263.501	263.840
450	264.179	264.518	264.857	265.195	265.534	265.872	266.210	266.548	266.886	267.224
460	267.562	267.900	268.237	268.574	268.912	269.249	269.586	269.923	270.260	270.597
470	270.933	271.270	271.606	271.942	272.278	272.614	272.950	273.286	273.622	273.957
480	274.293	274.628	274.963	275.298	275.633	275.968	276.303	276.638	276.972	277.307
490	277.641	277.975	278.309	278.643	278.977	279.311	279.644	279.978	280.311	280.644
500	280.978	281.311	281.643	281.976	282.309	282.641	282.974	283.306	283.638	283.971
510	284.303	284.634	284.966	285.298	285.629	285.961	286.292	286.623	286.954	287.285
520	287.616	287.947	288.277	288.608	288.938	289.268	289.599	289.929	290.258	290.588
530	290.918	291.247	291.577	291.906	292.235	292.565	292.894	293.222	293.551	293.880
540	294.208	294.537	294.865	295.193	295.521	295.849	296.177	296.505	296.832	297.160
550	297.487	297.814	298.142	298.469	298.795	299.122	299.449	299.775	300.102	300.428
560	300.754	301.080	301.406	301.732	302.058	302.384	302.709	303.035	303.360	303.685
570	304.010	304.335	304.660	304.985	305.309	305.634	305.958	306.282	306.606	306.930
580	307.254	307.578	307.902	308.225	308.549	308.872	309.195	309.518	309.841	310.164

590	310.487	310.810	311.132	311.454	311.777	312.099	312.421	312.743	313.065	313.386
600	313.708	314.029	314.351	314.672	314.993	315.314	315.635	315.956	316.277	316.597
610	316.918	317.238	317.558	317.878	318.198	318.518	318.838	319.157	319.477	319.796
620	320.115	320.435	320.754	321.073	321.391	321.710	322.029	322.347	322.666	322.984
630	323.302	323.620	323.938	324.256	324.573	324.891	325.208	325.526	325.843	326.160
640	326.477	326.794	327.110	327.427	327.744	328.060	328.376	328.692	329.008	329.324
650	329.640	329.956	330.271	330.587	330.902	331.217	331.533	331.848	332.162	332.477
660	332.792	333.106	333.421	333.735	334.049	334.363	334.677	334.991	335.305	335.619
670	335.932	336.246	336.559	336.872	337.185	337.498	337.811	338.123	338.436	338.748
680	339.061	339.373	339.685	339.997	340.309	340.621	340.932	341.244	341.555	341.867
690	342.178	342.489	342.800	343.111	343.422	343.732	344.043	344.353	344.663	344.973
700	345.284	345.593	345.903	346.213	346.522	346.832	347.141	347.451	347.760	348.069
710	348.378	348.686	348.995	349.303	349.612	349.920	350.228	350.536	350.844	351.152
720	351.460	351.768	352.075	352.382	352.690	352.997	353.304	353.611	353.918	354.224
730	354.531	354.837	355.144	355.450	355.756	356.062	356.368	356.674	356.979	357.285
740	357.590	357.896	358.201	358.506	358.811	359.116	359.420	359.725	360.029	360.334
750	360.638	360.942	361.246	361.550	361.854	362.158	362.461	362.765	363.068	363.371
760	363.674	363.977	364.280	364.583	364.886	365.188	365.491	365.793	366.095	366.397
770	366.699	367.001	367.303	367.604	367.906	368.207	368.508	368.810	369.111	369.412
780	369.712	370.013	370.314	370.614	370.914	371.215	371.515	371.815	372.115	372.414
790	372.714	373.013	373.313	373.612	373.911	374.210	374.509	374.808	375.107	375.406
800	375.704	376.002	376.301	376.599	376.897	377.195	377.493	377.790	378.088	378.385
810	378.683	378.980	379.277	379.574	379.871	380.167	380.464	380.761	381.057	381.353
820	381.649	381.946	382.242	382.537	382.833	383.129	383.424	383.720	384.015	384.310
830	384.605	384.900	385.195	385.489	385.784	386.078	386.373	386.667	386.961	387.255
840	387.549	387.843	388.136	388.430	388.723	389.016	389.310	389.603	389.896	390.188
850	390.481									

Application of different types of themocouples

Ansi coded material specifications

Type code	Positive LEG	Negative Leg	Recommended temp range F (C) of Prot TC	Application information
J	Iron Theromkanthal JP	Constantan Cupron Advance Thermocouple	32 to 1400 (0 to 760)	Suitable for vacuum reducing or inert atmosphere oxidizing atmosphere with reduced life iron oxidizes rapidly above 1000F (538 C) so only heavy gauge wire is recommended for high temperature. Bare elements should not be exposed to sulphurous atmosphere above 1000 F (538 C).
K	Chromel Tophal T1 Thermokanthal KP	Alumal Nial T2 Thermokanthal KN	32 to 2300 (0 to 1260)	Recommended for continuous oxidizing or neutral atmospheres. Mostly used above 1000f (538c.) subject to failure if exposed to sulphur. Preferential oxidation of chromium in positive leg at certain low oxygen concentrations causes green rot and large negative calibration drifts most serious

Type code	Positive LEG	Negative Leg	Recommended temp range F (C) of Prot TC	Application information
				in the 1500 – 1900 f range (816 – 1038 c). ventilations or inert – sealing of the protection tube can prevent this.
T	Copper	Constantan Cupron Advance	-300 to +700 (-184 to +371)	Useable in oxidizing, reducing, or inert atmosphere as well as vacuum. Not subject to corrosion in moist atmosphere limits or error published for sub-zero temperature ranges.
E	Chromel Tophel T1 Thermokanthal KP	Constantan Cupron Advance Thermokanthal JN	32 to 1600 (0 to 871)	Recommended for continuously oxidizing or inert atmospheres. Sub –zero limits error not established. Highest thermoelectric output of common calibrations.
R S	Platinum 13% Rhodium Platinum 10%Rhodium	Platinum Platinum	1000 to 2700 (538 to 1482)	Recommended for high temperature. Must be protected with non-metallic protection tube and ceramic insulators. Continued high temperature usages causes grain growth which can lead to mechanical failure. Negative calibration drift caused by rhodium diffusion to pure leg as well as from rhodium volatilization. Type R R is used in industry: type S in the laboratory.
B	Platinum 30% Rhodium	Platinum 6% Rhodium	1600 to 3100 (871 to 1705)	Same as R & S but output is lower. Also less susceptible to grain growth and drift.
N	Nicrosil 14.5% chrominum 1.4% Silicon 1% Magnesium	Nisil 4.2 % silicon 1% Magnesium Balance Nickel	32 to 2300 (0 to 1260)	Can be used in applications where type K elements have shorter life and stability problems due to oxidation and the development of green rot.

Comparison between thermocouple, RTD and Thermistor

	Thermocouple	RTD	Thermistor	Silcon
Temperature Range	-270 to 1800°C	-250 to 900°C	-100 to 450°C	-55 to 150°C
Sensitivity	10 of µV/°C	0.00358 Ω/ Ω °C (platinum)	Several Ω/ Ω°C	Based on a technology that is -2mV/°C sensitive
Accuracy	± 0.5°C	±0.01°C	±0.1°C	±.15°C
Linearity	Requires at least a 4th order polynomial (for curve –fitting) or equivalent lookup table.	Requires at least a 2nd order, polynomial (for curve –fitting) or equivalent lookup table.	Requires at least 3rd polynomials for curve fitting or equivalent look up table can also be linear zed to 10 bit accuracy over a 50° C temperature range.	At best within ±1°C. No linearization required.
Ruggedness	The larger gauge wires of the thermocouple make this sensor more rugged. Additionally,	RTDs are susceptible to damage as a result of vibration. This is due to the fact that	The most stable, hermetic thermistors are enclosed in glass, generally, thermistors	At rugged as any other IC in a similar plastic package

	Thermocouple	RTD	Thermistor	Silcon
	the insulation materials that are used enhance the thermocouples sturdiness.	they typically have 26 to 30 AWG leads which are prone to breakage.	are harder to handle, but not affected by shock or vibration.	
Excitation	None required	Current source	Voltage source	Typically: supply voltage
Output type	Voltage	Resistance	Resistance	Typically: supply voltage
Typical size	Bead diameter =5* wire diameter	0.25*0.25 in.	0.1*0.1in.	0.88mm X0.88mm 4 – bump WLCSP*to Plastic Dtp Packages

Comparison between thermocouple and RTD

Comparison chart of RTD Sensors and thermocouples		
Criteria	**RTD Sensor (Pt100)**	**Thermocouple**
Measurement range (max)	-200 to +850°C	-200 to +2600°C
Measurement range (typical)	-50 to 300 (Pt100 B)	0 to 1100°C (type K)
Long term stability	Good	Poor
Accuracy	Good	Poor
Repeatability	Good	Poor
Interchange ability	Excellent	Good
Tip sensitivity	Poor	Good
Signal strength	Higher – more resistant to EMI	Low – susceptible to EMI
Excitation	Yes	No
Cost	More expensive	Less expensive
Noise problems	No	Some
Extension cable	No	Yes – Must match Th/c
Best for	Consistent readings	High temperatures
Worst for	Surface readings	Long term stability
Hysteresis	Good	Excellent
Self-heating	Yes	No

Signal conditioning circuit for themocouple

Temperature Signal Conditioners

Types of Signal Conditioners According to Physical Value Measurement

A temperature signal conditioner is compatible with sensors that measure temperature or variations in temperature. Temperature signal conditioners are used to amplify the analog signals produced by temperature sensors, to filter out noise, and to push the signals forward for further analysis and display.

Thermocouples

Thermocouples are commonly used in many industrial application processes, Usually, thermocouple output is within the range of 80 mV. With such low output voltage, it is difficult for process monitoring and control devices to record and display the raw analog signal. Temperature signal conditioners amplify these signals.

In addition to amplification, signal conditioning is also necessary for cold junction compensation when processing the analog signal produced by a thermocouple. When a thermocouple is connected to an instrument for temperature measurement, the material difference generates a voltage at junctions known as “cold junctions” – which affects the actual output of the thermocouple, giving out erroneous results. Temperature signal conditioners compensate for such variations.

Temperature signal conditioners also perform linearization on the analog signal – so that the output voltage of a thermocouple is linear with temperature.

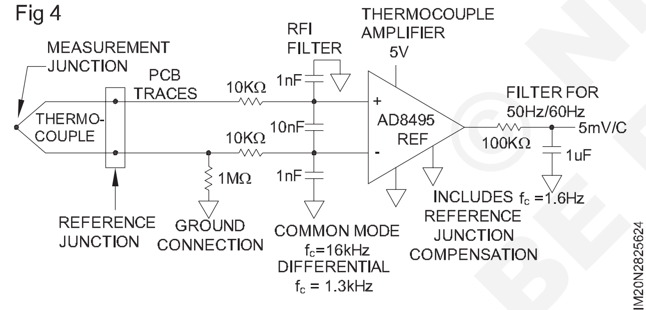
Thermistors

A thermistor is another commonly used temperature sensor in a variety of industrial applications. Thermistors are active temperature sensors – and as such, require current and voltage excitation. The stability and accuracy of the excitation signal directly affects the stability and accuracy of the sensor. Temperature signal conditioners also provide amplification and low pass filtering thermistors- performing these operations to modify signals so that they can be easily read by the digital devices of the data acquisition system.

RTDs

Resistance temperature Devices, or RTDs, are temperature sensors that use variation in resistance to calculate temperature. RTDs, like thermistors, require excitation voltage, amplification, and filtering – all of which can be performed by a temperature signal conditioner. RTD signal conditioning also eliminates unwanted signals from line resistance, non-linearity, and self – healing.

Fig 4



Reference junction compensation: The temperature of the thermocouple’s reference junction must be known to get an accurate absolute – temperature reading. When thermocouples were first used, this was done by keeping the reference junction in an ice bath. Depicts a thermocouple circuit with one end at an unknown temperature and the other end in an ice bath (0°C). This method was used to exhaustively characterize the various thermocouple types, thus almost all thermocouple tables use 0 C as the reference temperature.

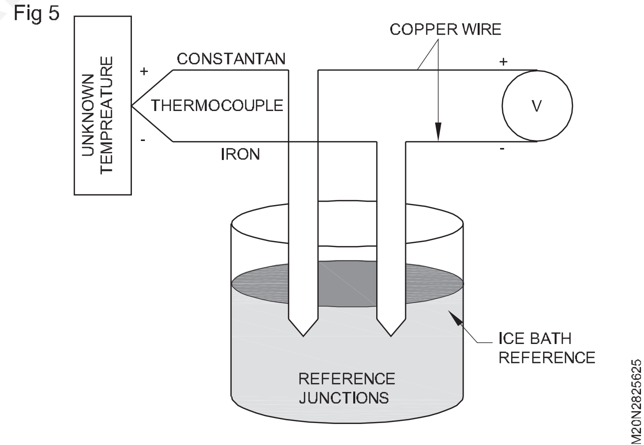
Basic iron - constantan thermocouple circuit.

But keeping the reference junction of the thermocouple in an ice bath is not practical for most measurement systems. Instead most systems use a technique called reference junction compensation, (also known as cold-junction compensation). The reference junction temperature is measured with another temperature sensitive device-typically an Ic , thermistor , diode, or RTD (resistance temperature detector). The thermocouple voltage reading is then compensated to reflect the reference junction temperature. It is important that the reference junction be read as accurately as possible – with an accurate temperature sensor kept at the same temperature as the reference junction. Any error in reading the reference junction temperature will show up directly in the final thermocouple reading.

Practical thermocouple solutions: Thermocouple signal conditioning is more complex than that of other temperature measurement systems. The time required for the design and debugging of the signal conditioning can increase a product’s time to market. Errors in the signal conditioning, especially in the reference junction compensation section, can lead to lower accuracy. The following two solutions address these concerns.

The first details a simple analog integrated hardware solution combining direct thermocouple measurement with reference junction compensation using a single IC. The second solution details a software-based reference junction compensation scheme providing improved accuracy for the thermocouple measurement and the flexibility to use many types of thermocouples.

Fig 5



Types of pyrometers

Objectives: At the end of this exercise you shall be able to
- **define pyrometer**
- **explain radiation pyrometer**
- **explain optical pyrometer.**

Pyrometers

All the temperature-measuring methods discussed earlier require physical contact of thermometer with the body whose temperature is to be measured. At high temperatures (above 1400°C), the thermometer may melt due to direct physical contact. To solve these problems a non-contact method of temperature sensing is used. Also, for bodies that are moving, a non-contacting means of temperature sensing is most convenient.

Pyrometry is a technique for measuring temperature without physical contact. It depends upon the relationship between the temperature of a hot body and the electromagnetic radiation emitted by the body, when a body is heated, it emits thermal energy known as heat radiation. (A black matt surface or a black body) is very good absorber of heat radiations and, also, a very good absorber of heat radiations and, also, a very good emitter of such radiations when heated. Phrometry is a technique for determining a body's temperature by measuring its electromagnetic radiation. There are two types of pyrometers generally used in industries:

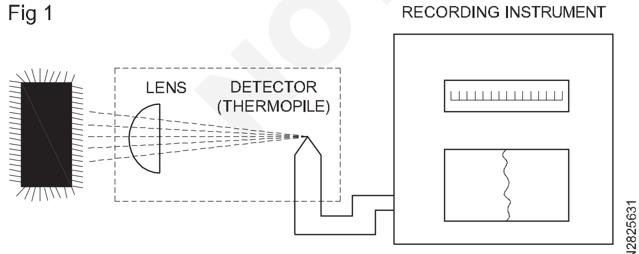
i Radiation pyrometers

ii Optical pyrometers

Radiation pyrometers (Fig 1)

Operation of radiation pyrometer is based upon the measurement of radiant energy emitted by the hot body. In page no 40 figure 1 shows a diagram of a radiation pyrometer. It consists of a lens to focus radiated energy from the body, whose temperature is required, on to a detector or receiving element. This receiving element may have a variety to froms such a resistance thermometer or a thermocouple or thermopile. A thermo pile consist of several thermocouples connected in series. Al temperature indicator, recorder or controller is attached with the receiving element to indicate the temperature.

Fig 1



A TYPICAL RADIATION PYROMETER

When the total energy radiated by a hot body, whose temperature is to be measured, enters the pyrometer it is focussed by the lens on to the detector. The detector is a thermopile whose measuring junctions are attached to a blackened disk. The disk absorbs energy when the pyrometer is focussed on a hot bod, and its temperature rises. The difference in temperature between the measuring junction attached to the disk and the reference junction attached to the case generates a voltage that is directly related to the temperature of the blockaded disk, which is indicated by recording instrument.

Sources of errors: radiation pyrometer have the following sources of errors:

i They are quite sensitive to any obstructions in the line of sight between the pyrometer and the hot body. They should not be used when infrared – absorbing water vapour, dust, or other particles are in the air.

ii They are also sensitive to emittance errors. To compensate for such errors, the device Should be calibrated using an optical pyrometer which is less sensitive to emittance errors. To compensate for such errors, the device should be calibrated suing an optical pyrometer which is less sensitive to emittance errors.

The radiation pyrometers measure temperature without direct physical contact with the object whose temperature is being measured. They are also capable of measuring low temperature than optical pyrometers.

Advantages: following are the advantages of radiation pyrometers:

i They are able to measure high temperatures.

ii In radiation pyrometers, there is no need for contact with target of measurement.

iii They possess fast response speed.

iv They have high output and moderate cost.

Disadvantages: following are the disadvantages of radiation pyrometers:

i Their scale is non-linear.

ii Errors due to presence of intervening gases or vapours that absorb radiating frequencies is possible in these pyrometers.

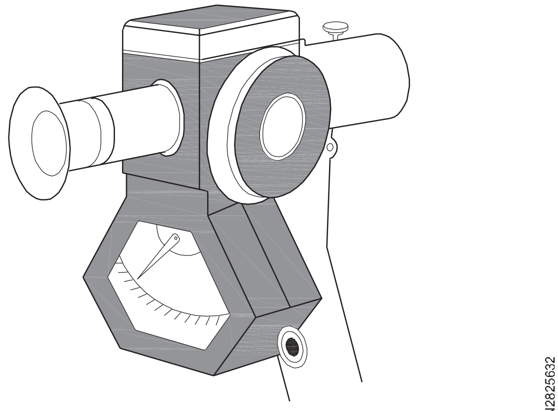
iii Emissivity of target material affect measurement.

Optical pyrometers

Optical pyrometers provide an accurate method of measuring temperature between 600 and 3000°C, and are very useful for checking and calibrating radiation pyrometers. But they are not suitable for recording or controlling temperatures.

The method of operation of optical of optical pyrometers is based on the comparison of the intensity brightness of the visual radiation emitted by the hot body with the radiation emitted by the source of known intensity. The brightness (or intensity) of radiation emitted by the hot body whose temperature is to be measured, is matched with the brightness of a calibrated reference (lamp) whose temperature is known. A typical industrial optical pyrometer is shown in Fig 2 for the temperature range from 700 to 3,000°C. Fig 3 shows the schematic arrangement of an optical pyrometer.

Fig 2

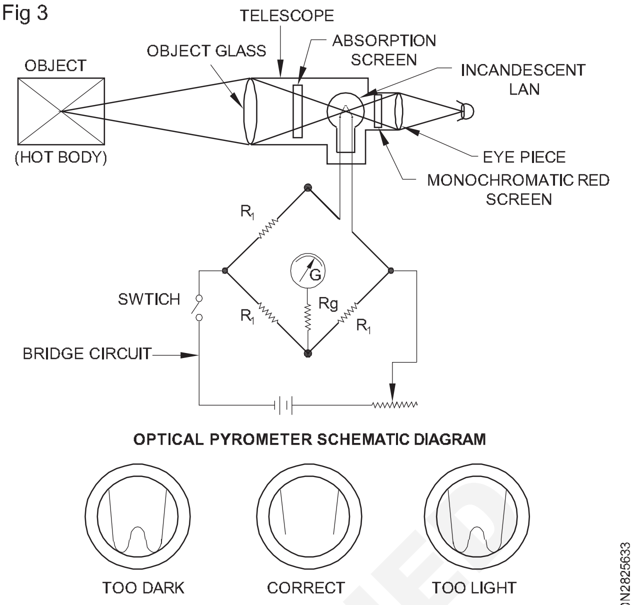


OPTICAL PYROMETER

An optical pyrometer consists of an incandescent lamp filament which is used as the reference source of radiation. this is arranged in the field of vision of a telescope through which both it the (filament) and the hot body, are viewed simultaneously. The filament is heated by a 2 volt battery in series with a rheostat by which the temperature of the filament is adjusted. This filament is connected in one arm of a wheat-stone bridge circuit across which is connected a moving coil galvanometer. The electrical resistance of the lamp filament varies in accordance with its temperature, while the resistance in other arms of the bridge are of a material, the ohmic value of which does not alter with change of temperature. As the temperature of the filament is increased the bridge is progressively thrown out of balance. The degree of unbalance is shown by the magnitude of the galvanometer deflection which is calibrated in terms of temperature.

In operation, the hot object is viewed through the telescope when the filament first appears as a dark line against the glowing background as shown at 'A' in Fig 3 on rotating the rheostat the temperature of the filament is progressively increased until the visible radiation matches that of the hot object. When the tip of the filament becomes invisible against the back ground as shown at 'B'

Fig 3



THE DISAPPEARING FILAMENT

When this stage is reached, the temperature may be read off from the galvanometer provided that the rheostat is not moved after the temperature match is obtained. An absorption screen (Fig 2), is used between the object and the filament that reduces the intensity of the radiation from the object reading the filament so that the filament may be matched to a hot mass which is at a considerably higher temperature than the filament itself. A monochromatic red screen is fitted to the eye piece so that it may be brought into the field of vision at will. Its function is to eliminate colour difference between the filament and the hot body to facilitate matching and also to prevent dazzle at the higher filament temperatures.

Advantages: Optical pyrometers have a number of advantages which are given below:

- i It possess flexibility, portability and its convenient for use.
- ii It is light in weight.
- iii It is useful for monitoring the temperature of moving objects and distant objects
- iv In this instrument there is no need for contact with target of measurement.
- v It is useful for high temperature.
- vi It has a good accuracy.

Disadvantages: optical pyrometers have certain disadvantages:

- i It is not useful for measuring the temperatures of clean burning gases that do not radiate visible energy.
- ii It is relatively expensive.
- iii It is prone to human errors caused by operator adjustment of temperature dial.
- iv It is subject to emissivity errors.

Measurement of Humidity

Objectives: At the end of this exercise you shall be able to
- **define absolute humidity and relative humidity**
- **explain sling psychrometer**
- **explan hair hugrometer**
- **explain thermal imager.**

Humidity

The humidity in a air affects chemical, garment, food, leather, pharmaceutical manufacturing industries. In order no manufacturing industries. In order no manufacture quality products it is necessary to cannot humidity.

Definition

Absolute humidity: it is amount of water vapour content present in air. It is expressed in gm per cubie meter of air (gm/m^3)

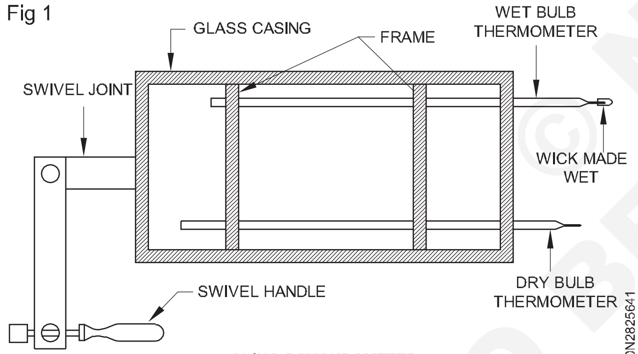
Relative humidity

Relative humidity is ratio of water vapour pressure actually present required to saturate the air at constant temperature and pressure it is expressed in percentage (%) 100%

Humidity refer to fully saturated air which contains all the moisture it can hold.

Psychrometer (Fig 1)

Fig 1



SLING PSYCHROMETER

Sling Psychrometer

Sling psychrometer is used to measure bother the dry bulb and wet bulb temperatures at time. These temperatures are a measure of humidity content in air.

The instrument frame which holds the thermometers. One mercury in glass thermometer whose sensing bulb is bare to directly contact the air and to measure the temperature which is called as th dry-bulb temperature. One mercury in glass thermometer whose sensing bulb is covered with a cotton or muslin wick made wet with pure water. This sensing bulb is covered with a cotton or muslin wick made wet with pure water. This sensing bulb covered with the cotton wick moistened is made to contact the air and the temperature indicated by this thermometer is called as the wet bulb-thermometer. The instrument frame carrying the thermometer is covered by a glass casing.

A swivel handle is attached to frame-glass casing –casing – thermometer arrangement to ensure that the air at the wet bulb always in immediate contact with the we wick. When a thermometer bulb is directly exposed to an air-water vapour mixture, the temperature indicated by the thermometer is the dry-bulb temperature.

When a thermometer bulb is covered by a constantly wet wick and if the bulb covered by the wet wick is exposed to air water vapour mixture, the temperature indicated by thermometer is the wet bulb temperature.

Operation of sling psychrometer

In order to measure the dry bulb and wet bulb temperature, the psychrometer frame-glass covering-thermometer arrangement to\\is rotated 5/ms to 10m/s to get the necessary air an important condition is that correct /accurate measurement of the wet bulb temperature is obtained only if air moves with velocity around the wet wick. In order to get this air velocity, the psycrometer is being rotated. The thermometer whose bulb is bare contracts the air indicates the dry bulb temperature. At the same time, the thermometer whose bulb is covered with the wet wick comes in contact with the air and when this pass on the wet wick present on the bulb of the thermometer, the moisture present in the wick starts evaporating and cooling effect is produced at bulb. Now the temperature indicated by the thermometer is the wet bulb thermometer which will naturally be lesser than the dry bulb temperature. if the psychrometer is rotated for a shorty period, then the wet bulb temperature recorded will not be proper. If the psychrometer is rotated for a short period, then the wet bulb temperature recorded will not be p[roper. If the psychrometer is rotated for a longer period, the wick will get dried soon and the wet bulb temperature will not be minimum value.

Application of sling psychrometer

It is used for checking humidity level in air-conditional rooms and installations.

It is used to set and check hair hygrometer,

It is used in the measurement range of 0 to 100% RH.

It is used for measuring wet bulb temperature between 0°C to 180-°C

Limitation of sling psychrometer

The measure medium is disturbed due to the act of measurement. the evaporation process at the wet bulb will add moisture to the air.

It cannot be used in automation requirement situations.

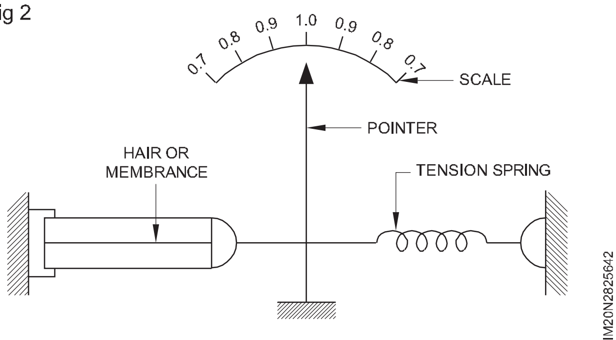
It cannot be used for continuous recording purpose.

If the wick is covered with dirt, the wick will become stiff and its water absorbing capacity will reduce, however, a stiff/dirty wick will resume normalcy when boiled in hot water.

Hair hygrometer (Fig 2)

Due to humidity, several materials undergo a change in physical , chemical and electrical properties. This property is used in a transducer designed anf calibrated to directly read the relative humidity. Certain hygroscopic materials, such as human hair, animal memberanes, wood, paer, etc, undergo changes in the linear dimensions when they absorb moisture from the surrounding air. This change in the linear dimension is used as the measurement of the humidity present in the air.

Fig 2



Human hair is used as a humidity sensor. The hair is arranged on a parallel beam and separated from each other to expose them to the surrounding air/atmosphere. Number of hairs are placed in parallel to increase the mechanical strength.

This hair arrangement is placed under a small tension by the use of a tension spring to ensure proper functioning.

The hair arrangement is connected to an arm and a link is attached to a pointer rotated at one end. The pointer sweeps over a calibrated scale of humidity.

Working of hair hygrometer

When air humidity is to be measured, this air is made to surround the hair arrangement and the hair arrangement absorb moisture from the surrounding air and expands or contracts in the linear direction.

This expansion or contraction of the hair arrangement moves the arm and the link and , therefore, the pointer to a suitable position on the calibrated scale and , therefore, indicates the humidity present in the air/atmosphere.

Application of hair hygrometer

These hydrometers are used in the temperature range of 0’C to 75’C

These hydrometers are used in the range of relative humidity (relative humidity)form 30 to 95%

Limitations of the hydrometer for the hair

These hydrometers are slow in response

If the hair hydrometer is used constlally , its calibration tends to change.

Thermal Imagers

Thermal imagers are devices that detect the infrared energy emitted, reflected by materials and convert the detected energy factor into a thermos gram

Importance of thermal imaging

Thermal imager absence may hundreds as or thousands of spot which gives as greater I formation regarding possible failure if any. There are the best instrument for application areas where distances and temperature high.

Safety

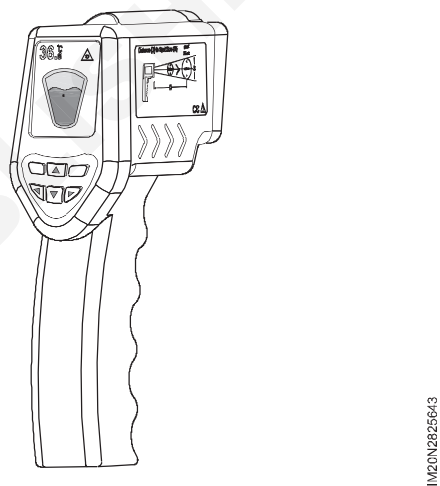
1 Do not are thermal imager under the explosive or damp or corrosive atmosphere.

2 Carefully read the manual before operation.

Shows thermal imager (Fig 1)

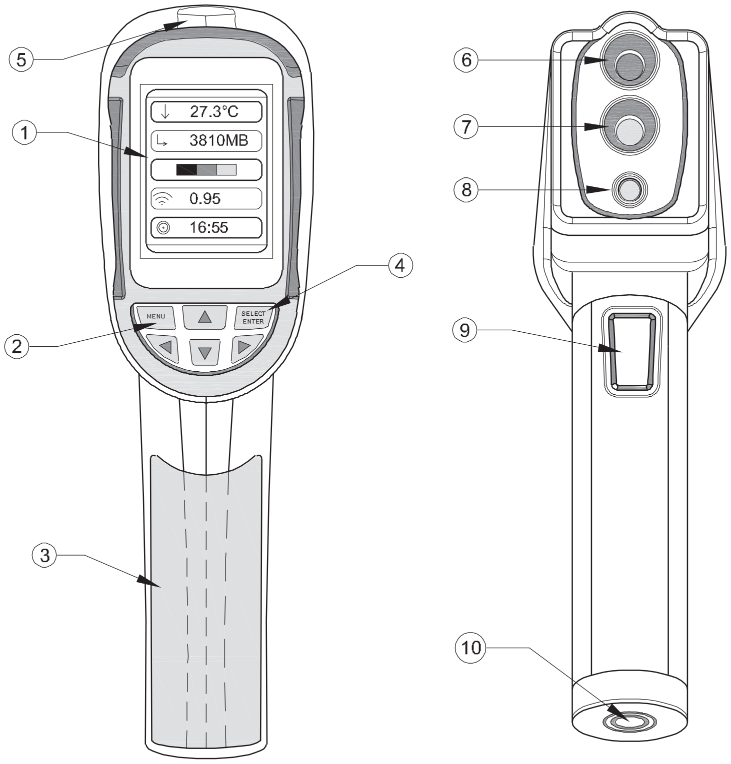
Shows the part of thermal imager (Fig 2)

Fig 3



Item	Description
1	TFT high definition color screen
2	Start-up/menu key
3	Battery cover
4	Select/enter key
5 6	Small SD card Infrared imaging sensor
7	Visible light camera
8	LED
9	Image capturing key
10	Interface for the installation of tripod

Fig 4



ITEM	DESCRIPTION
1	TFT HIGH DEFINITION COLOUR SCREEN
2	START - UP / MENU KEY
3	BATTERY COVER
4	SELECT / ENTER KEY
5	SMALL SD CARD
6	INFRARED IMAGING SENSOR
7	VISIBLE LIGHT CAMERA LED
8	LED
9	IMAGE CAPTURING KEY
10	INTERFACE FOR THE INSTALLATION OF TRIPOD

IM20N2825644

Specifications of thermal imager

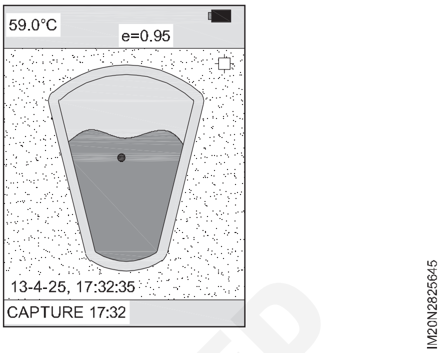
Display screen	2.4” full-angle high resolution
Color screen	
Resolution of infrared image	60 *60 (3600pixels)
Resolution of visible image	0.3 mega pixels
Field angels/shortest focal distane	20*20/ 0.5m
Thermal sensitivity	0.15°C
Range of temperature measurement	-20°C to +300°C
Accuracy of temperature measurement	±2% or ±2oC (±2% or ±4)
Emissivity	Adjustable 0.1 -1.0
Image capturing frequency	6Hz
Range of wave length	8-14um
Focal distance	Fixed focal distance
Color palette	Iron red, rainbow, rainbow high contrast, gray scale (white glow) and gray scale (black glow)
Vision option	25%step infrared to visional to infrared and visional image
Memory card	Mini SD card
File format	bmp
Power supply	AA battery *4
Battery life	6 hours
Auto power-off time	12 minutes
Authentication	CE (EN61326 -1:2006)
Dimension of product (L*W*H)	212mm*95mm*62mm
Weight	320g

Operating temperature	-5°C to ±40°C
Storage temperature	-20°C to ±50°C
Relative humidity	10% RH to 80 % RH

Measurement

The measured temperature of the center of pixel is displayed in the upper left corner of display screen. The setting of radiation coeffieient is also displayed in the upper riht corner of display screen. Move the product until hot spot or cold spot coincides with the center of pixel. Direct the product to the object whose temperature is higher or lowe than the surrounding temperature to get the optimum measured results.

Fig 5



Introduction to Recorders

Objectives: At the end of this exercise you shall be able to
- **explain the construction and working of shipchart recorder**
- **explain the construction and working of circular chart recorder**
- **explain the steps involved in installing the recorder**
- **explain the components of pneumatic recorder**
- **describe the method of adjusting the pressure calibrabium in a pneumatic recorder**
- **explain the construction connection to terminal, working principle and uses of paperless LED/LCD recorder.**

Introduction

In many of the industrial and research process it is necessary to monitor continuously the condition, state, or value of the process variable such as flow, force, pressure, temperature, current, voltage, electrical power etc…A Recorder thus records electrical and non electrical quantities as a function of time . this record may be written or printed and later on , can be examined and analyzed to obtain a better understanding and and control of the process . current and voltages can be recorded directly while the non- electrical quantities are recorded indirectly by first converting them to equivalent current or voltage with the help of transducers. The ever increasing emphasis on automation, continuously recording instrument are finding many applications in industry ..

Recording requirements

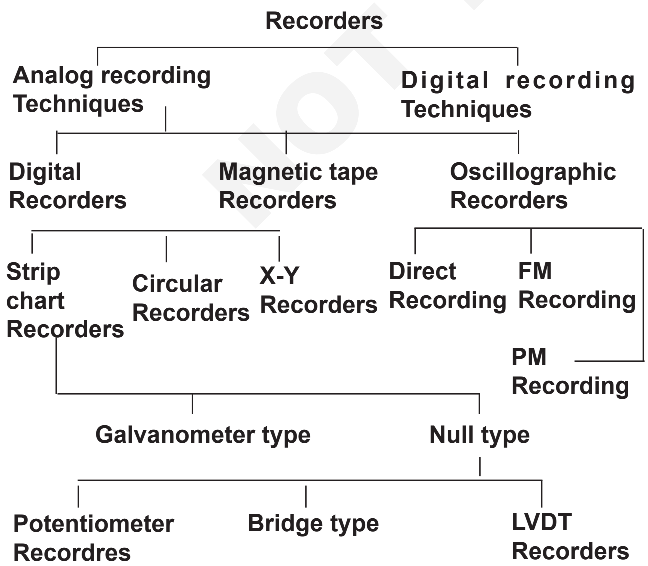
One of the important consideration in an instrumentation system is the method by which the data acquired is recorded . The recorder method should be consistent with the type of system. If we are dealing with a wholly analog system , then analog recording techniques should be used . while on the other hand ,if the

Thus there are two types of recording devises :

1 Analog recorders, and

2 Digital recorders.

Classification of recorders



Graphic recorders

Graphic recorders are devices which display and store a pen-and-ink record of the history of some physical event. The event may be a varying voltage or current obtained from an electric circuit under observation or perhaps a varying pressure which actuates a diaphragm and linkage to move a stylus in relation to a chart. A graphic recorder consists of:

1 a chart of displaying and storing the recorded information

2 a stylus moving in a proper relationship to the paper

3 Suitable inter-connection mean to couple the stylus to the information dource

There are a two type of graphic recorders:

I Strip-chart recorders

II Circular-chart recorders

Strip-chart Recorders

Strip -chart recorders are used to record a function varying with respect to time. They are generally used on the potentiometer type instrument or on the resistance thermometer.

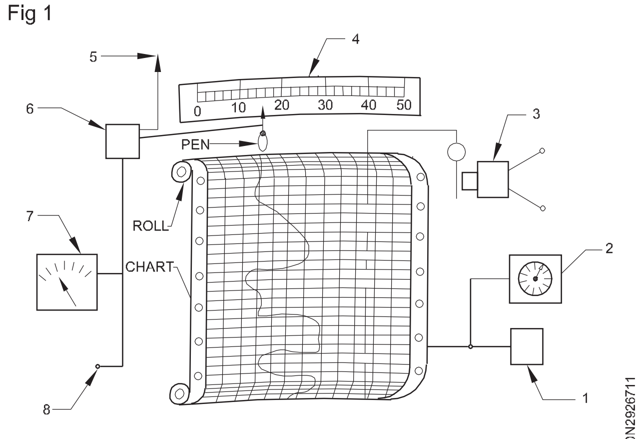
Construction and Working

The various parts of a strip-chart recorder are shown in Fig 1 consists of a long roll of graph paper known as chart, moving vertically, and is usually graduated in rectilinear coordinates. That chart id usually driven by a synchronous motor equipped with a speed selector switch to change the chart speed conveniently in fixed increments. A board range of chart speed is available from several inches per second to a fraction of an inch per hour. A feature available is a jump-spreed control whereby a low chart speed is established for monitoring a system.

Most recorder use a pointer attached to the stylus, so that the instantaneous value of the quantity being recorded can be measured directly on a calibrated scale. The assembly of a strip chart Recorder working principle is shown in Fig 2. This recorder uses a single pen and is servo driven.

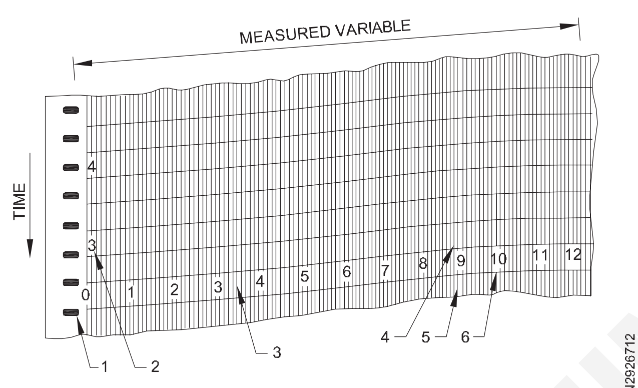
Assembly of a Single Pen Servo Operated Strip Chart Recorder (Fig 3)

Fig 1



BASIC STRIP - CHART RECORDER

Fig 2



SECTION OF AN 11-IN STRIP CHART

Most strip chart recorders use a servo feedback system, to ensure that the displacement of the pen (stylus) across the paper tracks the input voltage in the required frequency range.

A potentiometer system is generally used to measure the position of the writing head (stylus).

The chart paper drive system generally consists of a stepping motor which controls the movement of the chart paper at a uniform rate.

The data on the strip chart paper can be recorded by various methods.

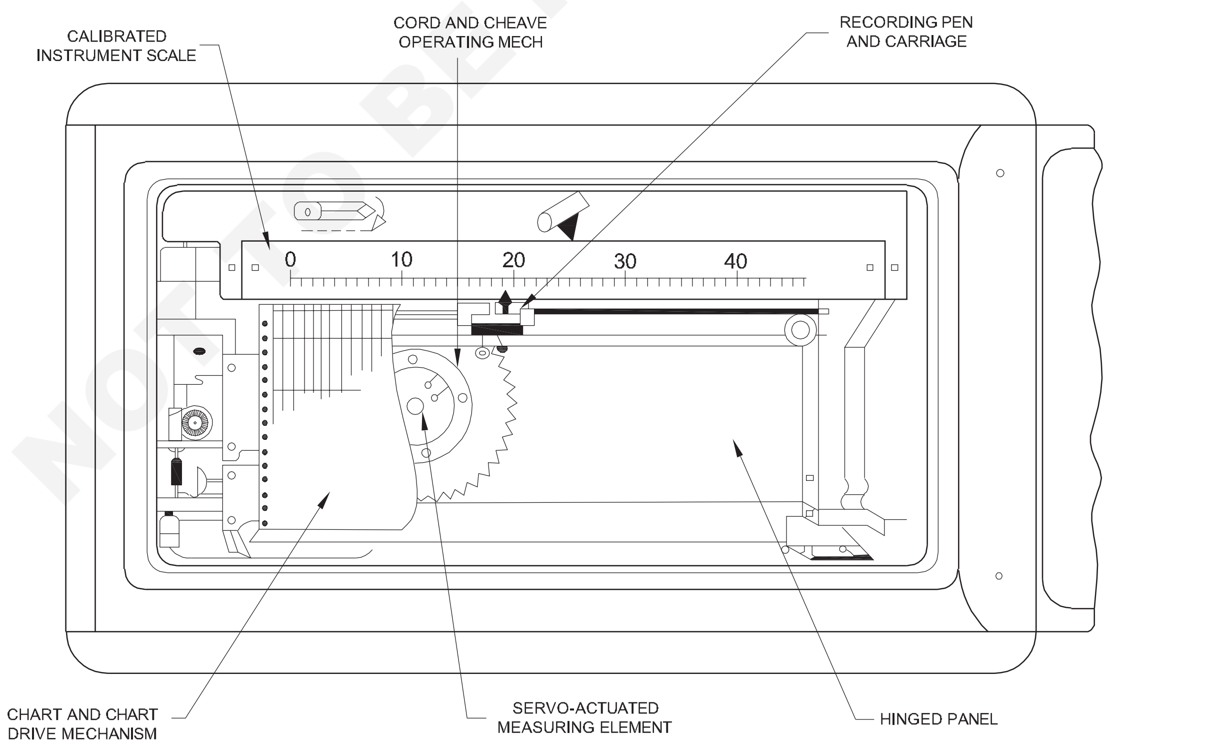
Pen and Ink stylus

The ink is supplied to the stylus from a refillable reservoir by capillary action. Modern technology has replaced these pens by disposable fibre tip pens. In addition, multichannel operation can be performed, i.e. at any instant, a maximum of six pens can be used to record data. When using multiple pens, staggering of the pens are necessary to avoid mechanical interference.

Impact printing

The original impact system consisted of a carbon ribbon placed between the pointer mechanism and paper, which provided the ink for recording data. The mark was made on the paper by pressing the pointer mechanism on it. The advantage of impact printing over the pen and ink method is that, it can record data on up to 20 variables simultaneously. This is achieved with the help of a wheel with an associated ink pad which provides the ink for the symbol on the wheel. The wheel is moved across the paper in response to the variable being recorded.

Fig 3



ASSEMBLY OF A SINGLE PEN SERVO OPERATED STRIP CHART RECODER

In some mechanisms, pressure sensitive paper is used. The markings on the paper are done with chopper bar, which applies the pressure on the paper. The frequency of the chopper bar is once per second.

Thermal Writing

In this system, a special movable pen which is thermally heated by passing an electric current through it is used. This system requires a thermally sensitive paper which changes its colour on application of heat.

Electric Writing

This technique is based on the principle of electrostatic

In this method, a special chart paper is used. This paper consists of a paper base coated with a layer of coloured dye (black, blue or red), which in turn is coated with a thin surface of aluminium.

$$\text{Period} = \frac{\text{time}}{\text{cycle}} = \frac{\text{time base}}{\text{chart speed}}$$

The stylus (pen) consists of a tungsten wire moving over the aluminium surface. Markings on the paper are achieved by applying a potential of 35 V to the stylus. This causes an electric discharge which removes the aluminium, revealing the coloured dye.

Optical Writing

In this technique of writing, a special photo sensitive chart paper, sensitive to ultra violet light is used. This technique is mostly used in galvanometer system.

Ultra violet light is used to reduce unwanted effects from ambient light. The paper can be developed in daylight or under artificial light without the need for special chemicals, which is not possible if ordinary light is used.

Most recorders use a pointer attached to the stylus. This pointer moves over a calibrated scale giving the instantaneous value of the quantity being recorded.

Paper drive system: The paper drive system should move the paper at a uniform speed. A spring wound mechanism may be used in most A synchronous motor is used for driving the paper.

Chart speed: Chart speed is a term used to express the rate at which the recording paper in a strip chart recorder moves. It is expressed in in/s or mm/s and is determined by mechanical gear trains. If the chart speed is known, the period of the recorded signal can be calculated as

and frequency can be determined as f= 1/period.

Advantages following are the advantages of strip-chart recorders:

i Chart usually is graduated in rectilinear coordinates to facilitate interpretation of record data. Direct operated strip-chart recorders usually employ curvilinear charts, but even these are easier to read than circular charts.

ii Long periods of operation are possible without renewal of chart papers Standard lengths up to 120 ft. (36 meters) in 12 in (300 mm) width is developed by available.

iii Long process periods are easily recorded

iv Readability is the same at all values of scale span.

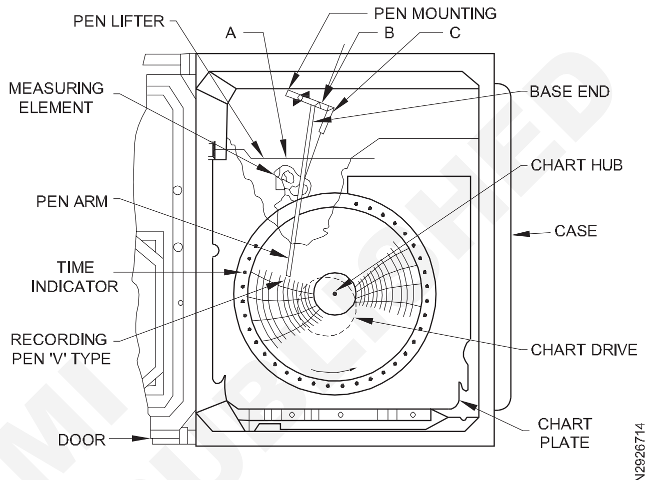
v 90 per cent or more of the chart width is used as recording area

vi They are adaptable to multi-point recording.

Circular Chart Recorder Working Principle

Circular Chart Recorder Working Principle - As the name implies, the data is recorded on a flat circular chart. The basic assembly of a single pen circular chart recorder is shown in Fig 4

Fig 4



ASSEMBLY OF A SINGLE PEN DIRECT-ACTING CIRCULAR CHART RECORDER

It consists of a measuring element, an operating mechanism, a chart drive, and a recording device, which may all be mounted on a single panel. The chart is usually mounted on a flat supporting plate and fastened in position by spring clips, which prevent it from curling. The measuring element could be a helical pressure tube or any other element. The operating mechanism consists of levers a and b and links c which convey motion from the measuring element to the recording device.

For optimum recording conditions, light uniform pressure, and a smooth flat chart surface must be ensured. The pen arm must be accurately fitted and locked. The chart is driven at a uniform rate by some timing device.

Circular Chart Drive

A conventional drive assembly consists essentially of a centre chart support spindle and an drive motor. The chart is generally centered and locked around the centre spindle. The chart speed may vary from one rotation in 15 minutes to one rotation in 30 days. A 30 cm circular chart has a maximum time-line length of approximately 100 cm in a revolution, whereas a 15 cm strip chart may move 25 m of chart in the same period.

The various drives for circular charts are classified as follows.

1 Mechanical (spring clock drive).

2 Pneumatic (air lock drive).

3 Electric (synchronous regulated dc motor or motor wound spring).

4 Dual powered drive (duplex), i.e. a synchronous motor and spring clock mechanical drive.

5 Externally controlled drives.

Advantages

Following are the advantages of circular-chart recorders

i Charts are flat, easy to handle and file...

ii The entire record of one process period (12 hr, 24 hr, 7 days etc.) is available at a glance.

iii Arc motion of the recording device permits the use of relatively simple measuring and recording mechanism.

iv Motion transmitted from the measuring mechanism to the recording device is easily modified to effect calibration.

v Simultaneous full-chart range recording of upto four separate variables is possible.

Limitations

Following are the limitations of circular- chart recorders:

i Time values toward the centre are difficult to read

ii The chart must be changed once every process period (12hr, 24 hr, 7 davs, etc.).

Installation

Location: The recorders should be installed in an area free from high humidity, corrosive fumes, and excessive vibrations. In addition, they should be kept a reason- able distance from transformers and conductors carrying high currents.

Installing the record roll

The following steps, along with the corresponding photographs, describe the proper method for installing a roll of chart paper in the recorder.

1 Press down the latches (1) on each end of the reroll spool (2) and then lift the spool out.

2 Grasp the supply-roll spool

3 And pull it up and out of the recorder

4 Hold a new record roll with the elongated holes to the right and then inset the supply – roll spool into the right hand side of the record roll.

5 Snap the new record roll into position while simultaneously holding down the paper supply indicator (4) and holding up the drag plate (5).

6 Lift up the two paper guides (6) and then pass the end of the chart paper above the drag plate (5) and between the roller (7) and writing table (8).

7 Pull through approximately 16 inches of paper, being careful not to tear the paper on the sprockets in the timing drum.

Remove the used record roll.

Tear the end of the chart paper into 'V' as Shown in be

Hold the re roll spool so that the gear is on the right-hand side, and then insert the end of the chart paper into the slot in the spool

Wind several turns of the chart paper onto the re roll spool (record side out)

Hold up the drag plat (5) and then snap the re roll Spool into position.

Pull a few inches of chart paper off the re roll spool

Installing the inkwell and pen

The proper method for installing an inkwell and pen is as follows:

1 Tilt way. the scale assembly up out of the way.

2 Place the new inkwell in the recorder (the side of the inkwell which has the tape or hole should be in the back of the case) and make sure that it is properly seated

3 Snap the two holding clips onto the grooves in the inkwell cover.

4 Remove the tape (if resent) covering the hold in the inkwell cover.

5 Place the stem of the pen carefully into the inkwell and then very carefully push the pen down into the spring clips on the pen saddle. A click will be "felt" on both sides when the pen has been pushed into the clips).

Pneumatic Recorder

These recorders are the Indestry Standard for accurate, reliable measurement and recording of pressure, defferential pressure and temperature in a variety of application. (Fig 5)

Mainpart of Preumatic

1 Case

2 Chast drive

3 Charts

5 Thermal system

6 Pressure Elements

Case

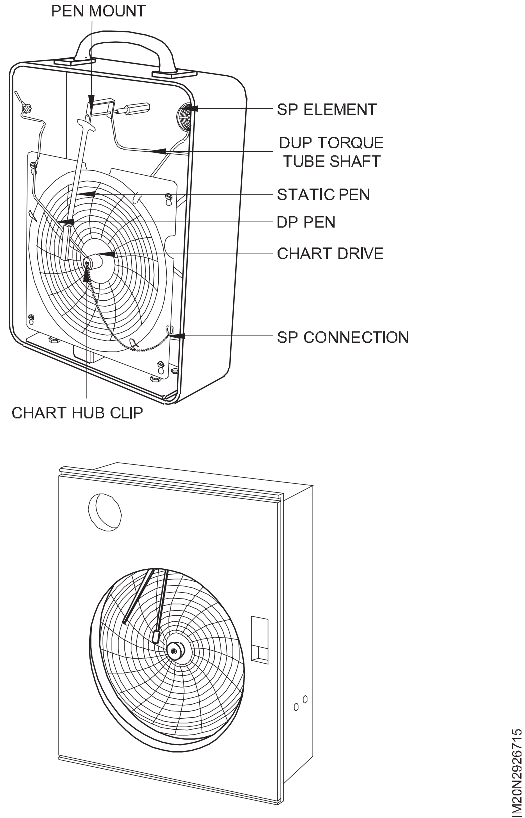
Recorders are available in a die cast aluminum case in wall,flush, pipestand and pedestal mount.

Chart drives

There are three types of chart dives: Multi-speed Battery Operated, Spring wound, and Electric.

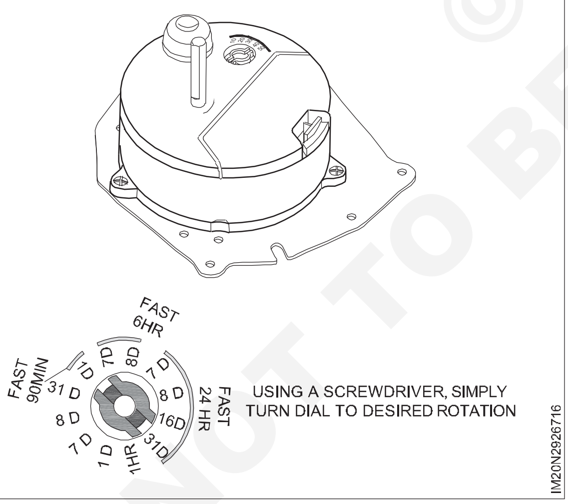
Quartz Multi-Speed Battery Operated Chart Drives (BOCD) - feature a rugged rotation speed selector.

Fig 5



An “OFF” position saves battery life. When “ON”, a pulsating red status light indicates that the unit is working, eliminating the need to double check the chart movement. This is particularly valuable in applications requiring slow rotational speeds) (Fig 6)

Fig 6



Spring Wound Drive is a dual speed type. By use of a shift lever, the drive can be set for 24 hour or 7 day rotation. Optional 15 minutes and 1 hour are available.) (Fig 7)

Electric Drives are furnished in various rotations and can be supplied with 110V/120V-60 Hz., and 220V - 50 Hz. (Fig 8)

Charts

Charts are available in 8 inch and 12 inch, and in a wide variety of ranges and rotations). (Fig 9)

Fig 7

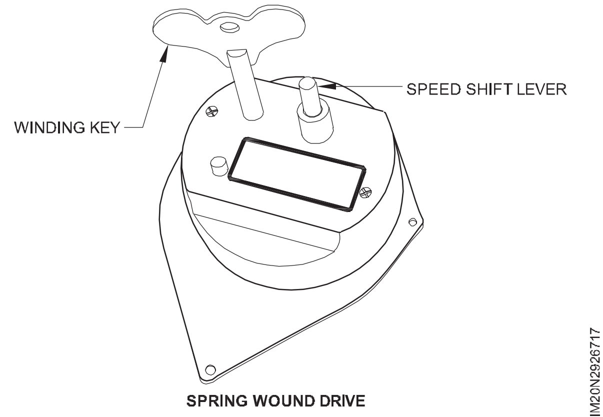


Fig 8

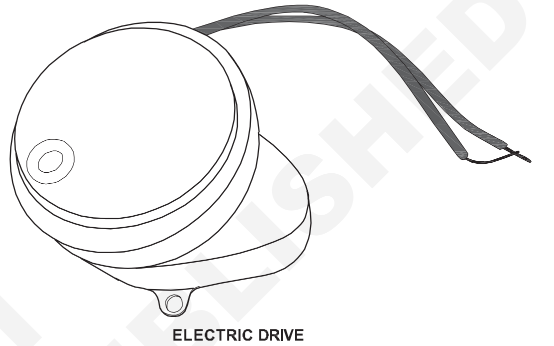
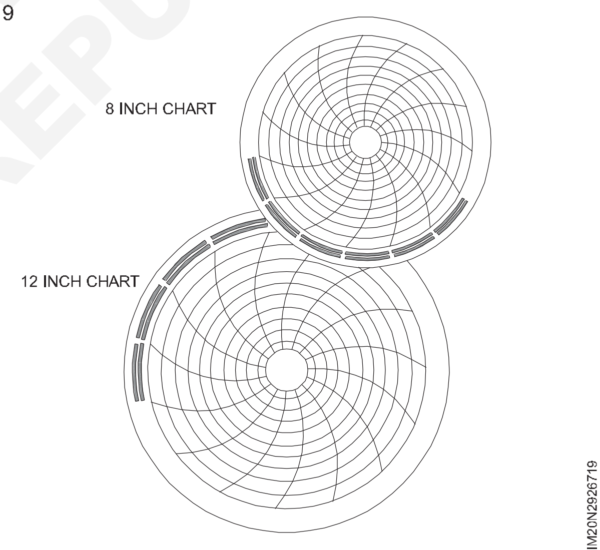


Fig 9



Pens

Chart Recorder Pens - Recorder Pens are included for each system specified. Standard colors are Red, Green and Blue. Black and Purple are also available. Pens should be checked periodically for cleanliness and sufficient ink. (Fig 10)

Pressure elements

The sensing element of the pressure measuring and recording system must be properly installed in order to achieve maximum accuracy. (Fig 11)

Fig 10

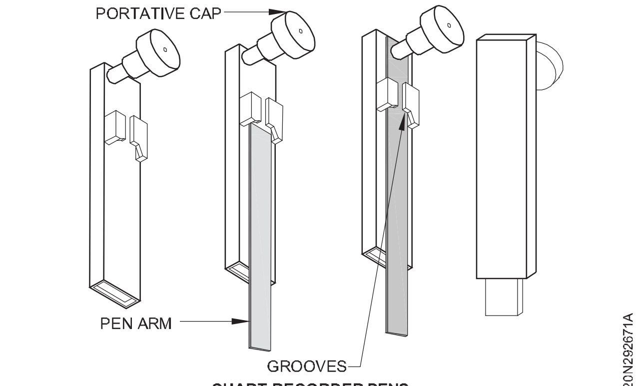
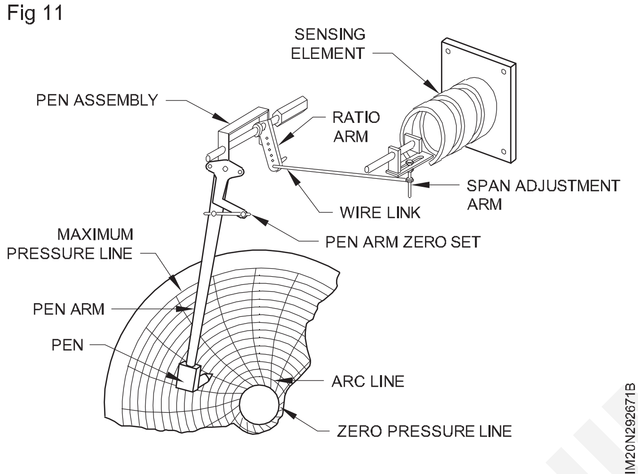


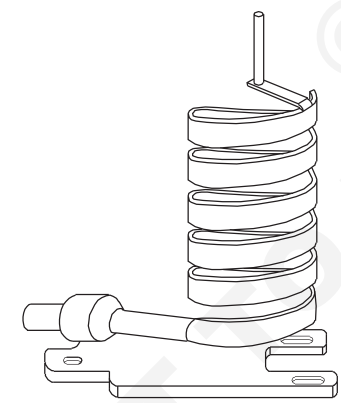
CHART RECORDER PENS

Fig 11



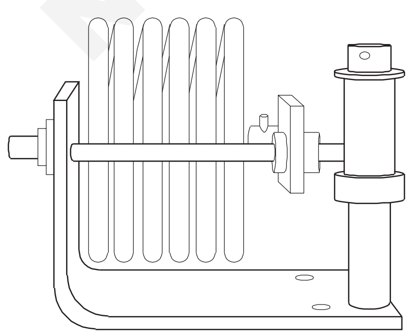
Different types of pressure elements (Figs 1&2)

Fig 1



HIGH-PRESSURE HELICAL WOUND BOURDEN COIL FOR RANGES 30 PSIG AND OVER

Fig 2



LOW-PRESSURE DIAPRAGM FOR RANGES 25 PSIG AND UBDER

Pressure calibration instruction-calibration check

Advantage

1 It does not need electricity.

2 It is used in PID Controller.

3 It is used to record pressure from o to 30,000 psi.

Disadvantage

1 It is sensitive to vibration and low accuracy

2 It is slow moving and drift actuator.

Paperless Recorder

LED/LCD

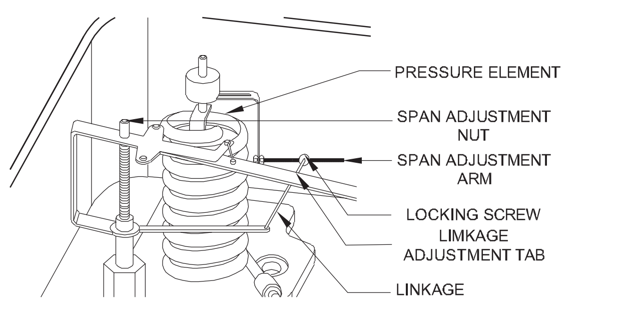
Introduction

Paperless recorder is a device that records the collected calculation data in the internal storage system of the instrument based on time. The stored data recorded in the instrument is displa No- on the LCD screen after calculation and simulation. There are normally digital display, bar graph display, curve display, alarm list and so on.

Construction of paperless recorder (Fig 3)

The paperless recorder is mainly composed of industrial special microprocessor, A/D converter, read-only memory ROM, random memory RAM, display controller, liquid crystal display. keyboard controller, alarm circuit, clock circuit and other parts. The data collected by the paperless recorder are commonly used temperature, pressure, flow, liquid level, voltage. for current, humidity, frequency, vibration, speed, etc.

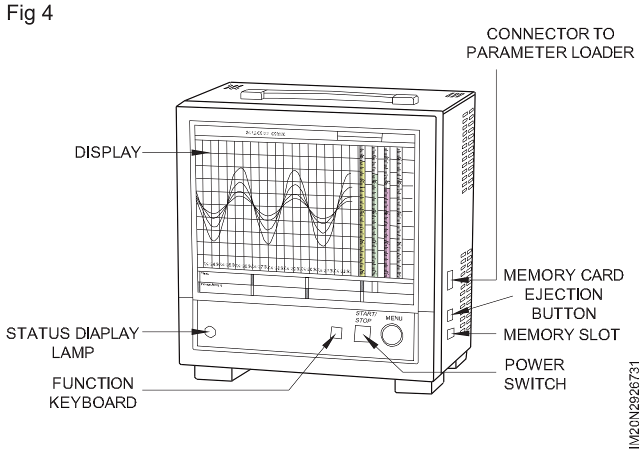
Fig 3



Operation of paperless Recorder (Figs 4&5)

The paperless recorder uses a single-chip microprocessor as the core to collect and process various data. The recorded data can be sent to the random memory RAM for storage, or sent to the LCD screen for display, or as needed Zoom in or zoom out at will to facilitate the operator to observe the state of the recorded signal, at the same time, the recorded signal can be compared with the set upper and lower limit signals, and an alarm signal will be issued once the limit it exceeds.

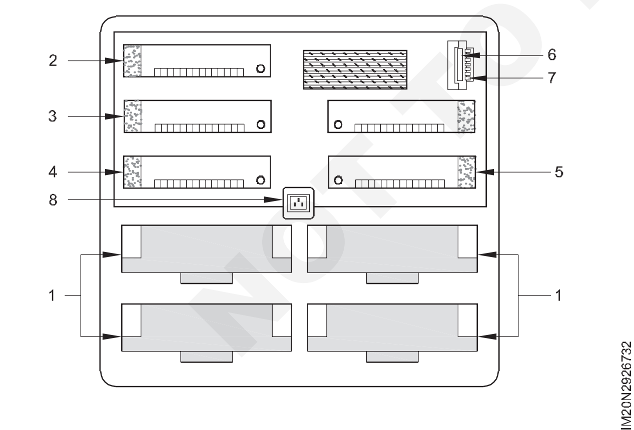
Fig 4



The A/D converter converts the analog quantity from the recorded signal into a digital quantity for the CPU to perform arithmetic processing. The read-only memory ROM is used to solidify the program. After the power is turned on, the ROM program can make the CPU work, random access memory RAM is used to store historical data processed by the CPU

According to difference in sampling time, data can be saved for days or decades. It has backup power which is for making sure that all recorded data won't lost when the power is off. The CPU can display data on the LCD screen through the display controller, which can generally be displayed on a 7-inch or 10.2-inch color LCD touch screen. The operator makes various settings through the operation buttons or the touchable screen, and the signal is transmitted to the CPU so that the CPU can work according to the requirements of the operator. When the recorded data exceeds the limit, the CPU sends a signal to the alarm circuit in time to generate an alarm output. The function of the clock circuit is to generate the recording time interval, time stamp or date required by the recorder and transmit it to the CPU.

Fig 5



In addition, paperless recorder is also equipped with a print controller and a communication controller, then data in CPU can connect with external micro printers and personal computers through them to achieve data printing and communication by connecting.

Uses of paperless recorder

It is mainly used for various industrial sites such as metallurgy, petroleum, chemical industry, building materials, papermaking food, pharmaceuticals, colleges and universities, biological research, heat treatment and water treatment, Paperless recorder abandons the shortages of traditional record method of using paper and pens, at the same time, it enhances the quality of recorder and the stability of the recorder, and more importantly, it reduces the operating cost of the recorder, facilitate management, improves work efficiency, and avoids the possibility of manual recording errors.

1 Display unit

Allows the Real time trend screen, Bar Graph Display screen, Analog Meter Display screen, Digital Display screen. Totalized Value Display screen, Historical trend screen and other various Parameter Set screens to be displayed.

2 Power switch

Used to turn the power ON or OFF.

3 Memory card slot

Used for inserting the memory card

4 Memory card ejection button

5 Connector to parameter loader

When changing parameters by using a loader, connect the exclusive cable (optional cable PHZP1801) to the connector.

6 Function keyboard

Used for operation, or setting and verifying each parameter.

7 Status display lamp

Displays power ON/OFF, LCD (screen) ON/OFF, and the recording status.

Lamp ON: Power: ON, LCD: ON (recording/recording stop)

Lamp blinking (ON/OFF for 2 sec): Power: ON, LCD: OFF (recording)

Lamp blinking (ON/OFF for 1 sec): Power: ON, LCD: OFF (recording stop)

Lamp OFF: Power: OFF

Connection to terminals

1 Input terminal

= Connect signal cable for each channel.

2 Alarm output relay terminal -1

= Connect Alarm relay output (DOI to 10).

3 Alarm output relay terminal -2

= Connect Alarm relay output (DO11 to 20).

4 Alarm output transistor terminal

= Connect Alarm transistor output (DO21 to 36).

5 DI input terminal

= Connect DI signal input (DII to 16).

6 Power terminal

= Connect power cables to LN terminal.

Power source to be connected should be free from

7 Ground terminal

= Connect to terminal (Class-D, 10092 or less).

8 Ethernet terminal

= Plug in the LAN cable for Ethernet communication.

Advantages of paperless recorder

1 The paperless recorder has no mechanical moving parts and requires less maintanance during use.

2 The data of the papaerless recorder is recorder is recorded in the electronic chip.

3 Paperless recorder has the advantages of paperless, real-time, high precision ,with communication ,searchable, intelligent.

Final control elements

Objectives: At the end of this exercise you shall be able to
- **explain final control elements in process loops**
- **explain hydraulic actucters**
- **explain relationship between pressure, volume, and temperature**
- **explain electric actuators**
- **explain feed back loops.**

A final control element is defined as a mechanical device that physically changes a process in response to a change in the control system set point. final control elements relevant to actuators include valves, dampers, fluid couplings, gates, and burner tilts to name a few. final control elements are an essential part of process control systems, allowing an operator to achieve a desired process variable output by manipulating a process variable set point.

Current trends in industry focus on improving quality and efficiency in an effort to reduce process costs. many industrial facilities are recognizing the bottom line savings found from improved process control performance through precise and consistent control of final control elements.

The final control element would make the required changes in the manipulated variables and this variable will satisfy the requirements. in a control system the selection of the proper control element and also the selection of control element, location is an important factor. we can describe the final control element as a component in a control system that would regulate the flow of energy to the process.

What does a final control element do in a control system?

The final control element is also known as the correcting part of the control system. this element would receive the input from the controller and this input will be converted into a proportional operation which will be performed on the process. in any type of control system, the final control element would correct a variable that is not close to the set point. as we discussed above mostly the final control element would be a valve or motor. the final control element can vary the controlled variable to the required value. this part in the control system implements the decision which is made by the controller.

The most frequently used final control elements are the control valves. such a control valve assembly has two main parts, the actuator (drive) which can be pneumatic, electric or hydraulic and the valve which manipulates the flows with a plug,ball,diaphragm or baffle.

Pneumatic actuators

Pneumatic actuators (Figs 1&2) are devices that convert the energy of compressed air or gas into a mechanical motion that regulates one or more final control elements. pneumatic actuators are devices that convert the energy of compressed air or gas into a mechanical motion that regulates one or more final control elements. pneumatic actuators are normally used to control processes requiring quick and accurate response, as they do not require a large amount of motive force.

Fig 1

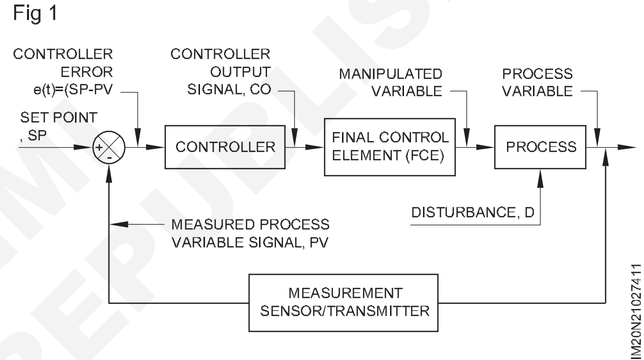
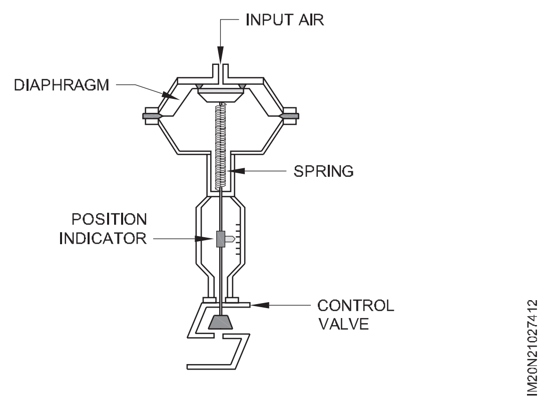


Fig 2

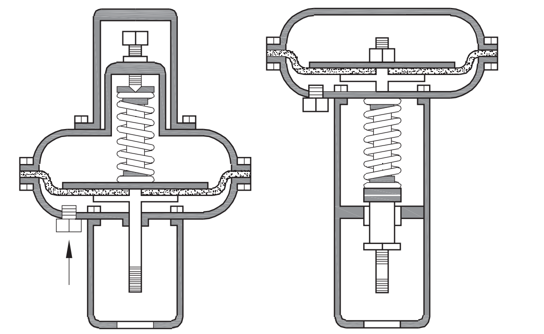


Diaphragm actuators

Diaphragm actuators have compressed air applied to a flexible membrane called the diaphragm. these types of actuators are single acting, in that air is only supplied to one side of the diaphragm, and they can be either direct acting (spring-to-retract) or reverse acting (spring-to-extend).

Actuators may be categorized as 'direct acting' or 'reverse acting' and some configurations are indicated in below Fig 3.

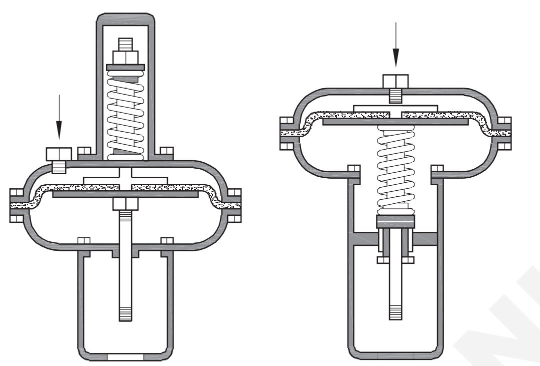
Fig 3



REVERSE ACTING

In a **reverse acting actuator** (Fig 4) an increase in the pneumatic pressure applied to the diaphragm lifts the valve stem (in a normally seated valve this will open the valve and is called ‘air to open’).

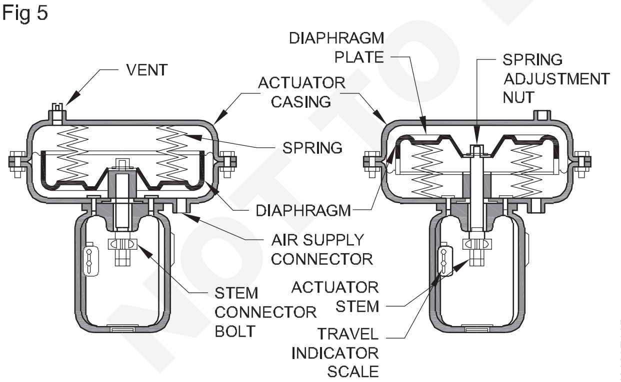
Fig 4



DIRECT ACTING

In a **direct acting actuator,** (Fig 5) an increase in the pneumatic pressure applied to the diaphragm extends the valve stem (for a normally seated valve this will close the valve and is called ‘air to close’).

Fig 5



AIR TO OPEN AIR TO CLOSE

Hydraulic actuator

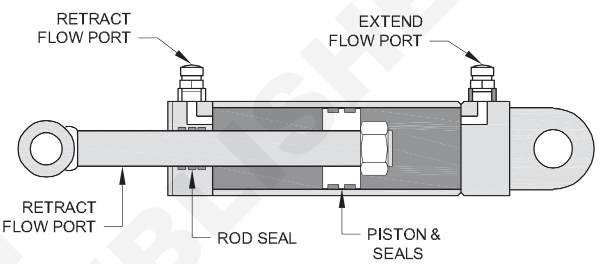
Hydraulic actuator (Fig 6) definition is, a device that is used to change the fluid’s pressure energy into mechanical is known as a hydraulic actuator. the hydraulic actuator includes a cylinder or a fluid motor that works through hydraulic power for mechanical operation.

The mechanical motion provides an output in the form of rotary, linear otherwise oscillatory motion. when liquids are almost unfeasible to compress, then a hydraulic actuator uses a large force.

The hydraulic actuator working principle is, it uses liquid pressure to work instead of instrument air pressure to provide a force on the diaphragm to move the valve actuator, then to the stem of the position valve. almost all types of hydraulic actuators use a piston instead of a diaphragm for changing liquid pressure into mechanical power.

This system mainly uses pascal’s law, which states that when the pressure is applied at a particular point to a limited fluid within a container then it transmits evenly in all the ways within the liquid & the container’s walls without any loss.

Fig 6



LINEAR ACTUATORS

Types of hydraulic actuator

hydraulic actuators are classified into three types based on actuation like linear actuator, rotary actuator, and semi-rotary actuator.

The advantages of a hydraulic actuator include the following.

- Design is simple
- Inexpensive
- strong construction
- High force capabilities
- Protection of the engine from overloads
- The rotating parts provide a quick change of operating modes.
- Transformation is simple from rotating movement to reciprocating one
- These actuators generate 25 times greater forces as compared to pneumatic cylinders of equivalent size.
- They also operate up to 4,000 psi.
- They can hold pressure & torque stable
- The pumps & motors within the actuator can be arranged at a considerable distance through a small amount of power loss.

The disadvantages of a hydraulic actuator include the following.

- Inflexibility

- High maintenance
- Sensitive to temperature
- Partial motion control capabilities
- Insufficient data collection capabilities
- Operating efficiency is low
- Its efficiency is low as compared to others
- Its operation conditions will influence its main characteristics
- They need several complementary parts like a liquid reservoir, pump, motor, heat exchangers, and release valves through noise decrease equipment.
- Loss of liquid can lead to less efficiency and hygiene problems resulting in potential damage to surrounding components and areas.

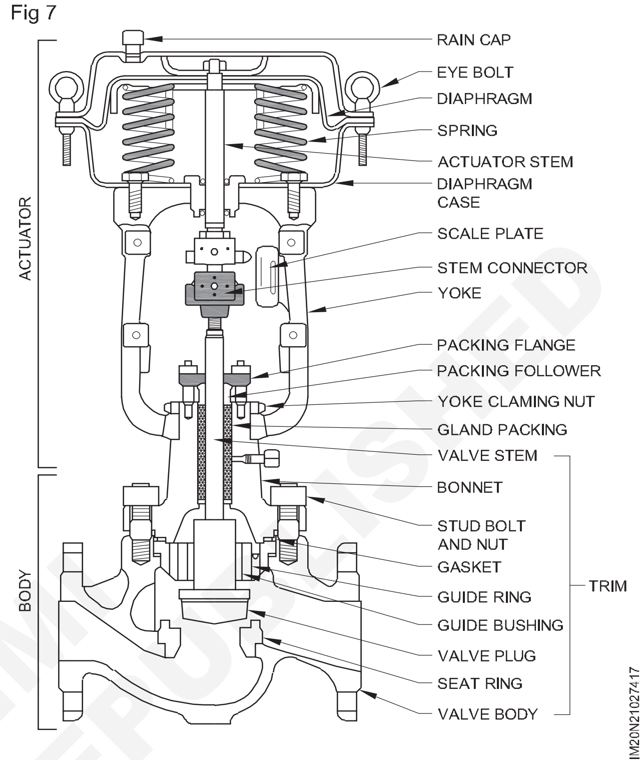
Applications

- The applications of hydraulic actuators include the following.
- These are used in high force-based applications.
- These are used for various applications like crane drives, winches, self-driven cranes, excavators, wheel motors in military vehicles, feeder drives, agitator drives & mixer, roll mills, trammels & kilns, drum drives for digesters, shredders for cars, tires, drilling rigs, high-powered lawn trimmers & trench cutters.
- Hydraulic jack
- Highly precise positioning for heavy loads
- Hydraulic brake
- Controlling oh close-loop velocity
- Hydraulic ram
- It can be used as a sensor

Components of pneumatic actuator

- **Rain cap** not to let water flow into the actuator for action of the air to open actuator is that the air will be from the bottom of the actuator so the holes are left blank.
- **Eye bolt f**or use on the hook. moving the valve
- **Diaphragm** is flexible. to change the incoming wind power and power passed to diaphragm plate to make actuator stem cell.
- **Spring i**s in the yoke actuator case or, depending on the design of the manufacturer. it will act as a force for actuator stem cell and a strong wind from the opposite direction to the plate diaphragm.
- **Actuator stem** is interconnected with actuator valve stem.
- **Diaphragm case** are the parts that are used for packing diaphragm plate consists of two parts: the upper and lower sections.
- **Scale plate** is based on the position of the valve between 0-100%.
- **Stem connector** is the link between them for actuator stem and plug stem. (Fig 7)
- **Yoke** is a component that is used for connecting sections of the actuator and valve body.

Fig 7



Valve body part

Part of body valve is included in the bonnet valve with which this segment is exposed to the fluid (fluid) directly, so choosing the required qualifications material (material) as well as fluid type, temp, pressure and. etc

- **Packing flange** is used for compression of the stud bolt to make the most of all the gland packing tight and fluid can not leak out of the neck bonnet.
- **Packing follwer** is the strength of packing flange gland pakcing tightly compressed to tighten over time.
- **Gland packing** is important that we prevent the leakage of fluid up to the neck and is in direct contact with bonnet plug stem the choice of material and type to fit so there is a huge need.most of the material used is ptfe or graphite and maintenance each time. the need to change the gland packing all times.
- **Valve stem** is the strength of the actuator and connected to plug.
- **Bonnet** was primarily used for supporting the position of the plug-time scroll up, scroll down to find it. no left and right but some manufacturers cut output to reduce the bonnet cost for the production and sale of the valve. the maintenance is also difficult. it is not to come and support the position of the plug and seat to meet constantly lapping.

- **Stud bolt and nut**
- **Gasket** is a device used to prevent leaks during the assembly of iron and steel as well as between the body and bonnet.
- **Guide ring** is located in bonnet order to align plug straight up. another reason for having guide ring bonnet, instead of doing all the reason to reduce maintenance time cost. because this section is always exposed to stem plug sometimes wear if not guide ring may be a whole instead of only replacing bonnet guide ring.
- **Guide bushing** is used for supporting guid ring again.
- **Valve plug** is essential to use the force of fluid flow. and determine the flow properties as linear, equal percentage or quick openning.
- **Seat ring i**s a component that is part of valve body and given the size of the rated cv of the valve and which supports plug and plug and seat ring must be close together. to be able to follow the class leakage as needed.
- **Valve body** , a major component of the round and get direct contact with the fluid.

The relationship between pressure and volume

Boyle's law:

At constant temperature, as the pressure on a gas increases, the volume of the gas decreases because the gas particles are forced closer together. conversely, as the pressure on a gas decreases, the gas volume increases because the gas particles can now move farther apart.

$$PV=constant \quad or \quad p_1v_1 = p_2v_2$$

A balloon is a good example of boyle's law in action. boyle's law applies to low pressure and not at high pressure because gases behave like ideal gas at high pressure. boyle's law is significant because it explains how gases behave.

The relationship between temperature and volume

Charles's law:

charles law states that the volume of an ideal gas is directly proportional to the absolute temperature at constant pressure.

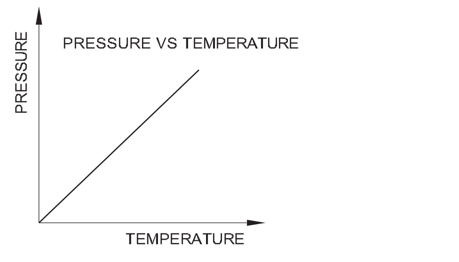
V/T = constant or $V_1/T_1 = V_2/T_2$

Effect of changing temperature on the pressure

The pressure of a given amount of gas is directly proportional to the temperature at a given volume. when the temperature of a system goes up, the pressure also goes up, and vice versa. the relationship between pressure and temperature of a gas is stated by the gay-lussac's law.

P/T= constant or $P_1/T_1 = P_2/T_2$

Fig 8



Piston actuators

Piston actuators Figs 9 & 10 are used when the stroke of a diaphragm actuator would be too short or the thrust is too small. compressed air is applied to a solid piston contained within a solid cylinder. simple designs have the air fed into a central chamber and the air forces the piston upwards. when the air pressure is removed, the shaft moves in the opposite direction due to the reverse force spring. piston actuators can also being double acting, meaning the air can be fed into either side of the piston since there is not a return spring.

Hydraulic actuators

Fig 9

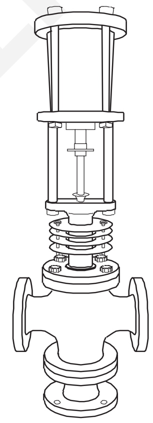
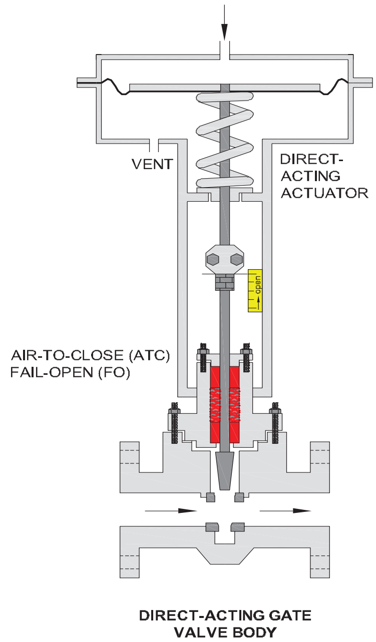


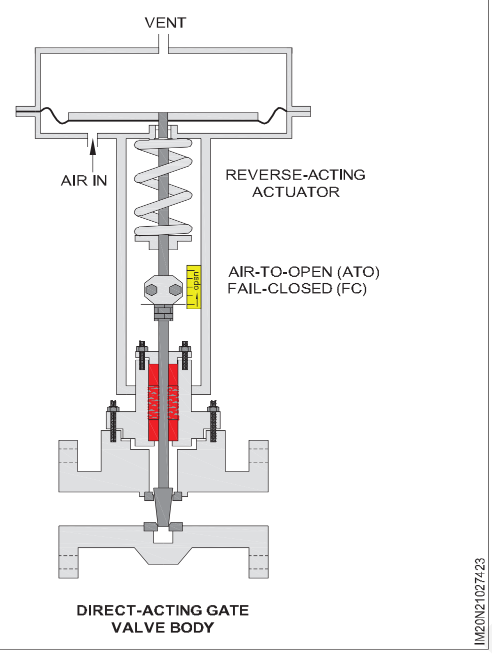
Fig 10



when a large amount of force is required to operate a valve (for example, the main steam system valves), hydraulic actuators are normally used. (Fig 11) A hydraulic actuator consists of a cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation. the mechanical motion gives an output in terms of linear, rotary or oscillatory motion.

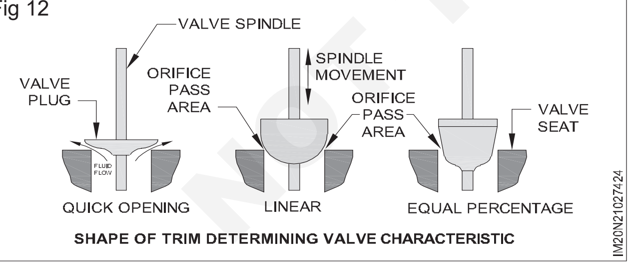
Electric actuators

Fig 11



An electric actuator (Fig 12) is a mechanical device used to convert electricity into kinetic energy in either a single linear or rotary motion. it automates damper or valve in order to increase process efficiency and complexity. to produce an electric linear actuator, the manufacturing process begins with the electric motor. each electric motor consists of two main components which are: stator – a permanent magnet that is stationary; rotor – sits in the center of the stator and is forced to undergo the magnetic field generated by the stator, thereby causing a spin in motion of the rotor.

Fig 12



Load set point compensation: Refers to a technique used in control systems to adjust the set point or reference signal of a controller based on the operating conditions or load changes in the system. The purpose of load set point compensation is to optimize the performance of the control system and improve its ability to respond to varying load conditions.

In many control systems, the set point is a fixed value that represents the desired operating point or target for the controlled variable. However, in some cases, the load on the system may vary due to factors such as changes in production demand, environmental conditions, or other external factors. This can affect the overall system performance and may require adjustments to the set point to achieve the desired control objectives.

Load set point compensation: Can be implemented using various techniques, depending on the specific application and control system design. Some common methods include:

Feedforward control: This technique uses a model or estimation of the load disturbance to predict its effect on the system and adjusts the set point accordingly. By anticipating the load changes, the controller can proactively respond to maintain the desired performance

Adaptive control: In adaptive control systems, the controller continuously updates its parameters or model based on the changing load conditions. This allows the controller to adapt its set point and control strategy to optimize performance under varying load conditions.

Gain scheduling: This approach involves adjusting the controller gains or parameters based on the operating conditions or load changes. By selecting appropriate gains for different load conditions, the controller can maintain stable and responsive control.

Fuzzy logic control: Fuzzy logic controllers use linguistic variables and rules to handle imprecise or uncertain information. Load set point compensation can be achieved by defining fuzzy rules that adjust the set point based on the load conditions or other relevant factors.

These are just a few examples of techniques used for load set point compensation. The specific method chosen depends on the system requirements, available information about load changes, and the desired performance objectives.

Basis of difference	Pneumatic actuator	Electric actuator
Design	The design of a pneumatic actuator is simple.	The design of an electric actuator is complex.
Installation	Industrial valve actuators are easier to install due to their simple design, but the motion profile is hard to change after sizing.	These devices are difficult to install due to their complex design, but the motion profile is easier to change after sizing.

Force & speed	Pneumatic actuators offer more force and speed per unit size than their counter-parts, and adjusting them is easy.	Electric actuators do not allow easy control and regulation of the force and speed in a system.
Stalling	It is easy to stall these actuators.	It is not easy to stall electric actuators during their use or operation.
Resistance to moisture	Pneumatic actuators are insensitive to moisture.	Electric actuators should be kept away from moisture.
component cost	the component costs of pneumatic actuators are low.	the component costs of electric actuators in butterfly valve are high.
operating cost	regardless of the low component costs of pneumatic actuators, their operating costs are pretty high.	the operating costs of an electric actuator are low compared to a pneumatic actuator.
heating	these actuators resist overheating due to their perfect design.	these actuators tend to overheat.
spring return	a pneumatic actuator offers an inexpensive spring return or fail-safe feature.	an electric actuator is not widely available in a spring return or fail-safe version.
torque to weight ratio	pneumatic actuators used in a v ball valve have a high torque-to-weight ratio.	electric actuators have a low torque-to-weight ratio compared to pneumatic actuators.
force	their force depends on the air pressure.	their force depends on the lead or screw pitch.
speed	these can operate in ½ to ¼ second to open or close a metal seated butterfly valve.	these can take up to and exceed two minutes to open or close a valve.
maintenance	the maintenance requirements of a pneumatic actuator are very high.	the maintenance needs of an electric actuator are minimal compared to its counterpart.

Advantages of using an electric actuator

- Low operating cost and minimal noise.
- Flexible motion control
- Slower cycle type than its counterpart.
- It doesn't need compressed air to work.
- It can produce linear and rotatory motion.

Feedback loops:

A feedback loop is the part of a system in which some portion (or all) of the system's output is used as input for future operations. each feedback loop has a minimum of four stages. during the first stage, input is created. during the second stage, input is captured and stored. during the third stage, input is analyzed and during the fourth stage, the insight gained from analysis is used to make decisions. feedback loops are an important aspect of closed loop control systems.

Control variable

A control variable is any variable that's held constant in a research study. it's not a variable of interest in the study, but it's controlled because it could influence the outcomes. since it remains constant, i.e in an unchanging state, it enables researchers and scientists to test and better understand the relationship between other variables.

Disturbance signals

A disturbance signal is commonly found in control systems. disturbance signals represent unwanted inputs which affect the control-system's output, a variable that we have no control over in the process and result in an increase of the system error. it is the job of the control-system engineer to properly design the control system to partially eliminate the affects of disturbances on the output and system error. the effect of disturbance is changing the purpose or reduce the efficiency of the output.

An example is sun shining in on a room cooled by an automatic air conditioner. in spite of the thermostat's efforts to lower the room temperature to a 72°f setpoint, the room may actually get hotter. these uncontrollable influences are known as disturbances.

control signals

Control signals are the output of learning and processing block, which are sent to different output interfaces to produce desired output in the real physical world. these signals can derive various output devices like motors, speakers, and displays etc.

Electrical control signals are usually of small voltage or current values which are unable to effect actuator movement. the most popular form of signal transmission used in modern industrial instrumentation systems is the 4 to 20 milliamp dc standard. this is an analog signal standard, meaning that the electric current is used to proportionately represent measurements or command signals.

Pneumatic signal, which is generated within the pressure-sensing element, usually has a gauge pressure in the range of 3 to 15 psi, covering the plant pressure from zero to maximum.

Control Valves

Objectives: At the end of this exercise you shall be able to
- **explain control valves its functions and components.**
- **explain valve characteristics**
- **explain different types of control valves**
- **explain valve positioners.**

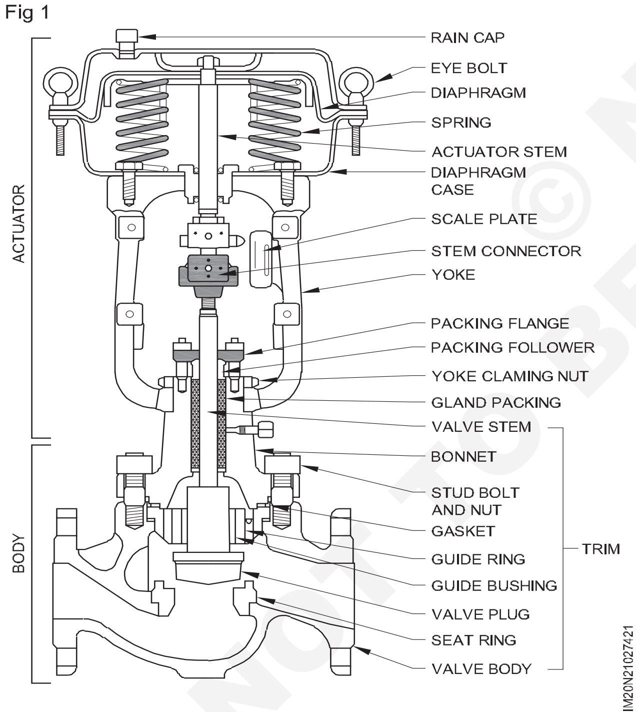
Control valves

The control valve is a critical part of the control loop and is a power operated device. the control valve is by far the most common final control element used in industry today. (Fig 1)

The control valve regulates or manipulates a flowing fluid, such as gas, steam, water, or chemical compounds to compensate for the load disturbance and keeps the regulated process variable as close as possible to the desired set point. control valves are used in many processes to control flow, pressure, temperature or other variables. the type of valve used will depend on the size of the pipe, the overall pressure that the system operates, the flowing media, process conditions, and other factors.

The two classes of control valves are linear motion and rotary motion.

Fig 1



A control valve consists of the following main parts:

body

It is a type of a pressure vessel containing an orifice or an opening. the controlled liquid is allowed to flow through the body of the valve. it helps to monitor the flow regulation behaviour.

Trim

Besides the body, trim is one such part of the valve that comes directly in contact with the fluid. it consists of the seat, disc, plug, and stem.

Actuator

It consists of electric or pneumatic mediums to provide the force required to operate the control valve.

Bonnet

It provides a mounting for the guide and actuator and a medium for the stem to pass through. it is made of the centrepiece, packing, packing nut and guide. the packing acts as a fastener between the bonnet and stem. it helps to avoid any leakage.

Control valves can be operated in different ways

Pneumatic actuated

Pneumatic actuators use an air or gas signal from an external source to produce a modulating control action. the actuator receives the force of the pneumatic signal through a top port. then, it distributes the signal across the actuator's diaphragm. as a result, the diaphragm exerts pressure on the diaphragm plate. this moves the valve stem downward in a way that strokes the control valve.

Electric actuated

They are motor-driven devices. they use an electrical signal that can help create a motor shaft rotation. this movement is converted into a linear motion, which helps to drive the stem in the valve for flow modulation.

Hydraulic actuated

Hydraulic actuators are similar in operation to pneumatic actuators except they use a fluid, hydraulic oil, as the signal fluid to control the action of the valve. they are used, in place of pneumatic or electric actuated valves when the force required to move the valve stem is high.

Control valve can be classified in different ways; based on:

a Action.

b Flow characteristics.

Types of control valves based on action

i Air to close. (Fig 2)

ii Air to open.(Fig 1)

Air-to-close: an increase in air pressure to the actuator is required to cause the valve to close. this is another way of saying the valve is fail open or normally open. air-to-open: an increase in air pressure to the actuator is required to cause the valve to open.

They are designed such that if the air supply fails, the control valve will be either fully open, or fully closed, depending upon the safety requirement of the process.

For example, if the valve is used to control steam or fuel flow, the valve should be shut off completely in case of air failure. on the other hand, if the valve is handling cooling water to a reactor, the flow should be maximum in case of emergency.

Valve flow coefficient (CV)

Valve flow coefficient (CV) is the flow capability of A control valve at fully open conditions relative to the pressure drop across the valve. it is defined as the volume of water (gpm in the us) at 60°f that will flow through a fully open valve with a pressure differential of 1 psi across the valve.

Types of control valves based on flow characteristics

Flow characteristic describes the relationship between the valve coefficient (cv) and the valve stroke. each throttling valve has a flow characteristic. As a valve opens, the flow characteristic allows a certain amount of flow through the valve at a particular percentage of the stroke. flow characteristic allows the valve to control the flow in a predictable manner, which is important when using a throttling valve.

The three most common types of flow characteristics are:

- Equal percentage flow characteristic
- Linear flow characteristic
- Quick open flow characteristic (Fig 3)

Equal percentage flow characteristics

The equal percentage valve characteristic produces the same percentage change in flow per fixed increment of valve stroke at any location on its characteristic curve.

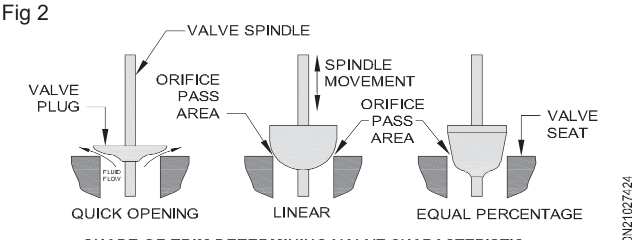
Linear flow characteristics

An inherent flow characteristic that can be represented by a straight line on a rectangular plot of flow coefficient (cv) versus rated travel. therefore equal increments of travel provide equal increments of flow coefficient, CV.

Quick opening flow characteristics

A quick opening valve plug produces a large increase in flow for a small initial change in stem travel. near maximum flow is reached at a relatively low percentage of maximum stem lift. (Fig 4)

Fig 2

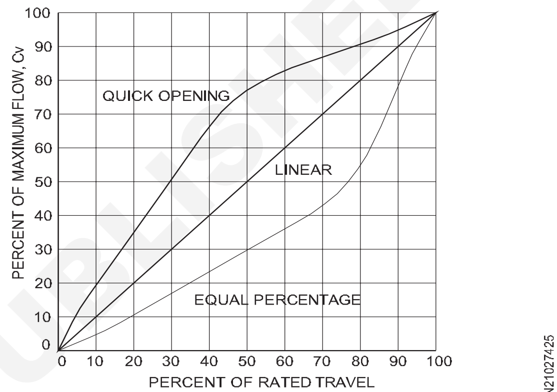


SHAPE OF TRIM DETERMINING VALVE CHARACTERISTIC

Globe valves

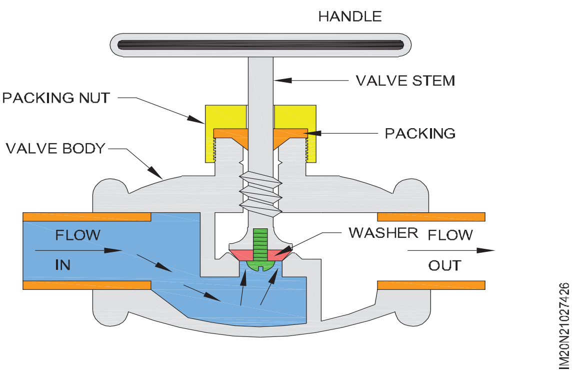
Globe valves, so-called because of their outside shape, are widely used in plant piping. they are suitable for manual and automatic operation. globe valve can be used for regulating flow or pressures as well as complete shutoff of flow. (Figs 3 & 4)

Fig 3



INHERENT CONTROL VALVE CHARACTERISTICS

Fig 4



A globe valve is a common device that performs flow control in a pipe system. the flow capability of the globe valve is estimated by a flow coefficient. to improve the control capability of the globe valve, a cage is utilized to adjust the flow coefficient in the valve. for example, if one feels like decreasing the flow coefficient, then a cage with numerous passageways will be considered rather than replacing a smaller valve and pipe.

A cage is such a device, which can be employed to adjust the flow rate in a globe valve appropriately. the main principle to use a cage is to design passageways in itself. the amount and the distribution of passageways in a cage affect the flow rate in the globe valve.

Best suited control: linear and equal percentage

Recommended uses

1 Throttling service/flow regulation

2 Frequent operation

Applications: liquids, vapours, gases, corrosive substances, slurries

Advantages

1 Efficient throttling

2 Accurate flow control

3 Available in multiple ports

Disadvantages

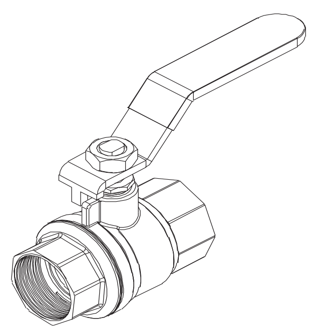
1 High pressure drop

2 More expensive

Ball valves

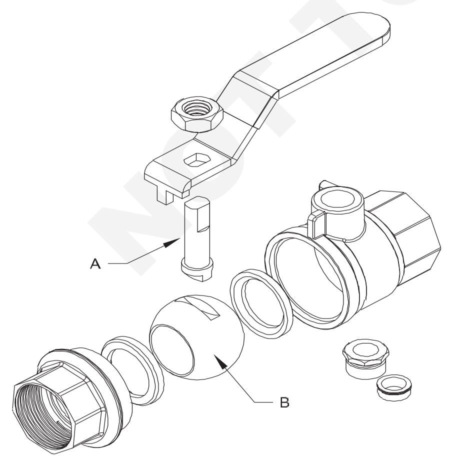
A ball valve is a shut off valve that controls the flow of a liquid or gas by means of a rotary ball having a bore. by rotating the ball a quarter turn (90 degrees) around its axis, the medium can flow through or is blocked. they are characterized by a long service life and provide a reliable sealing over the life span, even when the valve is not in use for a long time. (Figs 5&6)

Fig 5



BALL VALVE

Fig 6



BALL VALVE

Best suited control : Quick opening, linear

Recommended uses

1 Fully open/closed, limited-throttling

2 Higher temperature fluids

applications : most liquids, high temperatures, slurries

Advantages

1 low cost

2 high capacity

3 low leakage and maint.

4 Tight sealing with low torque

Disadvantages

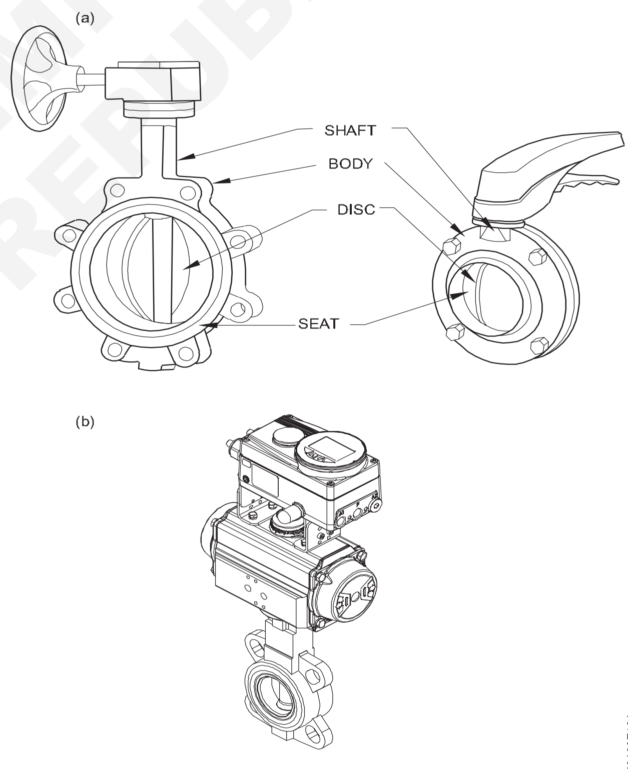
1 Poor throttling characteristics

2 Prone to cavitation

Butterfly valves

Butterfly valves are a family of quarter-turn rotational motion valves that are used in pipelines to shut-off flow. it is often said that butterfly valves can be used to regulate the flow. (Fig 7)

Fig 7



BUTTERFLY VALVES

Best suited control: linear, equal percentage

Recommended uses

1 Fully open/closed or throttling services

2 Frequent operation

3 Minimal fluid trapping in line

Applications: liquids, gases, slurries, liquids with suspended solids

Advantages

1 low cost and maint.

2 high capacity for control

3 good flow control

4 low pressure drop at lower flows

Disadvantages

1 High torque required

2 Prone to cavitation

Slide gate valves

Slide gate valve is an equipment that fits into a system which are specifically designed for handling dry bulk powders, pellets, and granules etc. slide gate valves shut-off of material or air stream in linear motion in which a flat plate slides into the flow stream. the gate can be closed or can open the slide plate on a moving column of material relentlessly (without any stoppage). (Fig 8)

sliding gate valve reduces turbulence and leads to quieter operation, reduced wear, longer seat life, short stroke, fast response, tight shut off and better control. the sliding gate seat set is perpendicular to the flow, unlike the traditional globe style design. with straight through flow, the turbulence is reduced and superior trim life is achieved. due to the short stroke length, a sliding gate valve is typically smaller and lighter weight. the short stroke reduces packing wear and lengthens the diaphragm life.

Diaphragm valves

Diaphragm valves are bi-directional, on-off throttle valves. they are used to control fluid flow by regulating the area with which media can enter and exit the valve, effectively changing its speed and velocity. they are so-called "diaphragm" valves because a thin, flexible membrane is used to control the opening and closing of the valve. they can be made with metal such as stainless steel, plastic, and even single-use materials. (Fig 9)

Fig 8

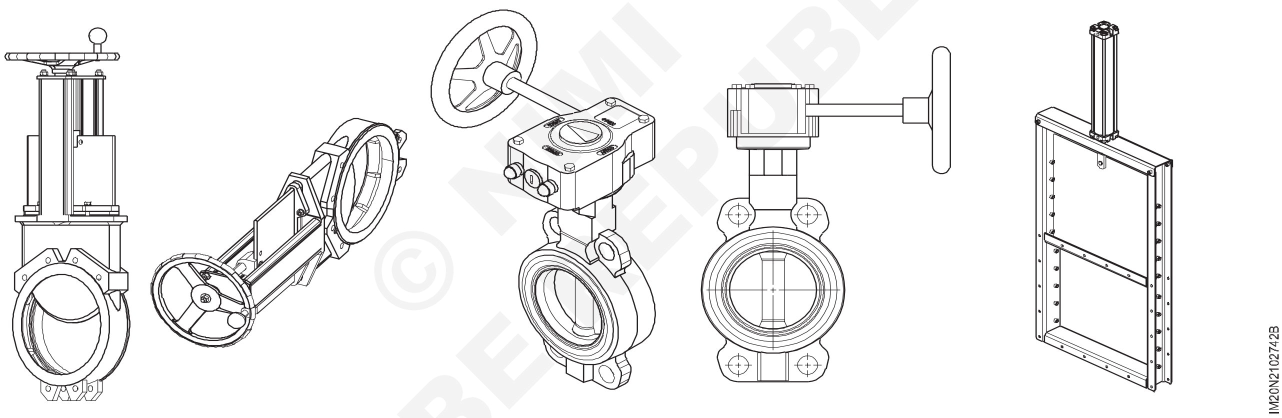
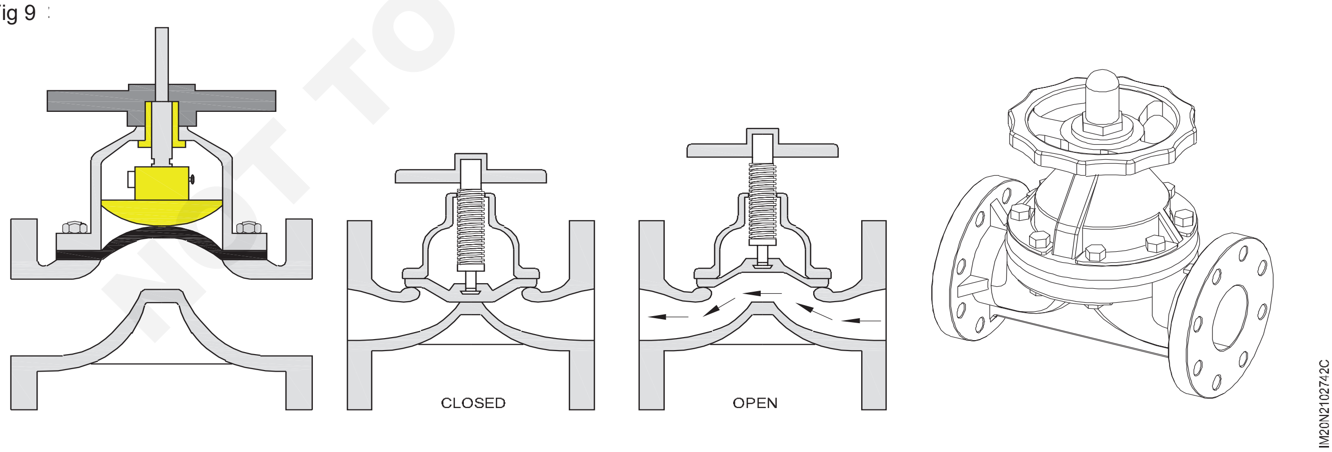


Fig 9

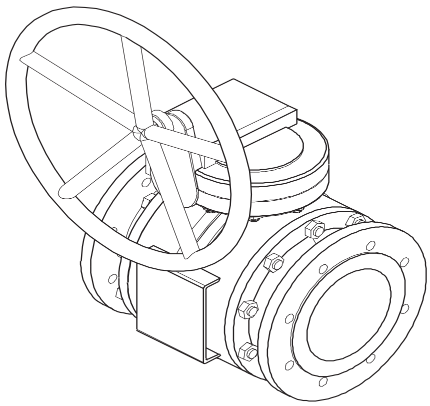


Their operation is not unlike controlling the flow of water through a flexible hose by pinching the hose. These valves are well suited for flows containing solid particulate matter such as slurries, although precise throttling may be difficult to achieve due to the elasticity of the diaphragm.

Split body valves

A split-body ball valve is a type of mechanical valve used to control the flow of liquid or gas in a pipe. it comprises two separate pieces—the body and the ball—joined together by a stem. when the stem is turned, the ball either blocks or allows the flow of liquid or gas to pass through the pipe.(Fig 10)

Fig 10



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Split-body ball valves are one of the most widely used in industrial applications and are incredibly versatile. they offer several levels of automation for various uses, such as controlling pressure, water flow, and temperature. due to their unique design that allows them to be split into separate bodies, installing or repairing these valves is much easier than traditional ball valve types.

Split-body ball valves are commonly used in many industries, including oil & gas production, water treatment plants, chemical processing facilities, food & beverage processing plants, pulp & paper mills, and more! these valves are so popular because they are reliable and easy to operate due to their simple design.

Check valve

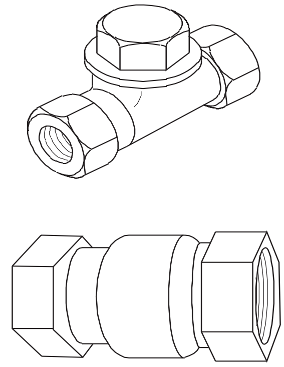
Another type of valve commonly used in conjunction with other valves is called a check valve. check valves are automatic valves that open with forward flow and close against reverse flow. they are also known as non-return valves. check valves are designed to restrict the flow to one direction. check valves are generally installed in pipelines to prevent backflow. (Fig 11)

A check valve is basically a one-way valve, in which the flow can run freely one way, but if the flow turns, the valve will close to protect the piping, other valves, pumps etc. if the flow reverses direction, the check valve closes. most common types of check valves are swing, lift (piston and ball), butterfly, stop and tilting-disk.

Fig 11

(a)

(b)



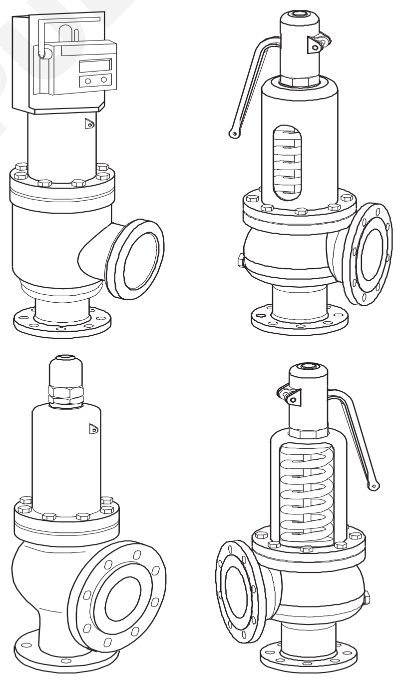
BRASS VERTICAL CHECK VALVE

IM20N2102742E

Relief valves

Relief valves are used to regulate the operating pressure of incompressible flow.(Fig 12) A relief valve or pressure relief valve (prv) is a type of safety valve used to control or limit the pressure in a system; excessive pressure might otherwise build up and create a process upset, instrument or equipment failure, explosion, or fire. to prevent major damage to equipment, and more importantly, injury to workers, relief valves can release elevated pressures before they become extreme.

Fig 12



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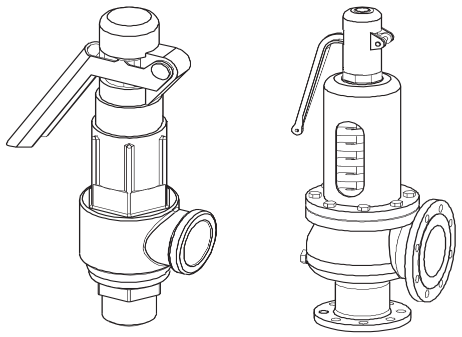
Safety valves

Safety valves are used to release excess pressure in gases or compressible fluids. the function of the safety valve is to protect life and property against failure to control system pressures, ie it offers the last means of reducing system pressure before total failure. (Fig 13)

In steam systems, safety valves are typically used for boiler overpressure protection and other applications such as downstream of pressure reducing controls. although their primary role is for safety, safety valves

Fig 13



are also used in process operations to prevent product damage due to excess pressure.

Selecting a valve type

When speaking of valves, it’s easy to get lost in the terminology.   valve types are used to describe the mechanical characteristics and geometry (ex/ gate, ball, globe valves). we’ll use valve control to refer to how the valve travel or stroke (openness) relates to the flow:

1 **Equal percentage:** equal increments of valve travel produce an equal percentage in flow change

2 **Linear:** valve travel is directly proportional to the valve stoke

3 **Quick opening:** large increase in flow with a small change in valve stroke

So how do you decide which valve control to use? here are some rules of thumb for each one:

1 Equal percentage valves

Equal percent (=%) valves are used on heat transfer processes because in case of heat transfer (temperature control), when the heat load is low, the heat transfer surface area available to transfer that heat (load) is large. on steam systems, equal percentage valves will usually be a better choice than linear valves, because if low pressure drops occur, they will have less of an affect on their performance over the complete range of valve movement.

a Used in processes where large changes in pressure drop are expected

b Used in processes where a small percentage of the total pressure drop is Permitted by the valve

c Used in temperature and pressure control loops

2 Linear

linear valves are used for water systems whilst steam systems tend to operate better with equal percentage valves. these valves are often used for liquid level control and certain flow control operations requiring constant gain.

a Used in liquid level or flow loops

b Used in systems where the pressure drop across the valve is expected to remain fairly constant (ie. steady state systems)

c used when the pressure drop across the valve is a large proportion of the total pressure drop.

3 Quick opening

These valves are normally utilized in two position “on-off” applications but may be used in some linear valve applications.

a Used for frequent on-off service

b Used for processes where “instantly” large flow is needed (ie. safety systems or cooling water systems)

eg: gate valves

Best suited control: quick opening

Recommended uses:

1 Fully open/closed, non-throttling

2 Infrequent operation

3 Minimal fluid trapping in line

Applications: oil, gas, air, slurries, heavy liquids, steam, non condensing gases, and corrosive liquids

optimizing control valve efficiency depends on

1 Correct control valve selection for the application,

2 Proper storage and protection,

3 Proper installation techniques, and

4 An effective predictive maintenance program.

Be sure the pipeline is clean

Foreign material in the pipeline could damage the seating surface of the valve or obstruct the movement of the valve plug, ball, or disk so that the valve does not shut off properly.

1 Clean all pipelines before installing.

2 Make sure pipe scale, metal chips, welding slag, and other foreign materials are removed.

3 Inspect pipe flanges to ensure a smooth gasket surface.

Inspect the control valve

Although valve manufacturers take steps to prevent shipment damage, such damage is possible and should be discovered and reported before the valve is installed.

1 Do not install a control valve known to have been damaged in shipment or while in storage.

2 Before installing, check for and remove all shipping stops and protective plugs or gasket surface covers.

3 Check inside the valve body to make sure no foreign objects are present.

use good piping practices

1 Most control valves can be installed in any position. however, the most common method is with the actuator vertical and above the valve body.

2 If horizontal actuator mounting is necessary, consider additional vertical support for the actuator.

3 Be sure the body is installed so that fluid flow will be in the direction indicated by the flow arrow

4 Be sure to allow ample space above and below the valve to permit easy removal of the actuator or valve plug for inspection and maintenance.

5 Be sure the flanges are properly aligned to provide uniform contact of the gasket surfaces. snug up the bolts gently after establishing proper flange alignment.

6 Tighten bolts in a criss-cross pattern to prevent leaks and to avoid the possibility of damaging, or even breaking, the flange.

Gland packing maintenance steps

1 Provides the pressure seal around the stem, should be replaced if leakage develops, or if the valve is completely disassembled for other maintenance or inspection.

2 Before loosening packing nuts, make sure there is no pressure in the valve body.

3 Blow out the old packing rings by applying pressure to the lubricator hole in the bonnet.

4 Clean the packing box. inspect the stem for scratches or imperfections that could damage new packing.

5 Check the trim and other parts as appropriate. after re-assembling, tighten body/bonnet bolting in a sequence similar to that for flanges.

6 Slide new packing parts over the stem in proper sequence, being careful that the stem threads do not damage the packing rings.

Valve Positioners are most commonly used to move a control valve to a specified position so that a process meets specific parameters (flow, pressure, temperature). a valve positioner is a device mounted on the actuator that exerts or reduces air pressure as necessary to make sure the valve achieves the correct position. when there is no positioner, the control signal goes directly to the actuator.

Valve positioners supply compressed air to the actuator (a mechanical part of the valve), detect the valve travel from the position of the valve stem, and adjust the air pressure to keep the proper travel as commanded by the control signals, which are generated using feedback control. stability of the control valve is very much improved by using valve positioners since it having the feedback, speed of response will be improved, for split range control systems , positioner must needed in control valves for calibrating the control valve (0 to 100 %) for 3-9 psi and 9-15 psi ranges. a positioner may be used as a signal amplifier or booster also.

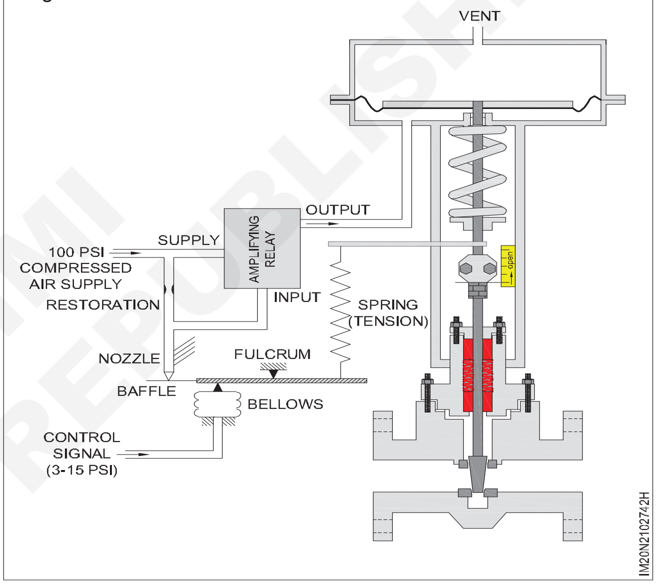
A positioner ensures that there is a linear relationship between the signal input pressure from the control system and the position of the control valve.this means that for a given input signal, the valve will always attempt to maintain the same position regardless of changes in valve differential pressure stem friction, diaphragm hysteresis and so on.

Positioners are of different types

Pneumatic positioners

The pneumatic valve positioner is an instrument used for positioning the control valve stem in accordance with the pneumatic signal of 3-15 psi received from a controller.it receive a control signal and translates that into the appropriate pneumatic output signal to the control valve actuator. The pneumatic valve positioner works on the principle of force balance principle. (Fig 14)

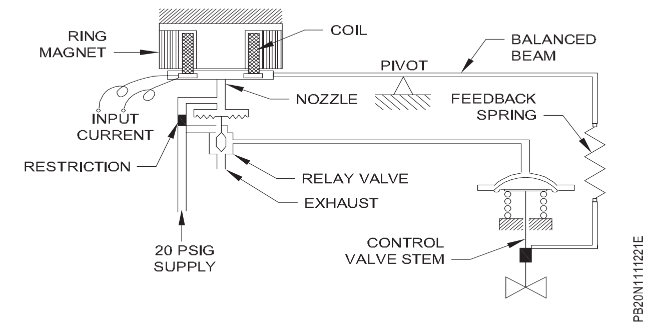
Fig 14



Electro pneumatic positioners

Electro pneumatic positioners (Fig 15) are conventional pneumatic positioners that have an additional integrated electro-pneumatic transducer. these valve positioners convert a 4-20mA input control signal to a proportional pneumatic output. the only difference between the two above positioners is that the electro pneumatic positioner is equipped with an i/p converter.

Fig 15



Positioners used in split range control system (Figs 16 & 17)

Fig 16

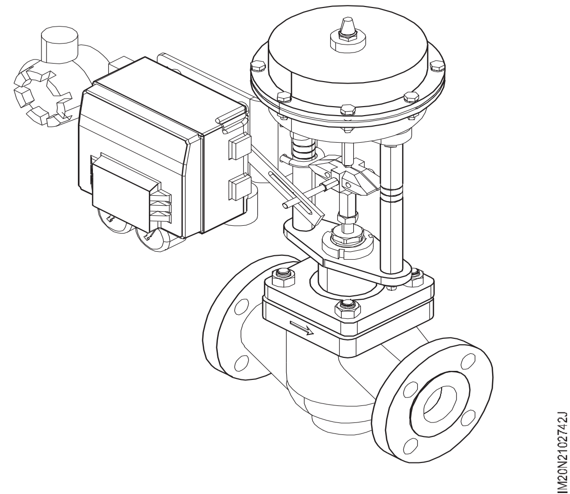
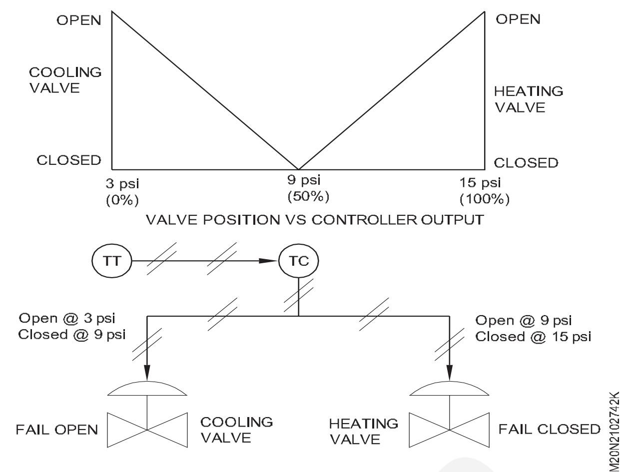


Fig 17



Control elements and applications

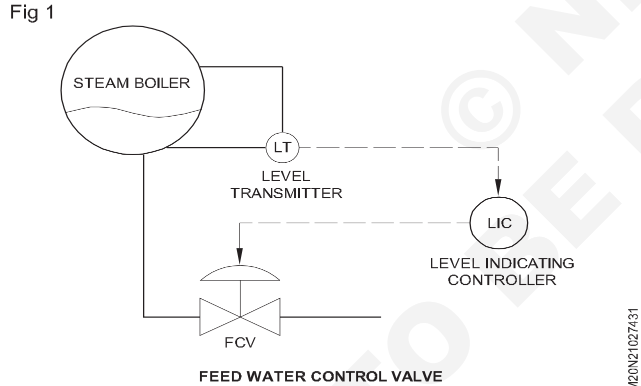
Objectives: At the end of this exercise you shall be able to

- **explain feedwater control system in boiler**
- **explain turbine control system**
- **explain limit switches and proximity sensors.**

Control elements applications

Feed water control system works in boiler

Fig 1



FEED WATER CONTROL VALVE

In this configuration, only the water level in the drum is being measured(hence the term" single element"). It is an electronic differential pressure transmitter with a high static pressure range. the high side of the transmitter is connected to the bottom of the drum. because of the drum's static pressure, the low side of the transmitter is connected to the top of the drum above the water/steam interface. this provides a reference for the transmitter by cancelling the static pressure effect and allowing only the water hydrostatic head to be measured.

The output of the electronic dp transmitter is the process input for the controller, lic and the output is then compared to a drum level set-point. any discrepancy between set-point and drum level causes an output from the controller in compensation.

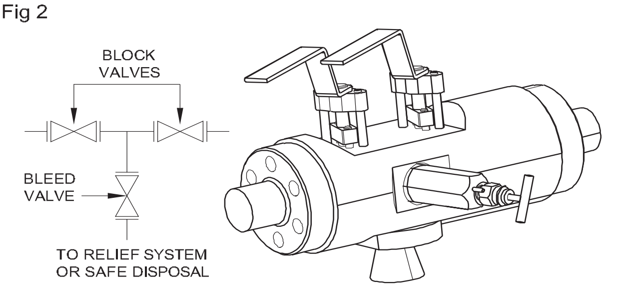
Because controller action is reverse, as the drum level increases, a resultant output signal will decrease to close the feedwater control valve. the output of the controller is fed to the feedwater control valve, fcv. if the feedwater valve is pneumatic, an Ip (current-to-pressure) converter is required to change the controller current output to accommodate the pneumatic valve.

Block valves

A block valve is another name for a shutoff valve. (Fig 2) a block valve stops the flow or changes the direction of the product from a storage tank to a dispensing point. block valves also called shutoff valves are flow control mechanisms put on storage tanks, and storage tank pipelines to stop the flow of fluid.

Block valves permit fluids to pass through with minimum flow restriction and pressure loss when fully open and yet provide a tight seal when fully closed. types of valves used in such service include gate valves, ball valves, and plug valves. typically, a block valve can be locked in either the open or closed position to prevent tampering.

Fig 2



DOUBLE BLOCK & BLEED VALVE

Sequential control systems

A control system in which the individual steps are processed in a predetermined order, progression from one sequence step to the next being dependent on defined conditions being satisfied. such a system may be time-dependent, in which the step transition conditions are functions of time only.

An example of sequential control is the car wash described above, which works after throwing money and pressing a button, thanks to which the car is washed with water and detergent and then polished.

Logic controllers are used to controls the operations in sequential control systems. logic controllers are implemented using relays and timers. a sequential motor control circuit is a circuit that controls the motors to operate in sequence. one motor cannot start until some other motor is running. for example, sequential control is used by machines such as hydraulic presses. the pressure pump operates before the hydraulic valves can be used.

Relay logics in process control

Relay logic is a method of implementing combinational logic in electrical control circuits by using several electrical relays wired in a particular configuration. he schematic diagrams for relay logic circuits are often called line diagrams, because the inputs and outputs are essentially drawn in a series of lines.

A relay logic circuit is an electrical network consisting of lines, or rungs, in which each line or rung must have continuity to enable the output device.

Relay logic basically consists of relays wired up in a particular fashion to perform the desired switching operations. the circuit incorporates relays along with other components such as switches, motors, timers, actuators, contactors etc. the relay logic control works efficiently to perform basic on/off operations by opening or closing the relay contacts but it involves a humongous wiring.

Automatic valve control

automatic control valves are specialty valves fitted with actuators that can be controlled by temperature or flow sensors. the valves are controlled by electrical, hydraulic, or pneumatic signals from sensors. the valves can be set to open, closed, or anywhere in between to accurately control flow. uses include water treatment plants, multi-story buildings, water storage towers, and reclaimed water systems.

Turbine control system

the turbine control system describes the control over the opening of control valves corresponding to demand signals, and steam flows into the turbine with the help of a governing system that facilitates the operation of the turbo set in an interconnected grid system.

The turbine control system is broadly classified into two systems namely,

1 safety control system

2 process control system

The purpose of the safety control system is to take care of the safety of workers and machinery equipment. this safety control system is intended to eliminate or minimize the activities that cause serious damage to the equipment and to persons working in the power plant.

Safety control system

- In the turbine safety control system, the shutoff valve works as the master safety element.
- This shutoff valve is operated by a solenoid for quick operation.
- Safety interlocks provided for safety issues must satisfy safe operating conditions during turbine start-up.
- The shutoff valve is now opened and steam is allowed to pass through the governor to the turbine in the proper way.
- The shutoff valve may get closed for the emergency condition that appears during normal turbine operation.
- High bearing temperatures, lube oil failure, over speed, high vibration, and high displacement are the causes of the shutoff valve needing to be closed.
- The figure above shows the overall safety monitoring system of a steam turbine.
- The turbine safety control system includes various measurements.

Whereas process control system monitors the process operations as per the application requirement.

Process control systems

- In a power station, the steam turbine must be operated as per application requirements.
- The turbine must respond to the electrical load fluctuations.
- An increase in the electrical load of the alternator makes the coupled turbine decelerate.
- At this time, the process control system allows more steam to compensate and allows the turbine to run at the required speed.
- The decrease in load will have the reverse action.

Throttle valves

A throttling valve is a type of valve that can start, stop, and regulate the flow of fluid from one point to another. in general, there will be a high-pressure difference between the upstream and downstream sides of the throttle valve. the pressure drop increases with the increase in flow restriction inside the throttling valve. A range of control methods is used for controlling these types of valves. different valves can work as throttling valves in different working conditions.

Throttling valves are valves used for opening, closing, or regulating a fluid flow. they are basically regulating valves as the discs of the throttling valves can regulate the flow, temperature, or pressure of the flow medium passing through it.

Examples of a throttling valve

Different valves can work as throttling valves. some common examples of valves working as a throttling valves are:

- diaphragm valve
- butterfly valve
- ball valve
- globe valve
- pinch valve
- needle valve, etc

Governor in steam turbine

Governor is the device used to control the speed in engines. a steam turbine governor is a component of the turbine control system that regulates rotational speed in response to changing load conditions. the governor output signal manipulates the position of a steam inlet valve or nozzles which in turn regulates the steam flow to the turbine.

Internal parts of control valve

The internal elements of a valve are collectively referred to as a valve's trim. it consists of the seat, disc, plug, and stem. it consists of electric or pneumatic mediums to provide the force required to operate the control valve. it provides a mounting for the guide and actuator and a medium for the stem to pass through. it is made of the centrepiece, packing, packing nut and guide.

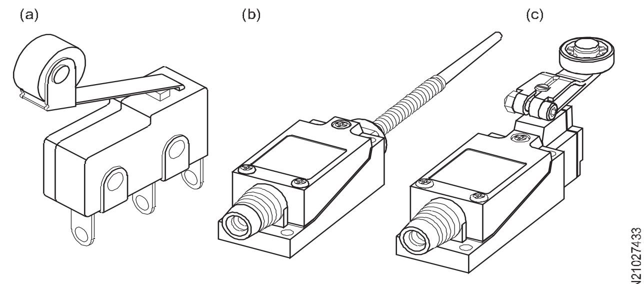
A valve's performance is determined by the disk and seat interface and the relation of the disk position to the seat.

Limit switch / micro switch (Fig 3)

Mechanical limit switches are Fig a,b,c contact sensing devices widely used for detecting the presence or position of objects in industrial applications. alimit switch is a switch operated by the motion of a machine part or the presence of an object. a limit switch can be used for controlling machinery as part of a control system, as a safety interlock, or as a counter enumerating objects passing a point.

You can integrate a limit switch into a wide range of electromechanical applications ranging from residential garage doors to material handling in warehousing and distribution.

Fig 3



LIMIT SWITCH / MICRO SWITCH

Proximity Sensor

A proximity sensor is a device that can detect or sense the approach or presence of nearby objects and for this it does not need physical contact. there are different kinds of proximity sensors.

A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal.

The object being sensed is often referred to as the proximity sensor's target. different proximity sensor targets demand different sensors.

Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object.

Proximity sensors are suitable for use in environments where the temperature fluctuates, or extreme temperatures are commonplace. although temperature compatibility will depend on the specific model, as a general rule, proximity sensors can be used in temperatures ranging from -50°c to 100° celsius.

They can also be used in environments where oil or water is used, giving them a firm advantage over alternative methods of detection.

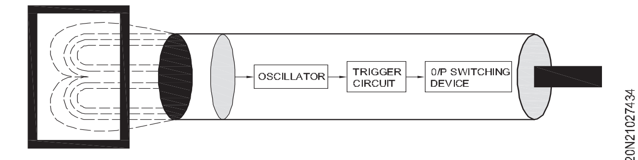
Proximity sensors can be used in a range of environments and for many different applications. they are beneficial to any application where it is necessary to detect an object in a defined range. this could include

- Transportation, logistics, and supply chain
- Inspection and quality assurance
- process control
- Level detection
- Food processing and manufacturing
- Agriculture

capacitive proximity sensor

It works on the principle of varying capacitance. so as the capacitance changes corresponding output signal generated also changes. capacitive proximity sensors work by detecting changes in capacitance between the sensor and an object. factors such as distance and the size of the object will affect the amount of capacitance. the sensor simply detects any changes in capacity generated between the two. (Fig 4)

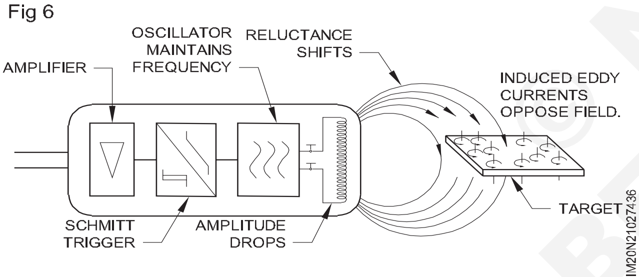
Fig 4



Capacitive proximity sensors are sensing device designed to detect both metallic and nonmetallic targets. they can detect lightweight or small objects that cannot be detected by mechanical limit switches.

The sensor coonsists of an oscillator, trigger circuit and output switching device. (Fig 5) as the target enters the electric field generated by the sensor, the electric field generated gets obstructed by the target resulting in a change in capacitance which results in change in amplitude of the oscillator circuit. when the target moves further from the sensor the amplitude of the oscillation decreases and when the target comes close amplitude increases . this change triggers the trigger circuit resulting in a change in the output of the sensor and thus glowing the output sensor led, with a voltage pulse of positive or negative.

Fig 6



Capacitive proximity sensors can detect media such as water, resin,plastic, rubber, paper, and metal, dependent on the dielectric constant of the object.

It should also be noted that capacitive sensors can be affected by their environment and possible interaction with other sensors.

Advantages of capacitive proximity sensors

- Contactless detection.
- A wide array of materials can detect.
- Able to detect objects through non-metallic walls with its wide sensitivity band.
- Well-suited to be used in an industrial environment.
- Contains potentiometer that allows users to adjust sensor sensitivity, such that only wanted objects will be sensed.
- No moving parts, ensuring a longer service life.

Disadvantages of capacitive proximity sensors

- Relative low range, though incremental increase from inductive sensors
- Higher price as compared to inductive sensors

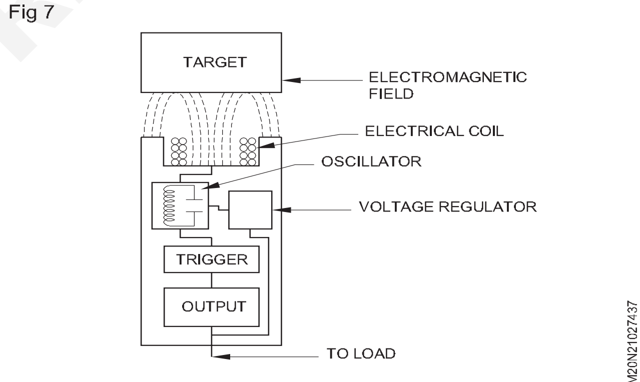
capacitive sensing technology uses in other sensing technologies such as:

- Flow
- Pressure
- Liquid level
- Spacing
- Thickness
- Ice detection
- Shaft angle or linear position
- Dimmer switches
- Key switches
- X-Y tablet
- Accelerometers

Inductive priximity sensor

Inductive proximity sensors are used for non-contact detection of metallic objects.inductive sensors work by detecting eddy currents causing magnetic loss, generated by external magnetic fields on a conductive surface. the detection coil generates an ac magnetic field, and impedance changes are detected as a result of generated eddy currents. (Fig 7)

Fig 7

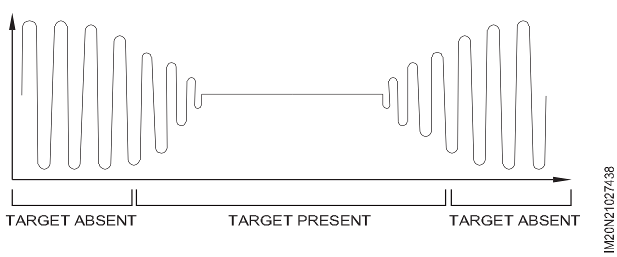


The oscillator creates a symmetrical, oscillating magnetic field that radiates from the ferrite core and coil array at the sensing face. when a ferrous target enters this magnetic field, small independent electrical currents (eddy currents) which are induced on the metal's surface.

An inductive proximity sensor has the frequency range from 10 to 20 hz in ac, or 500 hz to 5 khz in dc. because of magnetic field limitations, inductive sensors have a relatively narrow sensing range like from fractions of millimetres to 60 mm on an average.

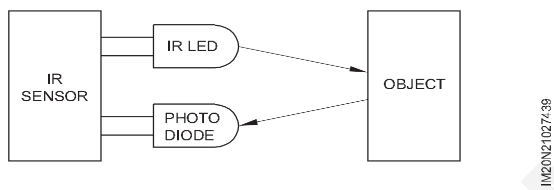
Due to this, load will be caused on the sensor that decreases the electromagnetic field amplitude. If the metal object moves towards the proximity sensor, the eddy current will increase accordingly. thus, the load on the oscillator will increase, which decreases the field amplitude.(Fig 8)

Fig 8



The schmitt trigger block monitors the amplitude of the oscillator and at particular level (predetermined level) the trigger circuit switches on or off the sensor. if the metal object or target is moved away from the proximity sensor, then the amplitude of the oscillator will increase. (Fig 9)

Fig 9



The above image shows the waveform of the inductive proximity sensor oscillator in the presence of the target and in the absence of the target.

Nowadays, inductive proximity sensors are available with different operating voltages. these inductive proximity sensors are available in ac, dc, and ac/dc modes (universal modes). the operating range of the proximity sensor circuits is from 10v to 320v dc and 20v to 265v ac.

Advantages of inductive proximity sensors

- Contactless detection
- Environment adaptability- resistant to common conditions seen in industrial areas such as dust and dirt
- Capable and versatile in metal sensing
- High switching rate
- No moving parts, ensuring a longer service life

Disadvantages of inductive proximity sensors

- Lack in detection range, averaging a max range of up to 60 mm
- Can only detect metal objects
- External conditions like extreme temperatures, cutting fluids or chemical affects on the performance of the sensor.

Applications of inductive proximity sensors

- Machine tolls, assembly line, automotive industry
- Detection of metal parts in harsh environments
- High speed moving parts

The difference between inductive and capacitive proximity sensor:

Inductive sensors use a magnetic field to detect objects. capacitive sensors use an electric field. in order to be sense by an inductive sensor an object must be conductive. this limits suitable targets to metal objects (for the most part). in order to be sense by a capacitive sensor the target doesn't need to be conductive.

A capacitive sensor will react to an object acting as a dielectric material as well as a conductive object. this makes metal and non-metal objects suitable targets.

IR sensor

IR sensor is an electronic device, that emits the light in order to sense some object of the surroundings. an ir sensor can measure the heat of an object as well as detects the motion. usually, in the infrared spectrum, all the objects radiate some form of thermal radiation. these types of radiations are invisible to our eyes, but infrared sensor can detect these radiations. (Fig 4)

The emitter is simply an IR led (light emitting diode) and the detector is simply an IR photodiode. Photodiode is sensitive to IR light of the same wavelength which is emitted by the IR led. when IR light falls on the photodiode, the resistances and the output voltages will change in proportion to the magnitude of the IR light received.

There are five basic elements used in a typical infrared detection system: an infrared source, a transmission medium, optical component, infrared detectors or receivers and signal processing. infrared lasers and infrared led's of specific wavelength used as infrared sources.

The emitter is an IR led and the detector is an IR photodiode. the IR photodiode is sensitive to the IR light emitted by an IR led. the photo-diode's resistance and output voltage change in proportion to the IR light received. this is the underlying working principle of the IR sensor.

When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the ir receiver. based on the intensity of the reception by the ir receiver, the output of the sensor defines.

Applications of IR sensor

- Night vision devices
- Radiation thermometers
- Infrared tracking
- IR imaging devices

Controllers

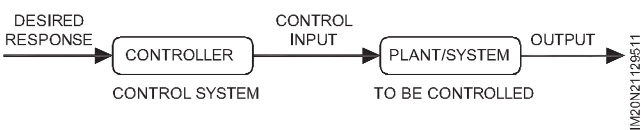
Objectives: At the end of this exercise you shall be able to
- **understand the controller parameters**.

Introduction to Controllers

A controller is a device that receives data from a measurement instrument, compares that data to a programmed setpoint, and, if necessary, signais a control element to take corrective action.

A system is a collection of things that are put together with the intention to perform a specific task. A control system is a mechanism that directs the input it receives through the systems and regulates their outputoutput. (Fig 1)

Fig 1



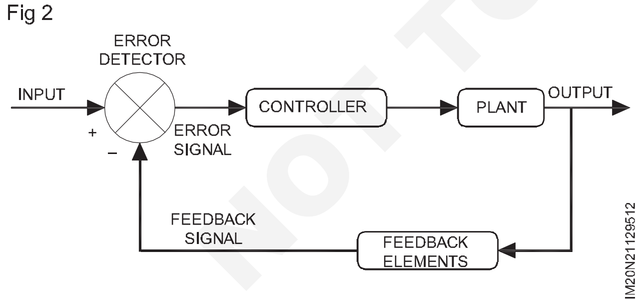
Process control refers to the methods that are used to control process variables when manufacturing a product. For example, factors such as the proportion of one ingredient to another, the temperature of the materials, how well the ingredients are mixed, and the pressure under which the materials are held can significantly impact the quality of an end product.

Manufacturers control the production process for three reasons:

- Reduce variability
- Increase efficiency
- Ensure safety

Basic block diagram of control system (Fig 2)

Fig 2



Plant or Process:

Plant or process is an important element of process control system in which variable of process is to be controlled The Process means some manufacturing sequence. It has one variable or multivariable output.

Feedback element or Sensor:

The feedback element or sensor is the device which converts the output variable into another suitable variable whi can acceptable by error detector.

Error detector

The error detector compares between actual signal and reference input i.e. set point.The error detector is subtract summing points whose output is an error signal to controller for comparison and for the corrective action.

Automatic controller

The controller detects the actuating error signal, which is usually at a very low power level, and amplifies it to a sufficiently high level Le means automatic controller comprises an error detector and amplifier.

Actuator or control element

The actuator is nothing but pneumatic or valve, a hydraulic motor or an electric motor, which produces an input to the plant according to the control signal getting from controller

Advantages of process control systems

1 Process control improves safety

No one wants an unsafe situation, but overengineering safety can put a company out of business almost as fast as major violation functional operations/process automation reduces the risk of injury at the operational level by removing workers from dangerous work procedures. Emergency response automated systems typically respond faster to emergencies by providing real-time monitoring

Smart safety devices provide better visibility into operations and help users understand process states, environment conditions, and other factors that affect safety and productivity

2 Reduce overhead costs and unplanned downtime

Technological advancements and industry-standard best practices will streamline operator training, reduce labor force requirements, and make process support systems and utilities more efficient. Process control system reduce the expenses, but it will also improve unplanned downtime by empowering the operators with actionable data to troubleshoot issues without needing a programmer

3 Increased production quality and capacity

with properly tuned control loops, the process becomes more efficient and produces higher-quality products with greater consistency Intelligent process controls can also deflect and correct process inefficiencies before they become issues, resulting in less operator

Interaction Also, with the right technologies and strategies implemented on the process control systern, we can able to startup the system faster when we have planned downtime for maintenance activities

4 Increased process visibility

A good process control system not only gives operators actionable data, but it will also give management actionable

data through focused and customizable reporting that can be made available anytime, anywhere. Whether that's on

our cell phone when we are out of the office or on our computer at the plant.

5 Planning and execution

Time and time again, we see our customers focus so much on execution that they miss opportunities such as a chance to upgrade their planning Efficient process control resulting in improved project execution as well as improved system performance

Process variable:

Instruments are used to monitor and control a process to keep the process within a correct limit. The parameters or quantities that we wish to control at the correct limit are called Process Variables.

A variable is something that can vary or change Because process variables can and do change, instrumentation

systems measure the variable then control the variable to keep the variable within the given limits

Set point:

The value for a process variable that is desired to be maintained is called set point or desired or target value.

Analog controllers and digital controllers

Objectives: At the end of this exercise you shall be able to
- **understand about analog and digital controllers**
- **understand types of controllers.**

Analog controllers:

Analog controllers can be implemented using analog components or approximated with digital controllers using standard analog to-digital transformations With analog control systems all the signals are analogs, ie a scaled version, of the quantities they represent In analog control system the controler is made up of resistors, capacitors, operational amplifiers, etc. Examples of analog controls speed control, positioning control, torque control, voltage control, etc.

Digital controllers:

Digital devices operate under software and can be altered with select keystrokes Digital control systems deals only with discrete signals, that is o's and 1's Noise, interference and distortion is comparatively less in case of digital control systems Digital circuits have high degree of flexibility.

Digital control systems are easily realisable using logic programs and use limited storage space Also, it takes considerable effort and cost to edit the analog control algorithms, with change of components However, digital controllers are easily reprogrammed without any additional cost.

Also digital circuits are easy to design since automation technique can be applied at vanous levels of circuit design. This involves minimum human interaction The available man power to design digital circuits is significantly large compared to that of analog circuit designers

Types of controllers

The actions of controllers can be divided into groups based upon the functions of their control mechanism. Each ty of controller has advantages and disadvantages and will meet the needs of different applications

Grouped by control mechanism function, the three types of controllers are

- Discrete controllers
- Multistep controllers
- Continuous controllers

Discrete controllers or ON-OFF Controllers (Fig 1)

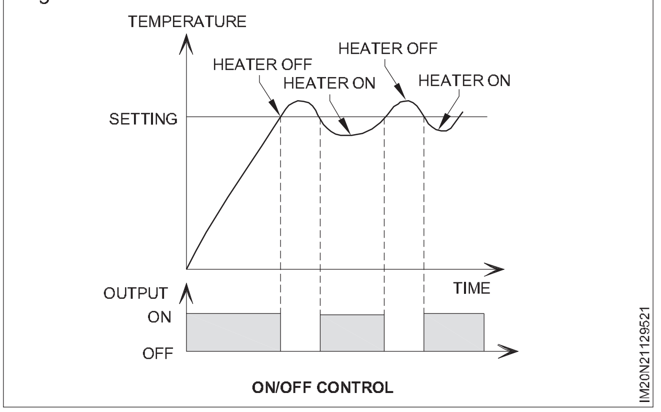
On-Off control is the simplest form of feedback control. An on-off controller simply drives the manipulated variable from fully closed to fully open depending on the position of the controlled variable relative to the setpoint.

A common example of on-off control is the temperature control in a domestic heating system. When the temperature is below the thermostat setpoint the heating system is switched on and when the temperature is above the setpoint the heating switches off

This type of control doesn't actually hold the variable at setpoint, but keeps the variable within proximity of setpoint in what is known as a dead zone.

- Control signal is either 0% or 100%.
- Control at setpoint not achievable, a deadband must be incorporated.

Fig 1



- Useful for large, sluggish systems particularly those incorporating electric heaters

On off control is like operating a switch. This type of temperature controller will turn on the heat when the process variable is below the set point and turn it off when the process variable is above the set point. These controllers normally include a delay, hysterisis and or a cycle time to reduce the cycling or "hunting" when the process variable is close to the set point. In truth, they are closer to thermostats than controllers, because they do not balance heat loss with heat gain at the desired value.

Advantages and disadvantages of ON-OFF controllers:

The main advantages of on-off controllers are: simplicity, inexpensive and digital output (only two states). The main disadvantages are. the controlled parameter will continuously switch around the setpoint and if the hysteresis is not correctly set, the deviation from the setpoint could be quite significant.

Direct and reverse acting controllers:

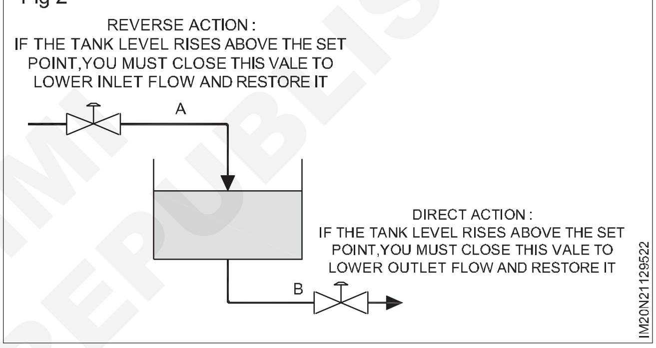
Direct action is called when the measured variable (also known as process variable PV) increases, the output increases. Reverse action is called when the measured variable increases, the output decreases.

For example, a cooling valve which is meant to control the air temperature in a room is usually direct acting, as when the temperature is above setpoint, the control signal will increase to further open the valve and let more cooling water through the coil. We say "temperature up, signal up".

Similarly, heating control valves are typically reverse acting, as when the temperature falls below setpoint, the controller output signal increases to let more heating water through the coil. Here, we say "temperature down, signal

up". The term "Control Action" most of the time is used to describe the direction of the change in control signal relative to the output variable. (Fig 2)

Fig 2



Proportional controllers

Objectives: At the end of this exercise you shall be able to
- **understand about proportional controllers.**

Proportional controllers:

process variable (or set point) and the current value of the variable

Proportional control is used where maintaining a process variable to a tighter tolerance and timely corrections are

required. Control systems in many industrial settings as well as some smart devices use proportional control.

For a proportional controller, there are two conditions and these are written below:

1 The deviation should not be large, i.e. there should not be a large deviation between the input and output.

2 The deviation should not be sudden.

The proportional controller compares the set point with the actual value or feedback process value and generates an error signal. The resulting error is multiplied with a multiplication factor to get the output. The multiplication factor iscalled the proportional gain factor (Kp)of the proportional controller.

If the error value is zero, then the controller output is zero. The more the value of the proportional gain factor KP), the faster is the response of the control system. The lesser the value of the proportional gain factor, the slower is the response of the control system

Increasing the **proportional gain factor (KP)** is that the **overshoots and undershoots** in the system increases. Also, by decreasing the proportional gain factor (KP), the output of the control system becomes slow which is not acceptable for many systems

Automatic/Manual control:

Manual controls rely on human actions. **Automated controls** rely on electronic actions

Automatic control system:

- This type of system is a self-operating system
- Automated control system is a type of closed loop control system.
- This type of system used to adjust and correct the errors without external effort
- Automatic control cystem is more reliable This type of system is more efficient
- Automatic control system is more accurate than manual type system
- This type of system decreases the work time. It takes less time to solve the problem which decreases the time
- Automated control system is a complex thing to develop.
- This type of system is safer in manufacturing/ construction.
- This type of system required more maintenance.
- This is a costly method to use continuous working is possible.
- Less skilled members can operate this system.

Manual control system:

- This is not a self-operating type system.
- Manual Control system is a open loop control system.
- This type of system needs an external effort to adjust and correct the errors.
- Manual control System is less reliable
- This type of system is less efficient
- Manual control System is less accurate compared to automatic.
- Work time is more
- This type of system use more time to solve the problems.
- This is less complex to develop.
- This type of system includes damages at the time of work.
- This type of system required less maintenance.
- Less cost compared to automatic.
- Due to this is operated by a humans continuous working is not possible.
- Skilled members are required to operate the manual type of system.

Split range control

Objectives: At the end of this exercise you shall be able to
- **understand split range controller working priciple**
- **understand advantages and disadvantages of splitrange control.**

Split range control:

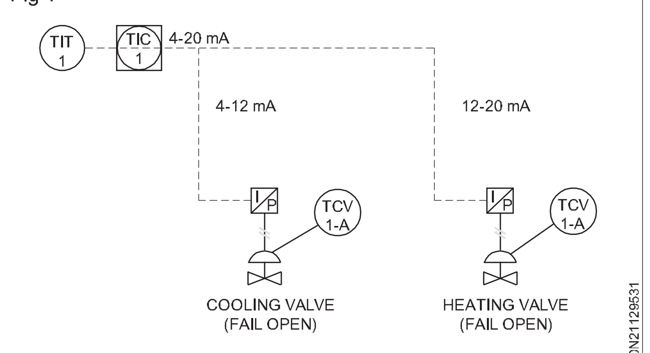
Split-range control is used when a single controller is employed to control two final control elements (two valves for example) in such a system, the controller struggle to keep one controlled variable at the set point using two manipulated variables

Typically, split-range control is found in temperature control applications

Split range control working principle: (Fig 1)

The concept of split-range control is easier to understand when ilustrated using applications such as a temperature control in such an application, the process needs to be heated or cooled depending of the product temperature

Fig 1



SPILT-RANGE FOR A TEMPERATURE CONTROL APPLICATOION

The below figure shows how the temperature transmitter, the controller, and the two control valves are connected for split-range control in a typical temperature control application

In the diagram above, the 0% to 100% range of the controller output is split in two between the two controller output is between 0% and 50%, it is the cooling valve that operates

This valve is fully open when the controller output is 0% and fully closed when the controller output is 50% If the controller output is between 50% and 100%, it is the heating valve that is in operation

At 50%, the heating valve starts to open and it is fully open at 100% of the controller output

In a split-range control installation, there are different ways to connect the valves so that they operate on two different ranges

In the example above, the current to pressure converters are used to split the controller output in two ranges

The first pressure to current converter responds to a current from 4 mA to 12 mA and will give 3-9 psi air output, while the other operates in a range from 12 mA to 20 mA will give 9-15 psi alt output

Advantages of Split Range Control

- We have more than one final control element so we can control the process effectively.
- We are using single controller for many final control element, so the control system will be cheap and loading will be educed
- We can use the split range control effectively where we have many source of one physical quantity to control as single output.

Disadvantages of split ranges control

- More than one physical quantity source are required.
- We are using single controller output to control all the manipulated variables so if there will be some fault in controller all the system will be unbalance and device will be damage.

Batch control

Objectives: At the end of this exercise you shall be able to
- **understand and Batch control and its advantages.**

Batch Control

This is an object oriented approach, which maximizes repeatability of the plant control as well as the production process. Typical batch applications include mixing, blending and reacting of products such as dairy products, beverages, and personal products

Batch processes are those processes that are taken from start to finish in batches. For example, mixing the ingredients for a juice drinks is often a batch process. Typically, a limited amount of one flavor (e.g., orange drink or apple drink) is mixed at a time.

For these reasons, it is not practical to have a continuous process running. Batch processes often involve getting the correct proportion of ingredients into the batch.

Level, flow, pressure, temperature, and often mass measurements are used at various stages of batch processes.

A typical Batch Control System consists of the following components

Field devices, as sensors, actuators and instrumentation that provide the Batch Control Systems with information and allow it to control the production process.

Batch Controller that receives the signals from the field devices and processes them according to predefined sequences to control actuators like, pumps, valves and motors

Human Machine Interface that allows interaction with the operators in the plant to monitor the status of the Batch Control Systems, to issue commands and to modify parameters

Batch Application that visualizes and develop recipes, and records results

Advantages of Batch control

- Decrease in recipe changeover times
- Decrease human errors
- Reduction of manpower required
- Increase flexibility
- Faster and more precise operation
- Increase of productivity Improve product consistency and quality
- Accelerate time to market
- Maximize Return On Investment (ROI)

Disadvantages of Batch control

- A disadvantage of batch control is that the process must be frequently restarted.
- Start-up presents control problems because, typically, all measurements in the system are below set point at start-up
- Another disadvantage is that as recipes change, control instruments may need to be recalibrated.

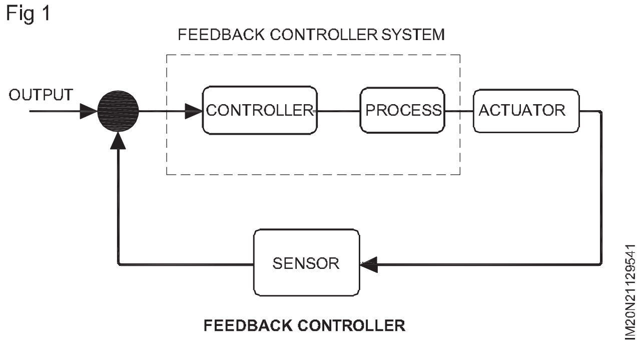
Feedbak Control

Objectives: At the end of this exercise you shall be able to
- **understand feed back control and its advantages.**

Feedback control (Fig 1)

A feedback loop measures a process vatable and sends the measurement to a controller for comparison to set point If the process variable is not at set point, control action is taken to return the process variable to set point Also call closed loop control system.

Fig 1



A feedback control system basically has five components-input (set value), output (process variable), process controlled, sensing devices, and actuating / control devices. Have a look at the below figure.

Let me explain this with a simple example of an air conditions

Consider the following things-

Temperature Set point set by the remote controller	- Input
Temperature	- Output
Temperature sensor	- sensing device
AHU	- process being controlled
Compressor	- control device

In this example set the temperature at 26 °C, start the AC On starting, it is found by the sensor that the current temperature is 32 °C. Based on this feedback, the controller inside will start the compressor The compressor will to bring down the temperature

Simultaneously, the sensor is continuously giving its feedback to the controller When the current temperature has finally reached its set point, the compressor will turn off Based on the turning-off condition, two cases can then happen- either the temperature will increase or will continue to decrease

If the temperature is again found to be increasing, then the compressor will again turn on to bring it down. And, the temperature is decreasing, then no action will be taken unless the temperature increases again. This is the basic concept of the feedback control system.

It is found that the calculation is mainly dependent on two main factors-required value and current value. T resulting difference between them is called the error. Based on this error, the controller decides how to Manipulate the controlling device so that it will try to bring the error to zero after a certain stage. This is what the feedback control system works on.

Advantages of Feedback Control System

1 Reduction of non-linear effects, which are most often seen in open-loop systems (without feedback

2 Reduction of external noise and disturbance

3 Increase in efficiency, accuracy, and quality.

4 Reduction in instability and process uncertainties.

5 The transient response can be easily controlled.

6 Improvement in gain and bandwidth.

Disadvantages of Feedback Control

The main disadvantage of feedback control is that the disturbance enters into the process and upsets it. It is only after the process output has moved from the setpoint that the controller takes corrective actions. Although most processes allow some fluctuation of controlled variable within a certain range, there are two process conditions which can make the overall effectiveness of feedback control quite unsatisfactory. One of these is the occurrence of disturbances of a very large magnitude. The other is the presence of a large time delay within the process.

Feed forward control system

Objectives: At the end of this exercise you shall be able to
- **understand feed forward control system**
- **understand the difference between feed back and feed foward control system.**

Feed forward control system

Feedforward control system is an open loop control system used to prevent errors from entering and affecting the process system. Unlike feedback control, it doesn't change the input based on errors. It varies the input variables in the system by measuring the disturbances and predicting their effects on the controlled variable. Hence it is also called Predictive control system.

Feed forward control is a control system that anticipates load disturbances and controls them before they can impact the process variable.

An advantage of feedforward control is that error is prevented, rather than corrected. However, it is difficult to account for all possible load disturbances in a system through feedforward control (Figs 1&2)

Fig 1

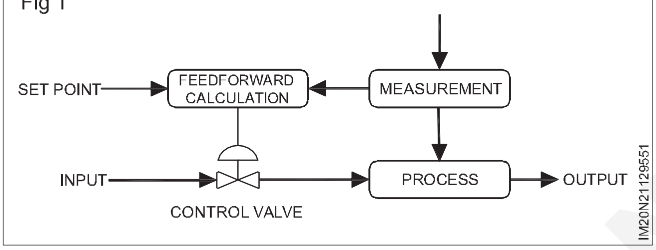
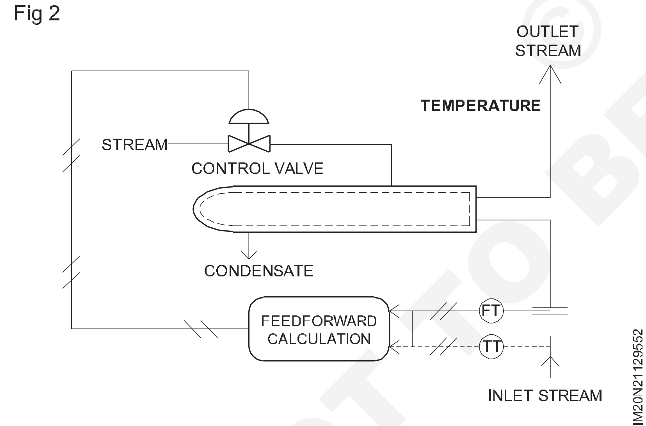


Fig 2



When the process starts, the input signal is passed to some external load. A sensor measures disturbances and the information is sent to the controller. Accordingly the Feedforward controller varies the input variables, thereby making the corrections before the error causes some change in the output. The stability of the system is unaffected by this.

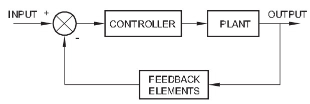
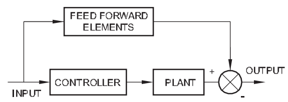
Consider a heat exchanger process where we are required to keep the temperature at a constant value.

Process variable will be the temperature of a heat exchanger and manipulated variable will be flow of the steam

When the steam enters the heat exchanger, it's flow and temperatureare measured by the flow and temperature transmitters and it's output is transmitted to the feedforward controller. Depending on the inlet steam flow and temperature, the control valve is adjusted by the feedforward controller to control the flow of the inlet steam that passes through the heat exchanger. So that temperature of the heat exchanger is maintained at a constant value.

Not all the disturbances are measured in a feedforward control system, hence for better perfomance, a feedback system should be used in conjuction withit as feedforward will handle the effects of disturbances while the feedback will take care of the unmeasured disturbances and errors in the system.

In general, feed forward systems should be used in cases where the controlled variable has the potential of being a major load disturbance on the process variable ultimately being controlled. The added complexity and expense of feed forward control may not be equal to the benefits of increased control in the case of a variable that causes only a small load disturbance.

S.No	Point of Difference	Feedback control system	Feed Forward Control System
1	**Definiton**	Systems in which corrective action is taken after disturbances affect the output	System in which corrective action is taken before disturbances affect the output
2	**Necessary requirement**	Not required	Measurable Disturbance or noise
3	**Corrective action**	Corrective action take after the disturbance occurs on the output	Corrective action taken before the actual disturbance occurs on the output
4	**Block Diagram**		
5	**Control Variable adjustment**	Variables are adjusted depending on errors	Variables are adjusted based on prior knowledge and predictions
6	**Example**	Use of roll sensor as feeedback element in ship stabilization system	Use of flowmeter as feed forward block in temperature control systems.

Ratio control system

Objectives: At the end of this exercise you shall be able to
- **understand ratio control system**
- **understand advantages and disadvantages of ratio control system.**

Ratio Control System

Ratio control is a special type of feedforward control that has widespread application in the process industries. The. objective is to maintain the ratio of two process variables as a specified value.

Ratio control is used when two fluids must be mixed together in a specific ratio. A practical way to do this is to use a standard control system to control the flow on one line. The same transmitter signal is used as a set point for a second controller which controls the flow in a second line. The ratio of one flow rate to the other can be changed by adjusting the gain (or proportional band) of the secondary controller.

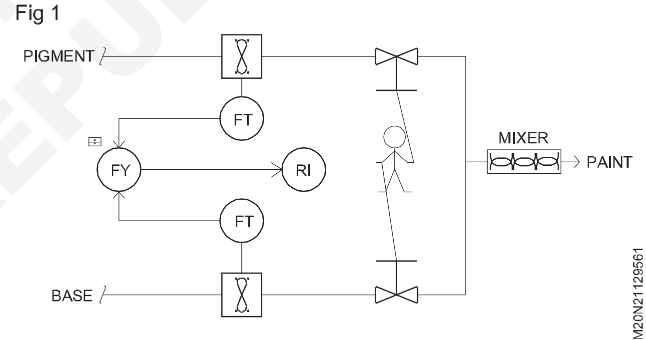
Many industrial processes also require the precise mixing of two or more ingredients to produce a desired product. Not only do these ingredients need to be mixed in proper proportion, but it is usually desirable to have precise control over the total flow rate as well

A simple example of ratio control is in the production of paint, where a base liquid must be mixed with one or more pigments to achieve a desired consistency and color. Two flow meters, a ratio calculating relay, and a display provide the human operator with a live measurement of pigment-to-base ratio.

One alteration we could make to this mixing system is to link the two manual control valve handles together in such a way that the ratio of base to pigment was mechanically established.

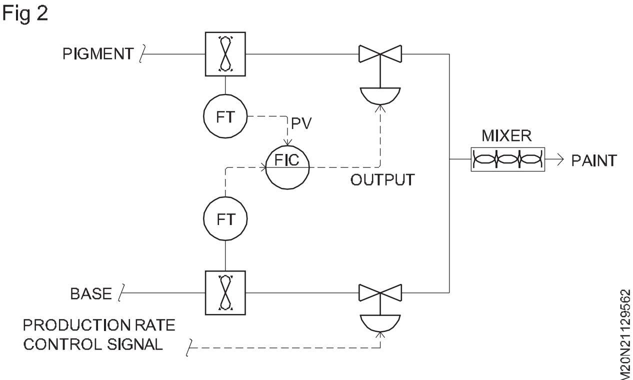
All the human operator needs to do now is move the one link to increase or decrease moved paint production. (Fig 1)

Fig 1



A more automated approach to the general problem of ratio control involves the installation of a flow control loop on one of the lines and a flow-sensing transmitter on the other line. The signal coming from the uncontrolled flow transmitter becomes the setpoint for the flow control loop. (Fig 2)

Fig 2



Here the flow transmitter on the uncooled the measures the flow rate of base sending a few rate signal to the pigment fow controer which acts to much flow rates if the calibrations of each flow transmiter are precisely equal to one another, the ratio of pigment to base will be 11 (equal) The flow of base liquid into the ming system is called a wild flow or wild vanable, since this flow rate is not controlled

by the rate control system. The only purpose served by the ratio control system is to match the pigment flow rate the wild (base) flow rate, so the same ratio of pigment to base will always be maintained regardless of total flow rate

Thus the flow rate of pigment will be held captive to match the wild base flow rate, which is why the controlled variable in a ratio system is sometimes called the captive vanable (in this case, a captive flow)

Advantages

- allows user to link 2 streams to produce and maintain a defined rapo between the streams
- simple
- no need of a complex model

Disadvantages

- not as useful for variables other than flow rates
- requires a ratio relationship between variables that needs to be maintained.

Cascade control system

Objectives: At the end of this exercise you shall be able to
- **understand the cascade control system**
- **understand advantages abd disadvantages of cascade control.**

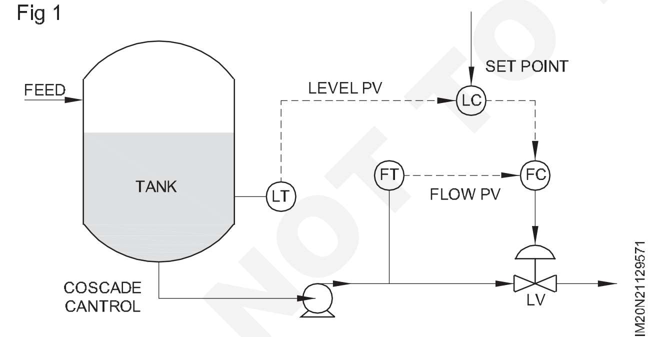
Cascade control system (Fig 1)

The cascade control loop is simply a cascade of two unique control loops. Cascade control is used for processes with slow dynamics such as temperature, level, humidity. Cascade control can be applied in a useful way to any process in which a measurable secondary variable directly influences the main controlled variable.

Cascade control involves the use of two controliers with the output of the first controller providing the second controller. In a cascade control arrangement, there are two (or more) controllers of which one controller's set point for the output drives the set point of another controller.

For example: a level controller driving the set point of a flow controller to keep the level at its set point. The flow controller, in turn, drives a control valve to match the flow with the set point the level controller is requesting

Fig 1



The controller driving the set point (the level controller in the example above) is called the primary, outer, or master controller The controller receiving the set point (flow controlier in the example) is called the secondary, inner or slave controller. Cascade control system can limit the effect of the disturbances entering the secondary variable on the primary output

Also it can limit the effect of actuator or secondary process gain vanations on the control system performance. Such gain variations usually arise from changes in operating point due to setpoint changes or sustained disturbances

When should cascade control be used?

Cascade control should always be used if you have a process with relatively slow dynamics (like level, temperature

composition, humidity) and a liquid or gas flow, or some other relatively-fast process, has to be manipulated to control

the slow process. For example: changing cooling water flow rate to control condenser pressure (vacuum), or changing steam flow rate to control heat exchanger outlet temperature. In both cases, flow control loops should be used as inner loops in cascade arrangements.

Advantages of cascade control system

- Isolation of load disturbances
- Improved speed of response
- The inner loop makes coarse adjustments, leaving the outer loop as the only option for fine-tuning
- Compensation for nonlinearities

Disadvantages of cascade control system

- Additional measurement required
- Additional controller required.So controller tuning of secondary controller is required.

Application of cascade control:

Lots of cascade contrul applications usually found at

- Arranging fuer (fuel oil) in the fumace
- Control the flow rate of hot and cold water on the Heat Exchanger. If excessive heat or hot fluid output temperature is too low, then the cascade control will prevent it
- Boiler temperature setting steam flow, and boiler drum level setting feedwater Blow

When to use cascade control loop?

- Inner loop should be faster (3 umes) than outer loop

What is the tuning sequence of cascade control?

- First tune the inner loop Enable cascade control Tune the outer loop

Pneumatic controller amd electronic controller

Objectives: At the end of this exercise you shall be able to
- **understaand pneumatic and electronic controller**
- **understand comparison between pneumatic and electronic controller.**

Pneumatic controller

A pneumatic controller is a mechanical device designed to measure temperature or pressure and transmit a corrective air signal to the final control element. Bourdon tubes, bellows, temperature elements, or displacers are used as the sensing elements.

A Pneumatic Controller operates through a coordination of its thermal or pressure sensing system and its air signal relay system. The controller's sensing bulb or pressure connection, installed within the process application, senses change within the measured variable and relays this information (input signal) to the controller

The controller mechanically compares the signal against a predetermined set point and sends a corrective air signal to a pneumatic control valve, which modulates process flow, thereby returning the application to the desired condition Pneumatic systems are used in many places in our everyday world, including train doors, automatic production ines mechanical clamps, and more. A pneumatic system uses air that is compressed in order to transmit and control energy.

The Controller continuously detects the difference between a process measurement and its set-point, and produces an output air signal of 3 to 15 psi.

The output signal is transmitted to a control valve or other control device. The process measurement, set point and output signal are indicated on the controller.

Electronic controller

An Electronic Controller uses electrical signals and digital algorithms to perform its receptive, comparative and corrective functions Principies of Operation, An electronic sensor (thermocouple, RTD or transmitter) instated at the measurement location continuously sends an input signal to the controller. They thus save considerable amounts of energy

Comparison between pneumatic and electronic controller

- Pneumatic control system needs large space, electronic control system needs less space.
- Pneumatic control systems limited programming possible, Electronic control systems can be easily programmble to any extend.
- Pneumatic control systems are slow responding, whereas Electronic control systems are having fast response Long distance communication is not possible in pneumatic control systems, It's possible with Electronic control systems
- Maintenance is more with pneumatic control systems compared with electronic control systems
- Pneumatic control systems are more costlier than electronic control systems
- Pneumatic control systems are more useful in highly inflammable areas, where electronic controllers are rarely using

Communication protocols

Objectives: At the end of this exercise you shall be able to
- **understand different types of communication protocols.**

Communication protocol

A communication protocol is a system of rules that allows two or more entities of a communications system to transmit information and it's the guidelines for communicating data. The protocol defines the rules, syntax and synchronization of communication and possible error recovery methods

Communication protocols allow different network devices to communicate with each other. They are used in both analog and digital communications and can be used for important processes, ranging from transferring files between devices to accessing the internet

Types of network protocols

There are three main types of network protocols. These include network management protocols, network communication protocols and network security protocols:

- Communication protocols include basic data communication tools like TCPIP and HTTP
- Management protocols maintain and govern the network through protocols such as ICMP and SNMP
- Security protocols include HTTPS, SFTP, and SSL

Communication protocols are vital to the functioning of a network. In fact, computer networks can't exist without these protocols. These protocols formally describe the formats and rules by which data is transferred over the network. This is a must-have for exchanging messages between your computing systems and in telecommunications, applying to both hardware and software.

Communication protocols also handle authentication and error detection as well as the syntax, synchronization and semantics that both analog and digital communications must abide by to function.

- HTTP- One of the most familiar protocols, hyper text transfer protocol (HTTP) is often referred to as the protocol of the internet. HTTP is an application layer protocol that allows the browser and server to communicate.
- TCP-Transmission Control Protocol (TCP) separates data into packets that can be shared over a network. These packets can then be sent by devices like switches and routers to the designated targets
- UDP-User Datagram Protocol (UDP) works in a similar way to TCP, sending packets of data over the network. The key difference between the two is that TCP ensures a connection is made between the application and server, but UDP does not.
- IRC-Internet Relay Chat (IRC) is a text-based communication protocol. Software clients are used to communicate with servers and send messages to other clients. This protocol works well on networks with a large number of distributed machines.
- IP- Internet Protocol can be viewed as addressing protocol which is most often used with TCP protocol as when the data packets are transferred from source to destination, they are assembled using the IP addresses of each data packet. TCP/IP together becomes the most powerful network protocol allowing various network nodes in the network.

Which protocol is right for You?

- For startups and small businesses, TCP and IP communication protocols are widely used and easy to manage
- For faster, more efficient file transfer, your business may benefit from using FTP protocols instead of relying on HTTP alone.
- For security. HTTPS is ubiquitous and reliable for data transfer over the network.

Controller modes (Propotional control)

Objectives: At the end of this lesson you shall be able to
- **understand the different controller modes**
- **understand the proportional controller mode**
- **understand the advantages and disadvantages of proportional controller mode.**

Controller modes: A controller is a mechanism that seeks to minimize the difference between the actual value of a system

(i.e. the process variable) and the desired value of the system (i.e. the set point.) . controllers are a fundamental part of control engineering and used ion all comples control systems.

Three basic modes on which the whole control action takes place, which are:

- Proportional controllers.
- Intergral controllers.
- Derivative controllers.

Proportional controllers: In a proportional controller the output isin proportional to the error signal. Proportional control action depends on the present error. Proportional control means "how much" the controller output is given to the final control element for making the process variable equal to the set point.

In the proportional control mode, the final control element is throttled to various positions that are dependent on the process systems conditions. The controller operates within a band that is between the 0% output point and where the output of the controller is proportional to the input signal.

For a proportional controller, there are two conditions and these are written below:

1 The deviation should not be large; i.e. ther should not be a large deviation between the input and output.

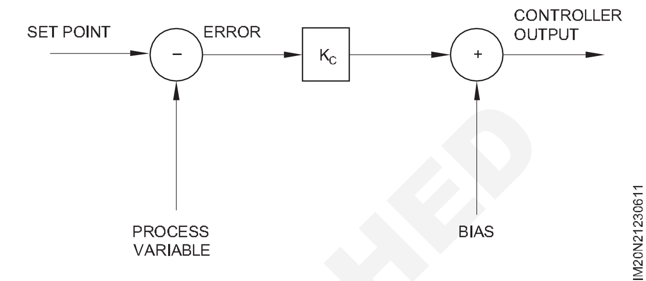
2 The deviation should not be sudden.

$A(t)=K_p \times e(t)$

Where Kp is proportional constant also known as controller gain, A(t) means controller output, e(t)

Means error proportional or P – controller gives output which is proportional to current error e(t). it compares desired or set point with actual value or feedback process value. The resulting error is multiplied with proportional constant to get the output . if the error value is zero, then this controller output is zero.

Fig 1



This controller requires biasing or manual reset when used alone. This is because it never reaches the steady state condition. It provides stable operation but always operation but always maintains the steady state error. Speed of the response is increased when the proportional constant Kp increases.

The proportional gain Kp determines the ratio of output response to the error signal. For instance, if the error term has a magnitufe of 10, a proportional gain of 5 would produce a proportioanal respose of 50 . in general , increasing the proportional gain will increase the speed of the control system response.

Advantages of the proportional controller

- The proportional controller helps in reducing the steady state error, thus makes the system more stable
- The slow response of the over damped system can be made faster with the help of these controllers

Disadvantages of proportional controller

- Due to the presence of these controllers, we get some offsets in the system.
- Proportional controllers also increase the maximum overshoot of the system.
- Proportional mode responds only to a change in error
- Proportional mode alone will not return the PV to SP

What will be the result if the proportional gain is set too high ?

1 large offset 2 possible cycling 3 stable loop

Propotional gain

Objectives: At the end of this lesson you shall be able to
- **understand about the proportional gains.**

Proportional gain

Description: proportional gain is the percentage change of the controller output relative to the percentage change in controller input. Gain, also called sensitivity, compares the ratio of amount of change in the final control element to amount of change in the controlled variable. Mathematically, gain and sensitivity are reciprocal to proportional band.

For instance , if the error term has a magnitude of 10, a proportional gain of 5 would produce a proportional response of 50. In general, increasing the proportional gain will increase the speed of the control system response.

A(t) = KP X e(t)

A(t) -controller output

K(p) –propotional gain

E(t)-Error signal

The proportional gain is the most important tuning parameter. It affects the responsiveness of the system. Alow gain makes the system sluggish and unresponsive. A gain that is too high makes the axis oscillate or vibrate. A proportional controller will have the effect of reducing the rise time and will reduce but never eliminate the steady state error.

For a low vale of Kp, the output signal will b e smaller. This means the system will be slower to respond, perhaps seeming a bit sluggish. With a low Kp value, it will also reach a point where the output signal is so small that it can't overcome the opposing force of the system and basically stall—never quite reaching the SP. This is called a 'steady-state error'since there is still a bit of error once the system stops responding and becomes steady .

On the positive side, a low Kp value can ensure minimal system overshoot since the output is going quite slowly by the time it reaches the SP

Naturally, when the Kp is increased, the opposite effect is true from what is listed above.

Propotional band

Objectives: At the end of this lesson you shall be able to
- **understand proportional band**
- **understand about offset error.**

Proportional band

Description: The proportional band is defined as the amount of change in input (or deviation), as a percent of span, required to cause the control output to change from 0% to 100%. In a PID controller, the PB (Proportional Band)is the iverse of the gain. One can write: PB =100 /Gain or Gain = 100/ PB where PB is in percent. Gain is the ratio of output change (%) over the measured variable change (%) that caused it. Where PB is the proportional band. Example: if the PB is 20%, then the gain is 5.

Proportional bans, (also called throttling range),is the change in vlue of the ontrolled variable that causes full travel of the final control element the proportional band of a particular instrument is expressed as a percent of full range. For example if full range of an instrument is 200oF and it takes a 50oF change in temperature to cause full valve travel the percent proportional band is 50oF in 200oF , or 25%.

The proportional band PB express the value necessary for 100% controller output. If PB=0, the gain or action factor Kp would be infinity – the control action would be ON/OFF.

Proportional band

While most controllers use controller gain (Kc) as the proportional setting, 0some controllers use proportional band (PB), which is expressed percent.

Table 1 shows the relationship between Kc and PB.

Controller gain (Kc)	Proportional band (PB)
0.1	100
0.2	500
0.5	200
1	100
2	50
5	20
10	10

Roughly said:

The higher gain the faster (and less stable) control.

The lower gain the slower (and more sable) control.

Translated to proportional band that means

The higher Pb the slower (and more stable) control.

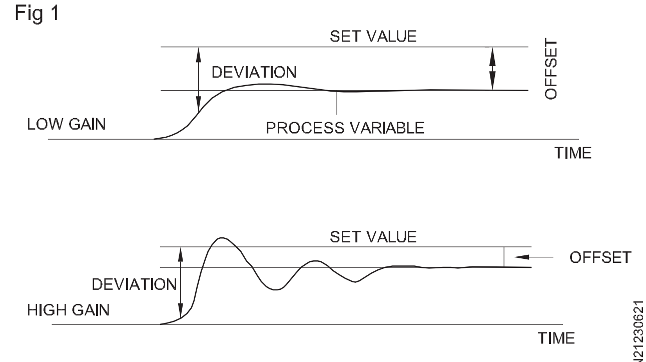
The lower Pb the faster(and less stable) control.

Offset error

Description: offset is the reading of an instrument with zero input. When a disturbance deviation from existing stale occurs in the process value being controlled, any corrective control action based purely on proportional control, will always leave out the error between the next steady state and the desired set point, and result in a residual error called the offset error. Because the error remains constant our P –controller will keep its output constant and the control valve will hold its position. The system now remains at balance, but the tank level remains below its set point. This residual sustained error is called Offset.

Whenever a process load change occurs and makes the process deviate from the steady state condition, the controller will respond and limit the excursion of the controlled variable. (Fig 1)

Fig 1



PROPORTIONAL -ONLY CONTROL

This sustained error due to the existence of a continuing process load change in a process controlled by a proportional only controller is termed offset error.

Integral action eliminates offset : To overcome this the PI controller was devised ,which uses a proportional term P to remove the gross error, and an integral term I to eliminate the residual offset error by integrating the error over time to produce an "I" component for the controller output.

Integral control mode

Objectives: At the end of this lesson you shall be able to
- **understand integral control mode**
- **understand about integral time.**

Integral mode or reset mode

Description: Action by a control mechanism that makes changes to the inputs of a manufacturing process based on the accumulated error over a period of time. Integral action controllers are often used in conjunction with proportional controllers, which make corrective changes in proportion to the amount of error in an input, in order to make input adjustments faster and more accurate.

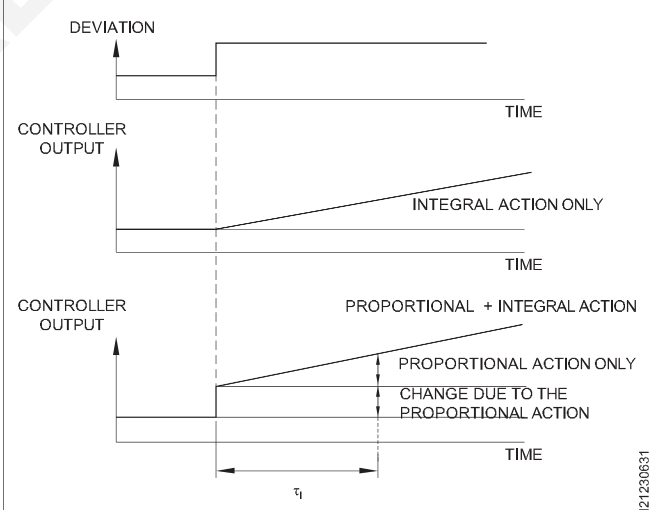
Integral control action depends on the past error. Its output depends on the error signal and also the time error has existed. That is "how long" the controller output is needed to nullify the error.

Most of the processes we will be controlling will have a clearlydefined set point. If we wish to restore the process to the set point after a disturbance then proportional action alone will be insufficient.

Integral Time: the time required to obtain the same manipulated variable as for the proportional action when using only an integral action. The shorter the integral time, the stronger the correction is of the integral action. (Fig 1)

Due to limitation of p-controller where there always exists an offset between the process variable and set point, I-controller is needed, which provides necessary action to eliminate the steady state error. (Fig 2)

Fig 1

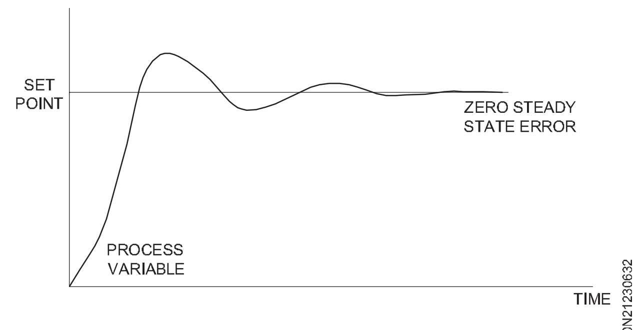


INTEGRAL ACTION

It integrates the error over a period of time until error value reaches to zero. It holds the value to final control device at which error becomes zero.

Integral control decreases its output when negative error takes place. It limits the speed of response and affects stability of the system. Speed of the response is increased by decreasing integral gain Ki.

Fig 2



PI - CONTROL ACTION

Derivative control mode

Objectives: At the end of this lesson you shall be able to
- **understand derivative control**
- **understand the action of derivative control.**

Derivative mode or set mode

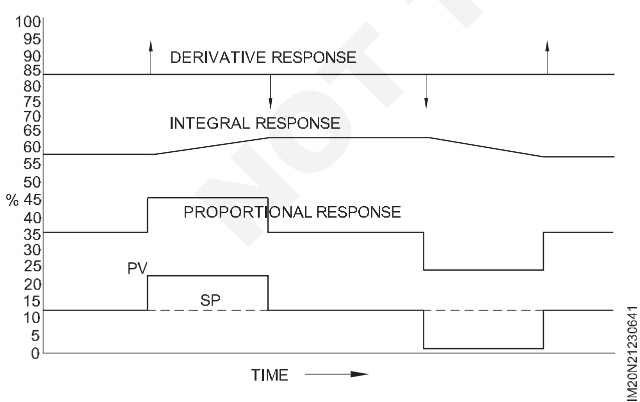
Description: when derivative control is applied, the controller senses the rate of change of the error signal and contributes a component of the output signal that is proportional to a derivative of the error signal.

Derivative action depends on the future error. It decides "how fast" the controller output is given by the controller to the final control element to nullify the error.

I- controller doesn't have the capability to predict the future behaviour of error. So it reacts normally once the set point is changed. D-controller overcomes this problem by anticipating future behaviour of the error. Its output depends on rate of change of error with respect to time, multiplied by derivative constant. It gives the kick start for the output thereby increasing system response.

It improves the stability of system by compensating by compensating phase lag caused by I-controller, increasing the derivative gain increases speed of response.

Fig 1



Proportional action directly mimics the shape of all input changes.

Integral action ramps at a rate proportional to the magnitude of the input step, for as long as the PV is unequal to the SP.

Once PV=SP again, integral action stops ramping and simply holds the last value.

Derivative action interprets each step as an infinite rate of change, and so generates a "spike" at the leading and at the trailling edges of each step.

The derivative or differential controller is never used alone. With sudden changes in the system the derivative controller will compensate the output fast. A derivative controller will in general have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response.

Derivative action is added to a proportional action controller in order to produce a phase advance in the controller output signal, i.e. its function is to produce a control correction sooner than would be possible with proportional action alone. It is often regarded as providing an anticipating action.

Closed –loop response

	Rise time	Maximum overshoot	Setting time	Steady state error
P	Decrease	Increase	Small change	Decrease
I	Decrease	Increase	Increase	Eliminate
D	Small change	Decrease	Decrease	Small change

Note that these correlations may not be exactly accurate, because P,I and D gains are dependent of each other.

Single mode controller

Objectives: At the end of this lesson you shall be able to
- **understand different modes of PID controllers**
- **understand charateristics of proportional mode**
- **understand the mode and three controllers.**

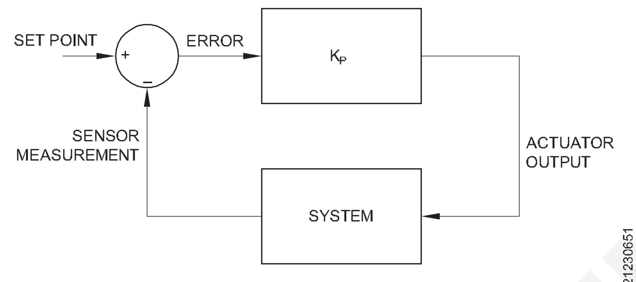
Single mode controller

The single mode control in the PID family is a proportional or P-only controller. Integral and derivative mode not used in single.

Proportional mode is a simple control system when the process variable changes the parameter is feedbacked to the controller. At controller, the PV is compared with the setpoint and takes the appropriate control action. This is proportional control action.

Fig 1 Proportional control block diagram

Fig 1



PROPORTIONAL CONTROL BLOCK DIAGRAM

Characteristics of proportional mode

The various characteristics of the proportional mod are:

1 when the error is zero , the controller output is constant equal to P0.

2 if the error occurs, then for every 1% of error the correction of Kp% is achieved. If error is positive , Kp % correction gets added to P0 and if error is negative , Kp% correction gets subtracted from P0.

3 the band of error exists for which the output of the controller is between 0 to 100% .

4 the gain Kp and error band PB are inversely proportional to each other

Two mode and three controllers

Due to offset error, proportional mode is not used alone. Similarly, integral and derivative modes are not used individually in practice. Thus, to tke the advantages of various modes together, the composite control modes are used. Composite modes of controller operation combine advantages of each pure mode. The various composite control modes are:

1 proportional +Integral mode (PI)

2 proportional +derivative mode(PD)

3 proportional +integral + Derivative Mode (PID)

Proportional-integral control

This is a control mode that results from a combination of proportional mode and integral mode. A PI controller accumulates the error as time passes and is multiplied by the constant Ki. It output the sum of your P and I terms. PI controllers have tow adjustment parameters to adjust.

The main advantage of this composite control mode is that the one-to-one correspondence of proportional mode is available and integral mode eliminates the inherent offset error.

PI control is a form of feedback control. it provides a faster response time than I-only control due to the addition of the proportional action. PI control stops the system from fluctuating, and it is also able to return the system to its set point. Although the response time for PI-control is faster than I-only control, it is still up to 50% slower than P-only control.

P-D (Proportional-derivative) controller mode:

The objective of using the PD controller is to increase the stability of the system by improving the control since it has the ability to predict the future error of the system response. This system cannot eliminate the offset error of the proportional controllers, however, it can handle rapid processload changes as long as the load change compensation error is acceptable.

The D mode is designed to be proportional to the change of the output variable to avoid the sudden changes that occur in the control output as a result of sudden changes in the error signal. In addition, D directly amplifies the process noise. So the D-only control is not used.

PD-control is combination of feedfrward and feedback control, bcause it operates on both te current process conditions and prerdicted process conditions. In PD – control , the control output

Is a linear combination of the error signal and its derivative. PD- control contains the proportional controls damping of the fluctuation and the derivative controls peddition of process error.

P-1-D Controller:

The P-I-D controller has the optimal control dynamics that include zero steady-state error, fast response (short rise time), no oscillations and greater stability. It is recommended in systems where compensation is required for frequent changes in load, set point , and available energy.

Proportional – integral –derivative control is a combination of all three types of control methods. PID-control is most commonly used it combines the advantages of each type of control. this indludes a quicker response time because of the P-only control, along with the decreased/zero offset from the combined derivative and integral controllers'. This offset was removed by additionally using the I-control.

The addition of D-control greatly increases the controller's response when used in combination because it predicts distrubaces to the system by measuring the change in error.

On the contrary, as mentioned previously, when used individually, it has a slower response time compared to the quicker P-only control. however, although the PID controller seems to be the most adequate controller, it is also the most expensive controller. Therefore, it is not used unless the process requires the accuracy and stability provided by the PID controller.

Controlled variable	Proportional control	PI control	PID control
Flow	Yes	Yes	No
Level	Yes	Yes	Rare
Temperature	Yes	Yes	Yes
Pressure	Yes	Yes	Rare
Analytical	Yes	Yes	Rare

Controller tuning

Objectives: At the end of this lesson you shall be able to
- **understand controller tuning methods**
- **understand zeigler - nichols methods of controller tuning.**

Controller tuning Controller tuning refers to the adjustments in the tuning parameters (proportional gain, integral gain and derivative gain) in order to ensure the best response of the controller.

Manual tuning is done by setting the reset time to its maximum value and the rate zero and increasing the gain until the loop oscillates at a constant amplitude. (When the response to an error correction occurs quickly a larger gain can be used. If response is slow a relatively small gain is desirable.)

Before the working of PID controller takes place, it must be tuned to suit with dynamics of the process to controlled. Designers give the default values for P, I and D terms and these values couldn't give the desired performance and sometimes leads to instability and slow control performances. Different types of tuning methods are developed to tune the PID controllers and require much attention from the operator to select best values of proportional, integral and derivative gains. Some of these are given below.

1 step change response method

2 trial and error method

3 zeigler-nichlos method

Step change response method: it is an open loop tuning technique. It produces response when a step input is applied to the system. initially, we have to apply some control output to the system manually and have to record response curve.

After that we need to calculate slope, dead time, rise time of the curve and finally substitute these values in P,I and D equations to get the gain values of PID terms Kp, Ki and Kd.

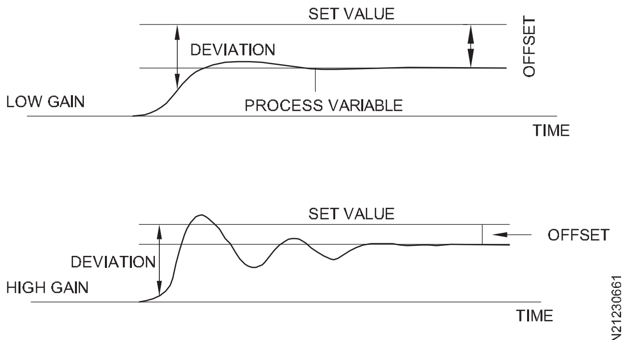
Trial and error method tuning

This is the simple method of tuning a PID controller once we get the clear understanding of PID parameters, the trial and error method become relatively easy.

- Set integral and derivative terms to zero first and then increase the proportional gain until the output of the control loop oscillates at a constant rate. This increase of proportional gain should be in such that response the system becomes faster provided it should not make system unstable.
- Once the P – response is fast enough, set the integral tem, so that the oscillations will be gradually reduced. Change this I-value until the steady state error is reduced, but it may increases overshoot.
- Once P and I parameters have been set to a desired values with minimal steady state error, increase the derivative gain until the system reacts quickly to its set point. Increasing derivative term decreases the overshoot of the controller response.

The objective controller tuning method is to find better perameters for good control and there are some trail and error methods which estimates the parameters based on some calculations . I.e the controller constants are changed to achieve some predetermined closed loop response.

Fig 1



PROPORTIONAL -ONLY CONTROL

Trial and error methods are depends on process dynamic behaviour , some process simply cannot stand for overshoot and must settle more gradual with slow response. For example consider a level controller the overshoot in level of the tank is not permitted because it may overflow . So extra care and knowledge of the process is needed in these methods to find better combination of parameters.

Ziegler Nichols method of controller tuning

The Ziegler – Nichols tuning is a method of tuning a PID controller. It is performed by setting the I (integral) and D (Derivative) gains to zero. The “P” (Proportional) can be then increased (From zero).

Until it reaches the ultimate gain. In whicht the output of the control loop has stable and consistent osilaations.

The goal of tuning is to ensure minimal process oscillations around the set point after a disturbance has occurred.

Programmable Logic Controllers

Objectives: At the end of this lesson you shall be able to
- **explain programmable logic controllers and its architecture**
- **explain advantages & disadvantages of PLC.**

Introduction : PLC is an industrially oriented computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices.

They are used in many industries such as oil refineries, manufacturing lines, conveyor systems and so on. Where ever there is a need to control devices the PLC provides a flexible way to “softwire” the components together.

The basic units have a CPU (a computer processor) that is dedicated to run one program that monitors a series of different inputs and logically manipulates the outputs for the desired control. They are meant to be very flexible in how they can be programmed while also providing the advantages of high reliability. Compact and economical over traditional control systems.

History of PLC : Programmable Logic Controllers (PLC) were originally invented for the U.S. automotive manufacturing industry to replace relay logic systems. The automotive industry adopted PLCs initially for software revisions, which replaced rewiring of control panels that were used during the changing of production models.

Before PLC creation, the process to change and update facilities for its new models each year was ery expensive and time-intensive since each relay had to be individually rewired.

In 1986, GM requested a proposal for a device that would electronically change this relay system.Winning this project bid. Dick Morely of Bedford Associate is known as the "fater" of the PLC with their 084 PLC as the first product of its kind.

Bedford Associates founded the company Modicon to help promote and service its 084 PLC, which was later sold to the German company now known as AEG. Schneider Electric in France is now the current owner of Modicon's 084 PLC. The PLC is now a vital part of many manufacturing industries saving critical man- hours and thousands od dollars.but the automotive industry continues to be perhaps the largest PLC user.

PLC's primary function is to electronically rewire the hard-wired control panels that, otherwise, require that each of the hundreds and even thousands of relays be replaced individually. PLCs accept data from swtiches, sensors and controls to control and drive various machines and devices.

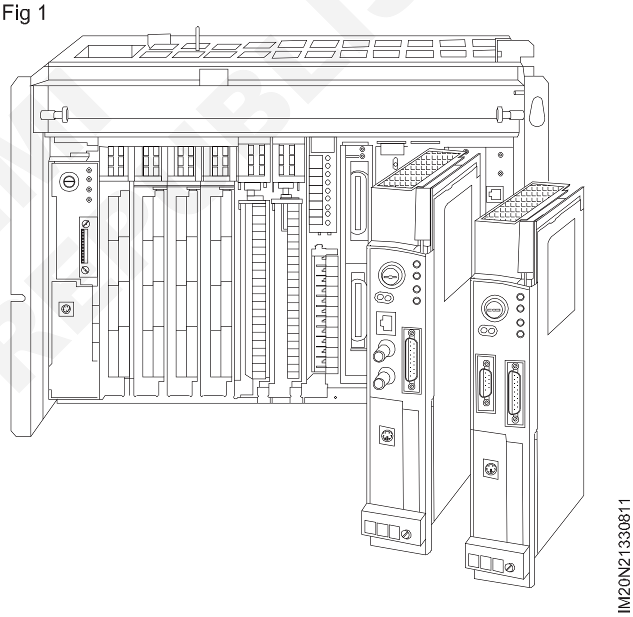
PLC functions have expanded from its basic replacement of relay logic circuits to more advanced features involving PIP implementation. The benefits and functions of the PLC are now found in industries beyond automotive manufacturing, including food processing, mining and environment control.

Early PLCs were programmed to resemble a schematic design of relay logic (known as ladder logic) to help reduce the training required for technicians, though some used more of an instruction list type of programming. PLCs today may take the foem of this ladder logic or slate logic a far more complex programming language.

Ladder logic is more often used today because it allows the PLC programmer to more easily detect issues with timing of the logic sequence. PLCs today are programmed using computer software which functions also as a troubleshooting tool for the PLC software.

PLC History (Fig 1)

Fig 1

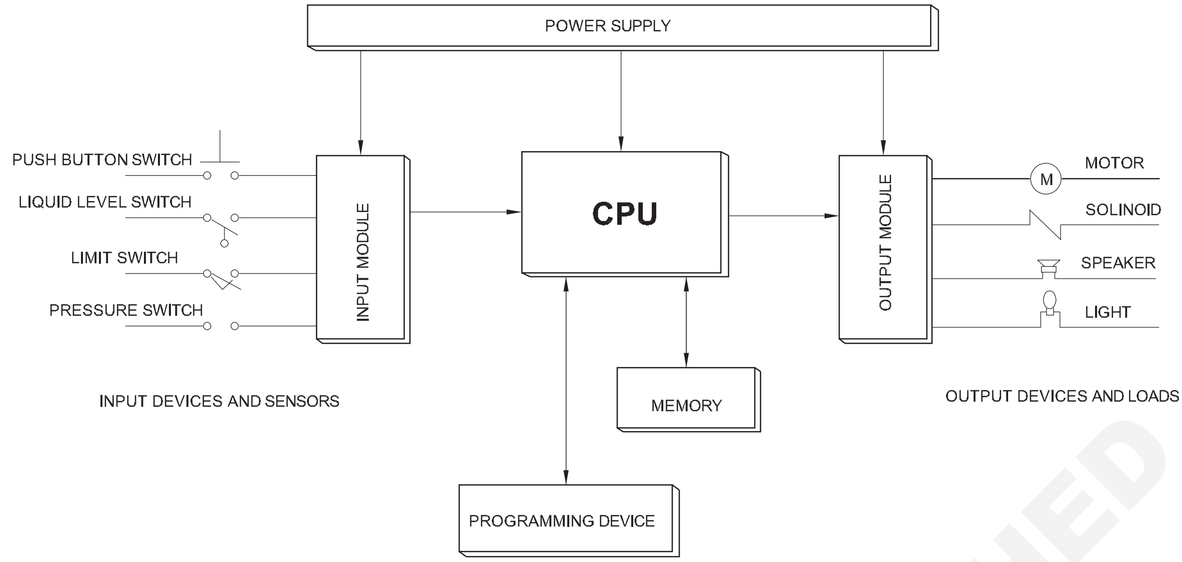


While PLCs have only been in existence for fewer than 50 years (as of 2016), the evolution from computing machines into their current form is interesting and illuminating. This section examines their history and parallel development with computers. To understand the history of programmable controllers, it is useful to examine where many of its elements came from.

- In 1968, a group of engineers from general motors developed the concept of PLC.
- MODICON is the first PLC.
- DICK MORLEY, who worked in MODICON is considered to be the "Father" of the PLC.
- PLCx were designed to replace relay logic system.

Architecture and Characteristics of PLC (Fig 2)

Fig 2



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PROGRAMMABLE LOGIC CONTROLLER OR PLC BLOCK DIAGRAM

Characteristics of PLC : PLCs require shorter installation and commissioning times than do hard wired systems. Although PLCs are similar to 'Conventional' computers in term of hardware technology, they have specific features suited for industrial control.

- Rugged, noise immune equipment.
- Modular plug-in construction, allowing easy replacement or addition of units (e.g. input/output).
- Standard imput/output connections and signal levels.
- Easily understood programming language.
- Ease of programming and reprogramming in-plant.
- Capable of communicating with other PLCs, computers and intelligent devices.
- Competitive in both cost and space occuped with relay and solid-state logic systems:

PLC Hardware

THe main components of a PLC consists:

1 Central Processing Unit (CPU)

2 Power supply

3 Programming device.

4 Input and Output (I/O) modules.

CPU

The CPU is the brain of the PLC and carries aout programmed operations.These operations or outputs are executed based on signals and data provided from connected inputs.

I/O Modules

PLC input modules connect various external devices, such as sensors, switches, and push buttons to the PLC to read various digital and analog parameters,such as temperature, pressure, flow, speed, etc.

Output modules convert signals from the CPU into digital or analog values to control output devices.

Power Supply

The power supply provides power to the PLC by converting the available incoming AC power to the DC power required by the CPU and I/O modules to operate properly.

Software

The PLC manufacturer typically dtermines PLC development software. Allen Bradley, Siemens, and GE and each have their own software development platfoems for programming their PLC models.

Once the platform is determined, the actual programming og the PLC logic can be done in a few different methods. The most common methods of PLC programming include ladder Logic, Function block and structured text.

Ladder Logic

Ladder logic is a graphical PLC programming language and is the most common method of programming. Ladder Logic can be used to execute talsks such as sequencing, counting, timing, data manipulation, and more.

Ladder Logic is structured similarly to relay logic; however, the physical switches and coils used in relay logic are replaced by the PLC's memory locations and I/O.

Structured Text

Structured text is a text-based PLC programming language and is similar to Python, Visual Basic, or Cooling languages.Programming with structured text has multiple advantages, such as the program requiring less space due to being text based instead of graphic based.

Additionally, the structured text can be combined with other programming languages, such as creating function blocks containing functions written in structured text.

Function Block

Function block PLC programs are represented in the form of graphical blocks. Signals or data flow into the function block from inputs connected to the PLC. When the incoming signals or data triggers the function blocks's pre-programmed function, the PLC executes one or more outputs.

Functions blocks can have standard functions such as timers, counters, calculating min and max values, obtaining averages, and more. (Fig 3)

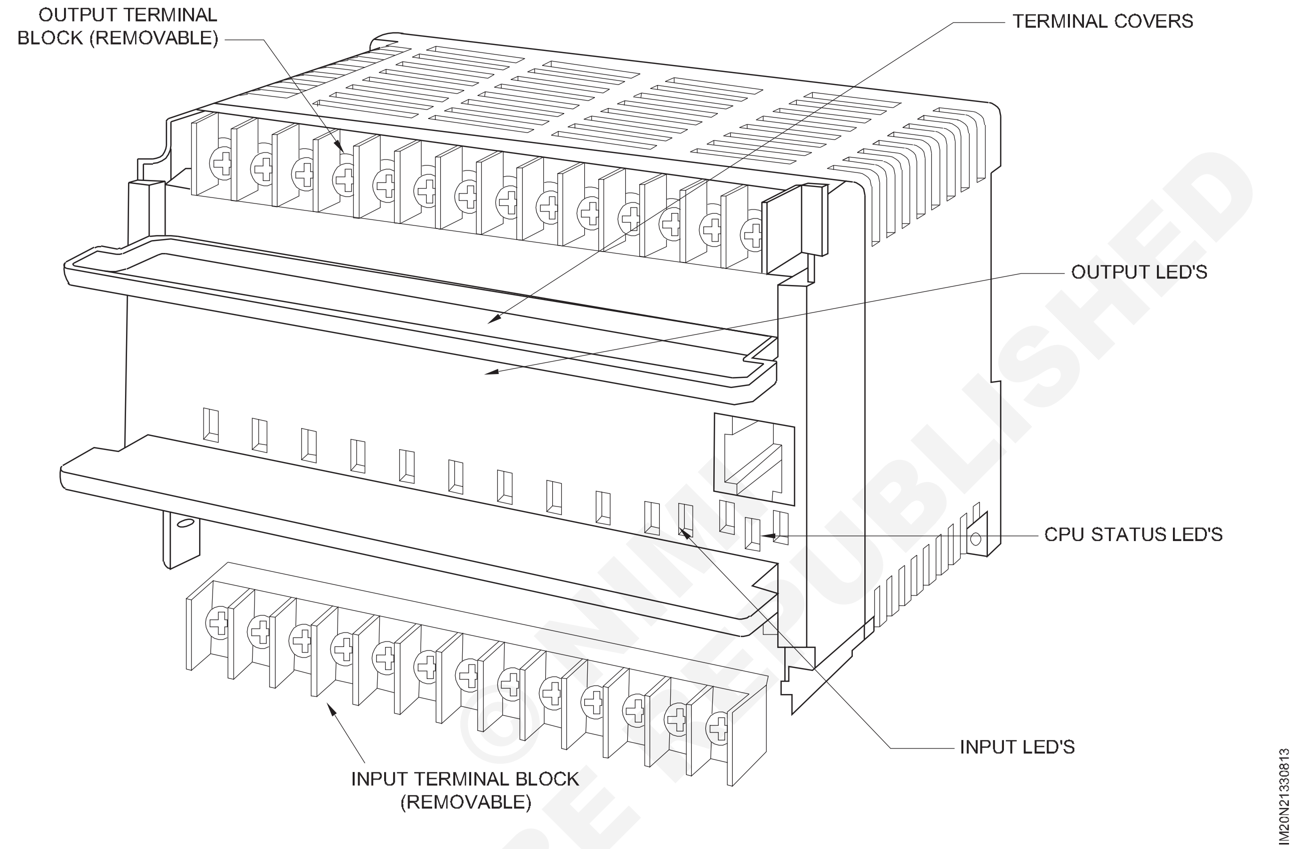
Classification of PLC

The two major types of PLC

1 Fixed/Integrated/Compact PLC

2 Modular PLC

Fig 3

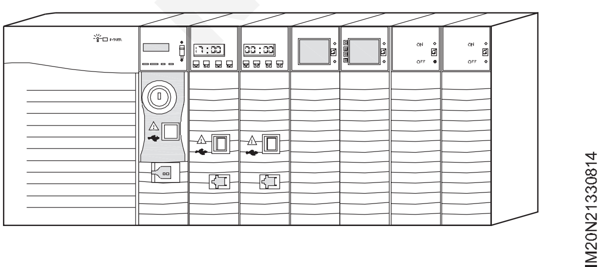


This type of PLC is most commonly called the **Fixed I/O PLC.**

"Fixed I/O" actually stands for Fixed "Input Output". When you buy compact PLCs you will notice that the input section and the output sections of the PLC are integrated into the microcontroller itself.

This means that every type of output or input is fixed and is determined by the manufacturer. (Fig 4)

Fig 4



The modular PLC is a type that allows multiple expansions of the PLC system through the use of modules. hence the term "Moduler"

Modules give the programmable logic controller additional features like increased number of I/O units, and they are usually easier to use because each component is independent of each other.

The power supply, communications module, Input/Output module are all separate to the actual microcontroller so you have to manually connect them to each other to create your PLC control system.

A type of modular PLC is the rack mount PLC, the communication module of the PLC resides in the rack itself, so all connections are centralized.

Types of PLC according to size

1 Mini PLC

Mini PLCs have usually have 128 to 512 I/O points which are already a LOT for a control system.

For small control system that is only predicted to scale up a little bit, mini PLCs are ideal to use instead of larger PLCs (above 512 I/O points).

2 Micro PLC

Micro PLCs are the ones that have 15 to 128 I/O points. They are most commonly used in very small automation or control system like amusement rides.

Why so ? Because amusement rides require that the controls are near the ride itself so this eliminates the requirement that there should be a "Central PLC" for all the rides in the amusement park. (Fig 1)

In addition, because each amusement ride can only add a couple of devices here and there for safety purposes, they would not require a high number of I/O points to the Micro PLC will already suffice.

3 Pico/Nano PLC

Pico PLCs have less than 15 I/O points.

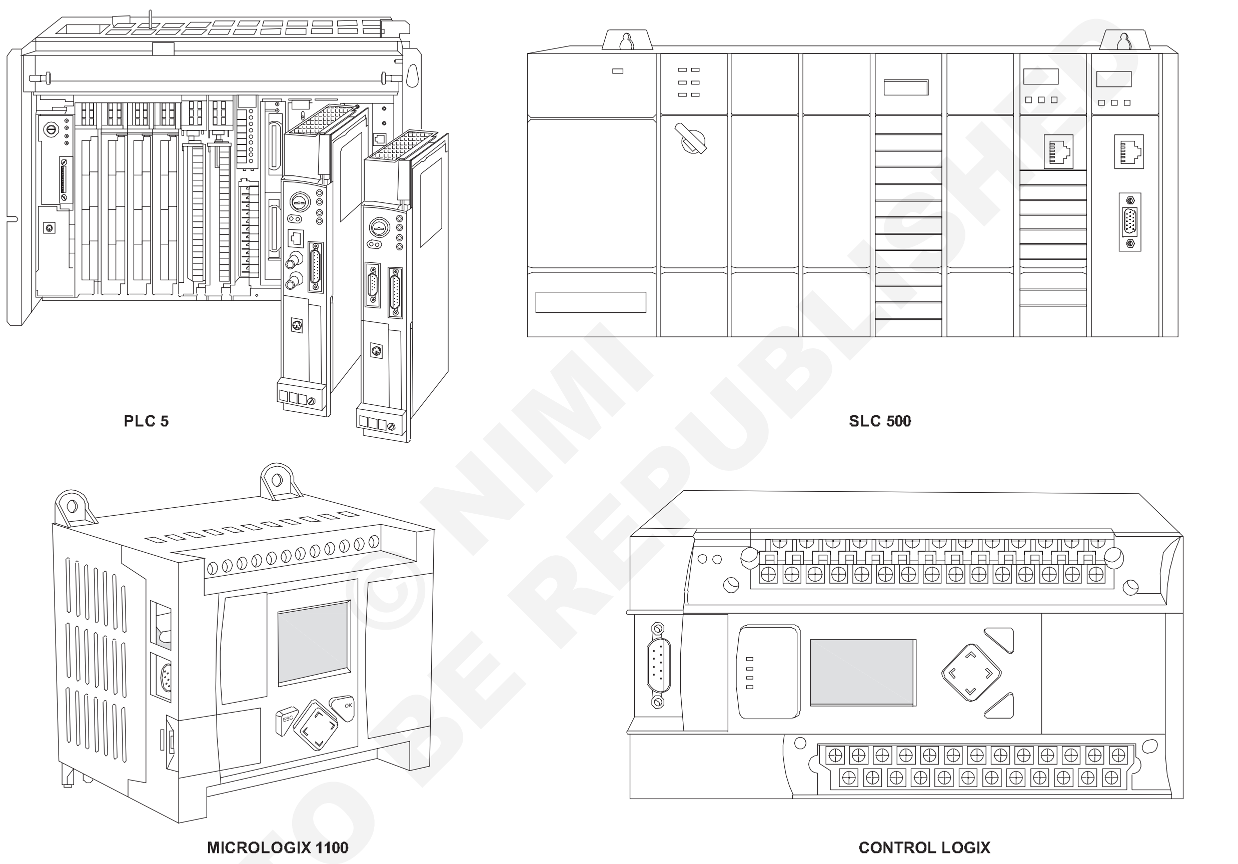
Usually, they are seen in PLC trainer systems because they are very easy to use (and usually comes with a display panel) and they do not look intimidating to beginners who want to know the basics of PLC first.

The thing that is really desirable in Pico/Nano PLC devices is the simplicity and compactness as they are usually just the size of your hand.

4 Medium End PLC which controls 512 to 4096 I/Os

5 High End PLC which controls more than 4096 I/Os

Fig 5



Advantages of PLC

There are many advantages that a PLC system holds over a relay system. One of the first and simplest advantages is reliability.

1 **Reliability :** The internal relay systems of a PLC are solid state. This means that the relay function is not mechanical like conventional relay systems and components. Traditional mechanical relays wear out much faster than the electronics in a solid state relay. Every time a mechanical relay opens and closes, the contacts will are slightly. The arcing can eventually destroy the contact.This is simply no the case with the solid state type relays found in our PLC systems.

2 **Ease of Troubleshooting :** Another advantage of a PLC system is the ease of troubleshooting. Ina PLC system, a good technician can read through the programming and usually figure out what is and isn't working.

In a relay system, there will be several more wires plus the relays and possibly other components that aren't needed in a PLC.This makes finding problems much harder.

Each physical relay needs a minimum of four wires to operate and functions.A relay output card on a PLC sends out one wire in the output device.

3 **Easy Expandability :** One of the best features that a PLC system has over a traditional relay system is versatility with the programming and easy expandability. For example, if you wanted to add a timer to make a motor turn on after five seconds,

you would just add it to the program and set it to five seconds in the PLC.

For a relay system, you would have to add an entirely new physical component. On top of that, you would have to add all of the proper wiring to make that timer work for the specific motor.This also makes expanding a system much cheaper. Not only for component costs but labor savings as well. If you have a relay system, someone will have to be paid to install a wire all of the new components.

4 **Smaller size :** The physical size requirements of a PLC system are far smaller than a cabinet needed for relay logic circuitry.

Most of the physical relays, timers, counters and controllers from a relay logic system are all contained in the PLC itself.

Depending on the machine, a cabinet containing the PLC can easily be a third of the size of a relay logic cabinet, Possibly even smaller.

The mechanical functions of relays simply wear out over time.Plus, the wiring required to operate a relay system is much more complicated than a PLC system. This can also cause higher costs to install and upgrade due to extra labor costs.

One of the major advantages is the veratility of a PLC with its programming and internal relays, timers,counters, among other features.

5 **Less power consumption :** Most of the PLCs are working on 24 DC power. Earlier when using electromechanical timers in large numbers, each timer needs separate power supply and also most of them need 230 V or 110 V AC.

6 **Fast and design for the rugged industrial environment**

7 **PLC cost is like 4 to 5 relay but can replace hundred of relay.**

8 **A wide range of control application.**

9 **Some complex task not possible with relays for example calculation Infiormation exchange text & Graphic display data processing networking.**

10 **Diagnostics are centrally available PLC Interface directly to the wired system.**

Disadvantages of PLC:

1 When a problem occurs, hold - up time is indefinite, usually long.

2 There are limitations of working PLCs under high temperature, vibration conditions.

3 Some PLCs turns on when power is restored and may cause any accident.

4 Fixed circuit operation.

5 PLCs are propitiatory, which means software and pats one manufacturer can't be easily used in combination with part of another manufacturer.

6 Number of optional modules must be added to maximize flexibility and performance.

Applications of PLC :

1 Turbine control in a power plant.

2 Baggage Handling system at airports.

3 Boiler Automation in various manufacturing plants.

4 Power management System on a Marine vessel.

5 Bottling System & Packaging system in Food & Beverage/Pharma industries.

6 Conveyor Automation.

7 Heavy Duty cranes.

8 In petroleum industry.

9 In chemical industry,

10 In cement industry.

11 In tyre industry.

12 In paper industry.

13 In steel and aluminium industry.

PLC Programming Languages

Objectives: At the end of this lesson you shall be able to
- **explain the methods of developing PLC programming.**

PLC programming Languages

1 Ladder Diagram (LD)

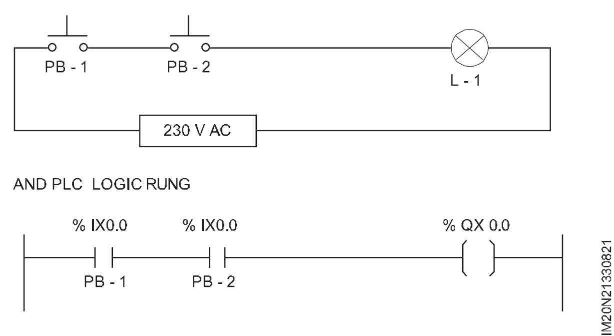
2 Sequential Function Chart : (SFC)

3 Function Block Diagram (FBD)

Ladder Diagram (LD)

Ladder Diagram was originally modeled from relay-logic which used physical devices, such as switches and mechanical relays to control processes.Ladder Diagram utilizes internal logic in replace all, except the physical devices that need an electrical signal to activate them. Ladder Diagram is built in the form of horizontal rungs with two vertical rails that represent the electrical connection on relay-logic schematics.

Fig 1



A simple conversion for relay logic to ladder logic example

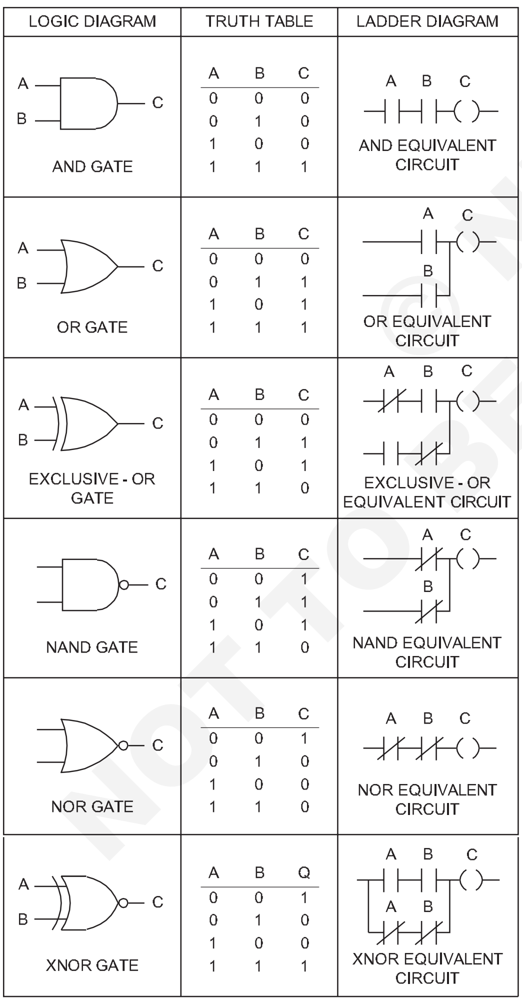
In a ladder diagrams, the rungs represent the logic flow through the symbolic code. When implementing a ladder logic programmable PLC there are seven basic parts of a ladder diagram that critical to know. They are rails, rungs, inputs,outputs, logic expressions, address notation /tag names and comments.

Each rung must start with an input or inputs and must end with at least one output. The term input is used for a control action, such as closing the contacts of a switch, used as an input to the PLC. The term output is used for a device connected to the output of a PLC e.g.a motor.

The inputs and outputs are all identified by their addresses, the notation used depending on the PLC manufacturer. This is the address of the input or output in the memory of the PLC.

One input can be used in multiple times in one program. One Output cannot be used multiple times in one program, except in Set Reset and Latch/Unlatch functions. (Fig 2)

Fig 2



Gate	A	B	C
AND GATE	0	0	0
	0	1	0
	1	0	0
	1	1	1
OR GATE	0	0	0
	0	1	1
	1	0	1
	1	1	1
EXCLUSIVE - OR GATE	0	0	0
	0	1	1
	1	0	1
	1	1	0
NAND GATE	0	0	1
	0	1	1
	1	0	1
	1	1	0
NOR GATE	0	0	1
	0	1	0
	1	0	0
	1	1	0
XNOR GATE (A B Q)	0	0	1
	0	1	0
	1	0	0
	1	1	1

If we wanted to draw a simple ladder diagram showing a lamp that is controlled by a hand switch, it would look like this:

The "L1" and "L2" designations refer to the two poles of a 120 VAC supply unless otherwise noted. L1 is the phase conductor, and L2 is the grounded ("neutral") conductor. (Fig 2)

Fig 3

Sequential Function Chart (SFC)

Sequential Function Chart (hereafter called SFC) is a graphical programming language that displays the process flow as a diagram, thereby allowing the user to control the sequential processes by describing the transition conditions and actions for each step.

SFC programming language makes it easier to visualize and design complex sequential systems. In this programming language, the operations are described as separate steps that are sequentially connected.

An example of this sequential connection can be seen in the operation of a washing machine.When a program is selected on the washing machine, it has multiple steps that come one after the other. When one step is over, the next automatically begins. The terms 'Steps' and 'state' represent the same concept in SFC programming.

Function Block Diagram (FBD)

The Function Block Diagram which is also agraphical type of language. The Function Block Diagram describes a function between inputs and outputs that are connected in blocks by connection lines.

Function blocks are objects which are defined in a PLC program to simplify the process of programming. Basically, it is a means of reducing the programming length and complexity written by the programmer.

Function Blocks were originally developed to create a system that you could set up many of the common,repeatable tasks, such as counters, timers, PID loops, etc.

I/O Devices

Objectives: At the end of this exercise you shall be able to
- **explain input/output device used by PLC**
- **explain I/O interface with PLC**
- **explain different types of encoders.**

Definition of I/O devices I/O devices are the pieces of hardware used by a human (or other system) to commuzicate with a computer. For instance, a keyboard or computer mouse is input device for a computer, while monitors and printers are output devices. The designatio of a device as either input or output depends on perspective.

In a PLC system there will usualty be dedicated modules for inputs and dedicated modules for outputs. An input module detects the status of input signals such as push-buttons, switches, contact and non contact sensors, temperature sensors, etc.. An output mod le control devices such as relays, rotor starters, lights, solenoid valves etc.

LO overview

LC I/O is the part of the PLC that connects the brain of the PLC, the CPU o the outside world. the machines In a PLC system there will usually be dedicated modules for inputs and dedicated modules for outputs

Discrete I/O

The most common type of PLC is discrete I/O. Sometimes discrete I/O is referred to as digital I/O. The concept is simple, discrete I/O are signals that are either on or off. Some examples of discrete input devices would be things like light switches, push-buttons and proximity switches.

Examples of discrete output devices are lights, relays and motor starters. From our dishwasher example in Part 1. some of the discrete inputs would the start button, the door switch and the water level switch. Some of the discrete outputs would be the water fill valve, the water drain valve and the heating element

Analog I/O

The other common form of PLC I/O is analog I/O, Analog I/O refers to signals that have a range of values much greater than just 1 or 0. For instance, an analog signal could produce a voltage anywhere in the range of 0-10 VDC The signal could be 2 V.3 V. 8.5 V, etc. In the PLC world, analog input modules usually ineasure analog inputs in one of the following forms: -10 to 10 VDC, 0-10 VDC, 1 to 5 VDC, 0 to 1 mA, or 1-20 mA

Basically the analog input module either measures voltage or current from the input device. There are other types of analog signals but these are definitely the most common Simrly, the analog output module can supply voltage or current signals in one the ranges I ment oned previously.

Some real-world examples of analog inputs in a industrial environment would include engine temperature sensors (RTDs, thermocouples, etc.), oil pressure sensors and weight being temperature sensor might report a temperature range of -50 to 150 degrees C corresponding to 4 20 mA. A weight scale might report a range of 0 to 1000 lb corresponding to 0 to 10V.

Signal Of I/O Modules

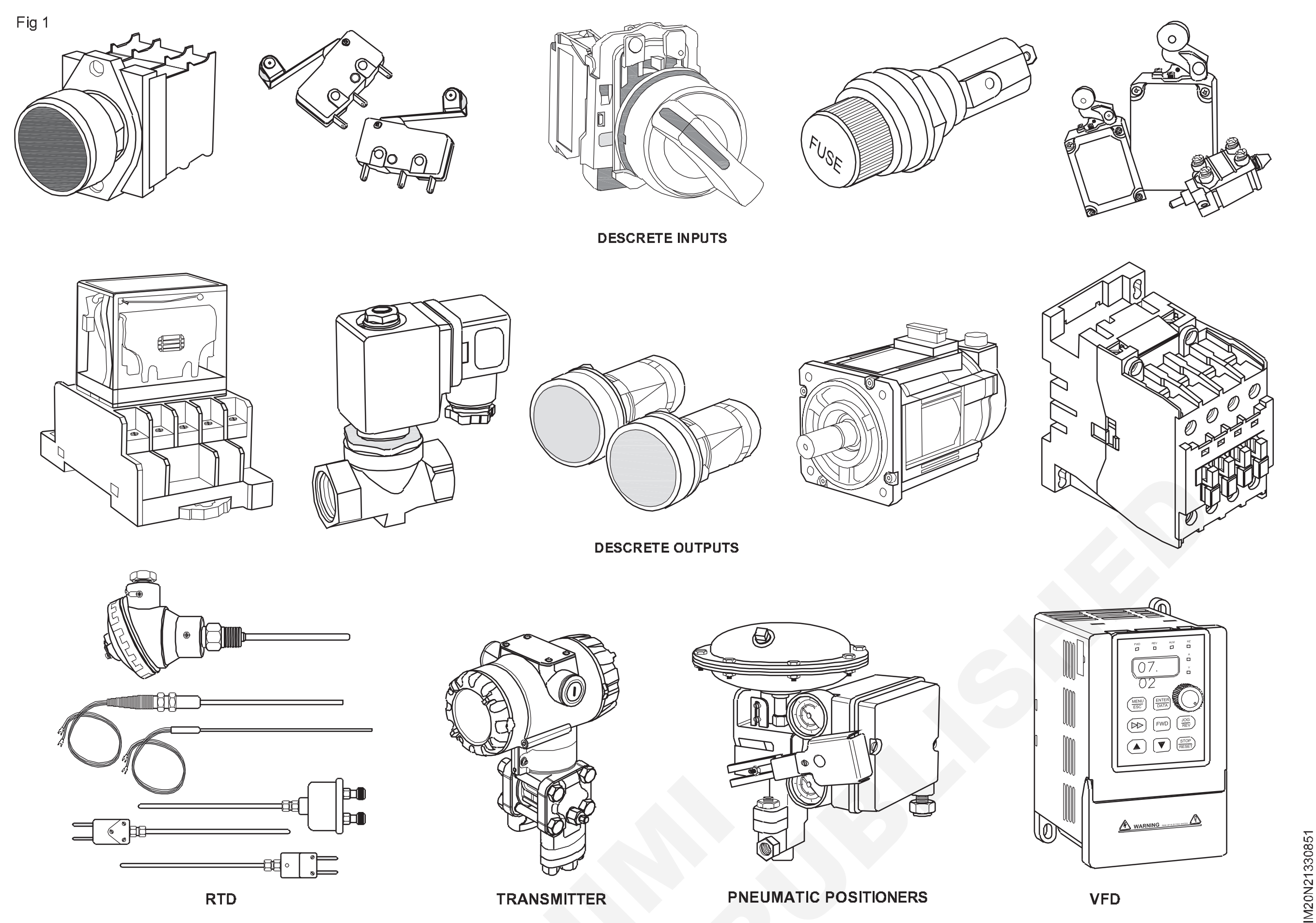
Discrete Type

I/P Devices	O/P Devices
Push Buttons	Relays
Switches	Contactors
Limit Switch	Lamps
Proximity sensor	Alarms hooters
Phptp sensor	LED
Contacts	Solenoled valves Coils

Analog Type

I/P Devices	O/P Devices
RTD	Analog ports
ThermocouplE	VFD
Transducers	Actuator
Transmitter	Valve positioner

Fig 1



I/o devices Interfacing

in the early days of programmable logic controllers, processor speed and memory were too limited to support anything but discrete (on/off) control functions. Consequently, the only I/O capability found on early PLCs were discrete in nature. Modern PLC technology, though, is powerful enough to support the measurement, processing, and output of analog (continuously variable) signals.

All PLCs are digital devices, in order to interface with an analog sensor or control device, some "translation" is necessary between the analog and digital worlds. Inside every analog input module is an ADC, or Analog-to-Digital Converter, circuit designed to convert an analog electrical signal into a multi-bit binary word.

Conversely, every analog output module contains a DAC, or Digital-to-Analog Converter, circuit to convert the PLC's digital command words into analog electrical quantities.

Analog I/O is commonly available for modular PLCs for many different analog signal types, including:

Voltage (0 to 10 volts, 0 to 5 volts)

Current (0 to 20 mA, 4 to 20 mA)

Thermocouple (millivolts)

RTD

Strain gauge

PLC Network I/O

Many different digital network standards exist for PLCs to communicate with, from PLC to PLC and between PLCs and field devices.

One of the earliest digital protocols developed for PLC communication was Modbus, originally for the Modicon brand of PLC.

Modbus

It was adopted by other PLC and industrial device manufacturers standard com protocol, and remains perhaps the most universal digital protocol available for vadical dingi devices today.

Modbus is a simple master-slave protocol. The master has full control of comication on for bus, whereas a slave will only respond when spoken to. The master will record outputs and read in inputs from each of its slaves, during every cycle.

Profibus originally developed by Siemens.

PROFIBUS has two variants: PROFIBUS DP and PROFIBUS PA. The PROFIBUS DP is one of the 2 variants that is used most frequently.

Profibus is essentially a data communication system that allows a relatively large number of components to share a two-core copper cable (bus system). This saves enormously in cabling and installaion costs compared to convertional non-digital systems. The optimal cable offers even more advantages such as:

- Minimizing of components
- Simpler designs
- Shorter testing and purchasing period
- Simpler maintenance

Encoders: Encoders can be used in linear measurements as well as rotary measurements, registration mark timing, web tensioning, backstop gauging, conveying, filling and more. But by far the most common application is providing feedback in motion control of electric motors.

An encoder is a sensor of mechanical motion that generates digital signals in response to motion. As as electro-mechanical device, an encoder is able to provide motion control system users with information concerning position, velocity and direction.

There are two differen types of encoders:

1 Linear

2 Rotary

A linear encoder responds to motion along a path, while a rotary encoder responds to rotational motion.

An encoder is generally categorized by the means of its output.

An incremental encoder generates a train of pulses which can be used to determine position and speed.

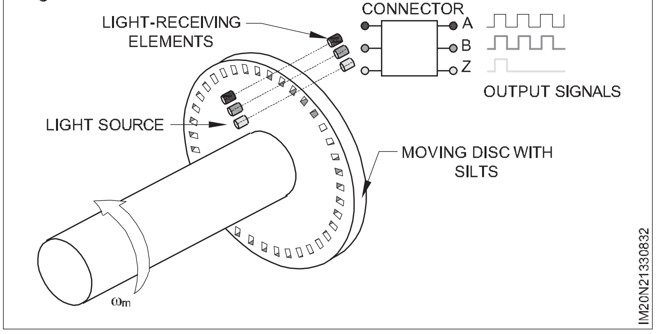
An absolute encoder generates unique bit configurations to track positions directly.

How do incremental encoders work?

Incremental rotary encoders utilize a transparent disk which contains opaque sections that are equally spaced to determine movement. A light emitting diode is used to pass through the glass disk and is detected by a photo detector.

This causes the encoder to generate a train of equally spaced pulses as it rotates. The output of incremental rotary encoders is measured in pulses per revolution which is used to keep track of position or determine speed.(Fig 2)

Fig 2



Absolute encoder

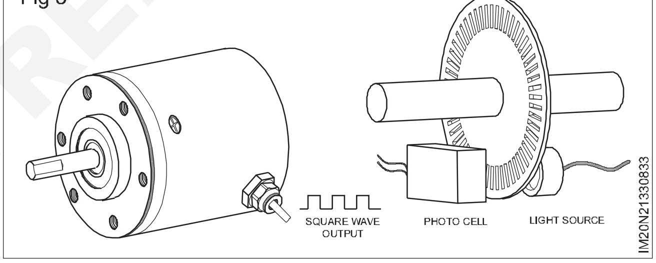
An absolute encoder contains components also found in incremental encoders. They implement a photo detector and LED light source but instead of a disk with evenly spaced lines on a disc, an absolute encoder uses a disk with concentric circle patterns.

How do absolute encoders work?

Absolute encoders utilize stationary mask in between the photo detector and the encoder disk as shown below. The output signal generated from an absolute encoder is in digital bits which correspond to a unique position. The bit configuration is produced by the light which is received by the photo detector when the disk rotates.

The light configuration received is translated into gray code. As a result, each position has its own unique bit configuration. (Fig 3)

Fig 3



An absolute encoder can tell you the exact position of the shaft in its rotation at any given time (and bow many rotations have transpired on a multi-turn absolute encoder). An incremental encoder can only report a change in position.

	Incremental Encoders	Absolute encoders
Output singal	The output signal is rectangular pulses	The output signal is a code signal
Position memory	When the power is turned off, It does not save the position	When the power is turned off, it remembers the position
Direction of rotaion	the shape of the generated output signal is the same regardless of the direction of rotation, only the order of the generated signal chahges	position regardless of the direction, the information is always about a specific position velocity depend-ing on the direction of rotaion, the generated speed value can be with "-" "+" sign.

OPTO isolators for safety

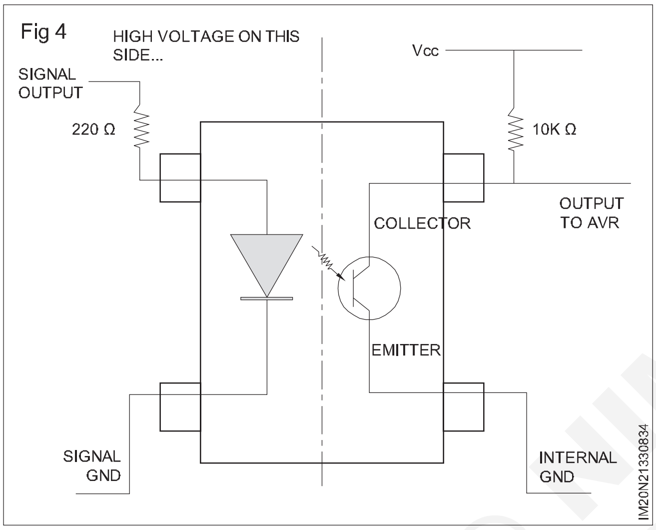
An opto-isolator (also called an optocoupler, photo coupler, or optical isolator) is an electronic component that transfers electrical signals between two isolated circuits by using fight.

Opto – isolators prevent high voltages from affecting the system receiving the signal.

Optocoupler functions as a galvanic isolation component. That is it maintains the connection between two devices or component without any direct conduction.

Components or devices like PLC,SCDA, Sensor etc. Say a sensor is to connected to a PLC, if it is directly connected – any fault in the circuit would damage the PLC.

Fig 4



The signal isolation enables supplying the input channels of the PLCs with a wide range of input signals.

The range of input signals might be : 5V,24V,110V and 230 V in the form of ON/OFF or digital discrete signals.

Outputs are often specified to be in the form of following types:

1 Relay type

2 Transistor type

3 Triac type

Relay Type

In this type the output signal from the PLC operates a relay which switches small current in the external circuit and isolates the PLC from the external circuit that having larger currents.

Since the relay outputs are relatively slow, thus it will be suitable for AC and DC switching.

Transistor Type

In this type transistor is using to switch current in the external circuit.

Output gives faster switching and being restricted to DC switching.

It is destroyed by over currents or high reverse voltage therefore a protection is used in the form of either a fuse or a built in electronic protection.

Triac Type

This type can be used with opto isolatiors to control the external loads which are connected to an AC power supply.

It is used always with AC and must be protected by fuses against over currents.

PLC Programming

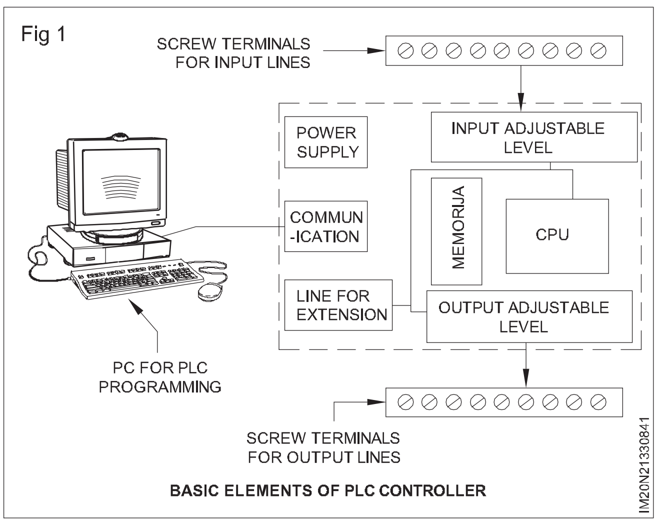
Objectives: At the end of this exercise you shall be able to
- **explain processing & programming for clims of PLC**
- **write ladder diagrams**
- **list programming symbols used in PLC**
- **explain timers & contends used in PLC**
- **explain data manipulation instructions used in PLC.**

Processing and programming

Central processing unit (CPU) is the brain of a PLC controller. The process of implements logic and controls communications among modules in the PLC. A CPU can perform date manipulation and arithmetic functions. It accepts input data and execules the user program before sending appropriate output commands to other control devices. CPU also takes care of communication among other parts of PLC controller, program execution, memory operation, overseeing input and setting up of an output.

PLC controllers have complex routines for memory checkup in order to ensure that PLC memory was not damaged. (Fig 1)

Fig 1



BASIC ELEMENTS OF PLC CONTROLLER

(Memory checkup is done for safety reasons) Generally speaking. CPU unit makes a great number of check-ups of the PLC controller itself so eventual errors would be discovered sarly.

Memory Units

This common types of memory used in PLCs are read only memory (ROM) and random access memory (RAM). A Rom location can be read, but not written, ROM is used to store programs and date that should not be altered. For example, the PLC's operating programs are sstored in ROM. User memory is divided into blocks having special functions. Some parts of a memory are used for storing input and output status. The real status of an input is stored either as "1" or as "0" in a specific memory bit. Each input or output has one corresponding bit in memory. Other parts os memory are used to store variable contents for variable used in user program. For exabple, timer value, or counter value would be stored in this part of the memory. The memory contains data for several types of information. Usually, the data tables, or image registers and the software programme are in the CPU modules memory.

A battery is used by some manufacturers to protect the memory contents form there be a power or memory module failure. Still others use various integrated circuit (IC) memory technologies and design schemes that will protect the memory contents without the use of a battery backup.

Manufacturers will state memory size in either "bytes" or "wordss. "A byte is eight bits, and a bit is the smallest digit in the binary code. It's either a logic "1" or a logic "0". A word is equal in length to two bytes or 10 bits. Not all manufacturers use 16-bit words, so be aware of what your PLC manufacturer has defined as is memory word bit size.

Ladder diagram, better known as ladder logic, is a programming language used to program PLCS (programable logic controllers). Of the various languages one can use to program a PLC. ladder logic's the only one directly modeled after electromechanical relay systems.

It uses long rungs laid out between two vertical bars representing system power. Along the rungs are contacts and coils, modeled after the contacts and coils found on mechanical relays. The contacts act as inputs and often represent switches or push-buttons, the coils behave as outputs such as a light or a motor

Outputs don't have to be physical, though, and can represent a single bit in the PLC's memory. This bit can then be used later on in the code as another input. Contacts are placed in series to represent AND logic and in parallel when using OR logic.

There are two differences between an electrical schematic and a ladder diagram. The fist difference is the control logic in an electrical schematic is represented using components whereas in a ladder diagram symbols are used.

The second difference is the control logic execution in an electrical schematic is as per the operation of an electrical circuit whereas in a ladder diagram it relies on the methodical nature of the PLC scan. (Figs 2&3)

Fig 2

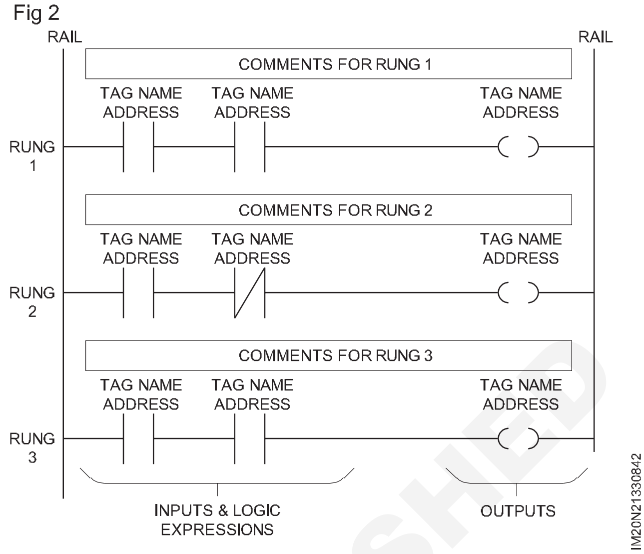


Fig 3

The AND function examines multiple PLC inputs and has one resulting output.

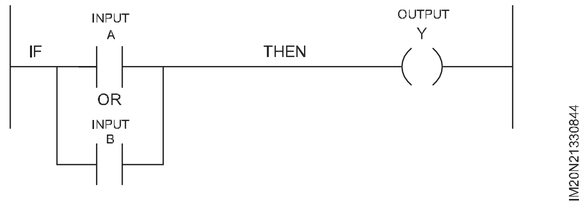
If we translate an AND function into a ladder diagram we can express it symbolically in the form of two normally open (NO) contacts (PLC inputs A and B) and a relay coil (PLC output Y). They are all connected in line, just like a series connection in an electric circuit.

Inputs		Output
A	B	Y
FALSE	FALSE	FALSE
FALSE	TRUE	FALSE
TRUE	FALSE	FALSE
TRUE	TRUE	TRUE

The AND function examines if all the PLC inputs are TRUE or "1", then the corresponding result is also TRUE or "I".

However if any one of the PLC inputs is FALSE or "0"then the corresponding result is also FALSE or "0".

Fig 4



he inputs are placed in the rung in what is known as a branch. This is the equivalent of a parallel connection in an electric circuit. The output is then connected in line with the rung.(Fig 4)

Inputs		Output
A	B	Y
FALSE	FALSE	FALSE
FALSE	TRUE	TRUE
TRUE	FALSE	TRUE
TRUE	TRUE	TRUE

The **CF function** examines if any of the PLC inputs are TRUE or "1", then the corresponding result is also TRUE or "I".

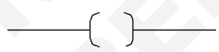
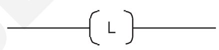
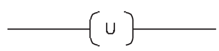
However, all the PLC inputs must be FALSE or "0" in order for the corresponding result is also be FALSE or "0".

PLC Data Logger

PLC Data logging is the process of gathering data from machines and connected devices sensors) for analysis. An example is the process of measuring the humidity in a factory oven as a digital value using a smart sensor.

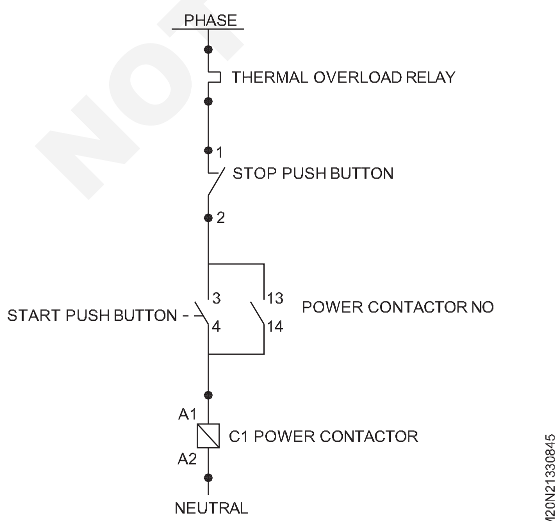
Data loggers benefit users in two ways. They avoid the time and expense of sending someone to take measurements in a remote location, and they enable much higher data density than is achievable through manual recording, providing higher quality data. Many different types of data loggers are available.

Commonly used Programming symbols

Instruction	Symbol	Description
Examine ON (Normally Open)		An input condition that is open when deenergized
Examine OFF (Normally Closed)		An input condition that is close when deenergized
Output coil		An output instruction that is true when the input conditions become true
Negated Output		An output instruction that is true all the time except when all input conditions true
Latch Output Coil		To hold an output ON
Unlatch		To unlatch the latched ON output

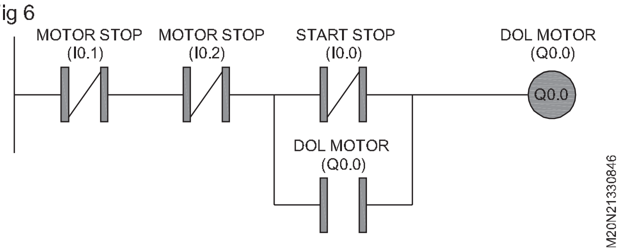
Direct online starter electrical circuit diagram (Fig 5)

Fig 5



Direct online starter ladder diagram (Fig 6)

Fig 6



Timers used in PLC

Timers and counters are used to activate or de-activate a device after a preset interval of time.

PLC timers are instructions that provide the same functions as on-delay and off-delay mechanical and electronic timing relays.

A PLC timer provides a preset delays the control actions. In general, there are three types of PLC timer delays, ON-delay timer, OFF-delay timer, and retentive timer on

On Delay Timer - this timer starts counting the time after the timer enabler is true and set the output bit to true after the time is reached. This timer is also called a on delay timer the timer can be reset by setting the enabler bit to false state

Off Delay Timer -This is a little tricky timer to understand. The timer sets the output bit to true as soon as the timer enabler is true. After the timer enabler is reset (or is in false) the timer counts the time and after reaching the specified time, switches off the output bit. In order to reset the timer, the enabler bit is again set to True but this will still keep the output bit True.

Retentive Timer on (RTO) This timer works same as On delay timer. Timer accumulator value won't reset even the enable input becomes off The timer can be reset only by an additional input called RESET input.

PLC Counters

A counter is a PLC instruction that either increments (counts up) or decrements (counts down) an integer number value when prompted by the transition of a bit from 0 to 1 ("false" to "true"). Counter instructions come in three basic types: up counters, down counters, and up/down counters.

There are two different types of counters, and count up and a count down. A count up timer is the most common, and on a low to high transition the counters accumulation value increments up by one.

A count down timer decrements by one. The counter also has a preset and and one bit preset the value that the counter will count to and when the accumulation value greater than or equal to the preset value then the done bit turns on. The last bit is the reset bit, which puts the accumulation vele back down to 0.

Data manipulation instructions

Data manipulation instructions are those that perform arithmetic, logic shift operation. Program control instructions provide decision making capabilities and change the path taken by the program when executed in the computer.

Data manipulation involves transferring data and operating on data with math functions, data conversion, data comparison and logical operations Data manipulation instructions enable the PLC to cake some of the qualities of a computer system. most PLC's are equipped with the capability to manipulate data. Each instruction requires two or more words of data memory for operation. The words of data memory are referred to as registers.

MOV (Move)-Moves the source value to the destination.

MVM (Masked Move)-Moves data from a source location to a selected portion of the destination

AND (And)-Performs a bitwise AND operation.

OR (Or)-Performs a bitwise OR operation.

XOR (Exclusive Or)-Performs a bitwise XOR operation.

NOT (Not) Performs a bitwise NOT operation. CLR (Clear)-Sets all bits of a word to zero.

LIM (Limit test)-Tests whether one value is within the limit range of two other values.

EQU (Equal) Tests whether two values are equal.

NEQ (Not Equal)-Tests whether one value is not equal to a second value.

LES (Less Than) - Tests thether one value is less than a second value.

GRT (Greater Than) - Tests whether one value is greaster than a second value.

LES (Less Than)--Tests whether one value is less than a second value.

GRT (Greater Than) -Tests whether one value is greater than a second value.

LEQ (Less Than or Equal) -1ests whether one value is less than or equal to a second value.

GEQ (Greater Than or Equal) -Tests whether one value is greater than or equal to a second value.

LEQ (Less Than orEqual) - Tests whether one value is less than or equal to a second value.

GEQ (Greater Than Equal) - Tests whether one value is greater than or equal to a second value.

Hart transmitters

Objectives: At the end of this exercise you shall be able to
- **explain about HART protocol**
- **explain steps in calibration of HART devices**
- **describe the advantages of HART communication**
- **explain about HART communication networks.**

Digital Control System

A digital control system is a control system that processes signals coming from sensors by means of a computer. The analogue signal (continuous in value and time) has to be sampled and take discrete values at given time intervals This process is known as signal digitalization.

Digital control has advantages over analog control in that digital operations can be easily controlled by a program, accuracy can be greater and digital circuits are less affected by noise

Need of Smart devices

Smart devices can be combined to bring intelligence to both objects and spaces, such at smart homes and buildings, and can help automate processes and controls. They can be used in almost any industry, from smart manufacturing to healthcare, helping to improve efficiency and optimize operations.

HART transmitter

“HART is an acronym for Highway Addressable Remote Transducer. The HART Protocol makes uses Frequency Shift Keying (FSK) standard to superimpose digital communication signals at a low level on top of the 4-20mA.

Features of HART

- Compatibility with standard 4-20mA wiring.
- Simultancias transmission of digital data.

Advantages of HART communication

- The benefits of selecting HART are
- Analog Capability,
- Digital Capability,
- Interoperability and Availability.
- Simultaneous analog and digital communication are facilitated by Analog Compatibility.
- HART can be used with a variety of sensors and devices.

Applications of HART

HART Protocol is an open standard used globally to send and receive digital information using analog wiring between smart devices and control systems.

HART Communication is the global standard for the process automation industry. An estimated 80%-90% of all measurement and control devices shipped each year are HART-enabled.

Used in smart devices and innovative technologies.

Working method of HART

The worldwide accepted standard for analog signals in the measurement industry is the 4 to 20mA signal. One key drawback of this signal standard is that it can only transmit one parameter or measured value.

A two-way or bidirectional communication protocol, which addresses this drawback, has been developed with which additional information can be transmitted using an alternating current signal superimposed on the 4 - 20mA analog signal. This system is called the HART communication protocol.

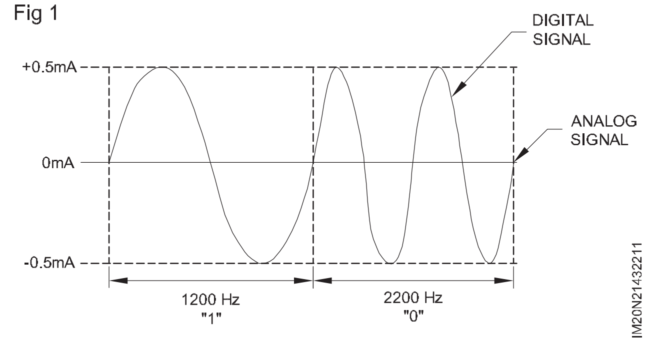
The HART communication protocol has become a widespread solution, allowing for convenient and efficient parameterization of smart (intelligent) measuring devices. Additionally, device-specific diagnostic data can be read which provides device information about the device’s physical health and allow for predictive maintenance. Monitoring various device parameters is also possibility with the HART protocol.

How the HART Protocol Works

The FSK (Frequency Shift Keying) procedure is the basis for the HART communication.

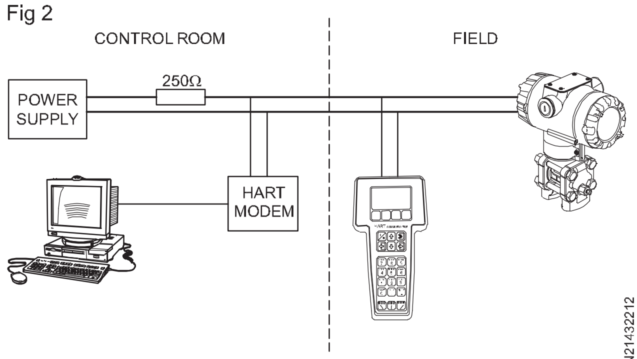
The HART digital signal is made up of two frequencies – 1,200 Hz representing bits 1 and 0, respectively as shown below: (Fig 1)

Fig 1



Sine waves of these two frequencies (shown in the diagram above) are superimposed on the direct current (dc) analog signal to provide simultaneous analog and digital communications. Because the average value of the FSK signal is always zero, the 4-20 mA analog signal is not affected. The HART protocol is often called a hybrid protocal because it combines analog and digital communication. A typical HART setup in a 4 – 20 mA system is shown below: (Fig 2)

Fig 2



HART PROTOCOL IN 4-20mA SYSTEM

In this setup, the HART devices (PC or handheld communicator) requests information from the field device (HART compatible). The field device suppliers the information which can then be used for condition monitoring, diagnostics, predictive maintenance and any other use that is required of the digital information supplied to the HART device. Meanwhile, the analog 4 – 20 mA signal is active and undistorted and can be used for control purposes while digital communication with HART is on-going.

HART Protocal

It is a hybrid analog + digital industrial automation open protocol. Most notable advantage is that it can communicate over 4-20 mA. HART is widely used in process and ranging from small automation applications upto highly sophisticated industrial applications.

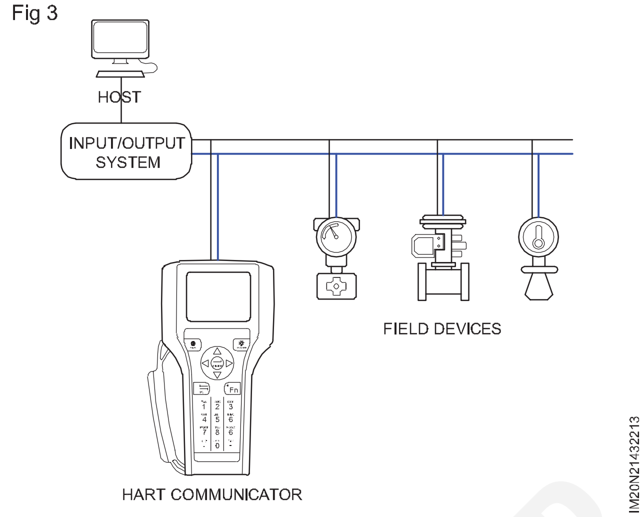
HART Communicator

HART communicator is a tool designed to communicate with process instruments HART communicators use 4-20mA analog wiring to establish communication with the HART- enabled devices. HART is an open communication protocol. HART communicators are suitable for processes that demand the use of several instruments for monitoring, calibration, or for processes in which the instruments are located in hazardous regions.

A HART communicator device consists of:

- LCD display
- Keypad .
- Battery
- Charging cable

Fig 3



PC based HART device configuration

Setting up a smart transmitter into a HART communicator is fairly simple and straightforward. However, one requirement is that you have to get yourself familiarized with the HART communicator if you are new to the device by reading the manual or better still get a tutorial from someone who has used the device previously.

The transmitter can be setup and commissioned before or after installation in the plant. In all cases. It is advisable to do a bench commissioning of the smart transmitter before installation to ensure proper operation, to familiarize yourself with transmitter functionality and to avoid exposing the transmitter electronics to a plant environment especially hazardous locations.

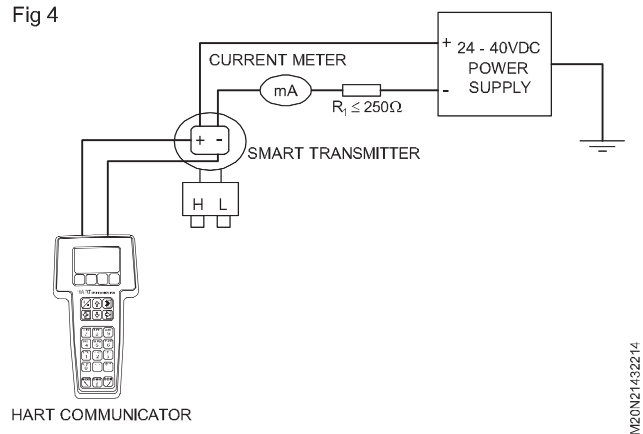
Commissioning the transmitter involves

Reviewing configuration data, setting output units, setting the 4-20Ma points, configuring the transmitter and testing the transmitter output.

How to Setup the Smart Transmitter Using the HART Communicator.

To configure the smart transmitter on the bench, connect the transmitter and communicator as shown below (Fig 4)

Fig 4



To power the transmitter, you will need a power supply capable of supplying at least 24VDC and a digital multimeter to measure output current. To enable communication with the HART communicator, a resistance of at least 250Ω must be present between the communicator loop connection and the 24VDC power supply.

Once your equipment have been setup as shown above, turn on the communicator by pressing the ON/OFF key. The communicator will search for any HART-compatible device in the loop and will Indicate when a connection is made. If a connection is not made, the HART communicator will indicate that no device was found.

Once the communicator establishes communication with the transmitter, output units can then be set the transmitter configured and calibrated appropriately.

Steps in calibration of HART

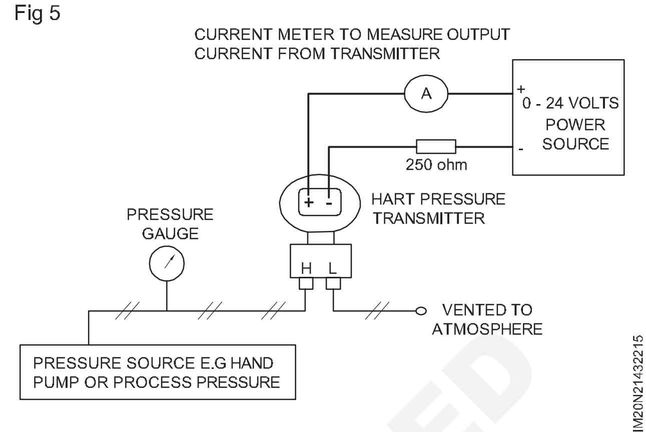
- Power supply: To energize the transmitter,
- 250ohm resistor: To convert current into the voltage, which is suitable for the control systems.
- Ammeter: ammeter is connected in series with the transmitter to measure the output current.
- Pressure source: Can be the process pressure or hand pumps to produce pressure supply to the transmitter.
- Pressure gauge: To measure the input pressure to the transmitter.

HART communicator: Used to view the pressure in the transmitter and to calibrate the pressure.

Procedure:

- Do the connection as shown in the above figure.
- Testing pressure is given to the HP line of the pressure transmitter and the LP line is set at ambient pressure, that is LP line is vented to atmosphere.
- Apply a lower range pressure that is 0psi pressure in most cases. Check the HART communicator for the transmitter is showing the same value as the pressure gauge shows.
- Check the ammeter reading also, an ammeter should show 4mA for 0psi pressure.
- Do the same check procedure for high range value of the pressure gauge. The ammeter should read 20mA current and the HART communicator should read the high range value as in the gauge.
- We need to calibrate the transmitter if transmitter shows incorrect value. The means if the transmitter shows.
- If the current for the corresponding pressure is incorrect. Then correct the transmitter reading by adjusting the span and zero to make get the correct reading.
- Rotate the span in a clockwise direction if the current value is showing lower the actual value should be. Or rotate anti-clockwise direction if the vaule is higher than the actual.
- If the pressure showing in the HART communicator is different from the gauge. Then the transmitter should be calibrated using the HART communicator. (Fig 5)
- For calibration, we only need to check upper range value and lower range value.

Fig 5



- If the HART is showing incorrect value for the upper range value or lower range value.
- Go to settings in HART > select URV or LRV, based on which should be corrected change the value in the HART communicator>save the data into the transmitter.

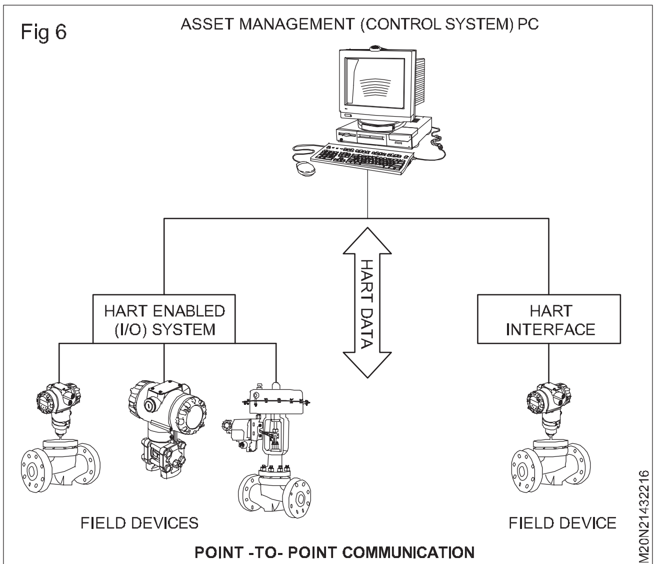
HART communication networks

HART devices can operate in one of two network configurations-point-to-point or multi-drop.

Point-to-Point network mode

In point-to-point mode, the 4-20mA signal is used to communicate one process variable, while additional process variables, configuration parameters, and other device data are transferred digitally using the HART Protocol. The 4-20mA analog signal is not affected by the HART signal and can be used for control. The HART communication digital signal gives access to secondary variables and other data that can be used for operations, commissioning, maintenance and diagnostic purposes. A typical point-to-point communication network is shown below: (Fig 6)

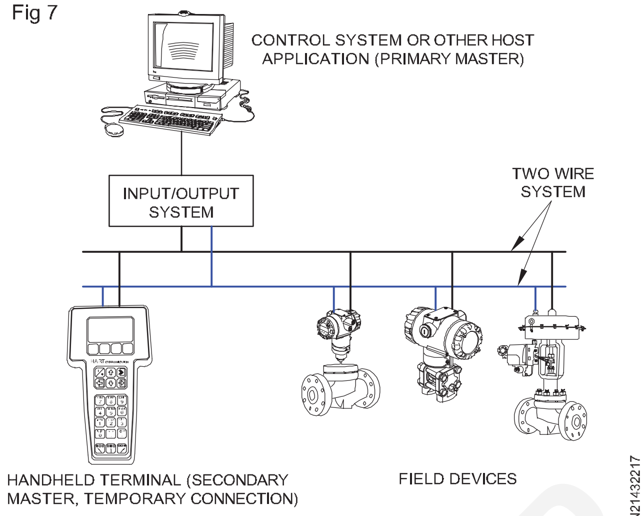
Fig 6



Multi-Drop Mode (Fig 7)

The HART communication protocol enables several instruments to be connected on the same pair of wires in a multi-drop network configuration. The current through each field device is fixed at a minimum value (typically 4mA) sufficient for device operation. The analog loop current does not change in relation to the process and thus does not reflect the primary variable. Communications in multi-drop mode are entirely digital Multi-drop connection is mostly used for supervisory control installations that are widely spaced such as pipelines, custody transfer stations, and tank farms. Below is shown a multi-drop network configuration.

Fig 7



MULTI-DROP CONFIGURATION

Network

Objectives: At the end of this lesson you shall be able to
- **describe the different types of networks used in digital instrument systems**
- **define topology and its uses**
- **explain about TCP/IP address.**

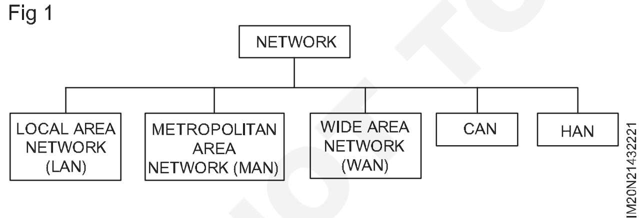
Network

Definition: A network is a group of computers that can communicate with each other to share information. When computers communicate with each other, they can share resources. These resources can be data, applications or hardware. We can connect two computes together with a cable, which results in a simple network.

Types of networks

There are primarily three categories of networks Namely Local area Networks (LAN), Metropolitan Area Network (MAN) and Wide Area Network) WAN). The category of a network is determined by its size, ownership, the distance it covers and its physical architecture. (Fig 1)

Fig 1



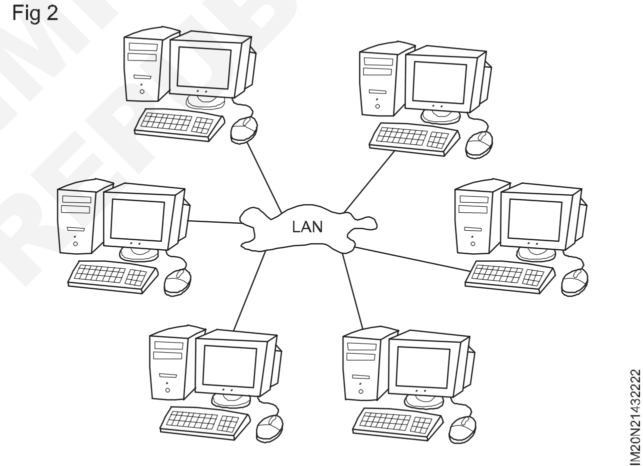
Types of Networks

LAN

A local area network (LAN) is usually owned and links the devices in a single office building or campus.

Depending on the needs of an organization and type of technology, used a LAN can be as sample as 2 PCs and a printer in someone's home office or it can extend throughout company and include voice sound and video peripherals. Currently LAN's size is limited to few kilometers. (Fig 2)

Fig 2



LANs are designed to allow resources to be shared between PCs or workstations. The resources to be shared can include hardware (e.g. a printer), software (e.g. a application program) or data.

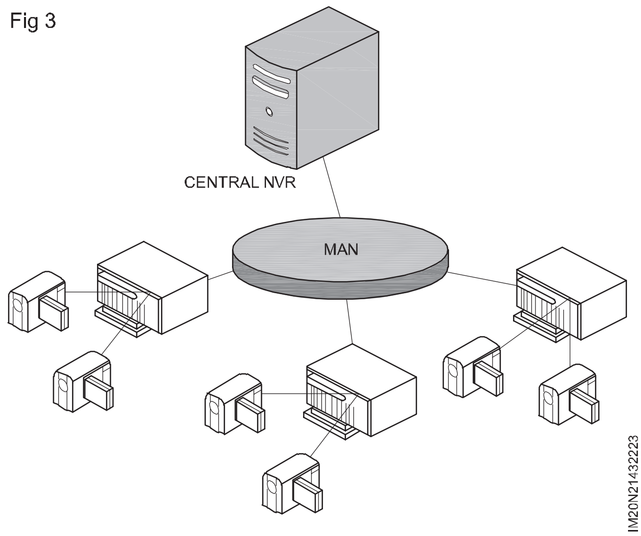
In addition to size, LANs are distinguished from other types of networks by their transmission media and topology. In general, a given LAN will use only one type of transmission medium. The most common LAN topologies are bus, ring and star

Traditionally, LANs have data rates in 4 to 16 Mbps range. Today, the speeds are increasing and can reach 100 Mbps with gigabit systems in development.

MAN

A Metropolitan area network (MAN) is designed to extend over an entire city It may be a single network such as a cable television network or it may be a means of connecting a number of LANs into a large network so that resources may be shared LAN - to - LAN as well as device-to-device. For example, a company can use MAN to connect the LANs in all its offices throughout a city. (Fig 3)

Fig 3



Metropolitan area network

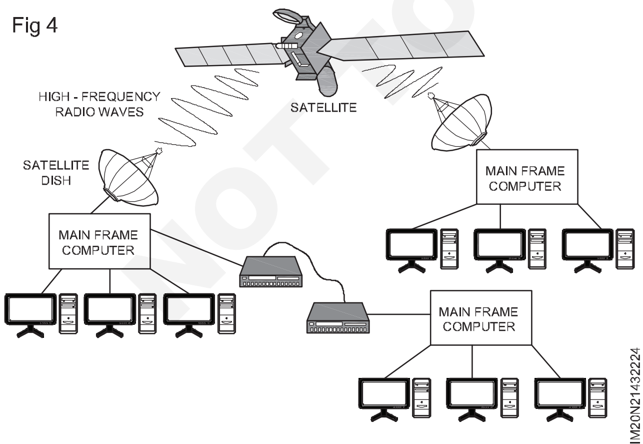
A MAN can be wholly owned and operated by a private company or it may be a service provided by a public company such as a local telephone company.

WAN

A wide area network (WAN) provides long distance transmission of data, voice, image and video information over large geographical areas that may comprise a country, continent or even the whole world.

In contrast to LANS (depend on their own hardware for transmission). WANS may utilize public, leased or private communication devices, usually in combinations and can therefore span unlimited number of miles. A WAN that is wholly owned and used by single company is often referred to as an enterprise network. (Fig 4)

Fig 4



CAN

A Controller Area Network (CAN bus) is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other in applications without a host computer. The devices that are connected by a CAN network are typically sensors, actuators, and other control devices. These devices are connected to the bus through a host processor, a CAN controller, and a CAN transceiver.

HAN

A Home Area Network (HAN) contained within a user's home that connects a person's digital devices, from multiple computers and their peripheral devices to telephones, VCRs, televisions, video games, home security systems, smart appliances, fax machines and other digital devices that are wired into the network.

This can be used to increase the quality of life inside the home in a variety of ways, such as automation of repetitious tasks, increased personal productivity, enhanced home security, and easier access to entertainment.

Types of Ethernet:

Several schemes have been devised to improve the performance of Ethernet LANs.

Two of them are

1 Fast Ethernet 2 Gigabit Ethernet.

Fast Ethernet

With new applications such as CAD, image processing and real time audio and video being implemented on LANS, there is a need for a LAN with a data rate higher than 10 Mbps. Fast Ethernet is a version of Ethernet with a 100 Mbps data rate. There is no change in the frame format and in the access method. The only two changes in the MAC layer are the data rate and the collision domain. The data rate is increased by a factor of 10.

In the physical layer, IEEE has designed two categories of Fast Ethernet:

1 100Base-X and

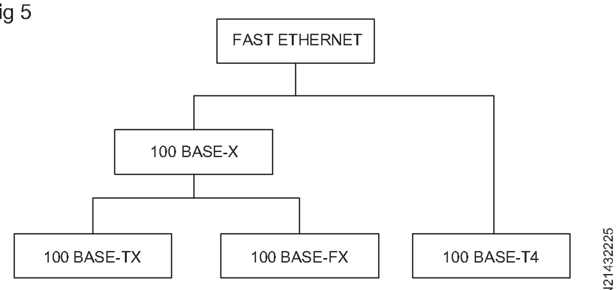
2 100Base-T4.

The first uses two cables between the station and the hub. The second one uses four. 100Base-X itself is divided into two types:

1 100Base - TX and

2 100Base - FX (Fig 5)

Fig 5



CATEGORIES OF FAST ETHERNET IMPLEMENTATIONS

Gigabit Ethernet

The migration from 10Mbps to 100 Mbps encourages the IEEE802 3 committee to design Gigabit Ethernet, which has a data rate of 1000 Mbps or 1 Gbps. The strategy is the same. The MAC layer and the access method remain the same, but the collision domain is reduced. In the physical layer, the transmission media and the encoding system change. Gigabit Ethernet is mainly designed to use optical fiber, although the protocol does not eliminate the use of twisted pair cables Gigabit Ethernet usually serves as a backbone to connect Fast Ethernet networks. (Fig 6)

Four implementations have been designed for Gigabit Ethernet:

1 100Base-LX

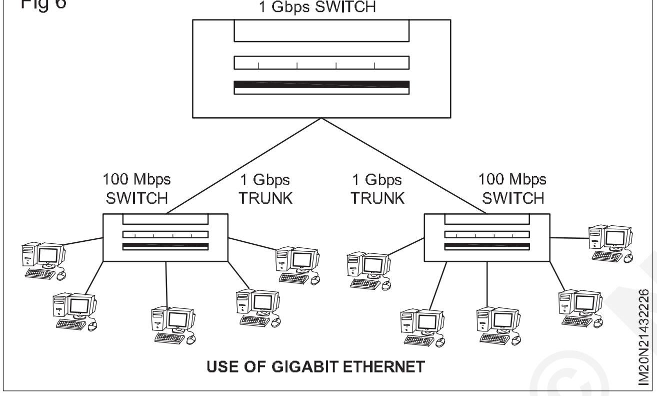
2 100Base-SX

3 100Base-CX and

4 100Base-T

The encoding is 8B/10B, which means a group of 8 binary bits are encoded into a group of 10 binary bits.

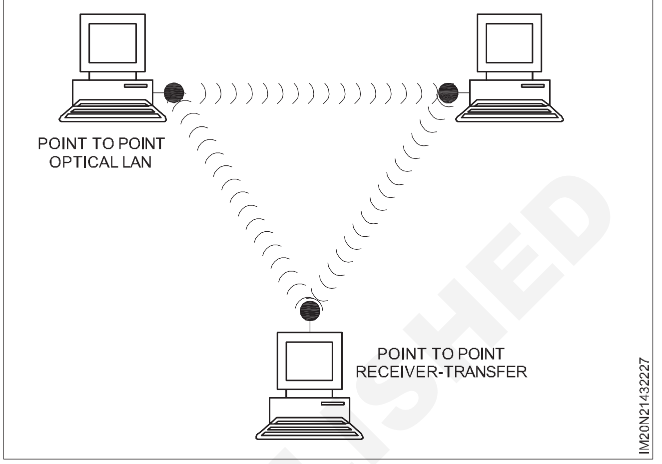
Fig 6



Point-to-point: Infrared beams can be tightly focused and directed at a specific target. Laser transmitters can transmit line-of-sight across several thousand meters.

One advantage of infrared is that an FCC license is not required to use it. Also, using point-to-point infrared media reduces attenuation and makes eavesdropping difficult. Typical point-to-point infrared computer equipment is similar to that used for consumer product with remote controls. Careful alignment of transmitter and receiver is required. Fig 7 shows how a network might use point-to-point infrared transmission.

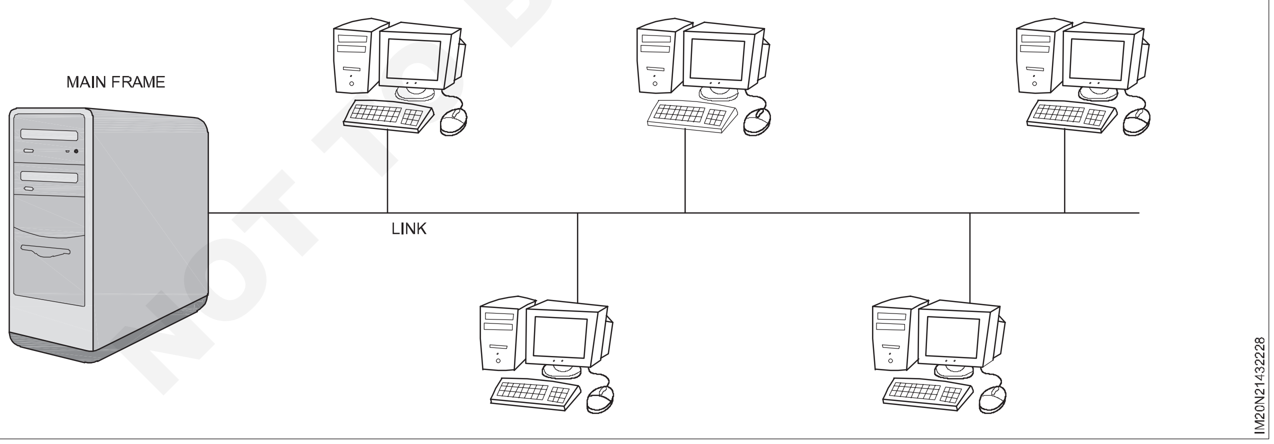
Fig 7



Definition of Multipoint Connection (Fig 8)

The multipoint connection is a connection established between more than two devices. The multipoint connection is also called multidrop line configuration. In multipoint connection, a single link is shared by multiple devices. So it can be said that the channel capacity is shared temporarily by every device connecting to the link. If devices are using the link turn by turn, then it is said to be time shared line configuration.

Fig 8



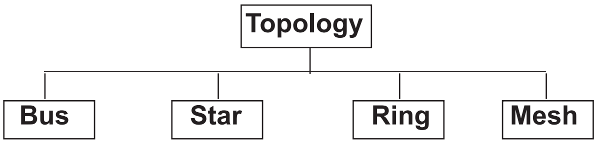
In a broadcast network, the packet transmitted by the sender is received and processed by every device on the link. But, by the address field in the packet, the receiver determines whether the packet belongs to it or not, if not, it discards the packet. If packet belongs to the receiver then keeps the packet and respond to the sender accordingly.

Network topologies

Objectives: At the end of this exercise you shall be able to
- outstand basic topologies
- compare different topologies.

Topologies

The topology of a network is the geometric representation of the reliWORK TOPOLOG of all the links and linking devices (usually called nodes) to each other. There are four basic topologies possible bus, star, ring and mesh. See figure below.



Basic topologies

These topologies describe how the devices in a network are interconnected rather than their physical arrangement. When choosing a topology, we have to consider the relative status of the devices to be linked i.e. whether the devices share the link equally (peer to peer) or one device controls the traffic and others must transmit through it (primary-secondary), Ring and mesh topologies are peer to peer transmission, star is primary-secondary. A bus topology is equally convenient for either.

Bus topology (Fig 1)

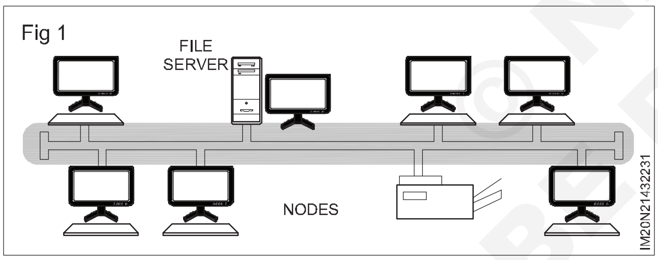


Fig 1

The bus topology consists of computers connected by a single cable called a backbone as in figure below. All the computers on the bus share in its capacity. This is the simplest method for connecting computers In a bus environment, 10Base2 or 10Base5 cable is used, and because all devices share the same bandwidth, the more devices, the slower the network In fact, it is probably not feasible for use with more than 10 workstations.

Bus topology: In a bus topology, the computers only listen for data being sent to them, they do not forward the data. This is called a passive topology. A generated signal moves from one end of the bus to the other end. To prevent the signal from bouncing back and forth, a terminator is located at each end of the cable.

Because all the computers are connected by the same cable, if one segment has a problem, the whole network is down.

Advantages

1 Cabling is easy to work with and extend with less cost.

2 Less cabling because all computers are in one line.

3 Layout is simple.

Disadvantages

1 Fault isolation is difficult because one break affects the entire network.

2 One break or bad termination brings down the entire network.

3 Heavy traffic can slow it down because all machines share same bandwidth.

Star topology (Fig 2)

In star topology, the computers are connected to a centralized hub by a cable segment as in figure. They require more cabling than ring or bus topologies, but each computer is connected to the hub by its own cable. Therefore if one computer connection goes down, it does not affect the rest of the network Because each workstation has its own connection, it is much easier to move them around or connect them to other networks 10BaseT -100BaseFX can be used a star topology A star topology can support up to 1024 workstations but it may not be feasible to connect them all to the same logical network.

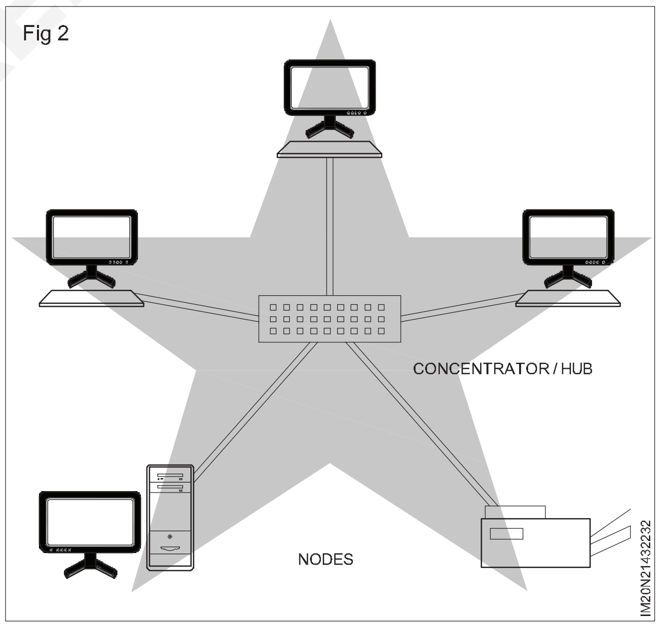


Fig 2

Advantages

1 The entire network is not disrupted when adding or removing computers.

2 If one computer fails, it does not affect the rest of the network.

3 It is easy to manage and monitor.

Disadvantages

1 It requires more cabling because each machine needs a separate connection to the central hub.

2 If the central hub fails, it brings down the entire network.

Ring topology

In ring topology, each computer connects directly to the next one in line forming a circle as shown in Fig 3. Data travels in a clockwise direction and each computer accepts the information intended for it and passes on the information for other computers. It uses a token, which is actually a small packet, to send information Every compact in the ring is responsible for either passing the token or creating a new one. Token passing uses the token, or series of bits, to grant devicepermission to transmit over the network. When a computer has information to send, it modifies the token and passes st on After the token reaches its final destination, it lets the sender know it has arrived safely, the sender then makes a new token, and the process starts over Most ring networks use fiber or twisted par as the medium.

This is known as active topology because each workstation is responsible for sending on the token Currently many ring networks implement a dual-ring network or small hub to address this problem.

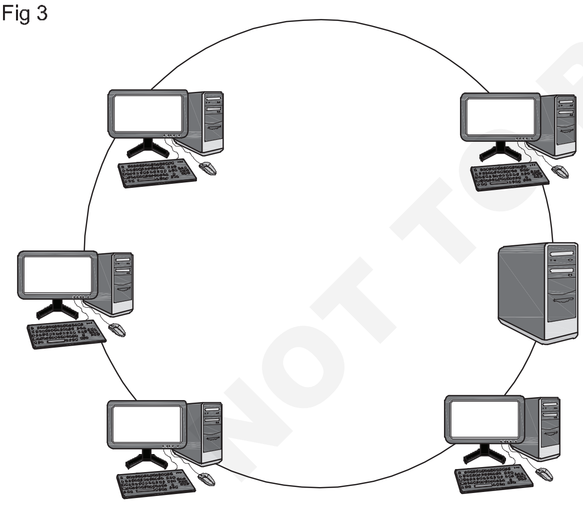
Advantages

1 Network performance is consistent due to token passing.

2 The length of the cable required is short.

3 Equal access is granted to all computers.

Fig 3



Disadvantages

1 Unidirectional traffic.

2 If one computer fails, it brings down the entire network.

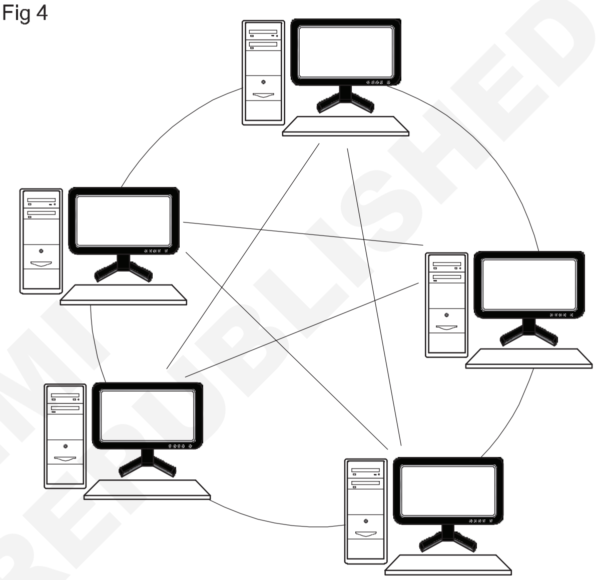
3 The entire network is disrupted when adding or removing computers.

Mesh topology (Fig 4)

In a mesh topology, all devices are connected to each other more than once to create fault tolerance as in figure below. A single device or cable failure will not affect the performance because the devices are connected by more than one means. This is more expensive as it requires more hardware and cabling. This type of topology can also be found in enterprise-wide networks with routers connected to other routers for fault tolerance.

So, a mesh topology is usually implemented in a limited fashion, for example, as a backbone connecting the main computers of a hybrid network that can include several other topologies.

Fig 4



MESH TOPOLOGY

Advantages

1 The use of dedicated links guarantees that each connection can carry its own data load.

2 In mesh topology, if one link becomes unusable, it does not affect the entire system.

3 Another advantage is privacy or security When every message sent travels along a dedicated line, only the intended recipient sees it.

4 The point-to-point links make fault identification and fault isolation easy.

Mesh topology

Disadvantages

1 Because every device must be connected to every other device, installation and reconfiguration are difficult.

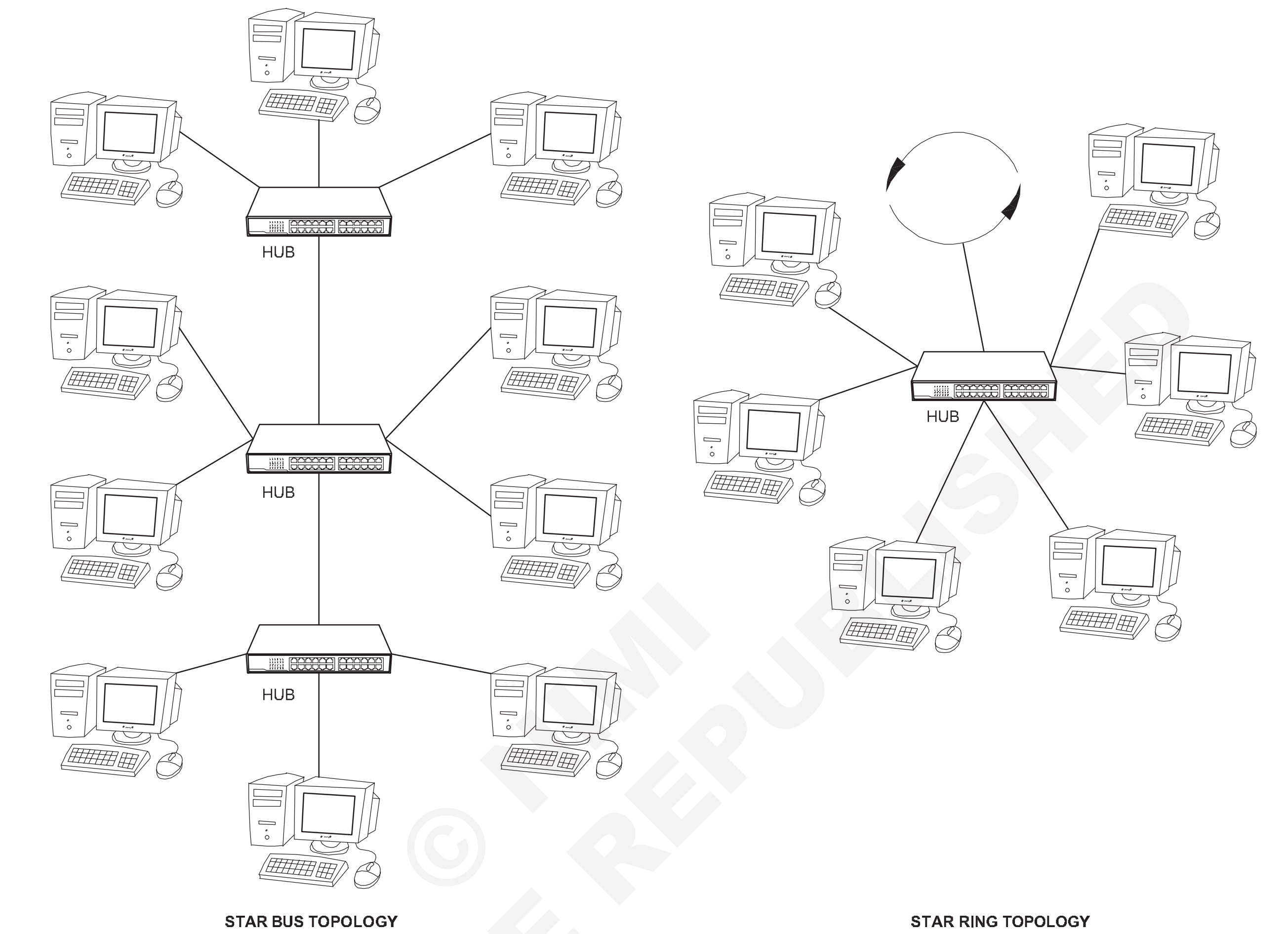
2 The sheer bulk of the wiring can be greater than the available space.

3 The hardware required to connect each link can be prohibitively expensive.

Hybrid topology

A network that combines several other topologies as subnet works linked together in a Large topology. For instance, in star bus topology, computers are connected to hubs in a star formation and then the hubs are connected via bus topology Refer figure below Although it is more expensive to implement, longer distances can be covered and networks can be isolated more easily. (Fig 5)

Fig 5



In a star ring topology, data is sent in a circular motion around the star Refer figure above. This eliminates the single point of failure that can occur in a ring topology. It uses token passing data transmission with the physical layout of a star.

Large networks are typically organized as hierarchies. A hierarchical organization provides advantages such as ease of management, flexibility and a reduction in unnecessary traffic. In a hierarchical network structure, a high-speed backbone of Fiber optic cable usually connects the servers.

Advantages

1 Fault detection and trouble shooting is easy.

2 It is easy to add new devices or network.

Disadvantages

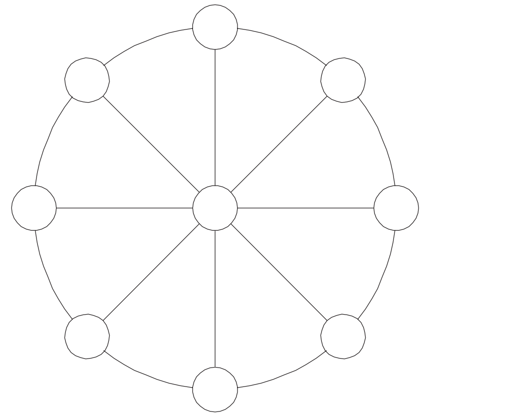
1 It is difficult to design.

2 The hubs used to connect two different networks are very expensive.

Delta -star-topology

The multicast connection form is Clearly different from the point-to-Point One, the optimal network topology will also be different if many multicast services are provided. The delta-star topology has been proposed as an effective topology day brow for a point-to-point network when reliability is a consideration. It may also be effective for multicast Services. (Fig 6)

Fig 6



Tree Topology (Fig 7)

In tree topology, the devices are arranged in a tree fashion similar to the branches of a tree. Devices at lower level are connected to devices at next higher level, which resembles a tree like structure. At higher levels of the tree, often point-to-point or point-to-multipoint connections are used.

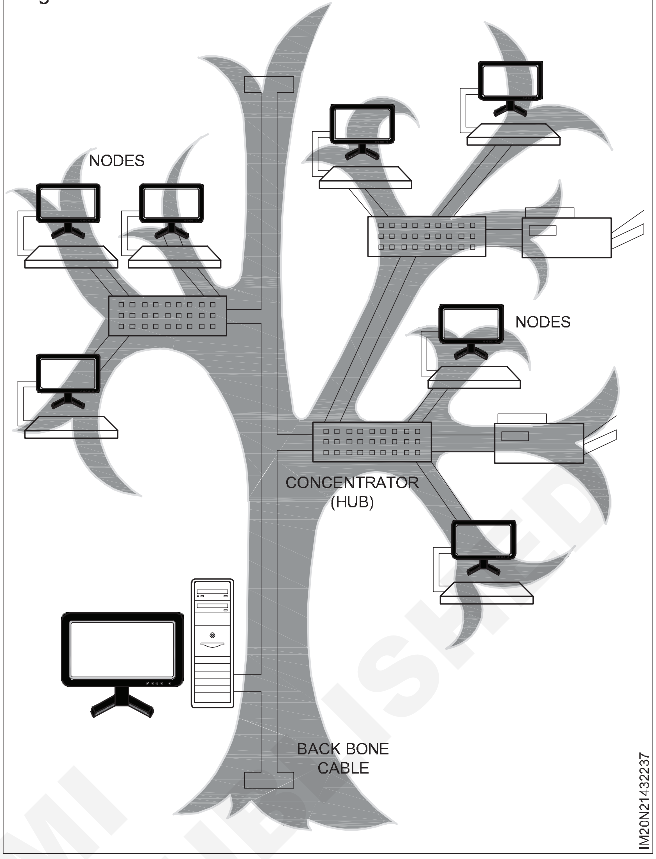
Tree topology based networks has a hierarchical structure as shown in below image. Structure of network in below image resembles an inverted tree.

Tree topology based networks are not suitable for small networks because of the requirement for additional devices and cables.

Tree topology is suitable for large networks, spread into many branches. Example. Big university campuses, hospitals etc.,

Main disadvantage of tree topology is that the connectivity between tree branches are dependent on main backbone switches. If there is no redundancy solution applied at backbone switches, connectivity between branches will fail.

Fig 7



Redundant Network

Network, redundancy is the process of providing multiple paths for traffic, so that data can keep flowing following even in the event of a failure. The idea is that if one device Jails another can automatically take over.

Protocols

Objectives: At the end of this exercise you shall be able to
- **understand types of protocols**
- **understand the applications of different protocols.**

Types of Protocols

Overview of TCP/IP

In 1970, a project was funded by the Advanced Research Project Agency (ARPA) of US Department of Defense to establish a packet switching network of computers called TYPES OF PROTOCOLS- Advanced Research Project Agency Network (ARPANET) that provided the basis for networking The conventions developed by ARPA to specify how individual computers could communicate across that network became TCP/IP The adaptability of TCP/IP and expansion of ARPANET became the backbone of today's Internet.

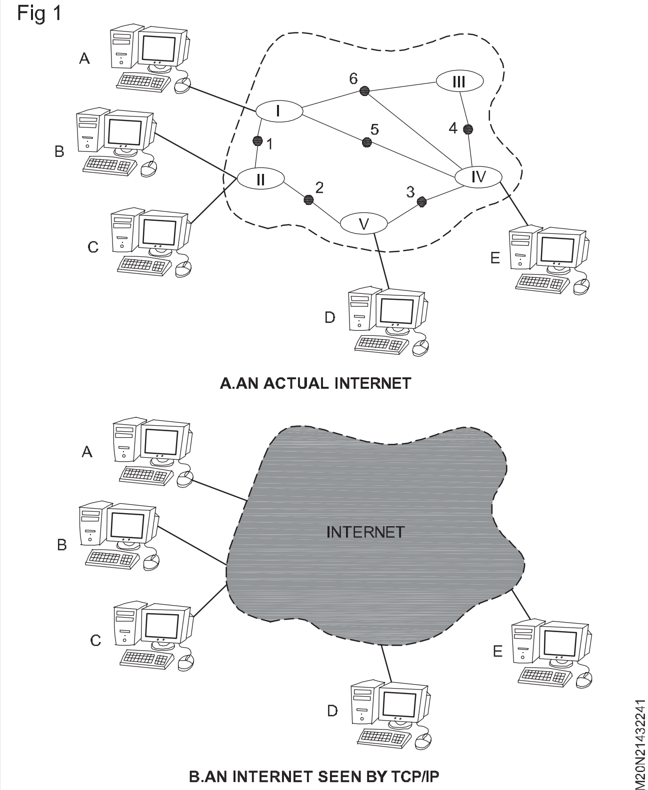
TCPAP

The Transmission Control Protocol/Internetworking Protocol is a set or protocols or a protocol suite that defines how all transmissions are exchanged across the internet.

TCP/IP and the Internet (Fig 1)

An internet under TCP/IP operates like a single network connecting many computers of any size and type Internally the Internet is an interconnection of independent physical networks linked together by

Fig 1



internetworking devices. Figure shoes the topology of a possible internet. In this example, the letters A, B, C and so on represent hosts A host in TCP/IP a computer. The solid circles in the figure numbered 1,2,3 and so on are roulers or gateways The larger ovals containing numerals represent separate physical networks.

TCP/IP and the Internet

TCP/IP considers all interconnected physical networks to be one huge network. It considers all the hosts to be connected to this larger logical network rather than to other individual physical networks.

TCP/IP and OSI

TCP/IP's implementation of the OSI model makes functionality simpler by mapping the same seven layers of the OSI model to a four layer model Unlike the OSI reference model, the TCP/IP model focuses more on delivering the internet connectivity than on functional layers It does this by acknowledging the importance of a structured hierarchical sequence of functions, yet leaves the protocol designers with the flexibility for implementation The OSI reference model is much better at explaining the mechanics of intercomputer communications, but because TCP/IP has become the internetworking model of choice, this model is more commonly used.

The table below compares the OSI and TCP/IP models.

OSI Reference model	TCP/IP Networking model
Application layer	
Presentation Layer	Application Layer
Session Layer	
Transport Layer	Transport Layer
Network Layer	
Data Link Layer	
Physical Layer	Network Interface Layer
Internet Layer	

Comparison of OSI reference model and TCP/IP Networking model

Application Layer: Maps to Layer 5 (Session). Layer 6 (Presentation) and Layer 7 (Application) of the OSI model. This is how applications and certain services access the network

Transport Layer: Maps to Layer 4 (Transport) of the OSI model It accepts data and segments it for transport across the network, making sure that the data is delivered error-free and in the proper sequence.

Internet Layer: Maps to Layer 3 (Network) of the OSI model. It manages the routing of packets that are to be forwarded on to different networks, relying on routable protocols for delivery.

Network Access Layer: Maps to Layer 1 (physical) and Layer 2 (Data Link) of the OSI model. It is responsible for the delivery of datagrams by creating a frame for the network type and then sending the data to the wire.

TCPIP is a suite of protocols and applications that enable a computer to communicate with other computers in a network. It doesn't matter what operating system the computers are ing as long as each system supports TCP/IP The computers then communicate and share information.

TCP/IP Transport layer's Protocols

The protocol layer above the Internet layer is the Transport layer. It is responsible for providing end-to-end data integrity. It also provides a reliable communication service so that an extended two-way conversation may take place.

It consists of two protocols TCP and UDP.

TCP provides connection oriented data transmission, can support multiple data streams and provides for flow and error control It uses sequence numbers and acknowledgments to guarantee delivery UDP does not provide either sequencing or acknowledgements. It is a connectionless protocol that is used in telephony traffic and the Remote Procedure Call (RPC).

The major difference between TCP and UDP is reliability TCP is highly reliable and UDP is a best effort simple delivery method. One of the main functions of TCP and UDP is as a port manages for the applications that are in the top layer. The destination port number is placed in the header and is used to pass traffic to the correct application.

Types of networking cables

Objectives: At the end of this exercise you shall be able to
- **describe types of network cables**
- **describe the advantages and disadvantages of coaxial cable and fiber optic cable**
- **describe the tools used in networking**
- **describe network connectors.**

Network media: Media are what the message is transmitted over Different media have different properties and are most effectively used in different environments for different purposes.

In computer networking the medium affects nearly every aspect of communication. Most important, it determines how quickly and to whom a computer can talk and how expensive the process is.

Cable media: Cables have a central conductor that consists of a wire or fiber surrounded by a plastic jacket Three types of cable media are twisted-pair coaxial and fiber-optic cable Two types of twisted-pair cable are used in networks unshielded (UTP) and shielded (STP).

Table summarizes the characteristics of these types of cable media, which are discussed in the following sections.

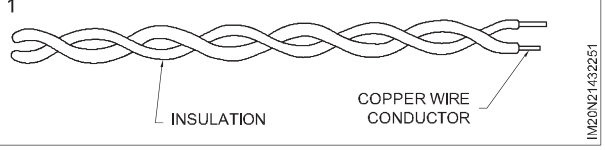
Factor	UTP	STP	Coaxial	Fiber-optic
Cost	Lowest	Moderate	Moderate	Highest
Installation	Easy	Fairly easy	Fairly easy	Difficult
Bandwidth capacity	1 to 155 Mbps (typically 10 Mbps)	1- to 155Mbps (typically 16 Mbps)	Typically 10 Mbps	2 Gtps (typically 100 Mbps)
Node capacity per segment	2	2	30 (10base 2) 100 (10 base 5)	2
Attenuation	High range of hundreds of meters)	High (range of hundreds of meters)	Lower (ange of a few kilometers)	Lowest (range of tens of kilometers)
EMI	Most vulnerable to EMI and eavesdropping	Less vulnerable than UTP but stil vulnerable to EMI and eavesdropping	Less vulnerable than UTP but still vulnerable to EMI and eavesdropping	Not affected by EMI or eavesdropping

Twisted-pair cable: Twisted-par cable uses one or more pairs of two twisted copper wires to transmit signals. It is commonly used as telecommunications cable.

When copper wires that are close together conduct electric signals there is a tendency for each wire to produce interference in the other. One wire interfering with another in this way is called crosstalk. To decrease the amount of crosstalk and outside interference, the wires are twisted. Twisting the wires allows the emitted signals from one wire to cancel out the emitted signals from the other and protects them from outside noise.

Twisted pairs are two color-coded, insulated copper wires that are twisted around each other. A twisted-pair cable consists of one or more twisted pairs in a common jacket. Fig 1 shows a twisted pair cable.

Fig 1



The two types of twisted-pair cable are unshielded and shielded.

Unshielded twisted-pair cable: Unshielded twisted-pair (UTP) cable consists of a number of twisted pairs with a simple plastic casing. UTP is commonly used in telephone systems Fig 2 shows a UTP cable.

The Electrical Industries Association (EIA) divides UTP into different categories by quality grade. The rating for each category refers to conductor size, electrical characteristics and twists per foot. The following categories are defined.

Categories of Unshielded Twisted Pair: In order to manage the network cabling you need to be familiar with the standards that may be used on modern networks. The categories of the unshielded twisted pair cable are described below.

Category 1

- It is a form of UTP that contains two pairs of wire.
- CAT suitable for voice communications but not for data.

- It can carry up to 120 kilobits per second (Kbps) of data.
- It usually used for telephone wire Data rate-1 Mbps. This type of wire is not capable of supporting computer network traffic and is not twisted.

Category 2

- It contains four wire pairs and can carry up to 4 Mbps of data.
- CAT 2 is rarely found on modem networks.
- Category 2 or CAT 2 is capable of transmitting data up to 4 Mbps. This of cable is seldom used.

Category 3

- CAT 3 made up of four twisted pair wires each twist is three times per foot. It is certified to transmit data up to 10 Mbps.
- CAT 3 has typically been used for 10 Mbps Ethernet or 4 Mops Token Ring networks.
- The CAT 3 cabling is gradually replaced with CAT5 to accommodate higher throughput.

Category 4

- CAT 4 is made up of four twisted-par wires special ized to transmit data up to 16 Mbps and is rarely is used in new installations.
- CAT 4 may be used for 16Mbps Token Ring or 10 Mbps Ethernet networks. It is guaranteed for signals as high as 20 MHz and Provides More protection against crosstalk and attenuation than CAT1, CAT2, or CAT 3.

Category 5

- CAT 5 is the most popular twisted par Ethernet ca bling designed for high signal integrity which is in cons mon use today.
- CAT 5 contains four wire pairs and supports up to 100 Mbps throughout.
- It is the most popular form of UTP for new network installations and upgrades to Fast Ethernet.

• In addition to 100 Mbps Ethernet, CAT 5 wiring can support other fast networking Cat 5 cables are often used in structured cabling for computer networks such as fast Ethernet.

Category 6

CAT 6 cabin was originally designed to support gigabit Ethernet is similar to CAT 5 were but contains a physical separator between the four

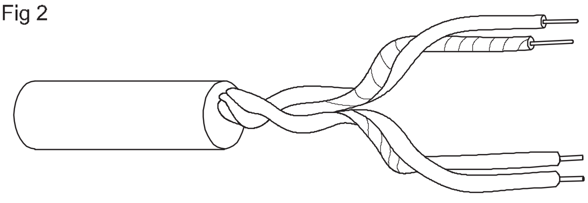
Twisted copper wires pairs to further reduce the electromagnetic interference.

a twisted-pair cable that contains four wire pairs, each wrapped in foil insulation. Additional foil insulation covers the bundle of wire pairs, and a fire-resistant plastic sheet covers the second foil layer.

The foil insulation provides excellent resistance to crosstalk and enables CAT 6 to support at least six times the throughput supported by regular CAT 5.

When the CAT6 is used as a patch cable is usually terminated in RJ-45 Electrical connectors.

Fig 2



IM20N21432252

Categories 1 and 2 were originally meant for voice communication and can support only low data rates. less than 4 megabits per second (Mops). These cannot be used for high-speed data communications Older telephone networks used Category 1 cable.

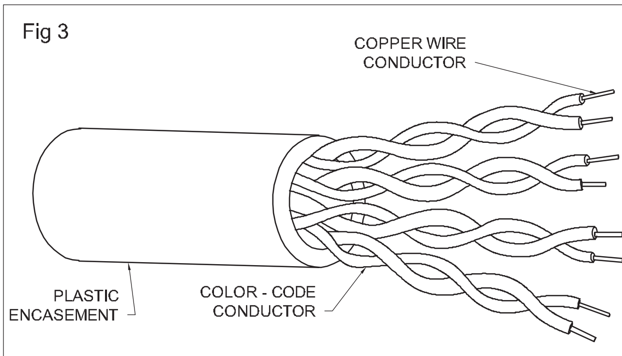
Category 3 is suitable for most computer networks Some innovations can allow data rates much higher. but generally Category 3 offers data rates up to 16 Mbps This category of cable is the kind currently used in most telephone installations

Category 4 offers data rates upto 20 Mbps

Category 5 offers enhancements over Category 3 such as support for Fast Ethernet, more insulation and more twists per foot, but Category 5 requires compatible equipment and more stringent installation. In a Category 5 installation, all media, connectors and connecting equipment must support Category 5 or performance will be affected

Data-grade UTP cable (Categories 3.4 and 5) consists of either four or eight wires. A UTP cable with four wires is called a two-pair Network topologies that use UTP require atleast two-pair wire You may want to include an extra pair for future expansion. Fig 3 shows a four-pair cable.

Fig 3



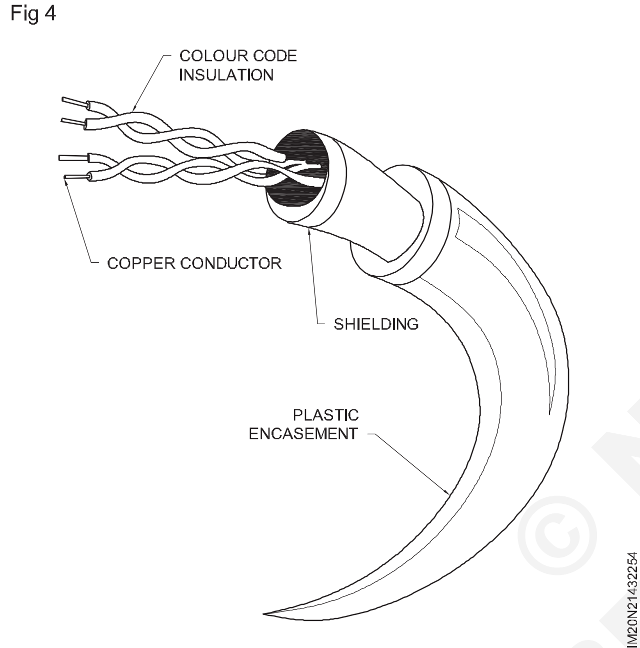
IM20N21432253

Because UTP cable was originally used in telephone systems UTP installations are often similar to telephone installations. For a four-pair cable, you need a modular RJ-45 telephone connector. For a two-pair cable, you need a modular RJ-11 telephone connector. These connectors are attached to both ends of a patch cable One end of the patch cable is then inserted into a computer or other device, and the other end is inserted into a wall jack. The wall jack connects the UTP drop cable (another length of cable) to a punch-down block.

The other side of the punch-down block is wired to a patch panel The patch panel provides connectivity through patch cables to other user devices and connectivity devices.

UTP's popularity is partly due to the first usage of the same in telephone systems. In many cases a network can be run over the already existing wires installed for the phone system, at a great savings in installation cost. Shielded twisted-pair cable The only difference be- tween shielded twisted pair (STP) and UTP is that STP cable has a shielded usually aluminium/polyester between the outer jacket or casing and the wires. Fig 4 shows STP Cable.

Fig 4



The shield makes STP less vulnerable to EMI because the shield is electrically grounded. If a shield is grounded correctly, it tends to prevent signals from getting into or out of the cable. It is a more reliable cable for LAN environments STP was the first twisted-pair cable to be used in LANS. Although many LANS now use UTP. STP is still used.

Transmission media specifications from IBM and Apple Computer use STP cable IBM's Token Ring network uses STP and IBM has its own specifications for different qualities and configurations of STP A completely different type of STP is the standard for Apple's Apple Talk networks. Networks that confirm to each vendor's specifications have their own special requirements, including. connector types and limits on cable length.

STP has the following characteristics

Cost: Bulk STP is fairly expensive. STP costs more than UTP and thin coaxial cable but less than thick coaxial or fiber-optic cabling

Installation: The requirement for special connectors can make STP more difficult to install than UTP An electrical ground must be created with the connectors. To simplify installation, use standardised and prewired cables.

Because STP is rigid and thick it to 1.5 inches in diameter), it can be difficult to handle.

Bandwidth capacity With the outside interference reduced by the shielding STP can theoretically 500 Mbps for a 100 meter cable length Fee installations fun at data rates higher than 150 Mbps Currently, most STP instalations have data rates of 10 Mbps.

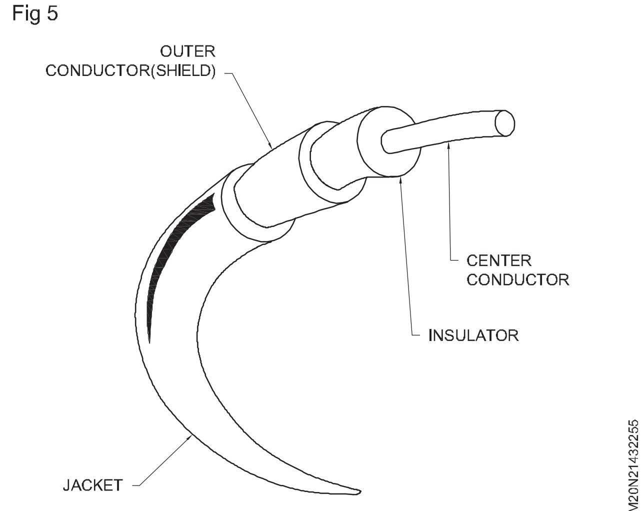
Node capacity: Since only two computers can be connected together by an STP cable, the number of computers in an STP network is not limited by the cable Rather it is limited by the hub or hubs that connect the cables together. In a Token Ring network which is the most common type of STP network, the useful upper limit is around 200 nodes in a single ring but depends on the type of data traffic in your network There is a fed maximum lent of 270 but you will probably never reach this limit.

Attenuation: STP does not outperform UTP by much in terms of attenuation The most common limit is 100 meters.

EMI: The biggest different between STP and UTP is the reduction of EM The shielding blocks a considerable amount of the interference. However, since it is copper wire STP a suffers from EMI and is vulnerable to eavesdropping.

Coaxial cable: Coaxial cable commonly called coax has two conductors that share the same axis A solid copper wire or stranded wire runs down the center of the cable and this wire is surrounded by plastic foam insulation The form is surrounded by a second conductor a wire mesh tube metallic foil or both. The wire mesh protects the wire from EMI. It is often called the shield. A tough plastic jacket forms the cover of the cable, providing protection and insulation Fig 5 shows a coaxial cable.

Fig 5



Coxial cable comes in different sizes. It is classified by (RG) and by the cable's resistance to direct or alternating electric currents (measured in ohms also called impedance)

The following are some coaxial cables commonly used in networking:

50 ohm, RG-8 and RG-11 used for thick ethernet.

50 ohm, RG-58 used for thin ethernet.

75 ohm, RG-59 used for cable TV.

93 ohm, RG-62 used for ARCnet

PVC and plenum cable: Polyvinyl chloride (PVC) commonly used in coaxial cabing because it is a flexible, inexpensive plastic well suited for use as insulation and cable jacketing PVC is often used in the exposed areas of an office.

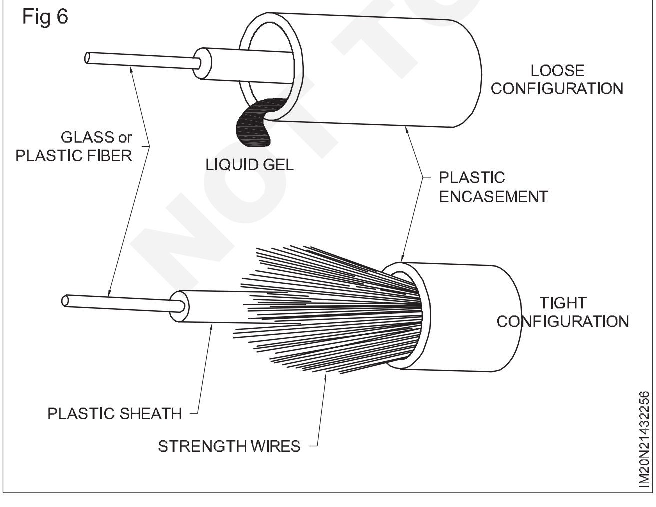
A plenum is the space between the false ceiling of an office and the floor above. The air in the plenum circulates with the air in the rest of the building, and there are strict fire codes about what can be placed in a plenum environment.

Because PVC gives off poisonous gases when burned. you cannot use it in a plenum environment. You must use plenum grade cable instead Plenum grade cable is certified to be free resistant to produce a minimum amount of smoke Plenum cable is also used in vertical runs (walls) without conduit (a tube to hold the cable). Plenum cable is more expensive and less flexible than PVC.

Fiber-optic cable: Fiber-optic cable transmits light signals rather than electrical signals It is enormously more efficient than the other network transmission media As soon as it comes down in price (both in terms of the cable and installation costs) fibre optic will be the choice. for network cabling.

Each fiber has an inner core of glass or plastic that conducts light. The inner core is surrounded by cladding a layer of glass that reflects the light back into the core. Each fiber is surrounded by a plastic sheath. The sheath can be either tight or loose. Fig 6 shows examples of these two types of fiber optic cables.

Fig 6

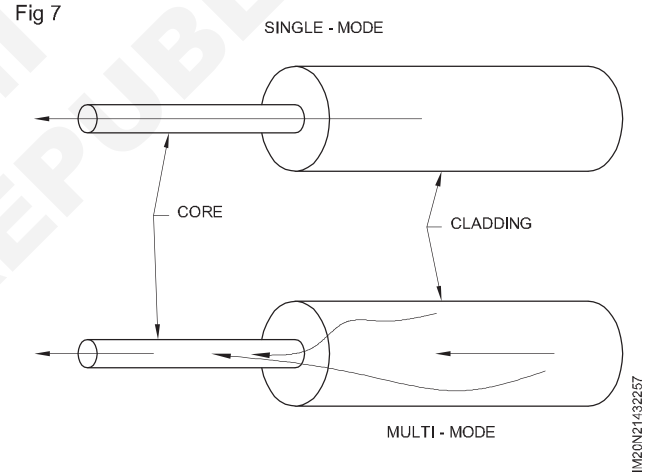


Tight configurations completely surround the fibers with a plastic sheath and sometimes include wires to strengthen the cable (although these wires are not required). Loose configurations leave a space between the sheath and the outer jacket, which is filled with a gel or other material The sheath provides the strength necessary to protect against breaking or extreme heat or cold The get strength wires and outer jacket provide extra protection.

A cable may contain a single fiber, but often fibers are bundled together in the center of the cable Optical fibers are smaller and lighter than copper wire. One optical fiber is approximately the same diameter as a human hair

Optical fibers may be multimode or single mode. Single mode fibers allow a single light path and are typically used with laser signaling Single mode fiber can allow greater bandwidth and cable runs than multimode but is more expensive Multimode fibers use multiple light paths The physical characteristics of the multimode fiber make all parts of the signal (those from the various paths) arrive at the same time, appearing to the receiver as though they were one pulse If you want to save money, look into multimode, since it can be used with LEDS (light emitting diodes) which are a more affordable light source than lasers. Fig 7 shows single mode and multi mode fibers.

Fig 7



Optical fibers are differentiated by core/cladding size and mode. The size and purity of the core determine the amount of light that can be transmitted. The following are the common types of fiber-optic cable.

8.3 micron core/125 micron cladding, single mode

62.5 micron core/125 micron cladding, multimode

50 micron core/125 micron cladding, multimode

100 micron core/140 micron cladding, multimode

A typical LAN installation starts at a computer or network device that has a fiber-optic network interface and (NIC). This NIC has an incoming interface and an outgoing interface. The interfaces are directly connected to fiber- optic cables with special fibre-optic connectors. The opposite ends of the cables are attached to a connectivity device or splice center.

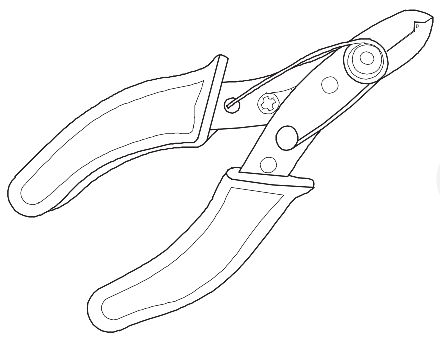
Configuring network adapters: Because network adapters have not been around since computers were invented. there is no assigned place for cards to be set to. Most adapter cards require their own interrupt port address and upper memory range. PCI motherboards automatically assign IRQ and post settings to your PCI card, so you don't need to worry about it.

Unfortunately, network adapters in computers with ISA buses can conflict with other devices, since no two devices should share the same interrupt or port. No software that comes with your computer will tell you every interrupt and port in use unless your computer is already running Windows NT, so you must be somewhat familiar with the hardware in your computer or use a program that can probe for free resources to find one. Many adapters have test programs that can tell you whether the adapter is working correctly with the settings you've assigned.

Cables Wire Cutter/Stripper (Fig 8)

Wire cutters are tools for cutting wire. This wire cutter is a small and simple tool for cable or wire stripping. It just takes only a few seconds to extract the outside of the cable. Wire cutters are commonly used to cut copper, brass, iron, aluminium, and steel wire. Some wire cutters have insulated handles which ensure that you will not get shocked from the wires you're working with. angle, leaving a flat tip. Diagonal cutters have inters ecting jaws that cut the wire at an.

Fig 8

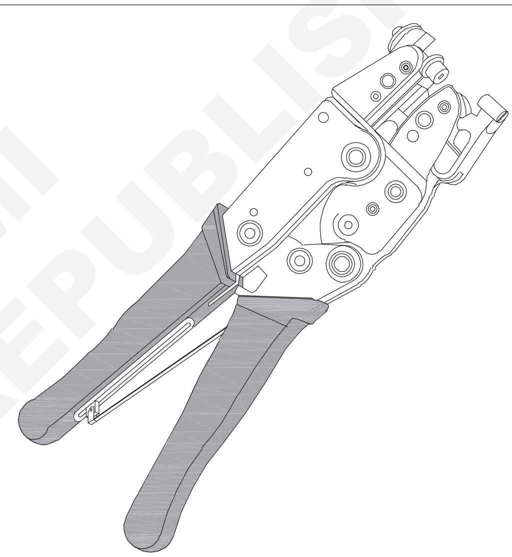


Crimp tool (Fig 9)

Crimping tool is one of the most crucial network connecting tools. In order to connect a connector to the cable, you will need a tool to crimp or connect. Known as the crimping tool, this tool is used to connect RJ-45, RJ-11 and other connectors to the end of a cable. Some crimping tools have a built-in wire cutter near the handle. This wire cutter can be used to cut a phone cable or a Cat5 cable. (

While using a crimping tool, the wires that need to be crimped are first placed into the connector. Once this is done, the jack with the wires is placed in the designated slot of the crimping tool and the handles of the tool are squeezed tight. By doing this, you can ensure that the plastic connector you are using punctures the wires inside and holds them all in place. This prevents the wires from loosening and coming out. If the wires are crimped securely in place, data can be easily transmitted by every wire. We offer several varieties of crimping tools such as the hex crimp tool.

Fig 9



Network cable connectors

Objectives: At the end of this exercise you shall be able to
- **understand types of connectors used in networks**
- **understand termination practise for ethernet cables.**

There are several types of network cables. Each type of network cable uses specific types of connectors to connect to another network cable or network interface card. To join two network cables or to connect a network cable to a NIC, you need appropriate connectors. In the following section, we will discuss some most common and popular network media connectors. (Fig 1)

Types of connectors

1 'F' connector

2 Terminator Connector

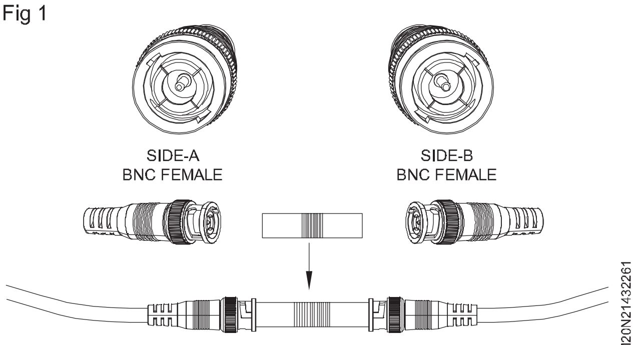
3 T Type connector

4 RJ11 Connector

5 RJ45 Connectors

6 Fiber cable connectors

Fig 1

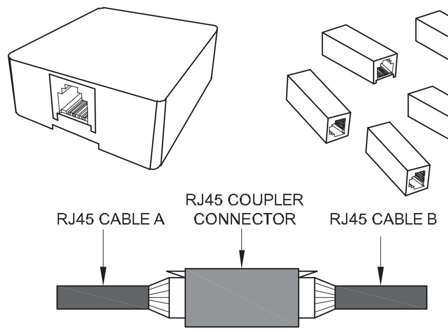


Barrel connectors

Barrel connectors are used to join two cables. Barrel connectors are female connectors on both sides. They allow you to extend the length of a cable. If you have two small cables, you can make a long cable by joining them through the barrel connector.

Barrel connectors that are used to connect STP or UTP cables are known as Ethernet LAN jointers or couplers. The following image shows Ethernet LAN jointers or couplers. (Fig 2)

Fig 2

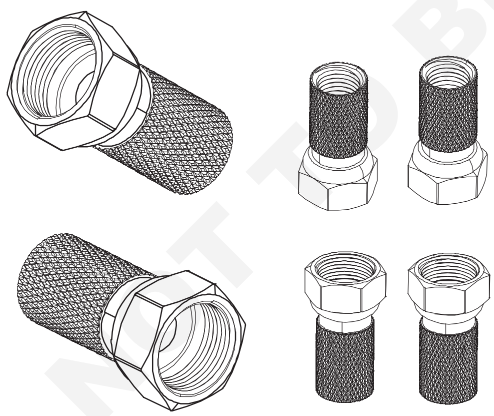


Barrel connectors do not amplify the signals. It means, after joining, the total cable length must not exceed the maximum supporting length of the cable. For example, a standard UTP cable supports a maximum distance of 100 meters. You can join two UTP cables if their sum is not more than 100.

F connectors (Fig 3)

An F connectors is used to attach a coaxial cable to a device. F connectors are mostly used to install home appliances such as dish TV, cable internet, CCTV camera, etc. The following image shows F connectors.

Fig 3



F CONNECTORS

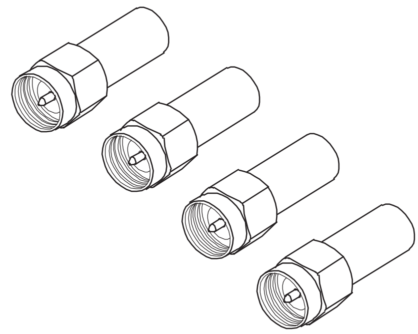
IM20N21432263

Terminator connectors (Fig 4)

When a device places signals on the coaxial cable, the signals travel along the end of the cable. If another device is connected to the other end of the cable, the device will receive the signal. But if the other end of the cable is open, the signals will bounce and return in the same direction they came from. To stop signals from bouncing back, all endpoints must be terminated.

A terminator connector is used to terminate the endpoint of a coaxial cable. The following image shows terminator connectors.

Fig 4



TERMINATOR CONNECTORS

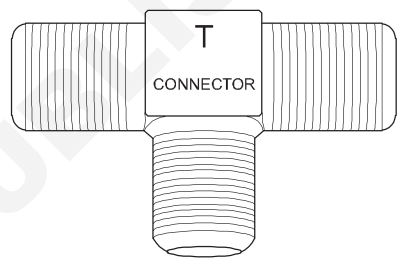
IM20N21432264

T type connectors (Fig 5)

A T connectors creates a connection point on the coaxial cable. The connection point is used to connect a device to the cable.

The following image shows T-type connectors.

Fig 5



T TYPE CONNECTORS

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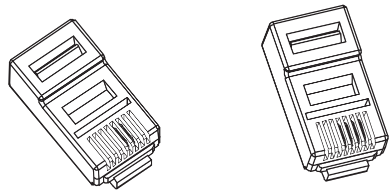
RJ – 11 Connectors (Fig 6)

RJ-11 connectors have the capacity for six small pins. However, in many cases, only two or four pins are used. For example, a standard telephone connection uses only two pins, and a DSL modem connection uses four pins. They have a small plastic flange on top of the connector to ensure a secure connection.

The following image shows RJ-11 connectors.

Fig 6

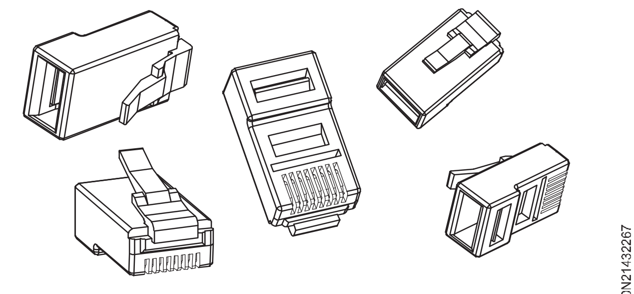


RJ-45 Connectors (Fig 7)

RJ-45 connectors look likes RJ-11 connectors, but they are different. They have 8 pins. They are also bigger in size than RJ-11. RJ-45 connectors are mostly used in computer networks. They are used with STP and UTP cables. Some old Ethernet implementations use only four of the eight pins. Modern Ethernet implementation uses all 8 pins to achieve the fastest data transfer speed.

The following image shows RJ-45 connectors.

Fig 7

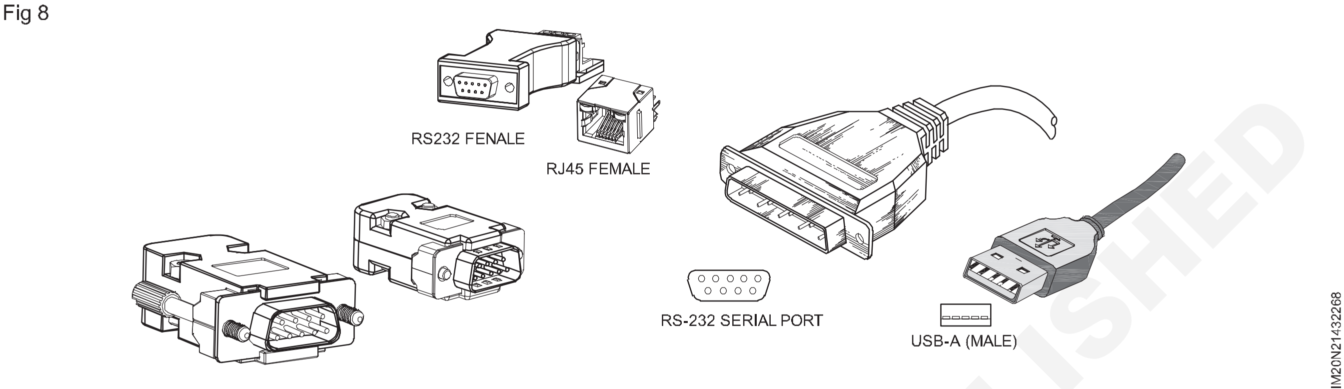


RJ-45 CONNECTORS

DB-9 (RS-232) connectors (Fig 8)

A DB-9 or RS-232 connector a device over a serial port. It has 9 pins. It is available in both male and female connectors. It is used for asynchronous serial communication. The other side of the cable can be connected to any popular connector type. For example, you can connect one side of the cable with a DB-9 connector and the other side of the cable with another DB-9 connector or with an RJ-45 or with a USB connector. The following image shows DB-9 connectors.

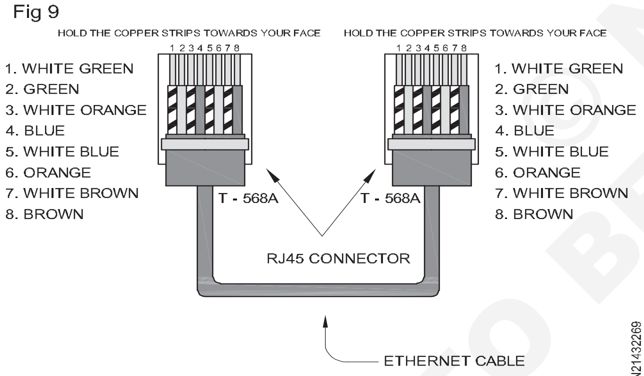
Fig 8



One of the most popular uses of a DB-9 connector is to connect the serial port on a computer with an external modern.

Table for T-568A (Fig 9)

Fig 9



ETHERNET WIRING DIAGRAM WITH COLOR CODE GUIDE

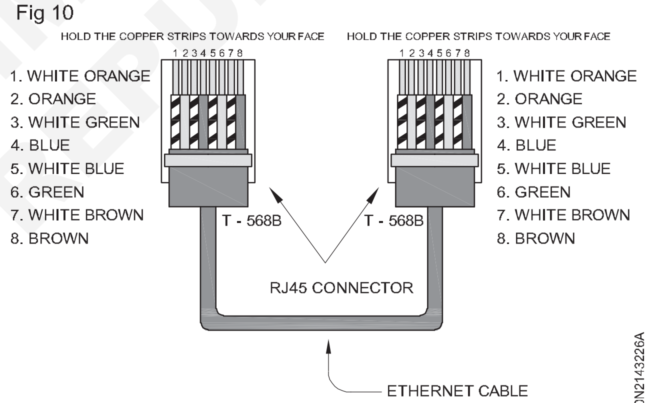
Ethernet Wiring Diagram with Color Code Guide

RJ 45 Pin	Color Codes	Function\Signal
1	White/Green	Data Transmit+
2	Green	Data Transmit-
3	White/Orange	Data Receive+
4	Blue	Unused
5	White/Blue	Unused
6	Orange	Data Receive-
7	White/Brown	Unused
8	Brown	Unused

Ethernet Cable Wiring Diagram with Color Code (T-568B)

Here, you can see the wiring diagram for the T-568B Ethernet cable. You can see here, that at one end T-568A connector is connected whereas on the other end T-568B connector is connected. (Fig 10)

Fig 10



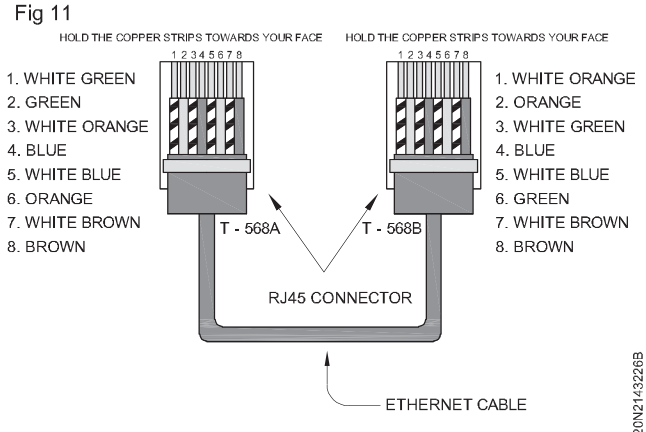
ETHERNET CABLE WIRING DIAGRAM (T-568B)

Here is the table, you can see the function and color code for both connectors. (Fig 11)

Ethernet wiring diagram for crossover cable

RJ 45 Pin	End 1 T-568A Color Codes	Function Signal	End 2 T-568B Color Codes
1	White/Green	Data Transmit+	White/ Green
2	Green	Data Transmit-	Orange
3	White/Orange	Data Receive+	White green
4	Blue	Unused	Blue
5	White/Blue	Unused	White/Blue
6	Orange	Data Receive-	Green
7	White/Brown	Unused	White brown
8	Brown	Unused	Brown

Fig 11



ETHERNET WIRING DIAGRAM FOR CROSSOVER CABLE

Digital communication basics

Objectives: At the end of this exercise you shall be able to
- **define modulation and demodulation**
- **explain different modulation technologies**
- **describe different pulse modulation techniques**
- **explain understand the basics of PWN PCM and FSK,**
- **explain signal to noise ratio.**

What is modulation?

The best way to define modulation is

The process of impressing low-frequency information to be transmitted on to a high-frequency wave, called the carrier wave, by changing the characteristics of either its amplitude, frequency, or phase angle is called modulation.

Another definition for modulation is.

The process of altering the characteristics of the amplitude, frequency, or phase and of the high-frequency signal in accordance with the instantaneous value of the modulating wave is called modulation.

Types of modulation

The sinusoidal carrier wave can be given by the equation.

$V_c = V_c \sin(W_ct+\theta) = V_c \sin 2\pi f_ct+\theta)$

Vc = Maximum value

fc = Frequency

θ = Phase relation

Wc = Angular velocity

f = time

Since the three variables are the amplitude, frequency, and phase angle, the modulation can be done by varying any one of them. Thus there are three modulation types namely.

- Amplitude modulation (AM)
- Frequency Modulation (FM)
- Phase Modulation (PM)

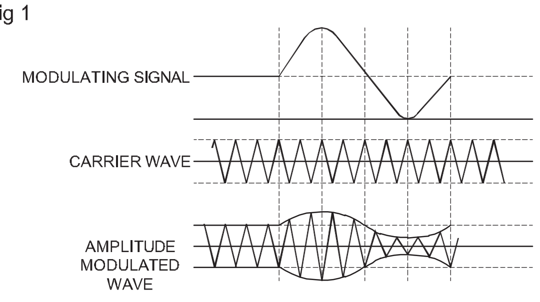
In India, radio broadcasting is done through amplitude modulation. Television broadcasting is done with amplitude modulation for video signals and frequency modulation for audio signals.

Amplitude modulation (AM)

Definition

The Method of varying amplitude of a high frequency carrier wave in accordance with the information to be transmitted, keeping the frequency and phase of the carrier wave unchanged is called amplitude modulation. The information considered as the modulating signal and it is superimposed on the carrier wave by applying both of them to the modulator. The detailed diagram showing the amplitude modulation process is given below. (Fig 1)

Fig 1



AMPLITUDE MODULATION

As shown above the carrier wave has positive and negative half cycles, Both these cycles are varied according to the information to be sent. The carrier then consists of since waves whose amplitudes follow the amplitude variations of the modulating wave. The carrier is kept in an envelope formed by the modulating wave. From the figure, you can also see that the amplitude variation of the high frequency carrier is at the signal frequency and the frequency of the carrier wave is the same as the frequency of the resulting wave.

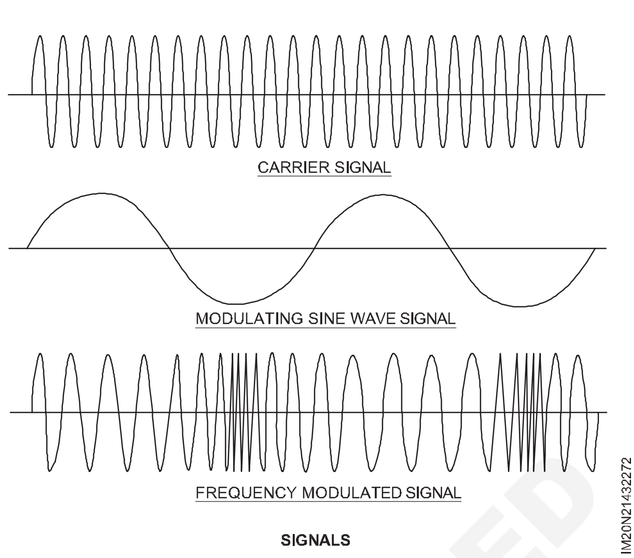
Frequency Modulation

The carrier frequency is varied according to the instantaneous amplitude of message signal or modulating signal by keeping the amplitude of carrier signal constant is called frequency. (Fig 2).

Phase Modulation

PM, is used in many applications to carry both analog and digital signals. Keeping the amplitude of the carrier signal Constant, the phase is varied according to the instantaneous amplitude of information signals.

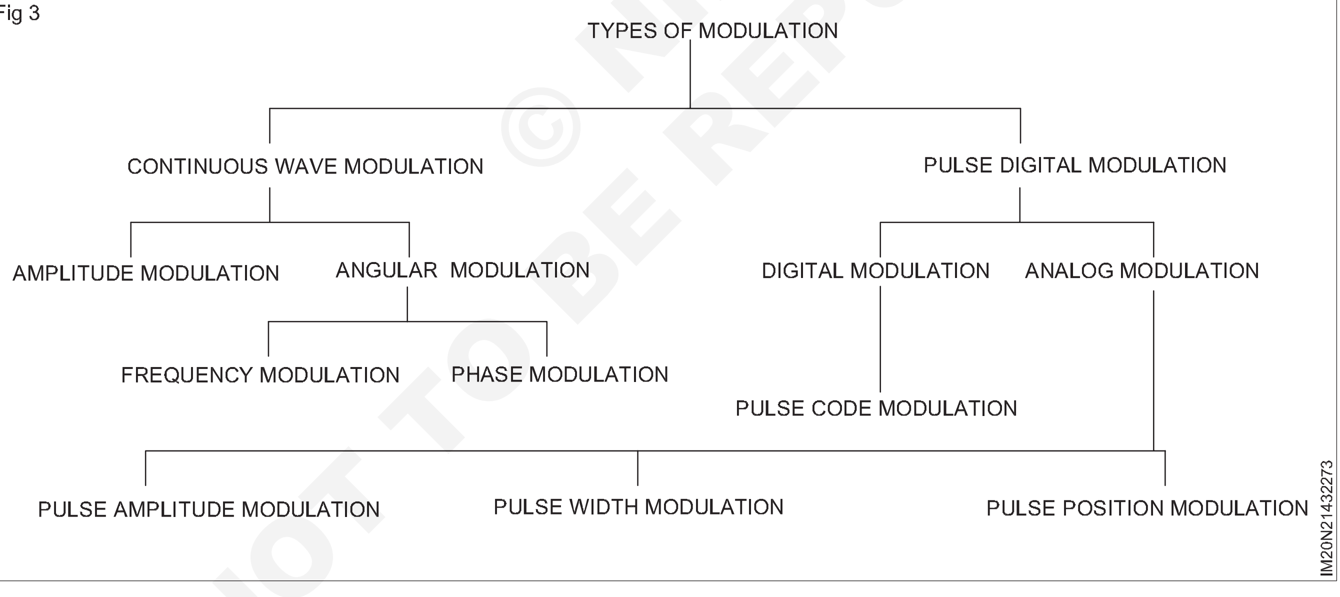
Fig 2



Pulse modulation technique

Objectives : At the end of this lesson you shall be able to
- **define pulse**
- **state the types of pulse modulation**
- **explain PCM,PAM,PWM and PPM**
- **state the advantages, disadvantage and applications of each type of modulation**
- **compare the different types of pulse modulation techniques.**

Fig 3



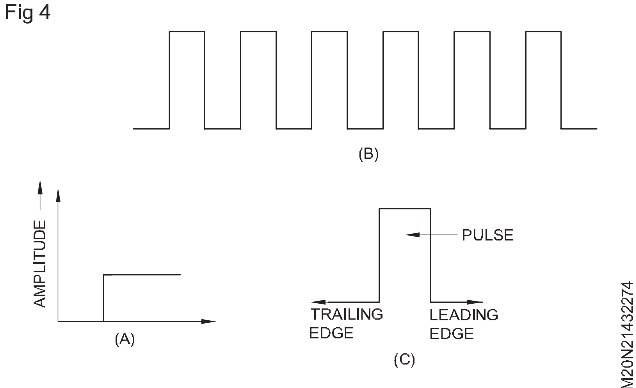
Types of modulation - Tree Diagram

AM, FM modulation & demodulation already we discussed in Semester 3 Communication Electronics topic. Here we can discussed with PWM, PPM.

Pulse

A pulse is an abruptly changing voltage or current wave which may or may not repeat itself as shown in Fig 4. The Fig 4(b) Shows a repetitive pulse train and Fig 4(c) shows a pulse with its trailing and leading edges.

Fig 4



Pulse modulation

It may be defined as a modulation system in which some parameter of a train of pulse is varied in accordance with the instantaneous value of the modulating signal. In this system, waveforms are sampled at regular intervals and the information is transmitted through the sampling rate. The parameters of the pulses which may be varied are : amplitude, width (or duration), position and time etc

In pulse modulation, there are different types of modulation techniques for analog and digital as given below:

PCM : Pulse Code Modulation for Digital Modulation.

PPM : Pulse Position Modulation for Analog Modulation

PWM : Pulse Width Modulation for Analog Modulation.

PAM : Pulse Amplitude Modulation for Analog Modulation.

1 Pulse Code Modulation (PCM)

PCM will transmit the analog in a digital form, whose signal is sampled at regular intervals of time and quantized at same quantum levels to digital code as shown in Fig 3. We know that digital code is nothing but binary code which consists of 1's and 0's that is logic1 and logic0. So we will transmit the digital data in the form of 1's and 0's. When the signal is received by the receiver, demodulator in the receiver will demodulate the binary signal back into pulses with same quantum levels like in modulator and these pulses are again used for regenerating the required analog signal.

Advantages of Pulse Code Modulation

1 Pulse code modulation will have low noise addition and data loss is also very low.

2 The received signal is exact replica of the transmitting signal without any distortion loss.

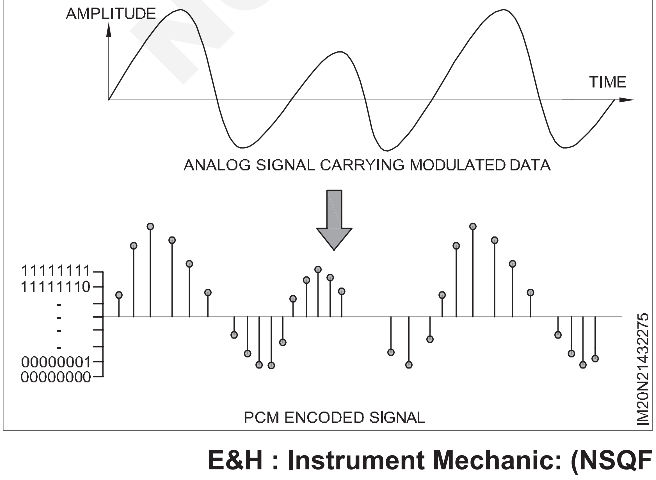
3 PCM can encode the data.

4 Multiplexing of signals can also be done using pulse code modulation. Multiplexing is nothing for adding the different signals and transmitting the signal at same time.

5 Pulse code modulation permits the use of pulse regeneration.

6 PCM can be used in storing data. (Fig 5)

Fig 5



Disadvantages of Pulse Code Modulation

1 Specialized complicated complex circuitry is required for transmitting and encoding.

2 Pulse code modulation receivers are costlier than other modulation receivers.

3 Developing pulse code modulation is bit complicated and checking the transmission quality is also difficult and takes more time.

4 It requires larger bandwidth than normal analog signals to transmit message.

5 Channel bandwidth should be more for digital encoding.

6 Decoding also needs special equipments and they are also too complex.

Applications of Pulse Code Modulation (PCM)

i Pulse code modulation is used in telecommunication systems, air traffic control systems etc.

ii Pulse code modulation is used in compressing the data that is why it is used in storing data in optical disks like DVD, CDs etc. PCM is even used in the database management systems.

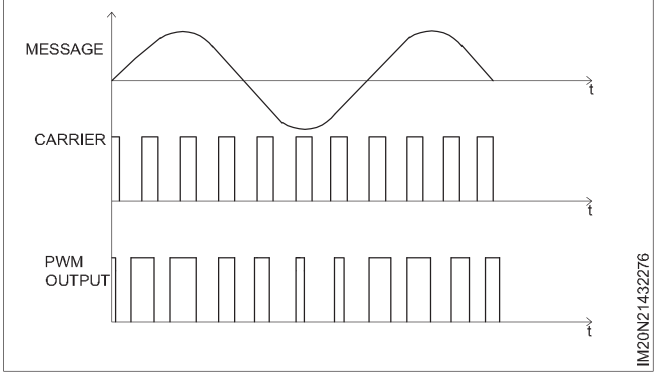
iii Pulse code modulation is used in mobile phones, normal telephones etc.

iv Remote controlled cars, planes, trains use pulse code modulations technique.

3 Pulse Width Modulation (PWM) or Pulse Duration Modulation (PDM)

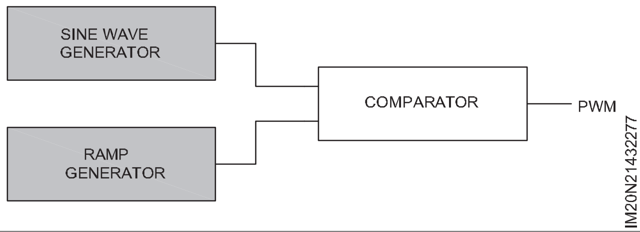
It is a type of analog modulation. In pulse width modulation or pulse duration modulation, the width of the pulse carrier is varied in accordance with the sample values of modulating signal as shown in Fig 6. In this the amplitude is made constant and width of pulse and position of pulse is made proportional to the amplitude of the signal.

Fig 6



The conventional method of generating a PWM modulated wave is to compare the message signal with a ramp waveform using a comparator. The block diagram required for the generation of a simple PWM is shown in the Fig 7.

Fig 7



Advantages of Pulse Width Modulation (PWM)

i Noise interference is less due to amplitude has been made constant.

ii Signal can be separated very easily at demodulation and noise can also be separated easily.

iii Synchronization between transmitter and receiver is not required.

Disadvantages of Pulse Width Modulation (PWM)

i Power will be variable because of varying in width of pulse. Transmitter can handle the power even for maximum width of the pulse.

ii Bandwidth should be large to use in communication, should be huge even when compared to the pulse amplitude modulation.

Applications of Pulse Width Modulation (PWM)

i PWM is used in telecommunication systems.

ii PWM can be used to control the amount of power delivered to a load without incurring the losses. So, this can be used in power delivering systems.

iii Audio effects and amplifications purposes also used.

iv PWM signals are used to control the speed of the robot by controlling the motors.

v PWM is also used in robotics.

vi Embedded applications.

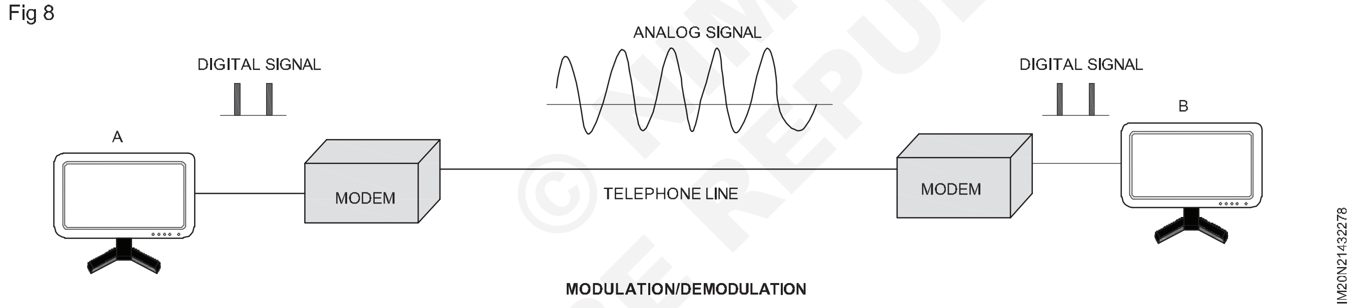
vii Analog and digital applications etc.

Signal to noise ratio

Signal – to noise ration (SNR or S/N) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. SNR is defined as the ratio of signal power often expressed in decibels. A ratio higher than 1:1 (greater than od B) Indicates more signal than noise.

Modem: Modem is a device which is used to connect computers with telephone system. Its full form is modulation and demodulation. It helps communication between computers through the existing telephone cables. Fig 8 given below shows the structure of data communication through modem.

Fig 8



Operation

The digital data from the computer is converted into analog data by the modem and is transmitted over the telephone line. The analog data received from the telephone line is converted to digital by the modem and is given to computer.

Block diagram of modem

USP interface

This interface is used to connect computer and modem through USP port. The user communicates to the modem with the help this interface.

Modem Processor and Memory

This unit is used to control the operations of the modem with respect to the Hayes commands. DTP switches are used to set auto answering.

Modem data pump and signal processor

This unit receives serial signal data and gives it to the modulator. Also it receives demodulated data from the demodulator and dives it to the mode processor.

Modulator

This unit is used to convert the digital data from computer into analog data (Signal). This process is called modulation. This is done by adding a carrier signal to the digital signal.

Demodulator

This unit is used to convert the analog data (Signal) from telephone system into digital data. This is done by eliminating the carrier signal from analog signal.

Phone interface

This interface is used to

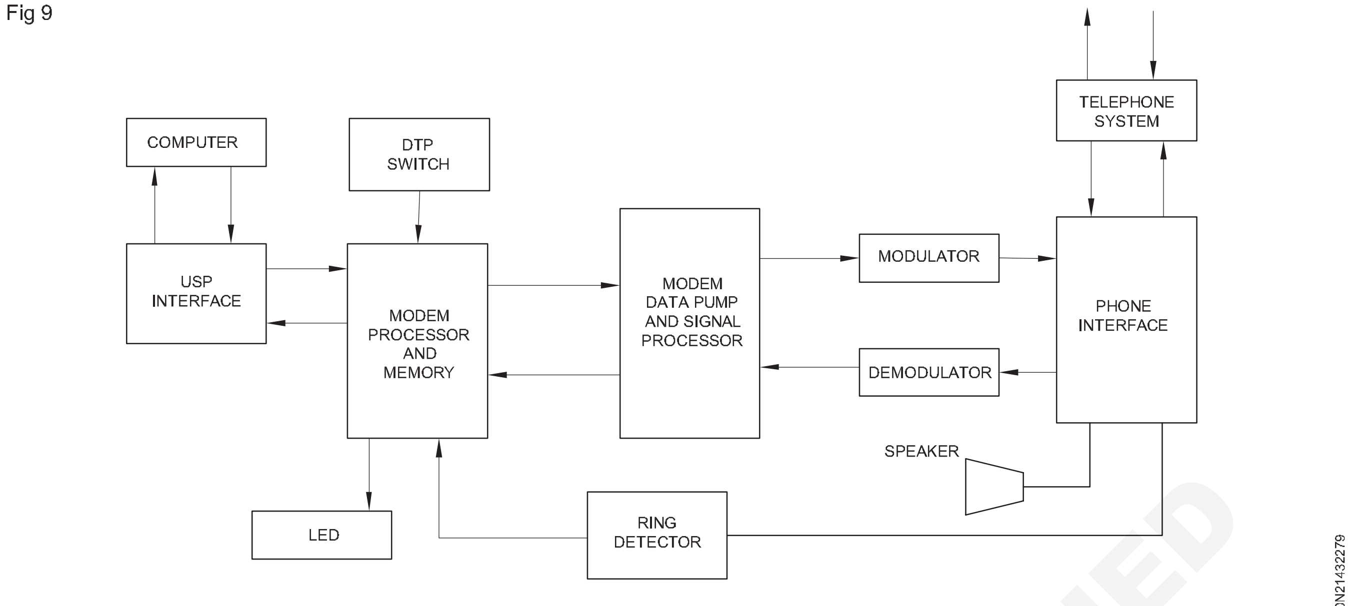
i Connect modem with the phone socket.

ii Dial the number for making communication.

iii Detect the incoming ring signals.

iv Connect speaker for giving voice information ring tone, data tone, engaged tone, etc.

Fig 9



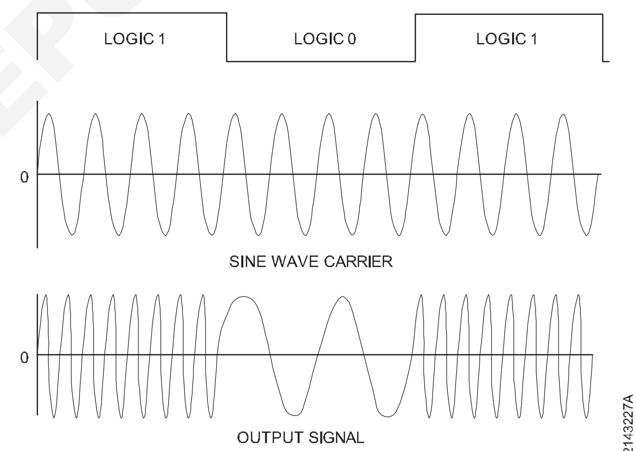
BLOCK DIAGRAM OF MODEM

Frequency shift keying (FSK)

Frequency shift keying (FSK) is one of several techniques used to transmit a digital signal on an analogue transmission medium. The frequency of a sine wave carrier is shifted up or down to represent either a single binary value or a specific bit pattern. The simplest from of frequency shift keying is called binary frequency shift keying (BFSE), in which the binary logic values one and zero are represented by the carrier frequency being shifted above or below the center frequency. In conventional BFSK systems, the higher frequency represents a logic high (one) and is referred to as the mark frequency. The lower frequency represents a logic low (zero) and is called the space frequency. The two frequencies are equip – distant from the center frequency. A typical BFSK output waveform is shown below.

If there is a discontinuity in phase when the frequency is shifted between the mark and space values, the form of frequency shift keying used is said to be non – coherent, otherwise it is said to be coherent. In more complex schemes, additional frequencies are used to enable more than one bit to be represented by each frequency used. This provides a higher data rate, but requires more bandwidth (representing a group of two binary values for example, would require four different frequencies.) It also increases the complexity of the modulator and demodulator circuitry, and increases the probability of transmission errors occurring.

Fig 10



BINARY FREQUENCY SHIFT KEYING (BFSK)

Supervisory control and data acquisition system

Objectives: At the end of this lesson you shall be able to
- **understand the fundamentals of SCADA**
- **understand the functions, applications and advantages of SCADA**
- **explain the difference between SCADA and PLC.**

Supervisory control and data acquisition system (SCADA)

Scada introduction

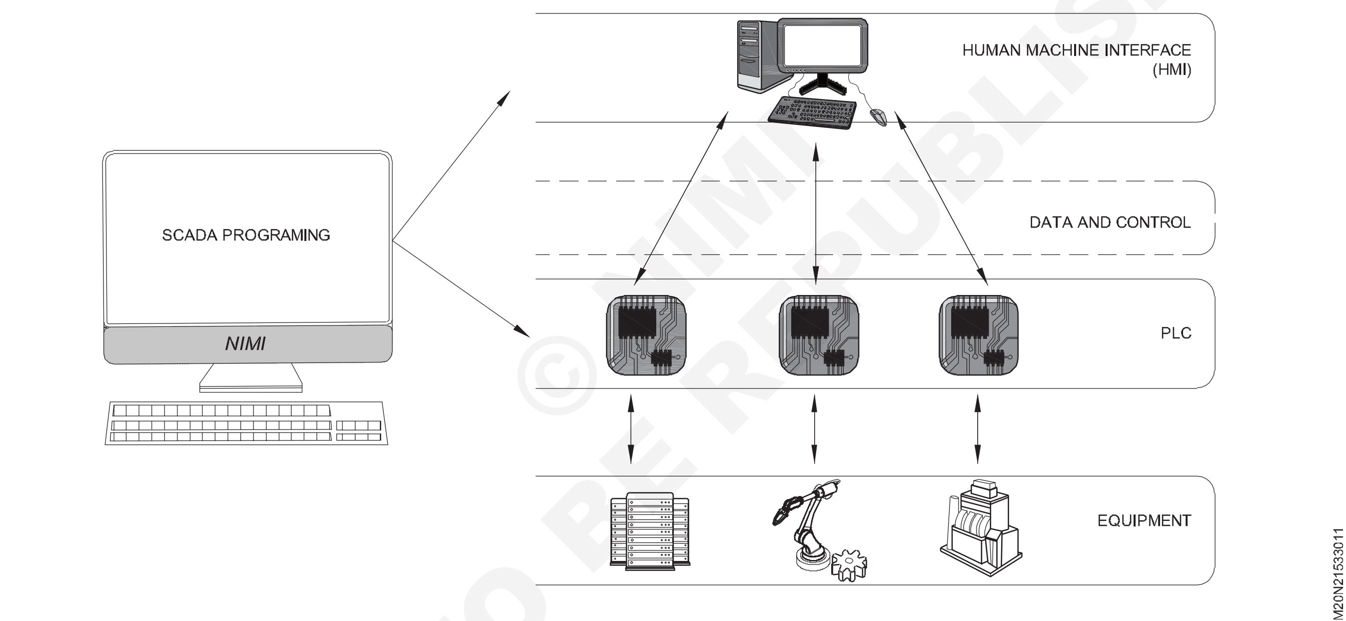
Supervisory Control and Date: Acquisition (SCADA) is a system that aims to monitor and control field devices at your remote sites. SCADA systems are critical as it helps maintain efficiency by collecting and processing real-time data. (Fig 1)

SCADA systems are used to control and monitor physical processes, examples of which are transmission of electricity, transportation of gas and oil in pipelines, water distribution, traffic lights, and other systems used as the basis of modern society.

SCADA Functions

- Data Acquisition
- Networked Data Communication

Fig 1



- Data Presentation
- Control

Data Acquisition

- First, the systems you need to monitor are much more complex than just one machine with one output. So a real-life SCADA system needs to monitor hundreds or thousands of sensors.
- Some sensors measure inputs into the system (for example, water flowing into a reservoir), and some sensors measure outputs (like valve pressure as water is released from the reservoir).
- Some of those sensors measure simple events that can be detected by a straightforward on/off switch, called a discrete input (or digital input).

Data Communication

- In real life, you want to be able to monitor multiple systems from a central location, so you need a communications network to transport all the data collected from your sensors.
- SCADA data is encoded in protocol format. The remote telemetry unit (RTU) is needed to provide an interface between the sensors and the SCADA network.
- The RTU encodes sensor inputs into protocol format and forwards them to the SCADA master, in turn, the RTU receives control commands in protocol format form the master and transmits electrical signals to the appropriate control relays.

Data Presentation

- A real SCADA system reports to human operators over a specialized computer that is variously called a master station, an HMI (Human-Machine Interface) or an HCI (Human-Computer Interface).
- The SCADA master station has several different functions. The master continuously monitors all

sensors and alerts the operator when there is an "alarm".

Control

- In real life, SCADA systems automatically regulate all kinds of industrial processes.
- For example, if too much pressure is building up in a gas pipeline, the SCADA system can automatically open a release valve.
- In a power station, Electricity production can be adjusted to meet demands on the power grid.

SCADA Vs HMI

HMIs are used to communicate with Programmable Logic Controllers and as such, the whole system is completed. Whereas SCADA represents a remote system used to communicate and collect data, HMI is a local machine capable of doing the same thing. But, the only difference is, as we said, that HMIs are local machines. The Human-Machine Interface is the user interface that connects the operator to a system, device or machine. HMI isn't a particular piece of hardware but rather a screen that allows a user to interact with a device

SCADA and HMIs are almost the same, yet still different. Both SCADA and HMIs play a huge part in an industrial system that encapsulates them, alongside PLCs. However, they function in a different way. An HMI uses some amount of data and visually represent it, allowing for greater understanding and more efficient supervising process. On the other hand, SCADA systems are focused on control-system operations and they have a huge capacity for data collection. The main advantage of SCADA systems over HMI is that they collect and record information.

SCADA and HMI systems are here to collect and display certain data, respectively. A PLC, as an industrial computer, serves as a bridge between the process and its control. As such, a PLC is often used in conjunction with SCADA systems and HMIs. An HMI is something that's ever- present in every type of industry and even in our homes in a form of a monitor or a tablet.

As the technology progressed, new types of HMI and SCADA systems are made. The prime example of modern HMI is touchscreen, which offers a lot of flexibility for the operator. With the growing trends in industrial hardware, both SCADA and PLCs got some boost. PLCs are now able to perform the most complex logical tasks, while SCADA systems are much more versatile and are able to collect a huge chunk of data.

PLC Vs SCADA

PLC is a physical hardware, whereas SCADA is software. The main difference is that a PLC is used for writing the control logic whereas a SCADA is used for displaying the graphics and providing set parameter access to the operator so that he can operate and control the variables written in the PLC.

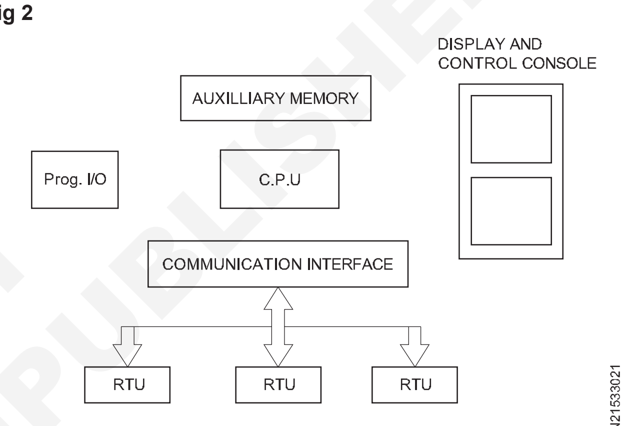
Compare BOTH plc & scada with computer components, then a PLC is a CPU and a SCADA is the monitor. A PLC cannot show the graphics and a SCADA cannot be used for control logic.

PLC is the hardware part where inputs and outputs are connected to it and logic is written inside using languages like a ladder, functional block diagram, structured text, instruction list, etc.

In SCADA, you have to design screens where you have to map the variables of the PLC in it. Using communication protocol, the PLC and SCADA communicate with each other. The main purpose of SCADA is that it records and manages data and reports, shows trends, shows alarms and basically, shows all the functions happening inside a PLC on its screens.

Blockdiagram of SCADA (Fig 2)

Fig 2



BLOCK DIAGRAM OF SCADA

Components of SCADA

1 Human Machine Interface (HMI)

It is an interface which presents process data to a human operator, and through this, the human operator monitors and controls the process.

2 Supervisory (computer) system

It gathers data on the process and sending commands (or control) to the process

3 Remote Terminal Units (RTUs)

It connects to sensors in the process, converting sensor signals to digital data and sending digital data to the supervisory system.

4 Programmable Logic Controller (PLCs)

It is used as field devices because they are more economical, versatile, flexible, and configurable than special-purpose RTUs.

5 Communication infrastructure

It provides connectivity to the supervisory system to the Remote Terminal Units.

Functions of SCADA components

- Data from sensors on individual assets is transmitted to the PLC

- The PLC translates that data into a format that can be used by the software
- Users access the data through the HMI on the software
- If the data crosses certain thresholds, a maintenance work order is created

SCADA Advantages and Applications

Advantages

- Increased reliability
- Reduced costs
- Improved worker safety
- Greater customer satisfaction
- Improves efficiency of the system
- Monitor wastewater treatment facilities
- Eliminates the need for manual data collection
- Their alarms and real-time views into operations can prevent small problems from becoming big ones, and can also speed restoration time.

Application of SCADA

SCADA is widely used in different areas from chemical, gas, water, communications and power systems

- Electric power system, operation and control
- Manufacturing industries or plants
- Telecom and IT based systems
- Water and sewage treatment plants and supply management
- Traffic controls
- Lift and elevator controls
- Buildings, facilities and environments
- Mass transit and railway traction

Distributed control system

Objectives: At the end of this lesson you shall be able to
- **understand and the fundamentals of DCS**
- **explain basic elements of DCS and history of DCS**
- **explain the advantages and applications of DCS**
- **understand about remote terminal unit (RTU) and its applications**
- **understand about central monitoring stations.**

Introduction to DCS

Distributed Control System is a specially designed control system used to control complex, largo and geographically distributed applications in industrial processes. In this controllers are distributed throughout the entire plant area

These distributed controllers are connected to both field devices and operating PCs through high- speed communication networks as shown in the figure below.

Discrete field devices such as sensors and actuators are directly connected to input and output controller modules through a communication bus. These field devices or smart instruments are capable of communicating with PLC's or other controllers while interacting with real-world parameters like temperature, pressure, etc.

Controllers are distributed geographically in various sections of the control area and are connected to operating and engineering stations which are used for data monitoring data logging alarming and controlling purpose via another high-speed communication bus

These communication protocols are of different types such as foundation filed bus HART Profibus, Modbus etc. DCS provides information to multiple displays for the user interface

Distributed Control System continuously interacts with the processes in process control applications ones, it gets instruction from the operator it also facilitates variable set points and opening and closing of valves for manual control by the operator. Its human machine interface (HM faceplates and trend display give the effective monitoring of industrial processes

Basic Elements of Distributed Control System

1 Engineering PC or controller. This controller is the supervisory controller over at the distributed processing controllers

2 Distributed controller or Local control unit: It can be placed near to field devices (sensors and actuators or certain locations where these field devices are connected via the communication link. It can sense and control both analog and digital inputs/outputs by analog and digital I/O modules. It collects the information from discrete field devices and sends this information to operating and engineering stations

3. Operating station or HMI: It is used to monitor entire plant parameters graphically and to log the data in plant database systems. The trend display of various process parameters provides effective display and easy monitoring

4. Communication media and protocol: Communication media consists of transmission cables to transmit the data such as coaxial cables, copper wires, fiber optic cables and sometimes it might be wireless: Communication protocols (includes Ethernet Foundation Fieldbus: Modbus, Device Net etc.) selected depend on the number of devices to be connected to this network.

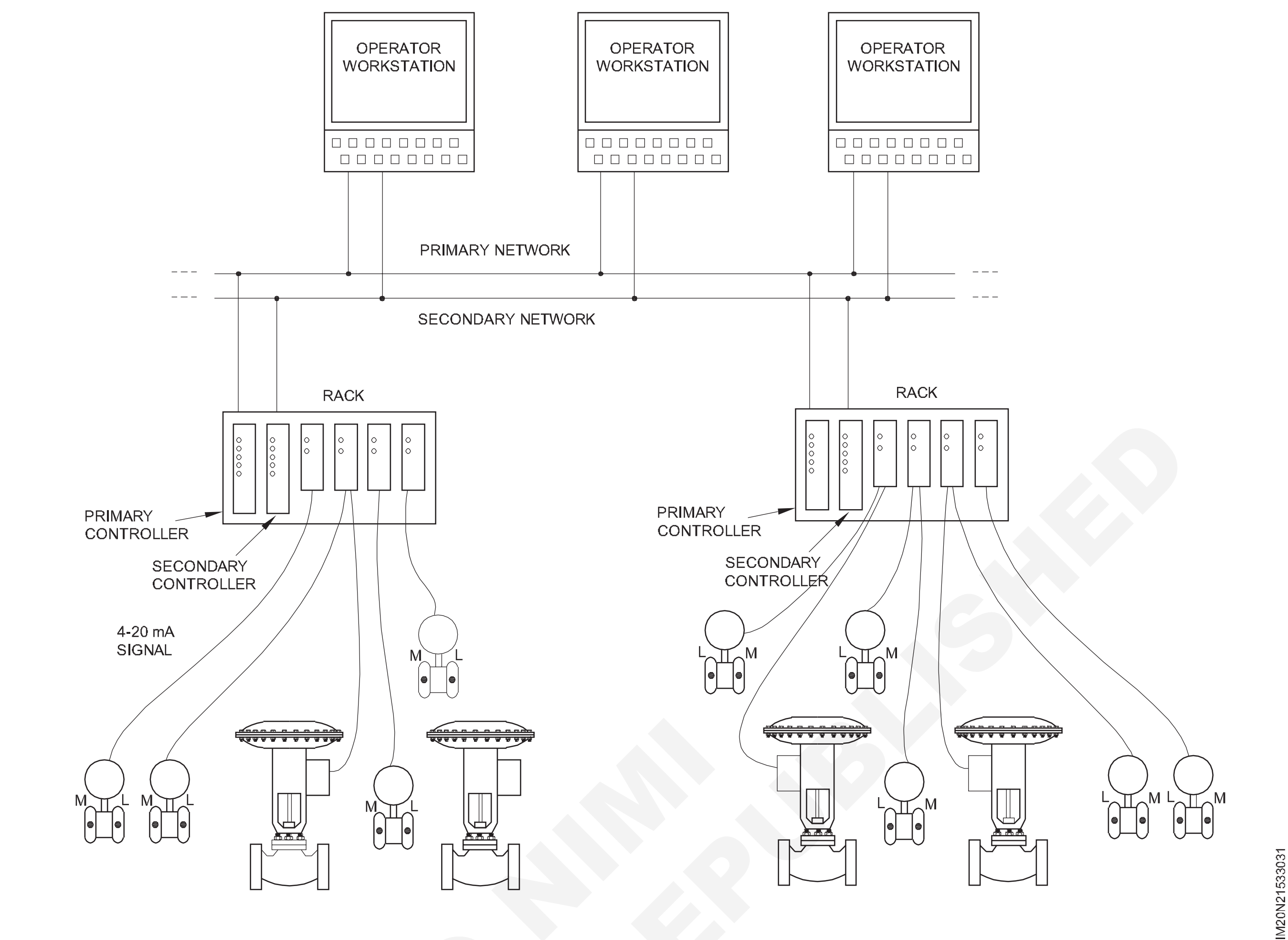
Important features of DCS

1 To handle complex processes

2 System redundancy

3 Predefined function blocks

Fig 1



4 More sophisticated HMI

5 Scalable platform

6 System security

History of DCS

The DCS was introduced in 1975. Both Honeywell and Japanese electrical engineering firm Yokogawa introduced their own independently produced DCSS at roughly the same time, with the TDC 2000 and CENTUM systems, respectively.

US-based Bristol also introduced their UCS 3000 universal controller in 1975.

In 1980, Bailey (now part of ABB) introduced the NETWORK 90 system.

The DCS largely came about due to the increased availability of microcomputers and the proliferation of microprocessors in the world of process control.

Computers had already been applied to process automation for some time in the form of both Direct Digital Control (DDC) and Set Point Control.

The DCS largely came about due to the increased availability of microcomputers and the proliferation of microprocessors in the world of process control.

Some suppliers that were previously stronger in the PLC business, such as Rockwell Automation, Siemens, were able to leverage their expertise in manufacturing control hardware to enter the DCS marketplace with cost effective offerings, while the stability/scalability/reliability and functionality of these emerging systems are still improving.

The traditional DCS suppliers introduced new generation DCS system based on the latest communication and IEC standards, which resulting in a trend of combining the traditional concepts/ functionalities for PLC and DCS into a one for all solution – named “process automation system”.

The latest developments in DCS include the following new technologies:

1 wireless systems and protocols

2 Remote transmission and logging

3 Mobile interfaces and controls

4 Embedded web – servers

DCS Advantages and applications

Advantages of DCS

- Handle complex structure
- Improved reliability

- Reduce downtime
- Reduce installation costs due to wire savings
- System redundancy
- HMI
- Scalable platform
- System security

Disadvantages of DCS

1 All information and data though presented in systematic format is hidden behind the CRT. Hence, it requires a skilled operator.

2 In an emergency, decisions have to be taken single handedly, as few operators are there in the control room.

3 Failure of one controller effects more than once loop. Hence it calls for very high MTBF (Mean time between failures) and high degree of redundancy.

Applications of DCS

- Chemical plants
- Petrochemical (oil) and refineries
- Pulp and paper mills (see also: quality control system QCS)
- Boiler controls and power plant systems.
- Nuclear power plants
- Environmental control system
- Water management system
- Water treatment plants

Remote terminal unit (RTU)

RTU is an acronym for **Remote Terminal Unit.** An RTU is an electronic device that is controlled by a microprocessor.

The device interfaces with physical objects to a distributed control system (DCS) or supervisory control and data acquisition (SCADA) system by transmitting telemetry data to the system.

A remote terminal unit (RTU) is a multipurpose device used for remote monitoring and control of various devices and systems for automation. It is typically deployed in an industrial environment and serves a similar purpose to programmable logic circuits (PLCs) but to a higher degree.

RTU's are widely used in environments with extreme temperatures and located in remote locations.

Some RTU's have a backup battery and charging circuit, such as solar power, that will allow the RTU to continue to operate even when AC power is lost.

Some RTUs may be programmed with languages such as Basic, Visual Basic and C#.

RTUS are even programmed in the same languages that PLCs are programmed with such as Ladder Logic and Structured Text.

Applications

- Remote monitoring of functions and instrumentation for:
- Oil and gas (offshore platforms, onshore oil wells, pump stations on pipelines)
- Networks of pump stations (wastewater collection, or for water supply)
- Environmental monitoring systems
- Mine sites
- Air traffic equipment such as navigation aids
- Hydro-graphic (water supply, reservoirs, sewage systems)
- Electrical power transmission networks
- Natural gas networks

Centre Monitoring Station (CMS)

What is a Central Monitoring Station

A central monitoring is a 24/7 center with highly trained operators who immediately respond to any incoming alarm events.

The top-priority at a central monitoring station is to make sure that the people they monitor are safe and to send out any emergency dispatch if needed.

The CMS System characteristics

- Signal Receivers to convert all alarm signals into raw protocol codes
- Central Station Software that allow operators to view, manage and catalog incoming alarm signals from a massive number of alarm panels.
- When an alarm occurs on a central station monitored security system, the control panel will immediately send out an alert to the station.
- If the panel is using a cellular or IP connection, the signal will pass through the servers an interactive service platform.
- Each signal transition is lightning fast, and the central station is usually contacted in a matter of seconds.
- Once a central station operator receives an alert from the user's system they will immediately get to action.
- Depending on their monitoring plan, they may try and contact the end user before just requesting dispatch from the local authorities. This is usually done to prevent false alarms.

Industrial communication protocols and field instruments

Objectives: At the end of this lesson you shall be able to
- **understand different industrial network system**
- **understand common field bus networks**
- **explain differences between Modbus & profibus**
- **explain field instruments**
- **explain different network topologies**
- **understand the electronic device description language.**

Types of Communication in DCS

Fieldbus

A fieldbus is an industrial network system for real-time distributed control. It is a way to connect instruments in a manufacturing plant. A fieldbus works on a network structure which typically allows daisy-chain, star, ring, branch, and tree network topologies.

Fieldbus is simply a means of communicating with input devices (sensors, switches, etc.) and output devices (valves, drives, indication lamps etc.) without the need to connect each individual device back to the controller (PLC, Industrial PC etc.). Therefore, overall, Fieldbus can reduce costs.

Examples of most common fieldbus networks are FOUNDATION fieldbus, Modbus and PROFIBUS.

- Foundation filed bus
- Modbus
- Profibus

FOUNDATION Fieldbus (FF) is a standard for digital field instrumentation enabling field instruments to not only communicate with each other digitally, but also to execute all continuo control algorithms (such as PID, ratio control, cascade control, feedforward control, etc.) traditionally implemented in dedicated control devices.

With Foundation technology, multiple devices-each with multiple LO signals same bus. Fieldbus-based control systems employ two-wire twisted pair cable and provide intrinsically safe device power suitable for all hazardous areas. can share the

Multiple devices can be connected on a single cable. Fewer cable trays and I/O cards (input/output) Fewer devices. Better and faster commissioning.

When the FF standard was being designed, two different network levels were planned: a "low speed" network for the connection of field instruments to each other to form network segments, and a "high speed" network for use as a plant-wide "backbone" for conveying large amounts of process data over longer distances.

The low-speed (field) network was designated HI, while the high-speed (plant) network was designated H2. Later in the FF standard development process, it was realized that existing Ethernet technology would address all the basic requirements of a high-speed "backbone, and so it was decided to abandon work on the H2 standard, settling on an extension of 100 Mbps Ethernet called HSE ("High Speed Ethernet) as the backbone FF network instead.

Modbus is a communication protocol developed by Modicon systems. Modbus is a simple master slave protocol, and the master has full control of the communication. The slave will only respond when asked. The master will record the outputs, and read the inputs from every slave during every cycle. The slave devices don't join the network, and they only respond when spoken to, and remain idle when they are not being spoken to. There's no requirement for a watchdog timer, and there's no requirement for diagnostics for the slave's health.

Modbus is frequently used to join a supervisory computer with a RTU (remote terminal unit) in systems of SCADA (supervisory control and data acquisition).

PROFIBUS is a smart, field-bus technology. Profibus stands for Process Field Bus. It is also a wired protocol just like Ethernet, but what differentiates Ethernet and Profibus is that Profibus can be implemented on a larger network than Ethernet. Profibus enables consistent data exchange between the systems.

If Modbus is the "granddaddy" of protocols, then Profibus is the young athlete - lean and fast. Profibus is also a master-slave type protocol like Modbus but with an additional woken ring protocol to allow for multiple masters.

Unlike Modbus, all devices go through a startup sequence during which they "join" the network. Each slave maintains a failsafe timer. If the master does not talk to it within a certain time limit, the slave goes into a safe state; the master must then go through the startup sequence again before further data exchange can occur.

Differences between Modbus and Profibus

MODBUS can operate on only I Master device per network.

PROFIBUS can operate on multiple Master devices per network.

MODBUS can be used on RS232, RS422, and RS485. The maximum limit for RS232 and RS422 is 1 master and I slave. The maximum limit for RS485 in MODBUS is one master and 3! slaves.

PROFIBUS only operates on RS 485 which supports 32 nodes and unlike MODBUS each node has the capability of being a master or a slave.

The MODBUS communication protocol is simpler in terms of implementation and ease of use.

The construction of PROFIBUS protocol ties it to only RS 485 which limits its usage.

MODBUS can operate on Ethernet

PROFIBUS cannot operate on Ethernet.

Field Instruments

Field instruments combine sensors, actors, intelligent signal processing, and robust communications while often operating in the harshest of environments.

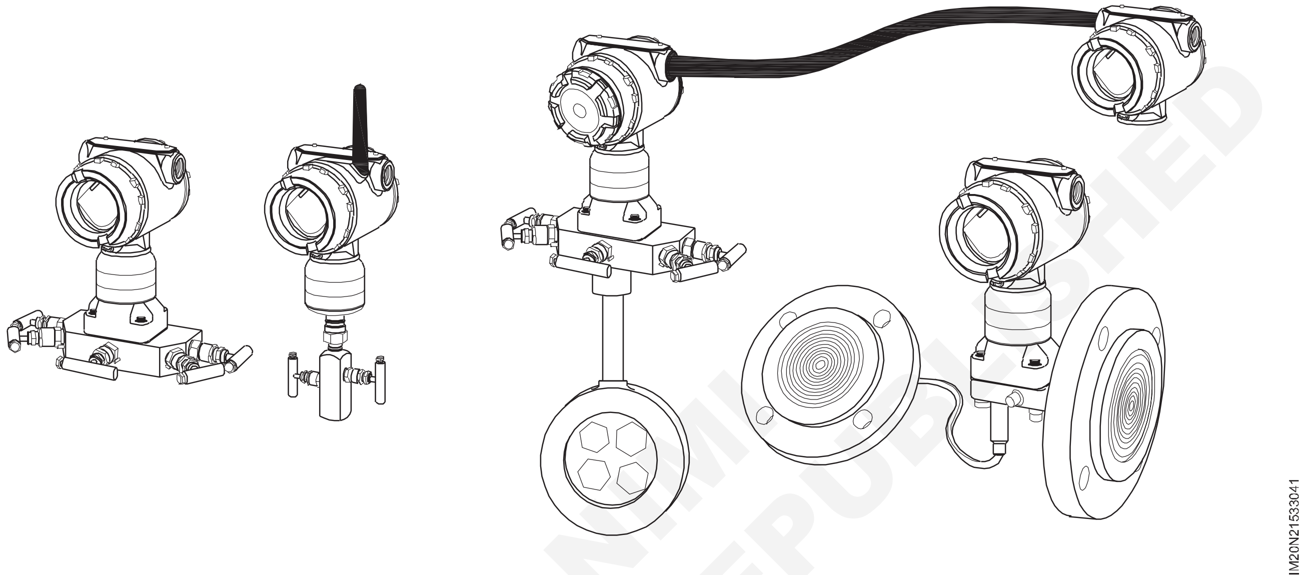
They are required captured and interpret data that is communicated to the cloud at the enterprise level.

Instruments are used to measure and control the conditions of process streams as they pass through a plant.

Different types

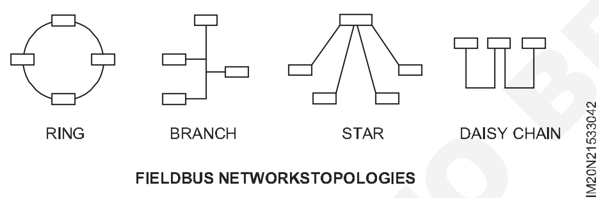
- Pressure transmitters
- Flow meters
- Temperature transmitters
- Level meters
- Field wireless
- Device smart communicators
- Distributed temperature sensor
- Fluid chemical injection controller.

Fig 1



Fieldbus topologies (Fig 2)

Fig 2



Prior to fieldbus protocols industrial controller system were connected using RS232 serial communications. The fieldbus connections are more closely compared to the typical Ethernet connections where you can connect multiple field devices to a single connection point that would then connect to the controller.

With the fieldbus devices such as sensors, motors, lamps, switches, these devices are connected to an " I/O data block", which is then connected to a " field distribution device", which is connected to a fieldbus power supply, then finally connected back to the programmable logic controller.

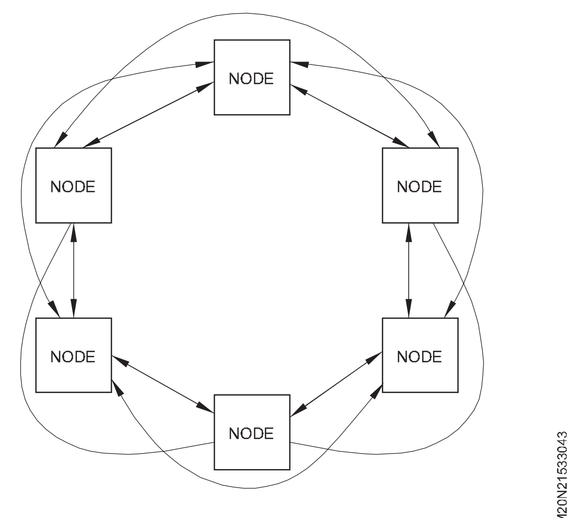
The connections to the fieldbus components, with the exception of the field devices themselves, are single cable connections. This connection scheme may vary depending on the fieldbus protocol that you are using.

Ring topology (Fig 3)

In a ring topology, each node is directly connected to two other nodes – one on each side – to form a continuous circular pathway for data to pass through.

A ring topology is a daisy chain in a closed loop. Data travels around the ring one direction. When one node sends data to another, the data passes through each intermediate node on the ring until it reaches its destination. The intermediate nodes repeat (retransmit) the data to keep the signal strong.

Fig 3



Advantages

- When the load on the network increases, its performance is better than bus topology.
- There is no need of network server to control the connectivity between workstations.

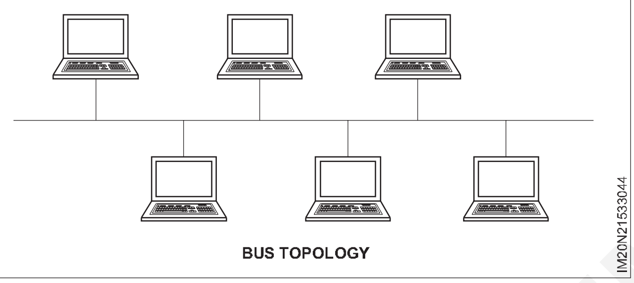
Disadvantages

- Aggregate network bandwidth is bottlenecked by the weakest link between two nodes.

Bus or Branch topology (Fig 4)

A bus network is a network topology in which nodes which nodes are directly connected to a common half-duplex link called a bus. A host on a bus network is called a station. In a bus network, every station will receive all network traffic, and the traffic generated by each stations has equal transmission priority.

Fig 4



Advantages of a bus topology

- The main advantages of bus topology ease of installation and cost.
- Every node is connected to the backbones by drop lines.
- Bus topology uses less cable than a star topology or a mesh topology.
- We do not need to purchase any additional devices such as switches or hub.

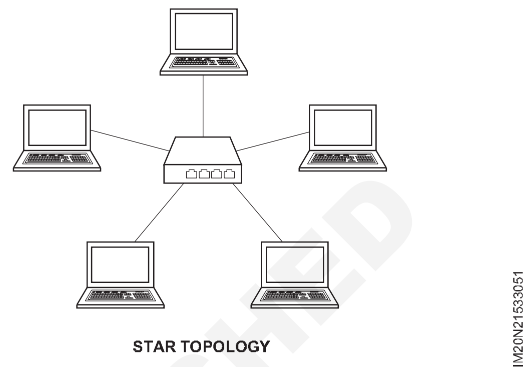
Disadvantages of a bus topology

- The main disadvantages of a bus topology is the difficulty to recognize the problem if your network goes down.
- When the network goes down, it is usually due to a break in the backbone cable segment.
- The bus topology is not very scalable.

Star topology (Fig 5)

In star topology, each device has a dedicated point-to point link to a central controller device, usually call a switch or hub. In this layout the devices are not directly linked to one another but to a centralized device. When a computer sends data to other computers on the network, it is sent along the cable to the bub or switch, which can then pass the packets to the computer or devices connected to it.

Fig 5



Advantages of star topology

- A star topology is robustness of the network. If one link fails, only that link is affected. All other links remain active.
- It's easy to identify the network problems.
- A star topology is scalability and simplicity of adding another system to the network.
- Centralize management and monitoring of network traffic can be vital to network success. It is less expensive then mesh topology.

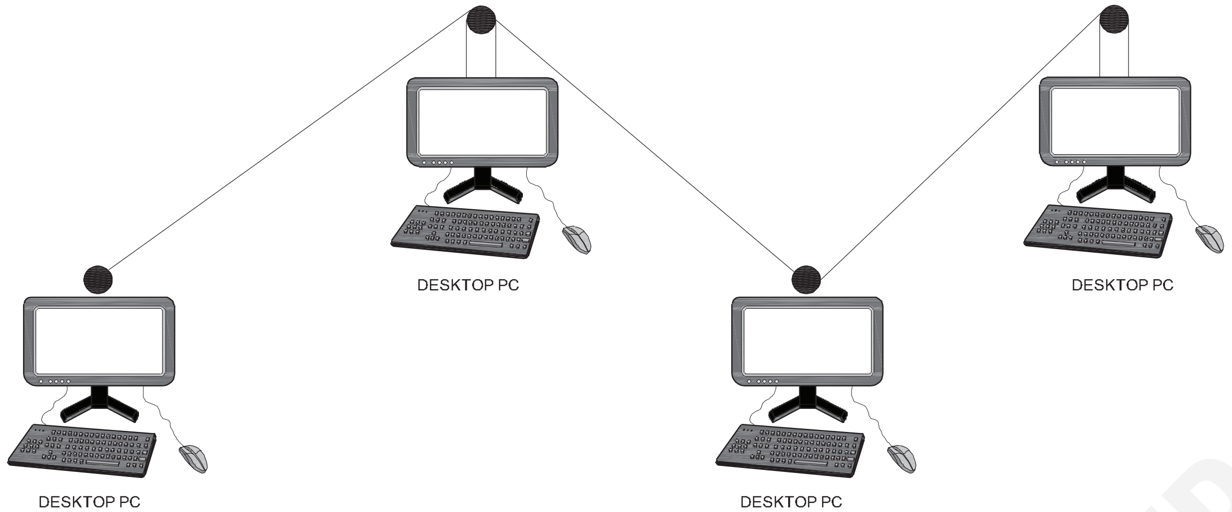
Disadvantages of star topology

- If the hub fails in a star topology the entire network goes down, so we still have a central point of failure. But this a much easier problem to trouble shoot than typing to find a cable break with a bus topology.

Daisy chain topology (Fig 6)

In a daisy chain network, one network node is connected to the next node in computer network. It is used to transmit the message down the line for a partway of computer network. Once the message is transmitted from the node, it goes down the passage until the concerned message reaches the destinated node. There are two types of daisy chain networks such as linear daisy chain and ring daisy chain. It can be connected in a linear structure or ring structure.

Fig 6



DAISY CHAIN TOPOLOGY

Advantages

With daisy chain topology, we connect monitors to each other directly. Instead of putting a cable in the laptop or desktop, it goes into another monitor. With daisy chaining you keep all cables organized and they won't tangle.

Disadvantages

The disadvantages associate with the linear daisy chain topology is that it allows the station to send and receive the data in a two-way fashion. Hence all the computer requires two receivers and two transmitters for successful communication.

Gateway network

Gateway networking definition: A gateway is connecting device (node) that can cannot two networks that employ different transmission protocols.

In a simpler term, a gateway in networking is a network node that acts as an entry point to another network.

A gateway in networking can be considered the most intelligent device among various network connecting devices. Intelligent in terms of operation, transmission speed, error control, data packet routing, etc. It is made up of both hardware and software components.

Types of Gateways

On basis direction of data flow, gateways are broadly divided into two categories.

Unidirectional gateways - they allow data to flow in only one direction.

Bid rectional gateways - They allow data to flow in both directions.

Features of a gateway

Gateway in computer network has a lot of different features. Let's explore some of the key features of a gateway.

- **Better visibility:** Network gateways are positioned at network boundaries, providing unparalleled visibility into traffic passing through the boundaries
- **Collects information:** A network gateway gathers data from other sections of the network to aid in diagnostics and troubleshooting.
- **Better security:** the location of network gateways at the network boundary provides them with the necessary control for security and serves as an important site for firewalls and security software.
- **Provides multi – protocol support:** Gateways are often built to accommodate a variety of protocols (protocol translation) to make the transmission of data between different networks using different network protocols easier.

Advantages of using a gateway in networking

Let's go through some of the advantages of using a gateway in networking:

- Uses a full – duplex mode of communication
- Filters data and works as an intelligent gadget
- Encapsulates and encapsulates the data packets
- Controls both collisions and the broadcast domain.
- Connect devices from two distinct networks that use different protocols.
- Consists of tighter and better security than any other network-connected gadget
- Possess the quickest data transmission speed among any network-connected gadget
- Preforms data translation and protocol conversion on the data packet based on the needs of the destination network.

Disadvantages of using a gateway in networking

As every coin has two sides, some drawbacks exist to employing gateway in a computer network. Let's go over those disadvantages:

- It is challenging to design and implement
- It is highly costly due to the high implementations costs.
- A particular system administration setup is required.

Electronic device description language (EDDL)

EDDL can theoretically be used with any protocol. However, the language is most widely used in the world of process automation with HART, foundation fieldbus, profibus, and EDDL can explain device parameters and their dependencies, visual representations for user interactions can be defined and communication paths with which the system can access device data can be described.

Device description language (DDL)

Device description language is the formal language describing the service and configuration of field devices for process and factory automation.

Fieldbus power supply

The fieldbus power supply provides power for the field devices and enables communication between the field devices and the control system via one common cable. It comes in two forms – as a compact power hub and as a basic power supply. The power hub consists of a motherboard and individual power supply modules.

Multidrop communication

Connecting several devices to a single communications channel. It typically refers to device that are polled in a master –slave configuration rather than in a peer – to – peer fashion.

Alarms and events

The difference between alarms and events is that alarms are unexpected and might need corrective action, while events are expected and of importance to the operator.

Alarms provide information pertaining to a system's operational condition that a network manager may need to act upon. An alarm might represent a change in an external condition, for example, a communications link has changed from connected to a disconnected state. Alarms can have these severities.

- Critical
- Major
- Minor
- Cleared – An alarm is considered inactive once it has been cleared

Events note the occurrence of an expected condition, such as an unsuccessful login attempt by a user

Process visualization

The visualize process comprises a number of nodes on a graph that represents the activities in the process. The nodes are linked by graph edges and these reflect the transitions that are defined in the process definition.

Trends

In SCADA graphical display of data is called trends.

There are two types of trends,

Real time trends

Historic trends

Real time trends

As the name explains itself, these are the graphs that display the values of data in real time and the graph updates for every instant of time we have specified.

Historical trends

As the name indicates, historic trends are used to display the data in real –time at the same time the old data can be retrieved and viewed on the run time.

Basics of Hydraulics

Objectives: At the end of this lesson you shall be able to
- **state the principles of hydraulics**
- **define force, weight, mass, pressure, work, power**
- **state pascal's law, bernoulics theorem , energy transmission of fluid power, the effect of heat on liquids.**

Introduction

A System that upon liquid an no transmitting fluid in called Hydraulic system

Example of Hydraulic system

1 Automobile braking and power streaming system

2 Hydraulics elevators

3 Hydraulic lifts in gasoline stations

Principles of Hydraulics

Force

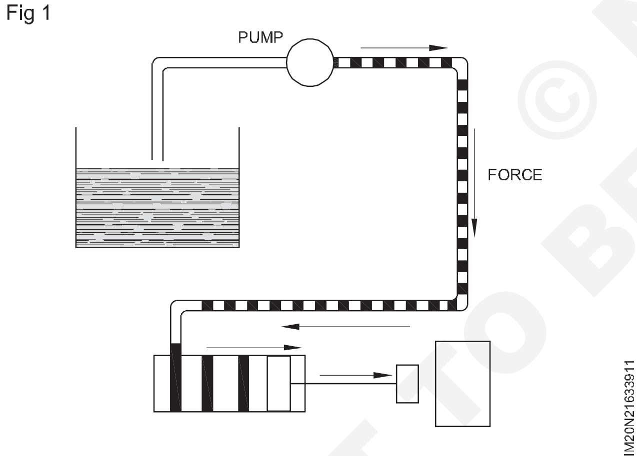
A Push or pull extend on a object to change its position or direction of more menu

Weight

A downward force that results from the gravitational Pull on an object.

Mass : The Amount of matter in an objects

Fig 1



Specific gravity : A measure of the density of a liquid.

Pressure: The amount of force extend on an object divided by the area.

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

Work

The Result of a body moved thought c distance by a force . w = F x d

Work = force x displacement

Power

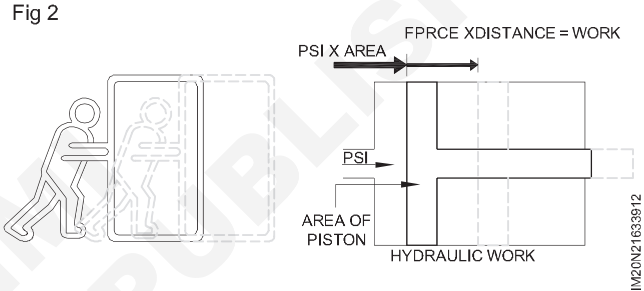
The amount of work done in a given amount of time

Energy

The rate of doing work is called Energy. The types of energy used in hydraulic system

- **Electrical Energy -** needed to operate to pump motor.
- **Hydraulic energy -** Produced by me pump
- **Kinetic Energy -** Produced when the hydraulic fluid mores a Piston
- **Potential energy -** produced when me piston as raised an object from one level to a higher level
- **Hear Energy -** produced by function in the pump motor, pump, Piston and hydraulic fluid.

Fig 2



Fluid power and hydraulies

Fluid power also called hydraulic power, transmitted by the controlled circulation of pressurized fluid to a motor that converts into a mechanical output capable of doing work on a load. Hydraulic power systems have grater flexibility that mechanical and electrical system s and can produce more power than such systems of equal size

Hydro mechanism is classified in to two sections

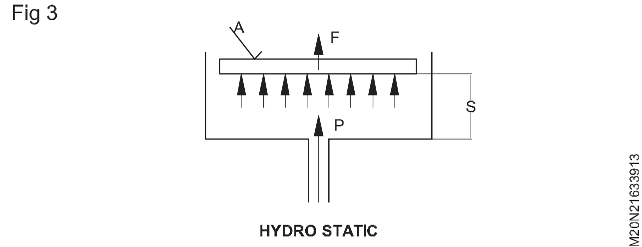
1 Hydrostatics

2 Hydro dynamics

Hydrostatic (Fig 3)

Hydrostatic pressure is the which rises above acertain level in the liquid due to the weight of the liquid mass

Fig 3



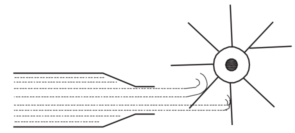
Hydrodynamics (Fig 4)

Hydrodynamics is the study of liquids in motion .specifically, it tooks at the ways different forces affect the movement of liquids.

Hydrodynamics is part of a larger filed called fuild mechanics that explain how energy and forces interact with fluids, including gases and liquids .

In this dynamic effect is generated through mass time's acceleration.

Fig 4



HYDRO DYNAMICS

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Properties of hydraulics

Objectives: At the end of this lesson you shall be able to
- **state the principles of hydraulics**
- **define force, weight, mass, pressure, work, power**
- **state pascal's law, bernoulics theorem , energy transmission of fluid power, the effect of heat on liquids.**

Incompressibility and no diffusion

One of the problem in hydraulic system is in compressibility it is not possible to stone a large amount of hydraulic fluid in a small tank because liquids are incompressible.

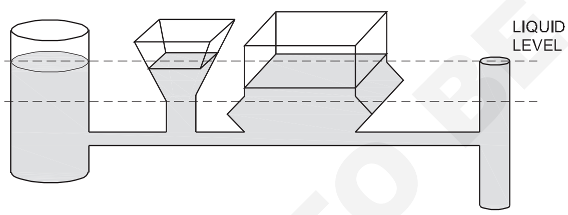
The slow evaporation rate of the fluid at atmosphenc pressure, hydrostatic fluid can be placed in a open container poured whom one container into another with out differing this is non diffusion .

Where an, cares cannot be placed in open container , become they would diffuse rapidly into the surrounding our

Hydrodynamics pressure

Fig 1 shows number of differently shaped , connected, open containers , note that the liquid level is the same in each container, regardless of the shape or size of the container. This occurs be cause pressure is developed with in a liquid by the weight of the liquid by above. This pressure is called hydrostatic pressure.

Fig 1



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Pascals Law (Fig 3)

It states that when pressure in exerted on a confined liquid, the pressure is transmitted equally in all the directions through the liquid as shown Fig 2.

Following condition are necessary for pascals law.

1 System must be closed.

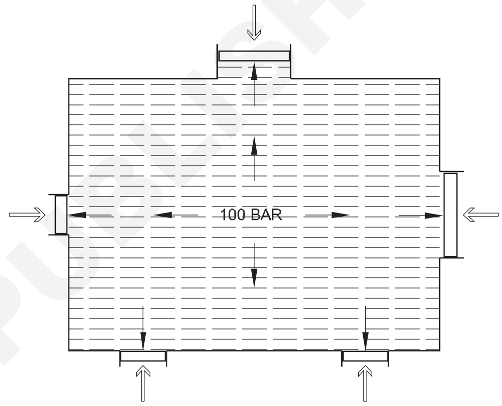
2 Fluid must be incompressible (Liquid only).

Transmission of hydraulic power

As shown in Fig 2A, A force of 10 psi applied to piston 1 is transmitted through the liquid in the cylinder to piston 2. Pascal's law states that pressure developed in a confined fluid is equal at every point. Therfore, the internal fluid pressure developed by piston 1 acts on piston 2. If the area of the each piston is the same, the force developed on piston 2 in the same as the force applied by piston1, discounting the friction losses. This principle is the basis for all hydraulic power transmission systems.(Fig 4)

As shown in figure 4B has been a single cylinder replaced by 2 separate cylinder. Both are of the same diameter and are connected by a hydraulic line. The conditions are not changed because the hydraulic system has not been changed.

Fig 2



PASICAL'S LAW

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This law makes the operation of fluid power system highly predictable.

Fig 3

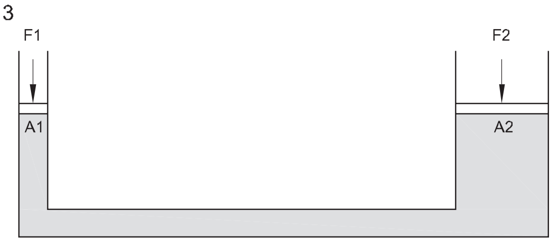

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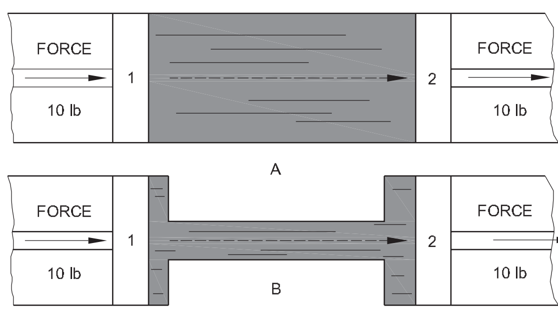
Fig 4



TRANSIMISSION OF FORCE

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If Piston area A1 of the vessel shown is designed to move forces can be transmitted since the pressure in the vessel is also transmitted to the larger piston area A2, where it produces a greater force.

Ratio of Force transmission F1 to F2

Pe = F1/A1 and Pe = F2/A2

Since the pressure is uniform at any point, so the following equation can be derived,

F1/A1 = F2/A2

Or, F1/F2 = A1/A2

i.e, The ratio of the forces is the same as that of the piston areas. If the area A2 is 5 times larger than the area of A1 then force F2 is also multipled by 5 times.

This is the principle of Hydraulic Press. An available pressure can produce a greater force by increasing the piston area.

Example: Calculate the pressure in a hydraulic press when F1 = 60N and A1 = 2 Cm2

Solution: As, Pe = F1/A1 = 600/2

= 300 kpa

= 3 bar.

Then calculate the force acting on piston area A2

As, F2 = (F1 X A2)A1

= (60X200)/20

= 6000N

Further investigation will show that the hydraulic press cannot simply produce a force from nothing. The piston strokes required are inversely proportional to the piston areas. The rule **"Any force gained is lost it distance."** is also applicable in Hydraulics as in Mechanics.

Flow of Fluids in pipes

Objectives: At the end of this lesson you shall be able to
- **understand different types of flow.**

Fluid flow in pipes

Upto certain velocities, the hydraulic fluid flow through pipe is laminar (i.e. flow in layers).During laminar flow the inner fluid layer mives faster while the outer layer, theoitically speaking is static in nature. (Fig 1)

If the velocity is increased and after the critical velocity the flow becomes Turbulent (i.e, it contains eddies).

This turbulence causes an increase in flow resistance and hydraulic losses and for this reason turbulent flow is not desirable.

The nature of flow is decided by the value of "Reynolds Number" which is defined as follows.

Reynolds Number = Inertia Force/Viscous Force

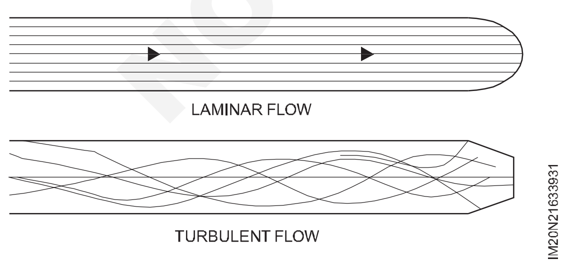
= pvd/

Re < 2100 Laminar Flow

Re > 3100, Turbulent Flow.

Re, 2100 - 3100, Transition Flow.

Fig 1



Fluid Energy in motion, the total energy of liquid in motion can be classified as,

- Potential energy.
- Kinetic energy
- Pressure energy

Potential Energy : Energy by virtue of the positon of the body is termed as potential energy. It is also called as stored energy. The potential energy in a liquid system is the equivalent of height of liquid column in the system.

Ep = mgh = V x p x g x h

Kinetic Energy : Kinetic Energy is the energy by virtue of motion of a body. Hence, Kinetic energy is closely associated with the velocity of flow.

For a body of mass m, the Kinetic energy h

h = mv2/2g

pressure Energy : Pressure Energy is the energy of a body by virtue of its condition. The pressure energy of a liquid column is expressed by dividing the pressure by the density of the fluid.

i.e, h = pressure Energy = P/p

where, P = Oil Pressure , p = Density of fluid

"rho" symbol for Density of fluid

Bernoulli's Principle

The principle states that the sum of all energies i.e, potential, Kinetic and Pressure energies at any point of fluid flow represents the total energy and it is same at any point of fluid flow.

$P_1 + 1/2\ pV_1^2 + pgh_1 = P_2 + 1/2\ pV_2^2 + pgh_2$

p = Fluid density

g = acceleration due to gravity

$p_1\ p_2$ Pressure energy at points 1 and 2

$V_1 V_2$ Velocity at points 1 and 2

The effect of heat on liquids

We know that liquids expand when they are heater. when played in a completely closed vessel and heated, is will exert great pressure on the vessel. Because liquids cannot be compressed, a very small rise in temperature cause large amount of pressure on cylinder, accumulation, and closed reservoirs. There internal pressures can also cause internal system damage.

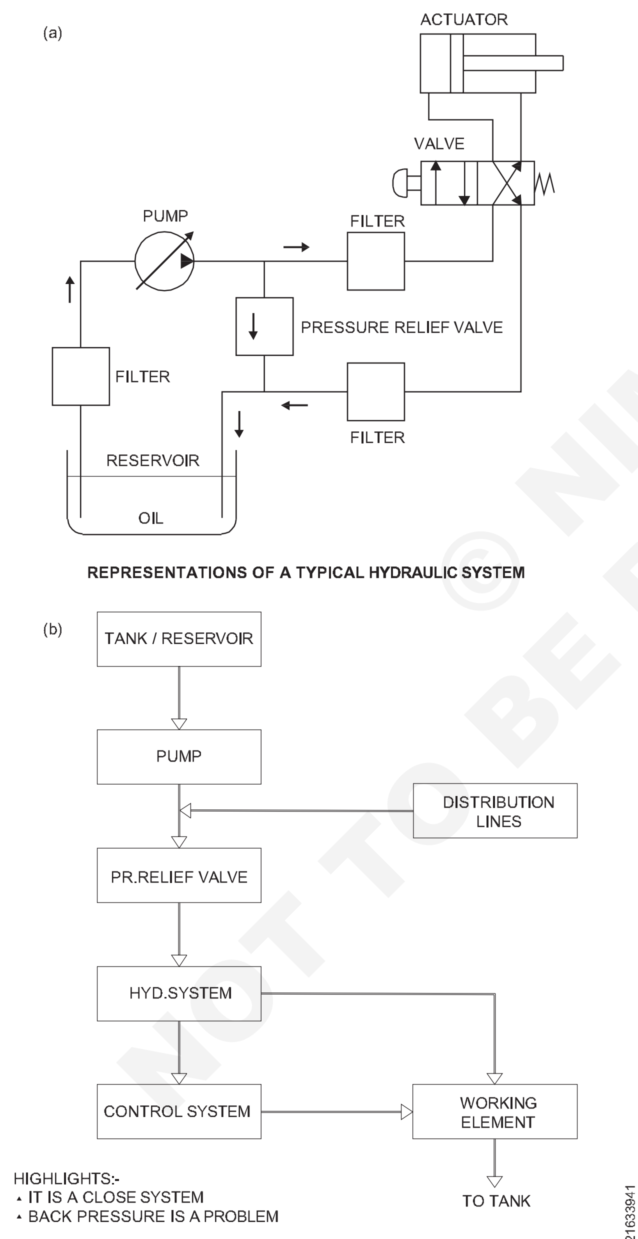
In many cases, heat causes seals and packings to leak because of the loweres oil viscosity. Unnecessary heating of the oil in a hydraulic system must be avoided. Otherwise cooling should be provided.

Basic hydraulic system

Objectives: At the end of this lesson you shall be able to
- **appreciate a typical hydraulic system**
- **define the components of a hydraulic power pack.**

A Typical Hydraulic System

Fig 1



REPRESENTATIONS OF A TYPICAL HYDRAULIC SYSTEM

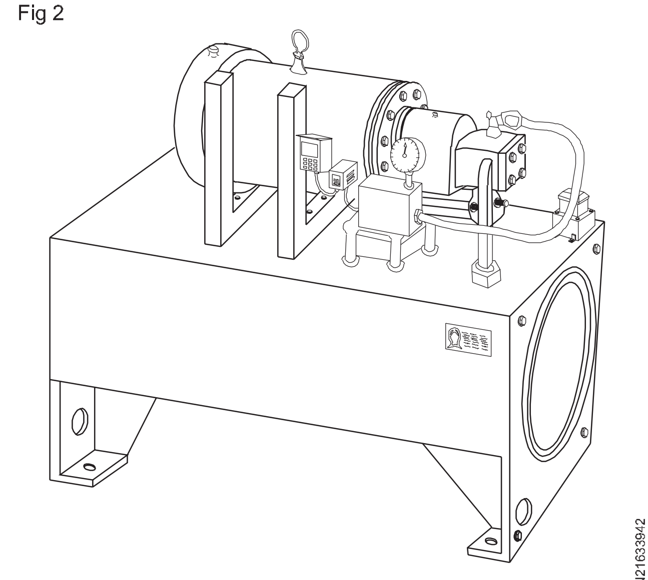
BASIC HYDRAULIC SYSTEM

A typical hydraulic system is shown in the schemaitc diagram of Fig 1. The system is a closed system and comprises a power pack, control valves, and actuators. The hydraulic power pack consists of a hydraulic pump coupled to engine, a reservoir filled with oil, and a pressure relief valve (PRV). The pump pushes the oil into the closed system. It develops a high pressure, when the pump flow encounters some opposition. Therefore, the mechanical energy provided by the prime mover of the pump is converted into hydraulic energy. This energy is transmitted to hydraulic actuators through the oil medium. Hydraulic actuators such as cylinders are used to convert the hydrostatic energy back to mechanical energy. Hydraulic valves are used to control the direction and the speed of the actuators. The pressure relief valve is used to limit the pressure in the system.

All system components are interconnected through fluid conductors, such as pipes, tubing and / or hoses, for the leak-free transmission of the hydraulic power. The pressurized oil media must be positively confined in the system, through the use of effective seals, for the efficient utilization of the power. Contaminants should not be allowed to accumulate in the system. Filters are used to remove contaminants in the oil medium.

Reservoir (Fig 2)

Fig 2



HYDRAULIC POWER PACK

A hydraulic power pack, employed in a hydraulic system, transforms the power conveyed by its prime mover into hydraulic power, at pressures and flow rates as required for all system actuators. It is usually a compact and portable assembly that contains components necessary to store and condition a given quantity of oil, and to push a part of the oil into the system. The essential components are reservoir (tank), pump, relief valve, pressure gauge etc. A reservoir is essentially a container that stores a sufficient quantity of oil required for the system. A well-designed reservoir in a hydraulic system allows most of the foreign matter to drop out of the oil and assists in dissipating heat from the oil.

Oil filter

Impurities can be introduced into a system as a result of mechanical wear, and external environmental influences. For the reason filters are installed in the hydraulic circuit to remove dirt particles from the hydraulic oil. The reliability of the system also depends on cleanliness of oil.

Pressure Relief Valve

A pressure relief valve (PRV) is used in a hydraulic system to limit the maximum working pressure of the system to a safe value in order to protect operating personnel against injury and system components against any damage.

External gear pump

Figure 5 illustrates the operation of an external gear pump with the help of its schematic diagrams in three critical positions. It basically consists of two close-meshing identical gears, enclosed in a close-fitting housing. Oil chambers are formed in the space enclosed by the gear teeth, pump housing, and side plates. Each of the gears is mounted on a shaft supported on bearings in the end covers. One of the gears - called the drive gear - is coupled to a prime mover through its drive shaft. The second gear is driven, as it meshes with the driver gear.

The gears rotate in opposite directions when driven by the prime mover, and mesh at a point in the housing between the inlet and outlet ports. When the gears rotate in the housing, the diverging teeth create an expanding volume at the inlet side of the pump. This creates a partial vacuum at the inlet chamber of the pump, which draws oil into the chamber from the system reservoir [Figure 5(a)]. The oil then travels around the periphery of the rotating gears as two streams [Figure 5(b)]. Since the pump has a positive internal seal against leakage, the oil is positively ejected out of its delivery port [Figure 5(c)]. Therefore, when run by the prime mover, the intermeshing gears displace a fixed volume of oil from the suction side to discharge side in one revolution of the drive shaft and crate a flow.

Internal gear pump

Figure 6 illustrates the operation of an internal gear pump with the help of its schematic diagrams in three critical positions. This pump consists of an outer rotor gear, an inner spur gear, and a crescent-shaped spacer, all enclosed in a housing. The inner gear with less number of teeth operates inside the rotor gear. The gears are set eccentric to each other. The stationary crescent spacer is machined into the space between these gears and separates them. The spacer divides the oil stream, and acts as a seal between the suction and discharge ports.

Any one of the gears can be driven through a shaft supported on bearings. Both the gears rotate in the same direction, when power is applied to the drive shaft. The rotation of gears causes the teeth to un-mesh near the inlet port and consequently a partial vacuum is created at the inlet chamber of the pump, which draws oil into the chamber from the system reservoir [Figure 6(a)]. Oil trapped between the inner and outer gear teeth on both sides of the spacer is carried from the inlet port to the delivery port, as the gears rotate [Figure 6(b & c)]. Since the pump has a positive internal seal against any leakage, the oil is positively ejected out of the delivery port.

Symbol for hydraulic components

Objectives: At the end of this lesson you shall be able to
- **read and interpret the circuit symbol**
- **state the uses of symbol in hydraulic components.**

In a hydraulic circuit symbols are used to represent individual component to impart representaion of hydraulics system in diagrams. A symbol identifies a component and its function. These symbols are as per ISO 1219 standards.

Pump and motor

Hydraulic pump and motor are represented by means of a circle. Triangle within the circle represent the direction of flow and positon of triangle differentiates between the symbol of pump or motor.

If triangle is filled darkened means it is meant for hydraulics fluid but if triangle is not filled means it is for gaseous pressure media or Pneumtic energy.(Fig 1 & 2)

Fig 1

HYDRAULIC ENERGY

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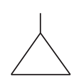
Fig 2



PNEUMATIC ENERGY

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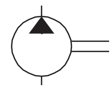
Symbols of pump and motor (Figs 3 to 9)

Fig 3



UNIDIRECTIONAL FIXED DISPLACEMENT PUMP

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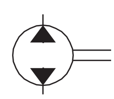
Fig 4



BIDIRECTIONAL FIXED DISPLACEMENT PUMP

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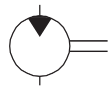
Fig 5



UNIDIRECTIONAL HYDRAULIC MOTOR

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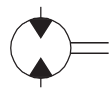
Fig 6



BIDIRECTIONAL HYDRAULIC MOTOR

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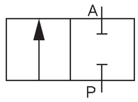
Fig 7



2/2-WAY VALVE

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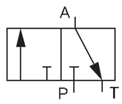
Fig 8



3/2-WAY VALVE

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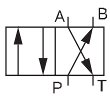
Fig 9



4/2-WAY VALVE

IM20N21633959

Direction control valve

Direction control valves are represented by several connected squares.

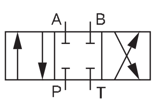
- The number of squares indicates the number of switching positions.
- Arrows in the squares indicate the direction of flow.
- Lines indicates how the ports are interconnected in the different switching positon.

Port designation

P	Pressure port
T	Tank port
A	Service port (output port)
B	Service port (output port)
L	Leakage port

Symbols of Direction control valve (Figs 10 to 11)

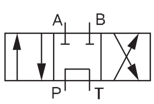
Fig 10



4/3-WAY CLOSE CENTRE VALVE

IM20N2163395A

Fig 11



4/3-WAY OPEN CENTRE VALVE

IM20N2163395B

Port should always be represented in the neutral position of valve

The neutral positon is a position which automatically come in valve due to spring force when no any command is available in valve, it is also the initial postion unless otherwise actuated.

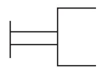
Actuating mechanism of valve

The switching position of direction control valve can be changed by various actuation methods.

Different mechanism of actuation of valve are shown in Fig 12 to 19

Mechanical actuation

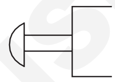
Fig 12



GENERAL MANUAL OPERATED

IM20N2163395C

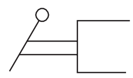
Fig 13



PUSH BUTTON

IM20N2163395D

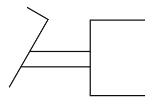
Fig 14



LEVER

IM20N2163395E

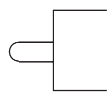
Fig 15



PEDAL

IM20N2163395F

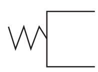
Fig 16



PUSH PIN

IM20N2163395G

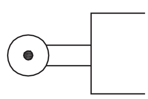
Fig 17



SPRING

IM20N2163395H

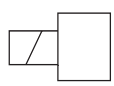
Fig 18



ROLLER

IM20N2163395I

Fig 19



SOLENOID

IM20N2163395J

Manual actuation

Electrical actuation

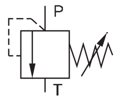
Pressure control valve

Pressure Control valve are represented by a single squares. Arrow within the square indicate the direction of fluid flow.

The position of arrow within the square indicates whether the valve is normally open or normally closed.

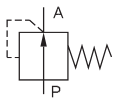
Symbols of pressure control valve (Fig 20 to 22)

Fig 20



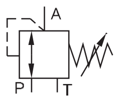
PRESSURE RELIEF VALVE

Fig 21



PRESSURE REDUCING VALVE

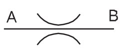
Fig 22



PRESSURE REGULATOR

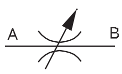
Flow control valve (Fig 23 to 25)

Fig 23



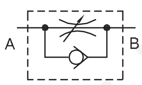
FIXED FLOW CONTROL VALVE

Fig 24



VARIABLE FLOW CONTROL VALVE

Fig 25

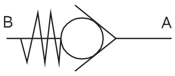


ONE WAY FLOW CONTROL VALVE

Non-return valves

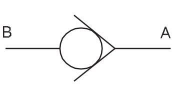
The symbol of non-return valve is a ball which is pressed against a sealing seat.(Fig 26 to 28)

Fig 26



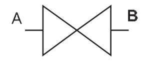
SPRING LOADED NRV

Fig 27



UNLOADED NRV

Fig 28

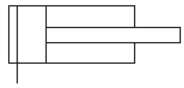


SHUT-OFF VALVE

Cylinder

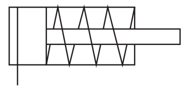
Single acting cylinders have one port and double acting cylinder have two ports (Fig 29 to 31).

Fig 29



SINGLE ACTING CYLINDER

Fig 30



SINGLE ACTING CYLINDER WITH SPRING

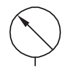
Fig 31

DOUBLE ACTING CYLINDER

Measuring devices

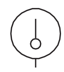
Measuring devices are shown in the Fig 32 to 36

Fig 32



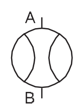
PRESSURE GAUGE

Fig 33



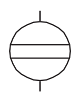
TEMPERATURE GAUGE

Fig 34



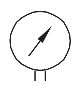
FLOW METER GAUGE

Fig 35



LEVEL GAUGE

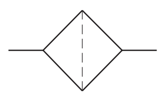
Fig 36



DIFFERENTIAL PRESSURE GAUGE

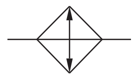
Other symbols (Fig 37 to 39)

Fig 37



FILTER OR STRAINER

Fig 38



COOLER

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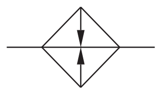
Fig 39



HEATER

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Symbols using Line (Fig 40 to 46)

Fig 40

WORKING LINE

IM20N2163395Z5

Fig 41

DRAIN OR BLEED LINE

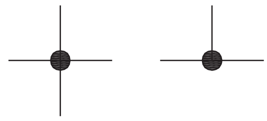
IM20N2163395Z6

Fig 42

FLEXIBLE PIPE FLEXIBLE HOSE

IM20N2163395Z7

Fig 43



PIPELINE JUNCTION

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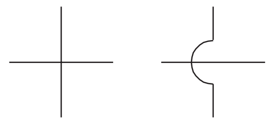
Fig 44



CROSSED PIPELINES

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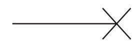
Fig 45



PLUGGED ON EQUIPMENT OR LINES

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Fig 46

QUICK-ACTING COUPLING

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Functions of Hydraulic Fluid

Objectives: At the end of this lesson you shall be able to
- **explain the functions of hydraulic fluid,physical properties & chemical properties**
- **explain the types of hydraulic fluids.**

Hydraulic Fluids

Functions of Hydraulic Fluids

The function of hydraulic fluid into transmit power effectively from one point in the system to another. Another function of hydraulic fluid is to lubricate the contacting surfaces of the mechanical working parts of the system. Because components such as vanes, gears, pistons and valve spools are manufactured to very closely tolerances the hydraulic fluid must reduce the friction between contacting surfaces of the components.

Hydraulic Fluid

Hydraulic Fluids can be grouped as,

- Mineral oil
- Water
- Water in oil emulsion
- Water Glycol
- Phosphate esters
- Silicon Fluid
- Halogenated Hydrocarbons.

Physical properties of fluid

Density : Mass per unit volume is called Density. denoted by p(rho) symbol

Specific Gravity : It is the ratio of density of the fluid to the density of ta standard fluid (water). It is a unitless quantites.

Viscosity : Resistance to fluid flow is called viscosity.

Dynamic viscosity : It is the measure tof fluid's resistance to flow when an external force is applied.

Viscosity Index : Viscosity index reflects the way how viscosity changes with temperature. The smaller the viscosity changes, the higher the viscosity index. The viscosity index of hydraulic system oil should not be less than 90. Multiple viscosity oil incorporate additives to viscosity index. Oil of this type generally exhibit both temporary and permanent decrease in viscosity due to the oil shear encountered in the operating hydraulic system.

The additives are selected to reduce wear, increase chemical stability, inhibit corrosion and depress the pour point.

Viscosity & pressure :

An important characteristics of hydraulic fluid is its change in viscosity, when subjected to pressure. In general, increased pressure on petroleum, oil fluids as a greater effect on the viscosity at high pressure than at low pressure.

Pour point

Another physical property of a hydraulic fluid is pour point, which is the lowest temperature at which it will flow the pour point should be lower than the operating temperature of the hydraulic system in which the fluid is to be used.

Fluid Selection

To choose a Hydraulic oil, the following points must be considered.

- Long life
- Acidity
- Lubricity
- Entrainment
- Seperation
- Demulsibility
- Compressibility
- Viscosity
- Viscosity Index
- Compatibility
- Cost

Component protection

Hydraulic fluids reduced the friction between rubbing surfaces by substituting the comparitively low friction in a lubricating film for the friction between a contacting surface as shown in fig. So the film should be slippery, so that the moving parts can move easily.

In order to protect surfaces from corrosion, the hydraulic fluid should cover all surfaces with a thin durable, protective film.

Chemical Properties

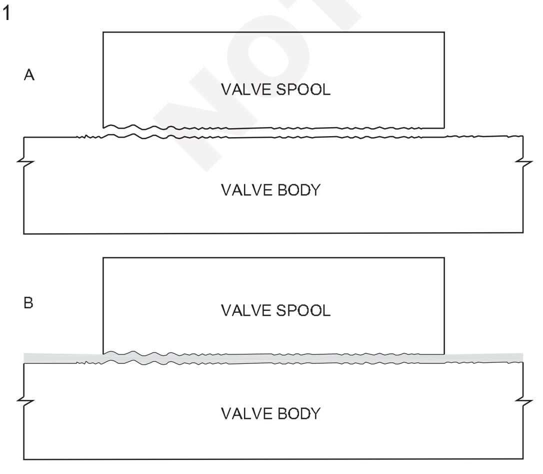
Resistance to oxidation is the most common factor that shorten fluid life. Fluid oxidation in a hydraulic system can be limited as controlled in three ways.

a Mechanically

b Chemically

c Proper maintenance.

Fig 1



System contamination

Oxidation is the greatest contaminator in a hydraulic system. All contaminants can be controlled through the use of chemicals and good maintenance procedures.

Water

Small amount of water get into the hydraulic fluid in the form of water vapour from the air that constantly fins its way into the system.

Dissolved air

The air solvtilety of a liquid is its ability to absorb or dissove air when hydraulic fluid has a considerable amount of dissolved air in it, a sudden pressure drop will reduce its ability to retain the air, which causes violent foaming this foaming can be minimized with screens or splash plates.

Corrosion and Rusting

Rust and corrosion are chemically induced processes that eat away at flow passages, valve ports,oxifies springs and valve spools in such a way that the flow characteristics of there parts are changed.

There are several ways of preventing or minimizing rusting and erosion.

Foaming

It is usually forms when hydraulic fluid is mixed with air from a free surface. As the air becomes trapped in the fluid it forms bubbles of air. As those bubbles begin to rise to the surface of the hydraulic fluid they group together to form foam.

The best way is to have the hydraulic system operated at moderate temperatures and pressures. In this way fluid oxidation and acid action are reduced and the air and water formations can be controlled. A fluid that is filtered properly and changed regularly, and that has suitable lubricating qualities, will help reduce corrosion and rusting.

Types of Hydraulic fluids

The following types of hydraulic fluids are commonly used in industrial hydraulic systems.

- Petroleum oils.
- Oil-in-water emulsions.
- Water - in - oil emulsions.
- Water based glycols.
- Chlorinated hydrocarbons.
- Phosphate esters.
- Silicones
- Silicanes esters.

Directional control valve

Objectives: At the end of this lesson you shall be able to
- **explain directional control valve classification**
- **explain direct acting solenoid valves**
- **explain pilot operated solenoid valves.**

Introduction

Directional control valves are used to control fluid flow in hydraulic lines and to start,stop or change the direction of motion of hydraulic cylinder and motors. There can be operated manually or automatically.

Classification of Directional control valve

- The number of paths (Three-way,four way)
- The number of positions to which the valve can be shifted (two-position, three-position)
- The total number of valve ports (Four port, five port)
- The way the fluid flows when the valve in the center position (open or blocked center)
- The type of actuator that shift the valve (Pilot operator, direct acting)

Review of two - way valves

Globe valve : It is used for air or fluid service for pressure upto 250 psi. It regular flow to a limited degree in the direction shown in Fig 1.

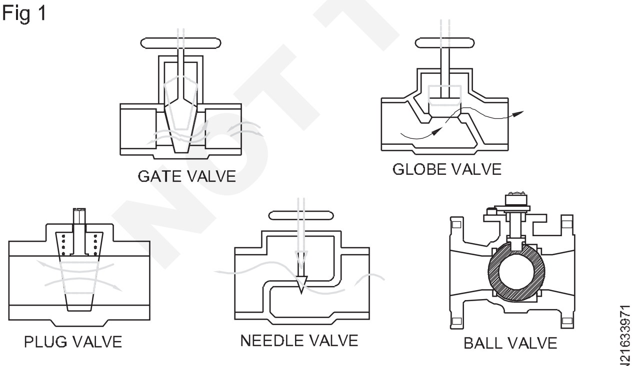
Gate valve : This valve is suitable for hydraulic system. It allows flow in either direction with low pressure losser.

Plug valves : This valve is only suitable for low pressure, service as low pressure losses, but frequently requires maintenance for leakage.

Ball valve : It is suitable for medium pressure service it is similar to plug valve and has very low pressure losses,both ball and plug valves allow flow in either directions.

Needle valve : It is suitable for very high pressure (10,000 to 50,000 psi) and is often used as a throttling valve as well as shelt off valve.

Fig 1



MANUALLY OPERATED TWO-WAY VALVE

One disadvantages of the needle valve is high pressure losses at high flow rates, because the valve heat is much smaller in diameter than the inlet and outlet connections.

Automatic two way valves

The most common type of automatic two way valve is solenoid operated.

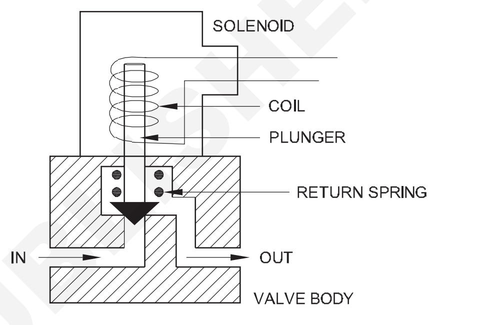
1 Direct acting solenoid valve

2 Pilot operated solenoid valve

Direct acting solenoid valve

It is shown in Fig 2 it is called normally closed valve because the valve is closed when the solenoid coil is deenergized. The plunger is held against the valve heat by the plunger spring when the solenoid coil is energized, the plunger is lifted from the heat, allowing fluid to flow in one direction as indicated pilot - operated solenoid valve.

Fig 2

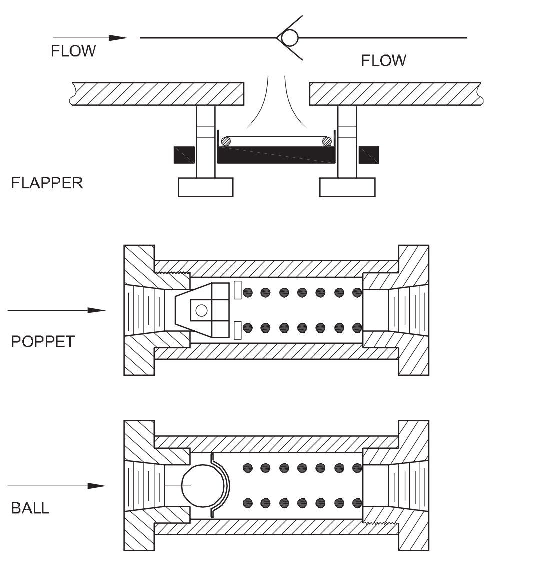


DIRECT-ACTION SOLENOID VALVE

Check valves

Another type of two way valve is check valve. It allows hydraulic fluid to flow in only one direction through a line. Mostly it is constructed with ball checks or poppets as shown in Fig 3

Fig 3



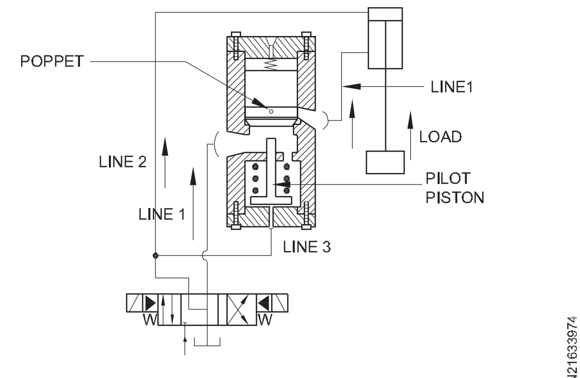
CHECK VALVE

Hydraulic fluid under pressure forms the check valve and flows through the valve to the outlet when the inlet pressure is reduced, pressured at the outlet closes the check against its seal and prevent reverse flow through the check valve.

Pilot operated check valves

In some applications, to have a controlled reverse flow through check valve pilot operated check valves are used.As shown in Fig 4 the load is reduced by hydraulic cylinder through the check valve and line1. The load is held in the raised position by fluid pressure above the popper in the check valve.To lower the load, pressure is applied in line 2 and pilot line 3. The pilot piston lefts the poppet check, releiving the pressure in line 1 and permitting the load and the pressure in line 2 to move the cylinder piston down to all cover, the pilot piston and the pressure in line 3 must be large enough to overcome the pressure above the poppet check.

Fig 4



PILOT- OPERATED CHECK VALVE

Spool valves

There are the most commonly used valves in hydraulic systems. Because of their construction they are partially balanced and therefore easy to operate even when used in high pressure systems.

Spool valve are constructed as two way, three way, four way and five way valves that can be operated manually or automatically.

Three - way spool valves

There valves have three primary or working connections. Pilot lines are not considered primary lines. Most three way spool valves resemble two - way spool valves and more fact and forth when they operate.

It can be used as a diverter valve or selector valves as in Fig 5. It shows the spool of a three-way diverting valve held in the non actuated position by the spring.

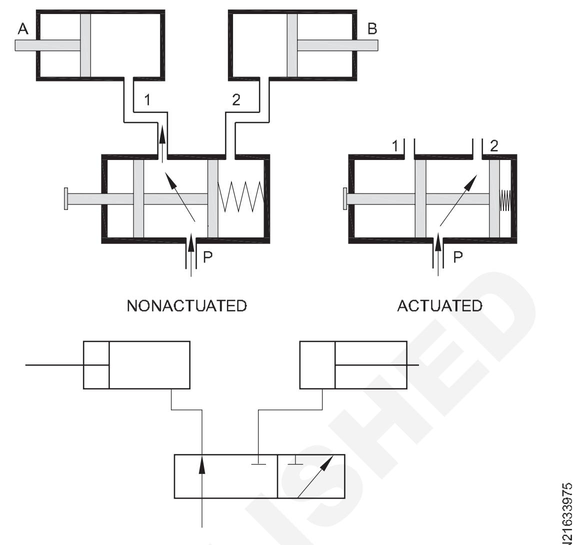
Hydraulic fluid at port p is able to flow through the valve and ouptort 1 to cylinder A when the valve is actuated, the spring is compressed and hydraulic fluid flows from port P through port 2 to cylinder B. The diverter valve operates only the cylinder. Return of the actuating fluid to the reservoir is accompished with another three way valve.

Hydraulic Motor control

A three way diverted valve can be used in two ways to control a hydraulic motor. The simplest way is to use the valve as an on/off valve than allows fluid to flow either to the motor or to the reservoir as shown in Fig 6 when the valve spool is moved ot the left pressurized fluid flows through the valve to the motor and then to the reservoir when the valve spool is pured to the right, the motor is unloaded by allowing the fluid on the motor side to return tot he reservoir through port T.

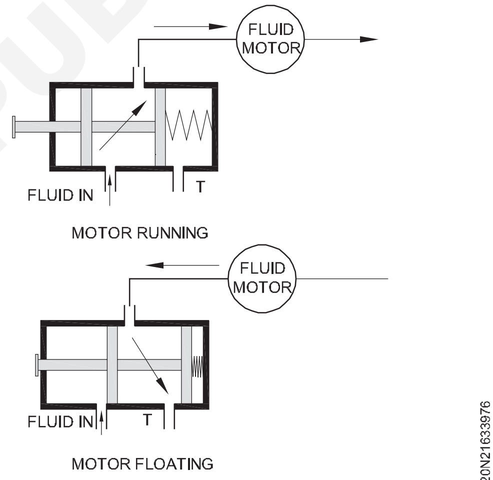
Unloading the fluid pressure permits the motor to count to stop.

Fig 5



THREE-WAY DIVERTER VALVE

Fig 6



Normally open and Normally closed

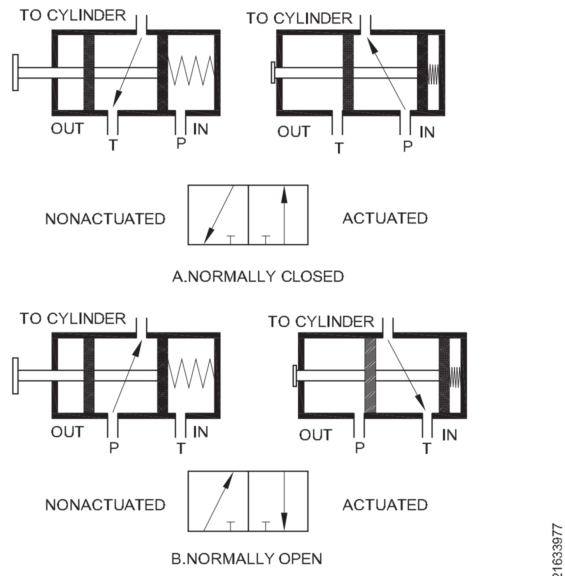
Three way valves like two way valves are classified as normally closed or normally open.

As in Fig 7, a normally closed valve has the flow blocked from the pressure inlet p to the cylinder when the valve is in a non actuated position. A normally open valve permits flow from the pressure inlet p to the cylinder when the valve is in a non actuated position as in Fig 7(B).

Holding valves

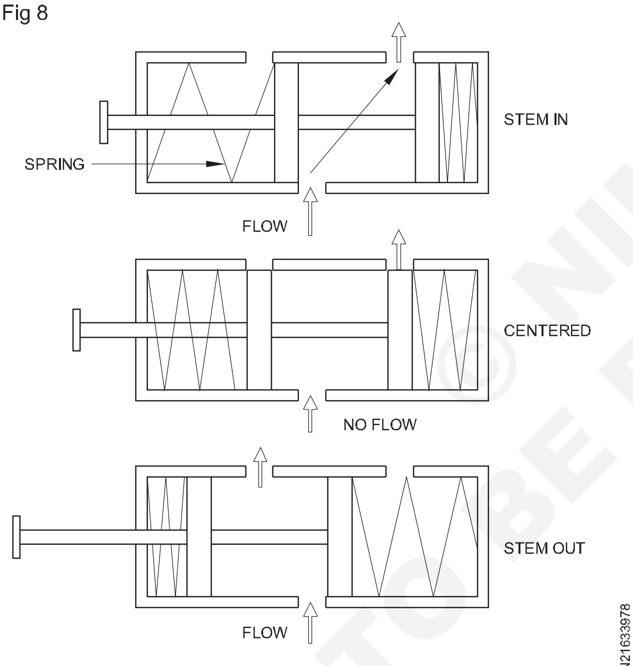
A three- way valve that is designed to hold all the ports blocked at one as shown in Fig 8 when the valve spool is in mid position, the left and right ports are closed. when the valve is shifted flow is possible between the left or right and center ports. To permit easier actuation, the valve usually is assembled with the spool mounted between two springs. The springs center the spool in the non actuated position.

Fig 7



THREE-WAY VALVE

Fig 8



THREE-WAY HOLDING VALVE

Four way valves

These valves has four primary working connections as shown in Fig 9 when a circuit becomes more complex four-way valves are used. It has a pressure fluid inlet P,a return line to the reservoir T, and connections 1 & 2.

Connections 1 & 2 connect the fluid outlet ports to the actuator, which is usually a cylinder or a motor.

There are only four external connections even though the valve has five internal ports (The two exhaust ports are directed to a common external connection). The number of external connections determines the valve classification. Most four-way valves are designed to perform as many functions as possible efficiently.

To accomplish this, most valves are manufactured with 3 operating positions middle (non - actuated) actuated to the left and actuated to the right.

Five-way valves

It is usually a special variation of a five - way valve. The difference between the two valves in simple. In four - way valve, the two exhaust ports are connected internally. In a five - way valve, they are not five connections are required. Separate exhaust connections are used so that the fluid leaving each side of the actuator can be regulated. This allows the actuator to travel at different speeds, hold its position or more in steps.

Fig 9

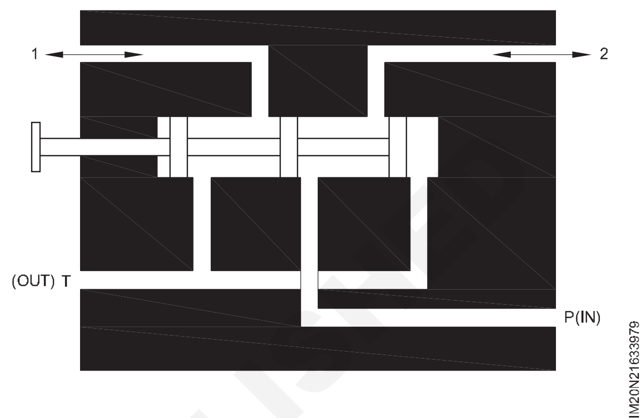
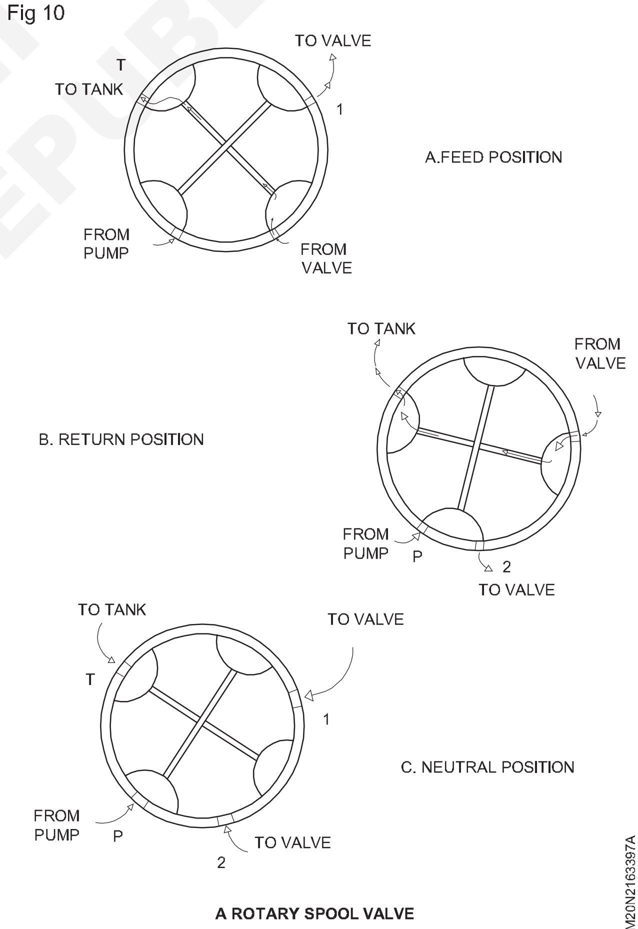


Fig 10



A ROTARY SPOOL VALVE

Rotary spool valves

Rotary spool valves are quite different in construction and operation from the other valves. They perform the same funciion of controlling fluid flow, and can be operated manually mechanically, hydraulically, pneumatically or electrically.

In portions the spool valve directs hydraulic fluid from the system pressure line to port 1, allowing fluid to enter the system,when the spool rotates to the return position, B fluid directed to port 2. In the neutral or centre position. C the ports to the spool valve and the actuator are closed and no fluid flows.

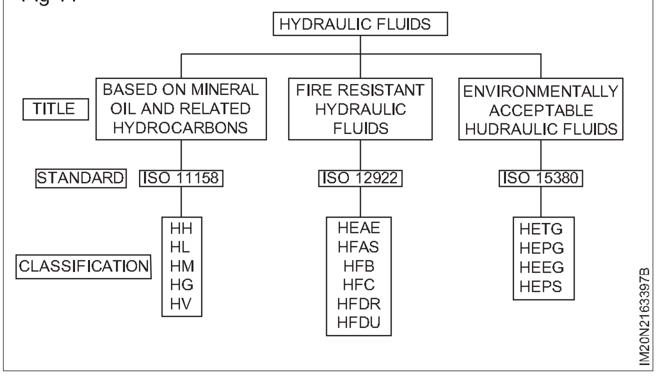
Schematic symbols

There are several ways which the spool of a valve can be shifted. The methods and their symbols shown in Fig 11

Flow Ratings

When you replace a hydraulic valve, it is important to know that the replacement valve has the required flow valve is insufficient for a required flow, pressure drop and energy losses will be excessive. If the valve is too large, energy losses will be low but initial cost and spare requirements will be high.

Fig 11



Principles of Pnuematics

Objectives: At the end of this exercise you shall be able to
- **explain the pneumatic principle**
- **state the law of pneumatics**
- **explain the transmission of pneumatic fluid power system**

Principles of Pneumatics :

A system that uses a gas for transmitting for us is called pneumatic system.

Examples of pneumatic system

- Pneumatic conveyors
- Control flow values in chemical process and air conditioning plants, door openers.
- Pneumatic system in an Industrial plant usually handles compressed air. It convert compressed air into work.

Example: Operating portable air tools such an drills, wrenches and chucks. Principles of pneumatics

Ex The amount of madder in an object.

Presume: The amount of force everted in an object divided by the area.

Work and energy

The result of a body moved through a distance by a for us W= F x d

Work = Force x distance

Energy: The rate of doing work is called energy.

Types of energy used in pneumatic system.

- **Electrical energy:** which operates the compressor motor,
- **Pneumatic energy:** Which is produced by the compressor.
- **Kinetic energy:** Produced when the compressed air is lifting or molding an object.
- **Potential energy:** Which the lifted or none object now as

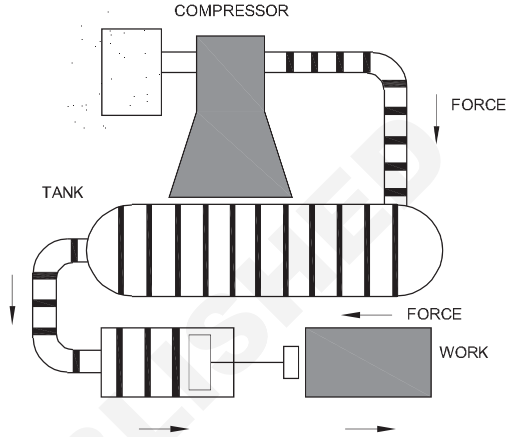
Peat energy: Produced by friction in the compressor motor, the compressor, the moving air and the moving piston

Compressibiling: Air is compressible and is stored in large quantities in small container. The more the air is compressed the higher its pressure.

Laws of pneumatics.

Pascal's law: It states that when a gas is confined under pressure in a closed container the pressure in transmitted equally in all directions by the gas. As show in Fig 1.

Fig 1



FORCE IN A PNEUMATIC SYSTEM

Boyles law : The absolute fig Pressure of a confined quantity of gas varies inversely with its volume, with its temperature does not change (Fig 3)

P1x V1= P2 V2

P1 S1 is are the pressures before and after compression. After compression

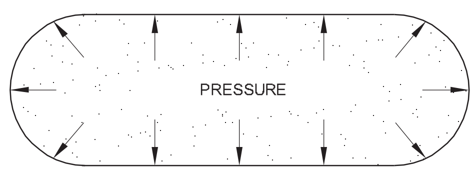
Charles law

It states that if the pressure of the confined quantity of gas remains same, the change into volume (V) of the gas varies directly with a change in the temperature to the gas.

V2 = V1 x T2/T1 (or)

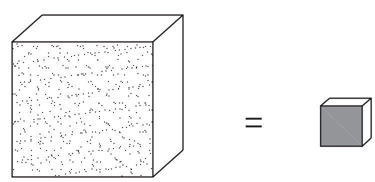
P2 = P1 X T2/T1

Fig 2



ACTION OF CONFINED AIR PRESSURE

Fig 3



$P_1 X V_1 = P_2 X V_2$

14.7 psi X $10 ft^3$ = 147 psi X $1ft^3$

BOYLE'S LAW

Ideal gas law: It states the pressure, volume and temperature of the second state of a gas are equal to pressure, volume and temperature of the first state.

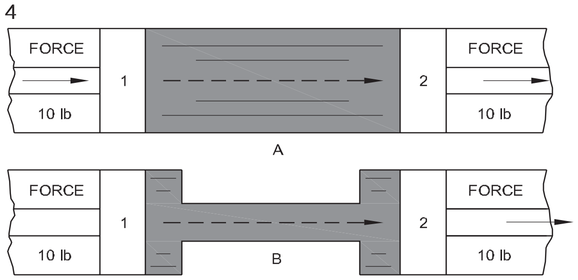
P1XV1/T1 = P2 x V2/T2

Transmission of pneumatic fluid power:

As shown in fig 4 force of 10 Psi applied to piston 1 is transmitted through the air in the cylinder to piston 2. Pascal's law states that pressure developed in a confined air is equal at every point. Therefore the internal air pressure developed by piston 1 acts on piston 2. If the area of the each piston is the same the force developed on piston 2 is the same as the force applied by piston 1, discounting the friction losses. This principle is the basis for all pneumatic power transmission systems.

As shown in fig 4 B a single cylinder has been replaced by 2 separate cylinder both are of the same diameter, and are connected by a pneumatic line. The conditions are not changed because the pneumatic system has not been changed

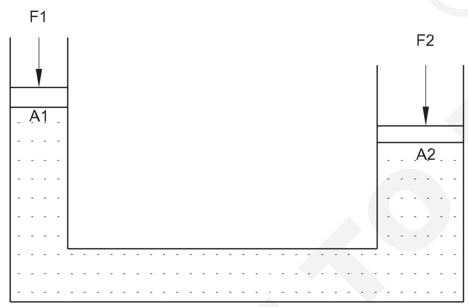
Fig 4



TRANSMISSION OF FORCE

This law makes the operation of fluid power system highly predictable. Fig 5

Fig 5



If piston area A1 of the vessel shown is designed to move, forces can be transmitted, since the pressure in the vessel is also transmitted to the larger piston area A2, where it produces a greater force.

Ratio of force transmission F1 to F2

Pe = F1/A1 and Pe = F2/A2

Since the pressure is uniform at any point, so the following equation can be derived,

F1/A1 = F2/A2

Or F1/F2 = A1/ A2

I.e, The ratio of the forces is the same as that of the piston areas. If the area A2 is 5 times larger than the area of A1 then Force F2 is also multiplied b2 is also multiplied b 5 times.

This is the principle of Hydraulic press. An available pressure can produce a greater force by increasing the piston area.

Example: Calculate the pressure in a pneumatic press when F1=60 and A1= 2 cm2

Solution: As, pe = F1/A1 =600/2 = 300 Kpa

= 3 Bar

Then calculate the force acting on piston area A2

As, F2 = (F1 X A2)/A1

= (60 x 200)/20

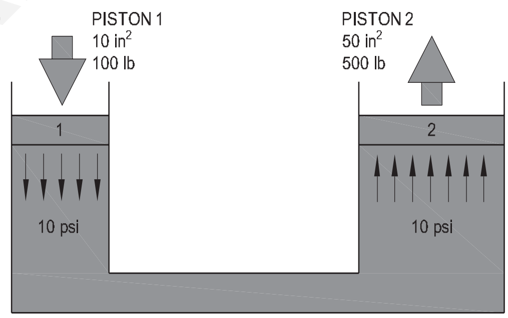
= 6000 N

Further investigation will show that the pneumatic press cannot simply produce a force form nothing. The piston strokes required are inversely proportional to the piston areas. The rule " Any force gained is lost in distance" is also applicable in pneumatic as in Mechanics.

Pneumatic Leverage

A similar arrangement of two pistons connected by an air line is shown in Fig 6. However, the pistons are placed in a vertical position and are of different sizes. If a force of 100 l b is applied to piston 1, the force is distributed over the 10 – in 2 area of the piston. A pneumatic pressure of 10 Psi (100 1b 10 in 2) builds up under piston 1 and throughout the system, including the 50 – in2 area under piston 2. The 10 psi pneumatic pressure exerts a maximum total force of 500 1b on piston 2 (10 psi x 50 in 2). This increase in force is pneumatic lever age, and occurs in all similar applications.

Fig 6



UNEQUAL PISTON AREAS

1.34 If the 500 – 1b force is applied against piston 2, the output force on piston 1 is only 100 1 b. The calculations remain the same:

500 1b 50 in2 = 10 psi

10 psi x 10 in2 = 100 1b

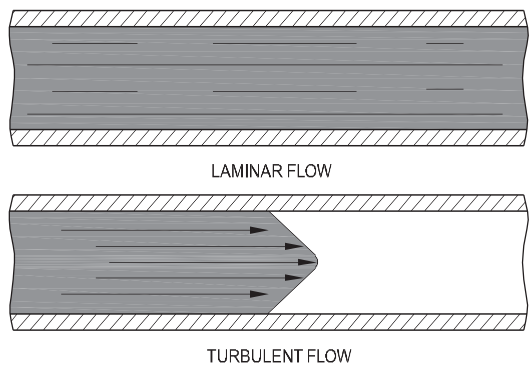
In this instance, the pneumatic leverage (or force) is decreased instead of increased.

Air Properties: Air is lighter than a liquid and will dilute into air, and that oil particles can be suspended in air

Air flow in pipes:

Laminas flow: of is ideal type of our flow in a pneumatic system because the air layers more in nearly parallel lines. (Fig 7)

Fig 7



STREAMLINE FLOW

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Turbulent flow: This flaw condition usually occurs be cause the flow passage to small for the designed flow velocity of the air when air must pass through a passage of reduced size, the restriction should be smooth and gradually

Viscosity of air: the Viscosity of air is its resistance to flow because it is a measure of the air's internal friction.

Dynamic viscosity : This is the measure of the activity of air molecules with microware in temperature.

Bernoulli's law : compered air in a pneumatic system possess two types of energy. Kinetic and potential

Kinetic energy is preserve when the air is moving and potential energy is a result of a air pressure as shown in fig 8.

Bernoulli's law states that if air velosing increases the kinetic energy of the air velocity also increases, while the total energy, (potential energy + Kinetic energy)

Fig 8

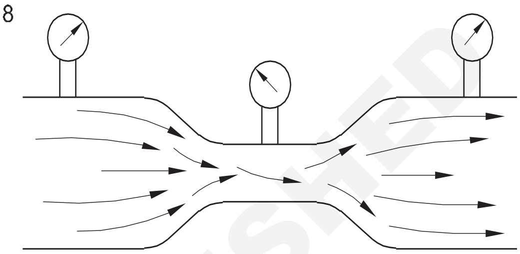

ILLUSTRATION OF BERNOULLI'S LAW

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Pnuematic power systems

Objectives: At the end of this lesson you shall be able to
- **explain component's of pneumatic power system**
- **describe applications of pneumatics**
- **describe symbols used in pneumatics.**

Components of pneumatic power systems

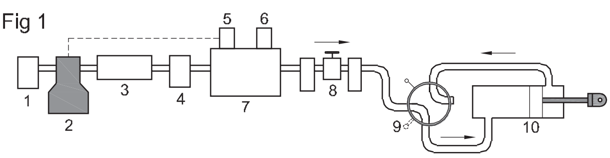
Many varieties of pneumatic systems are used in industrial plants. A pneumatic system is a piping circuit in which air under controlled pressure is used to transmit force to do work. It is often called an open system because it takes in air at atmospheric pressure, and exhausts air to the atmosphere when work is done.

A basic pneumatic system (Figs 1 to 3) is usually modified by the addition of other components which enable the system to perform a greater range of work and to function more reliably. The

Following components, shown in fig 1 -11 make up the modified basic pneumatic power system:

- An intake filter and silencer (1) to clean the air being used by the system
- A compressor (2) to compress room air and deliver it under pressure
- An aftercooler (3) for the compressed air
- A separator (4) to remove condensed water and oil form the air
- A Pressure (5) to start and stop the compressor as required.
- A relief valve (6) that functions if the pressure switch falls
- A tan (7) to store the compressed air
- A filter, pressure regulator, and lubricator assembly (8) to prepare the air for use
- A directional control valve setup, with safety features (9)

Fig 1



A MODIFIED BASIC PNEUMATIC SYSTEM

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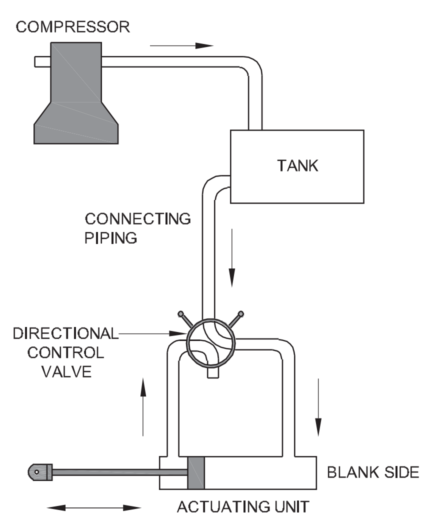
Fig 2



A BASIC PNEUMATIC SYSTEM

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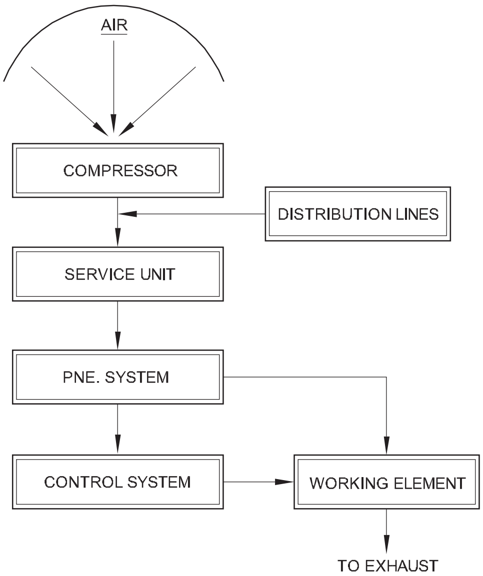
Fig 3



BASIC PNEUMATIC SYSTEM

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- An actuating unit (1) at each work station where necessary. Theses can be cylinders, motors, or air operated pumps.
- Piping to transmit the compressed air through the system. The piping also includes drip legs and dirt traps with valves for removing contaminats.

Application Of Pneumatics

Now a days pneumatics has fount applications in wide spheres, following are few examples:

- Pneumatic nut runner, Drill, Rivets etc.
- Vibratory Hammers
- Operation of Heavy or Hot Doors
- Operation of System Valves, for ir, water etc.
- Spray painting
- Clamping in Jigs/Fixtures
- Forming operations of Bending, Drawing, and flattening
- Bottling and filling Machines
- Test rigs
- Machine Tools
- Component and material conveyor transfer
- Pneumatic robots
- Spot welding Machines
- Wood working Machinery, Drives and feeds
- Auto gauging
- Lifting and Moving in slab moulding M/C
- Ramming and tamping in concrete
- Crop spraying and operation of other Tractor Equipment
- Dental drills

Pneumatic symbols

Objective: At the end of this lesson you shall be able to
- **identify components using ISO 1219 symbol**
- **interprete symbol of direction control valve symbol.**

Symbol: It is a representation of pneumatic component. Commonly pneumatic symbols are drawn as pe IS 1219 standards.

- Symbol does not indicate size of the component.
- It does not indicate orientation or arrangement of inner components.

Symbols uses sommon geometrical shape which is helpful to catagorise the type of component. The shpe used in general are:

Square: It represents a valve.

Circle: It represents compressor, pneumatic motor and gauge.

Line: It represents piping

Diamond: It represents filter, dryer, lubricator.

Cylinder: It represents receiver.

Rectangle: It represents cylinders.

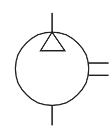
Dotted box: It represents an assembly of various components.

Traingle: It represents pneumatic energy i.e service air.

Symbol with circle

Compressor (Fig 1)

Fig 1



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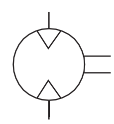
Pneumatic motor (Fig 2)

Fig 2



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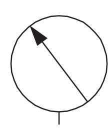
Pressure gauge (Fig 3)

Fig 3



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Symbol with diamond shape

Filter (Fig 4)

Lubricator (Fig 5)

Fig 4

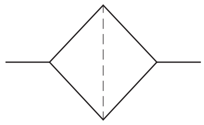

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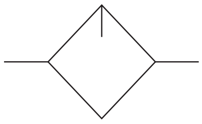
Fig 5



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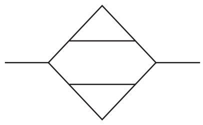
Dryer (Fig 6)

Fig 6



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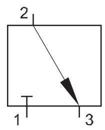
Symbol with square

As explained earlier square means valve. Look at the figure 7 given below.

Fig 7



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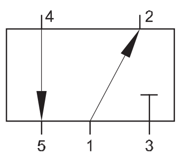
In this figure three extended lines 1,2 & 3 are shown which shows that the port, means where you connect pipes. Arrow inside the square shows the path of air flow inside the valve. The figure shows port 1 is closed but port 2 &3 are connected internally.

Fig 8



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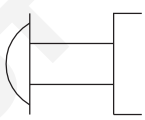
In figure 8 there are 5 ports namely 1,2,3,4, & 5 where you can connect pipes. The figure shows that ports 1 & 2 are connected such a way that flow direction is from 1 to 2, similarly ports 4 & 5 are connected in such a way that flow direction is 4 to 5, but port 3 is closed

Push button: It is a button type device when pressed by operator valve actuates Fig 9

Fig 9



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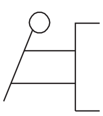
Lever: It is a handle type device when pressed by operator valve actuates Fig 10

Fig 10



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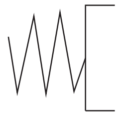
Mechanical Mecahnism: Valve is operated by some mechanical thing.

Spring: Common compression spring which actuates valve on de-compression Fig 11

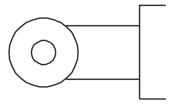
Fig 11



IM20N2173503B

Roller: It is like a lever with small wheel type device when pressed by some object valve actuates Fig 12

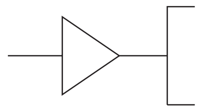
Fig 12



IM20N2173503C

Pilot: It is air operated mechanism Fig 13

Fig 13



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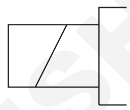
Solenoid: It is electrical operated mechanism Fig 14

Fig 14



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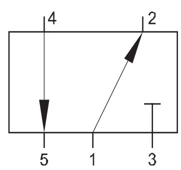
Identifying the direction control valve

To identify direction control valve follow the procedure given below

- Identify number of ports
- Identify number of positions.
- Identify actuation mechanism.
- Observe air flow path in the symbol, in each position.

Observe the symbol given in Fig 15

Fig 15



IM20N2173503F

In the Fig 16

- No of ports: Two (1 & 2)
- No. of Positions: Two: (2 Squares)
- Actuation methods: Push button (at left side), spring (at right side)

Write this information in the format given:

.... **Port** .... **Position**........ **operated** .... **return**

So you get:

2 Port 2 position push button operated spring return

Whenever you observe spring in the symbol it means “Normal” Position exists. Normal position refers to predominant unactuated condition.

In the symbol shown in Fig 22. Right side position is achieved due to spring when there is no force applied on push button, means right side position is the normal position.

It is important to note that whether input port (1 or P) is open or closed in normal position.

If input port is closed, we say normally closed valve.

If input is connected to output port (2,4or A,B) then we say normally open valve.

In the symbol shown above, in normal position input port is closed therefore valve is normally closed valve.

We can rewrite complete designation of the valve as follows:

2 Port 2 postion push button operated spring return normally closed Direction control valve.

Lets try to identify valves given in the next pages. Fig 16 to Fig 26

Fig 16

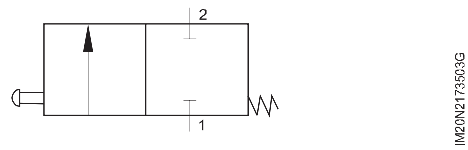


Fig 17

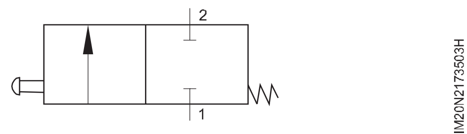


Fig 18

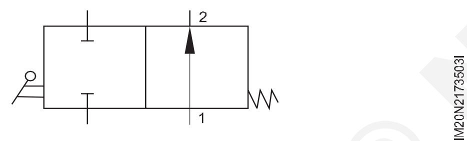


Fig 19

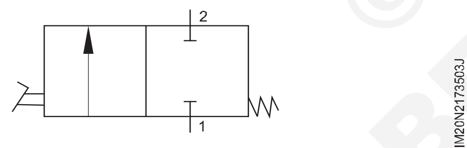


Fig 20

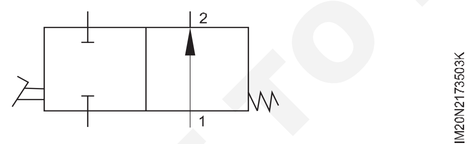


Fig 21

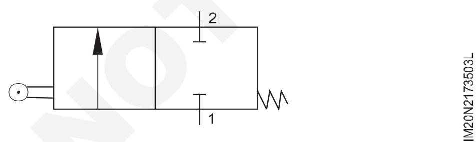


Fig 22

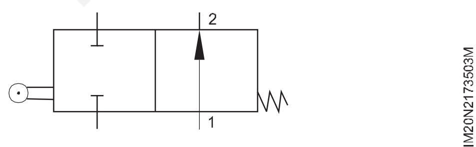


Fig 23

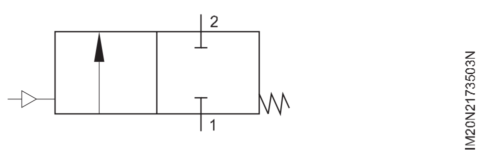


Fig 24

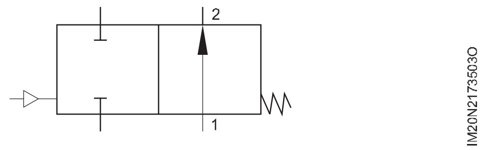


Fig 25

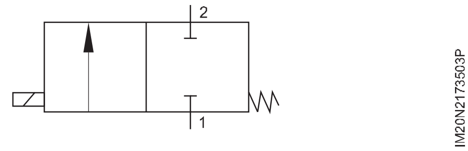
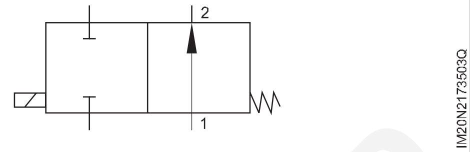


Fig 26



Designation

2 port 2 position push button operated spring return normally closed Direction control valve

2 port 2 position lever operated spring return normally closed Direction control valve.

2 port 2 position lever operated spring return normally open Direction control valve.

2 port 2 position foot pedal operated spring return normally closed Direction control valve.

2 port 2 position foot pedal operated spring return normally open Direction control valve.

2 port 2 position roller operated spring return normally closed Direction control valve.

2 port 2 position roller operated spring return normally open Direction control valve.

2 port 2 position pilot operated spring return normally closed Direction control valve.

2 port 2 position pilot operated spring return normally open Direction control valve.

2 port 2 position solenoid operated spring return normally closed Direction control valve.

2 port 2 position solenoid operated spring return normally open Direction control valve.

The port numbering has certain meaning as follows:

Input Port: Port where incoming compressed air is connected it is always "1" and also represented by port "P"

Output Port: From where air comes out of the valve is always even number "2" and "4" output ports are also represented by port "A" & "B"

Exhaust port: From where air is vented to the atmosphere is always odd number "3" and "5" output ports are also represented by port "R" & "S"

Types of valves

There are three types of valves used in pneumatics system.

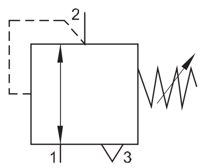
Pressure valve: Used to control pressure thereby force in the pneumatics. It is always represented by single square.

Direction control valve: Used to control the direction of movement of load connected to piston rod; like forward or reverse, clockwise or counter clockwise, It is always represented by combination of minimum two squares.

Flow control valve: Used to control speed of load, in this case square is not used.

Pressure regulator: Symbole of pressure regulator is shown in Fig 27

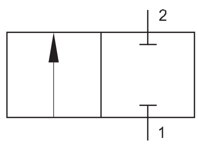
Fig 27



IM20N2173503R

Direction control valves: Look at the symbol shown in fig 28

Fig 28



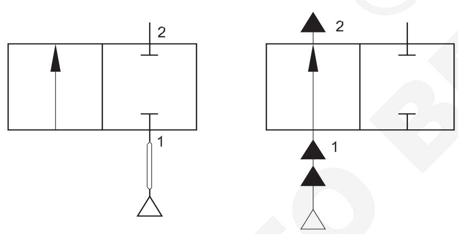
IM20N2173503S

In this symbol there are two squares drawn side by side, A square indicates position, thus right square indicate one position and left square other position.

Position refers to status. In the right position port 1 & 2 are closed, but in the left position both ports are connected.

Let us compare the two positions as shown in fig 29

Fig 29

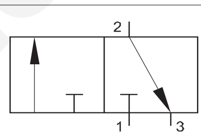


IM20N2173503T

In this valve there are 2 ports and 2 positions, hence called two port two position valve or simply 2/2 way valve.

3/2 way valve: By name it is clear this valve is having 3 ports and 2 position. Symbol is shown fig 30.

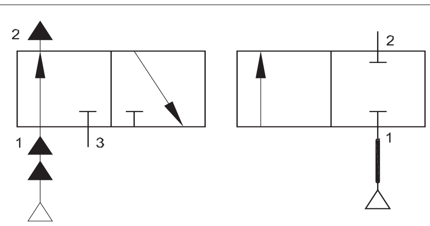
Fig 30



IM20N2173503U

Compare the two positions as shown in Fig 31.

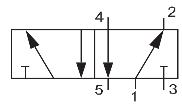
Fig 31



IM20N2173503V

5/2 way valve: By name it is clear this valve is having 5 ports and 2 position, symbol is shown in fig 32

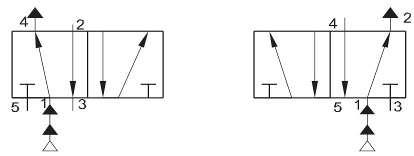
Fig 32



IM20N2173503W

Compare the two positions as shown in Fig 33

Fig 33



IM20N2173503X

Actuation mechanisms

It is a device which indicates how to operate the valve. There are several mechanisms available but our scope is limited to following mechanisms.

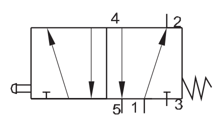
- Manual mechanism
- Mechanical mechanism
- Pilot mechanism
- Solenoid mechanism

Manual Mechanism

This mechanism is operated by a person, like

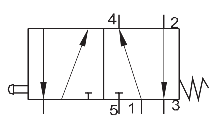
- Push button
- Lever
- Foot pedal

Fig 34



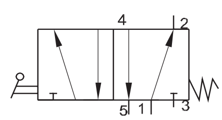
IM20N2173503Y

Fig 35



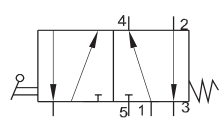
IM20N2173503Z

Fig 36



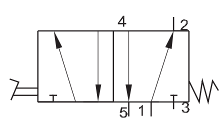
IM20N2173503Z1

Fig 37



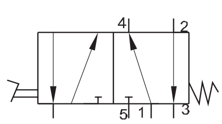
IM20N2173503Z2

Fig 38



IM20N2173503Z3

Fig 39



IM20N2173503Z4

Fig 40

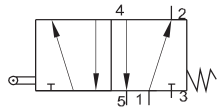


Fig 41

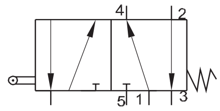


Fig 42

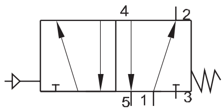
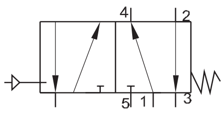


Fig 43



5 port 2 position push button operated spring return Direction control Valve, normally 1 is connected to 2.

5 port 2 position push button operated spring return Direction Control valve, normally 1 is connected to 4.

5 port 2 position lever operated spring return Direction control Valve, normally 1 is connected to 2.

5 port 2 position lever operated spring return Direction Control valve, normally 1 is connected to 4.

5 port 2 position foot pedal operated spring return Direction control Valve, normally 1 is connected to 2.

5 port 2 position foot pedal operated spring return Direction Control valve, normally 1 is connected to 4

5 port 2 position roller operated spring return Direction control Valve, normally 1 is connected to 2.

5 port 2 position roller operated spring return Direction Control valve, normally 1 is connected to 4

5 port 2 position Pilot operated spring return Direction control Valve, normally 1 is connected to 2.

5 port 2 position Pilot operated spring return Direction Control valve, normally 1 is connected to 4

Fig 44

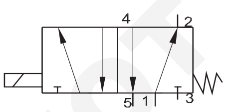


Fig 45

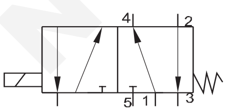


Fig 46

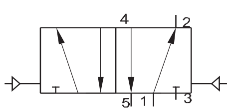
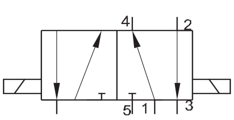


Fig 47



5 port 2 position solenoid operated spring return Direction Control valve, normally 1 is connected to 4

5 port 2 position double pilot operated Direction control valve

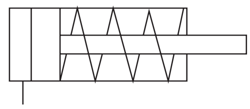
5 port 2 position double solenoid operated Direction control valve

Symbol with rectangle

In general rectangle is used to represent linear actuator like single acting cylinder and double acting cylinder.

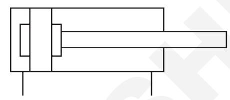
Single acting cylinder Fig 48

Fig 48



Double acting cylinder Fig 49

Fig 49



Symbol with cylinder:

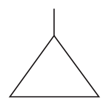
In general cylindrical shape is used to represent air receiver or air storing device Fig 50

Fig 50

Symbol with triangle:

In general triangular shape is used to represent air source Fig 51

Fig 51

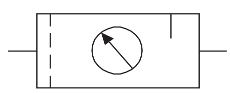


Symbol with dotted box:

Symbol shown in dotted box represents assembly of components like FRL, Time delay value.

FRL: It is an assembly of filter, regulator and lubricator. Fig 52

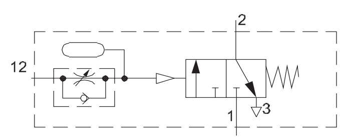
Fig 52



Time delay valve

It is an assembly of flow control valve, 3/2 way valve and an air receiver Fig 53

Fig 53



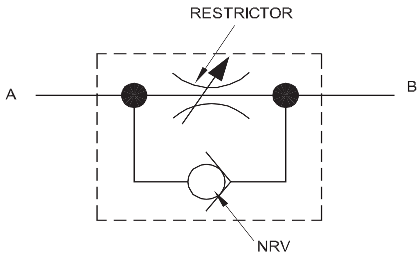
Other symbols

Non return valve Fig 54

Fig 54

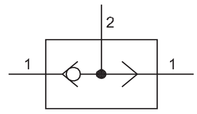
Flow control valve Fig 55

Fig 55



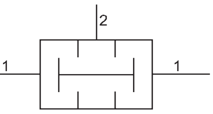
Shuttle valve Fig 56

Fig 56



AND valve (Twin pressure valve) Fig 57

Fig 57



Primary air treatment

Objectives: At this end of this lesson you shall be to
- **describe preliminary filtering**
- **describe effects of moisture in airlines**
- **explain water removal methods**

Primary air treatment

1 Air treatment

Contamination

In the form of dirt or rust particles, excess lubricant, and humidity often lead to disturbances in pneumatic equipment and damage to pneumatic components. Treating the air to remove contamination is accessories supplied with a compressor. The amount of air treatment required depends on the application and the requirement of the plant.

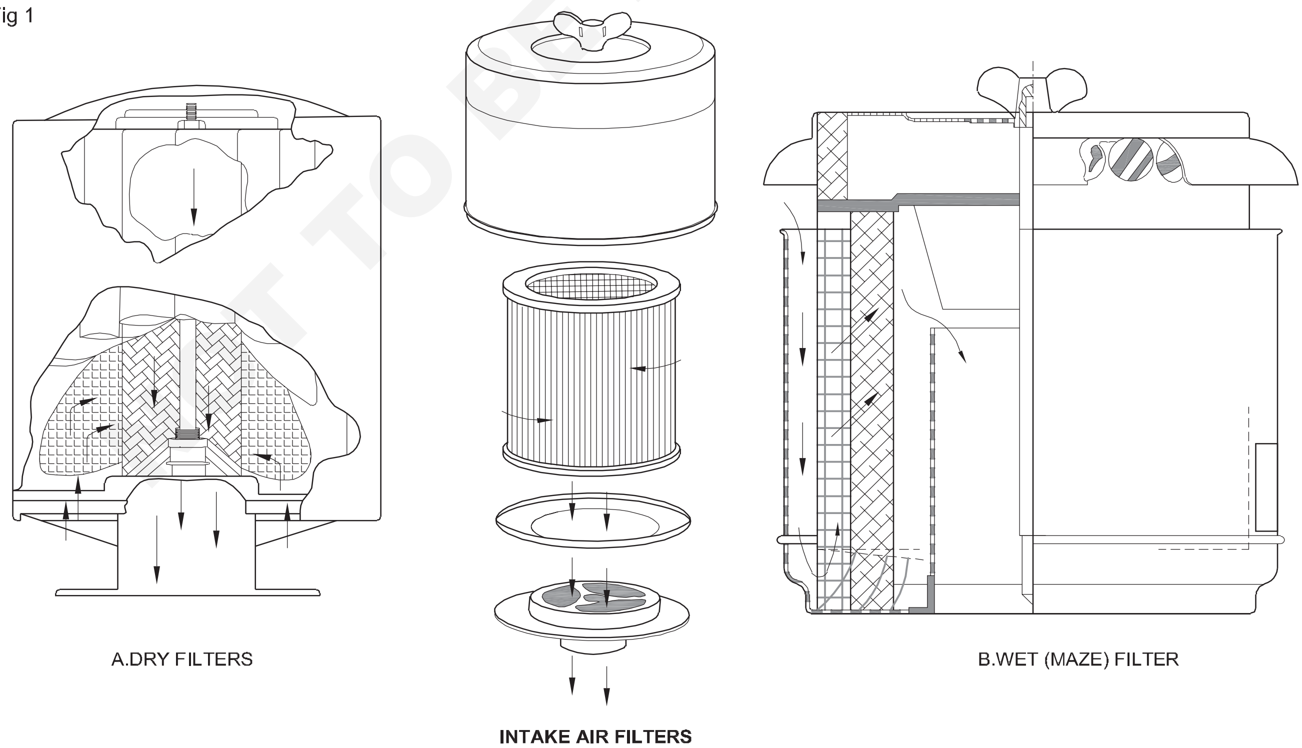
Preliminary filtering

Before the surrounding air enters the compressor, it must pass through a filter to remove must of the dirt and other solid contaminates. These filters can be of the dry or wet, type depending on the compressor manufacturer and application. Dry filters are made in different shapes as shown in fig 1 Wet filters are slightly different in construction and operation as shown in fir 15)

Relative humidity

The relative humidity is the ratio of absolute humidity to the saturulion humidity

Fig 1



R.H = Absolute humidity/Saturation humidity

Effects of moisture

Rust and corrosion can occur whenever moisture is present. This happens because of the chemical reaction between iron and moisture. Moisture in the air can cause rust and corrosion in tanks airlines, and equipment even if it does not condense as water.

Water removal

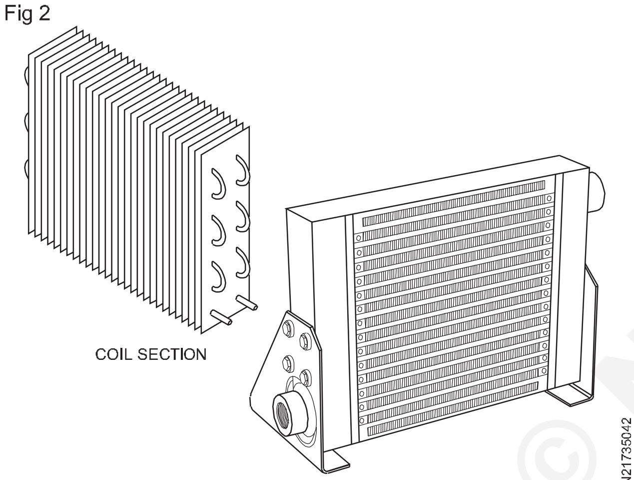
There are several ways to remove water and air from compressed air.

1 Condense the water vapor

2 Circulating the air through a dryer.

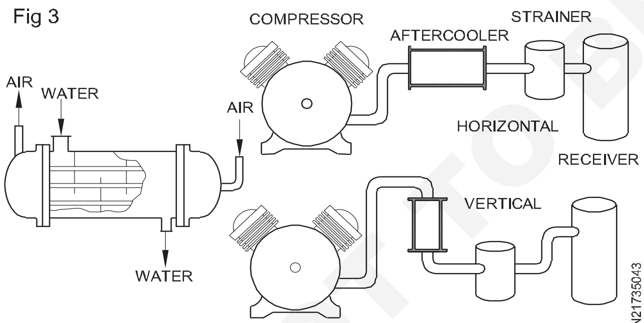
Most plants cool the air with an aircooled after cooler and remove the condensed vapour the aflir cooler is too types figs 2&3

Fig 2



AIR-COOLED AFTERCOOLERS

Fig 3



WATER-COOLED AFTERCOOLERS

1 Air cooled aflin coolens

2 Water cooled after coolers

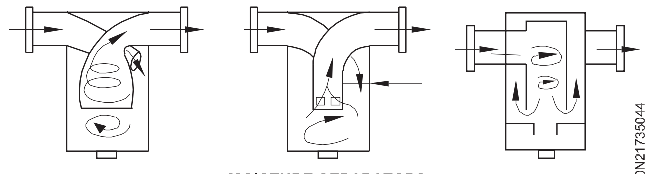
Dew point

The temperature at which water vapour condenses as it is cooled (or) The temperature at which the droplets starts to form droplets is called the dew point of the air

Moisture separators

Most separators separators separate the water particles from the air by causing the air to swift or by making sharp changes the direction of flow. The action of different separators is shown in fig 4

Fig 4



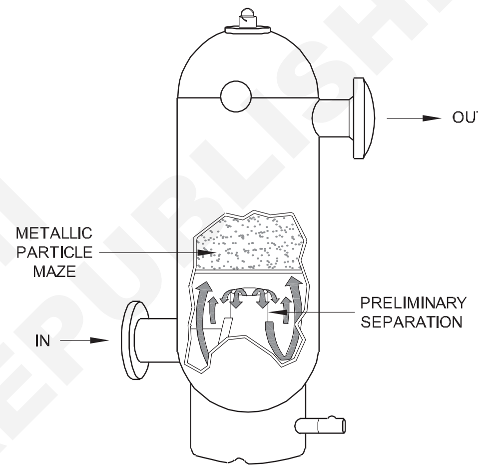
MOISTURE SEPARATORS

Air with water enters near the top and swirls around the outside of the housing. The swirling action causes the heavier moisture and old particles to be deposited on the outside wall. The particles then flow down into the moisture trap at the bottom of the separator.

Oil scrubber

Liquid separator will not remove enough moisture. Oil scrubber should be installed between the after cooler and the air receiver. As shown in Fig 5 removes oil and moisture from the system.

Fig 5



AN OIL SCRUBBER

Air dryers

Pneumatic or sensitive devices that require a dry supply of air. Usually air dryer installed in the system.

Types of air dryers

Deliquescent (Chemical)

Absorption (regenerative)

Absorption (regenerative)

Deliquescent air dryers fig 6

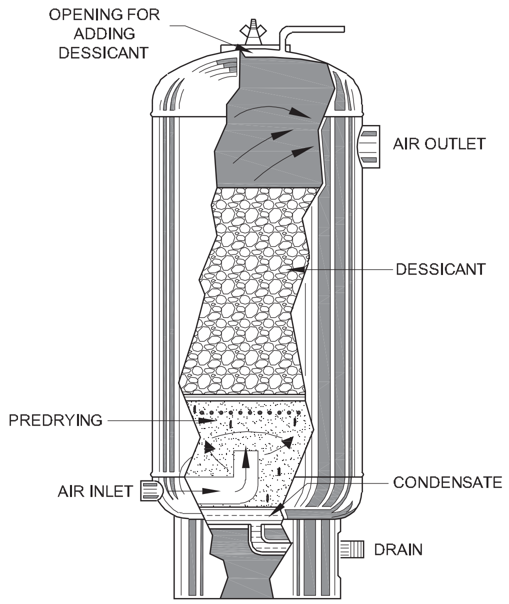
It is similar to oil scrubber. As the chemical absorbs moisture, it is slowly dissolves and becomes a liquid itself.

When the desiccant (chemical) dissolves it is said to deliquesce dirty air enters the inlet and passes through the deliquescent mist and this mist collects. Finest vapours and attracts moistures, chemically removing it from the air. The air that is discharged is dry and clean.

Absorption dryer Fig 7

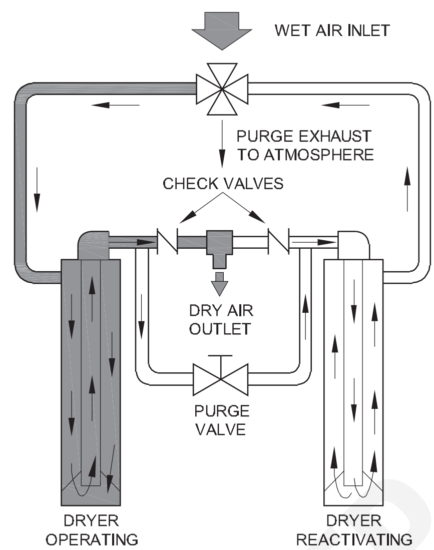
The air enters four way valve is directed to the left chamber. In this chamber the air being dried, the desiccant in the right chamber is being regenerated.

Fig 6



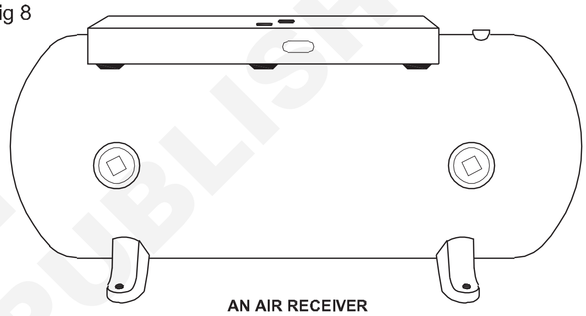
DELIQUESCENT DRYER

Fig 7



ADSORPTION DRYERS

Fig 8



AN AIR RECEIVER

Air receiver Fig 8

It is used to store compressed air. When an air receiver is selected for an application it must be the correct size for the volume of air in the system. This allows the receive to balance off available compressor capacity against much larger peak air flow demands that occur.

Air compressor parts and function

Objectives : At the end of this lesson you shall be able to
- **state construction of compressor**
- **explain parts of compressor**
- **describe working principle of compressor.**

Air compressor parts and functions

Air compressors are a type of machine tool and they work great with other power tools too. It basically provides other tools the ability to function and the power to do household as well as industrial improvement projects and installations. In order for tools to function at their best, air compressor must be working in its optium power and efficiency and that means that the parts of an air compressor must be working 100% of the time to make sure the work is done.

Parts of an air compressor (Fig 1)

The following are the main parts of an air compressor.

Motor

An air compressor needs an electric motor to power up the machine. The motor basically drives two belts a pulley which allows the transfer of power from the motor to the pump pistons and this is done through a flywheel and a crankshaft. One important thing need to install will be a magnetic starter to prevent the motor form overload.

Tank

This is the compressor part that stores the air being compressed. It is biggest part of the air compressor and it can range from 1-10 gallons or even more for bigger construction needs. The tank generally made of steel.

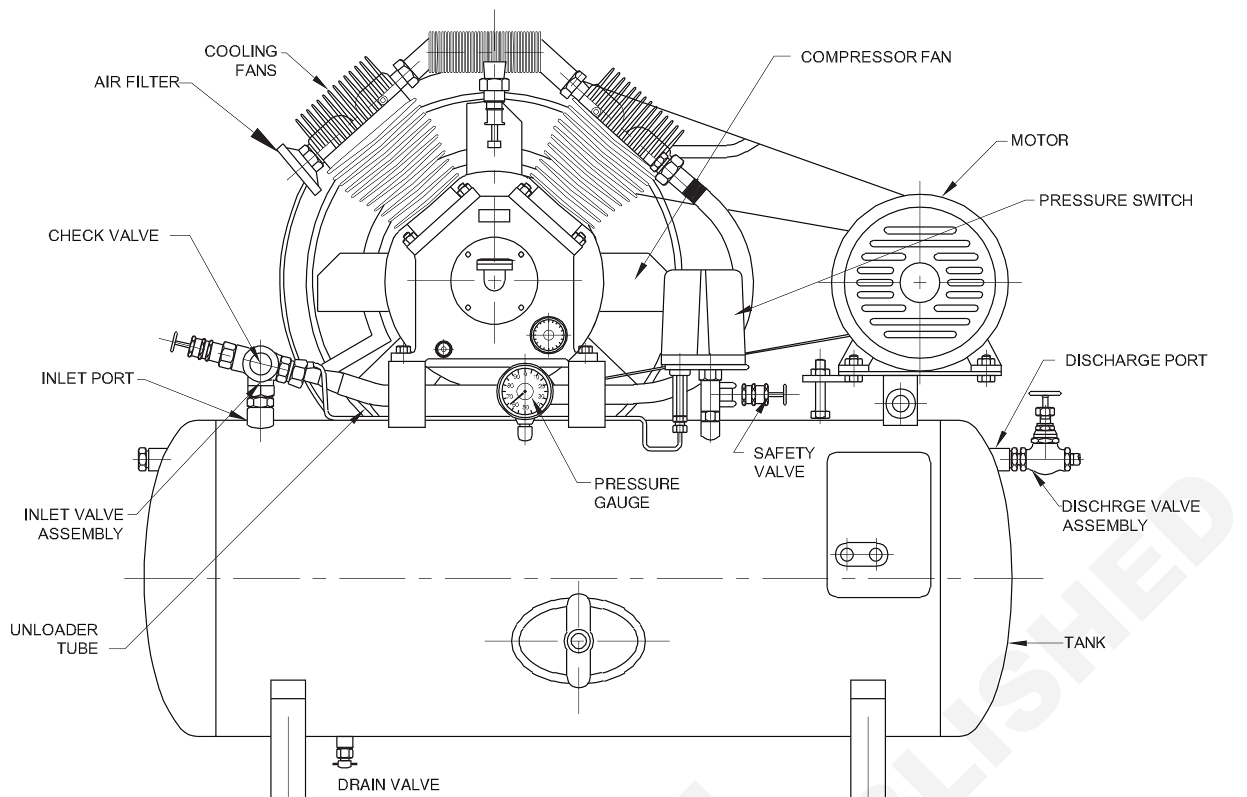
Pressure switch

The pressure switch automatically shuts down the motor when the receiver reaches the factory-set limit. Once the pressure level drops to a pre-set level then the pressure switch restarts the motor therefore resuming the pumping of air by the compressor. We can also call this as an emergency switch that regulates how much pressure in the tank can take.

Drain valve

The main purpose of the drain valve is exactly what its name impiles. It drains the oil,dirt, moisture, and other debris that might be trapped inside the tank. Simple maintenance of air compressors entails draining a tank from impurities and debris from use. Moisture and oil are the most common reasons for rust to develop inside the tank when not drained.

Fig 1



COMPRESSOR

Pressure gauge

This gauge measures compressed air pressure in the tank of the air compressor. It lets the user know that there is a problem if the measurement is higher than the regulated normal limit and serves as a warning to inspect the air compressor or stop the compression before the gauge reaches even higher pressure. On the contrary if the reading is very low from the normal allowed measurement, it also indicates a problem with the compressor such as a leak in the tank. This should also be checked right away to avoid any more complications and accidents.

Inlet port

This port is used to guide the inlet air towards the compressor inlet valve.

Inlet valve assembly

Inlet valve assembly compromises valve plate, and valve spring. Inlet valve controls the flow of air towards the cylinder of compressor. It is opening downwards to allow the air inside when the piston moves downwards. Valve plate is used to hold the inlet valve in proper position.

Cooling fins

Cooling fins are the extended part provided from the cylinder body to assure heat transfer from cylinder to surrounding.Generally these are made of aluminum.

Discharge Port

It is the opening provided at the top of compressor cylinder to guide discharge air towards the discharge line.

Discharge vavle assembly

It comprises discharge valve plate, valve plate and valve spring. Valve plate helps to hold the discharge valve in proper position. Valve is aimed for discharge the high pressure air when the piston reaches its top.

Air filter

Air filter is very important part in an air compressor. It helps to prevent the dirt and dust to enter inside the compressor cylinder. Filter is provided in the suction end of the compressor.

Safety valve

A safety valve is provided on the air storage tank or air outlet line ro prevent the danger occurred when the air pressure reaches beyond the capability of storage tank capacity.

Regulator

Generally an air regulator is provided in the discharge tube to regulate the high pressure air flow.

Check valve/Non return valve (NRV) and unloader tube

An one way check valve is provided in the bypass line in between air receiver tank and compressor head. It will open and admit the high pressure air towards the receiver tank while unloading is going on during the starting time. An unloader tube is connected at the inlet port of the check valve and the valve only opens in one direction (ie from compressor top to receiver air flow). During this time the high pressure air is unloaded towards tank through unloader tube.

Compressor fan

A compressor fan is connected at one end of the crank shaft to provide sufficient cooling air to compressor. It will prevent overheating of compressor.

Air compressor working principle

Working principle (Fig 1)

Air compressors collect and store air in a pressurized tank, and use pistons and valves to achieve the appropriate pressure levels within and air storages tank that is attached to the motorized unit. There are a few different types of piston compressors that can deliver even air pressures to the user.

Automotive compressors are combustion engine compressors that use the up-and-down storke of the piston to allow air in and pressurize the air with in the storage tank. Other piston compressors utilize a diaphragm, oil-free piston. These pull air in, and pressurize it by not allowing air to escape during the collection period.

Now the air compressor is capable of building extreme pressure in storage tanks capable of storing enormous amounts of pressurized gases for industrial use.

Air dryer

A compressed air dryer is used for removing water vapor from compressed air.

Compressed air dryers commonly found in a wide range of industrial commercial facilities.

Usage

Drying air for use in commercial or industrial processes that demand dry air:

Telecom industry (pressurizes its underground cables to repel moisture and avoid shorts).

Painting.

Pneumatic tools.

Textile manufacturing.

Pneumatic control systems.

Feed air for zeolite type oxygen and nitrogen generators.

Dental office air.

Truck and train air brake systems.

The process of air compression concentrates atmospheric contaminats, including water vapor. This raises the dew point of the compressed air relative to free atmospheric air and leads to condensation within pipes as the compressed air cools downstream of the compressor.

Excessive water in compressed air, in either the liquid or vapour phase, can cause a variety of operational problems for users of compressed air. These include freezing of outdoor air lines, corrosion in piping and equipment , malfunctioning of pneumatic process control instrument, fouling of processes and products and more

There are various types of compressed air dryers. Their performance characteristics are typically defined by the dew point.

- Refrigeraed dryers
- Deliquescent dryers
- Desiccant dryer
- Memberane dryers

Refrigerated dryer

Refrigeration dryers employ two heat exchangers, one for air-to-air one for air-to-refrigeration. These dryers are used in refrigeration compressors.

Deliquescent dryer

A deliquescent dryer typically consists of a pressure vessel filled with a hygroscopic medium that absorbs water vapor. The medium gradually dissolves-or deliquesces-to form a solution at the base of the pressure vessel. The liquid must be regulary drained from the vessel and new medium must be added.

Deliquescent dryers are used for removing water vapour from compressed air, natural gas, and waste gases.

Desiccant dryer

The term "desiccant dryer" refers to a abroad class of dryers. Other terms commonly used are regenerative dryer and twin tower dryer,and to a lesser extent absorption dryer.

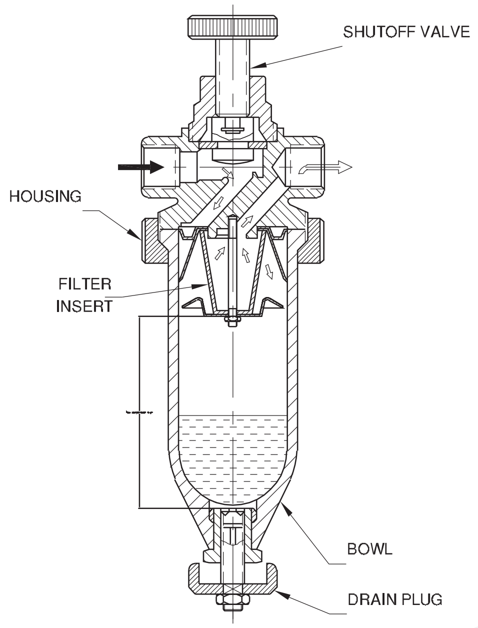
The compressed air is passed through a pressure vessel with two "towers" filed with a media such as activated alumina, silica gel, molecular sieve or other desiccant material. This desiccant material attracts the water from the compressed air via adsorption.

FRL unit (Filter, regulator, lubricator)

Objectives : At the end of this lesson you shall be able to
- **defind FRL unit**
- **state the types of FRL**
- **state the specifications of FRL.**

Fitter,regulator,lubricator (FRL) assemblies are pre-packaged or modular assemblies of air filters,pressure regulators,and gauges. Air leaving a compressor is hot,dirty,and wet and can cause damage to equipment and tools if it is not filtered.

Fig 1



The filter cleans compressed air by trapping solid particles and separating liquids,such as oil and water,that are trapped in the compressed air. Filters are installed in the air line upstream of regulators,lubricators,and all pneumatically-powered tools and equipment. They remove contaminants from pneumatic systems,preventing damage to equipment and reducing production losses due to contaminant-related downtime.

Pressure regulators control fluid pressure in compressed air systems. Regulators are also known as pressure reducing valves(PRVS). Pressure regulators maintain a constant output pressure regardless of input perssure variations and demands made on the system by downstream components.

Lubricators add controlled quantities of oil into the compressed air system to reduce the friction between moving components within air tools and other equipment that are powered by the system. Adding lubrication oil to the system also clears compressor oils that travel through the system in vapor form. To prevent build-up of oil within system components,mineral oils are added to the system to flush away the deposits.

Downstream equipment flow and pressure requirements determine the correct regulator and lubricator for the application. Manufactures offer flow characteristics charts on their products to help chose the correct combination of regulators and lubricators.

Types

There are several choices for regulator type.

- General-purpose regulators are designed for typical industrial use;they generally operate only above atmospheric pressure.
- High- pressure regulators are rated for inlet pressures higher than general purpose,typically over 1,000 psi.
- Low- pressure regulators have special design characteristics for precise control of pressures typically below 15-20 psi.
- Differential or bias regulators maintain a pressure differential between two locations in the system.
- Pressure- reducing valves provide a sub-circuit with a supply of fluid at a pressure that is less than the pressure in the main circuit.

Specifications

Performance specifications:

- **Regulating (adjustment) range** - Dictates the limits of adjustment control
- **Maximum flow (gas or air)** - Unnecessary to specify if primary application is liquid
- **Maximum pressure rating**- Refers to the pressure rating for the valve or inlet pressure for the regulator
- **Filter minimum particle size rating** - Applies to filter,regulator,and lubricator (FRL) assemblies. It is the smallest size particle that will be entrapped by the filter. This rating is an indication of the largest opening in the filter element.

Other important specifications include:

- Regulator type
- Medium
- Adjustement control
- Connectors or pipe size
- Body material
- Environmental parameters

Secondary Air treatment

Objectives : At the end of this lesson you shall be able to
- **Explain methods of treatments**
- **Explain contaminate separation & filtration**
- **Describe the types of media for surface filters & depth filters.**
- **Describe absorption filters**
- **Know the importance of lubricating air**

Secondary air treatment

Methods of treatment

Dirt & dust that do enter the system, as well as any moisture. Suit can be removed in a number of ways. The most common methods are separation and filteration.

Contaminant separation

There are two types separation

1 Gravity separation

2 Centrifugal separation

Gravity separation: Fig 1 The larger social and liquid particles suspended in the air settle and gravity separation takes nine and removes larger particles from the air.

Centrifugal separator Fig 1 (b)

When moving air is swirted in a circular path many solid & liquid particles are thrown outward. It is also called inertial separator

Contaminant filtration

Particles larger than 10 micros are classified as dust particles, and between 0.1 to 0.8 microns are called aersols. Aerosols removed by filters. Filter will stop 98% of the particles.

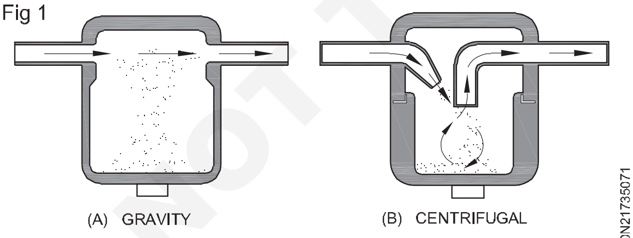
Filter classification & rating

There are two types of filters

1 Surface filter

2 Depth filter

Fig 1



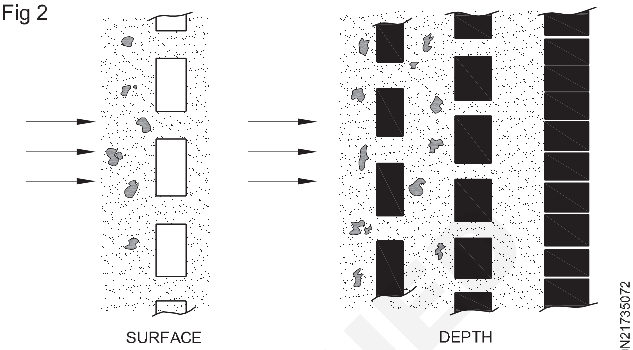
TWO METHODS OF CONTAMINANT SEPARATION

Surface filter collect particles an a single surface and depth filters collect particles on several layers. Depth filters are used to remove small particles from compressed air and surface filters are used for larger particles. (Fig 2)

Rating

Filter ratings are usually bared on the performance. A filter is given a nominal rating and absolute rating.

Fig 2



TYPES OF FILTER MEDIA

Nominal rating means no stop great percentage of particles of a given size (98% 95% so on) Absolute rating means stops 100% of a given particle size.

Types of media

The following materials are used mainly for surface filters.

- Metal shainers (screen, woven metal cloth, disuse or ribbons)
- Sintered metal powders.
- Thin felted fibers
- Thing membranes
- Woven cloth (Single layer)

Types of media for surface filter of depth filters

The following materials are commonly used for depth filters

- Felted or method of nonmetallic fibers
- Closely packed non metallic fibers.
- Closely packed fine metallic wire or ribbons.
- Oil bath filters
- Activated carbon and other dericants
- Papers

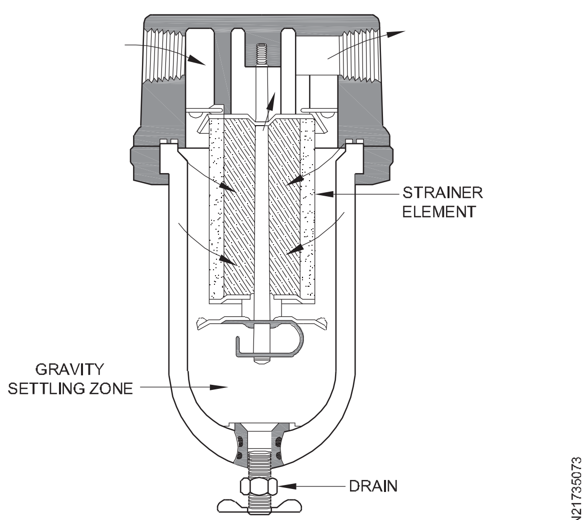
Surface filters Fig 3

Surface filters or strainers, of wire mesh used in pneumatic system. Strainess used in the pressure line may be made of metal ribbons disk or plastic impregrated paper. A strainer is usually planed in the line just ahead of the filter.

Depth filters

There are used in pneumatic systems. The type of filter medium used depends on the application

Fig 3



A STRAINER IN CROSS SECTION

It prevents large particles from entering the air compressor

In separators it is used to collect moisture, oil & solid particles from the air after it has been compressed

Depth air filters may be of the dry method or oil bath types.

Absorption filters: It is used in pneumatic system. It draws the moisture vapour into the absorbing medium & head of juor collecting it on the surface. Many absorption filters and the chemical medium that changes colour as it absorption moisture. Filteration in most absorption and absorption filters in the 0.5 and above It (Micron) range.

Lubricating the air

Most pneumatic power tools, control & cylinders require lubricated air to reduce wear and corrosion. Lubricating devices are installed in air line, pneumatic equipment that requires lubricated air must have clean, water tree and contaminated oil. Lubricators are classified into two baric types. They are leave & fine. It should be mounted after the pressure regularly valve. When installing the lubricator it is important to select proper type & size.

Piping hoses and fittings

Objectives: At the end of this lesson you shall be able to
- **explain requirements of piping, dimensions of piping and piping connections.**
- **define safety factors**
- **explain the methods of connecting pipes.**
- **know about metallic tubing, tube bending procedures**
- **explain non metallic tube hoses and fittings.**
- **explain tube installation the method of**

Piping requirements

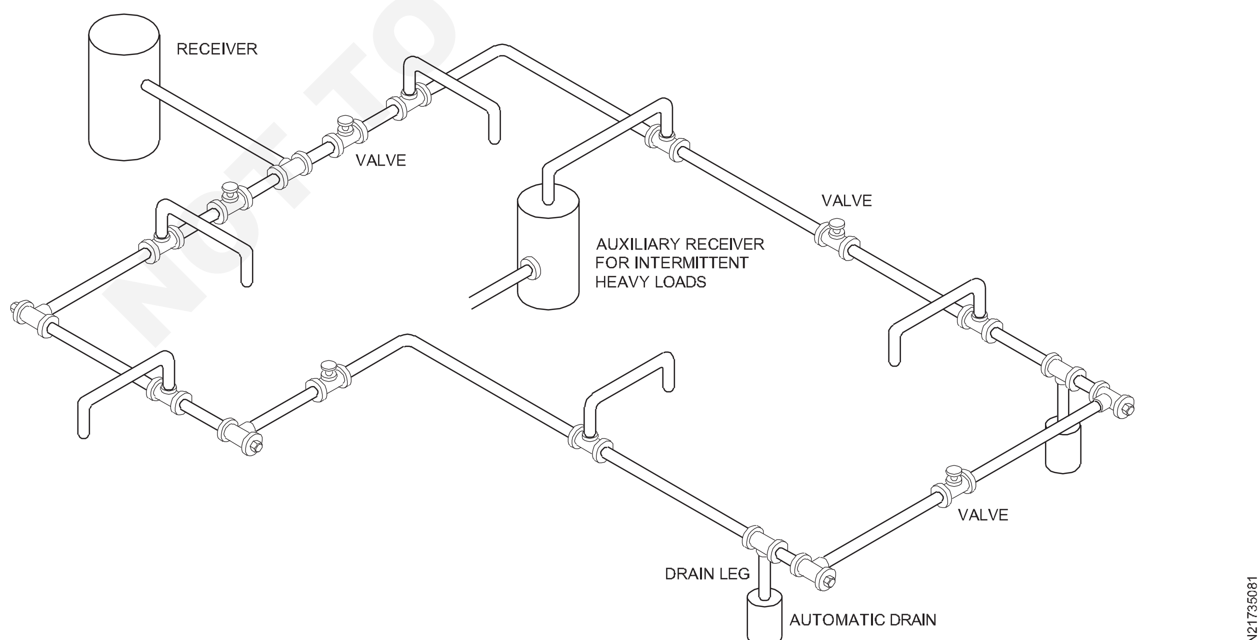
A compressed air system is installed in a plant provisions must be made for connecting the components like compressors, receivers, filters, separators and lubricators wherever they are needed. Fig 1 shows a typical pneumatic piping system.

It consist of compilations of pipe, tubing, hose and fittings there air lines should be free form leaks, high pressure drops and with stand pulation, vibration,

Air flow

For efficient air flow in a pipe it must flows smoothly. The number of fittings in the air line should be kept minimum and they should not restrict the flat.

Fig 1



COMPRESSED AIR PIPING SYSTEM

Piping dimensions

When selecting the pipe size that will provide minimum pressure drop, more than just the pipe diameter must be considered. Different pipe sizes have different pressure losses because of the friction between the grimmer pipe walls in the compressed air. The amount of pressure loss in a pipe is affected not only by the airflow volume and the pipe diameter, but also by the air pressure.

Safety factors:

It is the ratio between bursting pressure and the systems operating pressure.

Bursting pressure is the minimum pressure at which a component begins to split apart.

Piping connections:

There are three methods of connecting pipes in a pneumatic system

1 Threading

2 Melding

3 Hanging

Threading: Installation is easy high leakage & pressure drop

Welding

Less leakage and reduced pressure drop installation is not easy.

Hanging : Mostly when for medium and large sized piping and equipment.

Pipe applications:

Piping is used for compressor discharge, distribution and workstation lines. When connecting pipes follow these procedures

1 Carefully deburr threaded pipe ends on the inside and outside to remove sharp edges and loose bits of metal.

2 Clean out all file chips and saw chips before assembling piping and fittings

3 Use pipe compounds sparingly and never on the thread ends.

4 Support ling runs with straps or hangers.

5 Provide unions or hanges 10 permits easy disassembly is care additional connections must be made later

6 Avoid unnecessary fittings and too many joints.

Metallic tubing

Metallic tubing differs from pipe in general ways. All metallic tubing is recommended for pneumatic lines with pressure upto 250 Psi

1 It can be manufactured by a drawing process, by welding, by extension, or by rolling

2 Tubing has more accurate inside and outside diameters and better surface finishes.

3 Tubing is made in many different diameters and wall thicknesses.

4 Tubing is made on stronger and more flexible materials than pipe

5 Tubing materials include sheel, stainless steel, copper, aluminum and brass.

Table 1

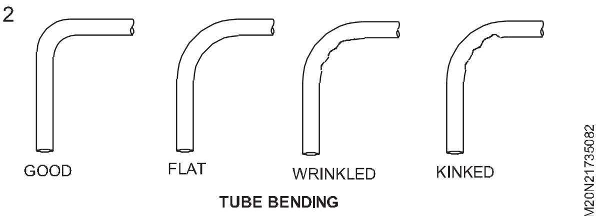
shows some of the sizes that are manufactured

Tubing size designation (in inches)					
Tube OD	**Wall thick-ness**	**Tube ID**	**Tube OD**	**Wall thick-ness**	**Tube ID**
1/2 (0.500)	0.035 0.042 0.065 0.072 0.095	0.430 0.416 0.370 0.356 0.310	7/8 (0.875)	0.049 0.058 0.072 0.095 0.109	0.777 0.759 0.731 0.685 0.657
5/8 (0.625)	0.035 0.042 0.065 0.072 0.095	0.555 0.541 0.495 0.481 0.435	1 (1.000)	0.049 0.058 0.083 0.109 0.120	0.902 0.884 0.834 0.782 0.760
3/4 (0.750)	0.049 0.065 0.072 0.095 0.109	0.652 0.620 0.606 0.560 0.532	11/4 (1.250)	0.049 0.058 0.083 0.109 0.120	1.152 1.134 1.084 1.032 1.010

Tube bending

Metal tubing is easier to install than pipe because it requires fewer connections. Most of the necessary changes in direction are made by pending the tube. Care must be used when bending tubing because once it is bent, it cannot be straightened. Bending tools are used to bend the tube to the proper radius. Fig 2 shows the bend radius for difference sizes of tubes.

Fig 2



Tube and pipe assembly

Objective: At the end of this lesson you shall be able to
- **state the various types of tubes and pipes fitting in an hydraulic system.**

Tubings in hydraulic system

In any hydraulic system the fluid should pass from one element to the other without breaking. For this purpose tubing is employed. Tubes act as a leakproof carrier for hydraulic fluid from and to the various elements used in the hydraulic circuits.

These pipes/tubes should be capable of withstanding pressure and also temperature. Thus the pipes also act as a area where the fluid dissipates the heat.

Normally the term tube and pipe is always leading to a confusion. What is the exact definition of a tube?

Difference between a tube and pipe

The difference between a pipe and tube is very narrow. Tube walls are usually thin contrary to the pipe walls which are thicker.

Tube generally is seamless in its design, whereas pipe may beveled.

Tubes, because of its thin wall cannot be threaded, whereas pipes can be threaded without affecting the strength.

Both tube and pipe are available in steel, but tubes are available in copper, brass, steel and also in plastic.

Bending of tubes are relatively easier compared to pipes, so tube have better flexibility over the pipes.

A main difference of the tube to a pipe is the inner wall of a tube is smooth, so as to provide a smooth flow of liquid resulting in a LAMINAR flow, which usually is a turbulent flow in a pipe, having not such a smoother inner side.

But generally even now in workplaces, both pipes and tubes are mentioned not precisely.

Tube material

Tubes are usually specified by their outside diameter and the length. Usually the length is made to customer requirement by cutting the tubes. Tubes are available in various materials such as copper, brass, aluminium, carbon steel and stainless steel. All tubes are usually seamless drawn tubes.

Classification of pipe fitting in hydraulics

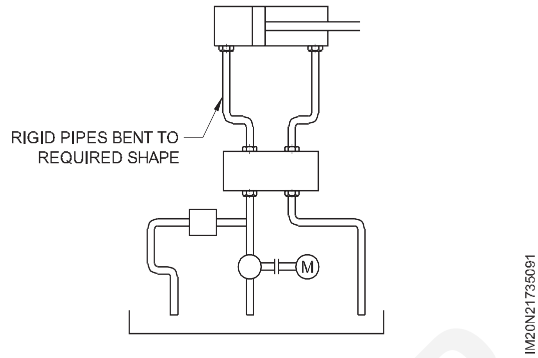
Tube/pipe fitting in hydraulics is usually classified as

- Rigid connections
- Flexible connection.

Rigid connections

Rigid tubing in done using metallic tubes. The tube is bent to the required length and shape and the various elements of the circuit is connected. (Fig 1)

Fig 1



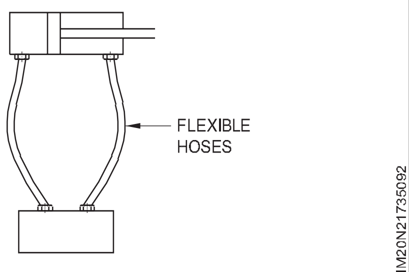
This type of connection is done where the circuit only built will not have any change in design or change in the position of the elements in future.

If there is a change then the existing pipes have to be disconnected and new pipes have to be bent fresh.

Flexible connection

This is a system in which the elements are connected with flexible tubes normally called as hoses. Flexible hoses are made of synthetic rubber tube reinforced with one or two braids of high tensile steel wire or with synthetic yarn suitably covered with weather resistant rubber. (Fig 2)

Fig 2



Flexible hoses are very good in taking up pulsating pressure which is dampened by the hose itself. In case of rigid pipe this would have resulted in vibration ultimately causing breakage or loosening of connector.

Advantages of using hoses

- Insulates against shock noise and vibration
- Connects stationary parts
- Makes connection easier in congested space
- Makes good temporary connections
- Provides connections and disconnections which are to be frequently changed.

Specification of hoses

Flexible hoses are specified according to the following informations,

- Internal diameter
- Length between the two end connectors
- Pressure and temp withstanding capacity

- Type of end fitting.

All these can be readily referred from manufacturers catalogue for the specific application. An example is given below.

dia.10 x 1000 x SAE100R2 x both ends female nuts.

Connectors

Connectors are the elements which connects the tube ends to the body of the various hydraulic elements. Connectors also serve various other purposes like change in size of tube, change in direction of flow, restriction of flow etc. Connectors can be grouped according to various parameters.

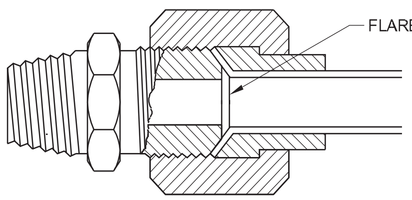
- According to the type of sealing design.
- According to the shape, size and purpose used for.

According to the type of sealing design

Flared fitting (Fig 3)

In this, the pipe is flared and fitted to the suitable connector.

Fig 3

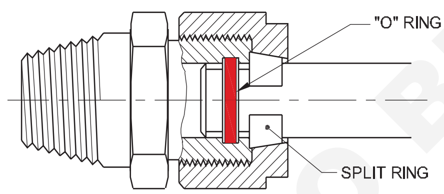


FLARE FITTING

'O' ring compression fitting (Fig 4)

In this type of `O' ring seals the pipe outside diameter. The split ring clamps the pipe in position.

Fig 4

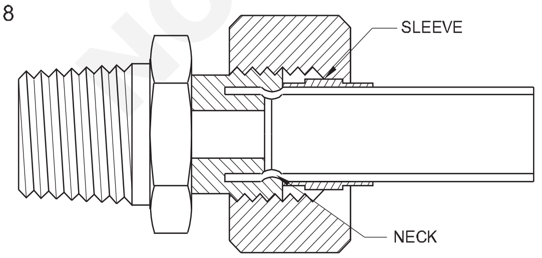


"O" RING COMPRESSION FITTING

Sleeve compression fitting (Fig 5)

In this the pipe is formed the neck seals the path for oil along with the sleeve.

Fig 8

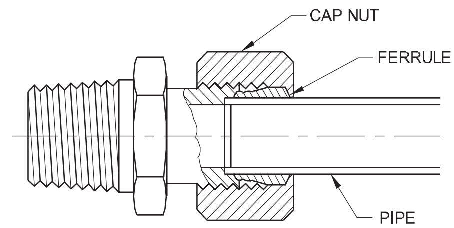


SLEEVE COMPRESSION FITTING

Ferrule compression fitting (Fig 6)

In this, the ferrule is of a special design, ferrule bites into the tube to form a permanent seal.

Fig 6



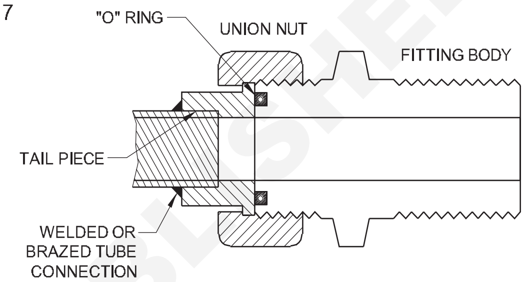
FERRULE COMPRESSION FITTING

O' ring fitting (Fig 7)

The pipe is welded with a ring with a flat face, this face seals against a 'O' ring.

Various fitting have been illustrated, each of these fittings have the corresponding connectors. The connection will be perfect only when the connection is made according to the manufacturers instructions.

Fig 7



"O" RING FITTING

The selection of the right type of connector depend upon various factors like

- Working pressure of system
- Frequency of assembly and disassembly
- Vibration or shock level in circuit
- Working area.

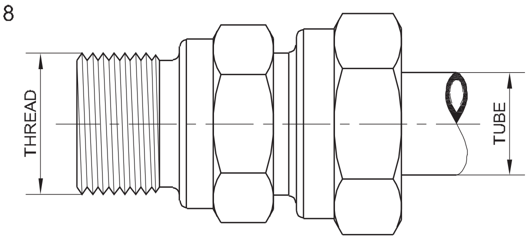
According to the size, shape and purpose of use

Connectors are used to connect either a tube to the body of a hydraulic element or a tube end to another tube end.

To connect a hydraulic element to a tube end

The connector shown (Fig 8) has threads which is screwed on to the body of the hydraulic element. On the other side a tube is fixed with proper sealing. This sealing is done by various methods as discussed in the previous exercise.

Fig 8



These connectors are available in various size according to the pipe it has to accommodate. The chart shows the pipe size and the threads on the connector.

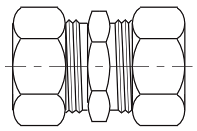
Pipe outside dia	British standard pipe thread (BSP)	Metric fine thread
6	R 1/4”	M22x1.5
8	R 1/4”	M14x1.5
10	R 3/8”	M16x1.5
12	R 3/8”	M18x1.5
14	R 1/2”	M20x1.5
16	R 1/2”	M22x1.5
20	R 3/4”	M27x2
25	R 1	M33x2
30	R 11/4”	M42x2
38	R 11/2”	M48x2

The various types of connectors in this category to take care of the flow direction of fluid as follows

Straight Connector (Fig 9)

To connect tube perpendicular to the body.

Fig 9



STRAIGHT CONNECTOR

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Elbow connector

To connect the tube end parallel to the body of the hydraulic elements.

Banjo connector

Banjo connector is similar to a elbow, but has the flexibility to turn 360 degree with the port axis. This helps in easy positioning of the pipe, with hydraulic elements.

Flange connection

Big size valves do not have threaded ports. They only have a hole as a port. In these case a flange is mounted on the body and the connector is mounted on the flange. This is also called as flush mounting.

Plug

A plug is used to block any port of the hydraulic element.

To connect a tube end to another tube end

‘T’ connector

Used to connect three pipe ends at a junction.

4 way connector

Connect 4 pipe ends at a junction.

Reducer

Connect two pipe ends of different size.

Do’s and don’ts in tube/hose fitting:

Life of tube/hose fitting depends very much on how the fitting has been designed and installed.

In case of the rigid connections the following has to be observed:

Tubes should be bent such that the bend has no flats or wrinkle at the bent corners.

Tubes should be installed and removed without springing, bending or damaging the tubing.

Support for tubes along the length if more than 1 meter long.

- Use minimum number of connectors.
- Use minimum number of bends in tubing.
- Design pipe lines in a neat and straight way to make fixing and maintenance easy.
- Use tubes and connectors according to the working pressure of the circuitry.
- Make sure tubes are kept clean and clear from chips dust etc. that enables to deduct apparent oil leakages.

Points to note while using flexible hose connections

- Flexible hoses are costly. Use of them has to be justified.
- Remember that the hose will change in length from +2% to +4% when pressurised. Provide slack or bend in the hose to compensate for any change in length which might occur.
- If high operating pressures are applied to a twisted hose, the hose may fail or the attaching nut becomes loose.
- Keep the bend radii of the hose as large as possible to avoid collapsing of line and restriction of flow.
- When hose lines pass close to a hot exhaust manifold protect the hose with a fire proof boot or metal baffle.
- Use elbows and adapters to ensure easier, cleaner installation for quick inspection and maintenance.
- When a hose assembly is to be subjected to considerable flexing or vibration remember that the metal hose fittings are not part of the flexible portion.
- Hose must be bent in the same plane as the motion of the part to which the hose is connected.
- Use metal wire mesh to cover the tube in areas where the hoses may come in contact with hot chips etc.

Tubing installation

The general procedure and precautions when installing tubing

1 Select tubing and fittings too how, pressure and service requirements.

2 Form lines with minimum number of bends.

3 Protect the lines from accidental damage

4 Avoid connections in straight runs.

5 Tubing assemblies should be installed and removable without bending or damaging the tube.

6 All tube assemblies should be installed and removed with hand tools.

7 Support long tubings runs with clamps or hangers.

Non metallic tubing

Non metallic or plastic tubing can be made of poly. Ethylene, poly, propelene, or poly, vinyl chloride the plastic tubing is limited to working pressures below 100psi and to temperatures below 190 plastic tube fittings.

Advantage

1 It is resistant to chemical attack.

2 It will not corrode

3 It is available in colours.

4 It is excellent for pilot control lines

Couplings

Quick disconnect couplings and evened for quick connection and disconnection of pneumatic forces with requiring shut off valves. One part of the coupling contains a leak proof, spring loaded poppet, or seal while the other part contains a device to open the poppet when the coupling is connected.

Fig 1

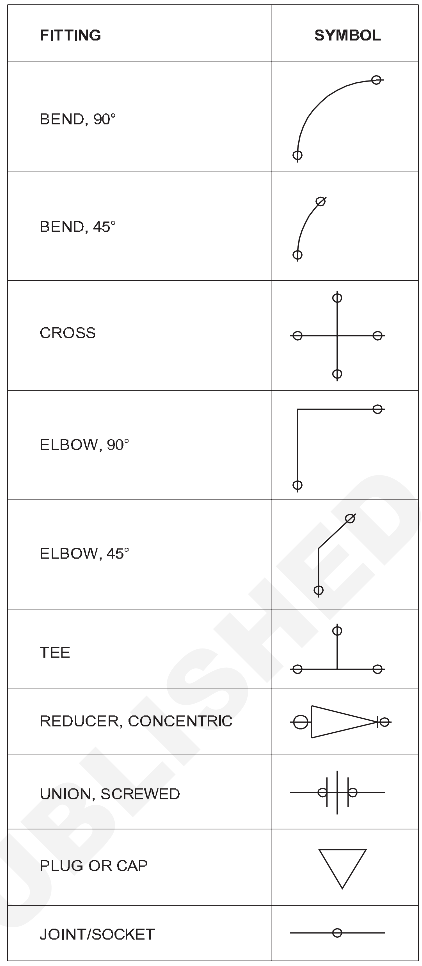

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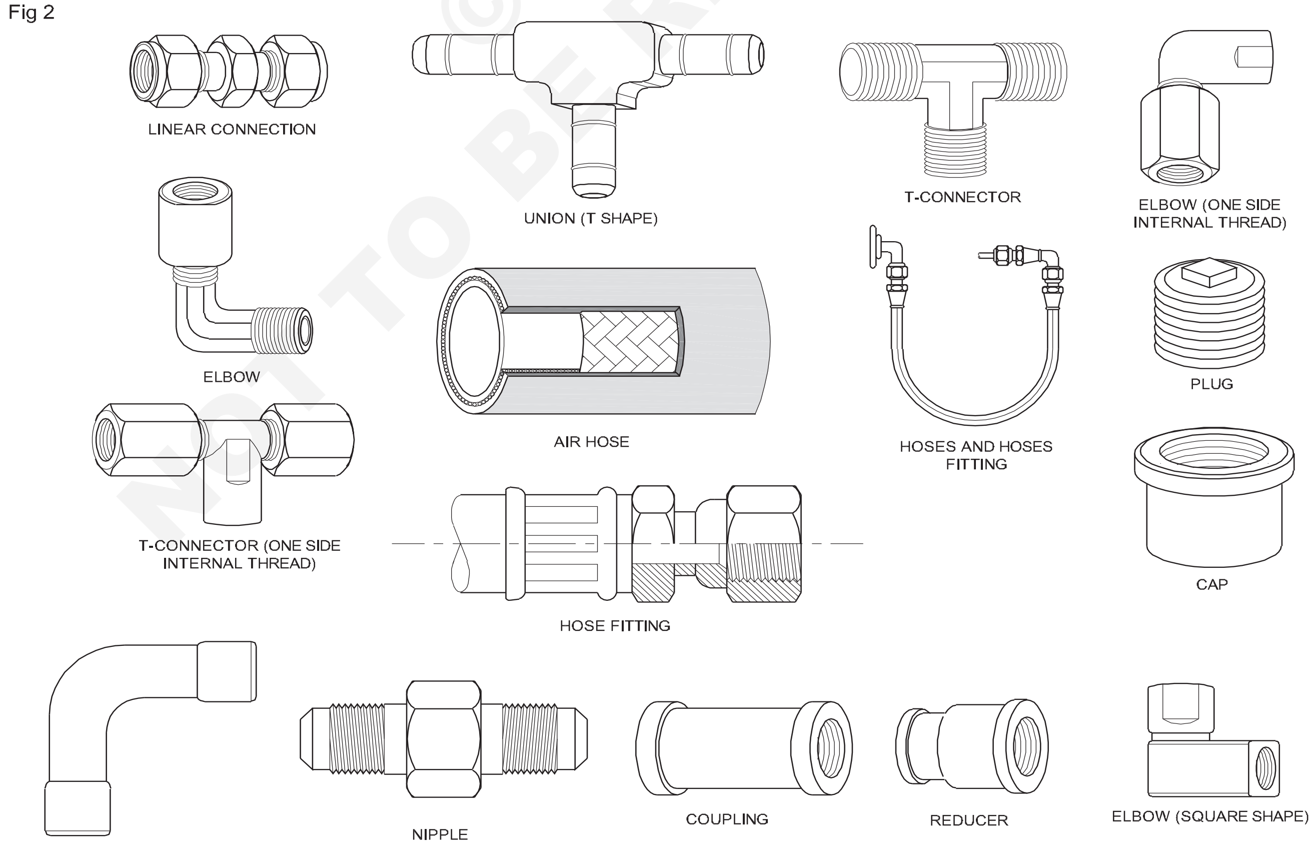
Fig 2



PNEUMATIC AND HYDRAULIC FITTINGS

IM20N217350A2

Basic of Analytical Instruments

Objectives: At the end of this lesson you shall be able to
- **explain pH measurement**
- **explain types of electrodes used for pH measurements**
- **explain relation between pH and mill volt**
- **explain the working of pH indicator and controllers**
- **explain working conductivity and dissolved oxygen meter.**

Exposure to Basic Analytical Instruments

Analytical Instruments

- Instruments that are used to analyze materials and to establish the composition
- provide
- qualitative information
- quantitative data

Analytical Instruments Definition

Analytical Instrumentsis the study of the separating identification and qualification of the chemical components of natural and artificial materials.

1 Importance about Analytical Instruments

An important part of the instrumentation industry analytical instrument play an important role in the analytical and detection business and become a weapon for safety testing with the introduction of a large number of support polices.

An industrial skills are the ability to collect information and to thoroughly analyze that information.

2 Names of Analytical Instruments

Analytical instruments include mass spectrometers,chromato graphs(e-g-GC and HPLC) spectorometers (e-g-AAS, X-ray, and flourcence) parctiele size analyzers, rheometers, elements) analyzers. (e-g- salt – analyzers, chn analyzers) thermal analyzers, and more.

3 Conditions for selecting Analytical Instruments

In choosing among the available methods, we give consideration to or all the following design criteria, accuracy , precision , sensitivity ,selectivity , rubstness raggedness,scale of operation analysis time, availability of equipment and cost.

pH measure of the * or * of aqueous or other liquid solutions, * widely used in chemistry,biology and agronomy, translates the values of the concentration of the hydrogen on which ordinally ranges between about 1 and 10 -4 grem equivalents per litre – into numbers between 0 and 14.

pH Meter Principle and working (Fig 1)

A pH meter is used to measure the acidity and alkalinity of a solution, or a pH meter is an electronic device used for measuring the pH of any solution, pH meter Calibration is required at regular intervals or as per the defined frequency to maintain its accuracy.

Fig 1

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pH Meter Principle

A Pit measures the voltage between the two electrodes. one is a glass electrode, and the other is a reference electrode. it displays the result of that voltage that is related to the corresponding pH value.

sometimes, if both electrons are present, it is called the combination electrode, and they are inserted into solution in which pH is to be tested. these two electrodes are immersed and, after immersing these electrodes in a solution. that H+ion in the test solution exchange for other positively charged ions presents on the glass ball. so there is an action between these plus ions of the solution and h + ions or positively charged ions present on the glass bulb. the amplifier detects the difference in electric potential between the two electrodes. the contrast of these potentials is called the pH unit .

Why Range of pH

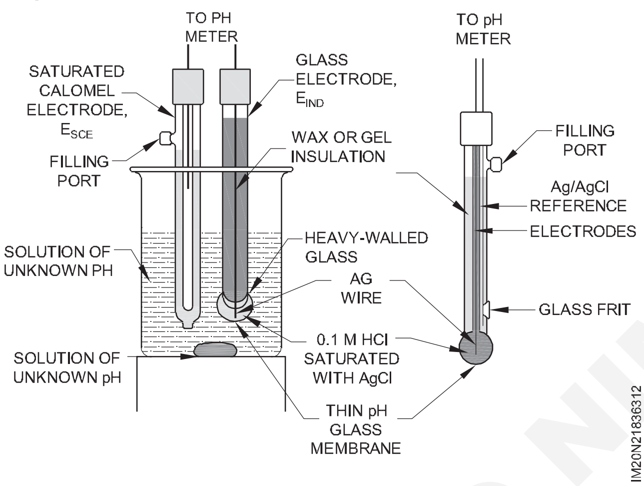
pH always measured between (1 to 14). the solution having the pH =1 is called an acidic solution, or generally, it is highly acidic. the solution with the pH =14 is highly alkaline, or it is a natural solution than the solutions having more h + ion concentration. it is highly acidic, and the solutions with more oh – ion are highly basic or highly alkaline.

Key components or parts of pH instrument

It consists of a probe, typically a three –in-one combination. the electrode has a hydrogen ion-sensitive glass electrode, a reference electrode, and a temperature probe. the temperature probe is used to ensure any temperature variation is corrected automatically.

At the tip of the probe is a sensitive glass bulb that detects the acidity or basicity of the solution and at the other end of the probe is a high input electronic meter that measures and displays the pH. (Fig 2)

Fig 2



Working of a pH meter

Turn on the pH meter and allow adequate time for it to initialize. remove the electrode from the storage solution gently. clean the electrode by rinsing it with deionized water under an empty waste beaker. once rinsed gently, blot dry with non – abrasive kim wipes or sure wipes to remove the excess water. do not rub the electrode as it can damage the sensitive membrane around it before taking any sample measurements.

First, calibrating the pH meter takes three color – coded standard buffer solutions of pH 7.0, 4.01, and 9.21 for calibration. the first buffer used for calibration is always the neutral buffer with a pH of 7.0; the second should always be near the expected sample pH, either 4.01 or 9.21.

Bases should be measured with buffers with a pH of 9.21, while acidic samples should be measured with a pH of 4.01. place the electrodes in the buffer solution with a pH of 7. 0 and allow the pH reading to stabilize at 7. if the h+ ion concentration determines the needed pH

Suppose the concentration of h+ ions inside the glass membrane electrode and solution of buffer solution present outside the electrode is the name. in that case, the pH equals 7l. once the standard with ph 7.0 is calibrated, rinse the electrode with distilled water and blood dry with kim wipes.

In the next step, if the sample's expected pH is acidic, select the buffer solution of pH 4.01,place the electrodes in the buffer with a pH value of 4.01 and press the calibrate button. allows the ph reading to stabilize at4.01. if the concentration of h+ ions inside the glass membrane electrode is lower than the buffer solution present outside the electrode, pH will be less than7.

Once the standard with pH 4.01 is also calibrated, rinse the electrode with distilled water and blood dry with kim wines similarly, you may skip the previous step of the expected pH of the sample is on the alkaline side and follow this step by using the buffer solution of pH 9.21.

Place the electrodes in the buffer with a pH value of 9.21 and press the calibrate button. allows the ph reading to stabilize at 9.21 if required ph10 buffer solution can be used the concentration of h+ inside the glass membrane electrode is higher than the buffer solution present outside the electrode. now the pH displayed is more than 7. repeat the rinse process just like the previous steps. now the pH meter is calibrated and ready to determine the pH of the test sample.

Place the electrodes in the given sample, and then press the measure button to leave the electrodes in your sample until the reading has stabilized. this will be the exact pH value of your solution. take the electrodes out, rinse them with distilled water and bolt dry with kim wipes. immerse the probe in three molar potassium chloride solutions for storage like this. consult your operation manual for optimal practices for your specific pH meter.

Application of pH meter

- It is used in the agriculture industry to determine the pH of soil.
- It's also used to test the quality of municipal drinking water and swimming pools.
- It's used to measure the pH valve of solutions in numerous chemical and pharmaceutical businesses.
- The pH meter is also used in the food business, particularly for dairy products such as cheese, curds, and yoghurts.

Advantage of pH meter

- Provide high accuracy for extended periods
- Easy to clean
- Required less space to install
- Pocket size pH meter is highly reliable and low cost

The Disadvantage of the pH meter

- Electrodes need to be clean timely to remove deposits. it may cause disturbance in reading.
- Careful to handing glass rods properly to avoid breakage

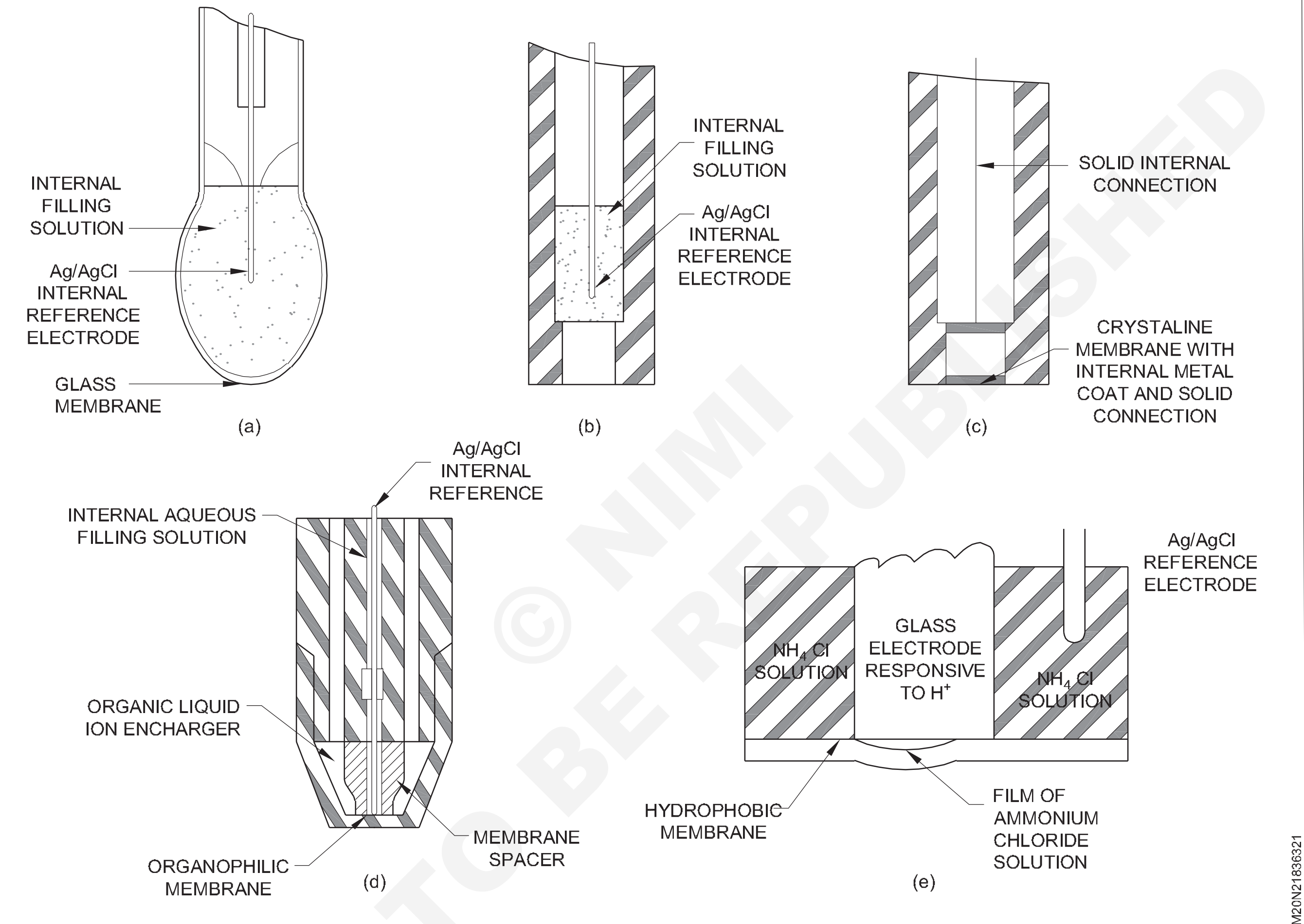
Types of Electrodes important pH Measurement

The electrodes play important roles in pH measurements. The various types of ion – selective electrodes used are described below

The glass electrodes, as shown in Fig 1 used for pH measurement, is designed to be selective to hydrogen ions but, by choosing the composition of the glass membrane, glass electrodes selective to sodium, potassium, ammonium, silver, and other equivalent modifications can be made.

In solid stat electrodes, the membrane consists of a single crystal or a compact disc of the active material. as shown in Fig 1(b),the membrane isolates the reference solution from the solution being measured. in Fig 1(c), the membrane is sealed with a metal backing with a solid metal connection. a solid state electrode selective to fluoride ions employs a membrane of lanthanum fluoride (L_aF_3). one, which is selective to sulphide ions, has a membrane of silver sulphide. there are also electrodes available for measurement of CL, Br, I, $cu^{2+}Pb^{2+}Cd^{2+}$, CN^- ions. (Fig 3)

Fig 1



Heterogeneous membrane electrodes are similar to the solid state electrodes.

In liquid ion exchange electrodes, as shown in Fig 1, a porous layer containing an organic liquid of low water solubility separates the internal reference solution and the measured solution. dissolved in the organic phase are large molecules in which the ions of interest are incorporated. the most important of these electrodes is the calcium electrode, but other electrodes in this class are available for the determination of Cl^-, ClO^-_4, NO^-_3, Cu^2+, Pb^2+, and BF^-_4 The liquid ion exchange electrodes have more chemical and physical limitations than the glass or solid state electrodes but they may be used to measure ions, which cannot yet be measured with a solid state electrode.

Gas – sensing membrane electrodes are not true membrane electrodes as no current passes across the membrane. they are complete electrochemical cells, monitored by anion- selective electrode as the internal chemistry is changed by the ion being determined passing from the sample solution across the membrane to the inside of the cell.example of this type of electrode is an ammonia electrode as shown in fig . the sensing surface of a flat – ended glass ph electrode is pressed tightly against a hydrophobic polymer membrane which is acting as a seal for the end of a tube containing ammonium chloride solution. a silver/silver chloride of free ammonia (NH2), but nit ions, between the sample solution and the film of ammonium chloride solution. the introduction of free ammonia changes

Relation between pH and mv

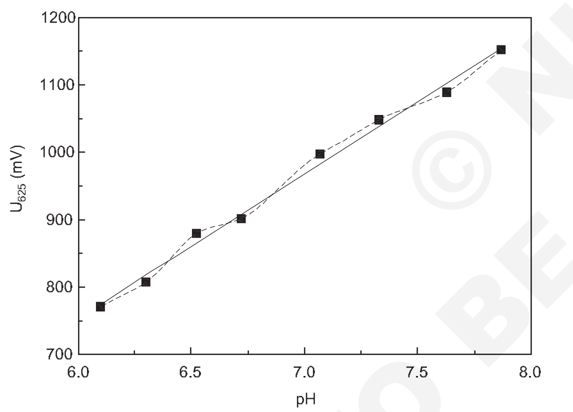
Bared upon me Nermst equation at 25c the out put of a pH meaning electrodes is equal to 59.16 per pH unit. at 7.00 pH which is me iso potential point for a perfect electrodes, the output is omv. as the solution pH increases more negation.

when a pH meter is a very solution voltmeter pH probe is placed into a solution on mv potential is generated in response to the my hydrogen ion ** at 25c a pH 7.0 solution mill generate 0 mv and there will be a 59.16 mv charge for each pH unit pH decrease with increase temperature chart pH =mv

pH Voltage	
pH alkaline	Milli (volts)
7 pH	0 mv
8 pH	-54.14 mv
9 pH	-114.29 mv

Fig 4 shows the relationship between the average voltage and pH value * for me eight testing vessels this line is used no convert voltage measured by me antimony electrodes of the capsule into pH reading

Fig 4

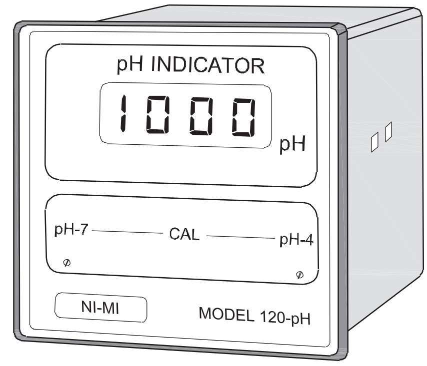


pH range	Description	Colour
1-3	Strong acid	Red
3-6	Weak acid	Orange/ yellow
7	Neutral	green
8-11	Weak alkali	Blue
11-14	Strong alkali	Violet/Indigo

pH indicator (Fig 5)

A pH indicator is a halochromic chemical compound added in small amounts to a solution so the pH (acidity or basicity) of the solution can be determined visually. Hence, a pH indicator is a chemical detector for hydronium ions (H_3O^+) or hydrogen ions (H^+) in the Arrhenius model. Normally, the indicator causes the color of the solution to change depending on the pH.

Fig 5



Universal Indicator

pH controller

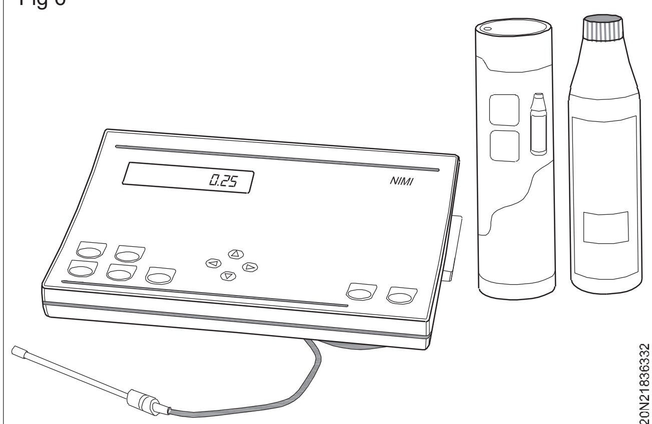
The pH process controller measures and regulates the pH of various substances and is able to influence the pH value. The pH process controller is a classic 2- point controller, depending on the application the controller can be used to influence the liquid in the direction of alkaline or acidic.

A pH electrode is connected to the pH controller via BNC plug. the screw connections can be used to connect a temperature probe for automatic temperature compensation to the pH process controller. the pH controller finds its application in electroplating, the control of fresh and wastewater or on the wastewater neutralization. due to the compact dimensions, the pH controller fits in every control panel

- small dimensions
- large led display
- connection via BNC and screw contacts
- for water treatment, electroplating
- 3- point calibration

Conductivity Meter (Fig 6)

Fig 6



Conductivity

Conductivity is the ability of a solution, a metal or a gas – in brief all materials- to pass an electric current. in solutions the current is carried by cations and anions whereas in metals it is carried by electrons.

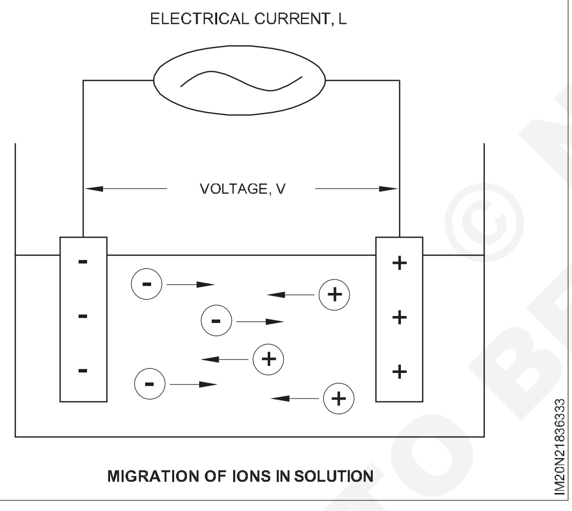
How well a solution conducts electricity depends on a number of factors:

- concentration
- mobility of ions
- valence of ions
- temperature

All substances possess some degree of conductivity. in aqueous solutions the level of ionic strength varies from the low conductivity of ultra pure water to the high conductivity of concentrated chemical samples.

Conductivity may be measured by applying an alternating electrical current (1) to two electrodes immersed in a solution and measuring the resulting voltage (v). during this process, the cations migrate to the negative electrode, the anions to the positive electrode and the solution acts as an electrical conductor. (Fig 7)

Fig 7



The Conductivity Meter

A typical conductivity meter applier an altercating current (i) at an “optimal frequency “ to two active electrode and measurer the potential (v). Both the current and the potential are used to calculate the conductance and cell constant to display the conductivity.

The Resistance of the solution (R) can be calculated using ohms law v= R^x I

R=V/I

where

v= voltage (volts)

i= current camperes

r = resistance of the solution (ohms)

conductance G is defined as the reaprocal of the electrical resistance (R) of a solution between 2 electrodes

G = I / R (S)

The conductivity meter in fact measures the conductance and displays the reading converted into conduetivity cell constant to the area (a) of the electrodes to the area (a) of the electrodes

K = cell constant (cm^{-1})

a= effective area of the electrodes (cm^2)

d = distance between the electrodes (cm)

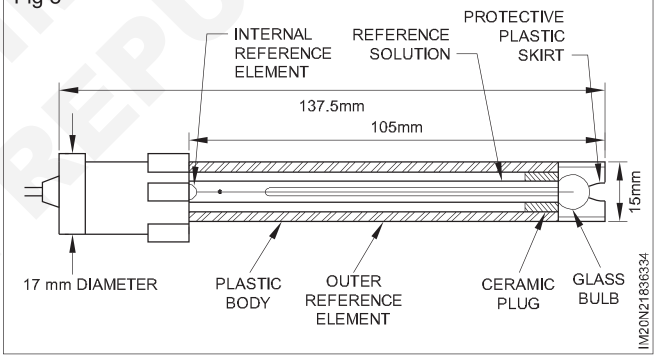
Inst Tools

Dissolved oxygen analyzer working principle

Dissolved oxygen refers to oxygen dissolved in water. its concentration is expressed as the amount of oxygen per unit volume and the unit is mg/L biologically, oxygen is an essential for respiration of underwater life and also acts as a chemical oxidizer. the solubility of oxygen in water is affected by water temperature, salinity, barometric pressure, etc. and decreases as water temperature rises.

Measurement of dissolved oxygen by the membrane electrode method (Fig 8)

Fig 8



The membrane electrode method measures a diffusion current or reduction current generated by the concentration of dissolved oxygen or partial pressure of oxygen to obtain the concentration of dissolved oxygen. this method is not affected by the pH value of water being measured, oxidation and reduction substances, color, turbidity, etc, and the measurement method offers good reproducibility.

when a sensor is in to water, an air layer forms on the membrane (Teflon membrane). the oxygen partial pressure (concentration) in the air layer is in equilibrium with the concentration of dissolved oxygen in the water. the membrane electrode method measures the oxygen concentration in the gas phase to indirectly obtain the concentration of dissolved oxygen in water.

Two types of Membrane Methods are

- Galvanic cell method
- Polarographic method