NARASARAOPETA ENGINEERING COLLEGE
NEC
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE FILE

Academic year	**: 2022-23**
Department	**: ME**
Course Name	**: B.Tech**
Student's Batch	**: 2022-23**
Regulation	**: R20**
Year and Semester	**: II B.Tech I Semester**
Name of the Subject	: Metrology and Instrumentation
Subject Code	: R20ME2103
Faculty In charge	: K. Kiran Chand

Kiran chand
Signature of Faculty

Head of the Department

NARASARAOPETA
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(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

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NARASARAOPETA
NEC ENGINEERING COLLEGE
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DEPARTMENT OF MECHANICAL ENGINEERING

INSTITUTE VISION AND MISSION

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

INSTITUTE VISION AND MISSION

VISION:

To emerge as a **Centre of excellence** in technical education with a blend of effective **student centric teaching learning** practices as well as **research** for the transformation of **lives and community**.

MISSION:

1. Provide the best class infrastructure to explore the field of engineering and research.
2. Build a passionate and a determined team of faculty with student centric teaching, imbibing experiential and innovative skills.
3. Imbibe lifelong learning skills, entrepreneurial skills and ethical values in students for addressing societal problems.

PRINCIPAL

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

DEPARTMENT VISION AND MISSION

NARASARAOPETA ENGINEERING COLLEGE

(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

DEPARTMENT VISION AND MISSION

VISION:

To strive for making competent **Mechanical Engineering Professionals** to cater the real time needs of Industry and **Research** Organizations of high repute with **Entrepreneurial Skills and Ethical Values.**

MISSION:

M1. To train the students with State of Art Infrastructure to make them industry ready professionals and to promote them for higher studies and research.

M2. To employ committed faculty for developing competent mechanical engineering graduates to deal with complex problems.

M3. To support the students in developing professionalism and make them socially committed mechanical engineers with morals and ethical values.

HOD-ME

NARASARAOPETA
ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

AND

PROGRAM SPECIFIC OUTCOMES (PSOs)

NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO 1: Excel in profession with sound knowledge in mathematics and applied sciences

PEO 2: Demonstrate leadership qualities and team spirit in achieving goals

PEO 3: Pursue higher studies to ace in research and develop as entrepreneurs.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1. The students will be able to apply knowledge of modern tools in manufacturing enabling to conquer the challenges of Modern Industry.

PSO2. The students will be able to design various thermal engineering systems by applying the principles of thermal sciences.

PSO3. The students will be able to design different mechanisms and machine components of transmission of power and automation in modern industry.

HOD-ME

NARASARAOPETA ENGINEERING COLLEGE
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DEPARTMENT OF MECHANICAL ENGINEERING

PROGRAM OUTCOMES (POs)

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

PROGRAM OUTCOMES (POs):

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

HOD-ME

NARASARAOPETA
ENGINEERING COLLEGE
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DEPARTMENT OF MECHANICAL ENGINEERING

BLOOM'S TAXONOMY LEVELS

REVISED Bloom's Taxonomy Action Verbs

Definitions	I. Remembering	II. Understanding	III. Applying	IV. Analyzing	V. Evaluating	VI. Creating
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas.	Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions.
Verbs	• Choose • Define • Find • How • Label • List • Match • Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Classify • Compare • Contrast • Demonstrate • Explain • Extend • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate	• Apply • Build • Choose • Construct • Develop • Experiment with • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize	• Analyze • Assume • Categorize • Classify • Compare • Conclusion • Contrast • Discover • Dissect • Distinguish • Divide • Examine • Function • Inference • Inspect • List • Motive • Relationships • Simplify • Survey • Take part in • Test for • Theme	• Agree • Appraise • Assess • Award • Choose • Compare • Conclude • Criteria • Criticize • Decide • Deduct • Defend • Determine • Disprove • Estimate • Evaluate • Explain • Importance • Influence • Interpret • Judge • Justify • Mark • Measure • Opinion • Perceive • Prioritize • Prove • Rate • Recommend • Rule on • Select • Support • Value	• Adapt • Build • Change • Choose • Combine • Compile • Compose • Construct • Create • Delete • Design • Develop • Discuss • Elaborate • Estimate • Formulate • Happen • Imagine • Improve • Invent • Make up • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution • Solve • Suppose • Test • Theory

derson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon.

NARASARAOPETA
ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE OUTCOMES
(COs)

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING
R20 REGULATION - COURSE OUTCOMES

II B. TECH I SEMESTER

Course Name: METROLOGY AND INSTRUMENTATION		Course Code: C213
CO	**After successful completion of this course, the students will be able to:**	
C213.1	**Explain** the design tolerances and fits for selected product quality.	
C213.2	**Illustrate** the standards of length, angle measurement.	
C213.3	**Demonstrate** the concepts of limit gauges and optical measurements.	
C213.4	**Explain** of various transducers to measure displacement.	
C213.5	**Analyze** various temperature and pressure transducers for engineering applications.	

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE INFORMATION SHEET

NEC

Narasaraopeta Engineering College
(Autonomous)
Yallamanda(Post), Narasaraopet- 522601
Department of Mechanical Engineering

COURSE INFORMATION SHEET

PROGRAMME: B.Tech Mechanical Engineering	
COURSE: **METROLOGY & INSTRUMENTATION**	Year/Semester : **II/I** CREDITS: **3**
COURSE CODE: (R20ME2103) REGULATION: **Autonomous R20**	COURSE TYPE (CORE /ELECTIVE / BREADTH/ S&H): **CORE**
COURSE AREA/DOMAIN: Production	PERIODS: 6 Per Week.

COURSE OUTCOMES:

SNO	Course Outcome Statement
C213.1	**Explain** the design tolerances and fits for selected product quality.
C213.2	**Illustrate** the standards of length, angle measurement.
C213.3	**Demonstrate** the concepts of limit gauges and optical measurements.
C213.4	**Explain** of various transducers to measure displacement.
C213.5	**Analyze** various temperature and pressure transducers for engineering applications.

SYLLABUS:

UNIT	DETAILS
I	**SYSTEMS OF LIMITS AND FITS:** Introduction, nominal size, tolerance, limits, deviations, fits -Unilateral and bilateral tolerance system, hole and shaft basis systems- interchangeability, and selective assembly. International standard system of tolerances, selection of limits and Tolerances for correct functioning.
II	**LINEAR MEASUREMENT:** Length standards, end standards, slip gauges- calibration of the slip gauges, dial indicators, micrometers. **MEASUREMENT OF ANGLES AND TAPERS:** Different methods – bevel protractor, angle slip gauges- spirit levels- sine bar, rollers and spheres used to measure angles and tapers.
III	**LIMIT GAUGES:** Taylor's principles-design of GO and NO GO gauges; plug, ring, snap, gap, taper, profile and position gauges. **OPTICAL MEASURING INSTRUMENTS:** Tools maker's microscope and uses, autocollimators, optical projector, optical flats and their uses. Need of inspection, surface testing, surface finish, Laser instrumentation..
IV	**BASIC PRINCIPLES OF INSTRUMENTATION:** Selection of instrumentation, Units and standards – Static measurements – Scale and pointer type instruments – Definition of range, sensitivity, hysteresis, accuracy, precision, reliability, repeatability, linearity, drift, Static and dynamic response, reproducibility, calibration procedure, errors in measuring instruments, source of errors. **MEASUREMENT OF DISPLACEMENT:** Theory and construction of various transducers to measure displacement - LVDT, piezo electric, inductive, capacitance, resistance.

V	**MEASUREMENT OF TEMPERATURE:** Classification, ranges, various principles of measurement, expansion, electrical resistance, thermistor, thermocouple. **MEASUREMENT OF PRESSURE:** Units - classification – different principles used. Manometers, piston, bourdon pressure gauges, bellows - diaphragm gauges. Low pressure measurement, McLeod pressure gauge.

TEXT BOOKS	
T	**BOOK TITLE/AUTHORS/PUBLISHER**
T1	Engineering Metrology, Mahajan, DhanpatRai Publishers
T2	Measurement Systems Applications & design by D.S Kumar, Khanna Publishers
REFERENCE BOOKS	
R	**BOOK TITLE/AUTHORS/PUBLISHER**
R1	Engineering Metrology, R.K.Jain, Khanna Publishers.
R2	Engineering Metrology by I.C.Gupta, DhanpatRai Publishers.
R3	Mechanical and Industrial Measurements, R.K. Jain, Khanna Publishers.

TOPICS BEYOND SYLLABUS/ADVANCED TOPICS:

SNO	DESCRIPTION	Associated PO & PSO
1	CNC machining	PO1, PO3, PO5 & PSO1
2	Basics of non-conventional machining	PO1, PO3, PO5 & PSO1

WEB SOURCE REFERENCES:

1	http://www.ktunotes.in/ktu-me312-metrology-instrumentation-notes/
2	https://lecturenotes.in/subject/239/engineering-metrology-and-measurements-emm
3	http://www.faadooengineers.com/threads/10095-Metrology-and-instrumentation-full-notes-ebook-free-download-pdf
4	https://nptel.ac.in/courses/112106179/
5	https://nptel.ac.in/courses/112106138/
6	https://nptel.ac.in/syllabus/112106179/
7	http://www.nptelvideos.in/2012/12/mechanical-measurements-and-metrology.html
8	https://freevideolectures.com/course/2370/mechanical-measurements-and-metrology
9	https://www.btechguru.com/engineeringvideos/video-lesson/mechanical-measurements-and-metrology/mechanical-engineering/ebe88124f0f00287~85e97a1e40ccaec9.html

DELIVERY/INSTRUCTIONAL METHODOLOGIES:

☑ Chalk & Talk	☑ PPT	☐ Active Learning
☑ Web Resources	☑ Students Seminars	☐ Case Study
☐ Blended Learning	☑ Quiz	☑ Tutorials
☐ Project based learning	☑ NPTEL/MOOCS	☐ Simulation
☐ Flipped Learning	☐ Industrial Visit	☐ Model Demonstration
☐ Brain storming	☐ Role Play	☐ Virtual Labs

MAPPING CO'S WITH PO'S

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
C213.1	3	2	-	-	-	-	-	-	-	-	-		3	-	2
C213.2	3	2	2	-	-	-	-	-	-	-	-		3	-	2
C213.3	3	2	-	-	-	-	-	-	-	-	-		3	-	2
C213.4	3	2	-	-	-	-	-	-	-	-	-		3	-	2
C213.5	3	2	-	-	-	--		-	-	-	-		3	2	2
Average	3.00	2.00	2.00	-	-	-	-	-	-	-	-		3.00	2.00	2.00

MAPPING COURSE WITH POs & PSOs

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
C213	3.00	2.00	2.00	-	-	-	-	-	-	-	-	-	3.00	2.00	2.00

COURSE OUTCOME RUBRIC (ASSESMENT PER STUDENT):

ASSESMENT TOOL WITH WEIGHTAGE	METHOD	ATTAINMENT LEVEL 3 (EXCELLENT)	ATTAINMENT LEVEL 2 (GOOD)	ATTAINMENT LEVEL 1 (AVERAGE)	ATTAINMENT LEVEL 0 (POOR)
Internal tests (40%)	Direct	Student secured ≥ 60% marks of allocated marks for that CO	Student secured ≥ 60% and < 50% marks of allocated marks for that CO	Student secured ≥ 50% and <40% marks of allocated marks for that CO	Student secured < 40% marks of allocated marks for that CO
Assignments (20%)	Direct	Student secured ≥ 80% marks allocated for that CO	Student secured ≥ 70% and <80% marks allocated for that CO	Student secured ≥ 60% and <70% marks allocated for that CO	Student secured < 60% of marks allocated for that CO
End Semester Examination (30%)	Direct	Student secured grades A*&S* in External Exam	Student secured grades C*&B* in External Exam	Student secured grades D*&E* in External Exam	Student secured grades F* in External Exam
Course end Survey (10%)	Indirect	Student selected option	Student selected option	Student selected option	Student selected option

* Grade Definition: S: >= 90%; A: 80%-89%; B: 70%-79%; C: 60%-69%; D: 50%-59%; E: 40%-49%; F: <40%

Course Coordinator **Module Coordinator** **Head of the Department**

ANNEXURE I:

(A) PROGRAM OUTCOMES(POs) Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide validconclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

(B) PROGRAM SPECIFIC OUTCOMES (PSOs) :

PSO1.The students will be able to understand the modern tools of machining which gives them good expertise on advanced manufacturing methods.

PSO2.The students will be able to design different heat transfer devices with emphasis on combustion and power production.

PSO3.The students are able to design different mechanisms and machine components suitable to automation industry.

Cognitive levels as per Revised Blooms Taxonomy:

Cognitive Domain	Level	Key words
Remembering	K1	Choose, Define, Find, How, Label, List, Match, Name, Omit, Recall, Relate, Select, Show, Spell, Tell, What, When, Where, Which, Who, Why.
Understanding	K2	Classify, Compare, Contrast, Demonstrate, Explain, Extend, Illustrate, Infer, Interpret, Outline, Relate, Rephrase, Show, Summarize, Translate.
Applying	K3	Apply, Build, Choose, Construct, Develop, Experiment With, Identify, Interview, Make Use of, Model, Organize, Plan, Select, Solve, Utilize.
Analyzing	K4	Analyze, Assume, Categorize, Classify, Compare, Conclusion, Contrast, Discover, Dissect, Distinguish, Divide, Examine, Function, Inference, Inspect, List, Motive, Relationships, Simplify, Survey, Take part in, Test for, Theme
Evaluating	K5	Agree, Appraise, Assess, Award, Choose, Compare, Conclude, Criteria, Criticize, Decide, Deduct, Defend, Determine, Disprove, Estimate, Evaluate, Explain, Importance, Influence, Interpret, Judge, Justify, Mark, Measure, Opinion, Perceive, Prioritize, Prove, Rate, Recommend, Rule on, Select, Support, Value
Creating	K6	Adapt, Build, Change, Choose, Combine, Compile, Compose, Construct, Create, Delete, Design, Develop, Discuss, Elaborate, Estimate, Formulate, Happen, Imagine, Improve, Invent, Make up, Maximize, Minimize, Modify, Original, Originate, Plan, Predict, Propose, Solution, Solve, Suppose, Test, Theory

Unit wise Sample assessment questions

COURSE OUTCOMES: Students are able to

CO 1: Explain the design tolerances and fits for selected product quality.
CO 2: Illustrate the standards of length, angle measurement.
CO 3: Demonstrate the concepts of limit gauges and optical measurements.
CO 4: Explain of various transducers to measure displacement
CO 5: Analyze various temperature and pressure transducers for engineering applications

S NO	QUESTION	KNOWLEDGE LEVEL	CO
	UNIT I		
1	Distinguish between hole basis system and shaft basis system.	K2	CO1
2	Discuss in detail the salient features of the systems of limits and fits as per Indian standard.	K2	CO1
3	Determine the dimensions and tolerances of the shaft and hole having the size of 25H7/f8. 25mm falls in diameter steps of 18-30. Also indicate the type of fit and show the tolerances with sketch. Assume the following data, The fundamental deviation for shaft 'f' is $-5.5D_{0.41}$, The standard tolerance unit $i=0.45\ D_{1/3}+0.001D$, where D is the geometric mean of the lower and upper limits of diameter step in which the diameter consideration lies, D is in mm, The standard tolerance for IT7=16i and IT8=25i.	K2	CO1
4	On what factors the variation in size depends in any manufacturing process	K1	CO1
	UNIT 2		
1	State the essential requirements for accuracy in the construction of a sine bar. Why the sine bar is not recommended for angles larger than 45 with reference plain.	K4	CO2
2	Discuss briefly the working and operation bevel protractor.	K3	CO2
3	State the meaning wringing? What are the essential conditions for wringing of slip gauges? What precautions should be taken while using slip gauges?	K3	CO2
4	Explain how you determine the taper angle of a taper ring gauge using spheres and Depth micrometer. Derive the expression used.	K4	CO2
5	Enumerate the sources of errors in micrometers.	K3	CO2
	UNIT 3		
1	State and explain the Taylor's principle of gauge design with neat sketch of Plug gauge and Snap gauges.	K3	CO3
2	Mention the materials used for the manufacture of GO and NOGO gauges. Explain the disposition of tolerance on GO and NO GO gauges by taking reference to work tolerances.	K4	CO3
3	Explain how you determine the taper angle of a taper ring gauge using spheres and Depth micrometer. Derive the expression used.	K4	CO3
4	With a sketch, explain the construction of a tool maker's microscope. What are its applications?	K4	CO3

5	Write short notes on optical projector and their uses.	K3	CO3
6	What are interferometers? What are their advantages over optical flats?	K3	CO3
7	Explain the importance of inspection need in manufacturing & surface finishing	K2	CO3
	UNIT 4		
1	What are the various errors occur in the measuring instruments and explain the methods of elimination.	K3	CO4
2	Sketch and explain generalized measurement system and its functional elements.	K4	CO4
3	Explain various dynamic performance characteristics with sketches.	K3	CO4
4	Describe the terms (i) Linearity (ii) Calibration What is the relationship between sensitivity and range?	K3	CO4
5	Explain LVDT with neat sketch	K2	CO4
6	Classify the different types of errors.	K4	CO4
7	Explain piezo electric ,inductive ,capacitance, resistance	K5	CO4
	UNIT 5		
1	Explain different types of Manometers	K2	CO5
2	Explain bourdon pressure gauge	K4	CO5
3	With suitable diagram construct the bourdon tube pressure gauge	K3	CO5
4	Distinguish between thermistor and thermo couple	K4	CO5
5	Explain about bellow-diaphragm gauges and low pressure measurement	K5	CO5
6	Explain Mc Leod pressure gauge	K5	CO5

Model Question Paper

Code:II B.Tech II Semester Regular Examinations

Month/Year: OCTOBER/2021

Sub Code: **R20ME2103**

SUBJECT NAME: **METROLOGY AND INSTRUMENTATION**

(ME)

MODEL PAPER

Time: 3 hours

Max. Marks: 70

Note: Answer All **FIVE** Questions.

All Questions Carry Equal Marks (5 X 14 = 71M)

Time: 3 Hrs **Max. Marks: 70**

Note: 1.Answer FIVE Questions, choice from each unit.

Execution Plan

Sl. No	Activities	Time (Minutes)
1	To study the Question Paper and choose to attempt	5
3	33 Minutes x 5 Questions	165
4	Quick revision & Winding up	10
	Total	180

Answer any FIVE Questions

Q.No.		Questions	Marks
		Unit-I	
1	a	Distinguish between hole basis system and shaft basis system.	[14M]
		OR	
	b	Discuss in detail the salient features of the systems of limits and fits as per Indian standard.	[14M]
		Unit-II	
2	a	State the essential requirements for accuracy in the construction of a sine bar. Why the sine bar is not recommended for angles larger than 45 with reference plain	[7M]
		Discuss briefly the working and operation bevel protractor.	[7M]
		OR	
	b	State the meaning wringing? What are the essential conditions for wringing of slip gauges? What precautions should be taken while using slip gauges?	[14M]

	Unit-III		
3	a	Mention the materials used for the manufacture of GO and NOGO gauges. Explain the disposition of tolerance on GO and NO GO gauges by taking reference to work tolerances.	[14M]
		OR	
	b	Explain how you determine the taper angle of a taper ring gauge using spheres and Depth micrometer. Derive the expression used.	[14M]
	Unit-IV		
4	a	(i) Explain various dynamic performance characteristics with sketches. (ii) Explain piezo electric transducers.	[14M]
		OR	
	b	Classify the different types of errors.	[7M]
		Explain LVDT with neat sketch	[7M]
	Unit-V		
5	a	(i)Explain different types of Manometers (ii) Explain bourdon pressure gauge	[14M]
		OR	
	b	(i)Explain Mc Leod pressure gauge (ii) Distinguish between thermistor and thermo couple	[14M]

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NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

ACADEMIC CALENDAR

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

ACADEMIC CALENDAR

(B.Tech. 2021 Admitted Batch, Academic Year 2022-23)

2021 Batch 2nd Year 1st Semester			
Description	**From Date**	**To Date**	**Duration**
Commencement of Class Work	5-09-2022		7 Weeks
1st Spell of Instructions	5-09-2022	22-10-2022	
Assignment Test-I	26-9-2022	31-09-2022	
I Mid examinations	24-10-2022	29-10-2022	1 Week
2nd Spell of Instructions	31-10-2022	17-12-2022	7 Weeks
Assignment Test-II	21-11-2022	26-11-2022	
II Mid examinations	19-12-2022	24-12-2022	1 Week
Preparation & Practicals	26-12-2022	31-12-2022	1Week
Semester End Examinations	02-01-2023	14-01-2023	2 Weeks
2021 Batch 2nd Year 2nd Semester			
Commencement of Class Work	16-01-2023		7 Weeks
1st Spell of Instructions	16-01-2023	04-03-2023	
Assignment Test-I	06-02-2023	11-02-2023	
I Mid examinations	06-03-2023	11-03-2023	1 Week
2nd Spell of Instructions	13-03-2023	29-04-2023	7 Weeks
Assignment Test-II	03-04-2023	08-04-2023	
II Mid examinations	01-05-2023	06-05-2023	1 Week
Preparation & Practicals	08-05-2023	13-05-2023	1 Week
Semester End Examinations	15-05-2023	27-05-2023	2 Weeks
Commencement of 3rd Year 1st Sem Class Work	05-06-2023		

PRINCIPAL

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

TIME TABLE

NARASARAOPETA ENGINEERING COLLEGE: NARASARAOPET (AUTONOMOUS)
DEPARTMENT OF MECHANICAL ENGINEERING
II B.TECH I SEM TIME TABLE
Section-A

ROOM NO: 1216

Wef: 06/09/2022

	1	2	BREAK	3	4		5	6	7
TIMINGS	9.10-10.00	10.00-10.50	10.50-11.00	11.00-11.50	11.50-12.40	12.40-1.30	1.30-2.20	2.20-3.10	3.10-4.00
MON	NMT			MOS		L	FM&HM		ES
TUE	TD			M&I		U	MOS&M / M&I LAB		
WED	FM&HM			TD		N	SM / FM&HM LAB		
THU	ES	SM / FM&HM LAB				C	NMT		FM&HM
FRI	M&I	MOS&M/ M&I LAB				H	MOS		TD
SAT	MOS			M&I			NMT	FM&HM	TD

CODE	SUBJECT	FACULTY
NM&T	Numerical Methods and Transformations	Mrs.A.Aparna
FM&HM	Fluid Mechanics &Hydraulic Machinery	Mr. T.V. Rao
M&I	Metrology& Instrumentation	Mr.K.Kiran Chand
TD	Thermodynamics	Mr.K.Jail Sing
MOS	Mechanics of Solids	Mr.MD.Taju
FM&HM LAB	Fluid Mechanics &Hydraulic Machinery Lab	Mr. K.John Babu/ A.Pavan Kumar
MOS&M LAB	MOS & Metallurgy Lab	Dr.P.Suresh Babu/ MD.Taju
M&I LAB	Metrology& Instrumentation Lab	Dr.M.Venkanna Babu/ R.China Rao
SM	Solid Modelling	Dr. T. R. Santhosh kumar /Mr.M.Srinivasa Rao
ES	Environmental Studies	Dr.K.Srinivasulu

Signature of HOD

Signature of Principal

NARASARAOPETA
ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

SYLLABUS COPY

II B.Tech I SEMESTER	L	T	P	INTERNAL MARKS	EXTERNAL MARKS	TOTAL MARKS	CREDITS
	3	0	0	30	70	100	3
Code: R20ME2103	**METROLOGY AND INSTRUMENTATION**						

COURSE OBJECTIVES:

- Inspection of engineering parts with various precision instruments.
- Design of part, tolerances and fits.
- Principles of measuring instruments and gauges and their uses.
- Imparting the principles of measurement which includes the working mechanism of various displacement transducers, measurement of temperature and pressure gauges.

COURSE OUTCOMES:

After successful completion of this course, the students will be able to:

CO 1: Explain the design tolerances and fits for selected product quality.
CO 2: Illustrate the standards of length, angle measurement.
CO 3: Demonstrate the concepts of limit gauges and optical measurements.
CO 4: Explain of various transducers to measure displacement
CO 5: Analyze various temperature and pressure transducers for engineering applications

UNIT– I

SYSTEMS OF LIMITS AND FITS: Introduction, nominal size, tolerance, limits, deviations, fits - Unilateral and bilateral tolerance system, form tolerance, Assembly tolerance and tolerance estimation methods, hole and shaft basis systems- interchangeability and selective assembly. International standard system of tolerances, selection of limits and tolerances for correct functioning.

UNIT–II

LINEAR MEASUREMENT: Length standards, end standards, slip gauges- calibration of the slip gauges, dial indicators, micrometres.

MEASUREMENT OF ANGLES AND TAPERS: Different methods – bevel protractor, angle slip gauges- spirit levels- sine bar, rollers and spheres used to measure angles and tapers.

UNIT–III

LIMIT GAUGES: Taylor's principles-design of GO and NO GO gauges; plug, ring, snap, gap, taper, profile and position gauges.

OPTICAL MEASURING INSTRUMENTS: Tools maker's microscope and uses, autocollimators, optical projector, optical flats and their uses. Need of inspection, surface testing, surface finish, Laser instrumentation.

UNIT-IV

BASIC PRINCIPLES OF INSTRUMENTATION: Selection of instrumentation, Units and standards – Static measurements – Scale and pointer type instruments – Definition of range, sensitivity, hysteresis, accuracy, precision, reliability, repeatability, linearity, drift, Static and dynamic response, reproducibility, calibration procedure, errors in measuring instruments, source of errors.

MEASUREMENT OF DISPLACEMENT: Theory and construction of various transducers to measure displacement - LVDT, piezo electric, inductive, capacitance, resistance.

UNIT-V

MEASUREMENT OF TEMPERATURE: Classification, ranges, various principles of measurement, expansion, electrical resistance, thermistor, thermocouple.

MEASUREMENT OF PRESSURE: Units - classification – different principles used. Manometers, piston, bourdon pressure gauges, bellows - diaphragm gauges. Low pressure measurement, McLeod pressure gauge.

TEXT BOOKS:

1. Engineering Metrology, Mahajan, Dhanpat Rai Publishers.
2. Measurement Systems Applications & design by D.S Kumar, Khanna Publishers.

REFERENCE BOOKS:

1. Engineering Metrology, R.K.Jain, Khanna Publishers.
2. Engineering Metrology by I.C.Gupta, DhanpatRai Publishers.
3. Mechanical and Industrial Measurements, R.K. Jain, Khanna Publishers.

WEB REFERENCES:

1. https://www.youtube.com/watch?v=HpIEeBtJupY&list=PLbMVogVj5nJSZiwuh_tp50dKry8mCxzKA&index=1

E-BOOKS:

1. http://www.gvpce.ac.in/syllabi/Engineering%20Metrology.pdf

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

LESSON PLAN

NEC	**Narasaraopeta Engineering College** **(Autonomous)** **Yallmanda(Post), Narasaraopet- 522601**

DEPARTMENT OF MECHANICAL ENGINEERING
LESSON PLAN

Course Code	Course Title (Regulation)	sem	Branch	Contact Periods/Week	Sections
R20ME32103	METROLOGY & INSTRUMENTATION	II	Mechanical Engineering	6	A

COURSE OUTCOMES: Students are able to

CO1: Understand the design tolerances and fits for selected product quality. [K2]

CO2: Illustrate the standards of length, angle measurement. [K2]

CO3. Explain the concepts of limit gauges and optical measurements. [K2]

CO4. Explain of various transducers to measure displacement (K2)

CO5. Analyze various temperature and pressure transducers for engineering applications (K4)

Unit No	Outcome		Topics/Activity	Ref Text book	Total Periods	Delivery Method
			Unit-1			
1	CO1: Understand the design tolerances and fits for selected product quality. [K2]	1.1	SYSTEMS OF LIMITS AND FITS: Introduction, nominal size, tolerance, limits,	T1, R1,R2	2	Chalk & Talk, PPT
		1.2	deviations	T1, R1,R2	1	Chalk & Talk, PPT
		1.3	fits -Unilateral and bilateral tolerance system, hole and shaft basis systems	T1, R1,R2	2	Chalk & Talk, PPT,
		1.4	Interchangeability, selective assembly.	T1, R1,R2	1	Chalk & Talk, PPT,
		1.5	International standard system of tolerances,	T1, R1,R2	2	Chalk & Talk, PPT,
		1.6	Selection of limits and tolerances for correct functioning.	T1, R1,R2	1	Chalk & Talk, PPT,
		1.7	Problems on tolerance,allowance,fundmental deviations	T1, R1,R2	4	Chalk & Talk, Active Learing
			Unit-2			
2	CO2: Illustrate the standards of length, angle measurement. [K2]	2.1	LINEAR MEASUREMENT: Length standards, end standards,	T1, R1,R2	2	Chalk & Talk, PPT
		2.2	slip gauges- calibration of the slip gauges,	T1, R1,R2	2	Chalk & Talk, PPT
		2.3	Dial indicators, micrometers.	T1, R1,R2	2	Chalk & Talk, PPT
		2.4	MEASUREMENT OF ANGLES AND TAPERS: Different methods – bevel protractor	T1, R1,R2	1	Chalk & Talk, PPT
		2.5	angle slip gauges- spirit levels	T1, R1,R2	2	Chalk & Talk, PPT

		2.6	sine bar, rollers and spheres used to measure angles and tapers	T1, R1,R2	2	Chalk & Talk, PPT
3	CO 3: Explain the concepts of limit gauges and optical measurements. [K2]	**Unit-3**				
		3.1	LIMIT GAUGES: Taylor's principles	T1, R1,R2	2	Chalk & Talk, Quiz,PPT
		3.2	design of GO and NO-GO gauges; plug, ring,	T1, R1,R2	2	Chalk & Talk, Quiz PPT
		3.3	snap, gap, taper, profile and position gauges, Problems on GO & NO-GO gauge	T1, R1,R2	4	Chalk & Talk, PPT, Active Learing
1st MID EXAMINATIONS						
		3.4	OPTICAL MEASURING INSTRUMENTS: Tools maker's microscope and uses	T1, R1,R2	2	Chalk & Talk, Tutorial, Web PPT
		3.5	Autocollimators, optical projector, optical flats and their uses.	T1, R1,R2	2	Chalk & Talk, PPT
		3.6	Need of inspection, surface testing,	T1, R1,R2	1	Chalk & Talk, PPT
		3.7	Surface finish, Laser instrumentation.	T1, R1,R2	2	Chalk & Talk,PPT
4	CO 4: Explain of various transducers to measure displacement (K2)	**Unit-4**				
		4.1	BASIC PRINCIPLES OF INSTRUMENTATION: Units and standards – Static measurements – Scale and pointer type instruments	T2, R3	2	Chalk & Talk, NPTEL,PPT
		4.2	Definition of range, sensitivity, hysteresis, accuracy, precision, reliability, repeatability, linearity, drift	T2, R3	2	Chalk & Talk, Web Resources, PPT
		4.3	Static and dynamic response, reproducibility, calibration procedure	T2, R3	2	Chalk & Talk, PPT
		4.4	Errors in measuring instruments, source of errors.	T2, R3	2	Chalk & Talk, Student Seminar,PPT
		4.5	MEASUREMENT OF DISPLACEMENT: Theory and construction of various transducers to measure displacement	T2,R3	2	Chalk & Talk, NPTEL, PPT
		4.6	- LVDT, piezoelectric, inductive, capacitance, resistance.	T2, R3	2	Chalk & Talk, PPT
5	CO 5. Analyze various temperature and pressure transducers for engineering applications (K4)	**Unit-5**				
		5.1	MEASUREMENT OF TEMPERATURE: Classification, ranges, various principles of Measurement, expansion	T2, R3	3	Chalk & Talk, PPT
		5.2	Electrical resistance, thermistor, thermocouple.	T2, R3	2	Chalk & Talk, PPT
		5.3	MEASUREMENT OF PRESSURE: Units - classification – different principles used. Manometers, piston	T2, R3	2	Chalk & Talk, PPT

		5.2	Electrical resistance, thermistor, thermocouple.	T2, R3	2	Chalk & Talk, PPT
		5.3	MEASUREMENT OF PRESSURE: Units - classification – different principles used. Manometers, piston	T2, R3	2	Chalk & Talk, PPT
		5.4	Bourdon pressure gauges, bellows - diaphragm gauges.	T2, R3	2	Chalk & Talk, PPT
		5.5	Low-pressure measurement, McLeod pressure gauge.	T2, R3	2	Chalk & Talk, PPT
			Total No. of Classes	**62**		
			2nd MID EXAMINATIONS			
			END EXAMINATIONS			

TEXT BOOKS:

T1. Engineering Metrology, Mahajan, DhanpatRai Publishers
T2. Measurement Systems Applications & design by D.S Kumar, Khanna Publishers.

REFERENCES:

R1. Engineering Metrology, R.K.Jain, Khanna Publishers
R2. Engineering Metrology by I.C.Gupta, DhanpatRai Publishers.
R3. Mechanical and Industrial Measurements, R.K. Jain, Khanna Publishers.

Faculty **HOD** **Principal**

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

CO-POs & CO-PSOs MAPPING (COURSE ARTICULATION MATRIX)

NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING
COURSE ARTICULATION MATRIX

R20-REGULATION

Explanation of Course Articulation Matrix Table to be ascertained:

- Course Articulation Matrix correlates the individual COs of a course with POs and PSOs.
- The Course Outcomes are mapped with POs and PSOs in the scale of 1 to 3.
- The strength of correlation is indicated as **3** for **Substantial (High)** correlation, **2** for **Moderate (Medium)** correlation, and 1 for **Slight (Low)** correlation.

II B.Tech I SEMESTER

Course Code: C213	Course Name: METROLOGY AND INSTRUMENTATION														
COs	POs & PSOs														
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
C213.1	3	2	-		-	-	-	-	-	-	-	-	3	-	2
C213.2	3	2	2	-	-	-	-	-	-	-	-	-	3	-	2
C213.3	3	2	-	-	-	-	-	-	-	-	-	-	3	-	2
C213.4	3	2	-		-	-	-	-	-	-	-	-	3	-	2
C213.5	3	2	-	-	-	-	-	-	-	-	-	-	3	2	2
C213	3.00	2.00	2.00	-	-	-	-	-	-	-	-	-	3.00	2.00	2.00

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

WEB REFERENCES

WEB SOURCE REFERENCES:

1	http://www.ktunotes.in/ktu-me312-metrology-instrumentation-notes/
2	https://lecturenotes.in/subject/239/engineering-metrology-and-measurements-emm
3	http://www.faadooengineers.com/threads/10095-Metrology-and-instrumentation-full-notes-ebook-free-download-pdf
4	https://nptel.ac.in/courses/112106179/
5	https://nptel.ac.in/courses/112106138/
6	https://nptel.ac.in/syllabus/112106179/
7	http://www.nptelvideos.in/2012/12/mechanical-measurements-and-metrology.html
8	https://freevideolectures.com/course/2370/mechanical-measurements-and-metrology
9	https://www.btechguru.com/engineeringvideos/video-lesson/mechanical-measurements-and-metrology/mechanical-engineering/ebe88124f0f00287~85e97a1e40ccaec9.html

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

STUDENT'S ROLL LIST

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) :: NARASARAOPET		
DEPARTMENT OF MECHANICAL ENGINEERING		
II B.Tech I Sem		
SECTION-A		
S.No	HTNo	Name of the Student
1	20471A0301	ALAVALA ADITHYA VARA PRASAD
2	20471A0302	BATTULA RAJESH
3	20471A0303	BHIMAVARAPU HEMANTH KUMAR
4	20471A0304	BONAM JAYA PRAKASH
5	20471A0305	BOYAPATI PAVAN KUMAR
6	20471A0306	DADDANALA VEERANJIREDDY
7	20471A0307	DERANGILA PARDHU GANESH
8	20471A0308	DOPPALAPUDI S S NAGA RAVITEJA
9	20471A0309	EEDARA MOHON SAI
10	20471A0310	GANESH SAI PAVAN
11	20471A0311	GANGARAPU VENKATA REDDY
12	20471A0312	GERA KOTESWARA RAO
13	20471A0313	KARASALA PRASANTH
14	20471A0314	KARASANI PAVAN KUMAR REDDY
15	20471A0315	KATTA MAHESWAR
16	20471A0317	KESARI DHANUNJAYA REDDY
17	20471A0318	KOMARAGIRI SASIKUMAR
18	20471A0319	KOMERA SIVA NAGARAJU
19	20471A0320	KOTHA GOPI
20	20471A0321	KUNDURTHI NAVEEN
21	20471A0323	MADANU JOSEPH VINAY KUMAR
22	20471A0324	MADDUMALA RAMAKRISHNA
23	20471A0325	MAGANTI SASI PAVAN
24	20471A0326	MAKKENA SAMBASIVA RAO
25	20471A0327	MIRIYALA SASHANK
26	20471A0328	NALLA ABHIRAM CHOWDARY
27	20471A0329	NUTHAKKI RAKESH
28	20471A0330	ARAVAPALLI SAI SRINIVAS
29	20471A0331	PALETI JOHN HOSANNA
30	20471A0332	PERUMAALLA SRIKANTH
31	20471A0333	POLURI KRISHNA CHAITHANYA

32	20471A0334	PONNAGANTI CHANDU HARSHA VARDHAN
33	20471A0336	PATHAN MEERA VALI
34	20471A0337	POTTIMURTHI PURNA CHANDRA RAO
35	20471A0338	PRUDHVI DURGA BHARATH CHANDAN
36	20471A0339	RAMAVATHU BADDUNAIK
37	20471A0341	SHAIK APPAPURAM MAHABOOB SUBHANI
38	20471A0342	SHAIK ASIF
39	20471A0343	SHAIK GANGARAM ABDUL RAHAMAN
40	20471A0344	SHAIK GULLAPALLI NAGURVALI
41	20471A0345	SHAIK LAL AHAMAD BASHA
42	20471A0346	SHAIK MAHAMMAD FAREED
43	20471A0347	SHAIK MAHAMMAD YUNUS
44	20471A0348	SHAIK MANISHA
45	20471A0349	SHAIK PARVEZ
46	20471A0350	SHAIK SADHIK
47	20471A0351	SHAIK SALMAN
48	20471A0352	TIPPIREDDY AMARNATHREDDY
49	20471A0353	VADLAVALLI GANESH
50	20471A0354	VEERAGANDHAM VENKATA MANIKANTA
51	20471A0356	ADAKA GOPIRAJU
52	20471A0357	ATCHYUTHA PAVAN KUMAR
53	20471A0358	BALLE RAMANJANEYULU
54	20471A0359	BANDARU SAI GANESH
55	20471A0360	BERAM NARENDRA REDDY
56	20471A0361	CHEBROLU MANIKANTA SAI NITHIN
57	20471A0362	CHENNAMSETTY GOPI
58	20471A0363	GANGULA SUNNY
59	20471A0364	GANJI HANUMA KOTI GANESH
60	20471A0365	GANNNAVARAPU JAYA SRIKANTH
61	20471A0366	GUTTIKONDA AYYAPPA REDDY
62	20471A0367	MADDINENI AJAY
63	20471A0368	MANNEPALLI VEERA NARASIMHA
64	20471A0369	MARAGANI NAGA THIRUMALA RAO
65	20471A0370	PARELLA BALA GURAVAIAH
66	20471A0371	SETLAM RANENDRA VAMSHI

67	20471A0372	SHAIK GUTHIKONDA SALIM
68	20471A0373	SHAIK JAKIR
69	20471A0374	SHAIK MOHAMMAD TAHEER
70	20471A0375	THOTA SRIVAMSI NADH
71	20471A0376	YAKKANTI SAI KIRAN REDDY
72	21475A0301	PALLAPOTHU SAIKIRAN YADAV
73	21475A0302	SYED SARDAR VALI
74	21475A0303	DERANGULA GOPI KRISHNA
75	21475A0304	VADDANI RAKESH
76	21475A0305	SHAIK ADIL
77	21475A0306	JANAPAREDDI PRASAD
78	21475A0307	REPALLE YASHWANTH
79	21475A0308	RAMAVATHU PAVAN KUMAR NAIK
80	21475A0309	NELAVALLI VIKAS
81	21475A0310	DUDDU JOSEPH
82	21475A0311	MUNIKOLA SANTHOSH KUMAR
83	21475A0312	MORAPAKULA CHARAN TEJA
84	21475A0313	GODA SANDEEP
85	21475A0314	MOGILI PRAKASH
86	21475A0315	SHAIK MABU SUBHANI
87	21475A0316	DAGGUPATI VENKATA PRADEEP
88	21475A0317	NAGASURENDRA CHARI UPPALAPATI
89	21475A0318	NALLURI NAVEEN
90	21475A0319	ORCHU VENKATA RAVINDRA
91	21475A0320	NELLURI YASWANTH
92	21475A0321	PENUMALA PAVAN KUMAR
93	21475A0322	BAANANA PRADEEP KUMAR
94	21475A0323	BOJANKI DEMUDU BABU
95	21475A0324	DATTI CHANDU
96	21475A0325	BORUGADDA NITHIN
97	21475A0326	VARIKUTI KARTHIK VENKATA RAM
98	21475A0327	GOLLA SUNDARA SAMRAJYA SUGNAN
99	21475A0328	CHATTA VENKATRAMAIAH
100	21475A0329	KSHATRIYA JITHENDRA SINGH
101	21475A0330	BOMMALI BALA SIVA YOGENDRA SAI NANDU

102	21475A0331	REVALLA SAI
103	21475A0332	BANDI SRINIVAS
104	21475A0333	GURRAM SIVA GANESH
105	21475A0334	EMANI LEELA SHANKAR
106	21475A0335	KUPPALA SRINU

NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

HAND WRITTEN/PRINTED LECTURE NOTES

UNIT-I

SYSTEMS OF LIMITS AND FITS

Introduction:-

Precision and Accuracy:

– Precision refers to repeatability

– Accuracy refers of result to the true value

• Accuracy can be found by

$$Accuracy = \sqrt{(\text{Repeatability})^2 + (Systematic\ error)^2}$$

where, systematic error =True value- mean of set of readings

Metrology is derived from a Greek word which means "measurement". It is the science of measurement and measurement is the language of science. But, for engineering purposes it has limited to the measurement of length, angles and other quantities that can be expressed in linear and angular terms. It is concerned with the methods execution and estimation of accuracy of measurements.

Metrology plays a vital role in the field of engineering for the designing and manufacturing of various engineering products. It is used for measuring the size, shape, etc. The products obtained should be in the limits of the specification with dimensional accuracy. In order to improve the process of manufacturing, it is required to develop the means of measurement. Every type of quantity measured must be followed by the units, which gives the correct meaning to the quantity measured.

Significance of Metrology:

(a) Metrology is very helpful in the scientific investigation of our dynamic world.

(b) It plays a critical role in the fields of chemistry, nanotechnology, etc.

(c) Metrology provides an infrastructure not only for physical and natural sciences but also exceeds to comprise environment, medicine, agriculture and food.

(d) Various higher level studies demonstrate the impact of measurement to the society.

LIMITS:-

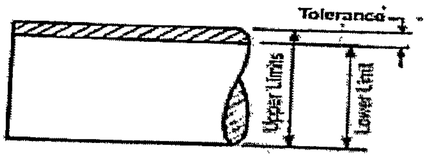
Limits can be defined as the permissible variation in dimension that is permitted to account for variability. Manufacturing process is a combination of three elements man, materials and machine. A change in any one or all of these will result in changes in sizes of manufactured parts. Usually in mass production, large number of components are to be made by different operators on different machines. So, it is impossible to make all components with exact dimensions.

The difference in dimensions vary from machine to machine, operator to operator and quality of the components. The dimension of the manufactured part can thus only be made to lie between two limits, maximum and minimum. The maximum limit is the maximum size permitted for the component whereas the minimum limit is the minimum size permitted for the component.

TOLERANCE:-

The permissible variation in size or dimension is called tolerance. Thus, the word tolerance indicates that a worker is not expected to produce the part to the exact size, but a definite small size error is permitted. The difference between the upper limit (high. limit) and the lower limit of a dimension represents the margin for variation in' workmanship, and is called a 'tolerance Zone'.

Tolerance can also be defined as the amount by which the job is allowed to go away from accuracy and perfectness without causing any functional trouble, when assembled with its mating part and put into actual service.



Tolerance

For example, a shaft of 25 mm basic size may be written as 25 ± 0.02. The maximum permissible size (upper limit) = 25.02 mm and the minimum permissible size (2000 limit) = 24.98 mm

Then, Tolerance = Uppor limit – Lower limit

= 25.02 – 24.98 = 0.04 mm.

Systems of Writing Tolerances:-

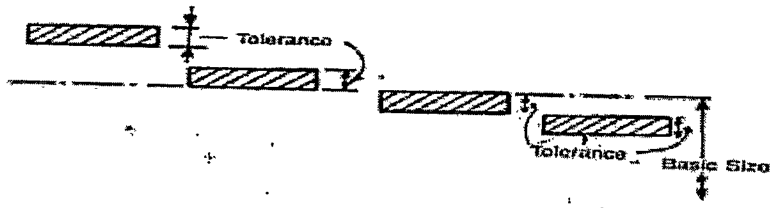
There are two systems of writing tolerances:

(i) Unilateral system

(ii) Bilateral system

(i) Unilateral System

In this system, the dimension of a part is allowed to vary only on one side of the basic size i.e., tolerance lies wholly on one side of the basic size either above or below it.



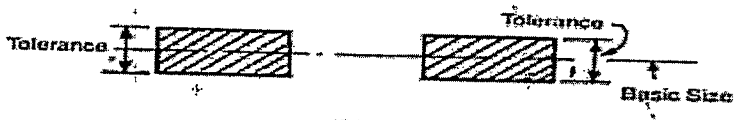
Unilateral Tolerance

Examples of unilateral tolerance are :

$25^{+0.02}_{+0.01}$, $25^{+0.02}_{-0.00}$, $25^{-0.01}_{-0.02}$, $25^{+0.00}_{-0.02}$ etc.

(ii) Bilateral system

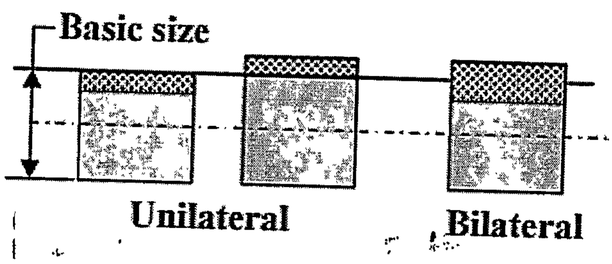
In this system, the dimension of the part is allowed to vary on both the sides of the basic size i.e., the limits of tolerance lie on either side of the basic size; but may not be necessarily equally disposed about it.



Bi-lateral tolerance.

e.g., $25^{\pm 0.02}$, $25^{+0.02}_{-0.01}$

In this system it is not possible to retain the same fit when tolerance is varied and .the basic size of one or both of the mating parts is to be varied. This system is used in mass production where machine setting is done for the basic size.



Advantages of Unilateral Dimensioning System:

1. Unilateral system of dimensioning is the easiest and simplest method to find the deviations.

2. It can standardize the 'Go' gauge ends without any difficulty.

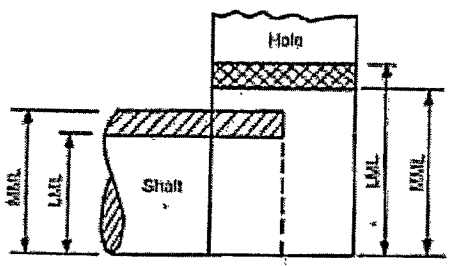
3. While machining the mating parts, the tolerance under this system facilitates the operator to a higher extent.

Advantage of Bilateral Dimensioning System:

This system is used in mass production, as the setting of machine for basic size is the main criteria.

Maximum and Minimum Metal Limits (or conditions):-

If the tolerance for the shaft is given as 25±0.05, the upper limit will be 25.05 mm and the lower limit will be 24.94 mm. The Shaft is said to have Maximum Metal Limit (MML) of 25.05 mm, since at this limit the shaft has maximum possible amount of metal. The limit of 24.95 will then be the minimum or "Least Metal Limit" (LML) because at this limit the shaft will have the least possible amount of metal.

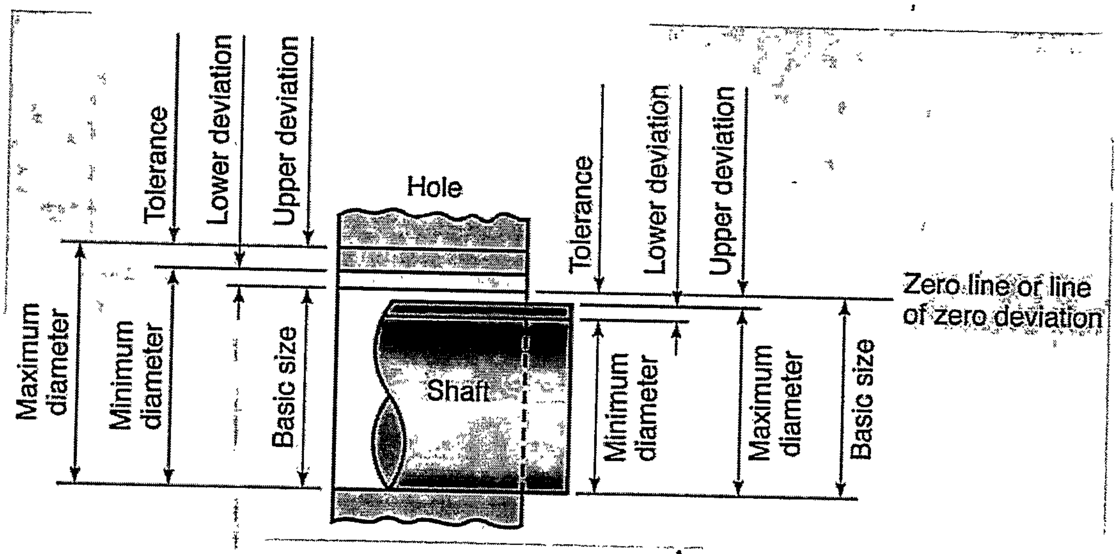


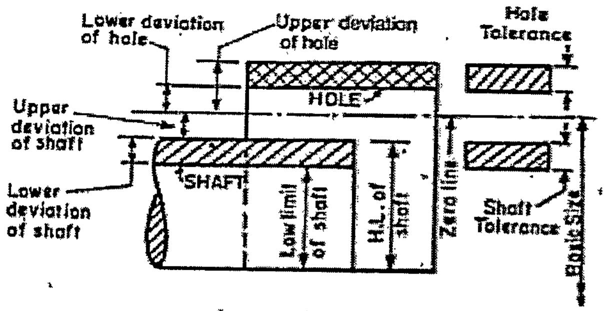
MML and LML

Similarly, if the hole is designated as 30±0.05mm, the upper limit will be 30.05 mm and the lower limit will be 29.95 mm. Then, the Maximum Metal Limit (MML) of hole will be equal to 29.95, since at this lower limit the hole has the maximum possible amount of metal; while the upper limit of 30.05 mm will be the minimum of 'Least Metal Limit' (LML) of hole as, at this limit the hole will have the least possible amount of metal.

Conventional Diagram of Limits and Fits:-

In the system of limits and fits, we are simply interested in the tolerance on shafts and holes and not in their sizes. Therefore, in the conventional simplified diagram the shaft is shown resting on the hole to make it easy to understand.





Conventional Diagram of Limits

Terminology for Limits and Fits:-

Basic or Nominal Size: It is the standard size of a part with reference to which the limits of variation of a size are determined. It is referred to as a matter of convenience. The basic size is the same for the hole and its shaft. It is the designed size obtained by calculations for strength.

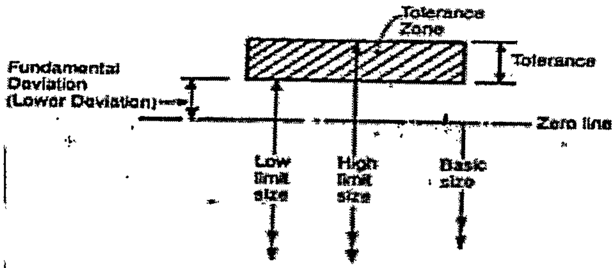
Zero line: It is a straight line drawn horizontally to represent the basic size. In the graphical representation of limits and fits, all the deviations are shown with respect to the zero line (datum line). The positive deviations are shown above the zero line and negative deviations below as shown in Fig (Conventional diagram of limits above).

Deviation: Deviation is the algebraic difference between the size (actual, maximum etc.) and the corresponding basic size.

Upper Deviation: It is the algebraic difference between the upper (maximum) limit of size and the corresponding basic size. It is a positive quantity when the maximum limit of size is greater than the basic size and a negative quantity when the upper limit of size is less than the basic size as shown in Fig. It is denoted by 'ES' for hole and 'es' for a shaft.

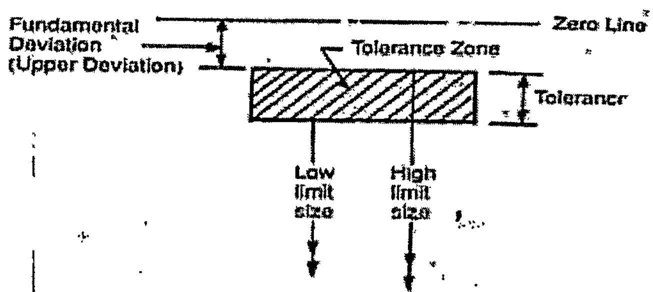
Lower Deviation: It is the algebraic difference between the lower limit of size and the corresponding basic size. It is a positive quantity when the maximum limit of size is greater than the basic size and a negative quantity when the lower limit of size is less than the basic size.

Fundamental Deviation: Fundamental deviation is that one of the two deviations (either the upper or the lower) which is the nearest to the zero line for either hole or a shaft. It fixes the position of the 'Tolerance Zone' in relation to the zero line as shown in Fig.



Lower deviation as fundamental deviation

The fundamental deviation for the hole is denoted by capital letters A, B, C,..... ZC and the same for shaft is denoted by small letters a, b, c zc etc. as explained later.



Upper deviation as fundamental deviation

From Fig it is clear that when the tolerance zone is above the zero line, lower deviation is the fundamental deviation. While, when the tolerance zone is below the zero line, upper deviation is the fundamental deviation.

FIT:-

Fit may be defined as a degree of tightness or looseness, between two mating parts to perform a definite function when they are assembled together.

The fit given the relationship between two mating parts that is shaft and hole. A fit can either provide a fixed joint or movable joint. For example a shaft running in a bearing can move in relation to it and thus forms a movable joint, whereas, a pulley mounted on the shaft forms a fixed joint.

Shaft: A term used by convention to designate all external features of a part, including those which are not cylindrical.

Hole: A term used by convention to designate all internal features of a part, including those which are not cylindrical.

Types of fits:-

On the basis of positive, zero and negative values of Clearance, there are three basic types of fits:

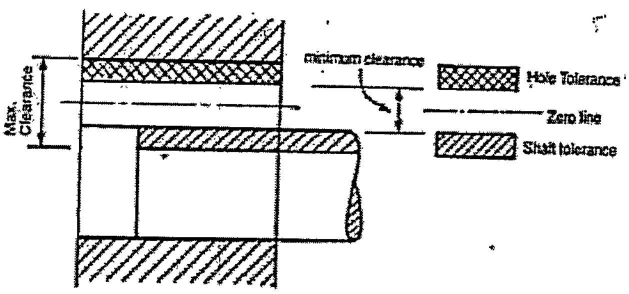
(1) Clearance Fit (2) Transition Fit and, (3) Interference Fit.

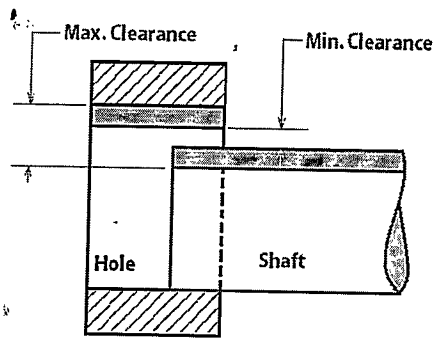
These are further classified in the following manner:

Fits

- ***Clearance Fit***
  - **(*a*) Slide Fit**
  - **(*b*) Easy slide Fit**
  - **(*c*) Running Fit**
  - **(*d*) Slack running Fit**
  - **(*e*) Loose running Fit**
- ***Transition Fit***
  - **(*a*) Push fit**
  - **(*b*) Wringing Fit**
- ***Interference Fit***
  - **(*a*) Force Fit**
  - **(*b*) Tight Fit**
  - **(*c*) Shrink fit**

(1) **Clearance Fit:** In this type of fit aha& is always smaller than the hole i.e., the largest permissible aha& diameter is smaller than the diameter of the smallest hole. So that the shaft can rotate or slide through with different degrees of freedom according to the purpose of mating part.





Clearance Fit

Clearance fit exists when the shaft and the hole are at their maximum metal conditions. The tolerance zone of the hole is above that of the shaft as shown in Fig.

Maximum Clearance: It is the difference between the minimum size of shaft and maximum size of hole.

Minimum Clearance: It is the difference between the maximum size of shaft and minimum size of hole.

i. Slide Fit: This type of fit has a very small clearance, the minimum clearance being zero. Sliding fits are employed when the mating parts are required to move slowly in relation to each other e.g., tailstock spindle of lathe, feed movement of the spindle quill in a drilling machine, sliding change gears in quick change gear box of a centre lathe etc. .

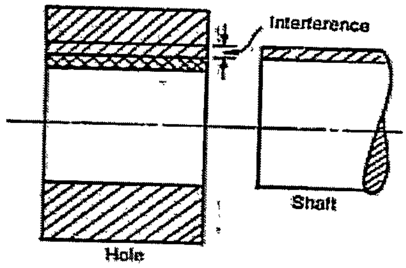
ii. Easy Slide Fit: This type of fit provides for a small guaranteed clearance. It serves to ensure alignment between the shaft and hole. It is applicable for slow and non-regular motion, for example, spindle of lathe and dividing heads, piston and slide valves, spigots etc.

iii. Running Fit: Running fit is obtained when there is an appreciable clearance between the ~mating parts. The clearance provides a sufficient space for a lubrication film between mating friction surfaces. It is employed for rotation at moderate speed, e.g., gear box bearings, shaft pulleys, crank shafts in their main bearings etc.

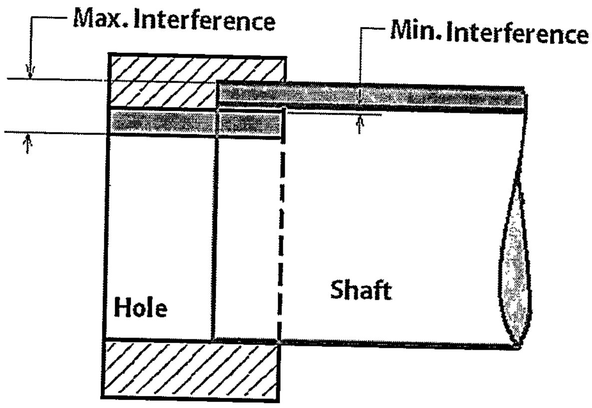
iv. Slack running Fit: It is obtained when there is a considerable clearance between the mating parts. This type of fit may be required as compensation for mounting errors e.g., arm shaft of I.C. engine, shaft of certifigual pump etc.

v. Loose running Fit: Loose running fit is employed for rotation at very high speed, eg., idle pulley on their shaft such as that used in quick return mechanism of a planer.

(2) Interference Fit: In this type of fit the minimum permissible diameter of the shaft is larger than the maximum allowable diameter of the hole. Thus the shaft and the hole members are intended to be attached permanently and used as a solid component.



Interference fit

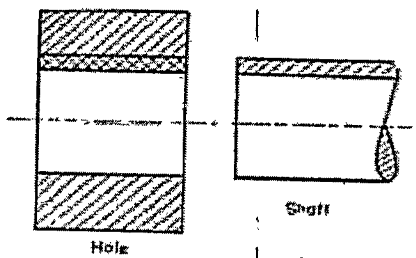


i. Force Fit: Force fits are employed when the mating parts are not required to be disassembled during their total service life. In this case the interference is quite appreciable and, therefore, assembly is obtained only when high pressure is applied. This fit, thus, offers a permanent type of assembly, e.g. , gears on the shaft of a concrete mixture, forging machine etc.

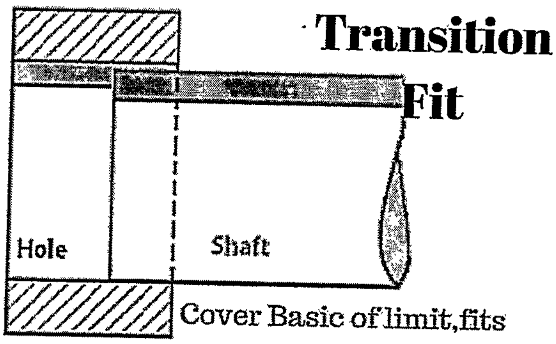
ii. Tight Fit: It provides less interference than force fit. Tight fits are employed for mating parts that may be replaced while overhauling of the machine, for example, stepped pulleys on the drive shaft of a conveyor, cylindrical grinding machine etc.

iii. Heavy force and Shrink Fit: It refers to maximum negative allowance. Hence considerable force is necessary for the assembly. The fitting of the frame on the rim can also be obtained first by heating the frame and then rapidly cooling it in its position.

(3) Transition Fit: Transition fit lies mid-way between clearance and interference fit. In this type the size limits of mating parts (shaft and hole) are so selected that either clearance or indifference may occur depending upon the actual sizes of the parts. Push fit and wringing fit are the examples of this type of fit.



Transition fit

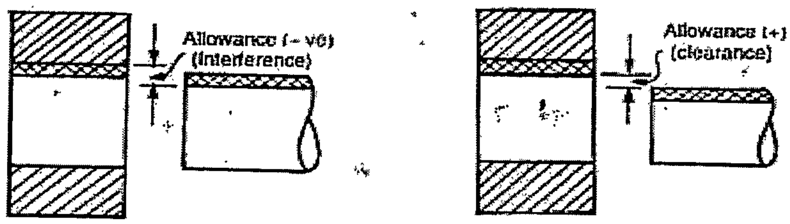


In this type of fit the tolerance zones of the hole and shaft overlap completely or in part.

i. Wringing Fit: A wringing fit provides either zero interference or a clearance. These are used where parts can be replaced without difficulty during minor repairs.

ii. Push Fit: The fit provides small clearance. It is employed for parts that must be disassembled during operation of a machine for example, change gears, slip bushing etc.

Allowance:



Allowance is the prescribed difference between the dimensions of two mating parts for any type of fit.

It is the intentional difference between the lower limit of hole and higher limit of the shaft. The allowance may be positive or negative.

The positive allowance is called clearance and the negative allowance is called interference.

Difference between Tolerance and Allowance:-

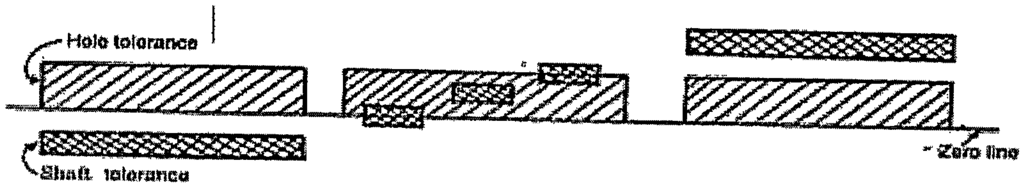
Tolerance	*Allowance*
1. It is the permissible variation in dimension of a part (either a hole or a shaft).	It is the prescribed difference between the dimensions of two mating parts (hole and shaft).
2. It is the difference between higher and lower limits of a dimension of a part.	It is the intentional difference between the lower limit of hole and higher limit of shaft.
3. The tolerance is provided on a dimension of a part as it is not possible to make a part to exact specified dimension.	Allowance is to be provided on the dimension of mating parts to obtain desired type of fit.
4. It has absolute value without sign.	Allowance may be positive (clearance) or negative (interference).

Systems of Obtaining Different Types of Fits:-

There are two systems of fit for obtaining clearance, interference or transition fit. These are:

(1) Hole basis system. (2) Shaft basis system.

(1) Hole basis system: In the hole basis system the hole is kept constant and the shaft sizes are varied to give the various types of fits. In this system lower deviation of the hole is zero i.e., the low limit of hole is the same as basic size. The high limit of hole and the two limits of size for the shaft are then varied to give the desired type of fit, as shown in Fig.

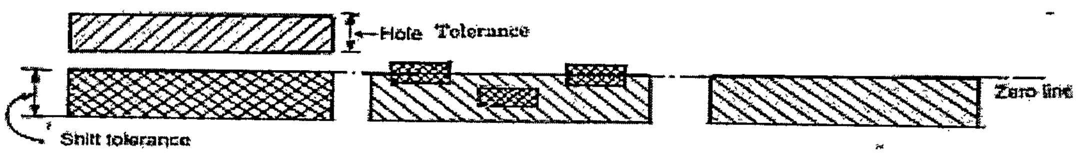


(a) Clearance Fit (b) Transition Fit (c) Interference Fit

Shaft basis System. In the shaft basis system the shaft is kept constant and the sizes of the hole are varied to give various types of fits.

In this system the upper deviation (fundamental deviation) of shaft is zero i.e., the high limit of shaft is the same as basic size and the various fits are obtained by varying the low limit of shaft and both the limits of hole.

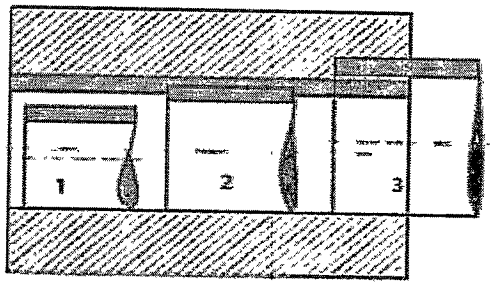
(2) Shaft basis system:



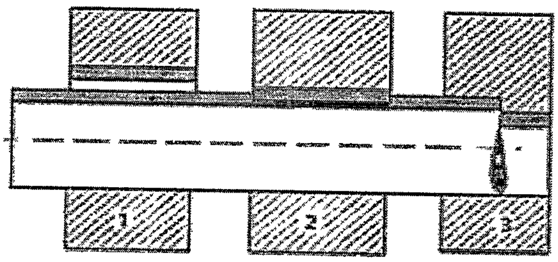
(a) Clearance Fit (b) Transition Fit (c) Interference Fit

The hole basis system is most commonly used because it is more convenient to make correct holes of fixed sizes, since the standard drills, taps, reamors and broaches etc. are available for producing holes and their sizes are not adjustable. On the other hand size of shaft produced by turning, grinding etc. can be very easily varied.

Shaft basis system is used when the ground bars or drawn bars are readily available. These bars do not require further machining and fit are obtained by varying the sizes of hole.



Hole Basis System



Shaft Basis System

1. Clearance 2. Transition 3.Interference

Difference between 'Hole Basis' and 'Shaft Basis' Systems:-

Hole Basis System	*Shaft Basis System*
1. Size of hole whose lower deviation is zero (H-hole) is assumed as the basic size.	Size of shaft whose upper deviation is zero (*h*-shaft) is assumed as basic size.
2. Limits on the hole are kept constant and those of shaft are varied to obtain desired type of fit.	Limits on the shaft are kept constant and those on the hole are varied to have necessary fit.
3. Hole basis system is preferred in mass production, because it is convenient and less costly to make a hole of correct size due to availability of standard drills and reamers.	This system is not suitable for mass production because it is convenient, time consuming and costly to make a shaft of correct size.
4. It is much more easy to vary the shaft sizes according to the fit required.	It is rather difficult to vary the hole sizes according to the fit required.
5. It requires less amount of capital and storage space for tools needed to produce shafts of different sizes.	It needs large amounts of capital and storage space for large number of tools required to produce holes of different sizes.
6. Gauging of shafts can be easily and conveniently done with adjustable gap gauges.	Being internal measurement, gauging of holes cannot be easily and conveniently done.

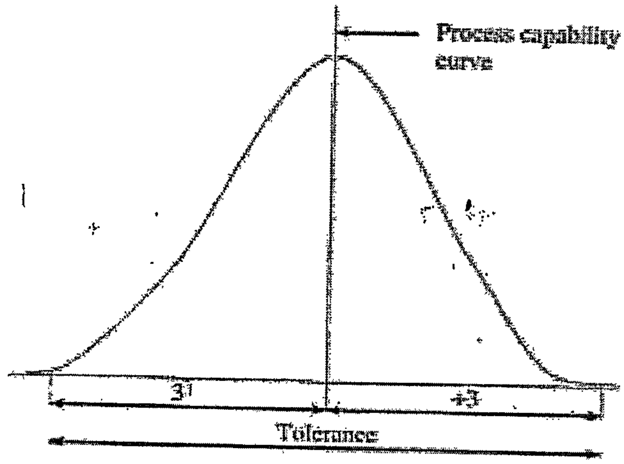
Types of Assemblies:-

There are three ways by which the mating parts can be made to fit together in the desired manner. These are:

(1) Trial and Error (2) Interchangeable Assembly (3) Selective Assembly

(1) Trial and Error: when a small number of similar assemblies are to be made by the same operator the necessary fit can be obtained by trial and error. This technique simply requires one part to be made to its nominal size as accurately as possible, the other part is then machined with a small amount at a time by trial and error until they fit in the required manner. This method may be used for "one off jobs", tool room work etc. where both parts will be replaced at once.

(2) Interchangeable Assembly:



It is a system of producing the mating parts in which large number of mating parts are produced. In earlier days, a single operator was confined with number of units and assemble it, which used to take long time and it was not economical. So to reduce the cost and time, mass production 'system was developed. In most production systems, the components are produced in one or more batches by different operations on different machines.

Advantages of Interchangeability:

1. This system reduces the production cost and increases the output

2. The operator need not Waste time in assembling the parts by trial and error method.

3. Worn out parts and defective parts can be easily replaced.

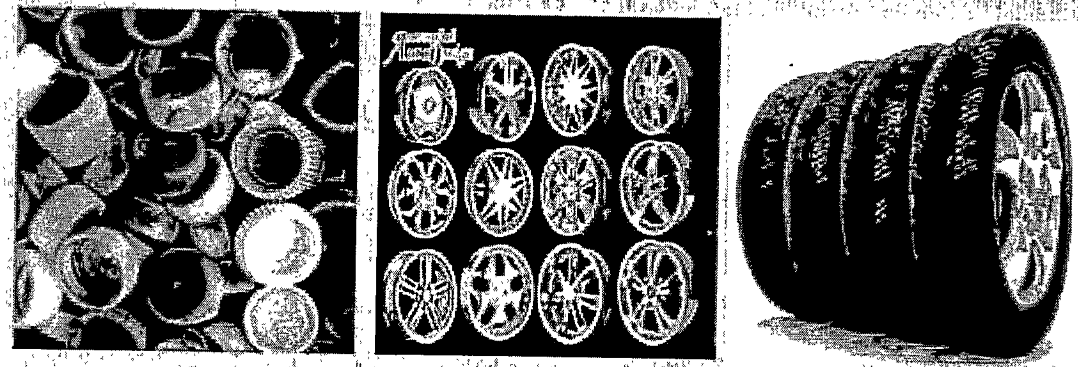
4. By this method, it is possible to produce mating parts at different places by different operators.

5. Maintenance cost and shut down period is reduced.

Example:

Any M6 bolt will fit to any M6 nut randomly selected.

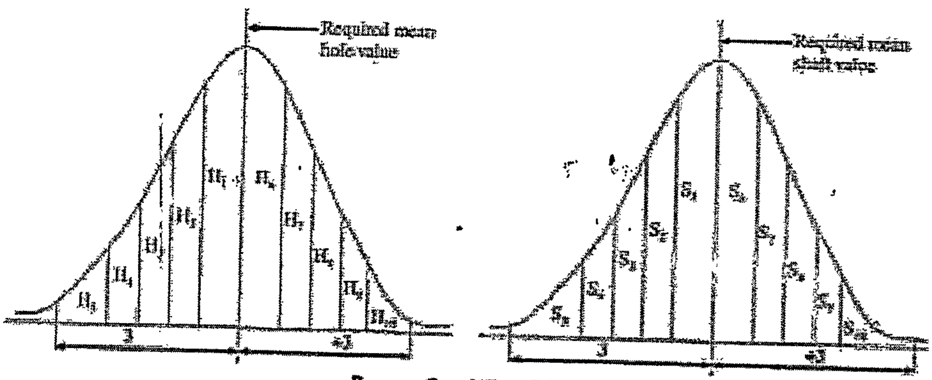
Examples of Interchangeable Manufacture



(3) Selective Assembly:

The need of the consumer is not only the quality, precision and trouble-free products but also the availability of products at economical prices. This is possible by automatic gauging for selective assembly. In this system, the parts are manufactured to rather wider tolerances and the products produced are classified into various groups according to their sizes by automatic gauging. Classification is made for formatting parts and only matched groups are assembled together.

If hole and shaft are to be produced with in a tolerance of 0.02 mm and both are in the curve of normal distribution, then automatic gauging divides 'them into parts with a 0.002 mm limit for selective assembly of individual pans. Consider an example of piston with cylinder. Let the size of the above be 60 mm and the clearance of 0. 12 mm is required for the assembly. Let the tolerance on bore and piston each be 0.04 mm. Then



Process Capability of Shaft and Hole

Dimension of bore diameter is $60^{\pm 0.12}$ mm and Dimension of piston is $59.88^{\pm 0.12}$ mm

The pistons and bores may be selected to give the clearance of 0.12 as given below.

Cylinder bore	59.98	60.00	60.02
Piston	59.86	59.88	59.90

What is the difference between international and British standards?

There are a few different standards, British standards, European Standards, American standards, Canadian....

The International Standards (IEC) are worldwide, European ones cover European countries and country specific ones cover that country. Many countries have similar standards.

The ones that cover larger areas (International and European) are used by the countries when they write their standards. An example might be BS EN numbered standards which are British standards that cover the requirements of the European standard. Some are country specific only (BS) and some cover international standards (IEC). It can be confusing but there should be a standard in each country to cover most engineering things.

The main difference is the geographical area that they cover. If you are say working in Britain and follow the BS requirements (or BS EN, or IEC) that applies then you can say that you are working to best practices and can't be faulted for that.

There will be small differences between them based on custom and practices for the countries

Indian Standard System of Limits and Fits (IS-919 and 2709)

The Indian standards are in line with the ISO (International Organizations for Standards) recommendations.

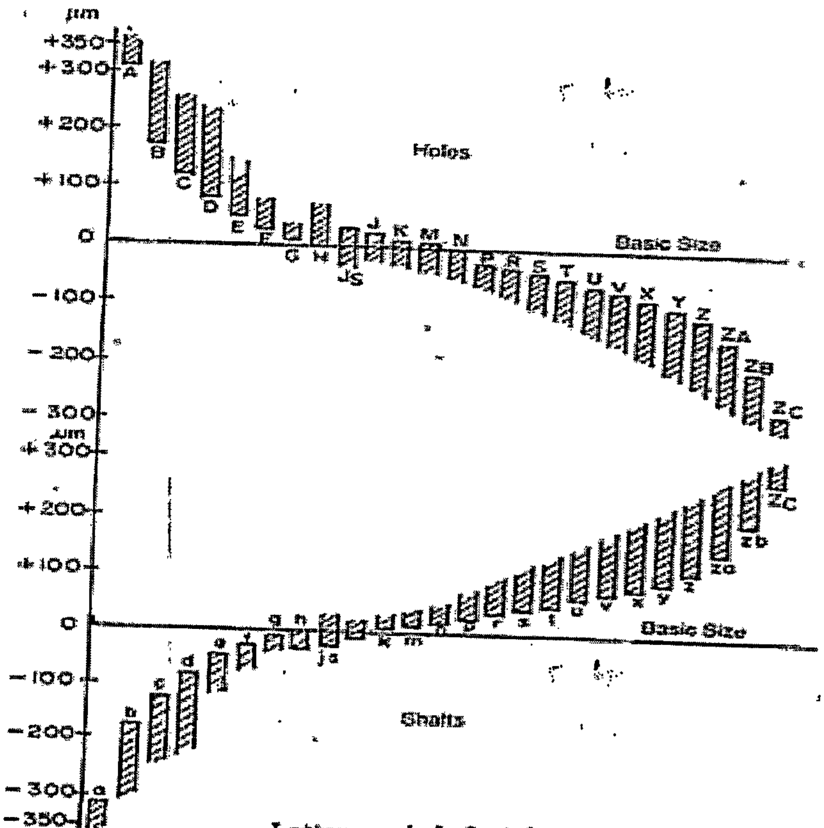
It consists of suitable combination of 18 grades of fundamental tolerances or in other words grades of accuracy for manufacture, and 25 types of fundamental deviations.

The 18 grades of fundamental tolerances are designated as IT01, IT0, IT1 to IT16. While, the fundamental deviations are indicated by letter symbols for both hole and shaft (capital letters 'A to Zc' for holes and small letters a to z_c for shafts. These are : A, B, C, D, E, F, G, H, J_S, J, K, M, N, P, R, S, T, U, V, X, Y, Z , Z_A, Z_B, Z_C).

Innumerable fits ranging from extreme clearance to those of extreme interference can be obtained by a suitable combination of fundamental tolerances and fundamental deviations. Each of 25 holes has a choice of 18 tolerances.

For shafts '*a*' to '*h*' the upper deviation is below the zero line and for shafts '*j*' to '*Zc*' it is above the zero line.

For holes '*A*' to '*H*' lower deviation is above the zero line and for J to Zc it is below the zero line as shown in Fig.



Letter symbols for tolerances (Diameter 30-40 mm)

Grades of Tolerance:

Grade of Tolerance: It is an indication of the level of accuracy. There are 18 grades of tolerances – IT01, IT0, and IT1 to IT16

IT01 to IT4 - For production of gauges, plug gauges, measuring instruments

IT5 to IT 7 - For fits in precision engineering applications

IT8 to IT11 – For General Engineering

IT12 to IT14– For Sheet metal working or press working

IT15 to IT16 – For processes like casting, general cutting work

Standard Tolerance: Various grades of tolerances are defined using the 'standard tolerance unit', (i) in µm, which is a function of basic size.

$$i = 0.45\sqrt[3]{D} + 0.001D$$

where, D (mm) is the geometric mean of the lower and upper diameters of a particular diameter step within which the chosen the diameter D lies.

Diameter steps in I.S.I are: (a-b, where a is above and b is up to, Refer Table in the following sheet)

1-3, 3-6, 6-10, 10-18, 18-30, 30-50, 50-80, 80-120, 120-180, 180-250, 250-315, 315-400 and 400-500 mm

It is understood that the tolerances have parabolic relationship with the size of the products. As the size increases, the tolerance within which a part can be manufactured also increases.

IT01 – 0.3 + 0.008D

IT0 – 0.5 + 0.012 D

IT1– 0.8 + 0.020D

Grades of Tolerance

IT2 to IT4 – the values of tolerance grades are placed geometrically between the tolerance grades of IT1 and IT5.

IT6 – 10 i; IT7 – 16i; IT8 – 25i; IT9 – 40i; IT10 – 64i; IT11 – 100i; IT12 –160i; IT13 – 250i; IT14 – 400i; IT15 – 640i; IT16 – 1000i.

Problems:-

EXAMPLE 1. Find the values of allowance, and tolerances for hole and shaft assembly for the following dimensions of mating parts :

Hole : $25^{+0.05}_{+0.00}$ Shaft : $25^{-0.02}_{-0.05}$

SOLUTION.

(*i*) Hole : Tolerance = High limit − Low limit

= 25.05 − 25 = 0.05 mm

(*ii*) Shaft : Tolerance = High limit − Low limit

Now, High limit = 25 − 0.02 = 24.98 mm

Low limit = 25 − 0.05 = 24.95 mm

∴ Tolerance = 24.98 − 24.95 = 0.03 mm

(*iii*) Allowance = Low limit of hole − High limit of shaft

= Maximum metal condition of hole − Maximum metal condition of shaft

= 25.00 − 24.98 = 0.02 mm

EXAMPLE 2. A 50 mm diameter shaft is made to rotate in the bush. The tolerances for both shaft and bush are 0.050 mm. Determine the dimension of the shaft and the bush to give a maximum clearance of 0.075 mm with the hole basis system.

SOLUTION. In the hole basis system lower deviation of hole is zero therefore low limit of hole = 50 mm

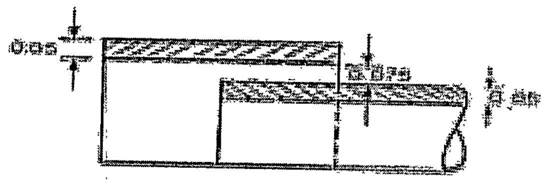


Fig. 6.44.

High limit of hole = Low limit + Tolerance

= 50.00 + 0.050 = 50.050 mm

High limit of shaft = Low limit of hole − Allowance

= 50.00 − 0.075 = 49.925 mm

Low limit of shaft = High limit − Tolerance

= 49.925 − 0.050 = 49.875 mm

Problem:

Evaluate limits and fits for a pair of – Diameter 6 H7/g6

Solution: The size 6 mm lies in the diametral step of 3-6, therefore, D is given by –

$$D = \sqrt{3 \times 6} = 4.24 mm$$

The value of fundamental tolerance unit is given by –

$$i = 0.45\sqrt[3]{D} + 0.001D$$

$$i = 0.45\sqrt[3]{4.24} + 0.001 \times 4.24$$

$$i = 0.7327 \mu m$$

Limits of tolerance for hole H7

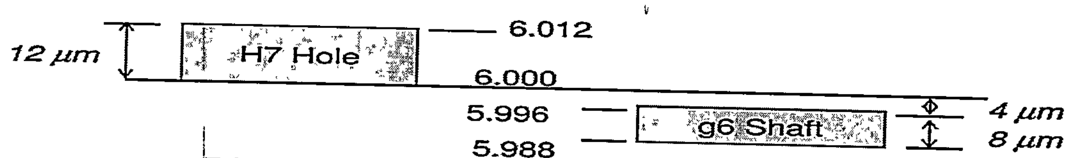
The standard tolerance is – 16 i = *16x0.7327 = 11.72 = 12* μm

The fundamental deviation H hole is – 0

Limits of tolerance for g6 shaft

The standard tolerance is – 10 i *10x0.7327 = 7.327 = 8* μm

Fundamental deviation for g shaft $= -2.5D^{0.34} = -2.5(4.24)^{0.34} = -4.085 = -4 \mu m$



Disposition of tolerance zone around the zero line

Fit

Maximum clearance = Maximum size of hole - Minimum size of shaft

= 6.012 – 6.988 = 0.024 mm = 24 μm

Minimum clearance = Minimum size of hole - Maximum size of shaft

= 6.000 - 6.996 = 0.004 mm = 4 μm

The type of fit is Clearance.

Problem:

Calculate the limits of sizes for ϕ 20 P7/h6 and identify the fit.

Therefore, D is given by –

$$D = \sqrt{18 \times 24} = 20.78 mm$$

The fundamental tolerance unit i is given by –

$$i = 0.45\sqrt[3]{20.78} + 0.001 \times 20.78 = 1.258 \mu m$$

Limits evaluation for P7 Hole

The fundamental deviation for p shaft is – IT7 + 0 to 5

The fundamental deviation P7 hole – IT6 + 0 to 5 =10 i + 5

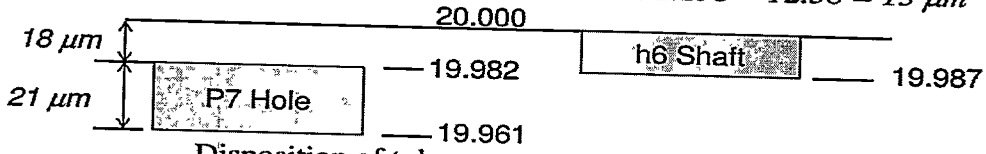
$$10 \times 1.258 + 5 = 17.58 = 18 \mu m$$

For grade 7 the standard tolerance is – 16 i = *16x1.258 = 20.128 = 21* μm

Limits evaluation for h6 Shaft

The fundamental deviation for h shaft is – 0

For grade 6 the standard tolerance is – 10 $i = 10x1.258 = 12.58 = 13\ \mu m$



Disposition of tolerance zone around the zero line

Fit

Maximum clearance = Maximum size of hole - Minimum size of shaft

= 19.982 – 19.987 = - 0.005 = - 5 μm

Maximum Interference = Minimum size of hole - Maximum size of shaft

= 19.961 - 20.000 –= - 0.039 mm = - 39 μm

The fit is Interference. But it can become Transition if you choose some value of FD for p shaft between IT7 + 1 to 5 μm

Problem:

Calculate the limits of tolerance and allowance for a 25 mm shaft and hole pair designated by H8d9.

Solution

25 mm diameter lies in the standard diameter step of 18-30 mm

$D=\sqrt{18 \times 30}=23.238$

Fundamental tolerance unit = $i = 0.45\sqrt[3]{D} + 0.001D$

$i = 1.307\ \mu$

For H8 hole

Fundamental tolerance (tolerance grade table) = 25i = 32.5~33μ =0.033 mm

For 'H' Hole, fundamental deviation is 0 (from FD Table)

Hence, hole limits are 25 mm and 25+0.033 = 25.033 mm

Hole Tolerance = 25.033 – 25 = 0.033 mm

For d9 shaft

Fundamental tolerance, (tolerance grade table) = 40i = 40 x 1.3 =52 μ = 0.052 mm

For 'd' shaft, fundamental deviation (from FD Table) = $-16D^{0.44}$ = - 0.064 mm

Hence, shaft limits are 25 – 0.064 =24.936 mm and 25 – (0.064+0.052) =24.884 mm

Shaft Tolerance = 24.936 – 24.884 = 0.052 mm

Problem:

2. Determine the tolerance on the hole and the shaft for a precision running fit designated by 50 H7g6.

Given: 1) 50 mm lies between 30- 50 mm

2) i (microns) = $0.45D^{1/3} + 0.001D$

3) Fundamental deviation for 'H' hole = 0

4) Fundamental deviation for 'g' shaft = $-2.5D^{0.34}$

5) IT7 = 16i and IT6 = 10i

State the actual maximum and minimum sizes of the hold and shaft and maximum and minimum clearance.

Solution

50 mm diameter lies in the standard diameter step of 30-50 mm

$D = \sqrt{30 \times 50} = 38.7$ mm

Fundamental tolerance unit = i (microns) = $0.45D^{1/3} + 0.001D = 1.5597\ \mu$

For H7 hole

Fundamental tolerance (tolerance grade table) = 16i = 24.9μ = 0.025 mm

For 'H' Hole, fundamental deviation is 0 (from FD Table)

Hence, hole limits are. $50^{+0.025}_{-0.000}$ mm

For g6 shaft

Fundamental tolerance (tolerance grade table) = 10i = 16μ = 0.016 mm

For 'g' shaft, fundamental deviation is $-2.5D^{0.34} = 9\ \mu$

Hence, shaft limits are. $50^{-0.009}_{-0.025}$ mm

Hole Tolerance = 25.033 − 25 = 0.033 mm

Maximum clearance = 50.025 - 49.975 = 0.05 mm

Minimum clearance = 50.000 - 49.991 = 0.009

Problem:

Calculate the Tolerances, Fundamental Deviation and limits of sizes for the hole and Shaft designated to 25H8/d9. The basic size is lies between 18 and 30.

Solution:

This means the basic size is 25 and the tolerance grade for the hole is 8(i.e IT8) and the shaft tolerance grade is 9 (i.e. IT9)

The geometric mean diameter is

D =√ (18×30) = 23.24 mm

The standard tolerance unit is

$$i = 0.45\sqrt[3]{D} + 0.001\ D$$

∴ Where D =The geometric mean diameter

$i = 0.45\ \sqrt[3]{(23.24)} + 0.001 \times 23.24$

$i = 0.45 \times 2.854 + 0.02324$

$i = 1.3074$ (In microns)

i = 1.3074 x .001 = 0.0013074 mm

The relative magnitudes for the tolerance grades from the below table

Tolerance Grade	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
Magnitude	7i	10i	16i	25i	40i	64i	100i	160i	250i	400i	640i	1000i

Tolerances for Hole grade (IT8) = 25*i* = 25 x 0.0013074 = 0.033mm

Tolerances for Shaft grad (IT9) = 40i = 40 x 0.0013074 = 0.052mm

Fundamental Deviation Calculations for the Hole

In this case, The designated hole is "H"

The Lower deviation (EI) of the hole always be zero

$EI = 0$

The upper deviation is represented by ES

$\therefore$ Where $EI = ES - IT$ (or) $ES = EI + IT$

$ES = 0 + 0.033$ ($\therefore$ where in this case grade 8 = 0.033mm from above)

$ES = 0.033$mm

<u>Therefore Hole tolerance can be calculated as</u>

The lower limit for the hole = Basic size + Hole Lower deviation = 25 + 0 = **25.000**mm

The upper limit for the hole = Basic size + Hole Upper deviation = 25+ 0.033 = **25.033**mm

Fundamental Deviation Calculations for the Shaft

From the above table, the upper deviation (*es*) for the shafts is = $-16\,(D)^{0.44}$

$es = -16\,(23.24)^{0.44}$

$es = -16 \times 3.9915$

$es = -63.86$ microns

$es = -63.86 \times 0.001$ mm

$es = -0.064$mm

The lower deviation (*ei*) can be calculated form the following relation

$ei = es - IT$ (or) $es = ei + IT$

$ei = -0.064 - 0.052$

$ei = -0.116$mm

Therefore Shaft tolerance can be calculated as

The lower limit for the Shaft = Basic size + Shaft Lower deviation = 25 + (-0.116) = **24.884**mm

The upper limit for the Shaft = Basic size + Shaft Upper deviation = 25+ (-0.064) = **24.936**mm

Unit – II

METROLOGY

Introduction:

Linear measurement applies to measurement of

- Length, Diameters, Heights, Thickness, Internal & External measurements.

These have series of accurately spaced lines (for example a **scale**).

Linear measuring instruments are designed either for:

- ❖ Line measurement
- ❖ End measurement

Linear instruments can be classified as:

1. Direct measuring instruments
2. Indirect measuring instruments

Direct measuring instruments:

i. Graduated
ii. Non-graduated instruments

Graduated instruments include of:

- Rules
- Vernier callipers
- Height gauges
- Depth gauges
- Micrometres
- Dial indicators

Non-graduated instruments include of:

- Callipers
- Straight edges
- Slip gauges
- Radius gauges

The different types of standards of length are:

1. **Materials standards:**
   a. **Line standard**: when length is measured as the distance between centres of two engraved lines.
      Ex: scale, rulers.

b. **End standard**: when length is measured as the distance between to flat parallel faces. **Ex**: slip gauges

Characteristics of line standards:

- Scale can be accurately embalmed, but the engraved lines posses' thickness and it is not possible to accurately measure.
- Scale is used over a wide range.
- Scale markings are subjected to wear. However, the ends are subjected to wear and this leads to undersize measurements.
- Scales are subjected to parallax error.

Steel Rule:

It is the simplest and most common measuring instruments in inspection. The principle behind steel rule is of comparing an unknown length to the one previously calibrated. The rule must be graduated uniformly throughout its length. Rules are made in 150, 300, 500 and 1000 mm length. There are rules that have got some attachment and special features with them to make their use more versatile. They may be made in folded form so that they can be kept in pockets. The degree of accuracy when measurements are made by a steel rule depends upon the quality of the rule, and the skill of the user in estimating part of a millimetre.

Calipers:

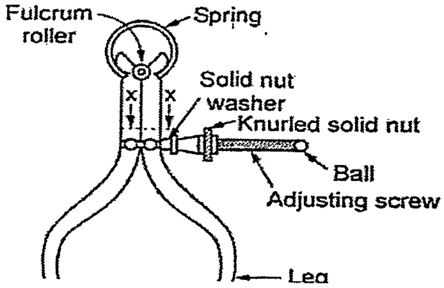
Calipers are used for measurement of the parts, which cannot be measured directly with the scale. Thus, they are accessories to scales. The calipers consist of two legs hinged at top, and the ends of legs span part to be inspected. This span is maintained and transferred to the scale.

Calipers are of two types: **spring type** and firm **joint type**.

Outside Spring Calipers

These are designed to measure outside dimensions. The accuracy in caliper measurement depends upon the inspectors' sense of feel. The legs are held firmly against the end of the proper dimensions by adjusting nut with the thumb and forefinger. For accurate settings, the distance between the outside calipers may be set by slip gauges or by micrometer anvils.

Figure 5.1 shows the diagrams of Outside spring calipers. A steel rule must be used in conjunction with them if a direct reading is desired.



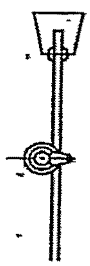


Figure: Outside Spring Caliper

Inside Spring Calipers:

They are designed to measure the inside dimensions. An inside spring caliper is exactly similar to an outside caliper with its legs bent outward as shown in Figure. Adjustment in them is generally made by knurled solid nut. They are used for comparing or measuring hole diameters, distances between shoulders, or other parallel surfaces of any inside dimensions. To obtain a specific reading, steel scale must be used as with the outside calipers.

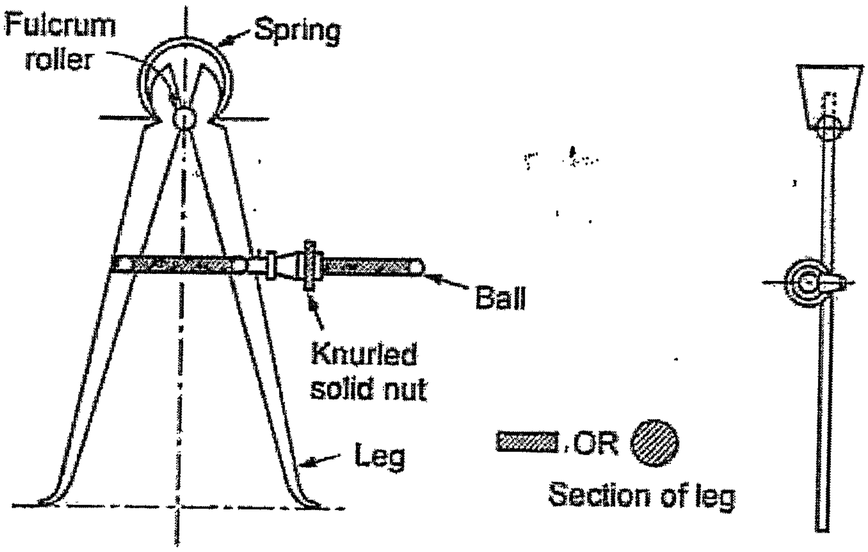


Figure: inside micrometere

Depth gauge:

This tool is used to measure the depth of blind holes, grooves, slots, the heights of shoulders in holes and dimensions of similar character. This is essentially a narrow steel rule to which a sliding head is clamped at the right angles to the rule as shown in Figure. The head forms a convenient marker in places where the rule must be held in a distance from the point being measured.

The depth gauge is made precisely so that the beam is perpendicular to the base in both directions. The end of the beam is square and flat like the end of the steel rule and the base is flat and true, free from curves or waviness.

It has the advantage of having a large measuring range without having to resort to the use of extension rods as compared to depth micrometer.

Following are the different parts of Vernier depth gauge:

1. Main scale
2. Vernier scale
3. Locking screw
4. Fine adjustment screw
5. Movable head
6. Measuring face

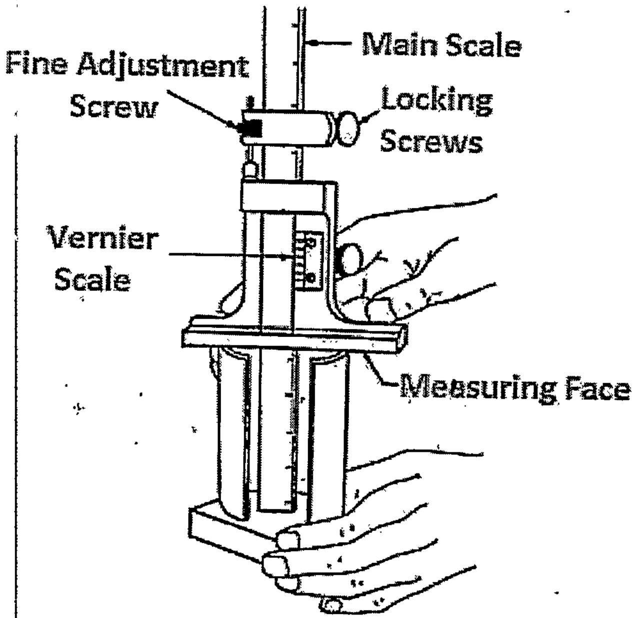


Figure: Vernier depth gauge

Vernier height gauge:

In the Vernier height gauge, the graduated scale or bar is held in a vertical position by a finely ground and lapped base. A precision ground surface plate is mandatory while using a height gauge.

□The feature of the job to be measured is held between the base and the measuring jaw. The measuring jaw is mounted on the slider which moves up and down, but held in place by tightening of a nut. A fine adjustment clamp is provided to ensure very fine movement of the slide in order to make a delicate contact with the job. □The main scale in a height gauge is stationary while the slider moves up and own.

The Vernier scale mounted on the slider gives readings up to an accuracy of 0.01mm.

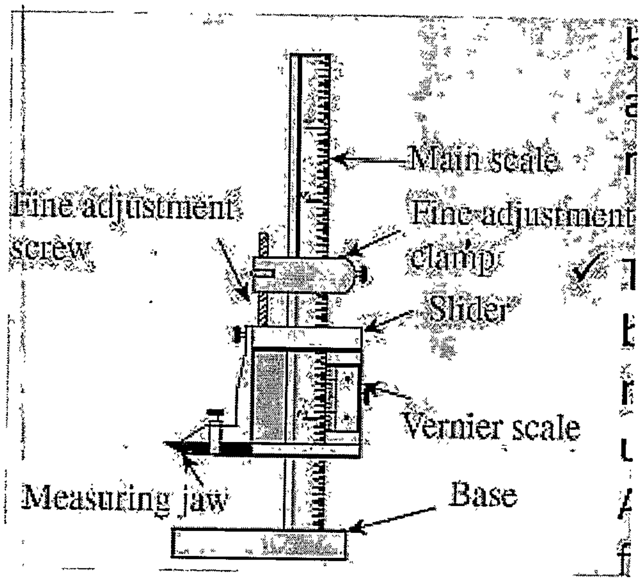


Figure: Vernier Height gauge

Characteristics of End standard:

- Highly accurate and used for measurement of closed tolerances in precision engineering as well as standard laboratories, tool rooms, inspection departments.
- They require more time for measurement and measure only one dimension.
- They wear at their measuring faces.

Micrometers:

Micrometer is one of the most widely used precision instruments. It is primarily used to measure external dimensions like diameters of shafts, thickness of parts etc. to an accuracy of 0.01 mm. The essential parts of the instruments shown in Figure consist of

(a) Frame
(b) Anvil and spindle
(c) Screwed spindle
(d) Graduated sleeve or barrel
(e) Thimble
(f) Ratchet or friction stop
(g) Spindle clamp

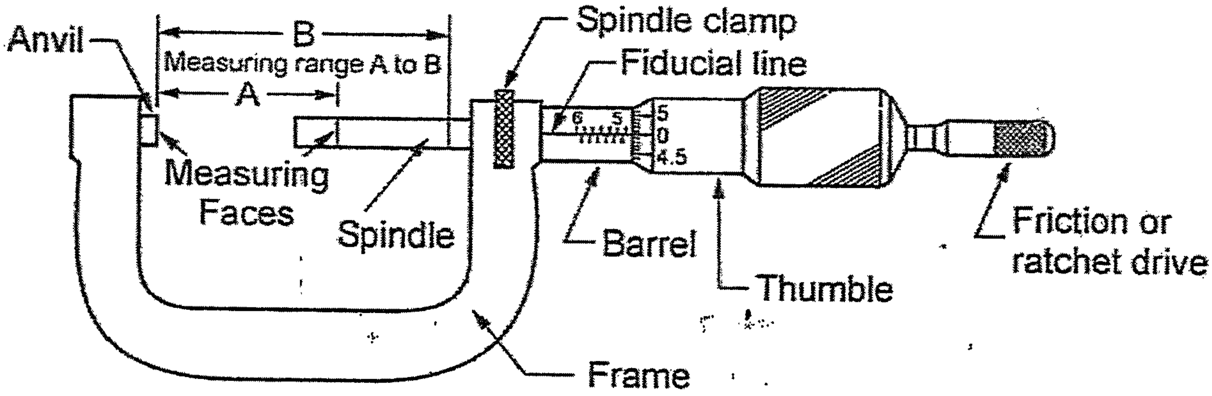


Figure: outside micrometer

The *frame* is made of steel, malleable cast iron or light alloy. The anvil shall protrude from the frame for a distance of at least 3-mm in order to permit the attachment of measuring wire support. The *spindle* does the actual measuring and possesses the threads of 0.5 mm pitch. The *barrel* has datum and fixed graduations *Thimble* is tubular cover fastened with the spindle. The bevelled edge of the spindle is divided into 50 equal parts, every fifth being numbered. *The ratchet* is a small extension to the thimble. It slips when the pressure on the screw exceeds a certain amount. It produces uniform reading and prevents damage or distortion of the instruments. The *spindle clamp* is used to lock the instrument at any desired setting.

Procedure for Reading in a Micrometer:

The graduation on the barrel is in two parts divided by a line along the axis of the barrel called the reference line. The graduation above the reference is graduated in 1 mm intervals. The first and every fifth are long and numbered 0, 5, 10, 15, etc. The lower graduations are marked in 1 mm intervals but each graduation shall be placed at the middle of the two successive upper graduations to be read 0.5 mm.

The thimble advances a distance of 0.5 mm in one complete rotation. It is called the pitch of the micrometer. The thimble has a scale of 50 divisions around its circumference. Thus, one smallest division of the circular scale is equivalent to longitudinal movement of 0.5 □ 1/50 mm = 0.01mm. It is the least count of the micrometer.

The job is measured between the end of the spindle and the anvil that is fitted to the frame. When the micrometer is closed, the line marked zero on the thimble coincides with the line marked zero on the barrel. If the zero graduation does not coincide, the micrometer requires adjustment.

To take a reading from the micrometer, (1) the number of main divisions in millimetres above the reference line, (2) the number of sub-divisions below the reference line exceeding only the upper graduation, and (3) the number of divisions in the thimble have to be noted down. For example if a micrometer shows a reading of 8.78 mm when

8 divisions above the reference line	= 8.00 mm
1 division below the reference line	= 0.50 mm
28 thimble divisions	= 0.28 mm
	8.78 mm

Inside Micrometer Caliper:

The measuring tips of inside micrometer are constituted by jaws with contact surface, which are hardened and ground to a radius. Unlike the conventional micrometer, an inside micrometer does not have any U-shape frame and spindle.

One of the jaws is held stationary at the end and second one moves by the movement of the thimble. A locknut is provided to check the movement of the movable jaw. This facilitates the inspection of small internal dimension.

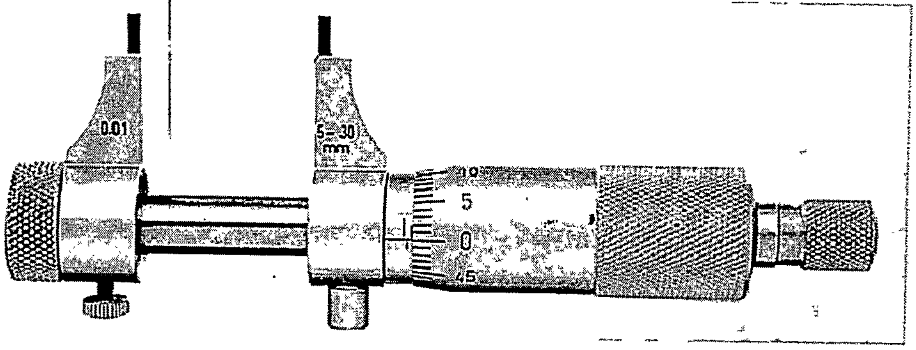


Figure: Inside micrometer

The inside micrometer is intended for internal measurement to an accuracy of 0.001 mm. In principle, it is similar to an external micrometer and is used for measuring holes with a diameter over 50 cm.

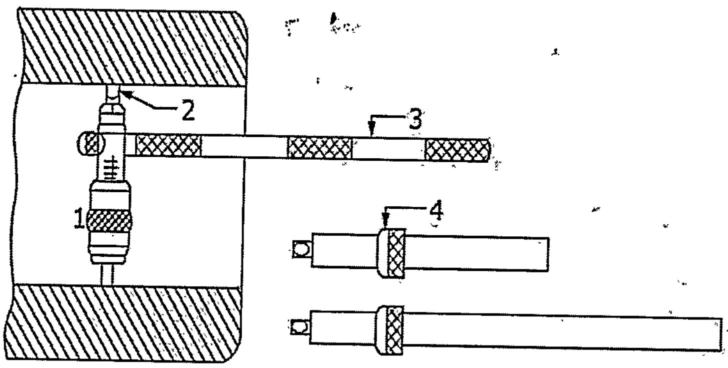
It consists of:

- Measuring unit
- Extension rod with or without spacing collar, and
- Handle.

When the micrometer screw is turned in the barrel, the distance between the measuring faces of the micrometer can vary from 50 to 63 mm. to measure the holes with a diameter over 63 mm, the micrometer is fitted with extension rods. The extension rods of the sizes 13, 25,50,100,150,200 and 600 mm are in common use.

The measuring tips of inside micrometer are constituted by jaws with contact surface, which are hardened and ground to a radius. Unlike the conventional micrometer, an inside micrometer does not have any U-shape frame and spindle. One of the jaws is held stationary at the end and second one moves by the movement of the thimble. A locknut is provided to check the movement of the movable jaw. This facilitates the inspection of small internal dimension.

(1) Micrometer
(2) Anvil
(3) Handle
(4) Extension Rod



- The measuring screw has a pitch of 0.5 mm. The barrel or sleeve is provided with a scale of 13 mm long and graduated into half-millimeter and millimeter divisions as in the external micrometer.

- A second scale is engraved on the beveled edge of the thimble. The beveled edge of the thimble is divided into 50 scale divisions roundv the circumference.
- Thus, on going through one complete turn, the thimble moves forward or backward by a thread pitch of 0.5 mm, and one division of its scale is, therefore, equivalent to a movement of 0.5 X1/50 = 0.01 mm.

Dial indicator or dial gauge:

Dial indicators are small indicating devices using mechanical means such as gears and pinions or levers for magnification system. They are basically used for making and checking linear measurements. - Many a times they are also used as comparators. Dial indicator, in fact is a simple type of mechanical comparator. - When a dial indicator is used as an essential part in the mechanism any set up for comparison measurement purposes; it is called as a gauge. - The dial indicator measures the displacement of its plunger or a stylus on a circular dial by means of a rotating pointer. - Dial indicators are very sensitive and versatile instruments. - They require little skill in their use than other precision instruments, such as micrometer vernier callipers, gauges etc. However, a dial indicator by itself is not of much unless it is properly mounted and set before using for inspection purposes.

Uses:

By mounting a dial indicator on any suitable base and with various attachments, it can be used for variety of purposes as follows.

1. Determining errors in geometrical forms, e.g., ovality out-of-roundness, taper etc.

2. Determining positional errors of surfaces, e.g., in squareness, parallelism, alignment etc.

3. Taking accurate measurements of deformation (extension compression) in tension and compression testing of material.

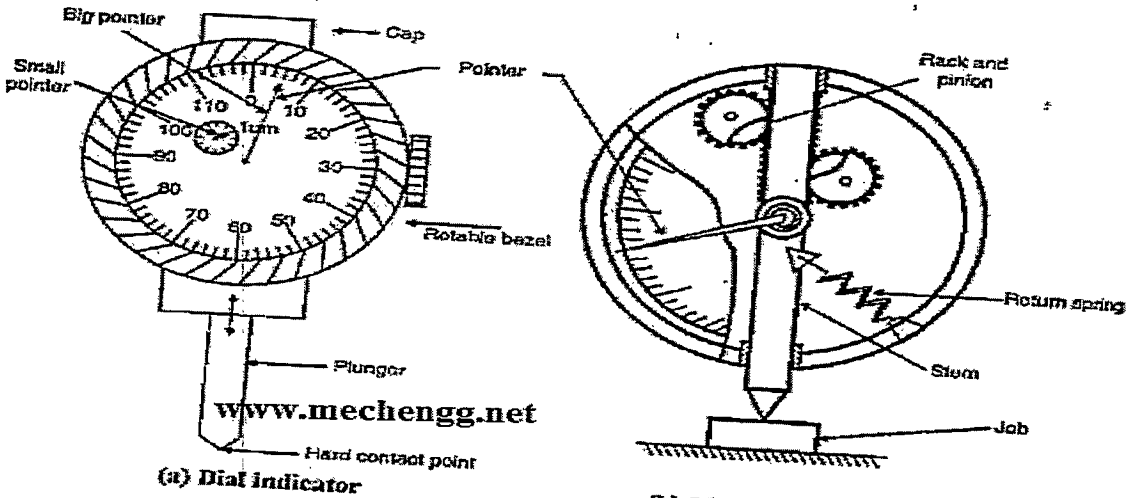
4. Comparing two heights or distances between narrow limits (comparator).

The practical applications of the use of dial indicator are:

1. To check alignment of lathe centers by using a suitable accurate bar between centers.

2. To check trueness of milling machine arbors.

3. To check parallelism of the shaper ram with table surface or like.

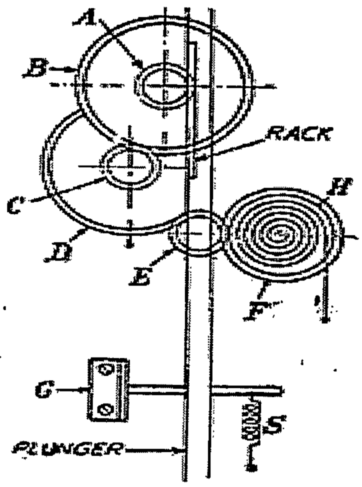


(a) Dial indicator

(b) Mechanism of dial indicator

The necessary high magnification ratio m this instrument is achieved by the use of gears and pinions arrangement in a small area, by arranging the gear train in a manner similar to a clock movement. Method of magnification used is shown in Fig.

There is a plunger which is a perfect sliding fit in its own bearings. This carries a rack which accurately meshes with a pinion A. The rotation of the plunger about its own axis is prevented by a pin attached to it, which is located in a slot in a rack guide G. In order to keep the plunger in an extended or normal position a light coil spring S is employed. The spring exerts a pressure of approximately 6 oz. A small movement of the contact point causes the rack to turn the pinion A with which it is meshed. A large gear B is attached to the same spindle as pinion A. The gear B is further meshed with a pinion C, which thus magnifies the movement of pinion A. Attached to the second pinion C is another gear D which meshes with



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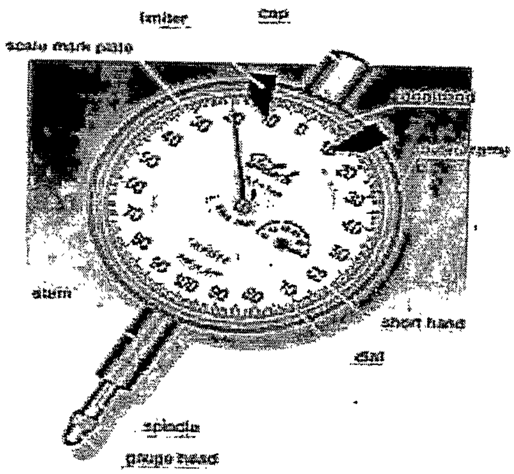
DIAL GAUGE

Dial gauges are used for checking flatness of surfaces and parallelism of bars and rods.

Used for linear measurement

Two pointer arms actuated by rack and pinion arrangement

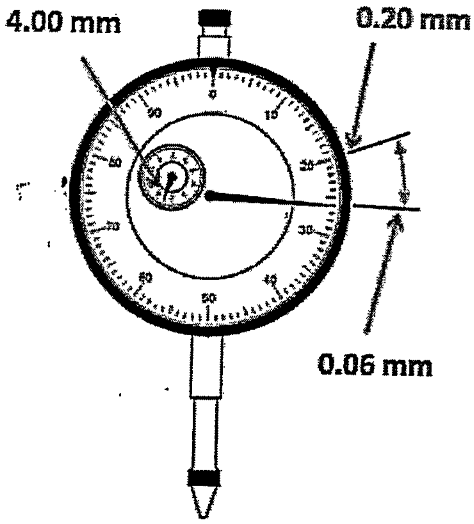
Rack is cut in spindle and spindle is made to come in contact with the work-piece



Step 4

To get the final measurement - **add up** the measurements from Steps 1, 2, & 3.

Step 1	4.00 mm
Step 2	+ 0.20 mm
Step 3	+ 0.06 mm
	Total = **4.26** mm



Requirement of a good dial indicator:

I. it should give trouble free and dependable readings over a longer period
II. the pressure required on measuring head to obtain zero reading must remain constant over the whole range.
III. The pointer should indicate the direction of movement of measuring plunger.
IV. The accuracy of the reading should be with in close limits of the various sizes and ranges.
V. The movement of the measuring plunger should be either in direction without affecting the accuracy.

Slip Gauges:

Slip gauges or gauge blocks are universally accepted end standard of length in industry. These were introduced by Johnson, a Swedish engineer, and are also called as johanson gauges

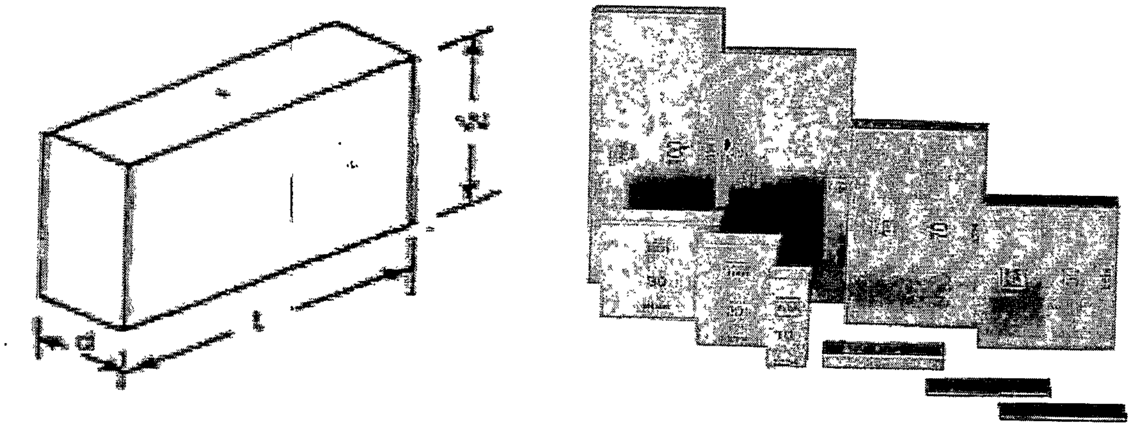


Figure: Dimension of a slip gauges

Slip gauges are rectangular blocks of high-grade steel with exceptionally close tolerances. These blocks are suitably hardened through out to ensure maximum resistance to wear.-

Slip gauges are rectangular blocks of steel having a cross-section of about 30 by 10 mm. The essential purpose of slip gauges is to make available end standards of specific lengths by temporarily combining several individual elements, each representing a standard dimension, into a single gauge bar. The combination is made by pressing the faces into contact and then imparting a small twisting motion while maintaining the contact pressure. This is called wringing. Wringing occurs due to molecular adhesion between a liquid film (thickness about

6 □m to 7 □m) and the mating surface. The combination made in that way can be used as reference for transferring the dimensions of the unit of length from the primary standard to gauge block of lower accuracy. It is also used for the verification and graduation of measuring apparatus and for direct measurement of linear dimensions of industrial components. For this purpose, control geometry of form such as flatness and parallelism of the surfaces and squareness of the gauging surfaces are essential. According to accuracy, the slip gauges can be graded into three categories, i.e. Grade 0, Grade I and Grade II. Generally,

two sets of slip gauges are available.

Normal Set

Slip gauges of the following dimensions are available in this type of set.

Table 5.1 : Normal Set

Range	Step	Pieces
1.001 to 1.009	0.001	9
1.01 to 1.09	0.01	9
1.1 to 1.9	0.1	9
1 to 9	1	9
10 to 90	10	9
	Total	45

Special Set

Slip gauges of the following dimensions are available in this type of set.

Table 5.2 : Special Set

Range	Step	Pieces
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 9.5	0.5	19
10 to 90	10	9
	Total	86

The cross-section of most commonly used rectangular slip gauges are as shown below.

Normal Size	Cross-sectional Area ($w \times d$) in mm
Up to 10 mm	$30^{+0.0}_{-0.3} \times 9^{-0.05}_{-0.3}$
Above 10 mm	$35^{+0.0}_{-0.3} \times 9^{-0.05}_{-0.3}$

Selection of Slip Gauges:

Standard procedure is followed in selecting slip gauges. It should be such that minimum number of slip gauges is chosen for combination of blocks depending on

the type of set available. The procedure will be clear if we explain it with an example:

Let us consider the case where we have to arrange a dimension of 56.421 mm and normal sets of slip gauges are available.

Always the last decimal point is to be considered first, i.e. 0.001 mm. Since gauge of 0.001 mm is not available, 1.001 mm slip gauge is to be selected.

The dimension left now is $56.421 - 1.001 = 55.42$ mm.

Now considering the second decimal place, slip gauge with 1.02 mm height is selected. The dimension left is $55.42 - 1.02 = 54.4$ mm.

Next for 54.4 mm, slip gauge with 1.4 mm is to be chosen and then 3.0 mm gauge. Finally, 50 mm gauge is to be chosen.

Thus, we have $50.000 + 3.000 + 1.400 + 1.020 + 1.001 = 56.421$ mm. All these five slip gauges are wrung properly to get the required dimension.

If special set of gauges be used, the combination in this case would have been $50.000 + 5.420 + 1.001 = 56.421$ mm.

Sine Principle and Sine Bars:

The sine principle uses the ratio of the length of two sides of a right triangle in deriving a given angle. It may be noted that devices operating on sine principle are capable of "self-generation."

The measurement is usually limited to 450 from loss of accuracy point of view. The accuracy with which the sine principle can be put to use is dependent in practice, on some form of linear measurement. -The sine bar in itself is not a complete measuring instrument. Another datum such as a surface plate is needed, as well as other auxiliary equipment, notably slip gauges, and indicating device to make measurements. Sine bars used in conjunction with slip gauges constitute a very good device for the precise measurement of angles. -Sine bars are used either to measure angles very accurately or for locating any work to a given angle within very close limits. -Sine bars are made from high carbon, high chromium, corrosion resistant steel, hardened, ground and stabilized.

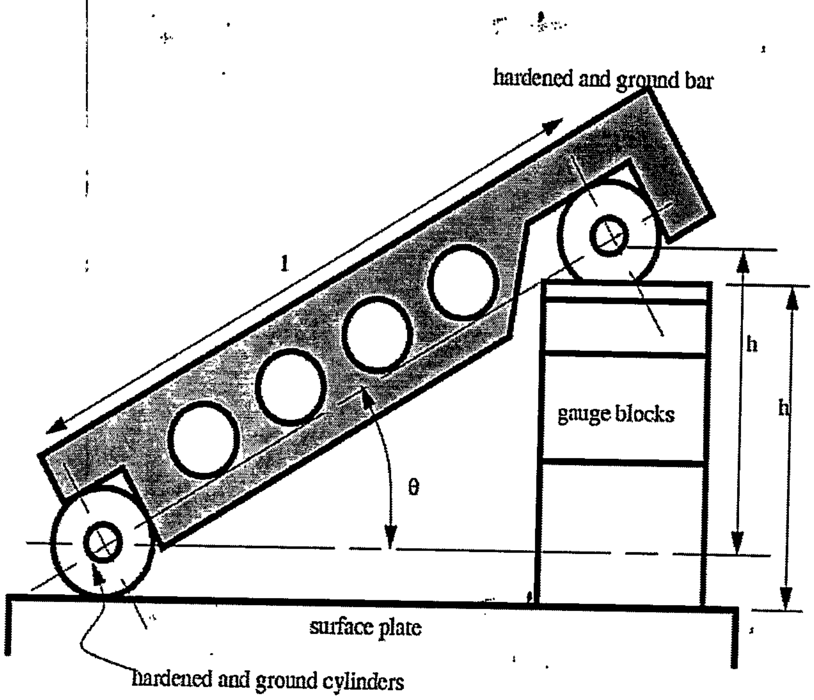


Figure: use of Sine bar

Where, L = distance between centres of ground cylinder (typically 5'' or 10'')

H = height of the gauge blocks

Θ=the angle of the plane

Θ = sin (h/l)

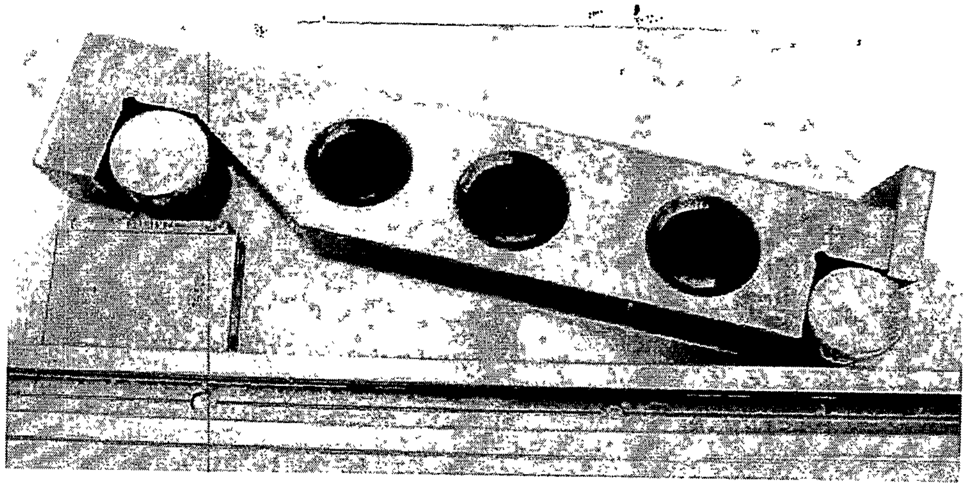


Figure: practical use of sine bar

Use of sine bar:

1.Measuring known angles or locating any work to a given angle.

For this purpose, the surface plate is assumed to be having a perfectly flat surface, so that its surface could be treated as horizontal.

One of the cylinders or rollers of sine bar is placed on the surface plate and other roller is placed on the slip gauges of height h.

Let the sine bar be set at an angle q.

Then sin θ= h/l,

where l is the distance between the centre of the rollers.

Thus knowing, h can be found out and any work could be set at this angle as the top face of sine bar is inclined at angle θto the surface plate.

The use of angle plates and clamps could —also be made in case of heavy components. For better results, both the rollers could also be placed on slip gauges Checking of unknown angles. Many a times, angle of a component to be checked is unknown.

In such a case, it is necessary to first find the angle approximately with the help of a bevel protector.

Let the angle be 8. Then the sine bar is set at an angle θ and clamped to an angle plate. Next, the work is placed on sine bar and clamped to angle plate as shown in Fig. Anda dial indicator is set at one end of the work and moved to the other, and deviation is noted.

Bevel protractor:

A simple Protractor is the basic device for measuring angles. At best, it can provide leastcount of one degree for smaller protractor and half degree for large protractors.

It is probably the simplest instrument for measuring the angle between two faces of component. □It consists of a base plate attached to the main body, and an adjustable blade which is attached to a circular plate containing Vernier scale.

□The adjustable blade is capable of rotating freely about the center of the main scale engraved on the body of the instrument and can be locked in any position. It is capable of measurement from 0 to 360 degree.

□The Vernier scale has 24 divisions coinciding with 23 main scale divisions. Thus, the least count of the instrument is 5'. This instrument is most commonly used in workshops for angular measurements till more precision is required.

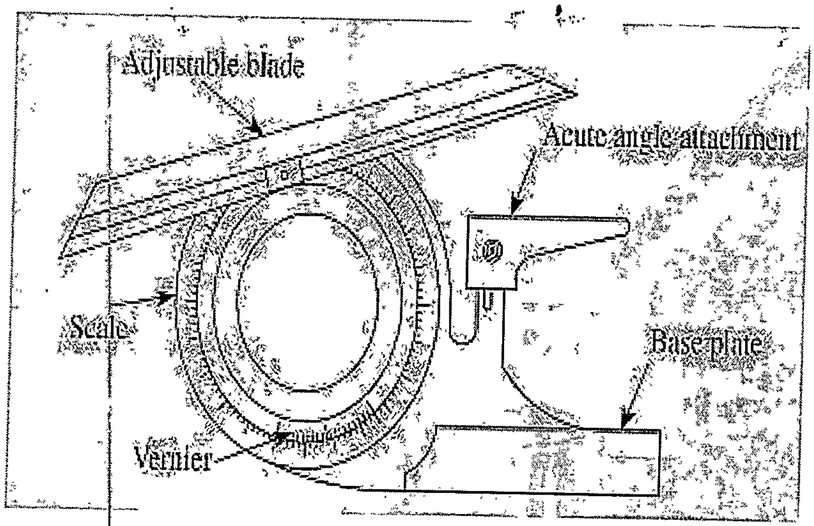
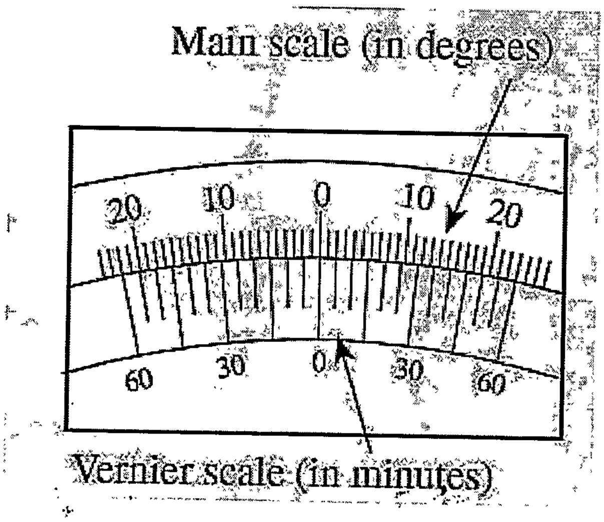


Figure: Vernier bevel protractor

The universal bevel protractor with 5 minutes accuracy is commonly found in all tool rooms and metrology laboratories. It has a base plate or stock whose surface has high degree of flatness and surface finish. The stock is placed on the work-piece whose angle is to be measured. An adjustable blade attached to a circular dial is made to coincide with the angular surface. It can be swivelled to the required angle and can be locked into position to facilitate accurate reading of the circular scale that is mounted on the dial.

The main scale on the dial is divided into four quadrants of 90 degrees each. Each division on this scale reads one degree. The degrees are numbered from 0 to 90 on either side of 0^{th} division. The Vernier scale has 24 divisions, which correspond to 46 divisions on the main scale. However, the divisions on the Vernier scale are numbered from 0 to 60 on either side of the 0^{th} division as shown in figure below.



Angle gauges:

Angle gauges, which are made of high-grade wear resistant steel work similar to slip gauges. While the slip gauges can be built up to give linear dimensions, angle gauges can be built up to give the required angle.

□The gauges come in a standard set of angle blocks that could be wrung together in a suitable combination to build an angle.

□C.E. Johansson who developed the slip gauges is also credited with the invention of angle gauge blocks.

□However, the first set of combination of angle gauges was devised by Dr. G.A. Tomlinson of the National Physical

Laboratory in the United Kingdom. He developed a set in the year 1939, which provided the highest number of angle combinations. His set of ten blocks could be used to set any ang le between 0 and 1800 in increments of 5'.

Illustration shows the way in which two-gauge blocks could be used in combination to generate two different angles.

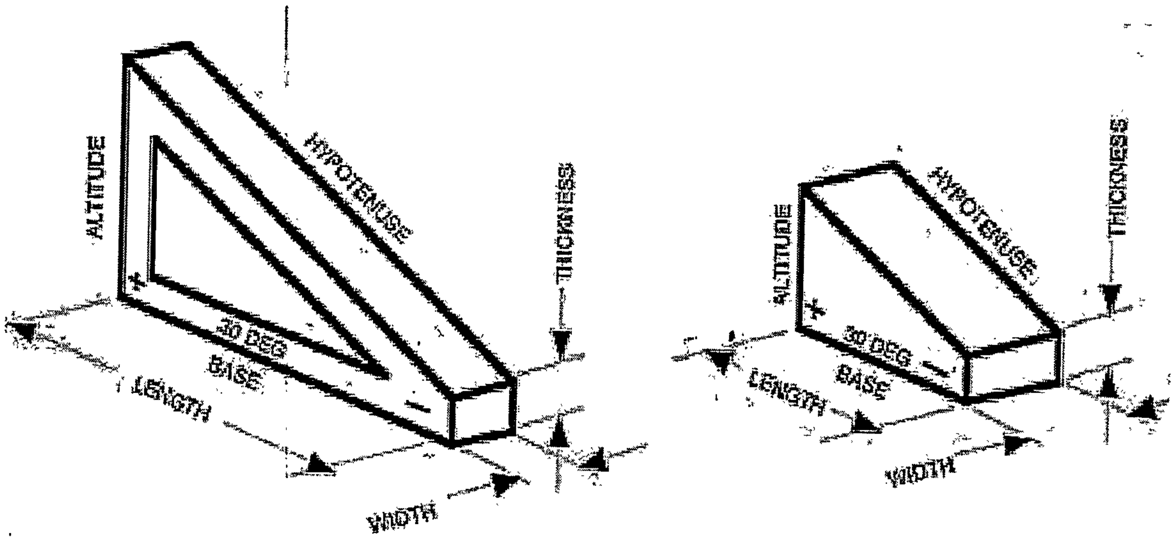
If a5 degree angle block is used along with 30 degree

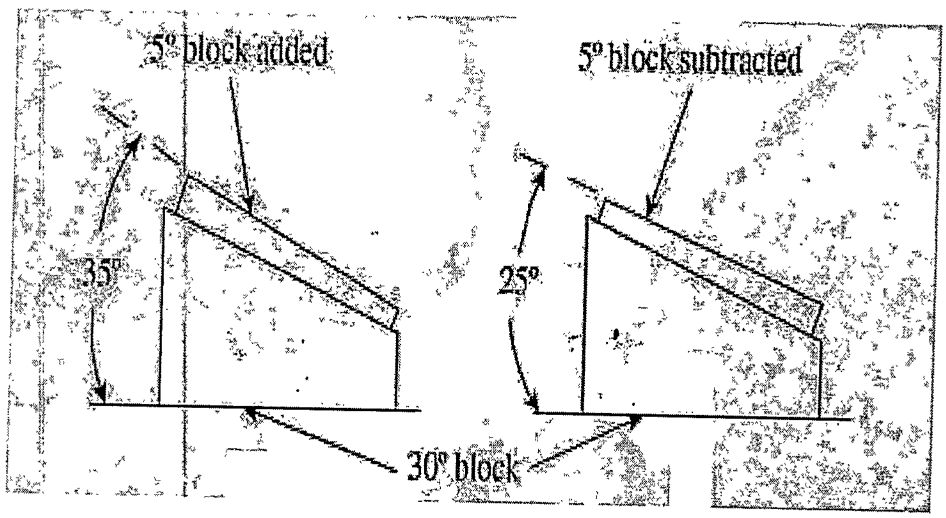
angle block as shown on the left, the resulting angle is 35 degree.

If the 5-degree angle block is reversed and combined with the 30-degree angle block as shown on the right, the resulting angle is 25 degree.

Angle gauges is a hardened steel block approximately 75mm long and 1mm wide which lapped flat working faces lying at a very precise angle to each other. It can be constructed at any angle from 0 to 360 degree by suitable combination of gauges. Each angle gauge is marked with 'V' which indicates the direction of included angle. To add the angles, all 'V' marks should be in same line and to subtract, 'V' marks should be in opposite direction.

Total angle = 37° 9′ 18″ (Not to scale)





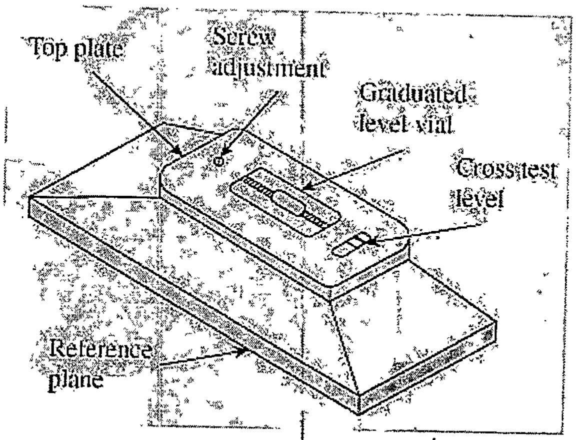
Uses of angle gauges:

(i) Direct use of angle gauges to measure the angle in the die insert

(ii) Use of angle gauges with square plate.

Spirit level:

The details of a typical spirit level are shown in figure. The base, called the reference plane, is seated on the machine part for which straightness or flatness is to be determined. When the base is horizontal, the bubble rests at the centre of the graduated scale, which is engraved on the glass. When the base of the spirit level moves out of the horizontal, the bubble shifts to the highest point of the tube. The position of the bubble with reference to the scale is a measure of angularity of the machine part.



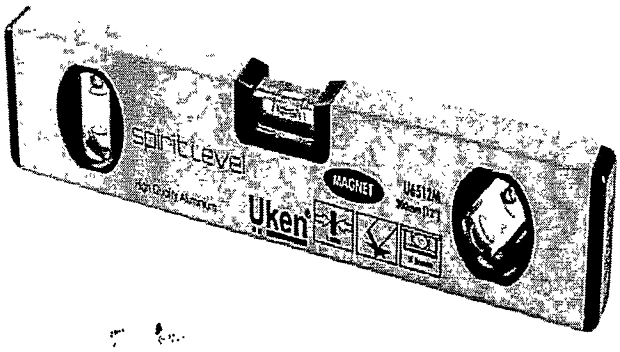


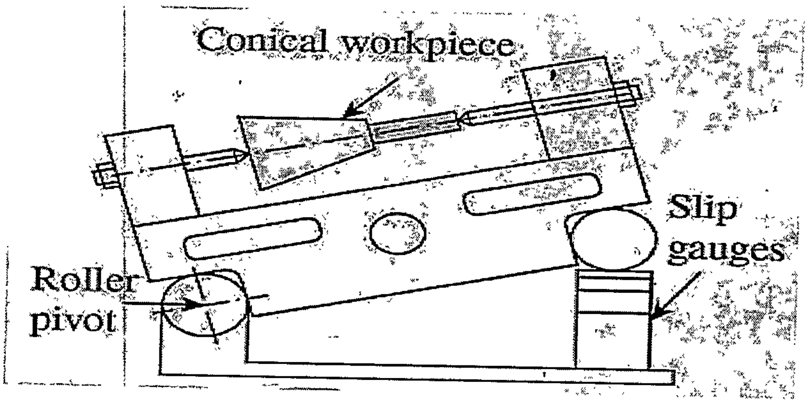
Figure: spirit level

Sine centre:

Sine centre provides convenient means for measuring angles of conical workpieces, which are held between centres as shown in figure.

One of the rollers is pivoted about its axis, thereby allowing the sine bar to be set to an angle by lifting the other roller.

The base of the sine centre has high degree of flatness and slip gauges are wrung and placed on it in order to set the sine bar to the required angle.



UNIT – III

LIMIT GAUGES

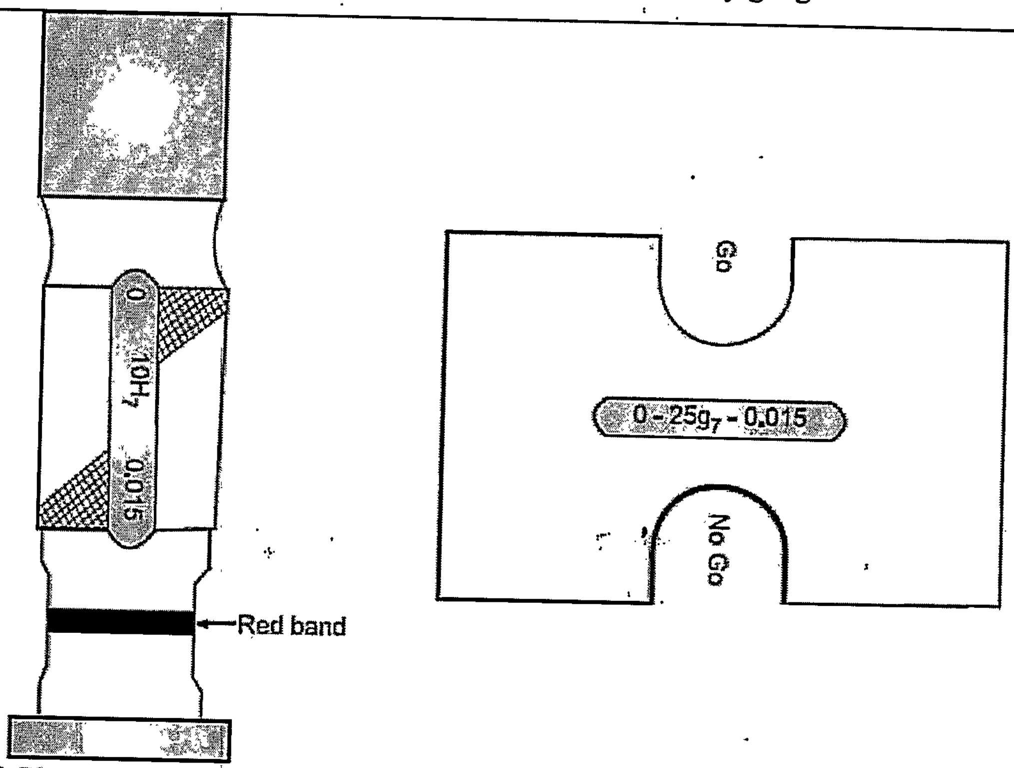
Introduction:

Gauging, done in manufacturing processes, refers to the method by which it is determined quickly whether or not the dimensions of the checking parts in production, are within their specified limits. It is done with the help of some tools called gauges. A gauge does not reveal the actual size of dimension.

A clear distinction between measuring instruments and gauges is not always observed. Some tools that are called gauges are used largely for measuring or layout work. Even some are used principally for gauging give definite measurement.

"GO" AND "NO GO" LIMIT GAUGES

Manufactured parts must be checked to determine, whether they lie between the given limits of size. In mass production, it will be very time consuming to measure the dimensions of each part, therefore instead of measuring actual dimensions of each part, the conformance of part produced with tolerance specifications can be checked by gauges.



(a) Plug gauge for checking hole (b) Snap gauge for checking shaft

Figure: Go and No-Go gauges

• Gauges are scaleless inspection tools of rigid design, which are used to check dimensions, form and relative positions of the surface of parts.

• They do not determine the actual size of part, but define whether deviations in the actual size or dimension of part produced are within the specified limits or not?

• They check whether the actual dimension of part produced lies between the two permissible limits of its size. Therefore, gauges consist of two sizes corresponding to their maximum and minimum limits.

• These limit gauges used for checking holes or shafts have two ends, labelled as 'GO' end and 'NO GO' end..

• End, which can be easily inserted in or around the component to be gauged (checked) is called as 'GO End'.

• And the other end, which cannot be inserted in or around the component to be gauged (checked), is called as 'NO GO' end.

• During gauging of component produced (either hole or shaft), if 'GO' end of the gauge goes and the 'NO GO' end does not go, then we conclude that, actual size or dimension of component manufactured lies within the specified permissible limits of size and it is suitable for assembly and use.

• Limit gauges (GO and NO GO) are widely used in engineering industries, due to their advantages prescribed below.

(i) Very easy to use.

(ii) No need of skilled labour to operate them. Therefore, semi-skilled labour can be employed.

(iii) Reduced inspection cost.

(iv) Very quick and less time consuming.

(v) No need of adjustments while using them.

(vi) No need of calculations to find variations in size of component produced.

Principle of GO and NO GO Gauges

• For checking the dimensions of work-piece, limit gauges usually have two working sizes; one corresponding to the low limit size and other to the high limit size of that dimension. These are known as GO and NO-GO gauges.

• The difference between the sizes of these two gauges is equal to the tolerance on the work-piece.

• Go gauge corresponds to low limit of size, whereas NO-GO gauge corresponds to high limit of size in case of hole.

• Go gauge corresponds to high limit of size, whereas NO-GO gauge corresponds to low limit of size in case of shaft.

• A part is considered to be good, if GO gauge enters it and NO-GO gauge does not enter it. This indicates that, the actual dimensions of part are within the specified limits.

• In case of hole, if both gauges fail to enter, it indicates that, hole is undersize, and in case of shaft, if both gauges fail to enter, it indicates that, shaft is oversize.

GAUGES AND THEIR CLASSIFICATIONS:

Gauges are the tools which are used for checking the size, shape and relative positions of various parts but not provided with graduated adjustable members. Gauges are, therefore, understood to be single-size fixed-type measuring tools.

Classifications of Gauges

a) Based on the standard and limit

i. Standard gauges
ii. Limit gauges or "go" and "not go" gauges

(b) Based on the consistency in manufacturing and inspection

(i) Working gauges
(ii) Inspection gauges
(iii) Reference or master gauges

(c) Depending on the elements to be checked

i. Gauges for checking holes
ii. Gauges for checking shafts
iii. Gauges for checking tapers
iv. Gauges for checking threads
v. Gauges for checking forms

(d) According to the shape or purpose for which each is used

i. Plug
ii. Ring
iii. Snap

iv. Taper
v. Thread
vi. Form
vii. Thickness
viii. Indicating
ix. Air-operated

TAYLOR'S PRINCIPLE

According to **Taylor's principle**, 'GO' and 'NO GO' gauges should be designed to check maximum and minimum material conditions as below:

'GO' Limit	This designation is applied to *'maximum material conditions'* i.e. upper limit of shaft and lower limit of hole.
'NO GO' Limit	This designation is applied to *'minimum material conditions'* i.e. lower limit of shaft and upper limit of hole.

'GO' and 'NO GO' plug gauges are used for checking holes.

(i) 'GO' for plug gauge: Size of minimum limit of hole, and

(ii) 'NO GO' for plug gauge: Size of maximum limit of hole.

• 'GO' and 'NO GO' snap or ring gauges are used for checking shafts.

(i) 'GO' for snap or ring gauge: Size of maximum limit of shaft, and

(ii) 'NO GO' for snap or ring gauge: Size of minimum limit of shaft.

• Taylor's principle states that, GO gauges should be of full form, such that, 'GO' gauge should check all possible elements of dimension at a time (such as roundness, taper, location etc.), whereas 'NO GO' gauge should check only one dimension at a time.

• As GO gauge assembles with mating component, it should check number of dimensions, including errors of form such as straightness, roundness, squareness etc., which are outside the maximum metal limit.

• NO-GO gauge can check only one dimension of part at a time in order to find out any dimensions, which are outside the minimum metal limit.

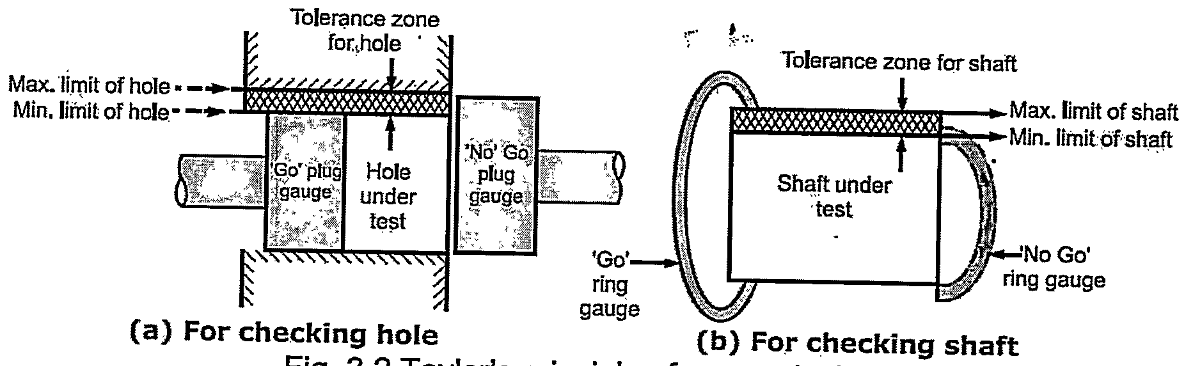
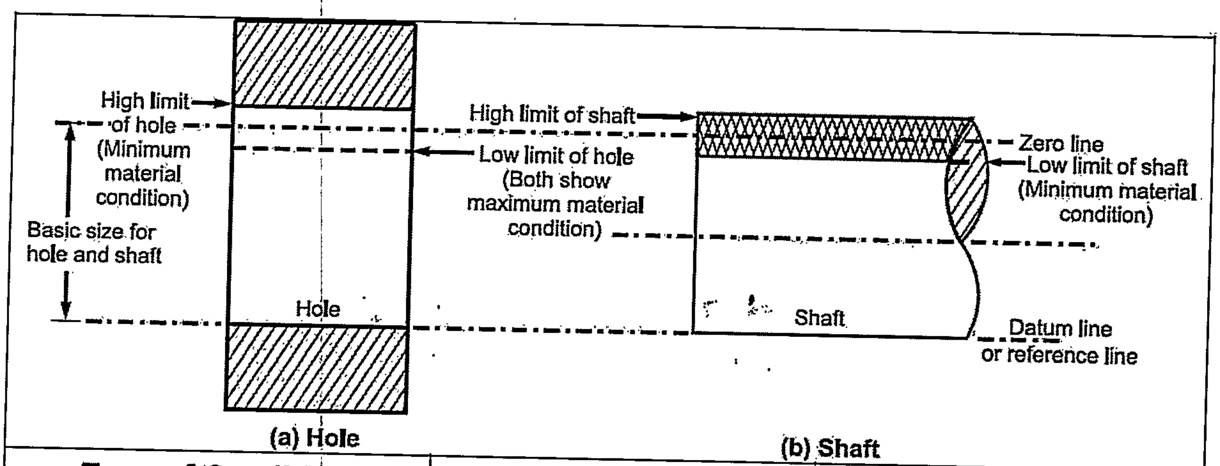


Fig. 3.2 Taylor's principle of gauge design

Maximum Material (Metal) Conditions and Minimum Material (Metal) conditions:

To understand this concept, let us take one shaft and one hole both having specified dimension $40^{\pm 0.05}$ mm.

Maximum material (metal) conditions	Minimum material (metal) conditions
For shaft, highest diameter possible is, Upper limit of shaft = 40 + 0.05 = 40.05 mm	For shaft, lowest diameter possible is, Lower limit of shaft = 40 − 0.05 = 39.95 mm.
For hole, lowest diameter permissible is, Lower limit of hole = 40 − 0.05 = 39.95 mm	For hole, highest diameter possible is Upper limit of hole = 40 + 0.05 = 40.05 mm



Type of Condition	For Hole	For Shaft
Maximum material condition	Low limit of hole	High limit of shaft
Minimum material condition	Upper/High limit of hole	Low limit of shaft.

INDIAN STANDARDS DESIGN OF GAUGES

Important Points for Design of gauges:

1. Shape of 'GO' gauge should exactly coincide with mating parts.
2. 'GO' gauge enables several dimensions to be checked simultaneously.
3. Inspection 'GO' gauges must always be put into conditions of maximum impossibility.
4. 'NO GO' gauges are used for checking single element of component.

5. Inspection 'NO GO' gauges must always be put into conditions of maximum possibility.

• For example, if a hole of size less than 63 mm is to be checked, the double ended plug gauge can be used.

• Double ended plug gauge forms GO gauge side on one end and NO GO side on another end. Refer Fig. 3.3.

• While checking or gauging a hole produced, both ends of double ended plug gauge are made to insert into the hole produced, one by one.

• If the hole produced is undersized, then, both 'GO' and 'NO GO' ends of plug gauge will not enter inside hole. But, if the hole produced is oversized, then both 'GO' end and 'NO GO' ends of plug gauge will enter inside hole.

• If the dimension of hole produced is correct (it means, dimension of hole produced lies between high limit and low limit of size), then end of plug gauge corresponding to lower limit will enter into the hole and another end of plug gauge corresponding to upper (high) limit will not insert into hole produced.

• Therefore, end of plug gauge corresponding to low limit of size is 'GO end', whereas another end of plug gauge corresponding to high limit of size is 'NO GO' end.

• Therefore, we conclude that, in case of plug gauge used for gauging or checking dimension of hole, the end corresponding to low limit is GO end and the end corresponding to high limit is NO GO end.

• Similarly, we can observe that, in case of ring gauges or snap gauges used for gauging or checking dimension of shaft, one ring corresponding to high limit is GO ring gauge and another ring corresponding to low limit is NO GO ring gauge.

• In case of plug gauges, 'NO GO' end is made shorter in length than 'GO' end, because it never enters the hole and need not have provisions to account for wear or prevent jamming as in case of 'GO' end. Whereas, 'GO' end is made larger in length due to following advantages.

(i) To check all possible dimensions of hole at a time, such as, roundness, taper, straightness after inserting it into hole thoroughly.

(ii) Longer end of double ended plug gauge is GO end, whereas, shorter end is NO GO end. Thus, GO end and NO GO end of double ended plug gauge can be distinguished very easily.

(iii) Longer GO end provides good support, while checking/gauge the dimension.

Standard Gauges:

Standard gauges are made to the nominal size of the part to be tested and have the measuring member equal in size to the mean permissible dimension of the part to be checked. A standard gauge should mate with some snugness.

Limit Gauges:

These are also called "go" and "no go" gauges. These are made to the limit sizes of the work to be measured. One of the sides or ends of the gauge is made to correspond to maximum and the other end to the minimum permissible size. The function of limit gauges is to determine whether the actual dimensions of the work are within or outside the specified limits. A limit gauge may be either double end or progressive. A double end gauge has the „go" member at one end and „no go" member at the other end. The „go" member must pass into or over an acceptable piece but the „no go" member should not. The progressive gauge has „no go" members next to each other and is applied to a workpiece with one movement. Some gauges are fixed for only one set of limits and are said to be solid gauges. Others are adjustable for various ranges.

Working Gauges:

Working gauges are those used at the bench or machine in gauging the work as it being made.

Inspection Gauges:

These gauges are used by the inspection personnel to inspect manufactured parts when finished.

Reference Gauges:

These are also called master gauges. These are used only for checking the size or condition of other gauges and represent as exactly as possible the physical dimensions of the product.

Hole Gauge

It is used to check the dimensions of the hole present in the element.

Shaft Gauge

It is used to check the dimensions of the shaft.

Taper Gauge

It is used to check the dimensions of the tapers.

Thread Gauge

It is used to check the threading of the element.

Form Gauge

It is used to check the forms of the elements.

Plain plug gauges are used to check whether the dimensions of hole lie within the specified limit or not.

- They are made up of suitable wear resisting steel and the gauging surfaces are suitably hardened.
- The gauging surfaces are first suitably stabilized using proper heat treatment process and then ground and lapped.
- They are provided with suitable anti-corrosive coating to prevent against corrosion.
- They are of two types:

a) Double ended type, for sizes upto 63 mm.

b) Single ended type, for sizes above 63 mm.

- They are designated with following parameters marked on handle.

  Nominal size.

  Class of tolerance.

  Actual values of tolerance.

  The word 'GO' on GO side.

  The word 'NO GO' on NO GO side.

  Some other standards.

- The 'NO GO' side is always painted with red band.
- Example: GO and NO GO plain plug gauge 25H7, IS: 3484.

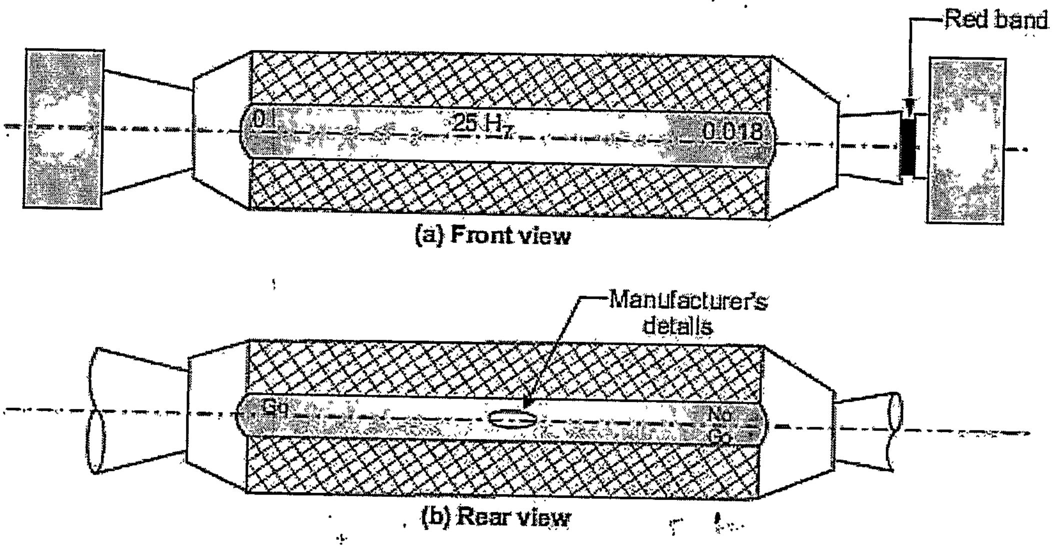


Figure: Plain plug gauge

Plain ring gauges are used to check whether, the obtained dimension of shaft lies within the specified limit or not.

- They are made up of suitable wear resisting steel and the gauging surfaces (contact surfaces) are suitably hardened.
- Gauging surfaces are first suitably stabilized using proper heat treatment process and then ground (using grinder) and lapped.
- An anti-corrosive coating is provided on the gauging or contact surfaces, to prevent against corrosion.
- Double ended type ring gauges are not found. Only single ended ring gauges are available in two designs, a) GO ring gauges, b) NO GO ring gauges.
- They are available in two ranges, (i) 3 to 70 mm in 10 steps and (ii) 70 to 250 mm in 17 steps.

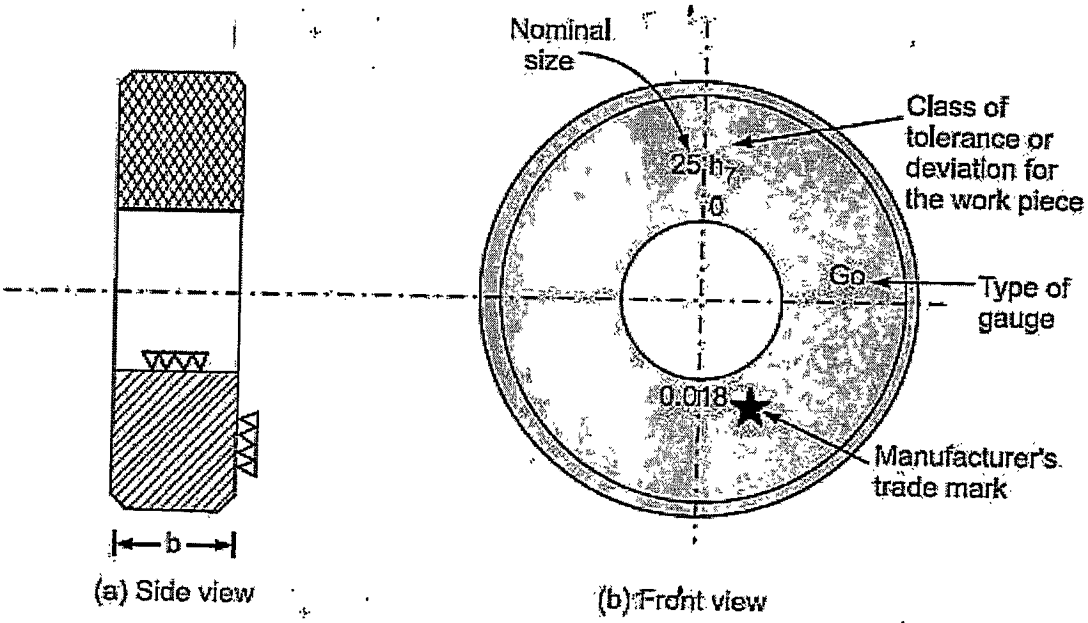


Figure: 'GO' type of plain ring gauge (single ended)

Figure shows 'GO' type of ring gauge (single ended), used to check diameter of shaft. A shaft is treated as acceptable, if it enters into hole of ring gauge. Similarly, we can draw a NO GO type planning gauge (single ended) to check diameter of same shaft. Only difference found in NO GO ring gauge is slight decrease in its hole diameter. A shaft is treated as acceptable if shaft does not enter into hole of NO GO ring gauge.

- They are designated with following parameters marked on handle.

  Nominal size.

  Class of tolerance.

  Actual values of tolerance.

  The word 'GO' on GO side.

  The word 'NO GO' on NO GO side.

  Some other standards.

  Manufacturer's trademark.

- Example: GO and NO GO plain ring gauge 25h7, IS: 3484.

Snap gauges are used to check, whether they obtained or produced dimension of shaft lies within the specified limit or not.

- They are made up of suitable wear resisting steel and the gauging surfaces are hardened to a hardness value of about 750.
- The gauging surfaces are first suitably stabilized using proper heat treatment process and then ground and lapped.

• They are provided with suitable anti-corrosive coating to prevent against corrosion.

• They are available in two designs, (a) Rib type, (b) Plate type snap gauges.

• According to dimension of shaft to be checked, two types of snap gauges are made available in market.

(i) Double ended snap gauges: Used to check shaft having diameter in the range of 3 mm to 100 mm.

(ii) Single ended snap gauges: Used to check shaft having diameter in the range of 100 mm and 250 mm.

• They are designated with following parameters marked on handle.

Nominal size.

Class of tolerance.

Actual values of tolerance.

The word 'GO' on GO side.

The word 'NO GO' on NO GO side.

Some other standards.

• The 'NO GO' side is always painted with red band.

• Example: GO and NO GO snap gauge 25h7, IS: 3484.

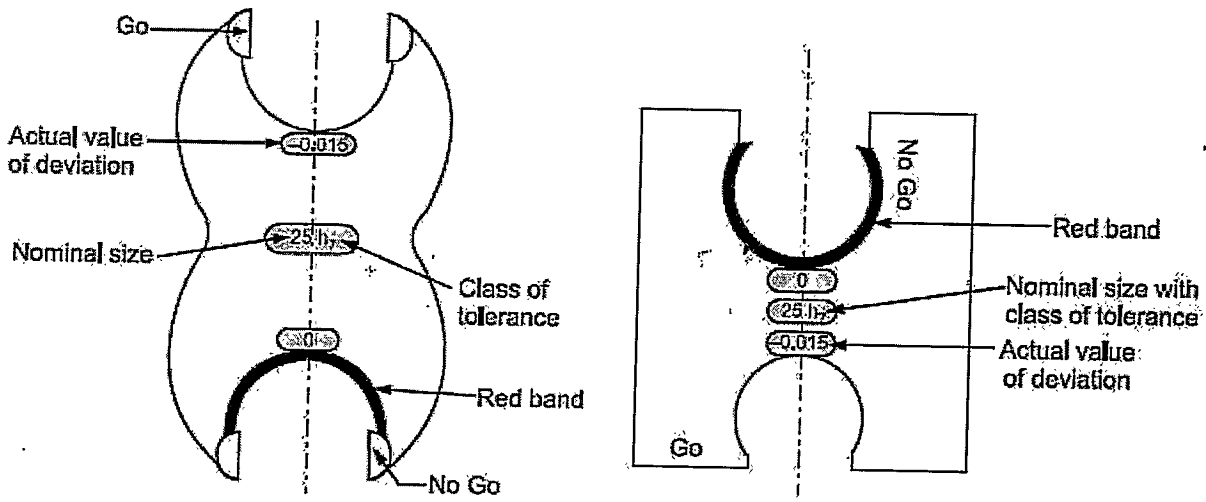


Figure: a. Rib type snap gauge b. platé type snap gauge

Advantages of Gauges are as below:

1. No other auxiliary equipment is needed.
2. Give quick result about conformance or non-conformance of the part produced.
3. No need of adjustment is required while using them.
4. No need of any calculation.

5. No need of external power supply.

6. No need of skilled workers. Gauges can be easily used by unskilled workers too.

7. Low inspection cost.

8. Less time consuming.

9. Preferred in mass production.

Disadvantages of Gauges are as below:

1. Gauges cannot measure the dimension/size of component produced.

Therefore, inspection by gauges does not provide detailed information about the parts produced.

2. Their use is limited to particular jobs only. For example: Hole and shafts produced in mass production. Gauges cannot be used for inspection of costly items like diamonds.

3. It is very un-economical to manufacture gauges in small quantity, because of high capital cost and running cost involved in gauge maker industries. Therefore, gauges should be manufactured in sufficiently large quantity, to reduce production cost per gauge.

Material for Gauges

High Carbon Steel is a relatively inexpensive and suitable material for gauges.

The material used for gauges should have good hardness. For this purpose, gauges are heat treated before their practical use.

Heat treatment consists of hardening the steel by heating to 730°C followed by quenching in water.

After heat treatment, the gauges are stabilized by maintaining them at a tempering temperature of 200°C for 8-10 hours.

Materials used: High carbon steel, Mild steel, Oil hardened steel, cast iron etc.

Desirable properties of material used for gauges:

(i) Hardness to resist wear.

(ii) Corrosion resistant.

(iii) Stability to maintain size and form.

(iv) Ease of Machinability.

(v) Low coefficient of thermal expansion.

Plug Gauges:

These gauges are used for checking holes of many different shapes and sizes. There are plug gauges for straight cylindrical holes, tapered, threaded square and splined holes. Figure 4.1 shows a standard plug gauge used to test the nominal size of a cylindrical hole.

Figure 4.2 shows a double-ended limit plug gauge used to test the limits of size. At one end, it has a plug minimum limit size, the „go" end and; at the other end a plug of maximum limit, the „no go" end. These ends are detachable from the handle so that they may be renewed separately when worn in a progressive limit plug gauge. The „go" and „no go" section of the gauge are on the same end of the handle. Large holes are gauged with annular plug gauges, which are shell-constructed for light weight, and flat plug gauges, made in the form of diametrical sections of cylinders.

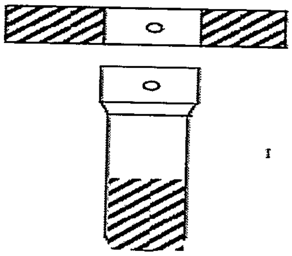


Figure 4.1 : Standard Ring and Plug Gauges

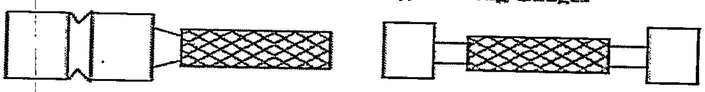


Figure: Progressive and Double Ended Limit Plug Gauges

Ring Gauges:

Ring gauges are used to test external diameters. They allow shafts to be checked more accurately since they embrace the whole of their surface. Ring gauges, however, are expressive manufacture and, therefore, find limited use. Moreover, ring gauges are not suitable for measuring journals in the middle sections of shafts. A common type of standard ring gauge is shown in Figure 4.1. In a limit ring gauge, the „go" and „no go" ends are identified by an annular groove on the periphery. About 35 mm all gauges are flanged to reduce weight and facilitate handling.

Taper Gauges:

The most satisfactory method of testing a taper is to use taper gauges. They are also used to gauge the diameter of the taper at some point. Taper gauges are made in both the plug and ring styles and, in general, follow the same standard construction as plug and ring gauges. A taper plug and ring gauge is shown in Figure 4.3.

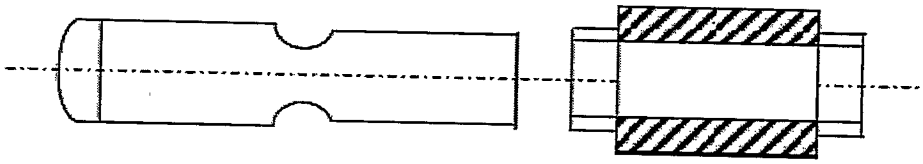


Figure: Taper Plug and Ring Gauge

When checking a taper hole, the taper plug gauge is inserted into the hole and a slight pressure is exerted against it. If it does not rock in the hole, it indicates that the taper angle is correct.

The same procedure is followed in a ring gauge for testing tapered spindle.

The taper diameter is tested for the size by noting how far the gauge enters the tapered hole or the tapered spindle enters the gauge. A mark on the gauge show the correct diameter for the large end of the taper.

To test the correctness of the taper two or three chalk or pencil lines are drawn on the gauge about equidistant along a generatrix of the cone. Then the gauge is inserted into the hole and slightly turned. If the lines do not rub off evenly, the taper is incorrect and the setting in the machine must be adjusted until the lines are rubbed equally all along its length. Instead of making lines on the gauge, a thin coat of paint (red led, carbon black, Purssian blue, etc.) can be applied.

The accuracy of a taper hole is tested by a taper limit gauge as shown in Figure. This has two check lines „go“ and „no go“ each at a certain distance from the end of the face. The go portion corresponds to the minimum and „no go“ to the maximum dimension.

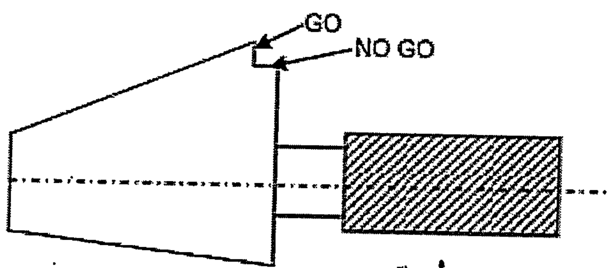


Figure: Limit Taper Plug Gauge

Snap Gauges:

These gauges are used for checking external dimensions. Shafts are mainly checked by snap gauges. They may be solid and progressive or adjustable or double-ended. The most usual types are shown in Figure.

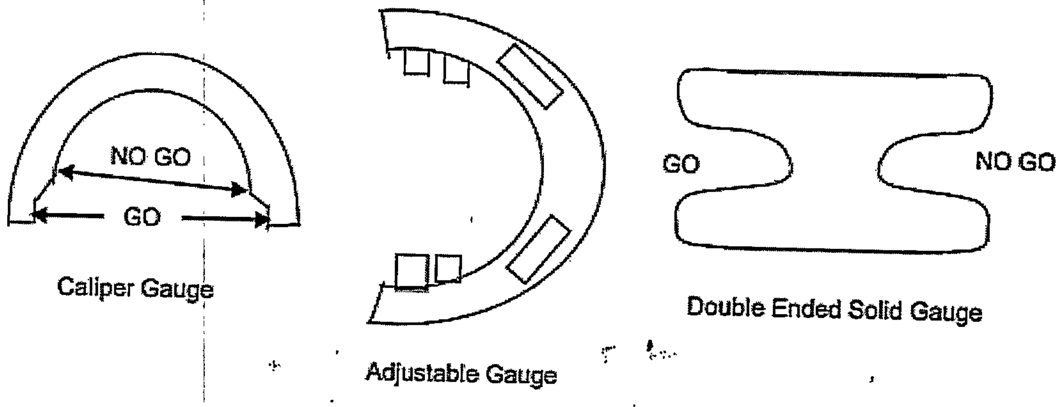


Figure: Snap Gauges

Solid or non-adjustable caliper or snap gauge with „go" and „no go" each is used for large sizes.

(b) Adjustable caliper or snap gauge used for larger sizes.

This is made with two fixed anvils and two adjustable anvils, one for „go "and another for the „no go".

The housing of these gauges has two recesses to receive measuring anvils secured with two screws. The anvils are set for a specific size, within an available range of adjustment of 3 to 8 mm. The adjustable gauges can be used for measuring series of shafts of different sizes provided the diameters are within the available range of the gauge.

(iii) Double-ended solid snap gauge with „go" and „no go" ends is used for smaller sizes.

Thread Gauges:

Thread gauges are used to check the pitch diameter of the thread. For checking internal threads (nut, bushes, etc.), plug thread gauges are used, while for checking external threads (screws, bolts, etc.), ring thread gauges are used. Single-piece thread gauges serve for measuring small diameters. For large diameters the gauges are made with removable plugs machined with a tang. Standard gauges are made single-piece. Common types of thread gauges are shown in Figure.

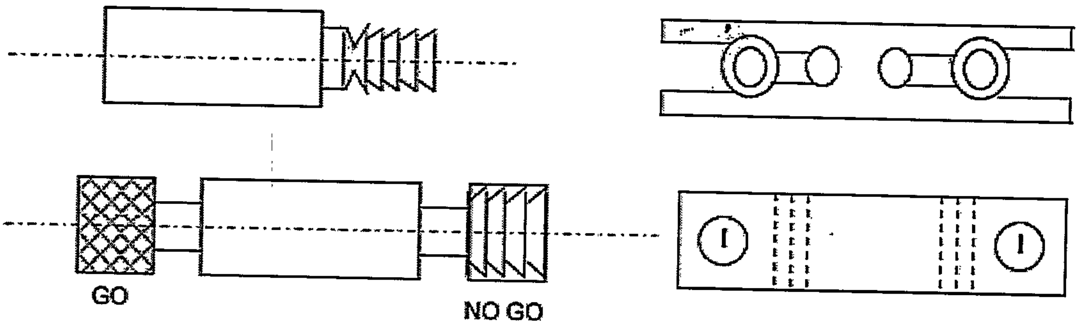


Figure: Thread Gauge

Standard plug gauges may be made of various kinds:

a) Plug gauge with only threaded portion.
b) Threaded portion on one end and plain cylindrical plug on opposite end to give correct "core" diameter.
c) Thread gauge with core and full diameters.

Limit plug gauges have a long-thread section on the „go" and a short-threaded section on the "no go" end to correspond to the minimum and maximum limits respectively.

Roller rings gauges, similarly have „go" and „no go" ends. They may also be solid and adjustable.

Roller Snap gauges are often used in production practice for measuring external threads.

They comprise a body, two pairs „go" rollers and two pairs „no go" rollers.

Taper thread gauges are used for checking taper threads. The taper-ring thread gauge are made in two varieties – rigid (non-adjustable) and adjustable. The "go" non-adjustable ring gauges are full threaded while the „no go" have truncated thread profile.

A **profile gauge** or **contour gauge** is a tool for recording the cross-sectional shape of a surface. Contour gauges consist of a set of steel or plastic pins that are set tightly against one another in a frame which keeps them in the same plane and parallel while allowing them to move independently, perpendicularly to the frame. When pressed against an object, the pins conform to the object. The gauge can then be used to draw the profile or to copy it on to another surface.

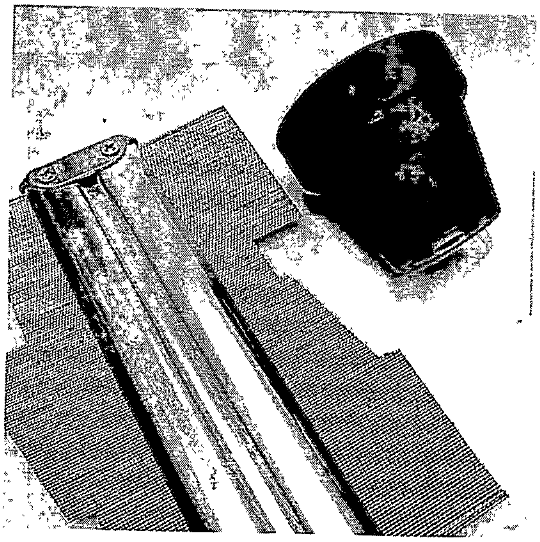


Figure: profile gauge

Applications:

- Designing in metal or wood working
- For easily decoration.
- Used to record the profile of pots (also known as pottery gauge)

Position Gauge:

- This Gauge Is Used For Checking The Hole Position With respect to Centre
- We Use High Quality Steel for Making the Gauges.

Optical Measurements instruments:

In this section of the chapter, one will learn about basic principles involved in optical measurements, interference and interferometry, and also about various instruments used in optical measurements like tool maker's microscope (micrometre microscope), autocollimator, auto dekkor, optical projector, optical square and optical flats. In this section, the major focus is to get knowledge on optical projectors and microscopes, so that one can use it readily in a laboratory or a workplace where these instruments are used.

In engineering measuring instruments of an optical nature, the formation of images by lens systems represents the basic principle on which most of these instruments are based.

Optical methods of measurement can be divided into two general classes; those in which the object being measured is viewed or magnified by a projector or microscope, and those in which the application of optics is indirect. Instruments as optical dividing heads, where lens systems are used to give the necessary magnification for the reading of a scale, or to provide magnification of a mechanical movement by means of optical lever.

Tool maker's microscope:

The toolmaker's microscope is an optical measuring machine equipped for external & internal length measurements as well as measurements on screw threads, profiles, curvatures & angles.

A toolmakers microscope is a measuring device that can be used to measure up to 1/100th of an mm. It works on the principle of a screw gauge, but a few changes were added to it to make its operation easier. It needs application of optics too. A light focuses on the object & through lens we can see the shadow of the object, which resembles the object. More clear shadow would be enhance the accuracy of measurement.

Principle of Measurement

A ray of light from a light source is reflected by a mirror through 90°.

It then passes through a transparent glass plate. A shadow image of the outline or counter of the workspaces passes through the objective of the optical head & is projected by a system of three prisms to a ground glass screen. Observations are made through an eyepiece. Measurements are made by means of cross lines engraved on the ground glass screen. The screen can be rotated through 360° the angle of rotation is read through an auxiliary eyepiece.

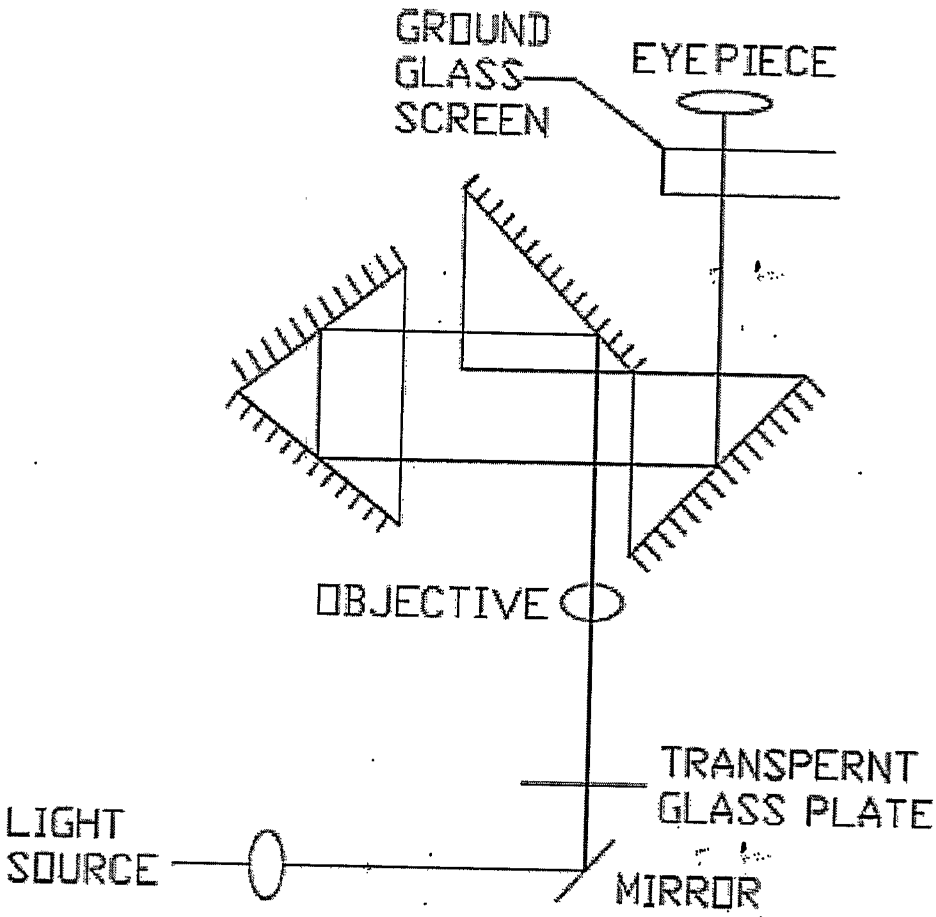


Fig 3.7. Principe of measurement

Construction:

TMM (toolmakers microscope) has got a robust & strong base such that it can bear & withstand sudden loads. A column with a track is present to carry lens, along with illuminating source in certain TMM's. Lens has two perpendicular straight lines marked that act as reference lines. Object to be measured is placed on glass table. Glass table is provided with 3 scales on it.

Two scales are meant for measuring in X & Y directions & the movement of table the respective direction. The other scale is meant for measuring rotation as well as rotation of table.

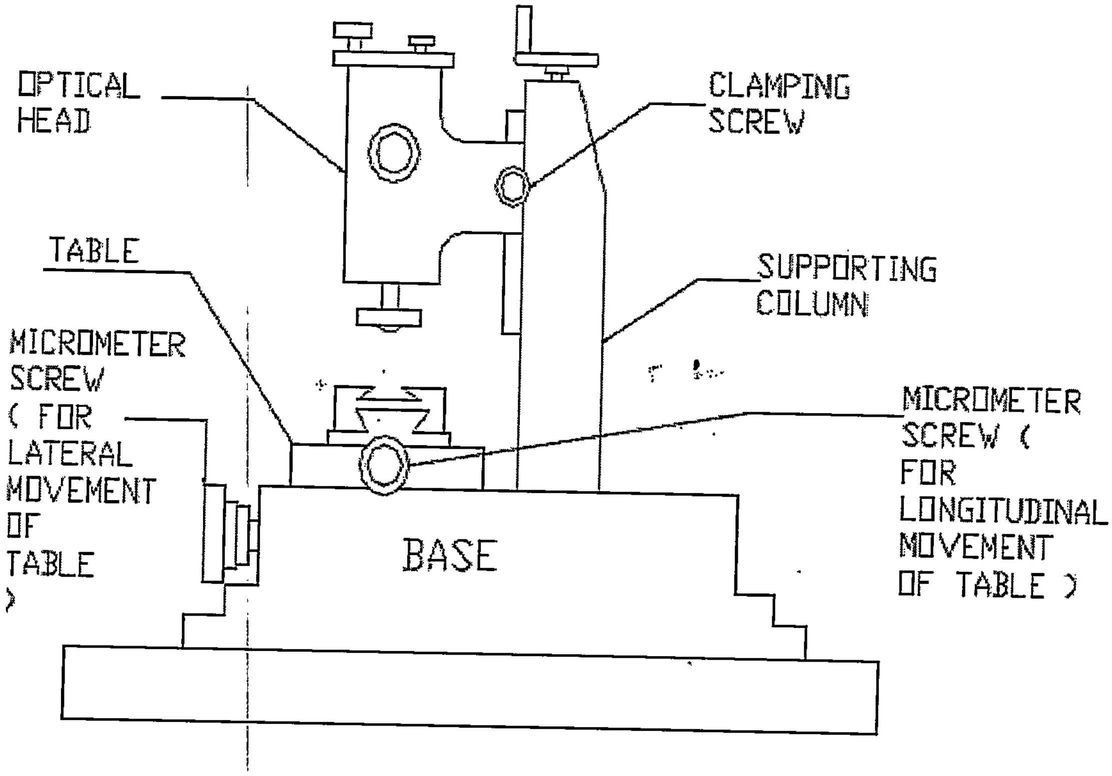
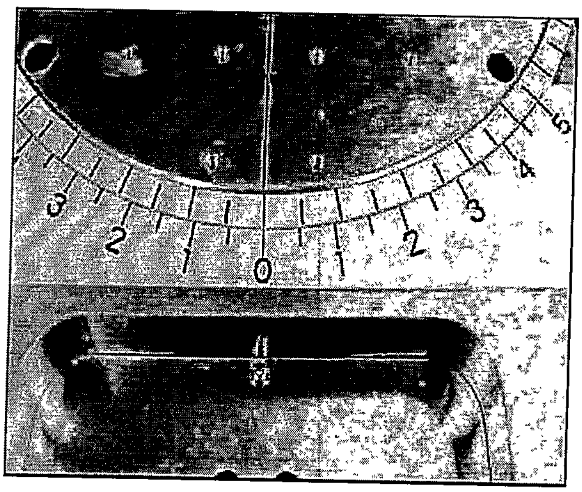


Fig. 3.8. Tool Maker's Microscope



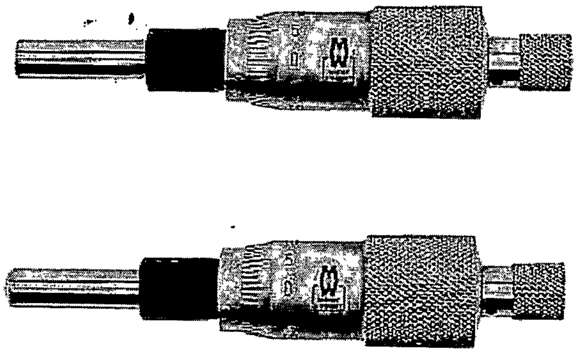


Fig. 3.9. Scales on Microscope

Working:

The component being measured is illuminated by the through light method.

- A parallel beam of light illuminates the lower side of work-piece which is then received by the objective lens in its way to a prism that deflects the light rays in the direction of the measuring ocular & the projection screen.
- The direction of illumination can be tilted with respect to the work-piece by tilting the measuring head & the whole optical system. This inclined illumination is necessary in some cases as in screw thread measurements.

Applications:

1. Length measurement in Cartesian & polar co-ordinates.
2. Angle measurements of tools.
3. Thread measurements i.e., profile major & minor diameters, height of lead, thread
4. Angle, profile position with respect to the thread axis & the shape of thread.
5. Comparison between centers & drawn patterns & drawing of projected profiles.
6. Used for measuring the shape of different components like the template, formed cutter, milling cutter, punching die, and cam

Autocollimator:

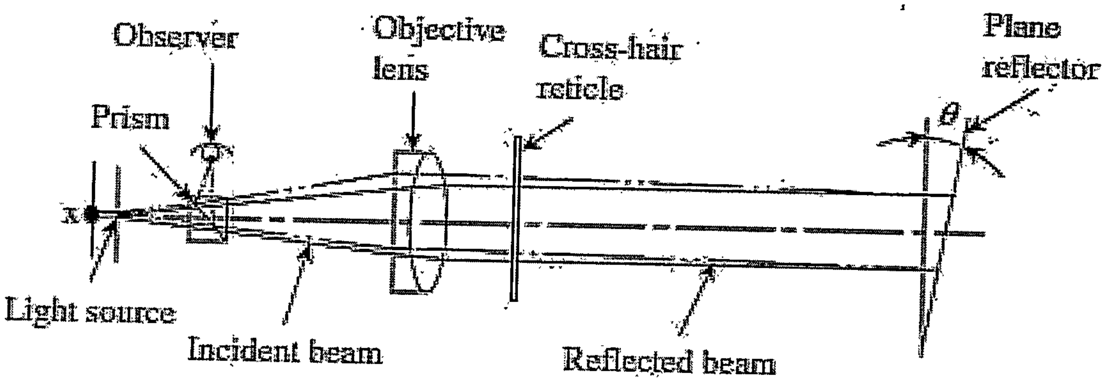


Fig. 3.10 Principle of autocollimator

It is a special form of telescope, which is used to measure small angles with high degree of resolution. It is used for various applications such as precision alignment, verification of angle standards, and detection of angular movement and so on.

It projects a beam of collimated light on to a reflector, which is deflected by a small angle about the vertical plane. The light reflected back is magnified and focused either on to an eye piece or a photo detector. The deflection between the beam and the reflected beam is a measure of angular tilt of the reflector.

The reticle is an illuminated target with cross hair pattern, which is positioned in the focal plane of an objective lens. A plane mirror perpendicular to the optical axis serves the purpose of reflecting an image of the pattern back on to the observation point.

A viewing system is required to observe the relative position of the image of the cross wires. This is done in most of the autocollimators by means of a simple eye piece.

If rotation of the plane reflector by an angle θ results in the displacement of the image by an amount d, then, $d = 2f\theta$, where f is the focal length of the objective lens.

It is clear from this relationship that the sensitivity of autocollimator depends on the focal length of the objective lens. Longer the focal length, larger is the linear displacement for a given tilt of the plane reflector.

Classification of Autocollimator

Autocollimators may be classified into three types:

1. Visual or conventional autocollimator
2. Digital autocollimator, and
3. Laser autocollimator

Visual Autocollimator

The displacement of the reflected image is determined visually in this type of autocollimator. A pinhole light source is used, whose reflected image is observed by the operator through an eye piece.

Visual collimators are typically focused at infinity, making them useful for both short distance as well as long distance measurements.

Digital Autocollimator

Digital autocollimator uses an electronic photo detector to detect the reflected light beam. A major advantage of this type of collimator is that it uses digital signal processing technology to detect and process the reflected beam. This enables filtering out of stray scattered light, which sharpens the quality of the image.

Laser Autocollimator

Laser autocollimators represent the future of precision angle measurement in the industry. Superior intensity of the laser beam makes it ideal for measurement of angles of very small objects (1 mm in diameter) as well as long measuring range extending to 15 meters or more. Another marked advantage is that a laser autocollimator can be used for the measurement of non mirror quality surfaces. in addition, high intensity of the laser beam creates ultra low noise measurements, thereby increasing the accuracy of measurement.

Angle Dekker

Angle dekkor is a small variation on the autocollimator. This instrument is essentially used as comparator and measures the change in angular position of the reflector in two planes.
It has an illuminated scale, which receives light directed through a prism. The light beam carrying the image of the illuminated scale passes through the collimating lens as shown in figure and falls on to the reflecting surface of the work piece.

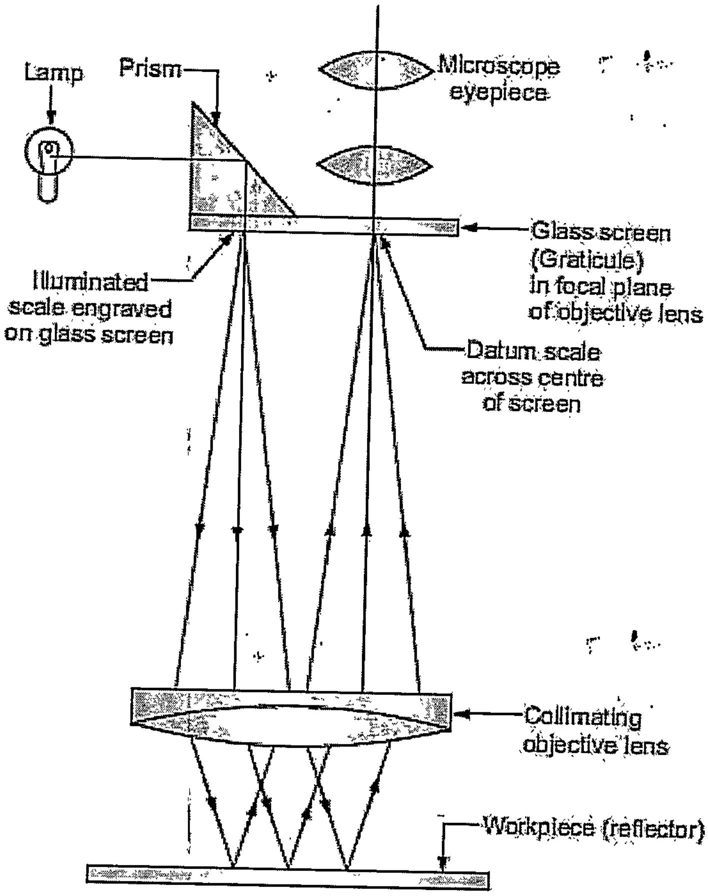


Fig.3.11 Angle Dekkor

After getting reflected from the work piece it is refocused by the lens in field view of eyepiece. While doing so, the image of the illuminated scale would have undergone a rotation of 900 with the optical axis.

Now, the light beam will pass through the datum scale fixed across the path of the light beam as shown in figure.

When viewed through the eye piece, the reading on the illuminated scale measures angular deviations from one axis at 90 ° to the optical axis and the reading on the fixed datum scale measures the deviation about an axis mutually perpendicular to this.

Working

Angle dekkor is capable of measuring small variations in the angular setting i.e. determining the angular tilt.

For measuring the angle of a component, the working principle is the method of measurement by comparison.

Thus, first of all, the angle gauge combination is set up to the nearest angle of component and the angle dekkor is set, such that, zero reading is obtained on the illuminating scale.

The angle gauge build up is then removed and replaced by the component under test. A straight edge is used to ensure that, there is no change in lateral positions.

The new positions of reflected (illuminated) scale with respect to fixed scale gives the angular tilt of the component from set angle.

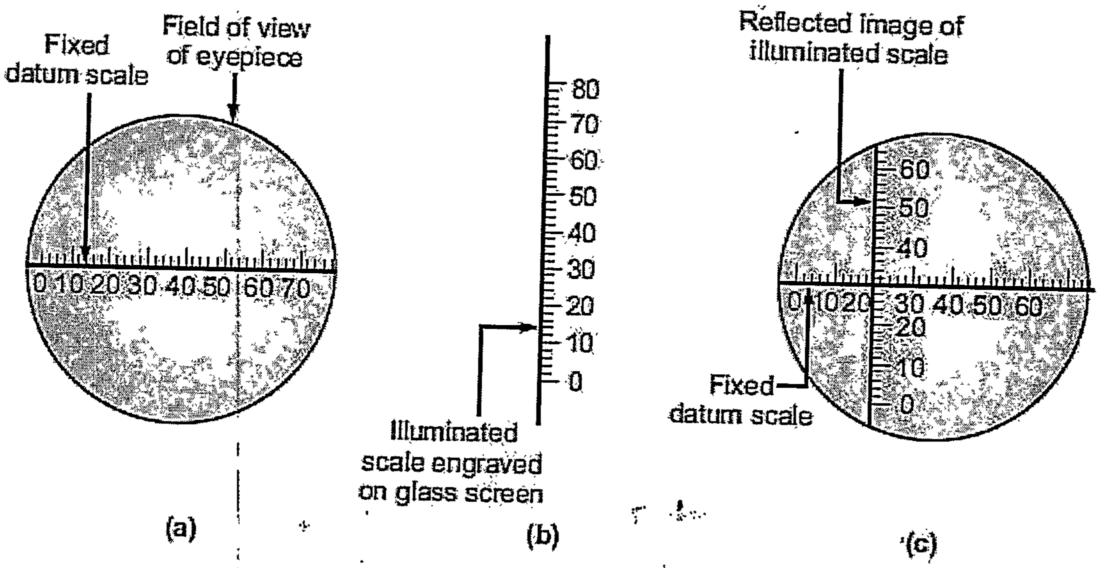


Fig. 3.12 Eyepiece view of angle dekkor

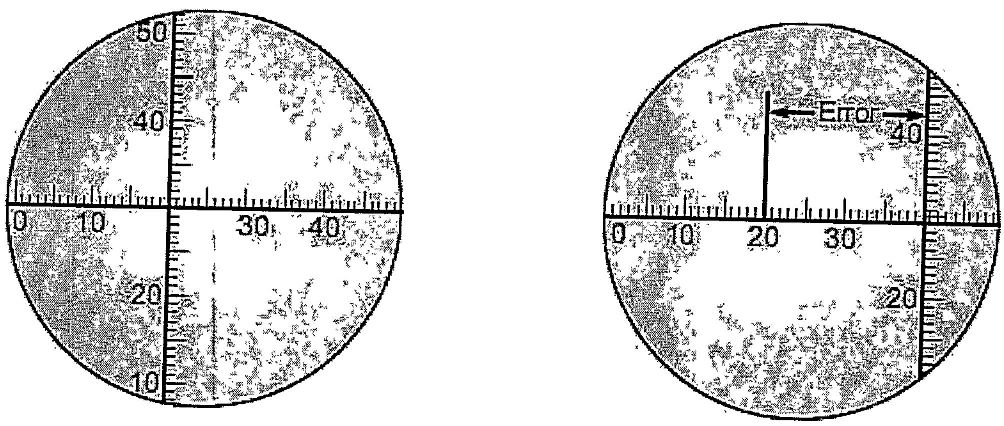


Fig. 3.13 Final positions of vertical illuminated scale showing horizontal and vertical angular displacement

Applications of Angle Dekkor:

In combination with angle gauges, it is used in:

(a) Measuring angle of a component.

(b) Angular setting of machines.

(c) Checking slope angles of V-blocks.

(d) Measuring angle of taper gauge...

Optical squares

An optical square is useful in turning the line of sight 90 degrees from its original path. The incident ray is reflected internally from two faces and emerges out of the square at exactly 900 to the incident light. Any slight deviation or misalignment of the prism does not affect the right angle movement of the light ray.

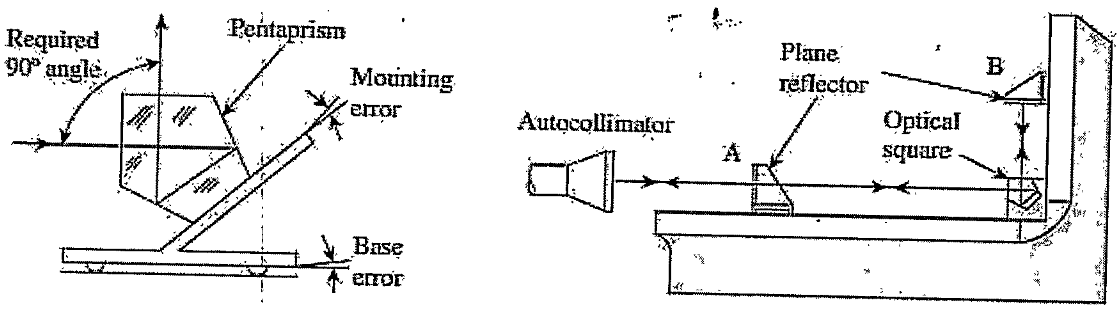


Fig. 3.14. a) Optical square b) Use of an optical square to test squareness

Optical Flats

1. An optical flat is a disk of high quality glass or quartz. When an optical flat is laid over a flat reflecting surface, it orients at a small angle θ, because of the presence of air cushion between the two surfaces.

2. When light from a monochromatic light source is made to fall on an optical flat, which is oriented at a very small angle with respect to a flat reflecting surface, alternate band of light and dark patches are seen by the eye.

3. In case of a perfectly flat surface, the fringe pattern is regular, parallel and uniformly spaced. Any deviation from this pattern is a measure of error in the flatness of the surface being measured.

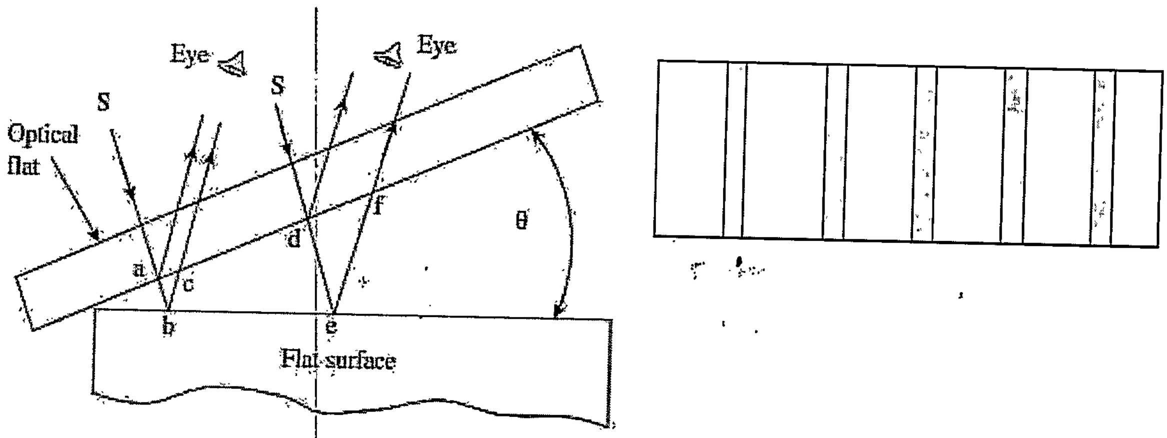


Fig. 3.15. a) Optical flats principle (Fringe formation) b) Interference fringe

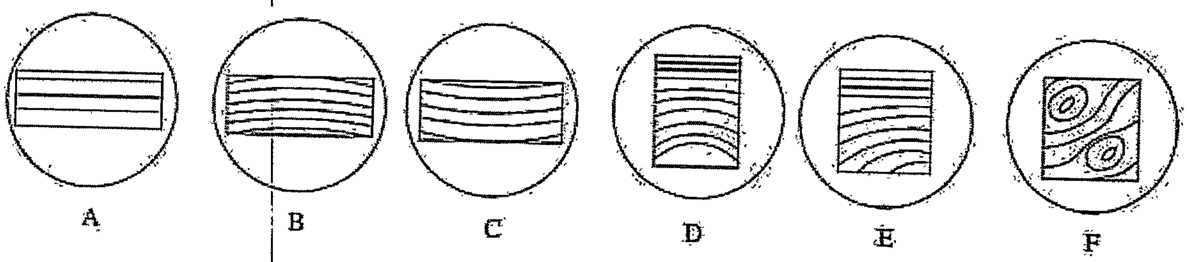


Fig 3.16. Fringe patterns reveal surface conditions

Table 3.1 Fringe patterns and the resulting surface conditions

Fringe pattern	Surface condition
A	Block is nearly flat along its length.
B	Fringes curve towards the line of contact, showing that the surface is convex and high in the centre.
C	Surface is concave and low in the centre.
D	Surface is flat at one end but becomes increasingly convex.
E	Surface is progressively lower towards the bottom left-hand corner.
F	There are two points of contact, which are higher compared to other areas of the block.

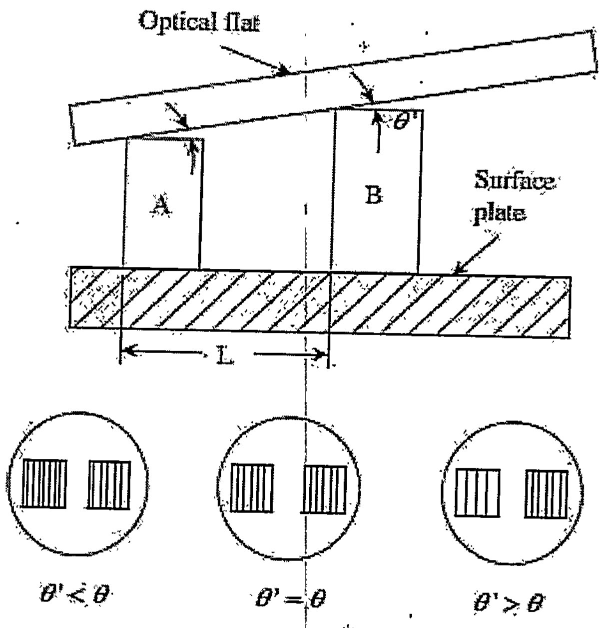


Fig. 3.16 Height measurement using an optical flat

Now, let the number of fringes on the reference block be N over a width of l mm. If the distance between the two slip gauges is L and λ is the wavelength of the monochromatic light source, then the difference in height h is given by the following relation:

$$h = \frac{\lambda L N}{2l}$$

Important note: The term 'scale' is used when rulings are spaced relatively far apart, requiring some type of interpolating device to make accurate settings. The term 'grating' is used when rulings are more closely spaced, producing a periodic pattern without blank gaps. Of course, gratings cannot be either generated or read manually. They require special read-out systems, usually photoelectric. The only element that makes a microscope a measuring instrument is the 'reticle'.

Examples: 1. the fringe patterns shown in Fig. 3.17 were observed for four different specimens when viewed through an optical flat. Give your assessment about the nature of surface conditions.

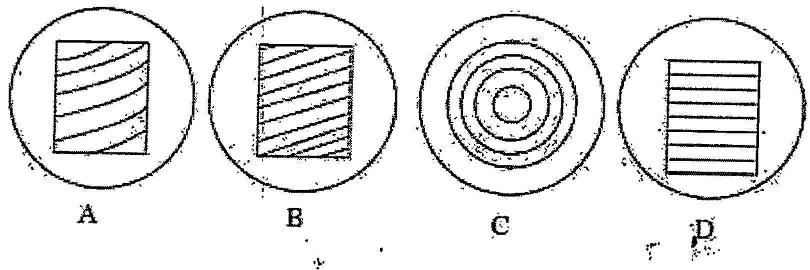


Fig.3.17. Fringe patterns viewed through an optical flat

Solution

Case A: The surface is flat from lower right to upper left, but slight curvature of fringes away from the line of contact indicates that it is slightly concave

Case B: The surface is flat in the direction that the fringes run. However, it is higher diagonally across the centre, where the fringes are more widely spaced, than at the ends.

Case C: Circular fringes with decreasing diameters indicate the surface to be spherical. By applying a small pressure at the centre of the fringes, if the fringes are found to move towards the centre, the surface is concave. On the other hand, if the fringes move away from the centre, the surface is convex.

Case D: Parallel, straight, and uniformly spaced fringes indicate a flat surface.

Example: 2. Two flat gauges are tested for taper over a length of 25 mm on a surface plate using an optical interferometer. Determine the taper of gauge surfaces if the wavelength of light source is 0.5 μm.

(a) Gauge A: The number of fringes on the gauge surface is 15 and that on the surface plate is 5

(b) Gauge B: The number of fringes on the gauge surface is 5 and that on the surface plate is 8.

Solution

Amount of taper for gauge $A = (15-5)\times\frac{\lambda}{2} = 10\times\frac{0.5}{2} = 2.5\,\mu m.$

Amount of taper for gauge $B = (8-5)\times\frac{\lambda}{2} = 3\times\frac{0.5}{2} = 0.75\,\mu m.$

UNIT-III R.R.C.

Introduction

- ✓ The toolmaker's microscope is an optical measuring machine equipped for external & internal length measurements as well as measurements on screw threads, profiles, curvatures & angles.
- ✓ A toolmakers microscope is a measuring device that can be used to measure up to 1/100th of an mm.
- ✓ It works on the principle of a screw gauge, but a few changes were added to it to make its operation more easier.
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- ✓ More clear shadow would be enhance the accuracy of measurement.

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- ✓ It then passes through a transparent glass plate.
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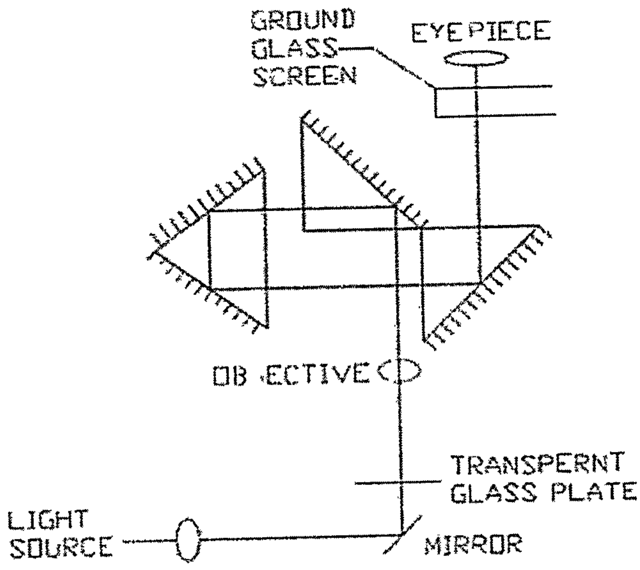

❑ Principle of Measurement

Construction

- ✓ TMM (toolmakers microscope) has got a robust & strong base such that it can bear & withstand sudden loads.
- ✓ A column with a track is present to carry lens, along with illuminating source in certain TMM's.
- ✓ Lens has two perpendicular straight lines marked that act as reference lines.
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- ✓ Glass table is provided with 3 scales on it
- ✓ Two scales are meant for measuring in X & Y directions & the movement of table the respective direction.
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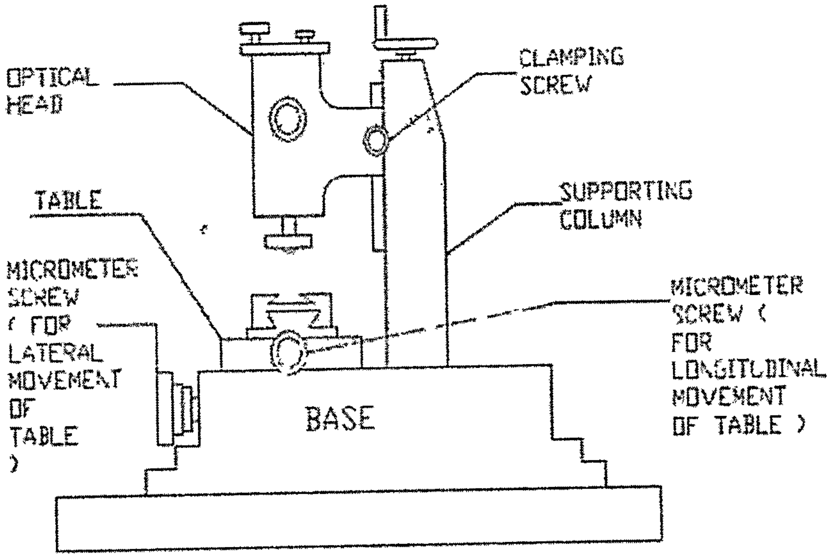
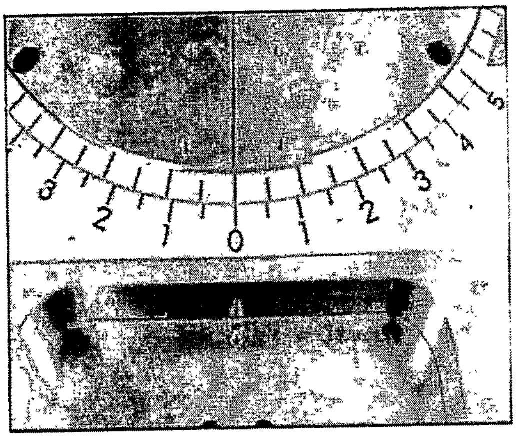
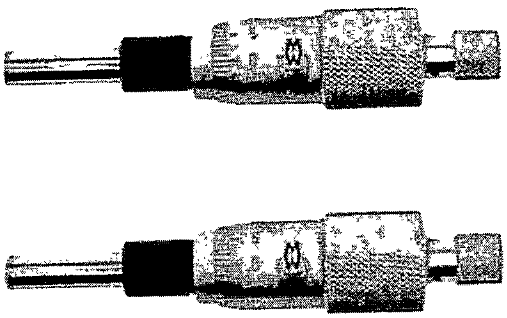
Application

- ✓ Length measurement in Cartesian & polar co-ordinates.
- ✓ Angle measurements of tools.
- ✓ Thread measurements i.e., profile major & minor diameters, height of lead, thread
- ✓ angle, profile position with respect to the thread axis & the shape of thread.
- ✓ Comparison between centers & drawn patterns & drawing of projected profiles.
- ✓ Used for measuring the shape of different components like the template, formed cutter, milling cutter, punching die, and cam



- Tool Maker's Microscope





- Scales On Microscope

OPTICAL PROJECTOR:

Optical projector is a device which is works on the principle of optics. It has become an indispensable instrument in modern metrological laboratories because of its versatility and ease in use. Using optical projectors it is possible to measure those components which are difficult to be measured by other methods due to typical size, material composition or dimensional characteristics. It displays the magnified image (which should be clear, sharp and dimensionally accurate) of the objects located by some handling device or staging fixture on an appropriate viewing screen (located near the operator's normal eye level for his convenience).

the magnified image serves as an aid to more precise determination of dimension, from. Etc…

an optical projector of

(i) a projector (having a light source, a condensor or collimating leens system to direct the light part and into the optical system),

(ii) suitable work holding table which may be fixed or movable

(iii) projections optics including both mirrors and lenses.

(iv) screen where the image of the work piece is projected and where measurements or comparisons are made.

(v) measuring devices. A good optical projector must have a precise optical system, and means for precise mechanical measurement.

while the optical projector displays a two dimensional projections of a part, it may be noted that all parts are not ideally suited to optical gauging. The performance of optical projectors is also depends on its optical design, manufacturing and assembly. All these factors directly influence the quality of image formed, the accuracy of the magnified image, and the contrast in the image.

contrast and accuracy of image are also influenced by the aberrations in the optical system. Actually the aberrations in the optical element make the light rays passing through optical element to deviate from the desire path.

the most common aberrations found in the optical projectors are distortion (non- uniform magnification from centre to edge of screen), field curvature (out of focus centre to edge due to spherical shapes of the screen), chromatic aberrations (dispersion of white light by optical system and inability to focus all the colours simultaneously in the plane of screen. Lateral colour (appearance of distinct blue and red fringes at the edge of image caused by unequal magnification of these two colours in the image) image quality and contrast. The contrast of image is also influenced by viewing screen mirrors and mechanical mounting of the optical element to reduce flare and stray light.

The image of the test piece is produced on the screen by a beam of light. The light sources being a tungsten lamp, filament lamp or high pressure mercury or zenon arc lamp. A strong beam of light consisting of concentrated bundle of parallel light rays is produced by optical means. Beam should be large enough diameter to provide coverage on the test piece and adequate illumination intensity at the screen. Two common arrangements of light sources used in optical projectors are (i) shadow (ii) surface

The shadow image of the object may be produced either on horizontal scale or vertical screen.

Surface illumination produces a reflected image of the face of the object. High intensity light is required for projecting surface characteristics

the object to be tested is placed (staged) on the work table. The space in which the parts can be staged is decided by the focal clearance or working distance of the optical system.

The light beam after passing the object to be projected passes into the projection system. Comprising lenses and mirrors which must be held in accurate alignment on rigid supports. The lenses are used to obtain the desired magnification and mirrors to direct the beam of light on screen. It is possible to change the magnification by changing the lenses.

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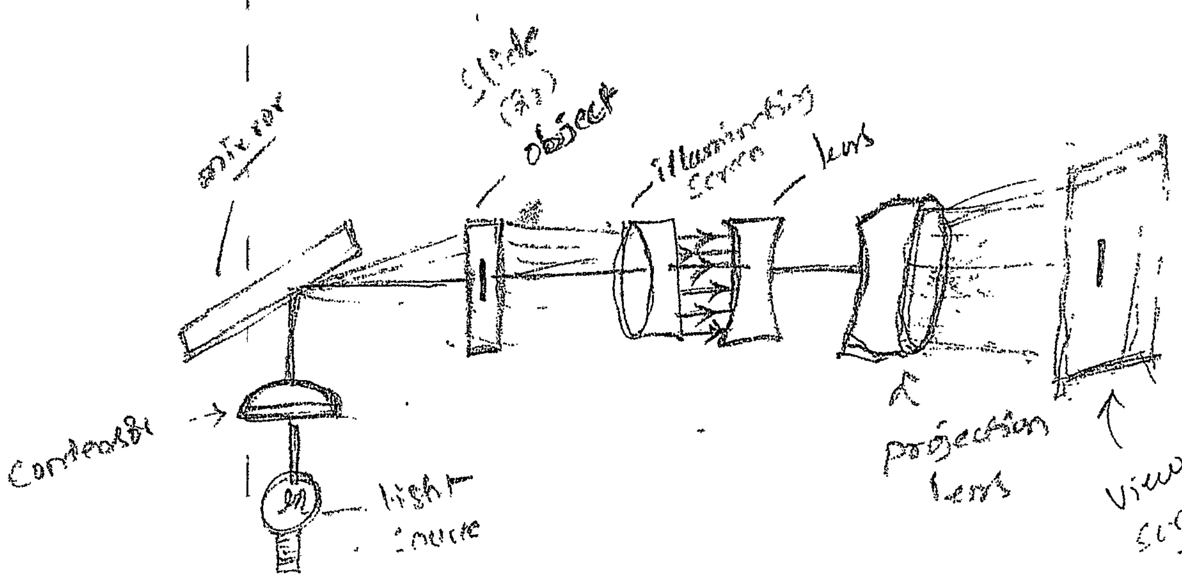
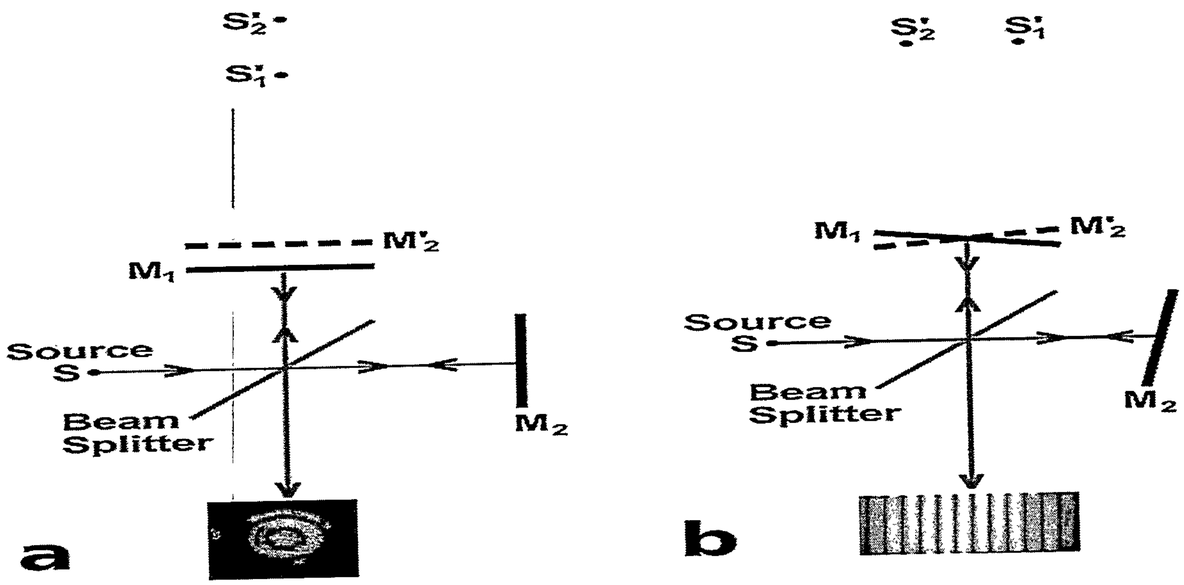


INTERFEROMETRY:

Interferometry is a family of techniques in which waves, usually electromagnetic waves, are superimposed causing the phenomenon of interference in order to extract information. Interferometry is an important investigative technique in the fields of astronomy, fiberoptics,engineering metrology,opticalmetrology, oceanography, seismolog y, spectroscopy (and its applications to chemistry), quantum mechanics, nuclear and particle physics, plasma physics, remote sensing, biomolecular interactions, surface profiling, microfluidics, mechanical stress/strain measurement, velocimetry, and optometry.

Interferometers are widely used in science and industry for the measurement of small displacements, refractive index changes and surface irregularities. In an interferometer, light from a single source is split into two beams that travel different optical paths, and then combined again to produce interference. The resulting interference fringes give information about the difference in optical path length.



Interferrometry.

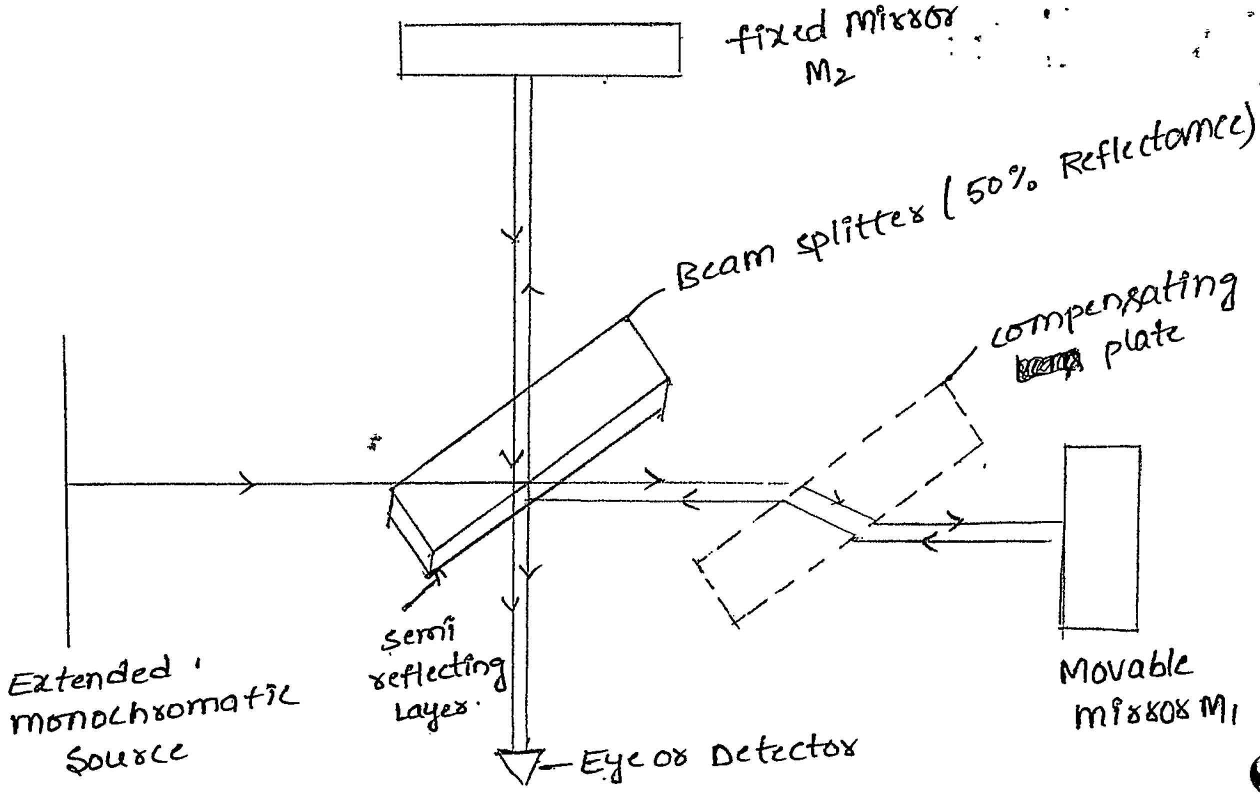
Types of interferrometers :-

The various types of interferrometers are

1. Michelson interferrometer
2. Fabry - perot interferrometer
3. Fringe counting interferrometer
4. NPL flatness interferrometer.
5. pitter NPL gauge interferrometer
6. Zeiss gauge block interferrometer
7. Multiple beam interferrometer.
8. Laser interferrometer ... etc.

1. Michelson interferrometer :-

This is the oldest type of interferro -meter. It utilises monochromatic light from an extended source. The monochromatic light falls on a beam splitter D consisting of semi-reflecting layer. Thus the light ray is devided into two paths. one is transmitted through compensating plate P to the mirror M1 and the other is reflected through beam splitter D to mirror M2. From both these mirrors, the rays are reflected back and these reunit at the semi-reflecting surface from where they are transmit to the eye as shown in fig and thus the fringes can be observed. Where Mirror M2 is fixed and mirror M1 is movable i.e it is attached to the object whose dimen -ons is to be measured.



Michelson interferometer.

2. NPL flatness interferometer :-

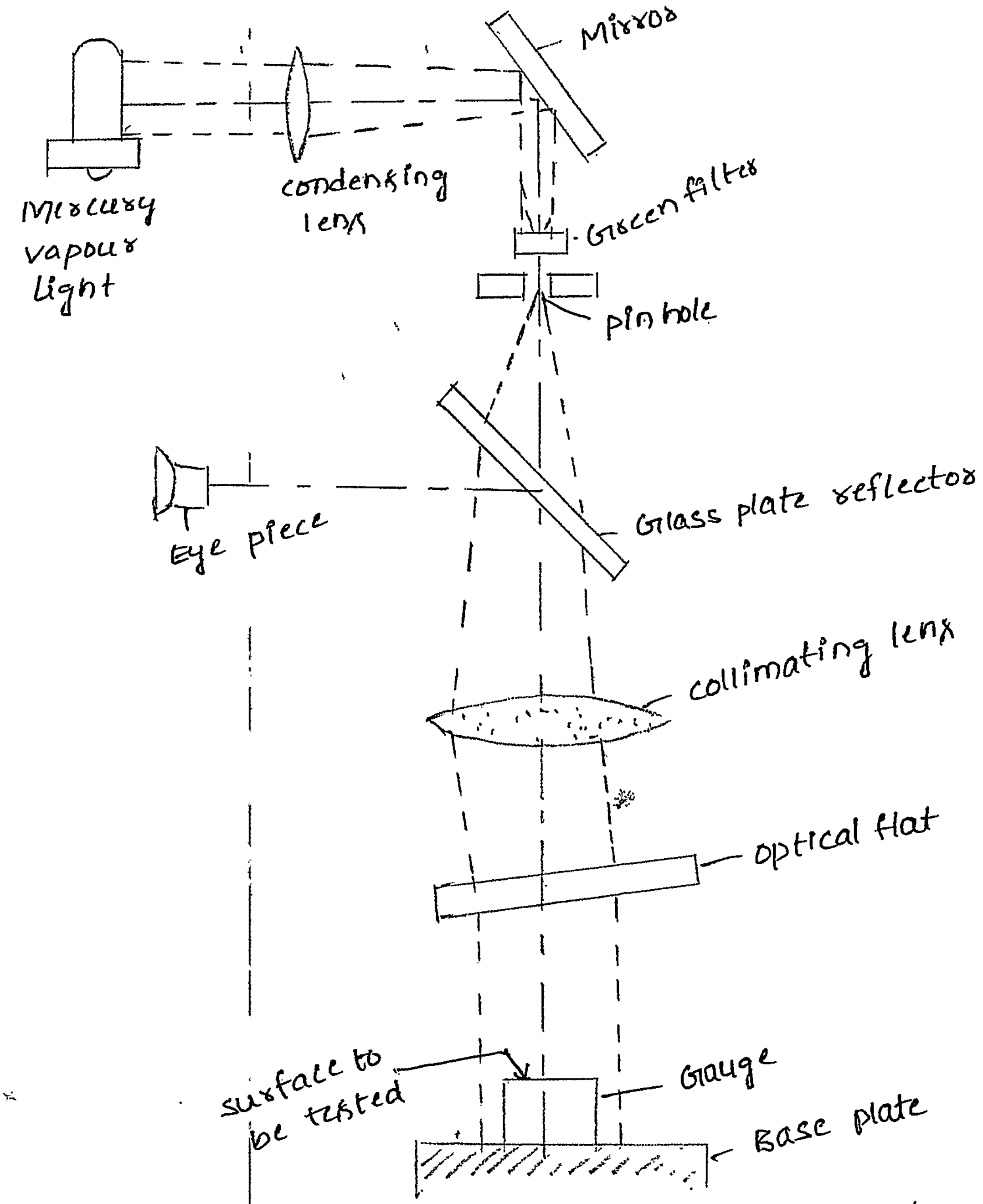
NPL flatness interferometer is an instrument, used for checking the flatness of flat surface. In this instrument mercury vapour lamp is used as a light source whose radiations are passed through a green filter and thus leaving a green monochromatic Light. The wave lenght of resulting monochromatic radiation is of the order of 0.5 μm. This radiation is then brought to focus on pin hole in order to obtain an intense point of source of monochromatic Light, which is in the focal plane of a collimating lens, and is thus projected as a parallel beam of light.

The beam is directed onto the gauge to be tested, which is wrung on the base plate, via an optical flat so that opticle fringes are formed across the face of the gauge, the fringes being viewed from directly by means of a thick glass plate semi reflector set at 45° to the optical axis.

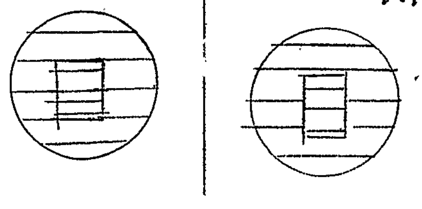
If the gauge face is flat and parallel to the base plate, the fringe pattern produced will be straight, parallel and equally spaced.

In case taper is present, then the fringe pattern obtained is as shown in figure 13.10(1).

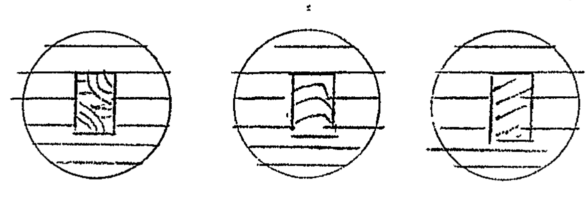
When the gauge surface is convex or concave the fringe pattern as shown in figure 13.10(2) is obtained.



NPL flatness interferometer



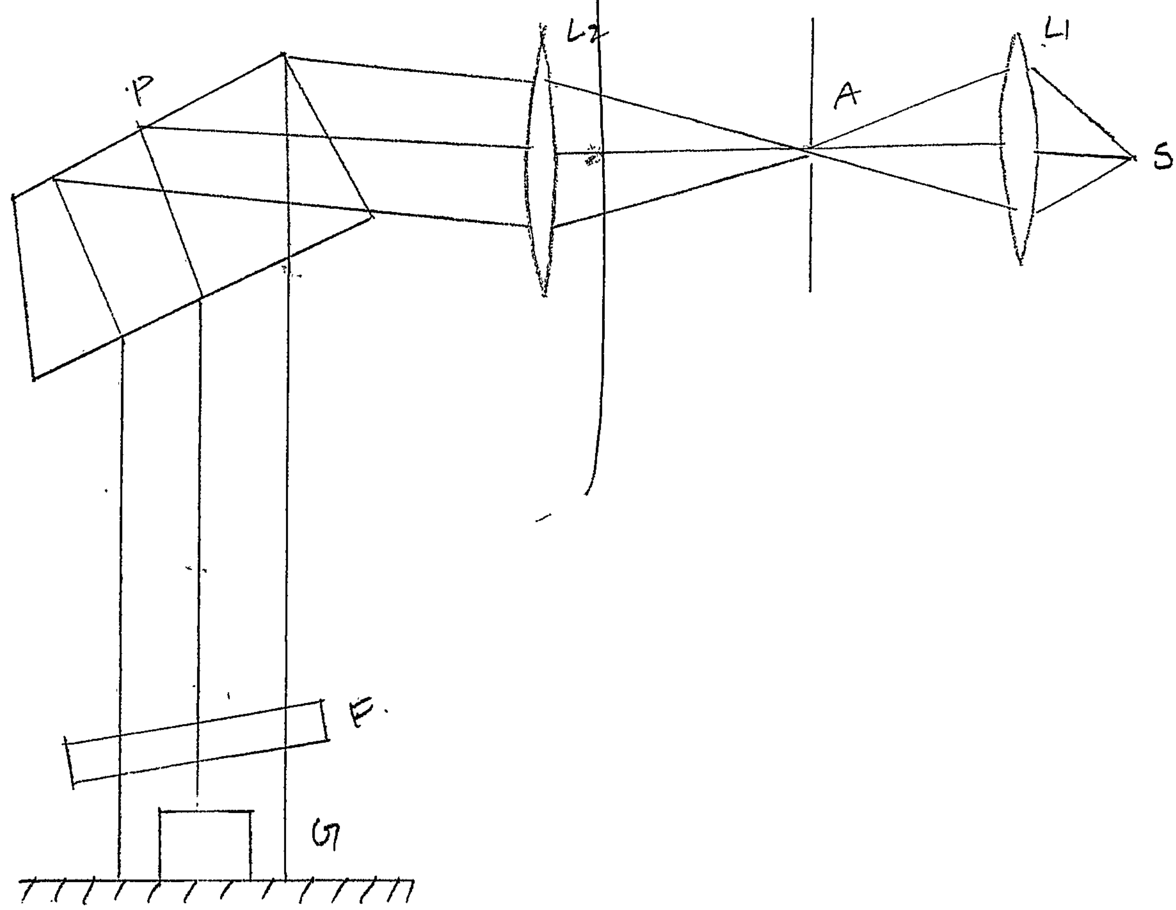
13.10(1)



13.10(2).

3. The pitter – N.P.L gauge interferrometer :–

This is also called as the gauge lenght interferrometer, as it is used for determining actual dimensions or absolute lenght of the gauges. Fig 13.11 shows the schematic arrangement of NPL gauge interferrometer. The light from the sources fall on slit A through lens L_1. After collimation by lens L_2 it goes through constant deviation prism P whose rotation determines wavelenght passed through reference flat (F) to upper surface of gauge block G and base plate B to which it is wrung. Light is reflected back in mirror P and it's patterns are observed through a telescope. The field of view is also shown in fig 13.11. The instrument should be used in standard conditions of temparature and pressure.



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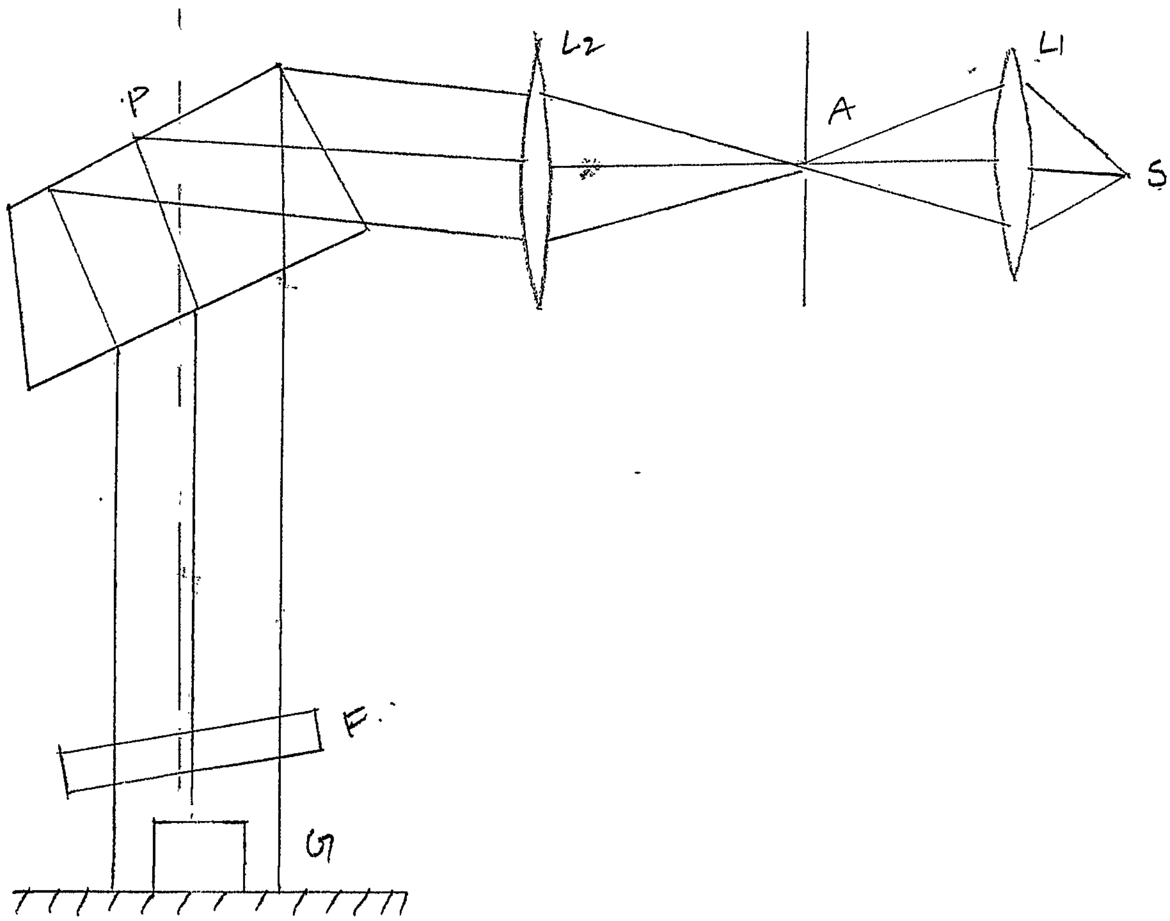


K.K.C

6.5.1 Autocollimators

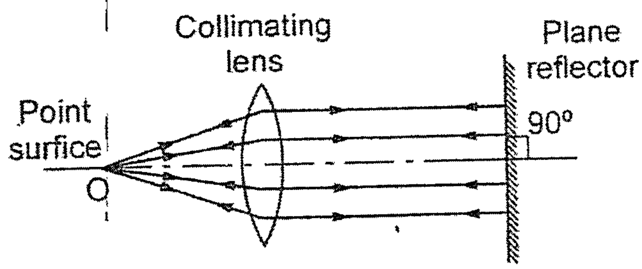
Principle

The two main principles used in an autocollimator are

(a) the projection and the refraction of a parallel beam of light by a lens, and

(b) the change in direction of a reflected angle on a plane reflecting surface with change in angle of incidence.

To understand this, let us imagine a converging lens with a point source of light O at its principle focus, as shown in Figure 6.7(a). When a beam of light strikes a flat reflecting surface, a part of the beam is absorbed and the other part is reflected back. If the angle of incidence is zero, i.e. incident rays fall perpendicular to the reflecting surface, the reflected rays retrace original path. When the reflecting plane is tilted at certain angle, the total angle through which the light is deflected is twice the angle through which the mirror is tilted. Thus, alternately, if the incident rays are not at right angle to the reflecting surface they can be brought to the focal plane of the light sources by tilting the reflecting plane at an angle half the angle of reflection as shown in Figure 6.7(b).



(a) Reflector is at 90° with the Direction of Rays

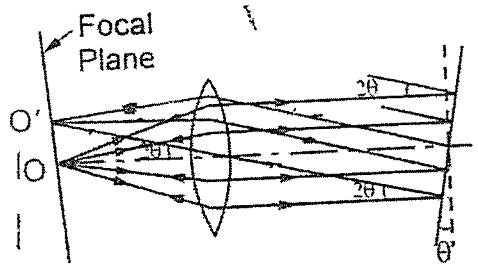


Figure 6.7(b) : Reflector is not at Right Angles to the Direction of the Rays

Now, from the diagram, $OO' = 2\theta \times f = x$, where f is the focal length of the lens.

Thus, by measuring the linear distance x, the inclination of the reflecting surface θ can be determined. The position of the final image does not depend upon the distance of the reflector from the lens. If, however, the reflector is moved too long, the reflected ray will then completely miss the lens and no image will be formed.

Working

In actual practice, the work surface whose inclination is to be obtained forms the reflecting surface and the displacement x is measured by a precision microscope which is calibrated directly to the values of inclination θ.

The optical system of an autocollimator is shown in Figure 6.8. The target wires are illuminated by the electric bulb and act as a source of light since it is not convenient to visualize the reflected image of a point and then to measure the displacement x precisely. The image of the illuminated wire after being reflected from the surface being measured is formed in the same plane as the wire itself. The eyepiece system containing the micrometer microscope mechanism has a pair of setting lines which may be used to measure the displacement of the image by setting to the original cross lines and then moving over to those of the image.

Generally, a calibration is supplied with the instrument. Thus, the angle of inclination of the reflecting surface per division of the micrometer scale can be directly read.

Autocollimators are quite accurate and can read up to 0.1 seconds, and may be used for distance up to 30 meters.

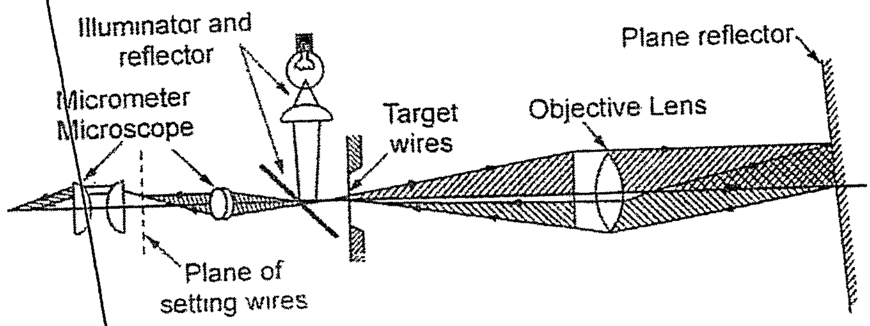


Figure 6.8 : Optical System of an Autocollimator

SAQ 4

Describe the principle and working of an autocollimator.

6.6 SUMMARY

In this unit, principles and techniques of angular measuring devices have been discussed. The unit begins with description of line standard angular measuring devices like protractor and bevel protractor. Next, face standards angular measuring devices, viz. slip gauges and sine bars are discussed. Instruments used for measurement of inclinations, viz. spirit level inclinometers are discussed in the next section. The unit finishes with the discussion of the principle and working of angle comparator, viz. autocollimators.

6.7 KEY WORDS

Protractor : It is the simplest angle-measuring device and can give reading up to 5′.

Clinometer : It is a device for measuring angle between two faces. It uses the principle of spirit level.

Sine Bar : It is an indirect angle-measuring instrument which gives measurement up to 2″.

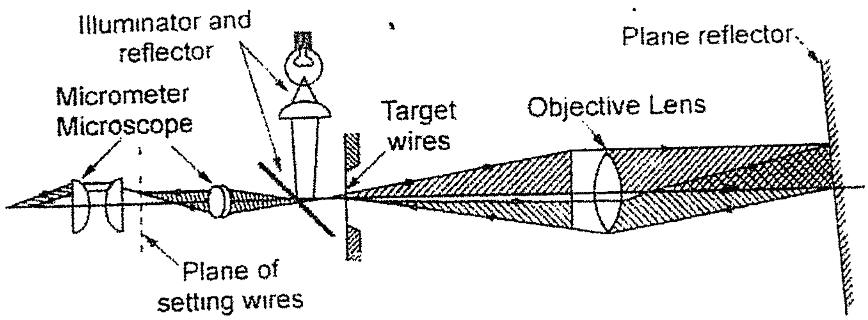
Angle Gauges : It is a precision angular measuring device that can give accuracy up to 3″.

Vial : The closed glass tube of accurate size in a spirit level, which is used for storing the liquid, is called the vial. It is graduated in linear scale and the bubble moves inside it.

Autocollimator : It is an angle comparator based on the principle of reflection of light. Least measurement given by autocollimator is up to 1′.

Generally, a calibration is supplied with the instrument. Thus, the angle of inclination of the reflecting surface per division of the micrometer scale can be directly read.

Autocollimators are quite accurate and can read up to 0.1 seconds, and may be used for distance up to 30 meters.



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unit - III

2.3.1 Purpose of using limit gauges

- Components are manufactured as per the specified tolerance limits, upper limit and lower limit. The dimension of each component should be within this upper and lower limit.
- If the dimensions are outside these limits, the components will be rejected.
- If we use any measuring instruments to check these dimensions, the process will consume more time. Still we are not interested in knowing the amount of error in dimensions.
- It is just enough whether the size of the component is within the prescribed limits or not. For this purpose, we can make use of gauges known as limit gauges.

The common types are as follows:

1) Plug gauges.
2) Ring gauges.
3) Snap gauges.

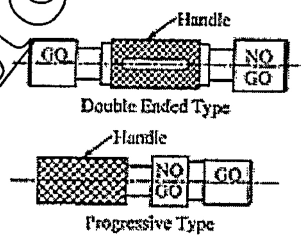

Fig 2.9 Plug Gauge

2.4 PLUG GAUGES

- The ends are hardened and accurately finished by grinding. One end is the GO end and the other end is NOGO end.
- Usually, the GO end will be equal to the lower limit size of the hole and the NOGO end will be equal to the upper limit size of the hole.
- If the size of the hole is within the limits, the GO end should go inside the hole and NOGO end should not go.
- If the GO end and does not go, the hole is under size and also if NOGO end goes, the hole is **over size**. Hence, the components are rejected in both the cases.

Plug, Ring, snap, ... taper, profile & position gauges

UNIT II

LINEAR AND ANGULAR MEASUREMENTS

1. Double ended plug gauges

In this type, the GO end and NOGO end are arranged on both the ends of the plug. This type has the advantage of easy handling.

2. Progressive type of plug gauges

In this type both the GO end and NOGO end are arranged in the same side of the plug. We can use the plug gauge ends progressively one after the other while checking the hole. It saves time. Generally, the GO end is made larger than the NOGO end in plug gauges.

2.5 TAPER PLUG GAUGE

Taper plug gauges are used to check tapered holes. It has two check lines. One is a GO line and another is a NOGO line. During the checking of work, NOGO line remains outside the hole and GO line remains inside the hole.

They are various types taper plug gauges are available as shown in fig. Such as

1) Taper plug gauge — plain
2) Taper plug gauge — tanged.
3) Taper ring gauge plain
4) Taper ring gauge — tanged.

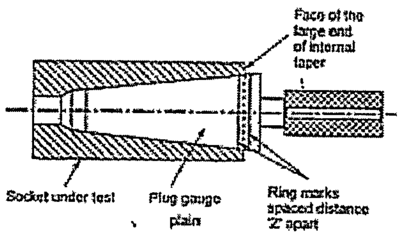

Fig 2.10 Taper Gauge

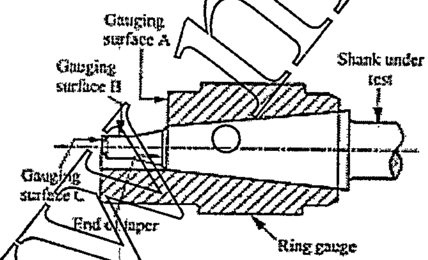

Fig 2.11 Taper ring Gauge plain

2.6 RING GAUGES

- Ring gauges are mainly used for checking the diameter of shafts having a central hole. The hole is accurately finished by grinding and lapping after taking hardening process.
- The periphery of the ring is knurled to give more grips while handling the gauges. We have to make two ring gauges separately to check the shaft such as GO ring gauge and NOGO ring gauge.
- But the hole of GO ring gauge is made to the upper limit size of the shaft and NOGO for the lower limit.
- While checking the shaft, the GO ring gauge will pass through the shaft and NOGO will not pass.
- To identify the NOGO ring gauges easily, a red mark or a small groove cut on its periphery.

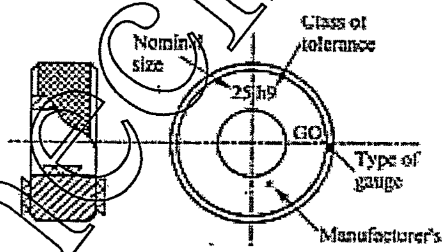

Fig 2.12 Ring Gauge

2.7 SNAP GAUGE

Snap gauges are used for checking external dimensions. They are also called as gap gauges. The different types of snap gauges are:

1. Double Ended Snap Gauge

- This gauge is having two ends in the form of anvils. Here also, the GO anvil is made to lower limit and NOGO anvil is made to upper limit of the shaft. It is also known as solid snap gauges

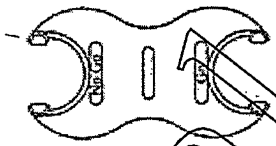

Fig 2.13 Double ended Snap Gauge

2. Progressive Snap Gauge

This type of snap gauge is also called caliper gauge. It is mainly used for checking large diameters up to 100mm. Both GO and NOGO anvils at the same end. The GO anvil should be at the front and NOGO anvil at the rear. So, the diameter of the shaft is checked progressively by these two ends. This type of gauge is made of horse shoe shaped frame with I section to reduce the weight of the snap gauges.

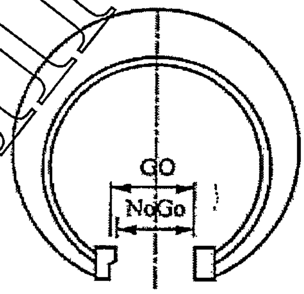

Fig 2.14 Progressive Snap Gauge

3. Adjustable Snap Gauge

Adjustable snap gauges are used for checking large size shafts made with horseshoe shaped frame of I section. It has one fixed anvil and two small adjustable anvils. The distance between the two anvils is adjusted by adjusting the adjustable anvils by means of setscrews. This adjustment can be made with the help of slip gauges for specified limits of size.

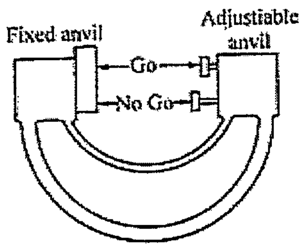

Fig 2.15 Adjustable Snap Gauge

4. **Combined Limit Gauges**

A spherical projection is provided with GO and NOGO dimension marked in a single gauge. While using GO gauge the handle is parallel to axes of the hole and normal to axes for NOGO gauge.

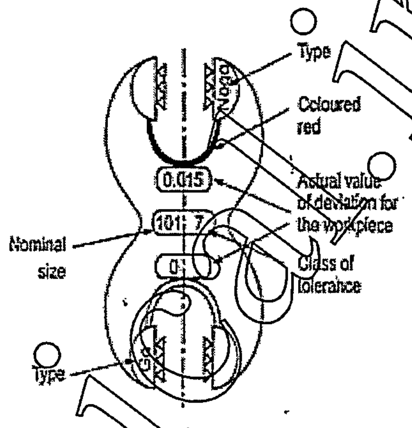

Fig 2.16 Combined Limit Gauge

5. **Position Gauge**

It is designed for checking the position of features in relation to another surface. Other types of gauges are also available such as contour gauges, receiver gauges, profile gauges etc.

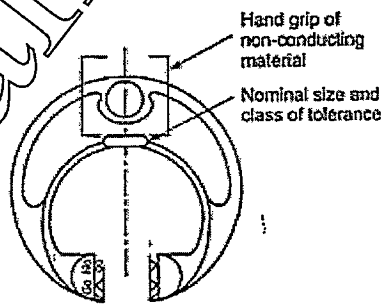

Fig 2.17 Position Gauge

2.8 TAYLOR' S PRINCIPLE

It states that GO gauge should check all related dimensions. Simultaneously NOGO gauge should check only one dimension at a time.

Maximum metal condition

It refers to the condition of hole or shaft when maximum material is left on i.e. high limit of shaft and low limit of hole.

Minimum metal condition

If refers to the condition of hole or shaft when minimum material is left on such as low limit of shaft and high limit of hole.

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UNIT-VI

Measurement of Temperature

- **Measurement of Temperature:-**

Temperature is probably, most widely measured and frequently controlled variable encountered in industrial processing of all kinds measurement of temperature is involved in thermo dynamics, heat transfer and many chemical operations. Basically all the properties of matter such as size, colour, electrical and magnetic characteristics and the physical states (solid, liquid, gas) change with changing temperature.

Definition:

Temperature may be defined as the degree of hotness and coldness of a body are an environmental measured on a definite scale.

The temperature of a substance is a measure of the hotness, or coldness, of that substance. It is the thermal site of a body or a substance which determines whether it will give heat to, or receive heat from, other bodies. If two bodies are placed in contact then heat tends to flow from a body at a higher temperature to a body at a lower 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 is usually taken to mean "quantity of heat" Temperature and heat flow are 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 remember that in temperature measurement, two bodies in intimate contact are at the same temperature only if there is no heat flow between them.

Temperature scales:

Temperature scales are based upon some recognized fixed points. At least two fixed points are required which are constant in temperature and can be easily reproduced as:

(i) Centrigrade and fahren heat scales:

On both these scales the freezing point and boiling point of water are used as fixed point. The freezing point. The centigrade scale abbreviated as ^{0}c, assigns 0 ^{0}c to the ice point and 100^{0}c to the steam point and the intervals between these points is divided into 100 equal points. The corresponding values of the Fahrenheit scale deviated ^{0}F are 32 ^{0}F and 212^{0}F with the interval divided into 180 equal parts.

(ii) kelvin and rankine absolute scales:-

On the kelvin and Rankine scales the absolute and hypothetically placed at -273.2°c and -459.7°F.

(iii) Thermo dynamic scale:-

The efficiency of an ideal engine operating up on the control cycle between any two temperatures is given by.

$$\frac{T1-T2}{T1} = \frac{Q1-Q2}{Q1}$$

This can be written as $T1/T2 = Q1/Q2$

4. International temperature scale:-

This scale has been established and adopted provide an experimental basis for the calibration of specific thermometers to indicate temperatures as close as possible to the Kelvin thermodynamic scale. The International temperature scale covers the range from the boiling point of oxygen to the highest temperatures of incandescent bodies and names. The main features of this scale, adopted in 1948 at the Ninth General Conference on Weights and Measures are:

(1) Temperatures are to be designated as of and denoted by the symbol t. The name Celsius was officially adopted to replace the name Centigrade.

(2) The scale is based upon a number of fixed and reproducible equilibrium temperatures to which numerical values are assigned.

Fundamental fixed points and their numerical values (at standard atmospheric pressure of 1013250 dynes/cm^2)

FIXED POINT	TEMPARATURE°C
1.Temparature of equilibrium between liquid oxygen and it's vapour (oxygen point)	-182.97
2 .Temperature of equilibrium between ice and (saturated) water (ice point) fundamental fixed point.	0
3. Temperature of equilibrium between liquid, Water and its vapour (steam point)-fundamental fixed point.	100
4. Temperature of equilibrium between liquid, sulphur and it's vapour (sulphur point)	444.60
5.Temparature of equilibrium between solid and liquid silver(silver point)	960.8
6. Temperature of equilibrium between the solid and liquid gold (gold point)	1063

Classification:-

The instruments for measuring temperature have been classified in the first place according to the nature of change produced in the testing body by the change of temperature. The following four broad categories have been proposed.

1. Expansion thermometers.

2. Change of state thermometer.

3. Electrical methods of measuring temperature.

4. Radiation and optical pyrometer.

1. EXPANSION THERMO METERS:-

(a) Expansion of solids

(i) Bimetaliic thermometer

(ii) Solid rod thermometer

(b) Expansion of liquids

(i) liquid in glass thermometer

(ii) liquid in metal thermometer

(C) Expansion of gases-gas thermometer

2. Change of state thermometers:-

Liquid in metal thermometers (or) vapour pressure thermometers.

3. Electrical methods of measuring temperature:-

(a) Electrical resistances bulbs.

(b) Thermistors.

(c) Thermo couples and thermopiles.

4. Radiation and optical pyrometers:-

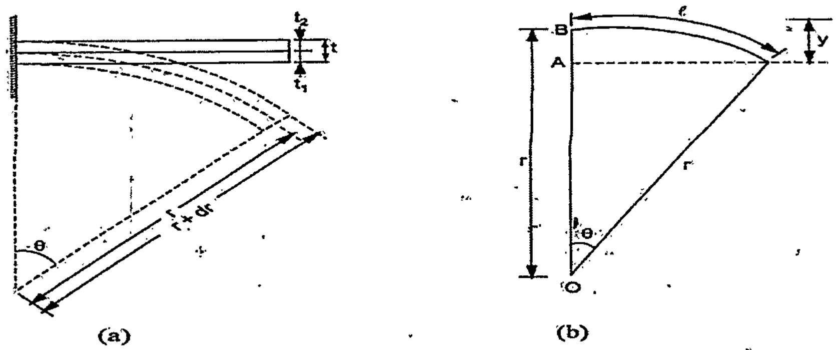
Optical pyrometers (total radiation pyrometer).

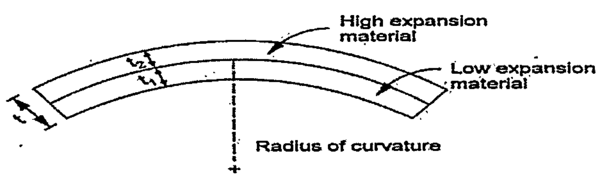
Ranges:-

Type	Range°C	Accuracy°C
1.Glass thermometers		
(a) mercury filled	-39 to 400	0.3 to 1.0
(b) H_g+N_2	-39 TO 540	0.3 TO5.5
(C) Alcohol filled	-70 to 65	0.5 to 1.0

2.Pressure gauge thermometer.		
(a) vapour pressure type	11 to 200	1 to 5.5
(b) liquid (or) gas type filled	-150 to 600	1 to 5.5
3.Bimetallic thermometer	-74 to 540	0.3 to 14.0
4.Resistance thermometer	-240 to 980	0.003 to 3.0
5.Thermo couples		
(a) base metals	-185 to 1150	0.3 to 11.0
(b) Percious metals	-185 to 1150	0.3 to 11.0
6.Thermistors	-100 to 260	Depends up on ageing
7.pyrometers		
(a) optical	760 and above	11 for black body
(b) radiation	540 and above	11-16 for black body
8.fusion	590 to 3600	As low as 20-30 under optimum conditions.

Bimetallic thermometer:- (or) solid expansion:-





The bi-metal strip

Construction:-

A bimetallic strip consists of two pieces of different materials firmly bonded together by bending. For a bi-metal in the form of a straight cantilever beam temp changes cause the free end to deflect because of the different expansion rates of the components. This deflection can be correlated quantitatively to the temp change.

The radius of curvature of the bend of a straight bi-metal beam may be calculated as

$$r = t\frac{\left[3(1+m)^2 + (1+mn)\left(m^2 + 1/mn\right)\right]}{6(\alpha_2 - \alpha_1)(T - T_0)(1+m)^2}$$

where t is combined thickness of the bonded strip, $(t_1 + t_2)$

m is the ratio of thickness of low to high expansion materials, t_1 / t_2

n is the ratio of moduli of elasticity of low to high expansion material, E_1 / E_2

Normally the two expansion material is invar and the high expansion material is brass. The respective coefficient of expansion for invar and brass.

The respective coefficients of expansion for invar and brass are 0.009×10^{-4} per °C and 0.189×10^{-4} per °C.

When bimetallic strip in the form of cantilever is assumed to bend to a circular are than

$$\frac{r+dr}{r} = \frac{\text{expanded length of strip having higher expansion coefficient}}{\text{expanded length of strip having lower expansion coefficient}}$$

If

$$= \frac{l\left[1+\alpha_2 (T-T_0)\right]}{l\left[1+\alpha_1 (T-T_0)\right]}$$

Simplification gives

$$r = \frac{dr\left[1+\alpha_1 (T-T_0)\right]}{(\alpha_2 - \alpha_1)(T-T_0)}$$

With the low expansion metal of invar and the thickness of each metal strip $t/2$,

$\alpha_1 = 0$ and $dr = t/2$

With these stipulations, equation 10.13 reduces to

$$r = \frac{t}{2\alpha_2 (T-T_0)}$$

Bimetallic elements can be arranged in the flat spiral the single helix and the multiple helix configuration.

Characteristics:-

1. Low cost.
2. Simple and compact

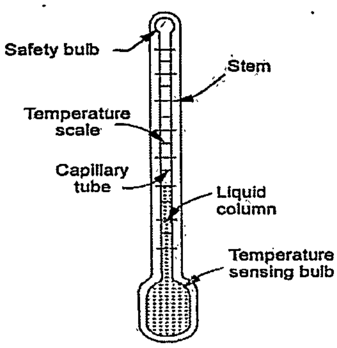
Applications:-

1. Control of gas flow
2. electric iron boxes
3. Domestic ovaus.

Liquid in glass thermometers:-

The liquid in gas thermometers is one of the most common types of temp measuring devices. The unit consists of glass envelope, responsive liquid and indicating scale.

Liquid	range°C
Mercury	-3.5 to 510
Alcohol	-80 to 70
Toluene	-80 to 100
Peutane	-200 to 30
Creosote	-5 to 200



Liquid-in-glass thermometer

The choice in the type *of glass used is a mater* of economics influenced by the range of the thermometer. Higher the range, higher the cost. For temperature up to 450 °Cnormal glass used.at high temp up to 550°C. Above this temp quartz thermometers have been used.

Salient features/characteristics:-

1. Low cost and simplicity of use
2. Portable
3. Ease of checking for physical damage

4. Absence of need for auxiliary instruments.

5. No need of additional indicating instruments

6. Range limited to about 600°C.

Calibration of liquid in glass thermometer:-

1. Complete immersion

2. Total immersion

3. Partial immersion

Correction factor c_s= 0.00018N(T1-T2)

C_s=Stem Correction In Degrees To Be Added algebrically To The Indicated

Temp N= Numberof degrees of exposed

T1= Reading of the primary thermometer

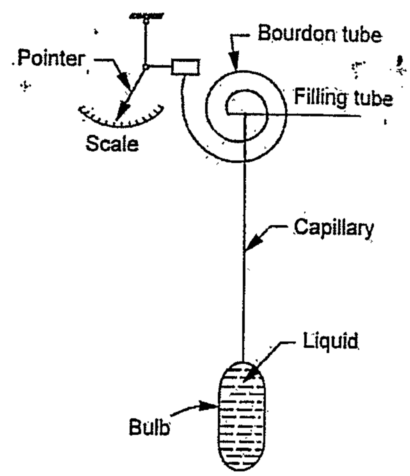
and T2= Average temperature of exposed

stem.

Liquid in metal thermometers:-

The two distinct disadvantages of liquid in glass thermometers are

1. The glass is very fragile and hence care should be taken in handling these thermometers.
2. The position of the thermometer for accurate temp measurement is not always the best position for reading the scale of the thermometer



Filled-system thermometer

Both of these disadvantages are overcome in mercury in steel thermometer. The principle of operation is again the differential expansion of liquid which is used.

(i) a temperature sensitive element (bulb) filled with expanding fluid

(ii) a flexible capillary tube

(iii) a pressure or volume sensitive device such as Bourdon tube, bellows or diaphragms, and

(iv) a device for indicating or recording a signal related to the measured temperature.

Advantages and limitations :

* Simple and inexpensive design of the system

* Quite rugged construction, minimum possibility of, damage or failure in shipment, installation and use

* Fairly good response, accuracy and sensitivity

* Remote indication upto about 100 m possible with capillary lines.

Gas Thermometer:-

This system is defined as "a thermal system with a gas and operating on the principle of pressure change with temperature change". The expansion, of a gas is governed by the ideal gas law:

$$PV = RT; \quad P = (RT/V)$$

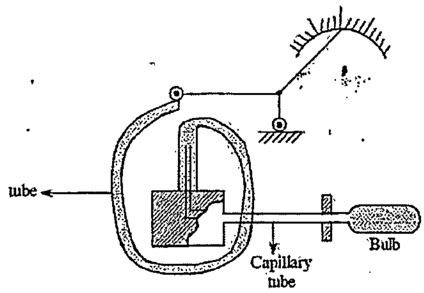


Figure: Gas Thermometer

Gas: Nitrogen gas

Range: -130°to 540°

The volume of gas required in the bulb is determined by the gas expansion and by the temperature range of the instrument.

$$V = K\left(\frac{\quad}{P_2 - P_2}\right)$$

Where subscripts 1, 2 refer to the conditions at the lowest and highest points of the scale.

➤ Electrical Methods:-

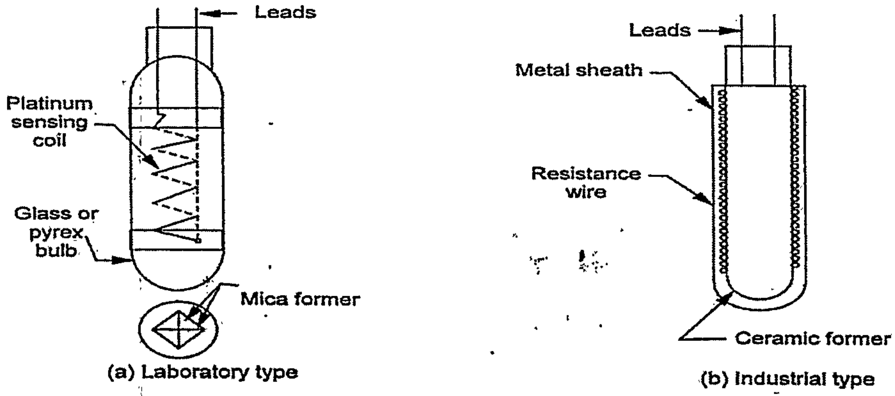
In electrical methods of measuring temperature, the temperature signal is converted into electrical signal either through a change in resistance or voltage development of emf.

1. Resistance Thermometers

2. Thermistors

3. Thermo couples

1. Resistance Thermometers:



Resistance thermometers

The resistance R (ohms) of an electrical conductor of resistivity ρ (ohms.c), length L (cm) and cross sectional area A (cm^2) is given by

$$R = \rho\, L/A$$

As temperature changes, the resistance of the conductor also changes. This is due to two factors : (*i*) dimensional change due to expansion or contraction and (*ii*) change in the current opposing properties of the material itself. For an unconstrained conductor, the latter is much more than 99% of the total change for copper. This change in resistance with temperature is used for measuring temperature.

Most metals become more resistant to the passage of electric current as they become hotter, *i.e.*, their resistance increases with growth in temperature. An adequate approximation of the resistance-temperature relationship is given by :

$$R_t = R_0(1 + \alpha t + \beta t^2) \quad \ldots(10.23)$$

where R_t is resistance at any temperature t °C, R_0 is resistance at zero °C, α and β are constants depending on the material. The constants R_0, α and β are determined at the ice, steam and sulphur points respectively. For platinum resistance thermometer, R_t / R_0 must not be less than 1.39 for t = 100 °C to indicate the purity of the metal and the stability.

Over a limited temperature range around zero °C, the following linear relationship is equally valid :

$$R_1 = R_0(1 + \alpha\, \theta_1)$$

The thermometer comprises a resistance element or bulb, suitable electrical leads and an indicating - recording or resistance measuring instrument. The resistance element is, usually in the form of a coil of very fine platinum, nickel or copper wound non -conductively. Onto an insulating ceramic former which is protected externally by a metal sheath. A laboratory type of resistance thermometer is often wound on a crossed mica former and enclosed in a pyrex tube. The tube may be evacuated or filled with an inert gas to protect the metal wire. Care is to be taken to ensure that the resistance wire is free from m mechanical stresses. A metal which has been strained will suffer a change in the resistance characteristics; the metal is therefore usually annealed at a temperature higher than that at which it is so operate.

Platinum is preferred because,

1. Physically stable (i.e., relatively indifferent to its environment, resists corrosion and chemical attack and is not readily oxidised) and has high electrical resistance characteristics.
2. Accuracy attainable with a platinum resistance thermometer is of the order of ± 0.01 of upto $500° C$ and within $\pm 0.1°C$ of upto $1200 °C$.

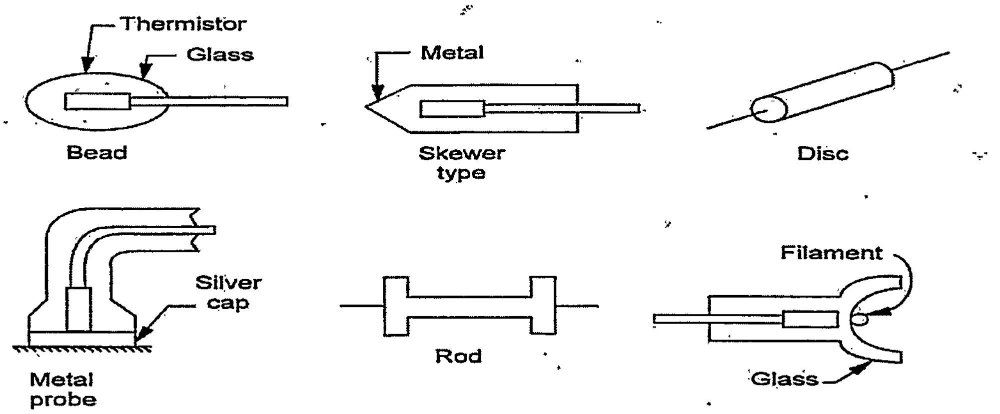
Advantages:-

* Simplicity and accuracy of operation

Possibility of easy installation and replacement of sensitive bulb

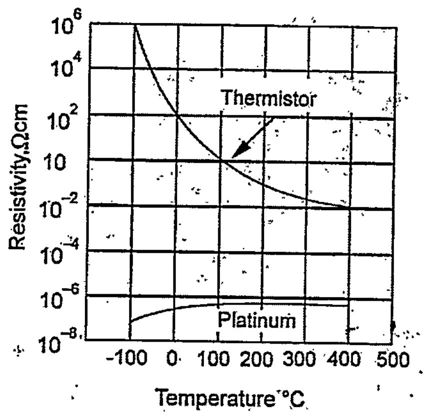
* Easy check on the accuracy of the measuring circuit by substituting a standard resistance for the resistance element.

2. Thermistors:



Typical thermistor forms

Thermistor is a contraction of term Thermal Resistor. They are essentially semi-conductors which behave as resistors with a high negative temperature coefficient. As -the temperature increases, the resistance goes down, and as the temperature decreases, the resistance goes up. This is just opposite to the effect of temperature changes on metals.



Thermistors are composed of sintered mixture of metallic oxides such as manganese. Nickel, cobalt, copper, iron and uranium. These metallic oxides are milled, mixed in appropriate proportions, are pressed into the desired shape with appropriate binders and finally sintered the electrical terminals are either embedded before sintering or baked afterwards. The electrical characteristics of thermistors are controlled by varying the type of oxide used and physical size and configuration of the thermistor.

Thermistors may be shaped in the form of beads, disks, washers, rods and `these standard forms are shown in Fig.

The mathematical expression for the relation- ship between the resistance of a thermistor and absolute temperature of thermistor is

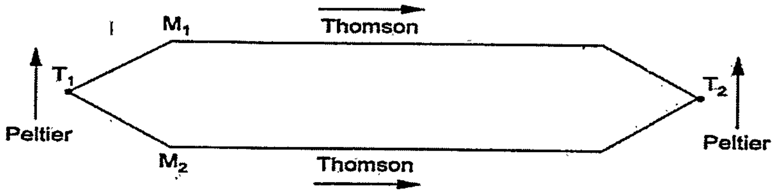
$$R_t = R_o e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)}$$

where R_t is the resistance at T °K, R_o is the resistance at absolute temperature T_o, β is constant depending on the thermistors formulation or grade, typical range is (3400 — 4000 °K).

3. Thermo couples:

The basic principle of temperature measurement by thermo-electricity was discovered by Seebeck in 1821 and is illustrated in Fig. 10.20. When two conductors of dissimilar metals M1 and M2 are joined together to form a loop (a thermocouple) and two unequal temperatures Tl1 and T2 are imposed at the two interface connections, an electric current we through the loop.

Experimentally it has been found that -the magnitude of the current is directly related to the two materials M1 and M2, and the temperature difference (T1 – T2). In the practical application of the effect, a suitable device is incorporated in the circuit to indicate any electromotive force or Bower current. For convenience of measurement and standardization, one of the two junctions is usually maintained at some constant known temperature. The output voltage of the circuit then indicates the temperature difference relative to the reference temperature. Most tabulations set the reference value to the triple point of water (O°C).



Basic thermocouple circuit

Thermo-electric effects arise in two ways:

* a potential difference always exists between two dissimilar metals in contact with each other (Peltier effect)

* a potential gradient exists even in a single conductor having & temperature gradient (Thomson effect)

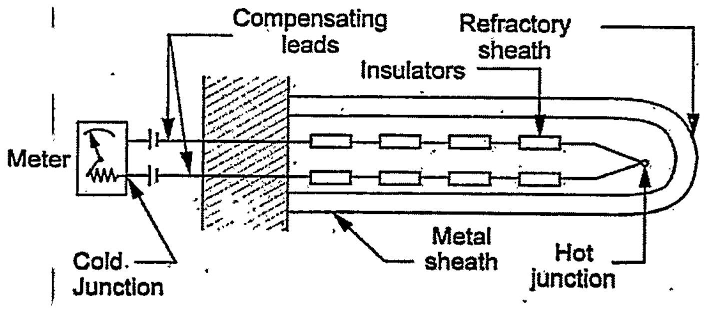
In commercial instruments, the thermocouple materials are so chosen that the Peltier and

Thomson emfs act in such a manner that the combined value is maximum and that varies directly with temperature.

Pyrometer:

Elements of a thermo-electric pyrometer **:** The essential elements of a thermo-electrical pyrometer are shown schematically in Fig.

* Two dissimilar conductors electrically insulated except at the hot junction, where the conductors may either be soldered or welded together, or may be completely separated from each other.
* a refractory and a metal sheath to protect the thermocouple from injurious furnace gases and to prevent it from mechanical damage.
* compensating leads which allow the measuring instrument to be placed at a



Element of a thermo-electric pyrometer

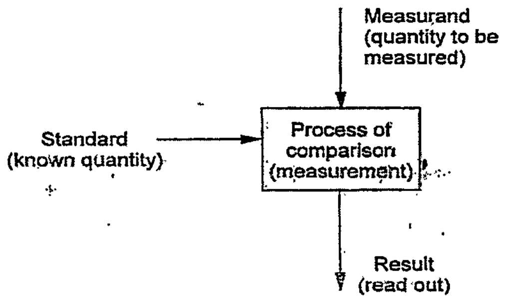
UNIT-1V

Measurement:-

The old measurement is used to tell us length, weight and temperature are a change of this physical measurement is the result of an opinion formed by one (or) more observes about the relative size (or) intensity of some physical quantities.

Definition:

The word measurement is used to tell us the length, weight, temperature, color or a change in one of these physical entities of a material. Measurement provides us with means for describing the various physical and chemical parameters of materials in quantitative terms. For example,the10 cm length of an object implies that the object is 10 times as large as 1 cm; the unit employed in expressing length.



Fundamental measuring process

These are two requirements which are to be satisfied to get good result from the measurement.

1. The standard must be accurately known and internationally accepted.
2. The apparatus and experimental procedure adopted for comparison must be provable.

Instrumentatio
n:-Definition:

The human senses cannot provide exact quantitative information about the knowledge of events occurring in our environments. The stringent requirements of precise and accurate measurements in thetechnological fields have, therefore, led to the development of mechanical aids called instruments.

Or

Definition: the technology of using instruments to measure and control physical and chemicalproperties of materials is called instrumentation.

In the measuring and controlling instruments are combined so that measurements provide impulsesfor remote automatic action, the result is called control system.

Uses:

-> study the function of different components and determine the cause of all functioning of the system,to formulate certain empirical relations.
-> to test a product on materials for quality control.
-> to discover effective components.
-> to develop new theories.
-> monitor a data in the interest of health and safety.

Ex:- fore casting weather it predicting in the earth case.

Methods of measurement:-

1. Direct and indirect measurement.
2. Primary and secondary & tertiary measurement.
3. Contact and non-contact type of measurement.

1. Direct and indirect measurement:

Measurement is a process of comparison of the physical quantity with a standard depending uponrequirement and based upon the standard employed, these are the two basic methods of measurement.

Direct measurement:

The value of the physical parameter is determined by comparing it directly withdifferent standards. The physical standards like mass, length and time are measured by direct measurement.

Indirect measurement:

The value of the physical parameter is more generally determined by indirectcomparison with the secondary standards through calibration.

The measurement is convert into an analogous signal which subsequently processand fed to the end device at present the result of measurement.

2. Primary and secondary & tertiary measurement:

The complexity of an instrument system depending upon measurement being made andupon the accuracy level to which the measurement is needed. Based upon the complexity of the measurement systems, the measurement are generally grouped into three categories.

i. Primary
ii. Secondary
iii. Tertiary.

In the primary mode, the sought value of physical parameter is determined by comparing it directly with reference standards the required information is obtained to sense of side and touch.

Examples are:

a) Matching of two lengths is determining the length of a object with ruler.
b) Estimation the temperature difference between the components of the container by inserting fingers.
c) Use of bean balance measure masses.
d) Measurement of time by counting a number of strokes of a block.

Secondary and tertiary measurement are the indirect measurements involving one transmission are called secondary measurements and those involving two convergent are calledtertiary measurements.

The measurement of static pressure by boundary tube pressure gauge is a typical example of tertiary measurement.

3. Contact and non-contact type of measurements:

Contact type:
Where the sensing element of measuring device as a contact with medium whose characteristics arebeing measured.

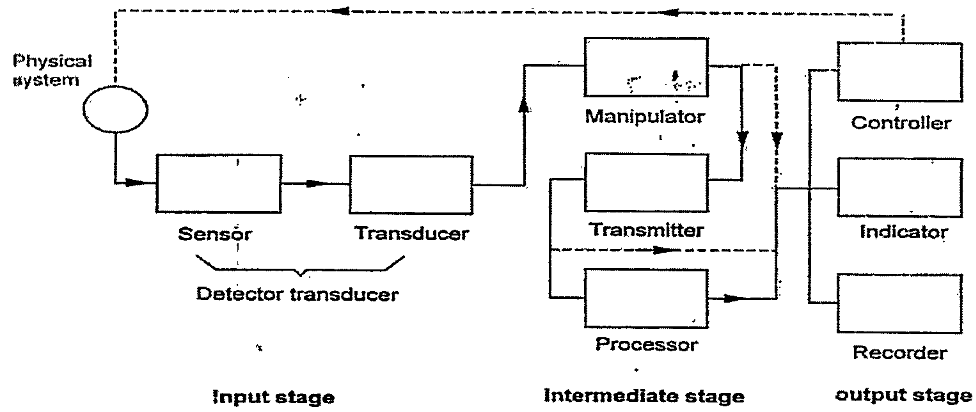
Non-contact type:
Where the sense doesn't communicate physically with the medium.

Ex:
The optical, radioactive and some of the electrical/electronic measurement belong to this category.

Objectives of instrumentation:-

1. The major objective of instrumentation is to measure and control the field parameters to increasesafety and efficiency of the process.
2. To achieve good quality.
3. To achieve auto machine and automatic control of process there by reducing human.
4. To maintain the operation of the plan within the design exportations and to achieve good quantityproduct.

Generalised measurement system and its functional elements:-



Generalised measurement system

1) Primary sensing element.

2) Variable conversion (or) Transducer element.

3) Manipulation of element.

4) Data transmission element.

5) Data processing element.

6) Data presentation element.

The principal functions of an instrument is the acquisition of information by Sensing and perception, theprocess of that information and its final presentation to a Human observer. For the purpose of analysis and synthesis, the instrument s are considered as systems (or) assembly of inter connected componentsorganised to perform a specified function. The different components are called elements.

1) PIMARY SENSING ELEMENT:

An element that is sensitive to the measured variable .The sensing element sense the condition , state (or) value of the process variable by extracting a small part of energy from the measurement and produces an output which is proportional to the input. Because of the energy expansion, the measuredquantity is always disturb. Good instruments are designed to minimise this loading effect.

2) Variable conversion (or) transducer element:

An element that converts the signal from one physical for to Another without changing the informationcontent of the signal.

Example:

- Bourdon tube and bellows which transfer pressure into displacement.
- Proving ring and other elastic members which converts force into displacement.
- Rack and Pinion: It converts rotary to linear and vice versa.
- Thermo couple which converts information about temperature difference to information in theform of E.M.F.

3) MANIPULATION ELEMENT:

It modifies the direct signal by amplification, filtering etc., so that a desired output is produced.

$$[\text{input}] \times \text{constant} = \text{Output}$$

4) DATA TRANSMISSION ELEMENT:

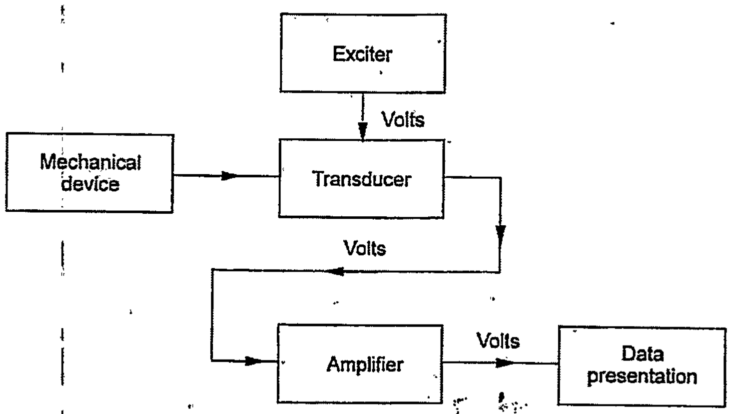
An element that transmits the signal from one location to another without changing the information content. Data may by transmitted over long distances (from one location to another) or short distances(from a test centre to a nearby computer).

5) DATA PROCESSING ELEMENT:

An element that modifies data before it is displayed or finally recorded. Data processing may be used forsuch purposes as:

- ✓ Corrections to the measured physical variables to compensate for scaling, non-linearity, zerooffset, temperature error etc.
- ✓ Covert the data into useful form, e.g., calculation of engine efficiency from speed, power inputand torque developed.
- ✓ Collect information regarding average, statistical and logarithmic values.

6) DATA PRESANTION ELEMENT:



Electro-mechanical measurement system

An element that provides record or indication of the output from the data processing element. Ina measuring system using electrical instrumentation, an exciter and an amplifier are also incorporatedinto the circuit.

The display unit may be required to serve the following functions.

- ✓ transmitting
- ✓ Signalling
- ✓ Registering
- ✓ Indicating
- ✓ recording

The generalised measurement system is classified into 3 stages:

a) Input Stage

b) Intermediate Stage

i. Signal Amplifications

ii. Signal Filtration

iii. Signal Modification

iv. Data Transmission

c) Output Stage

a) Input Stage:

Input stage (Detector-transducer) which is acted upon by the input signal (a variable to be measured) such as length, pressure, temperature, angle etc. and which transforms this signal in some other physicalform. When the dimensional units for the input and output signals are same, this functional element/stage is referred to as the transformer.

b) Intermediate Stage:

i. signal amplification to increase the power or amplitude of the signal without affecting its waveform.The output from the detector-transducer element' is generally too small to operate an indicator or a recorder and its amplification is necessary. Depending upon the type of transducer signal, the amplification device may be of mechanical, hydraulic/pneumatic, optical and electrical type.

ii. Signal filtration to extract the desired information from extraneous data. Signal filtration removes theunwanted noise signals that tend to obscure the transducer signal. Depending upon nature of the signaland situation, one may use mechanical, pneumatic or electrical filters.

iii. Signal modification to provide a digital signal from an analog signal or vice versa, or change the formof output from voltage to frequency or from voltage to current.

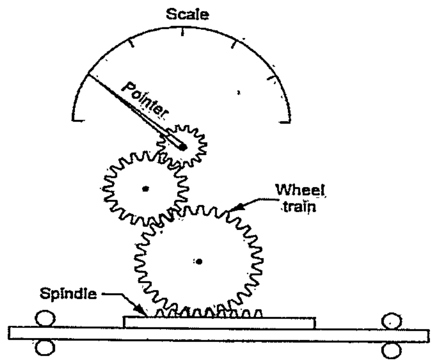
Iv. Data transmission to telemeter the data for remote reading and recording.

c) Output Stage:

which constitutes the data display record or control. The data presentation stage collects the outputfrom the signal-conditioning element and presents the same to be read or seen and noted by the experimenter for analysis. This element may be of:-

- ✓ visual display type such as the height of liquid in a manometer or the position of pointer on ascale
- ✓ numerical readout on an electrical instrument
- ✓ Graphic record on some kind of paper chart or a magnetic

tape.Example: Dial indicator



Dial indicator

CLASSIFICATION OF INSTRUMENTS:-

1) Automatic and Manual instruments:

2) Self generating and power operated

3) Self contact and remote indicating instruments

4) Deflection and null type

5) Analog and digital types

6) Contact and no-contact type

1) Automatic and manual instruments:

The manual instruments require the services of an operator while the automatic types donot. For example, the temperature measurement by mercury-in-glass thermometer is automatic as the instrument indicates the temperature without requiring any manual assistance. However, the measurement of temperature by a resistance thermometer incorporating; Wheatstone brigde in itscircuit is manual in operation as it needs an operator for obtaining the null position.

2) Self generating and power operated

Self-generated instruments are the output is supplied entirely by the input signal. The instrumentdoes not require any out side power in performing its function

Example: mercury in glass thermometer, bourdon pressure gauge, pitot tube for measuring

velocity So instruments require same auxillary source of power such as compound air,

electricity, hydraulic

supply for these operations and hence are called externally powered instruments (or) passiveinstruments.

Example:

- L.V.D.T(Linear Variable Differential Transducer)
- Strain gauge load cell
- Resistance thermometer and the mister.
- Self contained remote indicator.

3) Self contact and remote indicating instruments:

The different elements of a self-contained instrument are contained in one physical assembly. In a remote indicating instrument, the primary sensing element may be located at a sufficiently long distancefrom the secondary indicating element. In the modern instrumentation technology, there is a trend to instalremote indicating instruments where the important indications can be displayed in the central control rooms.

4) Deflection and null output instruments:

In null-type instruments, the physical effect caused by the quantity being measured is nullified (deflection maintained at zero) by generating an equivalent opposing effect. The equivalent null causingeffect then provides a measure of the unknown quantity. A deflection type instrument is that in which the physical effect generated by the measuring quantity (measurand) is noted and correlated to the measurand.

5) Analog and digital instruments:

The signals of an analog unit vary in a continuous fashion and can take on infinite number of values in agiven range. Wrist watch speedometer of an automobile, fuel gauge, ammeters and voltmeters are examples of analog instruments.

Instruments basically perform two functions:

(i) Collection of data and

(ii) control of plant and process

Accordingly based upon the service rendered, the instruments may also be classified as indicating instruments, recording instruments and controlling instruments.

<u>INPUT, OUTPUT CONFIGURATION OF A MEASURING INSTRUMENT:-</u>

Input-output relation of a measurement system

An instrument performs an operation on an input quantity (measurement/designed variable) to providean output called the measurements. The input is denoted by "i" and the output is denoted by "o".

According to the performance of the instrument can be stated in terms of an operational transferfunction(G).The input and output relationship is characterised by the operation 'G' such that

$$o=G\,i$$

The various inputs to a measurement system can be classified into-three categories:

i) Desired input:

A quantity that the instrument is specifically intended to measure. The desired input i_D produces anoutput component according to an input-output relation symbolised by G_D; here G_D represents the mathematical operation necessary to obtain the output from the input.

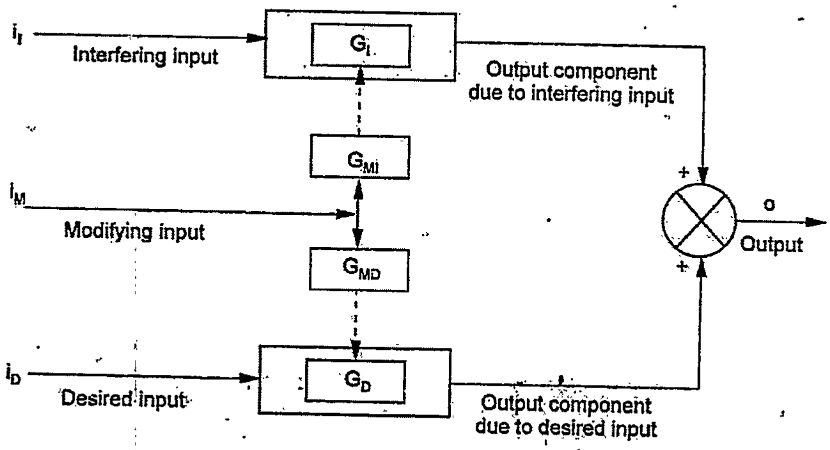
ii) Interfering input:

A quantity to which the instrument is unintentionally sensitive. The interfering input i_I would producean output component according to input-output relation symbolised by G_I

iii) Modifying input:

A quantity that modifies the input-6utput relationship for both the desired and interfering inputs. Themodifying input i_M would cause a change in G_D and/or G_I. The specific manner in which i_M affects G_D and G, is represented by the symbols G_{MD} and G_{MI}, respectively.

A block diagram of these various aspects has been illustrated in Fig.



Generalised input-output configuration

<u>Performance characteristics of a measuring instrument:-</u>

1. Static characteristics

2. Dynamic characteristics

The performance characteristics of an instrument system is conclusion by low accurately the systemmeasures the requires input and how absolutely it reject the undesirable inputs.

Error = measured value (V_m) – true value

((V_t)Correction = (V_t-V_m).

1. Static characteristics:

a) Range and span, b) Accuracy, error, correction, c) Calibration, d) Repeatability, e) Reproducibility

f) Precision, g) Sensitivity, h) Threshold, i) Resolution, j) Drift, k) Hysteresis, dead zone.

a) Range and span

The region between the limits with in which as instrument is designed to operate for measuring, indicating (or) recording a physical quantity is called the range of instrument. The range is expressed bystanding the lower and upper values. Span represents the algebraic difference between the upper and lower range values of the instruments.

Ex: -

Range - 10 C° to 80 C° Span=90°c

Range 5 bar to 100 bar Span=100-5=95 bar

Range 0 v to 75v Span=75volts

b) Accuracy, error, correction:

No instrument gives an exact value of what is being measured, there is always some uncertainty in themeasured values. This uncertainty express in terms of accuracy and error.

Accuracy of an indicated value (measured) may be defined as closeness to an accepted standard value(true value). The difference between measured value (V_m) and true value (V_t) of the quantity is expressed as instrument error.

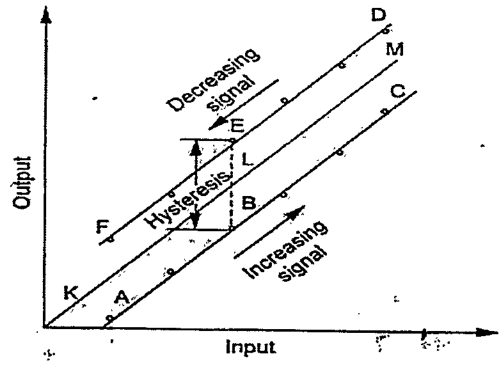
$E_s = V_m - V_t$

Static correction is defined as V_t-V_m

$C_s = V_t - V_m$

c) Calibration:

The magnitude of the error and consequently the correction to be applied is determined by making aperiodic comparison of the instrument with standards which are known to be constant. Measurement system conform to an Accepted standard is called the calibration. The graphical representation of the calibration record is called calibration curve and this curve relates standard valuesof input or measure and to actual values of output throughout the operating range of the instrument. A comparison of the instrument reading may be made with



Calibration curve

(i) a primary standard,

(ii) a secondary standard of accuracy greater than the instrument to be calibrated,

(iii) a known input source.

d) Repeatability:

Repeatability describes the closeness of the output readings, when the same input is applied repeatability over a short period of time with the same measurement conditions, same instrument andobserver, same location and same conditions of use maintained throughout.

e) Reproductability: Reproductability describes the closeness of output readings for the same input. When are changes in the method of measurement, observer, measuring instrument, and location, conditionsof use and time of measurement.

f) Precision:

The instrument ability to reproduce a certain group of the readings with a given accuracy is known as precision i.e., if a no of measurements are made on the same true value then the degree of closeness ofthese measurements is called precision.

It refers to the ability of an instrument to give its readings again and again in the same manner forconstant input signals.

g) Sensitivity:

Sensitivity of an instrument is the ratio of magnitude of response (output signal) to the magnitude of thequantity being measured (input signal) i.e.,

Sensitivity = Output signal/Input Signal = $\frac{\Delta\theta_2}{\Delta\theta_1}$

h) Threshold:

Threshold defines the minimum value of input which is necessary to cause detectable change from zerooutput.

When the input to an instrument is gradually increased from zero, then the input must reach to a certainminimum value, so that the change in the output can be detected. The minimum value of input refers to threshold.

i) Resolution:

It is defines as the increment in the input of the instrument for which input remains constant i.e., whenthe input given to the instrument is slowly increased for which the output remains same until the increment exceeds a different value.

j) Drift:

The slow variation of the output signal of a measuring instrument is known as draft.

The variation of the output signal is not due to any changes in the input quantity, but to the changes inthe working conditions of the components inside the measuring instruments.

k) Hysteresis, Dead zone:

Hysteresis is the maximum difference for the same measuring quantity (input signal) between the upscale and down scale reading during a full range measure in each direction.

Dead zone is the largest range through which an input signal can be varied without initiating any response from the indicating instrument it is due to the friction.

2. Dynamic characteristics:

a) Speed of response and measuring lag, b) Fidelity and dynamic error, c) Over shoot, d) Dead time anddead zone, e) Frequency response.

a) Speed of response and measuring lag:

In a measuring instrument the speed of response (or) responsiveness is defined as the rapidity withwhich an instrument responds to a change in the value of the quantity being measured.

Measuring lag refers to delay in the responds of an instrument to a change in the input signal. Thelag is caused by conditions such as inertia, or resistance.

b) Fidelity and dynamic errors:

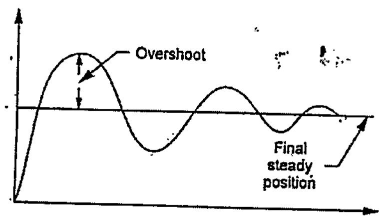
Fidelity of an instrumentation system is defined as the degree of closeness with which the system indicates (or) records the signal which is upon its. It refers to the ability of the system to reproduce the output in the same form as the input. If the input is a sine wave then for 100% fidelity the output shouldalso be a sine wave.

The difference between the indicated quantity and the true value of the time quantity is thedynamic error. Here the static error of instrument is assumed to be zero.

c) Over shoot:

Because of maximum and inertia. A moving part i.e., the pointer of the instrument does not immediatelycame to reset in the find deflected position. The pointer goes find deflected position. The pointer goes beyond the steady state i.e., it over shoots.

The over shoot is defined as the maximum amount by which the pointer moves beyond the steadystate.

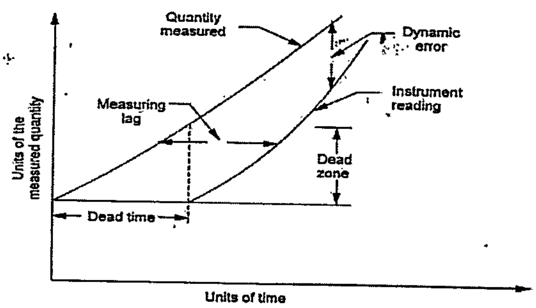


Overshoot

d) Dead time and dead zone:

Dead time is defined as the time required for an instrument to begin to respond to a change in the measured quantity it represent the time before the instrument begins to respond after the measuredquantity has been altered.

Dead zone define the largest change of the measured to which the instrument does not respond.



Dynamic terms

Dead zone is the result as friction backlash in the instrument.

e) Frequency response:

(The dynamic performance of both measuring and control system is determine by applying some knownand predetermined input signal to its primary sensing element and them)

Maximum frequency of the measured variable that an instrument is capable of following with error.

The usual requirement is that the frequencies of the measured should not exceed 60% of the naturalfrequency measuring instrument.

Sources of error:

1. Calibration of Instrument
2. Instrument reproducibility
3. Measuring arrangement
4. Work piece
5. Environmental condition
6. Observes skill

1. Calibration of Instrument:

For any instrument calibration` is necessary before starting the process of measurement. When the instrument is load frequently for long time, the calibration of instrument is used frequently for long time, the calibration of instrument may get disturbed. The instrument which is gone out of b ration cannot give actual value of the measured. Therefore the output produced by such an instrument haveerror. The error due to improper calibration of instrument is known as systematic instrumental error, and it occurs regularly.

Therefore this error can be eliminated by, properly calibrating the instrument at frequent intervals.

2. Instrument reproducibility:

Though an instrument is calibrated perfectly under group of conditions, the output produced by that instrument contains error. This occurs if the instrument is used under those set of conditions which arenot identical to the conditions existing during calibration. i.e., the instrument should be used under those set of conditions at which -.the instrument is calibrated. This type of error may occur systematically or accidentally.

3. Measuring arrangement:

The process of measurement itself acts as a source of error if the arrangement of different componentsof a measuring instrument is not proper.

Example:
While measuring length, the comparator law of Abbe should be followed. According to this, actual valueof length is obtained when measuring instrument and scale axes are collinear, and any misalignment of these will give error value. Hence this type of error can be eliminated by having proper arrangement of measuring instrument.

4. Work piece:

The physical nature of object (work piece) i.e., roughness, softness and hardness of the object acts as asource of error. Many opt mechanical and mechanical type of instruments contact the. Object under certain fixed pressure conditions. Since the response of soft and hard objects under these fixed conditions is different the output of measurement will be in error.

5. Environmental condition:

Changes in the environmental conditions is also a major source of error. The environmental conditionssuch as temperature, humidity, pressure, magnetic or electrostatic field surrounding the instrument may affect the instrumental characteristics. Due to this the result produced by the measurement may contain error.
There errors are undesirable and can be reduced by the following ways,

(a) Arrangement must be made to keep the conditions approximately constant.

(b) Employing hermetically sealing to certain components in the instrument, which eliminate the effectsof the humidity, dust, etc.

(c) Magnetic and electrostatic shields must be provided.

6. Observes skill:

It is a well-known fact that the output of measurement of a physical quantity is different from operatorto operator and sometimes even for the same operator the result may vary with sentimental and physical states. One of the examples of error produced by the operator is parallax error in reading a meter scale. To minimize parallax errors modern electrical instruments have digital display of output.

<u>Classification of errors and elimination of errors:</u>

No measurement can be made with perfect accuracy but it is important to find out what accuracy is and how different errors have entered into the measurement. A steady of errors is a first step in findingways to reduce them. Errors may arise from different sources and are usually classified as under.

1. Gross errors
2. Systematic (or) instrumental errors

3. Random (or) environmental errors

1. Gross errors:

This cause of errors mainly covers human mistakes in reading instruments and recording and calculating measurement result. The responsibility of the mistake normally lies with the experimental.

Ex: The temperature is 31.5^0c, but it will write as 21.5^0c it's an error however they can be avoided byadopting two means

1. Great care should be taken in reading and recording the data.
2. Two, three (or) even more readings should be taken for quantity under measurement

2. Systematic errors:

These type of errors are divided into three categories.

a. Instrumental errors
b. Environmental errors
c. Observational errors

a. Instrumentation errors:

These errors occurs due to three main reasons.

a. Due to inherent short comings of the instrument
b. Due to misuse of instruments
c. Due to loading effects of instruments.

b. Environmental errors:

These errors are caused due to changes in the environmental conditions in the area surrounding the instrument, that may affect the instrument characteristics, such as the effects of changes in temperature, humidity, barometric pressure or if magnetic field or electrostatic field.

These undesirable errors can be reduced by the following ways.

(i) Arrangement must be made to keep the conditions approximately constant.

(ii) Employing hermetically sealing to certain components in the instrument, which eliminate the effectsof the humidity dust, etc.

(iii) Magnetic or electrostatic shields must be provided.

c. Observational errors:

These errors are produced by the experiment. Enter. The most frequent error is the parallax errorintroduced in reading a meter scale.

These errors are caused by the habits of individual observers To minimize parallax errors modernelectrical instruments have digital display of output.

3. Random (or) accidental errors:

The causes of such errors is unknown (or) not determinable in the ordinary process making measurements. Such errors are normally small and follow the law of chance. Random errors they maybe treated mathematically according to the law of probability.

a. Certain human errors
b. Errors caused due to the disturbances to the equipment's
c. Errors caused by fluctuating experimental conditions.

a. Certain human errors:

These errors occur due to inconsistency in estimating successive readings from the instrument by anexperimenter. To reduce these errors it is necessary to exercise extreme care with mature and considered judgment in recording the observations.

b. Errors caused due to the disturbances to the equipment:

Precision errors in the instrument may arise from the outside disturbances to the measuring system. These disturbances may be variations or mechanical vibrations. Poorly controlled processes also lead torandom errors.

c. Errors caused by fluctuating experimental conditions:

These errors are caused due to some uncontrolled, disturbances which influence the instrument output. Line voltage fluctuations, vibrations of the instrument supports, etc., are common examples of this type.

LVDT (Linear variable differential Transducer):

LVDT full form is **Linear Variable Differential Transformer**. As the name suggests, many people get confused that it is a Transformer. But actually, it is a Transducer not a Transformer. Because its working principle is same as Transformer (i.e. Mutual Induction Principle) and also the output across its secondary coil is in the form of differential voltage, that's why it is named as Linear Variable Differential Transformer (LVDT).

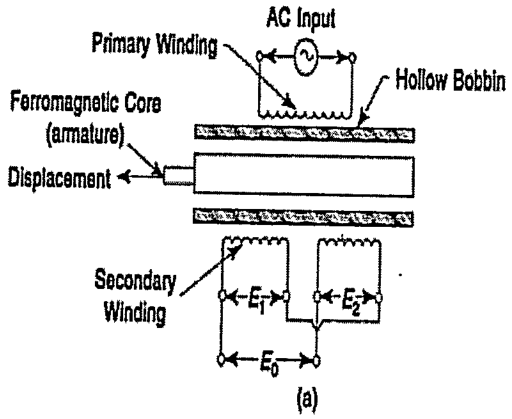
It is categorised as an Inductive Transducer used to measure the speed or position of an object. Generally most Inductive Sensors work on the principle of Transformer.

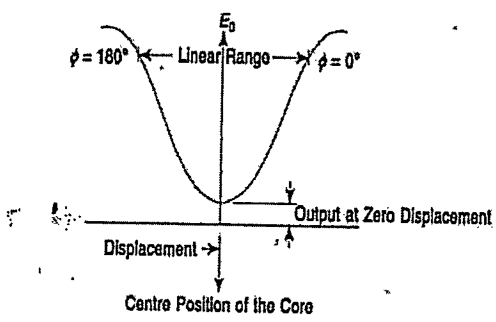
The linear variable-differential transformer (LVDT) is the most widely used inductive transducer totranslate linear motion into electrical signal.

Since LVDT is a secondary transducer, hence physical quantities such as Force, Weight, Tension, Pressure, etc are first converted into displacement by a primary transducer and then LVDT is used to measure it in terms of the corresponding Electrical signal.

Since LVDT is an AC-controlled device, so there is no electronics component inside it. It is the most widely used Inductive Sensor due to its high accuracy level. Its electrical output is obtained because of the difference of secondary voltages, hence it is called Differential Transformer.

LVDT Construction: A differential transformer consists of a primary winding and two secondary windings. Thewindings 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.





LVDT (a) Schematic Diagram of LVDT. (b) Variation of Output Voltage with Core Position.

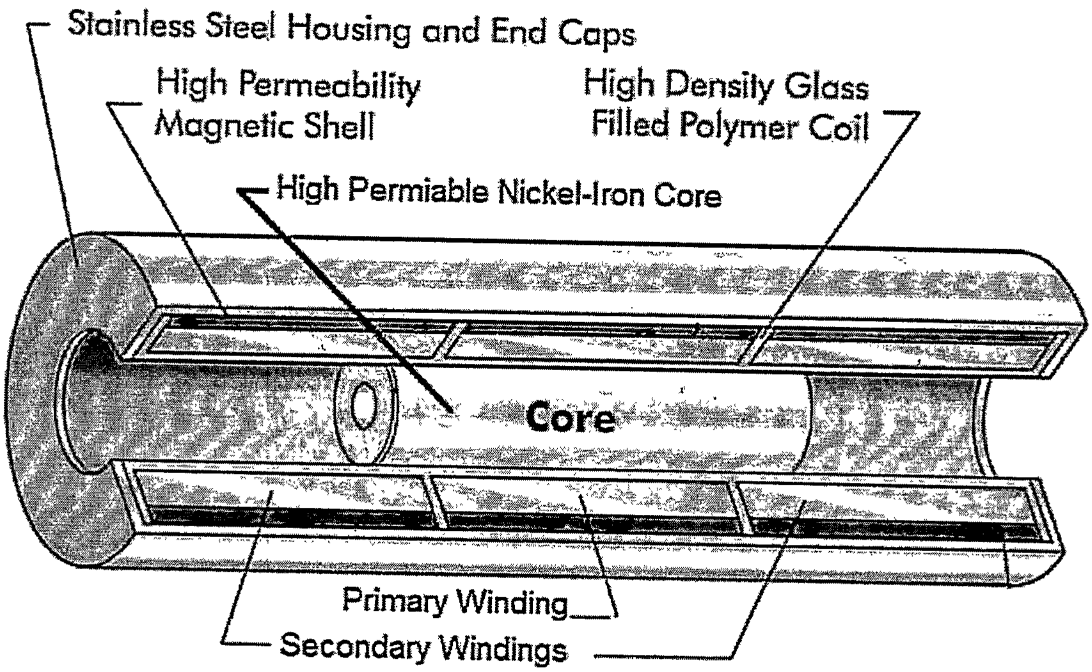


Figure: LVDT

Working: Any physical displacement of the core causes the voltage of one secondary winding to increasewhile 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 voltage from the input source. In the other direction fromthe null position, the differential voltage will again increase, but will be 180' out of phase with the voltage from the input source. By comparing the magnitude and phase of the output (differential) voltage with the input source. The amount 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.

Advantages of LVDT:

(i) The output voltage of these transducer is practically linear for displacements upto 5 mm.

(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 adverseeffects.

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

Disadvantages of LVDT:

(i) Rela6vely large displacements are required for appreciable differential output.

(ii) They are sensitive to stray magnetic fields but shielding is possible.

(iii) They are inherently low in power output.

Applications of LVDT:

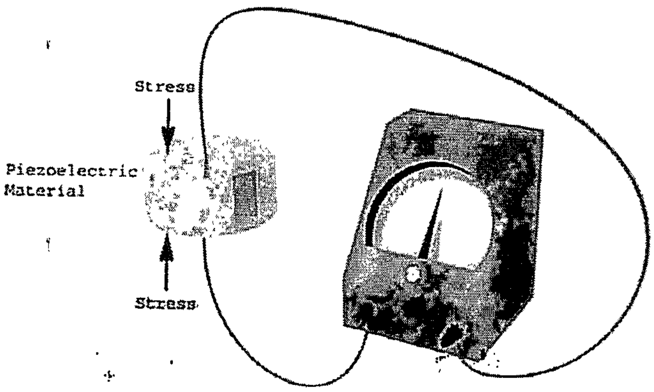
- **LVDT** is used to measure the physical quantities such as Force, Tension, Pressure, Weight, etc. These quantities are first converted into displacement by the use of primary transducers and then it is used to convert the displacement to the corresponding Electrical voltage signal.
- It is mostly used in industries as well as a servomechanism.
- It is also used in Industrial Automation, Aircraft. Turbine, Satellite, hydraulics, etc.

Piezoelectric Transducer:

A piezoelectric transducer (also known as a piezoelectric sensor) is a device that uses the piezoelectric effect to measure changes in acceleration, pressure, strain, temperature or force by converting this energy into an electrical charge.

A transducer can be anything that converts one form of energy to another. The piezoelectric material is one kind of transducers. When we squeeze this piezoelectric material or apply any force or pressure, the transducer converts this energy into voltage. This voltage is a function of the force or pressure applied to it.

The electric voltage produced by a piezoelectric transducer can be easily measured by the voltage measuring instruments. Since this voltage will be a function of the force or pressure applied to it, we can infer what the force/pressure was by the voltage reading. In this way, physical quantities like mechanical stress or force can be measured directly by using a piezoelectric transducer.

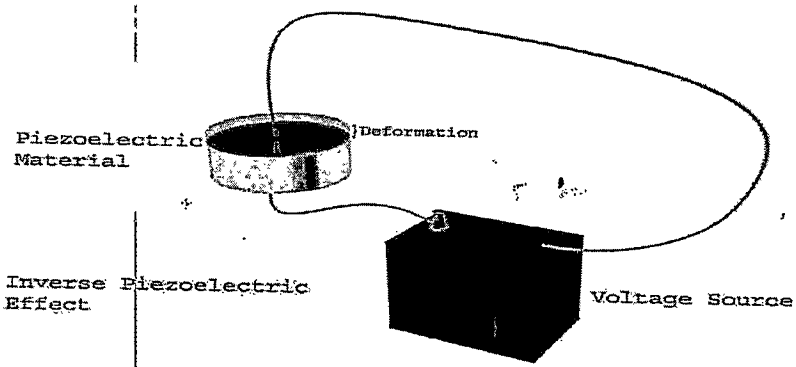


Piezoelectric Effect

Piezoelectric Actuator:

A piezoelectric actuator behaves in the reverse manner of the piezoelectric sensor. It is the one in which the electric effect will cause the material to deform i.e. stretch or bend.

That means in a piezoelectric sensor, when force is applied to stretch or bend it, an electric potential is generated and in opposite when on a **piezoelectric actuator**, an electric potential is applied it is deformed i.e. stretched or bend.



Inverse Piezoelectric Effect

A piezoelectric transducer consists of quartz crystal which is made from silicon and oxygen arranged in crystalline structure (SiO2). Generally, unit cell (basic repeating unit) of all crystal is symmetrical but in piezoelectric quartz crystal, it is not. Piezoelectric crystals are electrically neutral.

The atoms inside them may not be symmetrically arranged but their electrical charges are balanced means positive charges cancel out negative charge. The quartz crystal has the unique property of generating electrical polarity when mechanical stress applied to it along a certain plane. Basically, There are two types of stress. One is compressive stress and the other is tensile stress.

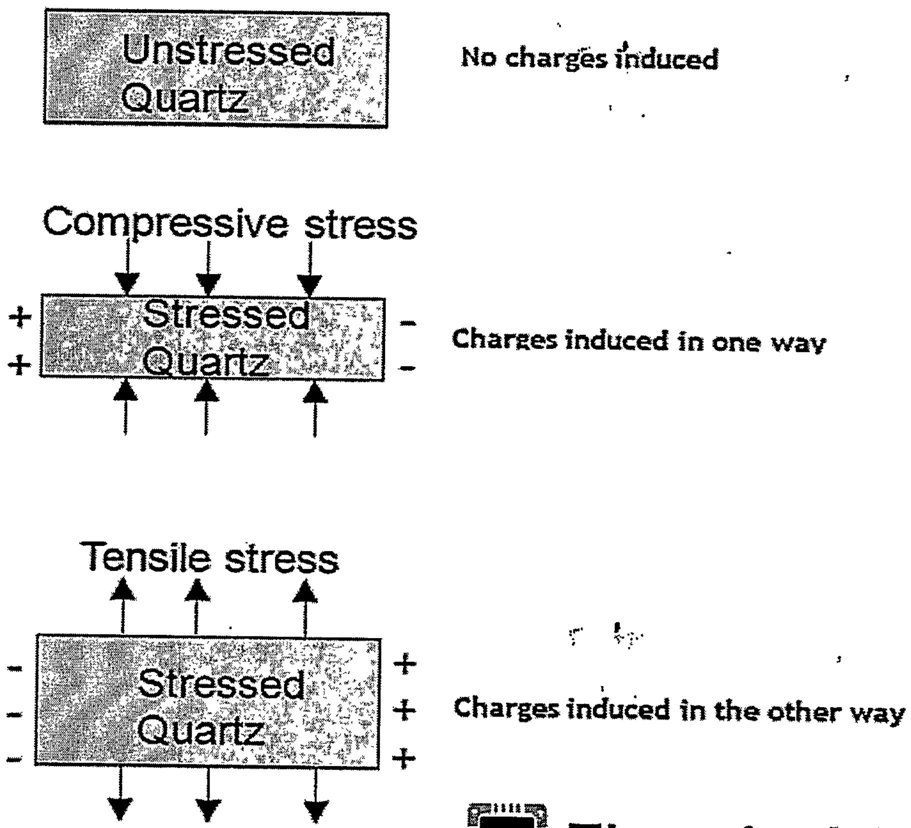


Figure: Stressed and unstressed Quartz material

When there is unstressed quartz no charges induce on it. In the case of compressive stress, positive charges are induced on one side and negative charges are induced in the opposite side. The crystal size gets thinner and longer due to compressive stress. In the case of tensile stress, charges are induced in reverse as compare to compressive stress and quartz crystal gets shorter and fatter.

A piezoelectric transducer is based on the principle of the piezoelectric effect. The word piezoelectric is derived from the Greek word piezen, which means to squeeze or press. The piezoelectric effect states that when mechanical stress or forces are applied on quartz crystal, produce electrical charges on the quartz crystal surface. The piezoelectric effect is discovered by Pierre and Jacques Curie. The rate of charge produced will be proportional to the rate of change of mechanical stress applied to it. Higher will be stress higher will be voltage.

Application of Piezoelectric Materials:

- In microphones, the sound pressure is converted into an electric signal and this signal is. ultimately amplified to produce a louder sound.
- Automobile seat belts lock in response to a rapid deceleration is also done using a piezoelectric material.
- It is also used in medical diagnostics.
- It is used in electric lighter used in kitchens. The pressure made on piezoelectric sensor creates an electric signal which ultimately causes the flash to fire up.
- They are used for studying high-speed shock waves and blast waves.
- Used infertility treatment.
- Used in Inkjet printers

The advantages of piezoelectric transducers are:

- No need for an external force
- Easy to handle and use as it has small dimensions
- High-frequency response it means the parameters change very rapidly

The disadvantages of piezoelectric transducers are:

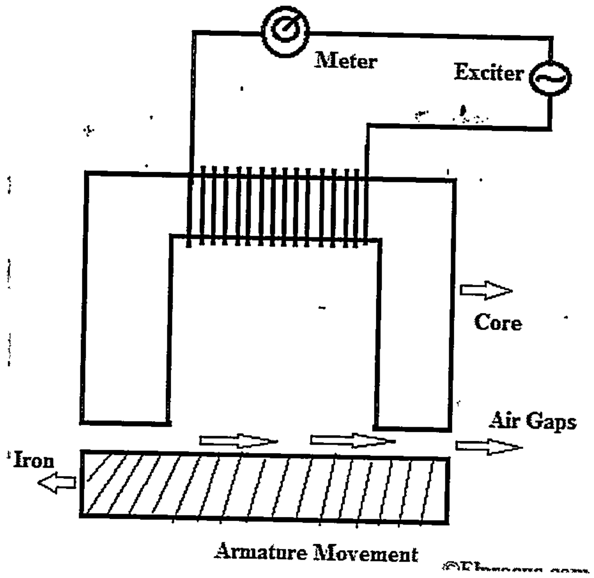
- It is not suitable for measurement in static condition
- It is affected by temperatures
- The output is low so some external circuit is attached to it
- It is very difficult to give the desired shape to this material and also desired strength

Inductive Transducer:

Write LVDT and in addition to

Inductive Transducer Working Principle

The working principle of an inductive transducer is the magnetic material's induction. Just like the electrical conductor's resistance, it depends on various factors. The magnetic material's induction can depend on different variables like the twists of the coil over the material, the magnetic material's size, & the flux's permeability.



The magnetic materials are used in the transducers in the path of flux. There is some air gap between them. The change in the circuit inductance can be occurred due to the air gap change. In most of these transducers, it is mainly used to work the instrument properly.

Inductive Transducer Applications

The applications of these transducers include the following.

- The application of these transducers finds in proximity sensors to measure position, touchpads, dynamic motion, etc.
- Mostly these transducers are used for detecting the kind of metal, to find miss lost parts otherwise counts the objects.
- These transducers are also applicable for detecting the movement of the apparatus which include belt conveyor and bucket elevator etc..

Inductive Transducer Advantages and Disadvantages

The advantages of inductive transducer include the following.

- The responsivity of this transducer is high
- Load effects will be reduced.
- Strong against ecological quantities

The disadvantages of inductive transducer include the following.

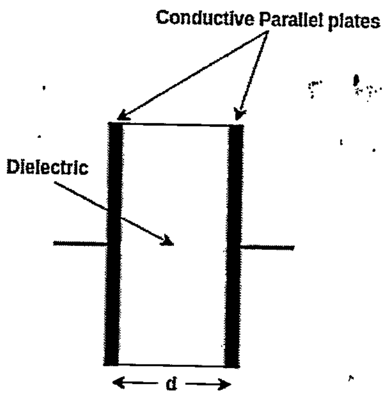
- The operating range will be reduced due to side effects.
- The working temperature should be under the Curie temperature.
- Sensitive to the magnetic field

Capacitive Transducer:

A capacitive transducer is a passive transducer that works on the principle of variable capacitances. It is used to measure physical quantities such as displacement, pressure, etc.

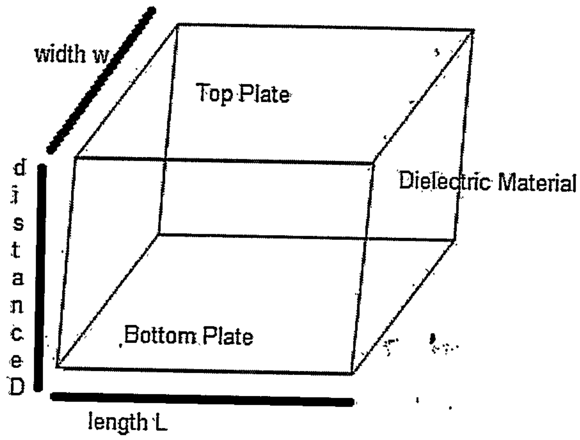
Construction of capacitive transducer

A capacitive transducer contains two conducting parallel metal plates separated by a dielectric medium. Dielectric mediums are like Air, Gas or Liquid.



Capacitive Transducer Working Principle:

The working principle of a capacitive transducer is variable capacitance. As per its structure, these are having two parallel metal pates which are maintaining the distance between them. In between them, dielectric medium (such as air) can be filled. So, the distance between these two metal plates and positions of the plates can change the capacitance. So, variable capacitance is the principle of these transducers. The basic difference between the normal capacitors and capacitive transducers is, the capacitor plates are constant in normal capacitors wherein these transducers, capacitor plates are the movable condition.



The capacitance of the variable capacitor can be measured by this formula.

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

C indicates the capacitance of the variable capacitance

ε_o indicates the permittivity of free space

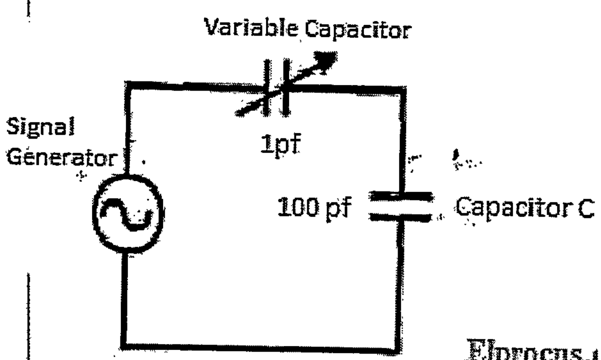
ε_r indicates the relative permittivity

A indicates the area of the plates

D indicates the distance between the plates

Capacitive Circuit Diagram:

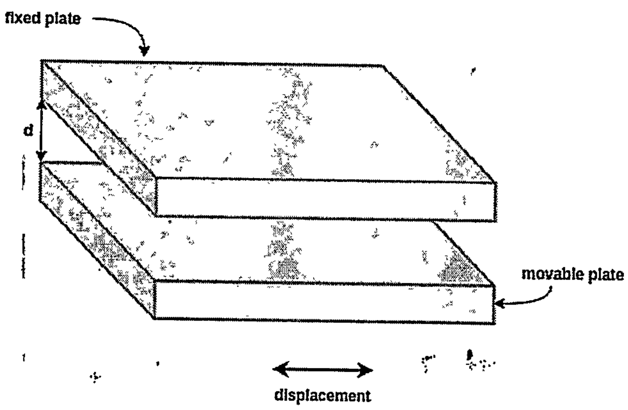
The above circuit diagram indicates the equivalent circuit diagram of a capacitive transducer. The difference between the variable capacitor to the normal capacitor is, the capacitance of the variable capacitor is varied whereas in a normal capacitor, the capacitance value is fixed & it cannot be changed.



capacitive-transducer-circuit-diagram

By changing the area of overlapping of plates:

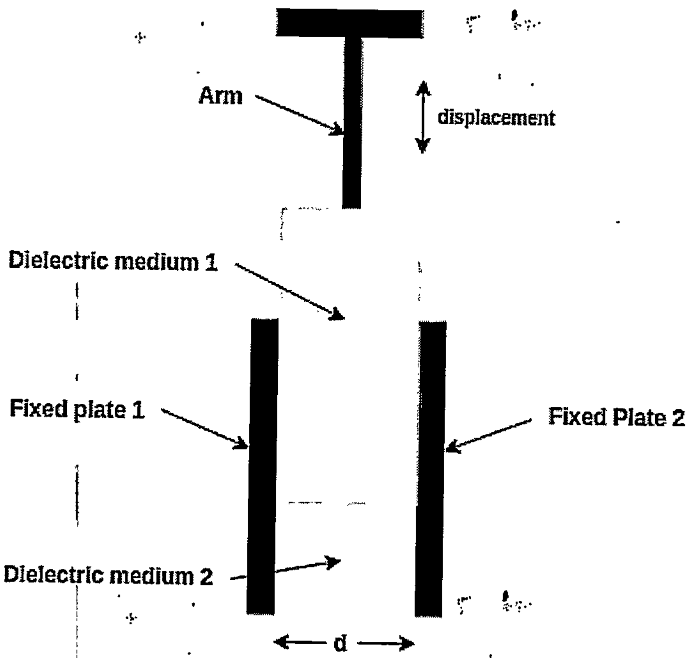
The capacitance can also be changed by varying the area of overlapping of plates.



As shown in the figure, one plate is kept fixed and the other movable. When the plate is moved, the area of overlapping of plates changes, and the capacitance also changes. The capacitance value and area are directly proportional to each other. These types of transducers are used to measure relatively large displacements.

By changing the permittivity of the dielectric medium:

Another method to change the capacitance value is by changing the permittivity of the dielectric material (ϵ). The permittivity and capacitance value are directly proportional to each other.



Advantages:

- These transducers offer high input impedance. So the loading effects value will be too low.
- The frequency response of these transducers is extremely high.
- These transducers are highly sensitive.
- These are consuming low power to operate. So, these transducers are called low power consuming devices.
- High resolution can be possible by using these transducers.

Disadvantages:

- It has a high output impedance. Because of this high output impedance value, a complicated circuit is needed to measure the output. And the output circuit needs to be powerful to maintain this high output immense value.
- These transducers exhibit non-linear behaviours due to edge effects.
- These are temperature-dependent. The external temperature value can affect this transducer capacitance value.

Applications:

- This transducer has a wide range of applications in determining the quantities like temperature, displacement, and pressure, etc. Capacitive transducer applications are listed below.
- These transducers have applications in the field of linear and angular displacement with the sensitivity factor.
- One of the best applications of this transducer is to find the humidity level. As the humidity value changes the capacitance value of this transducer also changes. By this value, we can measure the change in humidity.
- The variable capacitance pressure transducer is applicable to find the pressure variations by using the variable capacitance.

Resistive Transducer:

A resistive transducer is an electronic device that is capable of measuring various physical quantities like temperature, pressure, vibration, force, etc. These physical quantities are otherwise extremely difficult to measure as they can change easily. However, using this transducer, you can easily calculate the values of these quantities. The resistance of this transducer changes concerning the change in the physical quantities.

These transducers can function in both primary as well as in secondary mode but most of the time it is used as secondary. This is because the output of the primary transducer can be given as an input to this transducer. The primary transducers are used in the conversion of physical quantities to mechanical signals while the secondary transducers are used to convert the physical quantities to electrical signals directly without first converting them to mechanical signals. The resistive transducers are of different types like resistive pressure transducers, thermistors resistors, LDR, etc.

Working of a Resistive Transducer:

A resistive transducer is mainly used in the calculation of temperature, displacement, pressure, force. The working of a resistive transducer can be explained by considering a conductor rod as the transducer. The transducer works on the principle of the length of the conductor.

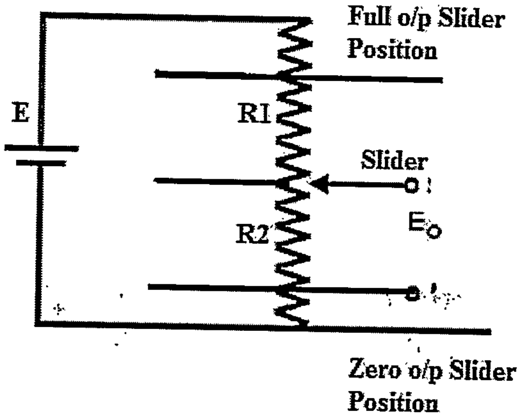
The length of the conductor is directly proportional to its resistance and is inversely proportional to its cross-sectional area. Here, if we consider the length of the conductor as L, the cross-sectional area as A, the resistance as R and the resistivity as ρ, then the resistance can be denoted as

$$R = \rho L/A$$

The resistance of the transducers can vary because of the change in environmental conditions as well as the physical properties of the conductor. Measuring devices like AC or DC can be used to measure the change in resistance.

Resistive Transducer Circuit:

The resistive transducer consists of a long conductor whose length can be varied with time. One end of the conductor is connected while the other end is connected to a brush or a slider that can freely move along the length of the transducers.



We can calculate the distance of the object by connecting the object to the slider of the resistive transducer. Whenever we apply energy to the object to displace it from its initial position, the slider will move along the length of the conductor as a result of which the length will change. The change in the length of the conductor will cause the resistance of the conductor to change as well. A transducer works in a way similar to that of a potentiometer which is used in the calculation of the angular and linear displacement.

Advantages:

- The resistive transducer can be used to give very quick results.
- The resistive transducers are available in various sizes and they have a considerably high amount of resistance.
- We can use both AC or DC for calculating the change in resistance.
- They are quite affordable and can be easily available in the market.
- It can be used to give accurate results.

Disadvantages:

- A lot of power is wasted in moving the sliding contacts.
- The sliding contacts can produce a lot of noise.

Applications of a Resistive Transducer:

- A resistive transducer is mainly used to measure the temperature in various kinds of applications. When there is a change in temperature, the temperature coefficient of the resistive transducer changes which can be used to determine the change in temperature.
- The resistive transducer can function as a potentiometer where the resistance of the transducer can be varied by changing the length of the conductor.
- A resistive transducer can be used in the calculation of the displacement. When we apply strain on the resistor, the resistance changes. This characteristic can be used in the measurement of displacement, force, and pressure.

Piezo electricity can be defined as the electrical polarization produced by mechanical strain on certain class of crystals. The rate of charge produced will be proportional to the rate of change of force applied as input. As the charge produced is very small, a charge amplifier is needed so as to produce an output voltage big enough to be measured.

33. Explain Construction and Working of Piezo Electric pressure transducer.

In 1880, Pierre and Jacques Curie determined that a small amount of voltage could be produced by applying large amounts of pressure to certain crystals of elements. This phenomenon is called the piezoelectric effect.

Construction:

When the piezoelectric effect is used in a pressure sensor, the sensor uses a diaphragm that deflects slightly when pressure is applied. A rod transfers this small amount of movement directly to the piezoelectric crystal Y1. The pressure on the crystal causes a small voltage to be produced that is proportional to the pressure. The voltage is amplified to traditional voltage signal values (0-10 volts) using charge amplifier. Crystal Y2 is for the purpose of compensation due to acceleration of device during use. Vibration is the major source of acceleration. Differential amplifier will subtracts all effects of accelerations and gives pressure alone.

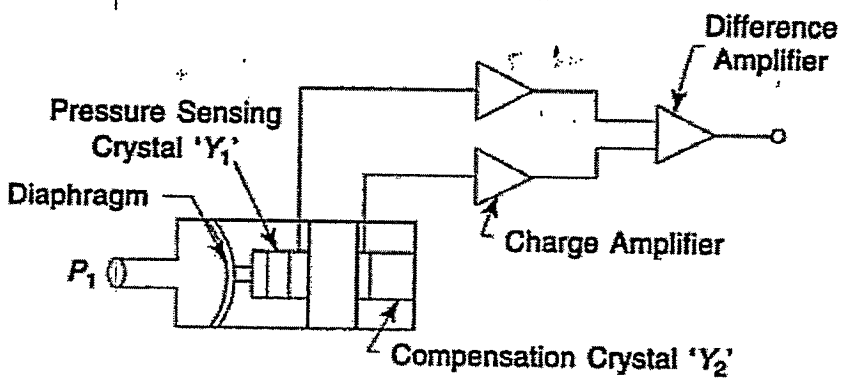


Fig. 9.26 *Piezoelectric Pressure Transducer.*

Working:

When pressure is applied to the diaphragm, it will deform the crystal Y1 and produce a small voltage. The amount of voltage is proportional to the amount of deformation. The amount of voltage that is produced is very small and the internal impedance of the crystal is very large, which makes the use of op amps a necessity to produce a usable signal. Charge amplifier will amplify the signals from both the crystals Y1 and Y2. Subtracted voltage at output of differential amplifier will be the calibrated in terms of the input pressure.

The best crystals that are used for this type of sensor come from ammonium dihydrogen phosphate and sintered ceramics.

34. List advantages and disadvantages of Piezo Electric pressure transducer.

Advantages

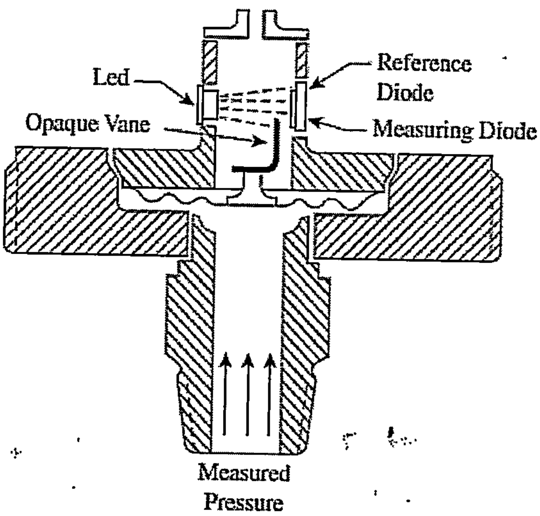
1. Very high frequency response.
2. Self-generating, so no need of external source.
3. Simple to use as they have small dimensions and large measuring range.
4. Barium titanate and quartz can be made in any desired shape and form. It also has a large dielectric constant. The crystal axis is selectable by orienting the direction of orientation.

Disadvantages

1. It is not suitable for measurement in static condition.
2. Since the device operates with the small electric charge, they need high impedance cable for electrical interface.
3. The output may vary according to the temperature variation of the crystal.
4. The relative humidity rises above 85% or falls below 35%, its output will be affected. If so, it has to be coated with wax or polymer material.

35. Explain Construction and Working of optical type pressure transducer.

Construction: Optical type pressure measurement is receiving considerable attention in recent years where the movement of a diaphragm, a bellows element or such other primary sensors are detected by optical means. The principle is nothing new, but the technique of adaptation in commercialization is varied in nature. A typical case with a diaphragm and a vane attached to it that covers and uncovers an irradiated photo diode with changing pressure is shown in the figure below. Reference diode is also used for the compensation.



Working:

The movement of elastic pressure sensors can be used to operate optical sensors. As the process pressure moves a diaphragm sensor, which in turn lifts a vane in front of an infrared light beam, the amount of light impinging on the measuring diode varies (Figure). A reference diode is also provided to compensate for the aging of the light source (LED) or for dirt buildup on the optics.

Calibration may be made directly in pressure from output voltage of photo diode. The ratio metric technique is often preferred for avoiding drift error in electronic components as they are likely to be equally affected and cancelled. The vane movement or the diaphragm movement is kept small for negligible hysteresis and good precision. The range may be adjusted from (0-400) MPa with an accuracy of 0.1 percent scan.

Advantages:

1. This transducer is insensitive to temperature variations, as such variations affect the measuring and reference diodes in the same way.
2. Because the amount of movement in the sensor is very small (0.5 mm), both the hysteresis and the repeatability errors are negligible.

Disadvantages:

1. Diode signals have non-linearity which may also vary from unit to unit.
2. Signal conditioning circuit may require more attention.
3. Temperature, though compensated, affects measurement to a certain extent which, in zero scale may be compensated by auto-zeroing facility.

Application:

This system is often used as a null detecting one in a force balance type pressure measurement, where the servo-system brings the sensor to the zero balance point.

36. Explain principle of working for Dead Weight Tester.

Working Principle:

Dead Weight Tester is based on the principle of Pascal's law. The law states that in a closed system of incompressible fluid, the pressure applied will exert equal amount of force in all the directions.

In Dead Weight Tester system, silicon oil is used within the closed boundaries of the Piston cylinder arrangement, piping, pressurization chamber and in the head on which the gauge to be tested/ calibrated is fixed. The oil is taken in to the pressurization chamber from oil bowl and all the air entrapped is vented off.

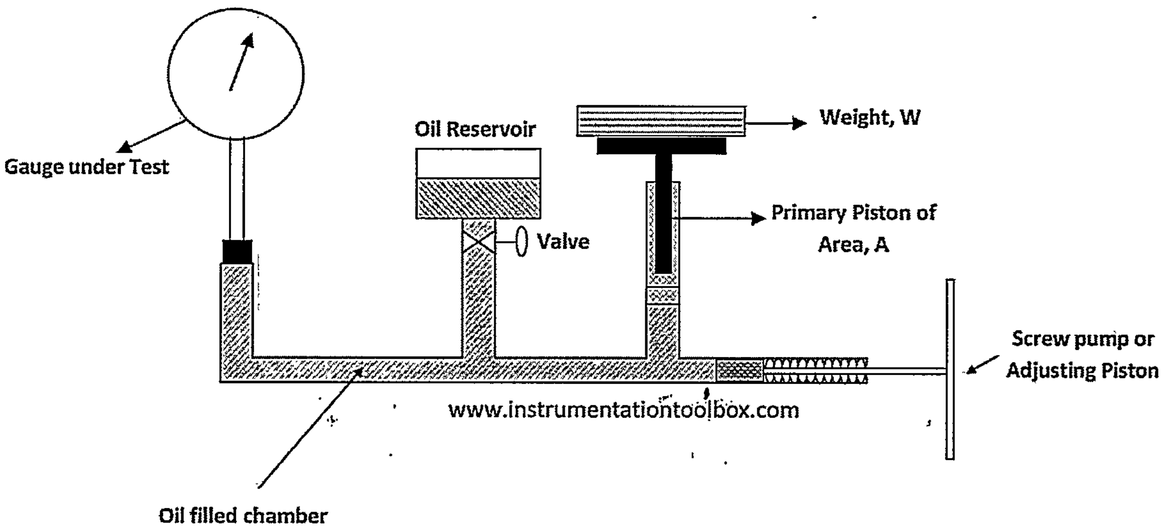
Once the system is full with air free oil, pressure is gradually increased from the pressurization chamber. Oil pressure starts increasing in all the areas including piston cylinder arrangement over which the dead weights are mounted.

As the force increases gradually and equals the amount of down ward force being exerted by the dead weights, the total system gains the state of equilibrium and just at that moment, the dead weights starts getting lifted up. At this condition, the amount of force operating in the entire system is same. The sum of pressure values stamped on weights lifted is operating on the pressure gauge element also, which is under test/ to be calibrated. Necessary corrections are made in the zero/ span adjustments in gauges/ Pressure transmitters.

37. Explain Construction and Working of Dead Weight Tester.

Construction:

The dead weight tester apparatus consists of a chamber which is filled with oil free impurities and a piston – cylinder combination is fitted above the chamber as shown in diagram. The top portion of the piston is attached with a platform to carry weights. A plunger with a handle has been provided to vary the pressure of oil in the chamber. The pressure gauge to be tested is fitted at an appropriate plate.



Working:

The dead weight tester is basically a pressure producing and pressure measuring device. It is used to calibrate pressure gauges. The following procedure is adopted for calibrating pressure gauges. Calibration of pressure gauge means introducing an accurately known sample of pressure to the gauge under test and then observing the response of the gauge. In order to create this accurately known pressure, the following steps are followed.

1. The valve of the apparatus is closed.
2. A known weight is placed on the platform.
3. Now by operating the plunger, fluid pressure is applied to the other side of the piston until enough force is developed to lift the piston-weight combination. When this happens, the piston weight combination floats freely within the cylinder between limit stops.
4. In this condition of equilibrium, the pressure force of fluid is balanced against the gravitational force of the weights plus the friction drag.

   Therefore, $PA = Mg + F$

   Hence: $P = (Mg + F) / A$

   Where, P = pressure

   M = Mass; Kg

   g = Acceleration due to gravity; m/s^2

   F = Friction drag; N

   A = Equivalent area of piston – cylinder combination; m^2

5. Thus the pressure P which is caused due to the weights placed on the platform is calculated.
6. After calculating P, the plunger is released.
7. Now the pressure gauge to be calibrated is fitted at an appropriate place on the dead weight tester. The same known weight which was used to calculate P is placed on the platform. Due to the weight, the piston moves downwards and exerts a pressure P on the fluid. Now the valve in the apparatus is opened so that the fluid pressure P is transmitted to the gauge, which makes the gauge indicate a pressure value. This pressure value shown by the gauge should be equal to the known input pressure P. If the gauge indicates some other value other than p the gauge is adjusted so that it reads a value equal to P. Thus the gauge is calibrated.

Applications:

It is used to calibrate all kinds of pressure gauges such as industrial pressure gauges, engine indicators and piezoelectric transducers.

38. List advantages and disadvantages of Dead Weight Tester.

Advantages:

- It is simple in construction and easy to use.
- It can be used to calibrate a wide range of pressure measuring devices.
- Fluid pressure can be easily varied by adding weights or by changing the piston cylinder combination.

Disadvantages:

- The accuracy of the dead weight tester is affected due to the friction between the piston and cylinder, and due to the uncertainty of the value of gravitational constant 'g'.

39. Explain Construction and Working of Ring balance type pressure gauge or manometer.

This device cannot be actually called a manometer, but it is often considered so.

Construction:

The tube is made of polythene or other light and transparent material. This tube is bent into in to the form of a ring and is supported at the centre by a suitable pivot. The tubular chamber is divided in to two parts by spilling, sealing, and filling with a suitable light liquid like kerosene or paraffin oil for isolating the two pressures. Pressure taps are made with two flexible tubings. Pressures p1 and p2 act against the sealed walls as shown in the figure below, and rotate the ring which is balanced by the counter weight w.

Working:

The ring balance contains a sensitive element in the form of a hollow ring with a partition. A compensating weight is attached to the lower part of the ring, which is filled with a liquid (water, oil, or mercury). For p1 = p2, the liquid level in both sections of the ring is the same and the center of gravity of the weight is located on the vertical axis, which passes through the center of the ring. For p1 > p2, the liquid level in the left-hand part is lowered, and the liquid level in the right-hand part is raised. The force created by the action of the pressure difference on the partition generates a moment that tends to turn the ring clockwise. This angle θ is used to measure the pressure.

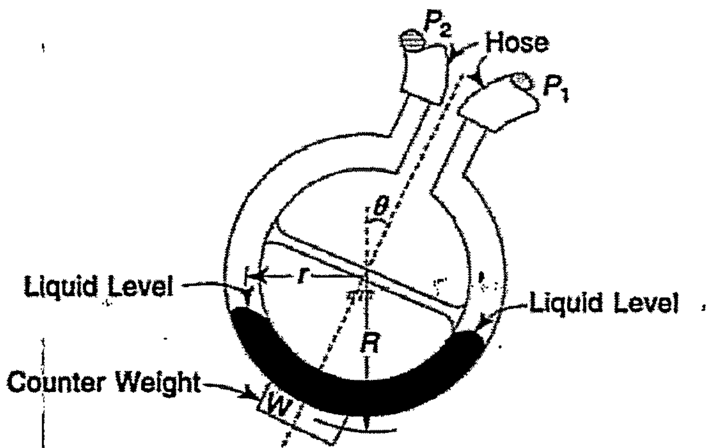


Fig. 9.19 *Ring Balance Gauge.*

40. Explain construction and working of McLeod gauge.

Principal:

A known volume gas is compressed to a smaller volume whose final value provides an indication of the applied pressure. The gas used must obey Boyle's law given by;

$$P1V1=P2V2$$

Where, P1 = Pressure of gas at initial condition (applied pressure).

P2 = Pressure of gas at final condition.

V1 = Volume of gas at initial Condition.

V2 = Volume of gas at final Condition.

Initial Condition = Before Compression. And Final Condition = After Compression.

- A known volume gas (with low pressure) is compressed to a smaller volume (with high pressure), and using the resulting volume and pressure, the initial pressure can be calculated. This is the principle behind the McLeod gauge operation.

$$P_1 = \frac{P_2 V_2}{V_1}$$

Construction:

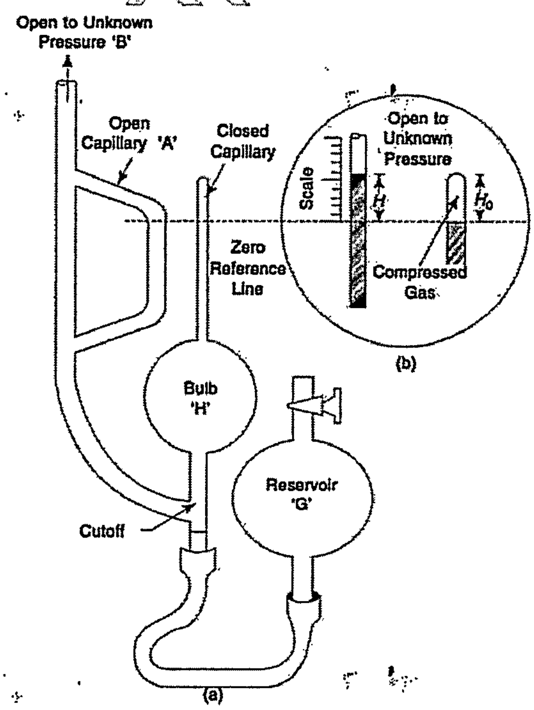


Fig. 9.14 McLeod Gauge (a) Before Measurement. (b) During Measurement.

A reference column is opened to unknown pressure 'B' with reference capillary tube. The reference capillary tube has a point called zero reference point on open capillary A. This reference column is connected to a bulb and closed capillary and the place of connection of the bulb with reference column is called as cut off point. It is called the cut off point, since if the mercury level is raised above this point, it will cut off the entry of the applied pressure to the bulb and measuring capillary. Below the reference column and the bulb, there is a mercury reservoir operated by a flexible tube.

Working:

The gauge is used to compress a small quantity of low pressure gas to produce a readable large pressure. Bulb H of the gauge is attached to closed capillary. The mercury level in the gauge is lowered up to cut off by lowering the reservoir, thereby allowing a little process fluid to enter H. By raising the reservoir, the gas is now compressed in the closed capillary till mercury rises to the zero mark in the side tube and open capillary A. The capillary A is required to avoid any error due to capillary.

The McLeod gauge is independent of gas composition. If, however, the gas contains condensable material and during compression it condenses, the reading of the gauge is faulty. The gauge is not capable of continuous reading and the scale is of square law type.

The compression of the gas in a closed capillary 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 tube. The difference in the height is used to calculate the pressure.

The pressure can also be calculated using following equitation:

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

Where P= Measured pressure

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

H= difference in heights of the two mercury column

H_0= height of the top of the closed capillary tube above the zero line.

Advantages of the McLeod Gauge:

- It is independent of the gas composition.
- It serves as a reference standard to calibrate other low pressure gauges.
- A linear relationship exists between the applied pressure and h
- There is no need to apply corrections to the McLeod Gauge readings.

Limitations of McLeod Gauge:

- The gas whose pressure is to be measured should obey the Boyle's law

- Moisture traps must be provided to avoid any considerable vapor into the gauge.
- It measure only on a sampling basis.
- It cannot give a continuous output.

41. Explain principle of working for thermal conductivity gauge.

Principle:

A hot wire, placed within an envelope, will transfer thermal energy from the wire to any gas molecules that come into contact with it, and that energy will be again transferred to the walls of the envelope. With continual motion of the gas molecules, a thermal equilibrium will be reached as long as the number of gas molecules (pressure) remains constant. If, though, the pressure changes and the wire is resistively heated by current from a constant power source, a new thermal equilibrium will be reached, and the temperature of the wire will change to reflect the new number of gas molecules that can carry heat away from the wire. This means that the temperature of the wire can be used as an indication of the pressure within the envelope.

This is the basic principle of all thermal conductivity gauges. The change in pressure vs. wire temperature remains fairly linear over a pressure range of about 10^{-3}– 1 torr. Below this range, heat transfer is mostly by radiation from the wire's surface and mostly by thermal convection above it. Thermal conductivity gauges covering this range have been in use for many years that fall into two main groups: thermocouple gauges and Pirani gauges.

42. Explain Construction and Working of Pirani gauge.

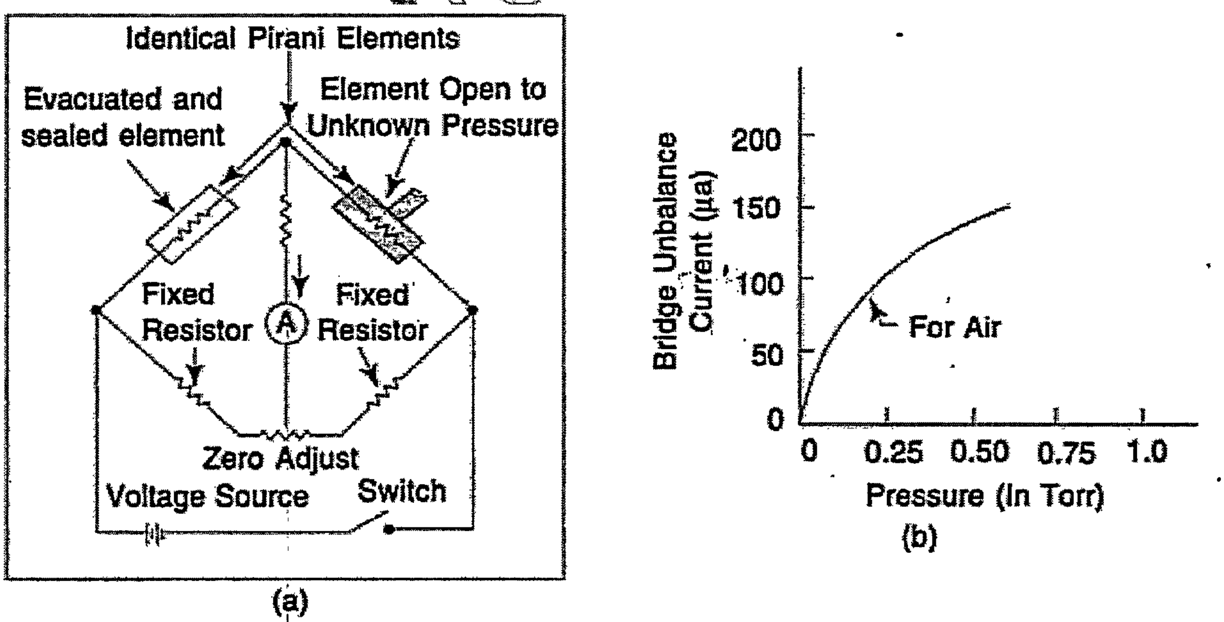


Fig. 9.15 *(a) & (b) Pirani Gauge.*

Construction:

The main parts of the arrangement are:

- A pirani gauge chamber which encloses a platinum filament.
- A compensating cell to minimize variation caused due to ambient temperature changes.
- The pirani gauge chamber and the compensating cell is housed on a wheat stone bridge circuit as shown in diagram.

Working:

1. A constant current is passed through the filament in the pirani gauge chamber. Due to this current, the filament gets heated and assumes a resistance which is measured using the bridge.
2. Now the pressure to be measured (applied pressure) is connected to the pirani gauge chamber. Due to the applied pressure the density of the surrounding of the pirani gauge filament changes. Due to this change in density of the surrounding of the filament its conductivity changes causing the temperature of the filament to change.
3. When the temperature of the filament changes, the resistance of the filament also changes.
4. Now the change in resistance of the filament is determined using the bridge.
5. This change in resistance of the pirani gauge filament becomes a measure of the applied pressure when calibrated.

Note: [higher pressure – higher density – higher conductivity – reduced filament temperature – less resistance of filament] and vice versa.

Applications of Pirani gauge

Used to measure low vacuum and ultra-high vacuum pressures.

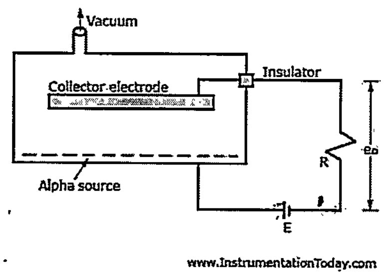
Advantages of Pirani gauge

- They are rugged and inexpensive
- Give accurate results
- Good response to pressure changes.
- Relation between pressure and resistance is linear for the range of use.
- Readings can be taken from a distance.

Limitations of Pirani gauge

- Pirani gauge must be checked frequently.
- Pirani gauge must be calibrated from different gases.
- Electric power is a must for its operation.

Alphatron



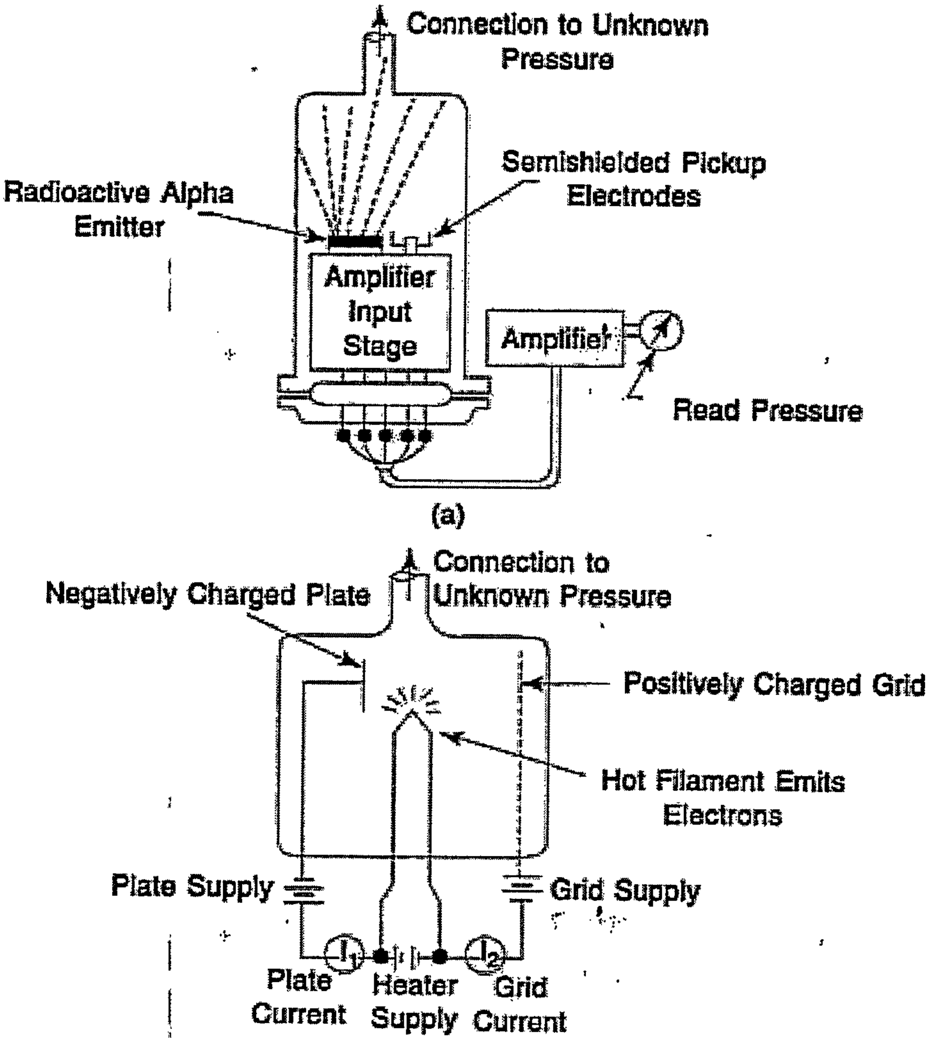


Fig. 9.17 *(a) An Alphatron Ionization Gauge.*
(b) A Hot Filament Ionization Gauge.

The ions produced by the alpha particles are collected by the collector electrode and a current between 10-13 Amperes will flow though the resistor R. The output voltage e0 is measured using a high input impedance output meter. The device has a range between 10^3 to 10^{-3} Torr.

Hot Filament Ionization Gauge:

In the hot Filament type, a column of gas is introduced into which, a potential difference V is applied to heater to create free electron in the space. This causes the electron with a charge to acquire a kinetic energy. This energy may be high enough to initiate ionization, and positive ions will be produced when the electrons collide with the gas molecules.

The grid is maintained at a large positive potential with respect to the cathode and the plate. The plate is at a negative potential with respect to the cathode. The positive ions available between the grid and the cathode will be drawn by the cathode, and those between the grid and the plate will be collected by the plate. These ions creates a currents I1 and I2 which is proportional to density and pressure of the gas.

44. Explain Construction and Working of Pressure switch.

A pressure switch turns an electric circuit 'ON' or 'OFF' at a preset pressure. This pressure is called the set point of the switch. A pressure switch is used in some form of control, e.g. to operate a solenoid valve at a given pressure, or start up a pump.

Construction:

The pressure switch is usually a micro switch or a mercury switch. A Burdon tube, a diaphragm or a bellows can be used to actuate the switch. Figure shows the simplest form of a pressure switch is used to actuate relay.

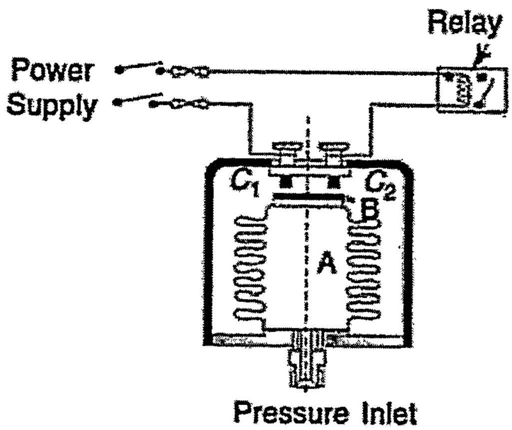


Fig. 9.27 *Pressure Switch.*

Working:

The pressure is fed to the inside of a bellows which carries a contact plate B. When pressure reaches a sufficient (or preset) value, the contact plate touches contact points C1 and C2, thus closing an electrical circuit to an alarm or motor control gear. The flexibility of the bellow ensures that the plate makes adequate contact with both points and gives a slight rubbing or wiping action that keeps the contact area clean.

The pressure switch can be modified so as to make a low pressure contact in addition to a high pressure contact. It is adjustable. The contact in a pressure switch may be normally closed when the pressure is below the set point. For example, the contacts in a normally open switch remains open until the pressure rises above the set point. Then the sensing element makes the contacts snap to the closed position. The contacts open again when the pressure falls below the set point. The contacts in a normally closed switch remain closed until the pressure rises above the set point. Then the contacts snap open and remain open until the pressure drops below the set point again. Most switches contains two sets of contacts, one normally open and the other normally closed.

A pressure switch has a "dead band", i.e. the pressure must fall below the set point before the switch resets to its normal position. The amount of dead band is the difference in pressure between the set point and the reset point. The pressure switch is used to operate safety valve which vents steam when the pressure exceeds the upper limit.

Uses of Pressure Switches:

Following are the uses of pressure switches:

- One of the most important use of the pressure switch is in limiting pressure, e.g. in steam power plants. The pressure of the steam entering a turbine must not exceed an upper limit. The pressure switch is used to operate safety valve which vents steam when the pressure exceeds the upper limit.
- An important use of the pressure switch is in the computer panel. In the computer panel, blowers are used for cooling purposes. Whenever the blower fails due to any reason, a pressure switch is actuated which cuts off the power supply of the panel. Thus, the computer panel components are protected from the high temperature which can occur due to failure of the blowers.

45. Explain Pneumatic Differential pressure transmitter.

Principle: It works on the principle of force balance.

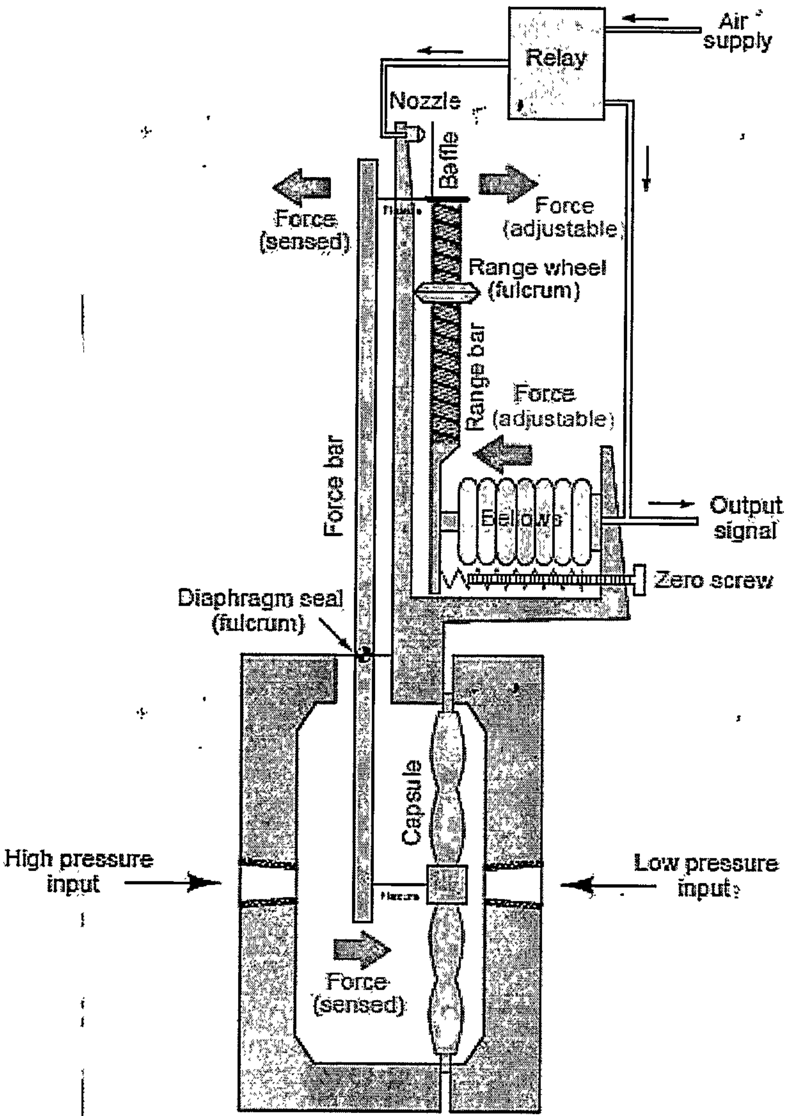
In the case of pressure instruments, pressure is easily converted into force by acting on the surface area of a sensing element such as a diaphragm or a bellows. A balancing force may be generated to exactly cancel the process pressure's force, making a force-balance pressure instrument. Like the laboratory balance scale, an industrial instrument built on the principle of balancing a sensed quantity with an adjustable quantity will be inherently linear, which is a tremendous advantage for measurement purposes.

Here, we see a diagram of a force-balance pneumatic pressure transmitter, balancing a sensed differential pressure with an adjustable air pressure which becomes a pneumatic output signal:

Force-Balance Pneumatic Pressure Transmitter balancing a sensed differential pressure transmitter with an adjustable air pressure which becomes a pneumatic output signal.

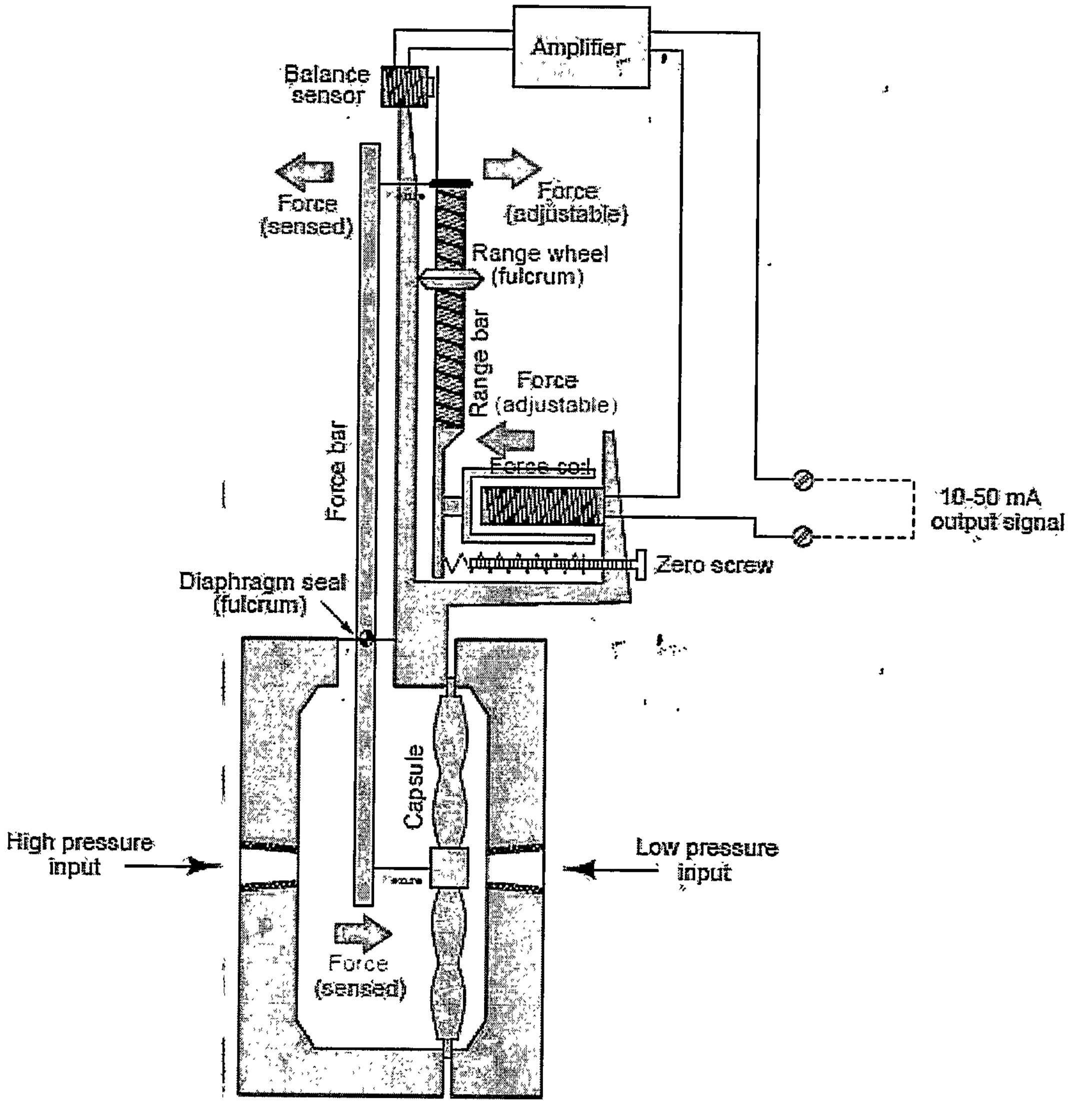
Differential pressure is sensed by a liquid-filled diaphragm "capsule," which transmits force to a "force bar." If the force bar moves out of position due to this applied force, a highly sensitive "baffle" and "nozzle" mechanism senses it and causes a pneumatic amplifier (called a "relay") to send a different amount of air pressure to a bellows unit.

The bellows presses against the "range bar" which pivots to counter-act the initial motion of the force bar. When the system returns to equilibrium, the air pressure inside the bellows will be a direct, linear representation of the process fluid pressure applied to the diaphragm capsule.



46. Explain Electronic Differential pressure transmitter.

With minor modifications to the design of this pressure transmitter2, we may convert it from pneumatic to electronic force-balancing:



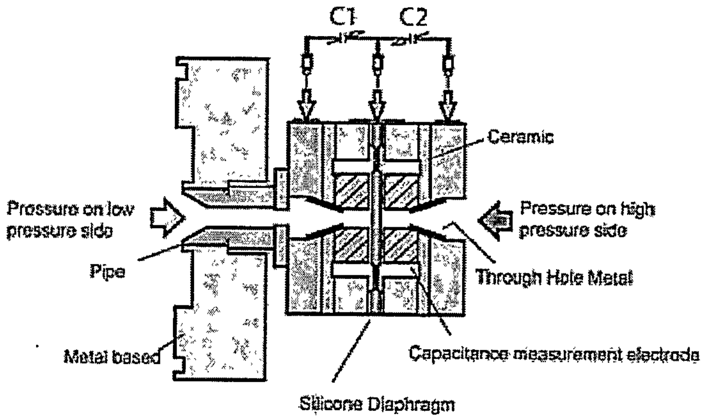
Differential pressure is sensed by the same type of liquid-filled diaphragm capsule, which transmits force to the force bar.

If the force bar moves out of position due to this applied force, a highly sensitive electromagnetic sensor detects it and causes an electronic amplifier to send a different amount of electric current to a force coil.

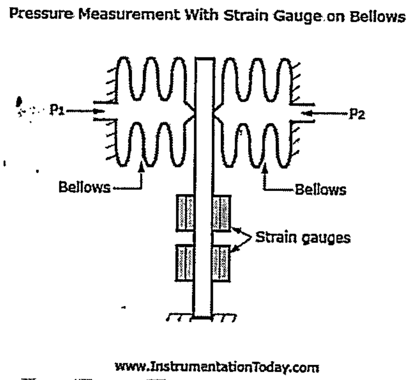
The force coil presses against the range bar which pivots to counteract the initial motion of the force bar. When the system returns to equilibrium, the mill ampere current through the force coil will be a direct, linear representation of the process fluid pressure applied to the diaphragm capsule.

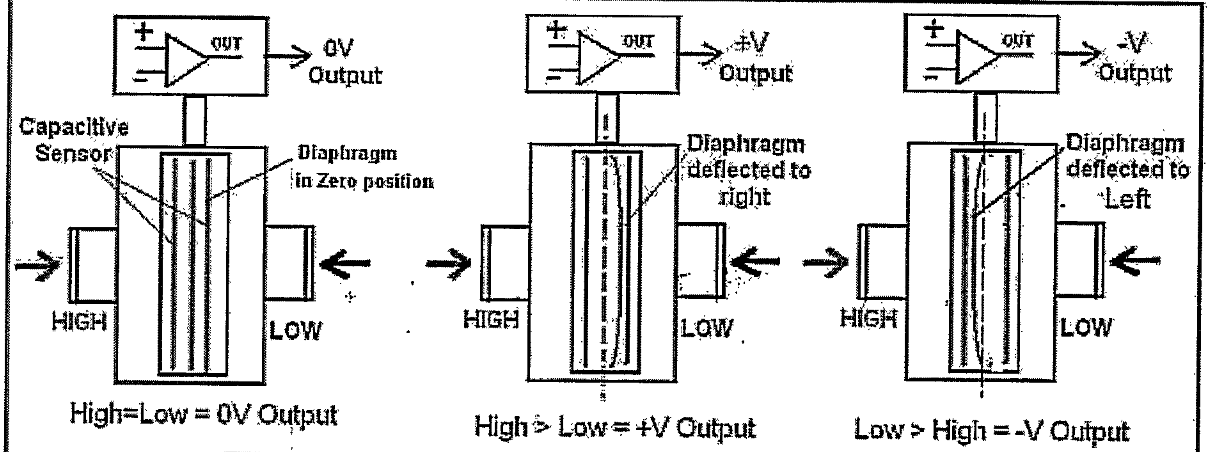
Based on the input pressure, diaphragm of the capsule deflects. This deflection is converted into an electrical signal. This is normally done by the sensors. The commonly used sensors are (a) Strain Gauge (b) Differential Capacitance (c) Vibrating wire. The sensor output is proportional to the applied pressure.

Capacitance type:



Strain Gauge Type:





Internal arrangement of Bottom & Top Half of DP Transmitter

Fig - 7

The electrical signal generated at the lower chamber by the sensor is in the range of milli-volt only. This signal is to be amplified to 0-5V or 0-10V range or is to be converted to 4-20mA for onward transmission to a remote instrument. This upper housing is the Transmitter portion of the DP Transmitter which houses the Electronic Unit.

2-Wire 4-20mA Current Transmitter:

A DC output current is generated which is directly proportional to the pressure range of the Differential Pressure Transmitter. The lower range is 4mA, and the upper range is 20mA. This controlled current output is not affected by load impedance variation and supply voltage fluctuations. This 4-20mA output is superimposed with digital communications of BRAIN or HART FSK protocol.

Industrial applications of Differential Pressure Transmitters:

There are unlimited industrial applications of Differential Pressure Transmitters.

- Oil and Gas flow metering in onshore, offshore and subsea applications.
- Water and effluent treatment plants. It is largely used to monitor filters in these plants.
- It is used to monitor Sprinkler Systems.
- Remote sensing of Heating Systems for Steam or Hot Water.
- Pressure drops across valves can be monitored.
- Pump control monitoring.

47. Explain Smart/Intelligent pressure transmitter.

Analog Transmitters The evaluation of the design of transmitters has been influenced, by two factors. One, by the requirements of users for improved performance coupled with reduced cost of ownership and, the other, by developments which have taken place in adjacent technologies, such as computer aided design (CAD), microelectronics, materials science and communication technologies. The most significant advances have resulted from the emergence of low power microprocessors and analog-to-digital converts (ADC) which, in conjunction with the basic sensor circuits, can function on the limited power (typically less than 40 megawatt) available at the transmitter in a conventional 4-20 mA measurement circuit. This has provided two distinct routes for improving the performance of transmitters: (a) by enabling non-linear sensor characteristics to be corrected, and (b) by enabling a secondary sensor to be included so that secondary effects on the primary sensor can be compensated.

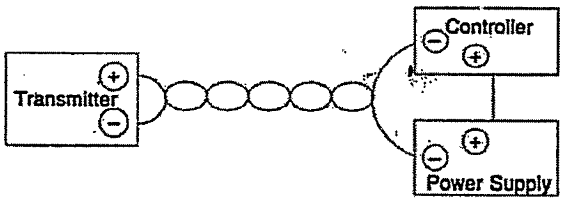


Fig. 14.1 *Conventional 4-20 mA Transmitter Circuit*

Smart Transmitters: Transmitters in which corrections are applied to the primary sensor signal using a microprocessor to process information which is embedded in memory; or those in which a microprocessor is used in conjunction with a secondary sensor to derive the corrections for the primary sensor signal, are termed as "smart' transmitters. Therefore, smart transmitter is a transmitter in which a microprocessor system is used to correct non-linearity errors of the primary sensor through interpolation of calibration data held in memory, or to compensate for the effect of secondary influences on the primary sensor by a secondary sensor adjacent to the primary sensor and interpolating stored calibration data for both the primary and secondary sensors. Figures illustrate the diagram of smart transmitters.

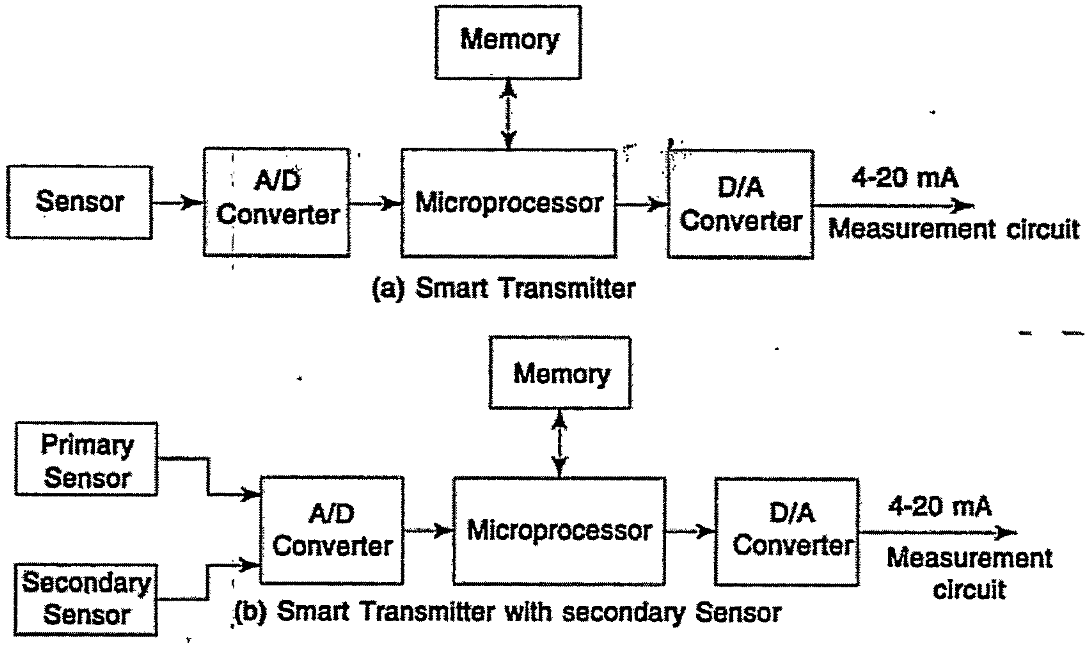


Fig. 14.2 *Smart Transmitter Circuits*

Intelligent Transmitters The inclusion of microprocessor in a transmitter has provided an opportunity to move from a regime in which only the measurement signal is transferred from the transmitter to a receiver, such as an indicator or controller; to one in which the microprocessor not only implements the smart functions mentioned above but also manages a communication facility. This enables data specific to the transmitter itself, such as its types, serial number, etc. to be stored at the transmitter and accessed via a measurement loop in which it is installed, as shown in Fig.

Other functions, such as setting or resetting the zero and span, details of the location and application, and running diagnostic routines to give warning of malfunctioning, can also be implemented. Such transmitters are called intelligent' transmitters.

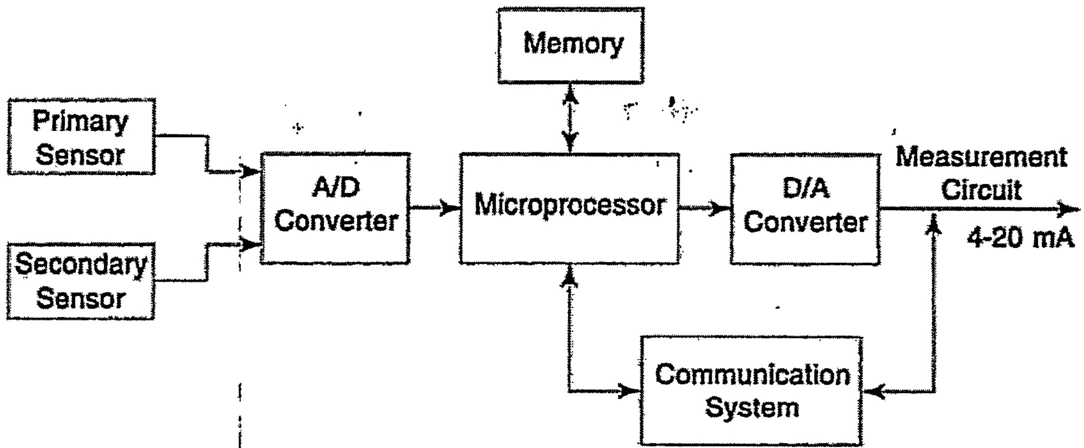


Fig. 14.3 *Smart and Intelligent Transmitter with Communication Facility*

Therefore, an intelligent transmitter is the one in which the functions of a microprocessor system are shared between (a) deriving the primary measure signal, (b) storing information regarding the transmitter itself, its application data and its location and (c) managing a communication system which enables two-way communication to be superimposed on the same circuit that the measurement signal, the communication being between the transmitter and either an interface unit connected at any access point in the measurement loop or at the control room.

Features of Smart and Intelligent Transmitters

- The use of microprocessors have contributed to the ability of the smart transmitters to calibrate the unit over a much wider range than the actual span needed for the particular application.
- It has much increased rangeability without sacrificing accuracy, because by memorizing the temperature and pressure effects on zero and span the smart transmitter can automatically correct for these variations, and therefore the performance of the unit is only a function of repeatability, linearity, and hysteresis.
- In addition to lower error and higher rangeability, the smart transmitters are also more flexible. Since their calibration curve is in the microprocessor memory, one can electronically change the zero and the span of the transmitter through the keyboard of a hand-held (portable) , also called HHTs. The microprocessor will automatically match the minimum and maximum signals to the newly set measurement inputs without affecting instrument calibration.
- Smart transmitters allow for two-way communications with the control room, can be automatically re zero the instrument by opening valves to equalize pressures on the two sides of a dp (differential pressure) cell and can monitor loop status, output, and configuration.
- Smart transmitters can memorize and recall tag numbers and failure or initialization modes, can provide damping and temperature compensation, and can change their outputs to maintain them fixed under certain conditions or to switch from direct to reverse action.
- They can linearize non-linear signals or provide other function generation functions, In addition to zero, span, and upper and lower range values, engineering units can also be changed.
- Recent smart transmitters are provided with standby sensors or with multiple sensors which allow the user to switch, for example, from an RTD (remote terminal device) to a TC (thermocouple) sensor while using the same transmitter.
- Recent smart transmitters are also available with automatic span switching which is useful in many applications where the process variable being detected changes over a wide range and better accuracy could be obtained if the transmitter switched to a low span when detecting low measurement values.

NARASARAOPETA
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DEPARTMENT OF MECHANICAL ENGINEERING

MID & ASSIGNMENT EXAMINATION QUESTION PAPERS WITH SCHEME AND SOLUTIONS

NARASARAOPETA ENGINEERING COLLEGE: NARASARAOPET (AUTONOMOUS)
DEPARTMENT OF MECHANICAL ENGINEERING
II B. TECH I - SEMESTER ASSIGNMENT TEST – I, September - 2022

SUBJECT: METROLOGY AND INSTRUMENTATION	**DATE:** 28-09-2022
DURATION: 30 MIN	**MAX MARKS:** 5 M

Q. No	Questions	Course Outcome (CO)	Knowledge Level as Per Bloom's Taxonomy	Marks
1	**Categorize** the types of fits,explanation with neat sketch	I	Analyzing (K4)	5
2	**Determine** the dimensions and tolerances of the shaft and hole having the size of 25H7/f8. 25mm falls in diameter steps of 18-30. Assume the following data, The fundamental deviation for shaft 'f' is $-5.5D^{0.41}$, The standard tolerance unit i=0.45 D1/3+0.001D , where D is the geometric mean of the lower and upper limits of diameter step in which the diameter consideration lies, D is in mm, The standard tolerance for IT7=16i and IT8=25i.	I	Evaluating (K5)	5
3	**Explain** about interchangeability and selective assembly	I	Evaluating (K5)	5
4	**Define** Limits, System of obataining different types of fits	I	Understanding (K2)	5
5	**Determine** limit dimensions for a clearance fit between mating parts of diameter 40 mm, providing a minimum clearance of 0.10 mm with a tolerance on the hole equal to 0.025mm and on shaft 0.05mm using both systems	I	Evaluating (K5)	5

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

II B.Tech I SEM I - Assignment Examination Scheme

1. Types of Fits and Explanation - 5 M
2. Problem Solution, dimension of Hole and Shaft - 5 M
3. Interchangeability and Selective Assembly, Explanation - 5 M
4. Definition of Limits, different types of fits - 5 M
5. Limit Dimensions for Hole and Shaft - 5 M

NARASARAOPETA ENGINEERING COLLEGE(AUTONOMOUS):NARASARAOPET
DEPDEPARTMENT OF MECHANICAL ENGINEERING
II B.Tech I – SEMESTER MID EXAMINATIONS –I, November -2022

SUBJECT: Metrology and Instrumentation	DATE: 09-11-2022
DURATION: 90 MIN	MAX MARKS: 25 M

Q.NO	Question	Course Outcome CO's	Knowledge level as per Bloom's Taxonomy	Marks
1	a) **Explain** hole basis system and shaft basis system with neat sketch.	CO1	Evaluating (K5)	5M
	b) Define fit and **classify** different types of fits with neat sketch	CO1	Analyzing (K4)	5M
2	a) Explain Micrometre with neat sketch.	CO 2	Evaluating (K5)	5M
	b) Explain with a neat sketch, the construction of Sine bar.	CO1	Evaluating (K5)	5M
3	**State** and explain the Taylor's principle of Gauge design	CO2	Evaluating (K5)	5M

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DEPDEPARTMENT OF MECHANICAL ENGINEERING
II B.Tech I – SEMESTER MID EXAMINATIONS –I, November -2022

SUBJECT: Metrology and Instrumentation	DATE: 09-11-2022
DURATION: 90 MIN	MAX MARKS: 25 M

Q.NO	Question	Course Outcome CO's	Knowledge level as per Bloom's Taxonomy	Marks
1	c) **Explain** hole basis system and shaft basis system with neat sketch.	CO1	Evaluating (K5)	5M
	d) Define fit and **classify** different types of fits with neat sketch	CO1	Analyzing (K4)	5M
2	c) Explain Micrometre with neat sketch.	CO 2	Evaluating (K5)	5M
	d) Explain with a neat sketch, the construction of Sine bar.	CO1	Evaluating (K5)	5M
3	**State** and explain the Taylor's principle of Gauge design	CO2	Evaluating (K5)	5M

NEC NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

II B.Tech I SEM I - MID Examination Scheme

1. a) Sketch and Explanation - 5 M

   b) Sketch and Classification - 5 M

2. a) Sketch and Explanation - 5 M

   b) Sketch and Explanation - 5 M

3. a) Principle and Explanation - 5 M

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(AUTONOMOUS)
DEPARTMENT OF MECHANICAL ENGINEERING
II B. TECH I - SEMESTER ASSIGNMENT TEST – II, December - 2022

SUBJECT: METROLOGY AND INSTRUMENTATION	**DATE:** 01-12-2022
DURATION: 30 MIN	**MAX MARKS:** 5 M

Q. No	Questions	Course Outcome (CO)	Knowledge Level as Per Bloom's Taxonomy	Marks
1	**Explain** the tool maker's microscope with a neat sketch.	III	Evaluating (K5)	5
2	**Describe** the Autocollimator working with a neat sketch.	III	Evaluating (K5)	5
3	Explain Optical flats with a neat sketch.	III	Evaluating (K5)	5
4	**Define** the following terms Range and span, Repeatability, Sensitivity, and Reproductability.	IV	Remembering (K1)	5
5	**Classify** the different methods of measurement.	IV	Analyzing (K4)	5

NARASARAOPETA ENGINEERING COLLEGE
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DEPARTMENT OF MECHANICAL ENGINEERING

II B.Tech I SEM II - Assignment Examination Scheme

1. Sketch and Explanation - 5 M
2. Sketch and Working - 5 M
3. Sketch and Explanation - 5 M
4. Static Characteristics Definition - 5 M
5. Classification of measurement - 5 M

NARASARAOPET ENGINEERING COLLEGE (AUTONOMOUS): NARASARAOPET
DEPARTMENT OF MECHANICAL ENGINEERING
II B. TECH I - SEMESTER II - MID EXAMINATION, December - 2022

Subject: **Metrology and Instrumentation**	Date: 21-12-2022
Duration : 90 Min	Max Marks: 25 M

Answer All Questions

Q. No	Questions	Course Outcome (CO)	Bloom's Taxonomy Levels	Marks
1	**Explain** the working of Tools makers' microscope with neat sketch.	3	Evaluating (K5)	5
2	a. **Categorize** the following main static characteristics (i) Accuracy (ii) Sensitivity (iii) Reproducibility (iv) Drift (v) Dead zone	4	Analyzing (K4)	5
	b. Sketch and **explain** the working of piezoelectric transducer.	4	Evaluating (K5)	5
3	a. **Explain** thermocouple with neat sketch.	5	Evaluating (K5)	5
	b. **Explain** the working of the Mcleod pressure gauge.	5	Evaluating (K5)	5

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DEPARTMENT OF MECHANICAL ENGINEERING
II B. TECH I - SEMESTER II - MID EXAMINATION, December - 2022

Subject: **Metrology and Instrumentation**	Date: 21-12-2022
Duration : 90 Min	Max Marks: 25 M

Answer All Questions

Q. No	Questions	Course Outcome (CO)	Bloom's Taxonomy Levels	Marks
1	**Explain** the working of Tools makers' microscope with neat sketch.	3	Evaluating (K5)	5
2	a. **Categorize** the following main static characteristics (i) Accuracy (ii) Sensitivity (iii) Reproducibility (iv) Drift (v) Dead zone	4	Analyzing (K4)	5
	b. Sketch and **explain** the working of piezoelectric transducer.	4	Evaluating (K5)	5
3	a. **Explain** thermocouple with neat sketch.	5	Evaluating (K5)	5
	b. **Explain** the working of the Mcleod pressure gauge.	5	Evaluating (K5)	5

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II B.Tech I SEM II - MID Examination Scheme

1. a) Sketch and Explanation -5 M
2. a) Static Characteristics - 5 M

   b) Sketch and Explanation -5 M
3. a) Sketch and Explanation - 5 M

   b) Working and Explanation - 5 M

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DEPARTMENT OF MECHANICAL ENGINEERING

UNIT WISE IMPORTANT QUESTIONS

S NO	QUESTION	KNOWLEDGE LEVEL	CO
	UNIT I		
1	Distinguish between hole basis system and shaft basis system.	K2	CO1
2	Discuss in detail the salient features of the systems of limits and fits as per Indian standard.	K2	CO1
3	Determine the dimensions and tolerances of the shaft and hole having the size of 25H7/f8. 25mm falls in diameter steps of 18-30. Also indicate the type of fit and show the tolerances with sketch. Assume the following data, The fundamental deviation for shaft 'f' is $-5.5D_{0.41}$, The standard tolerance unit $i=0.45\ D_{1/3}+0.001D$, where D is the geometric mean of the lower and upper limits of diameter step in which the diameter consideration lies, D is in mm, The standard tolerance for IT7=16i and IT8=25i.	K2	CO1
4	On what factors the variation in size depends in any manufacturing process	K1	CO1
	UNIT 2		
1	State the essential requirements for accuracy in the construction of a sine bar. Why the sine bar is not recommended for angles larger than 45 with reference plain.	K4	CO2
2	Discuss briefly the working and operation bevel protractor.	K3	CO2
3	State the meaning wringing? What are the essential conditions for wringing of slip gauges? What precautions should be taken while using slip gauges?	K3	CO2
4	Explain how you determine the taper angle of a taper ring gauge using spheres and Depth micrometer. Derive the expression used.	K4	CO2
5	Enumerate the sources of errors in micrometers.	K3	CO2
	UNIT 3		
1	State and explain the Taylor's principle of gauge design with neat sketch of Plug gauge and Snap gauges.	K3	CO3
2	Mention the materials used for the manufacture of GO and NOGO gauges. Explain the disposition of tolerance on GO and NO GO gauges by taking reference to work tolerances.	K4	CO3
3	Explain how you determine the taper angle of a taper ring gauge using spheres and Depth micrometer. Derive the expression used.	K4	CO3
4	With a sketch, explain the construction of a tool maker's microscope. What are its applications?	K4	CO3

5	Write short notes on optical projector and their uses.	K3	CO3
6	What are interferometers? What are their advantages over optical flats?	K3	CO3
7	Explain the importance of inspection need in manufacturing & surface finishing	K2	CO3
	UNIT 4		
1	What are the various errors occur in the measuring instruments and explain the methods of elimination.	K3	CO4
2	Sketch and explain generalized measurement system and its functional elements.	K4	CO4
3	Explain various dynamic performance characteristics with sketches.	K3	CO4
4	Describe the terms (i) Linearity (ii) Calibration What is the relationship between sensitivity and range?	K3	CO4
5	Explain LVDT with neat sketch	K2	CO4
6	Classify the different types of errors.	K4	CO4
7	Explain piezo electric ,inductive ,capacitance, resistance	K5	CO4
	UNIT 5		
1	Explain different types of Manometers	K2	CO5
2	Explain bourdon pressure gauge	K4	CO5
3	With suitable diagram construct the bourdon tube pressure gauge	K3	CO5
4	Distinguish between thermistor and thermo couple	K4	CO5
5	Explain about bellow-diaphragm gauges and low pressure measurement	K5	CO5
6	Explain Mc Leod pressure gauge	K5	CO5

NARASARAOPETA
NEC ENGINEERING COLLEGE
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DEPARTMENT OF MECHANICAL ENGINEERING

PREVIOUS QUESTION PAPERS

SUBJECT NAME: **METROLOGY AND INSTRUMENTATION**

Sub Code: **R20ME2103**

II B.Tech II Semester Regular Examinations

(ME)

MODEL PAPER

Note: Answer All **FIVE** Questions.
All Questions Carry Equal Marks (5 X 14 = 71M)

Time: 3 Hrs **Max. Marks: 70**

Note: 1.Answer FIVE Questions, choice from each unit.

Execution Plan

Sl. No	Activities	Time (Minutes)
1	To study the Question Paper and choose to attempt	5
3	33 Minutes x 5 Questions	165
4	Quick revision & Winding up	10
	Total	180

Answer any FIVE Questions

Q.No.		Questions	Marks
		Unit-I	
1	a	Distinguish between hole basis system and shaft basis system.	[14M]
		OR	
	b	Discuss in detail the salient features of the systems of limits and fits as per Indian standard.	[14M]
		Unit-II	
2	a	State the essential requirements for accuracy in the construction of a sine bar. Why the sine bar is not recommended for angles larger than 45 with reference plain	[7M]
		Discuss briefly the working and operation bevel protractor.	[7M]
		OR	
	b	State the meaning wringing? What are the essential conditions for wringing of slip gauges? What precautions should be taken while using slip gauges?	[14M]
		Unit-III	
3	a	Mention the materials used for the manufacture of GO and NOGO gauges. Explain the disposition of tolerance on GO and NO GO gauges by taking reference to work tolerances.	[14M]
		OR	

	b	Explain how you determine the taper angle of a taper ring gauge using spheres and Depth micrometer. Derive the expression used.	[14M]
		Unit-IV	
4	a	(i) Explain various dynamic performance characteristics with sketches. (ii) Explain piezo electric transducers.	[14M]
		OR	
	b	Classify the different types of errors.	[7M]
		Explain LVDT with neat sketch	[7M]
		Unit-V	
5	a	(i)Explain different types of Manometers (ii) Explain bourdon pressure gauge	[14M]
		OR	
	b	(i)Explain Mc Leod pressure gauge (ii) Distinguish between thermistor and thermo couple	[14M]

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ENGINEERING COLLEGE
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DEPARTMENT OF MECHANICAL ENGINEERING

CO-POs & CO-PSOs ATTAINMENT

Course Code: C213	Course Name: METROLOGY AND INSTRUMENTATION	Year/Sem: II/I

External Examination Assessment

S.No	Q.No	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
		a		b		a		b		a		b		a		b		a		b	
		i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii
	COs	I	I	I	I	II	II	II	II	III	III	III	III	IV	IV	IV	IV	V	V	V	V
	Max. Marks	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
1	21471A0301	5			5	5	5				5		5	5	3					4	5
2	21471A0302		5	4		4	5					3	5	6	5					2	4
3	21471A0303	6	5					5	4		6		4	3	6					3	3
4	21471A0304	6	6					5	3			6	4			6	5			3	4
5	21471A0305	5	2					4	6	5		3				2	2			2	3
6	21471A0306	6	6					5	3			6	4	6	5			3	4		
7	21471A0307	4	5			3	5				4	5		4	3			3	4		
8	21471A0309	4	5			3	5					5	4	4	3			3	4		
9	21471A0310	4	4			3	5			4			6	4	2			4	3		
10	21471A0311			5	3			4	4			5	2			3	2			3	5
11	21471A0312			5	6			4	5	5			5			6	4			6	4
12	21471A0314			4	4	2	5					5	3			2	3	2	3		
13	22475A0301	6	6			6	6				6		6			6	6			6	6
14	22475A0302	5	6			4	6					4	2	6	5					5	5
15	22475A0303			5	5			3	5	4		6				5	4	3	2		
16	22475A0304			5	6			4	6			5	3			6	6	2	2		
17	22475A0305	5	5					5	6			4	4	6	5			5	5		
18	22475A0306	5	5					4	5		5		5	5	5					5	5
19	22475A0307	5	5			4	6					4	6	5	5					4	6
20	22475A0308			5	2	5	4					6	2			3	3			2	3
21	22475A0309			4	4	4	4			6			2			6	3	4	3		
22	22475A0310	4	4					4	4			6	2			6	3			4	3
23	22475A0311	5	4					4	4	5			3	6	4					4	3
24	22475A0312	4	4			5	4					3	2	6	2			5	4		
25	22475A0313	5	4			6	5					5	5			5	5	5	5		
26	22475A0314			6	4	2	5				6	4		2	6			6	4		
27	22475A0315	2	3			2	3					2	5	1	2					2	4
28	22475A0316	6	5			6	4			5		4		4	5			3	3		
29	22475A0317	5	5			6	4					4	6	5	5			5	5		
30	22475A0318	4	5			4	4					4	4	4	4			4	4		
31	22475A0319	5	2					4	3		6	4		2	2					2	2
32	22475A0321	5	5					5	5	5			5			5	5			5	5
33	22475A0322	6	6			4	4					4	5			3	6			2	2
34	22475A0323			5	6	4	3					4	5			6	6	2	4		
35	22475A0324			5	5	5	5				5	5				6	6	5	5		
36	22475A0325			4	6			6	5			3	5	5	3			4	3		
37	22475A0326	6	5					6	6			5	5	3	3					4	3
38	22475A0327	5	5					5	5	5			5			6	5			5	5
39	22475A0328	6	4			4	6					5	5			4	4	5	4		
40	22475A0329	6	5			5	5					6	4	5	5			5	5		
41	22475A0330	4	4			3	2			5			3	4				4	5		
42	22475A0331			4	6	6	6					4	3	5	4			4	5		
43	22475A0332			4	4			6	4		6	4		4	4					4	3
44	22475A0333			5	5			5	5			5	5	5	5					4	5
45	22475A0334			6	5	4	4					4	6	5	5					4	2
46	22475A0335	4	4			6	4					5	4	3	4			6	6		
47	22475A0336	5	2			2	3					4	3	4	3			2	2		
48	22475A0337	5	3			4	4					4	4	3	4			4	4		

49	22475A0338		6	4			5	5					4	4	3	4					4	3
50	22475A0339		6	6			5	6			6			5			6	6			6	6
51	22475A0340		5	5			4	6				6	4				4	4			4	3
52	22475A0341		4	4			4	5					5	3	4	3			3	2		
53	22475A0342		6	5			5	5					5	4	5	5			5	5		
54	22475A0343		6	5			5	5				5		5	6	5			5	5		
55	22475A0344				6	3	4	4					4	4			5	4			3	3
56	22475A0345				6	6	5	5					5	5			5	5			5	5
57	22475A0346		6	6			6	4					4	5	5	6					6	4
58	22475A0347		6	6			6	6					5	5	5	6					6	4
59	22475A0348		6	6					5	5	6		5		6	5					6	5
60	22475A0349		4	5			5	6					5	6	4	4			4	2		
61	22475A0350				6	6	5	5					4	4			4	4	4	6		
62	22475A0351		6	6			6	5					6	6	5	5					5	6
63	22475A0352		6	6			6	5					5	4	6	3					5	6
No. of Students answered			44	44	19	19	43	43	20	20	12	11	50	53	40	39	23	23	30	30	33	33
50% of Max.Marks			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
No. of Students crossed 50% of Max Marks			43	39	19	16	35	39	19	17	12	11	45	40	32	27	18	17	20	20	23	20
% of Students crossed 50% of Max Marks			98	89	100	84	81	91	95	85	100	100	90	75	80	69	78	74	67	67	70	61
Attainment Level			3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	2	2	3	2

Course Outcome	I	II	III	IV	V
No.of Times repeated	4	4	4	4	4
Final CO Attainment Level	3	3	3	3	2

Rubrics:

If 50% of the students crossed 50% of the marks: Attainment Level 1

If 60% of the students crossed 50% of the marks: Attainment Level 2

If 70% of the students crossed 50% of the marks: Attainment Level 3

1. **Enter the question wise marks.**
2. **Identify the CO of each question.**
3. **Calculate the maximum marks of each CO.**
4. **Calculate the CO wise marks obtained by each student.**
5. **Calculate 50% of maximum marks of each CO.**
6. **Find number of students crossed 50% of maximum marks for each CO.**
7. **Find percentage of students crossed 50% of maximum marks for each CO.**
8. **Find the attainment level of each CO as per the above Rubrics.**

Course Code: C213	Course Name: METROLOGY AND INSTRUMENTATION	Year/Sem: II/I

Internal Examination Assessment

S.No	Roll. No	Test	Mid1					A1	Quiz 1						A2	Quiz 2	CO I	CO II	CO III	CO IV	CO V
		Q.No	1		2		3				2		3								
			1.a	1.b	2.a	2.b	3.a			1.a	2.a	2.b	3.a	3.b			Max. Marks	Max. Marks	Max. Marks	Max. Marks	Max. Marks
		COs	I	I	II	II	III	I		III	IV	IV	V	V							
		Max. Marks	5	5	5	5	5	5	10	5	5	5	5	5	5	10	25	20	35	25	20
1	21471A0301		5	4	4	4	5	5	3	5	5	5	0	5	5	5	17	11	23	20	10
2	21471A0302		5	3	3	5	5	5	7	5	5	5	3	2	5	5	20	15	27	20	10
3	21471A0303		5	5	5	3	4	5	3	5	4	5	4	4	5	3	18	11	20	17	11
4	21471A0304		5	5	3	2	5	4	6	4	5	5	5	5	5		20	11	20	15	10
5	21471A0305		0	0	5	5		3	4	5	5	5	0	5	5	2	7	14	16	17	7
6	21471A0306		1	4	4	3	2	3	4	4	4	3	3	5	5	5	12	11	20	17	13
7	21471A0307		4		0	4			4	5	4	5	0	5	5	4	8	8	18	18	9
8	21471A0309		5	4	5	4	2	5	5	4	5	4	1	0	5	4	19	14	20	18	5
9	21471A0310		1	4	5	1		3	4	3	5	5	0	5	5	2	12	10	14	17	7
10	21471A0311		3	5	3	0	5	3	3	5	5	5	3		4	2	14	6	19	16	5
11	21471A0312		5	5	5	5	5	5	6	5	5	5	5	5	5	7	21	16	28	22	17
12	21471A0314		4	3	4	4	0	3	2	4	0	3	0	0		3	12	10	9	6	3
13	22475A0301		5	5	5	5	5	5	5	5	5	5	5	5	5	6	20	15	26	21	16
14	22475A0302		5	5	5	5	1	5	4	4	5	4	4	4	5	3	19	14	17	17	11
15	22475A0303		4	5	5	3	3	4	4	5	5	2	3	1	4	4	17	12	20	15	8
16	22475A0304		5	4	2	4	2	5	2	3	5	2	5	5	5	3	16	8	15	15	13
17	22475A0305		5	5	4	4	5	5	5	5	5	5	4	5	5	3	20	13	23	18	12
18	22475A0306		4	4	4	5	5	5	4	5	5	2	5	5	5	3	17	13	22	15	13
19	22475A0307		5	5	5	5	5	5	2	5	5	5	4	4	5	5	17	12	22	20	13
20	22475A0308		5	5	4	4	0	5	6	5	5	4	5	5	5	5	21	14	21	19	15
21	22475A0309			3	5	5		4	5	5	3	4	4	5	5	5	12	15	20	17	14
22	22475A0310		5	5	5	5	2	4	4	4	5	5	4	4	5	4	18	14	19	19	12
23	22475A0311		4	5	5	5	5	3	3	4	5	4	3	5	5	5	15	13	22	19	13
24	22475A0312		5		5	5	5	3	4	4	5	5	0	3	5	4	12	14	22	19	7
25	22475A0313		0	5	5	5	3	3	5	5	5	5	4	1	4	3	13	15	20	17	8
26	22475A0314		0	5	5	5	4	5	5	5	5	5	4	5	5	6	15	15	25	21	15
27	22475A0315			4	5	2		2	5	4	0	5	0	0	5	2	11	12	16	12	2

28	22475A0316		5	[illegible]	5	5	5	5	5	4	5	4	4	4	5	4	20	15	23	18	12
29	22475A0317		5	5	5	4	5	5	4	4	5	4	3	3	5	4	19	13	22	18	10
30	22475A0318		4	2	5	4		2	3	5	0	5	5	3	5	3	11	12	16	13	11
31	22475A0319		4	5	3	1	3	4	4	5	5	5	3	3	5	3	17	8	20	18	9
32	22475A0321		5	4	5	2		3	4	5	4	5	4	2	5	4	16	11	18	18	10
33	22475A0322		5	4	4	5		5	5	2	4	5	5	0	5	2	19	14	14	16	7
34	22475A0323			3	5	5		3	3	5	5	0	3	2	5	5	9	13	18	15	10
35	22475A0324		4	5	5	5	3	4	6	5	5	5	4	5	5	4	19	16	23	19	13
36	22475A0325		4	4	5	4		3	4	5	5	5	4		4	4	15	13	17	18	8
37	22475A0326		4	5	5	5	0	3	4	4	5	5	3	1	5	3	16	14	16	18	7
38	22475A0327		5	4	4	5	4	5	5	5	5	4	4	4	5	5	19	14	24	19	13
39	22475A0328			5	5	0	3	3	4	5	0	4	5	5	5	5	12	9	22	14	15
40	22475A0329			5	5	5	4	3	4	3	5	4	5	5	5	5	12	14	21	19	15
41	22475A0330		3	4			3	2	3	4	0	3	2	0	5	5	12	3	20	13	7
42	22475A0331		5	5	5	5	3	2	5	5	5	5	4	5	5	5	17	15	23	20	14
43	22475A0332		2	4	5	4	1	2	5	3	0	3	3	4	5	5	13	14	19	13	12
44	22475A0333		5	4	4	3	5	3	5	4	4	3	4	4	5	4	17	12	23	16	12
45	22475A0334			4	5	5	5	4	5	5	5	5	4	5	5	5	13	15	25	20	14
46	22475A0335		5	4	5	4	5	3	4	4	5	4	4	5		2	16	13	15	11	11
47	22475A0336			4	3	2	1	0	5	5	2		5	1	5	4	9	10	20	11	10
48	22475A0337		3	5	3	5	5	1	4	4	5	5	5	5	5	5	13	12	23	20	15
49	22475A0338		5	5	0	5	5	3	4	4	4	3	4	4	3	3	17	9	19	13	11
50	22475A0339		5	5	5	5	5	5	4	5	5	5	5	5	5	4	19	14	23	19	14
51	22475A0340		5	2	5	2	5	4	7	5	5	1	4	5	5	4	18	14	26	15	13
52	22475A0341		5	5	5	4		3	4	5	5	3	4	5	5	3	17	13	17	16	12
53	22475A0342		5	5	5	4		5	3	5	5	5	5	5	5	3	18	12	16	18	13
54	22475A0343		5	5	5	4	3	5	4	5	5	5	5	5	5	5	19	13	22	20	15
55	22475A0344		2	5	5	5	0	4	3	5	5	1	5	3	5	6	14	13	19	17	14
56	22475A0345		5	5	5	5	3	5	4	5	5	5	5	5	5	4	19	14	21	19	14
57	22475A0346		3	5	5	5	5	5	5	5	5	5	5	5	5	2	18	15	22	17	12
58	22475A0347		5	5	5	5	4	5	4	5	5	5	5	5	5	5	19	14	23	20	15
59	22475A0348		5	5	5	1		5	4	5	4	5	4	3	5	2	19	10	16	16	9
60	22475A0349		5	5	5	4		5	4	5	5	5	5	5	5	5	19	13	19	20	15
61	22475A0350			5	5		2	5	3	5	5	0	5	0	5	3	13	8	18	13	8
62	22475A0351		4	5	5	5		5	2	5	5	4	4	5	5	4	16	12	16	18	13
63	22475A0352		5	5	2	5	5	5	5	5	5	5	5	5	5	8	20	12	28	23	18

50% of maximum marks	12.5	10	17.5	12.5	10
No. of Students crossed 50% of max. marks	49	55	48	59	46
% of students crossed 50% of max. marks	78	87	76	94	73
Attainment Level	3	3	3	3	3

Rubrics:

If 50% of the students crossed 50% of the marks: Attainment Level 1
If 60% of the students crossed 50% of the marks: Attainment Level 2
If 70% of the students crossed 50% of the marks: Attainment Level 3

1. **Enter the question wise marks for mid examinations, assignments & quiz.**
2. **Identify the CO of each question.**
3. **Calculate the maximum marks of each CO based mid exams, assignments and quiz.**
4. **Calculate the CO wise marks obtained by each student.**
5. **Calculate 50% of maximum marks of each CO.**
6. **Find number of students crossed 50% of maximum marks for each CO.**
7. **Find percentage of students crossed 50% of maximum marks for each CO.**
8. **Find the attainment level of each CO as per the above Rubrics.**

Course Code: C213	Course Name: METROLOGY AND INSTRUMENTATION	Year/Sem: II/I

CO Attainment

CO	CO Attainment Level (Internal)	CO Attainment Level (External)	Direct CO Attainment Level (Internal * 30%) + (External * 70%)	Indirect CO Attainment Level	Total CO Attainment Level (Direct CO Attainment * 90% + Indirect CO Attainment * 10%)
C213.1	3	3	3.00	2.82	2.98
C213.2	3	3	3.00	2.64	2.96
C213.3	3	3	3.00	2.72	2.97
C213.4	3	3	3.00	2.56	2.96
C213.5	3	2	2.30	2.92	2.36
C213					2.85

1. Copy the Direct CO Attainment Level (Internal) and Direct CO Attainment Level (External) from the previous sheets and then find the Direct CO Attainment Level.
2. Find Direct CO attainment level using the formula:
   CO Attainment Level (Internal) * 30% + CO Attainment Level (External) * 70%
3. Copy Indirect CO Attainment Level.
4. Find the CO attainment level using the formula:
   Direct CO Attainment Level *90% + Indirect CO Attainment Level * 10%

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CO-PO & CO-PSO Mapping

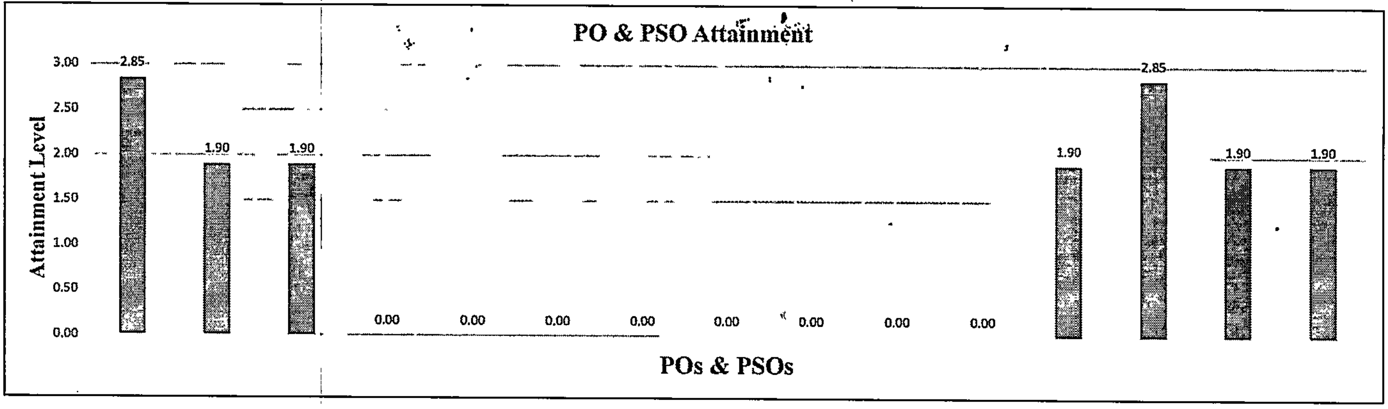
COs	POs & PSOs														
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
C213.1	3	2	-		-	-	-	-	-	-	-	2	3	-	2
C213.2	3	2	2	-	-	-	-	-	-	-	-	2	3	-	2
C213.3	3	2	-	-	-	-	-	-	-	-	-	2	3	-	2
C213.4	3	2	-		-	-	-	-	-	-	-	2	3	-	2
C213.5	3	2	-	-	-	-	-	-	-	-	-	2	3	2	2
C214	3.00	2.00	2.00	-	-	-	-	-	-	-	-	2.00	3.00	2.00	2.00

Total CO Attainment through Direct & Indirect Assessment

CO Attainment	2.85

PO & PSO Attainment

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
PO Attainment	2.85	1.90	1.90	-	-	-	-	-	-			1.90	2.85	1.90	1.90



1. Copy CO - PO matrix and CO attainment matrix from previous pages and find PO attainment.
2. PO attainment is calculated as per the following formula:
   POi * Total CO attainment Level / 3 where 'i' ranges from 1 to 12

1. Copy CO - PSO matrix and CO attainment matrix from previous pages and find PSO attainment.
2. PSO attainment is calculated as per the following formula:
   PSOi * Total CO attainment Level / 3 where 'i' ranges from 1 to 3