UNIVERSITY OF ENGINEERING & MANAGEMENT,JAIPUR

Lecture-wise Plan

Subject Name: Mathematics-III **Subject Code-M401**
Year: 2nd Year **Semester: Fourth**

Module Number	Topics	Number of Lectures
1	**Fourier Series & Fourier Transform**	**8L**
	Introduction	1
	Fourier Series for functions of period 2π, Fourier Series for functions of period 2L	3
	Fourier Integral Theorem, Fourier Transform of a function, Fourier Sine and Cosine Integral Theorem.	1
	Properties of Fourier Transform, Fourier Transform of Derivatives.	1
	Convolution Theorem, Inverse of Fourier Transform.	2
2	**Introduction to Functions of a Complex Variable & Conformal Mapping, Complex Integration, Residue & Counter Integration**	**8L**
	Complex functions, Limit, Continuity and Differentiability, Analytic functions	1
	Cauchy-Riemann Equations, Harmonic function and Conjugate Harmonic function	1
	Construction of Analytic functions: Milne Thomson method.	1
	Simple curve, closed curve, smooth curve & contour, complex Integrals.	1
	Cauchy's theorem, Cauchy-Goursat theorem, Cauchy's integral formula, Cauchy's integral formula	2
3	**Basic Probability Theory, Random Variable & Probability Distributions. Expectation**	**12L**
	Introduction	1
	Conditional probability, Independent events & Multiplication Rule.	1
	Baye's theorem	1
	Random variable	1
	Probability density function & probability mass function.	2
	Expectation & Variance	1
	Binomial & Poisson distributions and related problems.	2
	Uniform, Exponential, Normal distributions and related problems.	3
4	**Partial Differential Equation (PDE) and Series solution of Ordinary Differential Equation (ODE)**	**7L**
	Origin of PDE, its order and degree, concept of solution in PDE.	1
	Different methods: Separation of variables, Laplace & Fourier transform methods.	3
	PDE I: One dimensional Wave equation.	1
	PDE II: One dimensional Heat equation	1
	PDE III: Two dimensional Laplace equation.	1

Assignment:

Module-1:

1. Write the statement of Fourier integral Theorem.
2. If the Fourier series of function $f(x)$ is given by $a_0+\sum_{n=1}^{\infty}a_n\cos nx+\sum_{n=1}^{\infty}b_n\sin nx$, then a_n is given by?
3. If the Fourier series of function $f(x)$ is given by $a_0+\sum_{n=1}^{\infty}a_n\cos nx+\sum_{n=1}^{\infty}b_n\sin nx$, then b_n is given by?
4. If the Fourier series of function $f(x)$ is given by $a_0+\sum_{n=1}^{\infty}a_n\cos nx+\sum_{n=1}^{\infty}b_n\sin nx$, then a_n is given by?
5. If the Fourier series of function $f(x)$ is given by $a_0+\sum_{n=1}^{\infty}a_n\cos nx+\sum_{n=1}^{\infty}b_n\sin nx$, then b_n is given by?
6. If $F(p)$ is the Fourier transform of $f(x)$, then the Fourier transform of $f(ax)$ is given by?
7. If $F(p)$ is the Fourier transform of $f(x)$, then the Fourier transform of $f(x-a)$ is given by?
8. If $F(p)$ is the Fourier transform of $f(x)$, then the Fourier transform of $f(ax)$ is given by?
9. If $F(p)$ is the Fourier transform of $f(x)$, then the Fourier transform of $f(x-a)$ is given by?
10. Define periodic function
11. Define even function
12. Write the relation between two orthogonal functions.
13. IF convolution of two functions exists then the value of $F\left\{\frac{1}{\sqrt{2\circledR}}\int_{-\infty}^{\infty}f(u)g(x-u)du;p\right\}=$
14. IF convolution of two functions exists then the value of $F\left\{\frac{1}{\sqrt{2\circledR}}\int_{-\infty}^{\infty}f(u)g(x-u)du;p\right\}=$
15. IF convolution of two functions exists then the value of $F\left\{\frac{1}{\sqrt{2\circledR}}\int_{-\infty}^{\infty}f(u)g(x-u)du;p\right\}=$
16. IF convolution of two functions exists then the value of $F\left\{\frac{1}{\sqrt{2\circledR}}\int_{-\infty}^{\infty}f(u)g(x-u)du;p\right\}=$
17. Obtain the Fourier series for the function $f(x)=x^2,-\circledR<x<\circledR$.
18. Obtain the fourier series for the function $f(x)=\frac{1}{4}(\circledR-x^2),0<x<2\circledR$.
19. Obtain the fourier series for the function $f(x)=\sin ax,-\circledR<x<\circledR$. a being non-integer value.
20. Obtain the fourier series for the function $f(x)=x,-\circledR<x<\circledR$.

Module-2:

21. Write Cauchy- Riemann equations for a function $f(z)=u(x,y)+iv(x,y)$.

22. Write necessary condition for a function $f(z)=u(x,y)+iv(x,y)$ to be analytic.
23. Write necessary and sufficient condition for a function $f(z)=u(x,y)+iv(x,y)$ to be analytic.
24. Write sufficient condition for a function $f(z)=u(x,y)+iv(x,y)$ to be analytic.
25. State Cauchy's integral theorem.
26. Write Cauchy's integral formula.
27. Write type of singularity of the function $\frac{\sin z}{z}$ at $z=0$.
28. Write type of singularity of the function $\frac{z^3}{(z+1)^2(z-5)^4}$ at $z=5$.
29. Write type of singularity of the function $\frac{1}{(z+1)^2(z-3)^2}$ at $z=-1$.
30. Write type of singularity of the function $\frac{z^2}{(z+1)(z-3)^2}$ at $z=3$.
31. Examine that the function $f(x,y)=y^3-3x^2y$ is harmonic or not.
32. Examine that the function $f(x,y)=\frac{1}{2}\log(x^2+y^2)$ is harmonic or not.
33. Examine that the function $f(x,y)=\frac{x-y}{x^2+y^2}$ is harmonic or not.
34. Examine that the function $f(x,y)=2x(1-y)$ is harmonic or not.
35. Evaluate $\int_0^{1+i} z^2 dz$, where z is complex number.
36. Evaluate $\int_0^{1+2i} (1+z^2) dz$, where z is complex number.
37. Evaluate $\int_0^{2+i} e^z dz$, where z is complex number.
38. Evaluate $\int_0^{1+i} (z^2+3z+2) dz$, where z is complex number.
39. Find the residue at the poles of $f(z)=\frac{\cot® z}{(z-a)^2}$.
40. Find the residue at the poles of $f(z)=\frac{z^2-2z}{(z+1)^2(z^2+4)}$.
41. Find the residue of $f(z)=\frac{z^3}{z^2-1}$ at $z=\infty$.
42. Find the residue of $f(z)=\frac{e^z}{z\sin mz}$ at $z=0$.

Module-3:

1. If for two events A and B we have the following probabilities:

$P(A)=P(A|B)=\frac{1}{4};P(B|A)=\frac{1}{2}.$ Then check A and B are independent or not.

2. If $P(A\cap B)=\frac{1}{2}, P(\overline{A}\cap\overline{B})=\frac{1}{2}$ and $2P(A)=P(B)=p,$ then find the value of $p.$
3. If for two events A and B we have the following probabilities:
   $P(A)=P(A|B)=\frac{1}{4};P(B|A)=\frac{1}{2}.$ Then find $P(\overline{A}|B)=.$
4. If $P(A\cap B)=\frac{1}{2}, P(\overline{A}\cap\overline{B})=\frac{1}{3}$ and $P(A)=P(B)=p,$ then find the value of $p.$
5. If A and B are any two events and $P(A)=p_1;P(B)=p_2;P(A\cap B)=p_3.$ Then $P(\overline{A}\cup\overline{B})=$
6. If A and B are any two events and $P(A)=p_1;P(B)=p_2;P(A\cap B)=p_3.$ Then $P(\overline{A\cup B})=$
7. If A and B are any two events and $P(A)=p_1;P(B)=p_2;P(A\cap B)=p_3.$ Then $P(\overline{A}\cap\overline{B})=$
8. If A and B are any two events and $P(A)=p_1;P(B)=p_2;P(A\cap B)=p_3.$ Then $P(\overline{A}\cup B)=$
9. State Baye's theorem for mutually disjoint events.
10. If $f(x)=\begin{cases} ke^{-2x} & x\geq 0 \\ 0 & otherwise \end{cases}$, then what will be the value of k for which $f(x)$ be probability density function?
11. If $f(x)=\begin{cases} x & 0<x<1 \\ 0 & otherwise \end{cases}$, then $f(x)$ is probability density function or not?
12. If $f(x)=\begin{cases} ke^{-x} & x\geq 0 \\ 0 & otherwise \end{cases}$, then what will be the value of k for which $f(x)$ be probability density function?
13. If $f(x)=\begin{cases} k(1-e^{-x})^2 & x\geq 0 \\ 0 & otherwise \end{cases}$, then what will be the value of k for which $f(x)$ be probability density function?
14. Write the formula for mathematical expectation of a discrete random variable X with probability mass function $f(x).$
15. Write the formula for mathematical expectation of a continuous random variable X with probability density function $f(x).$
16. Write the formula for mathematical expectation of a discrete random variable X with probability mass function $f(x).$
17. Write the formula for mathematical expectation of a continuous random variable X with probability density function $f(x).$

18. A card is drawn from pack of 52 cards, find the probability of getting a king or a heart or a red card?
19. A card is drawn from a pack of 52 cards, if the value of faces cards 10, aces cards 1 and other according to denomination, find the expected value of the no. of point on the card.
20. A bag contains 10 red and 15 white balls. Two balls are drawn in succession. What is the probability that one of them is white and other red?
21. State Bayes' theorem.
22. A and B take turns in throwing two dice on the understanding that the first to throw 9 will be awarded a prize. If A has the first turn, show their respective chances of winning are in the ratio 9 : 8.
23. Three groups of children contain respectively 3 girls and 1boy; 2 girls and 2 boys; 1 girls and 3 boys, One child is selected at random from each group. Find the chance of selecting 1 girl and 2 boys.
24. A manufacturer supplies quarter horsepower motors in lots of 25. A buyer, before taking a lot, tests at random a sample of 5 motors and accepts the lot if they are all good; otherwise he rejects the lot. Find the probability that :(i) he will accept a lot containing 5defective motors ;(ii) he will reject a lot containing only one defective motors.
25. In an examination with multiple-choice questions, each question has four, out of which one is correct. A candidate ticked the answer either by his skill or by copying from his neighbours, The probability of guess is 1/3, copying is 1/6. The probability of correct answer by copying is 1/8. If a candidate answers a question correctly find the probability that he know the answer.
26. An urn contains 10 white and 3 black balls. Another urn contains 3 white and 5 black balls. Two balls are drawn at random from first urn and placed in the second urn and then one ball is taken at random from the latter. What is the probability that it is a white ball ?
27. Define the random variable, Explain the types of random variable with example.
28. A can hit a target 4 times in 7 shots, B 3 times in 5 shots and C three times in 5 shots. All of them fire one shot each simultaneously at the target. What is the probability that (i) 2 shots hit (ii) At least two shots hit ?
29. The probability that a student A solves a mathematics problem is 2/5 and the probability that a student B solves the problem is 2/3. What is the probability that (a) the problem is not solved (b) the problem is solved (c) both A and B solve the problem.
30. A company has four production section S_1, S_2, S_3& S_4 which contribute 30%, 20% 22% & 28% respectively produced 1%, 2%, 3% & 4% defective units, if a small unit is selected random & found to be defective, what is the probability that the unit selcected has came from (a) Section S_1 (b) Section S_4
31. From a city population, the probability of selecting a male or a smoker is 7/10, a male smoker is 2/5 and a male if a smoker is already selected is 2/3, find the probability of selecting (a) non-smoker (b) a male (c) a smoker if a male is first selected.
32. There are two bags A and B. A contains n white and 2 black balls & B contains 2 white and n black balls, one of the two bags is selected at random and two balls are drawn from it without replacement. If the both balls are drawn are white and the probability that the bag A was used to drawn the ball is 6/7. Find the value of n.

Module-4:

1. Bessel function of order $p = \pm\frac{1}{2}$, show that $J_{1/2}(x) = \sqrt{2/\text{®}x}\sin x$ and $J_{-1/2}(x) = \sqrt{2/\text{®}x}\cos x$.
2. Determine the order p of the following Bessel equation:
   a) $x^2 y'' + xy' + (x^2 - 9)y = 0$

b) $x^2 y'' + xy' + x^2 y = 0$

3. Solve the following heat flow problem:

$$\frac{\partial u}{\partial t} = 7\frac{\partial^2 u}{\partial x^2} \quad , \quad 0 < x < \text{®} \quad , \quad t > 0.$$

$$u(0,t) = u(\text{®} \; ,t) = 0 \; , \quad t > 0 \; ,$$

$$u(x,0) = 3\sin 2x - 6\sin 5x \quad , \; 0 < x < \pi.$$

4. Prove that F satisfies the Laplace’s equation: $F = Cz^n$

$$\nabla^2 F = \frac{\partial^2 F}{\partial x^2} + \frac{\partial^2 F}{\partial y^2} = 0$$

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lecture-wise Plan

Subject Name: **Basic Environmental Engineering** Subject Code: **CH-401**
Year: **2nd Year** Semester: Fourth

Module Number	Topics	Number of Lectures
1	**Chapter 1: General**	**6L**
	1. Basic ideas of environment, basic concepts, man, society & environment, their interrelationship.	1L
	2. Mathematics of population growth and associated problems, Importance of population study in environmental engineering, definition of resource, types of resource, renewable, non-renewable, potentially renewable, effect of excessive use vis-à-vis	2L
	3. Materials balance: Steady state conservation system, steady state system with non conservative pollutants, step function.	1L
	4. Environmental degradation: Natural environmental Hazards like Flood, earthquake, Landslide-causes, effects and control/management; Anthropogenic degradation like Acid rain-cause, effects and control. Nature and scope of Environmental Science and Engineering.	2L
	Chapter 2: Ecology	**6L**
	1. Elements of ecology: System, open system, closed system, definition of ecology, species, population, community, definition of ecosystem-components types and function.	1L
	2. Structure and function of the following ecosystem: Forest ecosystem, Grassland ecosystem, Desert ecosystem, Aquatic ecosystems, Mangrove ecosystem (special reference to Sundar ban); Food chain [definition and one example of each food chain], Food web.	2L
	3. Biogeochemical Cycle- definition, significance, flow chart of different cycles with only elementary reaction [Oxygen, carbon, Nitrogen, Phosphate, Sulphur].	1L
	4. Biodiversity- types, importance, Endemic species, Biodiversity Hot-spot, Threats to biodiversity, Conservation of biodiversity.	2L
	Chapter 3: Air pollution and control	**7L**
	1. Atmospheric Composition: Troposphere, Stratosphere, Mesosphere, Thermosphere, Tropopause and Mesopause	1L
	2. Energy balance: Conductive and Convective heat transfer, radiation heat transfer, simple global temperature model [Earth as a black body, earth as albedo], Problems.	1L
	3. Green house effects: Definition, impact of greenhouse gases on the global climate and consequently on sea water level, agriculture and marine food. Global warming and its consequence, Control of Global warming. Earth's heat budget.	1L
	4. Lapse rate: Ambient lapse rate Adiabatic lapse rate, atmospheric stability, temperature inversion (radiation inversion). Atmospheric dispersion: Maximum mixing depth, ventilation coefficient, effective stack height, smokestack plumes and Gaussian plume model.	1L

	5. Definition of pollutants and contaminants, Primary and secondary pollutants: emission standard, criteria pollutant.	1L
	Sources and effect of different air pollutants- Suspended particulate matter, oxides of carbon, oxides of nitrogen, oxides of sulphur, particulate, PAN.	
	6. Smog, Photochemical smog and London smog. Depletion Ozone layer: CFC, destruction of ozone layer by CFC, impact of other green house gases, effect of ozone modification.	1L
2	7. Standards and control measures: Industrial, commercial and residential air quality standard, control measure (ESP. Cyclone separator, bag house, catalytic converter, scrubber (ventury), Statement with brief reference).	1L
	Chapter 4: Water Pollution and Control	**8L**
	1. Hydrosphere, Hydrological cycle and Natural water.	1L
	2. Pollutants of water, their origin and effects: Oxygen demanding wastes, pathogens, nutrients, Salts, thermal application, heavy metals, pesticides, volatile organic compounds.	2L
	3. River/Lake/ground water pollution: River: DO, 5 day BOD test, Seeded BOD test, BOD reaction rate constants, Effect of oxygen demanding wastes on river[deoxygenation, reaeration], COD, Oil, Greases, pH.	1L
	4. Lake: Eutrophication [Definition, source and effect]. Ground water: Aquifers, hydraulic gradient, ground water flow (Definition only)	1L
	5. Standard and control: Waste water standard [BOD, COD, Oil, Grease], Water Treatment system [coagulation and flocculation, sedimentation and filtration, disinfection, hardness and alkalinity,softening] Waste water treatment system, primary and secondary treatments [Trickling filters, rotating biological contractor, Activated sludge, sludge treatment, oxidation ponds] tertiary treatment definition.	2L
	6. Water pollution due to the toxic elements and their biochemical effects: Lead, Mercury, Cadmium, and Arsenic	1L
3	**Chapter 5: Land Pollution**	**3L**
	1. Lithosphere; Internal structure of earth, rock and soil	1L
	2. Solid Waste: Municipal, industrial, commercial, agricultural, domestic, pathological and hazardous solid wastes; Recovery and disposal method- Open dumping, Land filling, incineration, composting, recycling. Solid waste management and control (hazardous and biomedical waste).	2L
	Chapter 5: Noise Pollution	**2L**
	1. Definition of noise, effect of noise pollution, noise classification [Transport noise, occupational noise, neighbourhood noise]	1L
	2. Definition of noise frequency, noise pressure, noise intensity, noise threshold limit value, equivalent noise level, $L10$ (18 hr Index) , $n\ Ld$, Noise pollution control.	1L
	Chapter 6: Environmental Management	**2L**
	1. Environmental impact assessment, Environmental Audit, Environmental laws and protection act of India, Different international environmental treaty/ agreement/ protocol.	2L
Total Number Of Hours = 34L		

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lecture-wise Plan

Subject Name: **Basic Environmental Engineering** Subject Code: **CH-401**
Year: **2nd Year** Semester: Fourth

Assignment:

Module-1.
1. Write short notes for the following:
(a) Flood (b) Landslides (b) Earthquake (c) Acid Rain

2. Suppose an anemometer at a height of 40 m above ground measure wind velocity =5.5 m/s. Estimate the wind speed at an elevation of 500 m in rough terrain if atmosphere is unstable (i.e., k = 0.2).

Module-2.
1. A BOD test is run using 50 ml of wastewater mixed with 100 ml of pure water. The initial DO of the mixture is 6 mg/l and after 5 days it becomes 2 mg/l. After a long time, the DO remains fixed at 1 mg/l.
(i)What is the 5 days BOD (BOD_5)?
(ii)What is the ultimate BOD (BOD_u)?
(iii)What is the remaining BOD after 5 days?
(iv)What is the reaction rate constant measured at 20°C?
(v)What would be the reaction rate if measured at 35°C?

2. Draw the flow diagram for the following (a) Surface water treatment (b) Waste water Treatment.

3. Draw the Oxygen sag curve.

Module-3.
1. a) If two machines produces sounds of 80 dB and 120 dB simultaneously, what will be the total sound level.
b) Calculate the intensity of 100 dB sounds.

2. Write a report on the environmental problems related to an abandoned airport. Mention various measures by which it can be used again for other purposes.

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Lecture-wise Plan

Subject Name: Data Structure & Algorithm **Subject Code-CS(EE)401**
Year: 2nd Year **Semester: Fourth**

Module Number	Topics	Number of Lectures
1	**Introduction:**	**5L**
	1. Why we need data structure? Concepts of data structures: a) Data and data structure b) Abstract Data Type and Data Type. Algorithms and programs, basic idea of pseudo-code. .	1
	2. Algorithm efficiency and analysis, time and space analysis of algorithms – order notations.	4
	Linear data structure:	
2	**Array:**	**2L**
	1. Different representations – row major, column major. Sparse matrix - its application and usage. Array representation of polynomials.	2
3	**Linked List:**	**7L**
	1. Singly linked list, circular linked list, doubly linked list, linked list representation of polynomial and applications.	7
4	**Stack and Queue:**	**6L**
	1. Stack and its implementations (using array, using linked list), applications.	2
	2. Queue, circular queue, dequeues. Implementation of queue- both linear and circular (using array, using linked list), applications.	4
5	**Recursion:**	**3L**
	1. Principles of recursion – use of stack, differences between recursion and iteration, tail recursion.	1
	2. Applications - The Tower of Hanoi, Eight Queens Puzzle.	2
	Non Linear data structure:	
6	**Trees:**	**8L**
	1. Basic terminologies, forest, tree representation (using array, using linked list). Binary trees - binary tree traversal (pre-, in-, post- order), threaded binary tree (left, right, full) - non-recursive traversal algorithms using threaded binary tree, expression tree.	4
	2. Binary search tree- operations (creation, insertion, deletion, searching). Height balanced binary tree – AVL tree (insertion, deletion with examples only). B- Trees – operations (insertion, deletion with examples only	4
	Graphs:	**5L**
	1. Graph definitions and concepts (directed/undirected graph, weighted/un-weighted edges, sub-graph, degree, cut-	

7	vertex/articulation point, pendant node, clique, complete graph, connected components – strongly connected component, weakly connected component, path, shortest path, isomorphism). Graph representations/storage implementations – adjacency matrix, adjacency list, adjacency multi-list.	1
	2. Graph traversal and connectivity – Depth-first search (DFS), Breadth-first search (BFS) – concepts of edges used in DFS and BFS (tree-edge, back-edge, cross-edge, forward-edge), applications.	2
	3. Minimal spanning tree – Prim's, Kruskal and Dijkstra algorithm (basic idea of greedy methods).	2
8	**Sorting, Searching and Hashing Technique:**	
	Sorting Algorithms:	6L
	Bubble sort and its optimizations, insertion sort, shell sort, selection sort, merge sort, quick sort, heap sort (concept of max heap, application – priority queue), radix sort.	6
	Searching:	2L
	Sequential search, binary search, interpolation search.	2
	Hashing:	2L
	Hashing functions, collision resolution techniques.	2
Total Number Of Hours = 46		

Faculty In-Charge HOD, CSE Dept.

Assignment:

Module-1(Introduction):

1. DefineAbstractData Type, big oh, big omega, theta notationoftimecomplexity.
2. Findthetotalfrequency count of following code.

```
for send=1ton do
    forreceive=1tosenddo
        forack=2toreceivedo
            message=send-(receive+ack)
            ack=ack-1
            send=send+1
        end
    end
end
```

Module-2 (Linear data Structure):

1. Write a function to insert a element after 4th position in an array.
2. Write a function to insert a element before 4th position in a single linked list
3. Write a function to insert a element after a particular data element 4 in a doubly linked list.
4. Write a function to concatenate two circular linked list.

5. Write a function to implement stack and queue using linked list.
6. Convert infix to prefix and postfix.
   A+B+C-D/E*R(S*T)/W+G
7. Define tail and tree recursion, explain them with example.

Module-3(Non-linear data structure):

1. Why AVL tree is required?
2. Construct the AVL tree.
   B,D,A,G,H,R,J,T,C,Y,X
3. Write a short note on B-Tree.
4. Write an algorithm of DFS and Dijkstra algorithm.

Module-4(Sorting, Searching and Hashing):

1. Explain quick and radix sort with example.
2. Why binary search is better than linear search.
3. Write down different techniques of collision resolution techniques.

UNIVERSITY OF ENGINEERING & MANAGEMENT,JAIPUR

Lecture-wise Plan

Subject Name: **Thermal Power Engineering** Subject Code-ME(EE)401

Year: 2nd Year Semester: Fourth

Module Number	Topics	Number of Lectures
1	Water Tube & Fire Tube boilers,	1L
	Circulating Principles, Forced Circulation,	1L
	Critical pressure, Super heaters,	1L
	Reheaters, attemperators,	1L
	induced draught, forced draught and secondary air Fans,	1L
	Boiler performance analysis and heat balance.	1L
	Combustion Systems, Environmental Protection–	1L
	ESP ,Cyclone Separator ,Dust Collector etc	1L
2	Rotary Thermodynamic devices –	1L
	Steam turbines &their classifications –	1L
	Impulse &Reaction type Turbines,	1L
	Thermodynamics of compressible fluid-flow,	1L
	equation and continuity–	1L
	Isentropic flow through nozzles, velocity diagram	1L
3	Blade efficiency, optimum velocity ratio,	1L
	, velocity & pressure compounding,	1L
	losses in turbines, erosion of turbine blades,	1L
	turbine governing,	1L
	performance analysis of turbine,	1L
	Condensing system.	1L
	multi-staging	1L
4	IC Engines – classification.	1L
	Analysis of a standard cycle,	1L
	fuel characteristic of SI &CI Engine,	1L
	Combustion, Engine performance.	1L
	Automotive Engine exhaust emission and their control	1L
5	Gas turbine Analysis	1L
	– Regeneration Reheating,	1L
	Isentropic efficiency.	1L
	Combustion efficiency	1L
Total lectures		**30L**

ASSIGNMENT I

1. Explain the construction and working of Steam power plant with a layout. (16)
2. (a)Discuss the relative merits of different out plant coal handling.

(b) Describe the hydraulic ash handling system.
3. (a)Draw a chart showing operations and devices used in coal handling plant. (8)
(b) Describe different types of coal conveyors.
4. Explain the construction and working of any one High pressur
5. Explain the construction and working of any one
6. Draw the layout of MHD open cycle generator and explain its function of components (16)

ASSIGNMENT II-

1. (a) Draw a line diagram of ash handling system in steam power plant. (8)
(b) Explain the different coal handling process. (8)
2. (a)Explain the principle involved in preparation of coal and what are methods of preparation (10)
(b)What are the different types of dust collectors used (06).
3. What are the different types of pulverizing mills? Explain in neat sketch. (16)
4. What are the different types of cooling towers?. Explain with its neat sketch (16)
5. Explain various draught system with neat sketch (16)

ASSIGNMENT III-

1. Explain the construction and working of Nuclear power plant with a layout. (16)
2. (a) What is a chain reaction? How it is controlled. (5)
(b) Describe the fast breeder reactor. (6)
(c) What is function of shield? What are the different types of shields? (5)
3. (a) With neat sketch explain the boiling water reactor power plant. (8)
(b) What are the advantages and disadvantages of nuclear power plant? (8)
4. (a) What are the advantages and disadvantages of breeder reactor? (5)
(b) What do you mean by fission of nuclear fuel? (5)
(c) Explain briefly about radiation hazards and shielding? (6)
5. (a) What do you understand by thermal shielding? (4)
(b) What are the functions of a reflector? (4)
(c) Explain the working and characteristic features of a homogeneous reactor. (8)

ASSIGNMENT IV-

1. Explain the construction and working of Gas turbine power plant with a layout. (16)
2. (a) Explain with the help of a block diagram the fuel storage and supply system of diesel power plant. (8)
(b) Explain with the help of a block diagram the water cooling system of diesel power plant. (8)
3. (a) Mention the advantages and disadvantages of a diesel power plant over a gas turbine power plant. (8)
(b) Give a maintenance schedule for Diesel engine power plant. (8)
4. Describe the following systems in brief with respect Diesel Power Plant.
i. Fuel storage and supply system (5)

ii. Exhaust system (5)
iii. Lubrication system (6)
5. (a) Draw a neat layout of a diesel power plant and label all the components. (10)
(b) List the advantages of diesel power plant s over other thermal power plants. (6)
6. (a) Explain the cooling system of a Diesel power plant. (8)
(b) What are the different types of engines used in Diesel power plants. (8)
7. With a neat sketch explain the working of a simple constant pressure gas turbine. Mention its advantages and disadvantages. (16)
8. (a) With help of a block diagram explain the main components of a open cycle gas turbine power plant. (8)
(b) Give the classification of gas turbine power plants. (8)
9. (a) Give the advantages and disadvantages of open cycle gas turbine power plant. (8)
(b) A simple open cycle gas turbine plant works between the pressures of 1 bar and 6 bar and temperatures of 300 K and 1023 K. The calorific value of the fuel used is 42 MJ/kg. Find :
(i) Airfuel ratio
(ii) Thermal efficiency of the plant if the mechanical and generating efficiencies are 95% and 97% respectively. Assume air flow = 20 kg/s and compression and expansion are isentropic. (8)

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

LAB MANUAL

Subject Name: Electric Machine-I **Subject Code-EE401**
Year: 2^{nd} Year **Semester: Fourth**

Module Number	Topics	Number of Lectures
1	**Introduction**	**6L**
	1. Electromechanical Energy Conversion Principle, Singly Excited Magnetic System and Doubly Excited Magnetic system. Physical concept of torque production- Electromagnetic torque and Reluctance torque	2
	2. Concept of General terms pertaining to Rotating Machines: Electrical &Mechanical degree, Pole pitch, Coil, Generated EMF in full pitched coil, Generated EMF in a short pitched coil.	2
	3. Distribution factor, Pitch factor. MMF produced by Distributed Windings, MMF of a coil, MMF of single phase distributed Winding.	2
2	**DC Machines:**	**12L**
	1. EMF generated in the armature. Methods of Excitation, Armature reaction & its effect in the performance, Methods of decreasing the effects of Armature reaction, Effect of Brush shift.	3
	2. Commutation process, Resistance commutation, Delayed commutation, Voltage commutation, Improvement of Commutation.	2
	3. Operating Characteristics of DC Generators: Separately Excited generators, Shunt Generators, Series Generators and Compound Generators.	2
	4. Torque equation of D.C. motor, Operating Characteristics of Shunt, Series &Compound motors.	2
	5. Losses and efficiency of DC machines, Hopkinson's and Swinburne's test.	2
	6. D.C. Machine application: Generator application, Motor application.	1
3	**3-phase Induction motor:**	**9L**
	1. Types, construction, rotating magnetic field, principle of operation	2
	2. Development of equivalent circuit. Performance equations.	2
	3. Torque slip characteristics & power slip characteristics.	2
	4. Parameter estimation. Starting and speed control of Induction motors	2
	5. Flux and MMF phasors in Induction motors,	1
4	**3-phase Transformer:**	**11L**
	1. Determination of polarity and connections (star/star, star/delta, delta/star, star/zigzag, delta/zigzag, open-delta), Phasor groups.	3
	2. Effect of unbalanced loading, Production of Harmonics in Transformer and its suppression.	1
	3. 3-phase to 2-phase transformation, Scott connection, 3-phase	3

	to 6-phase connections, Double star and Double delta.	
	4. 3-winding transformer: Parameter estimation, application.	2
	5. Parallel operation of Transformers, Introduction to Tap changing transformer and its function.	2
Total Number Of Hours = 38		

Shubhajit Pal
Faculty In-Charge

Prof. Aniruddh Mukherjee
HOD, EE Dept.

Assignment:

Module-1(Introduction):

1. Explain the procedure by which a point charge experiences a force when placed inside an electrical flux field.
2. What is Distribution factor, Pitch factor? Explain the importance of these factors.

Module-2 (DC Machines):

1. What is the necessity of commutation process in case of DC generator operation? Also describe the process with appropriate diagram.
2. A 4-pole 350V DC long shunt compound generator supplies a load of 15KW at the rated voltage. The armature, series field and shunt field resistances are 0.2Ω, 0.25Ω, and 300Ω respectively. The armature is lap wound with 50 slots, each slot containing 6 conductors. If the flux per pole is 50mWb, calculate the speed of the generator.
3. Explain the term "Back e.m.f." and describe the concept of torque production in case of a DC motor.
4. A 580V series motor runs at 550r.p.m. taking a current of 55A. Calculate the speed and percentage change in torque if the load is reduced so that the motor is taking 40A. Total resistance of the armature and field circuits is 0.8Ω. Assume flux and field current to be proportional.
5. "A DC series motor is best suited for traction drive" – Explain the statement

Module-3 (3-Phase Transformer):

1. Derive the conditions that should be met in case of parallel operation of two transformers with the support of mathematical expressions.
2. Derive the relation between the number of turns of main transformer and teaser transformer in case of scott-connection if same magnitude of voltage is needed in two phases of its output terminal. Also note down the applications of this type of connection.
3. An ordinary 100KVA two winding transformer's voltage profile is defined as 11500/2300V. If an auto transformer is formed by connecting the windings of two winding transformer in series, what will be the probable voltage ratios and output?

Module-4 (3-Phase Induction Motor):

1. Explain the concept of slip power recovery in case of speed control of three phase induction motor?
2. Prove that when 3-ϕ windings displaced in space by 120° are supplied by 3-ϕ currents displaced in time by 120°, the resulting magnetic flux is rotating in nature.

3. A 6-pole, 50Hz, 3-ϕ induction motor develops a total torque of 160Nm while running on full load. The rotor frequency is 2.5Hz. Find a) Rotor input power, b) Rotor copper loss, and c) Efficiency

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

LAB MANUAL

Subject Name: **ELECTRICAL & ELECTRONIC MEASUREMENT** Subject Code: **EE402**

Year: **2nd Year** Semester: **Fourth**

Module Number	Topics	Number of Lectures
1	**Introduction :**	**11L**
	1. Method of measurement, Measurement system, Classification of instruments	1L
	2. Definition of accuracy, Precision, Resolution, Speed of response	1L
	3. Error in measurement, Classification of errors	1L
	4. loading effect due to shunt and series connected instruments	2L
	5. General features, Construction, Principle of operation and torque equation of Moving coil, Moving iron, Electrodynamometer, Induction instruments	3L
	6. Principle of operation of the Electrostatic, Thermoelectric, Rectifier type instruments	2L
	7. Extension of instrument ranges and multipliers	1L
2	**Instrument transformer**	**9L**
	1. Disadvantage of shunt and multipliers, Advantage of Instrument transformers	1L
	2. Principle of operation of Current & Potential transformer, errors	3L
	Measurement of power	
	1. Principle of operation of Electro dynamic & Induction type wattmeter. Wattmeter errors.	2L
	Measurement of resistance	
	1. Measurement of medium, low and high resistances, Megger.	3L
3	**Measurement of Energy**	**3L**
	1. Construction, theory and application of AC energy meter	2L
	2. testing of energy meters	1L
	Potentiometer	**3L**
	1. Principle of operation and application of Crompton's DC potentiometer	1L

	2. Polar and Co-ordinate type AC potentiometer. Application	2L
	ACBridges	**4L**
	1. Measurement of Inductance, Capacitance and frequency by AC bridges.	4L
4	**Cathode ray oscilloscope(CRO)**	**3L**
	1. Measurement of voltage, current, frequency & phase by oscilloscope	1L
	2. Sampling and storage oscilloscope	1L
	3. Double beam CRO.	1L
	Electronic Instruments	**4L**
	1. Advantages of digital meter over analog meters, Digital voltmeter, Resolution and sensitivity of digital meters	2L
	2. Digital multimeter, Digital frequency meter, Signal generator	2L
	Sensors &Transducers	**3L**
	1. Introduction to sensors &Transducers, Strain gauge	1L
	2. LVDT, Temperature transducers	2L
	3. Flow measurement using magnetic flow measurement.	1L
Total Number Of Hours = 40L		

Assignment:

Module-1(Introduction):

1. The following data refer to measurement in a single phase AC load

Instrument	Reading	Full scale	Maximum uncertainty as % of full scale
Voltmeter	200 V	2A	1%
Ammeter	2A	2A	0.5%
Wattmeter	320W	480W	1%

Find the power factor of the load and maximum percentage of uncertainty in the value obtained?

2. Define accuracy sensitivity, dead zone and reproducibility?
3. A voltage has a true value of 1.50V. An analog indicating instrument with a scale range of 0-2.50V shows a voltage of 1.46V. What are the values of absolute error and correction? Express the error as a fraction of true value and the full scale deflection?
4. Explain loading effect due to shunt connected instrument?
5. A multimeter having a sensitivity of 2000Ω/V is used to measure the voltage across a circuit having an output resistance of 10kΩ. The open circuit voltage of the circuit is 6V. Find the

reading of the multimeter when it is set to it's 10V scale. Find percentage error due to loading effect?

6. Explain Dynamic characteristic of a measurement system?
7. Describe eddy current damping and air friction damping technique used in indicating type instrument?
8. Differentiate absolute error and relative error?
9. A 0-150 V voltmeter has a guaranteed accuracy of 1% of full scale reading. The voltage measured by this instrument is 75 V. Calculate the limiting error in percentage?
10. Describe the spring control technique and gravity control technique used in indicating type instrument?

Module-2 (Power and resistance measurement , Instrument transformer):

1. Explain Loss of charge method for high resistance measurement?
2. Describe direct deflection method of measuring high resistance?
3. Draw the equivalent circuit and phasor diagram of a current transformer?
4. What do you mean by Ratio error in practical current transformer?
5. The magnetising current of a ring core current transformer, of ratio 1000/5 A, when operating at full primary current and with a secondary burden of non inductive resistance of 1 Ω is 1 A at a power factor of 0.4. Neglecting the effect of magnetic leakage, calculate-
   i) The phase displacement between primary and secondary currents?
   ii) The ratio error at full load assuming that there has been no turn compensation?
6. Mention the difference between Current Transformer and Potential Transformer?
7. Derive the expression for bridge sensitivity while measuring unknown resistance using Wheatstone bridge method?
8. State and explain Blondel's theorem?
9. How three phase power can be measured using 3 watt meters?
10. Describe how three phase power can be measured using only two watt meters?

Module-3(AC Bridges, Potentiometer, Measurement of Energy):

1. How capacitance can be measured using De Sauty's bridge
2. Describe the operation of a DC potentiometer and also explain how standardisation of this instrument is done to get direct reading for measurement of unknown voltage?
3. Describe the operation of phase shifting transformer?
4. Explain how AC potentiometer works?
5. A basic slide wire potentiometer has a working voltage of 3V with negligible internal resistance. The resistance of slide wire is 400Ω and it's length is 200 cm. A 200 cm scale is placed along the slide wire. The slide wire has 1mm scale divisions and it is possible to read up to 1/5 of a division. The instrument is standardised with 1.018V standard cell with sliding contact at the 101.8 cm mark on scale. Calculate –
   i) Working current?
   ii) The resistance of series rheostat?
   iii) The measurement range?
   iv) The resolution of instrument?
6. How unknown frequency can be measured using Wien's bridge ?
7. In a Wheatstone bridge the value of resistances of various arms are P=1000 Ω, Q=100 Ω, R=2005 Ω and S=200 Ω. The bridge is balanced when PS=RQ. The battery has an emf of 5V and negligible internal resistance. The galvanometer has a current sensitivity of 10 mm/μA

and an internal resistance of 100 Ω. Calculate the deflection of galvanometer and the sensitivity of the bridge in terms of deflection per unit change in resistance?

8. Derive the expression of unknown inductance for measurement of inductance using Anderson's bridge? Also draw the phasor diagram of the bridge at balanced condition?

9. Explain the significance of standardization of potentiometer? How potentiometer gives more accurate result than voltmeter while measuring unknown voltage?

10. Explain how self-inductance can be measured using Maxwell's Inductance Bridge?

Module-4(Electronic instruments, CRO, Sensors and Transducers):

1. Describe how thermocouple can be used for temperature measurement?
2. Write down the difference between sensors and transducers? Define Strain Gauge?
3. Prove that $G_f = 1 + 2\gamma$

   Where G_f is the gauge factor of the strain gauge and γ is the Poisson's ratio.
4. Explain the operating principle of LVDT?
5. Describe the block diagram of Cathode Ray Oscilloscope and explain each block?
6. A resistance strain gauge with a gauge factor of 2 is cemented to a steel member which is subjected to a strain of $1x\ 10^{-6}$. If the original resistance value of the gauge is 130 ohm calculate the change in resistance?
7. How temperature is measured using thermocouple?
8. Write short note on RTD?
9. What are the main advantages of digital meter over analog meters
10. Explain the operation of a signal generator?

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR
LAB MANUAL

Title of Course: Data structure & Algorithm Lab
Course Code: CS(EE)491
L-T-P scheme: 0-0-3 **Course Credit: 2**

Objectives:
1. Develop problem solving ability using Programming.
2. Develop ability to design and analyze algorithms.
3. Introduce students to data abstraction and fundamental data structures.
4. Develop ability to design and evaluate Abstract Data Types and data structures.
5. Apply data structure concepts to various examples and real life applications

Learning Outcomes:
The course will use hands on practice and applying the knowledge gained in theory course to different day to day real world applications..Upon the completion of data structure and algorithm practical course, the student will be able to:
- **Understand** and implement different type of data structure techniques
- **Analyze** the hashing method.
- **Implement** different type of sorting searching techniques.

Course Contents:
Exercises that must be done in this course are listed below:
Exercise No.1: Implementation of array operations
Exercise No. 2: Implementation of linked lists: inserting, deleting a linked list.
Exercise No. 3: Stacks and Queues: adding, deleting elements
Exercise No. 4: EvaluationProblem: Evaluation of infix to postfix expressions on stack.
Exercise No. 5: Circular Queue: Adding & deleting elements
Exercise No. 6: Implementation of stacks using linked lists, Polynomial addition, Polynomial multiplication
Exercise No. 7: Sparse Matrices: Multiplication, addition.
Exercise No. 8: Recursive and Non-recursive traversal of Trees
Exercise No. 9: Threaded binary tree traversal. AVL tree implementation
Exercise No. 10: Application of sorting and searching algorithms

Text Book:
1. Yashavant Kanetkar, Abduln A.P.J. Kalam," Data Structure Through C",2nd edition, BPB Publications
2. Seymour Lipschutz,"Data Structures**",**Revised First edition,McGraw Hill Education.

Recommended Systems/Software Requirements:
1. Intel based desktop PC with minimum of 166 MHZ or faster processor with at least 64 MB RAM and 100 MB free disk space.
2. Turbo C or TC3 complier in Windows XP or Linux Operating System.

Exercise No.1: Implementation of array operations
Description:
An array is a collection of similar data elements. These data elements have the same data type.The elements of the array are stored in consecutive memory locations and are referenced by an index(also known as the subscript). The subscript is an ordinal number which is used to identify an element of the array.There are a number of operations that can be performed on arrays. These operations include:
KATraversing an array
2) Inserting an element in an array
MASearching an element in an array
NADeleting an element from an array

QASorting an array in ascending or descending order

Aim: Write a program to insert a number at a given location in an array.

Algorithm:

The algorithm `INSERT` will be declared as `INSERT(A,N,POS,VAL)`. The arguments are

Step1: `A`, the array in which the element has to be inserted

Step2: `N`, the number of elements in the array

Step3: `POS`, the position at which the element has to be inserted

Step4: `VAL`, the value that has to be inserted

Program:

```
#include <stdio.h>
#include <conio.h>
int main()
{
 int i, n, num, pos, arr[10];
 clrscr();
 printf("\n Enter the number of elements in the array : ");
 scanf("%d", &n);
 for(i=0;i<n;i++)
 {
  printf("\n arr[%d] = ", i);
  scanf("%d", &arr[i]);
 }
 printf("\n Enter the number to be inserted : ");
 scanf("%d", &num);
 printf("\n Enter the position at which the number has to be added : scanf("%d", &pos);
 for(i=n–1;i>=pos;i—)
  arr[i+1] = arr[i];
 arr[pos] = num;
 n = n+1;
 printf("\n The array after insertion of %d is : ", num);
 for(i=0;i<n;i++)
 printf("\n arr[%d] = %d", i, arr[i]);
 getch();
 return 0;
}
```

Input:

```
 Enter the number of elements in the array : 5
 arr[0] = 1
 arr[1] = 2
 arr[2] = 3
 arr[3] = 4
 arr[4] = 5
 Enter the number to be inserted : 0
 Enter the position at which the number has to be added : 3
```

Output:

```
 The array after insertion of 0 is :
 arr[0] = 1
 arr[1] = 2
 arr[2] = 3
 arr[3] = 0
 arr[4] = 4
 arr[5] = 5
```

Aim:Write a program to delete a number from a given location in an array.

Algorithm:

The algorithm `DELETE` will be declared as `DELETE(A, N, POS)`. The arguments are:

Step2: N, the number of elements in the array
Step3: POS, the position from which the element has to be deleted

Program
```
#include <stdio.h>
#include <conio.h>
int main()
{
 int i, n, pos, arr[10];
 clrscr();
 printf("\n Enter the number of elements in the array : ");
 scanf("%d", &n);
 for(i=0;i<n;i++)
 {
  printf("\n arr[%d] = ", i);
  scanf("%d", &arr[i]);
 }
 printf("\nEnter the position from which the number has to be deleted : ");
 scanf("%d", &pos);
 for(i=pos; i<n–1;i++)
  arr[i] = arr[i+1];
 n—;
 printf("\n The array after deletion is : ");
 for(i=0;i<n;i++)
  printf("\n arr[%d] = %d", i, arr[i]);
 getch();
 return 0;
}
```
Input:
Enter the number of elements in the array : 5
arr[0] = 1
arr[1] = 2
arr[2] = 3
arr[3] = 4
arr[4] = 5
Enter the position from which the number has to be deleted : 3
Output:
The array after deletion is :
arr[0] = 1
arr[1] = 2
arr[2] = 3
arr[3] = 5

Lab assignment:
1) Merging two arrays
2) Sorting an array in ascending or descending order

Exercise No. 2: Implementation of linked lists: inserting, deleting a linked list.

Description:
A singly linked list is the simplest type of linked list in which every node contains some data anda pointer to the next node of the same data type. By saying that the node contains a pointer to the next node, we mean that the node stores the address of the next node in sequence.
A new node is added into an already existing linked list like
Case 1: The new node is inserted at the beginning.
Case 2: The new node is inserted at the end.

Case 4: The new node is inserted before a given node.
Before we describe the algorithms to perform insertions in all these four cases, let us first discuss an important term called OVERFLOW. Overflow is a condition that occurs when AVAIL = NULL or no free memory cell is present in the system. When this condition occurs, the program must give an appropriate message.
A node is deleted from an already existing linked list like
Case 1: The first node is deleted.
Case 2: The last node is deleted.
Case 3: The node after a given node is deleted.
Before we describe the algorithms in all these three cases, let us first discuss an important termCalled UNDERFLOW. Underflow is a condition that occurs when we try to delete a node from a linked list that is empty. This happens when START = NULL or when there are no more nodes to delete.
Note that when we delete a node from a linked list, we actually have to free the memory occupied by that node. The memory is returned to the free pool so that it can be used to store other programs and data. Whatever be the case of deletion, we always change the AVAIL pointer so that it points to the address that has been recently vacated.
Algorithm:
Insertion(A) Inserting a Node Before a Given Node in a Linked List

Step 1: IF AVAIL=NULL
Write OVERFLOWGo to Step 12
[END OF IF]
NEW_NODE
Step 2: SET = AVAIL
Step 3: SET AVAIL=AVAIL □□□NEXT
Step 4: SET NEW_NODE ->DATA=VAL
Step 5: SET PTR=START
Step 6: SET PREPTR=PTR
Step 7: Repeat Steps8and9while PTR DATA != NUM
Step 8: SET PREPTR=PTR
Step 9: SET PTR=PTR->NEXT
[END OF LOOP]
Step 10:PREPTR->NEXT = NEW_NODE
Step 11: SET NEW_NODE-> NEXT=PTR
Step 12: EXIT
Insertion(B) Inserting a Node After a Given Node in a Linked List
Step 1: IF AVAIL=NULL
Write OVERFLOW Go to Step 12
[END OF IF]
Step 2: SET = AVAIL->NEW_NODE
Step 3: SET AVAIL=AVAIL->NEXT
Step 4: SET DATA=VAL->NEW_NODE
Step 5: SET PTR=START
Step 6: SET PREPTR=PTR
Step 7: Repeat Steps8and9while PREPTR->DATA!= NUM
Step 8: SET PREPTR=PTR
Step 9: SET PTR=PTR->NEXT
[END OF LOOP]
Step 10: PREPTR->NEXT =NEW_NODE
Step 11: SET NEW_NODE->NEXT=PTR
Step 12: EXIT

Deletion
Step 1: IF START=NULL
Write UNDERFLOW
Go to Step 10
[END OF IF]
Step 2: SET PTR=START
Step 3: SET PREPTR=PTR

Step 5: SET PREPTR=PTR
Step 6: SET PTR=PTR->NEXT
[END OF LOOP]
Step 7: SET TEMP=PTR
Step 8: SET PREPTR->NEXT=PTR->NEXT
Step 9: FREE TEMP
Step 10:EXIT

Aim:Write a program to create a linked list and perform insertions and deletions Write functions to sort and finally delete the entire list at once.

```
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>
#include <malloc.h>
struct node
{
 int data;
 struct node *next;
};
struct node *start = NULL;
struct node *create_ll(struct node *);
struct node *display(struct node *);
struct node *insert_beg(struct node *);
struct node *insert_end(struct node *);
struct node *insert_before(struct node *);
struct node *insert_after(struct node *);
struct node *delete_beg(struct node *);
struct node *delete_end(struct node *);
struct node *delete_node(struct node *);
struct node *delete_after(struct node *);
struct node *delete_list(struct node *);
struct node *sort_list(struct node *);
int main(int argc, char *argv[]) {
 int option;
 do
 {
  printf("\n\n *****MAIN MENU *****");
  printf("\n 1:  Create a list");
  printf("\n 2:  Display the list");
  printf("\n 3:  Add a node at the beginning");
  printf("\n 4:  Add a node at the end");
  printf("\n 5:  Add a node before a given node");
  printf("\n 6:  Add a node after a given node");
  printf("\n 7:  Delete a node from the beginning");
printf("\n 8:  Delete a node from the end");
printf("\n 9:  Delete a given node");
printf("\n 10: Delete a node after a given node");
printf("\n 11: Delete the entire list");
printf("\n 12: Sort the list");
printf("\n 13: EXIT");
printf("\n\n Enter your option : ");
  scanf("%d", &option);
  switch(option)
  {
case 1: start = create_ll(start);
 printf("\n LINKED LIST CREATED");
```

```
case 2: start = display(start);
   break;
case 3: start = insert_beg(start);
   break;
case 4: start = insert_end(start);
   break;
case 5: start = insert_before(start);
   break;
case 6: start = insert_after(start);
   break;
case 7: start = delete_beg(start);
   break;
case 8: start = delete_end(start);
   break;
case 9: start = delete_node(start);
   break;
case 10: start = delete_after(start);
   break;
case 11: start = delete_list(start);
 printf("\n LINKED LIST DELETED");
   break;
case 12: start = sort_list(start);
   break;
  }
}while(option !=13);
return 0;
struct node *create_ll(struct node *start)
struct node *new_node, *ptr;
printf("\n Enter -1 to end");
printf("\n Enter the data : ");
scanf("%d", &num);
while(num!=-1)
new_node = (struct node*)malloc(sizeof(struct node));
new_node -> data=num;
  if(start==NULL)
  {
 new_node -> next = NULL;
   start =
new_node;
  }
  else
  {
   ptr=start;
   while(ptr->next!=NULL)
   ptr=ptr->next;
   ptr->next =
new_node;
   new_node->next=NULL;
  }
  printf("\n Enter the data : ");
  scanf("%d", &num);
 }
 return start;
}
struct node *display(struct node *start)
{
```

```
 ptr = start;
 while(ptr != NULL)
 {
  printf("\t %d", ptr -> data);
  ptr = ptr -> next;
 }
 return start;
}
struct node *insert_beg(struct node *start)
{
 struct node *new_node;
 int num;
 printf("\n Enter the data : ");
 scanf("%d", &num);
 new_node = (struct node *)malloc(sizeof(struct node));
 new_node -> data = num;
 new_node -> next = start;
 start = new_node;
 return start;
}
struct node *insert_end(struct node *start)
{
 struct node *ptr, *new_node;
 int num;
 printf("\n Enter the data : ");
 scanf("%d", &num);
 new_node = (struct node *)malloc(sizeof(struct node));
 new_node -> data = num;
 new_node -> next = NULL;
 ptr = start;
 while(ptr -> next != NULL)
 ptr = ptr -> next;
 ptr -> next = new_node;
 return start;
}
struct node *insert_before(struct node *start)
{
 struct node *new_node, *ptr, *preptr;
 int num, val;
 printf("\n Enter the data : ");
 scanf("%d", &num);
 printf("\n Enter the value before which the data has to be inserted : ");
 scanf("%d", &val);
 new_node = (struct node *)malloc(sizeof(struct node));
 new_node -> data = num;
 ptr = start;
 while(ptr -> data != val)
 {
  preptr = ptr;
  ptr = ptr -> next;
 }
 preptr -> next = new_node;
 new_node -> next = ptr;
 return start;
}
struct node *insert_after(struct node *start)
```

```
 struct node *new_node, *ptr, *preptr;
 int num, val;
 printf("\n Enter the data : ");
 scanf("%d", &num);
 printf("\n Enter the value after which the data has to be inserted : ");
scanf("%d", &val);
new_node = (struct node *)malloc(sizeof(struct node));
new_node -> data = num;
ptr = start;
preptr = ptr;
while(preptr -> data != val)
 {
 preptr = ptr;
 ptr = ptr -> next;
 }
preptr -> next=new_node;
new_node -> next = ptr;
return start;
struct node *delete_beg(struct node *start)
struct node *ptr;
ptr = start;
start = start -> next;
 free(ptr);
return start;
struct node *delete_end(struct node *start)
struct node *ptr, *preptr;
ptr = start;
while(ptr -> next != NULL)
 {
 preptr = ptr;
 ptr = ptr -> next;
 }
preptr -> next = NULL;
 free(ptr);
return start;
struct node *delete_node(struct node *start)
struct node *ptr, *preptr;
int val;
printf("\n Enter the value of the node which has to be deleted : ");
scanf("%d", &val);
ptr = start;
if(ptr -> data == val)
 {
start = delete_beg(start);
return start;
}
 else
 {
while(ptr -> data != val)
  {
   preptr = ptr;
   ptr = ptr -> next;
  }
  preptr -> next = ptr -> next;
  free(ptr);
  return start;
```

```
}
struct node *delete_after(struct node *start)
{
 struct node *ptr, *preptr;
 int val;
 printf("\n Enter the value after which the node has to deleted : ");
 scanf("%d", &val);
 ptr = start;
 preptr = ptr;
 while(preptr -> data != val)
 {
  preptr = ptr;
  ptr = ptr -> next;
 }
 preptr -> next=ptr -> next;
 free(ptr);
 return start;
}
struct node *delete_list(struct node *start)
{
              struct
              node     *ptr;
 if(start!=NULL){
  ptr=start;
  while(ptr != NULL)
  {
   printf("\n %d is to be deleted next", ptr -> data);
   start =
delete_beg(ptr);
   ptr =
start;
  }
 }

 return start;
}
struct node *sort_list(struct node *start)
{
 struct node *ptr1, *ptr2;
 int temp;
 ptr1 = start;
 while(ptr1 -> next != NULL)
 {
  ptr2 = ptr1 -> next;
  while(ptr2 != NULL)
  {
   if(ptr1 -> data > ptr2 -> data)
   {
          temp = ptr1 -> data;
          ptr1 -> data = ptr2 -> data;
          ptr2 -> data = temp;
   }
   ptr2 = ptr2 -> next;
  }
  ptr1 = ptr1 -> next;
  }
```

}

Input:

3
4
5

Output:

*****MAIN MENU *****
1: Create a list
2: Display the list
3: Add a node at the beginning
4: Add the node at the end
5: Add the node before a given node
6: Add the node after a given node
7: Delete a node from the beginning
8: Delete a node from the end
9: Delete a given node
10: Delete a node after a given node
11: Delete the entire list
12: Sort the list
13: Exit

Enter your option : 1
Enter the data :3
Enter your option : 2
3
Enter your option : 3
Enter the data : 4
Enter your option : 6
Add after given node:4
Enter the data : 5
Enter your option : 2
4 5 3
Enter your option : 10
Delete after a given node:5
Enter your option : 2
4 5

Lab Assignment:

1) WAP to implement circular linked list.
2) WAP to insert and delete an element in a doubly linked list(all cases).

Exercise No. 3: Stacks and Queues: adding, deleting elements

Description:

A stack is a linear data structure which uses the same principle, i.e., the elements in a stack are added and removed only from one end, which is called the TOP. Hence, a stack is called a LIFO (Last-In First-Out) datastructure, as the element that was inserted last is the first one to be taken out.

A stack supports three basic operations: push, pop, and peek. The push operation adds an element to the top of the stack and the pop operation removes the element from the top of the stack. The peek operation returns the value of the topmost element of the stack.

Aim: Write a program to perform Push, Pop, and Peek operations on a stack.

Algorithm:

Insertion:

Step 1: IF TOP=MAX-1
PRINT OVERFLOW
Goto Step 4

Step 2: SET TOP=TOP+1
Step 3: SET STACK[TOP]=VALUE
Step 4: END

Deletion:
Step 1: IF TOP=NULL
            PRINT UNDERFLOW
      Goto Step 4
      [END OF IF]
Step 2: SET VAL=STACK[TOP]
Step 3: SET TOP=TOP-1
Step 4: END

Peek:
Step 1: IF TOP=NULL
            PRINT STACK IS EMPTY
      Goto Step 3
Step 2: RETURN STACK[TOP]
Step 3: END

Program:

```
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>
#define MAX 3 // Altering this value changes size of stack created
int st[MAX], top=-1;
void push(int st[], int val);
int pop(int st[]);
int peek(int st[]);
void display(int st[]);
int main(int argc, char *argv[]) {
 int val, option;
 do
 {
  printf("\n *****MAIN MENU*****");
  printf("\n 1. PUSH");
  printf("\n 2. POP");
  printf("\n 3. PEEK");
  printf("\n 4. DISPLAY");
  printf("\n 5. EXIT");
  printf("\n Enter your option: ");
  scanf("%d", &option);
  switch(option)
  {
  case 1:
   printf("\n Enter the number to be pushed on stack: ");
   scanf("%d", &val);
   push(st, val);
   break;
  case 2:
   val = pop(st);
   if(val != -1)
   printf("\n The value deleted from stack is: %d", val);
   break;
  case 3:
```

```
   if(val != -1)
   printf("\n The value stored at top of stack is: %d", val);
   break;
  case 4:
   display(st);
   break;
  }
 }while(option != 5);
 return 0;
}
void push(int st[], int val)
{
 if(top == MAX-1)
 {
  printf("\n STACK OVERFLOW");
 }
 else
 {
  top++;
  st[top] = val;
 }
}
int pop(int st[])
{
 int val;
 if(top == -1)
 {
  printf("\n STACK UNDERFLOW");
  return -1;
 }
 else
 {
  val = st[top];
  top--;
  return val;
 }
}
void display(int st[])
{
 int i;
 if(top == -1)
 printf("\n STACK IS EMPTY");
 else
 {
  for(i=top;i>=0;i--)
  printf("\n %d",st[i]);
  printf("\n"); // Added for formatting purposes
 }
}
int peek(int st[])
{
 if(top == -1)
 {
  printf("\n STACK IS EMPTY");
  return -1;
 }
```

```
 return (st[top]);
}
```

Output

```
*****MAIN MENU*****
1. PUSH
2. POP
3. PEEK
4. DISPLAY
5. EXIT
Enter your option : 1
Enter the number to be pushed on stack : 500
Enter your option : 1
Enter the number to be pushed on stack : 700
Enter your option : 4
700        500
Enter your option : 3
Enter your option : 4
700
Enter your option : 2
Enter your option : 4
500
```

Description:

A queue is a FIFO (First-In, First-Out) data structure in which the element that is inserted first is the first one to be taken out. The elements in a queue are added at one end called the REAR and removed from the other end called the FRONT. Queues can be implemented by using either arrays or linked lists.

Aim: Write a program to perform Insertion, Deletion, and Peek operations on a queue.

Algorithm:

Insertion:

```
Step 1: IF REAR=MAX-1
                Write OVERFLOW
        Goto step 4
        [END OF IF]
Step 2: IF FRONT=-1 and REAR=-1
                SET FRONT=REAR =ELSE
                SET REAR=REAR+1
        [END OF IF]
Step 3: SET QUEUE[REAR]=NUM
Step 4: EXIT
```

Deletion:

```
Step 1: IF FRONT=-1OR FRONT>REAR
                Write UNDERFLOW
        ELSE
                SET VAL=QUEUE[FRONT]
                SET FRONT=FRONT+1
        [END OF IF]
Step 2: EXIT
```

Program:

```
#include <stdio.h>
#include <conio.h>
#define MAX 10 // Changing this value will change length of array
int queue[MaX];
int front = -1, rear = -1;
void insert(void);
int delete_element(void);
int peek(void);
void display(void);
int main()
{
```

```
 do
 {
  printf(“\n\n ***** MAIN MENU *****”);
  printf(“\n 1. Insert an element”);
  printf(“\n 2. Delete an element”);
  printf(“\n 3. Peek”);
  printf(“\n 4. Display the queue”);
  printf(“\n 5. EXIT”);
  printf(“\n Enter your option : “);
  scanf(“%d”, &option);
  switch(option)
  {
  case 1:
   insert();
   break;
  case 2:
   val = delete_element();
   if (val != -1)
   printf(“\n The number deleted is : %d”, val);
   break;
  case 3:
   val = peek();
   if (val != -1)
   printf(“\n The first value in queue is : %d”, val);
   break;
  case 4:
   display();
   break;
  }
 }while(option != 5);
 getch();
 return 0;
}
void insert()
{
 int num;
 printf(“\n Enter the number to be inserted in the queue : “);
 scanf(“%d”, &num);
 if(rear == MAX-1)
 printf(“\n OVERFLOW”);
 else if(front == -1 && rear == -1)
 front = rear = 0;
 else
 rear++;
 queue[rear] = num;
}
int delete_element()
{
 int val;
if(front == -1 || front>rear)
 {
 printf(“\n UNDERFLOW”);
 return -1;
 }
 else
 {
 val = queue[front];
 front++;
 if(front > rear)
 front = rear = -1;
 return val;
 }
```

```
if(front==-1 || front>rear)
 {
 printf("\n QUEUE IS EMPTY");
 return -1;
 }
 else
 {
 return queue[front];
 }
void display()
int i;
printf("\n");
if(front == -1 || front > rear)
printf("\n QUEUE IS EMPTY");
 else
 {
 for(i = front;i <= rear;i++)
 printf("\t %d", queue[i]);
 }
```

Output:

```
***** MAIN MENU *****"
1. Insert an element
2. Delete an element
3. Peek
4. Display the queue
5. Exit
Enter your option : 1
Enter the number to be inserted in the queue : 50
```

Exercise No. 4: Evaluation Problem: Evaluation of infix to postfix expressions on stack.

Description:

Infix, postfix, and prefix notations are three different but equivalent notations of writing algebraic expressions. For example, if an expression is written as A+B in infix notation, the same expression can be written as AB+ in postfix notation. The order of evaluation of a postfix expression is always from left to right. Even brackets cannot alter the order of evaluation. The expression (A+B)*C can be written as: [AB+]*C =>AB+C* in the postfix notation.

Aim:Write a program to convert a given infix expression into its postfix Equivalent, Implement the stack using an array.

Algorithm:

Step 1: Add)to the end of the infix expression
Step 2: Push(onto the stack
Step 3: Repeat until each character in the infix notation is scanned
IF a(is encountered, push it on the stack
IF an operand (whetheradigit oracharacter) is encountered, add it to thepostfix expression.
IF a)is encountered, then
a. Repeatedly pop from stack and add it to the postfix expression until a (is encountered.
b. Discard the (.That is, remove the(from stack and do notadd it to the postfix expression
IF an operator is encountered, then
a. Repeatedly pop from stack and add each operator (popped from the stack) to thepostfix expression which has the same precedence orahigher precedence than)
b. Push the operator to the stack
[END OF IF]
Step 4: Repeatedly pop from the stack and add it to the postfix expression until the stack is empty
Step 5: EXIT

Program:

```
#include<stdio.h>
#include<string.h>
#include<stdlib.h>
```

```
char stack[MAX];
int top=1;
char pop();  /*declaration of  pop function*/
void push(char item); /*declaration of  push function*/
int prcd(char symbol)  /*checking the precedence*/
{
   switch(symbol) /*assigning values for symbols*/
   {
      case '+':
      case '-': return 2;
      break;
      case '*':
      case '/': return 4;
      break;
      case '^':return 6;
      break;
      case '(':
      case ')':
      case '#':return 1;
     break;
  }
}
int(isoperator(char symbol))  /*assigning  operators*/
{
   switch(symbol)
   {
       case '+':
       case '*':
   case '-':
      case '/':
      case '^':
      case '(':
      case ')':return 1;
      break;
      default:return 0;
   }
 }
/*converting infix to postfix*/
void convertip(char infix[],char postfix[])
{
 int i,symbol,j=0;
 stack[++top]='#';
 for(i=0;i<strlen(infix);i++)
 {
  symbol=infix[i];
  if(isoperator(symbol)==0)
  {
      postfix[j]=symbol;
       j++;
  }
  else
  {
      if(symbol=='(')
      push(symbol);   /*function call  for pushing elements into the stack*/
      else if(symbol==')')
      {
```

```
        {
            postfix[j]=pop();
            j++;
        }
        pop();     /*function call  for popping elements into the stack*/
    }
   else
   {
        if(prcd(symbol)>prcd(stack[top]))
        push(symbol);
        else
        {
           while(prcd(symbol)<=prcd(stack[top]))
           {
             postfix[j]=pop();
              j++;
           }
          push(symbol);
        }/*end of else loop*/
     }/*end of else loop*/
    } /*end of else loop*/
   }/*end of for loop*/
  While (stack[top]!='#')
  {
     postfix[j]=pop();
      j++;
   }
   postfix[j]='\0'; /*null terminate string*/
}
/*main program*/
void main()
 {
      char infix[20],postfix[20];
      printf("enter the valid infix string \n");
      gets(infix);
      convertip(infix,postfix);    /*function call   for converting infix to postfix */
      printf("the corresponding postfix string is:\n");
     puts(postfix);
  }
/*push operation*/
void push(char item)
{
    top++;
    stack[top]=item;
 }
/*pop operation*/
char pop()
{
    char a;
    a=stack[top];
    top--;
    return a;
 }
```

Input:
A+B*C
Output:

Exercise No. 5: Circular Queue: Adding & deleting elements

Description:

In the circular queue, the first index comes right after the last index.The circular queue will be full only when `FRONT=0` and `REAR=Max-1`. A circular queue is implemented in the same manner as a linear queue is implemented.

Aim: Write a program to implement a circular queue using array.

Algorithm:

Insertion:

```
Step 1: IF FRONT = and Rear=MAX-1
                Write OVERFLOW
                Goto step 4
        [End OF IF]

Step 2:
IF FRONT=-1 and REAR=-1
        SET FRONT=REAR =0
ELSE IF REAR=MAX-1and FRONT !=0
                SET REAR =0
  ELSE
                SET REAR=REAR+1
[END OF IF]
Step 3: SET QUEUE[REAR]=VAL
Step 4: EXIT
Deletion:
Step 1: IF FRONT=-1
                Write UNDERFLOW
                Goto Step 4
        [END of IF]
Step 2: SET VAL=QUEUE[FRONT]
Step 3: IF FRONT=REAR
                SET FRONT=REAR=-1
        ELSE
                IF FRONT=MAX -1
                        SET FRONT =0
                ELSE
                        SET FRONT=FRONT+1
                [END of IF]
        [END OF IF]
Step 4: EXIT
```

Program:

```
#include <stdio.h>
#include <conio.h>
#define MAX 10
int queue[MAX];
int front=–1, rear=–1;
void insert(void);
int delete_element(void);
int peek(void);
void display(void);
int main()
{
 int option, val;
 clrscr();
 do
 {
  printf("\n ***** MAIN MENU *****");
  printf("\n 1. Insert an element");
  printf("\n 2. Delete an element");
  printf("\n 3. Peek");
  printf("\n 4. Display the queue");
```

```
 printf("\n Enter your option : ");
 scanf("%d", &option);
 switch(option)
 {
  case 1:
   insert();
   break;
  case 2:
   val = delete_element();
   if(val!=–1)
   printf("\n The number deleted is : %d", val);
   break;
  case 3:
   val = peek();
   if(val!=–1)
   printf("\n The first value in queue is : %d",     break;
  case 4:
   display();
   break;
 }
}while(option!=5);
getch();
return 0;
}
void insert()
{
int num;
printf("\n Enter the number to be inserted in the queue : ");
scanf("%d", &num);
if(front==0 && rear==MAX–1)
 printf("\n OVERFLOW");
else if(front==–1 && rear==–1)
{
 front=rear=0;
 queue[rear]=num;
}
else if(rear==MAX–1 && front!=0)
{
 rear=0;
 queue[rear]=num;
}
else
{
 rear++;
 queue[rear]=num;
}
}
int delete_element()
{
int val;
if(front==–1 && rear==–1)
 {
 printf("\n UNDERFLOW");
 return –1;
 }
val = queue[front];
if(front==rear)
 front=rear=–1;
else
{
 if(front==MAX–1)
```

```
  front++;
 }
 return val;
}
int peek()
{
 if(front==–1 && rear==–1)
 {
  printf("\n QUEUE IS EMPTY");
  return –1;
}
 else
 {
  return queue[front];
 }
}
void display()
{
 int i;
 printf("\n");
 if (front ==–1 && rear= =–1)
  printf ("\n QUEUE IS EMPTY");
 else
 {
  if(front<rear)
  {
   for(i=front;i<=rear;i++)
    printf("\t %d", queue[i]);
  }
  else
  {
   for(i=front;i<MAX;i++)
    printf("\t %d", queue[i]);
   for(i=0;i<=rear;i++)
    printf("\t %d", queue[i]);
  }
 }
}
```

Output

```
***** MAIN MENU *****
1. Insert an element
2. Delete an element
3. Peek
4. Display the queue
5. EXIT
Enter your option : 1
Enter the number to be inserted in the queue : 25
Enter your option : 2
The number deleted is : 25
Enter your option : 3
QUEUE IS EMPTY
Enter your option : 5
```

Exercise No. 6: Implementation of Polynomial addition, Polynomial multiplicationusing linked lists.

Description:

A polynomial is represented in the memory using a linked list. Consider a polynomial $6x^3+9x^2+7x+1$. Every individual term in a polynomial consists of two parts, a coefficientand a power. Here, 6, 9, 7, and 1 are the coefficients of the terms that have 3, 2, 1, and 0 as theirpowers respectively.

Every term of a polynomial can be represented as a node of the linked list

Aim:Write a program to add two polynomials.

Program:

```
#include <stdio.h>
typedef struct pnode
{
float coef;
int exp;
struct pnode *next;
}p;
p *getnode();
void main()
{
p *p1,*p2,*p3;

p *getpoly(),*add(p*,p*);

void display(p*);
clrscr();
printf("\n enter first polynomial");
p1=getpoly();
printf("\n enter second polynomial");
p2=getpoly();
printf("\nthe first polynomial is");
display(p1);
printf("\nthe second polynomial is");
display(p2);
p3=add(p1,p2);
printf("\naddition of two polynomial is :\n");
display(p3);

}
p *getpoly()
{
p *temp,*New,*last;
int flag,exp;
char ans;
float coef;
temp=NULL;
flag=1;
printf("\nenter the polynomial in descending order of exponent");
do
{
printf("\nenter the coef & exponent of a term");
scanf("%f%d",&coef,&exp);
New=getnode();
if(New==NULL)
printf("\nmemory cannot be allocated");
New->coef=coef;
New->exp=exp;
if(flag==1)
{
temp=New;
last=temp;
flag=0;
}
else
{
last->next=New;
last=New;
}
```

```
ans=getch();
}
while(ans==’y’);
return(temp);
}
p *getnode()
{
p *temp;
temp=(p*) malloc (sizeof(p));
temp->next=NULL;
return(temp);
}
void display(p*head)
{
p*temp;
temp=head;
if(temp==NULL)
printf(“\npolynomial empty”);
while(temp->next!=NULL)
{
printf(“%0.1fx^%d+”,temp->coef,temp->exp);
temp=temp->next;
}
printf(“\n%0.1fx^%d”,temp->coef,temp->exp);
getch();
}
p*add(p*first,p*second)
{
p *p1,*p2,*temp,*dummy;
char ch;
float coef;
p *append(int,float,p*);
p1=first;
p2=second;
temp=(p*)malloc(sizeof(p));
if(temp==NULL)
printf(“\nmemory cannot be allocated”);
dummy=temp;
while(p1!=NULL&&p2!=NULL)
{
if(p1->exp==p2->exp)
{
coef=p1->coef+p2->coef;
temp=append(p1->exp,coef,temp);
p1=p1->next;
p2=p2->next;
}
else
if(p1->expexp)
{
coef=p2->coef;
temp=append(p2->exp,coef,temp);
p2=p2->next;
}
else
if(p1->exp>p2->exp)
{
coef=p1->coef;
temp=append(p1->exp,coef,temp);
p1=p1->next;
}
}
```

```
{
temp=append(p1->exp,p1->coef,temp);
p1=p1->next;
}
while(p2!=NULL)
{
temp=append(p2->exp,p2->coef,temp);
p2=p2->next;
}
temp->next=NULL;
temp=dummy->next;
free(dummy);
return(temp);
}
p*append(int Exp,float Coef,p*temp)
{
p*New,*dum;
New=(p*)malloc(sizeof(p));
if(New==NULL)
printf("\ncannot be allocated");
New->exp=Exp;
New->coef=Coef;
New->next=NULL;
dum=temp;
dum->next=New;
dum=New;
return(dum);
}
```

Input:
A^2+2A+2
A^3+3A+3
Output:
A^3+A^2+5A+5

Lab Assignment:

1) Write a program to multiply two polynomials.

Exercise No. 7: Sparse Matrices: Multiplication, addition.

Description:

Sparse matrix is a matrix that has large number of elements with a zero value. In order to efficiently utilize the memory, specialized algorithms and data structures that take advantage of the sparse structure should be used. If we apply the operations using standard matrix structures and algorithms to sparse matrices, then the execution will slow down and the matrix will consume large amount of memory. Sparse data can be easily compressed, which in turn can significantly reduce memory usage.

Aim: Write a program to multiply sparse matrices.

Program:

```
#include<stdio.h>
#include<conio.h>
#include<alloc.h>
#define MAX1 3
#define MAX2 3
#define MAXSIZE 20
#define TRUE 1
#define FALSE 2
struct sparse
{
int *sp ;
int row ;
```

```
} ;
void initsparse ( struct sparse * ) ;
void create_array ( struct sparse * ) ;
int count ( struct sparse ) ;
void display ( struct sparse ) ;
void create_tuple ( struct sparse*, struct sparse ) ;
void display_tuple ( struct sparse ) ;
void prodmat ( struct sparse *, struct sparse, struct sparse ) ;
void searchina ( int *sp, int ii, int*p, int*flag ) ;
void searchinb ( int *sp, int jj, int colofa, int*p, int*flag ) ;
void display_result ( struct sparse ) ;
void delsparse ( struct sparse * ) ;
void main( )
{
struct sparse s[5] ;
int i ;
clrscr( ) ;
for ( i = 0 ; i<= 3 ; i++ )
initsparse ( &s[i] ) ;
create_array ( &s[0] ) ;
create_tuple ( &s[1], s[0] ) ;
display_tuple ( s[1] ) ;
create_array ( &s[2] ) ;
create_tuple ( &s[3], s[2] ) ;
display_tuple ( s[3] ) ;
prodmat ( &s[4], s[1], s[3] ) ;
printf ( "\nResult of multiplication of two matrices: " ) ;
display_result ( s[4] ) ;
for ( i = 0 ; i<= 3 ; i++ )
delsparse ( &s[i] ) ;
getch( ) ;
}
/* initialises elements of structure */
void initsparse ( struct sparse *p )
{
p -> sp = NULL ;
p -> result = NULL ;
}
/* dynamically creates the matrix */
void create_array ( struct sparse *p )
{
int n, i ;
/* allocate memory */
p -> sp = ( int * ) malloc ( MAX1 * MAX2 * sizeof ( int ) ) ;
/* add elements to the array */
for ( i = 0 ; i< MAX1 * MAX2 ; i++ )
{
printf ( "Enter element no. %d: ", i ) ;
scanf ( "%d", &n ) ;
* ( p -> sp + i ) = n ;
}
}
/* displays the contents of the matrix */
```

```
{
int i ;
/* traverses the entire matrix */
for ( i = 0 ; i< MAX1 * MAX2 ; i++ )
{
/* positions the cursor to the new line for every new row */
if ( i % 3 == 0 )
printf ( "\n" ) ;
printf ( "%d\t", * ( s.sp + i ) ) ;
}
}
/* counts the number of non-zero elements */
int count ( struct sparse s )
{
int cnt = 0, i ;
for ( i = 0 ; i< MAX1 * MAX2 ; i++ )
{
if ( * ( s.sp + i ) != 0 )
cnt++ ;
}
return cnt ;
}
/* creates an array that stores information about non-zero elements */
void create_tuple ( struct sparse *p, struct sparse s )
{
int r = 0 , c = -1, l = -1, i ;
/* get the total number of non-zero elements */
p -> row = count ( s ) + 1 ;
/* allocate memory */
p -> sp = ( int * ) malloc ( p -> row * 3 * sizeof ( int ) ) ;
/* store information about total no. of rows, cols, and non-zero values */
* ( p -> sp + 0 ) = MAX1 ;
* ( p -> sp + 1 ) = MAX2 ;
* ( p -> sp + 2 ) = p -> row - 1 ;
l = 2 ;
/* scan the array and store info. about non-zero values in the 3-tuple */
for ( i = 0 ; i< MAX1 * MAX2 ; i++ )
{
c++ ;
/* sets the row and column values */
if ( ( ( i % 3 ) == 0 ) && ( i != 0 ) )
{
r++ ;
c = 0 ;
}
/* checks for non-zero element, row, column and non-zero value is assigned to the matrix */
if ( * ( s.sp + i ) != 0 )
{
l++ ;
* ( p -> sp + l ) = r ;
l++ ;
* ( p -> sp + l ) = c ;
l++ ;
```

```
}
}
}
/* displays the contents of the matrix */
void display_tuple ( struct sparse s )
{
int i, j ;
/* traverses the entire matrix */
printf ( "\nElements in a 3-tuple: " ) ;
j = ( * ( s.sp + 2 ) * 3 ) + 3 ;
for ( i = 0 ; i< j ; i++ )
{
/* positions the cursor to the new line for every new row */
if ( i % 3 == 0 )
printf ( "\n" ) ;
printf ( "%d\t", * ( s.sp + i ) ) ;
}
printf ( "\n" ) ;
}
/* performs multiplication of sparse matrices */
void prodmat ( struct sparse *p, struct sparse a, struct sparse b )
{
int sum, k, position, posi, flaga, flagb, i , j ;
k = 1 ;
p -> result = ( int * ) malloc ( MAXSIZE * 3 * sizeof ( int ) ) ;
for ( i = 0 ; i< * ( a.sp + 0 * 3 + 0 ) ; i++ )
{
for ( j = 0 ; j< * ( b.sp + 0 * 3 + 1 ) ; j++ )
{
/* search if an element present at ith row */
searchina ( a.sp, i, &position, &flaga ) ;
if ( flaga == TRUE )
{
sum = 0 ;
/* run loop till there are element at ith row in first 3-tuple */
while ( * ( a.sp + position * 3 + 0 ) == i )
{
/* search if an element present at ith col. in second 3-tuple */
searchinb ( b.sp, j, * ( a.sp + position * 3 + 1 ), &posi, &flagb ) ;
/* if found then multiply */
if ( flagb == TRUE )
sum = sum + * ( a.sp + position * 3 + 2 ) * * ( b.sp + posi * 3 + 2 ) ;
position = position + 1 ;
}
/* add result */
if ( sum != 0 )
{
* ( p -> result + k * 3 + 0 ) = i ;
* ( p -> result + k * 3 + 1 ) = j ;
* ( p -> result + k * 3 + 2 ) = sum ;
k = k + 1 ;
}
}
```

```
}
/* add total no. of rows, cols and non-zero values */
* ( p -> result + 0 * 3 + 0 ) = * ( a.sp + 0 * 3 + 0 ) ;
* ( p -> result + 0 * 3 + 1 ) = * ( b.sp + 0 * 3 + 1 ) ;
* ( p -> result + 0 * 3 + 2 ) = k - 1 ;
}
/* searches if an element present at iith row */
void searchina ( int *sp, int ii, int *p, int *flag )
{
int j ;
*flag = FALSE ;
for ( j = 1 ; j<= * ( sp + 0 * 3 + 2 ) ; j++ )
{
if ( * ( sp + j * 3 + 0 ) == ii )
{
*p = j ;
*flag = TRUE ;
return ;
}
}
}
/* searches if an element where col. of first 3-tuple is equal to row of second 3-tuple */
void searchinb ( int *sp, int jj, int colofa, int *p, int *flag )
{
int j ;
*flag = FALSE ;
for ( j = 1 ; j<= * ( sp + 0 * 3 + 2 ) ; j++ )
{
if ( * ( sp + j * 3 + 1 ) == jj && * ( sp + j * 3 + 0 ) == colofa )
{
*p = j ;
*flag = TRUE ;
return ;
}
}
}
/* displays the contents of the matrix */
void display_result ( struct sparse s )
{
int i ;
/* traverses the entire matrix */
for ( i = 0 ; i< ( * ( s.result + 0 + 2 ) + 1 ) * 3 ; i++ )
{
/* positions the cursor to the new line for every new row */
if ( i % 3 == 0 )
printf ( "\n" ) ;
printf ( "%d\t", * ( s.result + i ) ) ;
}
}
/* deallocates memory */
void delsparse ( struct sparse *s )
{
if ( s -> sp != NULL )
```

```
if ( s -> result != NULL )
free ( s -> result ) ;
}
```

Input:

First matrices

```
[0 2 3]
[4 0 0]
[0 0 5]
```

Second matrices

```
[0 0 7]
[0 8 0]
[0 9 6]
```

Output:

```
[0 43 18]
[0  0 28]
[0 45 30]
```

Lab assignment:

1) Write a program to add two sparse matrices.

Exercise No. 8: Recursive and Non-recursive traversal of Trees

Description:

A binary tree is a data structure that is defined as a collection of elements called nodes. In a binary tree, the topmost element is called the root node, and each node has 0, 1, or at the most 2 children. A node that has zero children is called a leaf node or a terminal node. Every node contains a data element, a left pointer which points to the left child, and a right pointer which points to the right child. The root element is pointed by a `'root'` pointer. If `root = NULL`, then it means the tree is empty.

Aim: Write a program to implement a binary tree using recursion.

Program:

```
#include<stdio.h>
#include<conio.h>
#include<alloc.h>
struct node
{
int data;
struct node *left,*right;
};
struct node *root;
void insert(int x)
{
  struct node *p,*previous,*current;
  p=(struct node *)malloc(sizeof(struct node));
  if(p==NULL)
  {
    printf("\n Out of memory");
  }
  p->data=x;
  p->left=NULL;
  p->right=NULL;
  if(root=NULL)
  {
    root=p;
    return;
  }
  previous=NULL;
  current=root;
  while(current!=NULL)
  {
      previous=current;
      if(p->data<current->data)
```

```
          current=current->right;
          }
     if(p->data<previous->data)
          previous->left=p;
     else
 previous->right=p;
}
void inorder(struct node *t)
{
  if (t!=NULL)
  {
  inorder(t->left);
  printf("\n %5d",t->data);
  inorder (t->right);
  }
}
void del(int x)
{
   int tright=0,tleft=0;
   struct node *ptr=root;
   struct node *parent=root;
   struct node *t1=root;
   struct node *temp=root;
   while(ptr!=NULL&& ptr->data!=x)
   {
      parent=ptr;
      if (x<ptr->data)
            ptr=ptr->left;
      else
           ptr=ptr->right;
   }
   if (ptr==NULL)
   {
     printf("\n Delete element not found");
     return ;
   }
   else if(t1->data==x && (t1->left ==NULL || t1->right==NULL))
          if(t1->left==NULL)
             t1=t1->right;
          else
             t1=t1->left;
   else if (ptr->left==NULL)
     if (x<parent->data)
       parent->left=ptr->right;
     else
       parent->right=ptr->right;
   else if (ptr->right==NULL)
     if (x<parent->data)
       parent->left=ptr->left;
     else
       parent->right=ptr->left;
   else
   {
   temp=ptr;
   parent=ptr;
   if((ptr->left)>=(ptr->right))
   {
      ptr=ptr->left;
      while(ptr->right!=NULL)
      {
           tright=1;
```

```
      }
      temp->data=ptr->data;
      if(tright)
           parent->right=ptr->left;
      else
           parent->left=ptr->left;
    }
 else
    {
     ptr=ptr->right;
     while (ptr->left!=NULL)
     {
           tleft=1;
           parent=ptr;
           ptr=ptr->left;
      }
      temp->data=ptr->data;
      if(tleft)
           parent->left=ptr->right;
      else
           parent->right=ptr->right;
    }
    free(ptr);
  }
}

void main()
{
int op,n,srchno;
root=(struct node *)malloc(sizeof(struct node));
root->data=30;
root->right=root->left=NULL;
clrscr();
do
{
    printf("\n 1.Insertion");
    printf("\n 2.Deletion");
    printf("\n 3.Inorder");
    printf("\n 4.Quit");
    printf("\n Enter your choice\n");
    scanf("%d",&op);

  switch (op)
   {
    case 1: printf("\n Enter the element to insert\n");
            scanf("%d",&n);
            insert(n);
            break;
    case 2: printf("\n Enter the element to be deleted\n");
            scanf("%d",&srchno);
            del(srchno);
            break;
    case 3: printf("\n The inorder elements are\n");
            inorder(root);
            getch();
            break;
    default: exit(0);
   }
  }while(op<4);
  getch();

  }
```

1 2 3

Output:

Enter the element to insert1
Enter the element to insert2
Enter the element to insert3
The inorder elements are
2 1 3

Lab assignment:

1) Write a program to implement a binary tree without using recursion

Exercise No. 9: AVL tree implementation

Description:

An AVL tree is the same as that of a binary search tree but with a little difference.
In its structure, it stores an additional variable called theBalance Factor. Thus, every node has a balance factor associated with it. The balance factor of a node is calculated by subtracting the height of its right sub-tree from the height of its left sub-tree. A binary search tree in which every node has a balance factor of –1, 0, or 1 is said to be height balanced. A node with any other balance factor is considered to be unbalanced and requires rebalancing of the tree.
Balance factor = Height (left sub-tree) – Height (right sub-tree)

Aim: Write a program to implement AVL tree

Program:

```
#include <stdio.h>
typedef enum { FALSE ,TRUE } bool;
struct node
{
 int val;
 int balance;
 struct node *left_child;
 struct node *right_child;
};
struct node* search(struct node *ptr, int data)
{
 if(ptr!=NULL)
   if(data < ptr -> val)
   ptr = search(ptr -> left_child,data);
   else if( data > ptr -> val)
   ptr = search(ptr -> right_child, data);
 return(ptr);
}
struct node *insert (int data, struct node *ptr, int *ht_inc)
{
 struct node *aptr;
struct node *bptr;
if(ptr==NULL)
 {
 ptr = (struct node *) malloc(sizeof(struct node));
 ptr -> val = data;
 ptr -> left_child = NULL;
 ptr -> right_child = NULL;
 ptr -> balance = 0;
 *ht_inc = TRUE;
 return (ptr);
 }
if(data < ptr -> val)
 {
 ptr -> left_child = insert(data, ptr -> left_child, ht_inc);
 if(*ht_inc==TRUE)
  {
   switch(ptr -> balance)
   {
```

```
case -1: /* Right heavy */

ptr -> balance = 0;
   *ht_inc = FALSE;
   break;

case 0: /* Balanced */

ptr -> balance = 1;

break;
   case 1: /* Left heavy */

aptr = ptr -> left_child;
    if(aptr -> balance == 1)
     {

printf("Left to Left Rotation\n");

ptr -> left_child= aptr -> right_child;

aptr -> right_child = ptr;

ptr -> balance = 0;

aptr -> balance=0;
     ptr = aptr;
     }
    else
     {
     printf("Left to right rotation\n");

bptr = aptr -> right_child;
     aptr -> right_child = bptr -> left_child;

bptr -> left_child = aptr;

ptr -> left_child = bptr -> right_child;

bptr -> right_child = ptr;

if(bptr -> balance == 1 )

pt
r -> balance = -1;
```

```
else


pt
r -> balance = 0;


if(bptr -> balance == -1)


aptr -> balance = 1;


else


aptr -> balance = 0;


bptr -> balance=0;


ptr = bptr;
     }
    *ht_inc = FALSE;
    }
  }
 }
if(data > ptr -> val)
{
  ptr -> right_child = insert(info, ptr -> right_child, ht_inc);
  if(*ht_inc==TRUE)
  {
   switch(ptr -> balance)
    {


case 1: /* Left heavy */
     ptr -> balance = 0;
     *ht_inc = FALSE;
     break;


case 0: /* Balanced */
     ptr -> balance = -1;
     break;
    case -1: /* Right heavy */

 aptr = ptr -> right_child;
  if(aptr -> balance == -1)
     {
    printf("Right to Right Rotation\n");
  ptr -> right_child= aptr -> left_child;
    aptr -> left_child = ptr;
      ptr -> balance = 0;
      aptr -> balance=0;
  ptr = aptr;
     }
  else
     {
  printf("Right to Left Rotation\n");
```

```
  aptr -> left_child = bptr -> right_child;
bptr -> right_child = aptr;
ptr -> right_child = bptr -> left_child;
  bptr -> left_child = pptr;
if(bptr -> balance == -1)
ptr -> balance = 1;
      else
ptr -> balance = 0;
      if(bptr -> balance == 1)
  aptr -> balance = -1;
      else
  aptr -> balance = 0;
      bptr -> balance=0;
  ptr = bptr;
}/*End of else*/
*ht_inc = FALSE;
    }
   }
  }
 return(ptr);
}
void display(struct node *ptr, int level)
{
 int i;
 if ( ptr!=NULL )
  {
  display(ptr -> right_child, level+1);
  printf(“\n”);
  for (i = 0; i < level; i++)
   printf(“ “);
  printf(“%d”, ptr -> val);
  display(ptr -> left_child, level+1);
  }
}
void inorder(struct node *ptr)
{
 if(ptr!=NULL)
  {
  inorder(ptr -> left_child);
  printf(“%d “,ptr -> val);
  inorder(ptr -> right_child);
  }
}
main()
{
 bool ht_inc;
 int data ;
 int option;
 struct node *root = (struct node *)malloc(sizeof(struct node));
root = NULL;
while(1)
  {
 printf(“1.Insert\n”);
 printf(“2.Display\n”);
 printf(“3.Quit\n”);
 printf(“Enter your option : “);
 scanf(“%d”,&option);
 switch(choice)
   {
   case 1:
   printf(“Enter the value to be inserted : “);
   scanf(“%d”, &data);
```

```
    root = insert(data, root, &ht_inc);
 else
 printf("Duplicate value ignored\n");
  break;
 case 2:
   if(root==NULL)
    {
 printf("Tree is empty\n");
    continue;
    }
   printf("Tree is :\n");
   display(root, 1);
 printf("\n\n");
printf("Inorder Traversal is: ");
 inorder(root);
   printf("\n");
   break;
  case 3:
   exit(1);
 default:
 printf("Wrong option\n");
    }
  }
 }
```

Input:

6 11 2 4 3 5

Output:

2 3 5 4 6 11

Lab Assignment:

1) Write a program to implement AVL tree

Exercise No. 10: Application of sorting and searching algorithms

Description:

To search an element in an array is known as searching and to sort the element in an ascending and descending order is known as sorting.Two type of searching linear and binary. Mainly five type of sorting like bubble ,insertion ,selection, merge and quick sort.here we mainly focus on binary search and merge and quick sort.

Aim:Implement Binary search without using recursion

Program:

```
#include<stdio.h>

int main(){

    int a[10],i,n,m,c=0,l,u,mid;

    printf("Enter the size of an array: ");
    scanf("%d",&n);

    printf("Enter the elements in ascending order: ");
    for(i=0;i<n;i++){
         scanf("%d",&a[i]);
    }

    printf("Enter the number to be search: ");
    scanf("%d",&m);

    l=0,u=n-1;
    while(l<=u){
         mid=(l+u)/2;
```

```
            c=1;
            break;
        }
        else if(m<a[mid]){
            u=mid-1;
        }
        else
            l=mid+1;
    }
    if(c==0)
        printf("The number is not found.");
    else
        printf("The number is found.");

    return 0;
}
```

OUTPUT:

Enter the size of an array: 5
Enter the element in ascending order: 2 4 8 9 12
Enter the number to be search: 3
The number is not found.

Aim: Implement Merge Sort using Divide and Conquer approach

Program:

```
#include<stdio.h>
#include<conio.h>
void merge(int [],int ,int ,int );
void part(int [],int ,int );
int main()
{
 int arr[30];
 int i,size;
 printf("\n\t------- Merge sorting method -------\n\n");
 printf("Enter total no. of elements : ");
 scanf("%d",&size);
 for(i=0; i<size; i++)
 {
   printf("Enter %d element : ",i+1);
   scanf("%d",&arr[i]);
 }
 part(arr,0,size-1);
 printf("\n\t------- Merge sorted elements -------\n\n");
 for(i=0; i<size; i++)
 printf("%d ",arr[i]);
 getch();
 return 0;
}

void part(int arr[],int min,int max)
{
 int mid;
 if(min<max)
```

```
   mid=(min+max)/2;
   part(arr,min,mid);
   part(arr,mid+1,max);
   merge(arr,min,mid,max);
 }
}

void merge(int arr[],int min,int mid,int max)
{
  int tmp[30];
  int i,j,k,m;
  j=min;
  m=mid+1;
  for(i=min; j<=mid && m<=max ; i++)
  {
     if(arr[j]<=arr[m])
     {
         tmp[i]=arr[j];
         j++;
     }
     else
     {
         tmp[i]=arr[m];
         m++;
     }
  }
  if(j>mid)
  {
     for(k=m; k<=max; k++)
     {
         tmp[i]=arr[k];
         i++;
     }
  }
  else
  {
     for(k=j; k<=mid; k++)
     {
        tmp[i]=arr[k];
        i++;
     }
  }
  for(k=min; k<=max; k++)
     arr[k]=tmp[k];
}
```

Output:

Enter the no of elements:7

7 8 9 4 5 3 1

The unsorted list is: 7 8 9 4 5 3 1

1 3 4 5 7 8 9

Aim:Implement Quick Sort using Divide and Conquer approach

Program:

```
#include<stdio.h>
#include<stdlib.h>
#include<time.h>
#define MAX 6000

void quick(int x[],int lb,int ub);
int partition(int x[],int lb,int ub);

void main()
{
        int i,n,x[MAX];
        time_t start,end;
        clrscr();
        printf("Enter the number of elements: ");
        scanf("%d",&n);

        for(i=0;i<n;i++)
                x[i]=rand();

        printf("\nEntered array is \n");
        for(i=0;i<n;i++)
                printf("%d ",x[i]);

        start=time(NULL);
        quick(x,0,n-1);
        end=time(NULL);
        printf("Sorted array is as shown:\n");
        for(i=0;i<n;i++)
                printf("%d ",x[i]);
        printf("\nTIME for %d elements : %f", n, difftime(end,start));
        getch();

}

void quick(int x[],int lb,int ub)
{
        int j;
        if(lb<ub)
        {
                printf("\n");
                j=partition(x,lb,ub);
                quick(x,lb,j-1);
                quick(x,j+1,ub);
        }
}

int partition(int x[],int lb,int ub)
```

```
{
        int a,down,up,temp;
        a=x[lb];
        up=ub;
        down=lb;
        while(down<up)
        {
                while(x[down]<=a&&down<ub)
                        down++;
                while(x[up]>a)
                        up--;
                if(down<up)
                {
                        temp=x[down];
                        x[down]=x[up];
                        x[up]=temp;
                }
        }
        x[lb]=x[up];
        x[up]=a;
        return up;
}
```

Output:

```
Enter the number of elements:5
    Entered array is
      41   18467    6334    26500    19169
    Sorted array is as shown
      41   6334     18467    19169    26500
```

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR
LAB MANUAL

Title of Course: Thermal Power Engineering Lab
Course Code: ME(EE) 481
L-T –P Scheme: 3P **Course Credits: 2**

Course Description & Objectives:

In this laboratory, students will have the opportunity to study the working principle of IC engines (both SI and CI engines), performance and characteristics in terms of heat balancing, economical speed variations, air fuel ratio influence on the engine to reinforce classroom theory by having the student perform required tests, analyze subsequent data, and present the results in a professionally prepared report.
The machines and equipment used to determine experimental data include cut models of 4stroke diesel engine, 2stroke petrol engine, 4stroke and two stroke petrol engines with required specifications, Multi cylinder SI engine, Single cylinder Diesel engine for performance and speed test which is suitable to tests on variable compression ratios.

Course Outcomes:

1. **Determine** the valve timing diagram of SI engine & CI engine.
2. **Analyze** the influence of variations in TDC and BDC operations
3. **Calculate** the IP,BP, brake thermal efficiency.
4. **Calculate & Compare** the performance characteristics.
5. **Experiment** on IC engine load variations with Air fuel ratio.
6. **Apply** the concept of Morse test on SI engine.(multi cylinder).
7. **Analyse** the efficiency of reciprocating air compressor
8. **Determine** the principle of various parameters in boilers.

Course Contents:

1. StudyofCutModels–BoilersIC Engines

   !LanchashireBoiler

   !Bahcock&WillcoxBoiler

   !CochranBoiler

   !VerticalTubularBoiler

!LocomotiveBoiler

!4SDieselEngine

!4S PetrolEngine

!2S PetrolEngine

2. LoadTeston4StrokePetrolEngine&DieselEngineby ElectricalLoadBox.
3. LoadTeston4StrokeDieselEnginebyRopeBrakeDynamometer.
4. HeatBalanceon4StrokeDieselEnginebyRopeBrakeDynamometer&byElectricalLoadBox.
5. ValveTimingDiagramon 4S DieselEngineModel&4S PetrolEngineModel.
6. TofindtheCalorificValueofDieselFuel&CoalbyBombCalorimeter.
7. TofindtheFlashPoint&FirePointof Petrol&DieselFuel.
8. TofindtheCloudPoint&PourPointofPetrol&DieselFuel.
9. TofindCarbonParticlePercentageinDieselEngineExhaustSmokebySmokemeterandtracethe BHPVs.%CarbonCurve.
10. Measurementof theQualityofSteam–Enthalpy&Drynessfraction.

11. Tofindoutthe Boilerperformance–Boilerefficiency&Steamevaporationrate.

12. TovisitaThermalPowerStation&studyofthefollowings:

a)Boiler b)Steampipe c)Furnace
d)Economizere)Preheaterf)Steamturbines
g)Alternator h)Watertreatmentplant i)E.S.P.

TEXT BOOK:

1. Nag. P.K., "Power Plant Engineering", Third Edition, Tata McGraw – Hill Publishing Company Ltd., 2008.
2. . P.K.Nag-EngineeringThermodynamics–TMH

REFERENCES:

1. El-Wakil. M.M., "Power Plant Technology", Tata McGraw – Hill Publishing Company Ltd., 2010.
2. Black & Veatch, Springer, "Power Plant Engineering", 1996.
3. Thomas C. Elliott, Kao Chen and Robert C. Swanekamp, "Power Plant Engineering", Second Edition, Standard Handbook of McGraw – Hill, 1998.
4. Godfrey Boyle, "Renewable energy", Open University, Oxford University Press in association with the Open University, 2004.

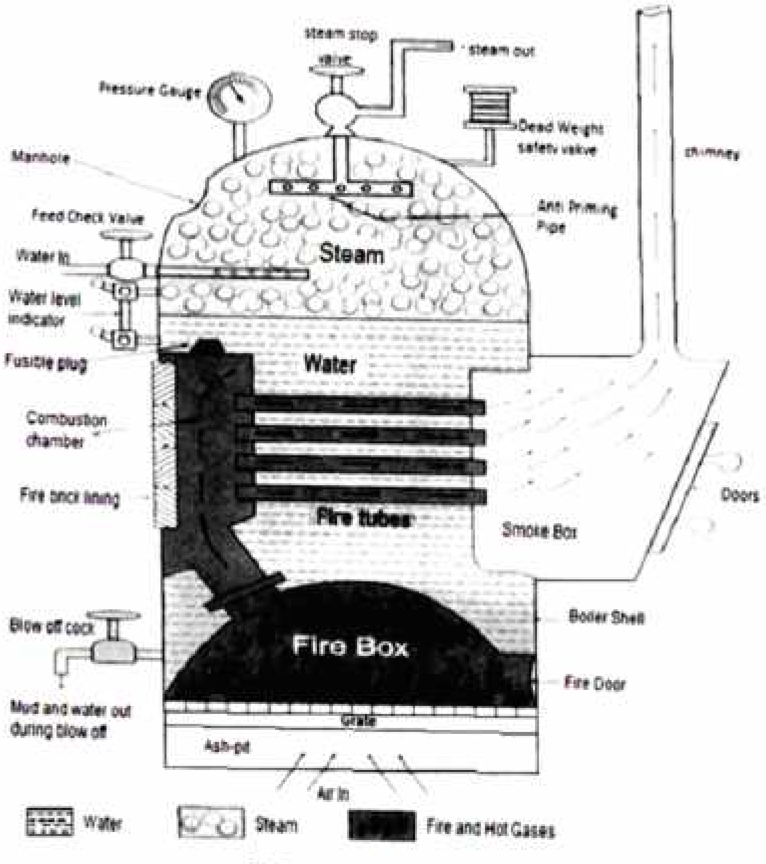
Experiment No: 1

AIM:- To study Low pressure Boiler and their mountings and accessories .
Apparatus: - Model of Cochran and Lancashire Boiler
Theory:-
Boiler: - A steam boiler is a closed vessel in which steam is produced from water by combustion of fuel.
Classification of Boiler:
Boilers are classified on the basis of following-
1. According to contents in the Tube:
a) Fire tube boiler: In fire tube boilers, the flue gases pass through the tube and water surround them.
b).Water tube boiler: In water tube boiler, water flows inside the tubes and the hot flue gases flow outside the tubes.
2. According to the pressure of steam:
a). Low pressure boiler: A boiler which generates steam at a pressure of below 80 bars is called low pressure boiler. Examples-Cochran boiler, Lancashire boiler etc.
b). High pressure boiler: A boiler which generates steam at a pressure higher then 80 bar is called high pressure boiler. Example- Babcock and Wilcox boiler etc.

COCHRAN BOILER:
Cochran boiler is a vertical, multitublar fire tube, internally fired, natural circulation boiler.
Construction:
Figure shows a Cochran boiler. It consists of a vertical cylindrical shell having a hemispherical top and furnace is also hemispherical in shape. The fire grate is arranged in the furnace and the ash pit is provided below the grate. A fire door is attached on the fire box. Adjacent to the fire box, the boiler has a combustion chamber which is lined with fire bricks. Smoke or fire tubes are provided with combustion chamber. These tubes are equal in length and arranged in a group with wide space in between them. The ends of these smoke tubes are fitted in the smoke box. The chimney is provided at the top of the smoke box for discharge of the gases to the atmosphere. The furnace is surrounded by water on all sides except at the opening for the fire door and the combustion chamber. The smoke tubes are also completely surrounded by water. Different boiler mountings and accessories are located at their proper place.

Working:

The hot gas produced from the burning of the fuel on the grate rises up through the flue pipe and reaches the combustion chamber. The flue gases from the combustion pass through the fire tubes and the smoke box and finally are discharged through the chimney. The flue gases during their travel from fire box to the chimney gives heat to the surrounding water to generate steam.



COCHRAN BOILER

Specification of Cochran Boiler:
Diameter of the drum → 0.9 m to 2.75 m
Steam pressure → 6.5 bar to 15 bar

Lancashire boilers: Lancashire is a stationary fire tube, internally fired, horizontal, natural circulation boiler. It is a commonly used in sugar – mills and textiles industries where along with the power steam and steam for the process work is also needed.

The specifications of Lancashire boiler are given below:
Diameter of the shell – 2 to 3 m.
Length of the shell – 7 to 9 m
Maximum working pressure – 16 bar
Steam capacity – 9000 kg/h
Efficiency – 50 to 70 %

Lancashire boiler consists of a cylindrical shell inside which two large tube are placed. The shell is constructed with several rings of cylindrical from and it is placed horizontally over a brick work which forms several channels for the flow of hot gasses. These two tubes are also constructed with several rings of cylindrical form. They pass from one end of the shell to other end all covered with water. The furnace is placed at the front end of the each tube and they are known as furnace tubes. The coal is introduced through the fire hole into the great. There is a low brick work fire bridge at the back of the gate to prevent the entry of the burning coal of ashes into interior of the furnace tubes. The combustions from the grate pass up to the back end of the furnace tube and then in downward direction. There after they move through the bottom channel or bottom flue upto the front end of the boiler where they are divided and pass upto the side flues.

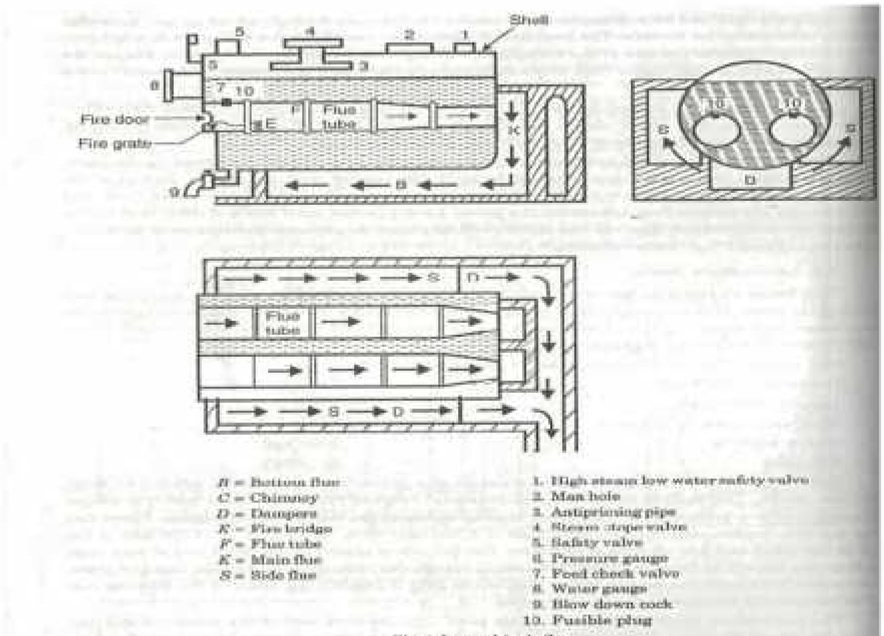


Fig. 4. Lancashire boiler.

BOILER MOUNTINGS: -

The components which are fitted on the surface of the boiler for complete safety and control of steam generation process are known as boiler mountings. The following are the various important mountings of a boiler.

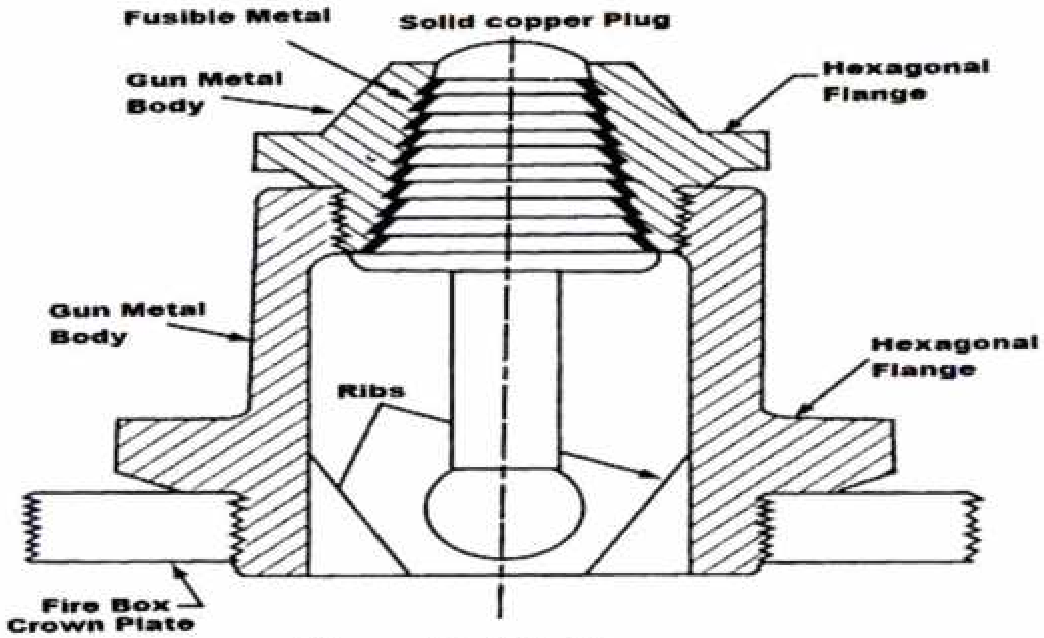


Figure- Fusible Plug

Fusible Plug:- It is fitted to the crown plate of the furnace of the fire. The function of fusible plug is to extinguish the fire in the fire box, when water level in the boiler comes down the limit and it prevents from blasting the boiler, melting the tube and over heating the fire-box crown plate. A fusible plug is shown in fig. It is located in water space of the boiler. The fusible metal is protected from direct contact of water by gun metal plug and copper plug. When water level comes down, the fusible metal melts due to high heat and copper plug drops down and is held by gun metal ribs.

Steam comes in contact with fire and distinguishes it. Thus it prevents boiler from damages.

Blow off Cock: The blow off cock as shown in fig., is fitted to the bottom of a boiler drum and consists of a conical plug fitted to body or casing. The casing is packed, with asbestos packing, in groves round the top and bottom of the plug. The asbestos packing is made tight and plug bears on the packing. Blow off cock has to principle function are:

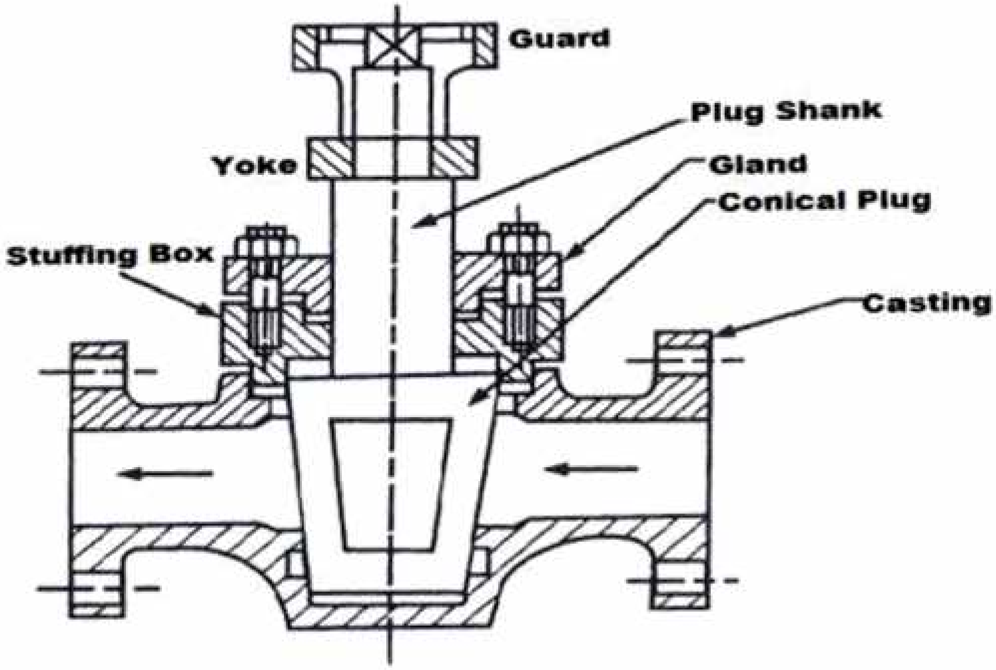


Figure- Blow Off Cock

BOILER ACCESSORIES:
The appliances installed to increase the efficiency of the boiler are known as the boiler accessories. The commonly used accessories are:

Economiser: Economiser is a one type of heat exchange which exchanges the some parts of the waste heat of flue gas to the feed water. It is placed between the exit of the furnace and entry into the chimney. Generally economiser is placed after the feed pump because in economiser water may transfer into vapour partially, which creates a priming problem in feed pump water into the boiler drum. If economiser is used before feed pump it limits the temperature rise of water. It consists of vertical cast iron tubes attached with scraper. The function of scraper is to remove the root deposited on the tube, mechanically.

Air Pre-heater:- The function of air pre-heater is to increase the temperature of air before it enters the furnace. It is installed between the economiser and the chimney. The air required for the purpose of combustion is drawn through the air pre-heater and its temperature is raised when passed through ducts. The preheated air gives higher furnace temperature which results in more heat transfer to the water and reduces the fuel consumption. There are three types of pre-heaters.

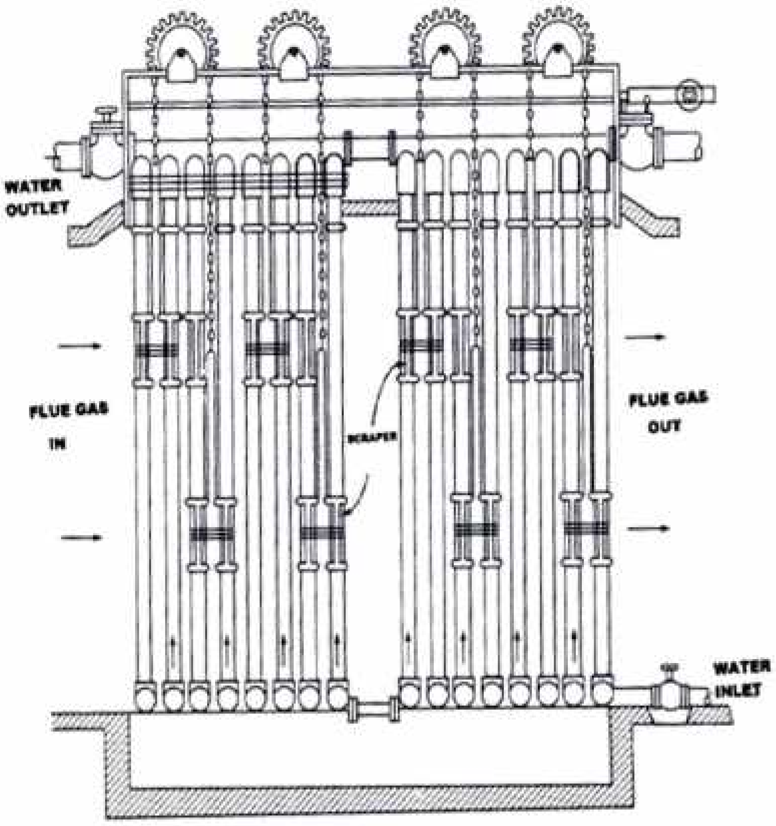


Figure- Economiser

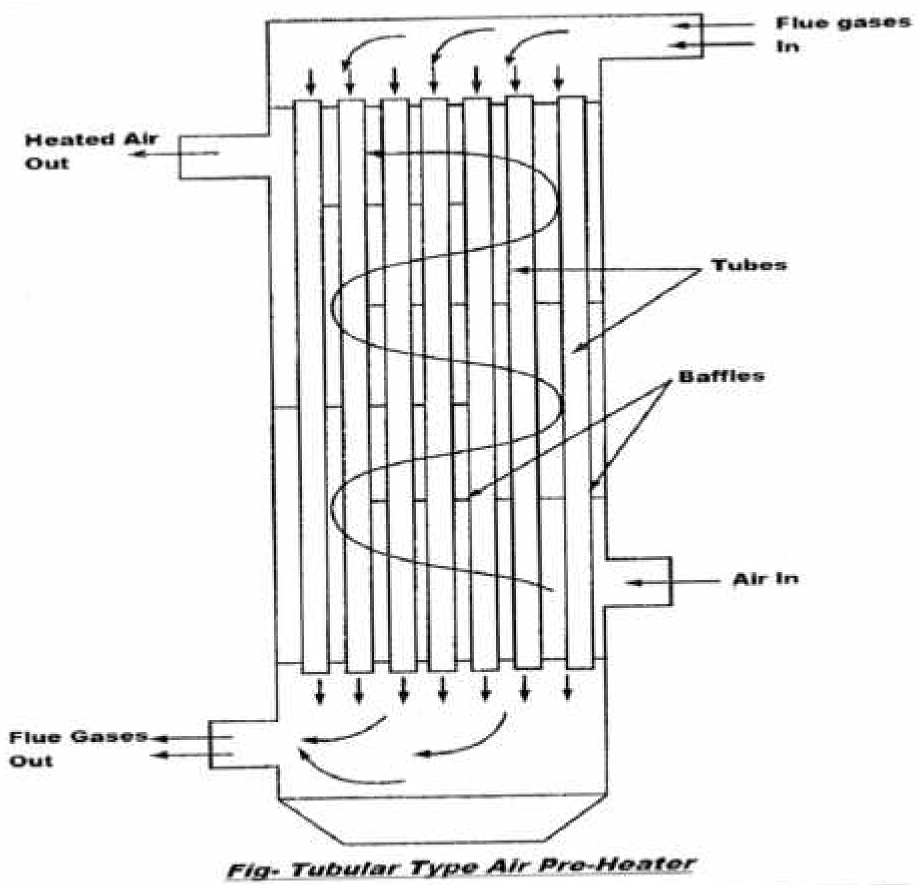


Fig- Tubular Type Air Pre-Heater

Experiment No: 2

AIM:-To study the working and construction of high pressure Boiler.

Apparatus: - Model of Babcock & Wilcox Boiler.

High pressure boiler: A boiler which generates steam at a pressure higher then 80 bar is called high pressure boiler. Example- Babcock and Wilcox boiler etc.

BABCOCK AND WILCOX BOILER:

Babcock and Wilcox boiler is a horizontal shell, multitubular, water tube, externally fired, natural circulation boiler.

Construction: Figure shows the details of a Babcock and Wilcox water tube boiler. It consists of a drum mounted at the top and connected by upper header and down take header. A large number of water tubes connect the uptake and down take headers. The water tubes are inclined at an angle of 5 to 15 degrees to promote water circulation. The heating surface of the unit is the outer surface of the tubes and half of the cylindrical surface of the water drum which is exposed to flue gases.

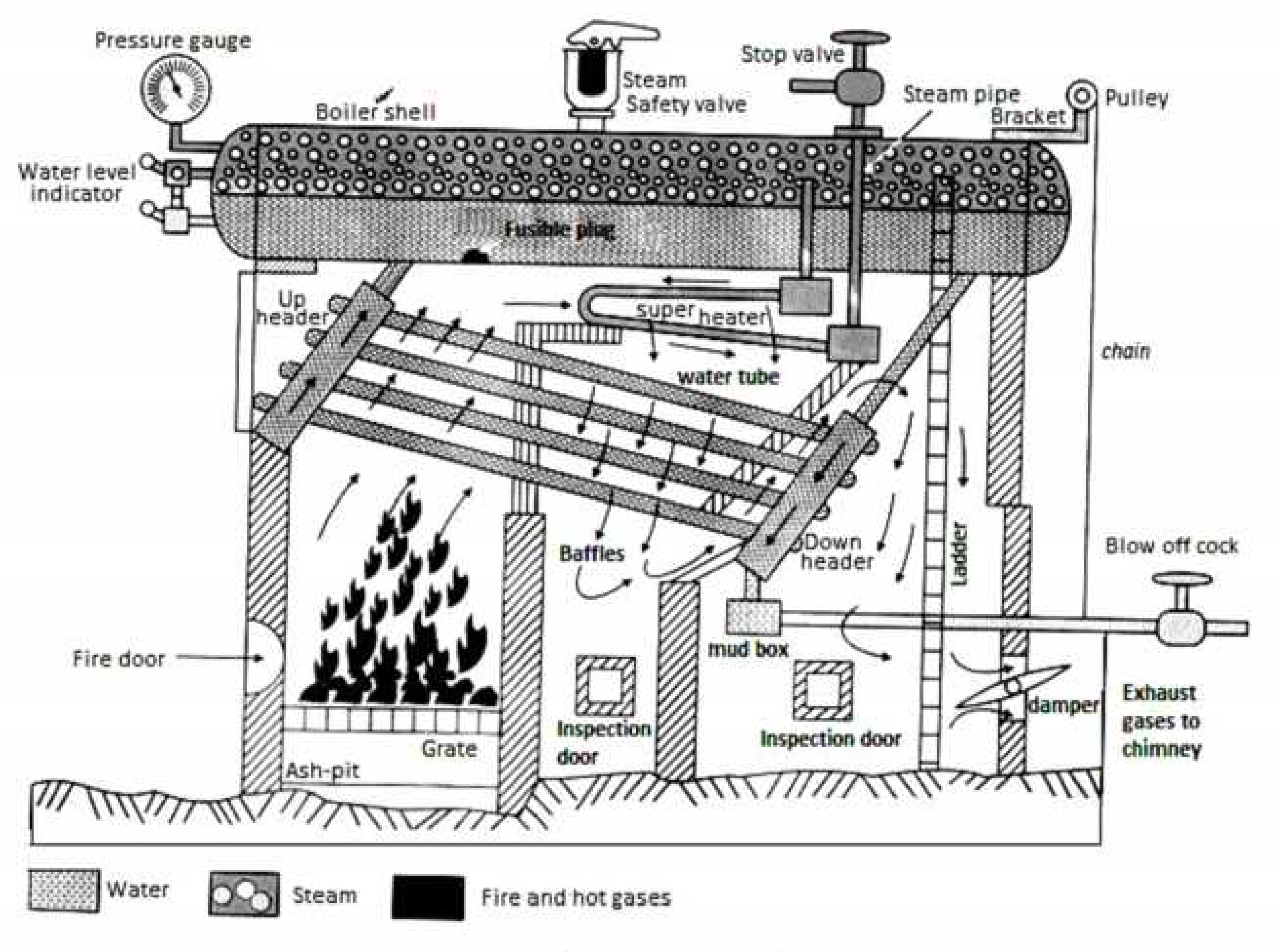
Below the uptake header the furnace of the boiler is arranged. The coal is fed to the chain grate stoker through the fire door. There is a bridge wall deflector which deflects the combustion gases upwards. Baffles are arranged across the water tubes to act as deflectors for the flue gases and to provide them with gas passes. Here, two baffles are arranged which provide three passes of the flue gases. A chimney is provided for the exit of the gases. A damper is placed at the inlet of the chimney to regulate the draught. There are superheating tubes for producing superheated steam. Connections are provided for other mounting and accessories.

Working:

The hot combustion gases produced by burning of fuel on the grater rise upwards and are deflected by the bridge wall deflector to pass over the front portion of water tubes and drum. By this way they complete the first pass. With the provision of baffles they are deflected downwards and complete the second pass. Again, with the provision of baffles they rise upwards and complete the third pass and finally come out through the chimney. During their travel they give heat to water and steam is formed. The flow path of the combustion gases is shown by the arrows outside the tubes. The circulation of water in the boiler is due to natural circulation set-up by convective currents (due to gravity). Feed water is supplied by a feed check valve.

The hottest water and stem rise from the tubes to the uptake header and then through the riser it enters the boiler drum. The steam vapours escape through the upper half of the drum. The cold water flows from the drum to the rear header and thus the cycle is completed.

To get superheated steam, the steam accumulated in the steam space is allowed to enter into the super heater tubes which are placed above the water tubes. The flue gases passing over the flue tubes produce superheated steam. The steam thus superheated is finally supplied to the user through a steam stop valve.



Babcock and Wilcox Boiler

Specification of Babcock and Wilcox Boiler:

Diameter of the drum	-	1.22 m to 1.83 m
Length of the drum	-	6.096 to 9.144 m
Size of water tubes	-	7.62 to 10.16 cm
Size of super heater tube	-	3.84 to 5.71cm
Working pressure	-	100bar
Steaming capacity	-	40,000 Kg/hr (Maximum)
Efficiency	-	60 to 80%

<u>BOILER MOUNTINGS</u>: -

The components which are fitted on the surface of the boiler for complete safety and control of steam generation process are known as boiler mountings. The following are the various important mountings of a boiler.

Steam Stop Valve- A valve placed directly on a boiler and connected to the steam pipe which carries steam to the engine or turbine is called stop valve or junction valve. It is the largest valve on the steam boiler. It is, usually, fitted to the highest part of the shell by means of a flange as shown in fig.

The principal functions of a stop valve are:

1. To control the flow of steam from the boiler to the main steam pipe.
2. To shut off the steam completely when required.

The body of the stop valve is made of cast iron or cast steel. The valve seat and the nut through which the valve spindle works, are made of brass or gun metal.

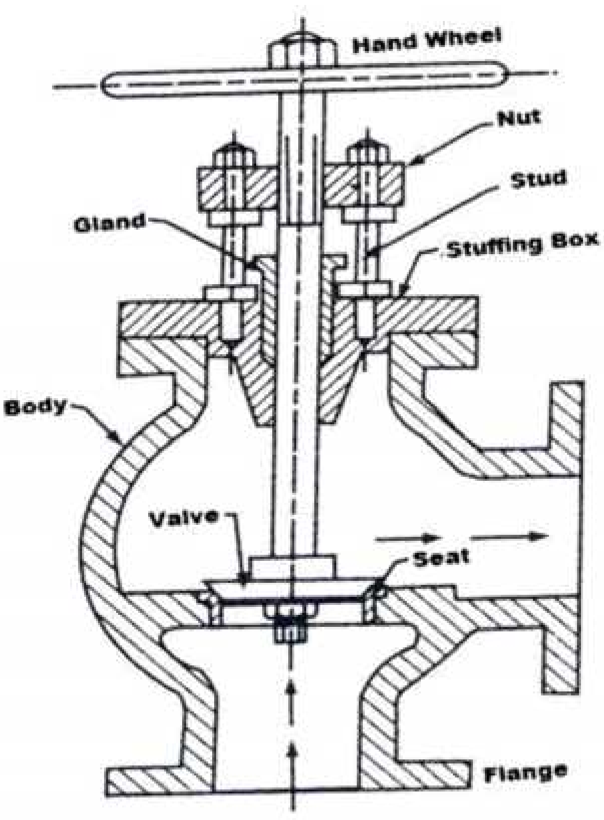


Figure-Steam Stop Valve

BOILER ACCESSORIES:

The appliances installed to increase the efficiency of the boiler are known as the boiler accessories. The commonly used accessories are:

Steam Injector- An injector is a device which is used to lift and force water into a boiler i.e. operating at high pressure. It consists of a group of nozzles, so arranged that steam expanding in these nozzles imparts its kinetic energy to a mass of water. There are many advantages of using injector such as they occupy minimum space, have low initial costs and maintenance cost. Though the steam required to operate the injector is much more than that in the feed pump for an equivalent duty; the injector has the advantage that practically the whole of the heat of the steam is returned back to the boiler.

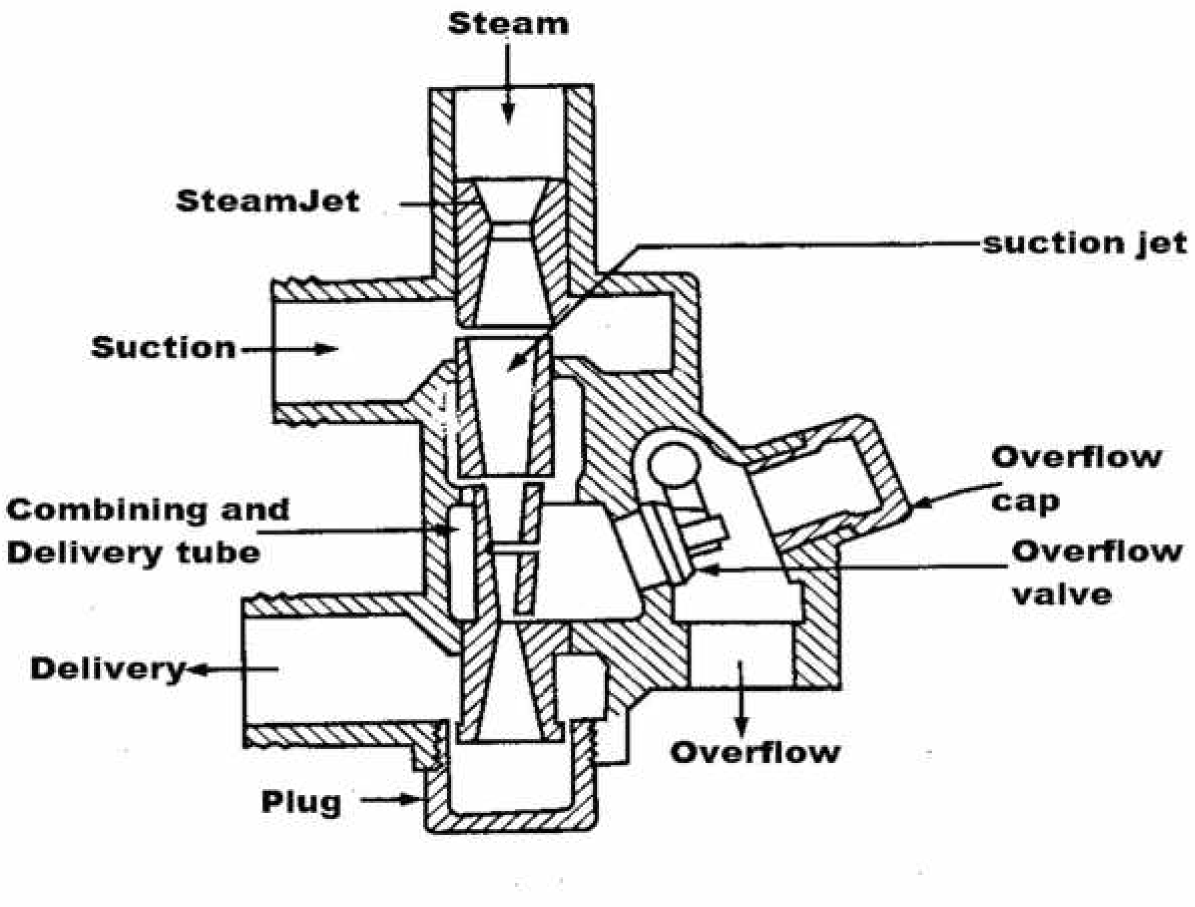


Figure- Injector

RESULT: We have studied successfully of high pressure boiler and their mounting and accessories.

Aim: To Study the working of Impulse and Reaction steam turbines.

Apparatus: Model of Impulse and Reaction steam turbines.

Theory:

Steam turbines: The steam turbine is a prime mover in which the potential energy of steam is transformed into kinetic energy and latter in its turn is transformed into the mechanical energy of the rotation of the turbine shaft.
Classification of steam turbine: With respect to the action of steam, turbines are classified as:

- Impulse turbine
- Reaction turbine

1. Impulse turbine:-

It is a turbine, which runs by the impulse of steam jet. In this turbine, the steam is first made to flow through a nozzle. Then the steam jet impinges on the turbine blades with are curved like bucket and are mounted on the circumference of the wheel. The steam jet after impinges glide over the concave surface of blades and finally leave the turbine. The top portion of Impulse turbine exhibits a longitudinal section through the upper half, the middle portion shows one set of nozzle which is followed by a ring of moving blades, while lower part indicate changes in press and velocity during the flow of steam through the turbine. The principle equation of this turbine is the well known "De Laval" turbine.

2. Reaction turbine:-

In a Reaction turbine, the steam enters the wheel under pressure and flow over the blades. The steam while gliding proper the blades and then makes them to move. The turbine runner is rotated by the reactive forces of steam jets. In this, there is a gradual pressure drop takes place continuously over the fixed and moving blades. The fuel of fixed blades is that they after allow it expand to a larger velocity as the steam passes over the moving blades. Its K.E. is absorbed by them a three stage Reaction turbine

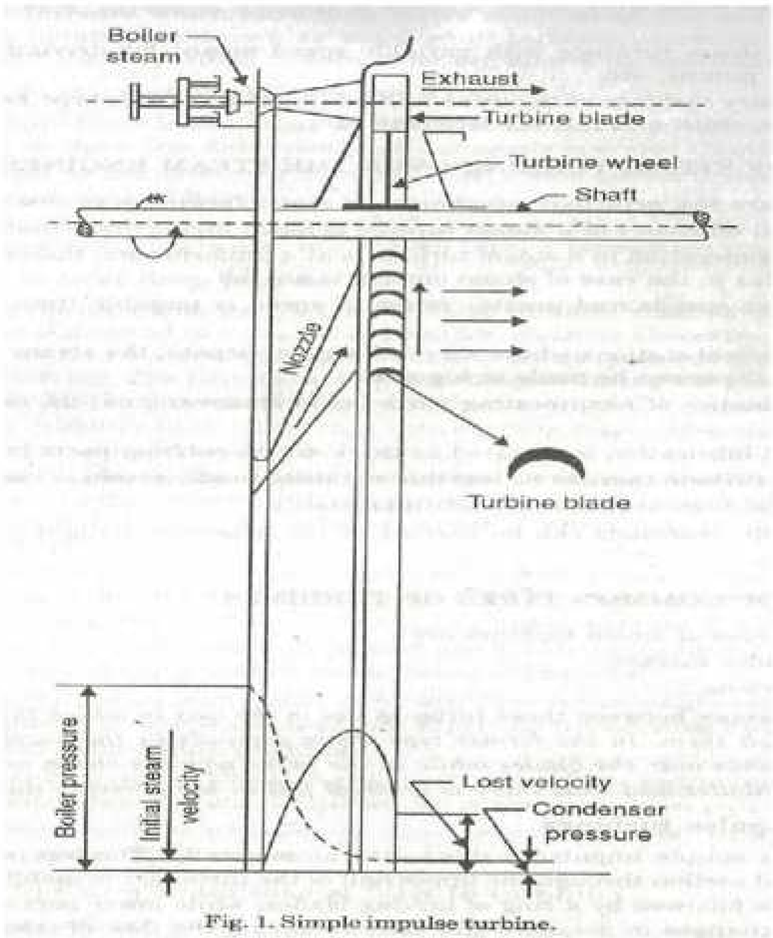


Fig. 1. Simple impulse turbine.

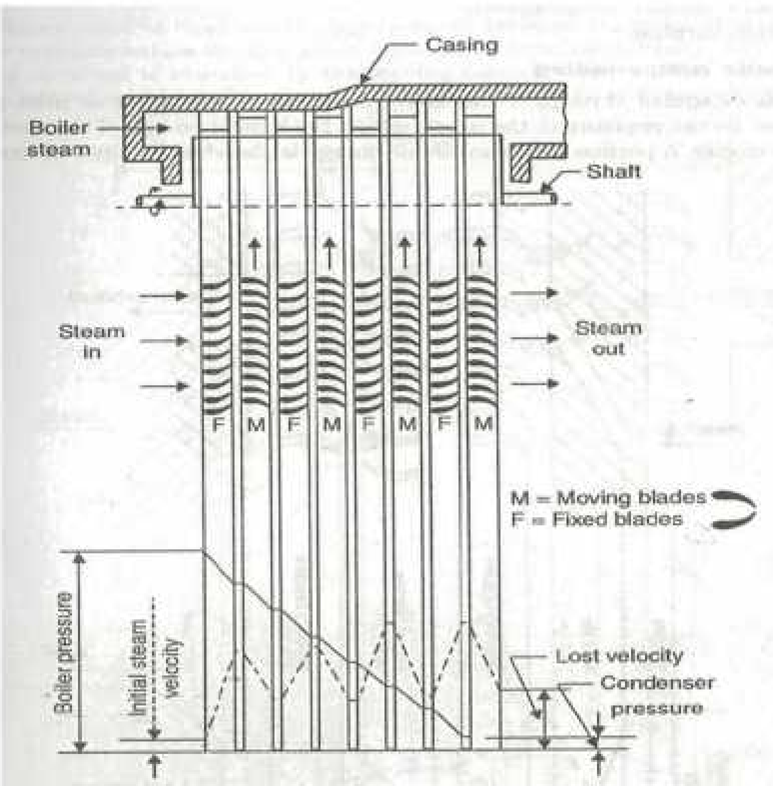


Fig. 2. Reaction turbine (three stage).

Compounding:- If the steam is expended from the boiler pressure in one stage the speed of rotor becomes tremendously high which drop up practical complicacies. The several methods of reducing this speed to lower value, all these methods utilized a multiple system of rotor in series. Keyed on a common shaft and the steam pressure or jet velocity is absorbed in stage as the steam flows over the blades, this is known as compounding.

a) Velocity compounding:-

Steam is expanded through a stationary nozzle from the boiler or inlet pressure to condenser pressure. So the pressure in the nozzle drops, the K. E. of steam increase due to increase in velocity. A portion of this available energy is absorbed by a row of moving blades. The steam then flow through the second row of the blades which are fixed. They redirect the steam flow without altering its velocity to the following nearest row moving blades. Where again work is done on them and steam with a low velocity from the turbine.

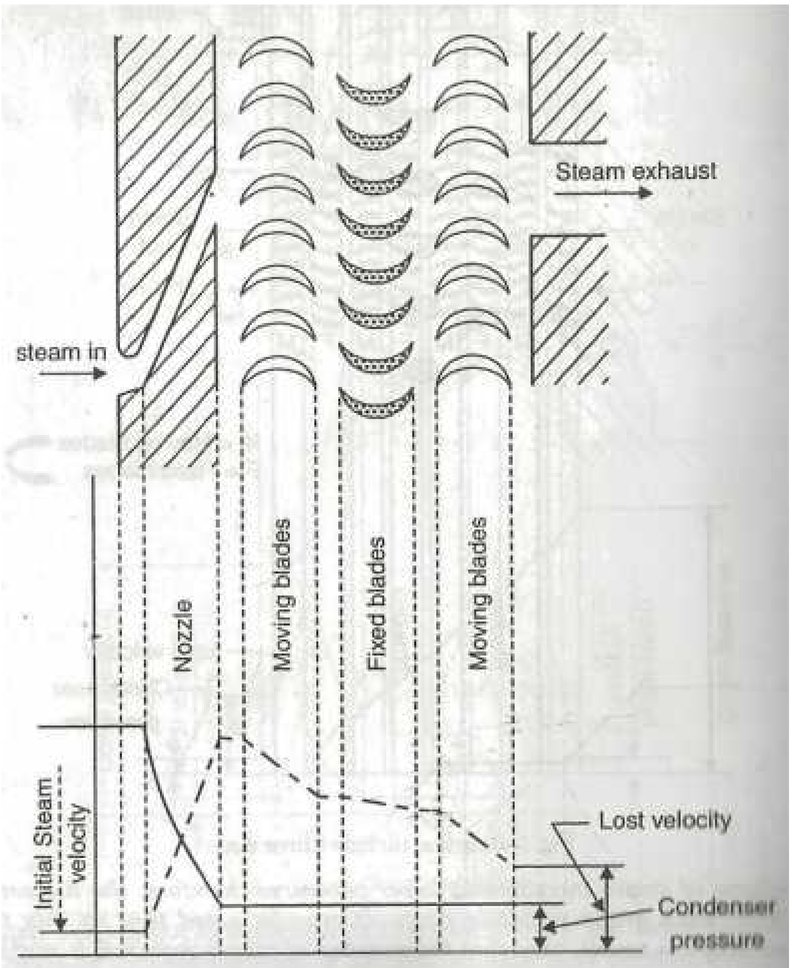


Fig. 3. Velocity compounding.

b) **Pressure compounding:-**

In this rings of fixed nozzle incorporated between ring of moving blades. The steam of boiler pressure enters the first set of nozzle and expands partially. The K.E. of steam thus obtained in absorbed by the moving blades. The steam then expands partially in the second set of nozzles whose its pressure again falls and the velocity increases. The K.E. thus obtained is observed by the second ring of moving blades. This is repeated in stage 3 and steam finally leaves the turbine at low velocity and pressure.

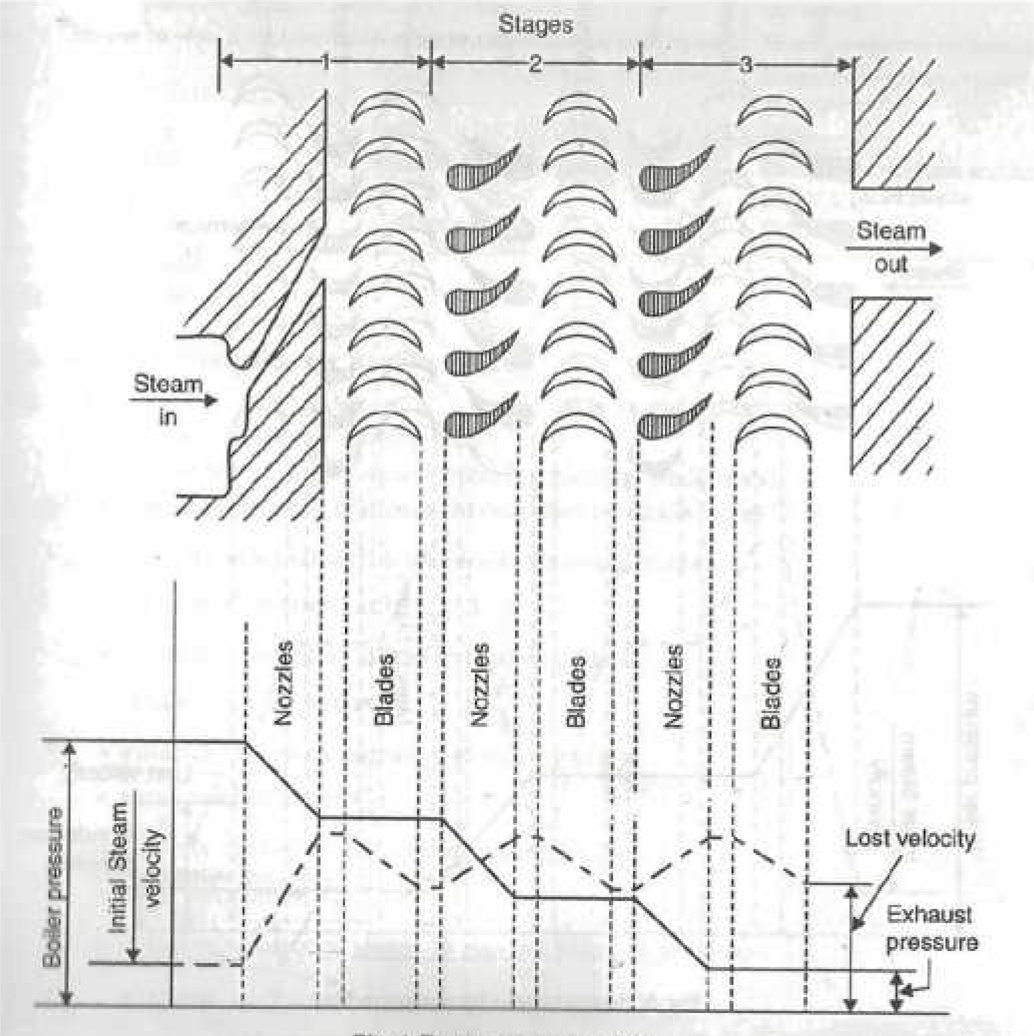


Fig. 4. Pressure compounding.

c) **Pressure-Velocity compounding:-**

This method is the combination of velocity and pressure compounding. The total drop in steam pressure is divided into stages and velocity obtained in each stage is also compounded. The ring of nozzle, are fired at beginning of each stage and pressure remains constant during each stage.

Conclusion: Thus, the study is completed for the working of Impulse and Reaction steam turbines.

Aim: To prepare heat balance sheet for a given Boiler.

Theory- Efficiency of a boiler is the ratio of heat utilized in producing steam to he heat liberated in the furnace. Also the heat utilized is always less than heat liberated in the furnace.

The difference of heat liberated in the furnace and heat utilized is known as heat loss in the boiler. The following are important losses:

1. Heat loss in dry flue gases

   $= m_g \times c_{pg}(t_g - t_b)$

   Where m_g= Mass of dry flue gases per kg of fuel,
   C_{pg}= Mean specific heat of dry flue gases,
   T_g= Temperature of flue gases leaving chimney
   T_b= Temp. of boiler room

2. Heat lost in moisture present in the fuel

   $= m_m(h_{sup} - h_b) = m_m[h_g + c_p(t_g - t) - h_b]$
   $= m_m[2676 + c_p(t_g - 100) - h_b]$

   Where m_m = Mass moister per kg of fuel
   C_p= Mean specific heat of superheated steam in flue gases,
   H_b= Enthalpy of water at boiler room temp.

3. Heat lost to steam formed by combustion of hydrogen per kg of fuel

   $= 9H_2[2676 + c_p(t_g - 100) - h_b]$

4. Heat loss due to unburnt carbon in ash pit

   $= m_1 \times c_1$

   Where m_1 = mass of carbon in ash pit per kg of fuel
   C_1= calorific value of carbon

5. Heat loss due incomplete combustion of carbon to carbon monoxide

   $= m_2 \times c_2$

   Where m_2= mass of carbon monoxide in flue gas per kg of fuel

   C_2= calorific value of carbon monoxide

Numerical-

Draw the heat balance sheet from the data given below which boiler generating 500 kg/hr of steam at 10.5 bar pressure and 0.97 dryness fraction.

Fuel used and its calorific value : 75kg/hr and 31500KJ/kg

Moisture present in the fuel : 6% by mass

Mass of dry flue gases : 10kg/kg of fuel

Temp. of flue gases : 315°C

Specific heat of flue gases : 1.1 KJ/kgK

Temperature of boiler room : 38°C

Feed water temperature : 50°C

Solution

Given: p= 10.5 bar; m_s= 500kg ; m_f= 75kg/hr ; m_m= 0.06 kg/kg of fuel ; m_g= 10kg/kg of fuel ; C= 31500KJ/kg ; t_g= 315°C; t_b= 38°C; t_1 = 50°C ; c_{pg}= 1.1 KJ/kgK; x= 0.97

Heat supplied per kg of fuel

= (1-0.06)31500

= 29610 KJ

1. Heat utilized in raising steam per kg of

   fuel: $m_e = m_s/m_f$ = 500/75 = 6.67 kg

   From steam table enthalpy of feed water at
   50ºC H_f = 209 KJ/kg
   Enthalpy of steam at 10.5 bar
   H_f = 772.0 KJ/kg H_{fg} = 2006.0 KJ/kg

   Heat utilized in raising steam per kg of fuel

   $= m_e(h-h_{f1}) = m_e(h_f+xh_{fg}-h_{f1})$

   = 6.67(722 + 0.97×2006 - 209)

   = 16740 KJ/kg of fuel

2. Heat carried by dry flue gas
   $= m_g \times c_{pg}(t_g-t_b)$
   = 10×1.1(315-38) = 3047 KJ/kg of fuel

3. Heat lost in moisture present in the fuel per kg of fuel

   From steam table at
   38ºC H_b = 159.1 KJ/kg
   $Q_m = m_m[2676 + c_p(t_g - 100) – h_b]$
   $= 0.06[2676 + 2.1(315-100) -159.1]$
   $= 178.1$ KJ/kg of fuel
4. Heat lost by radiation:
   = 29610 – (16740 + 3047 + 178.1)
   = 9644.9 KJ/kg of fuel

Heat supplied	KJ	Heat Expenditure	KJ	%
Heat supplied 1 kg of fuel	29610	1. Heat utilized in raising steam 2. Heat carried by dry flue gas 3. Heat lost in moisture present in the fuel per kg of fuel 4. Heat lost by radiation	16740 3047 178.1 9644.9	56.33 10.29 0.60 32.57
			29610	100%

Experiment No: 7

Aim: To find power output & efficiency of a steam turbine.

Theory: A steam turbine is a device that takes hot, high-pressure steam and extracts mechanical energy from it. This energy can then be used to do useful work that uses steam turbines is the steam power plant, which generates electricity used in everyday life.

Work done on the blade

The work done on the blade may be found out from the change of momentum of the steam jet during its flow over the blade.

From Newton's second law of motion

Force on the wheel = mass of steam × acceleration

= mass of steam/sec. × change of velocity

$= \dot{m} \{c_{w1} - (-c_{wo})\}$

$= \dot{m} (c_{w1} + c_{wo})$

Work done on the blade per second = force × distance travelled/sec.

$= \dot{m} (c_{w1} + c_{wo}) \times c_{bl}$

$= \dot{m}\, c_w c_{bl} / 1000$ KW

Blade efficiency = ________________

$= 2c_{bl}(c_{w1} + c_{w2})/c_1^2$

Example 1. *In a De Laval turbine steam issues from the nozzle with a velocity of 1200 m/s. The nozzle angle is 20°, the mean blade velocity is 400 m/s, and the inlet and outlet angles of blades are equal. The mass of steam flowing through the turbine per hour is 1000 kg. Calculate :*

(i) *Blade angles.*

(ii) *Relative velocity of steam entering the blades.*

(iii) *Tangential force on the blades.*

(iv) *Power developed.*

(v) *Blade efficiency.*

Take blade velocity co-efficient as 0.8.

Solution. Absolute velocity of steam entering the blade, $C_1 = 1200$ m/s

Nozzle blade, $\alpha = 20°$

Mean blade velocity, $C_{bl} = 400$ m/s

Inlet blade angle, θ = Outlet blade angle, ϕ

Blade velocity co-efficient, $K\left(\frac{C_{r_0}}{C_{r_1}}\right) = 0.8$

Mass of steam flowing through the turbine, $m_s = 1000$ kg/h.

Refer Fig. 8. Procedure of drawing the inlet and outlet triangles (LMS and LMN) respectively is as follows :

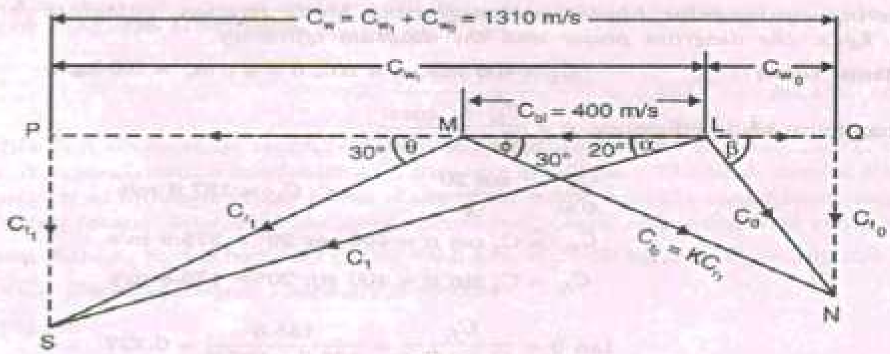


Fig. 8

- Select a suitable scale and draw line *LM* to represent C_{bl}(= 400 m/s).
- At point *L* make angle of 20° (α) and cut length *LS* to represent velocity C_1(= 1200 m/s). Join *MS*. Produce *M* to meet the perpendicular drawn from *S* at *P*. Thus *inlet triangle* is completed.

By measurement : $\theta = 30°,\ C_{r_1} = MS = 830$ m/s

$\theta = \phi = 30°$ (given)

Now, $C_{r_0} = KC_{r_1} = 0.8 \times 830 = 664$ m/s

- At point *M* make an angle of 30° (φ) and cut the length *MN* to represent C_{r_0} (= 664 m/s). Join *LN*. Produce *L* to meet the perpendicular drawn from *N* at *Q*. Thus *outlet triangle* is completed.

(i) **Blade angles θ, φ :**

As the blades are symmetrical (given)

$\therefore \quad \theta = \phi = 30°$. **(Ans.)**

(ii) **Relative velocity of steam entering the blades, C_{r_1} :**

$C_{r_1} = MS = 830$ m/s. **(Ans.)**

(iii) **Tangential force on the blades :**

$$\text{Tangential force} = m_s(C_{w_1} + C_{w_0}) = \frac{1000}{60 \times 60}(1310) = 363.8 \text{ N.} \quad \textbf{(Ans.)}$$

(iv) **Power developed, P :**

$$P = m_s(C_{w_1} + C_{w_0})C_{bl} = \frac{1000}{60 \times 60} \times \frac{1310 \times 400}{1000} \text{ kW} = 145.5 \text{ kW.} \quad \textbf{(Ans.)}$$

(v) **Blade efficiency, η_{bl} :**

$$\eta_{bl} = \frac{2C_{bl}(C_{w_1} + C_{w_0})}{C_1^2} = \frac{2 \times 400 \times 1310}{1200^2} = 72.8\%. \quad \textbf{(Ans.)}$$

Aim: To find the condenser efficiencies.

Theory: Steam condenser is a closed space into which steam exits the turbine and is forced to give up its latent heat of vaporization. It is a necessary component of a steam power plant because of two reasons. It converts dead steam into live feed water. It lowers the cost of supply of cleaning and treating of working fluid. It is far easier to pump a liquid than a steam. It increases the efficiency of the cycle by allowing the plant to operate on largest possible temperature difference between source and sink. The steam's latent heat of condensation is passed to the water flowing through the tubes of condenser. After steam condenses, the saturated water continues to transfer heat to cooling water as it falls to the bottom of the condenser called, hot well. Types of condenser

1. Jet condenser
2. Surface condenser

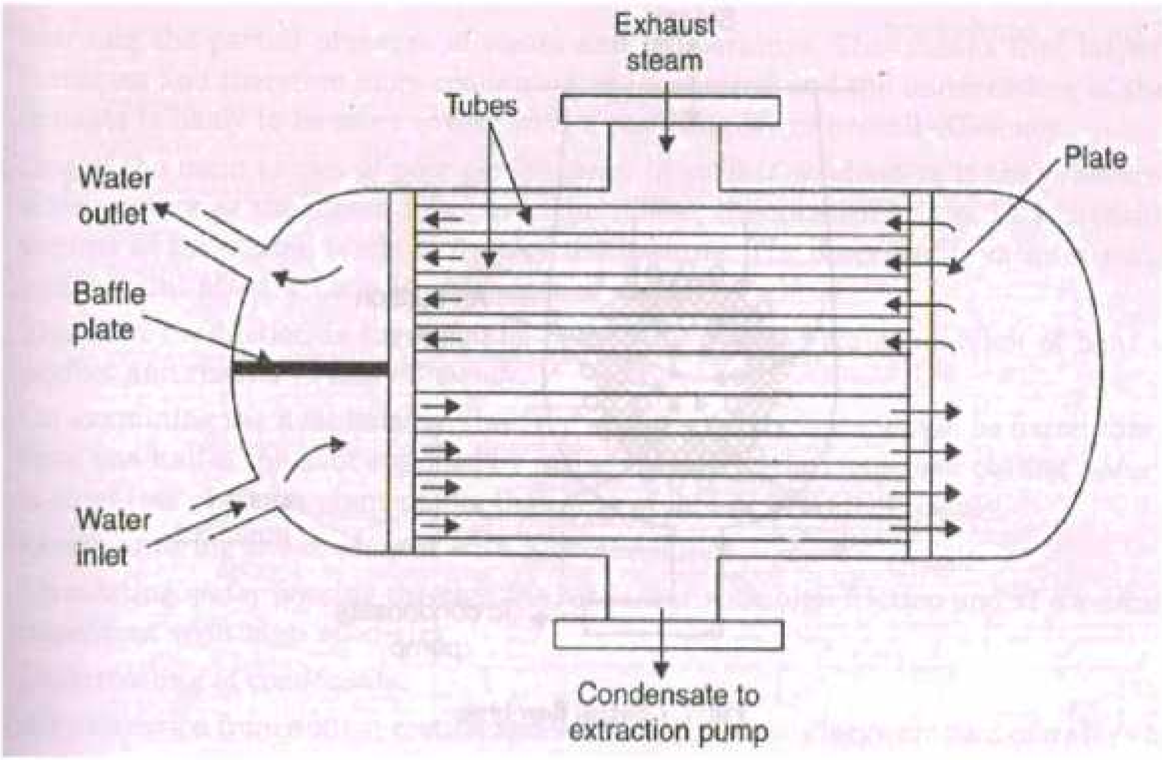
Jet condenser:-

In jet condenser the exhaust steam and water come in direct contact with each other and temperature of the condensate is same as that of cooling water leaving the condenser. The cooling water is usually sprayed into the exhaust steam to cause, rapid condensate.

Surface condenser:- In surface condenser the exhaust steam and water do not come into direct contact. The steam passes over outer surface of tubes through which a supply of cooling water is maintained. There may be single-pass or double-pass. In single pass condenser the water flow in one direction only through all the tubes, while in two-pass condenser the water flow in one direction through the tubes and returns through the remainder.

Comparison between jet and surface condenser

Jet condenser	Surface condenser
Cooling water and are mixed up. Low manufacturing cost. Require small floor area. The condensate cannot be used as feed water in the boiler unless the cooling water is free from impurities. It requires less quantity of cooling water. Less suitable for higher capacity plants.	Cooling water and steam are not mixed up. High manufacturing cost. Require large floor space. Condensate can be reused as feed water as it does not mix with cooling water. It requires large quantity of cooling water. More suitable for higher capacity plants.



Condenser efficiency

It is defined as the ratio of the difference between outlet and inlet temperature of cooling water to the difference between temperature corresponding to the vacuum in the condenser and inlet temperature of cooling water i.e.,

Condenser efficiency =

Numerical

The inlet cooling water temp for a surface condenser is 9°C and outlet temp is 27°C. The vacuum in the condenser is 715mm of mercury when the barometer read 760 mm. find the condenser efficiency.

Solution:

Absolute pressure = 760 – 715

= 45 mm of mercury

= $13600 \times 9.81 \times 45 \times 10^{-3}$

= 0.0612 bar

From steam table

Saturation temp corresponding to this pressure

= 36.2°C

Condenser efficiency =

$= \frac{27-9}{36.2-9}$

= 66.2%

Experiment No: 7

Aim: To study cooling tower and find its efficiency.

Apparatus: Cooling Tower set up.

Theory:

Cooled water is needed for, for example, air conditioners, manufacturing processes or power generation. A cooling tower is equipment used to reduce the temperature of a water stream by extracting heat from water and emitting it to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly. Cooling towers are able to lower the water temperatures more than devices that use only air to reject heat, like the radiator in a car, and are therefore more cost-effective and energy efficient.

Cooling towers use the evaporative cooling principle to cool the circulated water, and they can achieve water temperatures below the dry bulb temperature - t_{db} - of the air cooling air and they are in general smaller and cheaper for the same cooling loads than other cooling systems. Cooling towers are rated in terms of approach and range, where the approach is the difference in temperature between the cooled-water temperature and the entering-air wet bulb - t_{wb} –temperature the range is the temperature difference between the water inlet and exit states. Since a cooling tower is based on evaporative cooling the maximum cooling tower efficiency is limited by the wet bulb temperature -t_{wb} - of the cooling air. The water consumption - the make up water - of a cooling tower is about 0.2-0.3 liter per minute and ton of refrigeration. Compared with the use and waste of city water the water consumption can be reduced with about 90 - 95%.

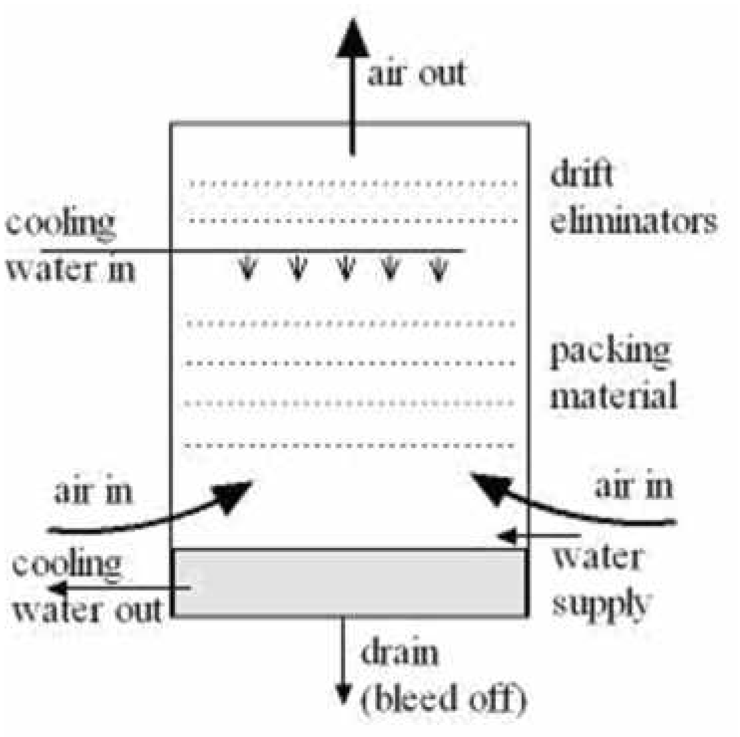
There are two main types of cooling towers

1. Natural draught
2. Artificial draught (Mechanical type)

a. Forced draught (Forced fan)
b. Induced draught (Suction fan)

Natural draught:-

When the circulation of air through the tower is by natural convection, it is known as a natural draught. In this, hot water from the condenser is pumped to top of tower where it is sprayed down through a series of spray nozzles. The hot water after giving its heat to air which circulates through the tower due to natural convection, gets cooled and is collected from bottom of tower.



Artificial draught:-
When the circulation of air through the tower is by artificial convection i. e. Forced fan, Suction fan is known as artificial draught. It is of two types:-

(a) Forced draught:-
The tower is completely encased with discharged opening at the top and fan at the bottom to produce flow of air.

(b) Induced draught:-
Here fan is placed at the top which draws air through the tower. The warm water to be cooled introduce at the top of the tower through spray nozzles. It falls through a series of trays which are arranged to keep the falling water to be broken up into fins drops. The cooled water is collected at the bottom.

Procedure:
1. Make the initial setting as per equipment.
2. Start the experiment and take the temperature readings.
3. Complete the calculations.

Observations & Calculations:

Sr. No.	T_i	T_o	T_{wb}	μ

Cooling Tower Efficiency

The cooling tower efficiency can be expressed as
$\mu = (t_i - t_o)\ 100 / (t_i - t_{wb})$ where
μ = cooling tower efficiency - common range between 70 - 75%
t_i = inlet temperature of water to the tower (^oC or ^oF)
t_o = outlet temperature of water from the tower (^oC or ^oF)
t_{wb} = wet bulb temperature of air (^oC or ^oF)

The temperature difference between inlet and outlet water ($t_i - t_o$) is normally in the range 10 - 15 ^oF.

Conclusion: Hence the efficiency of the cooling tower is _________.

Aim: To find out efficiency of a Rankine cycle.

Theory:- It may be recalled that neglecting pump work, the efficiency of a Rankine cycle is equal to

$$\eta = 1 - h2$$

- The enthalpy of steam h_1 is determined by the pressure and temperature of steam at inlet to the steam turbine.
- The enthalpy of feed water h_3 is determined by condenser pressure.
- The isentropic heat drop = (h_1 –h_2) is determined by the pressure and temperature at entrance to the steam turbine and the pressure at the end of expansion in the turbine i.e. the condenser pressure.

Numerical

In a thermal power plant operating on Rankine cycle, steam at 15 bar and 250°C enter a turbine which generates 40 KW indicated power. If the steam consumption is 300 kg/hr and condenser is maintained at 0.15 bar, determine the final condition of steam, determine Rankine efficiency and relative efficiency. Neglect pump work.

Solution: From steam table

At 15 bar, (steam is superheated)

h_1 = 2923.5 KJ/kg

s_1 = 6.709 KJ/kgK

At 0.15 bar

h_f = 226 KJ/kg

h_{fg} = 2372.2 KJ/kg

s_f = 0.775 KJ/kg

s_{fg} = 7.254 KJ/kg

(a) consider adiabatic expansion from state 1 to 2

$s_1 = s_2$; $s_1 = (s_f + x_2 . s_{fg})$

$6.709 = 0.755 + x_2 \times 7.254$

$x_2 = 0.821$

(b) $h_2 = (h_f + x_2 h_{fg})_{0.15\ bar}$

$= 226 + 0.821 \times 2372.2$

$= 2174.4$ KJ/kg

$h_3 = (h_f)_{0.15\ bar} = 226$ KJ/kg

$\eta = 1 - h2 = 2923.5 - 2174.4 = 0.278$ or 27.8%

1− 32923.5−226

(c) Indicated power = 40 KW = 40 KJ/kg

Heat input = $(h_1 - h_3)$ = (2923.5 -226) KJ/kg

40

Indicated thermal efficiency = 224.79 = 0.718

And relative efficiency = 00.178278 = 0.64 or 64%

Aim:- To study the working of Bomb Calorimeter.

Construction:- The bomb is a thick walled constant volume vessel made of stainless steel which provides considerable resistance to corrosion and can withstand a pressure of about 150 bar. The unit has silica crucible in which is placed a weighted quantity of the fuel sample. The bomb is provided with an electric connection for producing spark, a connection for oxygen supply and a release valve for burnt gages. The bomb is surrounded by jacket containing water. The temperature of this water is kept uniform with the help of motor driven stirrer. The water temperature is measured by a special thermometer reading up to 0.01 degree. The bottom of the bomb also contains about 5gm of water to absorb vapours of sulphur or nitrate in fuel.

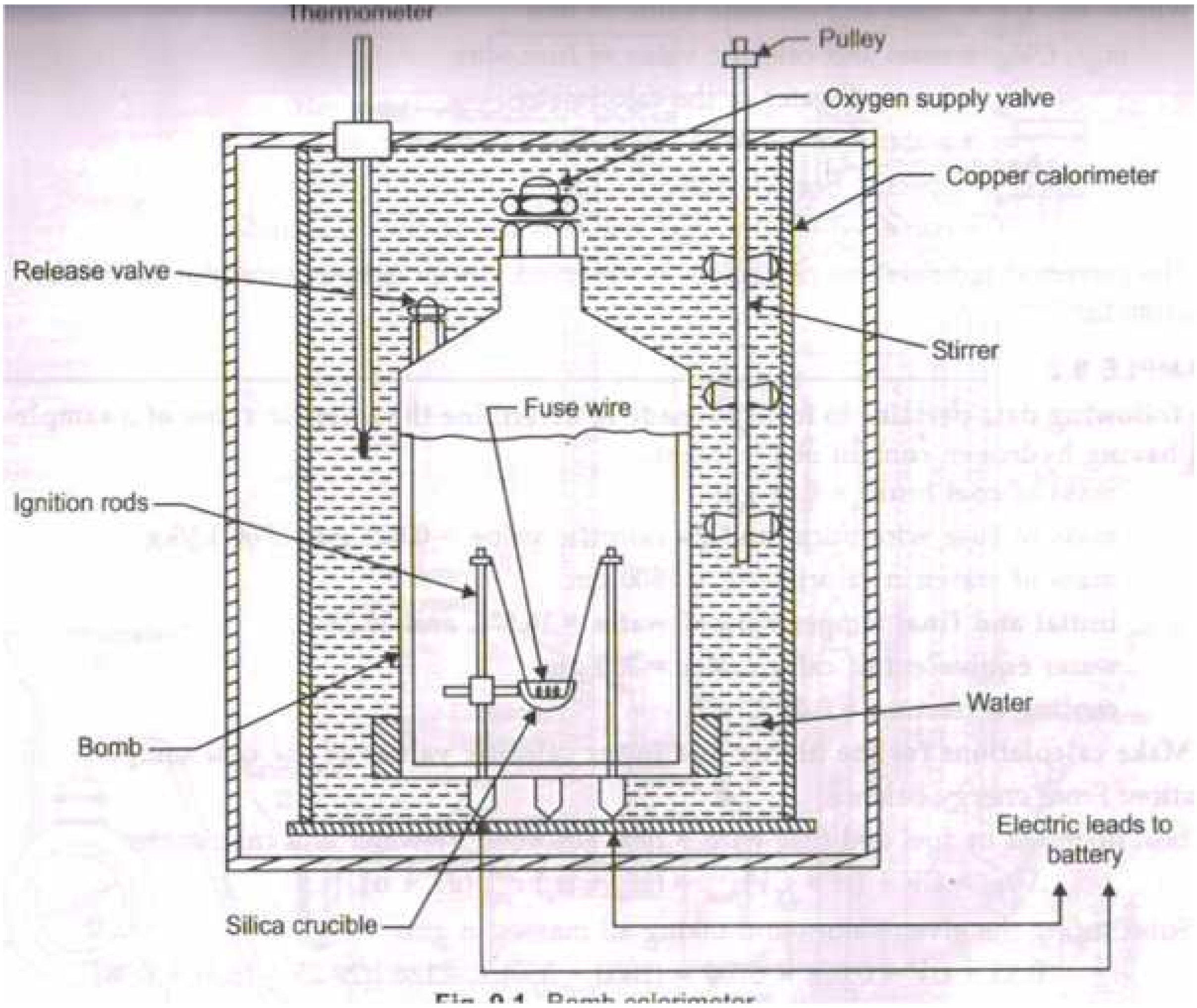


Fig. Bomb Calorimeter

Procedure:- The steps necessary for the conduct of test run are outlined below:

1. A fuel pallet (briquette) of 0.75 to 1 gm is accurately weighed and placed in the crucible.
2. A fuse wire of known mass is stretched between the electrodes and it is ensure that the fuse wire is in contact with the fuel.
3. The oxygen required for burning of fuel is admitted in the bomb through oxygen valve to a pressure of about 25-30 bar.
4. The bomb is placed in the calorimeter (water jacket) which contains a measured quantity of distilled water.
5. The water in the calorimeter is continuously stirred at moderate rate and temperature readings are noted. When the temperature becomes constant, the electric circuit is closed and fuel gets ignited. Due to combustion of fuel, heat is liberated and temperature of water starts rising. Temperature readings are noted at regular intervals until constantancy is observed.
6. Having completed the experiment, the bomb is removed from the calorimeter. The pressure is slowly released through the exhaust valve and the content of the bomb are weighed.

Calculation: The heat generated by the combustion of fuel and fuse wire is partly absorbed by water and partly by the metal of bomb and calorimeter. That is

$$\mathbf{m_f \times CV + m_{fw}\, CV_{fw} = (m_w + m)c_{pw}dT}$$

where m_f, CV = mass and calorific value of fuel

m_{fw} , CV_{fw} = mass and calorific value of fuse wire

m_w = mass of water in the calorimeter

m = water equivalent of bomb and calorimeter

c_{pw} = specific heat of water

dT = corrected temperature rise of water in the calorimeter

The corrected temperature rise refers to observed rise in temperature plus correction for radiation loss.

Precautions:

1. Make sure that all the valves and connections are in proper position before performing the experiment.
2. Check the connections to battery carefully.
3. The oxygen supply valve should be carefully monitored.

AIM: To study and find volumetric efficiency of a reciprocating air compressor.

Apparatus: Two Stage Air Compressor Test Rig consists of a double stage reciprocating type air compressor driven by 2 HP Motor through a belt. The outlet of the air compressor is connected to reservoir (Tank) and suction is connected to another air tank with a calibrated orifice plate and a water manometer. Bellow is fitted on one side of the air tank to regulate the flow. Temperature of inlet air, after single compression, inlet and outlet of second compression and pressure in reservoir and at intermediate stage can be measured by thermometers and gauges.

Utilities Required:
Electricity 3 kW, 220V AC, Single Phase, Floor Area 1.5 x 0.75 m, Tachometer.

Theory:
Reciprocating compressors are often used with air reservoirs to provide compressed air for industrial and civil duties driving air tools etc.

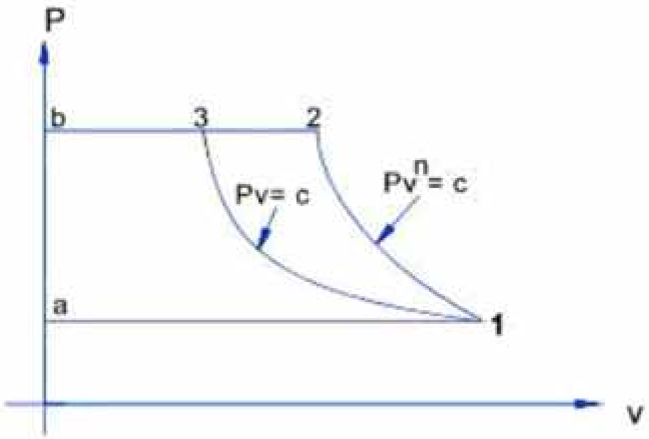
The figure below shows a hypothetical indicator diagram for a single stage -single acting reciprocating compressor.

a-1. Air is drawn into the cylinder on the suction stroke

1-2. The suction valve is closed and air is compressed according to the law $Pv^n = c$

2-b. The delivery valve opens and air is delivered under pressure

b -a. The delivery valve closes and the suction valve opens



The cycles shown is assumed to follow a series of equilibrium states and the gas is assumed to follow the equation of state , PV = RmT throughout....

The theoretical work done on the air per cycle is the area enclosed by [a-1-2-b- a] which equals

$$W = P_2V_2 + \frac{P_2V_2 - P_1V_1}{n-1} - P_1V_1$$

$$= (P_2V_2 - P_1V_1)\left(1 + \frac{1}{n-1}\right)$$

$$= \left(\frac{n}{n-1}\right)(P_2V_2 - P_1V_1)$$

Procedure:

1. Take the initial readings as required like cylinder diameter, pressures, volumes, etc.
2. Now, run the compressor to required time and note the relevant readings.
3. Calculate volumetric efficiency as per the observations and formulas as above.

Observations & Calculations:

HP	RPM	Tank Dimensions (L,B,H)	Max Pressure	No of cylinders

P1	P2	P3	P4	P5	V1	V2	V3	V4	V5	r	n	c	Volumetric Efficiency

Conclusion: Hence the volumetric efficiency of the reciprocating air compressor is ___________.

LOAD TEST ON 4-STROKE, SINGLE CYLINDER DIESEL ENGINE TEST RIG

LOAD TEST ON 4-STROKE, SINGLE CYLINDER DIESEL ENGINE TEST RIG

AIM:

To conduct a load test on 4-stroke, single cylinder diesel engine, to study its performance under various loads.

EQUIPMENT/APPARATUS:

1. 4- Stroke, single cylinder Diesel engine with a rope break dynamometer.
2. Tachometer (0-2000 rpm.)
3. Stopwatch.

SPECIFICATIONS:

Make	:	Kirloskar model AVI
Bore	:	80mm
Stroke	:	110 mm
Rated Speed	:	1500 rpm
Max. B.P	:	3.7KW (5 H.P)
Compression Ratio	:	16 .5:1
Orifice Diameter	:	30mm
Fuel	:	Diesel
Density of Diesel	:	0.827 gm / ml
Calorific Value of Diesel	:	45,350 KJ / kg
Brake drum diameter	:	0.3m
Rope diameter	:	0.015m
Equivalent diameter	:	0.315 m

DESCRIPTION:

This is a water cooled single cylinder vertical diesel engine is coupled to a rope pulley break arrangement to absorb the power produced. Necessary weights and spring balances are included to apply load on the break drum. Suitable cooling water arrangement for the break drum is provided. Separate cooling water lines are provided for the engine cooling. Thermocouples are provided for measuring temperature. A fuel measuring system consists of a fuel tank mounted on a stand, burette, and a 3-way cock.

Air consumption is measured by using a M.S. tank, which is fitted with a standard orifice and a U-tube water manometer that measures the pressures inside the tank.

THEORY:

Single cylinder stationary, constant speed diesel engines are generally quality governed. As such the air supplied to the engine is not throttled as in the case of S.I. engines. To meet the power requirements of the shaft, the quantity of fuel injected into the cylinder is varied by the rack in the fuel pump. The rack is usually controlled by a governor or by a hand. The air flow rate of single cylinder engine operating at constant speed does not vary appreciably with the output of the engine. Since the fuel flow rate varies more or less linearly with output, the fuel air ratio increases with output. Performance tests can be conducted either at constant speed (or) at constant throttle. The constant speed method yields the F.P. of the engine.

STARTING THE ENGINE:

1. Engage de-compression lever before cranking.
2. Crank the engine and disengage the de-compression lever.
3. Adjust the governor to attain the rated speed.

PROCEDURE:

1. Open the three way cock so that fuel flows to the engine directly from the tank.
2. Open the cooling water valves and ensure water flows through the engine.
3. Start the engine and allow running on no load condition for few minutes.
4. Load engine by adding weights upon the hanger.
5. Allow the cooling water in the brake drum and adjust it to avoid spilling.
6. Allow the engine to run at this load for few minutes.
7. Note the following readings
    a) Engine speed.
    b) Weight on the hanger.
    c) Spring balance
    d) Manometer
    e) Time for 10 cc of fuel consumption
8. Repeat the above procedure at different loads.
9. Stop the engine after removing load on the engine.

PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine up to recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed.

GRAPHS

1. T.F.C Vs B .P
2. S.F.C Vs B .P
3. $\rightarrow_{B\ th}$ Vs B .P
4. $\rightarrow_{th}$ Vs B .P
5. $\rightarrow_{m}$ Vs B .P

OBSERVATIONS:

Manometer reading h_1 = ……….. cm of water

Manometer reading h_2 = ……….. cm of water

S.NO	Load on the brake drum			Speed, Rpm	Time for 10 cc of fuel , Sec	T.F.C, Kg/hr	S.F.C, Kg/Kw-hr	B.P, KW	H.I, KW	I.P, K.W	I.M.E.P ,KPa	B.M.E.P, KPa	Efficiencies			
	W_1 Kg	W_2 Kg	W Kg										→B th	→th	→m	→Vol
1																
2																
3																
4																
5																

SAMPLE CALCULATIONS:

1 Engine output (Brake Power) [B.P] $= \dfrac{2\sigma NT}{60 \times 1000}$ …… KW

Where,

N = Rated speed ….. Rpm,

W_0 = Weight of hanger = 1.0 kg

W_1 = Weight on hanger ………. kg

W_2 = spring balance reading ……….kg

R_e = Effective brake drum radius = (R + r) … m

Where R is Brake drum radius

r is Rope radius

W = Net Load = $[(W_1\text{-}W_2) + W_0] \times 9.81$ ……… N

T= ($W * R_e$)…………N-m

2 Indicated Power

Time for 10cc of fuel consumption, t = ……. Sec,

Mass of fuel consumption per min, $m_f = \dfrac{10}{t} \times \dfrac{Sp.Gravity\ of\ diesel}{1000} \times 60$ ..kg/ min.

Total Fuel consumption, TFC = … $m_f \times 60$….kg / hr.

Specific fuel consumption, SFC = $\dfrac{T.F.C}{B.P}$ ……..Kg / Kw-hr

Heat Input, HI = $\frac{TFC \times CV}{60 \times 60}$ …….KW

Where CV is calorific value of Diesel = 45,350 KJ / kg

Indicated Power, I.P = B.P + F.P

Where F. P = Frictional Power from William's line diagram (TFC Vs B.P)

3. Brake thermal efficiency, $\eta_{B\ th} = \frac{B.P}{HI} \times 100$

4 Indicated thermal efficiency, $\eta_{th} = \frac{I.P}{HI} \times 100$

5 Mechanical efficiency, $\eta_{m} = \frac{B.P}{I.P} \times 100$

6 I.M.E.P = $\frac{I.P \times 60}{L \times A \times n \times K}$ …..KPa

7 B.M.E.P. = $\frac{B.P \times 60}{L \times A \times n \times K}$ …….KPa

Where L = Stroke of length ……'m'

A = Cross section area of piston in 'm^2'

n = Number of working strokes = $\frac{N}{2}$ (for 4 stroke engine)

K = Number of cylinders =1

8 Volumetric Efficiency, $\eta_{vol} = \frac{V_s}{V_t} \times 100$

i) <u>Actual Air intake:</u>

Manometer reading h_1 = ………….cm of water

Manometer reading h_2 = ………….cm of water

Difference in water level, $h_w = \frac{h_1 - h_2}{100}$ ……………….m of water

Equivalent air column, $h_a = h_w \times \frac{Density\ of\ water}{Density\ of\ air} = h_w \times \frac{1000}{1.16}$ ….m. of air

Orifice diameter, d = 0.03 m

Area of orifice, $a = \frac{\pi \times (0.03)^2}{4}$ ……..m^2

Actual Volume of air intake, $V_a = 60 \times C_d \times a \times \sqrt{2gh_a}$ ……..m^3 / min.

Where C_d = 0.62

Mass of air intake, $m_a = \rho_a \times V_a$ ……kg / min

Density of air ρ_a = 1.16 Kg/m^3

ii) <u>Theoretical Air intake:</u>

Diameter of piston, D = 0.102 m

Stroke length, L = 0.116 m

Engine speed, N = ………..rpm

Theoretical volume of air intake, V_t = $\frac{|®}{4} \; | \; D^2 \; | \; L \; | \; \frac{N}{2}$ …..m^3 / min

Volumetric efficiency, $\rightarrow_{vol} = \frac{Vs}{Vt} \, | 100$

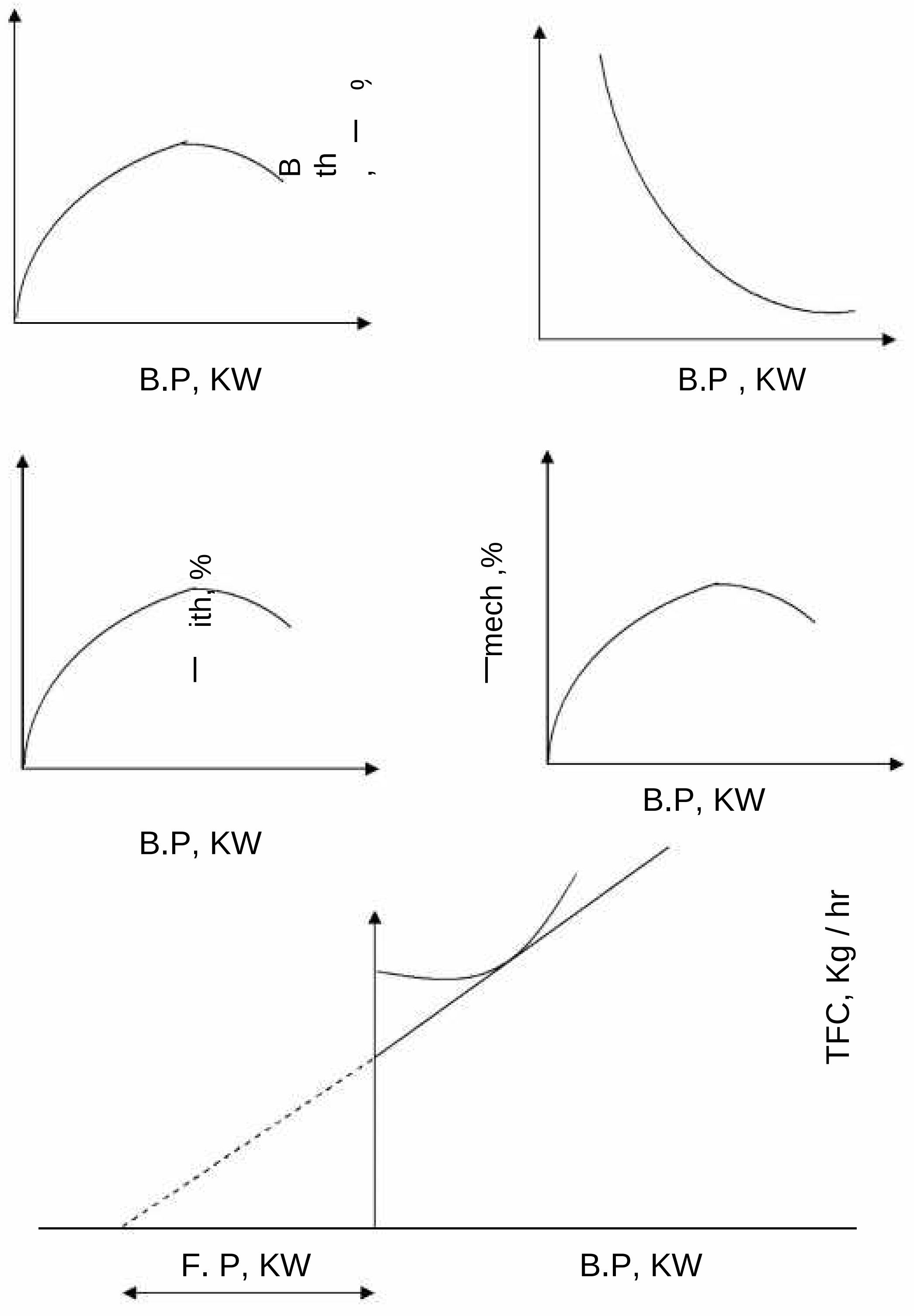
Swept volume at STP, $V_s = V_a \; | \; \frac{Ts}{Ta}$…….$m^3$/min

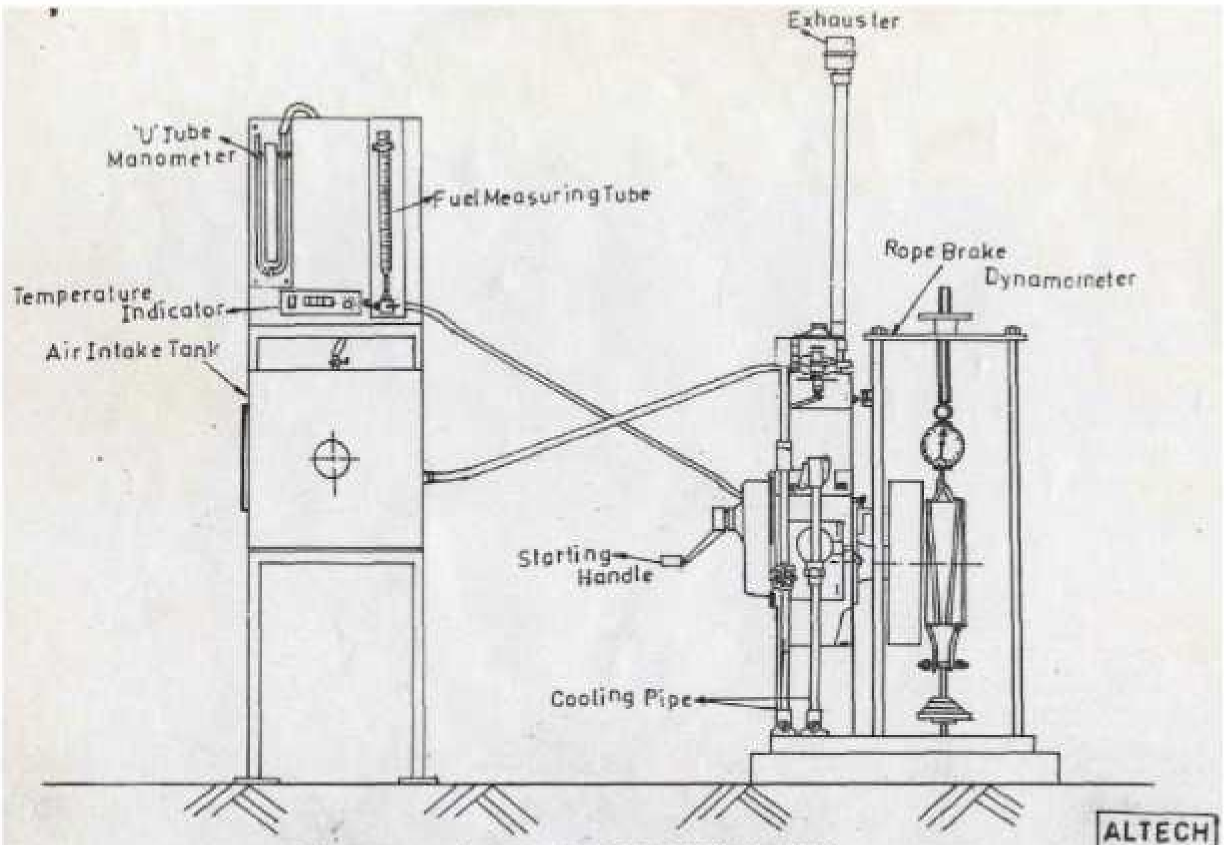
Where T_a = Ambient Temperature……. ^{0} K

T_s = Standard Temperature, 288^0K

9 Air- Fuel Ratio = $\frac{Mass\ of\ actual\ air\ intake\ per\ minute\ (kg/min)}{Mass\ of\ fuel\ intake\ per\ minute\ (kg/min)}$ X $\frac{m_a}{m_f}$

MODEL GRAPHS:





SINGLE CYLINDER DIESEL ENGINE WITH
MECHANICAL DYNAMOMETER TEST RIG

LOAD TEST ON 4-STROKE, MULTI CYLINDER PETROL ENGINE TEST RIG

LOAD TEST ON 4-STROKE, MULTI CYLINDER PETROL ENGINE TEST RIG

AIM: To conduct a load test on 4-stroke,4-cylinder petrol engine and study its performance under various loads.

EQUIPMENT REQUIRED:

1. 4-stroke, 4 -cylinder petrol engine with a hydraulic dynamometer.
2. Tachometer (0-2000 rpm)
3. Stop watch

SPECIFICATIONS:

Make	:	Ambassador
No. of cylinders	:	4
Bore	:	73 mm
Stroke	:	90 mm
Rated Speed	:	1500 rpm
B. P.	:	7.35 KW(10 HP)
Orifice Diameter	:	35mm
Fuel	:	Petrol
Specific Gravity of petrol	:	0.716
Density of petrol	:	716 kg/m^3
Caloric value of petrol	:	47100 KJ/kg

DESCRIPTION:

The test rig consists of a multi cylinder petrol engine coupled to a hydraulic dynamometer. The engine is Ambassador Brand and is 4-cylinder 4-stroke vertical engine developing 7.35 KW(10HP) at 1500 rpm. This type of engine is best suited for automobiles which operate at varying speed. The engine is fitted on a rigid bed and is coupled through a flexible coupling to a hydraulic dynamometer, acts as the loading device. All the instruments are mounted on a suitable panel board. Fuel consumption is measured with a burette and a 3-way cock which regulates the flow of fuel from the tank to the engine.

Air consumption is measured by using a M.S. tank, which is fitted with a standard orifice and a U-tube water manometer that measures the pressures inside the tank.

STARTING THE ENGINE:

1. Disengage the clutch and start the engine using the ignition key.
2. Engage the clutch slowly.
3. Adjust the throttle valve, so that the engine attains rated speed.

PROCEDURE:

1. Open the three way cock so that fuel flows to the engine directly from the tank.
2. Open the cooling water valves and ensure water flows through the engine.
3. Open the water line to the hydraulic dynamometer.
4. Start the engine and allow it to run on no load for a few minutes.
5. Operate the throttle valve so that the engine picks up the speed to the required level.
6. Load engine with hydraulic dynamometer-loading is done by turning the handle in the direction marked. If sufficient loaded is not absorbed by the dynamometer at the required speed, the outlet valve in the dynamometer can be closed to increase the pressure (as indicated by the pressure gauge) and hence the load.
7. Engine speed decreases with increase in load. Hence to increase the speed, open the throttle valve.
8. Allow the engine to run at this load for few minutes
9. Note the following readings
    a) Engine speed.
    b) Hydraulic dynamometer reading.
    c) Manometer reading.
    d) Time for 10 cc of fuel consumption
10. Repeat the above procedure at different loads.
11. Stop the engine after removing the load on the engine.

PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine upto recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed.

GRAPHS:

1. T.F.C Vs B .P
2. S.F.C Vs B .P
3. $\rightarrow_{B\ th}$ Vs B .P
4. $\rightarrow_{th}$ Vs B .P
5. $\rightarrow_{m}$ Vs B .P

OBSERVATIONS:

Manometer reading h_1 = ……….. cm of water

Manometer reading h_2 = ……….. cm of water

Sl. No0	Load on the Dynamometer W Kg	Speed, Rpm	Time for 10 cc of fuel (sec)	T.F.C Kg/hr	S.F.C Kg/Kw.hr	B.P KW	H.I. KW	I.P KW	I.M.E.P KPa	B.M.E.P. KPa	Efficiencies			
											→ B th	– I th	– m	→vol
1														
2														
3														
4														
5														

CALCULATIONS:

1 Brake Power (BP) = $\frac{W \times N}{2000 \times 1.36}$ …….KW

Where,

N= rated speed …… rpm,

W=load on the Dynamometer …….. Kg

2 Indicated Power

Time for 10cc of fuel consumption, t = ……. Sec,

Mass of fuel consumption per min, $m_f = \frac{10}{t} \times \frac{density\ of\ diesel}{1000} \times 60$ …kg/ min.

Total Fuel consumption, TFC = $m_f \times 60$….kg / hr.

Specific fuel consumption, SFC = $\frac{T.F.C}{B.P}$ ……..Kg / Kw-hr

Heat Input, HI = $\frac{TFC \times CV}{60 \times 60}$ …….KW

Where CV is calorific value of Petrol = 47100 KJ / kg

Indicated Power, I.P = B.P + F.P

Where F.P = Frictional Power from William's line diagram (TFC Vs B.P)

3. Brake thermal efficiency, $\eta_{B\,th} = \frac{B.P}{HI} \times 100$

4 Indicated thermal efficiency, $\eta_{th} = \frac{I.P}{HI} \times 100$

5 Mechanical efficiency, $\eta_{m} = \frac{B.P}{I.P} \times 100$

6 I.M.E.P = $\frac{I.P \times 60}{L \times A \times n \times K}$ …..KPa

7 B.M.E.P. = $\frac{B.P \times 60}{L \times A \times n \times K}$ …….KPa

Where L = Stroke of length ……'m'

A = Cross sectional area of piston in 'm^2'

n = Number of working strokes = $\frac{N}{2}$ (for 4 stroke engine)

K = Number of cylinders = 4

8 Volumetric Efficiency, $\eta_{vol} = \frac{V_s}{V_t} \times 100$

i. <u>Actual Air intake:</u>

Manometer reading h_1 = …………..cm of water

Manometer reading h_2 = …………..cm of water

Difference in water level, $h_w = \frac{h_1 - h_2}{100}$ ………………..m of water

Equivalent air column, $h_a = h_w \times \frac{Density\ of\ water}{Density\ of\ air} = h_w \times \frac{1000}{1.16}$ ….m. of air

Orifice diameter, d = 0.035 m

Area of orifice, $a = \frac{3.14 \times (0.035)^2}{4}$ ……..m^2

Actual Volume of air intake, $V_a = 60 \times C_d \times a \times \sqrt{2gh_a}$ …….m^3 / min.

Where C_d = 0.62

Mass of air intake, $m_a = \rho_a \times V_a$ ……kg / min

Density of air ρ_a = 1.16 Kg/m^3

ii. <u>Theoretical Air intake:</u>

Diameter of piston, D = 0.073 m

Stroke length, L = 0.090 m

Engine speed, N = ………..rpm

Theoretical volume of air intake, $V_t = \frac{\pi}{4} \times D^2 \times L \times \frac{N}{2} \times 4$ …..m^3 / min

Volumetric efficiency, $\eta_{vol} = \frac{Vs}{Vt} \times 100$

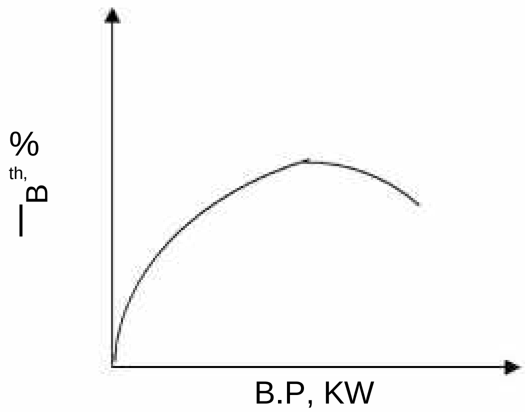
Swept volume at STP, $V_s = V_a \times \frac{Ts}{Ta}$ …….m^3/min

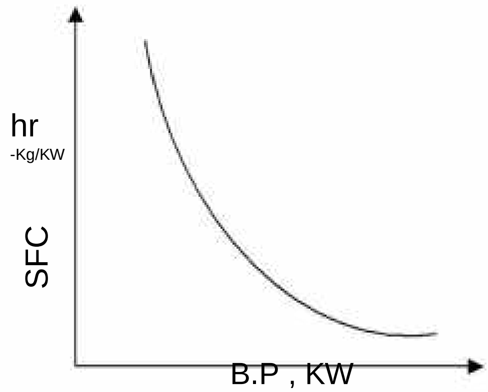
Where T_a = Ambient Temperature …….^{0} K

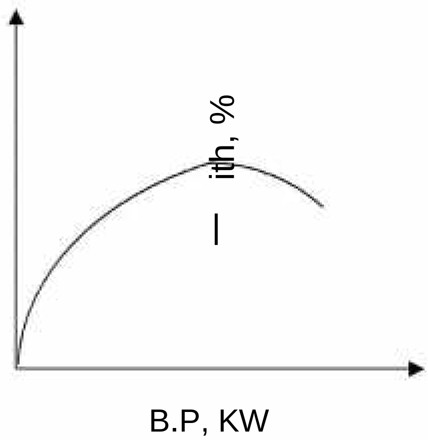
T_s = Standard Temperature, 288^0K

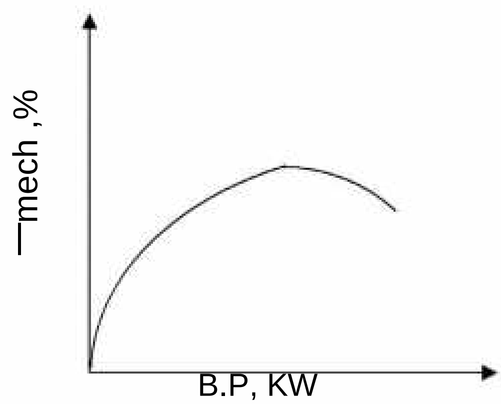
9 Air Fuel Ratio = $\frac{Mass\ of\ actual\ air\ intake\ per\ minute\ (kg/min)}{Mass\ of\ fuel\ intake\ per\ minute\ (kg/min)} X \frac{m_a}{m_f}$

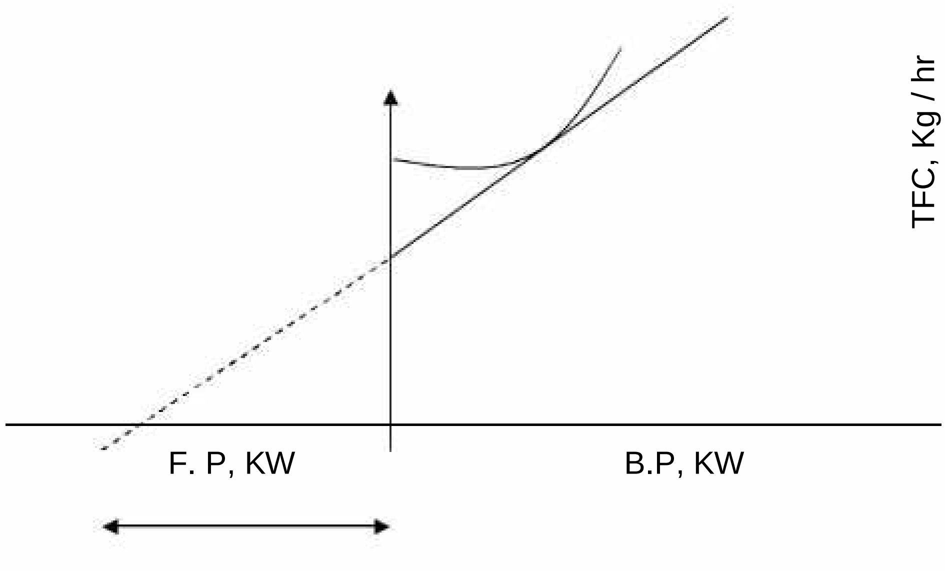
MODEL GRAPHS:

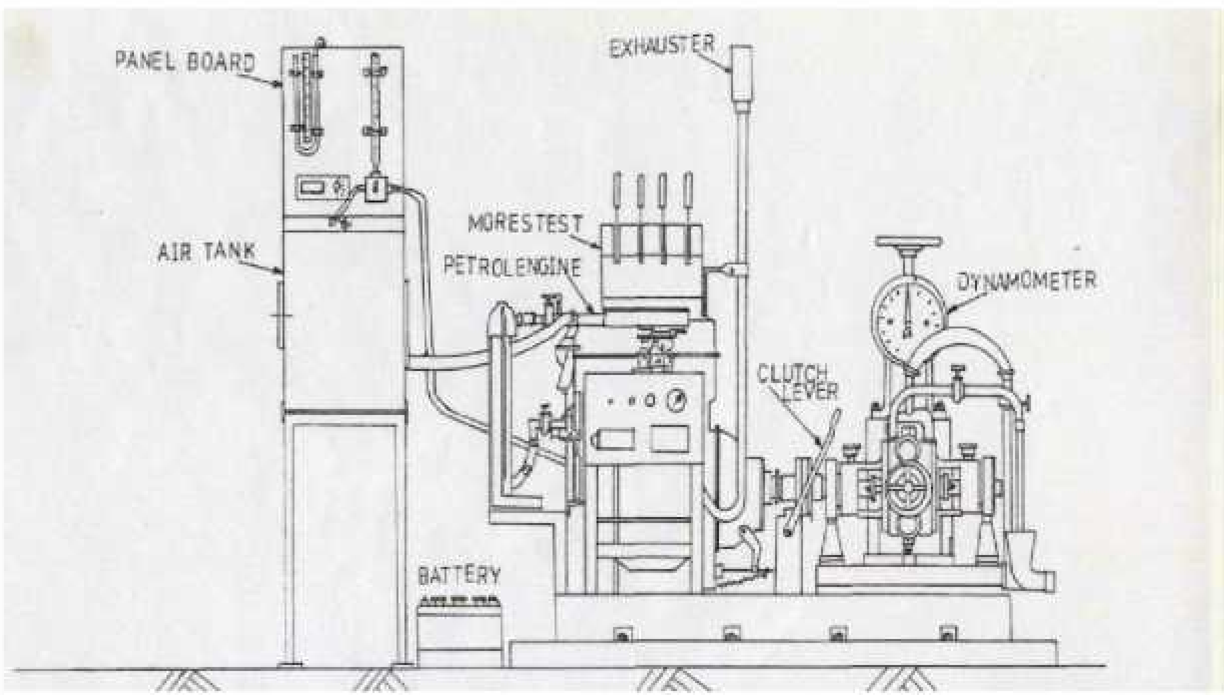











PANEL BOARD
EXHAUSTER
AIR TANK
MORESTEST
PETROLENGINE
DYNAMOMETER
CLUTCH LEVER
BATTERY

LOAD TEST ON 4-STROKE, SINGLE CYLINDER PETROL ENGINE TEST RIG

LOAD TEST ON 4-STROKE, SINGLE CYLINDER PETROL ENGINE TEST RIG

AIM: To conduct a load test on a 4-stroke, single cylinder petrol engine and study its performance under various loads.

EQUIPMENT/APPARATUS:

1. 4 –stroke ,Single cylinder , petrol engine with electrical loading
2. Tachometer
3. Stopwatch

.**SPECIFICATIONS:**

Make	:	Greaves
Stroke	:	66.7mm
Bore	:	70mm
Capacity	:	256 cc
Rated R.P.M	:	3000rpm
Out put	:	2.2KW
Fuel	:	Petrol
Sp. Gr. Of petrol	:	0.716
Calorific Value of petrol	:	47100 KJ/Kg

DESCRIPTION:

Petrol engine is an air cooled, single cylinder, Vertical, 4-stroke engine developing about 2.2 KW (3HP) at 3000RPM. The engine is rope started.

The petrol engine is coupled to an alternator, which serves as a loading device. The power generated by the alternator is absorbed using water rheostat. Suitable control panel with voltmeter and ammeter is provided to measure the power generated. Fuel consumption is measured with a burette and a three-way cock, which regulates the flow of petrol from the tank to the engine.

EXPERIMENTAL PROCEDURE:

1. Open the three way cock so that fuel flows to the engine directly from the tank.
2. Start the engine and allow running on no load condition for few minutes.
3. Load the engine, by loading the water rheostat.

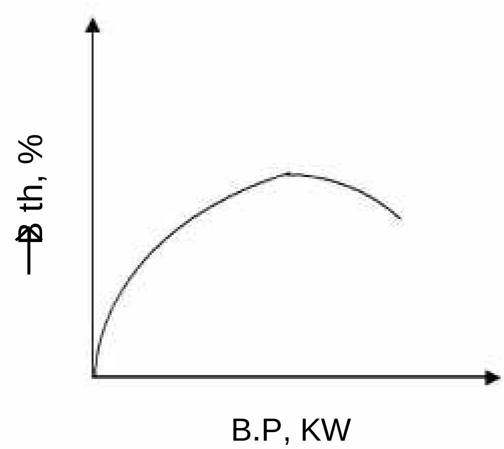
4. Note the following readings
    a) Speed.
    b) Voltmeter reading.
    c) Ammeter reading.
    d) Time taken for 10 c.c of petrol consumption.
5. Repeat the above procedure at different loads.
6. Stop the engine after removing load on the engine

PRECAUTIONS:

1. Before starting the engine check all the systems such as cooling, lubrication and fuel system.
2. .For stopping the engine, load on the engine should be removed

MODEL GRAPHS :

1. —B th Vs B.P



OBSERVATIONS:

S.NO	1	2	3	4	5
Output voltage, V …. volts					
Out put current, A….. amps					
Alternator output,P …… KW					
Engine Speed, N …… Rpm					
Engine output, $B.P_{Eng}$ ….. KW					
Time for 10c.c of fuel consumption t, sec					
Engine input, HI… …. KW					
Thermal efficiency %					

SAMPLE CALCULATIONS:

1. Engine output (Brake Power):

   Voltmeter reading =V…..volts

   Ammeter reading =A ….amps

   Power generated by alternator, P = $\frac{V \times A}{1000}$……. KW

   Engine out put, $B.P_{eng}$= $\frac{P}{0.8}$……. KW

   (Where 0.8 is assumed as alternator efficiency)

2. Indicated Power

   Time for 10cc of fuel consumption, t = ……. Sec,

   Mass of fuel consumption per min, m_f = $\frac{10}{t} \times \frac{Sp.Gravity\ of\ Petrol}{1000} \times 60$ ..kg/ min.

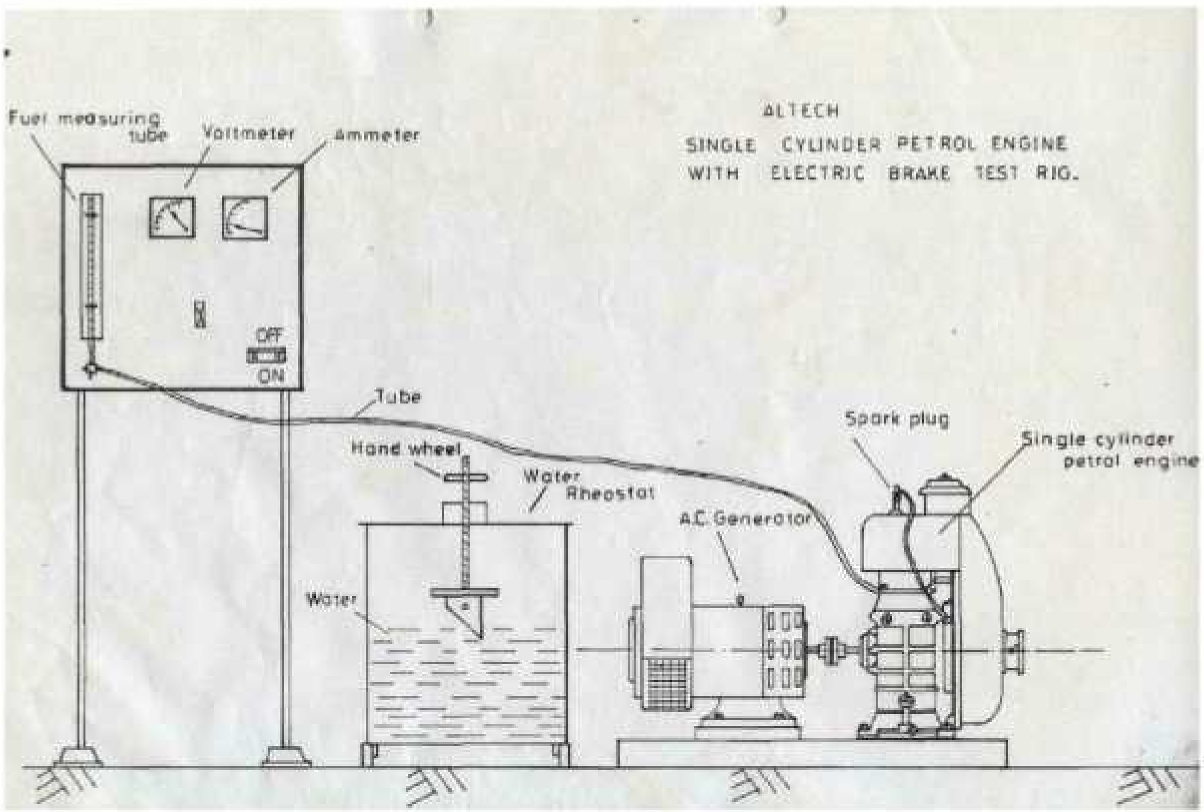
Total Fuel Consumption TFC = … $m_f \times 60$….kg / hr.

Heat Input, HI = $\dfrac{TFC \times CV}{60 \times 60}$ …….KW

Where CV is calorific value of petrol = 47100 KJ/ kg

3. Brake thermal efficiency, $\eta_{B\,th} = \dfrac{B.P}{HI} \times 100$

RESULT:


ALTECH
SINGLE CYLINDER PETROL ENGINE
WITH ELECTRIC BRAKE TEST RIG.
Fuel measuring tube
Voltmeter
Ammeter
OFF
ON
Tube
Spark plug
Single cylinder petrol engine
Hand wheel
Water Rheostat
A.C. Generator
Water

LOAD TEST ON 2- STROKE, SINGLE CYLINDER PETROL ENGINE TEST RIG

LOAD TEST ON 2- STROKE, SINGLE CYLINDER PETROL ENGINE TEST RIG

AIM: To conduct a load test on a single cylinder, 2- Stroke petrol engine and study its performance under various loads.

EQUIPMENT & APPARATUS:

1. 2-Stroke, Single Cylinder Petrol Engine with Rope Brake Dynamometer
2. Tachometer
3. Stop Watch

SPECIFICATIONS:

Make	:	Bajaj
Stroke	:	66.7mm
Bore	:	70mm
Capacity	:	150cc
Rated R.P.M	:	3000rpm
Out put	:	2.2KW
Fuel	:	Petrol
Sp. Gr. Of petrol	:	0.716
Calorific Value of petrol	:	47100 KJ/Kg
Lubrication	:	3% mixture of self mixing oil and petrol

DESCRIPTION:

Petrol engine is an air cooled, single cylinder, Vertical, 2-stroke engine. The engine is kick started.

The petrol engine is coupled through the gear box to a water cooled rope brake dynamometer to absorb the power produced. The speed ratio between the engine and brake drum is 5:1(Top gear engaged). Fuel consumption is measured with a burette and a stop watch. A three-way cock, which regulates the flow of petrol from the tank to the engine.

PROCEDURE:

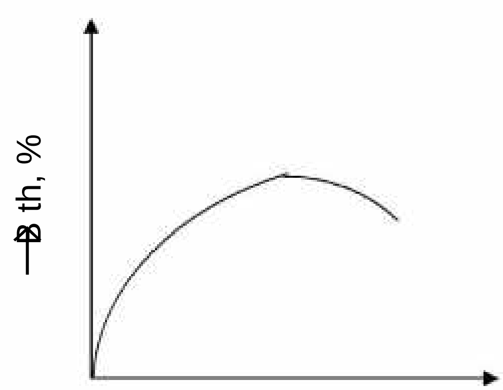
1. Open the three way cock so that fuel flows to the engine directly from the tank.
2. Start the engine and allow running on no load condition for few minutes.
3. Load the engine, by adding weights on the hanger.
4. Note the following readings
    a) Speed.
    b) Weight on the hanger.
    c) Spring balance.
    d) Time taken for 10 c.c of petrol consumption.
5. Repeat the above procedure at different loads.
6. Stop the engine after removing load on the engine

PRECAUTIONS

1. Use only petrol mixed with 2T oil – use higher oil /petrol ratio to compensate for the lack of cooling air (air flow over the engine while moving) in the stationary test rig
2. Changing gear oil regularly.
3. Never run the engine with insufficient fuel

MODEL GRAPHS :

→ß th Vs B.P



OBSERVATIONS:

Particulars	1	2	3	4	5
Weight on Hanger , W_1…. Kg					
Spring balance reading, W_2 …..Kg					
Net load ,W					
Engine Speed ,N_{Eng} ……Rpm					
Brake Drum Speed, N…..Rpm					
Engine output, B.P ….. KW					
Time for 10c.c of fuel consumption t, sec					
Engine input, HI… …. KW					
Thermal efficiency %					

SAMPLE CALCULATIONS:

1. Engine output (Brake Power) [B.P] = $\frac{2\sigma NT}{60 | 1000}$ …… KW

Where,

N_{Eng} = Engine speed….rpm

N = Brake Drum speed ….. Rpm

N $= \frac{N_{Eng}}{5}$

W_0 = Weight of hanger = 1.0 kg

W_1 = Weight on hanger ………. kg

W_2 = spring balance reading ……….kg

W = Net Load = $[(W_1-W_2) + W_0] | 9.81$ ……… N

R_e = Effective brake drum radius = (R+ r)… m

Where R is Brake drum radius = 0.2 m

r is Rope radius = 0.015m

T = $(W * R_e)$…………N-m

Time for 10cc of fuel consumption, t = ……. Sec,

Mass of fuel consumption per min, $m_f = \frac{10}{t} \times \frac{Sp.Gravity\ of\ Petrol}{1000} \times 60$ ..kg/ min.

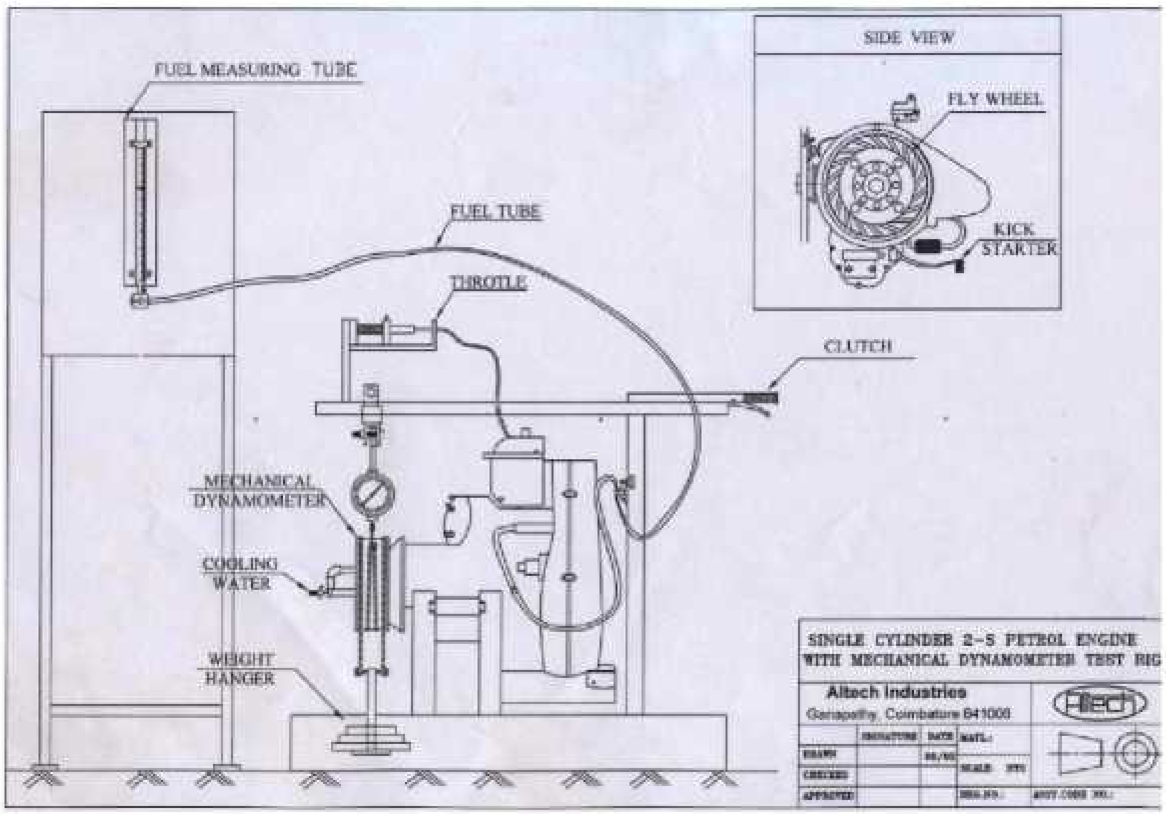
Total Fuel Consumption TFC = $m_f \times 60$….kg / hr.

Heat Input, HI = $\frac{TFC \times CV}{60 \times 60}$ …….KW

Where CV is calorific value of given fuel = 47100 KJ/ kg

2. Brake thermal efficiency, $\eta_{b\,th} = \frac{B.P}{HI} \times 100$

RESULT


SIDE VIEW
FLY WHEEL
KICK STARTER
FUEL MEASURING TUBE
FUEL TUBE
THROTLE
CLUTCH
MECHANICAL DYNAMOMETER
COOLING WATER
WEIGHT HANGER
SINGLE CYLINDER 2-S PETROL ENGINE WITH MECHANICAL DYNAMOMETER TEST RIG
Altech Industries
Ganapathy, Coimbatore 641006

LOAD TEST ON 4-STROKE, SINGLE CYLINDER VARIABLE COMPRESSION RATIO PETROL ENGINE TEST RIG

LOAD TEST ON 4- STROKE, SINGLE CYLINDER PETROL ENGINE TEST RIG WITH VARIABLE COMPRESSION RATIO

AIM: To conduct a load test on a single cylinder, 4-stroke variable compression ratio petrol engine and study its performance under various compression ratios .

EQUIPMENT REQUIRED:

1. Single cylinder petrol engine with electrical loading.
2. Stop watch

SPECIFICATIONS:

Make	:	Crompton Greaves
Stroke, L	:	66.7mm
Bore, D	:	70mm
Swept volume, V	:	256 cm^3
Rated R.P.M	:	3000rpm
Out put	:	2.2KW
Compression ratio, CR	:	4.67:1
Orifice Diameter	:	15mm
Fuel	:	Petrol
Sp. Gr. Of petrol	:	0.716
Calorific Value of petrol	:	47100 KJ/Kg
Staring	:	By rope
Loading	:	Electrical, Air heater connected to AC Generator
Cooling	:	Air cooling

INTRODUCTION:

Internal combustion engines develop varying brake power depending on the compression ratio, while the other parameters held constant. For compression ignition engines, the compression ratio is brought to be above certain value for ignition to take place, but the spark ignition engines can be operated at lower compression ratios. The ignition being controlled by spark strength and advance.

The effect of compression ratio, which of present concern is studied in the present test rig.

DESCRIPTION:

The Test Rig consists of Four-Stroke Petrol Engine (Air Cooled) to be tested for performance is coupled to AC Generator .To facilitate the change in compression ratio, an auxiliary head-piston assembly above the main head has been provided. The auxiliary piston is operated up-down by hand wheel-screw rod assembly to fix the required compression ratio. When the piston is in the bottom most position, the compression ratio is at its maximum value, and in the top most position it is at minimum value of 2s. The minimum clearance volume is 35 cc when the piston it is at bottom most position. The charge from this initial volume of clearance is determined by the displacement of the piston and thus used for calculation of the compression ratio.

Compression Ratio $= \frac{SweptVolume + ClearenceVolume}{ClearenceVolume}$

Swept Volume : 250 cc (fixed)

Clearance Volume : Initial clearance volume + Additional clearance volume due to auxiliary piston movement

Clearance Volume $: 35cc + \frac{\pi d^2}{4cc} \times l$

Where, d is the diameter of auxiliary piston = 70 mm, l is the axial movement of piston.

The hand wheel which operates the screw holding the auxiliary piston is provided with holes circumferentially along the locking plate. The bolts used for locking the movement of screw are loosened and the hand wheel is operated. A scale with the compression ratio directly marked is provided for indicating this. After adjusting to the required compression ratio, all the bolts are tightened well before conducting experiment. The rate of fuel Consumption is measured by using Volumetric Pipette. Air Flow is measured by Manometer, connected to air box.

The different electrical loading are achieved by loading the Electrical generator in steps which is connected to the Air Heaters (Resistance Load)The engine speed & AC Alternator speed are measured by electronic digital counter. Temperatures at air inlet and engine exhaust gas are measured by electronic digital temperature indicator with thermocouple.

The whole instrumentation is mounted on a self-contained unit ready for operation.

PROCEDURE:

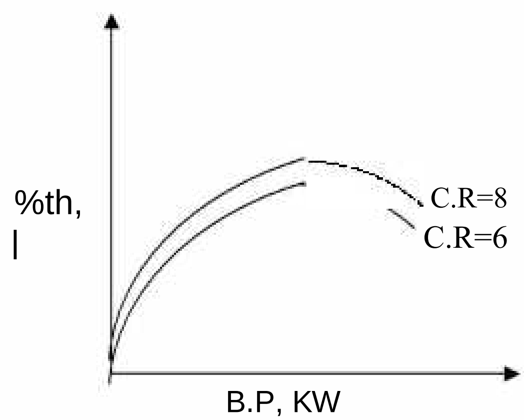
1. Loosen the locking bolt of the auxiliary piston screw rod assembly
2. Rotate the hand wheel and bring the indicator to the required compression ratio
3. Lock the screw rod assembly before conducting the experiment for the compression ratio selected.
4. Open the 3-way cock. So that fuel flows into the engine.
5. Supply the cooling water to engine head.
6. Start the engine and allow it to run on no load condition for few minutes.
7. Apply the load on the engine by switching ON the heater switch which is provided on the control panel loading the AC generator by switching
8. Allow the engine to run at this load for few minutes.
9. Note the following readings.
   a) Engine Speed
   b) Energy meter
   c) Manometer
   d) Time for 10cc of fuel consumption
10. Repeat the procedures 8 & 9 at different loads.
11. Stop the engine after removing load on the engine
12. Change the compression ratio and repeat the above procedure.

PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine upto recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed
5. Don’t increase the compression ratio beyond 8.0

GRAPHS

1. ➙ th Vs B .P



OBSERVATIONS:

Compression Ratio =6

S.NO	Loading Switches	Speed rpm	Time for 10 cc fuel consumption, Sec	Energy meter reading for 'n' number of revolutions, Sec	m_f Kg/min	T.F.C, Kg/hr	H.I KW	B.P (elec) KW	B.P (eng), KW	$\eta_{thermal}$

Compression Ratio =8

S.NO	Loading Switches	Speed rpm	Time for 10 cc fuel consumption, Sec	Energy meter reading for 'n' number of revolutions, Sec	m_f Kg/min	T.F.C, Kg/hr	H.I KW	B.P (elec) KW	B.P (eng), KW	$\eta_{thermal}$

SAMPLE CALCULATIONS:

Engine output (Brake Power):

Engine out put, B.P (elec) = $\frac{n \times 60 \times 60}{E_m \times t}$ ……. KW

B.P (eng) = $\frac{BP_{elec}}{\eta_{tran}}$……. KW

Where

n = No. of revolution of energy meter

E_m = Energy meter constant = rev / Kw – hr

t= time for ' n' revolutions of energy meter in sec

η_{trans} = transmission efficiency = 0.7=

Indicated Power

Time for 10cc of fuel consumption, t = …19.66…. Sec,

Mass of fuel consumption per min, m_f = $\frac{10}{t} \times \frac{Sp.Gravity.of.petrol}{1000} \times 60$

……. Kg / min.

Total Fuel Consumption, TFC = $m_f \times 60$….kg / hr.

Heat Input, HI = $\frac{TFC \times CV}{60 \times 60}$ …….KW

=

Where CV is calorific value of given fuel = 47100 KJ/ kg

Brake thermal efficiency, $\eta_{B\,th} = \frac{B.P}{HI} \times 100$

Result:

HEAT BALANCE TEST ON 4-STROKE, SINGLE CYLINDER DIESEL ENGINE TEST RIG

HEAT BALANCE TEST ON 4-STROKE, SINGLE CYLINDER DIESEL ENGINE TEST RIG

AIM: To conduct a Heat Balance Test on a 4- stroke single cylinder vertical diesel engine at different loads and to draw up a heat balance sheet on minute basis.

EQUIPMENT / APPARATUS:

1. 4-Stroke,Single cylinder Diesel engine with a rope break dynamometer.
2. Tachometer (0-2000 rpm.)
3. Stopwatch.

SPECIFICATIONS

Make	:	Kirloskar model AVI
Bore	:	80mm
Stroke	:	110 mm
Rated Speed	:	1500 rpm
Max. B.P	:	3.7KW
Compression Ratio	:	16 .5:1
Orifice diameter	:	30mm
Fuel	:	Diesel
Density of Diesel	:	0.827 gm / ml
Calorific Value of Diesel	:	45,350 KJ / kg
Brake drum diameter	:	0.3m
Rope diameter	:	0.015m
Equivalent diameter	:	0.315 m

DESCRIPTION:

This is a water cooled four stroke single cylinder vertical diesel engine is coupled to a rope pulley break arrangement to absorb the power produced,. Necessary weights and spring balances are included to apply load on the break drum. Suitable cooling water arrangement for the break drum is provided. Separate cooling water lines are provided for the engine cooling. Thermocouples are provided for measuring temperature. A fuel measuring system consists of a fuel tank mounted on a stand, burette, and a 3-way cock. Air consumption is measured by using a M.S. tank, which is fitted with a standard orifice and a U-tube water manometer that measures the pressures inside the tank.

Test Rig is provided with exhaust gas calorimeter. The exhaust gas pipe is connected to a heat exchanger wherein, the gases are cooled by a cooling water line. Thermocouples are provided to measure the inlet and outlet temperatures of exhaust gas as well as cooling water for the calorimeter.

THEORY:

Part of the heat supplied to an I.C. engine through the fuel is utilized in doing useful work, and the rest is wasted in over coming friction, in exhaust gases and in engine cooling water. A statement of the supplied heat, useful work and heat wasted in over coming friction, exhaust gases, engine cooling is called heat balance sheet. It may be drawn on the basis of unit time or cycle of operation.

The heat balance thus gives a picture about the utility of heat supplied through the fuel. The losses depends up on type of the engine, service to which it is employed, load, atmospheric conditions etc. A designer is interested to keep the losses as low as possible in order to maximize the rated power. Two important factors that influence the losses are speed and output of an engine. The loss due to friction increases considerably more due to increase in engine speed than by an increase in load. Heat carried away by engine water increases slowly with load while heat carried away by exhaust gases increases abruptly beyond 80% of the rated power output due to higher combustion temperatures, inefficient combustion etc.

STARTING THE ENGINE:

1. Engage de-compression lever before cranking.
2. Crank the engine and disengage the de-compression lever.
3. Adjust the governor to attain the rated speed.

PROCEDURE:

1. Open the three way cock so that fuel flows to the engine directly from the tank.
2. Open the cooling water valves and ensure water flows through the engine.
3. Start the engine and allow running on no load condition for few minutes.
4. Load engine by adding weights upon the hanger.
5. Allow the cooling water in the brake drum and adjust it to avoid spilling.
6. Allow the engine to run at this load for few minutes.
7. Adjust the cooling water regulators such that the temperature raise of Cooling water for engine jacket is around 5^0C and for calorimeter around 25^0C.
8. Note the following readings
    a) Engine Speed
    b) Weight on the hanger
    c) Spring balance
    d) Manometer
    e) Time for 10cc of fuel consumption
    f) Volume of Cooling water (Calorimeter) collected for 1 min.
    g) Volume of Cooling water (Engine)collected for 1 min
    h) Inlet and outlet temperatures of engine cooling water
    i) Inlet and outlet temperatures of calorimeter cooling water
    j) Inlet and outlet temperatures of exhaust gases
    k) Ambient temperate
9. Repeat the above procedure for different loads.
10. Stop the engine after removing load on the engine

11.PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine upto recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed.

OBSERVATIONS:

Full Load ,W= $\frac{B.P \mid 60 \mid 1000}{2\sigma NR \mid 9.81}$ ……. kg

S.No	Particulars	¼ Load	½ Load	¾ Load	Full Load
1	Rated Speed, N …..rpm				
2	Difference of Water Manometer Reading, h_w…….m				
3	Time for 10cc of Fuel Consumption, t…..sec				
4	Volume of Cooling water (Calorimeter) collected for 1 min. ,V_{wc}……… m^3/min				
5	Calorimeter Cooling Water Flow Rate, m_{wc} …Kg/min				
6	Volume of Cooling water (Engine)collected for 1 min,V_{we}……… m^3/min				
7	Engine Cooling Water Flow Rate, m_{we} ….. Kg/min				
8	Engine Cooling water inlet temperature, T_1 …^{0}C				
9	Engine Cooling water Outlet temperature, T_2 ….^{0}C				
10	Calorimeter Cooling water inlet temperature, T_3 ……^{0}C				
11	Calorimeter Cooling water outlet temperature T_4……^{0}C				
12	Calorimeter Exhaust gas inlet temperature, T_5 ……^{0}C				
13	Calorimeter Exhaust gas Calorimeter outlet temperature, T_6 …..^{0}C				
14	Room temperature, T_7 ….^{0}C				

CALCULATIONS:

1 Engine output (Brake Power) [B.P] $= \frac{2\sigma NT}{60 | 1000}$ …… KW

Where,

N = Rated speed ….. Rpm,

W_0 = Weight of hanger = 1.0 kg

W_1 = Weight on hanger ………. kg

W_2 = spring balance reading ……….kg

R_e = Effective brake drum radius = (R+r) … m

Where R is Brake drum radius

r is Rope radius

W = Net Load = $[(W_1\text{-}W_2)+ W_0] | 9.81$ ……… N

T = $(W * R_e)$…………N-

m 2 Indicated Power

Time for 10cc of fuel consumption, t = ……. Sec,

Mass of fuel consumption per min, $m_f = \frac{10}{t} | \frac{Sp.Gravity\ of\ diesel}{1000} | 60$ ..kg/ min.

Total Fuel Consumption, TFC = … m_f | 60….kg / hr.

Specific fuel consumption, SFC = $\frac{T.F.C}{B.P}$ ……..Kg / Kw-hr

Heat Input, HI = $\frac{TFC \times CV}{60 \times 60}$ …….KW

Where CV is calorific value of given fuel = 45350 KJ / kg

Actual Air intake:

Manometer reading h_1 = ………….cm of water

Manometer reading h_2 = ………….cm of water

Difference in water level, h_w = $\frac{h_1 - h_2}{100}$ ……………….m of water

Equivalent air column, h_a = $h_w \times \frac{\text{Density of water}}{\text{Density of air}} = h_w \times \frac{1000}{1.16}$ ….m. of air

Orifice diameter, d = 0.03 m

Area of orifice, a = $\frac{3.14 \times (0.03)^2}{4}$ ……..m^2

Theoretical Volume of air intake, $V_a = 60 \times C_d \times a \times \sqrt{2gh_a}$ m^3 / min.

Where C_d = 0.62

Mass of air intake, m_a = $\rho_a \times V_a$ ……kg / min

Density of air ρ_a = 1.16 Kg/m^3

Total mass of Exhaust Gas, m_g = $m_a + m_f$ kg/min

The specific heat of exhaust gas is determined by equating

Heat lost by exhaust gas = Heat carried by cooling water

Heat lost by exhaust gas , H_{eg} = m_g | C_{pg} | (T_5 - T_6)

Heat gained by calorimeter cooling water, H_{wc}= m_{wc} | C_{pw} | (T_4- T_3)

Specific heat of gas, C_{pg} = ……. kJ/kg.k

Heat input, HI = T.F.C | CV…… KJ/min

Heat Equivalent of B.P , $H_{B.P}$ = B.P | 60 ………..KJ/min

Heat lost by exhaust gas, H_{eg} = m_g | C_{pg} | (T_5 - T_6) …..KJ/min

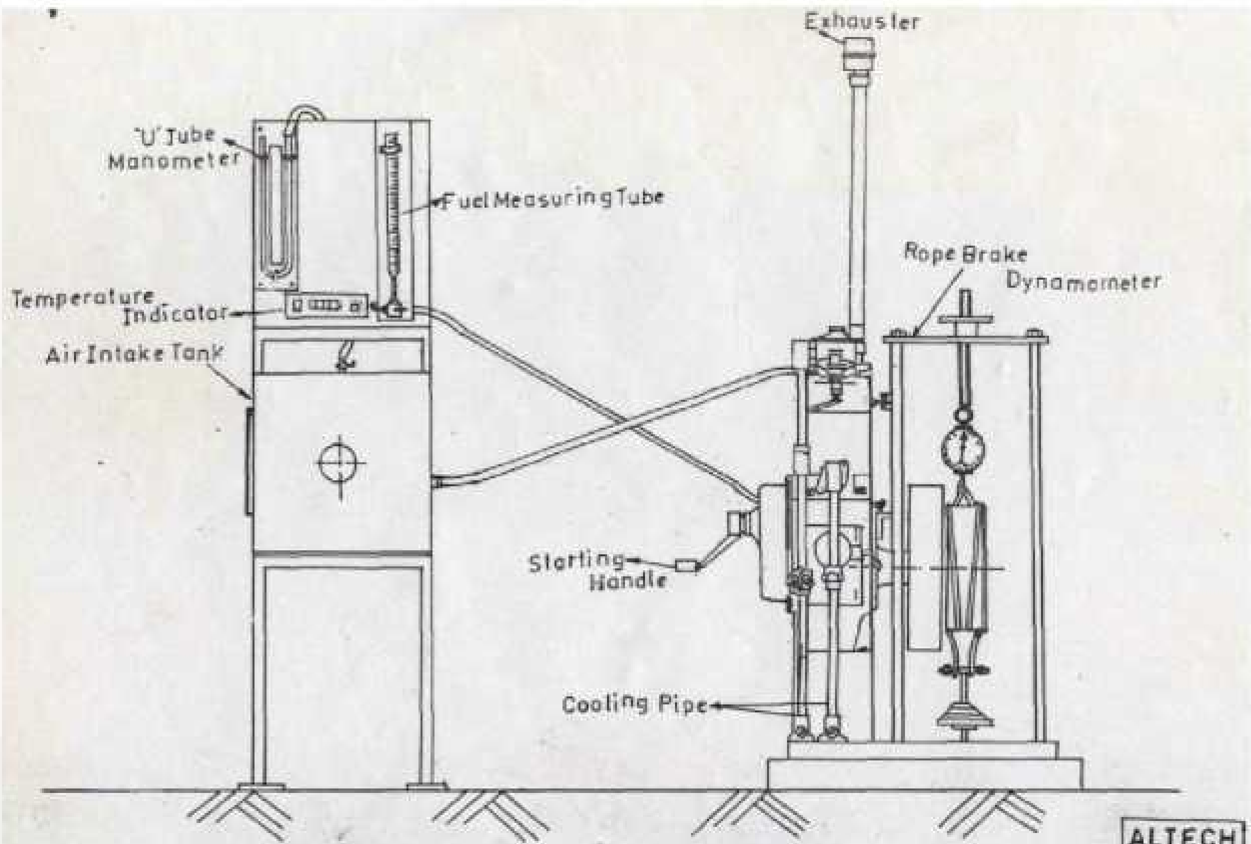
Heat Carried by engine Cooling water, H_{we}= m_w | C_{pw} | (T_2 – T_1)… KJ/min

Heat unaccounted loss , H_u = HI – (H_{eg} + H_{we} + H_{BP})

HEAT BALANCE SHEET ON MINUTE BASIS:

Heat Supplied	KJ / min	%	Heat distributed	KJ/ min	%
Heat supplied by the fuel		100	1.Heat in B.P 2.Heat carried by engine Cooling water 3.Heat Carried by exhaust gases 4.Unaccounted losses (radiation, friction, etc.,)		100
		100			100

RESULT:



SINGLE CYLINDER DIESEL ENGINE WITH MECHANICAL DYNAMOMETER TEST RIG

HEAT BALANCE TEST ON 4-STROKE, MULTI CYLINDER PETROL ENGINE TEST RIG

HEAT BALANCE TEST ON 4-STROKE, MULTI CYLINDER PETROL ENGINE TEST RIG

AIM: To conduct a Heat Balance Test on a four stroke Multi-cylinder Petrol Engine at different loads and to draw up a heat balance sheet on minute basis.

EQUIPMENT / APPARATUS REQUIRED:

1. 4-Stroke, 4-Cylinder petrol engine with a hydraulic dynamometer.
2. Tachometer (0-2000 rpm.)
3. Stop watch

SPECIFICATIONS:

Make	:	Ambassador
No.of cylinders	:	4
Bore	:	73 mm
Stroke	:	90 mm
Rated Speed	:	1500 rpm
B. P.	:	7.35 KW (10 HP)
Orifice diameter	:	35mm
Fuel	:	Petrol
Specific Gravity of petrol	:	0.716
Density of petrol	:	716 kg/m^3
Caloric value of petrol	:	47,100 KJ/kg

DESCRIPTION:

The test rig consists of a multi cylinder petrol engine coupled to a hydraulic dynamometer. The engine is Ambassador Brand and is 4-cylinder 4-stroke vertical engine developing 7.35 KW(10HP) at 1500 rpm. This type of engine is best suited for automobiles which operate at varying speed. The engine is fitted on a rigid bed and is coupled through a flexible coupling to a hydraulic dynamometer that acts as the loading device. All the instruments are mounted on a suitable panel board. Fuel consumption is measured with a burette and a 3-way cock which regulates the flow of fuel from the tank to the engine.

Air consumption is measured by using a M.S. tank, which is fitted with a standard orifice and a U-tube water manometer that measures the pressures inside the tank.

Test Rig is provided with exhaust gas calorimeter. The exhaust gas pipe is connected to a heat exchanger wherein, the gases are cooled by a cooling water line. Thermocouples are provided to measure the inlet and outlet temperatures of exhaust gas & cooling water for the calorimeter.

THEORY:

Part of the heat supplied to an I.C. engine through the fuel is utilized in doing useful work, and the rest is wasted in over coming friction, in exhaust gases and in engine cooling water. A statement of the supplied heat, useful work and heat wasted in over coming friction, exhaust gases, engine cooling is called heat balance sheet. It may be drawn on the basis of unit time or cycle of operation.

The heat balance thus gives a picture about the utility of heat supplied through the fuel. The losses depends up on type of the engine, service to which it is employed, load, atmospheric conditions etc. A designer is interested to keep the losses as low as possible in order to maximize the rated power. Two important factors that influence the losses are speed and output of an engine. The loss due to friction increases considerably more due to increase in engine speed than by an increase in load. Heat carried away by engine water increases slowly with load while heat carried away by exhaust gases increases abruptly beyond 80% of the rated power output due to higher combustion temperatures, inefficient combustion etc.

STARTING THE ENGINE:

1. A charged battery is used to start the engine.
2. Disengage the clutch and start the engine using the ignition key.
3. Engage the clutch slowly.
4. Adjust the throttle valve, so that the engine attains rated speed.

PROCEDURE:

1. Open the three way cock so that fuel flows to the engine directly from the tank
2. Open the cooling water valves and ensure water flows through the engine
3. Open the water line to the hydraulic dynamometer
4. Start the engine and allow to run on No load condition for a few minutes
5. Operate the throttle valve so that the engine picks up the speed to the required level
6. Load engine with hydraulic dynamometer-loading is done by turning the handle in the direction marked. If sufficient loaded is not absorbed by the dynamometer at the required speed, the outlet valve in the dynamometer can be closed to increase the pressure (as indicated by the pressure gauge) and hence the load.
7. Engine speed with increase in load. Hence to increase the speed, open the throttle valve.
8. Adjust the cooling water regulators such that the temperature raise of cooling water for engine jacket is around 5^0C and for calorimeter around 25^0C.
9. Allow the engine to run at this load for few minutes
10. Note the following readings
    a) Engine Speed.
    b) Dead Weight.
    c) Spring balance.
    d) Manometer.
    e) Time for 10cc of fuel consumption.
    f) Volume of Cooling water (Calorimeter) collected for 1 min
    g) Volume of Cooling water (Engine)collected for 1 min
    h) Inlet and outlet temperatures of engine cooling water,

i) Inlet and outlet temperatures of exhaust gas calorimeter cooling water
j) Inlet and outlet temperatures of exhaust gases
k) Ambient temperate

11. Repeat the above procedure at different loads
12. Stop the engine after removing the load on the engine.

PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine upto recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed.

OBSERVATIONS:

Full Load, W= $\frac{B.P \times 2000 \times 1.36}{N}$ ……. Kg

S.No	Particulars	¼ Load	½ Load	¾ Load	Full Load
1	Rated Speed, N …..rpm				
2	Difference of Water Manometer Reading, h_w…….m				
3	Time for 10cc of Fuel Consumption, t…..sec				
4	Volume of Cooling water (Calorimeter) collected for 1 min. ,V_{wc}……… m^3/min				
5	Calorimeter Cooling Water Flow Rate, m_{wc} ….Kg/min				
6	Volume of Cooling water (Engine)collected for 1 min,V_{we}……… m^3/min				
7	Engine Cooling Water Flow Rate, m_{we} …..kg/min				
8	Engine Cooling water inlet temperature, T_1 …^{0}C				
9	Engine Cooling water Outlet temperature, T_2 ….^{0}C				
10	Calorimeter Cooling water inlet temperature, T_3 ……^{0}C				
11	Calorimeter Cooling water outlet temperature T_4……^{0}C				
12	Calorimeter Exhaust gas inlet temperature, T_5 ……^{0}C				
13	Calorimeter Exhaust gas Calorimeter outlet temperature, T_6 …..^{0}C				
14	Room temperature, T_7 …. ^{0}C				

SAMPLE CALCULATIONS:

1 Brake Power ,B.P = $\frac{W \times N}{2000 \times 1.36}$ …….Kw

Where,

N= rated speed …… rpm,

W=load on the Dynamometer …….. Kg

2 Indicated Power

Time for 10cc of fuel consumption = ……. Sec,

Mass of fuel consumption per min, $m_f = \frac{10}{t} \times \frac{Sp.gravity\ of\ Petrol}{1000} \times 60$ ..Kg/ min.

Total Fuel Consumption, TFC = $m_f \times 60$….Kg / hr.

Specific fuel consumption, SFC = $\frac{T.F.C}{B.P}$ ……..Kg / Kw-hr

Heat Input, HI = $\frac{TFC \times CV}{60 \times 60}$ …….KW

Where CV is calorific value of petrol = 47100 KJ / kg

Actual Air intake:

Manometer reading h_1 = ………….cm of water

Manometer reading h_2 = ………….cm of water

Difference in water level, $h_w = \frac{h_1 - h_2}{100}$ ……………….m of water

Equivalent air column (h_a) = $h_w \times \frac{Density\ of\ water}{Density\ of\ air} = h_w \times \frac{1000}{1.16}$ ….m. of air

Orifice diameter (d) = 0.035 m

Area of orifice (a) = $\frac{3.14 \times (0.035)^2}{4}$ ……..m^2

Actual Volume of air Intake, $V_a = 60 \times C_d \times a \times \sqrt{2gh_a}$ m^3 / min.

Where $C_d = 0.62$

Mass of air intake $m_a = \rho_a \times V_a$ ……kg / min

Density of air $\rho_a = 1.16$ Kg/m^3

Total mass of Exhaust Gas, $m_g = m_a + m_f$ kg/min

The specific heat of exhaust gas is determined by equating

Heat lost by exhaust gas = Heat carried by cooling water

Heat lost by exhaust gas, $H_{eg} = m_g \times C_{pg} \times (T_5 - T_6)$

Heat gained by calorimeter cooling water, $H_{wc} = m_{wc} \times C_{pw} \times (T_4 - T_3)$

Specific heat of gas, C_{pg} = ……. kJ/kg.k

Heat input, HI = T.F.C × CV…… KJ/min

Heat Equivalent of B.P, $H_{B.P}$ = B.P × 60 ………..KJ/min

Heat lost by exhaust gas, $H_{eg} = m_g \times C_{pg} \times (T_5 - T_6)$ …..KJ/min

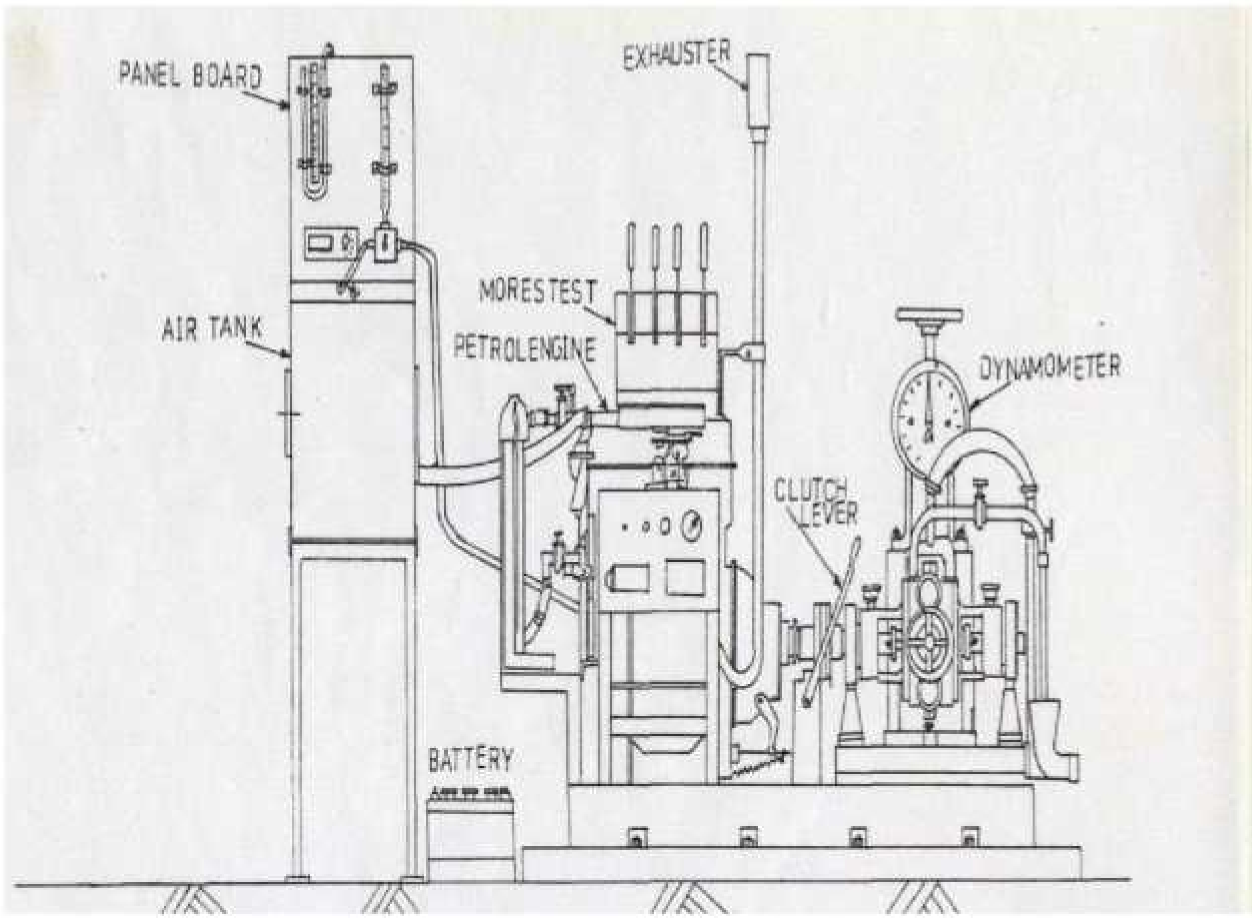
Heat Carried by engine Cooling water, $H_{we} = m_{we} \times C_{pw} \times (T_2 - T_1)$... KJ/min

Heat unaccounted loss, $H_u = HI - (H_{eg} + H_{we} + H_{BP})$…KJ/min

HEAT BALANCE SHEET ON MINUTE BASIS:

Heat Supplied	KJ / min	%	*Heat distributed*	*KJ/ min*	%
Heat supplied by the fuel		100	1.Heat in B.P 2.Heat carried by Engine Cooling water, H_{we} 3.Heat Carried by exhaust gases , H_{eg} 4.Unaccounted losses, H_u (radiation, friction, etc.,)		100
		100			100

RESULT:


PANEL BOARD
EXHAUSTER
MORESTEST
AIR TANK
PETROLENGINE
DYNAMOMETER
CLUTCH
LEVER
BATTERY

HEAT BALANCE TEST ON 4-STROKE, SINGLE CYLINDER, VARIABLE COMPRESSION RATIO PETROL ENGINE TEST RIG

HEAT BALANCE TEST ON 4-STROKE, SINGLE CYLINDER, VARIABLE COMPRESSION RATIO PETROL ENGINE TEST RIG

AIM: To conduct a Heat Balance Test on a four stroke single cylinder 4-stroke petrol engine by varying compression ratio and to draw up a heat balance sheet on minute basis

EQUIPMENT REQUIRED:

1. Single cylinder petrol engine with a electrical loading.
2. Stop watch

SPECIFICATIONS:

Make	:	Crompton Greaves
Stroke, L	:	66.7mm
Bore, D	:	70mm
Swept volume, V	:	256 cm^3
Rated R.P.M	:	3000rpm
Out put	:	2.2KW
Compression ratio, CR	:	4.67:1
Orifice Diameter	:	15mm
Fuel	:	Petrol
Sp. Gr. of petrol	:	0.716
Calorific Value of petrol	:	47100 KJ/Kg
Staring	:	By rope
Loading	:	Electrical , Air heater connected to AC Generator
Cooling	:	Air cooling cylinder

INTRODUCTION:

Internal combustion engines develop varying brake power depending on the compression ratio, while the other parameters held constant. For compression ignition engines, the compression ratio is brought to be above certain value for ignition to take place, but the spark ignition engines can be operated at lower compression ratios. The ignition being controlled by spark strength and advance. The effect of the compression ratio on heat balance which of present concern is studied in the present test rig.

DESCRIPTION:

The Test Rig consists of Four-Stroke Petrol Engine (Air Cooled) to be tested for performance is coupled to AC Generator .To facilitate the change in compression ratio, an auxiliary head-piston assembly above the main head has been provided. The auxiliary piston is operated up-down by hand wheel-screw rod assembly to fix the required compression ratio. When the piston is in the bottom most position, the compression ratio is at its maximum value, and in the top most position it is at minimum value of 2 s. The minimum clearance volume is 35 cc when the piston it is at bottom most position. The charge from this initial volume of clearance is determined by the displacement of the piston and thus used for calculation of the compression ratio.

Compression Ratio	$= \frac{SweptVolume \,\Gamma\, ClearenceVolume}{ClearenceVolume}$
Swept Volume	: 250 cc (fixed)
Clearance Volume	: Initial clearance volume + Additional clearance volume due to auxiliary piston movement
Clearance Volume	$: 35cc \,\Gamma\, \frac{\sigma \lfloor\rfloor d^{2} \perp l}{4cc}$

Where, d is the dia of auxiliary piston = 70 mm, l is the axial movement of piston.

The hand wheel which operates the screw holding the auxiliary piston is provided with holes circumferentially along the locking plate. The bolts used for locking the movement of screw are loosened and the hand wheel is operated. A scale with the compression ratio directly marked is provided for indicating this. After adjusting to the required compression ratio, all the bolts are tightened well before conducting experiment. The Rate of Fuel Consumption is measured by using volumetric pipette. Air Flow is measured by Manometer, connected to air box

The different electrical loading are achieved by loading the Electrical generator in steps which is connected to the air heaters (Resistance Load).The engine speed & AC Alternator speed are measured by electronic digital counter.

Temperatures at air inlet and engine exhaust gas are measured by electronic digital temperature indicator with thermocouple.

The whole instrumentation is mounted on a self-contained unit ready for operation.

THEORY:

Part of the heat supplied to an I.C. engine through the fuel is utilized in doing useful work, and the rest is wasted in over coming friction, in exhaust gases and in engine cooling water. A statement of the supplied heat, useful work and heat wasted in over coming friction, exhaust gases, engine cooling is called heat balance sheet. It may be drawn on the basis of unit time or cycle of operation.

The heat balance thus gives a picture about the utility of heat supplied through the fuel. The losses depends up on type of the engine, service to which it is employed, load, atmospheric conditions etc. A designer is interested to keep the losses as low as possible in order to maximize the rated power. Two important factors that influence the losses are speed and output of an engine. The loss due to friction increases considerably more due to increase in engine speed than by an increase in load. Heat carried away by engine water increases slowly with load while heat carried away by exhaust gases increases abruptly beyond 80% of the rated power output due to higher combustion temperatures, inefficient combustion etc.

PROCEDURE:

1. Loosen the locking bolt of the auxiliary piston screw rod assembly
2. Rotate the hand wheel and bring the indicator to the required compression ratio
3. Lock the screw rod assembly before conducting the experiment for the compression ratio selected.
4. Open the 3-way cock. So that fuel flows into the engine.
5. Supply the cooling water to engine head.
6. Water is supplied exhaust gas calorimeter.
7. Start the engine and allow it to run on no load condition for few minutes.
8. Apply the stated load on the engine by switching ON the heater switch which is provided on the control panel loading the AC generator by switching
9. Allow the engine to run at this load for few minutes.
10. Adjust the cooling water regulators such that the temperature for calorimeter around 25^0C.
11. Note the following readings.
    a) Engine Speed, N rpm
    b) Energy meter reading
    c) Manometer reading , h_w m of water
    d) Time for 10cc of fuel consumption , t sec
    e) Calorimeter Cooling Water Flow Rate
    f) Inlet and outlet temperatures of exhaust gas calorimeter cooling water
    g) Inlet and outlet temperatures of exhaust gases
    h) Ambient temperate
12. Repeat the above procedure for different compression ratios.
13. Stop the engine after removing load on the engine.

PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine upto recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed
5. The maximum limit of the compression ratio is 8.0.

	Particulars	C.R 8	C.R 7	C.R 6
1	Rated Speed, N …..rpm			
2	Manometer Reading, h_w…….,mm of water			
3	Time for 10cc of Fuel Consumption, t…..sec			
4	Energy meter reading for 'n' number of revolutions			
5	Calorimeter Cooling Water Flow Rate, m_{wc} …Kg/min			
6	Exhaust gas Calorimeter Cooling water inlet temperature, T_2 ……^{0}C			
7	Exhaust gas Calorimeter Cooling water outlet temperature T_3……^{0}C			
8	Calorimeter Exhaust gas inlet temperature, T_4 ……^{0}C			
9	Calorimeter Exhaust gas Calorimeter outlet temperature, T_5 …..^{0}C			
10	Room temperature, T_1 …. ^{0}C			

SAMPLE CALCULATIONS:

Engine output (Brake Power):

Engine out put, $B.P_{(elec)} = \frac{n \times 60 \times 60}{E_m \times t}$ ……. KW

$B.P_{(eng)} = \frac{BP_{elec}}{\eta_{tran}}$ ……. KW

Where

n = No. of revolution of energy meter

E_m = Energy meter constant = rev / Kw – hr

t= time for ‘ n’ revolutions of energy meter in secs

η_{trans} = transmission efficiency = 0.7=

Time for 10cc of fuel consumption, t = ……. Sec,

Mass of fuel consumption per min, $m_f = \frac{10}{t} \times \frac{Sp.Gravity\ of\ petrol}{1000} \times 60$ ..Kg/ min

Total Fuel Consumption, TFC = … $m_f \times 60$….kg / hr.

Specific fuel consumption, SFC = $\frac{T.F.C}{B.P}$ ……..Kg / Kw-hr

Heat Input, HI = $\frac{TFC \times CV}{60 \times 60}$ …….KW

Where CV is calorific value of given fuel = 47100 KJ / kg

Actual Air intake:

Manometer reading, $h_w = \frac{h_w}{1000}$ ………………m of water

Equivalent air column, $h_a = \frac{h_w \times Density\ of\ water}{Density\ of\ Air}$ X $\frac{h_w \times 1000}{1.16}$ ….m. of air

Orifice diameter, d = 0.015 m

Area of orifice, $a = \frac{3.14 \times (0.015)^2}{4}$ ……..m^2

Volume of air, $V_a = 60 \times C_d \times a \times \sqrt{2gh_a}$ m^3 / min.

Where C_d = 0.62

Mass of air intake, $m_a = \rho_a \times V_a$ ……kg / min

Density of air ρ_a = 1.16 Kg/m^3

Total mass of Exhaust Gas, $m_g = m_a + m_f$ kg/min

The specific heat of exhaust gas is determined by equating

Heat lost by exhaust gas = Heat carried by cooling water

Heat lost by exhaust gas, $H_{eg} = m_g \times C_{pg} \times (T_4 - T_5)$

Heat gained by calorimeter cooling water, $H_{wc} = m_{wc} \times Cpw \times (T_3 - T_2)$

Specific heat of gas, C_{pg} = ……. kJ/kg.k

Heat input ,HI= T.F.C | CV…… KJ/min

Heat Equivalent of B.P ,$H_{B.P}$= B.P | 60 ……….KJ/min

Heat lost by exhaust gas, H_{eg} = m_g | C_{pg} | (T_4- T_5) …..KJ/min

Heat unaccounted loss ,H_u = HI – (H_{eg} + H_{Fp} + H_{BP})

HEAT BALANCE SHEET ON MINUTE BASIS:

Heat Supplied	KJ / min	%	Heat distributed	KJ/ min	%
Heat supplied by the fuel		100	1.Heat equivalent to B.P 2.Heat Carried by exhaust gases 3.Unaccounted losses (radiation, friction, etc.,)		100
		100			100

RESULT:

MORSE TEST ON 4-STROKE, MULTI CYLINDER PETROL ENGINE TEST RIG

MORSE TEST ON 4-STROKE, MULTI CYLINDER PETROL ENGINE TEST RIG

AIM:

To conduct Morse test on a 4-stroke,multi cylinder (4 – cylinder) petrol engine to establish friction power, mechanical efficiency

EQUIPMENT REQUIRED:

1. 4-stroke,4 -cylinder petrol engine with a hydraulic dynamometer with provision to cut off ignition to each cylinder
2. Tachometer (0-2000 rpm).
3. Stop watch

SPECIFICATIONS:

Make	:	Ambassador
No.of cylinders	:	4
Bore	:	73 mm
Stroke	:	90 mm
Rated Speed	:	1500 rpm
B.P	:	7.35Kw (10 Hp)
Fuel	:	Petrol
Specific Gravity of petrol	:	0.716
Density of petrol	:	716 kg/m^3
Caloric value of petrol	:	47100 KJ/kg

DESCRIPTION:

The test rig consists of a multi cylinder petrol engine coupled to a hydraulic dynamometer. The engine is Ambassador brand and is 4-cylinder, 4-stroke vertical engine developing 7.35Kw at 1500 rpm. This type of engine is best suited for automobiles which operate at varying speed. The engine is fitted on a rigid bed and is coupled through a flexible coupling to a hydraulic dynamometer that acts as the loading device. All the instruments are mounted on a suitable panel board. Fuel consumption is measured with a burette and a 3-way cock which regulates the flow of fuel from the tank to the engine.

Air consumption is measured by using a M.S. tank, which is fitted with a standard orifice and a U-tube water manometer that measures the pressures inside the tank.

To conduct Morse test, an arrangement is provided to cut off the ignition to each spark plug.

THEORY:

The frictional power of an I.C. engine is determined by the following methods:

a) William's line method
b) Indicator area method
c) Motoring test
d) Morse test

The Morse test is applicable for multi cylinder petrol (or) diesel engine. The engine is run at the rated speed and the output is measured. Then one cylinder is made not to fire by Cut-off ignition, under this condition, the other cylinder operates the engine. As a consequence the speed of the engine falls. The output is measured by restoring the speed to the original value by decreasing the load. The difference between two outputs gives the indicated power of the cylinder cutout.

Thus the indicated power of all cylinders can be evaluated and by deducting brake power from the indicated power of all cylinders, the frictional power of the engine can be estimated.

Let I.P of cylinders 1,2, 3 & 4, be $I.P_1$ $I.P_2$, $I.P_3$, &$I.P_4$ respectively. Let F.P. of the engine be 'F.P' at a given load. Thus for a four cylinder engine.

$$I.P_1+I.P_2+I.P_3+I.P_4 - F.P = B.P \quad \ldots\ldots\ldots (1)$$

Where 'B.P' is the Brake Power. of engine when all cylinders are working.

When first cylinder is cut out $I_1 = 0$, but Friction power of the engine remains at F.P

$$\text{Then } I.P_2 + I.P_3 + I.P_4 - F.P = B.P_1 \text{ .... (2)}$$

By (1) – (2) we have	$I.P_1 = B.P - B.P_1$
Similarly	$I.P_2 = B.P - B.P_2$
	$I.P_3 = B.P - B.P_3$
	$I.P_4 = B.P - B.P_4$
I.P. of the engine	$I.P = I.P_1 + I.P_2 + I.P_3 + I.P_4$
F.P. of the engine	$F.P = I.P - B.P$

STARTING THE ENGINE:

1. Disengage the clutch and start the engine using the ignition key.
2. Engage the clutch slowly.
3. Adjust the throttle valve, so that the engine attains rated speed.

PROCEDURE:

1. Open the three- way cock so that fuel flows to the engine directly from the tank
2. Open the cooling water valves and ensure water flows through the engine
3. Open the water line to the hydraulic dynamometer
4. Start the engine and allow to run on No Load condition for few minutes
5. Operate the throttle valve so that the engine picks up the rated speed
6. Load the engine at full load and maintain the speed at rated rpm i.e., 1500 rpm by adjusting the throttle and dynamometer loading wheel.
7. Allow the engine to run at this load for a few minutes.
8. Cut-off ignition to the first cylinder, and thus speed is decreased.

9. Without disturbing the throttle valve position, decrease the load on the engine, until the original speed is restored.
10. Note the dynamometer reading, restore the ignition to the first cylinder
11. Repeat the above procedure by cutting off ignition to each of the cylinders.
12. Note the dynamometer readings for each cylinder when they are cut -off.
13. Engine stopped after removing the load.

PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine upto recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed.

OBSERVATIONS:

Rated Speed=1500 rpm

S.No	Condition	Dynamometer load ,W Kg	B.P, KW	I.P, Kw
1	All cylinders working	W		
2	1st cylinder cut-off	W_1		
3	2nd cylinder cut-off	W_2		
4	3rd cylinder cut-off	W_3		
5	4th cylinder cut-off	W_4		

SAMPLE CALCULATIONS:

‘B.P = $\frac{W \mid N}{2000 \mid 1.36}$ ……. KW

B.P$_1$= $\frac{W_1 \mid N}{2000 \mid 1.36}$ ……. KW

B.P$_2$= $\frac{W_2 \mid N}{2000 \mid 1.36}$ ……. KW

B.P$_3$= $\frac{W_3 \mid N}{2000 \mid 1.36}$…… KW

B.P$_4$= $\frac{W_4 \mid N}{2000 \mid 1.36}$…… KW

I.P$_1$ = B.P-B.P$_1$ ……KW

I.P$_2$ = B.P-B.P$_2$……KW

I.P$_3$ = B.P-B.P$_3$ ……Kw

I.P$_4$ = B.P-B.P$_4$….. Kw

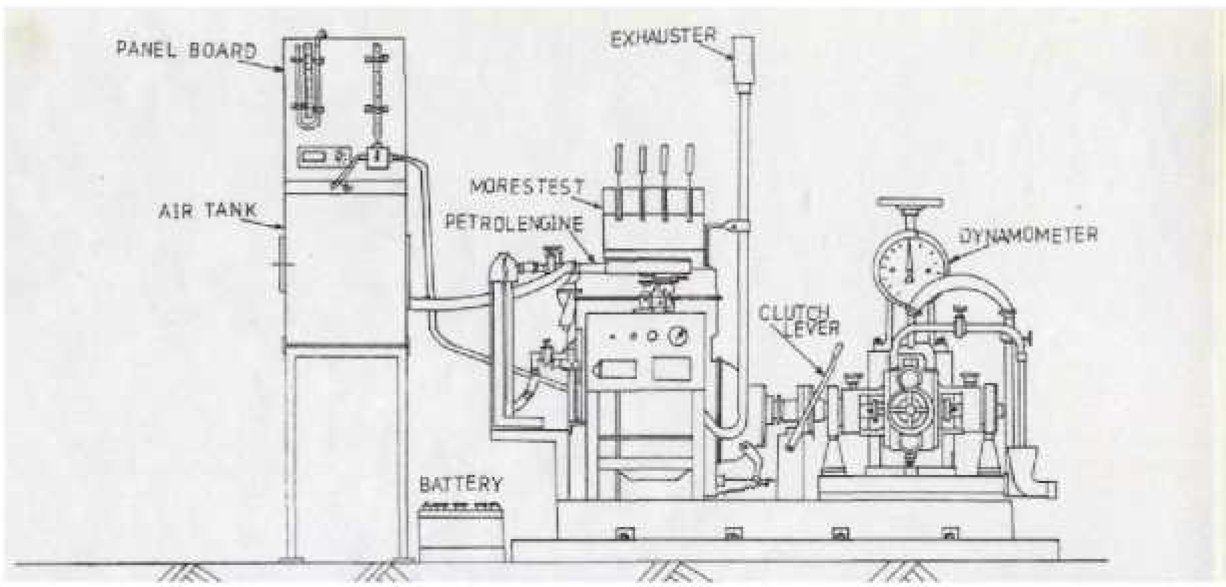
I.P = I.P$_1$+I.P$_2$+I.P$_3$+I.P$_4$ ....Kw

F.P = I.P-B.P……Kw

Frictional power, F.P = …….KW

Mechanical efficiency ¦$_m$ = $\frac{B.P}{I.P} \mid 100$

RESULT :


PANEL BOARD
EXHAUSTER
AIR TANK
MORESTEST
PETROLENGINE
DYNAMOMETER
CLUTCH LEVER
BATTERY

MOTORING & RETADATION TEST ON 4-STROKE, SINGLE CYLINDER DIESEL ENGINE TEST RIG

MOTORING & RETARDATION TEST ON 4-STROKE, SINGLE CYLINDER DIESEL ENGINE TEST RIG

AIM:

To conduct a Motoring and retardation test on 4-stroke, single cylinder diesel engine, to calculate frictional power developed by the engine

EQUIPMENT/APPARATUS:

1. 4- Stroke, single cylinder Diesel engine with a swinging field type electrical dynamometer.
2. Stopwatch.

SPECIFICATIONS:

Make	:	Kirloskar
Bore	:	85mm
Stroke	:	110 mm
Rated Speed	:	1500 rpm
Max. B.P	:	3.7KW (5 H.P)
Compression Ratio	:	16 .5:1
Orifice Diameter	:	16mm
Fuel Oil	:	Diesel
Density of Diesel	:	0.827 gm / ml
Calorific Value of Diesel	:	45,350 KJ / kg

DESCRIPTION :

The Test Rig consists of Four-Stroke Diesel Engine to be tested for performance is connected to D.C machine with Swinging field arrangement. The Rate of Fuel Consumption is measured by using the Burette reading against the known time. Swinging field arrangement to find friction power. The water flow rate for cooling the engine is measured separately by water meter, The Air flow is measured by orifice and manometer. The different electrical loadings are achieved by operating the dimmerstat of dynamometer in steps. The mechanical energy is measured by spring balance and radius of torque arm (Also by torque arm). The engine speed (RPM) is measured by electronic digital counter. Temperature at different points is measured by electronic digital temperature indicator with thermocouple. The whole instrumentation is mounted on a self-contained unit ready for operation.

THEORY:

The frictional power of an I.C. engine is determined by the following methods

a) William's line method
b) Indicator area method
c) Retardation test
d) Motoring test
e) Morse test.

MOTORING TEST

In this test the engine is steadily operated at the rated speed by its own power and allowed to remain under given speed and load conditions for sufficient time so that the temperature of the engine components, lubricating oil and cooling water reaches a steady state. A swinging field type electric dynamometer is used to absorb the power during this period. The ignition is then cut –off and by suitable electric switching devices the dynamometer is converted to run as a motor so as to crank the engine at the same speed at which is previously operating. The power supply from the above dynamometer is measured which is a measure of the frictional power of the engine at that speed.

STARTING THE ENGINE:

1 Check the Diesel Level in the diesel tank.
2 Check the Water Flow through Engine cylinder.
3 First, switch -ON the MCB (Mains) of the control panel at the right bottom side .
4 Then , switch-ON the Console & ensure that all the phase indicators glow and the also , Blower of the DC Machine running. All the digital indicators should be in ON position. Check the direction of blower as shown on the blower.

5 Balance the swinging field spring balances to zero.

6 Keep the Change -over Switch in the Motor position (left) & toggle switch in the starting position, then push the Green Button of the DC Drive & observe whether the engine has started rotating & after gaining a speed of about 1000 RPM , then place the de-compression
valve immediately. Now the engine will start running and then continuously bring back change - over switch to the OFF position.

7 Allow sometime so that speed stabilizes.

8 Now, keep the change -over switch to the generator position (right) & keep the field intensity Knob at the maximum position . Now observe the power in the digital watt meter .

9 Before starting the engine ensure that water is flowing through the engine.

PROCEDURE:

1. Put the selector switch of “motor / generator” to “motor” position.
2. Now, select required speed using “Speed Control” of motor.
3. Now, the left spring balance starts indicating the friction developed by the Engine.
4. Take down the readings of speed and spring balance reading.

OBSERVATIONS

S.No	Speed , Rpm	Load in kg, F_m	Friction power , W

SAMPLE CALCULATIONS:

Frictional power, FP = $\frac{2 \times \pi \times N \times F_M \times r \times 9.81}{60}$ W

Where, N Speed of the Engine, rpm

r, Torque arm Distance = 0.145 m

F_M Spring Balance (Left side)Reading in Kg

RESULT

RETARDATION TEST:

This test involves the method of retarding the engine by cutting the fuel supply. When the engine is stopped suddenly its retardation in speed is directly related to the frictional resistance inside the engine. The engine is made to run at no load and rated speed .when the engine is running under steady operating conditions the supply of fuel ids cut off and simultaneously the time of fall in speeds by say 20% , 40%, 60% , 80% of the rated speed is recorded. The tests are repeated once again with 50% load on the engine. A graph connecting time for fall in speed (x- axis) and speed (y – axis) at no load as well as 50 % load conditions is drawn as shown in fig.

.

In this set up to stop the engine running from supply of fuel a valve is provided. As the engine has run for sufficient time, the valve is cutoff and at the same time digital timer is switched on. Time for reduction in speed till a particular speed is noted.

STARTING THE ENGINE:

1. Check the Diesel Level in the diesel tank.
2. Check the Water Flow through Engine cylinder.
3. First, switch -ON the MCB (Mains) of the control panel at the right bottom side .
4. Then , switch-ON the Console & ensure that all the phase indicators glow and the also , Blower of the DC Machine running. All the digital indicators should be in ON position. Check the direction of blower as shown on the blower.
5. Balance the swinging field spring balances to zero.
6. Keep the Change -over Switch in the Motor position (left) & toggle switch in the starting position, then push the Green Button of the DC Drive & observe whether the engine has started rotating & after gaining a speed of about 1000 RPM , then place the de-compression valve immediately. Now the engine will start running and then continuously bring back change - over switch to the OFF position.
7. Allow sometime so that speed stabilizes.
8. Now, keep the change -over switch to the generator position (right) & keep the field intensity Knob at the maximum position . Now observe the power in the digital watt meter .
9. Before starting the engine ensure that water is flowing through the engine

PROCEDURE:

1. Check the fuel and lubricating oil levels.
2. Supply the fuel to the engine.
3. Open the cut off valve to enter the fuel into the engine
4. Now starting the engine by DC motor (steps 2-8) and by releasing the decompression lever
5. Connect the water supply to the engine for cooling

6. After initial worm up the engine, cut of the fuel supply using (cut off valve) at no load.
7. Then note down the time for decreasing speed from 1500- 500 rpm by using digital timer and digital RPM indicator.
8. The above procedure is followed for 50% load (i.e 7Kg).

OBSERVATIONS

S.No	Drop in speed	Time for fall of speed at no load, t_2 Sec	Time for fall of speed at 7Kg load, t_3 Sec	Frictional Torque, T_F,Nm	Frictional power, FP, W	Indicated Power, IP, W	Mechanical efficiency

PRECAUTIONS:

1. Don't start or stop the engine with load.
2. Don't forget supply of cooling water to the engine.
3. After starting the engine remove the handle carefully from the shaft.
4. **<u>Take the time carefully for dropping of the speed</u>**

<u>SAMPLE CALCULATIONS:</u>

Load Torque on drum (T_L) $= M \times r \times 9.81$ N m

M- Mass in Kg of spring Balance

r - Radius of torque arm = 0.145 m

Frictional load Torque (T_F) $= \dfrac{t_3}{t_2 - t_3} \times T_L$

t_2 = Retardation time at no load

t_3 = Retardation time at 50% load

Frictional power (F.P) = $\dfrac{2 \times \pi \times N \times T_F}{60}$ W

Brake power B.P = $\frac{2 \times \pi \times N \times T}{60}$ W

Mechanical Efficiency = $\frac{B.P}{I.P} \times 100$

RESULT:

DETERMINATION OF AIR FUEL RATIO & VOLUMETRIC EFFICENCY WITH VARIABLE COMPRESSION RATIO ON 4-STROKE, SINGLE CYLINDER PETROL ENGINE TEST RIG

DETERMINATION OF AIR FUEL RATIO & VOLUMETRIC EFFICENCY WITH VARIABLE COMPRESSION RATIO ON 4-STROKE, SINGLE CYLINDER PETROL ENGINE TEST RIG

AIM: To conduct a load test on a single cylinder, 4-stroke variable compression ratio petrol engine and study air fuel ratio and volumetric efficiency under various compression ratios .

EQUIPMENT REQUIRED:

1. Single cylinder petrol engine with electrical loading.
2. Stop watch.

SPECIFICATIONS:

Make	:	Crompton Greaves
Stroke, L	:	66.7mm
Bore, D	:	70mm
Swept volume, V	:	256 cm^3
Rated R.P.M	:	3000rpm
Out put	:	2.2KW
Compression ratio, CR	:	4.67:1
Fuel	:	Petrol
Sp. Gr. Of petrol	:	0.716
Calorific Value of petrol	:	47100 KJ/Kg
Staring	:	By rope
Loading	:	Electrical, Air heater connected to AC Generator
Cooling	:	Air cooling

INTRODUCTION:

Internal combustion engines develop varying brake power depending on the compression ratio, while the other parameters held constant. For compression ignition engines, the compression ratio is brought to be above certain value for ignition to take place, but the spark ignition engines can be operated at lower compression ratios. The ignition being controlled by spark strength and advance.

The effect of compression ratio, which of present concern is studied in the present test rig.

DESCRIPTION:

The Test Rig consists of Four-Stroke Petrol Engine (Air Cooled) to be tested for performance is coupled to AC Generator .To facilitate the change in compression ratio, an auxiliary head-piston assembly above the main head has been provided. The auxiliary piston is operated up-down by hand wheel-screw rod assembly to fix the required compression ratio. When the piston is in the bottom most position, the compression ratio is at its maximum value, and in the top most position it is at minimum value of 2s. The minimum clearance volume is 35 cc when the piston it is at bottom most position. The charge from this initial volume of clearance is determined by the displacement of the piston and thus used for calculation of the compression ratio.

Compression Ratio $= \frac{SweptVolume + ClearenceVolume}{ClearenceVolume}$

Swept Volume : 250 cc (fixed)

Clearance Volume : Initial clearance volume + Additional clearance volume due to auxiliary piston movement

Clearance Volume $: 35cc + \left(\frac{\pi d^2}{4cc}\right) l$

Where, d is the diameter of auxiliary piston = 70 mm, l is the axial movement of piston.

The hand wheel which operates the screw holding the auxiliary piston is provided with holes circumferentially along the locking plate. The bolts used for locking the movement of screw are loosened and the hand wheel is operated. A scale with the compression ratio directly marked is provided for indicating this. After adjusting to the required compression ratio, all the bolts are tightened well before conducting experiment. The rate of fuel Consumption is measured by using Volumetric Pipette. Air Flow is measured by Manometer, connected to air box.

The different electrical loading are achieved by loading the Electrical generator in steps which is connected to the Air Heaters (Resistance Load)The engine speed & AC Alternator speed are measured by electronic digital counter. Temperatures at air inlet and engine exhaust gas are measured by electronic digital temperature indicator with thermocouple.

The whole instrumentation is mounted on a self-contained unit ready for operation.

PROCEDURE:

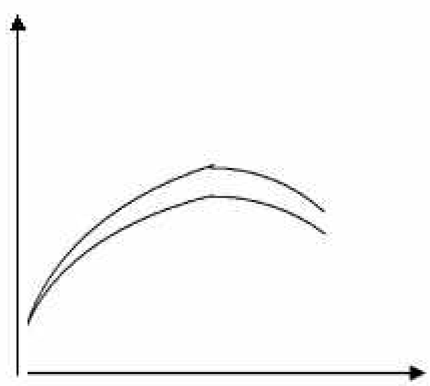
1. Loosen the locking bolt of the auxiliary piston screw rod assembly
2. Rotate the hand wheel and bring the indicator to the required compression ratio
3. Lock the screw rod assembly before conducting the experiment for the compression ratio selected.
4. Open the 3-way cock. So that fuel flows into the engine.
5. Supply the cooling water to engine head.
6. Start the engine and allow it to run on no load condition for few minutes.
7. Apply the load on the engine by switching ON the heater switch which is provided on the control panel loading the AC generator by switching
8. Allow the engine to run at this load for few minutes.
9. Note the following readings.
   a) Engine Speed
   b) Energy meter reading
   c) Manometer
   d) Time for 10cc of fuel consumption
10. Repeat the steps 7,8 & 9 at different loads
11. Stop the engine after removing load on the engine
12. Repeat the above procedure for different compression ratios.

PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine upto recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed
5. Don’t increase the compression ratio beyond 8.0

GRAPHS

B .P Vs →3 th



→3 th

OBSERVATIONS:

Compression ratio =

S.NO	Loading switches	Air consumption, mm of water	Speed, Rpm	Time for 10 cc fuel consumption, Sec	Energy meter reading for 'n' number of revolutions, Sec	Mass of air intake, m_a, Kg/min	Mass of fuel consumption, m_f, Kg/min	Swept volume, m^3/min	Theoretical volume, m^3/min	→vol	Air fuel ratio
1	0										
2	1										
3	2										
4	3										
5	4										
6	5										

OBSERVATIONS:

Compression ratio =

S.NO	Loading switches	Air consumption , mm of water	Speed, Rpm	Time for 10 cc fuel consumption, Sec	Energy meter reading for 'n' number of revolutions, Sec	Mass of air intake, m_a , Kg/min	Mass of fuel consumption , m_f , Kg/min	Swept volume , m^3/min	Theoretical volume , m^3/min	→vol	Air fuel ratio
1	0										
2	1										
3	2										
4	3										
5	4										
6	5										

SAMPLE CALCULATIONS:

Time for 10cc of fuel consumption, t = ……. Sec,

Mass of fuel consumption per min, $m_f = \frac{10}{t} \times \frac{Sp.Gravity\ of\ petrol}{1000} \times 60$ .. Kg / min

Volumetric Efficiency, $\eta_{vol} = \frac{V_s}{V_t} \times 100$

<u>Actual Air intake:</u>

Manometer reading, $h_w = \frac{h_w}{1000}$ ……………….m of water

Equivalent air column, $h_a = h_w \times \frac{Density\ of\ water}{Density\ of\ air} = h_w \times \frac{1000}{1.16}$ ….m. of air

Orifice diameter, d = 0.015 m

Area of orifice, $a = \frac{\pi \times (0.015)^2}{4}$ ……..m^2

Actual Volume of air intake, $V_a = 60 \times C_d \times a \times \sqrt{2gh_a}$ ……..m^3 / min.

Where $C_d = 0.62$

Swept volume at STP, $V_s = V_a \times \frac{Ts}{Ta}$ …….m^3/min

Where T_a = Ambient Temperature……. ^{0}K

T_s = Standard Temperature, 288^0K

Mass of air intake, $m_a = \rho_a \times V_a$ ……kg / min

Density of air $\rho_a = 1.16$ Kg/m^3

Theoretical Air intake:

Diameter of piston, D = 0.070 m

Stroke length, L = 0.066.7 m

Engine speed, N = ………..rpm

Theoretical volume of air intake, V_t = $\frac{\pi}{4} \times D^2 \times L \times \frac{N}{2}$ …..m^3 / min

Volumetric efficiency, $\eta_{vol} = \frac{Vs}{Vt} \times 100$

Air- Fuel Ratio = $\frac{Mass\ of\ actual\ air\ intake\ per\ minute\ (kg/min)}{Mass\ of\ fuel\ intake\ per\ minute\ (kg/min)}$ X $\frac{m_a}{m_f}$

RESULT;

ECONOMICAL SPEED TEST ON 4-STROKE, MULTI CYLINDER PETROL ENGINE TEST RIG

ECONOMICAL SPEED TEST ON 4-STROKE, MULTI CYLINDER PETROL ENGINE TEST RIG

AIM: To conduct a economical speed test on 4-stroke,4-cylinder petrol engine at various loads, for a given output

EQUIPMENT REQUIRED:

1. 4-stroke, 4 -cylinder petrol engine with a hydraulic dynamometer.
2. Tachometer (0-2000 rpm)
3. Stop watch

SPECIFICATIONS:

Make	:	Ambassador
No. of cylinders	:	4
Bore	:	73 mm
Stroke	:	90 mm
Rated Speed	:	1500 rpm
B. P.	:	7.35 KW(10 HP)
Orifice Diameter	:	35mm
Fuel	:	Petrol
Specific Gravity of petrol	:	0.716
Density of petrol	:	716 kg/m^3
Caloric value of petrol	:	47100 KJ/kg

DESCRIPTION:

The test rig consists of a multi cylinder petrol engine coupled to a hydraulic dynamometer. The engine is Ambassador Brand and is 4-cylinder 4-stroke vertical engine developing 7.35 KW(10HP) at 1500 rpm. This type of engine is best suited for automobiles which operate at varying speed. The engine is fitted on a rigid bed and is coupled through a flexible coupling to a hydraulic dynamometer, acts as the loading device. All the instruments are mounted on a suitable panel board. Fuel consumption is measured with a burette and a 3-way cock which regulates the flow of fuel from the tank to the engine.

Air consumption is measured by using a M.S. tank, which is fitted with a standard orifice and a U-tube water manometer that measures the pressures inside the tank.

STARTING THE ENGINE:

1. Disengage the clutch and start the engine using the ignition key.
2. Engage the clutch slowly.
3. Adjust the throttle valve, so that the engine attains rated speed.

PROCEDURE:

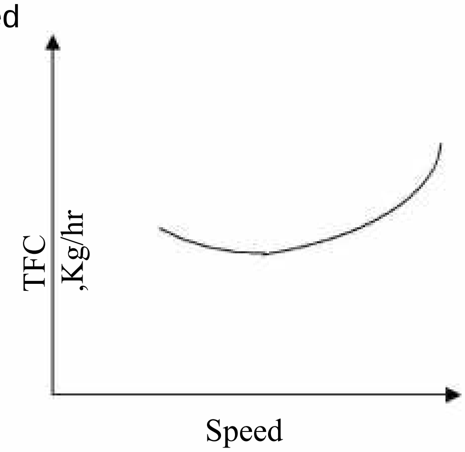
1. Before stating the engine, calculate the net load to be applied on hydraulic dynamometer at different speeds for maintaining constant B.P of the engine
2. Open the three way cock so that fuel flows to the engine directly from the tank.
3. Open the cooling water valves and ensure water flows through the engine.
4. Open the water line to the hydraulic dynamometer.
5. Start the engine and allow it to run on no load for a few minutes.
6. Operate the throttle valve so that the engine picks up the speed to the required level.
7. The engine is loaded to the calculated value with hydraulic dynamometer is done by turning the handle in the direction marked. If sufficient loaded is not absorbed by the dynamometer at the required speed, the outlet valve in the dynamometer can be closed to increase the pressure (as indicated by the pressure gauge) and hence the load.
8. Regulate the speed to the desired value by controlling the fuel supply to the engine
9. Note down the time taken for 10cc fuel consumption
10. Repeat the above procedure at different speeds under constant B.P of the engine
11. Repeat the above procedure for another constant B.P

PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine upto recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed.

GRAPHS:

1. T.F.C Vs Speed



OBSERVATIONS:

Sl. No0	Load on the Dynamometer W Kg	Speed, Rpm	Time for 10 cc of fuel (sec)	T.F.C Kg/hr
1				
2				
3				
4				
5				
6				

SAMPLE CALCULATIONS:

Brake Power (BP_{max}) = $\frac{W_{max} \times N}{2000 \times 1.36}$ …….KW

Where,

N= rated speed …… rpm,

W_{max}= Full load on the Dynamometer …….. Kg

Full Load, W_{max}= $\frac{B.P \times 2000 \times 1.36}{N}$ ……. Kg

If Output power, B.P = I/2 $B.P_{max}$

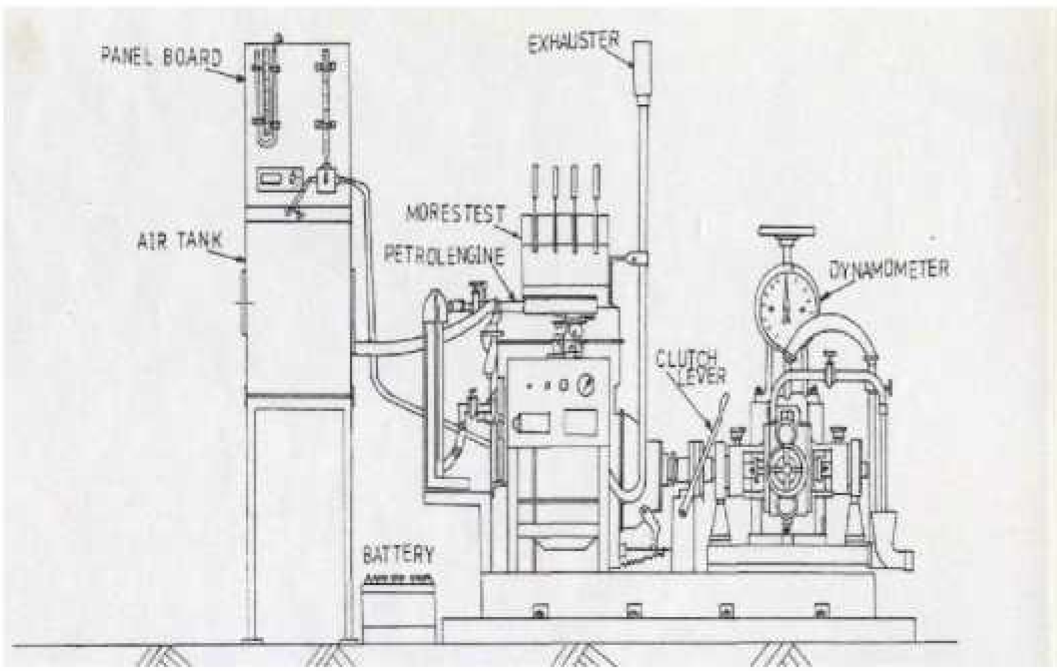
Load on Dynamometer, W = $\frac{B.P \times 2000 \times 1.36N}{N}$

Time for 10cc of fuel consumption, t = ……. Sec,

Mass of fuel consumption per min, m_f = $\frac{10}{t} \times \frac{density\ of\ diesel}{1000} \times 60$ …kg/ min.

Total Fuel consumption, TFC = mf × 60….kg / hr.

RESULT :


PANEL BOARD
EXHAUSTER
MORESTEST
AIR TANK
PETROLENGINE
DYNAMOMETER
CLUTCH
LEVER
BATTERY

PERFORMANCE TEST ON TWO STAGE RECIPROCATING AIR COMPRESSOR

PERFORMANCE TEST ON TWO STAGE RECIPROCATING AIR COMPRESSOR AIM:

To conduct performance test on reciprocating air compressor, to determine it's volumetric efficiency and Isothermal efficiency.

EQUIPMENT /APPARATUS:

1. Two stage air compressor
2. Tachometer 0-2000 rpm
3. Stop watch

SPECIFICATIONS:

Make	: Altech
Dia. of low pressure piston	: 70 mm
Dia. of High Pressure Piston	: 50 mm
Stroke	: 90 mm
Operating Pressure	: 8 kgf / cm^2
Speed	: 700 rpm
Diameter of orifice	: 20mm
Power	: 3 HP

DESCRIPTION:

The air compressor is a two stage, reciprocating type. The air is sucked from atmosphere and compressed in the first cylinder. The compressed air then passes through an inlet cooler into the second stage cylinder, the compressed air then goes to reservoir through safety valve. This valve operates an electrical switch that shuts off the motor when pressure exceeds the set limit.

The test consists of an air chamber containing an orifice plate and a u-tube manometer, the compressor and an induction motor.

PROCEDURE:

1) Open the discharge valve of the compressor and drain off air completely and close the valve.

2) Start the compressor, by starting the compressor motor& observe the pressure developing slowly

3) At the particular test pressure, the outlet valve is opened slowly and adjusted so that the pressure in the tank maintained constant.

4) At the particular test pressure, note the following reading

(i) Manometer,

(ii) Speed of the compressor,

(iii) Pressure,

(Iv) Time taken for 10 revolutions of energy meter.

5) Adjust the discharge valve so that pressure changes again.

6) Repeat the above procedure for different pressures.

7) Switch off the power supply and stop the compressor.

PRECAUTIONS:

1. Check oil level in the compressor crank case
2. The orifice should never be closed
3. At the end of the experiment the outlet valve at the air reservoir should be opened as the compressor is to be started again at low pressure to prevent undue strain on the piston

OBSERVATIONS:

S.No.	Pressure (kgf/cm^2)	Energy meter reading for 'n' Number of revolutions	Difference in manometer reading, h_w cm	Speed N rpm	Actual Volume V_a m^3/sec	Theoretical Volume, V_t m^3/sec	¦ vol

S.No.	Gauge Pressure (kgf/cm^2)	Motor input= $\frac{3600 \mid n}{k \mid t}$ Kw	Motor output= $motorinput \mid 0.8$	Compressor input= $motorinput \mid 0.8 \mid 0.95$	Compressor output= $P_a \mid V_a \mid ln\ C$	¦ iso

CALCULATIONS:

1. Actual Air intake:

Manometer reading h_1 = …………..cm of water

Manometer reading h_2 = …………..cm of water

Difference in water level, $h_w = \frac{h_1 Z h_2}{100}$ m of water

Equivalent air column, $h_a = \frac{h_w \mid Density\ of\ water}{Density\ of\ Air}$ X $\frac{h_w \mid 1000}{1.16}$ ….m. of air|

Where

h_w = m. of water column

h_a =m. of air column

∂_w =Density of water in kg/m^3 (1000 kg/m^3)

∂_a =Density of air in kg/m^3 (1.16 kg/m^3)

2. The actual volume of air compressed, $V_a = C_d \times a \times \sqrt{2gh_a}$ …..m3 / Sec

Where

C_d=co efficient of discharge for the orifice =0.62

Orifice diameter = 0.02 m

Area of orifice, $a = \frac{\pi \times (0.02)^2}{4}$ = …..m^2

h_a=equivalent air column in 'm'

4. Theoretical volume of air compressed, $V_t = \frac{\frac{\pi}{4} \times D^2 \times L \times N}{60}$ …..m^3 / Sec

Diameter of piston, D = 0.07

m Stroke length, L = 0.09 m

Speed of the compressor, N = ……..rpm

4. Volumetric efficiency = $\frac{V_a}{V_t} \times 100$

5. Compressor = Motor input $\times 0.8 \times 0.95$ …..KW

input Where

Energy meter constant, K= 200 Rev/Kwh

Time for 'n' number of rev. = t sec

Motor input $= \frac{3600 \times n}{K \times t}$ …….. KW

Efficiency of motor = 80%

Output of motor = Motor input $| \; 0.8$

Belt transmission efficiency = 95 %(assumed)

Compressor input = Motor input $| \; 0.8 \; | \; 0.95$ …..KW

6. Compressor output = $P_a \; | V_a \; | \; ln \; C$ …….Kw

Compression ratio, C $= \dfrac{Gauge\ pressure \; \Gamma \; Atm.\ pressure}{Atm.\ pressure}$

$= \dfrac{\text{Gauge pressure } \Gamma \text{ 1.0325}}{1.0325}$

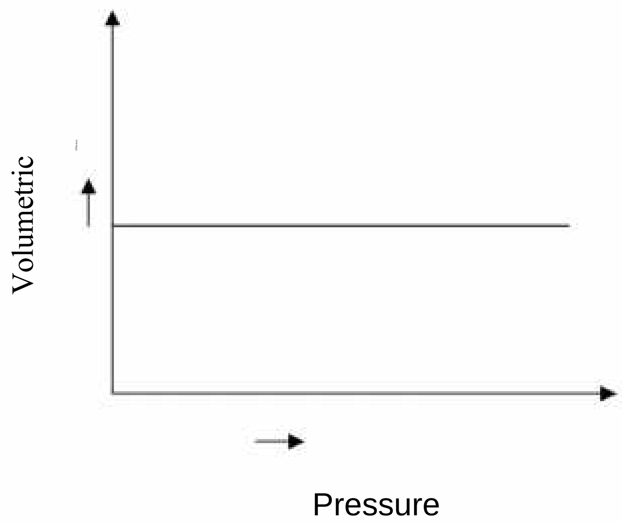
Note: Gauge pressure in Kgf/cm^2

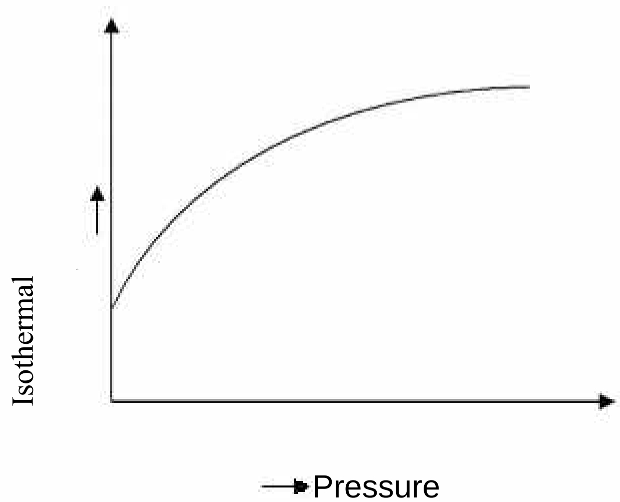
P_a= Atmospheric pressure = 101.325 KPa

V_a= Actual volume of air compressed m^3/sec

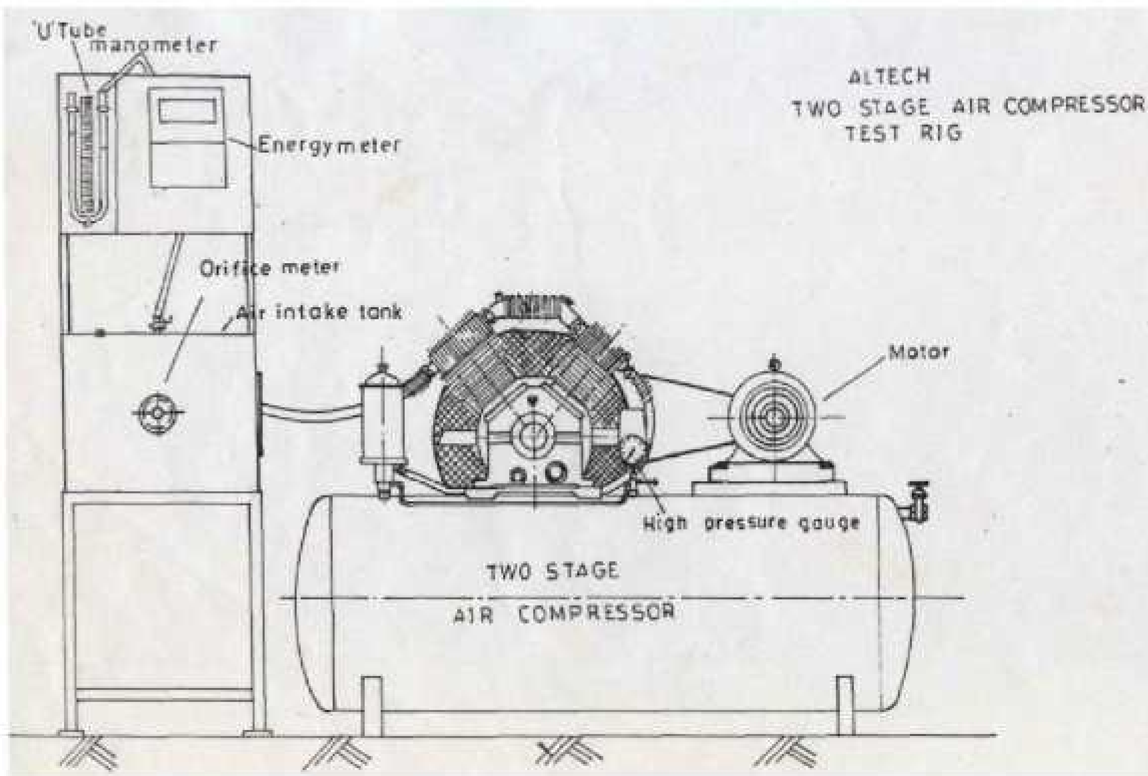
7. Isothermal efficiency $= \dfrac{Compressor\ output}{Compressor\ input} \; | \; 100$

Model Graphs:

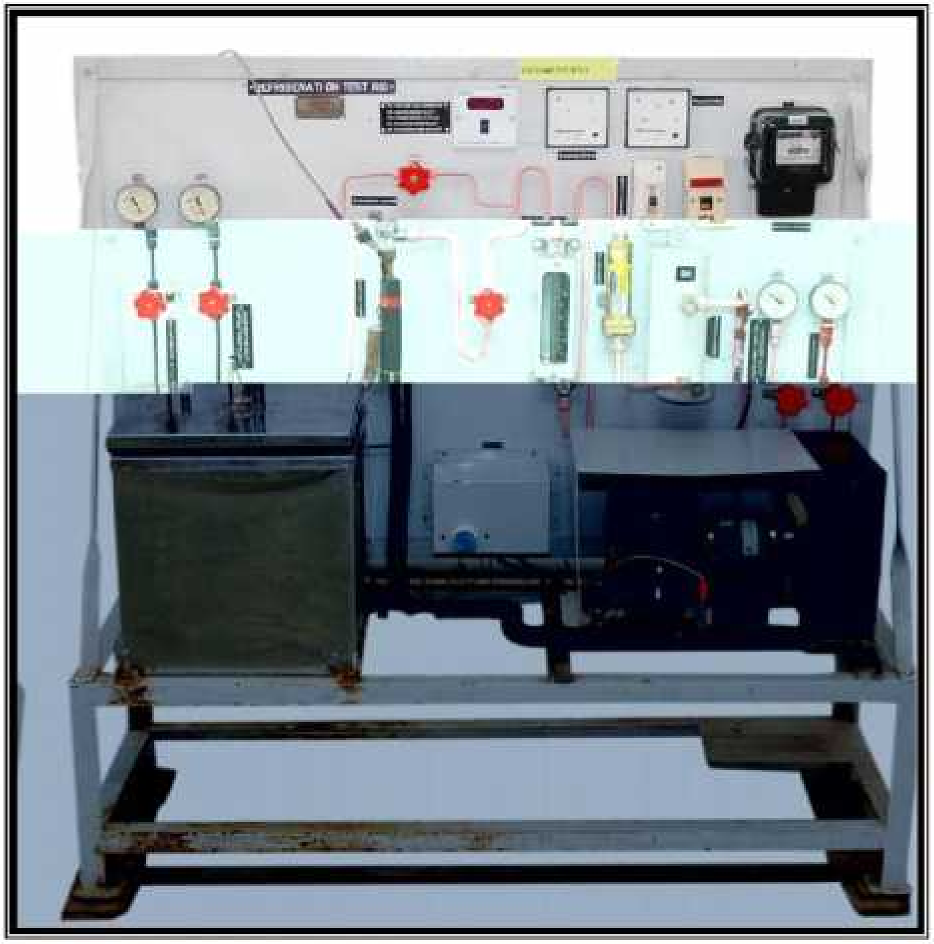




Result:


'U'Tube manometer
Energymeter
Orifice meter
Air intake tank
ALTECH
TWO STAGE AIR COMPRESSOR
TEST RIG
Motor
High pressure gauge
TWO STAGE
AIR COMPRESSOR

PERFORMANCE TEST ON REFRIGERATION TEST RIG



PERFORMANCE TEST ON REFRIGERATION TEST RIG

AIM:

To conduct a performance test on a refrigerator with Freon 12 refrigerant to determine the coefficient of performance.

EQUIPMENT /APPARATUS:

1. Refrigeration test rig
2. Measuring jar
3. Stop watch

SPRCIFICATIONS:

Make	:	Altech
Compressor	:	1 / 3 Ton of refrigeration
Condenser	:	Air Cooled
Expansion Device	:	i) Capillary Tube ii) Expansion Valve
Evaporator Coil	:	Immersed in water Tank of stainless steel
Refrigerant	:	Freon – 12.

DESCRIPTION:

The test rig consists of a hermetically sealed compressor. The compressed refrigerant from the compressor is sent to an air cooled condenser and the condensate in liquid form is sent to the expansion valve /capillary tube for throttling. Due to throttling temperature of the refrigerant falls and the cold refrigerant absorbs heat from the water in the evaporator tank. The refrigerant is then returned to the compressor.

A suitable filter and a transparent rotameter to visually observe the liquid. Refrigerant is fitted in the refrigerant line from condenser to evaporator. A thermocouple is provided to measure the temperature of the water in the evaporator tank. An energy meter is provided to measure the energy input to the compressor. Suitable pressure gauges are provided at the compressor inlet (evaporator outlet), condenser inlet (compressor outlet), condenser outlet (before throttling) and evaporator inlet (after throttling) to study the refrigeration cycle operating between the two pressures. A thermostat is provided for the cutting off the power to compressor when the water temperature reaches asset value. A voltmeter and an ammeter are provided to monitor the inlet power supply. A voltage stabilizer is provided for the protection of compressor. Provisions are provided in the refrigerant pipe lines for charging the test rig with additional refrigerant if necessary. Additional 4 No's of thermocouples are fitted at the condenser and evaporator inlet and outlet for studying the temperature at the 4 points in the refrigeration cycle

THEORY:

A refrigerator consists of a compressor connected by suitable pipelines to a condenser, a capillary tube and an evaporator. Refrigerant (Freon12) in vapor state from the evaporator is compressed in the compressor and sent to the condenser. Here it condenses's in to liquid and it is then throttled. Due to throttling temperature of refrigerant drops and the cold refrigerant passes through the evaporator absorbing heat from the object to be cooled. The refrigerant is then returned to the compressor and the cycle is completed

PROCEDURE:

1. Fill up the evaporator tank with a know quantity of water (say 10-15 litres).
2. Switch on the compressor.
3. After about 5 minutes (after steady state had set in) note the initial energy meter reading and water temperature in the evaporator.
4. After a known period of time, say 30 minutes note down the energy meter reading and water temperature.
5. Calculate the actual COP.
6. Note the Refrigerant pressures at compressor inlet (evaporator outlet), condenser inlet (compressor outlet), condenser outlet (before throttling) and evaporator inlet (after throttling) using the pressure gauges.

7. Note the Temperatures at compressor inlet (evaporator outlet), condenser inlet (compressor outlet), condenser outlet (before throttling) and evaporator inlet (after throttling) using the thermocouples provided.
8. Draw pressure- enthalpy diagram.
9. Calculate the theoretical COP
10. Calculate the relative cop

PRECAUTIONS:

1. Before noting the water temperature, physically Stir the water to ensure that the temperature is uniform in the water tank
2. Since COP depends upon the evaporator temperature and condenser temperature, the calculated COP (which is an average value) will be different for varying evaporator, condenser and water temperatures.
3. When the compressor turns off (by the thermostat) or is switched off manually, do not turn on the power immediately. Allow a few minutes for the pressure in the compressor inlet and outlet to equalize. The time delay provided in the voltage stabilizer is for this purpose only. Immediate starting will cause under load on the compressor and may even lead to burn out

SAMPLE CALCULATIONS:

ACTUAL COP:

Quantity of water in evaporator tank, m =….. Kg

Time taken for experiment, t =…..hours

Initial temperature of water, T_0 =…..^{0}C

Final temperature of water, T_f = …..^{0}C

Initial energy meter reading, E_0 = ….Kwh

Initial energy meter reading, E_f = ….Kwh

Refrigerating effect per hour = $\frac{m(T_0 - T_f)}{t}$

Energy input = $\frac{E_f \; Z E_o}{t}$ …..KW

Actual Coefficient of Performance, COP = $\frac{refrigerating\ effect}{Energy\ input}$

Actual COP =

THEORETICAL COP:

Theoretical COP is calculated from the pressure measured from pressure gauges (evaporator and condenser pressures) and the temperatures measured from four thermocouples located at four points of the thermodynamic cycle (refer figure 1).

S.No	Reading	Temperature, ^0C	Pressure, Psi	Pressure, Bar
1	Condenser inlet			
2	Condenser outlet			
3	Evaporator inlet			
4	Evaporator outlet			

Note: Bar = $\frac{Psi}{14.5}$ +1

From P-h diagram for R-12

Enthalpy of refrigerant at evaporator outlet, (before compression) h_1 = ….Kj/Kg

Enthalpy of refrigerant at condenser inlet, (after compression) h_2 = … …..Kj /kg

Enthalpy of refrigerant at condenser outlet, (before throttling) h_3 = ………..Kj/Kg

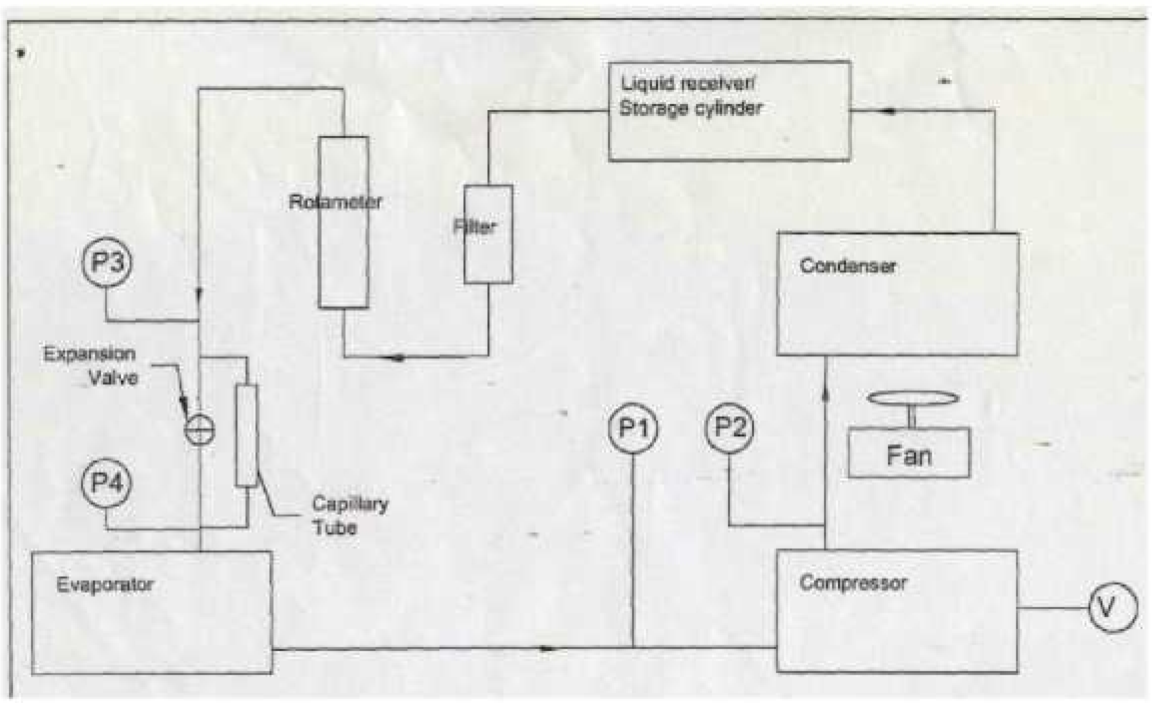
Enthalpy of refrigerant at evaporator inlet, (after throttling) h_4 = ……………Kj/Kg

$$\text{Theoretical COP} = \frac{(h_1 - h_4)}{(h_2 - h_1)}$$

$$= \frac{(h_1 - h_3)}{\;}$$

$$\text{Relative COP} = \frac{\text{Actual COP}}{\text{Theoritical COP}}$$

RESULT :


Liquid receiver/
Storage cylinder
Rotameter
Filter
P3
Condenser
Expansion
Valve
P1
P2
Fan
P4
Capillary
Tube
Evaporator
Compressor
V

PERFORMANCE TEST ON AIR CONDITIONING TEST RIG

PERFORMANCE TEST ON AIR CONDITIONING TEST RIG

AIM:

To conduct a performance test on an air conditioning test rig to determine the Coefficient Performance (COP).

EQUIPMENT /APPARATUS:

1. Air condition test rig
2. Stop watch

SPECIFCATIONS:

Make	:	Altech
Compressor	:	1 .5 Ton of refrigeration
Condenser	:	Air Cooled
Expansion Device	:	i) Capillary Tube ii) Expansion Valve
Refrigerant	:	Freon – 22.
Duct cross section	:	0.17 | 0.28

DESCRIPTION:

The test rig consists of a hermetically sealed compressor. Compressed refrigerant from the compressor is sent to an air cooled condenser and the condensate in liquid form is passed through an expansion valve or a capillary tube for throttling. Due to throttling, temperature of the refrigerant falls and the cold refrigerant passes through a liquid / vapour–air heat exchanger to absorb heat from the air to be chilled / conditioned. This heat exchanger is called the evaporator. A blower is used to circulate the air through this evaporator. The warm refrigerant is then returned to the compressor. A thermostat is provided to cut off compressor when the air temperature reaches the required value.

A filter is provided in the refrigerant line to remove any moisture. Wet bulb and dry bulb thermometers are provided to measure the temperature of the ambient air and conditioned air. An energy meter is provided to measure the energy input to the compressor and fan. A voltmeter and an ammeter are provided to monitor the power supply conditions. Provisions are provided in the refrigerant pipe lines for charging the test rig with additional refrigerant if necessary. Suitable pressure gauges are provided at the inlet and outlet of the compressor and evaporator to study the refrigerant vapor pressure at the various points. Additional 4 no's of thermocouples are fitted at the condenser and evaporator inlet and outlet for studying the temperature at the 4 points in the refrigeration cycle.

PROCEDURE:

1. Note the ambient dry bulb and wet bulb temperatures.
2. Turn on the air conditioner and set the thermostat at the required temperature.
3. After steady state had set in, note the wet bulb and dry bulb temperatures of the conditioned / chilled air in the duct.
4. Measure air velocity with the Pitot tube using the water manometer connected to the Pitot tube.
5. Note the time taken for 10 revolutions of energy meter disc to calculate the input energy.
6. Calculate the COP.

PRECAUTIONS:

1. Ensure the wet bulb temperature wick is always immersed in water and if necessary add water to the wick.
2. Align the pitot tube to flow direction such that the water level in the manometer is maximum before taking a velocity reading. Due to the low air velocities, the water column difference in the manometer will be only very small (about 1.5 to 2 mm).

3. Refrigerant pressures from the pressure gauges and temperature from the thermocouples can be used to study the vapor pressure at various points in the refrigerant cycle and prepare a enthalpy-pressure diagram.
4. When the compressor turns off (by the thermostat) or is switched off manually, do not turn on the power immediately. Allow a few minutes for the pressure in the compressor inlet and outlet to equalize. The time delay provided in the voltage stabilizer is for this purpose only. Immediate starting will cause under load on the compressor and may even lead to burn out.

CALCULATIONS:

1. Air flow rate:

   Manometer reading h_1 = ……….. cm of water

   Manometer reading h_2 = ……….. cm of water

Pitot tube water manometer level Difference, $h_w = \frac{h_1 - h_2}{100}$ …………m of water

Equivalent air column, $h_a = h_w \times \frac{\text{Density of water}}{\text{Density of air}} = h_w \times \frac{1000}{1.16}$ ….m. of air

Air velocity, $V = \sqrt{2gh_a}$ m/sec.

Duct cross sectional area, A = 0.17 x 0.28 m^2

Volume flow rate of air, Q = $A \times V$ …..m^3/Sec.

Mass flow rate of air, m = $\rho_a \times Q$ …. Kg/sec.

2. <u>Air conditiong Effect:</u>

Condition I refers to ambient and 2 refers to the air conditioned / chilled air.

Ambient dry bulb temperature , T_{1D} = ….0^0C

Ambient wet bulb temperature, T_{1w} =….0^0C

Chilled dry bulb temperature, T_{2D} =….0^0C

Chilled wet bulb temperature, T_{2w} =….0^0C

Refrigeration effect is the total heat removed from the air from condition 1 to condition 2. This can be obtained either from psychrometric calculations or directly from the psychrometric chart.

From the psychrometric chart

Total enthalpy of air at condition 1 h_1= ………….. KJ / Kg

Total enthalpy of air at condition 2 h_2 = ………. KJ / Kg

Heat removed from air per Kg (Refrigeration effect), (h_1-h_2)=…….. KJ/Kg

Total heat removed by the air conditioner, $H = m \times (h_1 - h_2)$ KJ

3. Input Energy to the Air-conditioner:

Energy meter constant, K = 1800 Rev / Kwh.

Time taken for ‘n’ revolutions of energy meter disc, t = …… seconds

Input energy, $E = \frac{3600 \times n}{K \times t}$ ….. KW

4. COP of Air-conditioner:

$$\text{COP of air conditioner} = \frac{\textit{refrigeration effect}}{\textit{input energy}}$$

5. Theoretical COP:

Theoretical COP is calculated from the pressure measured from pressure gauges (evaporator and condenser pressures) and the temperatures measured from four thermocouples located at four points of the thermodynamic cycle

S.No	Reading	Temperature, 0^0C	Pressure, Psi	Pressure, Bar
1	Condenser inlet			
2	Condenser outlet			
3	Evaporator inlet			
4	Evaporator outlet			

Note: Bar = $\frac{Psi}{14.5}$

From P-h diagram R-22

Enthalpy of refrigerant at evaporator outlet, (before compression) h_1 = ….Kj/Kg

Enthalpy of refrigerant at condenser inlet, (after compression) h_2 = … …..Kj /kg

Enthalpy of refrigerant at condenser outlet, (before throttling) h_3 = ………..Kj/Kg

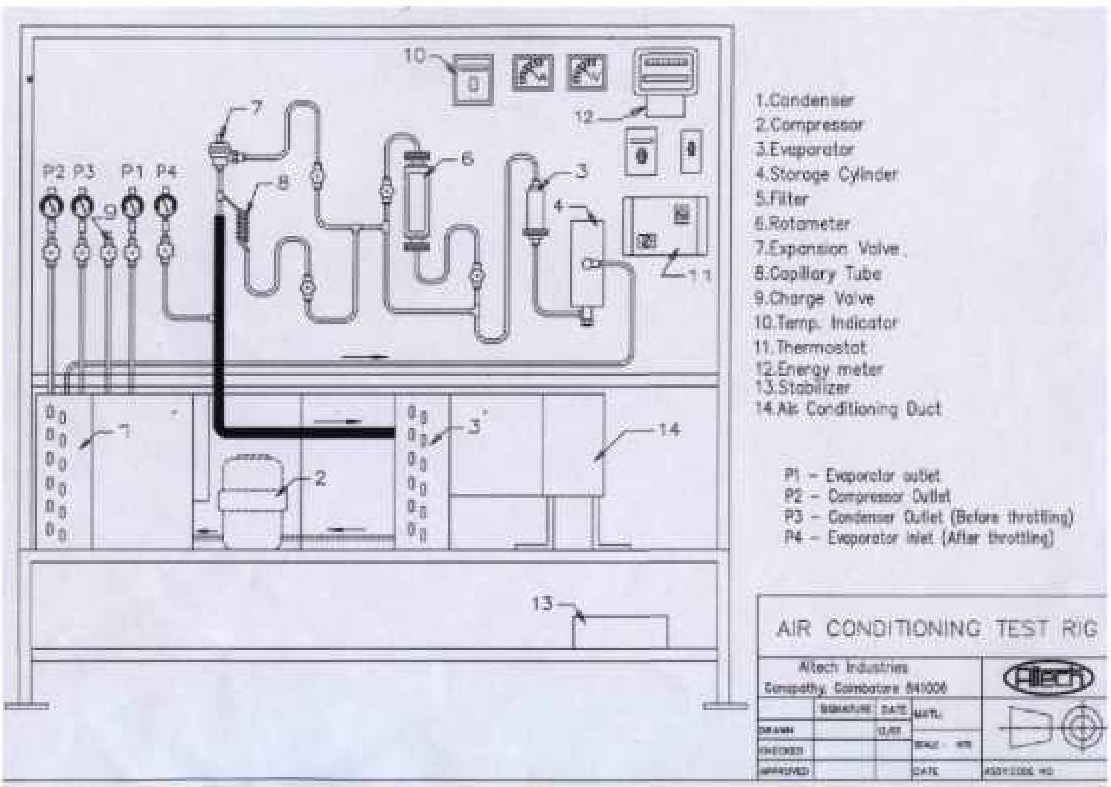
Enthalpy of refrigerant at evaporator inlet, (after throttling) h_4 = …………….Kj/Kg

6, Theoretical COP = $\frac{(h_1 \, \mathrm{Z} h_4)}{(h_2 \, \mathrm{Z} h_1)}$

$= \frac{(h_1 \, \mathrm{Z} h_3)}{(h_2 \, \mathrm{Z} h_1)}$

7. Relative COP = $\frac{Actual\ COP}{Theoritical\ COP}$

RESULT:


P2 P3 P1 P4
1.Condenser
2.Compressor
3.Evaporator
4.Storage Cylinder
5.Filter
6.Rotameter
7.Expansion Valve
8.Capillary Tube
9.Charge Valve
10.Temp. Indicator
11.Thermostat
12.Energy meter
13.Stabilizer
14.Air Conditioning Duct
P1 – Evaporator outlet
P2 – Compressor Outlet
P3 – Condenser Outlet (Before throttling)
P4 – Evaporator inlet (After throttling)
AIR CONDITIONING TEST RIG
Altech Industries
Ganapathy, Coimbatore 641006
SIGNATURE
DATE
DRAWN
CHECKED
APPROVED
DATE

PERFORMANCE TEST ON HEAT PUMP TEST RIG

PERFORMANCE TEST ON HEAT PUMP TEST RIG

AIM:

To conduct a performance test on a heat pump, to determine the Coefficient of Performance (COP).

EQUIPMENT /APPARATUS:

1. Heat pump test rig
2. Stop watch

SPECIFCATIONS:

Make	:	Altech
Compressor	:	1 .5 Ton of refrigeration
Condenser	:	Air Cooled
Expansion Device	:	i) Capillary Tube ii) Expansion Valve
Refrigerant	:	Freon – 22.
Duct cross section	:	0.17 | 0.28

DESCRIPTION:

The test rig consists of hermetically sealed compressor. Compressed and hot refrigerant gas from the compressor is sent to an air cooled condenser. An axial fan drives ambient air through this condenser and transfers heat from the hot refrigerant to the air and the warm air is ducted out. The refrigerant coming out of the condenser is in a liquid form and is passed through a capillary tube for throttling. Due to throttling, temperature of the refrigerant falls and the cold refrigerant passes through liquid / vapor-air heat exchanger to absorb heat from the ambient air. This heat exchanger is called the evaporator. A blower circulates air through this evaporator to remove the heat from the refrigerant. The warm refrigerant is then returned to the compressor.

A filter is provided in the refrigerant line to remove any moisture. Wet bulb and dry bulb thermometers are provided to measure the temperature of the ambient air and conditioned air. An energy meter is provided to measure the energy input to the compressor and fan. A voltmeter and an ammeter are provided to monitor the power supply conditions. Provisions are provided in the refrigerant pipe lines for charging the test rig with additional refrigerant if necessary. Suitable pressure gauges are provided to measure the compressor and evaporator pressure.

THEORY:

The heat pump uses a standard refrigeration cycle to pump heat from an external, comparatively low-temperature source to an inside space to be warmed. Here the useful energy is the heat discharged from the condenser instead f the heat absorbed by the evaporator as in an air conditioner or refrigerator. The heat pump is used in cold climatic regions for space warming. The advantage of using a heat pump over a simple electric space heater is that while in the electric heater the efficiency is 1.0-all electrical energy is converted into thermal energy, the efficiency (COP) of a heat pump is greater than 1.0.

PROCEDURE:

1. Note the ambient dry bulb and wet bulb temperatures.
2. Turn on the heat pump and set the thermostat at the required temperature.
3. After steady state had set in, note the wet bulb and dry bulb temperatures of the warm air in the duct.
4. Measure air velocity with the Pitot tube using the water manometer connected to the Pitot tube.
5. Note the time taken for 10 revolutions of energy meter disc to calculate the input energy.
6. Calculate the COP.

PRECAUTIONS:

1. Ensure the wet bulb temperature wick is always immersed in water and if necessary add water to the wick.
2. Align the pitot tube to flow direction such that the water level in the manometer is maximum before taking a velocity reading. Due to the low air velocities, the water column difference in the manometer will be only very small (about 1.5 to 2 mm).
3. Refrigerant pressures from the pressure gauges and temperature from the thermocouples can be used to study the vapor pressure at various points in the refrigerant cycle and prepare an enthalpy-pressure diagram.
4. When the compressor turns off (by the thermostat) or is switched off manually, do not turn on the power immediately. Allow a few minutes for the pressure in the compressor inlet and outlet to equalize. The time delay provided in the voltage stabilizer is for this purpose only. Immediate starting will cause under load on the compressor and may even lead to burn out.

CALCULATIONS:

1. <u>Air flow rate:</u>

Pitot tube water manometer level Difference, $h_w = \frac{h_1 - h_2}{100}$ …………m of water

Equivalent air column, $h_a = h_w \times \frac{Density\ of\ water}{Density\ of\ air} = h_w \times \frac{1000}{1.16}$ ….m. of air

Air velocity, $V = \sqrt{2gh_a}$ m/sec.

Duct cross sectional area, A = 0.39 x 0.235 m^2

Volume flow rate of air, Q = $A \times V$ …..m^3/sec.

Mass flow rate of air, m = $\rho_a \times Q$ …. Kg/sec.

2. <u>Heating Effect:</u>

Condition I refers to ambient and 2 refers to the warm air.

Ambient dry bulb temperature , T_{1D} = ….0^0C

Ambient wet bulb temperature, T_{1w} =….0^0C

Warm air dry bulb temperature,T_{2D} =….0^0C

Warm air Wet bulb temperature, T_{2w} =….0^0C

Alternatively,

Heating effect is the total heat added from the air from condition 1 to condition 2. This can be obtained either from psychrometric calculations or directly from the psychrometric chart.

From the psychrometric chart

Total enthalpy of air at condition 1 h_1 =…….KJ / Kg

Total enthalpy of air at condition 2 h_2 =…….KJ / Kg

Heat added from air per Kg ,(h_1-h_2)= ……… KJ/Kg

Total heat added by the Heat pump, H = $m \mid (h_1 \ \text{Z} h_2)$ KJ

Input Energy to the Heat pump:

Energy meter constant, N = 1800 Rev / Kw h.

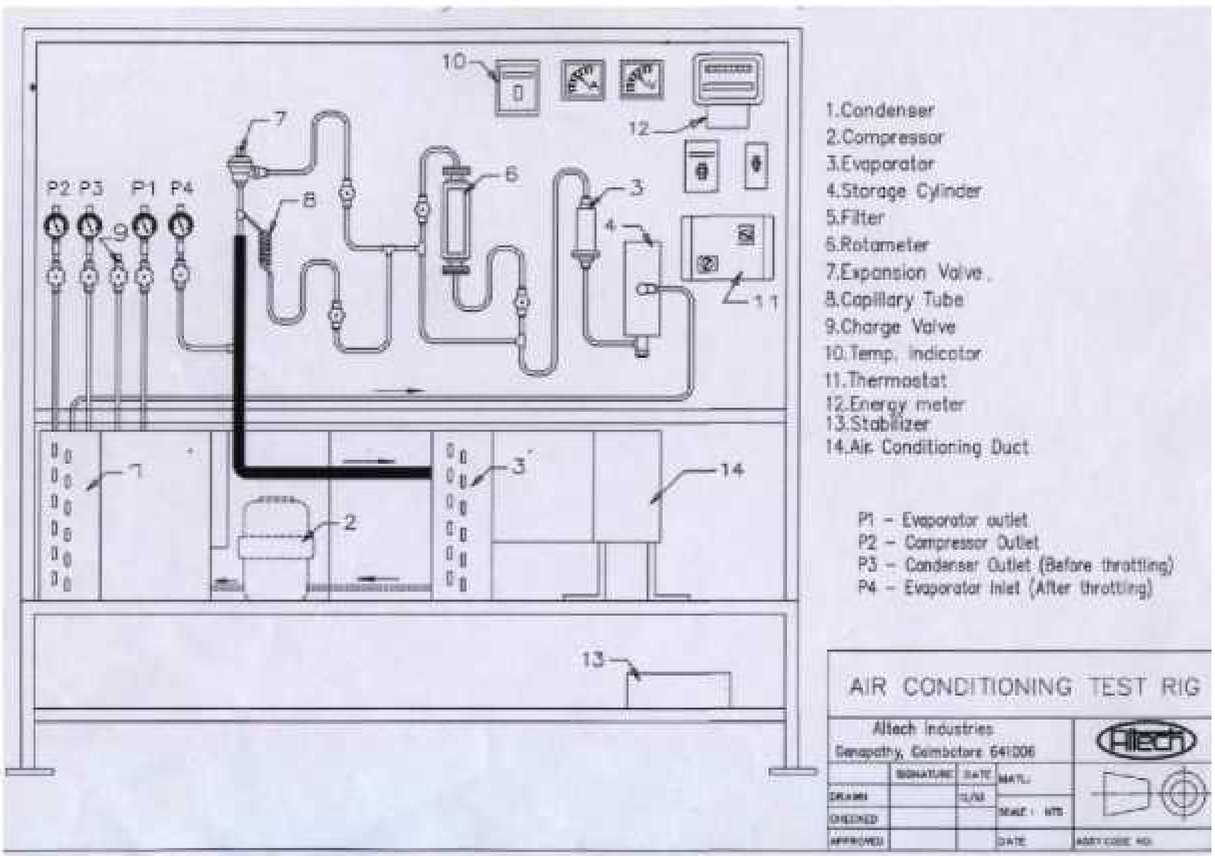
Time taken for ‘n’ revolutions of energy meter disc, t = …… seconds

Input energy, $E = \frac{3600 \times n}{N \times t}$ ….. KW

COP of Air-conditioner:

COP of heat pump = $\frac{\textit{Heating effect}}{\textit{input energy}}$

RESULT:



10
7
12
6
3
8
P2 P3 P1 P4
9
4
11
1
3'
14
2
13
1.Condenser
2.Compressor
3.Evaporator
4.Storage Cylinder
5.Filter
6.Rotameter
7.Expansion Valve.
8.Capillary Tube
9.Charge Valve
10.Temp. indicator
11.Thermostat
12.Energy meter
13.Stabilizer
14.Air Conditioning Duct
P1 – Evaporator outlet
P2 – Compressor Outlet
P3 – Condenser Outlet (Before throttling)
P4 – Evaporator Inlet (After throttling)
AIR CONDITIONING TEST RIG
Altech Industries
Ganapathy, Coimbatore 641006

VALVE TIMEING DIAGRAM

AIM: To draw the of a four-stroke single cylinder vertical diesel engine.

APPARATUS: Thread, scale, chalk piece.

THEORY:

Valve timing is the determination of points in the cycle at which the valves are set to open and close. In the ideal cycle the inlet and exhaust valves open at dead centers. There are two factors: Mechanical and Dynamical for the actual valve timing to be different from the theoretical valve timing.

a) Mechanical factor:

The valves of a reciprocating engine are opened closed by cam mechanism. To avoid noise and wear, the valve should be lifted slowly. For the same reason the valve cannot be closed abruptly else it will bounce on its seat. Then the opening and closing periods are spread over a considerable number of crank shaft degrees. As a result the opening of the valve must commence a head of time at which it is fully opened. The same reason applied for the closing time and valve must close after dead centers.

b) Dynamic factor:

Besides the mechanical factor the actual valve timing is set taking the dynamic effects of gas flow into consideration. As the piston moves all in the suction stroke, the fresh air is drawn into the cylinder through the inlet valve when the piston reaches the BDC and to move towards TDC in the compression stroke, the inertia of the centering fresh air tends to cause to continue to move in the cylinder after BDC. So maximum air is taken in.

The exhaust valve is set to pen before BDC. By earlier opening of the exhaust valve, the scavenging period is increased. Also earlier opening means that exhaust pressure is higher than the atmospheric pressure, which helps in scavenging process. The exhaust valve is closed a few degrees after TDC. The inertia of the exhaust gases tends to scavenge the cylinder by carrying out a greater mass gas lift in Clarence volume. For some period there is valve overlapping i.e., the kinetic energy of fresh charge helps in forcing out at exhaust gases.

PROCEDURE:

1. T.D.C. is identified and marked on the fly wheel with respect to one fixed point in the engine.
2. The circumference of fly wheel is measured using thread and scale.
3. The BDC is marked on the flywheel by taking half the circumference.
4. The cover on the valve casing is removed and inlet and exhaust valves and their push rods are identified.
5. By slowly cranking the camshaft in the direction of rotation the opening of inlet valve is marked on the fly wheel w.r.t. fixed point when the push rod of inlet fixed point when the push rod of inlet valve is becomes tight to move.
6. Mark a point on the fly wheel where the inlet valve is completely closed.
7. In the same way mark the points where the exhaust valve open and close.
8. The distance of opening of inlet valve and closing of exhaust valve from TDC and closing of inlet valve and opening of the exhaust valve from BDC are measured using thread and scale.
9. The angles of opening and closing of inlet and exhaust valves are calculated w.r.t. TDC and BDC.

PRECAUTIONS:

1. The decompression level must be operated when conducting the test.
2. Cranking should be the carefully and slowly so that the salient points are located carefully.

OBSERVATIONS: circumference of the fly wheel = 2 σ R

Sl.No.	Event	Distance from nearest dead center	Angle
1	IVO		
2	IVC		
3	EVO		
4	EVC		

IVO = Inlet valve open

IVC = Inlet valve close

EVO = Exhaust valve open

EVC = Exhaust valve close

RESULT:

STUDY OF BOILERS

STUDY OF BOILERS

BOILER DEFINITION:

A simple boiler may be defined as a closed vessel in which steam is produced from water by combustion of fuel.

CLASSIFICATION OF BOILERS:

1. **Horizontal, Vertical or Inclined:**

   If the axis of the boiler is horizontal, the boiler is called as horizontal, if the axis is vertical, it is called vertical boiler and if the axis is inclined it is known as inclined boiler. The parts of a horizontal boiler can be inspected and repaired easily but it occupies more space. The vertical boiler occupies less floor area.

2. **Fire Tube and Water Tube:**

   In the fire tube boilers, the hot gases are inside the tubes and the water surrounds the tubes.

   Examples: Cochran, Lancashire and Locomotive boilers.

   In the water tube boilers, the water is inside the tubes and hot gases surround them.

   Examples: Babcock and Wilcox, Sterling, Yarrow boiler etc

3. **Externally Fired and Internally Fired:**

   The boiler is known as externally fired if the fire is outside the shell.

   Examples: Babcock and Wilcox, Sterling, boiler.

4. **Forced Circulation and Natural Circulation:**

   In forced circulation type of boilers, the circulation of water is done by a forced pump.

   Examples: velox, Lamont, Benson boiler.

5. **Higher Pressure and Low Pressure Boilers:**

   The boilers which produce steam at pressures of 80bar and above are called high-pressure boilers.

   Examples: Babcock and Wilcox, velox, Lamont, Benson boilers.

   The boilers which produce steam at pressure below 80 bar are called low pressure boilers.

   Examples: Cochran, Cornish, Lancashire and locomotive boilers.

6. **Stationary and Portable:**

Primarily, the boilers are classified as either stationary (land) or mobile (marine and locomotive)

- Stationary boilers are used for power plant steam, for central station utility power plants, for plant process steam etc.
- Mobile boilers or portable boilers include locomotive type, and other small units for temporary use at sites (just as in small coal field pits)

7. **Single Tube and Multi Tube Boilers:**

The fire tube boilers are classified as single tube and multi tube boilers, depending upon whether the fire tube is one or more than one. The examples of the former type are Cornish, simple vertical boiler and rest of the boilers are multi tube boilers.

Essentials of a good steam boiler:

A good boiler should possess the following features:

1. The boiler should produce the maximum weight of steam of the required quality at minimum expenses.
2. Steam production rate should be as per requirements
3. It should be absolutely reliable
4. It should be light in weight
5. It should be capable of quick starting
6. There should be an easy access to the various parts of the boiler for repairs and inspection
7. The boiler components should be transportable without difficulty
8. The installation of the boiler should be simple
9. The tubes of the boiler should not accumulate soot or water deposits and should be sufficiently strong to allow for wear and corrosion.
10. It should occupy minimum space
11. The water and gas circuits should be such as to allow minimum fluid velocity (for low frictional losses)

BOILER TERMS

Shell: The shell of a boiler consists of one or more steel plates bent into a cylindrical form and riveted or welded together. The shell ends are closed with the end plates

Setting: The primary function of setting is to confine heat to the boiler and form a passage for gases. It is made of brickwork and may form the wall of the furnace and the combustion chamber. It also provides support in some types of boilers (e.g. Lancashire boilers)

Furnace: it is a chamber formed by the space above the grate and below the boiler shell, in which combustion takes place. It is also called a firebox.

Water space and steam space. The volume of the shell that is occupied by the water is termed water space while the entire shell volume less the water and tube s (if any) space is called steam space

Mountings. The item such as stop valve, safety values, water level gauges, fusible plug blow off cock, pressure gauges, water level indicator etc.

Accessories: The items such as superheaters, economizers, feed pumps etc. are termed as accessories and they form integral part of the boiler. They increase the efficiency of boiler.

Water Level: The level at which water stands in the boiler is called water level. The space above the water level is called steam space.

Foaming: formation of steam bubbles on the surface of boiler water due to high surface tension of the water.

Scale: A deposit of medium to extreme hardness occurring on water heating surfaces of a boiler because of an undesirable condition in the boiler water.

Blowing Off: The removal of the mud and other impurities of water form the lowest part of the boiler (where they usually settle) is termed as blowing off. This is accomplished with the help of a blow off cock or valve.

Lagging: blocks of asbestos or magnesia insulation wrapped on the outside of a boiler shell or steam piping

Refractory: a heat insulation material, such as firebrick or plastic fire clay, used for such purposes as lining combustion chambers.

FIRE TUBE BOILER:

SIMPLE VERTICAL TUBE BOILER:

It consists of a cylindrical shell, the greater portion of which is full of water (which surrounds the fire box also) and remaining is the steam space. At the bottom of the firebox is grate on which fuel is burnt and the ash from it falls in the ash pit. The firebox is provided with two cross tubes. This increases the heating surface and the circulation of water. The cross tubes are fitted inclined. This ensures efficient circulation of water. At the ends of each cross tube at provided hand hoes to give access for cleaning these tubes. The combustion gases after heating the water and thus converting it into steam escape to the atmosphere through the chimney. Manhole is provided to clean the interior of the boiler and exterior of the combustion chamber and chimney. The various mountings are

1. Pressure gauge
2. Water level gauge or indicator
3. Safety valve
4. Steam stop valve
5. Feed check valve
6. Man hole

COCHRAN BOILER

It is one of the best types of vertical multi tubular boiler, and has a number of horizontal fire tubes

Cochran boiler consists of a cylindrical shell with a dome shaped top where the space is provided for steam. The furnace is one-piece construction and is seamless. Its crown has a hemispherical shape and thus provides maximum volume of space. The fuel is burnt on the grate and ash is collected and disposed of from ash pit. The gases of combustion produced by burning of fuel enter the combustion chamber through the flue tube and strike against firebrick lining which directs them to pass through number of horizontal tubes, being surrounded by water. After which the gases escape to the atmosphere through smoke box and chimney. A number of hand holes are provided around the outer shell for cleaning purposes.

The various boiler mountings are

1. Water level gauge
2. Safety valve
3. Steam stop valve
4. Blow off cock
5. Man hole
6. Pressure gauge

CORNISH BOILER:

This form of boiler was first adopted by Trevithick, the Cornish engineer, at the time of introduction of high-pressure steam to the early Cornish engine, and is still used. It consists of a cylindrical shell with flat ends through which passes a smaller flue tube containing the furnace. The products of combustion pass from the fire grate forward over the brick work bridge to the end of the furnace tube: they then return by two side flues to the front end of the boiler, and again pass to the back end of a flue along the bottom of the boiler to the chimney.

The various boiler mountings which are used on this boiler are

1. Steam sop valve
2. Pressure gauge
3. Water gauge
4. Fusible flug
5. Manhole
6. Blow off cock
7. High steam low water safety valve
8. Feed check valve

The advantage possessed by this type of boiler is that the sediment contained in the water falls to the bottom, where the plates are not brought into contact with the hottest portion of the furnace gases. The reason for carrying the product of combustion first through the side flues, and lastly through the bottom flue, is because the gases, having parted with much of their heat by the time they reach the bottom flue, are less liable to unduly heat the plates in the bottom of the boiler, where the sediment may have collected.

LANCASHIRE BOILER

This boiler is reliable, has simplicity of design, ease of operation and less operating and maintenance costs. It is commonly used in sugar mills and textile industries where along with the power steam and steam for the process work is also needed. In addition this boiler is used where larger reserve of water and steam are needed.

The Lancashire boiler consists of a cylindrical shell inside which two large tubes are placed. The shell is constructed with several rings of cylindrical form and it is placed horizontally over a brick work which forms several channels for the flow of hot gases. These tow tubes are also constructed with several rings of cylindrical form. They pass form one and of the shell to the other and are covered with water. The furnace is placed at the front end of each tube and they are known as furnace tubes. The coal is introduced through the fire hole into the grate. There is low brick work fire bridge at the back of the gate to prevent the entry of the burning coal and ashes into the interior of the furnace tubes.

The combustion products from the grate pass up to the back end of the furnace tubes and then in downward direction. Thereafter they move through the bottom channel or bottom flue upto the front end of the boiler where they are divided and pass upto the side flues. Now they move along the two side flues and come to the chimney flue from where they lead to the chimney. To control the flow of hot gases to the chimney, dampers (in the form of sliding doors) are provided. As a result the flow of air to the grate can be controlled.

LOCOMOTIVE BOILER:

It is mainly employed in locomotives through it may also be used as a stationary boiler. It is compact and its capacity for steam production is quite high for its size as it can raise large quantity of steam rapidly.

The locomotive boiler consists of a cylindrical barrel with a rectangular fire box at one end and a smoke box at the other end. The coal is introduced through the fire hole into the grate, which is placed at the bottom of the firebox. The hot gases which are generated due to burning of the coal are deflected by an arch of firebricks, so that walls of the firebox may be heated properly. The firebox is entirely surrounded by water except for the fire hole and the ash pit, which is situated below the firebox, which is fitted with dampers at its front and back ends. The dampers control the flow of air to the grate. The hot gases pass from the firebox to the smoke box through a series of fire tubes and then they are discharged into the atmosphere through the chimney. The fire tunes are placed inside the barrel. Some of these tubes are of larger diameter and the others of smaller diameter. The super heater tubes are placed inside the fire tubes of larger diameter. Te heat of the hot gases is transmitted into the water through the heating surface of the fire tubes. The steam generated is collected over the water surface.

A dome shaped chamber known as steam dome is fitted on the upper part of the barrel, from where the steam flows through a steam pipe into the chamber. The flow of steam is regulated by means of a regulator. From the chamber it passes through the superheater tubes and returns to the superheated steam chamber (not shown) from which it is led to the cylinders through the pipes, on to each cylinder.

In this boiler natural draught connot be obtained because it requires a very high chimney which connot be provided on a locomotive boiler since it has to run on rails. Thus some artificial arrangement has to be uses to produce a correct draught. As such the draught here is produced by exhaust steam from the cylinder, which is discharged through the blast pipe to the chimney. When the locomotive is standing and no exhaust steam is available form the engine fresh steam from the boiler is uses for the purpose.

The various boiler mountings inside :

1. Safety valve
2. Pressure gauge
3. Water level indicator
4. Fusible plug
5. Manhole
6. Manhole
7. Blow off cock
8. Feed check valve

Merits

1. High steam capacity

2. Low cost of construction
3. Portability
4. Low installation cost
5. Compact

Demerits:

1. There are chances to corrosion and scale formation in the water legs due to the accumulation of sediments and the mud particles
2. It is difficult to clean some water spaces
3. Large flat surfaces need bracing
4. It connot carry high over loads without being damaged by overheating
5. There are practical constructional limits for pressure and capacity which do not meet requirements

The water tune boilers are used exclusively, when pressure above 10 bar and capacity in excess of 7000kg of steam per hour is required. Babcock and Wilcox water tube boiler is an example of horizontal straight tube boiler and may be designed for stationary or marine purposes.

BABCOCK AND WILCOX WATER TUBE BOILER

Babcock and Wilcox boiler with longitudinal drum. It consists of a drum connected to a series of front end and rear end header by short riser tubes. To these headers are connected a series of inclined water tubes of solid drawn mild steel.

The angle of inclination of the water tubes to the horizontal is about 15o or more. A hand hole is provided In the header in front of each tube for cleaning and inspection of tubes. A feed valve is provided to fill the drum and inclined tubes with water the level of which is indicated by the water level indicator. Through the fire door the fuel is supplied to grate where it is burnt. The hot gases are forced to move upwards between the tubes by baffle plates provided. The water from the drum flows through the inclined tubes via down take header and goes back into the shell in the form of water and steam via uptake header. The steam gets collected in the steam space of the drum. The steam then enters through the antipriming pipe and flows in the superheater tubes where it is further heated and is finally taken out through the main stop valve and supplied to the engine when needed.

At the lowest pint of the boiler is provided a mud collector to remove the mud particles through a blow down cock

The entire boiler except the furnace are hung by means of metallic slings or straps or wrought iron girders supported on pillars. This arrangement enables the drum and the tubes to expand or contract freely. The brickwork around the boiler encloses the furnace and the hot gases.

A Babcock Wilcox water tube boiler with cross draw differs from longitudinal drum boiler in a way that how drum is place with reference to the axis of the water tubes of the boiler. The longitudinal drum restricts the number of tubes that can be connected to one drum circumferentially and limits the capacity of the boiler. In the cross drum there is no limitation of the number of connecting tubes.

The pressure of steam in case of cross drum boiler may be as high as 100 bar and steaming capacity upto 27,000 kg/hr

LOAD TEST ON 4-STROKE, TWIN CYLINDER DIESEL ENGINE TEST RIG

LOAD TEST ON 4-STROKE, TWIN CYLINDER DIESEL ENGINE TEST RIG

AIM:

To conduct a load test on 4-stroke, Twin cylinder diesel engine, to study its performance under various loads.

EQUIPMENT/APPARATUS:

1. 4- Stroke, twin cylinder Diesel engine with a hydraulic dynamometer.
2. Stopwatch.

SPECIFICATIONS:

Make	:	Kirloskar model AVI
Bore	:	87.5mm
Stroke	:	110 mm
No of cylinders	:	2
Rated Speed	:	1500 rpm
Max. B.P	:	10KW
Compression Ratio	:	16 .5:1
Orifice Diameter	:	25mm
Fuel	:	Diesel
Density of Diesel	:	0.827 gm / ml
Calorific Value of Diesel	:	45,350 KJ / kg

DESCRIPTION:

This is a water cooled twin cylinder vertical diesel engine is coupled to a hydraulic dynamometer arrangement to absorb the power produced. Separate cooling water lines are provided for the engine cooling. Thermocouples are provided for measuring temperature. A fuel measuring system consists of a fuel tank mounted on a stand, burette, and a 3-way cock.

Air consumption is measured by using a M.S. tank, which is fitted with a standard orifice and a U-tube water manometer that measures the pressures inside the tank.

THEORY:

Twin cylinder stationary, constant speed diesel engines are generally quality governed. As such the air supplied to the engine is not throttled as in the case of S.I. engines. To meet the power requirements of the shaft, the quantity of fuel injected into the cylinder is varied by the rack in the fuel pump. The rack is usually controlled by a governor or by a hand. The air flow rate of twin cylinder engine operating at constant speed does not vary appreciably with the output of the engine. Since the fuel flow rate varies more or less linearly with output, the fuel air ratio increases with output. Performance tests can be conducted either at constant speed (or) at constant throttle. The constant speed method yields the F.P. of the engine.

STARTING THE ENGINE:

1. Engage de-compression lever before cranking.
2. Crank the engine and disengage the de-compression lever.
3. Adjust the governor to attain the rated speed.

PROCEDURE:

1. Open the three way cock so that fuel flows to the engine directly from the tank.
2. Open the cooling water valves and ensure water flows through the engine.
3. Start the engine and allow running on no load condition for few minutes.
4. Open the water line to the hydraulic dynamometer
5. Load engine with hydraulic dynamometer-loading is done by turning the handle in the direction marked. If sufficient loaded is not absorbed by the dynamometer at the required speed, the outlet valve in the dynamometer can be closed to increase the pressure (as indicated by the pressure gauge) and hence the load.
6. Allow the engine to run at no load for few minutes.
7. Note the following readings
    a) Engine speed.
    b) Hydraulic dynamometer reading.
    c) Manometer
    d) Time for 10 cc of fuel consumption
8. Repeat the above procedure at different loads.
9. Stop the engine after removing load on the engine.

PRECAUTIONS:

1. Before stating the engine check all the systems such as cooling , lubrication and fuel system
2. Ensure oil level is maintained in the engine up to recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed.

GRAPHS

1. T.F.C Vs B .P
2. S.F.C Vs B .P
3. →B th Vs B .P
4. →th Vs B .P
5. →m Vs B .P

OBSERVATIONS:

Manometer reading h_1 = ……….. cm of water

Manometer reading h_2 = ……….. cm of water

S.NO	Load on the Dynamometer ,W kg	Speed , Rpm	Time for 10 cc of fuel , Sec	T.F.C, Kg/hr	S.F.C, Kg/Kw-hr	B.P, KW	H.I, KW	I.P, K.W	I.M.E.P ,KPa	B.M.E.P, KPa	Efficiencies			
											→B th	→th	→m	→Vol
1														
2														
3														
4														
5														

SAMPLE CALCULATIONS:

1 Brake Power (BP) = $\dfrac{W \times N}{2000 \times 1.36}$ …….KW

Where,

N= rated speed …… rpm,

W=load on the Dynamometer …….. Kg

2 Indicated Power

Time for 10cc of fuel consumption, t = ……. Sec,

Mass of fuel consumption per min, m_f = $\dfrac{10}{t} \times \dfrac{Sp.Gravity\ of\ diesel}{1000} \times 60$ ..kg/ min.

Total Fuel consumption, TFC = … $m_f \times 60$….kg / hr.

Specific fuel consumption, SFC = $\dfrac{T.F.C}{B.P}$ ……..Kg / Kw-hr

Heat Input, HI = $\dfrac{TFC \times CV}{60 \times 60}$ …….KW

Where CV is calorific value of Diesel = 45,350 KJ / kg

Indicated Power, I.P = B.P + F.P

Where F. P = Frictional Power from William's line diagram (TFC Vs B.P)

3. Brake thermal efficiency, $\eta_{b\,th} = \frac{B.P}{HI} \times 100$

4 Indicated thermal efficiency, $\eta_{i\,th} = \frac{I.P}{HI} \times 100$

5 Mechanical efficiency, $\eta_{m} = \frac{B.P}{I.P} \times 100$

6 I.M.E.P = $\frac{I.P \times 60}{L \times A \times n \times K}$ …..KPa

7 B.M.E.P. = $\frac{B.P \times 60}{L \times A \times n \times K}$ …….KPa

Where L = Stroke of length ……'m'

A = Cross section area of piston in 'm^2'

n = Number of working strokes = $\frac{N}{2}$ (for 4 stroke engine)

K = Number of cylinders =2

8 Volumetric Efficiency, $\eta_{vol} = \frac{V_s}{V_t} \times 100$

i) <u>Actual Air intake:</u>

Manometer reading h_1 = ………….cm of water

Manometer reading h_2 = ………….cm of water

Difference in water level, $h_w = \frac{h_1 - h_2}{100}$ ……………….m of water

Equivalent air column, $h_a = h_w \times \frac{Density\ of\ water}{Density\ of\ air} = h_w \times \frac{1000}{1.16}$ ….m. of air

Orifice diameter, d = 0.025 m

Area of orifice, $a = \frac{\pi \times (0.025)^2}{4}$ ……..m^2

Actual Volume of air intake, $V_a = 60 \times C_d \times a \times \sqrt{2gh_a}$ ……..m^3 / min.

Where C_d = 0.62

Mass of air intake, $m_a = \rho_a \times V_a$ ……kg / min

Density of air ρ_a = 1.16 Kg/m^3

ii) Theoretical Air intake:

Diameter of piston, D = 0.0875m

Stroke length, L = 0.110 m

Engine speed, N = ………..rpm

K =Number of cylinders

Theoretical volume of air intake, V_t = $\frac{\pi}{4} \times D^2 \times L \times \frac{N}{2} \times K$ …..m^3 / min

Volumetric efficiency, η_{vol} = $\frac{Vs}{Vt} \times 100$

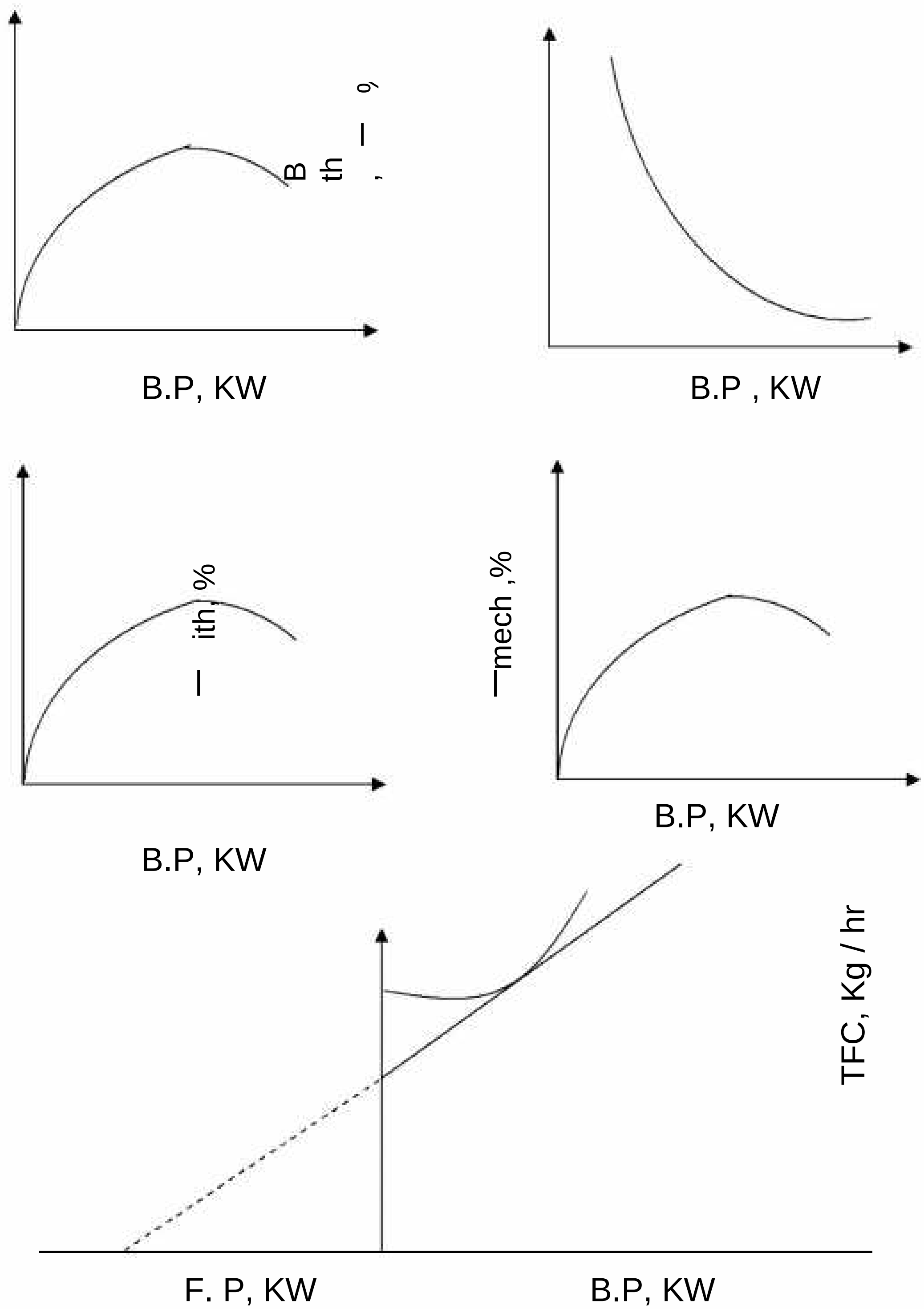
Swept volume at STP, V_s = $V_a \times \frac{Ts}{Ta}$ …….m^3/min

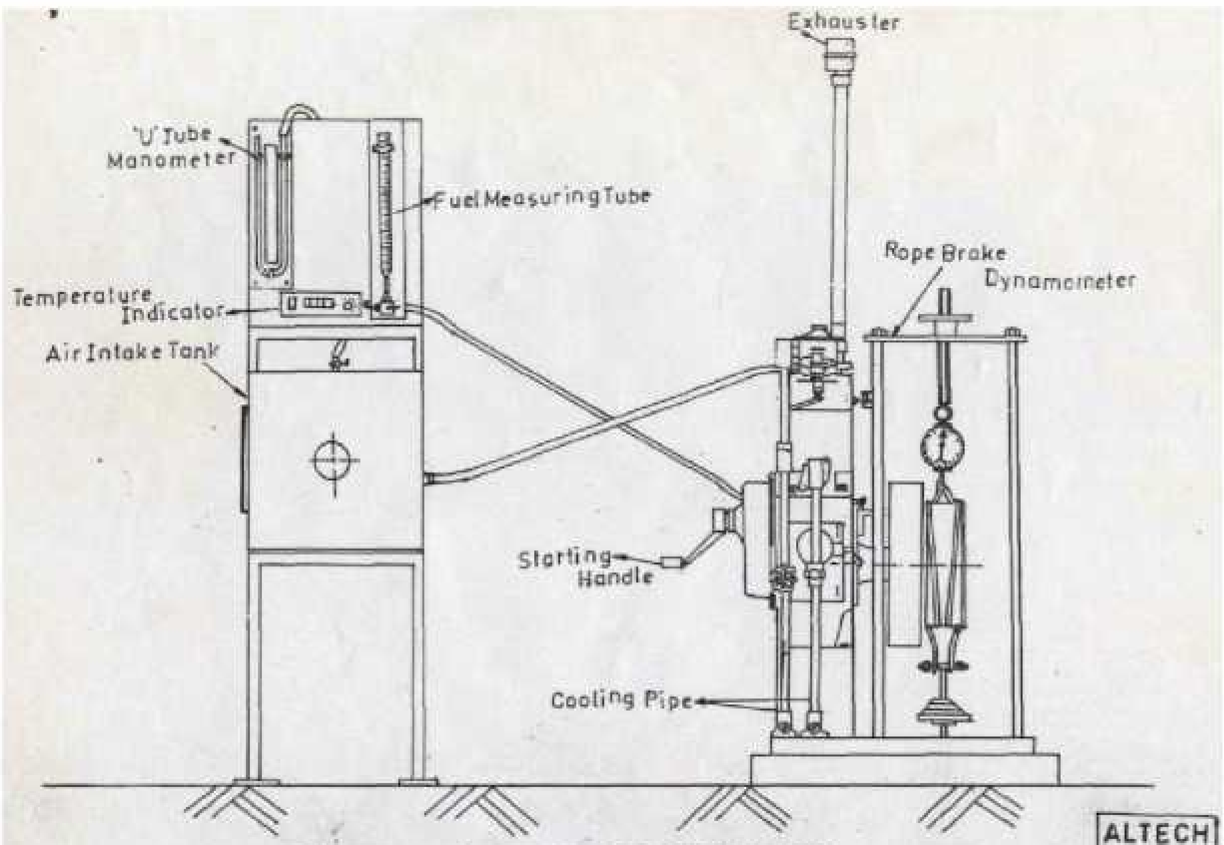
Where T_a = Ambient Temperature……. ^{0} K

T_s = Standard Temperature, 288^0K

9 Air- Fuel Ratio = $\frac{Mass\ of\ actual\ air\ intake\ per\ minute\ (kg/min)}{Mass\ of\ fuel\ intake\ per\ minute\ (kg/min)}$ X $\frac{m_a}{m_f}$

MODEL GRAPHS:





SINGLE CYLINDER DIESEL ENGINE WITH MECHANICAL DYNAMOMETER TEST RIG

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR
LAB MANUAL

Title of Course: Electric Machine-I Lab
Course Code: EE491
L-T-P scheme: 0-0-3 **Course Credit: 2**

Objectives:

1. Observe the Hopkinson's test and found that the efficiency for the both the generator and motor are same.
2. Observe the speed variation of the DC motor by the resistance of the armature and field
3. Perform the blocked rotor and No load test of a three phase induction motor and find out result to compare that with the theoretical one.

Learning Outcomes: By doing this practical students will gain the knowledge about the different parts of the DC machine and Three Phase Induction Motor. Upon the completion of this practical course, the student will be able to:

- Understand the efficiency of the same rated machine will be same for a dc generator and dc motor
- Understand the speed variation of the motor by varying the different resistance of the motor.
- Get a Knowledge about the result of the three phase induction Motor and find out that this results are helpful to find out the equivalent parameter of the motor.

Course Contents:
Exercises that must be done in this course are listed below:
Experiment No.1: Perform the Hopkinson's Test of Two same rated DC Machines
Experiment No. 2: Speed Control of DC Motor using armature resistance control
Experiment No. 3: Speed Control of DC Motor using field resistance control
Experiment No. 4: Perform the No load test of three phase Induction Motor
Experiment No. 5: Perform the Blocked Rotor test of Three Phase Induction Motor

Text Books:

1. Electrical Machine by Ashfaq Hussain

References:

1. A Text book of Electrical Technology (Volume-2) by B.L.Theraja, A.K. Theraja
2. Electrical Machinery by Dr.P.S. Bimbhra
3. Theory and Performance of Electrical Machine by J.B.Gupta

UNIVERSITY OF ENGINEERING AND MANAGEMENT, JAIPUR
Lab Manual

EXPERIMENT NO: 01

TITLE: Perform the Hopkinson's Test of Two same rated DC Machines

AIM: To Perform the Hopkinson's Test of Two same rated DC Machines

APPARATUS REQUIRED:

(i) Multi Meter
(ii) Hopkinson Test Panel
(iii) Two Same rated Dc Machine(One working as a Dc Generator and the other as a Dc motor)
(iv) A Taco Meter
(v) Connecting Wires

THEORY:

The efficiency of the DC machine can be accurately determined by the regenerative method, normally known as Hopkinson's test. This test overcomes the drawback of Swinburne's test, which does not take any account of the stray load losses occurring in DC machines under loaded condition. As such the efficiency, calculated by Swinburne's test is comparatively higher than the actual one. Hopkinson's test needs two identical DC machines coupled mechanically and connected electrically as shown in Fig. 'A'. One of the machines is operated as motor, driving the other machine as a generator. The output power of the generator is fed to the motor. Thus the power drawn from the supply is only to overcome the losses of both the machines. By varying the field current of generator and motor i.e. I4 and I3 any desired load can be adjusted on these two machines.

CIRCUIT DIAGRAM:

OBSERVATION TABLE:

S.No.	V_s	V_g	I_1	I_2	I_3	I_4

CALCULATION:

Armature copper losses in the generator = I_2^2 rg
Armature circuit copper losses in the motor = $(I1 + I2)^2\ r_m$
Total power drawn by the armature circuit of the motor = V x I_1 watts
Let the sum of iron losses and mechanical losses of each machine be Wc, then

$V \times I_1 = 2Wc + I_2^2\ rg + (I1 + I2)^2\ r_m$
Thus, $Wc = ½ [\ V \times I_1 – I_2^2 rg – (I1 + I2)^2\ r_m\ ]$

Efficiency of Motor
Shunt field copper losses of the motor = V x I3
Hence, total losses of the motor = $Wc + (I1 + I2)^2\ r_m + V \times I_3$

Total power input to the motor, P1 = V x (I1 + I2 + I3)

Thus, efficiency of the motor, $ή_m$= V(I1 + I2 + I3) – [Wc + (I1 + I2)2 rm + V I3]/ [V(I1 + I2 + I3)] *100 percent

DISCUSSION:

UNIVERSITY OF ENGINEERING AND MANAGEMENT, JAIPUR

Lab Manual

EXPERIMENT NO: 02

TITLE: Speed Control of DC Motor using armature resistance control

AIM: To Control the speed of the DC Motor by varying the armature resistance

APPARATUS REQUIRED:-

(i) MultiMeter
(ii) Connecting Wire
(iii) Speed Control test panel
(iv) A DC Motor
(v) A Rheostat
(vi) A Tachometer

THEORY:

Any D.C. motor can be made to have smooth and effective control of speed over a wide range. The shunt motor runs at a speed defined by the expressions.

Eb= ZNPθ ΘI γ ||||||||and Eb =V – IaRa|
i.e.,

N=(V -I R_a)/ Kθ |E||| where K X|ZP/ 60A

|
|
Since IaRa drop is negligible N α V and N ℑ|KΘ or N ℑ|1$Θ_f$

Where N is the speed, V is applied voltage, Ia is the armature current, and Ra is the armature resistance and Φ is the field flux.

Armature resistance control:
Speed control is achieved by adding an external resistance in the armature circuit. This method is used where a fixed voltage is available. In this method, a high current rating rheostat is required.
Disadvantages:
(a) Large amount of power is lost as heat in the rheostat. Hence, the efficiency is low.
(b) Speed above the rated speed is not possible. The motor can be run from its rated speed to low speeds.

CIRCUIT DIAGRAM:

OBSERVATION TABLE:

SI.No.	Armature Voltage	Armature Resistance	Speed

RESULT:

Draw a graph between the armature voltage and speed of the motor and show that the speed decreases as the armature voltage increases.

DISCUSSION:

EXPERIMENT NO: 03

UNIVERSITY OF ENGINEERING AND MANAGEMENT, JAIPUR
Lab Manual

TITLE: Speed Control of DC Motor using field resistance control

AIM: To Control the speed of the DC Motor by varying the field resistance

APPARATUS REQUIRED:-

(i) MultiMeter
(ii) Connecting Wire
(iii) Speed Control test panel
(iv) A DC Motor
(v) A Rheostat
(vi) A Tachometer

THEORY:

Any D.C. motor can be made to have smooth and effective control of speed over a wide range. The shunt motor runs at a speed defined by the expressions.

Eb= ZNPθ ΘΙ γ |||||||and Eb =V – IaRa|
i.e.,

N=(V -I R_a)/ Kθ |Ε|| where K Χ|ZP/ 60A

|
|
Since IaRa drop is negligible N α V and N ℑ|ΚΘ or N ℑ|1$Θ_f$

Where N is the speed, V is applied voltage, Ia is the armature current, and Ra is the armature resistance and Φ is the field flux.

Field flux control:
Speed control by adjusting the air gap flux is achieved by means of adjusting the field current i.e., by adding an external resistance in the field circuit. The disadvantage of this method is that at low field flux, the armature current will be high for the same load. This method is used to run the motor above its rated speed only.

CIRCUIT DIAGRAM:

OBSERVATION TABLE:

SI.No.	Field Resistance	Field current	Speed

RESULT:

Draw a graph between the Field current and speed of the motor and show that the speed increases as the field current increases.

DISCUSSION:

TITLE: Perform the No load test of three phase Induction Motor

AIM: To Perform the No load test of three phase Induction Motor

APPARATUS REQUIRED:-

(i) MultiMeter
(ii) Connecting Wire
(iii) No load test of induction motor panel
(iv) A Three Phase Induction motor
(v) A Variac
(vi) Two Watt Meter

THEORY:

The impedance of magnetizing path of induction motor is large enough to obstruct flow of current. Therefore, small current is applied to the machine due to which there is a fall in the stator-impedance value and rated voltage is applied across the magnetizing branch. But the drop in stator-impedance value and power dissipated due to stator resistance are very small in comparison to applied voltage. Therefore, there values are neglected and it is assumed that total power drawn is converted into core loss. The air gap in magnetizing branch in an induction motor slowly increases the exciting current and the no load stator I^2R loss can be recognized. One should keep in mind that current should not exceed its rated value otherwise rotor accelerates beyond its limit. The test is performed at poly-phase voltages and rated frequency applied to the stator terminals. When motor runs for some times and bearings get lubricated fully, at that time readings of applied voltage, input current and input power are taken. To calculate the rotational loss, subtract the stator I^2R losses from the input power.

CIRCUIT DIAGRAM:

OBSERVATION TABLE:

V_1= Supply Voltage

I_0= No Load Current measure by the ammeter

W= Core loss measure by the Two Wattemeter

$W_0=W_1-(-W_2)$

W_1=Power of the one wattmeter

W_2= Power of the second wattmeter

V_1	I_0	W_1	W_2

CALCULATION:

Let the total input power supplied to induction motor be W_0 watts. \

$$W_0 = \sqrt{3} V_1 I_0 Cos\Phi_0$$

$W_0=W_1-(-W_2)$

Therefore, $X_0 = V_1/ I_u$, $R_0= V_1/ I_w$

Where $I_w= I_0 \cos \emptyset$, $I_u= I_0 \sin \emptyset$

RESULT:

The Iron loss is obtained to ………W

DISCUSSION:

EXPERIMENT NO: 05

AIM: To Perform the Blocked Rotor test of three phase Induction Motor

APPARATUS REQUIRED:-

(i) MultiMeter
(ii) Connecting Wire
(iii) No load test of induction motor panel
(iv) A Three Phase Induction motor
(v) A Variac
(vi) Two Watt Meter

THEORY:

In the blocked rotor test, it should be kept in mind that the applied voltage on the stator terminals should be low otherwise normal voltage could damage the winding of the stator. In block rotor test, the low voltage is applied so that the rotor does not rotate and its speed becomes zero and full load current passes through the stator winding. The slip is unity related to zero speed of rotor hence the load resistance becomes zero. Now, slowly increase the voltage in the stator winding so that current reaches to its rated value. At this point, note down the readings of the voltmeter, wattmeter and ammeter to know the values of voltage, power and current. The test can be repeated at different stator voltages for the accurate value.

CIRCUIT DIAGRAM:

OBSERVATION TABLE:

V=Supply Voltage

I= Short Circuit Current

W_0= Power measure by the Wattmeter

$W_0=W_1-(-W_2)$

W_1= Power of the one wattmeter

W_2= Power of the second wattmeter

V	I	W_0

CALCULATION:

For Short Circuit Test:-

$W= I^2 R_{01}$

$R_{01} = W/I^2$

$Z_{01}= V/I$

$X_{01}^2= (Z_{01}^2- R_{01}^2)$

DISCUSSION:

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR
LAB MANUAL

Title of Course: Electrical & Electronic Measurement Lab
Course Code: EE 492
L-T-P scheme: 0-0-3 **Course Credit: 2**

Objectives:

1. To introduce the student fundamentals of Electronics Instruments and Measurement
2. To understand how measuring instruments work for measurement of electrical and non electrical quantity.
3. Providing practical ideas and an in-depth understanding of Measurement procedures.

Learning Outcomes: The students will have a detailed knowledge of the concepts of different measuring methods and the devices that has to be used for the purpose. Upon the completion of Operating Systems practical course, the student will be able to:

- **Understand** necessity of measuring devices and also proper selection of the devices
- **Use** proper instruments for measuring electrical and non electrical quantities**.**
- **Understand** effects of the internal impedances of meteres while measuring.
- **Analyze** General features of analog meteres
- **Learn** the application of ac and dc potentiometer to measure unknown emf
- **Understand** the fundamental concepts of CRO and it's use to measure electrical parameters

Course Contents:
Exercises that must be done in this course are listed below:

Exercise No. 1: Measure a resistance using Kelvin's Double Bridge
Exercise No. 2: Measure unknown capacitance using Schering Bridge
Exercise No. 3: Measure self inductance using Anderson's Bridge.
Exercise No. 4: Measure unknown value of capacitance using De Sauty Bridge
Exercise No. 5: Measure Unknown frequency using Wein's Bridge
Exercise No. 6: Measure three phase power and power factor
Exercise No. 7: Study the operation of CRO

Text Book:

1. A.K. Sawhney, A course in Electrical & Electronic Measurements & Instrumentation, Dhanpat Rai and sons

Recommended Systems/Apparatus Requirements:

1. Laboratory Kits, Multimeters, CRO, Connecting wires.

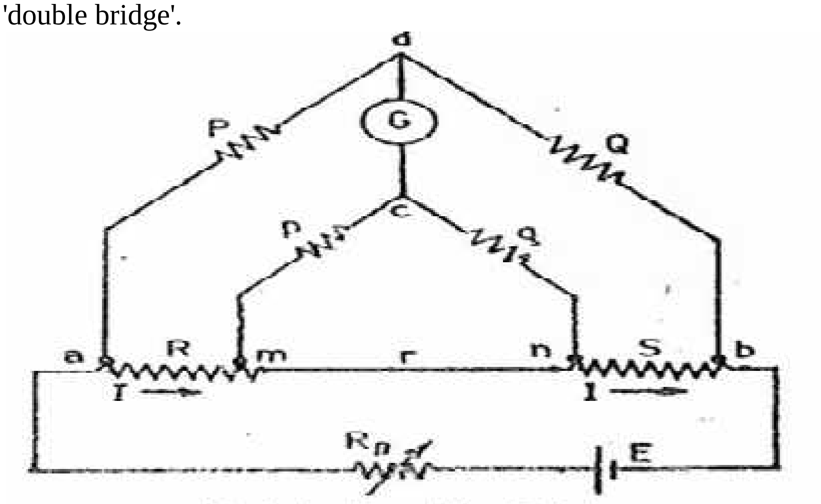
Experiment No: 1

Measure a resistance using Kelvin's Double Bridge

Aim: To measure a low resistance using Kelvin's Double Bridge.

Theory:

Kelvin Double Bridge is nothing but a modification of Wheatstone bridge. It is used for measuring of low resistance to a good precision. It compares two ratio arms P,Q and p,q and hence is called 'double bridge'.



Kelvin Double Bridge

P, Q, p, q are the resistances in the ratio arms. G is a galvanometer of D'Arsonal type, used as a null detector. S is a small standard resistor; R is a resistance under measurement. Usually low resistance consists of four leads. Two of them are called as voltage leads and remaining as current leads. "r" is the resistance of connecting lead between R and S.

Under balanced conditions,

$$E_{ab} = E_{amd}$$

$$E_{ac} = I\left[R + S + \frac{(p+q)r}{p+q+r}\right]$$

$$By\,equating\ E_{ab} = E_{amd}\ we\ get\ , R = \frac{P}{Q}S + \frac{qr}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right]$$

From the above equation, it is clear that the resis tance of connecting leads "r" has no effect on the measurement if the two sets of ratio arms have equal ratios ie, P/Q = p/q. The effect of thermo electric Emf can be eliminated by making other measurement with battery terminals reversed and taking the average of the two readings can eliminate the effect of thermo electric Emfs.

Procedure:

Procedure for the measurement of low resistance R using Kelvin Double Bridge

1. Move the Galvanometer switch to increase position. This connects the built-in galvanometer to the circuit. If an external more sensitive galvanometer is available, connect it to the terminals marked "extgalv" and put the galvanometer switch in "EXT" position.
2. Four terminals are provided for connecting unknown resistance of the bridge circuit. They are lab eled by "+C, +P, - C, - P". Here +C and - C constitute the current terminals. If the given unknown resistance is of four leads then connect the two potential leads to +P & -P and current leads to +C & -C with correct current polarity. If the unknown resistance has two terminals then the leads from +C and +P are connected to other terminals of unknown resistance.
3. Now, press the button on the panel and obtain the balance by varying the dials.

5.Find the tolerance of the resistance and tabulate the results.

Observation Table:

The example results are as given in the tabular form below:

S.No	For Kelvin Double Bridge Calculated Value	From Multimeter Theoretical Value(Ω)	% Tolerance

Conclusion:

Experiment No: 2

Measure unknown capacitance using Schering Bridge

Aim: To measure unknown capacitance using Schering Bridge

Theory:

Schering bridge is widely used for capacitance and dissipation factor measurement. It is extensively used in the measurement of capacitance.

At balance

$$(r_1 + 1 / j\omega C_x)\,(R_4 / (1 + j\omega C_4 R_4)) \qquad 1 / j\omega\, C_2 \times R_3$$

$$r_1 R_4 - jR_4 / \omega C_x \qquad -jR_3 / \omega C_2 + R_3 R_4 C_4 / C_2$$

Equating the real and imaginary parts,

$$R_1 = R_3 C_4 / C_2$$

$$C_x = C_2 (R_4 / R_3)$$

Dissipation factor, $D_1 = \tan\delta = \omega C_1 r_1$

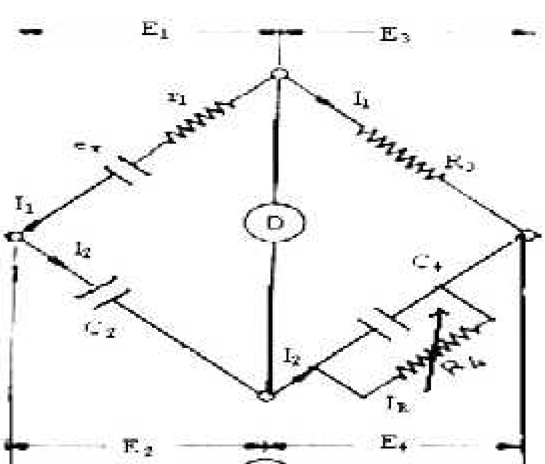
$\omega C_4 R_4$

Formula Used

$$C_x = C_2 (R_4 / R_3)$$

Where, C_2 Standard capacitor

R_3, R_4 = Non-inductive resistance



Cx - Unknown capacitance
C4 - variable Capacitor
R3, R4 - Non inductive resistance

Procedure:

1. The trainer is switched 'ON' and the unknown capacitance is connected in the terminals Cx
2. Initially the resistance R3 is kept some value and by varying the value of resistance R 4 the balanced condition is obtained
3. The balanced condition is checked
4. All the values are noted down.

Observation Table:

Sr. No.	R3 (1)	C2	R4 (2)	Cx Obs Value	Set Value
Unit	KΩ	μF	Ω	μF	μF
1					
2					

Conclusion:

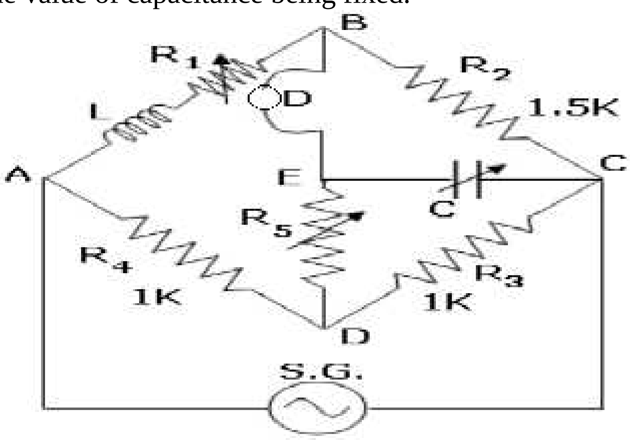
Experiment No: 3

Measure self inductance using Anderson's Bridge.

Aim: To measure self inductance using Anderson's Bridge

Theory:

Anderson's bridge is the most accurate bridge used for the measurement of self – inductance over a wide range of values, from a few micro-Henries to several Henries. In this method the unknown self-inductance is measured in terms of known capacitance and resistances, by comparison. It is a modification of Maxwell's L - C Bridge. In this bridge, double balance is obtained by the variation of resistances only, the value of capacitance being fixed.



Inductance of given coil L $C [(R_1 + R_2) R_5 + R_2 R_4]$ mH

Where C = Capacity of the standard capacitor (μF)

R_2, R_3, R_4 Known, fixed and non inductive resistances (KΩ)

R_1, R_5 Variable resistances (KΩ)

Procedure:

1. The circuit diagram of the bridge is as shown in the figure.
2. The coil whose self-inductance is to be determined, is connected in the arm AB, in series with a variable non-inductive resistor R1.
3. Arms BC, CD and DA contain fixed and non – inductive resistors R2, R3 and R4 respectively.
4. Another non - inductive resistor R5 is connected in series with a standard capacitor C and this combination is put in parallel with the arm CD.
5. The null detector is connected between B and E.
6. The signal generator is connected between A and C junctions.
7. Select one capacitor and one inductor and connect them in appropriate places using patch chords.
8. A perfect balance is obtained by adjusting R1 and R5 alternatively till the detector D indicate a minimum balance .
9. The values of R1 and R5 are measured with a multi-meter(While measuring the R1 and R5 values, they should be in open circuit) .
10. In the balance condition the self – inductance value of the coil is calculated by using the above formula.

Observation Table:

S.No.	Capacity (C) µ F	Resistance (R_1) Ω	Resistance (R_5) Ω	Calculated value (L) $C[(R_1+R_2)R_5+R_2R_4]$ mH	Standard value of L mH

Conclusion:

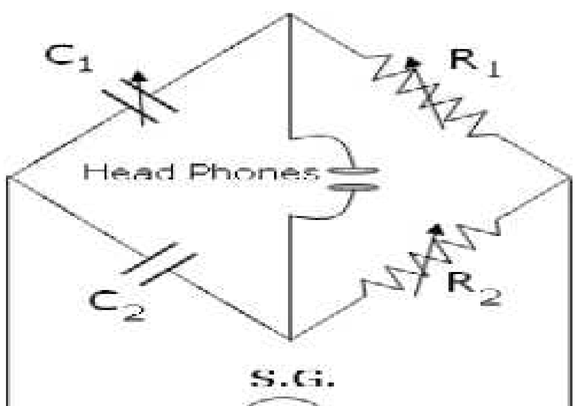
Experiment No: 4

Measure unknown value of capacitance using De Sauty Bridge

Aim: To measure unknown value of capacitance using De Sauty Bridge

Theory:

The De Sauty's bridge is an A.C Bridge works on the principle of Wheat stone's bridge. This bridge is used to determine the capacity of an unknown capacitor C2 in terms of the capacity of a standard known capacitor C1. Here R1 and R2 are non - inductive resistors. R1, R2, C1 and C2 are connected in a Wheat stone's bridge as shown in the figure. When the bridge is balanced, the ratios of impedances are equal



At balanced condition Capacity of a unknown capacitor

$$C2 = (R1 / R2) \times C1 \ \mu F$$

Procedure:

1. The connections are made as shown in the figure.
2. The resistance R1 and a condenser C1 are in series in one branch of the bridge and a resistance R2 and another capacitor C2 are in series in another branch.
3. The A.C signal generator frequency is adjusted to a fixed value of 1 KHz or below, which is convenient to our ear.
4. A resistance is unplugged in R1 and the resistance R2 is adjusted till the sound in the head - phone is reduced to zero level.
5. The value of R2 is measured with a multi-meter and noted. While measuring the resistances, they should be in open circuit.
6. The above process is repeated for different values of R1 and the values are noted in the table.
7. When the hum in the head – phone is at zero level , then the time constants of the upper and the lower braches of Wheat stone's bridge equal i.e. C1R1= C2R2

Observation Table:

S.No.	Capacity of known condenser C_1 µ F	Resistance R_1 Ω	Resistance R_2 Ω	Capacity of unknown condenser $C_2 = \frac{R_1}{R_2} X C_1$ µF	Standard Value of C_2 µF

Conclusion:

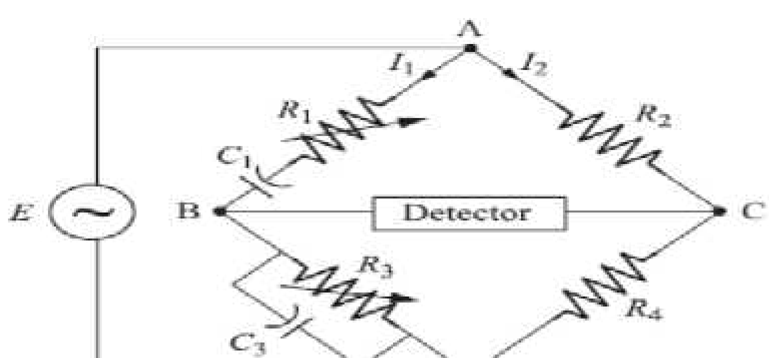
Experiment No: 5

Measure Unknown frequency using Wein's Bridge

Aim: To measure Unknown frequency using Wein's Bridge

Theory:

In this bridge circuit, there is a lead-lag network. Balancing of the bridge is easier because satisfying the phase angle equality condition can be achieved. This bridge can also be used to determine the frequency of the AC input in terms of the component values of the bridge circuit. In this AC Bridge, there is no inductor. Inductive losses because of stray fields cause problems in balancing of the bridge. Owing to the absence of L in the circuit, this can be effectively used for determining the frequency f of the AC input.



At balanced condition the unknown frequency can be given as

$$f= 1/[2\pi\sqrt{(R_1 R_3 C_1 C_3)}]$$

Procedure:

1. Connect mains cord to the Trainer.
2. Connect terminal 1 to 4(for evaluating unknown capacitance Cx1).
3. Rotate variable resistance R1 towards anti clockwise direction.
4. Select Frequency Selector f or any desired range of frequency.
5. Vary resistance R1 towards clockwise direction slowly.
6. Keep varying R1 until null condition is achieved
7. Now remove the patch cord between terminal 1 & 4 and record the value of R1 in the observation table using multimeter

Observation Table:

S No.	R1	R2 C1	C2	I
1				
2				
3				
4				
5				

Conclusion:

Experiment No: 6
Measure three phase power and power factor
Aim: To Measure three phase power and power factor
Theory:
Power consumed by a 3-phase balanced or unbalanced load (star connected) can be measured by using 2-wattmeters properly connected in the circuit.The current coil of the wattmeter are connected in series with the load in any two line. Where as the pressure coils are connected between these two lines and the third line. The phasor diagram of this circuit assuming balanced lagging load has been shown in the figure. Under running conditions the power consumed by the three phase system is the sum o the two individual wattmeters.

Mathematically, the total power consumed,

$$W1 + W2 = \sqrt{3}\times V\ \{\cos(30 - \emptyset) + \cos(30 + \emptyset)\}$$

Where,

Power consumed by wattmeter1=$\sqrt{3}\times V\ \{\cos(30 - \emptyset)\}$

Power consumed by wattmeter 2=$\sqrt{3}\times V\ \{\cos(30 + \emptyset)\}$

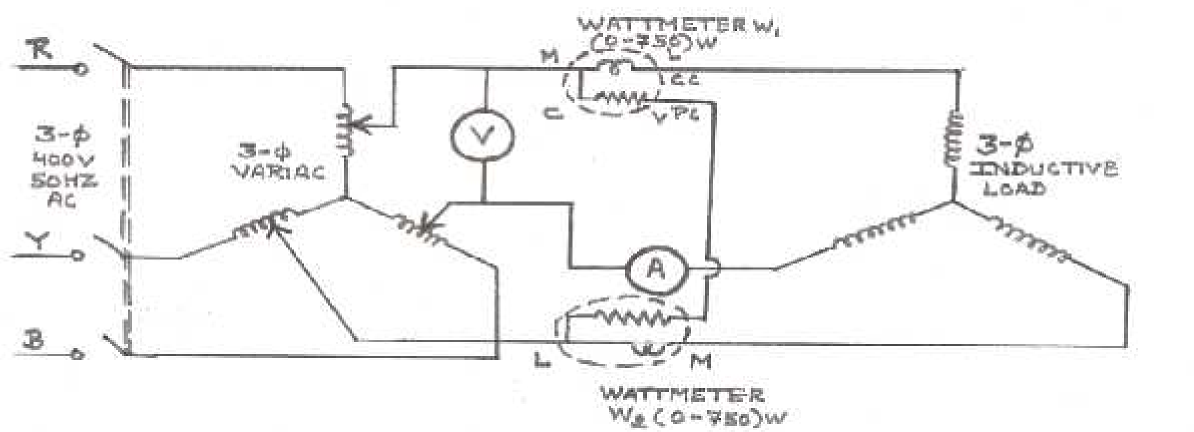
When the load power factor is less then 0.5 then wattmeter 2 will show the correct deflection and first wattmeter will show the reverse deflection. In the first wattmeter the current coil or voltage coil connection is reversed. Thus the wattmeter pointer direction is corrected. The net power is obtained

Power angle is given by

$$Ø = t\quad ^{-1}\sqrt{3}\times\frac{(W1 - W2)}{(W1 + W2)}$$

Then the power factor of the load can be calculated as:

$$\mathbf{c}\quad \boldsymbol{Ø} = \mathbf{c}\quad [\boldsymbol{t}\quad ^{-1}\sqrt{3}\times\frac{(\boldsymbol{W}\quad - \boldsymbol{W}\quad)}{(\boldsymbol{W}\quad + \boldsymbol{W}\quad)}]$$



Procedure:

1. Connect the circuit as shown in the diagram.
2. Vary the inductive load.
3. Note down the reading carefully.
4. If one wattmeter reads negative or gives reverse reading, the reading of wattmeter is taken by reversing the current coil terminal.

Observation Table:

Sl. No.	**Voltage VL (volts)**	**Current IL (amp)**	**Power W1 (Watts)**	**Power W2 (Watts)**	**Total Power P=W1+W2**	**Power Factor=cosØ**

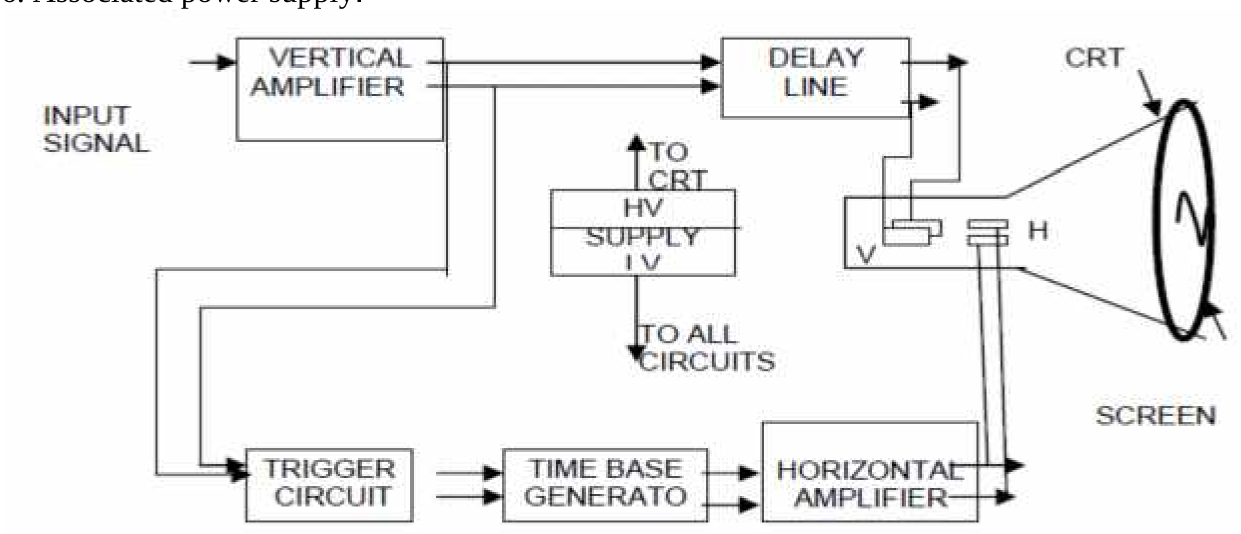
Conclusion:

Experiment No: 7
Study the operation of CRO
Aim: To Study of CRO & Measurement of frequency using Lissajous Patterns.

Theory:
The cathode ray oscilloscope is the most versatile measuring instrument available. We can measure following parameters using the CRO:
1. AC or DC voltage.
2. Time (t=1/f).
3. Phase relationship
4. Waveform calculation: Rise time; fall time; on time; off-time Distortion, etc.

We can also measure non-electrical physical quantities like pressure, strain, temperature, acceleration, etc., by converting into electrical quantities using a transducer.

Major blocks:
1. Cathode ray tube (CRT)
2. Vertical amplifier
3. Horizontal amplifier
4. Sweep generator
5. Trigger circuit
6. Associated power supply.



BLOCK DIAGRAM OF CRO

1. **The cathode ray tube** is the heart of CRO. The CRT is enclosed in an evacuated glass envelope to permit the electron beam to traverse in the tube easily. The main functional units of CRO are as follows.

Electron gun assembly, Deflection plate unit, Screen.

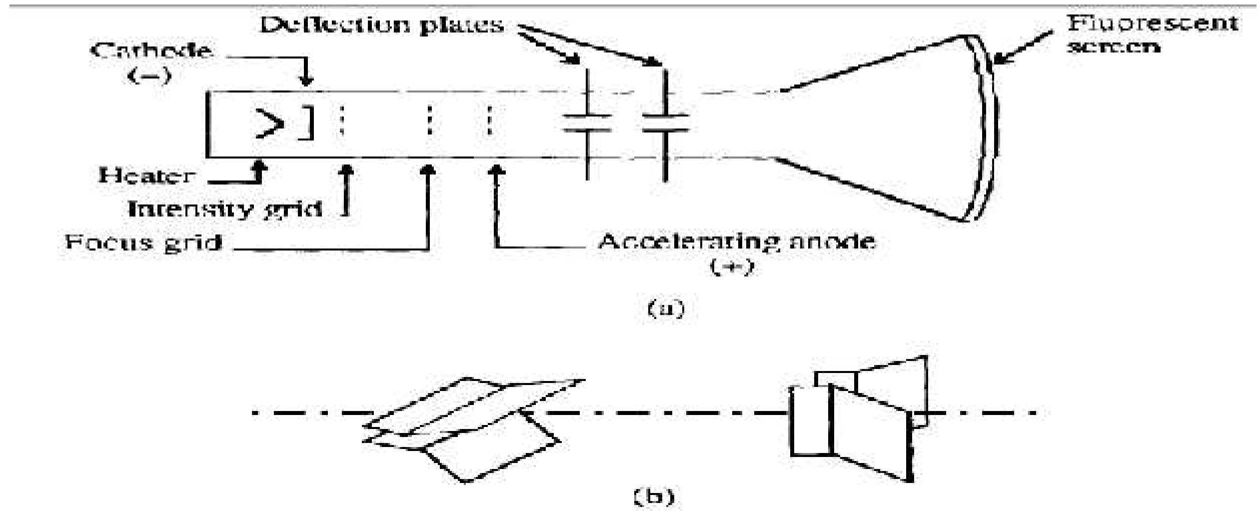


Figure 1 . Cathode-ray tube: (a) schematic, (b) detail of the deflection plates.

2. **Vertical Amplifier** is the main factor in determining the bandwidth and sensitivity of an oscilloscope. Vertical sensitivity is a measure of how much the electron beam will be deflected for a specified input signal. On the front panel of the oscilloscope, one can see a knob attached to a rotary switch labeled volts/division. The rotary switch is electrically connected to the input attenuation network. The setting of the rotary switch indicates what amplitude signal is required to deflect the beam vertically by one division.

3. **Horizontal amplifier** under normal mode of operation, the horizontal amplifier will amplify the sweep generator input. When the CRO is being used in the X-Y mode, the horizontal amplifier will amplify the signal applied to the horizontal input terminal. Although the vertical amplifier mush be able to faithfully reproduce low-amplitude and high frequency signal with fast rise time, the horizontal amplifier is only required to provide a faithful reproduction of the sweep signal which has a relatively high amplitude and slow rise time.

4. **Sweep generator and Trigger circuit** These two units form the Signal Synchronization unit of the CRO.

5. **Associated Power Supply:** The input signal may come from an external source when the trigger selector switch is set to EXT or from low amplitude AC voltage at line frequency when the switch is set to LINE or from the vertical amplifier when the switch is set to INT. When set for INT (internal triggering), the trigger circuit receives its inputs from the vertical amplifier.

Procedure:

1.1 Measurement of Voltage Using CRO :

A voltage can be measured by noting the Y deflection produced by the voltage; using this deflection in conjunction with the Y-gain setting, the voltage can be calculated as follows :

V = (no. of boxes in cm.) x (selected Volts/cm scale)

1.2 Measurement of Current and Resistance Using a CRO :

Using the general method, a correctly calibrated CRO can be used in conjunction with a known value of resistance R to determine the current I flowing through the resistor.

1.3 Measurement of Frequency Using a CRO :

A simple method of determining the frequency of a signal is to estimate its periodic time from the trace on the screen of a CRT. However this method has limited accuracy, and the observed signal, one has to measure the period, i.e. the time taken for 1 complete cycle, using the calibrated sweep scale. The period could be calculated by

T = (no. of squares in cm) x (selected Time/cm scale)

Once the period T is known, the frequency is given by

f (Hz)= 1/T(sec)

1.4. Measurement of Phase:

The calibrated time scales can be used to calculate the phase shift between two sinusoidal signals of the same frequency. If a dual trace or beam CRO is available to display the two signals simultaneously (one of the signals is used for synchronization), both of the signals will appear in proper time perspective and the amount of time difference between the waveforms can be measured. This, in turn can be utilized to calculate the phase angle∀, between the two signals.

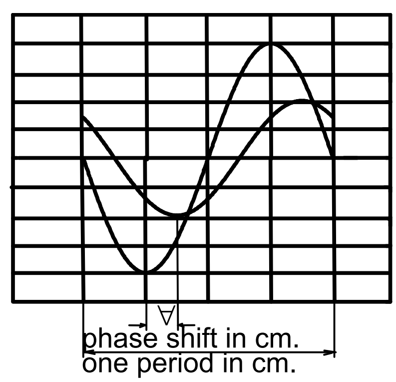


Figure 1:- PHASE SHIFT BETWEEN TWO SIGNALS

Referring to figure.1, the phase shift can be calculated by the formula;

$$- X \frac{\text{Phase shift in cm.}}{\text{One period in cm.}} \text{ x } 360\lceil$$

Note that the calculation does not involve the actual calibrated time base setting. In fact, the observed waveforms can be varied using the horizontal amplifier venire adjustment to obtain as many boxes for one full scale as desired. Another method for fast calculation is to multiply the scale factor by the phase difference (in cm) where the scale factor is degrees per box or degrees per cm.

1.5 Use of Lissajous Patterns for Frequency Measurements:

If a well calibrated CRO timebase is not available, a signal generator can be used to measure the frequency of an unknown sinusoidal signal. It is connected to the vertical channel (or horizontal) and the calibrated signal source is fed to the horizontal channel (or vertical).The frequency of the signal generator is adjusted so that a steady Lissajous pattern is obtained. The Lissajous pattern can be very involved to analyze. However, for the frequency measurement, all that is needed is the number of tangencies (points at the edge of arcs) along the vertical and horizontal lines.

The frequency relationship between the horizontal and vertical inputs is given by;

$$\frac{f_h}{f_v} X \frac{\text{No. of tangencies (vertical)}}{\text{No. of tangencies (horizontal)}}$$

from which f_V , the unknown frequency can be calculated.

Conclusion: