DRONACHARYA College of Engineering

LABORATORY MANUAL

B.Tech. Semester- IV

APPLIED THERMODYNAMICS
Subject code: LC-ME-212G

Prepared by:	**Checked by:**	**Approved by:**
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DEPARTMENT OF ROBOTICS AND AUTOMATION
DRONACHARYA COLLEGE OF ENGINEERING
KHENTAWAS, FARRUKH NAGAR, GURUGRAM (HARYANA)

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Vision and Mission of the Institute

Vision:

To impart Quality Education, to give an enviable growth to seekers of learning, to groom them as World Class Engineers and managers competent to match the expending expectations of the Corporate World has been ever enlarging vision extending to new horizons of Dronacharya College of Engineering.

Mission:

1. To prepare students for full and ethical participation in a diverse society and encourage lifelong learning by following the principle of 'Shiksha evam Sahayata' i.e. Education & Help.
2. To impart high-quality education, knowledge and technology through rigorous academic programs, cutting-edge research, & Industry collaborations, with a focus on producing engineers& managers who are socially responsible, globally aware, & equipped to address complex challenges.
3. Educate students in the best practices of the field as well as integrate the latest research into the academics.
4. Provide quality learning experiences through effective classroom practices, innovative teaching practices and opportunities for meaningful interactions between students and faculty.
5. To devise and implement programmes of education in technology that are relevant to the changing needs of society, in terms of breadth of diversity and depth of specialization.

Vision and Mission of the Mechanical Department

Vision:

"To become a Centre of Excellence in teaching and research in the field of Mechanical Engineering for producing skilled professionals having a zeal to serve society."

Mission:

M1: To create an environment where students can be equipped with strong fundamental concepts, various experiments and problem solving skills.

M2: To provide an exposure to emerging technologies by providing hands on experience for generating competent professionals.

M3: To promote Research and Development in the frontier areas of Mechanical Engineering and encourage students for pursuing higher education

M4: To inculcate in students ethics, professional values, team work and leadership skills.

Programme Educational Objectives (PEOs)

PEO 1: Engineers will practice the profession of engineering using a systems perspective and analyze, design, develop, optimize & implement engineering solutions and work productively as engineers, including supportive and leadership roles on multidisciplinary teams.

PEO 2: Continue their education in leading graduate programs in engineering & interdisciplinary areas to emerge as researchers, experts, educators & entrepreneurs and recognize the need for, and an ability to engage in continuing professional development and life-long learning.

PEO 3: Engineers, guided by the principles of sustainable development and global interconnectedness, will understand how engineering projects affect society and the environment.

PEO 4: Promote Design, Research, and implementation of products and services in the field of Engineering through Strong Communication and Entrepreneurial Skills.

PEO 5: Re-learn and innovate in ever-changing global economic and technological environments of the 21st century.

Programme Outcomes (POs)

Over completion of the Course our graduates will have ability to

Apply knowledge of computing, mathematical foundations, algorithmic principles, and engineering theory in the modeling and design of systems to real-world problems (fundamental engineering analysis skills).

1. Apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline.
2. Design and conduct experiments, as well as to analyze and interpret data (information retrieval skills). Practical application of engineering skills, combining theory and experience, and use of other relevant knowledge and skills.
3. Analyze a problem, identify, formulate and use the appropriate computing and engineering requirements for obtaining its solution(engineering problem solving skills).
4. Understand the appropriate codes of practice and industry standards.
5. Identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques.
6. Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.
7. Communicate effectively, both in writing and orally (speaking / writing skills).
8. Understand professional, ethical, legal, security and social issues and responsibilities (professional integrity).
9. Understand customer and user needs and the importance of considerations such as Aesthetics.
10. Use creativity to establish innovative solutions.
11. Adapt to a rapidly changing environment by having learned and applied new skills and new technologies.
12. To Significantly contribute to delivery of desired component, product, or process.
13. Formulate and solve moderately complex engineering problems, accounting for hardware/software/human interactions.
14. Recognize the importance of professional development by pursuing postgraduate studies or face competitive examinations that offer challenging and rewarding careers in computing.
15. Apply the Knowledge of management techniques which may be used to achieve engineering Objectives within that context.

Program Specific Outcomes (PSOs)

On successful completion of the Mechanical Engineering Degree programme, the Graduates shall exhibit the following:

PSO1: Apply the knowledge gained in Mechanical Engineering for design and development and manufacture of engineering systems.

PSO2: Apply the knowledge acquired to investigate research-oriented problems in mechanical engineering with due consideration for environmental and social impacts

PSO3: Use the engineering analysis and data management tools for effective management of multidisciplinary projects.

University Syllabus

List of Experiments:

1.To study low pressure boilers and their accessories and mountings.

2. To study high pressure boilers and their accessories and mountings.

3. To prepare heat balance sheet for given boiler.

4. To study the working of impulse and reaction steam turbines.

5. To find dryness fraction of steam by separating and throttling calorimeter.

6. To find power out put & efficiency of a steam turbine.

7. To find the condenser efficiencies.

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

9. To study cooling tower and find its efficiency.

10. To find calorific value of a sample of fuel using Bomb calorimeter.

11. Calibration of Thermometers and pressure gauges.

Note: 1. At least eight experiments should be performed from the above list.

Course Outcomes (COs)

At the end of the course, the student shall have practical exposure of:

CO212.1. Vapour power cycles and find and compare different cycles based on their performance parameters and efficiencies.

CO212.2. Steam boilers, their types and components.

CO212. 3. Fundamentals of flow of steam through a nozzle

CO212.4. Steam turbines and can calculate their work done and efficiencies.

CO212.5. Types and working of condensers and compressors and define their different type of efficiency.

CO-PO Mapping

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PO14	PO15	PO16
C212.1	3	3	3	-	2	-	3	3	3	2	-	3	3	-	-	3
C212.2	-	3	-	-	2	3	-	-		2	-	3	-	-	2	3
C212.3	-	-	3	3		3	-	-	3	-	3	-	3	3	-	
C212.4	3	-	3	-	2	-	3	3	-	2	-	3	-	3	2	3
C212.5	3	3	-	3	-	3	-	-	3	2	3	-	3	3	-	3

CO-PSO Mapping

	PSO1	PSO2	PSO3
C212.1	3	2	-
C212.2	2	3	-
C212.3	3	2	-
C212.4	3	2	2
C212.5	2	3	3

Course Overview

Students will able to learn about of I law for reacting systems and heating value of fuels and to learn about gas and vapor cycles and their first law and second law efficiencies. Students will able to understand about the properties of dry and wet air and the principles of psychrometry and will able to learn about gas dynamics of air flow and steam through nozzle. Students will learn the about reciprocating compressors with and without intercooling which help them to analyze the performance of steam turbines

LIST OF THE EXPERIMENTS mapped with COs

SNO	NAME OF THE EXPERIMENT	Cos
1.	To study low pressure boiler and their accessories and mountings.	CO212.2
2.	To study high pressure boiler and their accessories and mountings.	CO212.2
3.	To prepare heat balance sheet for given boiler.	CO212.2
4.	To study the working of impulse and reaction steam turbine .	CO212.4
5.	To find dryness fraction of steam by separating and throttling calorimeter.	CO212.1
6.	To find power output & efficiency of a steam turbine.	CO212.4
7.	To find the condenser efficiencies.	CO212.5
8.	To study and find volumetric efficiency of a reciprocating air compressor.	CO212.5
9.	To study cooling tower and find its efficiencies.	CO212.3
10.	To find calorific value of a sample of fuel using bomb calorimeter.	CO212.1

DOs and DON'Ts

DOs

1. Work deliberately and carefully.
2. Keep your work area clean.
3. Students must wear college uniform and carry their college ID.
4. Students should have separate note book for practical.
5. Students should have their own pencil, eraser, scale, along with pen and lab note book.
6. Handle the equipment /models carefully.

DON'Ts

1. Do not wander around the room, distract other students, startle other students or interfere with the laboratory experiments of others.
2. Do not eat food, drink beverages or chew gum in the laboratory.
3. Do not open any irrelevant internet sites on lab computer.

General Safety Precautions

Precautions (In case of Injury or Electric Shock)

1. To break the victim with live electric source, use an insulator such as fire wood or plastic to break the contact. Do not touch the victim with bare hands to avoid the risk of electrifying yourself.
2. Unplug the risk of faulty equipment. If main circuit breaker is accessible, turn the circuit off.
3. If the victim is unconscious, start resuscitation immediately, use your hands to press the chest in and out to continue breathing function. Use mouth-to-mouth resuscitation if necessary.
4. Immediately call medical emergency and security. Remember! Time is critical; be best.

Precautions (In case of Fire)

1. Turn the equipment off. If power switch is not immediately accessible, take plug off.
2. If fire continues, try to curb the fire, if possible, by using the fire extinguisher or by covering it with a heavy cloth, if possible, isolate the burning equipment from the other surrounding equipment.
3. Sound the fire alarm by activating the nearest alarm switch located in the hallway.

Emergency: Reception

Security : Main Gate

Guidelines to students for report preparation

All students are required to maintain a record of the experiments conducted by them. Guidelines for its preparation are as follows:

1) All files must contain a title page followed by an index page. The files will not be signed by the faculty without an entry in the index page.

2) Student's Name, Roll number and date of conduction of experiment must be written on all pages.

3) For each experiment, the record must contain the following

(i) Aim/Objective of the experiment

(ii) Pre-experiment work (as given by the faculty)

(iii) Lab assignment questions and their solutions

(iv) Test Cases (if applicable to the course)

(v) Results/ output

Note:

1. Students must bring their lab record along with them whenever they come for the lab.
2. Students must ensure that their lab record is regularly evaluated.

Lab assessment criteria

An estimated 10 lab classes are conducted in a semester for each lab course. These lab classes areassessed continuously. Each lab experiment is evaluated based on 5 assessment criteria as shown in following table. Assessed performance in each experiment is used to compute CO attainment as well as internal marks in the lab course.

GradingCriteria	Exemplary (4)	Competent (3)	Needs Improvement (2)	Poor (1)
AC1: Pre-Lab written work (this may be assessed through viva)	Complete procedure with underlined concept is properly written	Underlined conceptis written but procedure is incomplete	Not able to writeconcept and procedure	Underlined concept is not clearly understood
AC2: Manual Writing/ Modeling	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/tools are applied, Program/solution written is readable	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied	Assigned problem is properly analyzed &correct solution designed	Assigned problem is properly analyzed and corrected
AC3: Identification & Removal of errors	Able to identify errors and remove them	Able to identify errors/and remove them with little bit of guidance	Is dependent totallyon someone for identification of errors and their removal	Unable to understand the reason for errors even after they are explicitly pointed out
AC4:Execution & Demonstration	All variants of input /output are tested,Solution is well demonstrated and implemented concept is clearlyexplained	All variants of input /output are not tested, However, solution is well demonstrated and implemented concept is clearly explained	Only few variants of input /output are tested, Solution is well demonstrated but implemented concept is not clearly explained	Solution is not well demonstrated and implemented concept is not clearly explained

AC5:Lab Record Assessment	All assigned problems are well recorded with objective, design constructs and solution along with Performance analysis using all variants of input and output	More than 70 % ofthe assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants ofinput and output	Less than 70 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output	Less than 40 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants ofinput and output

EXPERIMENT NO. 1

Aim:- To study low pressure boilers and their accessories and mountings.

Apparatus Used:- Model of Lancashire boiler (low pressure boiler).

Theory:- 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. As result the flow of air to the grate can be controlled.

Mountings of boiler:-There are different fittings and device which are necessary for the operation and safety of a boiler. The various mountings used on the boiler:-

1. Water level indicator:-The function of a water level indicator is to indicate the level of water in the level constantly. It is also called water gauge.
2. Pressure gauge:- The function of a pressure gauge is to measure the pressure exerted inside the vessels. It is usually constructed to indicate upto double the maximum working pressure. Its dial is graduated to read pressure in kgf/cm^2 gauge. There are two type of pressure gauges:- (i) Bourdon tube type pressure gauge
   (ii) Diaphragm tube type pressure gauge
3. Safety valves:- The function of a safety valve is to release the excess steam when the pressure of steam inside the boiler exceeds the rated pressure. The various type of

safety valve is:-

(i) Dead weight safety valve
(ii) Spring loaded safety valve
(iii) High steam & low water safety valve

4. Fusible plug:- The function of a fusible plug is to prevent the boiler against damage due to overheating for low water level.
5. Blow off cock:- A blow off cock or valve performs the two functions:-
   (i) It may discharge a portion of water when the boiler is in operation toblow out mud scale or sediments periodically.
   (ii) It may empty the boiler when necessary for cleaning, inspection andrepair.
6. Feed check valve:- The function of a feed check valve is to control the supply of water to the boiler and to prevent the exception of water from the boiler when the pump pressureis less as pump is stopped.
7. Stop valve or Junction valve:- A junction valve is a valve which is placed directly over a boiler and connected to a steam pipe which carries steam to the engine. If a valve is placed in the steam pipe leading steam to the engine and placed near the engine. It usually termed as stop valve. The larger sizes are called Junction valve and smaller sizes Stop valve.

Accessories of boiler:- There are auxiliary plants required for steam boiler for their proper operation & for increase of their efficiency. The various accessories are:-

1. Feed pump:- The feed pump is a pump which is used to deliver feed water to the boiler . It is desirable that the quantity of water supplied should be at least equal to that evaporated and supplied to the engine. Two type of pumps which are commonly used as feed pump are :-
   (i) Reciprocating pump
   (ii) Rotary pump
2. Economiser:- An economiser is a device in which the waste heat of the flue gases is utilized for heating the feed water. Economiser is very important part of the boiler, with the help the economiser the efficiency of the boiler increased and the evaporative capacity of the boiler is increased. Economiser are of two type:-
   (i) Independent type
   (ii) Integral type
3. Air pre-heater:- The function of air preheatere is to increase the temperature of air before is enters the furnace. It is generally placed after the economiser. So that flue gases pass through the economiser and then to air preheat. Usually, there are three types of pre-heater:-
   (i) Tubular type
   (ii) Plate type
   (iii) Regenerative type

4. Super heater:- The function of a super heater is to increase the temperature of the steamabove its saturation point.
5. Injector:- The function of an injector is to feed water in to the boiler. It is commonly employed for vertical and locomotive boiler and does not find its applications in largecapacity high pressure boiler.

Conclusion : We have successfully studied of low pressure boiler and their mounting and accessories

Viva Questions :

1. What are the pressure criteria for low pressure boilers ?
2. Enlist different boiler accessories.
3. Enlist different boiler mountings.
4. Define functions of economizer.

EXPERIMENT NO. 2

Aim:- To study high pressure boilers and their accessories and mountings.

Apparatus Used:- 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 5to 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.

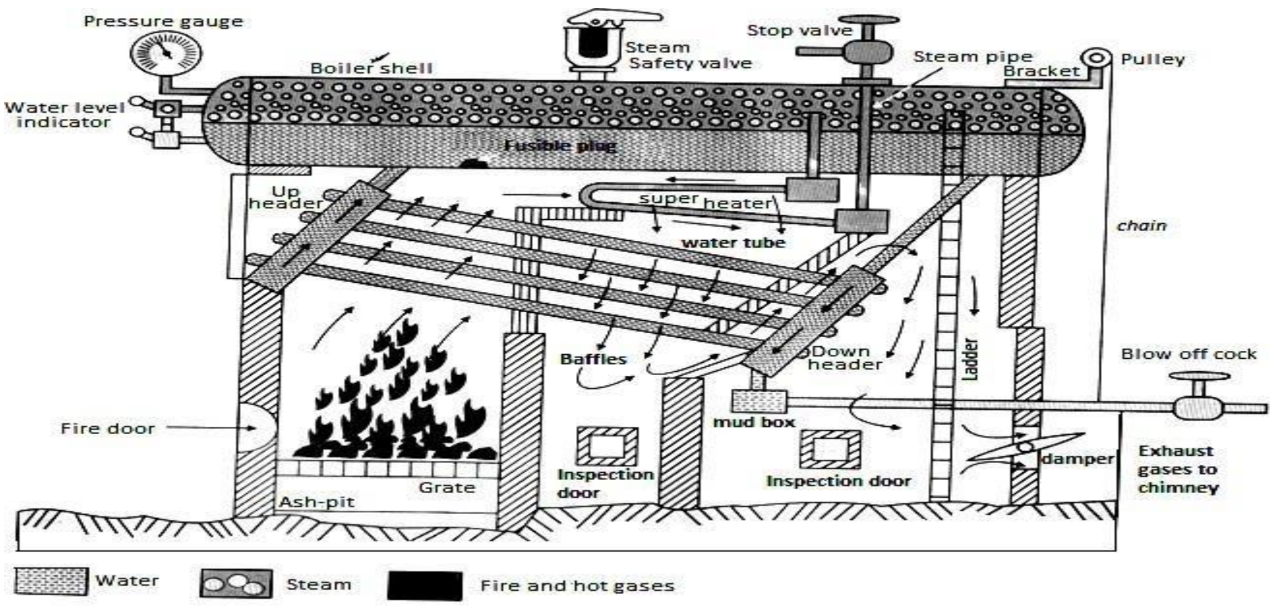
Below the uptake header the furnace of the boiler is arranged. The coal is fed to the chain grate stoker through the fire door. There is a bridge wall deflector which deflects the combustion gases upwards. Baffles are arranged across the water tubes to act as deflectors for the flue gases and to provide 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 (dueto 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 througha 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

Working pressure - 5.71cm

Steaming capacity - 100bar

Efficiency - 40,000 Kg/hr (Maximum)

60 to 80%

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.

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 onthe steam boiler. It is, usually, fitted to the highest part of the shell by means of a flange as shownin 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.

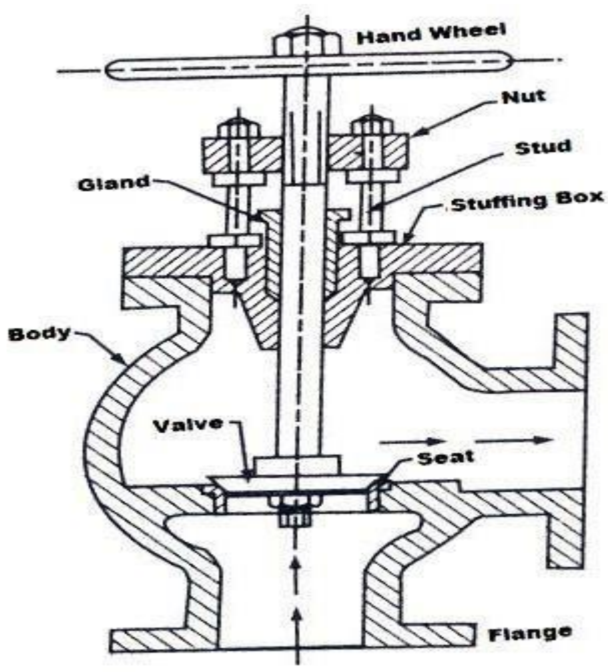


Figure-Steam Stop Valve

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 equivalentduty; the injector has the advantage that practically the whole of the heat of the steam is returned back to the boiler.

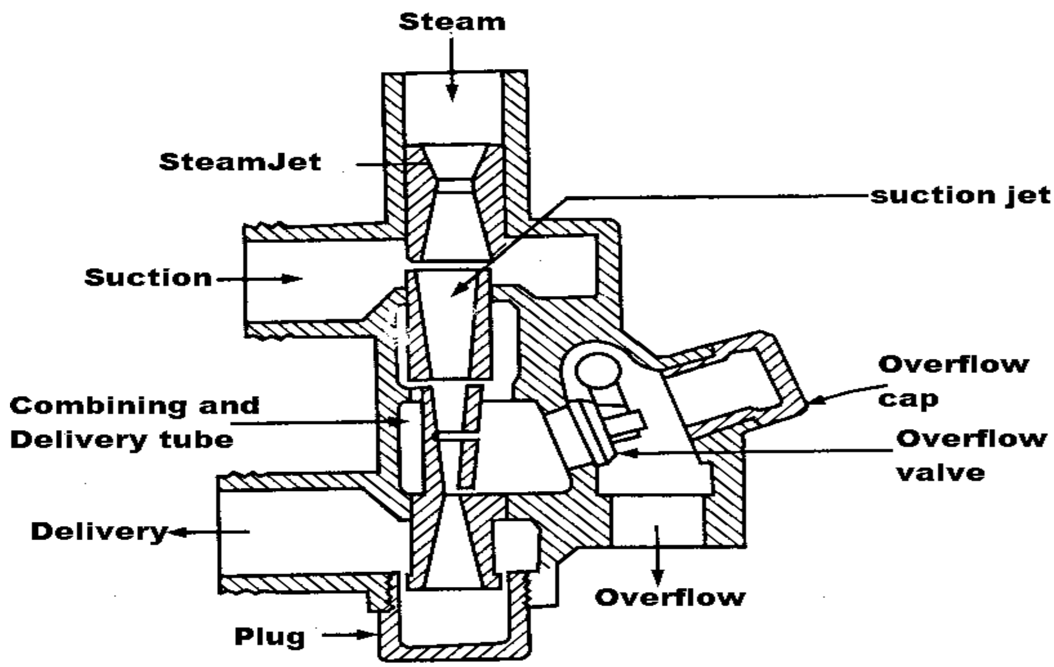


Figure- Injector

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

Viva questions:

1. What are the criteria of high pressure boiler?
2. Enlist high pressure boiler mountings.
3. What is natural circulation boiler?

EXPERIMENT NO 3

Aim:- To prepare heat balance sheet for given boiler.

Heat losses in the boiler:- The efficiency of boiler is never 100 % as only a portion of heat supplied by the fuel is utilized rest of it is lost:-

1. Heat carried away by dry product of combustion.
2. Heat carried away by the steam product by the combustion of hydrogen present in fuel.
3. Heat carried away by moisture in fuel and air.
4. Heat loss due to incomplete combustion of carbon to carbon monoxide instead of carbondioxide and thus escape of combustable matter in the flue gases and ash.
5. Heat loss due to radiation.

Method of minimizing the heat loss:-

1. The heat loss to chimney gases may be minimized by installing an economiser in between the boiler and chimney.
2. Loss of heat may be minimized by providing the boiler with an effective draught systemwhich will ensure sufficient supply of air through the fuel in furnace.
3. Heat loss due to unburnt fuel which may fall into ash pit may be minimized by properly sizing of coal.
4. Heat loss due to moisture content in the fuel may be minimized by making the fuel drybefore charging into the boiler furnace.
5. Heat loss due to external radiation may be minimized by providing effective covering ofinsulating material on the boiler parts which are liable to radiate heat.

Theory:- The boiler circulation are generally based upon the high calorific value of 1 kg of fuel considered as 100 %. The term for heat balanced sheet explain earlier.

Result:- The heat balanced sheet of a boiler is studied.

1. Heat utilized by generation of steam:-
   Useful heat absorbed, $H_1 = m (h_1\text{-}h_2)$
   H_1 = Equivalent evaporation. 2256.9 KJ
2. Loss due to moisture in fuel:-
   The moisture in the fuel is evaporated and superheated and thus the heat is lost.
   Loss due to moisture in fuel, $H_2 = m_1 (n_1^1\text{-}n_2^1)$
   Where m_1 = Mass of moisture per kg of fuel of fired
   N_1^1 = Enthalpy of steam formed
   N_2^1 = Enthalpy of liquid at temperature of boiler furnace.
3. Loss due to H_2O vapour from combustion of Hydrogen:-
   This is found similarly to loss due to moisture in fuel.
4. Loss due to moisture in air:-

This is also found in the similar way as above and it is generally negligible.

5. Loss due to dry flue gases:-

This is the target loss that takes place inside the boiler. This is given by :-

$H_3 = m_2C_p (t_g-t_a)$

Where m_2= Mass of dry flue gases per kg of fuel.

C_p= Specific heat of dry flue gases

t_g = Temperature of flue gases

t_a = Temperature of atmospheric (gases) air

6. Loss due to incomplete combustion of carbon:-

This loss is caused by incomplete combustion of carbon to carbon monoxide instead of carbon dioxide. $H_4 = m_3$.CV of CO

$$H_4 = \frac{CO.C}{CO_2+CO}.\ CV\ of\ CO$$

C = Mass of carbon actually burned per kg of fuel

CO & CO_2 % by volume

CV = Number of heat unit generated by burning 1kg of carbon contained in CO to CO_2 = 23820 KJ/ Kg

7. Loss due to unconsumed combustion to refuse:-

This loss is due to some unburnt carbon falling into the asp hit.

$H_5 = m_4$ .CV

m_4 = Unburnt mass of carbon in refuse per Kg of fuel

CV = Calorific fuel of carbon.

HEAT BALANCE SHEET (Basis 1 Kg of low grade fuel)

Heat supplied (K J)	% age	Heat Expenditure (K J)	% age (in approx.)
Gross heat supplied	100	(a) Heat utilized in steam generation (b) Heat carried away by flue gases (c) Heat utilized in evaporating and superheating the moisture fuel and water vapour formed dueto burning of hydrogen of fuel. (d) Heat loss by incomplete combustion (e) Heat carried away by excess air (f) Heat carried away by carbon nash (g) Heat uncounted for such as radiation and erroretc.	78.00 12.00 4.750 3.00 1.500 0.500 0.250
Total	100	Total	100

RESULT : Heat Balance sheet is prepared for the Boiler

EXPERIMENT NO 4

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, turbine 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 level" 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.

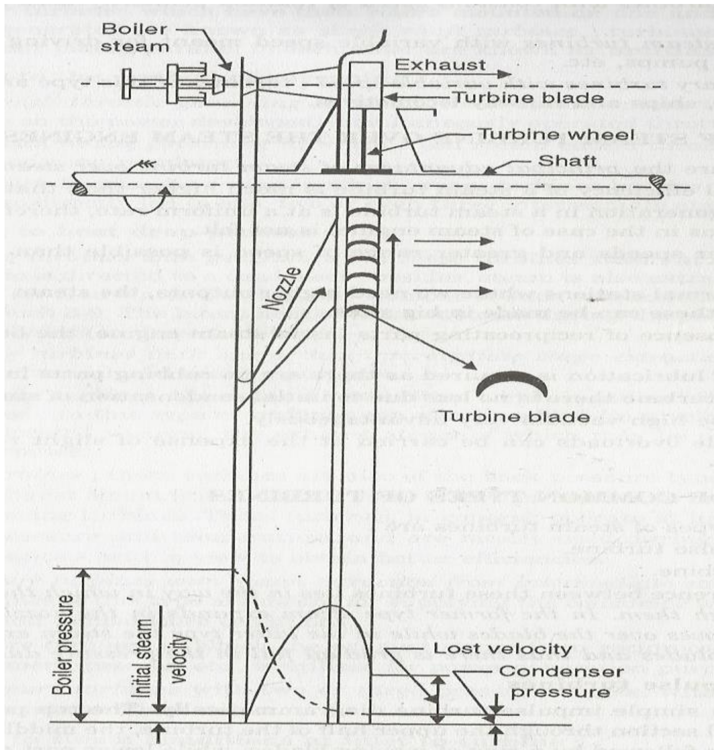


Fig. 1. Simple impulse turbine.

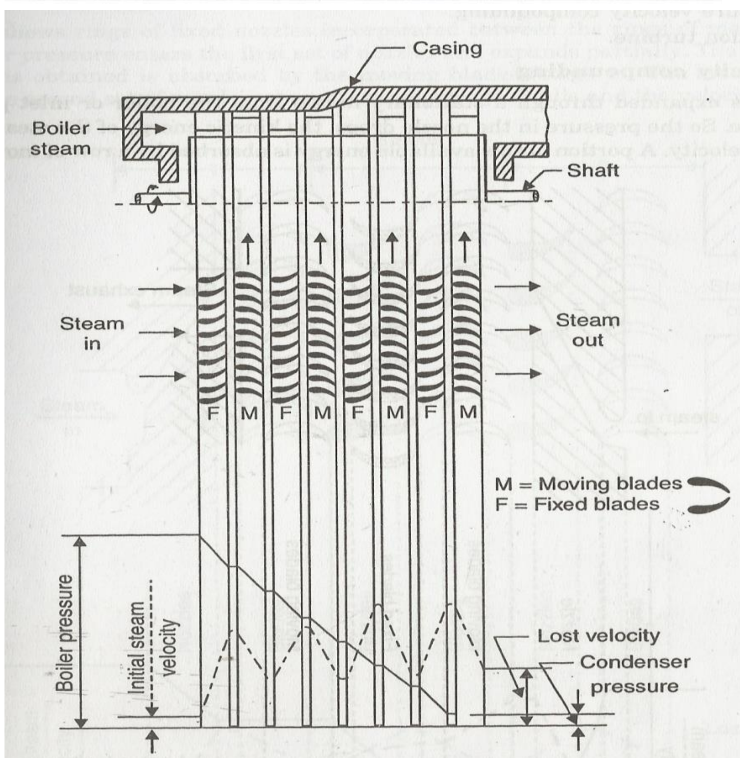


Fig. 2. Reaction turbine (three stage).

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 are 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:-

1. Velocity compounding:- Steam is expanded through a stationary nozzle from the boiler orinlet 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.

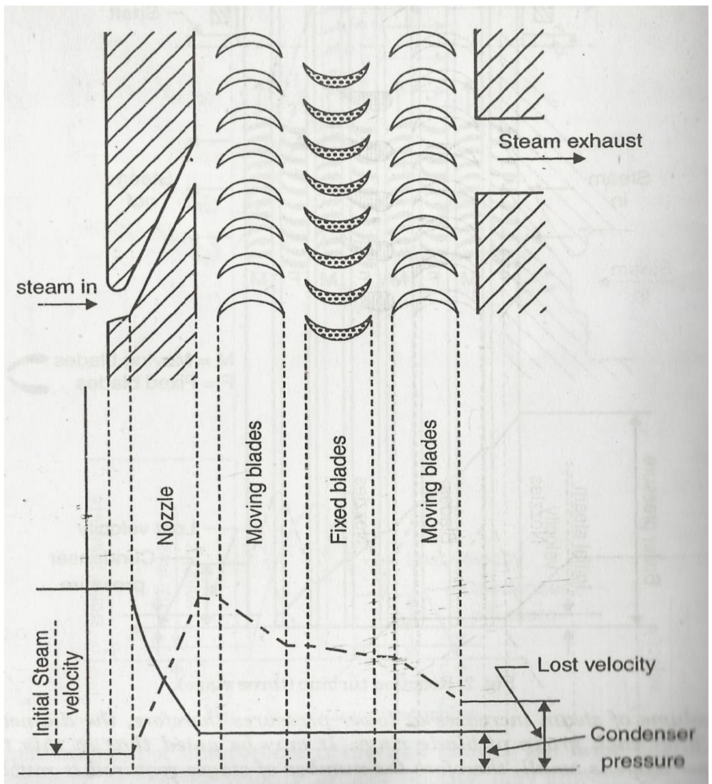


Fig. 3. Velocity compounding.

2. 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.

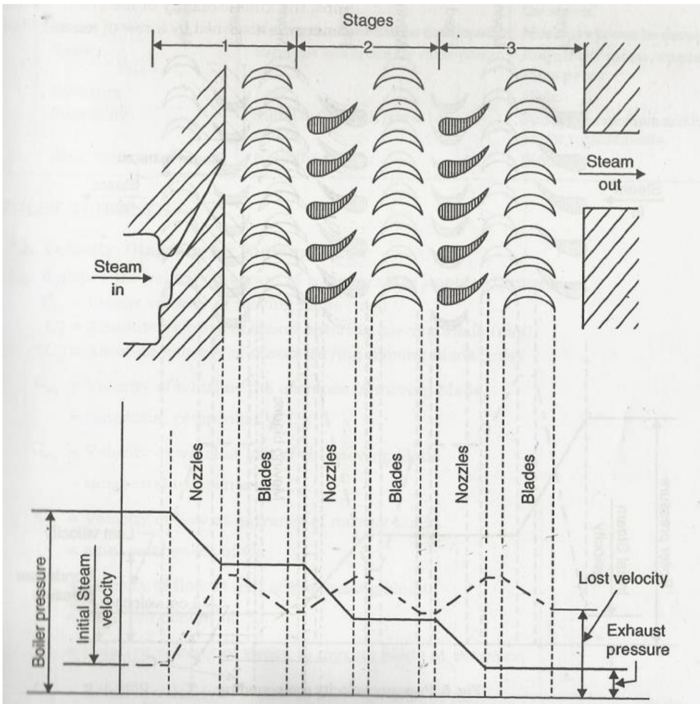


Fig. 4. Pressure compounding.

3. 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

Viva Question:

1. What is velocity compounding?
2. Explain in brief working of impulse turbine.
3. Differentiate impulse and reaction turbine

EXPERIMENT NO 5

Aim:- To find dryness fraction of steam by separating and throttling calorimeter.

Apparatus: Separating and throttling calorimeter

Theory:- Dryness Fraction:- It is defined as the ratio of mass of dry steam actually present to the mass of wet steam which contains it is defined (denoted) by letter x.

$$x = \frac{m_s}{m_s + m_w}$$

Where m_s = mass of dry steam

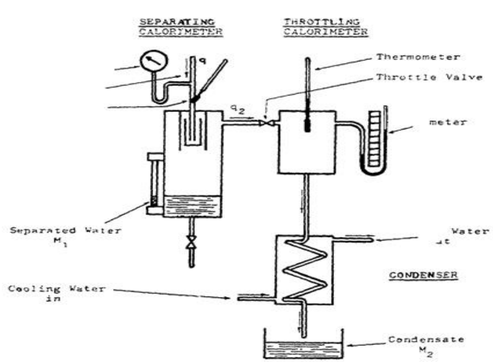
m_w = mass of water or wet steam

Steam generator separating & throttling calorimeter:-

In separating & throttling calorimeter are used. The steam passing from a calorimeter may be steam containing some water particle in it. This method is basically for a wet steam. In this case it is necessary to dry the steam partially before throttling. This is done by passing the steam sample from the main through a operating calorimeter.

In separating calorimeter the steam is made to change its direction suddenly & water as heavy then steam separate out there due to inertia. The quantity of water separate out is measured, then the steam is passed through the throttling calorimeter. After that steam from calorimeter is collected and condensed & measure the condensate

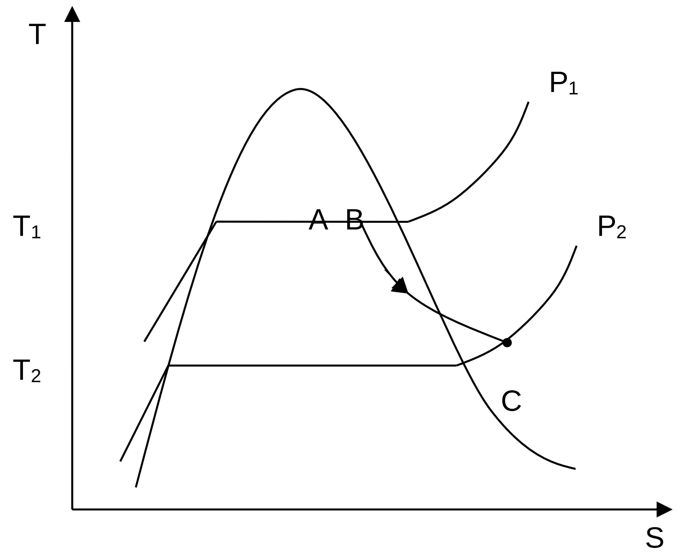
$$x_2 = \frac{h_3 - h_2}{h_{fg2}}$$



Schematic diagram for the separating and throttling Calorimeters

The separating calorimeter is a vessel used initially to separate some of the moisture from the steam, to ensure superheat conditions after throttling. The steam is made to change direction suddenly; the moisture droplets, being heavier than the vapor, drop out of suspension and are collected at the bottom of the vessel.

The throttling calorimeter is a vessel with a needle valve fitted on the inlet side. The steam is throttled through the needle valve and exhausted to the condenser. Suppose M kg of wet steam with a dryness fraction of x (state A) enters the separating calorimeter. The vapor part will have a mass of xM kg and the liquid part will have a mass of (1-x)M kg. In the separating calorimeter part of the liquid, say M_1 kg will be separated from the wet steam. Hence the dryness fraction of the wet steam will increase to x1 (state B) which will pass through the throttling process valve. After the throttling process the steam in the throttling calorimeter will be in superheated state (state C).



T-S diagram of the separating and throttling calorimeter.

From the steady flow energy equation;

$$Q - W = h_C - h_B$$

Since throttling takes place over a very small distance, the heat transfer is negligible, i.e., Q = 0. Then the steady flow energy equation for the throttling process becomes,

$$h_C = h_B$$

Hence, enthalpy after throttling = enthalpy before throttling

$$h_C = h_{f1} + x_1 h_{fg1}$$

If the pressure of the steam before throttling, the pressure and temperature of the steam after throttling, are known the value of x_1 can be calculated using steam tables.

$$\text{Dryness Fraction} = \frac{\text{Mass of dry steam}}{\text{Mass of mixture}}$$

Therefore,

$$X = \frac{x_1 M_2}{M_1 + M_2}$$

Where, M_2 is the mass of condensate.

PROCEDURE:

1. Start the boiler and supply steam to the separating and throttling calorimeter unit.
2. Start the cooling water flow through the condenser.
3. Open steam valve and allow the steam to flow through the calorimeters to warm through the steam.
4. Open the throttle valve and adjust to give a pressure at exhaust of about 5cm Hg measured on the manometer.
5. Drain the separating calorimeter.
6. Start the test and take readings at 2-3 minutes intervals.
7. When a reasonable quantity of condensate is collected measure the quantity of separated water and the quantity of condensate.

RESULTS AND CALCULATIONS:

Using the average values, obtain the specific enthalpy of steam at (state C) hence calculate the dryness fraction of incoming steam. Also calculate the specific enthalpy of incoming steam.

TABLE OF OBSERVATIONS

Reading #	**1**	**2**	**3**	**4**	**5**	**6**	**Ave.**
Steam pressure in main P_1 (bars)							
Steam pressure after throttling P_2 (bars)							

Temperature of main T_1 (°C)							
Temperature after throttling T_2 (°C)							
Quantity of Separated water M1 (kg)							
Quantity of condensate M_2 (Kg)							
Atmospheric pressure P_a (bars)							

Viva Questions:-

1. Define the term of quality of steam?
2. What is dryness fraction?
3. What is meant by calorimeter?
4. Define the construction of separating and throttling calorimeter?
5. Define the working of separating and throttling calorimeter.

EXPERIMENT NO 6

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

Theory:- The velocity of steam relative of the blades, can be very easily found out by the velocity diagram.

Let,

V_b = Linear velocity of moving blade (at inlet) in m/s
V_1 = Absolute velocity of steam entering moving blades in m/s
V_{r1} = Relative velocity of steam to moving blade at inlet
V_{f1} = Axial component of moving blade
V_{w1} = Tangential component of velocity V1
α = Angle to the tangent or nozzle angle
β = Entrance angle of moving blades
V_0 = Absolute velocity of steam at outlet from the moving blade
V_{r0} = Relative velocity of steam to moving blade at exit
Θ = Angle of discharge
γ = Angle of blade at outlet
Speed ratio, $P = \frac{V_b}{V_1}$

The effective component of steam jet which produces tangential force and cause the wheel to rotate is the velocity of wheel. So the work on blade is done by this tangential force and may be find out from the change in momentum in the direction of motion. The velocity of flow is responsible for producing the axial thrust on the wheel. If there is a friction loss then

$$V_{r0} = KV_{r1}$$

where Otherwise K is (1-friction) or (1-loss)$V_{r0} = V_{r1}$

Width of the blade:- From the Newton second low, tangential force on the wheel is equal to (m_s .a)

$F = m_s .a$
m_s /s .change in velocity
$m^o_s. (V_{w1}+V_{w0})$ ----------------- (1)

Because V_{w0} is already negative.

Work done by the blade / sec = (Force . Distance)/sec

Force. velocity = $F . V_b$
$= m^o_s. (V_{w1}+V_{w0}).V_b$----------------(2)

or = Power developed by the turbine in KW

Since the available energy of steam entering to the blades

- i.e. $m_s.V_1^2/2$------ w/d = $\frac{m_s. (V_{w1}+V_{w0}).V_b}{m_s.V_1^2/2}$
- $\eta_b = \frac{2 (V_{w1}+V_{w0}).V_b}{V_1^2}$
- Another method to calculate
  $\eta_b\eta_b = \frac{V_1^2 - V_0^2}{V_1^2}$

Axial thrust on wheel:-

= mass of steam / sec. change of axial components of velocity

= $m_s \cdot (V_{f1} - V_{f0})$

If h_d is the heat drop in the nozzle ring of an impulse wheel the total energy supplied per stage is h_d per Kg of steam

Then

Stage efficiency = $\dfrac{\text{w/d by blade}}{\text{Total energy supplied per stage}}$

$= \dfrac{V_b (V_{w1} - V_{w0})}{h_d}$

If there are no losses then stage efficiency shell be same as blade efficiency

$\eta_{stage} = \eta_b \cdot \eta_{nozzle}$.

Result : Power output and efficiency has been calculated for the given problem

Viva Questions:

1. What are the main components of a steam turbine?
2. How is the power output of a steam turbine calculated?
3. What factors affect the power output of a steam turbine?
4. How is the efficiency of a steam turbine defined and calculated?

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, $K\left(\dfrac{C_{r_0}}{C_{r_1}}\right) = 0.8$

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 :

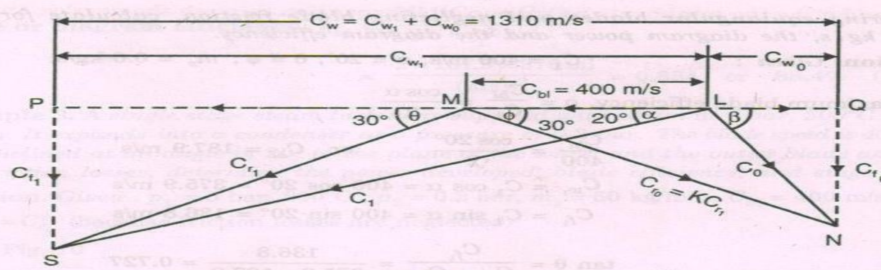


Fig. 8

- 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, $C_{r_2} = KC_{r_1} = 0.8 \times 830 = 664$ 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 :**

Tangential force $= \dot{m}_s(C_{w_1} + C_{w_0}) = \dfrac{1000}{60 \times 60}(1310) = 363.8$ N. **(Ans.)**

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

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

(*v*) **Blade efficiency, η_{bl} :**

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

EXPERIMENT NO 7

Aim:- To find the condenser efficiencies.

Theory:- Condenser is an appliance in which steam is condensed and the and the energy given up steam in the condensing process is passed to a coolant, which is water.

It is of two types, depending upon the way in which the cooling water cools the exhaust steam.

1. Jet condenser:- In this type of condenser, the cooling water and exhaust steam come into direct contact and the temperature of condensate is the same as that of cooling water leaving the condenser. It is the three of types:-

(a) Parallel flow type:- In which both exhaust steam and cooling water outer at the top of condenser and then flow in downward direction. The condensate and water are collected from the bottom.

(b) Contra flow type:- Exhaust steam and cooling water outer from the opposite direction. Usually the exhaust steam at the bottom and rises up while the cooling water enters atthe top and flow downward.

(c) Ejector type:- The mixing of exhaust steam and cooling water takes place in a series ob combining cones and K. E. of steam is utilized to assist in draining the water from the condenser into net well against the pressure of atmospheric. Parallel flow and contraflow condenser are further sub divided in two categories:-

(i) Low level type:- According to the position of condensing chamber, in case of low level type the over all height of the unit is low enough type. So that the condenser may be directly placed be near the steam turbine or engine. In this type of condenser, an extraction pump is required for drawing out the condensate, cooling water and air.

(ii) High level type :- High level condenser is similar to low level jet condenser except that it uses a barometric type or trail pipe for cooling the vacuum & removing the condensate & in some cases the non condensable gases.

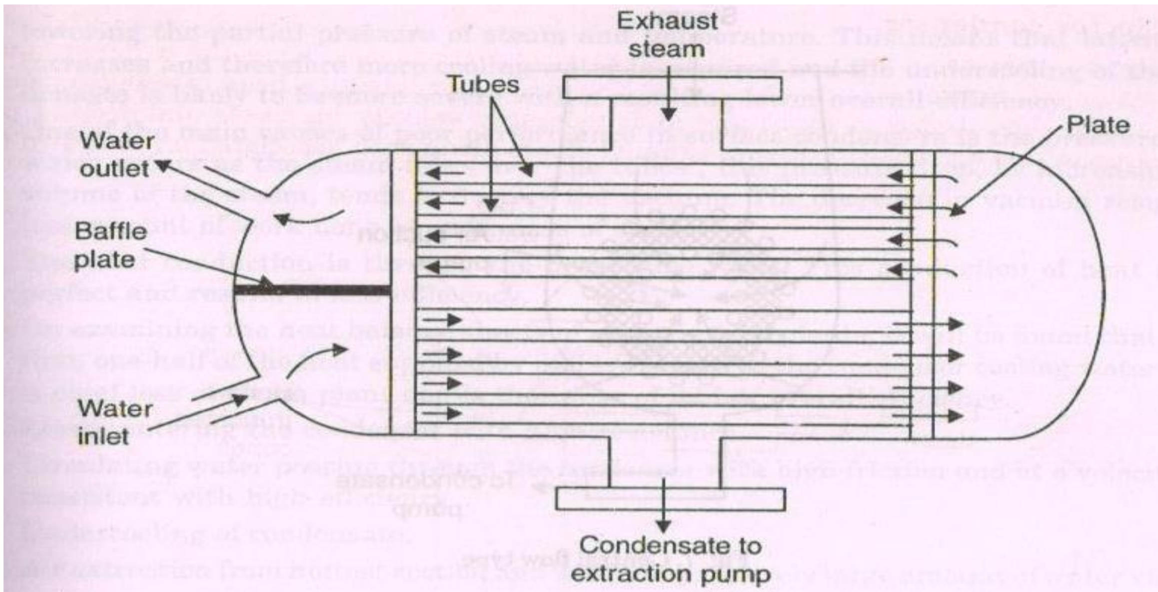
2. Surface condenser:- The exhaust steam and the cooling water don't come into direct contact. The steam to be condensed is made to flow over the out side of a nest of type through which the cooling water circulates. It is following types:-

(a) Down flow type:- The steam enters at the top and flows down over the tube through which water is circulated. As the condensed steam floe perpendicular to the direction of flow of cooling water in side the tubes, this condenser is also called cross- surface condenser.

(b) Central flow type:- In the centre of the tube nest is located the suction of air extracting pump thus resulting in the flow of steam rapidly inwards. There is better contact between the outer surface of tubes and the steam due to the volute casting round the nest of the tubes.

(c) Inverted type:- The steam after entering at the bottom rises up and then again flows down following a path near the outer surface of the condenser. The condensate extraction pump is providing at the bottom while the suction pipe of the air extraction pump connected to the top.

(d) Evaporative condenser:- When the supply of cooling water is limited, its quantity required to condensate the steam may be greatly reduced by covering the circulating water to evaporative under small particle pressure due to heat capacity of gilled pipe it has the periods without seriously affecting the vacuum.



Condenser efficiency:- Condenser efficiency is defined as the ratio of the difference between the outlet and inlet temperature of cooling water to the difference between the temperature corresponding the vacuum in the condenser and the inlet temperature of cooling water.

Condenser efficiency = Rise in temp. of cooling water / [(temp. correspondence to vacuum) - (inlet temp. of cooling water in condenser)]

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

barFrom steam table

Saturation temp corresponding to this pressure

= 36.2°C

Condenser efficiency = $\frac{temp\ rise\ of\ coling\ water}{vacuum\ temp - inlet\ coling\ water\ temp}$

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

= 66.2%

Result : Efficiency has been calculated

1. What is a condenser and what is its role in a steam power plant?
2. How is the condenser efficiency defined and calculated?
3. What are the factors that affect the condenser efficiency?
4. What are the main types of condensers used in steam power plants?

EXPERIMENT NO 8

Aim:- To study and find volumetric efficiency of a Reciprocating air compressor.
Also classify the air compressor (Rotary).

Theory:- This may be regarded as a machine which compresses or which is used to increase the pressure of air by reducing its volume.
Reciprocating compressor:- This is a machine which compresses air by means of piston reciprocating inside a cylinder.

Working:- It consist a piston which is enclosed within a cylinder and equipped with suction and discharge valve. The piston receives the power from the main shaft through a crank shaft and connecting rod. A fly wheel is fitted on the main shaft to ensure turning moment to be supplied throughout the cycle of operations.
Work done:-
(a) When the gas is compressed according to
low.PV^n = Constant
Work req /cycle $W = P_2V_2+(P_2V_2-P_1V_1 /n-1) – P_1V_1$
$= [(nP_2V_2-P_2V_2)+(P_2V_2-P_1V_1)-(nP_1V_1-P_1V_1)]/ n-1$
$= n (P_2V_2-P_1V_1) / n-1$
$W = P_1V_1n / n-1 (P_2V_2 / P_1V_1-1)$
$P_1V_1^n = P_2V_2^n$
$V_2 / V_1= (P_1 /P_2)^{-1/n}$
$W =P_1 V_1 n / n-1[(P_2 / V_1).(P_2 / P1)^{-1 / n} -1]$
$W = P_1 V_1 n / n-1[(P_2 / V_1)^{n-1 /n} -1]$ KJ / cycle
(b) When gas is compressed adiabatically:-
$W = P_1V_1r / r-1 [(P_2 / V_2)^{r-1 / r}-1]$ Kj / cycle
(c) When gas is compressed
isothermally:-$W = P_2V_2\log_e V_1 / V_2$ or
$P_1V_1\log_e V_1 / V_2$ KJ/ Cycle
P_1 & P_2 are in KN / m^2 & V_1 & V_2 are in m^3

Rotary compressor may be classified as:-
1. Positive displacement compressor
2. Non – positive displacement

compressorPositive displacement compressors are future classified as:-
(a) Roots blower
(b) Crescent or Vane blower
(c) Lysholm compressor
(d) Screw compressor

Non – positive compressor are classified as:-
(a) Centrifugal compressor
(b) Axial flow compressor

1. Positive displacement compressor:- It have two sets of mutually engaging cam surface or lobes. The air is trapped between the lobes and the pressure rise take place either be back blow ofair from receive by squeezing action and back blow of air.

(a) Roots blower:- in which back flow of high pressure air from the receive creates rise in pressure.

(b) Vane blower:- in which combined squeezing action and back flow of air creates rise in pressure.

2. Non – positive displacement compressor: - The pressure rise in these machine is not due to space reduction or back blow action of the high pressure air from the receive as in the case of positive compressor but is due to transfer of K. E. of the fluid to the pressure energy by one or more rotating rings of curved blades known as 'Impeller'.

(a) Centrifugal compressor:- The rotating member known as the Impeller consist a large number of blades and is mounted on the compressor shaft inside stationary casting. As the impeller rotates the pressure in the region a falls and hence the air enters through the eye and flow radially outwards through the impeller blades as of the compressor. Both velocity and pressure increase as the air flow through the cylinder or impeller blades. Air enters through the convergent passage formed by the diffuse blades.

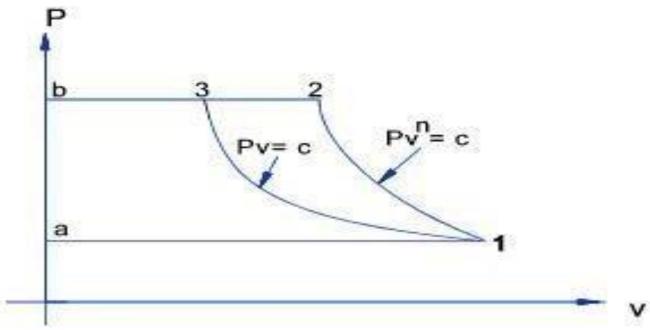
(b) Axial flow compressor:- It is more commonly used, the air flows in an axial direction right from the intake to the delivery. The working principle is illustrated in fig. The stator encloses the rotor both of which are provided with rings of blades. As the air enters in the direction it flows through the alternately arranged stator and rotor blade ring the air gets compressed successively. For efficient operation the blades are made of aerofoil section based on aero-dynamic theory.The annular area is made divergent as shown in order to keep the flow velocity constant throughout the length of compressor.

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

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.
3. The delivery valve opens and air is delivered under pressure, b -a. The delivery valve closes and the suction valve opens

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.



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

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

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

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

OBSERVATIONS & CALCULATIONS:

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

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

CONCLUSION: Hence the volumetric efficiency of the reciprocating aircompressor is___________.

Viva Questions:

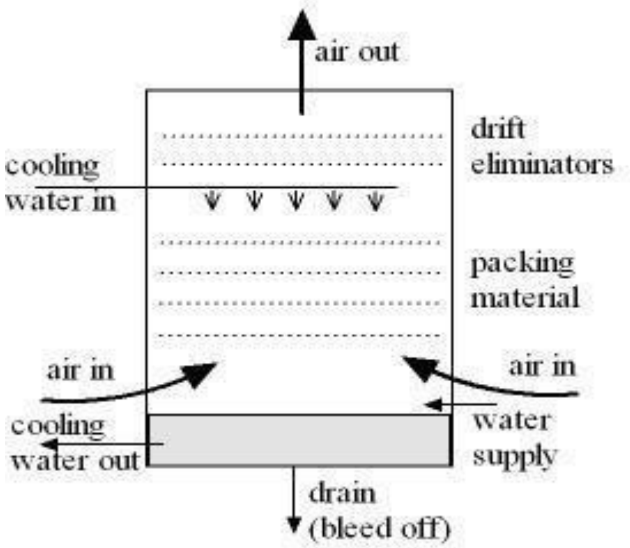
1. What factors can affect the volumetric efficiency of a reciprocating air compressor?
2. How does the suction pressure and discharge pressure influence the volumetric efficiency?
3. Can you explain the concept of clearance volume and its impact on the volumetric efficiency of a reciprocating air compressor?
4. What are some practical considerations or limitations in determining the volumetric efficiency experimentally?

EXPERIMENT NO 9

Aim:- To study Cooling tower and find its efficiency.
Theory:- It is a part of power plant. In large cities where acquisition of load is very expansive, we may cooling tower for cooling purpose as they are often placed on the root of the power plant.
Function:- Its function is to increase the surface area or cool water.
Types:-

1. Natural draught
2. Artificial draught (Mechanical type)
   (i) Forced draught (Forced fan)
   (ii) Induced draught (Suction fan)

1. 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.



2. 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 type:-

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

(ii) 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___.

Viva Questions:

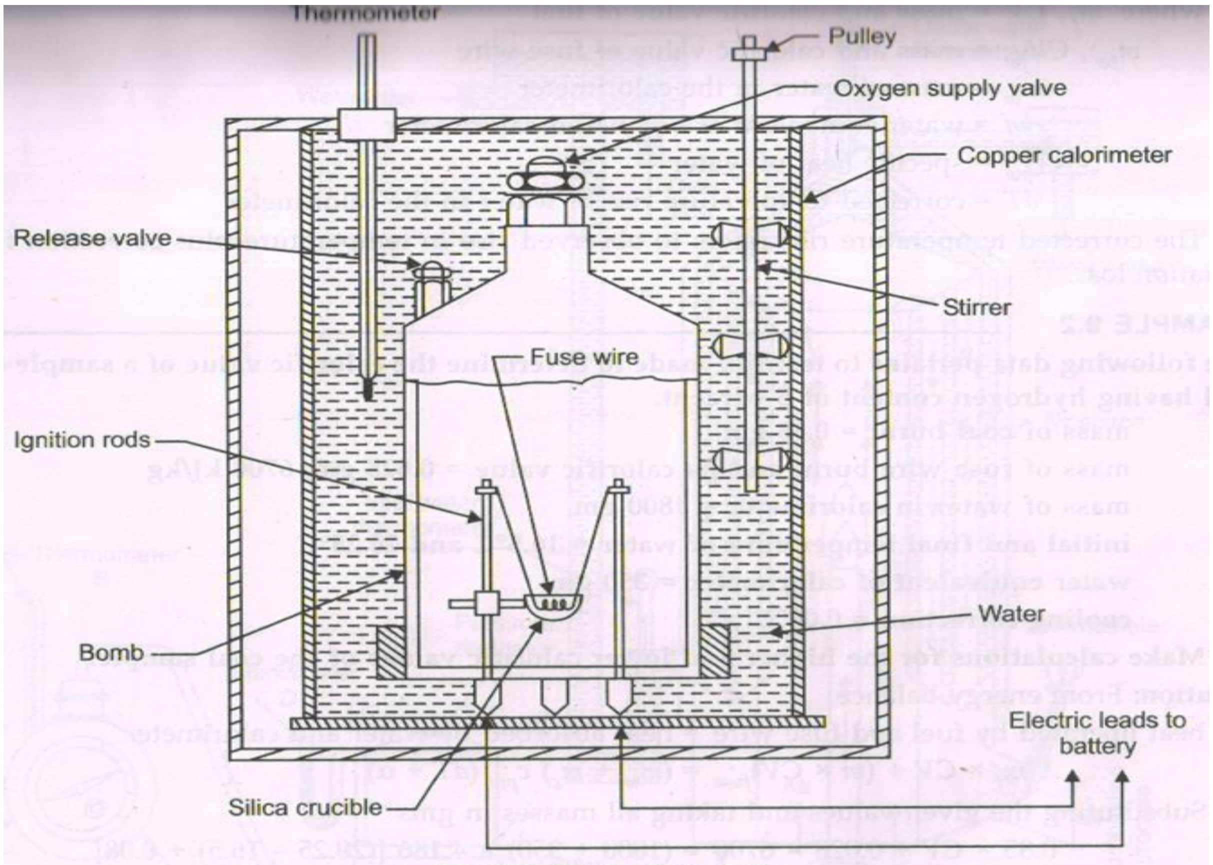
1. What are the different types of cooling towers commonly used?
2. Can you explain the concept of the cooling tower's "approach" and "range"?
3. What factors can affect the efficiency of a cooling tower?
4. How does the flow rate of the cooling water impact the cooling tower's efficiency?
5. What are some common methods used to improve the efficiency of cooling towers?

EXPERIMENT NO 10

Aim:- To find the calorific value of a sample of fuel using Bomb calorimeter.

Theory:- This calorimeter is used to determine the calorific value of solid and liquid fuels. The calorific value obtained by this calorimeter is the high calorific value at constant volume, because the fuel under test is went at constant volume in the closed vessel known as Bomb. The body of the bomb made of stainless steel which is capable of withstanding high pressure, heat and corrosion. It consists of a base which supports the Platinum crucible, the function of which is to contain the sample of fuel to be tested. The crucible act as conductor for the current which is used for igniting the fuel. The thread cover carries the oxygen valve for supplying oxygen and a release valve for exhaust gases.

The bomb is surrounded by a measured quantity of water contained in a container known as calorimeter. The calorimeter is future surrounded by a water jacket and an air space is provided between the two , to reduce losses of heat due to radiation. The lid of the casting is provided with suitable openings for the thermometer and stirrer. The stirrer is around the bomb and is moved up and down by means of crank and connecting rod arrangement.
Determination of calorific value of fuels by the Bomb calorimeter:-
The procedure for determine the C.V. of a non-volatile fuel is same as that of a solid fuel. A measured quantity of fuel is taken in the crucible and the ignition is effected through cotton threads which after dipping into the sample is attached to the paper disks which absorbs the liquid fuel and are then easily ignited. Thus the heat gained by water is equal to the heat given out by the sample of cotton thread or the paper disk. If the fuel under test is highly volatile, then the use of bomb calorimeter becomes dangerous because the fuel evaporates and gives out vapour which after mixing with oxygen will form an explosive mixture. Secondary, the fuel can not be measured in an open crucible without the loss in mass. In such a case the fuel is sucked in to a tired thin glass bulb by alternate heating and the cooling of the bulb, which is then sealed off and weighed. In order to break the bulb, when placed in the bomb it is encircled by cotton coated with paraffin wax, which is easily ignited. Such an arrangement is shown in fig. In may be noted that while calculating the C. V. of the fuel, due allowances is to be made for the C.V. of the wrapping.



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 weighted 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 isobserved.

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

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

where m_f, CV = mass and calorific value of fuel

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

= mass of water in the calorimeter

m = water equivalent of bomb and calorimeterc_{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 radiationloss.

Result : Calorific Value of Fuel can be determined

Viva Questions:-

1. Define the function of Bomb calorimeter?
2. What is it used?
3. Define the construction of Bomb calorimeter?
4. Define calorific value?

CALORIFIC VALUE OF SOME ELEMENTFUEL AT N.T.P.

SOLID FUELS

Fuel	Calorific value (Bomb calorimeter)	
	Higher	Lower
Anthracite	34.583	33.913
Bituminous coal	33.494	32.406
Lignite	21.646	20.390
Peat	15.910	14.486
Wood	15.826	14.319
Cock	30.731	30.480

GASOLINE FUELS

Fuel	C.V. , M J /m^3 at 15^0C atm.	
	Higher	Lower
Coal gas	20.11	17.95
Produce gas	6.06	6.02
Blast furnace gas	3.44	3.04
Natural gas	36.83	32.75
Carbon monoxide	11.84	11.84
Hydrogen gas	11.92	10.05

LIQUID FUEL

Fuel	C.V. , M J /kg (Bomb calorimeter)	
	Higher	Lower
Aviation gasoline	47.311	44.003
Motor gasoline	46.892	43.710
Vaporizing gasoline	46.055	43.210
Motor benzole	41.973	40.193
Kerosene	46.180	43.166
Diesel oil	45.971	43.166
Light fuel oil	44.799	42.077
Heavy fuel oil	43.961	41.366
Resudual fuel oil	42.054	39.961