RPSGOI MOHINDERGARH
RPS GROUP OF INSTITUTIONS
Balana, Satnali Road,
Mohindergarh, Haryana 123029
Ph.: 91-1285-241431
Mob.: 09466275566, 09416150201
E-mail: info@rpsinstitutions.org
Web : www.rpsinstitutions.org
Approved by **AICTE** (Govt. of India) & Affiliated to **M.D. University**, Rohtak

Steam & Power Generation Lab (ME-218-F)

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 study the working of impulse and reaction steam turbines.
4. To find the condenser efficiencies.
5. To study and find volumetric efficiency of a reciprocating air compressor.
6. To study cooling tower and find its efficiency.
7. To find calorific value of a sample of fuel using Bomb calorimeter.
8. To study the operation of a double stage air compressor.

EXPERIMENT NO. 1

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

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

Theory:- Lancashire is a stationary internally fired tube , horizontal, natural circulation boiler. 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.

The specifications of the Lancashire boiler is given below:-

Diameter of the shell – 2 to 3m.

Length of the shell – 7 to 9m.

Maximum working pressure – 16 bar.

Steam capacity – 9000kg/h.

Efficiency – 50 to 70%.

Construction of Lancashire Boiler:

Lancashire boiler consists

1. Cylindrical shell
2. Furnace tubes, bottom flue and side flues
3. Grate
4. Fire bridge
5. Dampers

Cylindrical shell

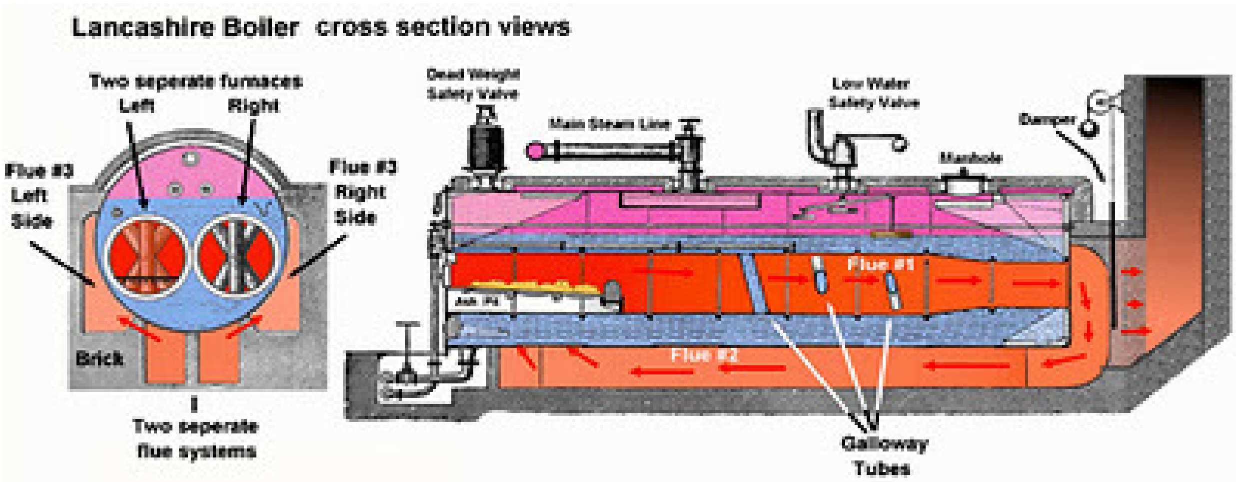
It is placed in horizontal position over a brick work. It is partly filled up with water. The water level inside the shell is well above the furnace tubes.

Furnace tubes, bottom flue and side flues:

Two large internal furnace tubes (flue tubes) extend from one end to the other end of the shell. The flues are built-up of ordinary brick lined with fire bricks. One bottom flue and two side flues are formed by brick setting, as shown in the figure.

Dampers:

Dampers is in the form of sliding doors are placed at the end of the side flues to control the flow of gases from side flues to the chimney flue.



Working of Lancashire boiler

Coal is fed to the grate through the fire hole and is burnt. The hot gases leaving the grate move along the furnace (flue) tubes up to the back end of the shell and then in the downward direction to the bottom flue. The bottom of the shell is thus first heated. The hot gases, passing through the bottom flue, travel up to the front end of the boiler, where they divide into two streams and pass to the side flues. This makes the two sides of the boiler shell to become heated. Passing along the two side flues, the hot gases travel up to the back end of the boiler to the chimney flue. They are then discharged into the atmosphere through the chimney. With the help of this arrangement of flow passages of hot gases, the bottom of the shell is first heated and then its sides. The heat is transferred to water through the surface of the two flue tubes (which remain in water) and bottom and sides of the shell. The arrangement of flues increases the heating surface of the boiler to a large extent. Dampers control the flow of hot gases and regulate the combustion rate as well as steam generation rate.

Boiler Mountings:

The boiler mountings are the part of the boiler and are required for proper functioning. In accordance with the Indian Boiler regulations, of the boiler mountings is essential fitting for safe working of a boiler. Some of the important mountings are:

Water level Indicator

Water level indicator is located in front of boiler in such a position that the level of water can easily be seen by attendant. Two water level indicators are used on all boilers.

Pressure Gauge

A pressure gauge is fitted in front of boiler in such a position that the operator can conveniently read it. It reads the pressure of steam in the boiler and is connected to steam space by a siphon tube. The most commonly, the Bourdon pressure gauge is used.

Safety Valve

Safety valves are located on the top of the boiler. They guard the boiler against the excessive high pressure of steam inside the drum. If the pressure of steam in the boiler drum exceeds the working pressure then the safety valve allows blow-off the excess quantity of steam to atmosphere. Thus the pressure of steam in the drum falls. The escape of steam makes a audio noise to warm the boiler attendant.

There are four types of safety valve.

1. Dead weight safety valve.
2. Spring loaded safety valve
3. Lever loaded safety valve
4. High steam and low water safety valve.

Fusible Plug

It is very important safety device, which protects the fire tube boiler against overheating. It is located just above the furnace in the boiler. It consists of gun metal plug fixed in a gun metal body with fusible molten metal. During the normal boiler operation, the fusible plug is covered by water and its temperature does not rise to its melting state. But when the water level falls too low in the boiler, it uncovers the fusible plug. The furnace gases heat up the plug and fusible metal of plug melts, the inner plug falls down The water and steam then rush through the hole and extinguish the fire before any major damage occurs to the boiler due to overheating.

Blow-Off Cock

The function of blow-off cock is to discharge mud and other sediments deposited in the bottom most part of the water space in the boiler, while boiler is in operation. It can also be used to drain-off boiler water. Hence it is mounted at the lowest part of the boiler. When it is open, water under the pressure rushes out, thus carrying sediments and mud.

Feed Check Valve

The feed check valve is fitted to the boiler, slightly below the working level in the boiler. It is used to supply high pressure feed water to boiler. It also prevents the returning of feed water from the boiler if feed pump fails to work.

Steam Stop Valve

The steam stop valve is located on the highest part of the steam space. It regulates the steam supply to use. The steam stop valve can be operated manually or automatically.

Boiler Accessories

The accessories are mounted on the boiler to increase its efficiency. These units are optional on an efficient boiler. With addition of accessories on the boiler, the plant efficiency also increases. The following accessories are normally used on a modern boiler:

(i) Economizer (ii) Super heater (iii) Air pre-heater (iv) Feed water pump

(v) Steam injector.

Economizer

An economizer is a heat exchanger, used for heating the feed water before it enters the boiler. The economizer recovers some of waste heat of hot flue gases going to chimney. It helps in improving the boiler efficiency. It is placed in the path of flue gases at the rear end of the boiler just before air pre-heater.

Super heater

It is a heat exchanger in which heat of combustion products is used to dry the wet steam, pressure remains constant, its volume and temperature increase. Basically, a super heater consists of a set of small diameter U tubes in which steam flows and takes up the heat from hot flue gases.

Air Pre-heater

The function of an air pre-heater is similar to that of an economizer. It recovers some portion of the waste heat of hot flue gases going to chimney, and transfers same to the fresh air before it enters the combustion chamber. Due to preheating of air, the furnace temperature increases. It results in rapid combustion of fuel with less soot, smoke and ash. The high furnace temperature can permit low grade fuel with less atmospheric pollution. The air pre-heater is placed between economizer and chimney.

Feed Water Pump

It is used to feed the water at a high pressure against the high pressure of steam already existing inside the boiler.

Steam Injector

A steam injector lifts and forces the feed water into the boiler. It is usually used for vertical and locomotive boilers and can be accommodated in small space. It is less costly. It does not have any moving parts thus operation is salient.

EXPERIMENT NO. 2

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

Apparatus Used:- Model of Babcock and Wilcox boiler (high pressure boiler).

Theory: Boiler is an apparatus to produce steam. Thermal energy released by combustion of fuel is used to make steam at the desired temperature and pressure. The steam produced is used for producing mechanical work by expanding it in steam engine or steam turbine, heating the residential and industrial buildings and performing certain processes in the sugar mills, chemical and textile industries.

Water tube or High Pressure boilers: High pressure boilers are Babcock and Wilcox, Sterling, etc. In water tube boiler, boiler feed water flows through the tubes and enters the boiler drum. The circulated water is heated by the combustion gases and converted into steam at the vapour space in the drum. These boilers are selected when the steam demand as well as steam pressure requirements are high as in the case of process cum power boiler . Most modern water tube boiler designs are within the capacity range 4,500 – 120,000 kg/hour of steam, at very high pressure.

Babcock and Wilcox boiler: It is a water tube boiler used in steam power plants. In this, water is circulated inside the tubes and hot gases flow over the tubes.

Construction of Babcock and Wilcox Boiler

The Babcock and Wilcox Boiler consists of:-

1. Steam and water drum (boiler shell)
2. Water tubes
3. Uptake-header and down corner
4. Grate and Mud box
5. Furnace and Baffles
6. Super heater
7. Inspection door and Damper

Steam and water drum (boiler shell): One half of the drum which is horizontal is filled up with water and steam remains on the other half. It is about 8 meters in length and 2 meter in diameter.

Water tubes: Water tubes are placed between the drum and furnace in an inclined position (at an angle of 10 to 15 degree) to promote water circulation. These tubes are connected to the uptake-header and the down-comer as shown.

Uptake-header and down take-header: The drum is connected at one end to the uptake-header by short tubes and at the other end to the down-corner by long tubes.

Furnace: Furnace is kept below the uptake-header.

Baffles: The fire-brick baffles, two in number, are provided to deflect the hot flue gases.

Mud box: Mud box is provided at the bottom end of the down comer. The mud or sediments in the water are collected in the mud box and it is blown-off time to time by means of a blow cock.
Inspection doors: Inspection doors are provided for cleaning and inspection of the boiler.

Working of Babcock and Wilcox Boiler:

Flow of flue gases: The hot flue gases rise upward and pass across the left-side portion of the water tubes. The baffles deflect the flue gases and hence the flue gases travel in the zig-zag manner (i.e., the hot gases are deflected by the baffles to move in the upward direction, then downward and again in the upward direction) over the water tubes and along the super heater.

Water circulation: That portion of water tubes which is just above the furnace is heated comparatively at a higher temperature than the rest of it. Water, its density being decreased, rises into the drum through the uptake-header. Here the steam and water are separated in the drum. Steam being lighter is collected in the upper part of the drum. The water from the drum comes down through the down –comer into the water tubes. A continuous circulation of water from the drum to the water tubes and water tubes to the drum is thus maintained. The circulation of water is maintained by convective currents and is known as "natural circulation".

The boiler is fitted with necessary mountings. Pressure gauge and water level indicator are mounted on the boiler at its left end. Steam safety valve and stop valve are mounted on the top of the drum. Blow-off cock is provided for the periodical removed of mud and sediments collected in the mud box.

EXPERIMENT NO. 3

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

Apparatus: Model of Impulse and Reaction steam turbines.

Theory: 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:

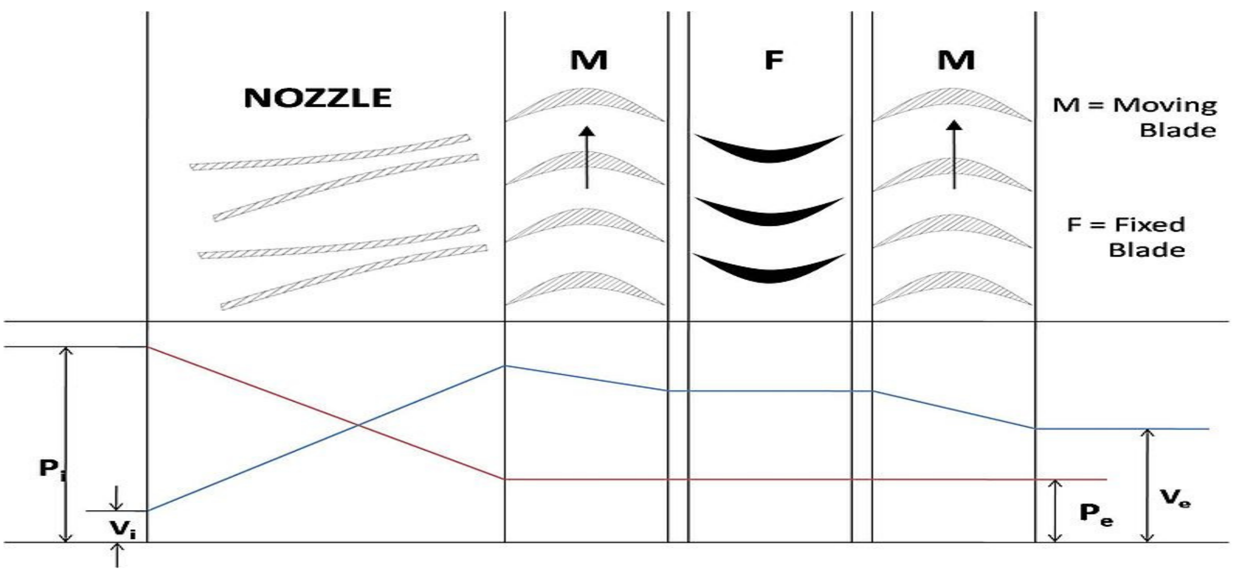
1. Impulse turbine
2. Reaction turbine

Impulse turbines: There is no change in the pressure of the steam as it passes through the moving blades. There is change only in the velocity of the steam flow. An impulse turbine has fixed nozzles that orient the steam flow into high speed jets. These jets contain significant kinetic energy, which is converted into shaft rotation by the bucket-like shaped rotor blades, as the steam jet changes direction. A pressure drop occurs across only the stationary blades, with a net increase in steam velocity across the stage. As the steam flows through the nozzle its pressure falls from inlet pressure to the exit pressure (atmospheric pressure, or more usually, the condenser vacuum). Due to this high ratio of expansion of steam, the steam leaves the nozzle with a very high velocity. The steam leaving the moving blades has a large portion of the maximum velocity of the steam when leaving the nozzle. The loss of energy due to this higher exit velocity is commonly called the carry over velocity or leaving loss

Reaction turbines: There is change in both pressure and velocity as the steam flows through the moving blades. In the reaction turbine, the rotor blades themselves are arranged to form convergent nozzles. This type of turbine makes use of the reaction force produced as the steam accelerates through the nozzles formed by the rotor. Steam is directed onto the rotor by the fixed vanes of the stator. It leaves the stator as a jet that fills the entire circumference of the rotor. The steam then changes direction and increases its speed relative to the speed of the blades. A pressure drop occurs across both the stator and the rotor, with steam accelerating through the stator and decelerating through the rotor, with no net change in steam velocity across the stage but with a decrease in both pressure and temperature, reflecting the work performed in the driving of the rotor.

Compounding of steam turbines: It is the method in which energy from the steam is extracted in a number of stages rather than a single stage in a turbine. A compounded steam turbine has multiple stages i.e. it has more than one set of nozzles and rotors, in series, keyed to the shaft or fixed to the casing, so that either the steam pressure or the jet velocity is absorbed by the turbine in number of stages.

Velocity compounding of impulse turbine: The velocity compounded Impulse turbine was first proposed by C G Curtis to solve the problem of single stage Impulse turbine for use of high pressure and temperature steam. The rings of moving blades are separated by rings of fixed blades. The moving blades are keyed to the turbine shaft and the fixed blades are fixed to the casing. The high pressure steam coming from the boiler is expanded in the nozzle first. The Nozzle converts the pressure energy of the steam into kinetic energy. It is interesting to note that the total enthalpy drop and hence the pressure drop occurs in the nozzle. Hence, the pressure thereafter remains constant. This high velocity steam is directed on to the first set (ring) of moving blades. As the steam flows over the blades, due the shape of the blades, it imparts some of its momentum to the blades and losses some velocity. Only a part of the high kinetic energy is absorbed by these blades. The remainder is exhausted on to the next ring of fixed blade. The function of the fixed blades is to redirect the steam leaving from the first ring moving blades to the second ring of moving blades. There is no change in the velocity of the steam as it passes through the fixed blades. The steam then enters the next ring of moving blades; this process is repeated until practically all the energy of the steam has been absorbed



A schematic diagram of the Curtis stage impulse turbine, with two rings of moving blades one ring of fixed blades is shown in figure. The figure also shows the changes in the pressure and the absolute steam velocity as it passes through the stages. where,

P_i = pressure of steam at inlet

V_i = velocity of steam at inlet

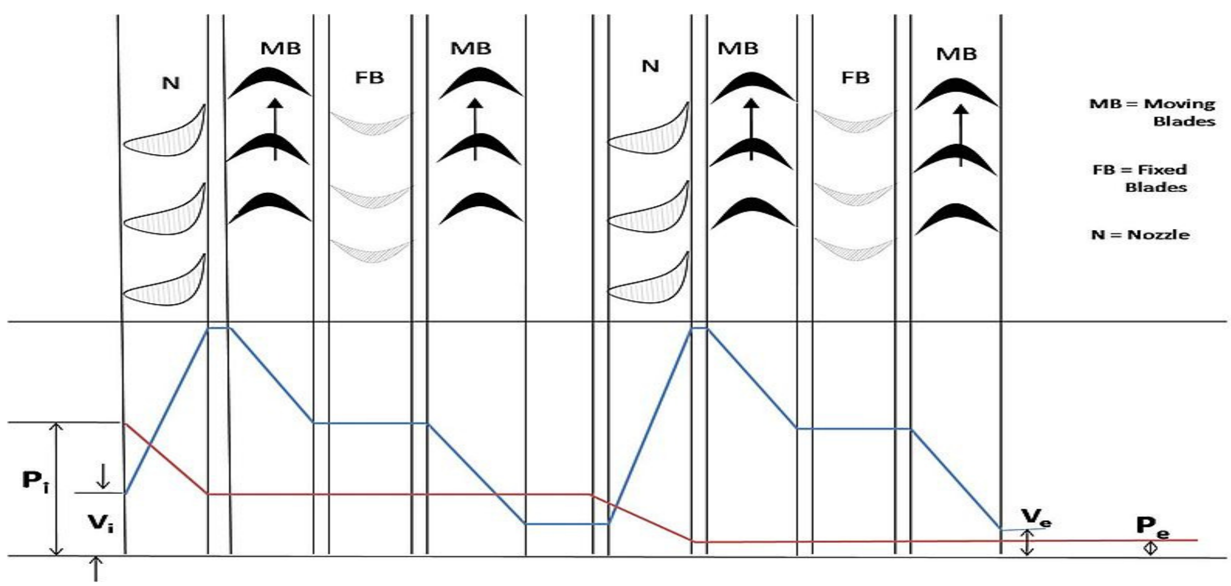
P_o = pressure of steam at outlet

V_o = velocity of steam at outlet

In the above figure there are two rings of moving blades separated by a single of ring of fixed blades. As discussed earlier the entire pressure drop occurs in the nozzle, and there are no subsequent pressure losses in any of the following stages. Velocity drop occurs in the moving blades and not in fixed blades

Pressure compounding is the method in which pressure in a steam turbine is made to drop in a number of stages rather than in a single nozzle. The arrangement consists of a number of simple impulse turbines in series mounted on a common shaft. The exit steam from one turbine is made to enter the nozzle of the succeeding turbine. Each of the simple impulse turbines would then be termed a "stage" of the turbine. Each stage comprises its ring of nozzle and blades. The steam from the boiler passes through the first nozzle ring where its pressure drops and velocity increases. The high velocity jet steam is directed onto the first moving blades wherein nearly all of its velocity is absorbed. The steam pressure remains unaltered. The steam from the first ring of moving blades enters the second ring of nozzles where its pressure is further reduced. The next ring of moving blades absorbs the velocity obtained from this second ring nozzle. The process is repeated in the remaining rings until the whole of the pressure has been absorbed.

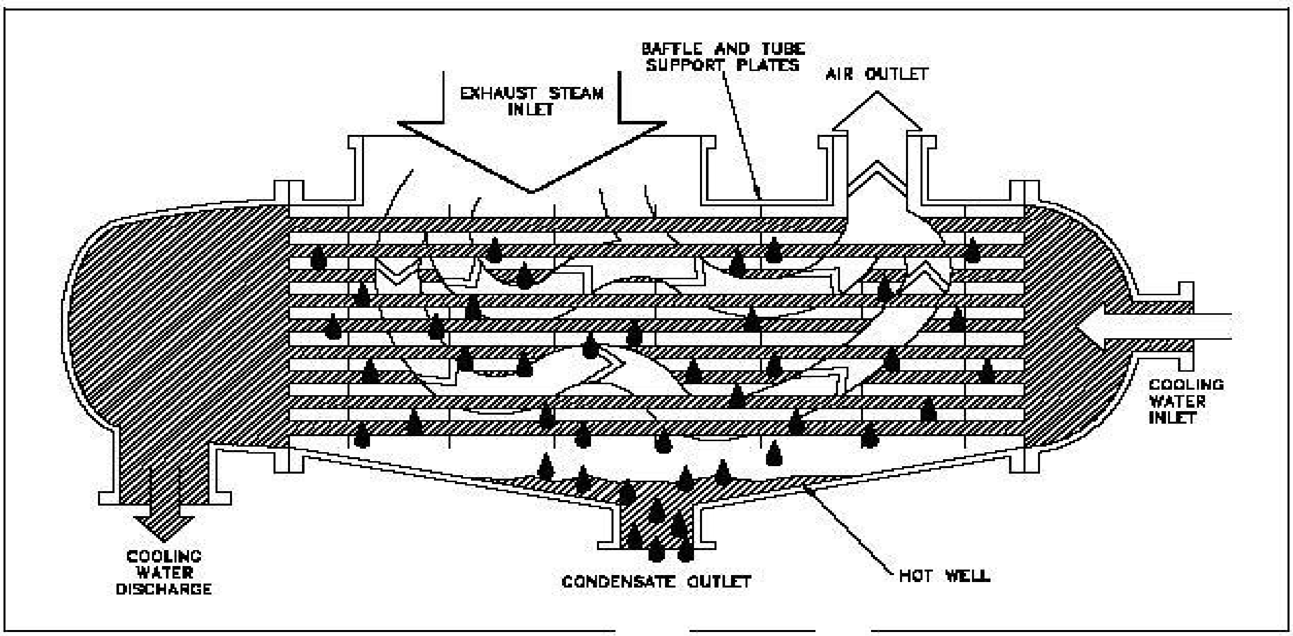
Pressure-velocity compounding:- It is a combination of the above two types of compounding. The total pressure drop of the steam is divided into a number of stages. Each stage consists of rings of fixed and moving blades. Each set of rings of moving blades is separated by a single ring of fixed blades. In each stage there is one ring of fixed blades and 3-4 rings of moving blades. Each stage acts as a velocity compounded impulse turbine. The fixed blades act as nozzles. The steam coming from the boiler is passed to the first ring of fixed blades, where it gets partially expanded. The pressure partially decreases and the velocity rises correspondingly. The velocity is absorbed by the following rings of moving blades until it reaches the next ring of fixed blades and the whole process is repeated once again.



Experiment No: 4

Objective: 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. This is called sub cooling and certain amount is desirable. The difference between saturation temperature corresponding to condenser vacuum and temperature of condensate in hot well is called condensate depression.



There are two primary types of condensers that can be used in a power plant; they are direct contact or jet condenser and surface condenser.

Direct contact condensers condense the turbine exhaust steam by mixing it directly with cooling water. The older type Barometric and Jet-Type condensers operate on similar principles. In a jet condenser, steam escapes with cooling water and this mixture inhabits recovery of condensate to be reused as boiler feed water. In this case, the cooling water should be fresh and free from harmful impurities. However, with moderate size turbine units the jet condensers can be used if enough supply of good quality cooling water is available. Steam surface condensers are the most commonly used condensers in modern power plants. The exhaust steam from the turbine flows in the shell (under vacuum) of the condenser, while the circulating water flows in the tubes. The source of the circulating water can be a river, lake, pond, ocean or cooling tower.
The main function of a condenser is to only remove the latent heat of vaporization so that the temperature of condensate becomes equal to the saturation temperature of steam corresponding to the condenser pressure. It further theoretically elaborates complete absence of under cooling of condensate. Therefore, the maximum temperature to which cooling water can be raised is the condensate temperature at the minimum possible condenser pressure where only latent heat of vaporization is extracted without any under cooling. The condenser efficiency is given as the ratio of actual rise in the temperature of outlet cooling water to the maximum possible temperature rise in a saturated temperature at condenser pressure corresponding to the inlet cooling water temperature.
Mathematically,
Condenser efficiency = (Actual rise in the cooling water temperature)/{[Saturation temperature at condenser pressure] – [inlet cooling water temperature]}
Condenser efficiency = (T2 – T1)/(T3 – T1).
T1 and T2 are inlet and outlet cooling water temperature, and T3 is saturation temperature at condenser pressure.

Conclusion: Hence the condenser efficiency is __________.

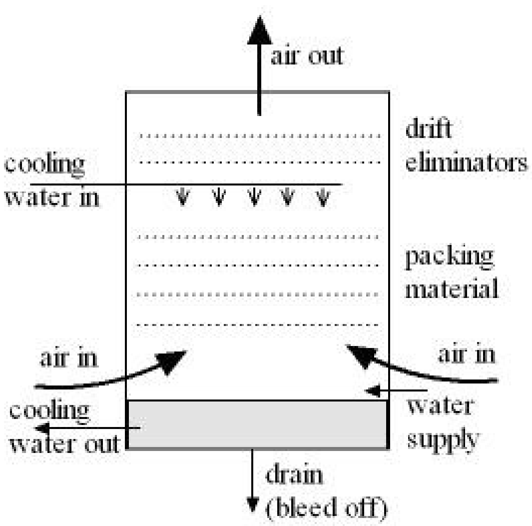
Experiment No: 5

Objective: 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.



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. There are two main types of cooling towers

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:

T_i	T_o	T_{wb}	M

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)

t_o = outlet temperature of water from the tower (^oC)

t_{wb} = wet bulb temperature of air (^oC)

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 __________.

Experiment No: 6

Objective: To calibrate the given thermocouples and to plot the calibration curve.

Introduction: A thermocouple consists of two conductors of different materials (usually metal alloys) that produce a voltage in the vicinity of the point where the two conductors are in contact. The voltage produced is dependent on, but not necessarily proportional to, the difference of temperature of the junction to other parts of those conductors. Thermocouples are a widely used type of temperature sensor for measurement and control and can also be used to convert a temperature gradient into electricity

Principle of operation: In 1821, the German–Estonian physicist Thomas Johann See beck discovered that when any conductor is subjected to a thermal gradient, it will generate a voltage. This is now known as the thermoelectric effect or See beck effect. Any attempt to measure this voltage necessarily involves connecting another conductor to the hot end. This additional conductor will then also experience the temperature gradient, and develop a voltage of its own which will oppose the original. Fortunately, the magnitude of the effect depends on the metal in use. Using a dissimilar metal to complete the circuit creates a circuit in which the two legs generate different voltages, leaving a small difference in voltage available for measurement. That difference increases with temperature, and is between 1 and 70 microvolt's per degree Celsius (µV/°C) for standard metal combinations. The voltage is not generated at the junction of the two metals of the thermocouple but rather along that portion of the length of the two dissimilar metals that is subjected to a temperature gradient. Because both lengths of dissimilar metals experience the same temperature gradient, the end result is a measurement of the difference in temperature between the thermocouple junction and the reference junction.

Theory: In the simplest arrangement, the thermocouple is connected directly to the indicating instrument. The terminals of the instrument form the cold junction of the thermocouple

Type	Temperature range ℃ (continuous)	Temperature range ℃ (short term)
K	0 to +1100	−180 to +1300
J	0 to +750	−180 to +800
T	−185 to +300	−250 to +400

J

Type J (iron–constantan) has a more restricted range than type K (−40 to +750 °C), but higher sensitivity of about 55 µV/°C. The Curie point of the iron (770 °C) causes an abrupt change in the characteristic, which determines the upper temperature limit.

K

Type K (chromel {90% nickel and 10% chromium}alumel {95% nickel, 2% manganese, 2% aluminium and 1% silicon}) is the most common general purpose thermocouple with a sensitivity of approximately 41 µV/°C, chromel positive relative to alumel. It is inexpensive, and a wide variety of probes are available in its −200 °C to +1250 °C / -330 °F to +2460 °F range. Type K was specified at a time when metallurgy was less advanced than it is today, and consequently characteristics may vary considerably between samples. One of the constituent metals, nickel, is magnetic; a characteristic of thermocouples made with magnetic material is that they undergo a deviation in output when the material reaches its Curie point; this occurs for type K thermocouples at around 350 °C . Wire color standard is yellow (+) and red (-).

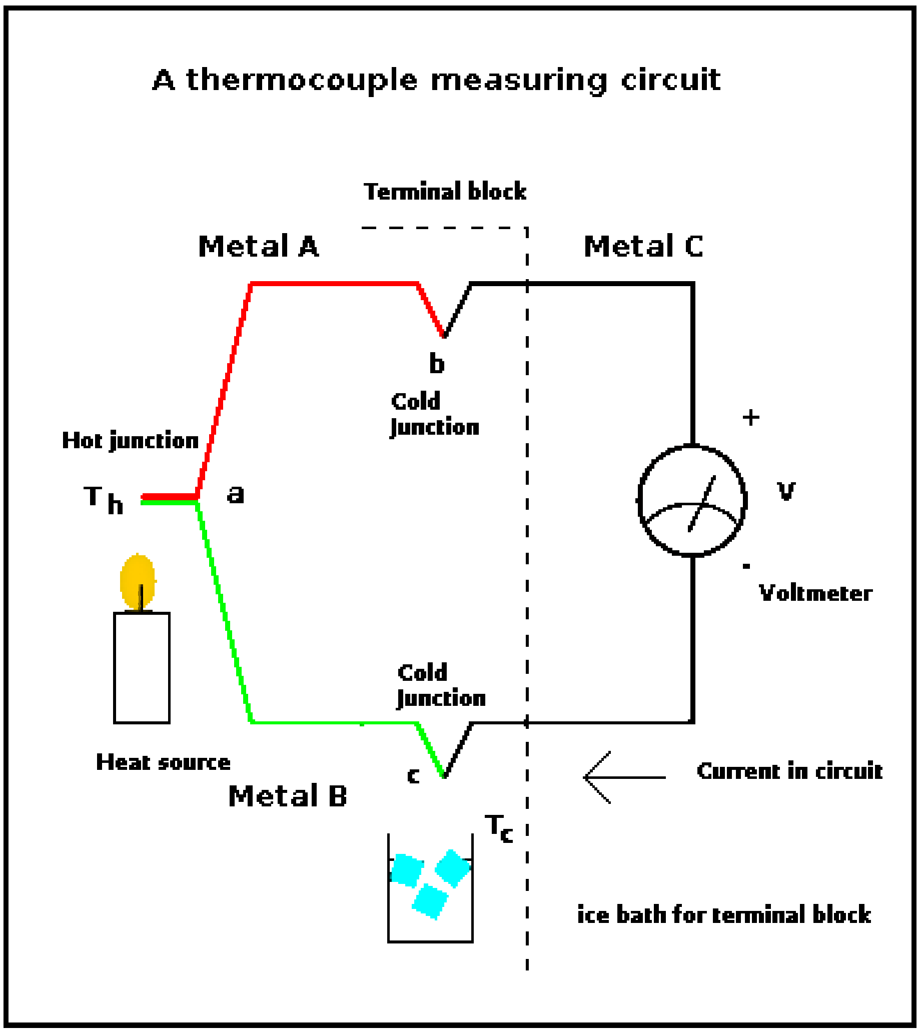
T

Type T (copper – constantan) thermocouples are suited for measurements in the −200 to 350 °C range. Often used as a differential measurement since only copper wire touches the probes. Since both conductors are non-magnetic, there is no Curie point and thus no abrupt change in characteristics. Type T thermocouples have a sensitivity of about 43 µV/°C.

The major requirements of the thermocouple materials are:

1. They must not deteriorate.
2. They must produce a measurable, stable electrical output.
3. They must be economical.
4. They must be mechanically strong.

Thermocouples are available in a large variety of designs for many diverse applications. In the most common design, the conductors are joined together usually by welding to form a measuring junction. The wires are separated beyond the welded junction and insulated, usually by fibrous glass, ceramic insulators etc. The calibration of thermocouple is done by observing the milli volts developed across the measuring junction for a range of temperature of a liquid being heated A is used as a reference temperature. A plot of milli volts vs. temperature is the calibration curve. The sensitivity of calibration curve is different for different types of thermocouple and none has a linear rate of change of e.m.f. output per degree of temperature change. Each type of thermocouple has a unique non linear response to temperature. the thermocouple circuit can be represented as given below:



Description: The setup consists of constant temperature bath with heating element. This heat source is controlled with the help of PID controller at any preset valve. A thermocouple pocket is provided to insert the thermocouple in it.

Experimental procedure:

1. Immerse the thermocouple into the electric heated bath.
2. Switch on the power supply and set the temperature of the bath.
3. Connect the lead wires from thermocouple to the milli voltmeter.
4. Start taking the reading of the PID controller and corresponding voltage on the milli-voltmeter.

Observation & calculation:

Temperature ^{o}c					
Milli volt					

Precaution & maintenance instructions:

1. Never exceed the set point of DTC than 100^{o} c.
2. Always pull the needle with the help of needle puller.
3. Always take precaution at the time of handling the needle.
4. Never touch the inner mechanism.

Experiment No: 7

Objective: To find calorific value of a sample of fuel by using bomb calorimeter.

Theory: A bomb calorimeter is a type of constant-volume calorimeter used in measuring the heat of combustion of a particular reaction. Bomb calorimeters have to withstand the large pressure within the calorimeter as the reaction is being measured. Electrical energy is used to ignite the fuel; as the fuel is burning, it will heat up the surrounding air, which expands and escapes through a tube that leads the air out of the calorimeter. When the air is escaping through the copper tube it will also heat up the water outside the tube. The temperature of the water allows for calculating calorie content of the fuel the whole bomb, pressurized with excess pure oxygen (typically at 30atm) and containing a weighed mass of a sample (typically 1-1.5 g) and a small fixed amount of water (to saturate the internal atmosphere, thus ensuring that all water produced is liquid, and removing the need to include enthalpy of vapourization in calculations), is submerged under a known volume of water (ca. 2000 ml) before the charge is electrically ignited. The bomb, with the known mass of the sample and oxygen, form a closed system - no gases escape during the reaction. The weighted reactant put inside the steel container is then ignited. Energy is released by the combustion and heat flow from this crosses the stainless steel wall, thus raising the temperature of the steel bomb, its contents, and the surrounding water jacket. The temperature change in the water is then accurately measured with a thermometer. This reading, along with a bomb factor (which is dependent on the heat capacity of the metal bomb parts), is used to calculate the energy given out by the sample burn. A small correction is made to account for the electrical energy input, the burning fuse, and acid production (by titration of the residual liquid). After the temperature rise has been measured, the excess pressure in the bomb is released.

Basically, a bomb calorimeter consists of a small cup to contain the sample, oxygen, a stainless steel bomb, water, a stirrer, a thermometer, the insulating container (to prevent heat flow from the calorimeter to the surroundings) and ignition circuit connected to the bomb. By using stainless steel for the bomb, the reaction will occur with no volume change observed

Since there is no heat exchange between the calorimeter and surroundings → $Q = 0$ (adiabatic) ;no work performed → $W = 0$ Thus, the total internal energy change $\Delta U(\text{total}) = Q + W = 0$

Also, total internal energy change $\Delta U(\text{total}) = \Delta U(\text{system}) + \Delta U(\text{surroundings}) = 0$ → $\Delta U(\text{system}) = - \Delta U(\text{surroundings}) = -C_v \, \Delta T$ (constant volume → $dV = 0$)

where C_v = heat capacity of the bomb

Before the bomb can be used to determine heat of combustion of any compound, it must be calibrated. The value of C_v can be estimated by C_v(calorimeter) = m (water). C_v (water) + m (steel). C_v (steel)

m (water) and m (steel) can be measured;

C_v(water)= 1 cal/g.K

C_v(steel)= 0.1 cal/g.K

In laboratory, C_v is determined by running a compound with known heat of combustion value: $C_v = H_c/\Delta T$

Common compounds are benzoic acid (H_c = 6318 cal/g) or p-methyl benzoic acid (H_c = 6957 cal/g).

Temperature (T) is recorded every minute and ΔT = T(final) - T(initial)

A small factor contributes to the correction of the total heat of combustion is the fuse wire. Nickel fuse wire is often used and has heat of combustion = 981.3 cal/g

In order to calibrate the bomb, a small amount (~ 1 g) of benzoic acid, or p-methyl benzoic acid is weighed. A length of Nickel fuse wire (~10 cm) is weighed both before and after the combustion process. Mass of fuse wire burned Δm = m(before) - m(after)

The combustion of sample (benzoic acid) inside the bomb ΔH_c = ΔH_c (benzoic acid) x m (benzoic acid) + ΔH_c (Ni fuse wire) x Δm (Ni fuse wire)

$\Delta H_c = C_v. \Delta T \rightarrow C_v = \Delta H_c/\Delta T$

Once C_v value of the bomb is determined, the bomb is ready to use to calculate heat of combustion of any compounds by $\Delta H_c = C_v. \Delta T$

Experimental procedure:

1. Open the bomb ring and take the bomb lid out. Connect Nicron wire in groove of electrode and keep S.S. crucible in the ring which is in the electrode.
2. Keep the sample in crucible. Connect cotton thread from Nicron wire to sample.
3. Keep bomb lid on the bomb, tight it with its S.S. ring.
4. Fill up gas 30ml in bomb through oxygen cylinder by connecting regulating valve and copper pipe as per drawing.
5. Keep this bomb in calorimeter vessel.

6. Keep the calorimeter in water jacket. There are two connecting leads out of them one connect from water jacket terminal to bomb terminal and second to firing unit terminal.
7. Fill the water up to the level of the S.S. ring of the bomb in calorimeter vessel. Put the black combined lid on the water jacket in particular direction. There is a small slot in combined lid and small pin in water jacket. Small pin of water jacket come in the small slot of combined lid.
8. Connect the two pin plug of stirrer in the socket which is on the back side of firing unit and dip the stirrer pipe in the water which is in calorimeter vessel and tight with the screw of stirrer.
9. Tight the screw of stirrer with the pin which is on the top of the water jacket which is on the right side.
10. Connect the vibrator, timer and illuminator with magnifier connect the socket of magnifier which is also on the back side of firing unit.
11. Tight the vibrator on the top of water jacket threaded portion.
12. Dip the bulb of Backmen thermometer in the water through holding the Backmen thermometer in the clamp of vibration and note the initial temp. of Backmen thermometer.
13. Press the green button to check the continuity if the bulb indicate it means the circle is complete then to push the red button for fire the sample.
14. After firing the sample heat will generate which will transferred in the water of calorimeter vessel.
15. Note the rise temp. of Backmen thermometer. The difference rise temp. initial temp. is the actual temp. of the sample.
16. After that calculate the calorific value with formula indicate in instruction table.

Precautions:

a. Do not use too much sample. The bomb cannot be expected to withstand the effects of combustible charges which liberate more than 10,000 calories. This generally limits the total weight of combustible material to not more than 1.10gm.

b. Do not charge with more oxygen than is necessary and do not fire the bomb if an overcharge of oxygen should accidentally be admitted.

c. Keep all parts of the bomb, especially the insulated electrode assembly in good repair at all times. Do not fire the bomb if gas bubbles are leaking from the bomb when it is submerged in water.

d. Stand back from the calorimeter for at least 15 seconds after firing and above all, keep clear of the top of the calorimeter. if the bomb explodes , it is most likely thst the force of explosion will be directed upwards.

e. Proceed with caution and use only a fraction of the allowable maximum sample when testing materials which burn rapidly, or which have explosive characteristics.

RPSGOI MOHINDERGARH
RPS GROUP OF INSTITUTIONS
Balana, Satnali Road, Mohindergarh, Haryana 123029
Ph.: 91-1285-241431
Mob.: 09466275566, 09416150201
E-mail: info@rpsinstitutions.org
Web : www.rpsinstitutions.org
Approved by **AICTE** (Govt. of India) & Affiliated to **M.D. University**, Rohtak

EX

PERIMENT NO. 8

Objective: To study the operation of a double stage air compressor.

Aim:

- **To find out the volumetric efficiency**
- **To find out isothermal efficiency**
- **To calculate the compression ratio**

Introduction: Air compressor is a device which sucks the air from atmosphere and compresses it and delivers it in tank. It compresses the air by means of a reciprocating piston, which reciprocates in a stationary cylinder. It can be single stage or multi stage . it can single acting or double acting.

Theory: Double stage reciprocating air compressor consists of two cylinders. One is called low pressure cylinder and another is called high pressure cylinder. When piston in low pressure cylinder is at its outer dead centre (ODC) the weight of air is zero (neglecting clearance volume), as piston moves towards inner dead centre (IDC) pressure falls below atmospheric pressure & suction valves opens due to pressure difference. The fresh air is drawn inside the low pressure cylinder through air cleaner. This air is further compressed by piston and pressure inside & outside the cylinder is equal, at this point suction valves closed. As piston moves towards ODC compression of air took place and when the pressure of air is in range of 1.5 kg/centimeter square to 2.5 kg/centimeter square delivery valves opens & this compressed air is then entered into High pressure Cylinder through inter cooler. This called as Low Pressure Compression. If suction & discharge stroke took place on both side of piston then it is called Double Acting Low Pressure

Compression. When air pressure in high pressure cylinder is below to the receiver pressure, suction valves of high pressure cylinder opens & low compressed air from Low Pressure Cylinder drawn into High Pressure Cylinder. As piston moves towards the ODC, this air is further compressed. When air pressure from low pressure cylinder and inside the high pressure cylinder is equal, suction valves closed. Now air is further compressed by piston until the pressure in the High Pressure Cylinder exceeds that in the receiver & discharge valves opens. This desired high pressure air is then delivered to receiver. Same procedure is repeated in every cycle of operation. If suction & discharge stroke took place on both side of piston then it is called Double Acting High Pressure Compression. In Double Stage Reciprocating Air Compressor air pressure can be developed in range of 5.5 kg/centimeter square to 35 kg/centimeter square.

Experimental procedure:

1. Close the outlet valve of tank and start the compressor.
2. Let the receiver pressure rise up to around $2kg/cm^{2.}$. Now open the delivery valve so that constant delivery pressure is achieved.
3. Wait for some time and see that delivery pressure remains constant. Now not down the pressure.
4. Record the time for 10 pulses of energy meter.
5. Recode the manometer reading.
6. Record the temperature of air at inlet, before second stage and after second stage.
7. Find out the rpm of compressor with the help of RPM indicator.
8. Repeat the same procedure for different delivery pressure.

Observation & calculation:

DATA:

d = 0.0935m

L = 0.078m

do = 0.011m

dp = 0.022m

ρ_m = $1000kg/m^3$

ρ_a = $1.21 kg/m^3$

C_d = 0.64

E.M.C. = 3200 pulses/kw-hr

P_a $= 1.03327 \times 10^5 \ N/m^2$

R = 0.16m

N_m = 1440

Table:

S.NO.	N, RPM	P_d, kg/cm^2	h_1, cm	h_2, cm	W, Kg	P	t_p, sec

h = $(h_1 - h_2)/100$, m

ΔH = $(\rho_m/\rho_a - 1) \times h$, m of air

a_o = $\pi/4 \times d^2_o$, m^2

a_p = $\pi/4 \times d^2_p$, m^2

Q_a = $C_d (a_o a_p/(\sqrt{} a_p^2 - a_o^2)) \times \sqrt{2g\Delta H}$, m^3/sec

Q_t = $(\pi \times d^2 \times L \times N)/(60 \times 40)$, m^3/sec

□$_v$ = $Q_a / Q_t \times 100\%$

$E_i = (P\times 3600)/(t_p\times EMC)$, kw

$T = W\times g\times R$, Nm

$E_s = 2\pi n_m T/60\times 1000$, kw

$r = ((P_d\times 10^5) + P_a)/P_a$

$E_{iso} = (Q_a\times \log r \times P_a)/1000$, kw

$\square_{iso} = E_{iso}/ E_s\times 100\%$

Nomenclature:

h = manometer pressure difference, m

ΔH = total head, m of air

a_o = cross-sectional area of orifice, m^2

a_p = cross-sectional area of pipe, m^2

Q_a = actual volume of air, m^3/sec

Q_t = swept volume of compressor, m^3/sec

$\square_v$ = volumetric efficiency, %

E_i = input power, kw

T = torque , Nm

E_s = shaft power, kw

r = compression ratio.

E_{iso} = isothermal power, kw

$\square_{iso}$ = isothermal efficiency, %

C_d = coefficient of discharge

d = bore diameter, m

d_o = diameter of orifice, m

d_p = diameter of pipe, m

L = length of stroke, m

N = RPM of compressor

N_m = RPM of motor

EMC = energy meter constant, pulses/kwh

R = radius of swinging field dynamometer, m