COURSE MATERIAL

IV Year B. Tech II- Semester

MECHANICAL ENGINEERING

POWER PLANT ENGINEERING

R22A0343

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

(Autonomous Institution-UGC, Govt. of India)
Secunderabad-500100, Telangana State, India.
www.mrcet.ac.in

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

DEPARTMENT OF MECHANICAL ENGINEERING

CONTENTS

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

VISION

- To establish a pedestal for the integral innovation, team spirit, originality and competence in the students, expose them to face the global challenges and become technology leaders of Indian vision of modern society.

MISSION

- To become a model institution in the fields of Engineering, Technology and Management.
- To impart holistic education to the students to render them as industry ready engineers.
- To ensure synchronization of MRCET ideologies with challenging demands of International Pioneering Organizations.

QUALITY POLICY

- To implement best practices in Teaching and Learning process for both UG and PG courses meticulously.
- To provide state of art infrastructure and expertise to impart quality education.
- To groom the students to become intellectually creative and professionally competitive.
- To channelize the activities and tune them in heights of commitment and sincerity, the requisites to claim the never - ending ladder of **SUCCESS** year after year.

For more information: www.mrcet.ac.in

VISION

To become an innovative knowledge center in mechanical engineering through state-of-the-art teaching-learning and research practices, promoting creative thinking professionals.

MISSION

The Department of Mechanical Engineering is dedicated for transforming the students into highly competent Mechanical engineers to meet the needs of the industry, in a changing and challenging technical environment, by strongly focusing in the fundamentals of engineering sciences for achieving excellent results in their professional pursuits.

Quality Policy

- ✓ To pursuit global Standards of excellence in all our endeavors namely teaching, research and continuing education and to remain accountable in our core and support functions, through processes of self-evaluation and continuous improvement.
- ✓ To create a midst of excellence for imparting state of art education, industry-oriented training research in the field of technical education.

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Department of Mechanical Engineering

PROGRAM OUTCOMES

Engineering Graduates will be able to:

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

12. **Life-long learning**: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1 Ability to analyze, design and develop Mechanical systems to solve the Engineering problems by integrating thermal, design and manufacturing Domains.

PSO2 Ability to succeed in competitive examinations or to pursue higher studies or research.

PSO3 Ability to apply the learned Mechanical Engineering knowledge for the Development of society and self.

Program Educational Objectives (PEOs)

The Program Educational Objectives of the program offered by the department are broadly listed below:

PEO1: PREPARATION

To provide sound foundation in mathematical, scientific and engineering fundamentals necessary to analyze, formulate and solve engineering problems.

PEO2: CORE COMPETANCE

To provide thorough knowledge in Mechanical Engineering subjects including theoretical knowledge and practical training for preparing physical models pertaining to Thermodynamics, Hydraulics, Heat and Mass Transfer, Dynamics of Machinery, Jet Propulsion, Automobile Engineering, Element Analysis, Production Technology, Mechatronics etc.

PEO3: INVENTION, INNOVATION AND CREATIVITY

To make the students to design, experiment, analyze, interpret in the core field with the help of other inter disciplinary concepts wherever applicable.

PEO4: CAREER DEVELOPMENT

To inculcate the habit of lifelong learning for career development through successful completion of advanced degrees, professional development courses, industrial training etc.

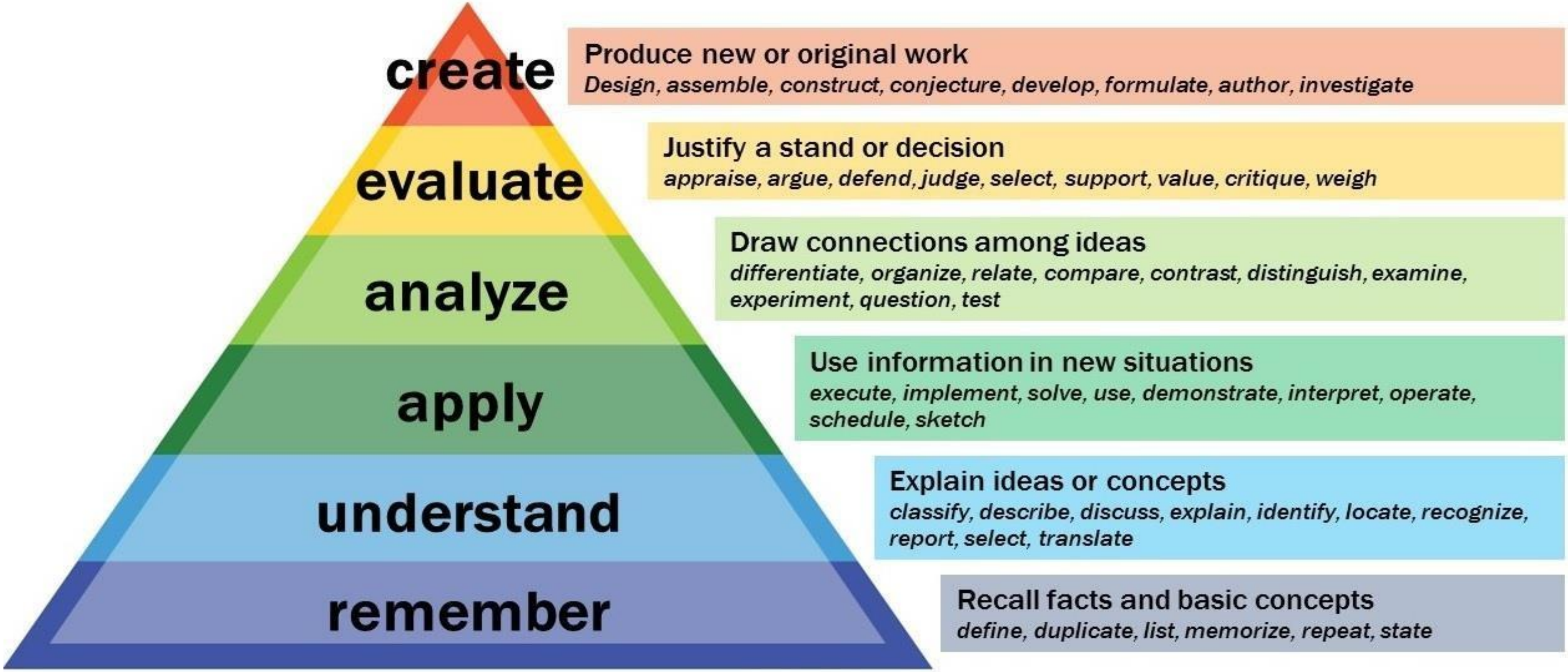
PEO5: PROFESSIONALISM

To impart technical knowledge, ethical values for professional development of the student to solve complex problems and to work in multi-disciplinary ambience, whose solutions lead to significant societal benefits.

Blooms Taxonomy

Bloom's Taxonomy is a classification of the different objectives and skills that educators set for their students (learning objectives). The terminology has been updated to include the following six levels of learning. These 6 levels can be used to structure the learning objectives, lessons, and assessments of a course.

1. **Remembering**: Retrieving, recognizing, and recalling relevant knowledge from long- term memory.
2. **Understanding**: Constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.
3. **Applying**: Carrying out or using a procedure for executing or implementing.
4. **Analyzing**: Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure or purpose through differentiating, organizing, and attributing.
5. **Evaluating**: Making judgments based on criteria and standard through checking and critiquing.
6. **Creating**: Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.



create
evaluate
analyze
apply
understand
remember
Produce new or original work
Design, assemble, construct, conjecture, develop, formulate, author, investigate
Justify a stand or decision
appraise, argue, defend, judge, select, support, value, critique, weigh
Draw connections among ideas
differentiate, organize, relate, compare, contrast, distinguish, examine, experiment, question, test
Use information in new situations
execute, implement, solve, use, demonstrate, interpret, operate, schedule, sketch
Explain ideas or concepts
classify, describe, discuss, explain, identify, locate, recognize, report, select, translate
Recall facts and basic concepts
define, duplicate, list, memorize, repeat, state

MALLA REDDY COLLEGE OF ENGINEERING &TECHNOLOGY

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IV Year B. Tech, ME-ISem

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(R17A0326) POWER PLANT ENGINEERING

Course Objectives:

The goal of this course is to be aware of the design of conventional and alternative power-generation plants. The learning objectives include

•Analysis and preliminary design of the major systems of conventional fossil-fuel steam-cycle power plants.

•A working knowledge of the basic design principles of nuclear, gas turbine, combined cycle, hydro,wind, geothermal, solar, and alternate power plants.

•Awareness of the economic, environmental, and regulatory issues related to power generation.

UNIT – I

Introduction to the Sources of Energy – Resources and Development of Power in India.Steam Power Plant: Plant Layo Working of different Circuits, Fuel and handling equipments, types ofcoals, coal handling, choice of handling equipme coal storage, Ash handling systems.Combustion Process: Properties of coal – overfeed and underfeed fuel beds, trave grate stokers,spreader stokers, retort stokers, pulverized fuel burning system and its components, combustion needs draught system, cyclone furnace, design and construction, Dust collectors, cooling towers and heatrejection. Corrosio feed water treatment.

UNIT – II

Internal Combustion Engine Plant: Diesel Power Plant: Introduction – IC Engines, types, construction–Plant layout with auxiliaries – fuel supply system, air starting equipment, lubrication and cooling system –super charging.Gas Turbine Plant: Introduction – classification - construction – Layout with auxiliaries – Principles ofworking of closed and open cycle gas turbines. Combined Cycle Power Plants and comparison.

UNIT – III

Hydro Electric Power Plant: Water power – Hydrological cycle / flow measurement – drainage area characteristics – Hydrographs – storage and Pondage – classification of dams and spill ways.

Hydro Projects and Plant: Classification – Typical layouts – plant auxiliaries – plant operation pumped storage plants

UNIT – IV

Nuclear Power Station: Nuclear fuel – breeding and fertile materials – Nuclear reactor – reactor operation. Types of Reactors: Pressurized water reactor, Boiling water reactor, sodium-graphite reactor, fast Breeder Reactor, Homogeneous Reactor, Gas cooled Reactor, Radiation hazards and shielding – radioactive waste disposal.

UNIT – V

Power Plant Economics and Environmental Considerations: Capital cost, investment of fixed charges, operating costs, general arrangement of power distribution, Load curves, load duration curve. Definitions of connected load, Maximum demand, demand factor, average load, load factor, diversity factor – related exercises. Effluents from power plants and Impact on environment – pollutants and pollution standards – Methods of Pollution control.

Course Objectives:

- To create awareness about various sources of energy,working of thermal power plants and combustionprocess
- To understand how Diesel and gas power plants arefunctioning
- To understand how power is achieved from renewable sources of energy and functions of hydro-electric powerplants
- Able to learn about Nuclear powerplants.
- To apply the concepts of economics in powerplants

REFERENCE BOOKS:

1. Power Plant Engineering/ P.K.Nag II Edition /TMHPublishers
2. An Introduction to Power Plant Technology / G.D. Rai/KhannaPublishers
3. Power plant Engg /Elanchezhian/I.K. InternationalPublishers

Course Outcomes:

- Enable students to understand about the coal handling and ash handling systems in thermal powerplants
- Tounderstandvariousgaspowercyclesandcombinedpowercycles
- TointerpretNuclearpowerstationandvarioussafetymeasurestobefollowed
- Toillustratethestudentstogettheexposureofdifferentrenewableenergyresources
- To execute and exemplify economics of power plants and waste disposal methods in Nuclear powerplants

UNIT 1

UNIT I (SYLLABUS)

Introduction to power plant engineering

A power plant is an industrial facility used to generate electric power with the help of one or more generators which converts different energy sources into electric power.

A power plant or a power generating station, is basically an industrial location that is utilized for the generation and distribution of electric power in mass scale, usually in the order of several 1000 Watts. These are generally located at the sub-urban regions or several kilometers away from the cities or the load centers, because of its requisites like huge land and water demand, along with several operating constraints like the waste disposal etc.

Electricity is produced at an electric power plant. Some fuel source, such as coal, oil, natural gas, or nuclear energy produces heat. The heat is used to boil water to create steam. The steam under high pressure is used to spin a turbine.

For this reason, a power generating station has to not only take care of efficient generation but also the fact that the power is transmitted efficiently over the entire distance and that's why, the transformer switch yard to regulate transmission voltage also becomes an integral part of the power plant.

At the center of it, however, nearly all power generating stations has an AC generator or an alternator, which is basically a rotating machine that is equipped to convert energy from the mechanical domain (rotating turbine) into electrical domain by creating relative motion between a magnetic field and the conductors.

Thermal power plant

A thermal power station or a coal fired thermal power plant is the most conventional method of generating electric power with reasonably high efficiency. It uses coal as the primary fuel to boil the water available to superheated steam for driving the steam turbine.

The steam turbine is then mechanically coupled to an alternator rotor, the rotation of which results in the generation of electric power. Generally in India, bituminous coal or brown coal are used as fuel of boiler which has volatile content ranging from 8 to 33% and ash content 5 to 16 %. To enhance the thermal efficiency of the plant, the coal is used in the boiler in its pulverized form.In coal fired thermal power plant, steam is obtained in very high pressure inside the steam boiler by burning the pulverized coal. This steam is then super heated in the super heater to extreme high temperature. This superheated steam is then allowed to enter into the turbine, as the turbine blades are rotated by the pressure of the steam.

The turbine is mechanically coupled with alternator in a way that its rotor will rotate with the rotation of turbine blades. After entering into the turbine, the steam pressure suddenly falls leading to corresponding increase in the steam volume. After having imparted energy into the turbine rotors, the steam is made to pass out of the turbine blades into the steam condenser of turbine. In the condenser, cold water at ambient temperature is circulated with the help of pump which leads to the condensation of the low pressure wet steam.

In thermal power plants, the heat energy obtained from combustion of solid fuel (mostly coal) is used to convert water into steam, this steam is at high pressure and temperature. This steam is used to rotate the turbine blade turbine shaft is connected to the generator.

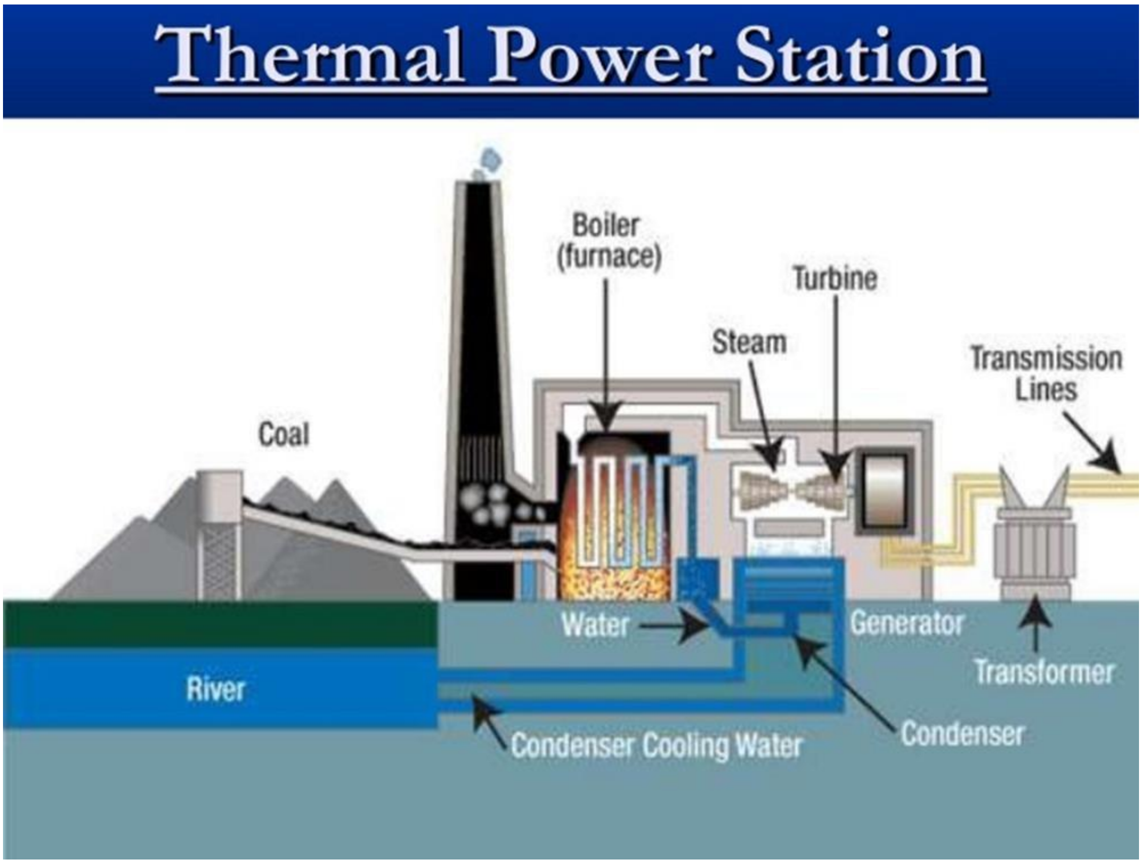


Fig. A typical thermal power plant

Components Thermal Power Plant

1. Coal handling plant
2. Stoker
3. Pulverizer
4. Boiler
5. Superheater
6. Eonomiser & Air preheater
7. Reheater
8. Deaerator
9. Condenser
10. Primary air fan
11. Turbine(prime mover)
12. Draft fan & chimney
13. Electo-static precipitator
14. Cooling tower
15. Ash handling plant
16. Electrical equipment
    a. Generator
    b. Transformers
    c. Switch yard

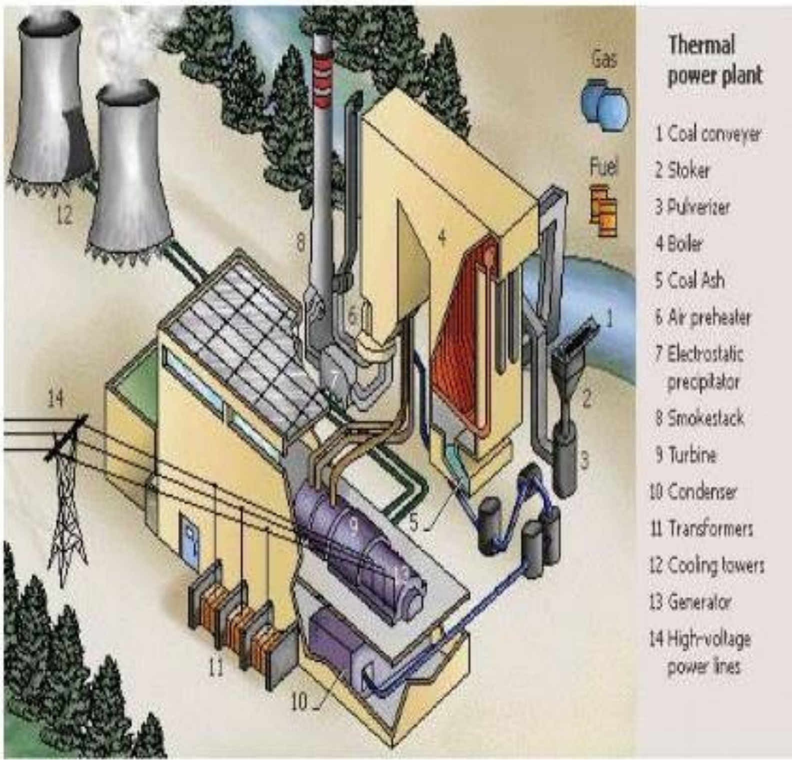


Fig. Components of a thermal power plant

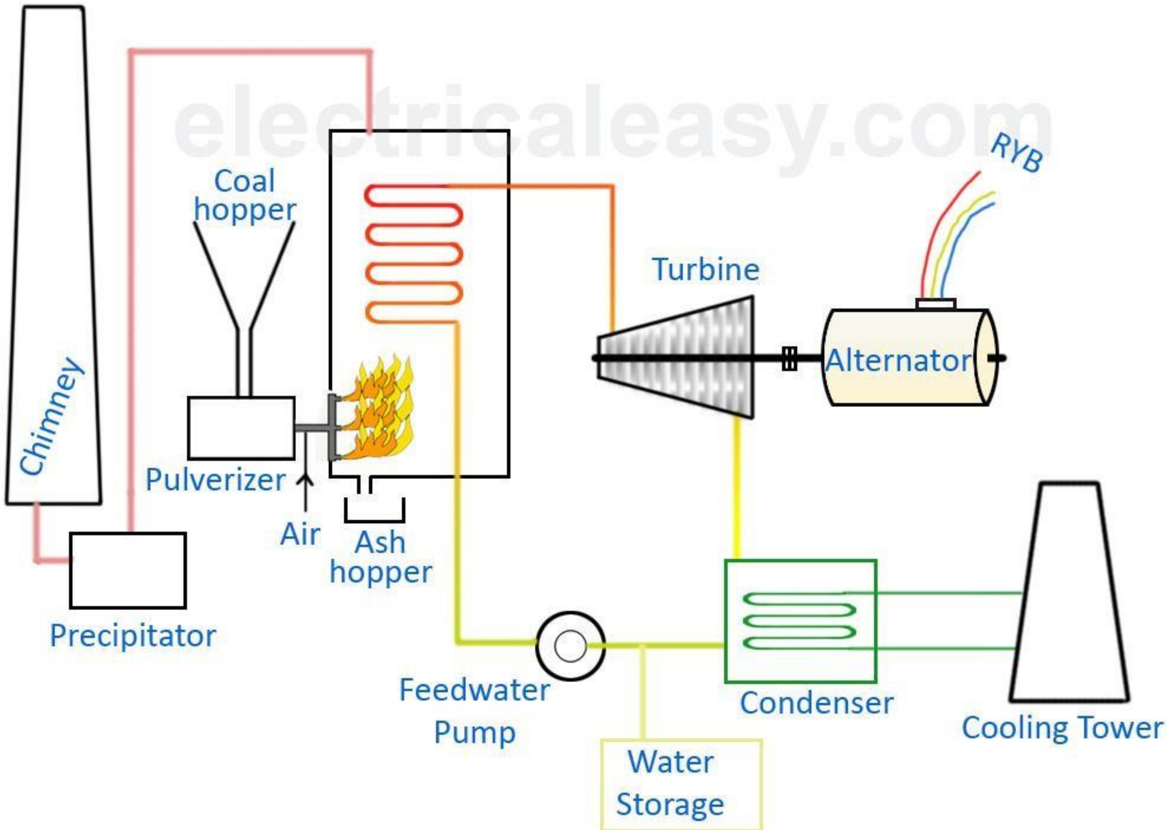


Fig. Layout of a basic thermal power plant

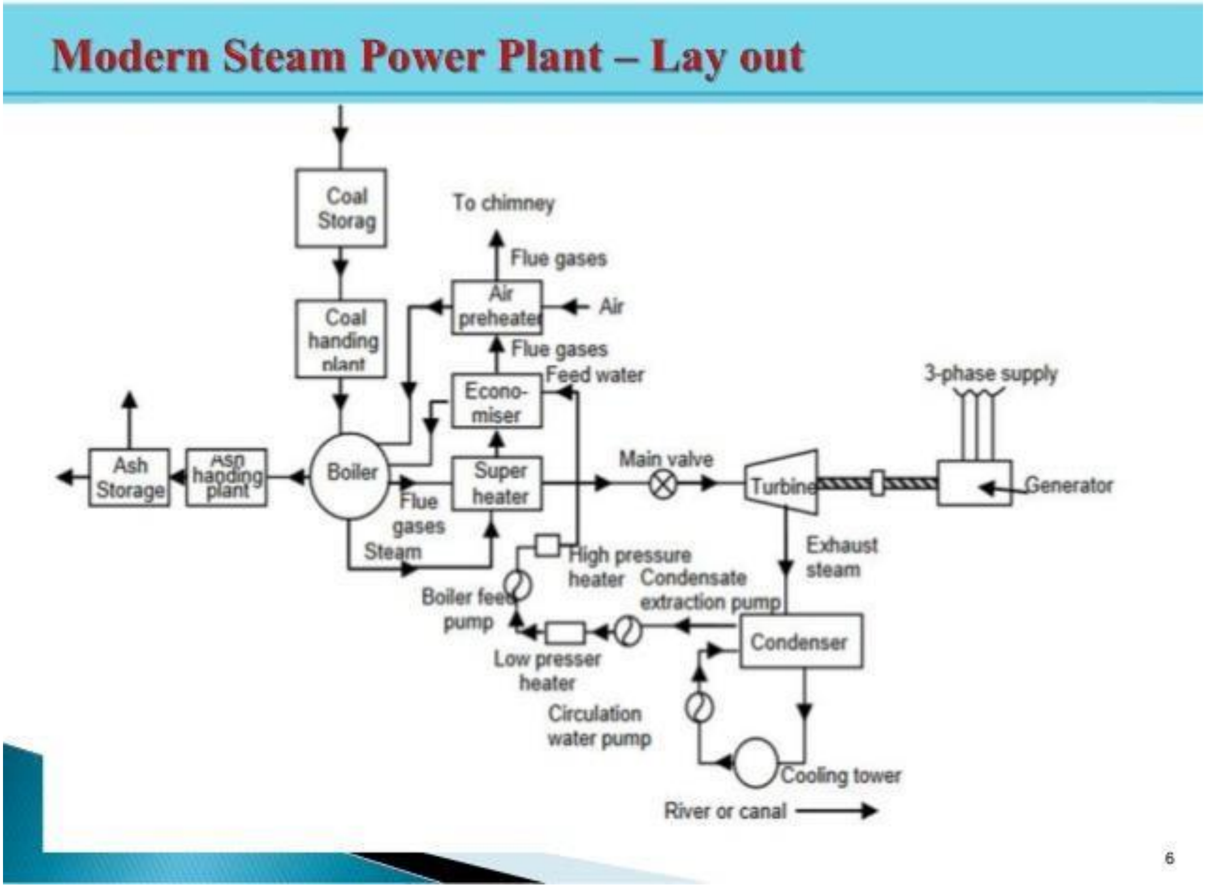


Fig. Layout of a modern thermal power plant

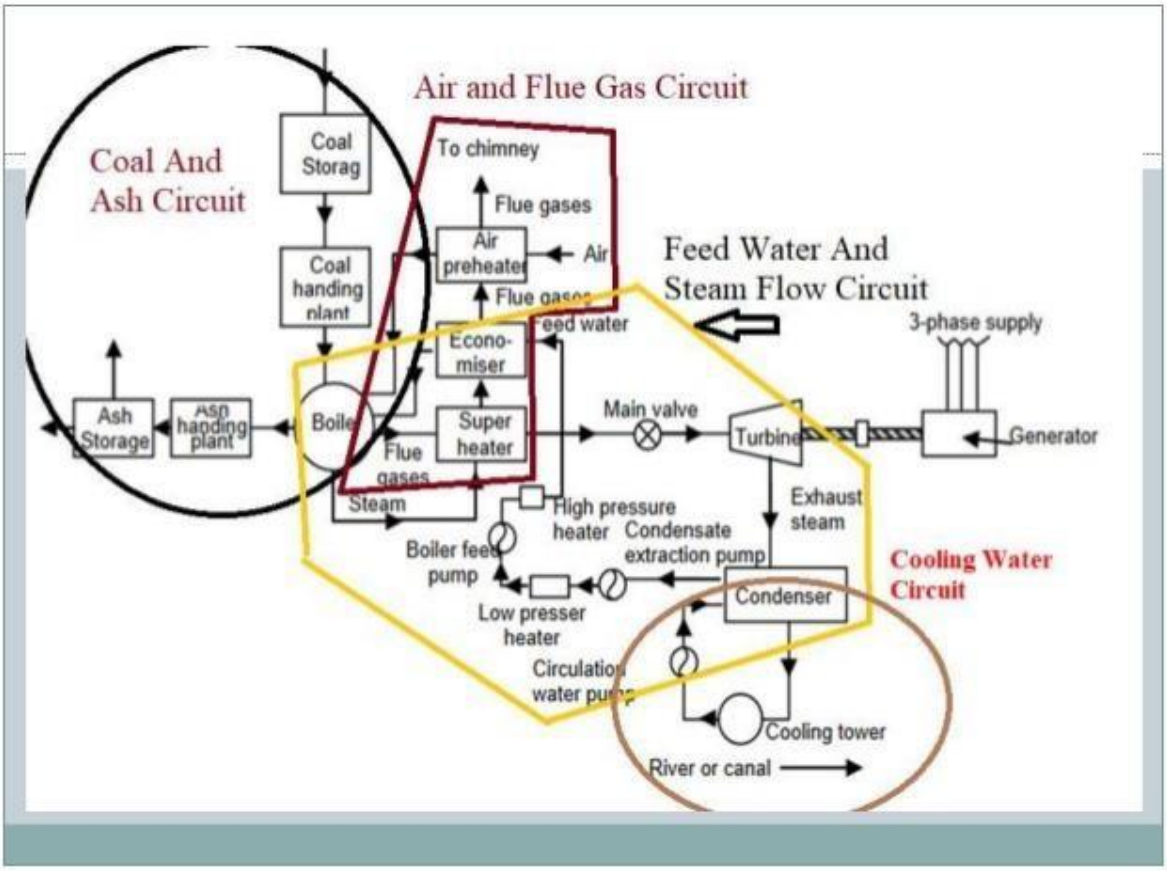


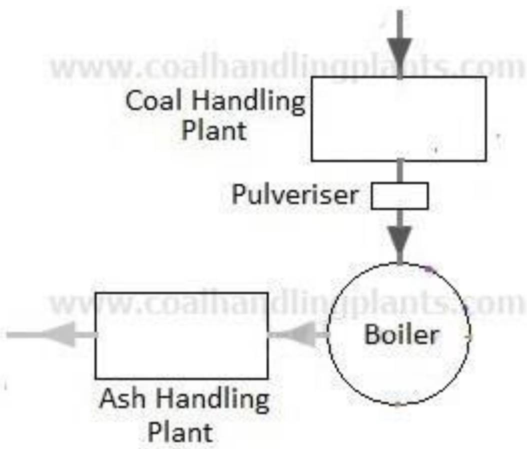
Fig. The four circuits of modern thermal power plant

A steam power plant, also known as thermal power plant, is using steam as working fluid. Steam is produced in a boiler using coal as fuel and is used to drive the prime mover, namely, the steam turbine. In the steam turbine, heat energy is converted into mechanical energy which is used for generating electric power. Generator is an electro-magnetic device which makes the power available in the form of electrical energy.

The layout of the steam power plant consists of four main circuits. These are:

1. Coal and ash circuit
2. Air and flue gas circuit
3. Water and steam circuit and
4. Cooling water circuit

1. Coal and ash circuit



Coal from the storage yard is transferred to the boiler furnace by means of coal handling equipment like belt conveyor, bucket elevator, etc., ash resulting from the combustion of coal in the boiler furnace collects at the back of the boiler and is removed to the ash storage yard through the ash handling equipment.

Ash Disposal:

Indian coal contains 30% to 40% ash. A power plant of 100MW 20 to 25 tonnes of hot ash per hour. Hence sufficient space near the power plant is essential to dispose such large quantities of ash.

2. **Air and Flue gas circuit**

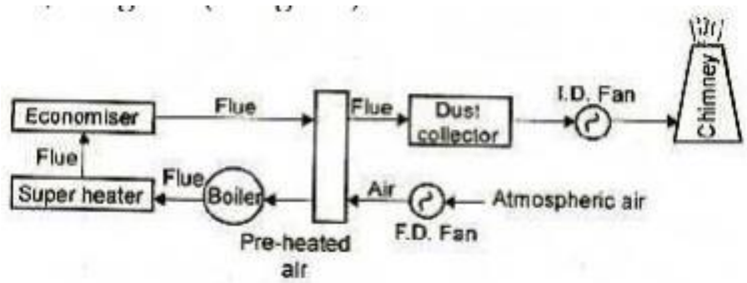


Figure: Air and flue gas circuit

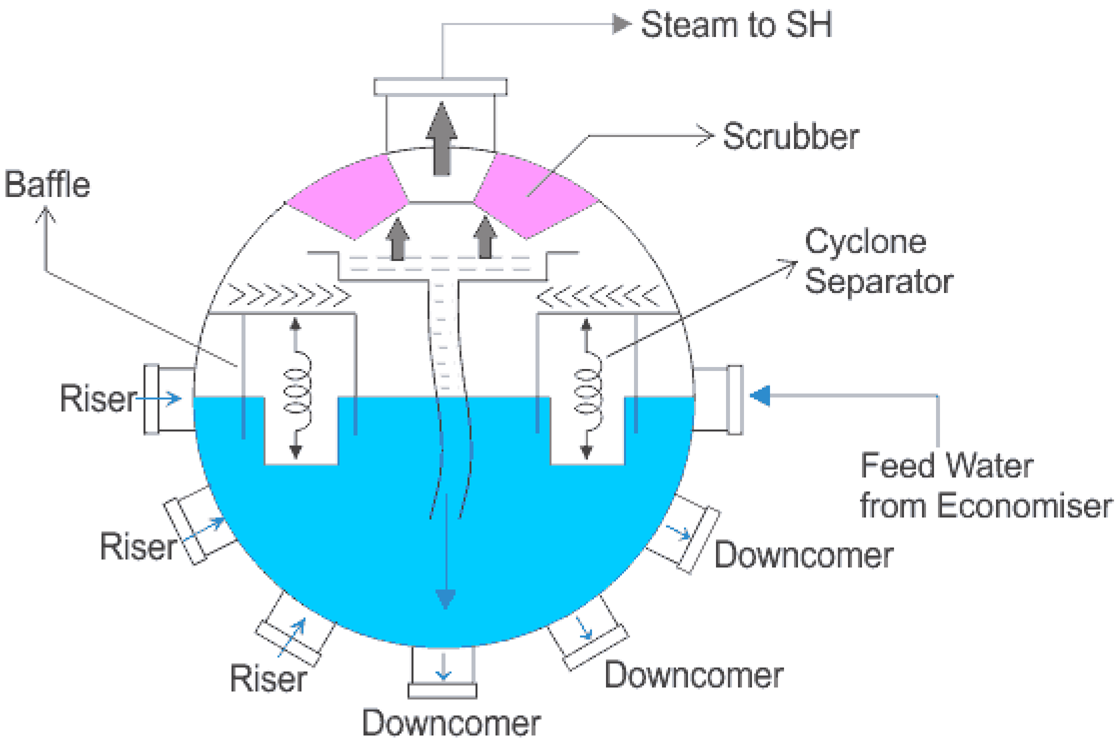
Air is taken from the atmosphere to the air preheater. Air is heated in the air preheater by the heat of flue gas which is passing to the chimney. The hot air is supplied to the furnace of the boiler.

The flue gases after combustion in the furnace, pass around the boiler tubes. The flue gases then passes through a dust collector, economizer and pre-heater before being exhausted to the atmosphere through the chimney. By this method the heat of the flue gases which would have been wasted otherwise is used effectively. Thus the overall efficiency of the plant is improved.

Air Pollution:

The pollution of the surrounding atmosphere is caused by the emission of objectionable gases and dust through the chimney. The air pollution and smoke cause nuisance to people surrounding the planet.

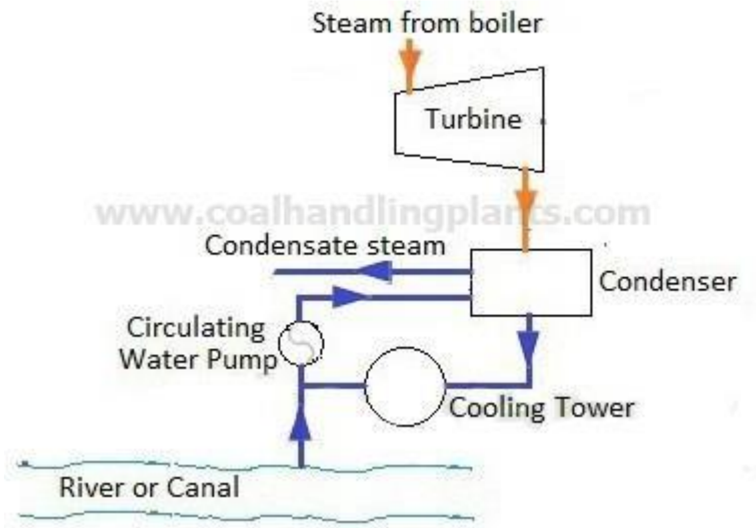
3. **Feed water and steam flow circuit**



The steam generated in the boiler passes through super heater and is supplied to the steam turbine. Work is done by the expansion of steam in the turbine and the pressure of steam is reduced. The expanded steam then passes to the condenser, where it is condensed.

The condensate leaving the condenser is first heated in a l.p. water heater by using the steam taken from the low pressure extraction point of the turbine. Again steam taken from the high pressure extraction point of the turbine is used for heating the feed water in the H.P water heater. The hot feed water is passing through the economizer, where it is further heated by means of flue gases. The feed water which is sufficiently heated by the feed water heaters and economizer is then fed into the boiler.

4. **Cooling water circuit**



Abundant quantity of water is required for condensing the steam in the condenser. Water circulating through the condenser may be taken from various sources such as river or lake, provided adequate water supply is available from the river or lake throughout the year.

If adequate quantity of water is not available at the plant site, the hot water from the condenser is cooled in the cooling tower or cooling ponds and circulated again.

Advantages of thermal power plants

1) Initial cost is low compared with hydro-plant.
2) The power plant can be located near load center, so the transmission losses are considerably reduced.
3) The generation of power is not dependent on the nature's mercy like hydro plant.
4) The construction and commissioning of thermal plant requires less period of time than a hydro plant.

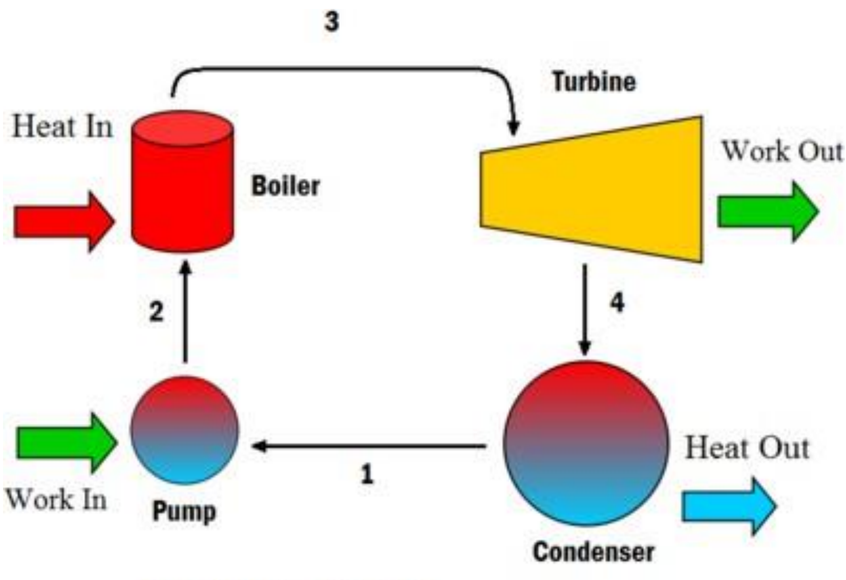
Disadvantages of thermal power plants

1) It pollutes the atmosphere due to production of large amount of smoke and fumes.
2) It is costlier in running cost as compared to hydroelectric plants.
3) The heated water that comes from thermal power plant has an adverse effect on the lives in the water and disturbs the ecology.

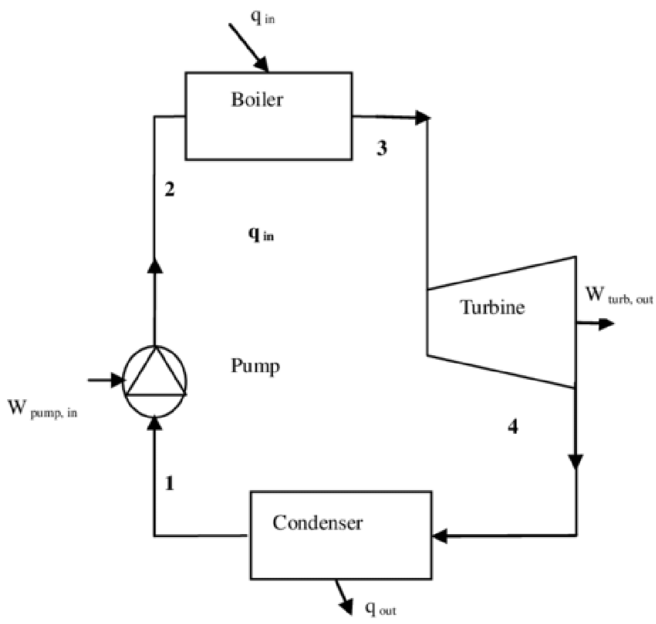
List of thermal power plants in Telangana--- to be observed

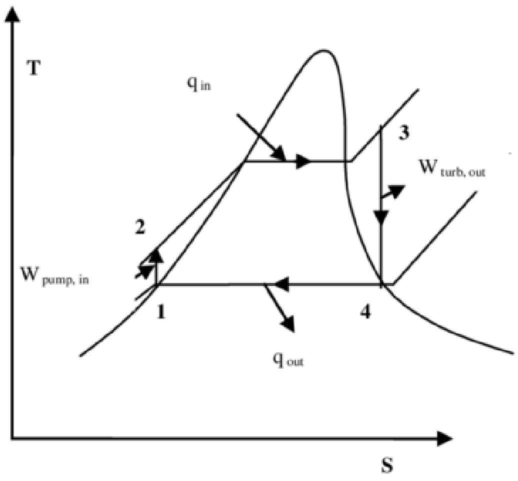
Rankine cycle

The Rankine cycle is a model used to predict the performance of steam turbine systems. It was also used to study the performance of reciprocating steam engines. The Rankine cycle is an idealized thermodynamic cycle of a heat engine that converts heat into mechanical work while undergoing phase change.



Rankine Cycle





T-S diagram

Thermodynamic analysis:

1-2: Isentropic compression process in the pump

2-3: Isobaric heat absorption process in the evaporator.

3-4: Isentropic expansion process in the expander.

4-1 : Isobaric heat rejection process in the condenser.

The Rankine cycle is a model used to predict the performance of steam turbine systems. The Rankine cycle is an idealized thermodynamic cycle of a heat engine that converts heat into mechanical work while undergoing phase change.

Rankine cycle is a reversible cycle which have two constant pressure and two constant temperature processes. Working fluid in Rankine cycle undergoes 4 processes, expansion in turbine, heat addition in Boiler, heat rejection in Condenser and compression in pump.

The thermal efficiency improvement techniques of Rankine cycle are:

i. By decreasing average temperature at which heat is rejected from the working fluid (steam) in the condenser. (Lowering condenser Pressure)
ii. By increasing steam temperature entering the turbine.

Super critical boilers

A supercritical steam generator is a type of boiler that operates at supercritical pressure, frequently used in the production of electric power. In contrast to a subcritical boiler in which bubbles can form, a supercritical steam generator operates at pressures above the critical pressure

Advantages of SC Technology

I) Higher cycle efficiency means Primarily – less fuel consumption – less per MW infrastructure investments – less emission – less auxiliary power consumption – less water consumption

II) Operational flexibility – Better temp. control and load change flexibility – Shorter start-up time – More suitable for widely variable pressure operation 28

Economy

Higher Efficiency (η%)

- Less fuel input.
- Low capacity fuel handling system
- Low capacity ash handling system.
- Less Emissions.

Approximate improvement in Cycle

- Efficiency Pressure increase: 0.005 % per bar
- Temp increase : 0.011 % per deg K

At supercritical pressures, steam turbine efficiency improves significantly compared to the typical subcritical cycle. Ultra-supercritical steam conditions provide even greater efficiency improvements. The combination of utilizing supercritical throttle pressures along with an increase in throttle temperatures results in cost reductions in fuel usage and handling, flue gas treatment and ash disposal. B&W's supercritical and ultra-supercritical boilers are designed to take full advantage of variable pressure turbine operation.

Specific advantages include:

- For a given output, lower fuel consumption, and thus lower carbon emissions, than other less efficient systems
- The load change rate capability of the system is not restricted by the turbine
- Steam temperature at the inlet and outlet of the re heater is nearly constant over a wide load range

- The boiler feed water pump power is significantly reduced at lower loads
- Short start up times
- Higher plant efficiency over the entire load range

Supercritical boilers have working range of pressure and temperature above 220.64 bars and 374°C (Critical pressure and temperature of water). There occurs no bubbles formation in this type of boiler. Subcritical boilers works below critical pressure and temperature.

Supercritical Pressure:

Critical point in water vapor cycle is a thermodynamic state where there is no clear distinction between liquid and gaseous state of water. Water reaches to this state at a critical pressure above 22.1 MPa and 374oC.

A steam boiler or **steam generator** is a closed vessel in which water is heated, vaporized and converted into steam at a pressure higher than atmospheric pressure.

A Boiler is the biggest and most critical part of a thermal power plant.

Applications of Boiler:

- Operating steam engines.
- Operating steam turbines.
- Operating reciprocating pumps.
- Industrial process work in chemical engineering.
- For producing hot water required to be supplied to room in very cold areas.
- In thermal power stations.
- The heat content of the steam is large and thus it is suitable for process heating in many industries like sugar mills, textile mills, dairy industry and also in chemical industries.

Definition of some useful terms used in Boiler:

- **Boiler shell:** The boiler shell consists of a hollow cylindrical body made up of steel plates riveted or welded together.

- **Furnace:** Furnace is that part of the boiler in which the fuel is conveniently burned to produce heat. This heat is utilized in generating steam in the boiler.

- **Grate:** The grate is a space on which the fuel is burnt. It consist of a combination of several cast-iron bars so arranged that the fuel may be placed on it. Some space is always provided in between two consecutive bars so that may flow to the fuel from below the great and ashes may drop into the ash pit provided beneath the Grate. Grate may be circular or rectangular in shape.

- **Grate area:** The area of the great upon which the fuel burns is called great area. Grate area is always measured in square meters.

- **Heating surface:** The heating surface is the surface of a boiler which is exposed to hot gases on one side and water of the other.

- **Water space and steam space:** Water space is the volume of the boiler which is occupied by water. The remaining space is called steam space because it is needed for storage of steam in the boiler until it id s drawn off through the steam pipe.

- **Flue gases:** Flue gases are hot gases produced due to the combination of fuel in the boiler furnace. Flue gas usually contains water vapor (H_2O), Carbon dioxide (CO_2), Carbon monoxide (CO), Nitrogen (N_2). Flue gas includes complete and incomplete products of combustion of fuels.

Classifications or Types of Boiler:

There are large number of boiler designs, but they may be classified according to the following ways:

According to the circulation of gases:

- **Fire-tube boiler**

- **Water-tube boiler**

Fire-tube boiler:

Fire tube boilers are those boilers in which hot gases produced by the combination of fuel in the boiler furnace while on their way to chimney pass through a number of tubes (called fuel tubes or smoke tubes) which are immersed in water.
Heat is transferred from the hot gasses to water through the walls of tubes.

Example of fire tube boilers are **Cochran boiler, locomotive boiler** etc.

Fire tubes boilers are also known as a **smoke tube boiler**.

Water-tube boiler:

Water-tube boilers are those boilers in which water flows through a number of tubes (called water tubes) and the hot gases produced by the combustion of fuel in the boiler furnace while on their way to chimney pass surrounding the tubes.

The heat from the hot gases is transferred to the water through the walls of the water tubes. Examples of water tube boilers are **Bab-cock and Wilcox boiler, Benson boiler,** etc.

According to Circulation of water:

i. **Free circulation**

ii. **Forced circulation**

Free circulation:

In any water heating vessel heat is transmitted from one place to another not by condition but by convection because water is a bad conductor of heat.

Let vessel containing water be heated at its bottom, as the water in the bottom portion is heated therefore its density becomes reduced in comparison to the density of water in the upper portion of the vessel, as a result, the less dense water at the bottom portion of the vessel rise up and comparatively more dense and cold water at the upper portion of the vessel comes down to take its place and thus a convection current is set up in the water until temperature off all water becomes the same.

The method of circulation of water described above is known as free circulation.

In boilers like **Lancashire, Babcock, and Wilcox,** etc. free circulation of water takes place.

Advantages of free circulation:

The advantages of free circulation are:

Free circulation of water helps to maintain a uniform temperature true everywhere within the boiler so that unequal expansion of various parts of the boiler is prevented.

Free circulation of water facilities the escape of steam from the heating surface as soon as it formed. If steam does not escape quickly after its formation the boilerplates do not remain constantly in touch with water and as a result, these plates may be overheated.

Forced Circulation:

In forced circulation, pumps are used to maintain the continuous flow of water in the boiler. In such a case, the circulation of water takes place due to pressure created by the pump.

The forced circulation system is adopted in more high pressure, high capacity boilers of all of which are water tube type boiler.

Advantages of forced circulation:

i. The rate of heat transfer from the flue gases to the water higher.

ii. Tubes having comparatively smaller diameters can be used. This reduces the overall weight of the boiler.

iii. The number of boiler drums required may be reduced.

iv. Less scale formation in the boilers is required.

v. Steam can be quickly generated.

vi. The fluctuation of load can be easily met without taking the help of any complicated controlled device.

vii. Chance of overheating of the boilerplates in minimum.

viii. Weight per unit mass of steam generated is less.

According to the number of tubes used:

According to the number of tubes, Boilers may be classified as:

i. **Single tube boiler**

ii. **Multi-tube boiler**

Single tube boiler:

Cornish boiler may be termed as a single tumbler boiler because it has only one flue tube.

Multi-tube boiler:

Cochran boiler may be termed as multi-tube boiler because it has a number of flue tubes.

According to the nature of use:

According to nature use, boilers are classified as

Stationary boilers

locomotive boilers

Marine boilers.

Stationary boilers:

For the generation of thermal power and for process work (in chemical, sager and textile industries) boilers used are called stationary boiler.

Locomotive boilers:

Boilers used in locomotive steam engines are called locomotive boilers.

Marine boilers:

Boilers used in steamships are called marine boilers.

According to the nature of the fuels used:

1. Fuel-fired
2. Gas fired
3. Liquid fuel fired
4. Electrically fired
5. Nuclear fired

NOTE:

Babcock and Wilcox boilers use solid or gaseous fuel. Volex boilers use oil fuel.

According to the pressure of the boiler:

1. **High-pressure boiler**
2. **Medium-pressure boiler**
3. **Low-pressure boiler**

High-pressure boiler:

The pressure of the boiler **above 80 bar**.

Medium-pressure boiler:

It has a working pressure of steam **from 20 bar to 80 bar**. It is used for power generation or process heating.

Low-pressure boiler:

This type of boiler produces steam **at 15-20 bar** pressure. This is used for process heating.

According to the position of the axis of the boiler shell:

According to the position of the axis of the boiler shell, boilers are classified as:

1. **Vertical boiler**
2. **Horizontal boiler**

Vertical boiler:

If the boiler axis is vertical, it is called a vertical boiler. For example, **Cochran boiler**.

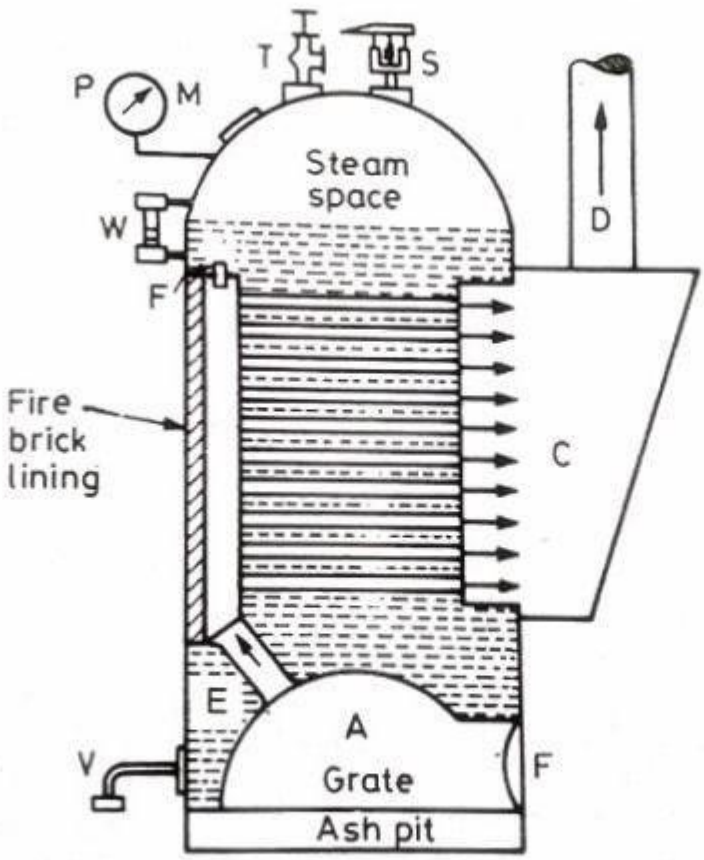
Horizontal boiler:

If the boiler axis is horizontal, it is called a horizontal boiler.

For example, **Lancashire boiler**.

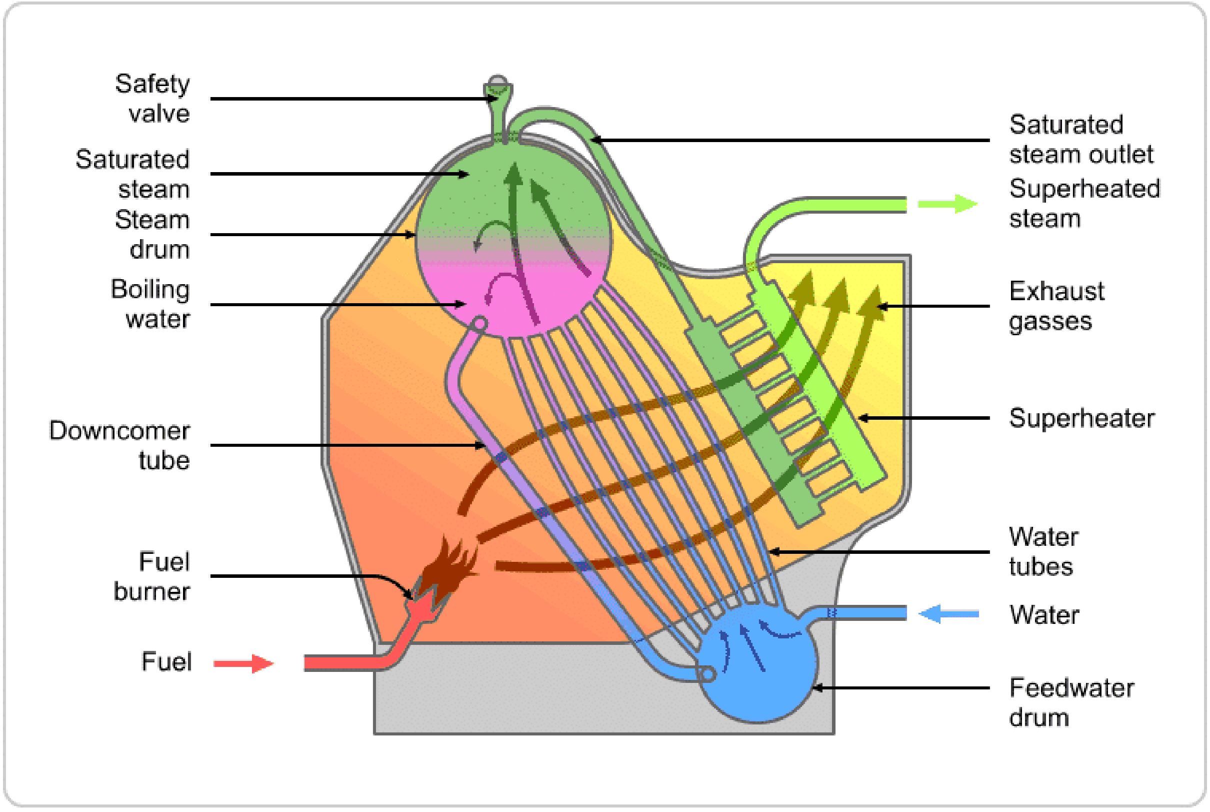
So this are the classifications of the Boiler, now see the schematic diagram of a Boilers.

Fire Tube Boiler Schematic Diagram:



C-Smoke box
E-Short pipe
F-Fusible plug
S-Safety valve
W- Water Level Indicator
D- Chimney
M- Manhole
T-Steam stop valve
V-Blow off valve
P- Pressure Gauge

Water Tube Boiler Schematic Diagram:



Types of Fuel Used in Boiler:

The fuel has been categorized in three formats:

Solid Fuels:

Wood, Coal, Briquettes (a block of compressed coal dust), Pet Coke, Rice Husk.

Liquid Fuels:

LDO (Light Diesel Oil), Furnace oil.

Gaseous Fuels:

LPG (Liquified Petroleum Gas), LNG (Liquified Natural Gas), PNG (Piped Natural Gas) can be used to carry out the combustion for a specific purpose.

The Necessity of Boiler:

The most common function for any boiler, whether it is an industrial or residential boiler, is to serve as the central heating mechanism for a home, business facility, hospital, commercial complex, etc.

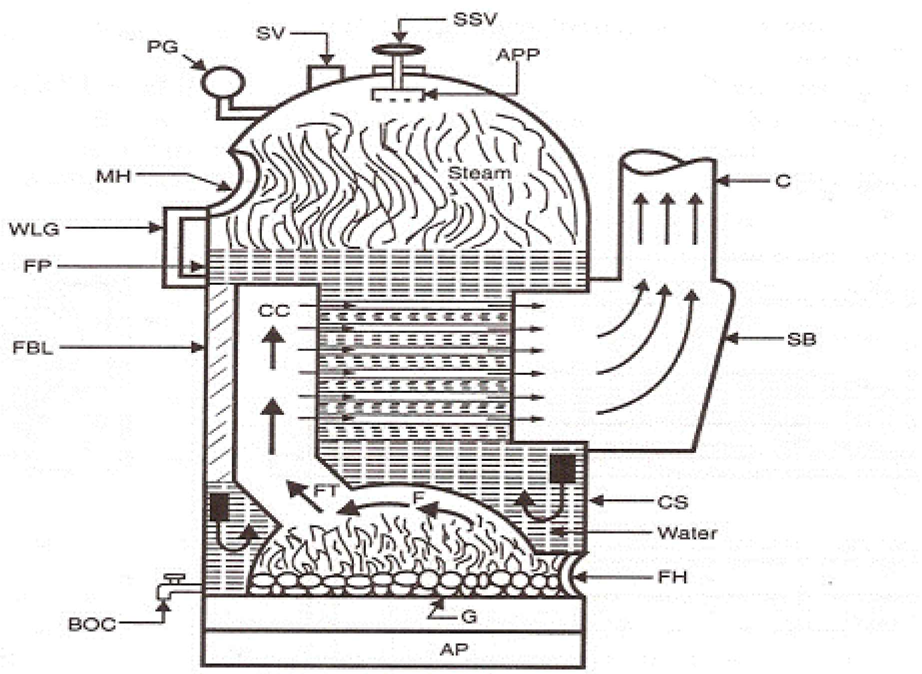
No matter what setting they are used in, boilers operate with the same basic functions and mechanisms that work together to create a contained, heat-generating combustion process.

Boilers draw natural gas from gas lines running through our streets and use this gas to fuel the combustion process for heat creation and distribution throughout a building.

The boiler system relies on a burner to initiate the combustion process, and then heat in the form of steam or hot water moves through the system using pumps, radiators, and heat exchangers.

Boiler manufacturers are making use of rapidly improving technology to build equipment that is cost-efficient, environmentally friendly, and powerful.

Cochran boiler:



CS = Cylindrical shell
CC = Combustion chamber
FBL = Fir brick lining
F = Furnace (dome shaped)
BOC = Blow off cock
SSV = Steam stop valve
APP = Antipriming pipe
PG = Pressure gauge
FT = Flue tube
SB = Smoke box
C = Chimney
FH = Fire hole
G = Grate
AP = Ash pit
SV = Safety valve
MH = Man hole
WLG = Water level gauge

Cochran Boiler is a vertical drum axis, natural circulation, natural draft, low pressure, multi-tubular, solid fuel fired, fire tube boiler with internally fired furnace. It is the modified form of a simple vertical boiler. In this boiler, the fire tubes are placed horizontally.

A vertical boiler with horizontal fire-tubes is a type of small vertical boiler, used to generate steam for small machinery. It is characterized by having many narrow fire-tubes, running horizontally. Boilers like this have been widely used on ships as either auxiliary or donkey boilers.

Main Parts of Cochran Boiler:

The Main parts of Cochran boiler are:

1. Shell
2. Grate
3. Combustion chamber
4. Fire tubes
5. Fire hole
6. Firebox (Furnace)
7. Chimney
8. Man Hole
9. Flue pipe

1. Shell:

The main body of the boiler is known as a shell.

It is hemispherical on the top, where space is provided for steam.

This hemispherical top gives a higher volume to area ratio which increases the steam capacity.

2. Grate:

The area where the fire is placed known as a grate.

It is placed at the bottom of the furnace where coal is burnt.

3. Combustion Chamber:

It is lined with fire bricks on the side of the shell to prevent overheating of the boiler.

Hot gases enter the fire tubes from the flue pipe through the combustion chamber.

The combustion chamber is connected to the furnace.

4. Fire Tubes:

There are various fire tubes whose one end is connected to the furnace and other to the chimney.

A number of horizontal fire tubes are provided, thereby the heating surface is increased.

5. Fire Hole:

The small hole is provided at the bottom of the combustion chamber to place fuel is known as a fire hole.

6. Fir Box (Furnace):

It works as a mediator of fire tubes and combustion chamber.

It is also dome-shaped like the shell so that the gases can be deflected back till they are passed out through the flue pipe to the combustion chamber.

7. Chimney:

It is provided for the exit of flue gases to the atmosphere from the smokebox.

8. Man Hole:

It is provided for the inspection and repair of the interior of the boiler shell.

9. Flue Pipe:

It is a short passage connecting the firebox with the combustion chamber.

Working Principle of Cochran Boiler:

The Cochran boiler works as same as other fire tube boiler.

First, The coal is placed at the grate through the fire hole

Then the air is entering into the combustion chamber through the atmosphere and fuel is sparked through fire hole.

Then flue gases start flowing into the hemispherical dome-shaped combustion chamber. This flue gases further moves into the fire pipes. And then

Heat is exchanged from flue gases to the water into the fire tubes.

The steam produce collected into the upper side of the shell and taken out by when the required pressure generated and then

The flue gases now send to the chimney through a firebox where it leaves into the atmosphere.

Now, this process repeats and runs continuously. The steam generates used into the small industrial processed.

Various boiler mounting and accessories are attached to the boiler for its efficient working:

1. Pressure Gauge: It measures the pressure of steam inside the boiler.

2. Safety Valve: It blows off the extra steam when the steam pressure inside the boiler reaches above safety level.

3. Water level Indicator: The position of the water level in the Cochran boiler is indicated by the water level indicator.

4. Stop Valve: Stop valve is used to transfer steam to the desired location when it is required. Otherwise, it stops the steam in the boiler.

5. Blow off Valve: It is used to blow off the settle down impurities, mud, and sediments present in the boiler water.

The application of Cochran boiler are:

- Variety of process applications in industries
- Chemical processing divisions
- Pulp and Paper manufacturing plants
- Refining units

Besides, they are frequently employed in power generation plants where large quantities of steam (ranging up to 500 kg/s) having high pressures i.e. approximately 16 mega pascals (160 bar) and high temperatures reaching up to 550 °C are generally required.

Features of Cochran boiler:

- In the Cochran boiler, any type of fuel can be used.
- It is best suitable for small capacity requirements.
- It gives about 70% thermal efficiency with coal firing and about 75% thermal efficiency with oil firing.
- The ratio of the grate area to the heating surface area varies from 10: 1 to 25:1

The advantages of Cochran Boiler:

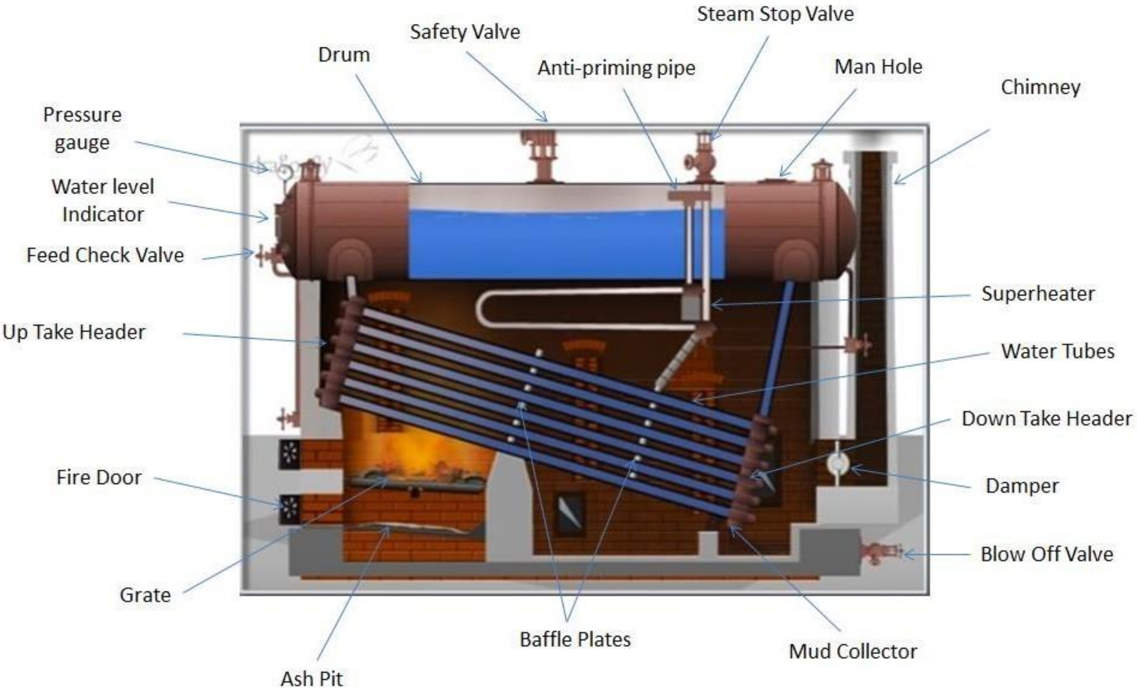
- Low floor area required.
- Low initialization cost.
- It is easy to operate.
- Transport from one place to another is very easy.
- It has a higher volume to area ratio.

Disadvantages of Cochran Boiler:

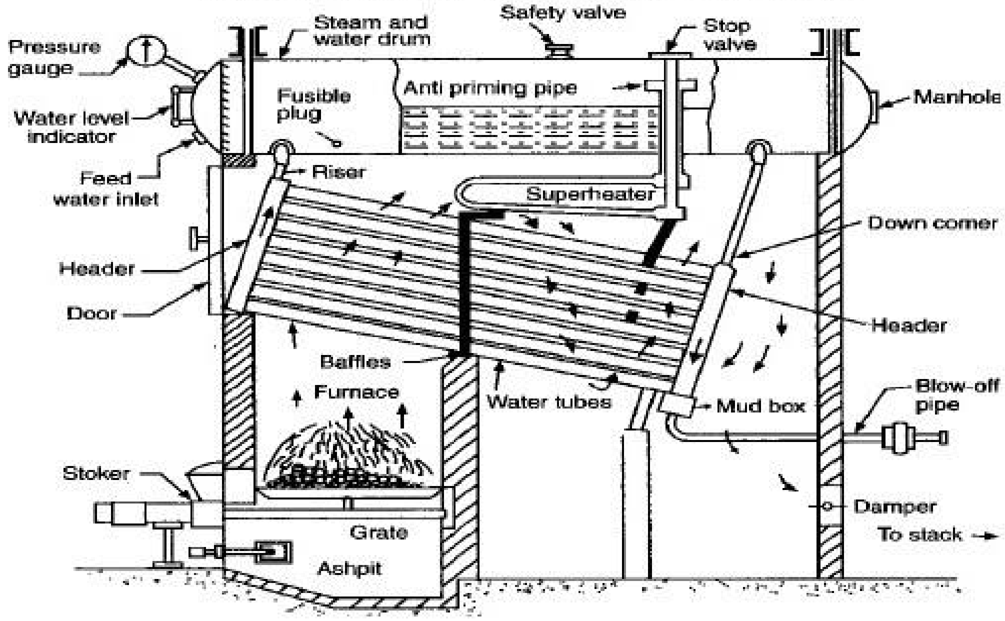
- Low steam generation rate.
- Limited pressure handles capacity.
- It is difficult to inspect and maintain.

Babcock and Wilcox boiler

The Babcock and Wilcox boiler are also is known as Longitudinal Drum Boiler or Horizontal Tubes Boiler it is water tube boiler in water tube boiler water remains inside the tube and hot gases are remains outside the tubes . ... According to their name this boiler is known as Babcock and Wilcox boiler.



BABCOCK & WILCOX BOILERS



This is a water tube boiler, used in steam power plants. In this type of boiler, water is circulated inside the tubes and hot gases flow over the tubes.

This is a Horizontal drum axis, natural draft, natural circulation, multitubular, stationary, high pressure, solid fuel fired, externally fired Water tube boiler.

A Babcock and Wilcox Boiler Parts or Construction consists of:

- Drum
- Water Tubes
- Uptake and Down take header
- Grate
- furnace
- Baffles
- Super heater
- Mud box
- Inspection Door
- Water Level Indicator
- Pressure Gauge

Drum:

This is a horizontal axis drum which contains water and steam.

Water tubes are placed between the drum and furnace in an inclined position (at an angle **Water tubes:**

of 10 to 15 degrees) to promote water circulation.

Uptake and Down take Header:

This is present at the front end of the boiler and connected to the front end of the drum. It transports the steam from the water tubes to the drum. and

This is present at the rear end of the boiler and connects the water tubes to the rear end of the drum.

It receives water from the drum.

Grate:

Coal is fed to the grate through the fire door.

Furnace:

The furnace is kept below the uptake-header.

Baffles:

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

Super heater:

It increases the temperature of saturated steam to the required temperature before discharging it from the steam stop valve.

Mud Box:

This is used to collect the mud present in the water.

Mud box is provided at the bottom end of the down-take header.

Inspection Door:

Inspection doors are provided for cleaning and inspection of the boiler.

Water Level Indicator:

The water level indicator shows the level of water within the drum.

Pressure Gauge:

The pressure gauge is used to check the pressure of steam within the boiler drum.

Working Principle of Babcock and Wilcox Boiler:

The working of Babcock and Wilcox boiler is first the water starts to come in the water tubes from the drum through down take header with the help of a boiler feed pump which continues to feed the water against the drum pressure.

The water present in the inclined water tubes gets heated up by the hot flue gases produced by the burning of coal on the fire grate.

These fuel gases are uniformly heated the water tube with the help of a baffle plate which works deflect the flues gas uniform throughout the tubes which absorbed the heating maximum from the flue gases.

As the hot flue gases come in contact with water tubes, It exchanges the heat with heater and converts into the steam.

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 current and it's known as Natural Circulation.

The Steam generated is moved upward, due to density difference and through the up-take header, it gets collected at the upper side in the boiler drum.

Anti-priming pipe inside the drum which works separates the moisture from the steam and sends it's to the superheated.

The super heater receives the water-free steam from an anti-priming pipe. It increases the temperature of the steam to the desired level and transfers it to the main steam stop valve of the boiler.

The superheated steam stop valve is either collected in a steam drum or send it's inside the steam turbine for electricity generation.

Applications Babcock and Wilcox Boiler:

The main application Babcock and Wilcox boiler to produce **high-pressure steam in power generation industries**.

Advantages of Babcock and Wilcox:

- The overall efficiency of this boiler is high.
- The steam generation rate is higher about 20 ton per hour at pressure 10 to 20 bars.
- The tubes can be replaced easily.
- The boiler can expand and contract freely.
- It is easy to repair maintenance and cleaning.

Disadvantages of Babcock and Wilcox Boiler:

- It is less suitable for impure and sedimentary water, as a small deposit of scale may cause the overheating and bursting of tubes. Hence, water treatment is very essential for water tube boilers.
- Failure in feed water supply even for a short period is liable to make the boiler overheated. Hence the water level must be watched very carefully during the operation of a water tube boiler.
- The maintenance cost is high.

A locomotive boiler is a device that is used to create steam from water by using heat energy. This is a horizontal drum axis, multi-tubular, natural circulation, artificial draft, forced circulation, medium pressure, solid fuel fired fire tube boiler that has an internal fire furnace

A locomotive boiler is a **Fire Tube Boiler**. It is a horizontal drum axis, multi-tubular boiler. Because this boiler has 116 general fire tubes and 38 super-heated fire tubes. Locomotive Boiler is an internally fired boiler. That's means boiler furnace located inside the main boiler shell or barrel. This boiler uses solid fuel like coal. It is also a forced circulation, mobile or portable type, and medium pressure fire tube boiler. The most common use of this boiler is in railway locomotive engines and in the marine sector because of its mobility. This boiler has a high steam generation rate.

Working of Locomotive Boiler:

The locomotive boiler uses solid fuel like coal. At first, the solid fuel is inserted on the grate. Then it ignites from the fire hole. When the fuel is burning inside the fire hole, it starts to generate necessary hot flue gases. Then a fire brick arch provides the path to flow the hot flue gases to a definite path before it entering into the long fire tubes of this boiler. As we know it also stops entering the burnt solid fuel particles into the fire tubes during the operation of the boiler. You will find two air in damper to flow fresh air into the combustion chamber.

When hot flue gases pass through the boiler firetubes then it heats the water surrounding the fire tubes. Water becomes heated by this continuous process and water becomes saturated steam. Generated saturated steam is collected at the top. Then this saturated steam from the dome (which is present at the top of the boiler) enters into the main steam pipe through the regulator valve. After this stem steam travels through the main steam pipe and reaches to the super-heater header. Form this super-heater header steam enters into another pipe called super heater element pipes. It is the place where saturated steam becomes superheated. Then superheated steam enters into the steam pipe of the smoke box.

When saturated steam becomes superheated then it goes to the cylinder containing piston. By this superheated steam engine piston moves inside the cylinder. Piston use to connect with the wheels of the steam engine and the wheels start rotating like a locomotive train. Then the exhaust steam from the cylinder enters into the blast pipe. When you are sending steam into the cylinder then only steam will come out as exhaust gas.

Burnt gases and smoke after passing through the fire tubes of the **boiler** then it enters into the smoke box. Then the exhaust steam coming out from the blast pipe and it pushes the smoke out of the boiler through the chimney. Smoke from burned solid fuel cannot escape out from the boiler by its own. For this reason, an artificial draft is created by exhaust steam which coming out from the steam engine cylinder. This artificial draft also pushes the smoke out of the smoke box and creates suction pressure for the hot flue gases. There is a platform under the Grate called ash-pit where ash is stored after burning of solid fuel.

Application of Locomotive Boiler:

Locomotive boilers are mostly used in railways and marines sectors. But the efficiency of this boiler is very less. This boiler cannot work in heavy load conditions. Locomotive Boiler is also used in traction engines, in portable steam engines, steam rollers, and some other steam road vehicles.

The best advantage if this boiler is it's portable. Because you can take and place this boiler in any place. The price of this boiler is less and it is capable of handling fluctuating demands of steam. This boiler has a high steam generation rate. It comes with the compact in size and easy operates.

After all those advantages it has some disadvantages like corrosion and scale formation. This boiler cannot work under heavy load conditions due to its overheating problems

Lancashire boiler

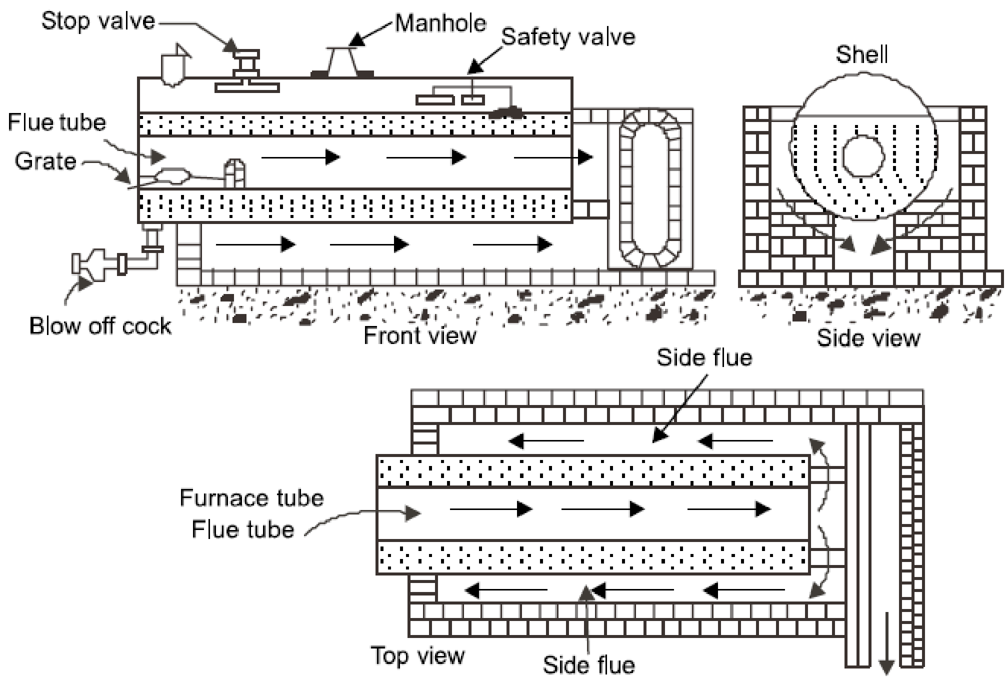


Fig. 11.9 *Cornish boiler*

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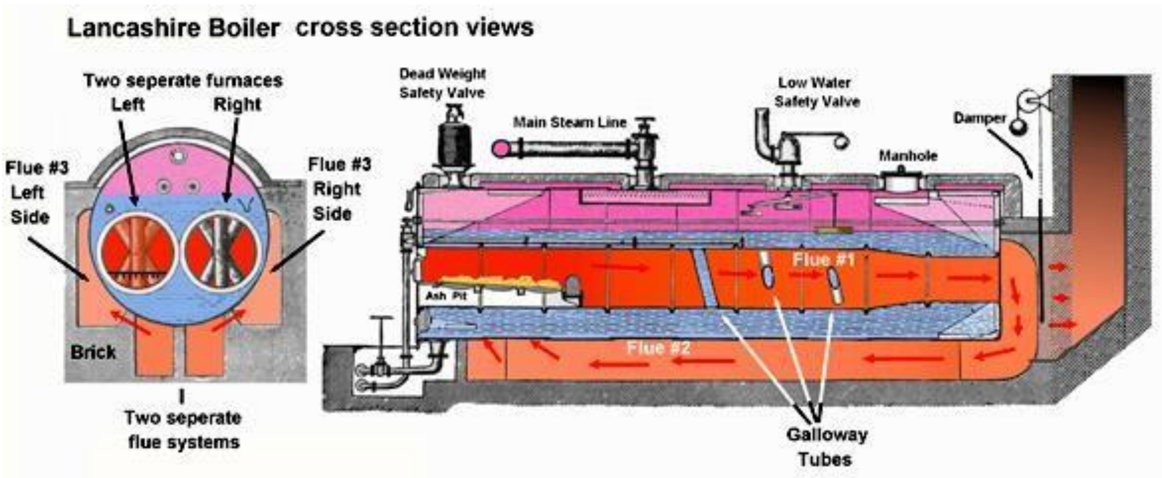


Lancashire Boiler is a horizontal type and stationary fire tube boiler. This boiler was invented in the year 1844, by William Fairbairn. This is an internally fired boiler because the furnace uses to present inside the boiler.

Lancashire boiler is a horizontal drum axis, natural circulation, natural draft, two-tubular, low pressure, stationary, fire tube boiler with furnace located internally. Its main purpose is to create steam and then this steam is used to drive steam turbines for power generation. It has high thermal efficiency and it is about 80 to 90 percent. It is mostly used in locomotive engines and marines etc.

Construction

1. Safety valve:

It is used to blow off the steam when the pressure of the steam inside the boiler exceeds the working pressure.

2. Water Level Indicator:

It indicates the level of water in the boiler. It is placed in front of the boiler. Two water level indicators are used in the boiler.

3. Pressure gauge:

The function of the pressure gauge is to indicate the pressure of the steam inside the boiler.

4. Steam stop valve:

Its function is to stop and allows the flow of steam from the boiler to the steam pipe.

5. Feed check valve:

It stops and allows the flow of water inside the boiler.

6. Blow off Valve:

Its function is to remove the sediments or mud periodically that is collected at the bottom of the boiler.

7. Manhole:

It is a hole provided on the boiler so that a man can easily enter inside the boiler for the cleaning and repairing purpose.

8. Fusible plug:

It is used to extinguish the fire inside the boiler when the water level inside the boiler falls to an unsafe level and prevents an explosion. It also prevents the damage that may happen due to the explosion.

9. Grate:

It is a platform that is used to burn solid fuel.

10. Fire door:

It is used to ignite the fuel present inside or outside the boiler.

11. Ash pit:

It is used to collect the ash of the fuel after the fuel is burnt.

WORKING

- Lancashire boiler consists of a horizontal cylindrical shell filled with water surrounding two large fire tubes.
- The cylindrical shell is placed over brickwork which creates several channels for the flow of hot flue gases.
- Solid fuel is provided by the fire door which then burnt over grate at the front end of each fire tube.
- A small arc shape brickwork is provided at the end of the grate to deflect the flue gases upward and prevent the entry of burning coal and ashes into the interior part of the fire tubes.
- The fire tubes are slightly conical at the rear end to increase the velocity of hot flue gases.
- When hot flue gases are allowed to pass through the downward channel at the front end of the fire tubes. Now, these gases pass through the side

channel towards the rear end of the fire tube and finally escape out through the chimney.

- There are dampers at each side channel to regulate the airflow.
- The feed check valve is used to feed the water uniformly to the boiler shell.
- Once the boiler is at quickly, water converts into steam by absorbing the heat from the flue gases. This steam is stored at the upper portion of the boiler where the anti-priming pipe separates the water from steam. Thus the steam stop valve receives the dry steam for various purposes.
- A manhole is provided at the top and bottom of the shell to allow a man to enter into the boiler and clean it.
- A blow-off valve is provided to remove the mud that has settled down. It is also used to clean the boiler.

Advantages

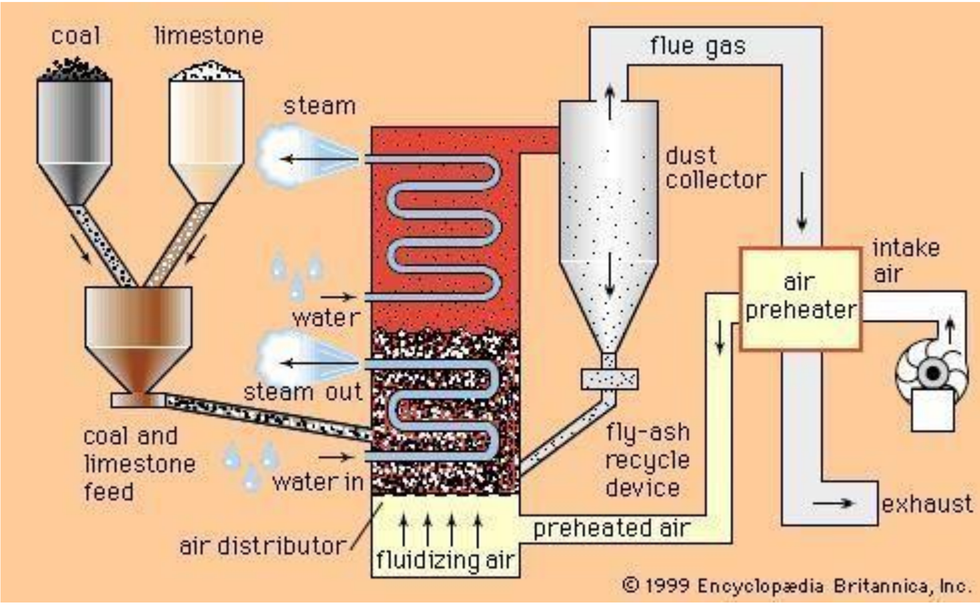
- It has high thermal efficiency; the thermal efficiency is about 80 to 90%.
- It is easy to operate.
- It can easily meet the load requirement.
- Easy to maintain.
- Generate a large amount of steam and hence more reliable.
- Low consumption of electricity due to natural circulation.

Disadvantages

- It is a low-pressure type boiler, so high-pressure steam is not produced.
- Tedious maintenance of brickwork.
- It has a limited grate area due to the small diameter of the flue tubes.
- The steam production rate is low. It is about 9000 kg/hr
- Corrosion occurs in the water legs.

Area of Application the Lancashire boiler is used to drive steam turbines, locomotives, marines, etc. it is used in industries like paper industries, textile industries, sugar industries, tire industries, and Etc.

FBC Boiler (Fluidized Bed Combustion)



A bed of solid particles is said to be **fluidized** when the **pressurized fluid** (liquid or gas) is passed through the medium and causes the solid particles to behave like a fluid under certain conditions.

Fluidization causes the transformation of the state of **solid particles** from static to dynamic.

Fluidized Bed Combustion is the ignition of a solid fuel under the conditions mentioned above.

Bubbling Fluidized Bed Combustion (BFBC)

Circulating Fluidized Bed Combustion (CFBC).

Bubbling **FBC** is used for **Fuels** with lower heating values such as Rice Husk.

Under such sort, the main factors leading to **fluidization** are as follows:

Solid Fuel Particle Size

Air Fuel Mixture

Fluidized Bed Combustion takes place when the **forced draught fan** supplies air to the Furnace of the Boiler. In the furnace, and is (used for Bubbling phenomenon) placed on the Bed and is heated before **fluidization**, the air enters the bed from the nozzles fitted on the Furnace Bed. And above the nozzles; the sand opposes the upward motion of the air.

But at sufficient velocities, when the pressure applied by the air becomes equal to the weight of the sand, **fluidization** of the sand occurs.

Now the fuel supplied by fuel conveyor is fed to the preheated bubbling sand and gets combusted away. This phenomenon also ensures complete combustion of the Fuel.

The heat released during **combustion heats** up the surrounding **boiler tubes** and **generates steam**. The major advantages of **Bubbling Fluidized Bed Combustion** are the enhanced thermal efficiency, easy ash removal.

Another type is the **Circulating Fluidized Bed Combustion**; it is applied to fuels with higher heating values such as **Petcoke**.

In this, the unburned fuel is fed again to the furnace with the help of a **Forced Draught fan** and ducts, ensuring enhanced combustion and higher heating and provides excellent fuel flexibility.

Also, the **fluidizing velocity of Air** in **CFBC** is comparatively higher than that of **BFBC**. One of the major drawbacks is the power consumption.

The motors installed in the **Forced Draught Fan** consume more power than the one installed in the same **capacity Boiler's (wood/coal fired) Forced Draught Fan**, because of elevated levels of draught requirement to create **fluidization**.

Condensers

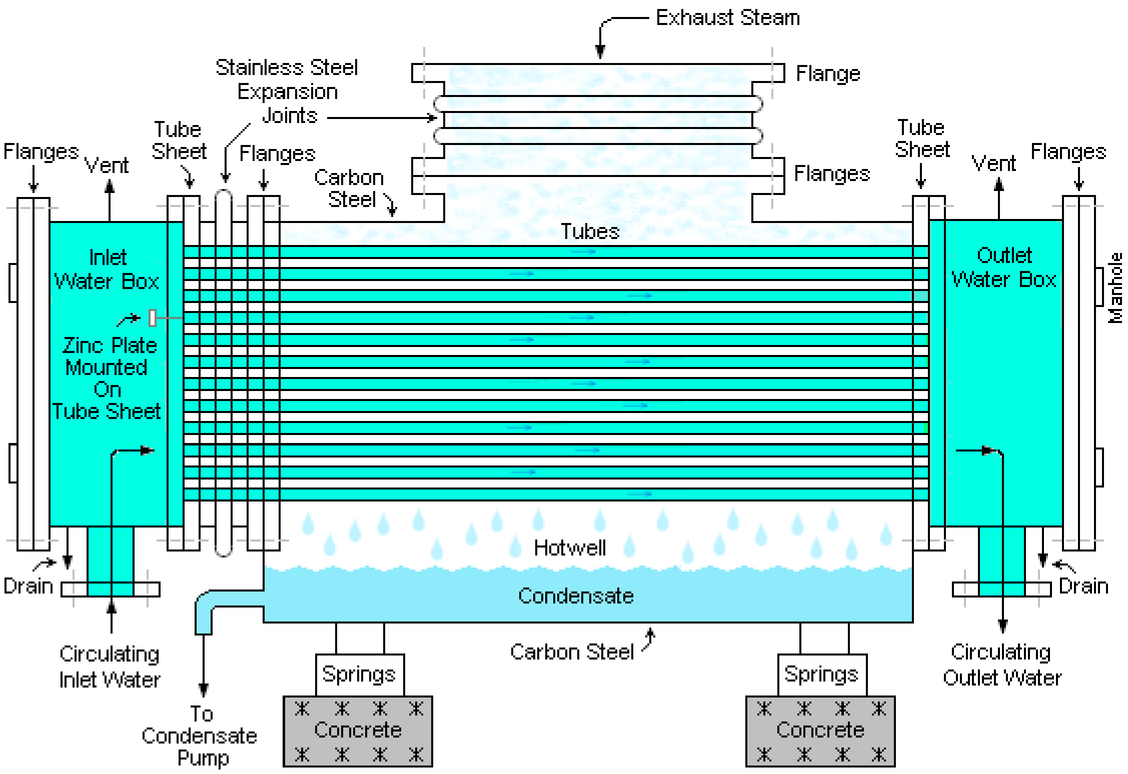
In thermal power plants, the purpose of a surface condenser is to condense the exhaust steam from a steam turbine to obtain maximum efficiency, and also to convert the turbine exhaust steam into pure water (referred to as steam condensate) so that it may be reused in the steam generator or boiler as boiler feed water.

Steam Condenser of Turbine. Steam condenser is a device in which the exhaust steam from steam turbine is condensed by means of cooling water. . Condensation of steam in a closed system, creates an empty place by

reduction of volume of the low pressure steam

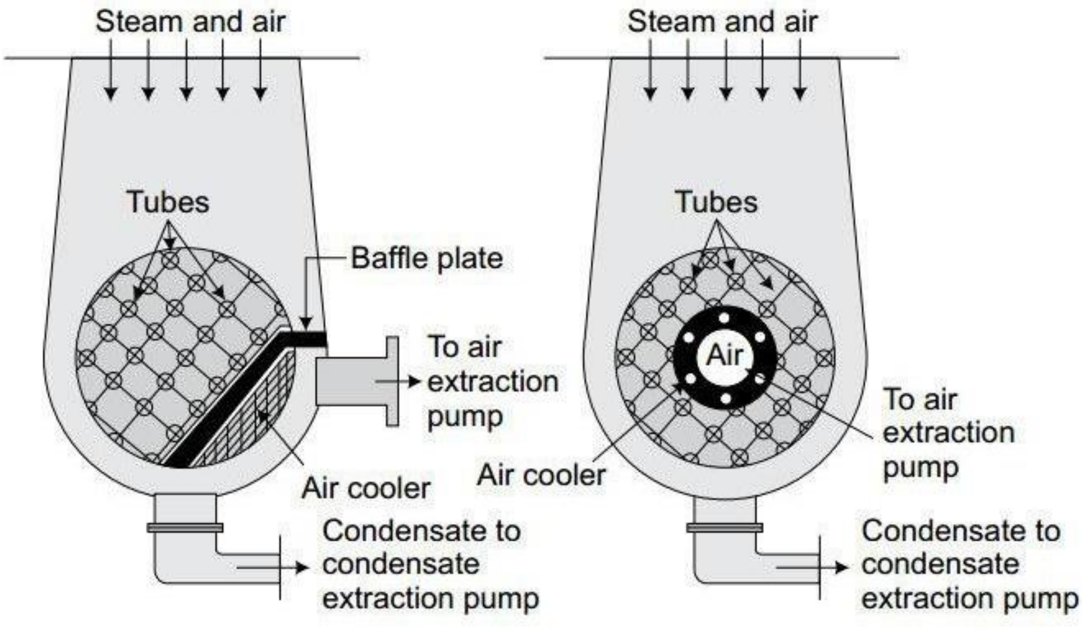
A condenser's function is to allow high pressure and temperature refrigerant vapor to condense and eject heat. There are three main types: air-cooled, evaporative, and water-cooled condensers.

The purpose of the condenser is to receive the high-pressure gas from the compressor and convert this gas to a liquid. It does it by heat transfer, or the principle that heat will always move from a warmer to a cooler substance.

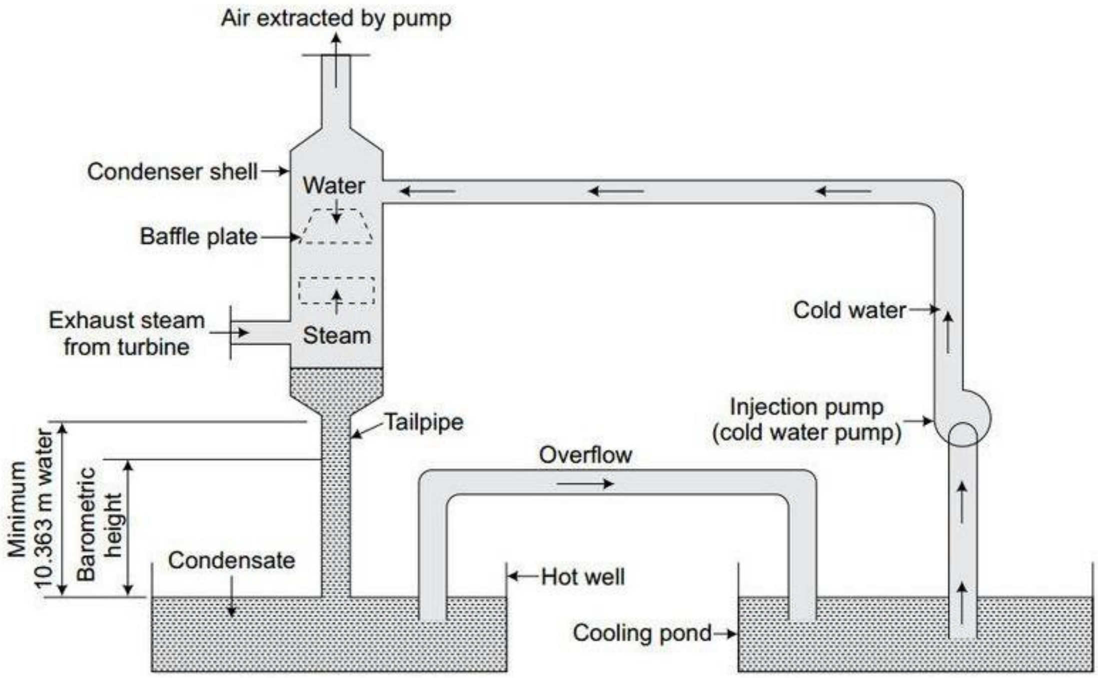


Note: Tubes are brass, cupro nickel, titanium or stainless steel. The tubes are expanded or rolled and bell mouthed at the ends in the tubesheets.

Typical Power Plant Condenser



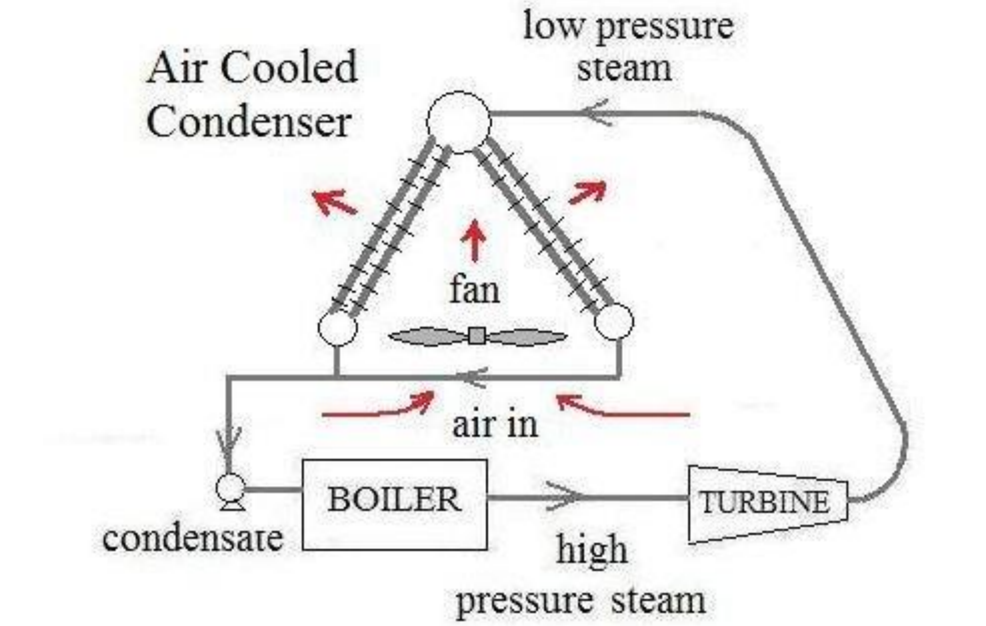
Down Flow **Central Flow**



Barometric or High Level Jet Condenser

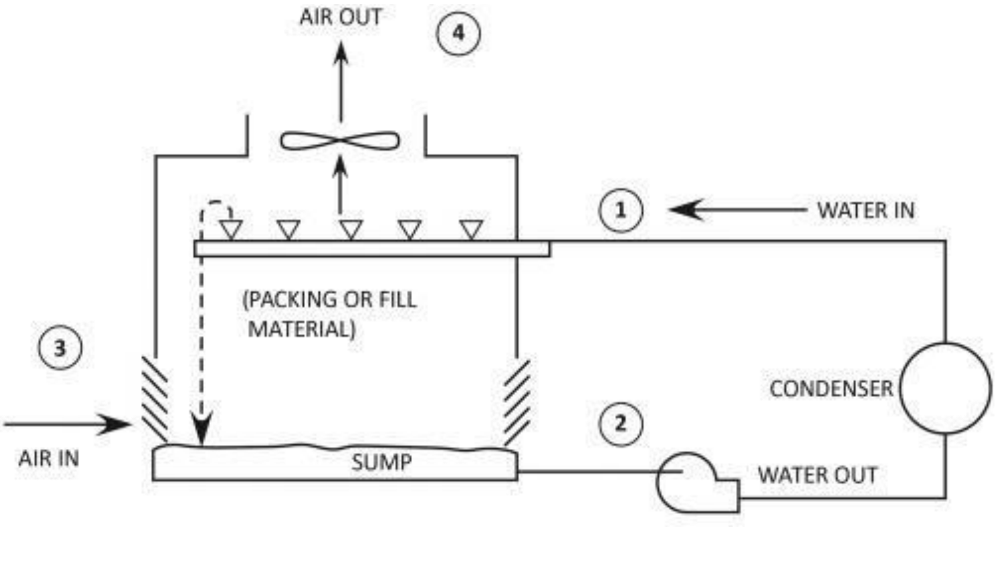
Air cooled condenser

An air cooled condenser (ACC) is a direct dry cooling system where steam is condensed inside air-cooled finned tubes. The cool ambient air flow outside the finned tubes is what removes heat and defines the functionality of an ACC

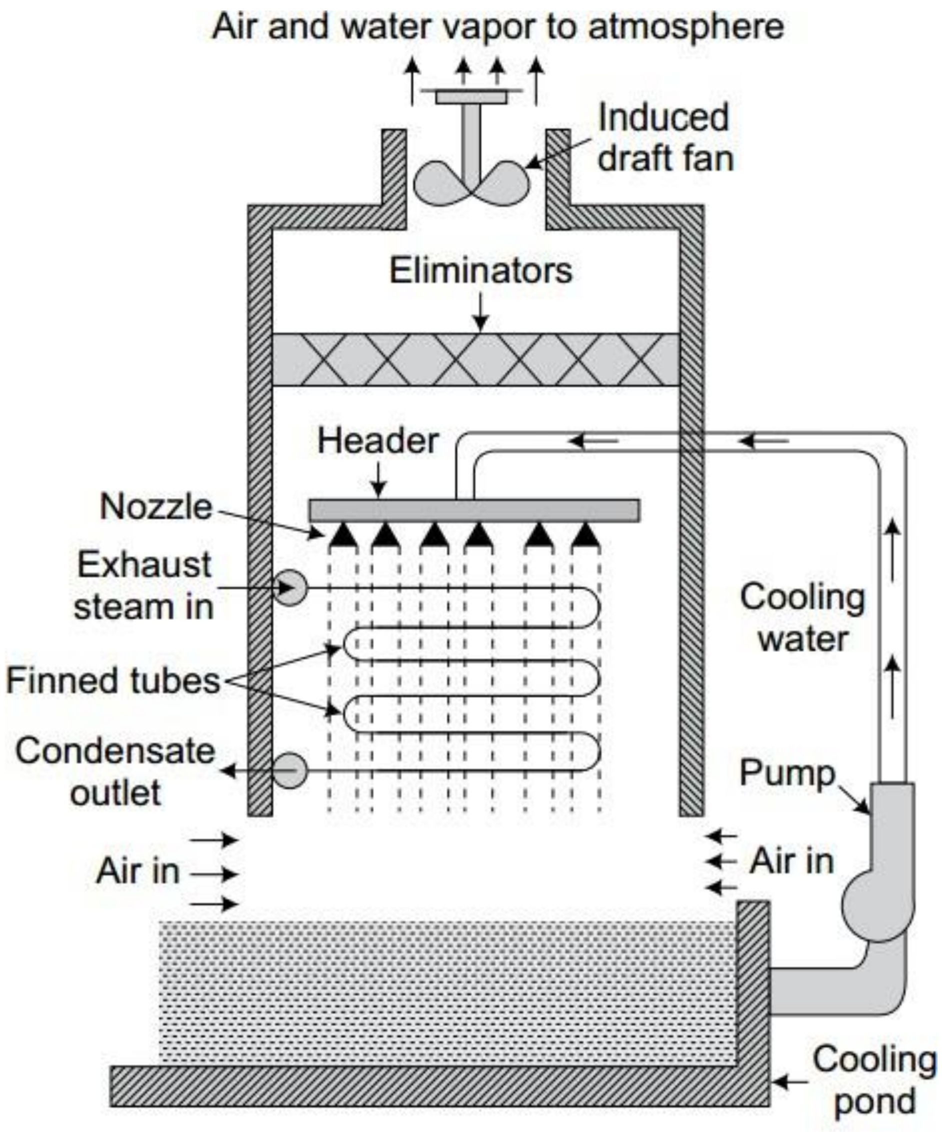


Steam Power Plant Rankine Cycle with Air Cooled Condenser

Water cooled condenser

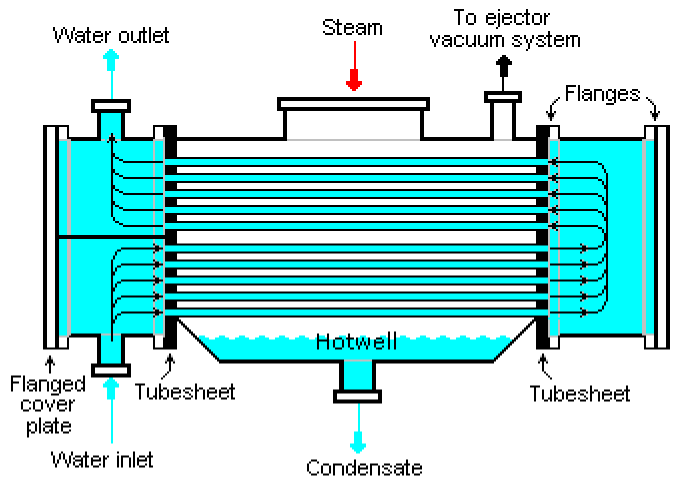


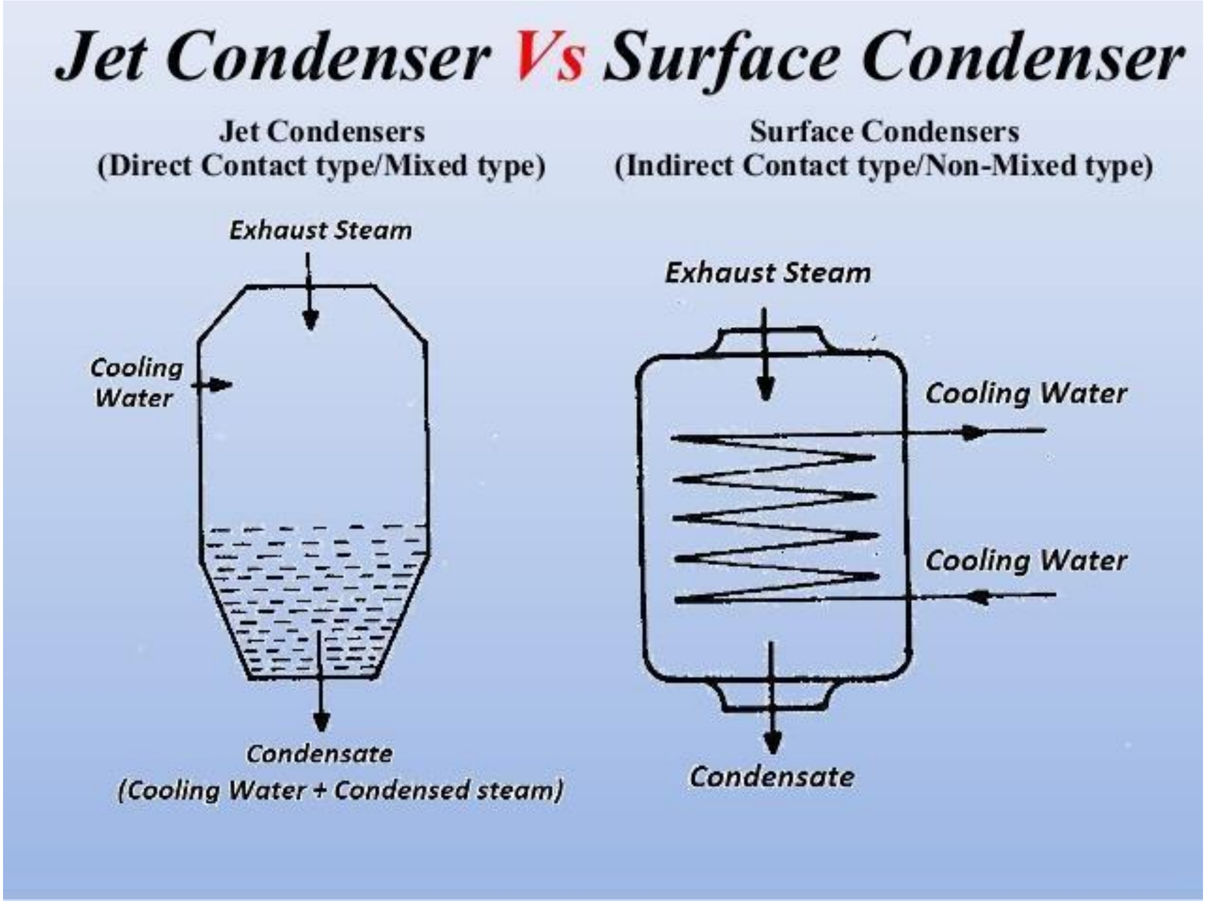
Evaporative condenser



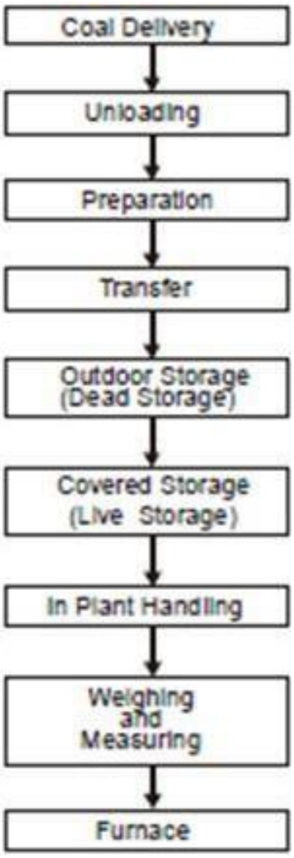
Evaporative Condenser

Surface condenser





Coal Handling



Steps in Coal Handling.

Coal handling plant

- Coal
- Unloading system
- Conveyor system
- Crushing system
- Feeding system
- Stacking system
- Magnetic separator/ metal detector
- Bin/chute vibratory system
- Coal weighment
- Coal sampling
- Fire fighting system
- Dust suppression system
- Dust extraction system

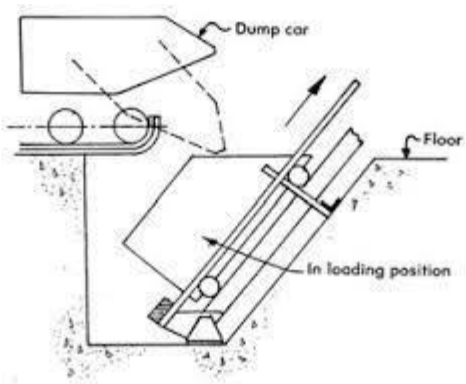
4-Aug-13

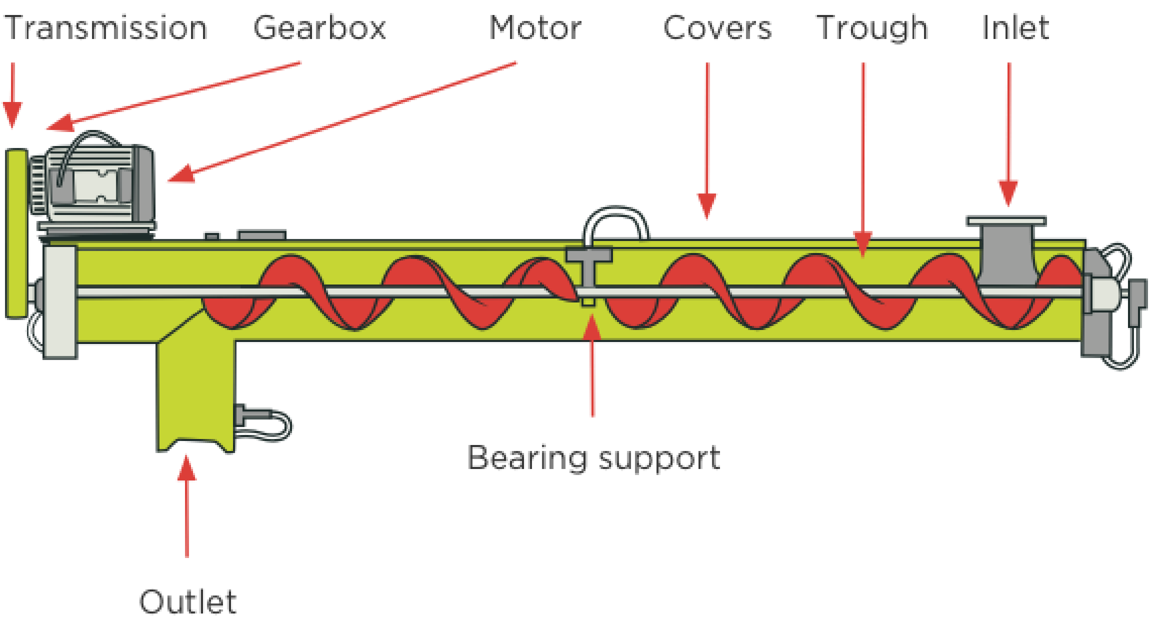
Belt conveyor

Screw conveyor

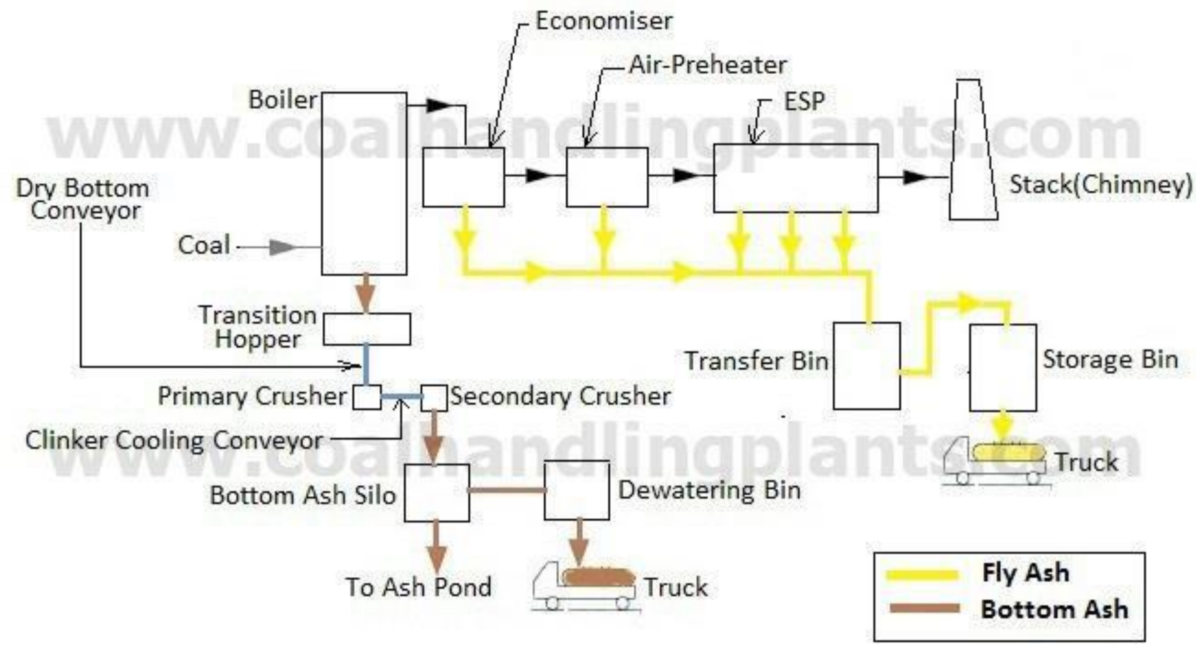
Helical conveyor

Skip hoist


Dump car
Floor
In loading position


Transmission
Gearbox
Motor
Covers
Trough
Inlet
Bearing support
Outlet

Ash handling systems



Ash handling refers to the method of collection, conveying, interim storage and load out of various types of ash residue left over from solid fuel combustion processes. The most common types of ash resulting from the combustion of coal, wood and other solid fuels.

Ash handling system are generally divided into three types fly ash handling system, bottom ash handling system and ash slurry disposal system.

Ash handling refers to the method of collection, conveying, interim storage and load out of various types of ash residue left over from solid fuel combustion processes.

The most common types of ash resulting from the combustion of coal, wood and other solid fuels.

- bottom ash
- bed ash
- fly ash
- ash clinkers

Ash handling systems may employ different forms of pneumatic ash conveying or mechanical ash conveyors.

A typical ash handling system may employ vacuum pneumatic ash collection with ash conveying from several ash pick up stations and resulting in delivery to an ash storage silo for interim holding prior to load out for disposal or reuse. Pressurized pneumatic ash conveying may also be employed.

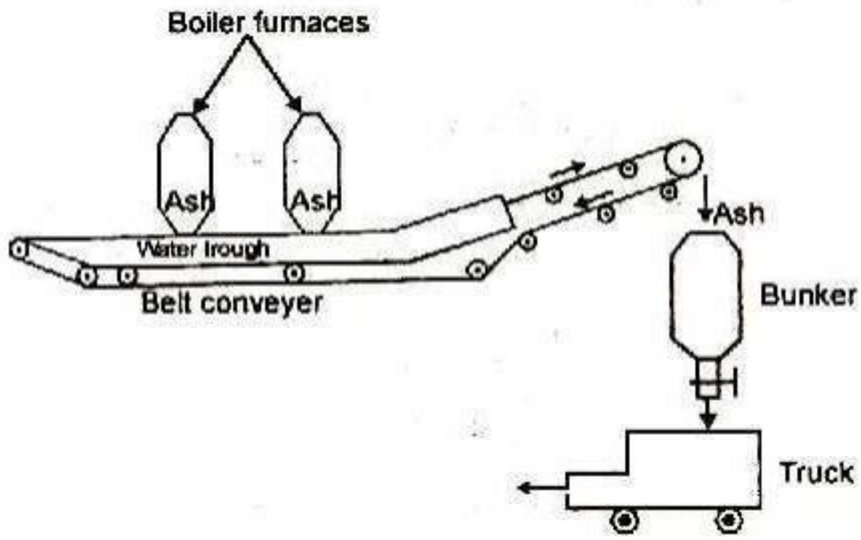
Coarse ash material such as bottom ash is most often crushed in clinker grinders (crushers) prior to being transported in the ash conveyor system.

Very finely sized fly ash often accounts for the major portion of the material conveyed in an ash handling system. It is collected from baghouse type dust collectors, electrostatic precipitators and other apparatus in the flue gas processing stream.

Ash mixers (conditioners) and dry dustless telescopic devices are used to prepare ash for transfer from the ash storage silo to transport vehicles.

Mechanical Ash handling system:

In this system ash cooled by water seal falls on the belt conveyor and is carried out continuously to the bunker.

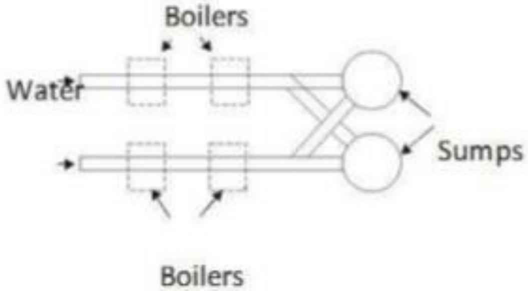


Hydraulic ash handling system

1. *Hydraulic system :*

1. Low Pressure Hydraulic System.

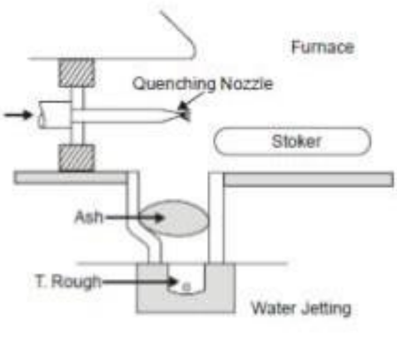
2. High Pressure Hydraulic System.

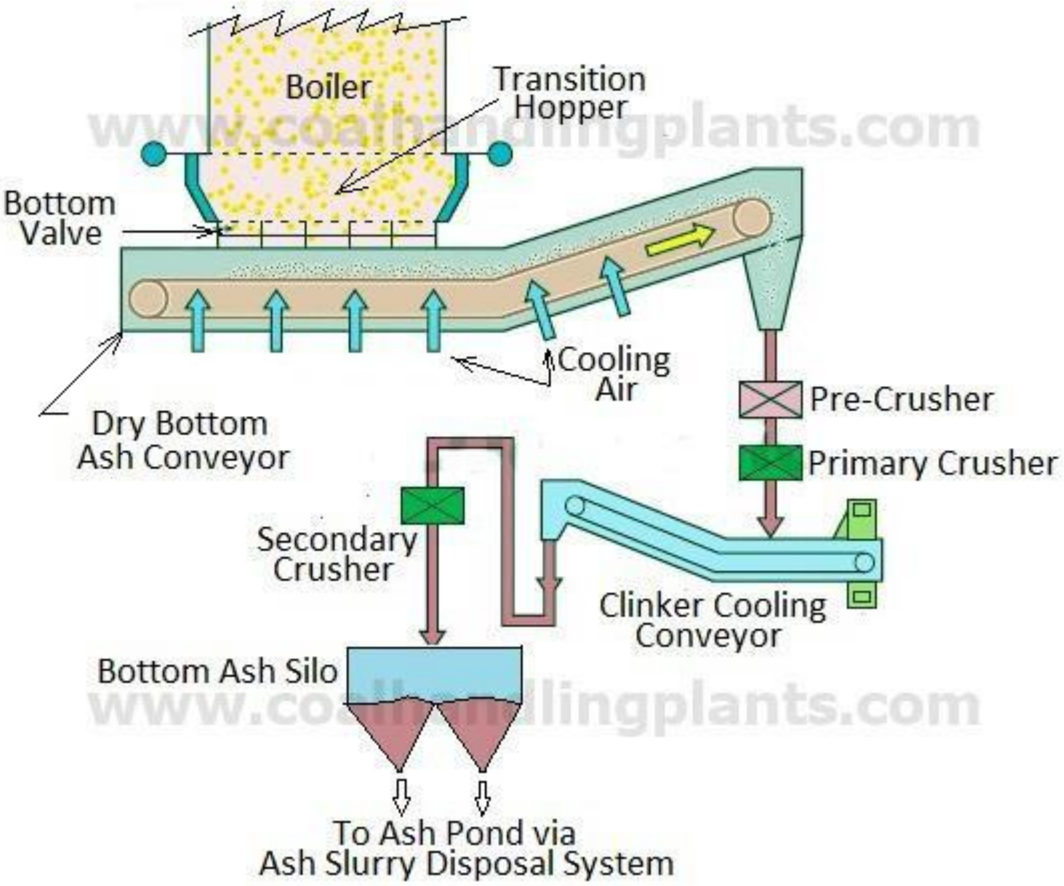


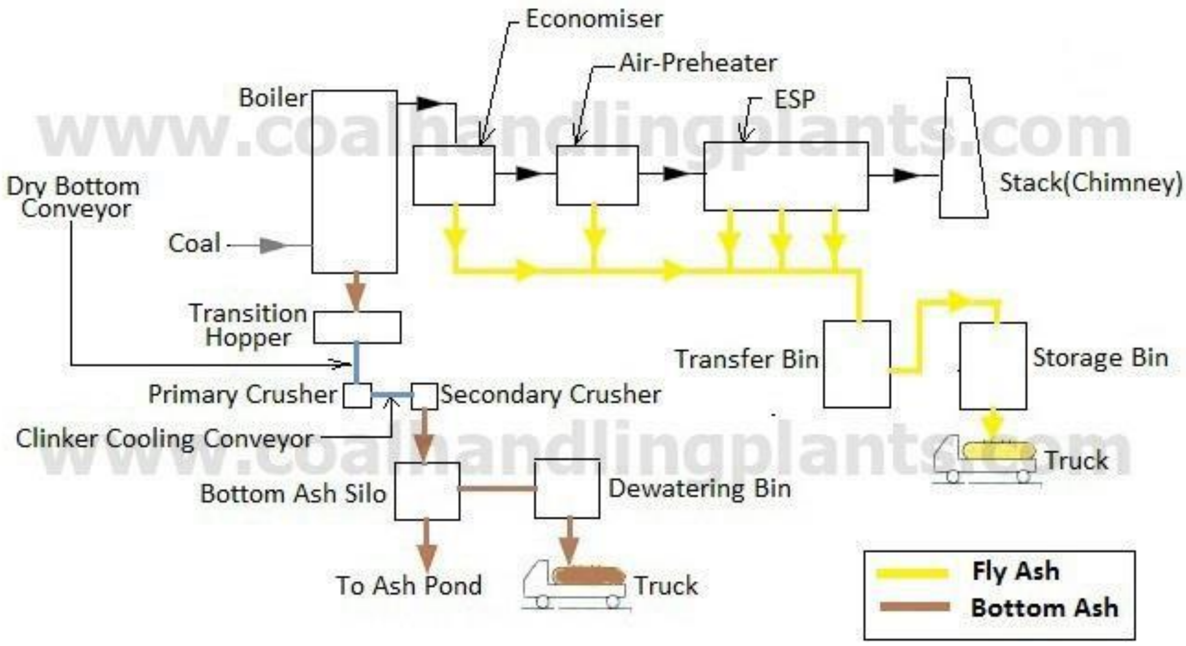
- In this method water at sufficient pressure is used to take away the ash to sump.
- Where water and ash are separated, the ash is then transferred to the dump site in wagons, rail cars or trucks.
- The loading of ash may be through a belt conveyor, grab buckets.
- If there is an ash basement with ash hopper the ash can fall, directly in ash car or conveying system.

Ash Handing Systems

- ***Water Jetting***: *In this method a low pressure jet of water coming out of the quenching nozzle is used to cool the ash. The ash falls into a trough and is then removed.*

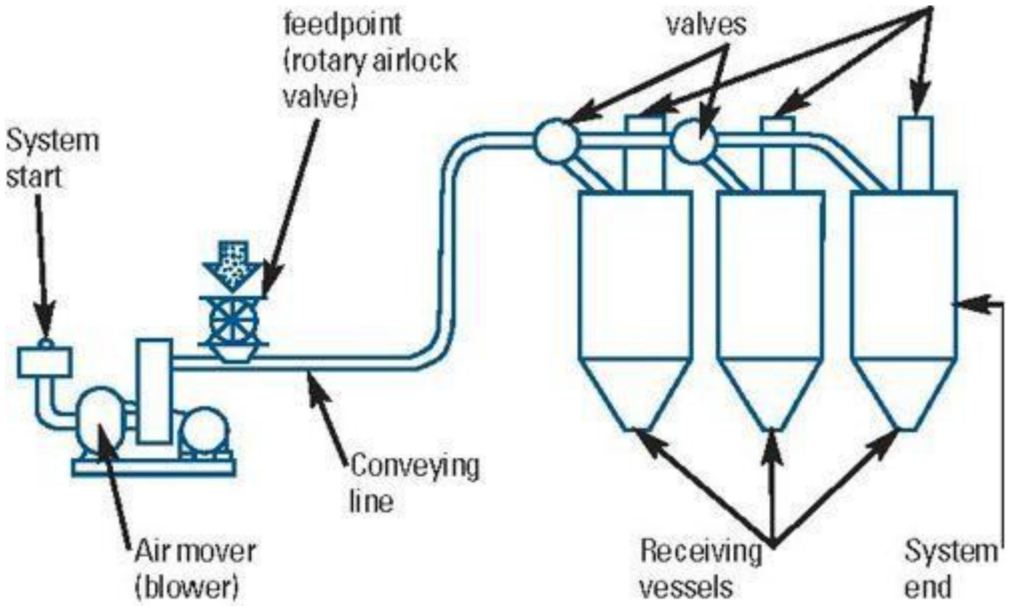






Pneumatic ash handling system

In this system ash from the boiler furnace outlet falls into a crusher where a lager ash particles are crushed to small sizes. The ash is then carried by a high velocity air or steam to the point of delivery. Air leaving the ash separator is passed through filter to remove dust etc. So that the exhauster handles clean air which will protect the blades of the exhauster.



Boiler Draught

Boiler draught is defined as the small difference between the pressure of outside cold atmospheric air and that of gases within a furnace or chimney. The draught is necessary to force air through the fuel grate to help in proper combustion of fuel and to remove the products of combustion.

Boiler draught is **defined** as the difference between absolute gas pressure at any point in a flow passage and the ambient (same elevation) atmospheric pressure. Draught is achieved a small pressure difference which causes the flow of air or gas to take place. It is measured in millimetre (mm) or water.

The draught is one of the most essential systems of the thermal power plant which support the required quantity of air for combustion and removes the burnt products from the system. To move the ait through the fuel bed and to produce a flow of hot gases through the boiler economiser, preheater and chimney require a difference of pressure.

This difference of pressure to maintaining the constant flow of air and discharging the gases through the chimney to the atmosphere is known as draught. Draught can be achieved by the use of chimney, fan, steam or air jet or a combination of these.

When the draught is produced with the help of chimney only, it is known as **Natural Draught** and when the draught is produced by any other means except chimney it is known as **Artificial Draught.**

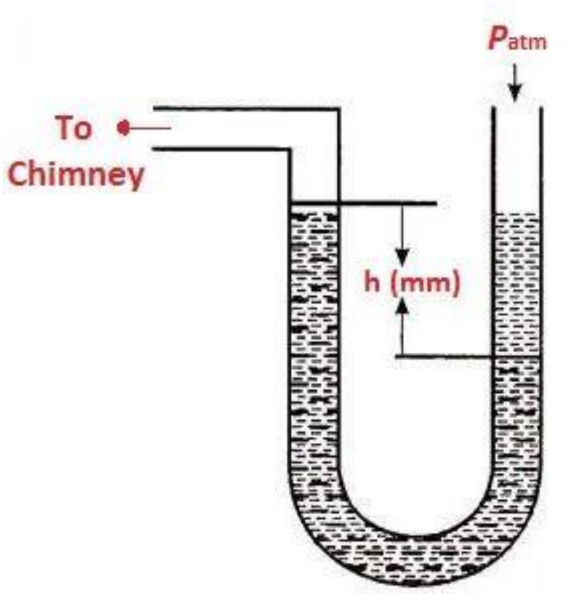
Purpose of Boiler Draught

- To provide an adequate supply of air for fuel combustion.

- For throw out the exhaust gases of combustion from the combustion chamber.
- To discharge these gases to the atmosphere through the chimney.

Measurement of Draught

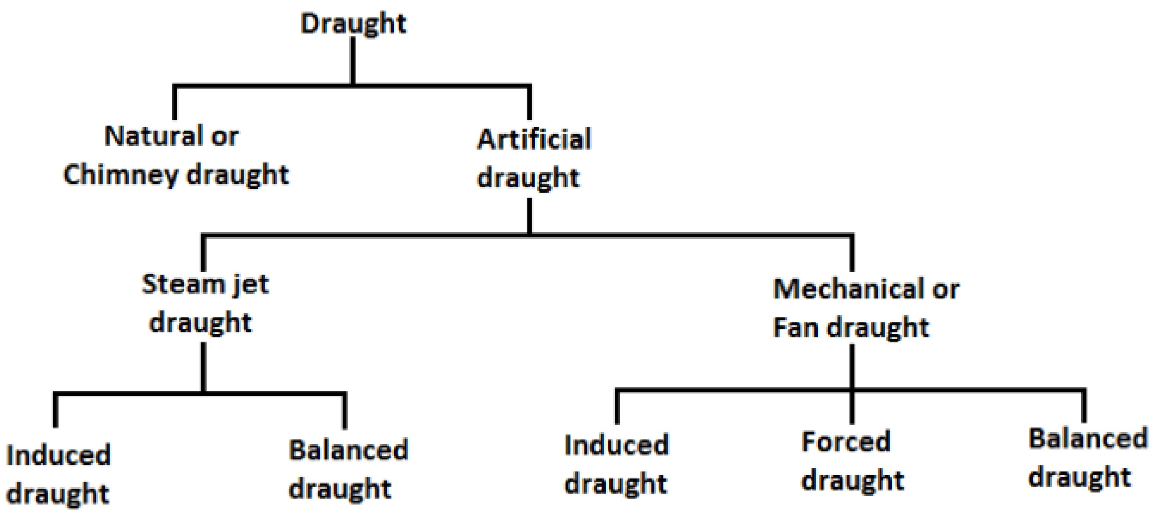
The amount of draught produce depends upon:



Draught Tube

1) The nature and depth of fuel at the furnace.
2) Design of combustion chamber or firebox.
3) The rate of combustion required.
4) Resistance is allowed in the system due to baffles, tubes, superheaters, economizers, air pre-heaters etc.

Classification of Boiler Draught



Classification of Draught

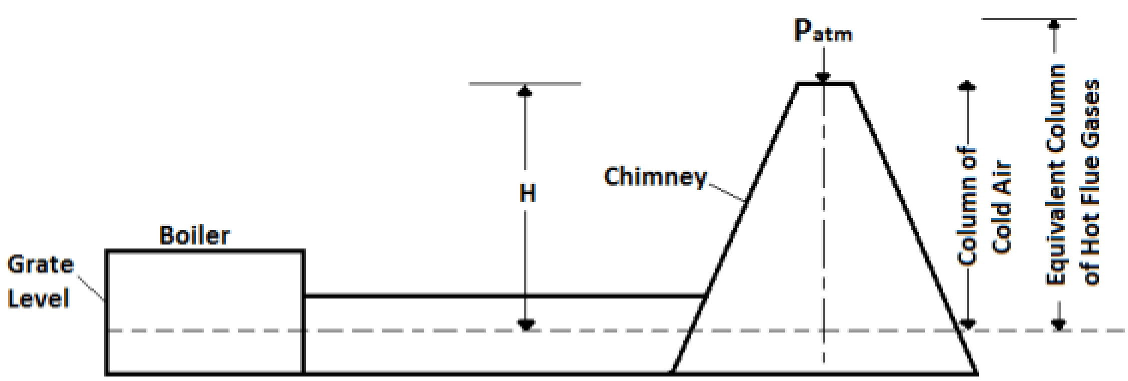
Types of Boiler Draught

In general, the draughts may be classified into the following two types,

- Natural Draught
- Artificial Draught

Natural Draught

Natural draught system employs a tall chimney as shown in the figure. The chimney is a vertical tubular masonry structure or reinforced concrete. It is formed for enclosing a column of flue gases to produce the draught.



Natural Draught

Advantages of Natural Draught

- It does not require any external power for producing the draught.
- The capital investment is less. The maintenance cost is low as there is no mechanical part.
- Chimney keeps the flue gases at a high place in the atmosphere which prevents the contamination of the atmosphere.
- It has a long life.

Disadvantages of Natural Draught

- The maximum pressure available for producing natural draught by the chimney is hardly 10 to 20 mm of water under the normal atmospheric and flue gas temperatures.
- The available draught reduces with increases in outside air temperature and for generating enough draught, the exhaust gases have to be discharged at relatively high temperatures resulting in the loss of overall plant efficiency. Thus maximum utilization of Heat is not possible.

Artificial or Mechanical Draught

It has been seen that the draught produced by the chimney is affected by the atmospheric conditions. It has no flexibility, poor efficiency and tall chimney are required. In most of the modern power plants, the draught applied must be freedom of atmospheric condition, and It should have more flexibility (control) to bear the fluctuation loads on the plant.

Today's steam power plants requiring 20 thousand tons of steam per hour would be impossible to run without the aid of draft fans. A chimney of a reasonable height would be incapable of improving enough draft to eliminate the huge volume of air and gases (400 x 103 m 3 to 800 x 10 3 m 3 per minutes). The further advantages of fans are to reduce the height of the chimney needed.

The draught required in the actual power plant is sufficiently high (300 mm of water) and to meet high draught requirements, some other system must be used, known as artificial draught. The artificial is produced by a fan and it is known as dan (mechanical) draught. Mechanical draught is preferred for central power stations.

Advantages of Artificial or Mechanical Draught

- It is more economical and its control is easy.
- The desired value of draught can be produced by mechanical means which cannot produced by means of natural draught.
- It increases the rate of combustion by which low-grade fuel can also be used.
- It reduces the smoke level and increases the heat transfer co-efficient no flue gases side thus increases the thermal efficiency of the boiler.
- In mechanical draught, It saves the energy and the heat of flue gases can be best utilized by it.
- In this way, it reduces fuel consumption and makes boiler operation cheaper.
- It reduces the height of chimney which now is only controlled by the requirement of pollution norms.

Disadvantages of Artificial or Mechanical Draught

- The initial cost of mechanical draught system is high.
- Running cost is also high due to the requirement of electricity but that is easily compensated by the savings in fuel consumption.
- Maintenance cost is also at a higher rate.
- Noise level of boiler is also high due to noisy fan/blower etc.

Types of Artificial or Mechanical Draught

The following are the two types of Artificial or Mechanical draught:

- Steam jet draught
- Mechanical or fan draught

1. Steam Jet Draught

It is a very simple and easy method of producing artificial draught without the need for an electric motor. It may be forced or induced depending on where the steam jet is installed. Steam under pressure is available in the boiler.

When a small position of steam is passed through a jet or nozzle, pressure energy converts to kinetic energy and steam comes out with a high velocity. This high-velocity steam carries, along with it, a large mass of air or flue gases and makes it flow through the boiler. Thus steam jet can be used to produce draught and it is a simple and cheap method.

Actually the steam jet is directed towards a fix direction and carries all its energy in kinetic form. It creates some vacuum in it's surrounding and attracts the air of flue gases either by carrying along with it. Thus it has the capacity to make the flow of the flue gases either by carrying or including towards chimney. It depends on the position of the steam jet.

Types of Steam Jet Draught

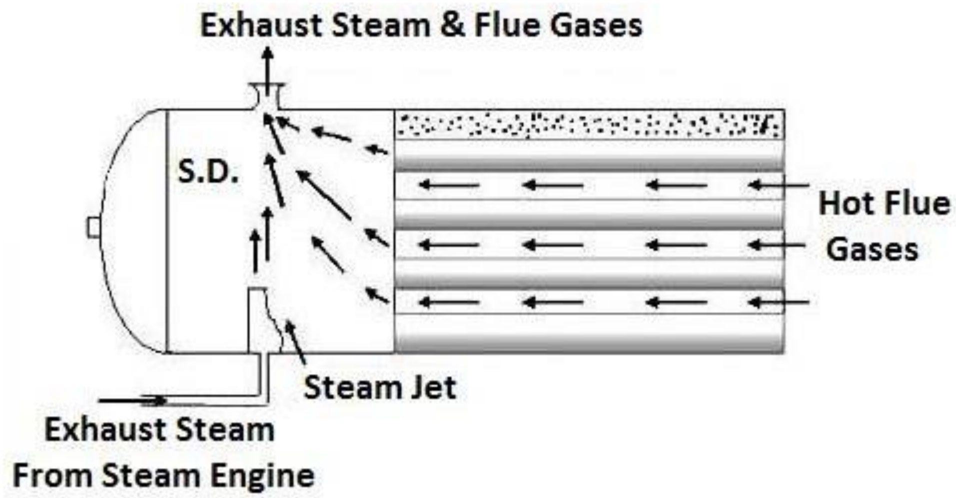
The following are the main two types of steam jet draught:

1) Induced steam jet draught.

2) Forced steam jet draught.

1. Induced Steam Jet Draught

The jet of steam is turned into a smoke box or chimney. The kinetic head of the steam is high but static head is low i.e., it produces a partial vacuum which brings the air through the grate, ash pit, flues and then to motor box and chimney.



Induced Steam Draught

This type of induced steam jet draught arrangement is used in locomotive boilers. Here the steam jet is absorbing the exhaust gases through boiler so it is Induced Steam Jet Draught.

2. Forced Steam Jet Draught

Steam from the boiler after having been throttled to a gauge pressure of 1.5 to 2 bar is supplied to the jet or nozzle installed in the ash pit. The steam rising out of nozzles with a great velocity drags air by the fuel bed, furnace, flue passage and then to the chimney. Here the steam jet is pushing or forcing the air and flue gases to flow through boiler hence it is forced steam jet draught.

Advantages of Induced Steam Jet Draught

1) It is quite simple and cheap.
2) The induced steam jet draught has the capability of using low-grade fuels.
3) It occupies very less space.
4) It is quite simple and cheap.
5) The initial cost is low.
6) Maintenance cost is low.
7) Exhaust steam from the steam engine or turbine can be used easily in the steam jet draught.

Disadvantages of Steam Jet Draught

1) It can operate only when some steam is generated.
2) Draught produced very low.

2. Mechanical or Fan Draught

The draught, produced by means of a fan or blower, is known as mechanical draught or fan draught. The fan used is, generally, of centrifugal type and is driven by an electric motor.

In an induced fan draught a centrifugal fan is placed in the path of the flue gases before they enter the chimney. It draws the flue gases from the furnace and forces them up through the chimney. The action of this type of draught is similar to that of the natural draught.

In case of forced fan draught, the fan is placed before the grate, and the air is forced into the grate through the closed ash pit.

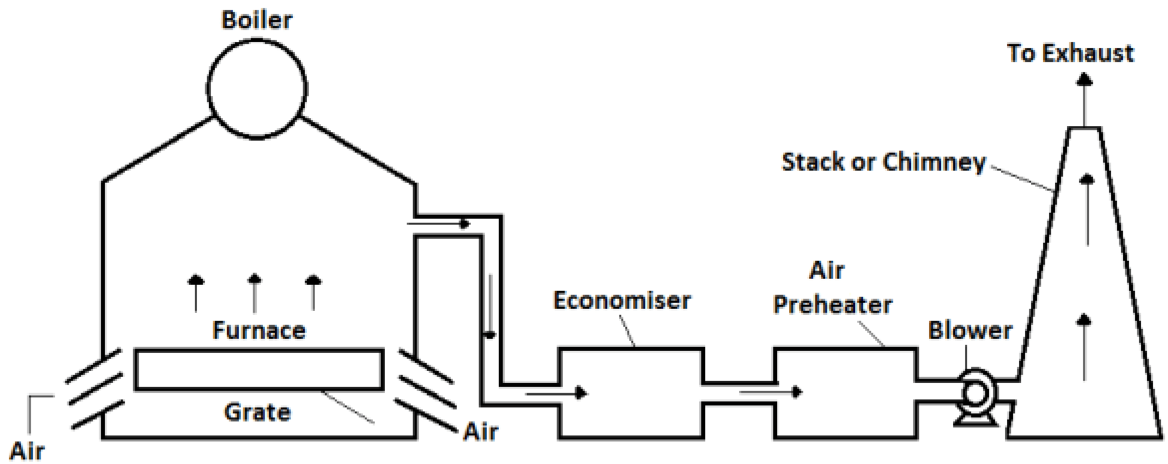
Types of Mechanical or Fan Draught

The following are the three types of mechanical or fan draught:

1. **Induced draught.**
2. **Forced draught.**
3. **Balanced draught.**

1. Induced draught

In induced draught, the blower is placed near the base of the chimney instead of near the grate. The air is absorbed in the system by decreasing the pressure through the system below the atmosphere. The induced draught fan sucks the burned gases from the furnace and the pressure inside the furnace is reduced below atmosphere and includes the atmospheric air to flow through the furnace.



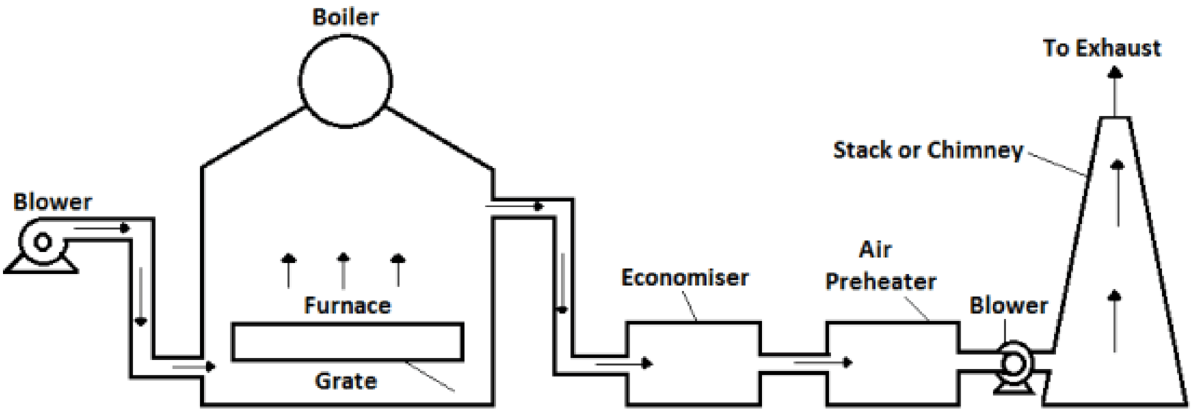
Induced Draught System

This draught system is known as positive draught system or forced draught system because the pressure and air are forced to flow through the system.

The arrangement of the system is shown in the figure. A stack or chimney is also in this system as shown in the figure but its function is to discharge gases high in the atmosphere to prevent the contamination. It is not much significant for producing draught, therefore, the height of the chimney may not be very much.

3. Balanced Draught

It is always better to use a combination of forced draught and induced draught instead of forced or induced draught alone. If the forced draught is applied alone, the furnace cannot be opened for firing or inspection because high-pressure air inside the furnace will quickly try to blow out and there is every possibility of blowing out the fire completely and furnace stops.



Balanced Draught System

If the induced draught is used alone, then also furnace can not be opened either for firing inspection because the cold air will try to rush into the furnace as the pressure inside the furnace is under atmospheric pressure. This reduces the effective draught and dilutes the combustion.

Comparison between Forced Draught and Induced Draught

Forced Draught	Induced Draught
Fan or blower is placed before the grate	Fan or blower is placed after the grate
The pressure inside the flue gases is slightly more than atmospheric pressure	The pressure inside the flue gases is slightly less than atmospheric pressure
Fan requires less power	Fan requires more power
The flow of the flue gases through the boiler is more uniform	The flow of the flue gases through the boiler is less uniform
The danger of fire in case pf leakage of flue gases.	No danger of fire in case of leakage of flue gases.

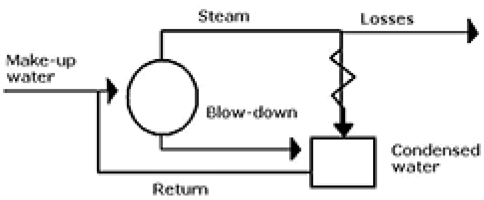
Boiler Feed Water Treatment

Boiler feed water is an essential part of boiler operations. The feed water is put into the steam drum from a feed pump. In the steam drum the feed water is then turned into steam from the heat. After the steam is used it is then dumped to the main condenser.

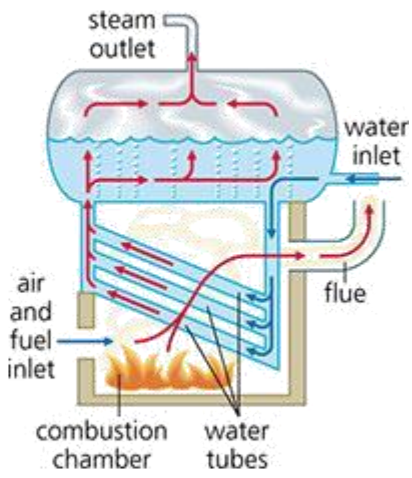
Boiler feed water

A boiler is a device for generating steam, which consists of two principal parts: the furnace, which provides heat, usually by burning a fuel, and the boiler proper, a device in which the heat changes water into steam. The steam or hot fluid is then recirculated out of the boiler for use in various processes in heating applications.

The water circuit of a water boiler can be summarized by the following :



The boiler receives the feed water, which consists of varying proportion of recovered condensed water (*return water*) and fresh water, which has been purified in varying degrees (*make up water*). The make-up water is usually natural water either in its raw state, or treated by some process before use. Feed-water composition therefore depends on the quality of the make-up water and the amount of condensate returned to the boiler. The steam, which escapes from the boiler, frequently contains liquid droplets and gases. The water remaining in liquid form at the bottom of the boiler picks up all the foreign matter from the water that was converted to steam. The impurities must be *blown down* by the discharge of some of the water from the boiler to the drains. The permissible percentage of blown down at a plant is strictly limited by running costs and initial outlay. The tendency is to reduce this percentage to a very small figure.



Proper treatment of boiler feed water is an important part of operating and maintaining a boiler system. As steam is produced, dissolved solids become concentrated and form deposits inside the boiler. This leads to poor heat transfer and reduces the efficiency of the boiler. Dissolved gasses such as oxygen and carbon dioxide will react with the metals in the boiler system and lead to boiler corrosion. In order to protect the boiler from these contaminants, they should be controlled or removed, trough external or internal treatment.

Methods of feed water treatment

1. Filtration and ultrafiltration.
2. Ion exchange/softening.
3. Membrane processes such as reverse osmosis and nanofiltration.
4. Deaeration/degasification.
5. Coagulation/chemical precipitation.

A boiler feed water treatment system might be made up of the technologies necessary to remove problematic **dissolved solids, suspended solids, and organic material**, including any number of the following:

i. **Iron:** either soluble or insoluble, iron can deposit on boiler parts and tubes, damage downstream equipment, and affect the quality of certain manufacturing processes
ii. **Copper:** can cause deposits to settle in high-pressure turbines, decreasing their efficiency and requiring costly cleaning or equipment change-outs
iii. **Silica:** if not removed to low levels, especially in high-pressure boilers, silica can cause extremely hard scaling
iv. **Calcium:** can cause scaling in several forms depending on the chemistry of the boiler feed water (e.g. calcium silicate, calcium phosphate, etc.)

v. **Magnesium:** if combined with phosphate, magnesium can stick to the interior of the boiler and coat tubes, attracting more solids and contributing to scale

vi. **Aluminum:** deposits as scale on the boiler interior and can react with silica to increase the likelihood of scaling

vii. **Hardness:** also causes deposits and scale on boiler parts and piping

viii. **Dissolved gasses:** chemical reactions due to the presence of dissolved gases such as oxygen and carbon dioxide can cause severe corrosion on boiler pipes and parts

Makeup water intake

Makeup water, or the water replacing evaporated or leaked water from the boiler, is first drawn from its source, whether raw water, city water, city-treated effluent, in-plant wastewater recycle (cooling tower blowdown recycle), well water, or any other surface water source.

Coagulation and chemical precipitation

After all the large objects are removed from the original water source, various chemicals are added to a reaction tank to remove the bulk suspended solids and other various contaminants. This process starts off with an assortment of mixing reactors, typically one or two reactors that add specific chemicals to take out all the finer particles in the water by combining them into heavier particles that settle out. The most widely used coagulates are aluminum-based such as alum and polyaluminum chloride.

Sometimes a slight pH adjustment will help coagulate the particles, as well.

Filtration and ultrafiltration

The next step is generally running through some type of filtration to remove any suspended particles such as sediment, turbidity, and certain types of organic matter. It is often useful to do this early on in the process, as the removal of suspended solids upstream can help protect membranes and ion exchange resins from fouling later on in the pretreatment process. Depending on the type of filtration used, suspended particles can be removed down to under one micron.

Ion exchange softening

When pretreating boiler feed water, if there's high hardness complexed with **bicarbonates, sulphates, chlorides, or nitrates**, a softening resin can be used. This procedure uses a strong acid cation exchange process, whereby resin is charged with a sodium ion, and as the hardness comes through, it has a higher affinity for calcium, magnesium, and iron so **it will grab that molecule and release the sodium molecule into the water**.

Dealkalization

After the softening process, some boiler feed water treatment systems will utilize dealkalization to reduce alkalinity/pH, an impurity in boiler feed water that can cause foaming, corrosion, and embrittlement. Sodium chloride dealkalization uses a strong anion exchange resin to replace bicarbonate, sulfate, and nitrate for chloride anions. Although it doesn't remove alkalinity 100%, it does remove the majority of it with what can be an easy-to-implement and economical process. Weak acid dealkalization only removes cations bound to bicarbonate, converting it to carbon dioxide (and therefore requiring degasification). It is a partial softening process that is also economical for adjusting the boiler feed water pH.

Reverse osmosis (RO) and nanofiltration (NF)

Reverse osmosis (RO) and nanofiltration (NF) are often used down the line in the boiler feed water treatment system process so most of the harmful impurities that can foul and clog the RO/NF membranes have been removed. Similar processes of separation, they both force pressurized water through semipermeable membranes, trapping contaminants such as bacteria, salts, organics, silica, and hardness, while allowing concentrated, purified water through. Not always required in boiler feed water treatment, these filtration units are used mostly with high-pressure boilers where concentration of suspended and dissolved solids needs to be extremely low.

Deaeration or degasification

At this point in the boiler feed water treatment process, any condensate being returned to the system will mix with the treated makeup water and enter the deaeration or degasification process. Any amount of gasses such as oxygen and carbon dioxide can be extremely corrosive to boiler equipment and piping when they attach to them, forming oxides and causing rust. Therefore, removing these gases to acceptable levels (nearly 100%) can be imperative to the service life and safety of the boiler system. There are several types of deaeration devices that come in a range of configurations depending on the manufacturer, but generally, you might use a tray- or spray-type deaerator for degasification or oxygen scavengers.

Distribution

After the boiler feed water has been sufficiently purified according to the boiler manufacturer's recommendation and other industry-wide regulations, the water is fed to the boiler where it is heated and used to generate steam. Pure steam is used in the facility, steam and condensate are lost, and condensate return is pumped back into the process to meet up with the pretreated makeup water to cycle through pretreatment again.

Binary cycles

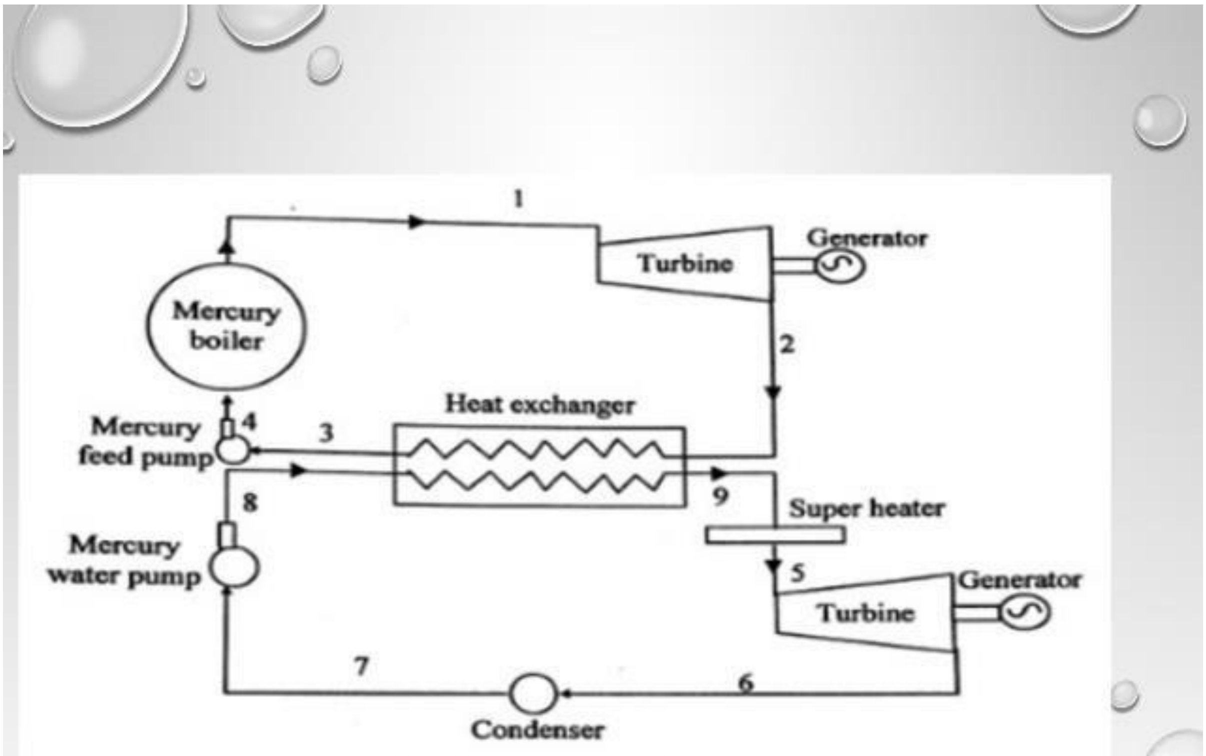
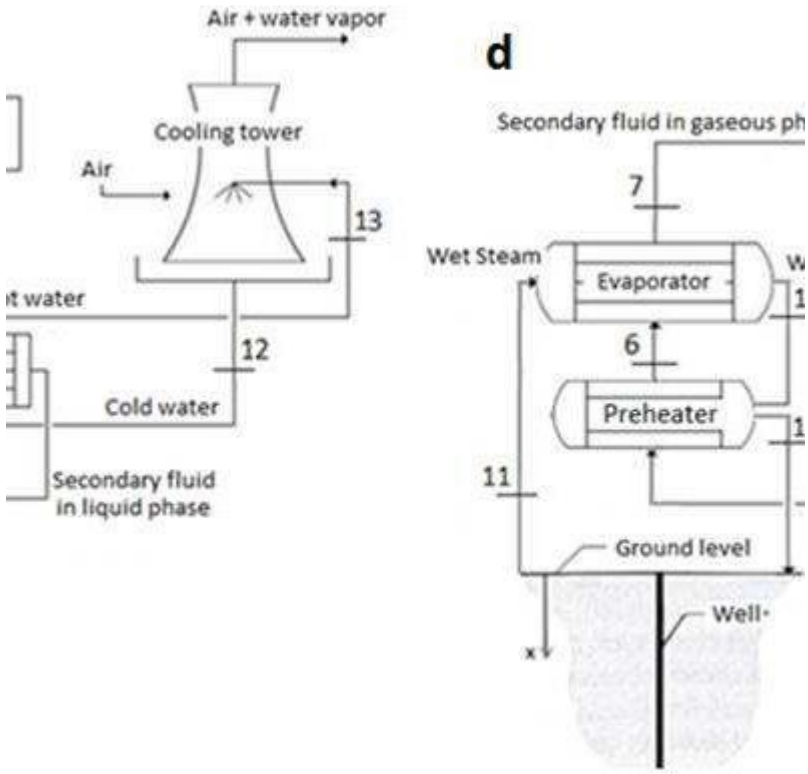


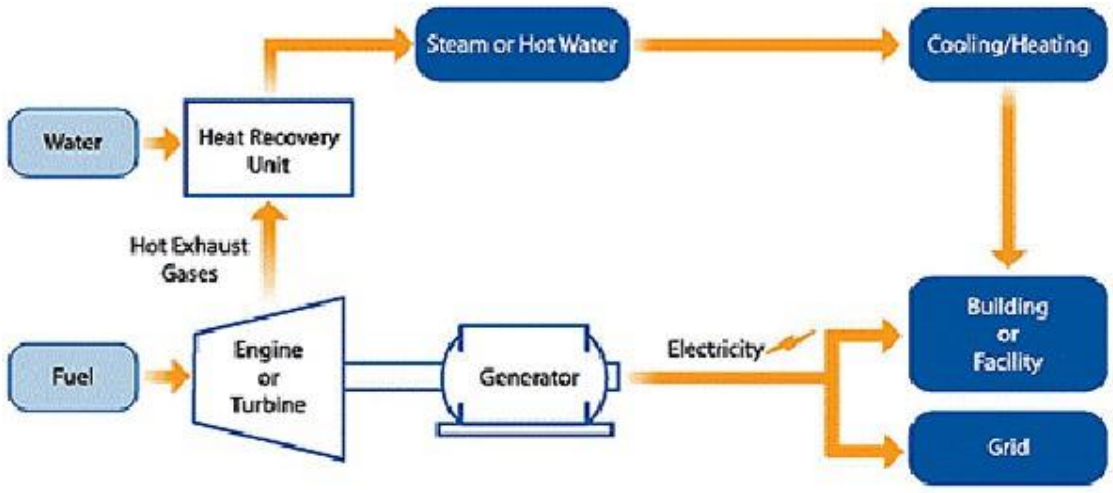
Figure 1.113 Layout of binary vapour cycle

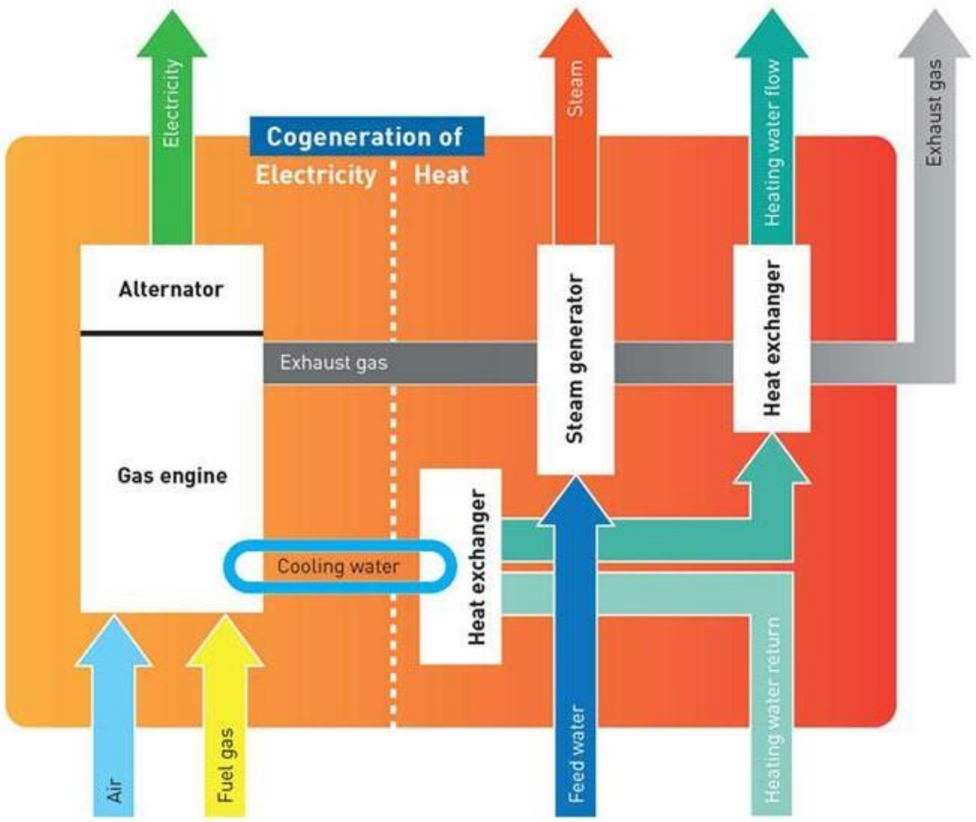


Binary Cycle Power Plant

- Low to moderately heated (below 400°F) geothermal fluid and a secondary (hence, "binary") fluid with a much lower boiling point that water pass through a heat exchanger. Binary cycle power plants are closed-loop systems, and virtually nothing (except water vapor) is emitted to the atmosphere.
- A binary cycle power plant is a type of geothermal power plant that allows cooler geothermal reservoirs to be used than is necessary for dry steam and flash steam plants
- Binary Power Plants. Binary plants, like dry-steam and flash-steam plants, make use of naturally sourced hot steam generated by activity from within the Earth's core. All geothermal plants convert thermal energy to mechanical energy, then finally to electrical energy.
- The vapor exiting the turbine is then condensed by cold air radiators or cold water and cycled back through the heat exchanger. A binary vapor cycle is defined in thermodynamics as a power cycle that is a combination of two cycles, one in a high temperature region and the other in a lower temperature region

Cogeneration





- Cogeneration—also known as combined heat and power, distributed generation, or recycled energy—is the simultaneous production of two or more forms of energy from a single fuel source. Cogeneration power plants often operate at 50 to 70 percent higher efficiency rates than single-generation facilities
- A conventional power plant makes electricity by a fairly inefficient process. A fossil fuel such as oil, coal, or natural gas is burned in a giant furnace to release heat energy. ... Cogeneration (the alternative name for CHP) simply means that the electricity and heat are made at the same time.

- Cogeneration is a more efficient use of fuel because otherwise-wasted heat from electricity generation is put to some productive use.This is also called combined heat and power district heating. Small CHP plants are an example of decentralized energy.
- Cogeneration is the process of producing electricity from steam (or other hot gases) and using the waste heat as steam in chemical processes. In contrast, a stand-alone power-producing plant typically converts less than 40% of the heat energy of fuel (coal, natural gas, nuclear, etc.) into electricity.

ASSIGNMNET QUESTIONS (Unit I)

1. Explain with a simple sketch working of thermal power plant with all the four circuits involved in it.
2. Describe the in plant coal handling with a neat diagram.
3. Explain the general layout of ash handling (different systems) and dust collection systems (classification) and draught (classification)
4. Make neat sketch and explain the working of

   (i)Chain stoker (Travelling grate) (ii) Spreader stoker (iii) Single and multi retort stoker

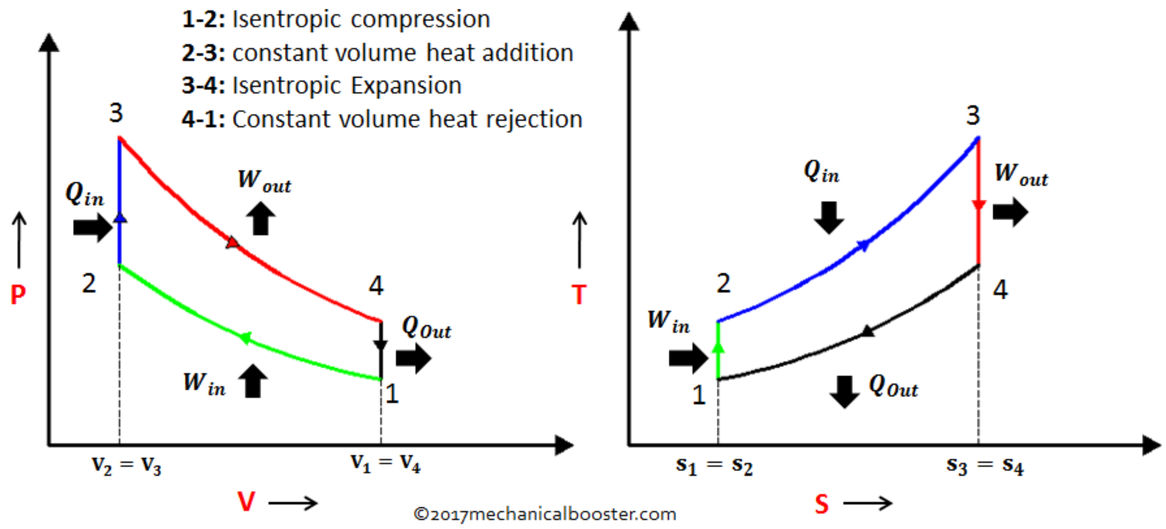
UNIT 2

UNIT II

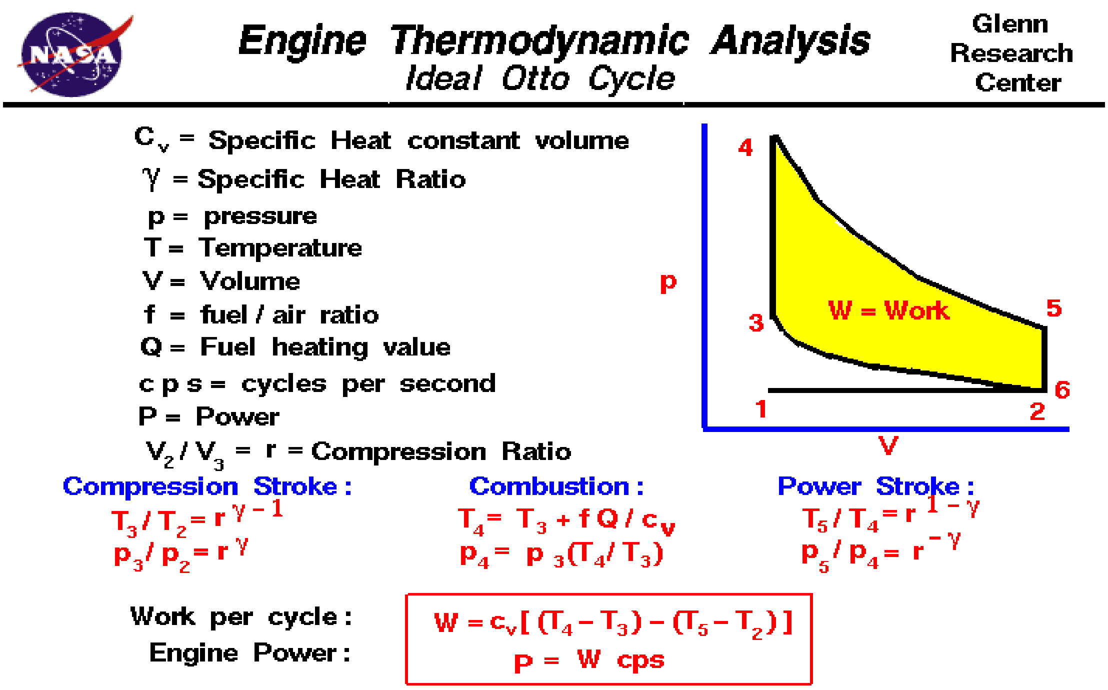
Otto, Diesel, Dual and Brayton cycle Otto cycle

An Otto cycle is an idealized thermodynamic cycle that describes the functioning of a typical spark ignition piston engine. It is the thermodynamic cycle most commonly found in automobile engines.

The Otto Cycle, describes how heat engines turn gasoline into motion. Like other thermodynamic cycles, this cycle turns chemical energy into thermal energy and then into motion. The Otto cycle describes how internal combustion engines (that use gasoline) work, like automobiles and lawn mowers.

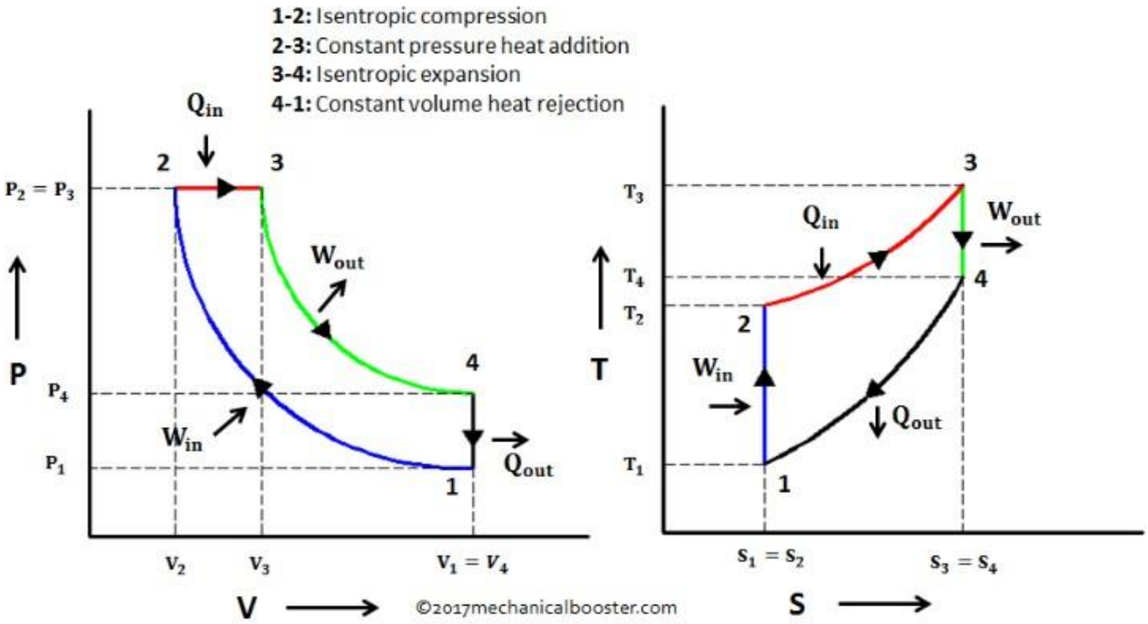


P-V and T-S Diagram of Otto Cycle

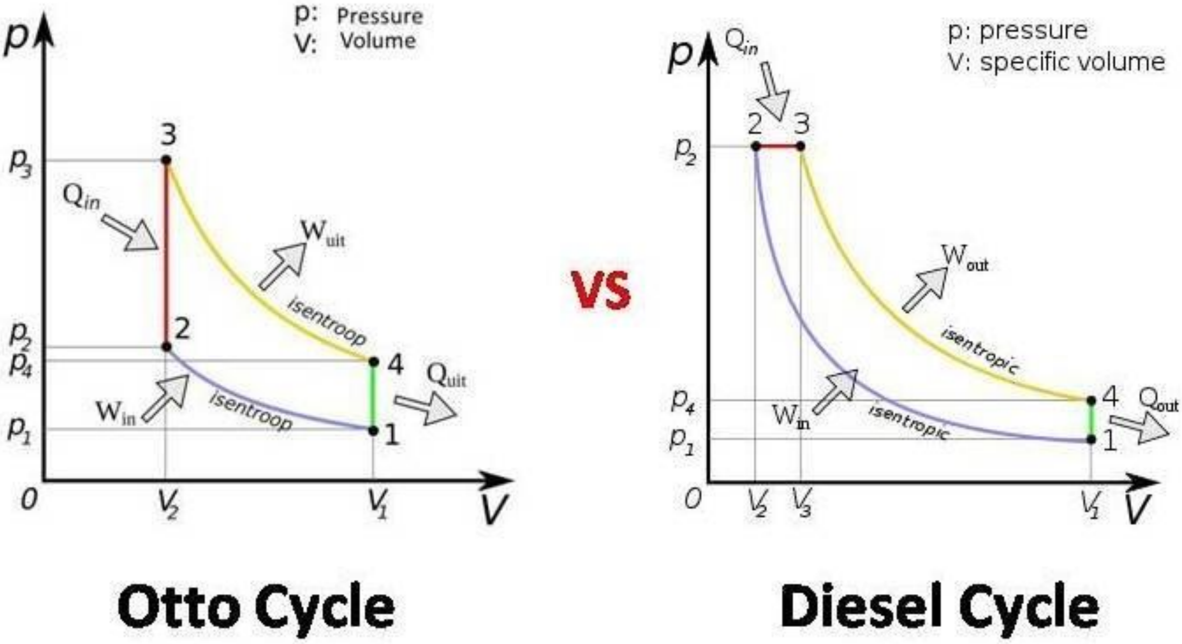


Diesel cycle

The Diesel cycle is a combustion process of a reciprocating internal combustion engine. In it, fuel is ignited by heat generated during the compression of air in the combustion chamber, into which fuel is then injected.



P-V and T-S Diagram of Diesel Cycle

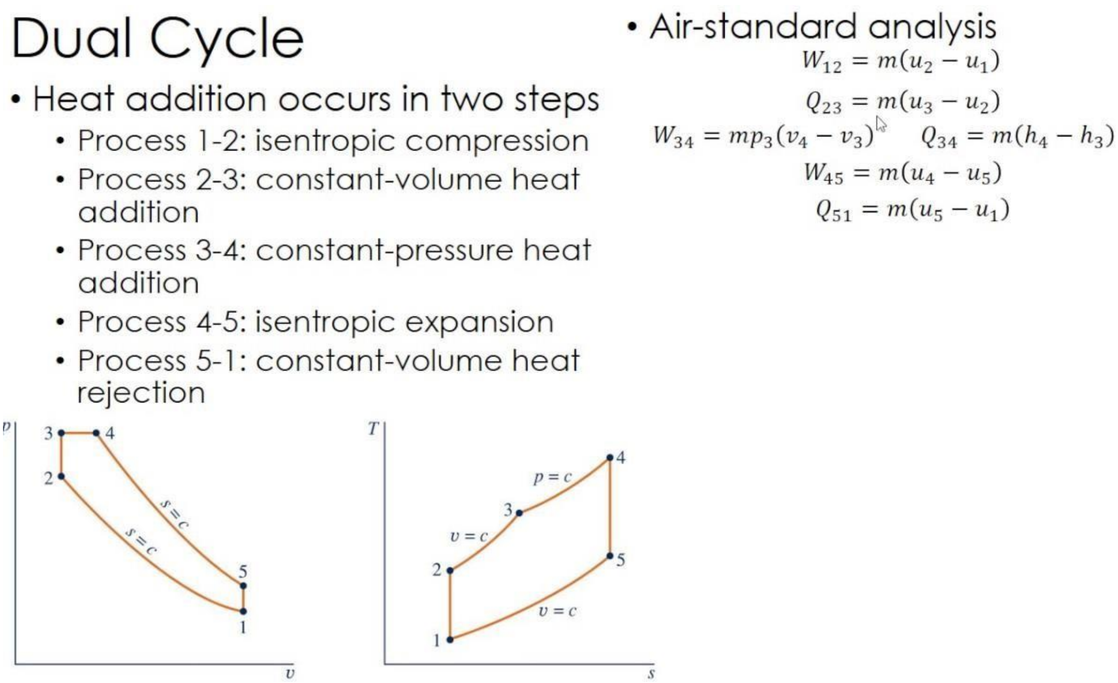


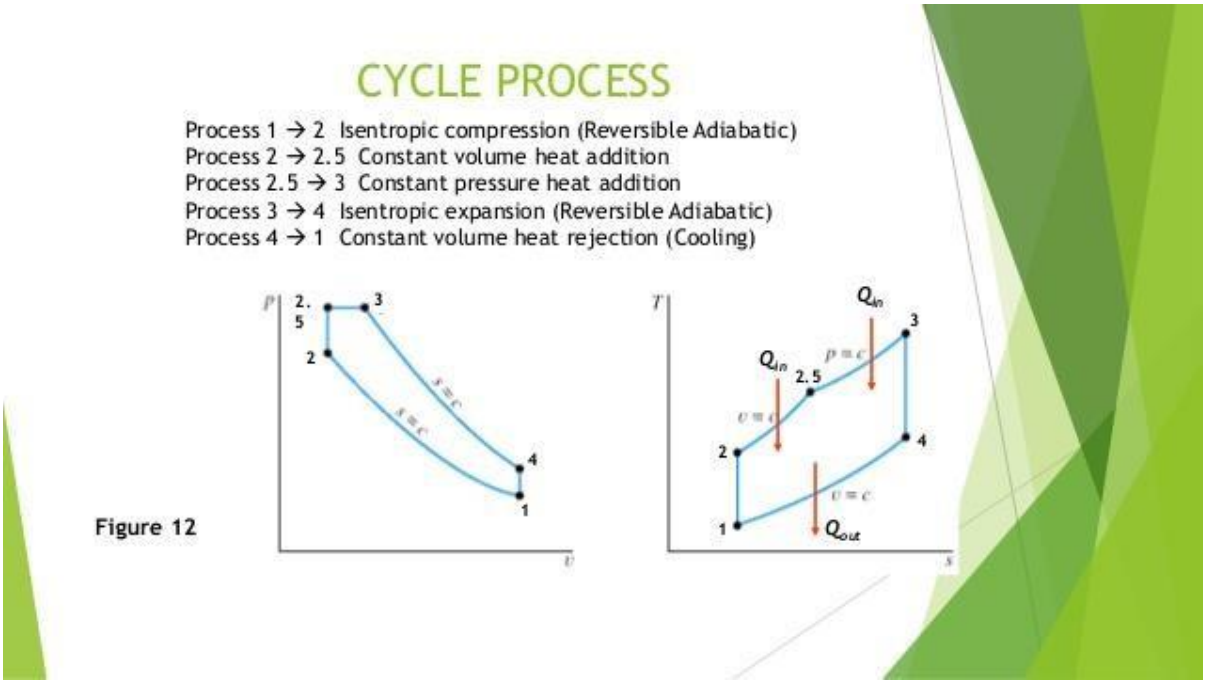
Dual cycle

The dual combustion cycle is a thermal cycle that is a combination of the Otto cycle and the Diesel cycle. Heat is added partly at constant volume (isochoric) and partly at constant pressure (isobaric), the significance of which is that more time is available for the fuel to completely combust. Because of lagging characteristics of fuel this cycle is invariably used for Diesel and hot spot ignition engines. It consists of two adiabatic and two constant volume and one constant pressure processes.

The dual cycle consists of following operations:

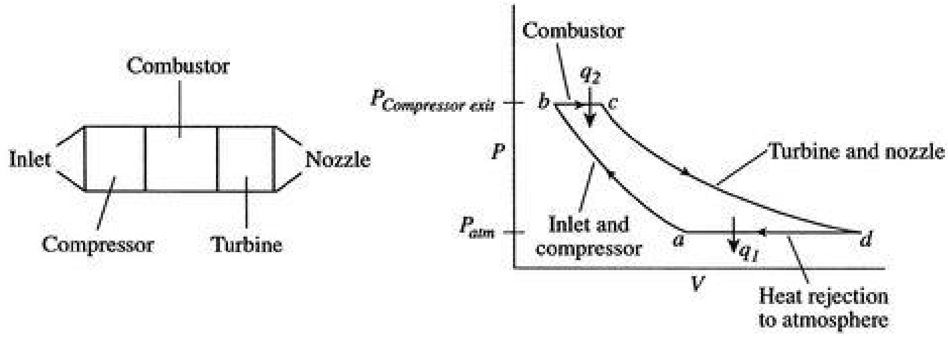
- Process 1-2: Isentropic compression
- Process 2-3: Addition of heat at constant volume.
- Process 3-4: Addition of heat at constant pressure.
- Process 4-5: Isentropic expansion.
- Process 5-1: Rejection of heat at constant volume.





Brayton cycle

The Brayton cycle is a thermodynamic cycle named after George Brayton that describes the workings of a constant-pressure heat engine. The original Brayton engines used a piston compressor and piston expander, but more modern gas turbine engines and air breathing jet engines also follow the Brayton cycle.



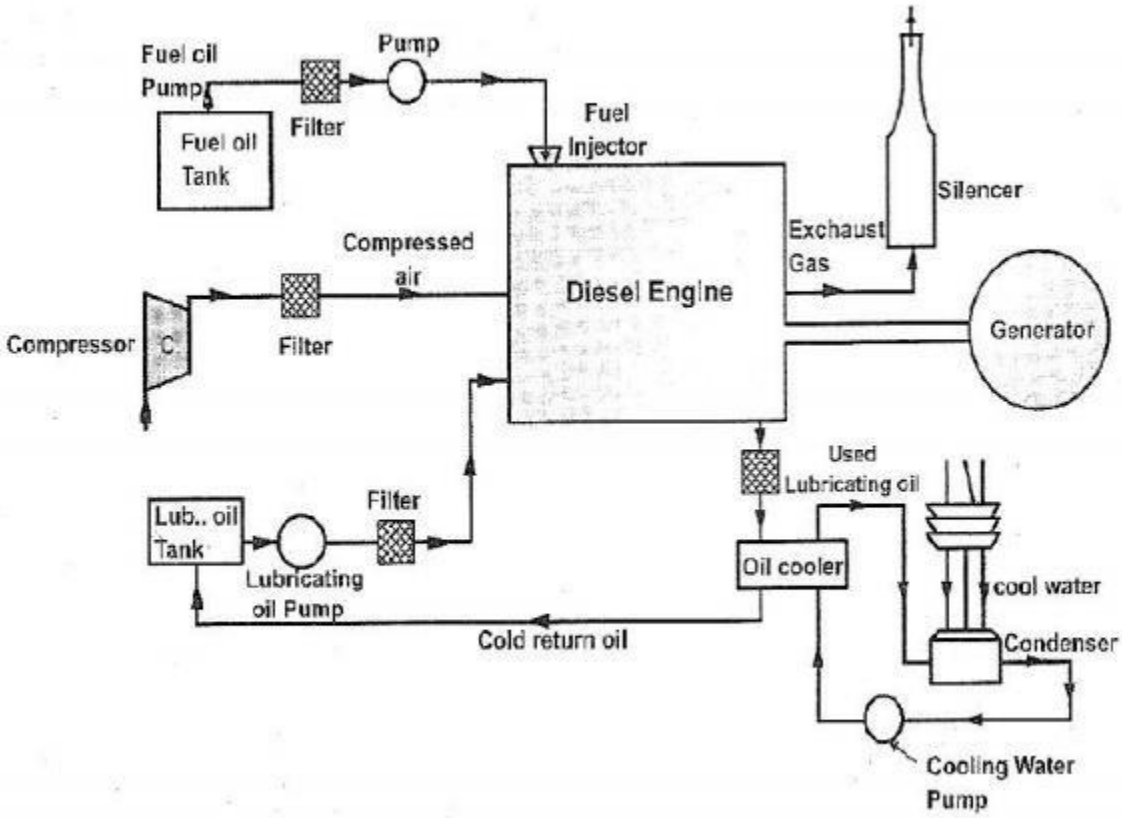
Diesel engine power plant

A Diesel Power Plant is wherein the prime mover of an alternator is a diesel engine. Using a diesel engine has its own pros and cons. Installation and operation are easier as compared to other power plants.

In a diesel power station, diesel engine is used as the prime mover. The diesel burns inside the engine and the products of this combustion act as the working fluid to produce mechanical energy. The diesel engine drives alternator which converts mechanical energy into electrical energy.

A Diesel power station (also known as Stand-by power station) uses a diesel engine as prime mover for the generation of electrical energy. This kind of power station can be used to produce limited amounts of electrical energy.

Layout of Diesel Engine Power Plant



- Air Intake System.
- Engine Starting system.
- Fuel System.
- Exhaust System.
- Cooling System.
- Lubricating System.

Air Intake System

This system supplies necessary air to the engine for fuel combustion. It consists of a pipe for supplying of fresh air to the engine. Filters are provided to remove dust particles from air because these particles can act as an abrasive in the engine cylinder.

Engine Starting System

For starting a diesel engine, initial rotation of the engine shaft is required. Until the firing start and the unit runs with its own power. For small DG set, the initial rotation of the shaft is provided by handles but for large diesel power station. Compressed air is used for starting.

Fuel Supply System

In fuel supply system there are one storage tank strainers, fuel transfer pump and all day fuel tank. Storage tank where oil in stored.

Strainer: This oil then pump to dry tank, by means of transfer pump.

During transferring from main tank to smaller dry tank, the oil passes through strainer to remove solid impurities. From dry tank to main tank, there is another pipe connection. This is over flow pipe. This pipe connection is used to return the oil from dry tank to main tank in the event of over flowing.

From dry tank the oil is injected in the diesel engine by means of fuel injection pump.

Exhaust System

The exhaust gas is removed from engine, to the atmosphere by means of an exhaust system. A silencer is normally used in this system to reduce noise level of the engine.

Cooling System

The heat produced due to internal combustion, drives the engine. But some parts of this heat raise the temperature of different parts of the engine. High temperature may cause permanent damage to the machine. Hence, it is essential to maintain the overall temperature of the engine to a tolerable level.

Cooling system of diesel power station does exactly so. The cooling system requires a water source, water source, water pump and cooling towers. The pump circulates water through cylinder and head jacket. The water takes away heat from the engine and it becomes hot. The hot water is cooled by cooling towers and is re-circulated for cooling.

Lubricating System

This system minimises the wear of rubbing surface of the engine. Here lubricating oil is stored in main lubricating oil tank. This lubricating oil is drawn from the tank by means of oil pump. Then the oil is passed through the oil filter for removing impurities. From the filtering point, this clean lubricating oil is delivered to the different points of the machine where lubrication is required the oil cooler is provided in the system to keep the temperature of the lubricating oil as low as possible.

Why diesel plants are not used for high capacity?

The mechanical power required for driving alternator comes from combustion of diesel. As the diesel costs high, this type of power station is not suitable for producing power in large scale in our country.

The advantages of diesel power stations include:

1. This is simple in design point of view.
2. Required very small space.
3. It can also be designed for portable use.
4. It has quick starting facility, the small diesel generator set can be started within few seconds.
5. It can also be stopped as when required stopping small size diesel power station, even easier than it's starting
6. As these machines can easily be started and stopped as when required, there may not be any standby loss in the system.
7. Cooling is easy and required smaller quantity of water in this type power station.
8. Initial cost is less than other types of power station.
9. Thermal efficiency of diesel is quite higher than of coal.

Disadvantages

- The cost of diesel is very high compared to coal. This is the main reason for which a diesel power plant is not getting popularity over other means of generating power. In other words the running cost of this plant is higher compared to steam and hydro power plants.
- The plant generally used to produce small power requirement.
- Cost of lubricants is high.
- Maintenance is quite complex and costs high.
- Plant does not work satisfactorily under overload conditions for a longer period.

Applications of diesel engine power plant

- Diesel power plant is used for electrical power generation in capacities ranging from 100 to 5000 H.P.
- They are commonly used for mobile power generation and are widely used in transportation systems consisting of railroads, ships, automobiles, and airplanes.
- They can be used as standby power plants.
- They can be utilized as peak load plants for some other types of power plants.
- For Industries where power requirement is small in the order of 500 kW, diesel power plants become more economical due to higher overall efficiency

Gas turbine power plant

The gas turbine is the engine at the heart of the power plant that produces electric current.

A gas turbine is a combustion engine that can convert natural gas or other liquid fuels to mechanical energy. This energy then drives a generator that produces electrical energy. It is electrical energy that moves along power lines to homes and businesses.

To generate electricity, the gas turbine heats a mixture of air and fuel at very high temperatures, causing the turbine blades to spin. The spinning turbine drives a generator that converts the energy into electricity.

The gas turbine can be used in combination with a steam turbine—in a combined-cycle power plant—to create power extremely efficiently.

1. Air-fuel mixture ignites.

- The gas turbine compresses air and mixes it with fuel that is then burned at extremely high temperatures, creating a hot gas.

2. Hot gas spins turbine blades.

- The hot air-and-fuel mixture moves through blades in the turbine, causing them to spin quickly.

3. Spinning blades turn the drive shaft.

- The fast-spinning turbine blades rotate the turbine drive shaft.

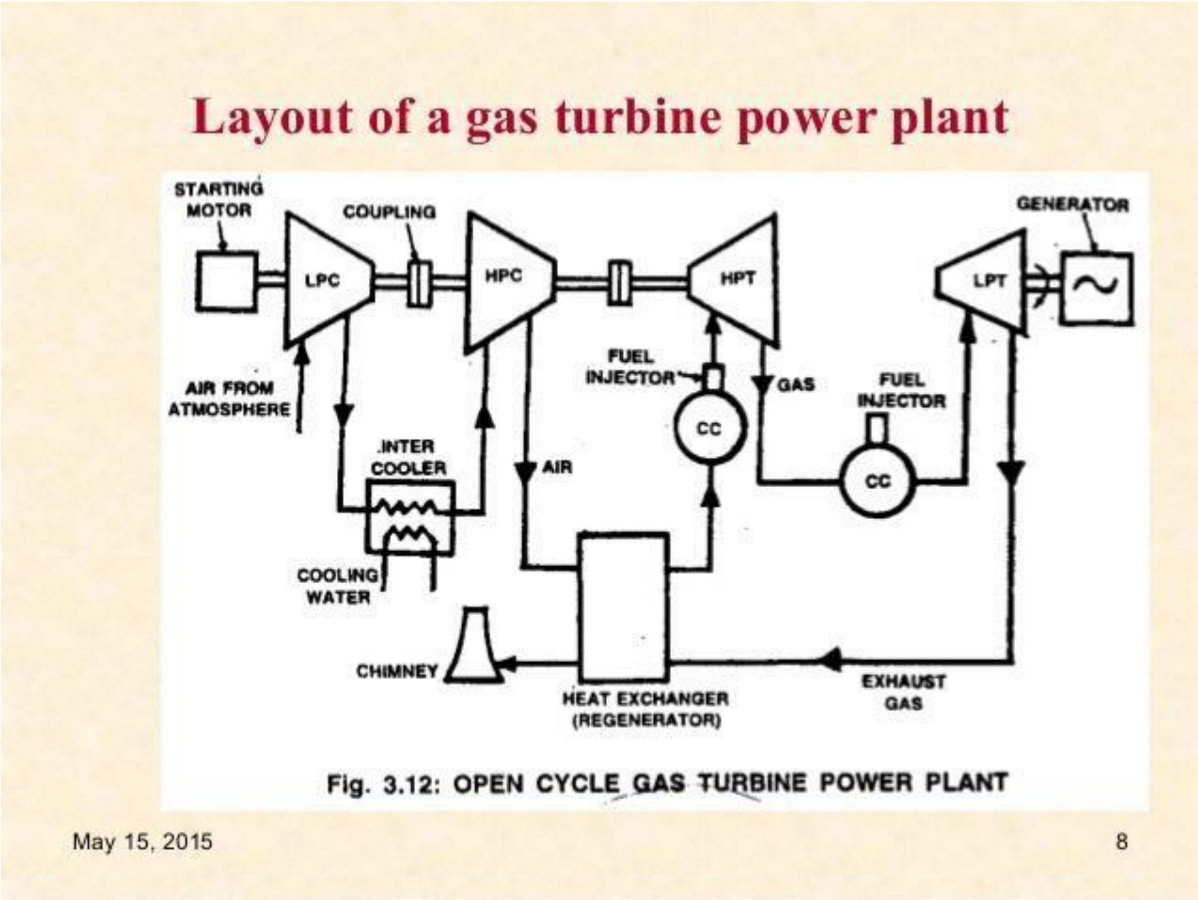
4. Turbine rotation powers the generator.

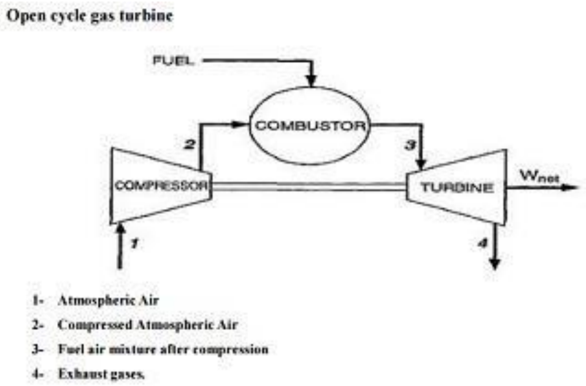
- The spinning turbine is connected to the rod in a generator that turns a large magnet surrounded by coils of copper wire.

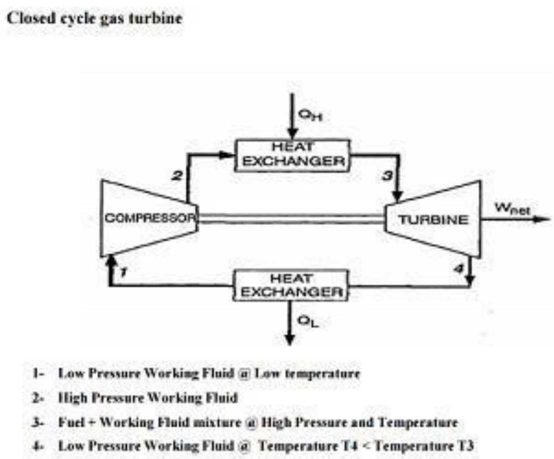
5. Generator magnet causes electrons to move and creates electricity.

- The fast-revolving generator magnet creates a powerful magnetic field that lines up the electrons around the copper coils and causes them to move.
- The movement of these electrons through a wire is electricity.

Layout


Layout of a gas turbine power plant
STARTING MOTOR
COUPLING
LPC
HPC
HPT
LPT
GENERATOR
AIR FROM ATMOSPHERE
FUEL INJECTOR
GAS
FUEL INJECTOR
CC
CC
INTER COOLER
AIR
COOLING WATER
CHIMNEY
HEAT EXCHANGER (REGENERATOR)
EXHAUST GAS
Fig. 3.12: OPEN CYCLE GAS TURBINE POWER PLANT
May 15, 2015
8


Open cycle gas turbine
FUEL
COMBUSTOR
2
3
COMPRESSOR
TURBINE
W_{net}
1
4
1- Atmospheric Air
2- Compressed Atmospheric Air
3- Fuel air mixture after compression
4- Exhaust gases.


Closed cycle gas turbine
Q_H
HEAT EXCHANGER
2
3
COMPRESSOR
TURBINE
W_net
1
4
HEAT EXCHANGER
Q_L
1- Low Pressure Working Fluid @ Low temperature
2- High Pressure Working Fluid
3- Fuel + Working Fluid mixture @ High Pressure and Temperature
4- Low Pressure Working Fluid @ Temperature T4 < Temperature T3

The gas turbine is made up of the following components:

- An air compressor.
- A combustor.
- A power turbine, which produces the power to drive the air compressor and the output shaft.

Compressor

Early gas turbines employed centrifugal compressors, which are relatively simple and inexpensive. They are, however, limited to low pressure ratios and cannot match the efficiencies of modern axial-flow compressors. Accordingly, centrifugal compressors are used today primarily in small industrial units.

An axial-flow compressor is the reverse of a reaction turbine. The blade passages, which look like twisted, highly curved airfoils, must exert a tangential force on the fluid with the pressures on one side of the blade higher than on the other. For subsonic flow, an increase in pressure requires the flow area to also increase, thus reducing the flow velocity between the blade passages and diffusing the flow. A row of compressor blades must be viewed as a set of closely spaced, highly curved airfoil shapes with which airflow strongly interacts. There will not only be a rise in pressure along the blades but a variation between them as well. Flow friction, leakage, wakes produced by the previous sets of blades, and secondary circulation or swirl flows all contribute to losses in a real unit. Tests of stationary blade assemblies, known as cascades, can be performed in special wind tunnels, but actual blade arrangements in a rotating assembly require special test setups or rigs.

Blades must be designed not only to have the correct aerodynamic shape but also to be light and not prone to critical vibrations. Recent advances in compressor (and turbine) blade design have been aided by extensive computer programs.

While moderately large expansion-pressure ratios can be achieved in a reaction-turbine stage, only relatively small pressure increases can be handled by a compressor stage—typically pressure ratios per stage of 1.35 or 1.4 to 1 in a modern design. Thus, compressors require more stages than turbines. If higher stage pressure ratios are attempted, the flow will tend to separate from the blades, leading to turbulence, reduced pressure rise, and a "stalling" of the compressor with a concurrent loss of engine power. Unfortunately, compressors are most efficient close to this so-called surge condition, where small disturbances can disrupt operation. It remains a major challenge to the designer to maintain high efficiency without stalling the compressor.

As the air is compressed, its volume decreases. Thus the annular passage area should also decrease if the through-flow velocity is to be kept nearly constant—*i.e.,* the blades have to become shorter at higher pressures. An optimum balance of blade-tip speeds and airflow velocities often requires that the rotational speed of the front, low-pressure end of the compressor be less than that of the high-pressure end. This is achieved in large aircraft gas turbines by "spooled" shafts where the shaft for the low-pressure end, driven by the low-pressure portion of the turbine, is running at a different speed within the hollow high-pressure compressor/turbine shaft, with each shaft having its own bearings. Both twin- and triple-spool engines have been developed.

Combustion chamber

Air leaving the compressor must first be slowed down and then split into two streams. The smaller stream is fed centrally into a region where atomized fuel is injected and burned with a flame held in place by a turbulence-generating obstruction. The larger, cooler stream is then fed into the chamber through holes along a "combustion liner" (a sort of shell) to reduce the overall temperature to a level suitable for the turbine inlet. Combustion can be carried out in a series of nearly cylindrical elements spaced around the circumference of the engine called cans, or in a single annular passage with fuel-injection nozzles at various circumferential positions. The difficulty of achieving nearly uniform exit-temperature distributions in a short aircraft combustion chamber can be alleviated in stationary applications by longer chambers with partial internal reversed flow.

Turbine

The turbine is normally based on the reaction principle with the hot gases expanding through up to eight stages using one- or two-spooled turbines. In a turbine driving an external load, part of the expansion frequently takes place in a high-pressure turbine that drives only the compressor while the remaining expansion takes place in a separate, “free” turbine connected to the load.

High-performance aircraft engines usually employ multiple spools. A recent large aircraft-engine design operating with an overall pressure ratio of 30.5:1 uses two high-pressure turbine stages to drive 11 high-pressure compressor stages on the outer spool, rotating at 9,860 revolutions per minute, while four low-pressure turbine stages drive the fan for the bypass air as well as four additional low-pressure compressor stages through the inner spool turning at 3,600 revolutions per minute (see below). For stationary units, a total of three to five total turbine stages is more typical.

High temperatures at the turbine inlet and high centrifugal blade stresses necessitate the use of special metallic alloys for the turbine blades. (Such alloys are sometimes grown as single crystals.) Blades subject to very high temperatures also must be cooled by colder air drawn directly from the compressor and fed through internal passages. Two processes are currently used: (1) jet impingement on the inside of hollow blades, and (2) bleeding of air through tiny holes to form a cooling blanket over the outside of the blades.

Control and start-up

In a gas-turbine engine driving an electric generator, the speed must be kept constant regardless of the electrical load. A decrease in load from the design maximum can be matched by burning less fuel while keeping the engine speed constant. Fuel flow reduction will lower the exit temperature of the combustion chamber and, with it, the enthalpy drop available to the turbine. Although this reduces the turbine efficiency slightly, it does not affect the compressor, which still handles the same amount of air. The foregoing method of control is substantially different from that of a steam turbine, where the mass flow rate has to be changed to match varying loads.

An aircraft gas-turbine engine is more difficult to control. The required thrust, and with it engine speed, may have to be changed as altitude and aircraft speed are altered. Higher altitudes lead to lower air-inlet temperatures and pressures and reduce the mass flow rate through the engine. Aircraft now use complex computer-driven controls to adjust engine speed and fuel flow while all critical conditions are monitored continuously.

For start-up, gas turbines require an external motor which may be either electric or, for stationary applications, a small diesel engine.

Advantages

1. It is smaller in size and weight as compared to an equivalent steam power plant. For smaller capacities, the size of the gas turbine power plant is appreciably greater than a high-speed diesel engine plant, but for larger capacities, it is smaller in size than a comparable diesel engine plant. If size and weight are the main consideration such as in ships, aircraft engines and locomotives, gas turbines are more suitable.
2. The initial cost and operating cost of the gas turbine plant are lower than an equivalent steam power plant.

3. The plant requires less water as compared to a condensing steam power plant.
4. The plant can be started quickly and can be put on load in a very short time.
5. There are no standby losses in the gas turbine power plant whereas in steam power plant these losses occur because the boiler is kept in operation even when the turbine is not supplying any load.
6. Maintenance cost of the gas turbine power plant is low and easier to maintain.
7. The lubrication of the plant is easy. In gas turbine plant, lubrication is needed mainly in compressor, turbine main bearing and bearings of auxiliary equipment.
8. The plant does not require massive foundations and building.
9. There is a significant simplification of the plant over a steam plant due to the absence of boilers with their feed water evaporator and condensing system.

Disadvantages

1. The significant part of the work developed by the turbine is used to derive the compressor. Therefore, network output of the plant is low.
2. The temperature of the products of combustion becomes too high, so service conditions become complicated even at moderate pressures.

Applications

1. Gas turbine plants are used as standby plants for the hydroelectric power plants.
2. Gas turbine power plants may be used as peak loads plant and standby plants for smaller power units.
3. Gas turbines are used in jet aircraft and ships. Pulverised fuel-fired plants are used in a locomotive.

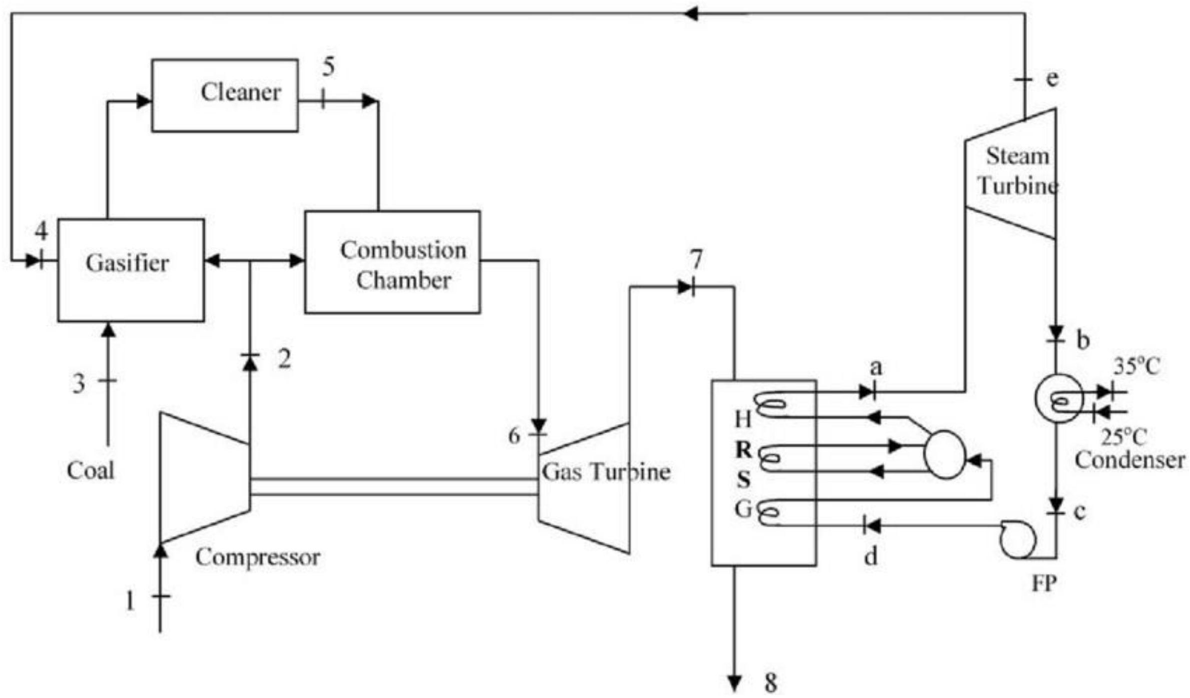
Combined cycle power plants

A combined cycle power plant is an assembly of heat engines that work in tandem from the same source of heat, converting it into mechanical energy. On land, when used to make electricity the most common type is called a combined cycle gas turbine plant.

A combined-cycle power plant uses both a gas and a steam turbine together to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power

A Combined Cycle Power Plant produces high power outputs at high efficiencies (up to 55%) and with low emissions. In a Conventional power plant we are getting 33% electricity only and remaining 67% as waste.

The major components of a combined cycle plant are a gas turbine, a heat recovery steam generator, a steam turbine, and balance of plant systems.



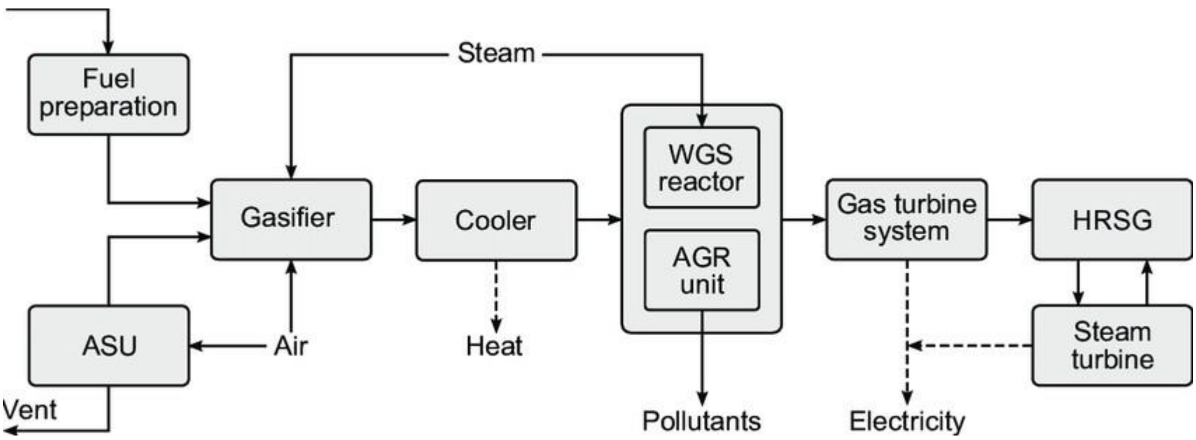
A combined-cycle power plant uses both a gas and a steam turbine together to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power.

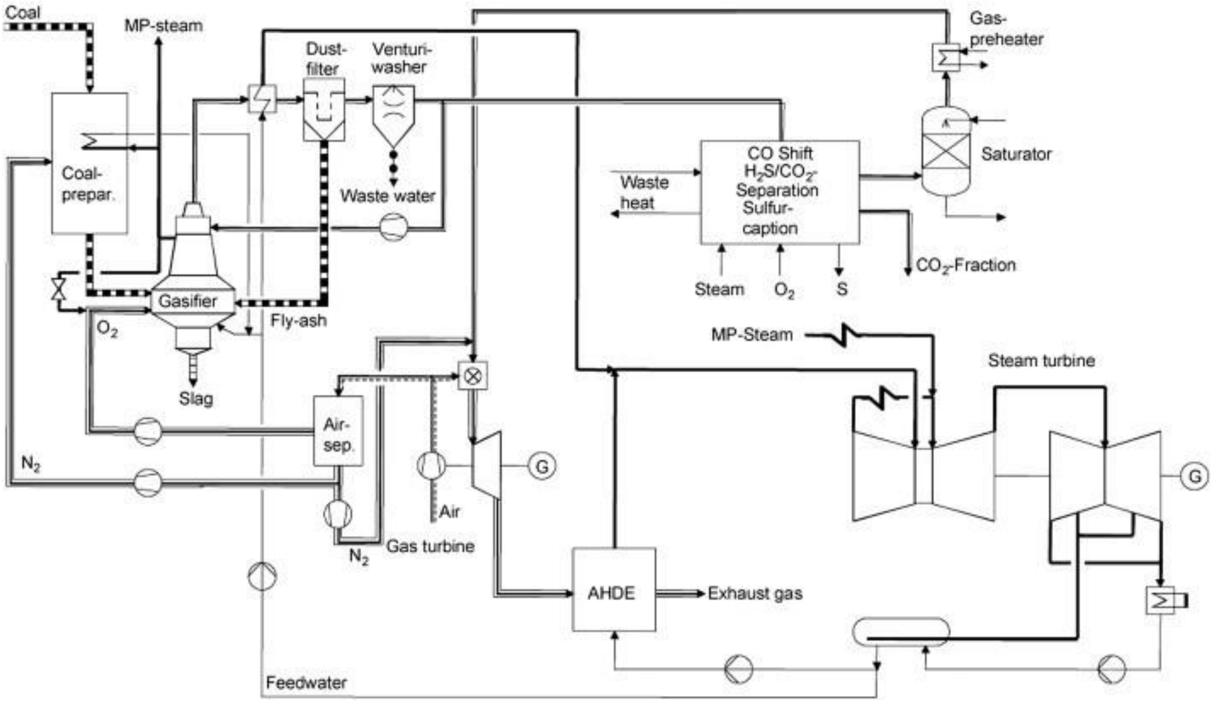
Co-generations uses waste heat for many different processes, such as space heating or drying. Combined-cycle power generation is a two-cycle electricity generation process that uses the heat from the first cycle to run a second cycle.

Integrated Gasifier based Combined Cycle systems

An integrated gasification combined cycle is a technology that uses a high pressure gasifier to turn coal and other carbon based fuels into pressurized gas—synthesis gas. It can then remove impurities from the syngas prior to the power generation cycle.

Integrated coal gasification combined cycle (IGCC) power plants are a next-generation thermal power system with significantly enhanced power generation efficiency and environmental performance due to its combination with coal gasification and the Gas Turbine Combined Cycle (GTCC) system.





A combined-cycle power plant uses both a gas and a steam turbine together to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power.

Combined Cycle Gas Turbines (CCGT) are a form of highly efficient energy generation technology that combines a gas-fired turbine with a steam turbine

Assignment questions (UNIT II)

1. Draw and explain the layout of modern diesel power plant showing the following systems.

i. Fuel supply system
ii. Lubrication system
iii. Supercharging
iv. Engine Starting system

2. Discuss the advantages of combined cycle power generation.

3. Explain the working of GT-ST combined cycle plant.

4. Give the classification of gas turbine power plant? List the essential components of gas turbine power plant and explain them briefly

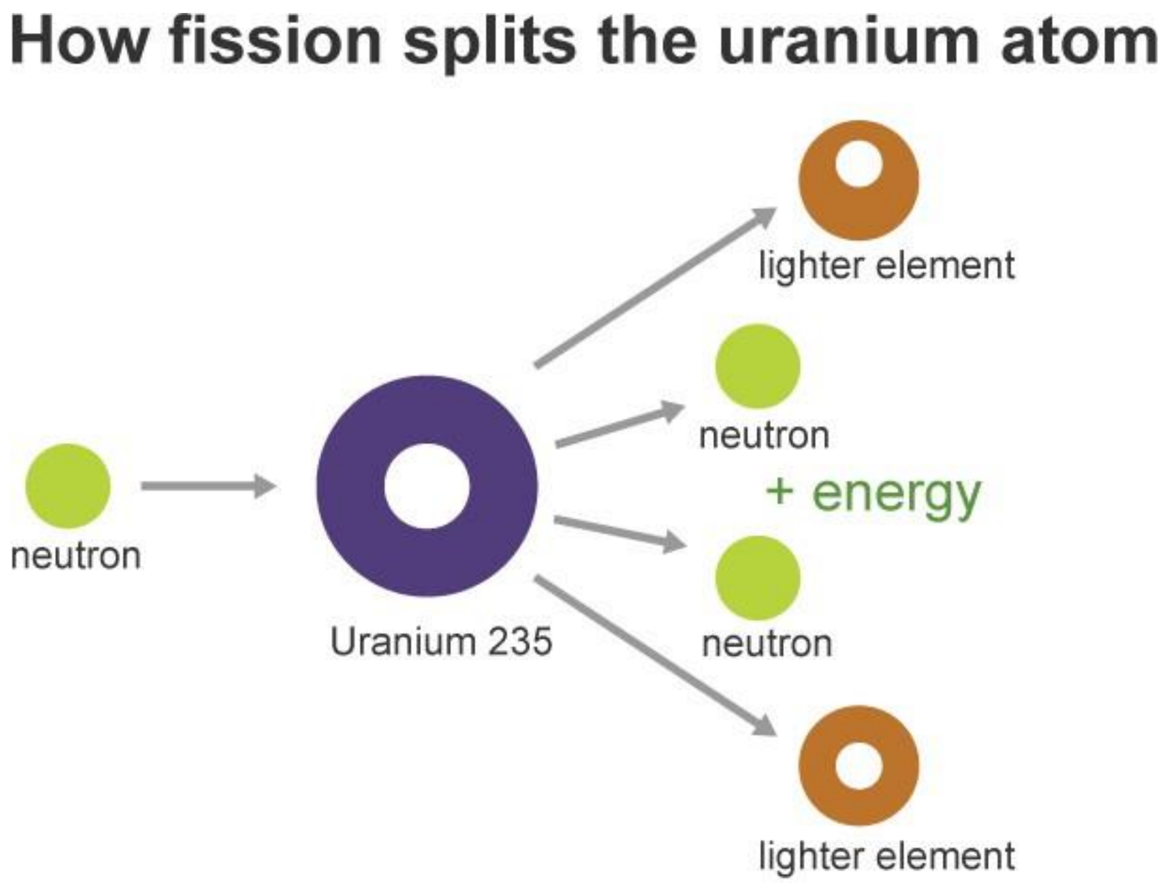
5. Discuss briefly methods available for improving thermal efficiency of a gas turbine plant.

UNIT 3

UNIT III (SYLLABUS)

Introduction to nuclear power

Nuclear power is a clean and efficient way of boiling water to make steam, which turns turbines to produce electricity. Nuclear power plants use low-enriched uranium fuel to produce electricity through a process called fission—the splitting of uranium atoms in a nuclear reactor.



Source: Adapted from National Energy Education Development Project (public domain)

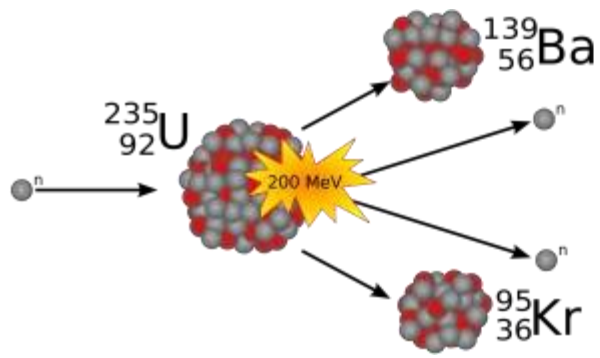
Nuclear fission products are the atomic fragments left after a large atomic nucleus undergoes nuclear fission. Typically, a large nucleus like that of uranium fissions by splitting into two smaller nuclei, along with a few neutrons, the release of heat energy (kinetic energy of the nuclei), and gamma rays.

Fusion only produces more energy than it consumes in small nuclei (in stars, Hydrogen & its isotopes fusing into Helium). The energy released when 4 Hydrogen nuclei (= protons) fuse (there are some decays involved as well) into a Helium nucleus is around 27 Million Electron Volts (MeV), or about 7 MeV per nucleon.

Introduction to Nuclear Reactor

A nuclear reactor, formerly known as an atomic pile, is a device used to initiate and control a self-sustained nuclear chain reaction. Nuclear reactors are used at nuclear power plants for electricity generation and in nuclear marine propulsion.

Before we start with the nuclear reactor, a basic understanding of nuclear fission is necessary. Nuclear fission is the process where the nucleus of a heavy atom splits into fragments of lighter nuclei. This process gives out energy. One of the ways to achieve this is to bombard the nucleus of heavy atoms with neutrinos. Along with producing energy (in terms of the 'missing mass'), the reaction also produces neutrons. These neutrons can be used to split other atoms further in the reaction.



Consider a general energy-producing plant, for example, a plant that burns coal to generate heat energy, which probably runs turbines to generate mechanical energy that can be converted to electricity.

The same thing happens in a nuclear reactor, with the difference that nothing is burnt over here. The reactor is powered using continuous fission reactions to generate a continuous flow of energy.

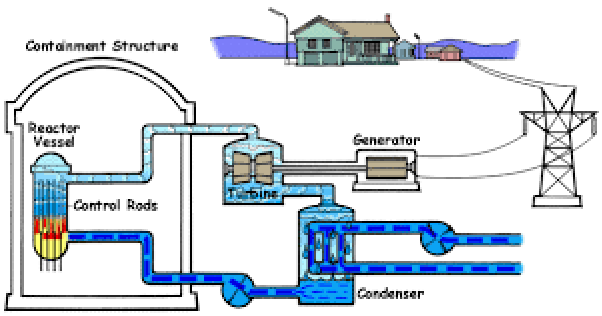
The kinetic energy produced during the fission reaction is converted into thermal energy. The fission products undergo extreme deceleration, where the KE is converted to heat. A neutron moderator can be used to check the speed in a reactor.

The heat produced is transferred to a coolant which is either used directly or indirectly by converting into steam. This can be used to operate turbines, thereby converting the thermal energy into mechanical energy.

In India, nuclear power is the 4th largest source of electricity generation. We have around 21 nuclear power reactors operating from around 7 plants over the country.

Main Components of a Nuclear Reactor:

• **The Core:** It contains all the fuel and generates the heat required for energy production.
• **The Coolant**: It passes through the core, absorbing the heat and transferring into turbines
• **The Turbine**: Transfers energy into the mechanical form
• **The Cooling Tower**: It eliminates the excess heat that is not converted or transferred
• **The Containment**: The enveloping structure that separated the nuclear reactor from the surrounding environment.



Components of a nuclear reactor

- Fuel. Uranium is the basic fuel.
- Moderator. Material in the core which slows down the neutrons released from fission so that they cause more fission.
- Control rods.
- Coolant.
- Pressure vessel or pressure tubes.
- Steam generator.
- Containment.
- Nuclear power plants in commercial operation or operable.

Fuel

Uranium is the basic fuel. Usually pellets of uranium oxide (UO2) are arranged in tubes to form fuel rods. The rods are arranged into fuel assemblies in the reactor core.* In a 1000 MWe class PWR there might be 51,000 fuel rods with over 18 million pellets.

Moderator

Material in the core which slows down the neutrons released from fission so that they cause more fission. It is usually water, but may be heavy water or graphite.

Control rods

These are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the core to control the rate of reaction, or to halt it.* In some PWR reactors, special control rods are used to enable the core to sustain a low level of power efficiently. (Secondary control systems involve other neutron absorbers, usually boron in the coolant – its concentration can be adjusted over time as the fuel burns up.) PWR control rods are inserted from the top, BWR cruciform blades from the bottom of the core.

Coolant

A fluid circulating through the core so as to transfer the heat from it. In light water reactors the water moderator functions also as primary coolant. Except in BWRs, there is secondary coolant circuit where the water becomes steam. (See also later section on primary coolant characteristics.) A PWR has two to four primary coolant loops with pumps, driven either by steam or electricity – China's Hualong One design has three, each driven by a 6.6 MW electric motor, with each pump set weighing 110 tonnes.

Pressure vessel or pressure tubes

Usually a robust steel vessel containing the reactor core and moderator/coolant, but it may be a series of tubes holding the fuel and conveying the coolant through the surrounding moderator.

Steam generator

Part of the cooling system of pressurised water reactors (PWR & PHWR) where the high-pressure primary coolant bringing heat from the reactor is used to make steam for the turbine, in a secondary circuit. Essentially a heat exchanger like a motor car radiator.* Reactors have up to six 'loops', each with a steam generator.

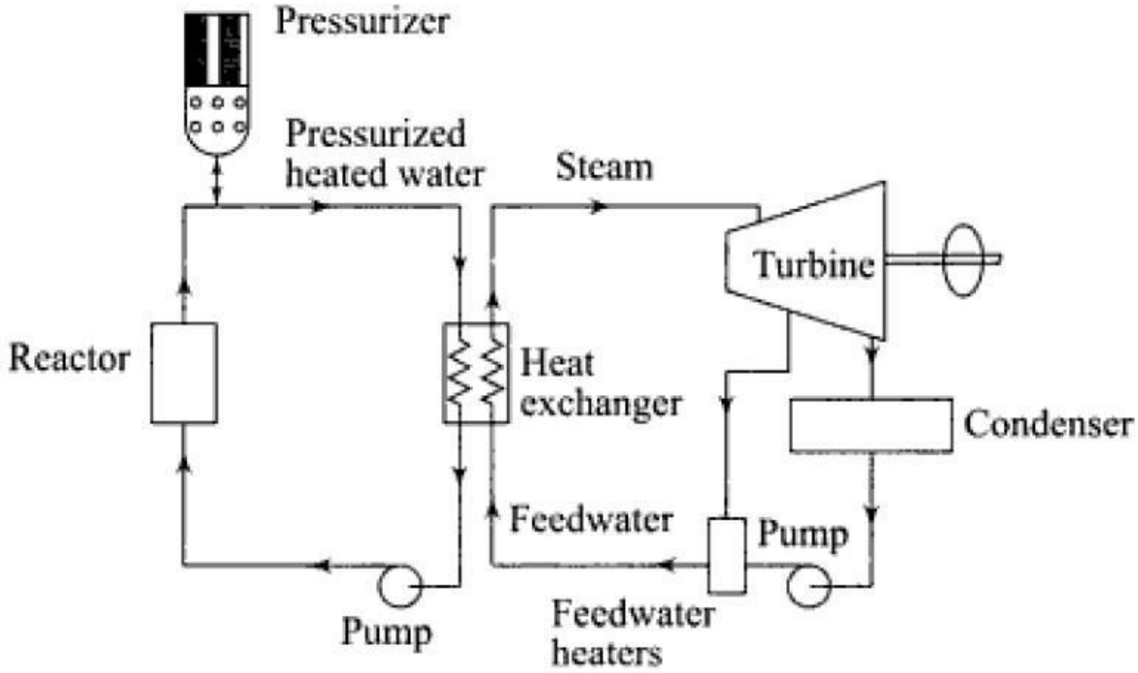
Containment

The structure around the reactor and associated steam generators which is designed to protect it from outside intrusion and to protect those outside from the effects of radiation in case of any serious malfunction inside. It is typically a metre-thick concrete and steel structure.

Newer Russian and some other reactors install core melt localisation devices or 'core catchers' under the pressure vessel to catch any melted core material in the event of a major accident.

Types of Reactors

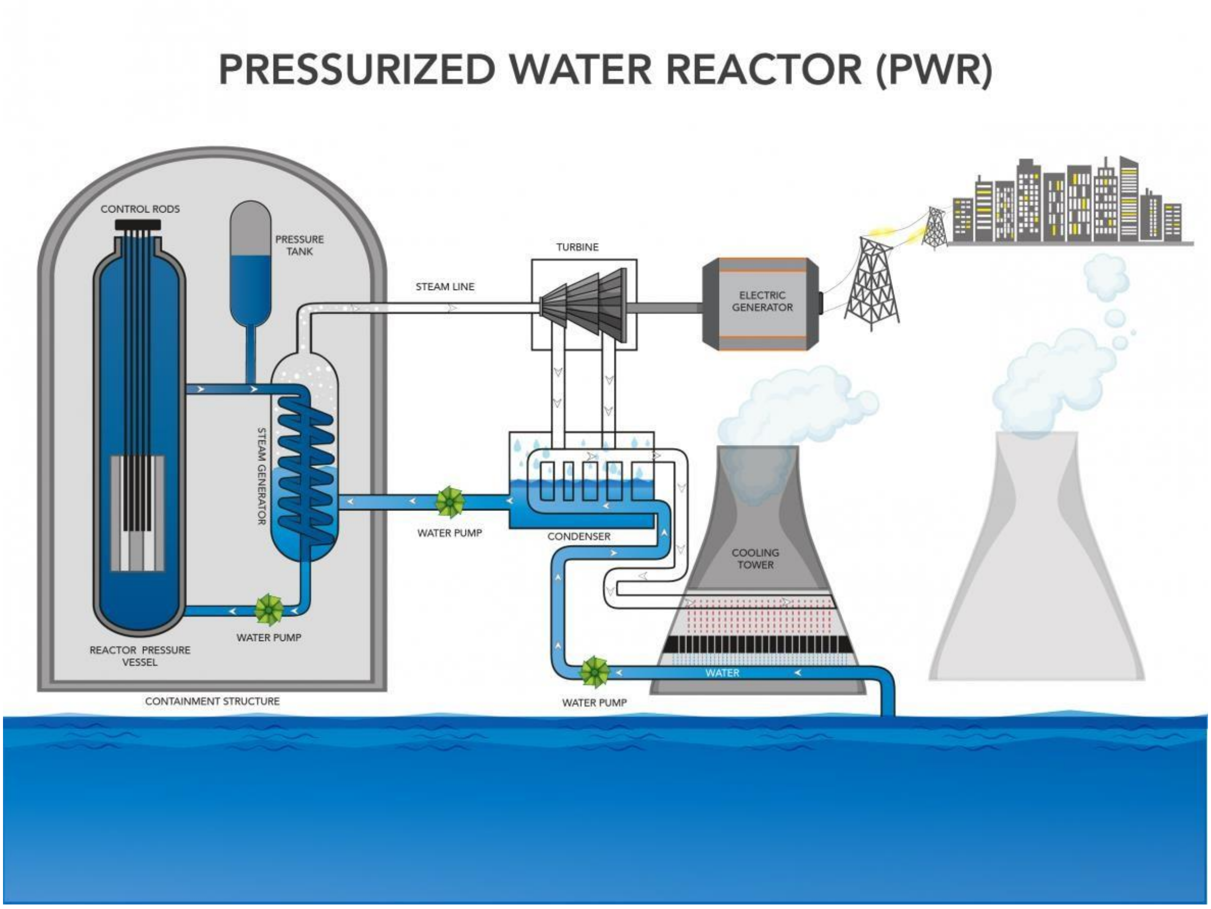
Pressurized Water Reactor



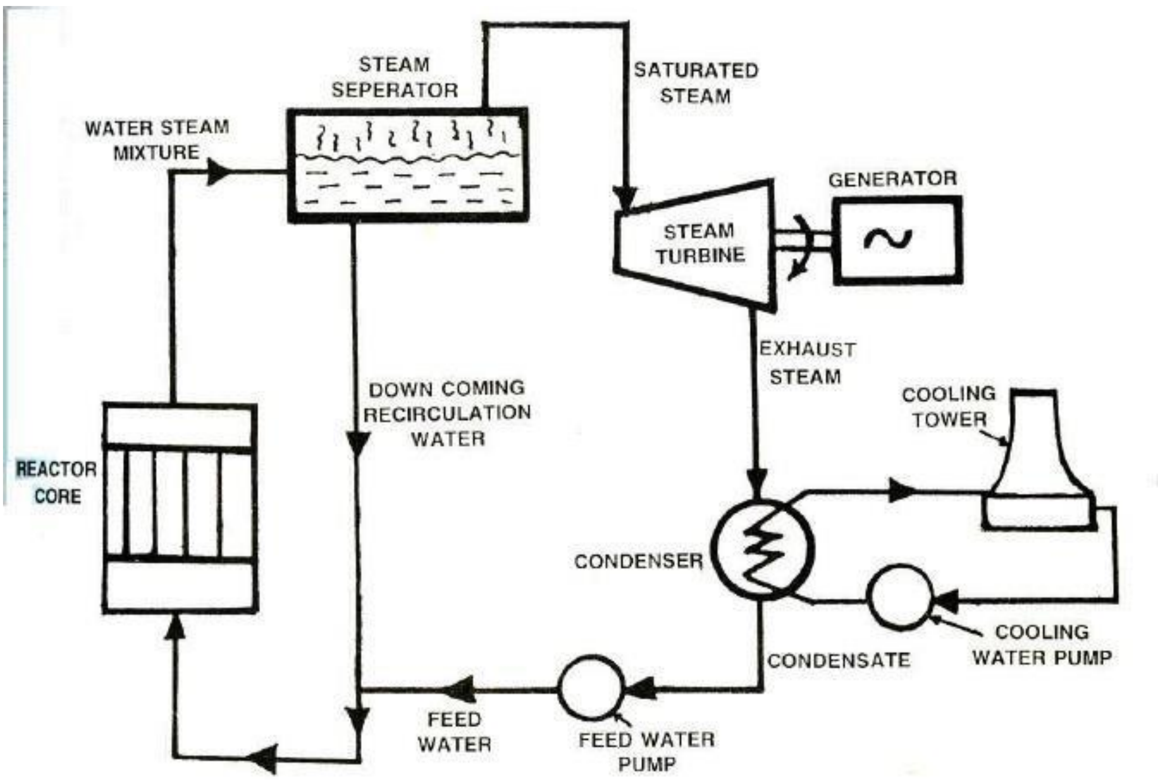
More than 65% of the commercial reactors in the United States are pressurized-water reactors or PWRs. These reactors pump water into the reactor core under high pressure to prevent the water from boiling.

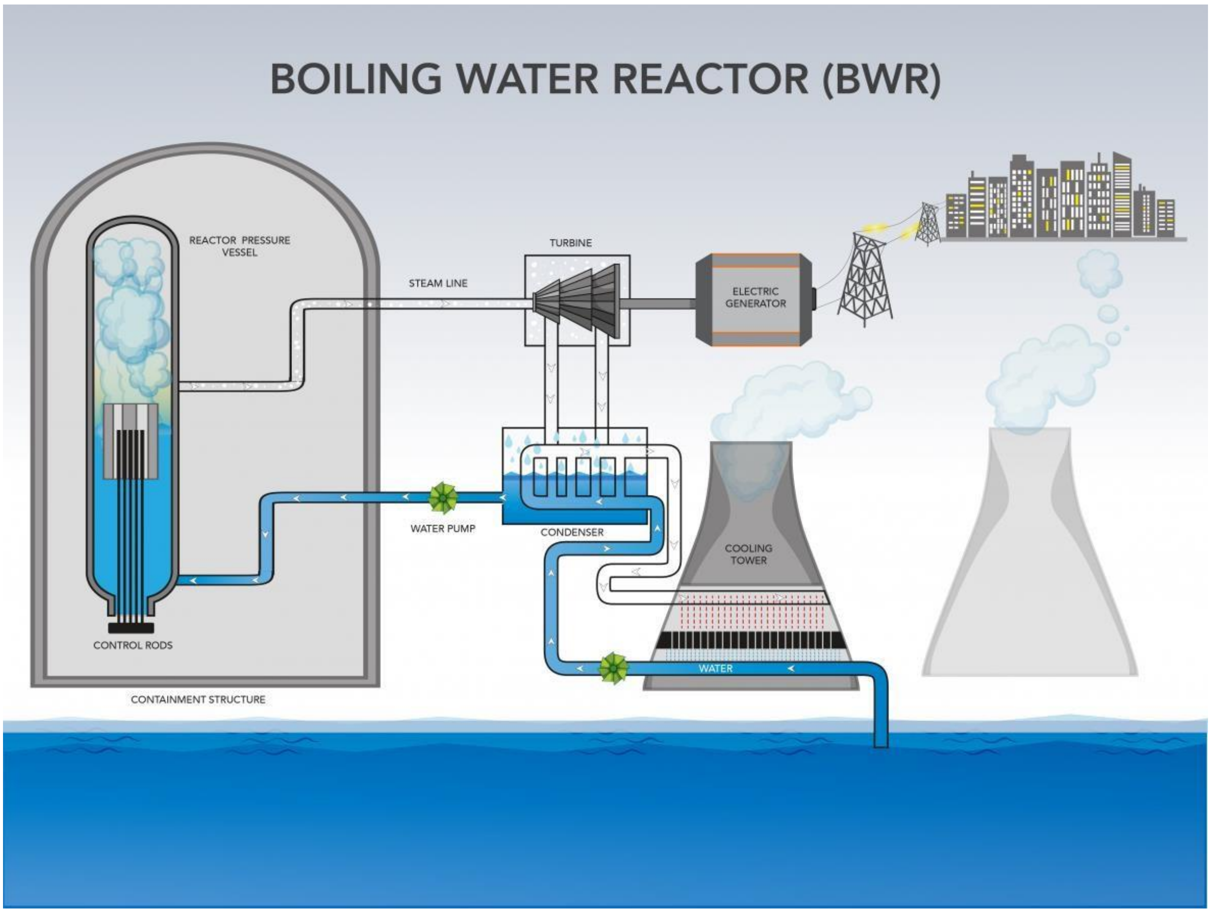
The water in the core is heated by nuclear fission and then pumped into tubes inside a heat exchanger. Those tubes heat a separate water source to create steam. The steam then turns an electric generator to produce electricity.

The core water cycles back to the reactor to be reheated and the process is repeated.



Boiling Water Reactor



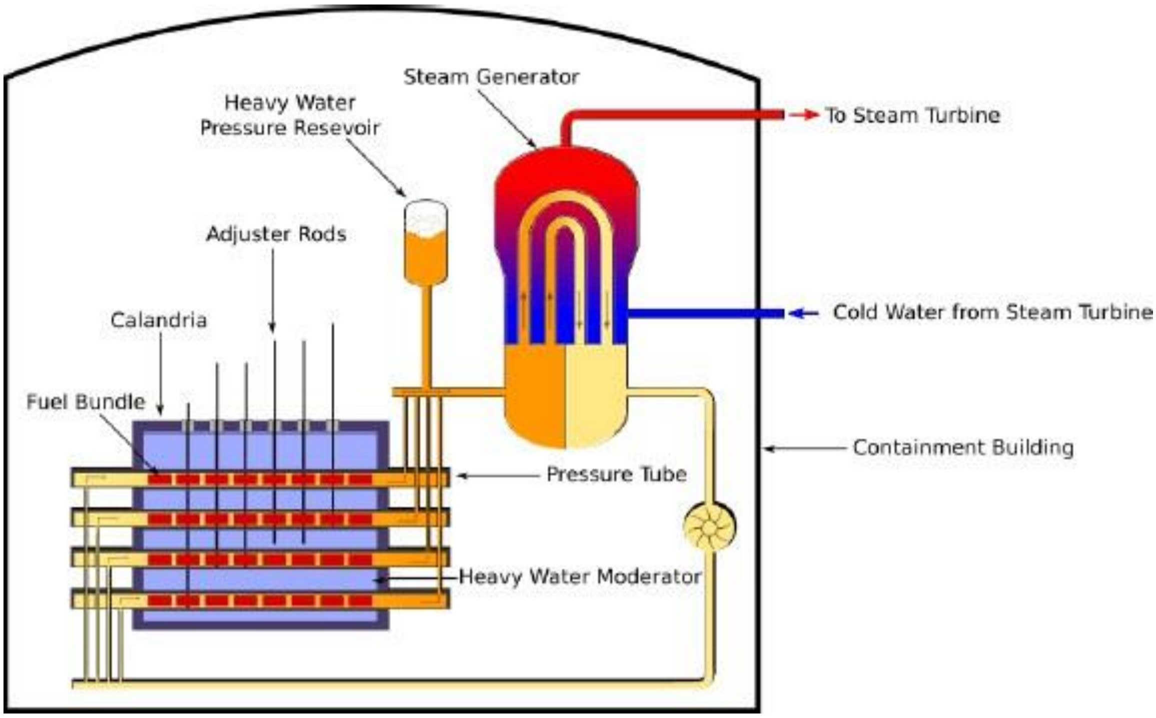


Roughly a third of the reactors operating in the United States are boiling water reactors (BWRs).

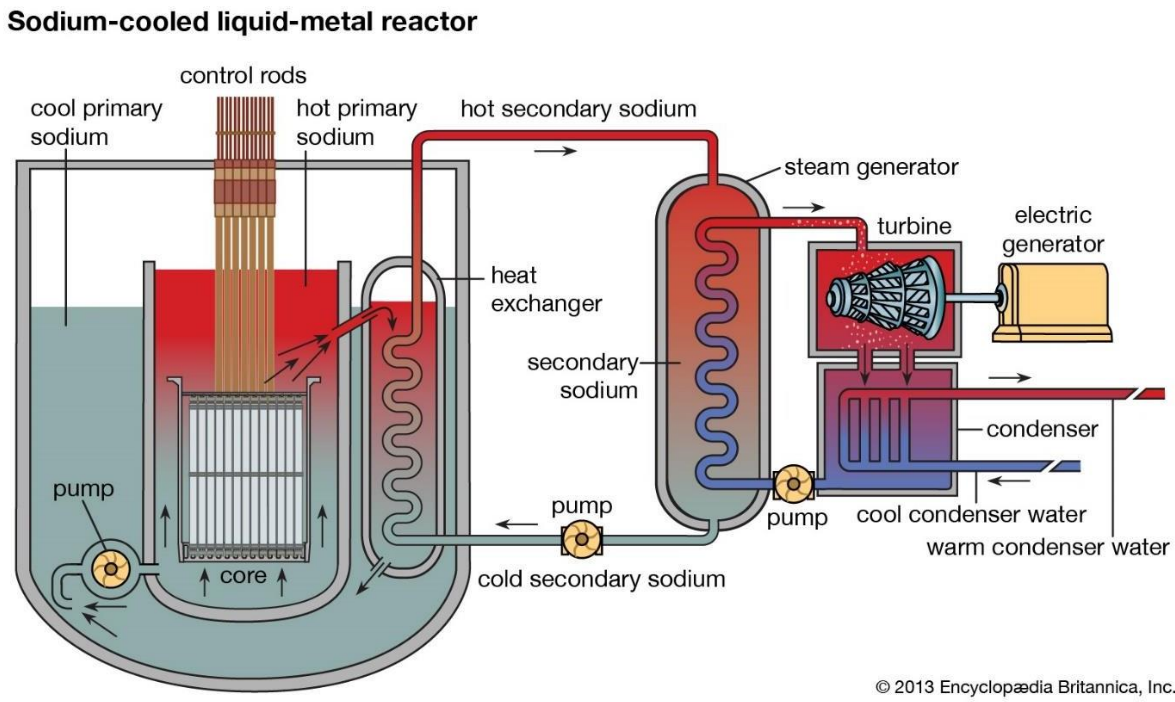
BWRs heat water and produce steam directly inside the reactor vessel. Water is pumped up through the reactor core and heated by fission. Pipes then feed the steam directly to a turbine to produce electricity.

The unused steam is then condensed back to water and reused in the heating process.

CANDU Reactor

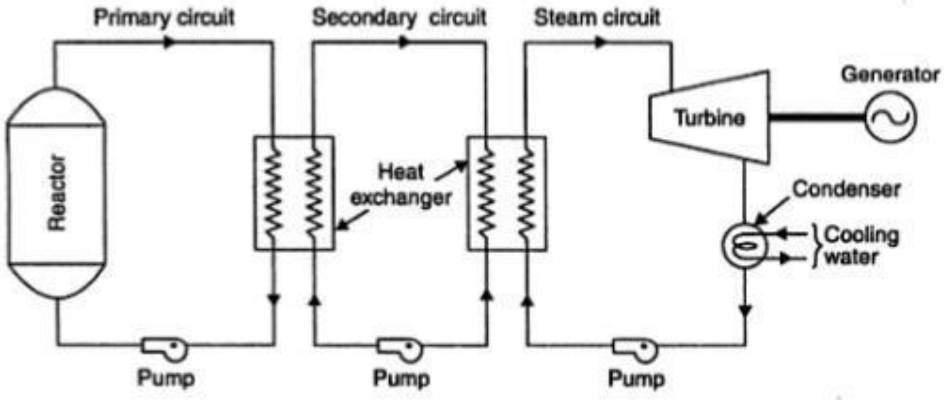


Liquid metal cooled reactor

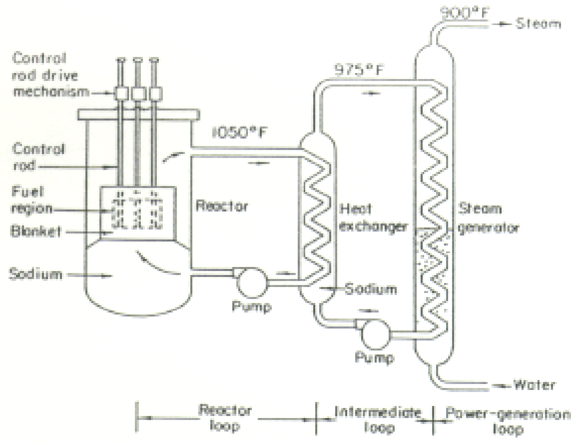


Liquid Metal Cooled Reactor

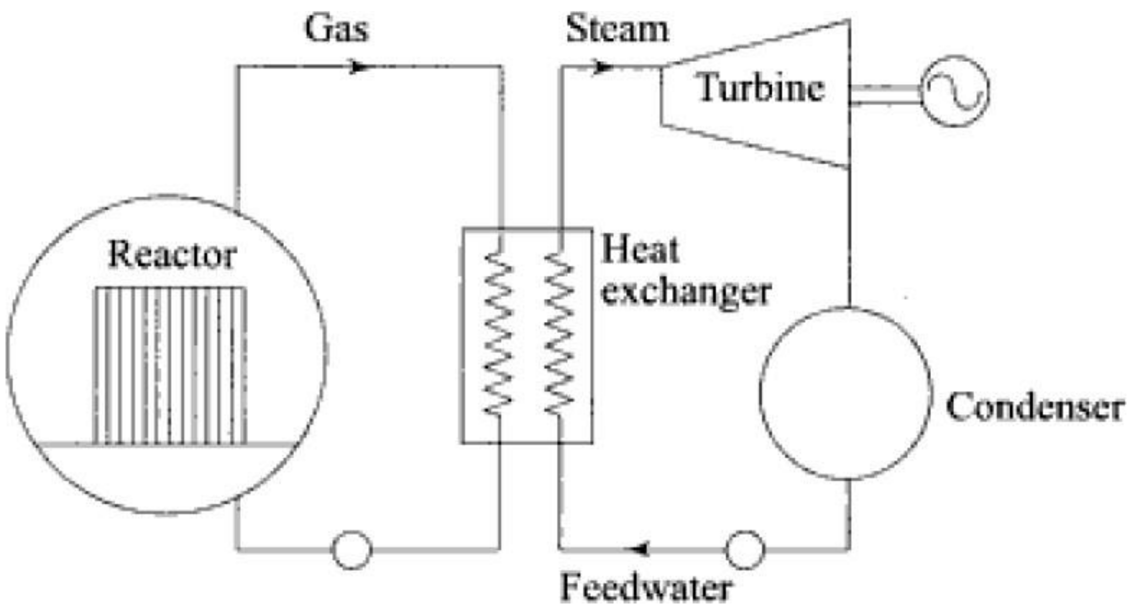
- Liquid metal reactor also called as **Sodium graphite reactor**
- Sodium works as a coolant and graphite works as moderator.
- Sodium boils at 880deg C, sodium is first melted by electric heating system and be pressurized to 7 bars. The liquid sodium is then circulated by the pump.



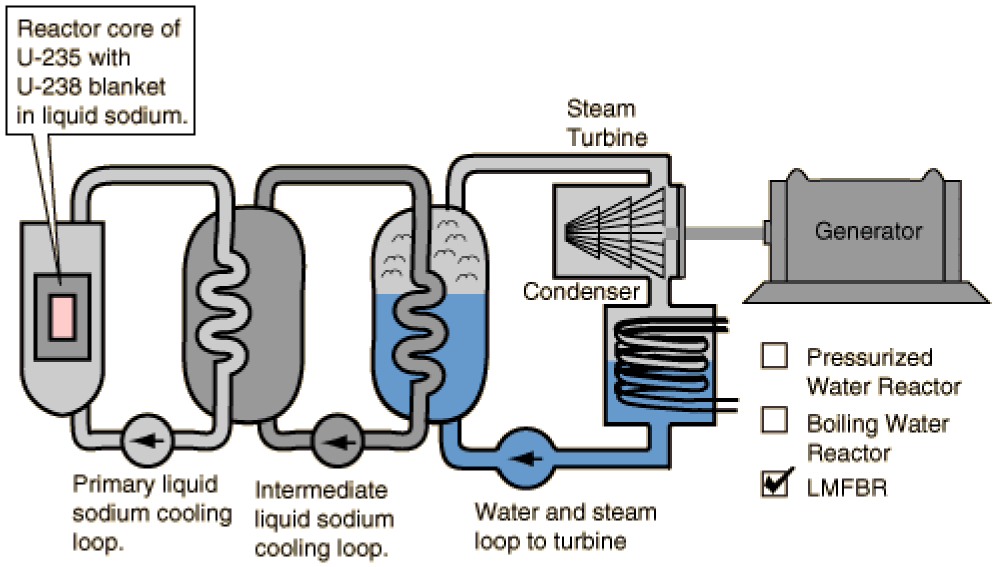
Liquid metal-cooled reactor.



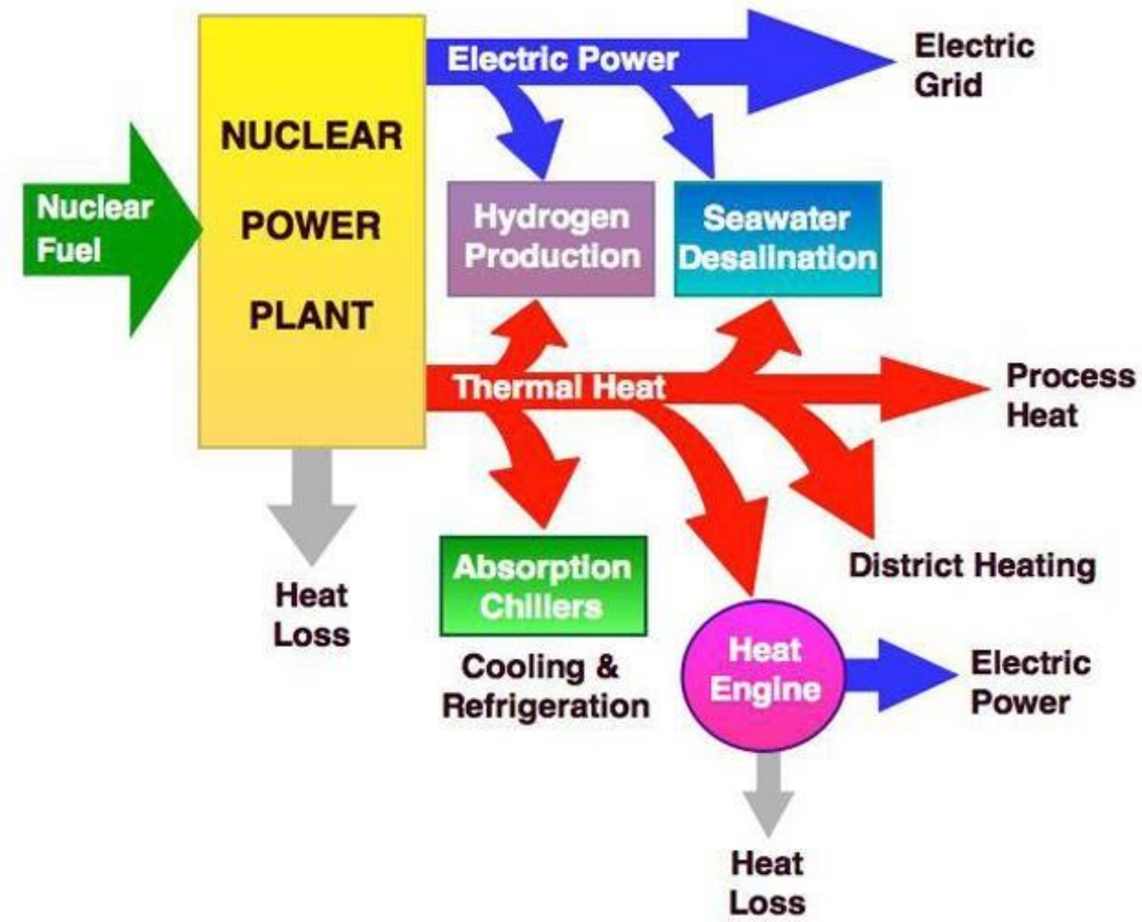
Gas cooled reactor

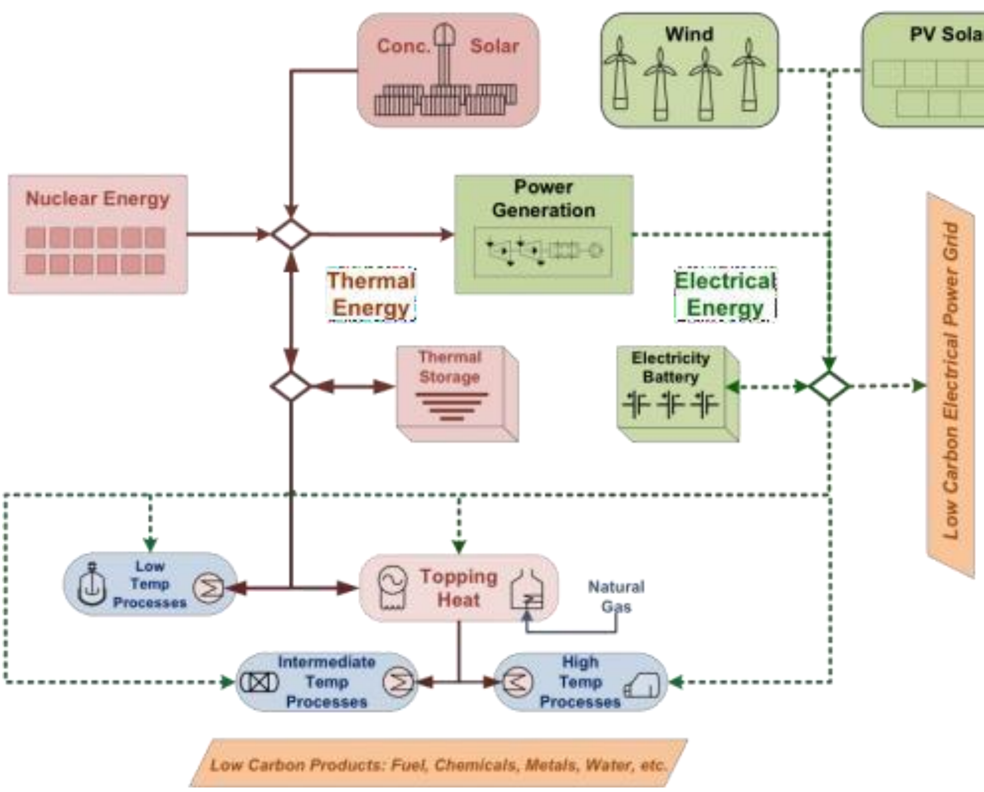


Fast breeder reactor



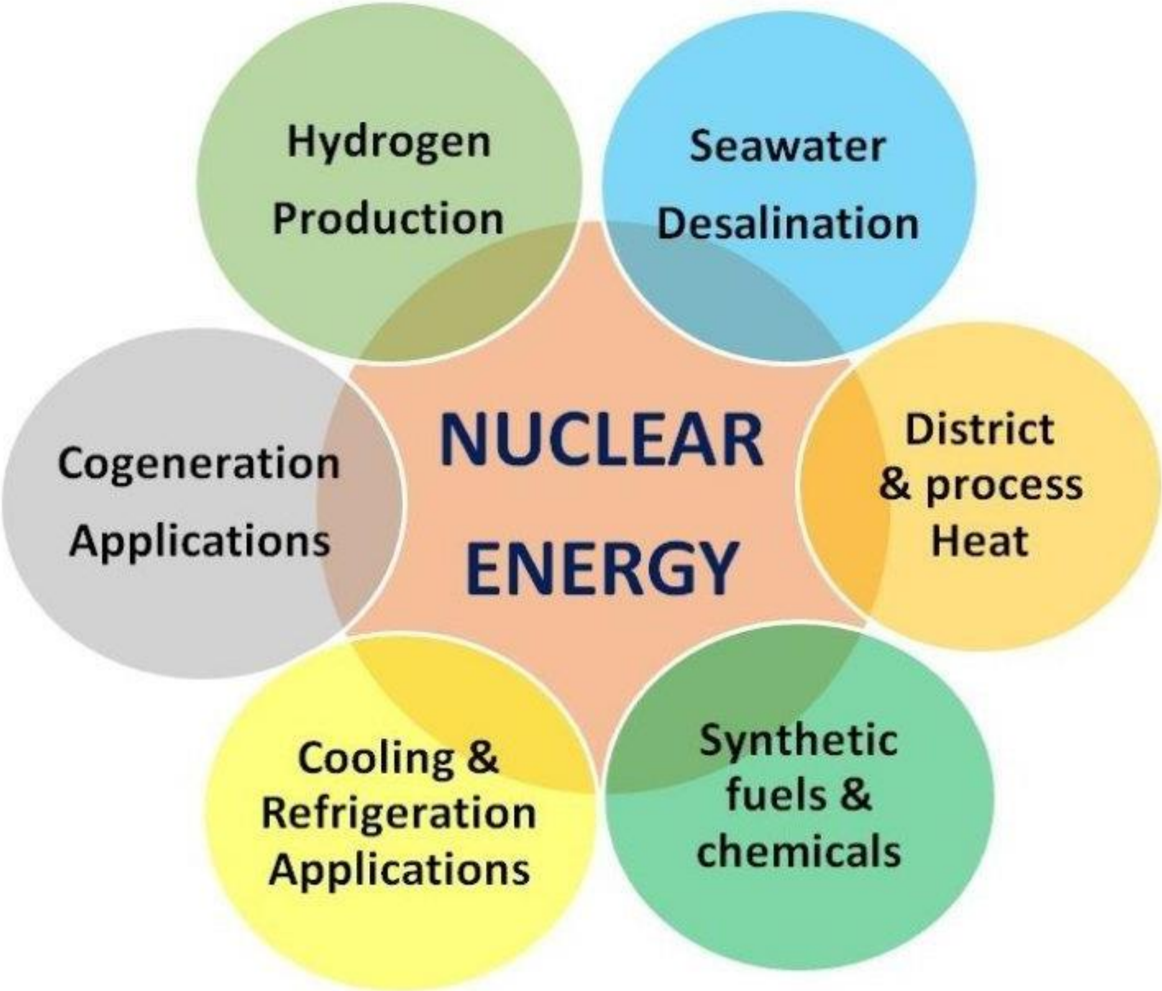
Industrial applications of nuclear cogeneration





Countries with Operating Nuclear Reactors

Country	Number of Operating Reactors
USA	99
France	58
Japan	43
Russia	34
China	26 (28 under construction)
South Korea	24
India	21
Canada	19
United Kingdom	16


Hydrogen
Production
Seawater
Desalination
Cogeneration
Applications
NUCLEAR
ENERGY
District
& process
Heat
Cooling &
Refrigeration
Applications
Synthetic
fuels &
chemicals

Advantages and disadvantages of nuclear energy

Advantages:

- -cause less pollution
- -it produce no greenhouse gases
- -small amount is needed for a large quantity of energy
- -it is reliable

Disadvantages

- -it is dangerous if we use it improerly
- - its spent fuel is dangerous and safety storage facility for it

Safety measures for Nuclear Power plants

23

SAFETY MEASURES IN NUCLEAR REACTOR CONTROL

Internal and External Hazards

Internal hazards

- Fire
- Explosion
- Flooding
- Missiles
  (e.g. from high energy components)
- Heavy load drop
  (e.g. from structural failures
  or crane failures)

External Hazards

Natural Hazards

- Earthquake
- Flooding
- Storm
- Lightning
- Other meteorological hazards

Man-made Hazards

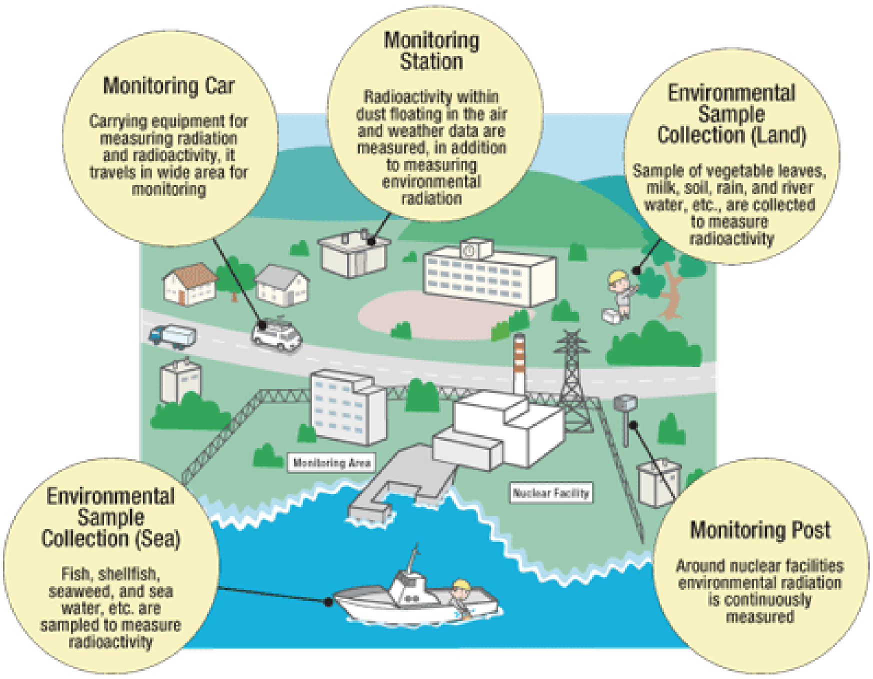
- Explosion (off-site)
- Fire (off-site)
- Aviation accidents

Typical exceedance probabilities for the design basis events: 10^{-4} - 10^{-5} per year

SAFETY MEASURES IN NUCLEAR REACTOR CONTROL

- The radioactivity of the fission products which accumulate in the fuel during reactor operation has an important influence on design of nuclear reactors.
- Accidents: Three mile island, Chernobyl, Fukushima Daichi.
- Radioactive material in the air or water constitutes a potential health hazard, special precautions should be taken.
- Nuclear energy can turn into a devastating enemy if handled without care and precautions.
- The engineered safety features are designed to prevent or minimize the escape of radioactive fission products present in the fuel.

Environmental Radiation Monitoring around Nuclear Facilities



Safety Measures for Nuclear Power Plants

- A nuclear power plant should be constructed **away** from human habitation (exclusion zone of 160km radius)
- The materials used for construction should be of **required standards.**
- Waste **water** should be **purified**.
- Should have a proper safety system, **plant** could be **shut down** when required.
- Regular **periodic checks** to be performed to evaluate not to exceed the permissible radioactivity value
- While **disposing** off the **wastes** it should be ensured that it doesn't contaminate the **river or sea**.

ASSIGNMENT QUESTIONS (UNIT III)

1. Nuclear power plant Layout and working procedure.
2. Define nuclear fission, nuclear fusion and chain reaction.
3. Draw nuclear reactor mark all the components and working.
4. Draw the schematic of the following reactors
   i. PWR
   ii. BWR
   iii. CANDU
5. Draw the schematic of the following reactors
   i. Liquid metal cooled reactor
   ii. GCR
   iii. Fast Breeder Reactor
6. Write the advantages, disadvantages and applications of nuclear power plants.