Sudan University of Science and Technology

College of Engineering

School of Mechanical Engineering

Power Department

CALCULATON OF UM-DABAKIR THERMAL EFFICIENCY

حساب الكفاءة الحرارية **لمحطة ام دباكر**

Project Submitted in Fulfillment for The Requirements of The Degree of B.Sc. (Honors) In Mechanical Engineering

(Power Department)

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الآيــــة

قال تعالى:

﴿ أَوَلَمْ يَرَ الَّذِينَ كَفَرُوا أَنَّ السَّمَاوَاتِ وَالْأَرْضَ كَانَتَا رَتْقًا فَفَتَقْنَاهُمَا وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ أَفَلَا يُؤْمِنُونَ ﴾

صدق الله العظيم

سورة الأنبياء الآية ﴿ ٣٠ ﴾

Dedication

To the fountain of patience and optimism and hope

To each of the following in the presence of God and His Messenger, my mother dear

To those who have demonstrated to me what is the most beautiful of my brother's life

To the big heart my dear father

To the people who paved our way of science and knowledge

All our teachers Distinguished

To the taste of the most beautiful moments with my friends

I guide this research.

Appreciation

Firstly we thank Allah for the blessings He has bestowed upon us by completing this research and secondly Our humble gratitude to Eng.Abdalla Mukhtarwho has been a great mentor to us and didn't save his time in order to help us.

Special thanks to the engineers in Um-Dabakir power station and to the engineers in Bahri power station to everyone contributed to make it possible to us.

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5-	picture taken from a computer in central control
6-	a picture shows the chimney

Abstract

This research studies Um-Dabakir power plant station as a case study for it has the highest efficiency in thermal generation for steam turbine power plants in Sudan. Field study has been conducted to study the environment in which the station is functioning. The needed parameters for the calculation of the efficiency have been studied and we found that the efficiency is the highest in Sudan. Regarding the economical sides, the station uses the optimum fuel which is available in Sudan with low costs (crude oil).

A computer program (MATLAB) has been used to calculate the thermal efficiency to the station.

التجريد

يتناول هذا البحث دراسة حساب الكفاءة لمحطات التوليد الحراري بواسطة **البخار** (لمحطة أم دباكر الحرارية)، حيث تم أخذ محطة أم دباكر للتوليد الحراري كدراسة حاله كونها المحطة الأعلى كفاءة بين محطات التوليد الحراري في السودان، و أستخدم برنامج الحاسوب **(ماتلاب)** لإيجاد الكفاءة للمحطة.

و تم القيام بزيارات ميدانية لمحطة أم دباكر وأخذت المعايير و القراءات المطلوبة لعمليات حساب الكفاءة لهذه المحطة.

و بعد إجراء هذه العمليات الحسابية التقليدية تم حساب الكفاءة و وجد أنها المحطة هي الأعلى كفاءة في المحطات الحرارية بواسطة البخار قي السودان.

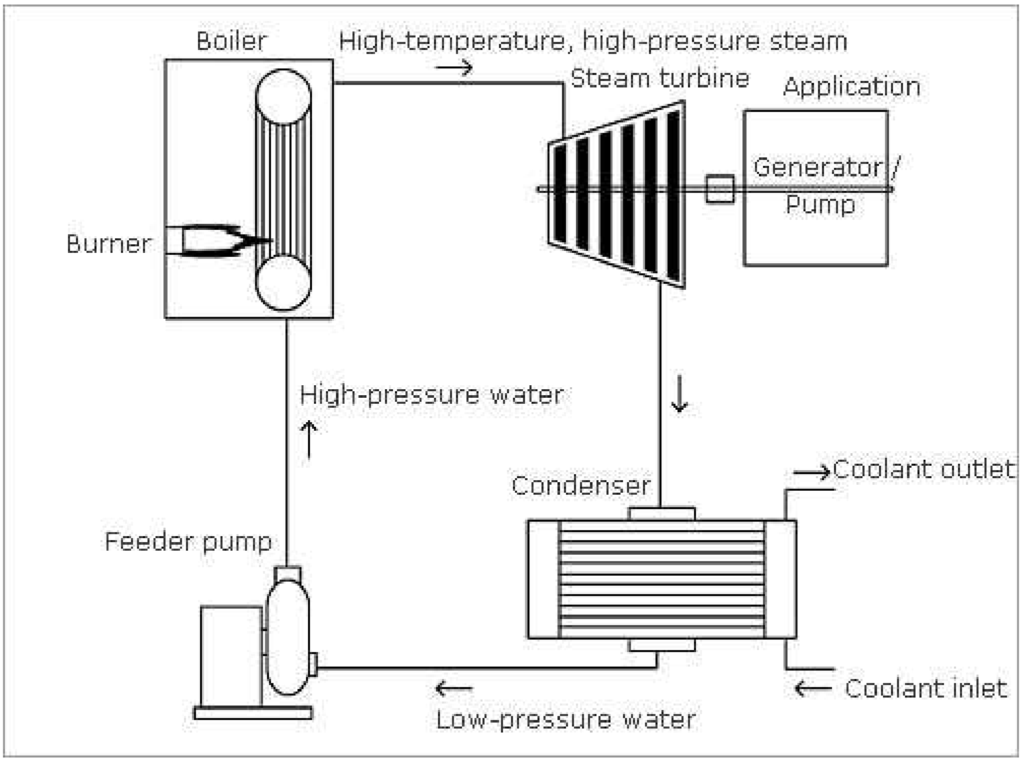
و من الناحية الاقتصادية وجد أن المحطة تستخدم الوقود الأمثل لتشغيلها و ذلك حسب الوقود المتوفر في السودان و هو البترول الخام بإعتباره الوقود الأرخص و الأكثر وفرة.

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Steam is an important medium of producing mechanical energy. Steam has the advantage that, it can be raised from water which is available in abundance it does not react much with the materials of the equipment of power plant and is stable at the temperature required in the plant. Steam is used to drive steam engines, steam turbines etc. Steam power station is most suitable where coal is available in abundance. Thermal electrical power generation is one of the major method. Out of total power developed in world about 60% is thermal. For a thermal power plant the range of pressure may vary from 10 bar to super critical pressures and the range of temperature may be from 250°C to 650°C.



essentials of steam power plant equipment(1.1)

1.2 Steam power plant must have following equipments:

1. A furnace to burn the fuel.
2. Steam generator or boiler containing water. Heat generated in the furnace is utilized to convert water into steam.
3. Main power unit such as an engine or turbine to use the heat energy of steam and perform work.
4. Piping system to convey steam and water.

In addition to the above equipment the plant requires various auxiliaries and accessories depending upon the availability of water, fuel and the service for which the plant is intended.

1.2.1The flow sheet of a thermal power plant consists of the following four main circuits:

(*i*) Feed water pump and steam flow circuit

(*ii*) Coal and ash circuit

(*iii*) Air and gas circuit

(*iv*) Cooling water circuit.

A steam power plant using steam as working substance works basically on Rankine cycle. Steam is generated in a boiler, expanded in the prime mover and condensed in the condenser and fed into the boiler again.

1.2.2The different types of systems and components used in steam power plant are as follows:

(*i*) High pressure boiler

(*ii*) Prime mover

(*iii*) Condensers and cooling towers

(*iv*) Coal handling system

(*v*) Ash and dust handling system

(*vi*) Draught system

(*vii*) Feed water purification plant

(*viii*) Pumping system

(*ix*) Air pre-heater, economizer, super heater, feed heaters.

This shows a schematic arrangement of equipment of a steam power station. Coal received in coal storage yard of power station is transferred in the furnace by coal handling unit. Heat produced due to burning of coal is utilized in converting water contained in boiler drum into steam at suitable pressure and temperature. The steam generated is passed through the super heater. Superheated steam then flows through the turbine. After doing work in the turbine die pressure of steam is reduced. Steam leaving the turbine passes through the condenser which maintain the low pressure of steam at the exhaust of turbine. Steam pressure in the condenser depends upon flow rate and temperature of cooling water and on effectiveness of air removal equipment. Water circulating through the condenser may be taken from the various sources such as river, lake or sea. If sufficient quantity of water is not available the hot water coming out of the condenser may be cooled in cooling towers and circulated again through the condenser. Bled steam taken from the turbine at suitable extraction points is sent to low pressure and high pressure water heaters. Super heater tubes, flow through the dust collector and then through economizer, air pre-heater and finally They are exhausted to the atmosphere through the chimney.

1.2.3Steam condensing system consists of the following:

(*i*) Condenser

(*ii*) Cooling water

(*iii*) Cooling tower

(*iv*) Hot well

(*v*) Condenser cooling water pump

(*vi*) Condensate air extraction pump

(*vii*) Air extraction pump

(*viii*) Boiler feed pump

(*ix*) Make up water pump.

1.3 POWER STATION DESIGN:

1.3.1 Power station design requires wide experience. A satisfactory design consists of the following steps:

(i) Selection of site

(ii) Estimation of capacity of power station.

(iii) Selection of turbines and their auxiliaries.

(iv) Selection of boilers, and their auxiliaries.

(v) Design of fuel handling system.

(vi) Selection of condensers.

(vii) Design of cooling system.

(viii) Design of piping system to carry steam and water.

(ix) Selection of electrical generator.

(x) Design and control of instruments.

(xi) Design of layout of power station. Quality of coal used in steam power station plays an important role in the design of power plant. The various factors to be considered while designing the boilers and coal handling units are as follows :

(*a*) Slogging and erosion properties of ash.

(*b*) Moisture in the coal. Excessive moisture creates additional problems particularly in case of pulverized fuel power plants.

(*c*) Burning characteristic of coal.

(*d*) Corrosive nature of ash.

1.4 Steam Turbine:

Steam turbine is one of the most important prime mover for generating electricity. This falls under the category of power producing turbo machines. In the turbine, the energy level of the working fluid goes on decreasing along the flow stream. Single unit of steam turbine can develop power ranging from 1 MW to 1000 MW. In general, 1 MW, 2.5 MW, 5 MW, 10 MW, 30 MW, 120 MW, 210 MW, 250 MW,350 MW, 500 MW, 660 MW, 1000 MW are in common use. The thermal efficiency of modern steam power plant above 120 MW is as high as 38% to 40%.The purpose of turbine technology is to extract the maximum quantity of energy from the working fluid, to convert it into useful work with maximum efficiency, by means of a plant having maximum reliability, minimum cost, minimum supervision and minimum starting time.

1.4.1 Principle of operation of steam turbine

The principle of operation of steam turbine is entirely different from the steam engine. In reciprocating steam engine, the pressure energy of steam is used to overcome external resistance and the dynamic action of steam is negligibly small. But the steam turbine depends completely upon the dynamic action of the steam. According to Newton's Second Law of Motion, the force is proportional to the rate of change of momentum (mass × velocity). If the rate of change of momentum is caused in the steam by allowing a high velocity jet of steam to pass over curved blade, the steam will impart a force to the blade. If the blade is free, it will move off (rotate) in the direction of force. In other words, the motive power in a steam turbine is obtained by the rate of change in moment of momentum of a high velocity jet of steam impinging on a curved blade which is free to rotate. The steam from the boiler is expanded in a passage or nozzle where due to fall in pressure of steam, thermal energy of steam is converted into kinetic energy of steam, resulting in the emission of a high velocity jet of steam which, Principle of working impinges on the moving vanes or blades of turbine

1.4.2 The main types of steam turbine

(*i*) **Impulse Turbine:**

If the flow of steam through the nozzles and moving blades of a turbine takes place in such a manner that the steam is expanded only in nozzles and pressure at the outlet sides of the blades is equal to that at inlet side; such a turbine is termed as impulse turbine because it works on the principle of impulse. In other words, in impulse turbine, the drop in pressure of steam takes place only in nozzles and not in moving blades. This is obtained by making the blade passage of constant cross- section area.

As a general statement it may be stated that energy transformation takes place only in nozzles and moving blades (rotor) only cause energy transfer. Since the rotor blade passages do not cause any acceleration of fluid, hence chances of flow separation are greater which results in lower stage efficiency.

(*ii*) Impulse-Reaction Turbine:

In this turbine, the drop in pressure of steam takes place in *fixed* (*nozzles*) *as well as moving blades.* The pressure drop suffered by steam while passing through the moving blades causes a further generation of kinetic energy within the moving blades, giving rise to reaction and adds to the propelling force which is applied through the rotor to the turbine shaft. Since this turbine works on the principle of impulse and reaction both, so it is called impulse-reaction turbine. This is achieved by making the blade passage of varying cross-sectional area (*converging type*).

In general, it may be stated that energy transformation occurs in both fixed and moving blades. The rotor blades cause both energy transfer and transformation. Since there is an acceleration of flowin moving blade passage hence chances of separation of flow is less which results in higher stage efficiency.

The disadvantages of steam power plant:

1-low efficient than diesel plants

2- starting up and bringing into the services take more time.

3-Cooling water required is more.

4-Space required is more.

5-Storage required for the fuel is more.

6-Ash handling is a big problem.

7- Not economical in areas which are remote from coal fields.

8-Manpower required is more.

9-For large units, the capital cost is more.

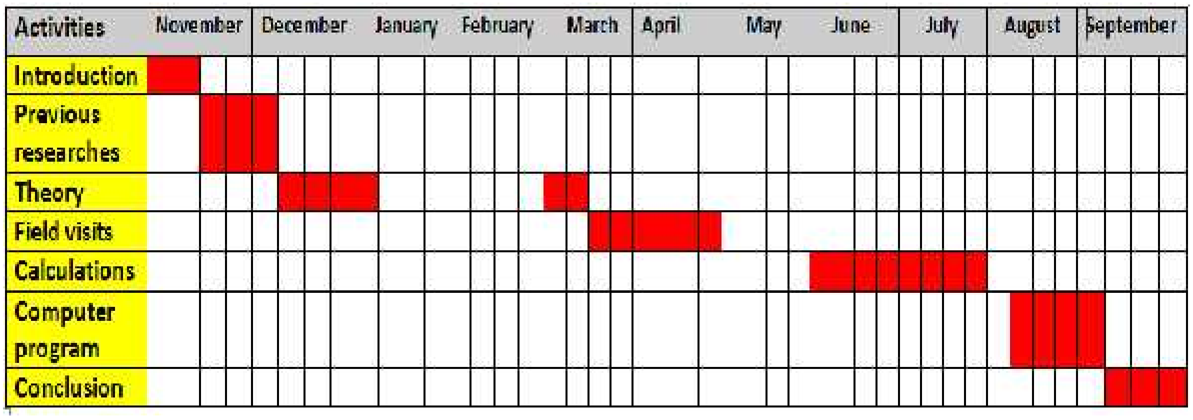
1.5 Project objectives:

-Maximum efficiency of the steam power plants.

-Discuss factors effect on steam plant performance.

-Develop a computer program for efficiency calculation.

1.6 Schedule of the activities (1.1)



1.7 Methodology:

We studied steam power plant and check all their equipments and we went to Um-Dabakir power station and collected the data needed then calculated the thermal efficiency.

CHAPTER TWO

PREVIOUS STUDIES AND THEORY

2.1 Study on design of condenser

To accommodate large turbine generators very large condensers are required so, twin units are used.

The cooling water temperature significantly affects the turbine back pressure. The higher is the back pressure and therefore the lower is thermal efficiency. For example, an inlet cooling water temperature of 55°Fwill provide a condenser backpressure of a

Approximately 1.5 in Hg. A 95 °F inlet temperature results in a back pressure of approximately 3.5 in Hg . The lower the back pressure ,the higher is the turbine output .

So ,the condenser reduces backpressure , thereby increasing the output and efficiency of the turbine. Some of the major areas of condenser operation that affect overall plan performance and turbine backpressure is:

1. Cooling water temperature.
2. Temperature differential between exhaust steam andinlet cooling water.
3. Degree of tube fouling.
4. The velocity of cooling water.

2.2 Study of steam turbine efficiency

The aim of every steam turbine design is an optimum efficiency operation characterizing an optimal energy conversion. Overall efficiency of a steam turbine power plant, however, strongly depends on the turbine's performance. Thus any improvement, however slight, can increase power availability, decrease equipment and component costs, and generate sizeable operating savings. In today's highly competitive and deregulated market, optimizing steam turbine operation is no longer a goal but, rather, a necessity for power producers to remain competitive.

For some aging steam-turbine power plants, refitting them with gas turbine systems will boost availability. For others, however, it may be more cost-effective to upgrade existing steam turbines rather than replace them.

Since a steam turbine's efficiency ultimately depends on its condition, relative to its design, as a turbine's condition deteriorates with use its efficiency degenerates proportionately. A thorough evaluation of a steam turbine's design and operating condition can help increase a plant's efficiency by identifying improvements in one or more of three areas:

1. Combustion to improve fuel utilization and minimize environmental impact.
2. Heat transfer and aerodynamics to improve turbine blade life and performance.
3. Materials to permit longer life and higher operating temperatures for more efficient systems.

Pushing Efficiency Goals

Although computer-optimized turbine design and material improvements over the past few decades have enabled turbine manufacturers to reach the long-elusive goal of 50 percent efficiency (simple cycle) for steam turbine power generation, research and development continues to push the boundaries of the envelope.

To date, turbine manufacturers have mostly overcome the problem of stationary blade losses, a major concern with older steam turbines, by optimizing the design of the nozzle profiles. Further, using computer-aided tools, they have been able to design and manufacture a completely new generation of more efficient blading for retrofitting existing steam turbines, resulting in higher generation efficiencies.

Improvement in turbine performance has resulted not only from developments in modern blading, but also in the redesign of turbine sidewall contours in high-pressure first stages, and in the reduction of humid steam conditions in low-pressure turbine sections that cause erosion. Such improvements have increased turbine efficiency up to 10 percent and reduced downtime and maintenance costs.

In addition, steam turbine manufacturers have developed components (such as rotors and casings) using advanced materials that have improved resistance to corrosion. And, to cut steam turbine losses, which contribute to decreased power availability, turbine manufacturers now supply improved turbine seals and sealing systems.

Improving Cycle Efficiency

Although on-going development will continue to produce even greater efficiency gains in steam turbine operation, there are a number of measures power producers can take to improve the efficiency of their existing systems, including: further optimization of auxiliary power requirements and individual component configurations, as well as by reducing pressure losses.

The four primary causes of losses in steam turbine efficiency and performance are chemical deposits in the steam path; nozzle and bucket surface erosion; mechanical damage to nozzles and buckets due to foreign objects; and steam leakage through the unit's shaft packing, tip seals, and inlet steam pipes - with packing and tip seal losses accounting for more than 50% of a steam turbine's efficiency losses.

And, as steam turbines age, extreme operating temperatures and other conditions gradually cause internal components to deteriorate, introducing losses.

Specific system conditions that power producers should evaluate to improve steam turbine efficiency include: poorly maintained steam seals; eroded/damaged first stage nozzle block; damaged rotating elements and diaphragms; feed water heaters in/out of service; reduced load operation; manual turbine control; valve and horizontal joint leakages; turbine operation at unusually low steam flows; and operating low pressure turbines in condensing mode. In addition, steam turbines can be re-bladed to improve turbine efficiency. Other turbine cycle improvements could include a program to monitor leaking valves and replace them when necessary (valve cycle isolation).

Evaluating Performance Impacts By evaluating performance impacts of the many operating parameters on steam turbine power cycles, power producers can implement various changes in steam cycle mass and energy balances that will help improve overall power plant efficiency. Operating parameters include:

Steam pressure and temperature - Superheating steam supplied to the power cycle above its saturation point will raise the cycle's thermal efficiency. Likewise, increasing the pressure at which the boiler evaporates steam raises the system's saturation temperature, thus increasing the average temperature of heat added to the cycle, in turn, raising the cycle's thermal efficiency.

Exhaust pressure - Reducing condenser pressure (and temperature) also increases power cycle efficiency by capturing some of the previously unavailable work; and a lower exhaust pressure adds a very small amount of steam input.

Reheat temperature - Raising the average temperature of heat added will increase the power cycle. While reheating the steam after it has partially expanded through the turbine not only increases the average temperature of heat added, but also provides drier steam in the turbine's last stages. However, although additional reheating will further increase cycle efficiency, the gains will diminish with each additional reheat.

Feed water temperature - Raising the temperature of feed water entering the boiler increases the average temperature of added heat, thereby improving cycle efficiency. Called regenerative feed water heating, some of the partially expanded steam from the turbine is diverted to a heat exchanger to heat the boiler feed water, while the remainder of steam expands through the turbine. The process avoids adding low temperature heat into the cycle, with the increased average temperature of heat added improving the cycle efficiency.

(Although increasing the number of feed water heaters improves cycle efficiency, the incremental heat rates diminish with each additional heater. In addition, increased capital costs and restricted turbine arrangement limits economic benefits.)

Re-heater pressure drop - A one percent decrease in re-heater pressure drop improves heat rate and output approximately 0.1 percent and 0.3 percent, respectively. Typically, heater pressure system pressure drop is 10% of the high-pressure turbine exhaust pressure.

Extraction line pressure drop - An increase of 2% in extraction line pressure drop, for all heaters, results in approximately 0.09% lower output and heat rate. The design pressure drop for extractions not at turbine section exhausts, typically is 6% of the turbine stage pressure - 3% for the extraction nozzle and 3% for extraction piping and valves. The total drop for extractions at the turbine exhaust section is 3%, since there is no extraction nozzle loss.

Cycle makeup - Although makeup water is necessary for offsetting cycle water losses (principally from boiler blow down), energy extracted from the power cycle to pump and heat the additional water is wasted in the boiler blow down, resulting in a negative impact on the power cycle performance. Makeup cycle impact on net heat rate is approximately 0.4% higher per percent makeup; and on output, approximately 0.2% lower per percent makeup.

Turbine exhaust pressure - Reducing turbine exhaust pressure increases power cycle efficiency - except when the turbine exhaust is choked. However, both the turbine's characteristics (last stage blade design and exhaust area) and the unit's size tend to affect the impact of changing exhaust pressure on performance.

Air preheat - Preheating combustion air, with flue gas exhaust from the steam generator, improves boiler efficiency by lowering the flue gas exit temperature. The combustion air, however, must be preheated before it enters the air heater so as to maintain flue gas air heater-exit temperature above its dew point temperature, thereby preventing formation of sulfuric acid that will damage the air heater and ductwork. To minimize the impact on the turbine cycle, low-pressure extraction steam or hot water from the turbine cycle is often used as the preheating source.

Condensate sub-cooling - Cooling cycle condensate temperature (in the condenser hot well) below the saturation temperature, corresponding to the turbine exhaust pressure, decreases turbine output. The sub-cooling process increases duty on the first feed water heater, causing an increase in extraction flow to the heater that, in turn, increases the turbine heat rate.

Superheat and reheat spray flows - Extracting main steam and reheat spray flows from the boiler feed pump discharge adversely impact on turbine heat rate. For main steam spray, the flow evaporates in the boiler and becomes part of the main steam flow, which bypasses the high-pressure feedwater heaters making the cycle for this fraction of steam flow less regenerative. For reheat spray, not only does the cycle become less regenerative, but also the reheat spray flow bypasses the high-pressure turbine expanding only through the reheat turbine section. Thus the cycle is non-reheat for the reheat spray portion of steam flow.

Ambient wet-bulb temperature - Rising ambient wet bulb temperature results in an increase in condenser backpressure that adversely affects turbine output and heat rate. As the ambient wet bulb temperature increases, circulating water temperature to the condenser increases in power plants having evaporative cooling towers for cycle heat rejection, resulting in output and heat rate impacts of up to 1.5% to 2% occurring, depending on specific plant design conditions. Condenser and cooling tower designs also affect performance.

Top heater removal - Removing top heater(s) for servicing (such as for tube leaks) results in poorer turbine and plant heat rates. Their removal eliminates turbine extraction (for the heaters), thereby increasing steam flow through the turbine's remaining sections. For a given throttle flow, the greater flow increases turbine output while the lower final boiler feedwater temperature increases turbine cycle heat input. Plant operators should check with the turbine manufacturer for limitations on operation with heaters removed from service.

HP heater drains pump - Decreasing the steam turbine's throttle flow adversely impacts the turbine's cycle heat rate, because it decreases the available pressure between the turbine's final and preceding heater to pump the drains to the deaerator - making it necessary to add a high-pressure heat drains pump to the system. Alternatives include dumping heater drains to the condenser, or flashing heater drains to the condenser, both less effective than a pump for improving cycle heat rate.

Providing Efficiency Solutions:

Steam turbine improvements will improve the system's heat rate, thereby improving efficiency of operations, as well as decreasing maintenance costs. In addition, greater steam turbine efficiency also reduces or eliminates greenhouse gas emissions.

To help steam turbine owners and operators maintain or enhance unit efficiency, the Electric Power Research Institute of Palo Alto, Calif., has published a two-volume reference - Turbine Steam Path Damage: Theory and Practice - based on the technical expertise and practical experience of hundreds of researchers, equipment manufacturers, and turbine designers and operators over the last 50 years. The publication provides steam turbine solutions for increasing turbine availability and extending maintenance intervals, while operating the units safely and reliably; thereby, protecting the equipment's value and maximizing its lifetime. Resources: Black & Veatch, Kansas City, Miss.; Electric Power Research Institute (EPRI) Palo Alto, Calif.; Siemens AG, Erlangen, Germany.

2.3 STEAM TURBINE

2.3.1 Introduction

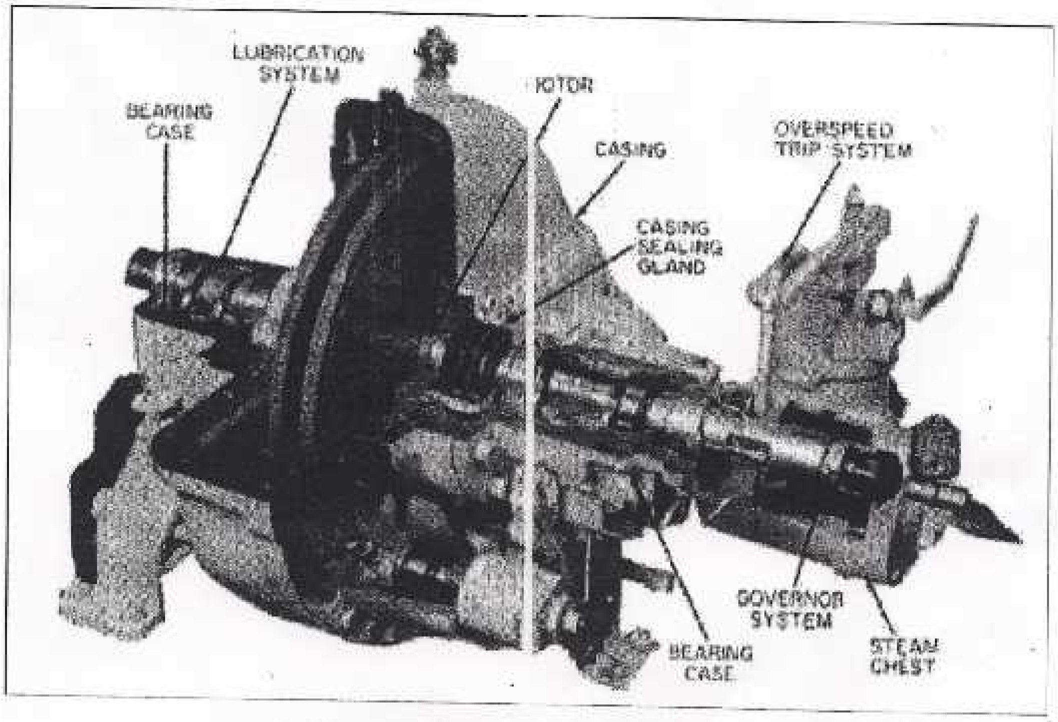
A steam turbine is a mechanical device that extracts thermal energy from pressurized steam, and converts it into useful mechanical work. It has almost completely replaced the reciprocating piston steam engine, primarily because of its greater thermal efficiency and higher power -to-weight ratio. Also, because the turbine generates rotary motion, rather than requiring a linkage mechanism to convert reciprocating to rotary motion, it is particularly suited for use driving an electrical generator .about 86% of the world's electricity is generated using steam turbines The steam turbine is a form of heat engine that derives much of its improvement in thermodynamic efficiency from the use of multiple stages in the expansion of the steam, rather than a single stage.

2.3.2 Definition

A steam turbine may be defined as a for n of heat engine in which the energy of the steam is transformed into kinetic energy by me ins of expansion through nozzles, and the kinetic energy of the resulting jet is in turn converted into force doing work on rings of balding mounted on a rotating part.

This definition may be restated:

A steam turbine is a prime mover which converts the thermal energy of steam directly into mechanical energy of rotation.



figure(2.1) components part of steam turbine

2.3.3 Application

Steam turbines are used in all of our major coal fired power stations to drive the generators or alternators, which produce electricity. The turbines themselves are driven by steam generated in 'Boilers' or 'Steam Generators' as they are sometimes called.

Energy in the steam after it leaves the boiler is converted into rotational energy as it passes through the turbine. The turbine normally consists of several stages with each stage consisting of a stationary blade (or nozzle) and a rotating blade. Stationary blades convert the potential energy of the steam (temperature and pressure) into kinetic energy (velocity) and direct the flow onto the rotating blades. The rotating blades convert the kinetic energy into forces, caused by pressure drop, which results in the rotation of the turbine shaft. The turbine shaft is connected to a generator, which produces the electrical energy. The rotational speed is 3000 rpm for Australian (50 Hz) systems and 3600 for American (60 Hz) systems.

2.4 Types of Steam Turbine

Steam turbines are made in a variety of sizes ranging from rare 1 hp (0.75 kW) units used as mechanical drives for pumps, compressors and other shaft driven equipment, to 2,000,000 hp (1,500,000 kW) turbines used to generate electricity. There are several classifications for modem steam turbines. A turbine may be classified with several descriptors, for example: an impulse type turbine may be a non condensing unit with two stages of reversing elements, cross-compounded with a low-pressure Reaction Turbine.

2.4.1 Impulse Turbines

An impulse turbine has fixed nozzles that orient the steam flow into high speed jets. These jets contain significant kinetic energy, which the rotor blades, shaped like buckets, convert into shaft rotation as the steam jet changes direction. A pressure drop occurs in the nozzle. The pressure is the same when the steam enters the blade as it leaves the blade. As the steam flows through the nozzle, its pressure falls from steam chest pressure to condenser pressure (or atmosphere pressure). Due to this relatively higher ratio of expansion of steam in the nozzle, the steam leaves the nozzle with a very high velocity. At a specific temperature and pressure steam has certain physical properties. The certain amount of heat or thermal energy contained within the steam increases with an increase of temperature o pressure or vice versa. The flow of steam through a channel such as a nozzle reduces its thermal energy, however this decrease in thermal energy is equivalent to gain of kinetic energy. The thermal energy is converted from thermal to kinetic causing lie steam to flow from high pressure, i.e. the steam chest, nozzle block, etc..to an area of low pressure, i.e. the turbine casing. The steam leaving the moving blades still retains a large portion of the velocity it had after leaving the nozzle. The loss of energy due to this higher exit velocity is commonly called the ‘'carry over velocity” or “leaving loss.” In impulse turbines, steam expansion only happens at nozzles.

2.4.2 Reaction Turbines

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

2.4.3 Steam Path Arrangements

Types of steam turbines include condensing, non condensing, reheat, extraction and induction.

2.4.4.1 Back Pressure Turbine

Non condensing or backpressure turbines are most widely used for process steam applications. The exhaust pressure is controlled by a regulating valve to suit the needs of the process steam pressure. These are commonly found at refineries, district heating units, pulp and paper plants, and desalination facilities where large amounts of low pressure process steam are available.

2.4.4.2 Condensing turbine

Condensing turbines are most commonly found in electrical power plants, and marine propulsion plants. These turbines exhaust steam in a partially condensed state, typically of a quality near 90%, at a pressure well below atmospheric to a condenser. These turbines are the mainstay of the electric power generation industry. The moisture in the last turbine stages requires more expensive materials; otherwise erosion of the blades becomes a major problem. Condensing turbines are used for all coal fired generating stations, all oil and gas fired steam electric plants, all nuclear power plants. and all combined cycle power plants.

2.4.4.3 Reheat Turbine

Reheat turbines are also used a1mos exclusively in electrical power plants. in a reheat turbine, steam flow exits from a high pressure section of the turbine and is returned to the boiler where it is further superheated. The steam then goes back into an intermediate pressure section of the turbine and continues its expansion. Virtually all reheat turbines are also closed as condensing turbines.

2.4.4.4 Extraction Turbine

Extraction turbines are common in many applications, particularly in certain manufacturing sectors, such as papermaking which require steam at a certain pressure and temperature. in an extracting turbine, some of the steam is taken from a point of the turbine having the desired temperature and pressure, and used for industrial process needs or sent to boiler feed water heaters. Extraction flows may be controlled with a valve, or left uncontrolled. A one-way valve is almost always located on the extraction piping. In the event of an emergency turbine shutdown, pressure from the extraction line could supply enough energy to over speed the turbine if there a loss of load on the machine the check valve prevent this from occurring.

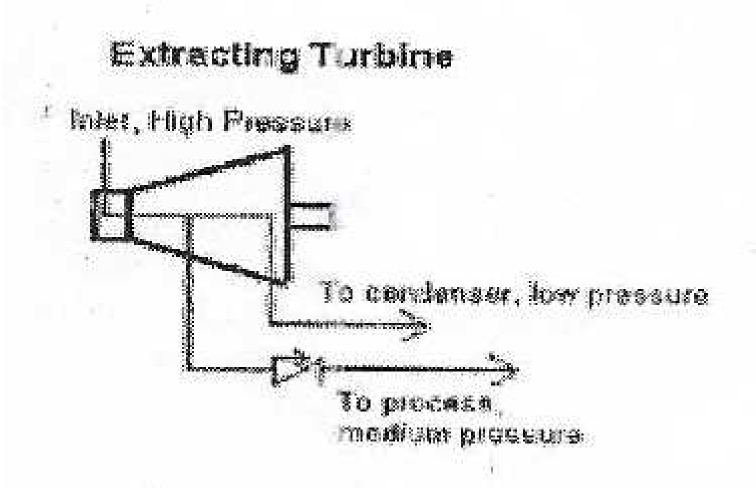


Figure (2.2) an extracting turbine

2.4.4.5 Cruising Turbine

Cruising turbines were used in US Navy designs of the 1950s and 60s. These turbines had staging which was designed for slow and medium speeds, with additional stages upstream which were only used for high speed operations. In normal cruising operation the upstream impulse stages were bypassed.

2.4.4.6 Reversing Turbine

Reversing Turbines are equipped with one or more stages of blades that are faced in the opposite direction of the main balding. A valving arrangement allows for the main steam line to be closed to the forward blades and opened to the reversing blade elements. These reversing blades are mounted on the same shaft as the forward elements, Normally the, reversing blades share the same condenser. During reversing operations, the forward blade elements are spinning backwards in hot steam. This incurs a large efficiency loss known as wind age loss. This steam is relatively stagnant and the forward blades may overheat during extended operation. Before the development of reversing turbines, steam turbine ships could not propel themselves in reverse. Reversing steam turbines were once common in the marine industry, although their use has declined with the rise of the diesel engine and electric drive. Induction turbines introduce low pressure steam at an intermediate stage to produce additional power.

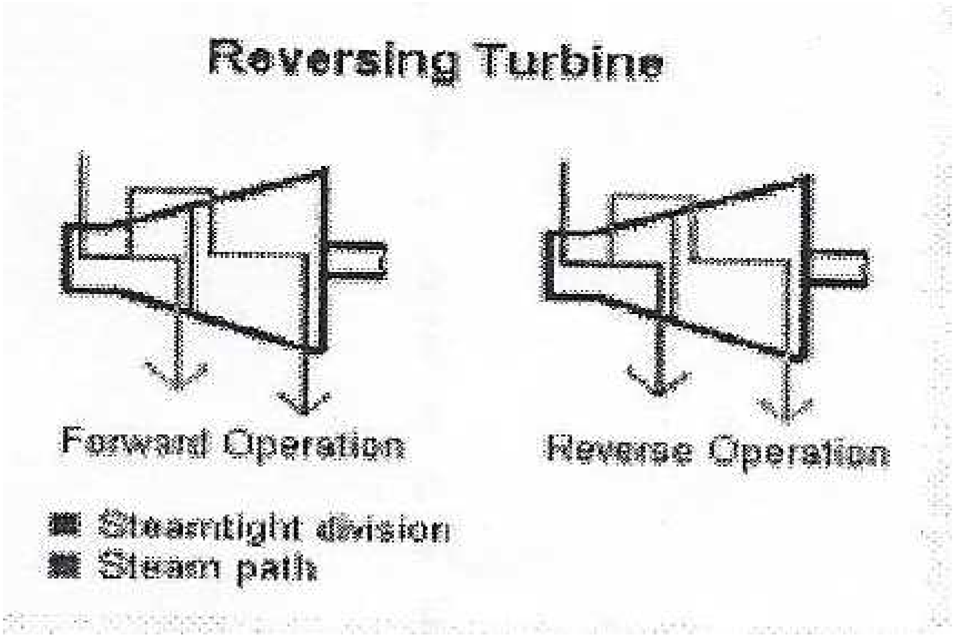


Figure (2.3) reversing turbine

2.5.1 Casing or shaft arrangements

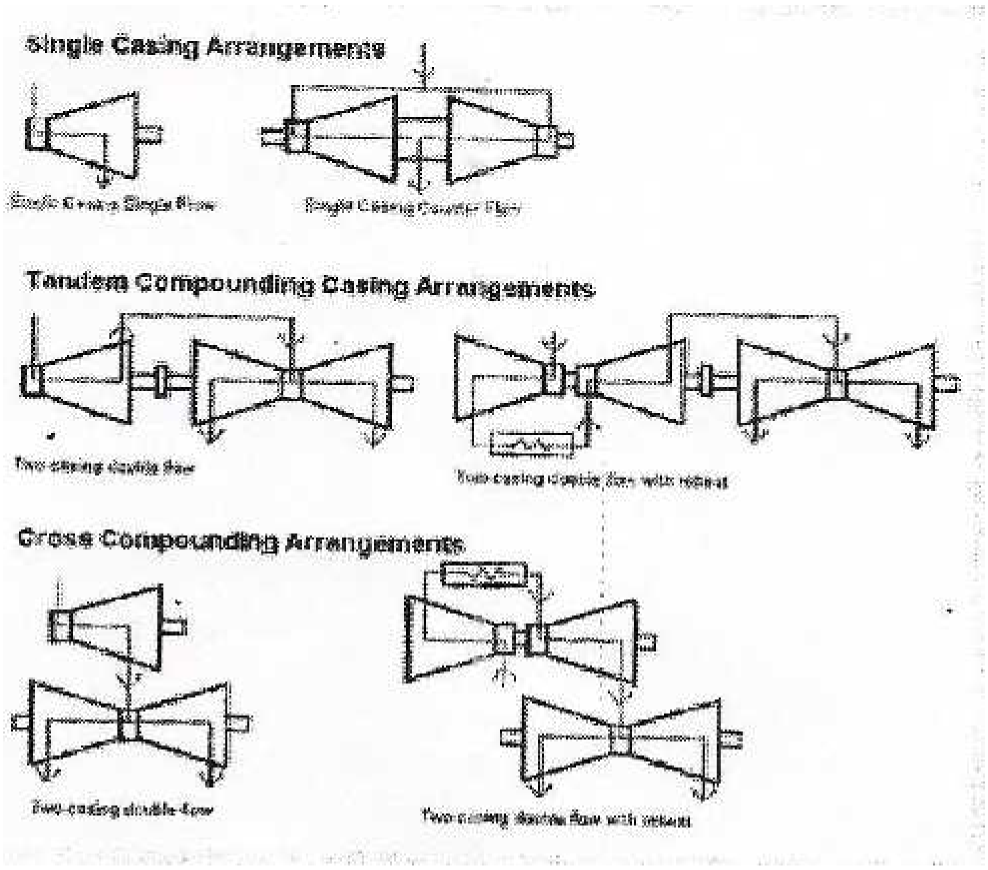


Figure (2.4) some of the more common casing and shaft arrangements

These arrangements include single. casing, tandem compound and cross compound turbines Single casing is the most basic arrangement where a single casing and shaft are coupled to a load Tandem compounding is used where two or more casings are directly coupled together to drive a single load on one shaft A cross compounded turbine arrangement features two or more shafts driving two or more loads that. may operate at different speeds Gearboxes have also been developed to input the multiple shafts of the cross compound arrangements and output a single shaft.

2.6 Theoretical Background:

A steam turbine develops mechanical work by converting to work the available heat energy in the steam expansion. Heat and mechanical work, being two forms of energy, can be converted from one to the other. The heat energy is converted in two steps. The steam expands in nozzles and discharges at a high velocity, converting the available heat energy to velocity (kinetic) energy. The high-velocity steam strikes moving blades, converting the velocity energy to work. Because the total heat energy available in the steam is converted to velocity (kinetic) energy, the magnitude of the steam velocity is dependent upon the available energy. The mechanical work that is developed in the turbine by the high-velocity steam striking the buckets is a function of the speed of the buckets. Maximum work occurs when the bucket velocity is approximately one-half the steam j et velocity for an impulse stage and one-fourth the steam jet velocity for a velocity-compounded impulse stage. Although the steam jet velocity is fixed by the available heat energy, the bucket velocity is fixed by the speed of the turbine and the diameter of the turbine wheel on which the buckets are mounted. The work developed, or the efficiency of the turbine, ignoring losses in the turbine, is therefore determined by the size of the turbine and the turbine (pump) speed for a fixed amount of available heat energy.

2.6.1 Principle of Operation and Design

An ideal steam turbine is considered to be an isentropic process, or constant entropy process, in which the entropy of the steam entering the turbine is equal to the entropy of the steam leaving the turbine. No steam turbine is truly isentropic, however, with typical’ isentropic efficiencies ranging from 20% - 95% based on the application of the turbine. The interior of a turbine comprises several sets of blades, commonly referred to as buckets. One set of stationary blades connected to the casing and one set of rotating blades is connected to the shaft. The sets Intermesh with certain minimum clearances, with the size and configuration :f sets varying to efficiently exploit the expansion of steam at each stage.

2.6.2 Function and Operation

The steam chest and the casing contain the steam furnished to the turbine, being connected to the higher pressure steam supply line and the lower pressure steam exhaust line, respectively. The steam chest, which is connected to the casing, houses the governor valve and the over speed trip valve . The casing contains the rotor and the nozzles through which the steam is expanded Directed against the rotating buckets. The rotor consists of the shaft and disk assemblies with buckets. The shaft extends Beyond the casing and through the bearing cases. One end of the shaft is used for coupling to the driven pump. The other en d serves the speed governor and the over speed trip systems.

The bearing cases support the rotor and the assembled casing and steam chest. The Bearing cases contain the journal bearings an d the rotating, oil seals, which prevent outward oil leakage and the entrance of water, dust, and steam. The steam end bearing case also contains the rotor positioning bearing and the rotating components of the .over speed trip system. An extension of the steam end bearing housing encloses the rotating components of the speed governor system.

The casing sealing glands seal. the casing and the shaft with spring backed segmented.

Carbon rings (supplemented by a spring-baked labyrinth section for the higher exhaust Steam pressures).

The governor system commonly consist so. spring-opposed rotating weights, a steam Valve, and an interconnecting linkage or servomotor system. Changes in the turbine inlet and exhaust steam conditions, and the power required by the pump will cause the turbine Speed to change. The change in speed results in a repositioning of the rotating governor weights and subsequently of the governor valve.

The over speed trip system usually consists of a spring-loaded pin or weight mounted in the turbine shaft or on a collar, a quick-closing valve that is separate from the governor valve, and interconnecting linkage. The centrifugal force created by rotation of the pin in the turbine shaft exceeds the spring loading at a preset speed. The resultant movement of the trip pin causes knife edges in the linkage to separate and permit the spring-loaded trip valve to close.

The trip valve may be closed by disengaging the knife edges manually, by an electric or pneumatic signal, by low oil pressure, or by high turbine exhaust steam pressure. The two usual types of lubrication systems are oil-ring and pressure. The oil-ring lubrication system employs an oil ring(s) that rotates on the shaft with the lower portion submerged in the oil contained in the bearing case. The rotating ring(s) transfers oil from the oil reservoir to the turbine shaft journal bearing and rotor-locating bearing. The oil in the bearing case reservoirs is cooled by water flowing in cooling water chambers or tubular heat exchangers.

A pressure lubrication system consists of an oil pump driven from the turbine shaft, an oil reservoir, a tubular oil cooler, an oil filter, and interconnecting piping. Oil is supplied to the bearing cases under pressure. The oil rings may be retained in this system to provide oil to the bearings during startup and shutdown when the operating speed and bearing design permit.

2.6.3 Operation and Maintenance

When warming up a steam turbine for use, the main steam stop valves (after the boiler) have a bypass line to allow superheated steam to slowly bypass the valve and proceed to heat up the lines in the system along with the steam turbine. Also a turning gear is engaged when there is no steam to the turbine to slowly rotate the turbine to ensure even heating to prevent uneven expansion and rotor bowing. After first rotating the turbine by the turning gear, allowing time for the rotor to assume a straight plane (no bowing), then the turning gear is disengaged and steam is admitted to the turbine. For most utility and industrial steam turbines, a starting and loading chart is included in the unit instruction manual.

The starting and loading chart is used to guide turbine operators in loading their units in such a way as to minimize rotor and shell thermal stresses, but also minimize the chances of the rotor heating faster than the shell, creating a rotor long condition. When starting a shipboard steam turbine (marine unit), steam is normally admitted t', the astern blades located in the LP turbine, and then to the ahead blades slowly rotating the turbine at 10 to 15 revolutions per minute (RPM) to slowly warm the turbine.

Problems with turbines are rare and maintenance requirements are relatively small. Any imbalance of the rotor can lead to vibration, which in extreme cases can lead to a blade letting go and punching straight through the casing. Also, it is essential that the turbine be turned with dry steam. If water gets into the steam and is blasted onto the blades (moisture carryover) rapid impingement and erosion of the blades can occur, possibly leading to imbalance and catastrophic failure. Also, water entering the blades will likely result in the destruction of the thrust bearing for the turbine shaft. To prevent this, along with controls and baffles in the boilers to ensure high quality steam, condensate drains are installed in the steam piping leading to the turbine.

2.6.4 Efficiency

To maximize turbine efficiency the steam is expanded in a number of stages. Work is generated from each steam expansion and pressure drop. These stages are characterized by how the energy is extracted from them and are known as either impulse or reaction turbines. Most modern steam turbines are a combination of the reaction and impulse balding stages. Typically in the United States and Canada, higher pressure sections are impulse type and lower pressure stages are reaction type.

2.7 BOILERS

2.7.1 Introduction:

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and cheap medium for transferring heat to a process. When water is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care.

The process of heating a liquid until it reaches its gaseous state is called evaporation. Heat is transferred from one body to another by means of (1) radiation, which is the transfer of heat from a hot body to a cold body without a conveying medium, (2) convection, the transfer of heat by a conveying medium, such as air or water and (3) conduction, transfer of heat by actual physical contact, molecule to molecule.

Boiler Specification

The heating surface is any part of the boiler metal that has hot gases of combustion on one side and water on the other. Any part of the boiler metal that actually contributes to making steam is heating surface. The amount of heating surface of a boiler is expressed in square meters. The larger the heating surface a boiler has, the more efficient it becomes. The quantity of the steam produced is indicated in tons of water evaporated to steam per hour. Maximum continuous rating is the hourly evaporation that can be maintained for 24 hours. F & A means the amount of steam generated from٤ at 100^{o}C to saturated steam at $100\ ^{o}$C

Indian Boiler Regulation

The Indian Boilers Act was enacted to consolidate and amend the law relating to steam boilers. Indian Boilers Regulation (IBR) was created in exercise of the powers conferred by section 28 & 29 of the Indian Boilers Act.

IBR Steam Boilers means any closed vessel exceeding 22.75 liters in capacity and which is used expressively for generating steam under pressure and includes any mounting or other fitting attached to such vessel, which is wholly, or partly under pressure when the steam is shut off.

IBR Steam Pipe means any pipe through which steam passes from a boiler to a prime mover or other user or both, if pressure at which steam

passes through such pipes exceeds 3.5 kg/cm^2 above atmospheric pressure or such pipe exceeds 254 mm in internal diameter and includes
in either case any connected fitting of a steam pipe.

2.7.2 Boiler Systems

The boiler system comprises of: feed water system, steam system and fuel system. The **feed water system** provides water to the boiler and regulates it automatically to meet the steam demand. Various valves provide access for maintenance and repair. The **steam system** collects and controls the steam produced in the boiler. Steam is directed through a piping system to the point of use. Throughout the system, steam pressure is regulated using valves and checked with steam pressure gauges. The **fuel system** includes all equipment used to provide fuel to generate the necessary heat. The equipment required in the fuel system depends on the type of fuel used in the system. A typical boiler room schematic is shown in Figure 2.5

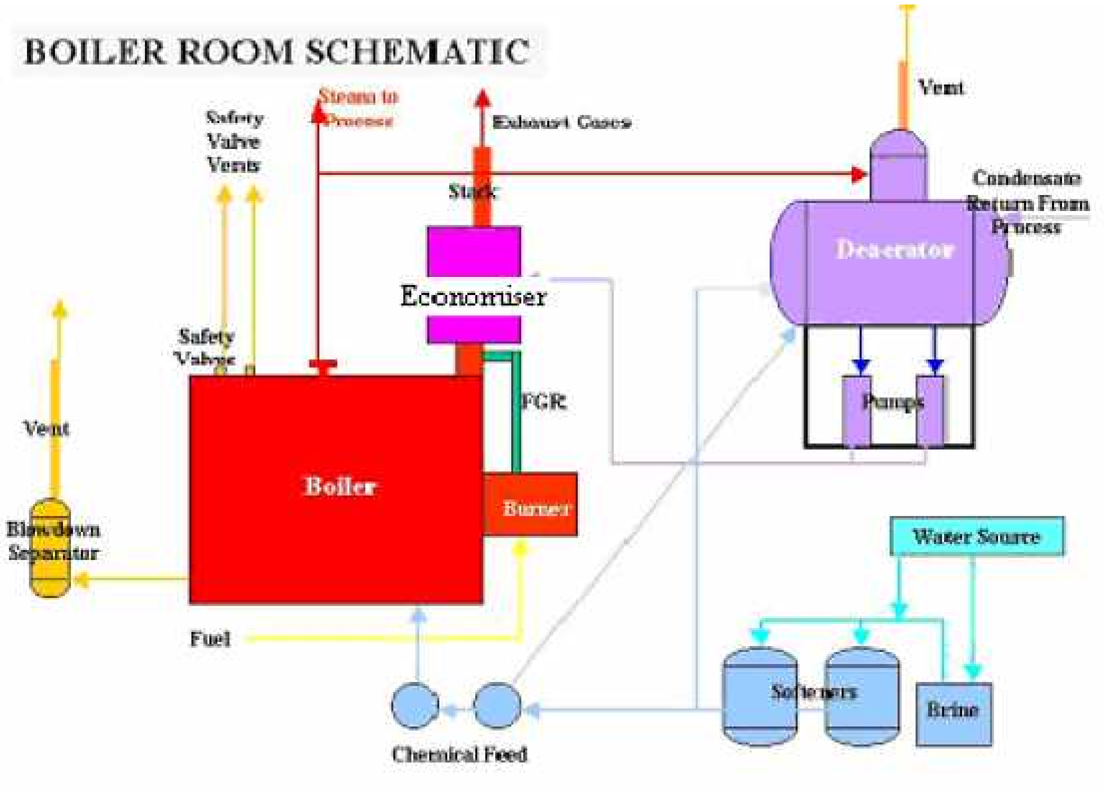


Figure (2.5) Boiler Room Schematic

The water supplied to the boiler that is converted into steam is called **feed water**. The two sources of feed water are:

(1) **Condensate** or condensed steam returned from the processes and

(2) **Makeup water** (treated raw water) which must come from outside the boiler room and plant processes. For higher boiler efficiencies, the feed water is preheated by economizer, using the waste heat in the flue gas.

2.7.3 Boiler Types and Classifications

There are virtually infinite numbers of boiler designs but generally they fit into one of two categories:

Fire tube or "fire in tube" boilers; contain long steel tubes through which the hot gasses from a furnace pass and around which the water to be converted to steam circulates. (Refer Figure 2.2). Fire tube boilers, typically have a lower initial cost, are more fuel efficient and easier to operate, but they are limited generally to capacities of 25 tons/hr and pressures of 17.5 kg/cm^2.

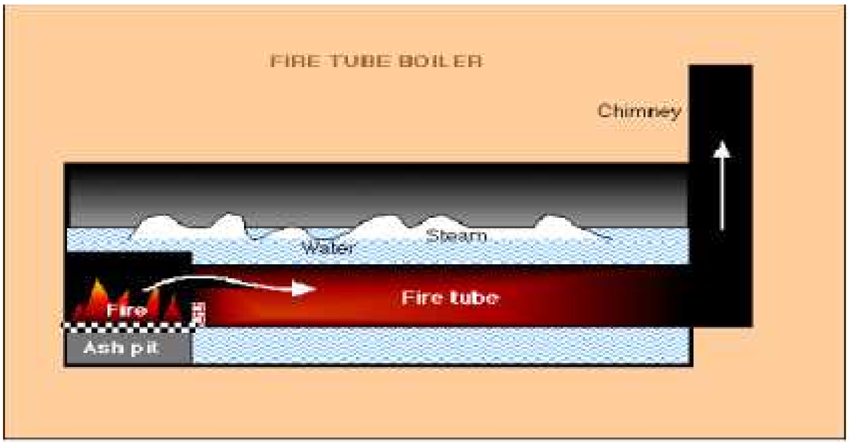


Figure (2.6) Fire Tube Boiler

Water tube or "water in tube" boilers in which the conditions are reversed with the water passing through the tubes and the hot gasses passing outside the tubes (see figure 2.3). These boilers can be of single- or multiple-drum type. These boilers can be built to any steam capacities and pressures, and have higher efficiencies than fire tube boilers.

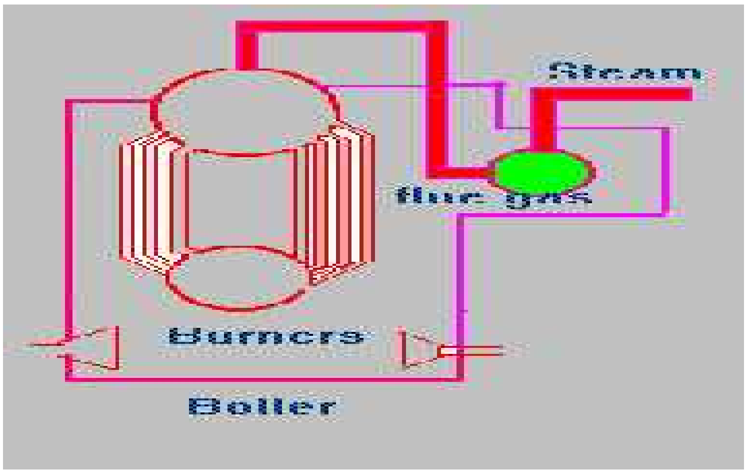


Figure (2.7) Water Tube Boiler

Packaged Boiler:

The packaged boiler is so called because it comes as a complete package. Once delivered to site, it requires only the steam, water pipe work, fuel supply and electrical connections to be made for it to become operational. Package boilers are generally of shell type with fire tube design so as to achieve high heat transfer rates by both radiation and convection (Refer Figure 2.8).

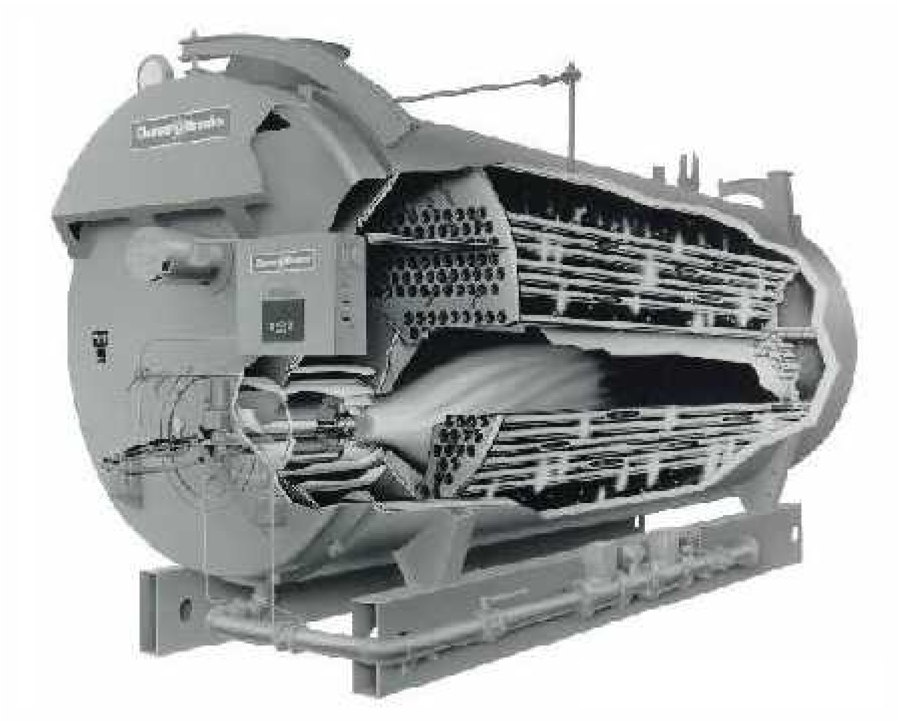


Figure (2.8) Packaged Boiler

The features of package boilers are:

- ❖ Small combustion space and high heat release rate resulting in faster evaporation.
- ❖ Large number of small diameter tubes leading to good convective heat transfer.
- ❖ Forced or induced draft systems resulting in good combustion efficiency.

❖ Number of passes resulting in better overall heat transfer.

❖ Higher thermal efficiency levels compared with other boilers.

These boilers are classified based on the number of passes - the number of times the hot combustion gases pass through the boiler. The combustion chamber is taken, as the first pass after which there may be one, two or three sets of fire-tubes. The most common boiler of this class is a three-pass unit with two sets of fire-tubes and with the exhaust gases exiting through the rear of the boiler.

Stoker Fired Boiler:

Stokers are classified according to the method of feeding fuel to the furnace and by the type of grate. The main classifications are:

1. Chain-grate or traveling-grate stoker.
2. Spreader stoker.

Chain-Grate or Traveling-Grate Stoker Boiler

Coal is fed onto one end of a moving steel chain grate. As grate moves along the length of the furnace, the coal burns before dropping off at the end as ash. Some degree of skill is required, particularly when setting up the grate, air dampers and baffles, to ensure clean combustion leaving minimum of unburnt carbon in the ash.

The coal-feed hopper runs along the entire coal-feed end of the furnace. A coal grate is used to control the rate at which coal is fed into the furnace, and to control the thickness of the coal bed and speed of the grate. Coal must be uniform in size, as large lumps will not burn out completely by the time they reach the end of the grate. As the bed thickness decreases from coal-feed end to rear end, different amounts of air are required- more quantity at coal-feed end and less at rear end (see Figure 2.9).

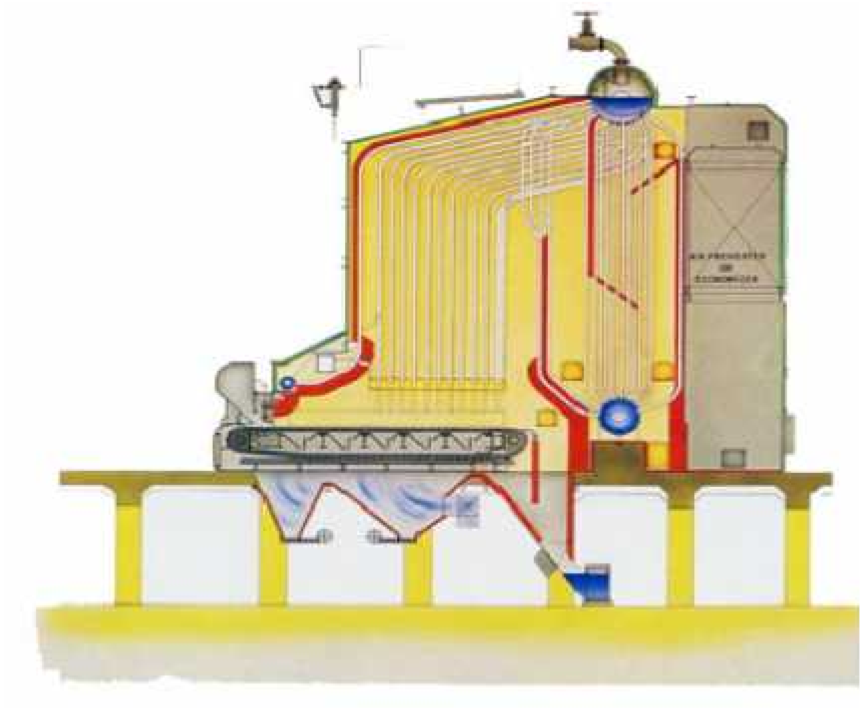


Figure (2.9) Chain Grate Stoker

Spreader Stoker Boiler

Spreader stokers utilize a combination of suspension burning and grate burning. The coal is continually fed into the furnace above a burning bed of coal. The coal fines are burned in suspension; the larger particles fall to the grate, where they are burned in a thin, fast-burning coal bed. This method of firing provides good flexibility to meet load fluctuations, since ignition is almost instantaneous when firing rate is increased. Hence, the spreader stoker is favored over other types of stokers in many industrial applications.

Pulverized Fuel Boiler

Most coal-fired power station boilers use pulverized coal, and many of the larger industrial water-tube boilers also use this pulverized fuel. This technology is well developed, and there are thousands of units around the world, accounting for well over 90% of coal-fired capacity.

The coal is ground (pulverized) to a fine powder, so that less than 2% is +300 micro meter (μm) and 70-75% is below 75 microns, for a bituminous coal. It should be noted that too fine a powder is wasteful of grinding mill power. On the other hand, too coarse a powder does not burn completely in the combustion chamber and results in higher unburnt losses.

The pulverized coal is blown with part of the combustion air into the boiler plant through a series of burner nozzles. Secondary and tertiary air may also be added. Combustion takes place at temperatures from 1300-1700°C, depending largely on coal grade. Particle residence time in the boiler is typically 2 to 5 seconds, and the particles must be small enough for complete combustion to have taken place during this time.

This system has many advantages such as ability to fire varying quality of coal, quick responses to changes in load, use of high pre-heat air temperatures etc.

One of the most popular systems for firing pulverized coal is the tangential firing using four burners corner to corner to create a fireball at the center of the furnace (see Figure 2.10).

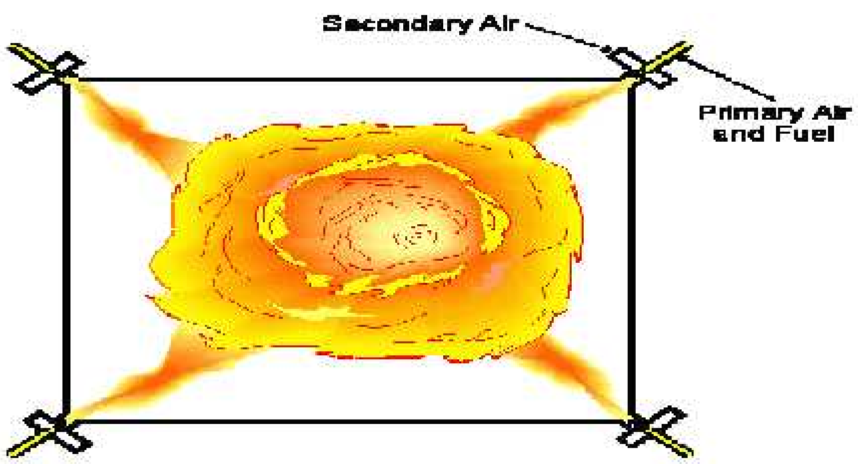


Figure (2.10) Tangential Firing

FBC Boiler

When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles are undisturbed at low velocity. As air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream. Further, increase in velocity gives rise to bubble formation, vigorous turbulence and rapid mixing and the bed is said to be fluidized.

If the sand in a fluidized state is heated to the ignition temperature of the coal and the coal is injected continuously in to the bed, the coal will burn rapidly, and the bed attains a uniform temperature due to effective mixing. Proper air distribution is vital for maintaining uniform fluidization across the bed.). Ash is disposed by dry and wet ash disposal systems.

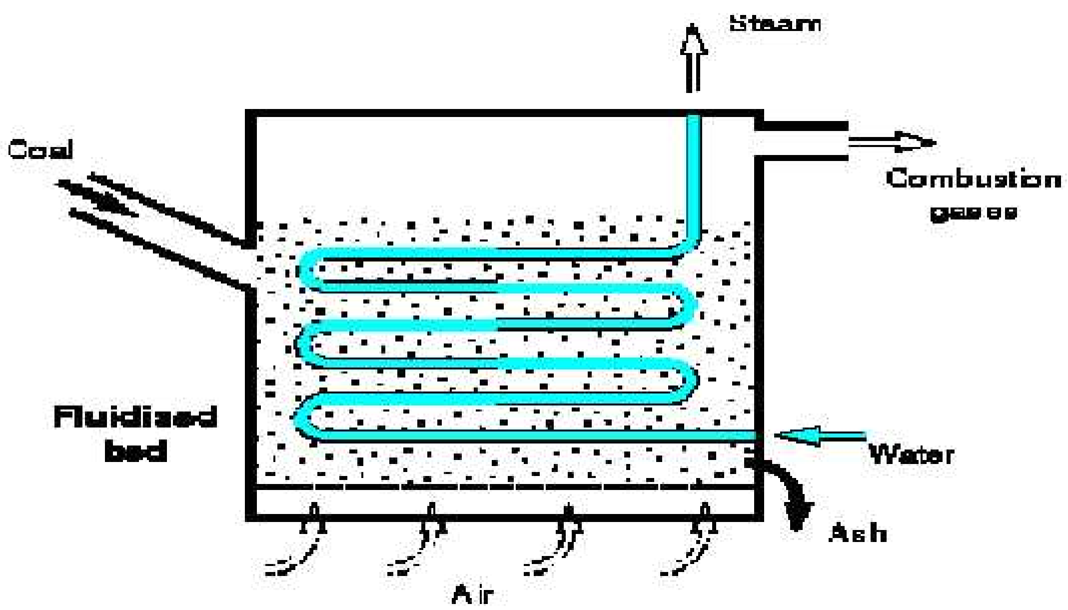


Figure (2.11)Fluidized Bed Combustion

Fluidized bed combustion has significant advantages over conventional firing systems and offers multiple benefits namely fuel flexibility, reduced emission of noxious pollutants such as SOx and NOx, compact boiler design and higher combustion efficiency. More details about FBC boilers are given in Chapter 6 on Fluidized Bed Boiler.

2.7.4 Performance Evaluation of Boilers

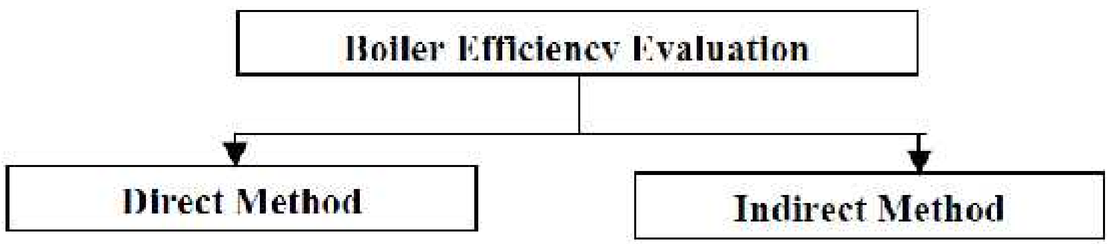
The performance parameters of boiler, like efficiency and evaporation ratio reduces with time due to poor combustion, heat transfer surface fouling and poor operation and maintenance. Even for a new boiler, reasons such as deteriorating fuel quality, water quality etc. can result in poor boiler performance. Boiler efficiency tests help us to find out the deviation of boiler efficiency from the best efficiency and target problem area for corrective action.

Boiler Efficiency

Thermal efficiency of boiler is defined as the percentage of heat input that is effectively utilized to generate steam. There are two methods of assessing boiler efficiency.

1) The Direct Method: Where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.

2) The Indirect Method: Where the efficiency is the difference between the losses and the energy input.



A. Direct Method

This is also known as 'input-output method' due to the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. This efficiency can be evaluated using the formula

$$Boiler\ Efficiency = \frac{Heat\ Output}{Heat\ Input} \times 100$$

Parameters to be monitored for the calculation of boiler efficiency by direct method are :

• Quantity of steam generated per hour (Q) in Kg/hr.

• Quantity of fuel used per hour (q) in Kg/hr.

• The working pressure (Kg/cm^2(g)) and superheat temperature (^{o}C), if any

• The temperature of feed water (^{o}C)

• Type of fuel and gross calorific value of the fuel (GCV) in Kj/Kg of fuel

$$Boiler\ Efficiency(\eta) = \frac{Q \times (h_g - h_f)}{q \times GCV} \times 100$$

Where, hg – Enthalpy of saturated steam in Kj/Kg of steam hf - Enthalpy of feed water in Kj/kg of water

Advantages of direct method:

* Plant people can evaluate quickly the efficiency of boilers

* Requires few parameters for computation

* Needs few instruments for monitoring

Disadvantages of direct method:

* Does not give clues to the operator as to why efficiency of system is lower

* Does not calculate various losses accountable for various efficiency levels

B. Indirect Method

There are reference standards for Boiler Testing at Site using indirect method namely British Standard, BS 845: 1987 and USA Standard is ‘ASME PTC-4-1 Power Test Code Steam Generating Units’.

Indirect method is also called as heat loss method. The efficiency can be arrived at, by subtracting the heat loss fractions from 100. The standards do not include blow down loss in the efficiency determination process. A detailed procedure for calculating boiler efficiency by indirect method is given below. However, it may be noted that the practicing energy mangers in industries prefer simpler calculation procedures.

2.8 Condenser:

2.8.1 Condenser in point

1- Device or unit used to condense vapor into liquid.

2- The condensing of the steam requires the condenser to remove heat of vaporization from steam and reject it.

3- Condenser is designed to reject this energy directly in to cooling water.

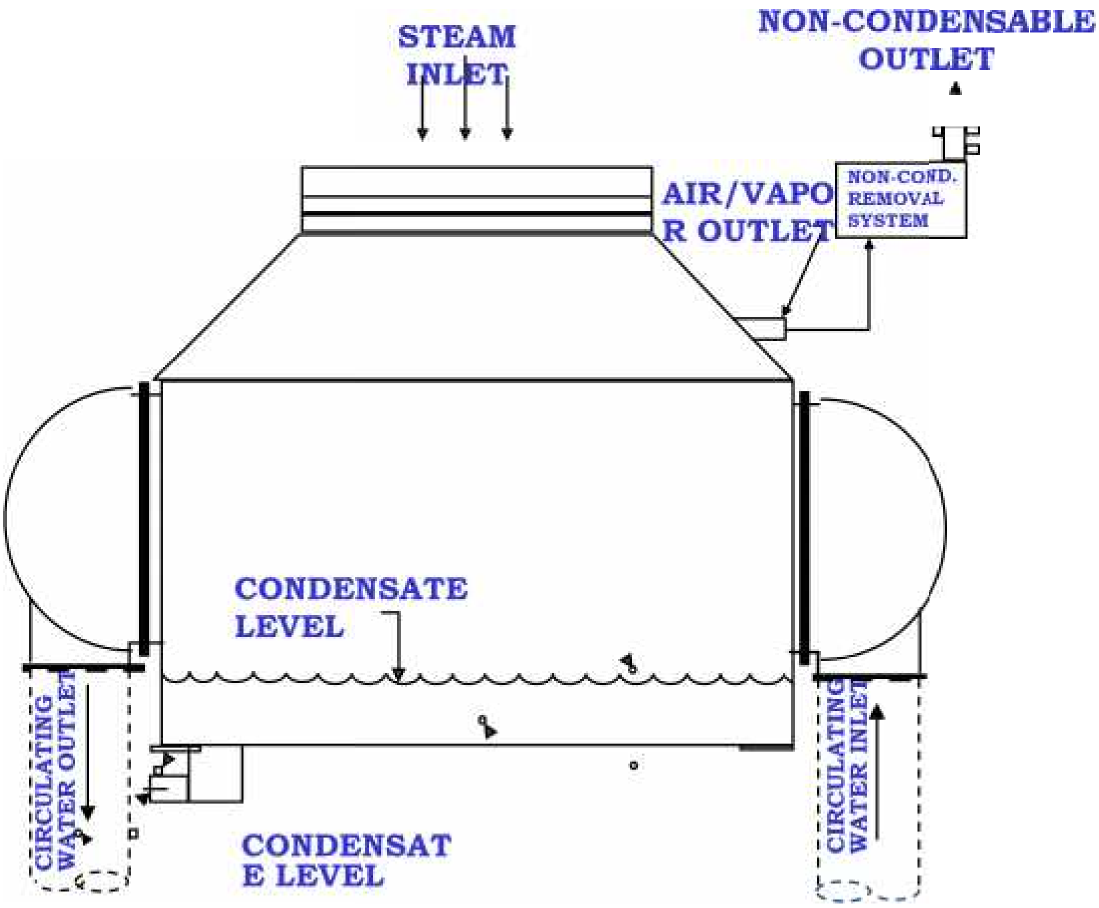


Figure (2.12)condenser wind box type

2.8.2 PRINCIPLE OF CONDENSATION

The steam from steam engine could be exhausted to the atmosphere in such a manner that the back pressure would below the atmospheric pressure.

Advantages of condenser:

1- It increases the work output per kg of steam supplied to the power plant.

2- Reduces the specific steam consumption.

3-Reduces the size of power plant of given capacity.

4- Improves the thermal efficiency of power plant.

5- Saves the cost of water to be supplied to boiler.

2.8.3 ELEMENTS OF CONDENSING PLANT

1- CONDENSER: In which the exhaust steam of the turbine is condensed by circulating cooling water.

2- CONDENSATE EXTRACTION PUMP: to remove the condensate from the condenser and feed it into the hot-well. The feed water from hot-well is further pumped to boiler.

3- COOLING TOWER:

A- The Ferro concrete made device (hyperbolic shape) in which the hot water from the condenser is cooled by rejecting heat to current of air passing in the counter direction.

B-Ring troughs are placed 8-10m above the ground level.

4- AIR EXTRACTION PUMP: to remove air from the condenser, such a pump is called dry air pump. If air and condensate both are removed, it is called as wet air pump.

5- CIRCULATING PUMP: used to supply feed water either from river or from the cooling tower pond to the condenser

2.8.4 TYPES OF CONDENSERS

1- **Jet condenser:**

The exhaust steam and cooling water come in direct contact as a result the steam is condensed.

2- **Surface condenser:**

The cooling water flows through network of tubes and the exhaust steam passes over these tubes.

2.9 Feed water pump:

A force pump for supplying water to a steam boiler. The water may be freshly supplied or returning condensate produced as a result of the condensation of the steam produced by the boiler. These pumps are normally high pressure units that take suction from a condensate return system and can be of the type Centrifugal pump or positive displacement type.

2.9.1Boiler Feed PUMP

1- To give the required pressure to the Feed water before entering into boiler.

2- Horizontal barrel type multi stage pump located at Zero meter height.

2.9.2 Construction and operation

Feed water pumps range in size up to many horsepower and the electric is usually separated from the pump body by some form of mechanical coupling. Large industrial condensate pumps may also serve as the feed water pump. In either case, to force the water into the boiler, the pump must generate sufficient pressure to overcome the steam pressure developed by the boiler. This is usually accomplished through the use of a centrifugal pump. Another common form of feed water pumps run constantly and are provided with a minimum flow device to stop over pressuring the pump on low flows The minimum flow usually returns to the tank or deaerator.

2.10 The Ideal Rankin cycle:

All four components associated with the ideal Rankin cycle are steady-flow devices, and thus all four processes that make up the Rankine cycle can be analyzed as steady-flow process. The kinetic and potential energy changes of water are small relative to the heat and work terms, are thus neglected. Energy analyses of the four components are given below.

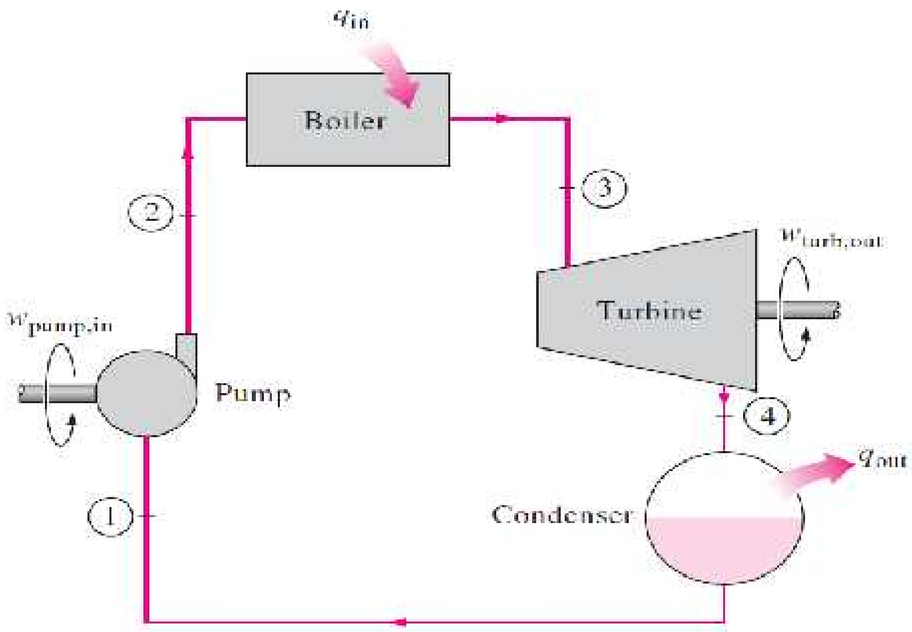


Fig (2.13) Schematic of the Rankine Cycle

Pump (process 1-2): Pump pressurized the liquid water from the condenser and going back to the boiler. Assuming no heat transfer with the surroundings, the energy balance in the pump is

$$\textbf{Pump(q=0)}\; w_{pump,in} = h_2 - h_1 \qquad \textbf{(2.1)}$$

Boiler (process 2-3): Liquid water enters the boiler and is heated to superheated state in the boiler. The energy balance in the boiler is

$$q_{in} = h_3 - h_2 \qquad \textbf{(2.2)}$$

Turbine (process 3-4): Steam from the boiler, which has an elevated temperature and pressure, expands through the turbine to produce work and then is discharged to the condenser with relatively low pressure. Neglecting heat transfer with the surroundings, the energy balance in the turbine is

$$w_{turbine,out} = h_3 - h_4 \qquad (2.3)$$

Condenser (process 4-1): Steam from the turbine is condensed to liquid water in the condenser. The energy balance in the condenser is

$$q_{out} = h_4 - h_1 \qquad (2.4)$$

For the whole cycle, the energy balance can be obtained by summarizing the four energy equations above. It yields,

$$(q_{in} - q_{out}) - (w_{turbine,out} - w_{pump,in}) = 0 \qquad (2.5)$$

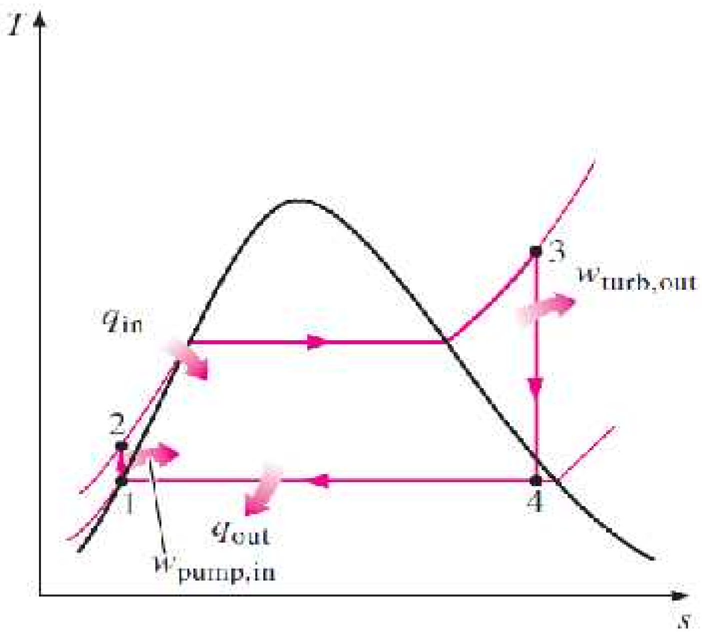
The thermal efficiency of the Rankine cycle is determined from

$$\eta_{th} = \frac{w_{net,out}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}} \qquad (2.6)$$

where the net work output from the cycle is

$$w_{net,out} = (w_{turbine,out} - w_{pump,in}) \qquad (2.7)$$

The Rankine cycle is an ideal cycle if water passes through the four components without irreversibilities and pressure drops. The ideal Rankine cycle consists of the following four processes, as shown on the T-s diagram on fig (2.14).



Fig(2.14) T- s Diagram of an Ideal Rankine Cycle

- 1-2: Isentropic compression in a pump.
- 2-3: Constant pressure heat addition in a boiler.
- 3-4: Isentropic expansion in a turbine.
- 4-1: Constant pressure heat rejection in a condenser.

2.10.1 Methods of Increasing the Efficiency of the Rankine Cycle

There are three ways to increase the efficiency of the simple ideal Rankine cycle:

1 Decreasing the condenser pressure.

2 Superheating the steam to a high temperature.

3 Increasing the boiler pressure.

2.10.1.1 Decreasing the condenser pressure

The effect of lowering the condenser pressure on the Rankine cycle efficiency is illustrated on a T-s diagram shown on fig (2.15). Steam exits as a saturated mixture in the condenser at the saturation temperature corresponding to the pressure in the condenser. So lower the pressure in the condenser, lower the temperature of the steam, which is the heat rejection temperature. The grey area is the net work increases due to the decreasing of the condenser pressure.

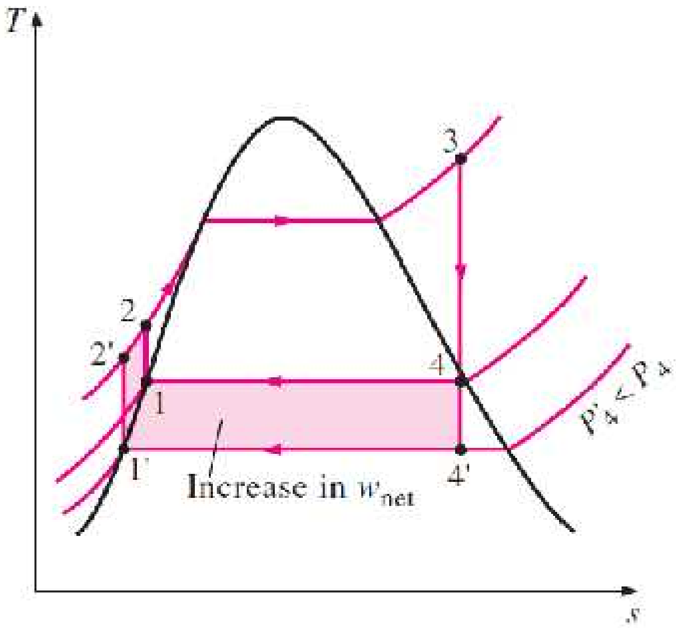


Fig (2.15) the Effect of Lowing the Condenser Pressure

2.10.1.2 Superheating the steam to a high temperature

The effect of superheating the steam to a high temperature on the Rankine cycle efficiency is illustrated on a T-s diagram shown on fig (2.16). By superheating the stream to a high temperature (from state 3 to state 3'), the average steam temperature during heat addition can be increased. The grey area is the net work increased due to superheating the steam to a high temperature.

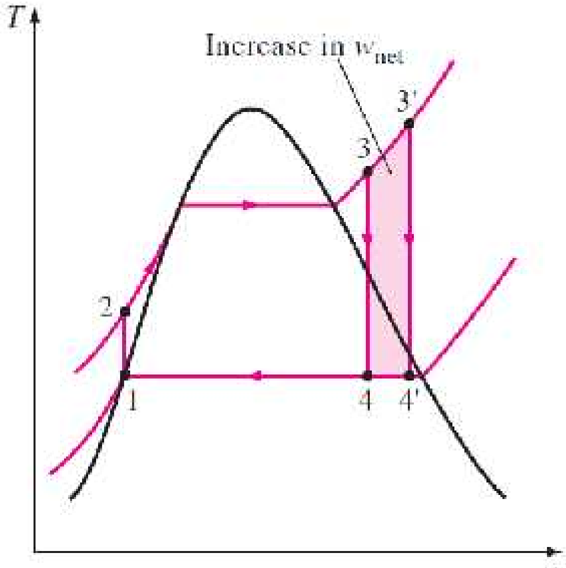


Fig (2.16) the Effect of Superheating the Steam to A Higher Temperature

2.10.1.3 Increasing the boiler pressure

The effect of increasing the boiler pressure on the Rankine cycle efficiency is illustrated on a T-s diagram shown on fig (2.17). If the operating pressure of the boiler is increased, (process 2-3 to process 2'-3'), then the boiling temperature of the steam rises automatically. For a fixed inlet turbine temperature, the upper grey area is the net work increased and the right gray area is the net work decreased. Also, the moisture content of the steam increases from state 4 to state 4', which is an undesirable side effect. This side effect can be corrected by reheating the steam, and results in the reheat Rankine cycle.

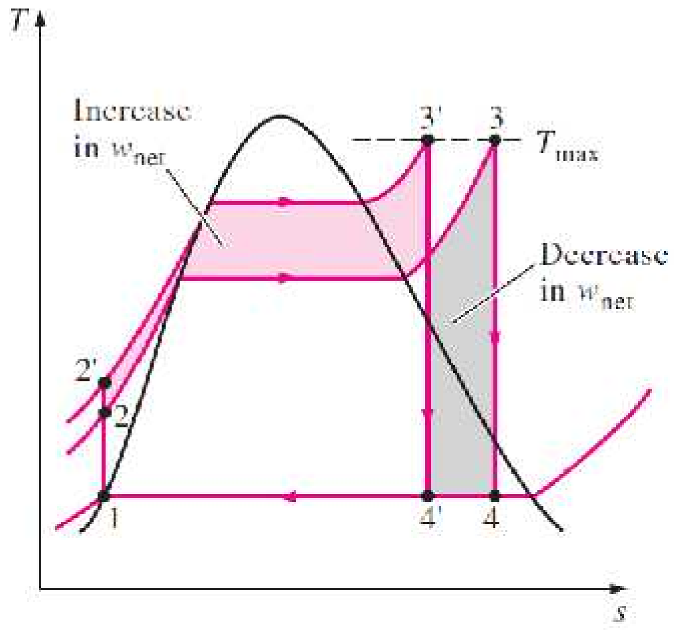


Fig (2.17) the Effect of Increase the Boiler Pressure

2.10.2 Regeneration cycle

The focus of this Search is **Regeneration** cycle. In a simple Rankine cycle, heat is added to the cycle during process 2-2'-3 on T-s diagram shown on fig (2.18).During this first stage (process 2-2'), the temperature of the water is low. That reduces the average temperature during heat addition (process 2-2'-3). To remedy this shortcoming, increasing the temperature of the feedwater (water leaving the pump and entering the boiler) can be considered. This is accomplished by extracting stream from the turbine to heat the feedwater. This process is called regeneration and the heat exchanger where heat is transferred from steam to feedwater is called a regenerator, or a feedwater heater. There are actually two main types of feedwater heaters. If the steam mixes with the compressed water from the pump, it is an open feedwater heater. If the steam does not mix with the compressed water from the pump, it is a closed feedwater heater.

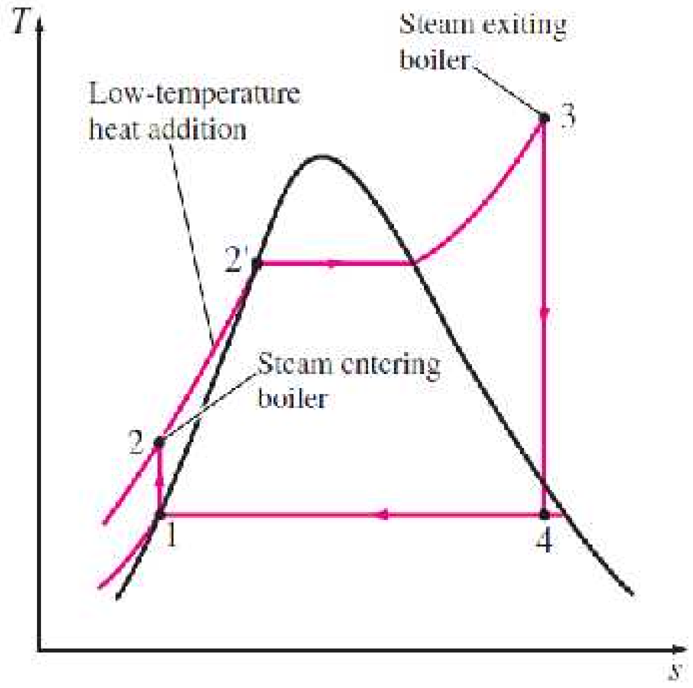


Fig (2.18) T-s Diagram of simple Rankine cycle

The schematic of a steam power plant with one open feed water heater is shown on fig (2.19). In an ideal regenerative Rankin cycle with an open Feed water heater.

Steam from the boiler (state 5) expands in the turbine to an intermediate pressure (state 6). At this state, some of the steam is extracted and sent to the feed water heater, while the remaining steam in the turbine continues to expand to the condenser pressure (state 7). Saturated water from the condenser (state 1) is pumped to the feed water pressure and send to the feed water heater (state 2). At the feed water heater, the compressed water is mixed with the steam extracted from the turbine (state 6) and exits the feed water heater as saturated water at the heater pressure (state 3). Then the saturated water is pumped to the boiler pressure by a second pump (state 4). The water is heated to a higher temperature in the boiler (state 5) and the cycle repeats again. The T-s diagram of this cycle is shown on fig (3.21).

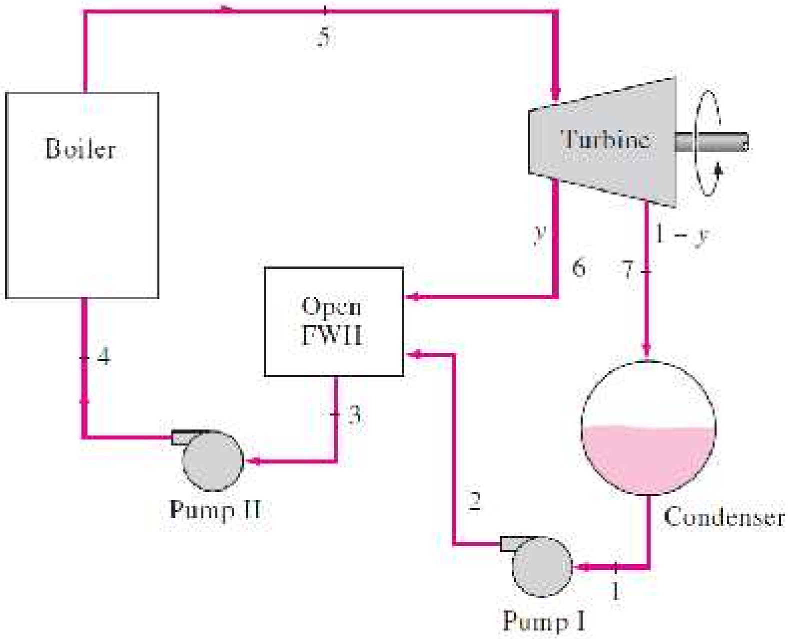


Fig (2.19) Schematic of a Power Plant Running an Ideal Regenerative Rankin Cycle with One Open Feed water heater

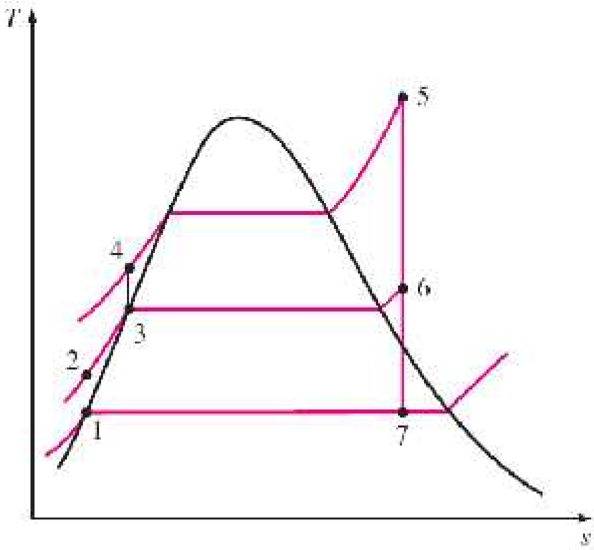


Fig (2.20)T-S Diagram of an Ideal Regenerative Rankin Cycle with One Open Feed water Heater

Note that the mass flow rate at each component is different. If 1 kg steam enters the turbine, y kg is extracted to the feed water heater and $(1 - y)kg$continues to expand to the condenser pressure. So if the mass flow rate at the boiler is $\dot{m}$, then the mass flow rates from other components are:

Condenser: $n \cdot (1 - y)$ (2.8)

Pump I: $n \cdot (1 - y)$ (2.9)

Feed water Heater: $n \cdot y + n \cdot (1 - y) = n \cdot$ (2.10)

Pump: $n \cdot$ (2.11)

For convenience, heat and work interactions for regenerative Rankin cycle is expressed per unit mass of steam flowing through the boiler They are:

Heat Input: $q_{in} = h_5 - h_4$ (2.12)

Heat Output: $q_{out} = (1 - y)(h_1 - h_7)$ (2.13)

Work Output: $w_{turbine,out} = (h_5 - h_6) + (1 - y)(h_6 - h_7)$ (2.14)

Work input: $w_{pump,in} = (1 - y)(h_2 - h_1) + (h_4 - h_3)$ (2.15)

The schematic of a steam power plant with one closed feed water heater is shown on fig (2.21).

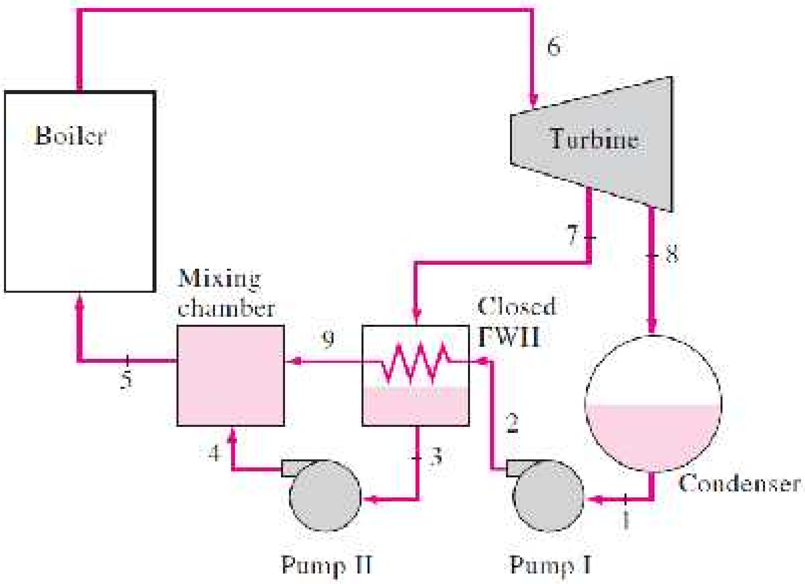


Fig (2.21) Schematic of a Power Plant Running an Ideal Regenerative Rankine Cycle with One Closed Feedwater Heater

In an ideal regenerative Rankine cycle with a closed feedwater, steam from the boiler (state 6) expands in the turbine to an intermediate pressure (state 7). Then some of the steam is extracted at this state and sent to the feedwater heater, while the remaining steam in the turbine continues to expand to the condenser pressure (state 8). The extracted stream (state 7) condenses in the closed feedwater while heating the feedwater from the pump. The heated feedwater (state 5) is send to the boiler and the condensate from the feedwater heater (state 3) is allowed to pass through a trap into a lower pressure heater or condenser. Another way of removing the condensate from the closed feedwater heater is pump the condensate forward to a higher-pressure point in the cycle (state 4). The T-s diagram of this cycle is shown on fig (2.22).

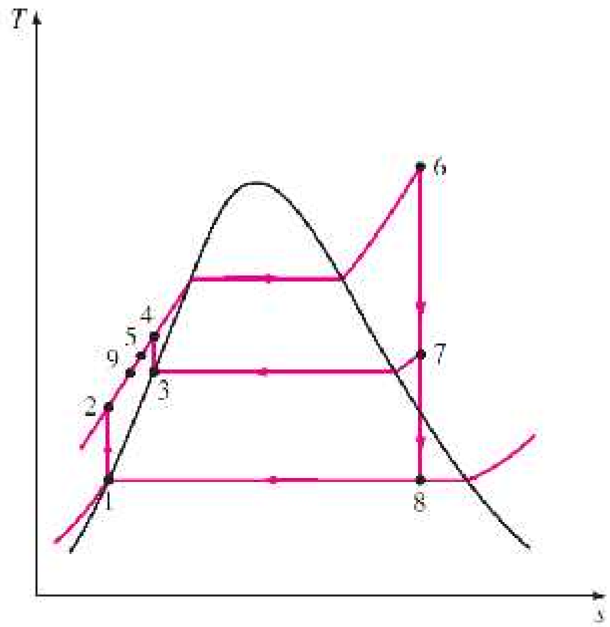


Fig (2.22)T-S Diagram of an Ideal Regenerative Rankine Cycle with One Closed Feedwater Heater

Heat and work interactions for regenerative Rankine cycle with one closed feedwater heater is expressed per unit mass of water flowing through the boiler. They are:

Heat Input: $q_{in} = h_6 - h_5$ **(2.16)**

Heat Output: $q_{out} = (1 - y)(h_1 - h_8)$ **(2.17)**

Work Output: $w_{turbine,out} = (h_6 - h_7) + (1 - y)(h_7 - h_8)$

Work input: $w_{pump,in} = (h_2 - h_1)(h_4 - h_3)$ (2**.18)**

The efficiency ratio of the actual efficiency to the ideal efficiency.

In the vapor cycles the efficiency ratio compares the actual cycle efficiency to the Rankine cycle efficiency,

$$\text{Efficiency ratio} = \frac{cycle\text{Efficiency}}{Rankine\text{Efficiency}} \quad \textbf{(2.19)}$$

The actual expansion process is irreversible & the actual compression of the water is irreversible, the isentropic efficiency of process is defined by:

Isentropic efficiency= $\frac{actualwork}{isentropicwork}$ for an expansion process (2**.20)**

Isentropic efficiency= $\frac{isentropicwork}{actualwork}$ for a compression process **(2.21)**

$$workratio = \frac{networkoutput}{grossworkoutput} \quad \textbf{(2.22)}$$

Both efficiency and work ratio are criteria of performance, another criteria of performance in steam plant is the specific steam consumption (ssc).it relates the power output to steam flow necessary to produce it. The steam flow indicates the size of plant and its component parts, and the (ssc) is a means where by the relative size of different plants can be compared. The (ssc) is the steam flow required to develop unit power out put.

$$ssc = \frac{1}{isentropicwork} kJ/kg \quad \textbf{(2.23)}$$

CHAPTER THREE

UM-DABAKIR FIELED DESCRIPTION

3.1 Pumps:

3.1.1 INTRODUCTION

The high pressure multistage barrel type Boiler Feed Pumps from BHEL have built into them years of rich experience gained in the design, manufacture and installation of Centrifugal Pumps, for Thermal Power Stations for over two decades.

3.1.2 Description of boiler feed pump

The pump is of Horizontal barrel casing cartridge type allowing the pump internals to be removed without disturbing the suction and discharge pipe work, or the alignment of the drive. Each pump is equipped with mechanical seals at the drive and non-drive end of the shaft. The discharge cover and suction guide are each provided with a cooling water jacket. The pump is of robust construction and does not require any warm up.

3.1.3 The pump consist of

1- Casing
2- Shaft
3- Impellers
4- Diffusers
5- Ring Sections
6- Suction Cover
7- Discharge Cover
8- Stuffing Box Assemblies

9- Balanced Drum

10- Bearing and Housings

11- Pump half coupling

Rotating assembly

The dynamically balanced rotating assembly consists of the shaft, impellers, keys, balance drum, thrust collar, shaft nut, pump half coupling etc. The balance drum is keyed and shrunk into the shaft and held in place against the shaft locating shoulder by the balance drum nut and lock washer. The alloy steel thrust collar is keyed to the shaft and secured against a shoulder on the shaft by a nut and lock washer.

Impellers

The Impellers are of single entry shrouded type fully machined externally and hand dressed internally. They are keyed and shrunk into the shaft all facing in one direction. These run within casing wearing rings and prevent wear on the impeller. Clearance are designed to attain high efficiency.

Shaft

The shaft is of forged steel, heat treated and chromium plated within the journal bearing top revent galling. The shaft has stepped diameters to facilitate fitting of impellers. The shaft is proportionally dimensioned to ensure low torsional stresses.

Balancing arrangement

The symmetric nature of the single entry impellers about the vertical place generates hydraulic axial thrust while permitting fluid flow, which pushes the rotor towards the suction end of the pump. The axial thrust of the pump is balanced by means of a balance drum secured to the shaft which rotates within a stationary bush in the discharge cover. The low pressure end of the balanced drum is connected by a return line to the suction. The residual hydraulic thrust is carried by an adequately rated double acting tilting pad thrust bearings.

Journal and thrust bearing

The rotating assembly is supported at each end of the shaft by a white metal lined journal bearing. The thrust bearing is fitted in the non-drive end bearing housing. The thrust and journal bearings are supplied with oil from the lubricating circuit. The bearing housings are in the form of castings split on the shaft axis.

Shaft sealing (mechanical seals)

The pump is fitted with mechanical seals. The seal unit consists of a stainless steel sleeve which is keyed to the shaft and drives the seal face ring. Multiple springs provide evenly distributed dynamic force leading on the stationary seal seat. A cooling water jacket is provided around the seal housing to cool the feed water within the seal chamber. Cooling of the seal seat is also provided by supplying cooled feed water directly to seal faces. The seals are capable of a satisfactory performance for all conditions encountered during starting, standby and shutting down operations.

Flexible coupling

The shafts of the Booster Pump and electric drive motor, drive motor and Gear Box, Gear Box and Boiler Feed Pump are connected by diaphragm type dry coupling.

Diffusers/ring sections

The diffuser/ring section assemblies consist of steel ring sections with integrally cast diffusers which are located onto the next by spigots and dowel pins and secured by socket head screws. The diffusers carry the crushing load between the pump suction and discharge cover apart from efficiency starting portion of the velocity energy at the top of the impeller into pressure energy.

Pump casing

The pump casing consists of a forged steel barrel with cast steel suction branch and forged steel discharge branches, mounting feet. The suction end of the casing is closed by a cast steel suction guide which as part of the pump integral cartridge is not attached to the pump casing. The discharge end of the casing is closed by a forged steel discharge cover secured to the casing. The sealing is done by 'O' ring and back up ring provided for in the suction guide and discharge cover. Transverse keys in the pump feet and longitudinal keys under the casing transfer moments and thrust to the base plate, while allowing the casing freedom to expand. Provision is made on the pump casing for a drain connection.

Foundation frame

The Boiler Feed Pump unit is provided with common foundation frames for Booster Pump, Electric Motor, Gear Box and Boiler Feed Pump which are grouted into the concrete. They are of welded steel construction.

Recirculation system

To impose a limit on the temperature rise across the pump and to ensure minimum quantity of feed flow through the pump, ON-OFF type high pressure recirculation control valve is provided.

Electric drive

The electric drive motor is a four pole squirrel cage induction motor. The terminal box shall be suitable for either top or bottom entry of cables and can be turned through 360 Deg C in steps of 180 degree.

3.2 BOILER:

3.2.1General description of steam generator

The Steam Generator is a box type, reheat, natural circulation, single drum, forced draft, outdoor type unit, designed for firing Crude Oil.

The complete furnace section is of welded wall type, arranged as a gas and pressure tight envelope. The circulation system will be complete with the necessary number of unheated down comers, supply and riser piping.

The superheated steam system has mainly three sections viz. The low Temperature super-heater (LTSH), the hanger platen super-heater and the final platen super-heater. One number super heater de super heater is provided in between the LTSH and the hanger platen super heater in the connecting link for controlling the superheated steam temperature over the control load range.

The complete Re-heater (RH) has been arranged in one section in the first pass of the Boiler. Re-heater desuperheaters are envisaged in the cold reheat steam piping at the inlet of the re-heater for emergency use.

The fuel oil system consists of fuel oil pumping and heating unit and fuel oil burners arranged at three elevations in the burner wind box sections.

The burner wind box sections are located in the four corners of the furnace and arranged for tilting tangential firing and capable of firing Crude Oil. The bottom most elevation is capable of firing LDO for start up purpose.

3.2.2 Tables(3.1) of Boiler parameters

Main steam	Parameters on Full load (125 MW)	Unit
Steam pressure from superheater outlet	14	Mpa
temperature from superheater outlet Steam	540	°C

Table (3.2)

Reheat steam	Parameters on Full load (125 MW)	Unit
Steam pressure from reheat inlet	3.92	Mpa
Steam pressure from reheat outlet	3.9	Mpa
Steam temperature to reheat inlet	335	°C
Steam temperature from reheat outlet	540	°C

3.2.3 Advantages

- Ability to burn Wide Variety of Fuels
- No Pulveriser
- Oil for Start-up only
- No Soot Blowers
- High Combustion/Boiler Efficiency Low Combustion Temperature
- Low Emissions - SO_x, NO_x
- Compact Boiler - High Heat Transfer rates
- Fast Load Response
- High Turn Down capability
- High Availability and Reliability

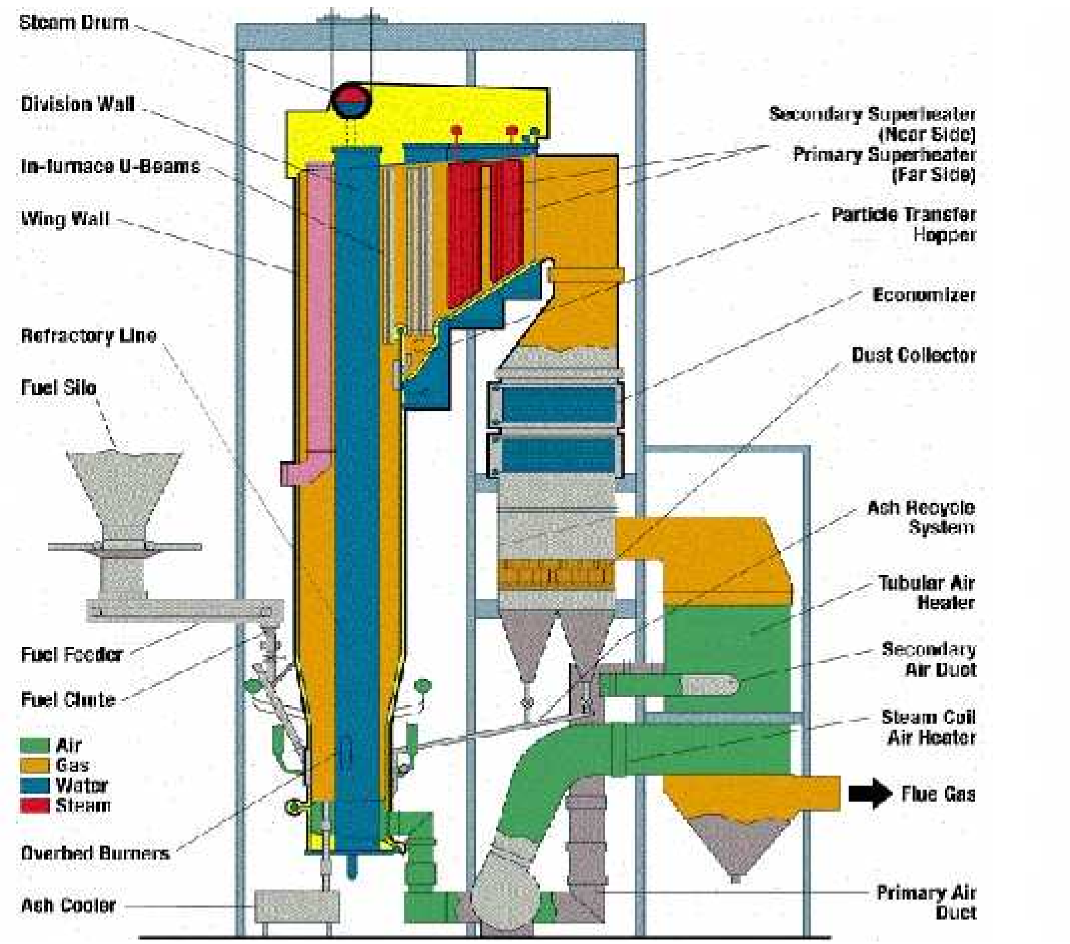


Figure (3.1) the boiler

3.3 TURBINE:

3.3.1General Design Features

The turbine is of condensing type, tandem compound design with separate HP/IP and LP cylinders. The combined HP/IP cylinder is of reverse flow design with high pressure and intermediate pressure blading. LP cylinder is of double flow type. The turbine is basically engineered on reaction principle with throttle governing to drive alternating current full capacity Turbo-generator.

3.3.2 Modular Concept

The turbine is built on the well-proven design philosophy of "Modular Principle" in steam turbine engineering field. The readily designed HP & LP modules are combined and sized to required power output, steam parameters and cycle configuration to give the most economical turbine set. This maneuverability is achieved without impairing the reliability of the modules, which are governed by the shape and configuration of rotors cylinders and distance between the bearings.

3.3.3 Construction Steam Flow

The turbine is a single shaft machine with separate HP-IP (Combined) and LP parts, the HP-IP cylinder with HP and IP flows in opposite direction and LP part with double flow cylinder. The individual turbine rotors and the generator rotor are connected by means of rigid coupling. The HP-IP cylinder has a throttle control governing. The initial steam is admitted before blading by two combined main steam stop and control valves which are bolted to the outer casing of the turbine. The line leading from HP exhaust branch to the re-heater is provided with swing check valves, which prevent the hot steam from re-heater flowing back into the HP turbine. The steam coming from the re-heater is passed to the IP part via., two combined reheat stop and control valves, which are bolted to the outer casing of the turbine. The two expansion areas are separated from each other by means of a shaft seal. Two cross-around pipes connect the IP part of combined HP-IP turbine and LP cylinder. Bleeds are arranged at several points of the turbine. Rotors

The rotating elements consisting of two mono block rotors of HP & LP turbines are coupled together by means of integrally forged flanges thus in effect forming a single shaft system.

3.3.4 Combined HP-IP Turbine

The combined HP-IP turbine is of reverse flow construction. Outer casing is axially split and supported on it's four paws. Inner casing is also axially split and supported kinematically and houses the guide blades. Main steam enters the inner casing through HP valves bolted to outer casing on both sides. The arrangement of inner casing confines the high steam inlet conditions to the admission branches of casing, while the joint of the outer casing is only subjected to the lower pressure and lower temperature at the exhaust (IP) of inner casing.

3.3.5 LP Turbine

The LP turbine is of triple shell double flow design. The outer shell is axially split and is fabricated out of plates. The outer casing consists of front and rear walls, two lateral longitudinal support beams and the upper part. The outer casing is supported by the ends of the longitudinal beams on the base plates of the foundation.

Steam admitted to the LP turbine from the IP turbine flows into the inner casing from both sides through steam inlet nozzles. Expansion joints are installed in the steam piping to prevent any undesirable deformation of casings due to thermal expansions of steam piping.

The LP casing has a double flow inner casing. This inner casing is of a double shell construction. The inner shell is suspended in the outer shell of the inner casing to allow free movement due to thermal expansion. The inner shell carries the front guide blade rows (drum blading). Three guide wheels (on both sides) carrying the last stage guide blade rows (LP blades) are also bolted to the outer shell of inner casing.

3.3.6 Turbine Governing System

The turbine has a high-pressure electro-hydraulic governing system. An electric system measures and controls speed and output. The electro-hydraulic actuators of the electric system operate the control valves in conjunction with the electro-hydraulic governing system. The electro-hydraulic governing system permits run-up control of the turbine up to rated speed and keeps speed low the swings following sudden load shedding.

The linear output frequency characteristic can be very closely set even during operation.

3.4 CONDENSER:

The condenser is surface type, fabricated construction and single shell. The condenser is mounted on saddles. A set of springs at the support or an expansion bellow at the condenser neck is provided to take care of thermal expansion in vertical direction. The condenser is firmly connected to the exhaust hood of the turbine.

On the water side the condenser is divided vertically into two independent water paths. This arrangement facilitates the operation of one half of the condenser when the other half is under maintenance.

The condenser is provided with integral air cooling zone from where air and non condensable gases are continuously drawn out with the help of air evacuation system.

3.4.1 The main functions of the condenser are

i. To condense the steam exhausted from the turbine to enable recycling of condensate.

ii. To maintain a vacuum such that the heat drop to be utilised in the turbine is optimum.

iii. To maintain the temperature of the condensate at the saturated level to remove the dissolved gases.

iv. To prevent the under cooling of the condensate to minimise thermal losses.

v. To facilitate the extraction of air and other gases to maintain high level of performance.

Condensation takes place on the outer surfaces of the tubes through which the cooling water is circulated. The tubes are arranged in bundles which are separated by adequate wide lanes. The selective layout of tube in the condenser ensures efficient heat transfer from steam to cooling water keeping the resistance to steam flow to the barest minimum.

3.4.2 The main parts of the condenser are

a. Shell
b. Water box
c. Tubes
d. Tube plates
e. Support plates
f. Super structure
g. Hotwell
h. Supports

Shell

The condenser shell is of carbon steel rectangular shape and fabricated construction. It is connected to the front and rear tube plates. The steam flow in condenser shell is guided with properly located baffles to have effective condensation with minimum sub cooling and efficient removal of air and non condensables.

The steam space is divided transversely by support plates.

Necessary connections on the condenser shell are provided for makeup, drains, vent, instruments etc.

Water box

Condenser water boxes are of carbon steel construction. The water boxes are of dome shaped and provided with hinge arrangement. With this arrangement the entire water box can be opened for facilitating repairs and replacement of tubes.

Water boxes are designed for even distribution of water. Cooling water inlet & outlet connections are connected to water boxes. Inspection holes are provided for routine maintenance and visual inspection. Water boxes are lined with rubber lining/FRP lining to protect against sea water corrosion in case of sea water supply.

Tubes

The condenser is provided with tubes. The tubes are secured to tube plates by roller expansion which provide good sealing arrangement against penetration of circulating water into steam space. The tube nest as, a whole is kept slightly inclined to provide self draining of tubes when the condenser is under shut down.

The cooling water flows inside the tubes and steam flows over the tubes. These tubes provide the necessary heat transfer surface. Each tube is tested in conformance to material specification and subjected to a hydraulic test pressure of 70 atm at supplier works.

Tube Plates

The tube plates are generally of carbon steel and connected to shell. The holes are drilled to a close tolerance and the tubes are roller expanded into the tube plates.

Non ferrous tube plates are employed for sea water application.

Support plates

The support plates are of carbon steel material and welded to the shell. The tubes are supported on support plates at regular intervals along its length which help in arresting vibration induced by running TG and consequently the tube damage.

Super Structure

The function of super structure is to enable even distribution of steam to tube bundle. It also houses steam dump device, if it is envisaged in the system. The super structure is made of carbon steel plates and strengthened from inside or outside by plates/flats/rods/angles/channels to retain its shape against atmospheric pressure.

Hot well

The condenser hotwell is of carbon steel material. It is welded at bottom of the shell and it has adequate storage capacity of water. It may be divided vertically into two sections. One or two condensate extraction connections are provided in the hotwell.

3.5 CHIMNEY:

The chimney will be 120m high, reinforced concrete shell having two /four flues. Individual flues will be of acid & heat resistant brick lining insulated on outer face with resin bonded rock wool insulation. This brick lining work will be supported on internal RCC platform at 10m interval. These platforms will be supported on steel beams which would span between simple supports on the shell. The platform structure shall be painted for acid and heat protection. External platforms of reinforced concrete or structural steel shall be generally provided at regular intervals along the height of chimney.

The grade level slab shall be of reinforced concrete having ironite finish. The chimney shall be provided with a raft foundation system depending upon soil characters tics. Apart from aviation warning lights, the complete external surface of the shell (wind shield) shall be painted in alternate band of red and white color and in line with aviation requirements, out of which the top 50 meter of paint shall

have acid and heat resistant properties and rest of the surface shall be painted with water proof cement paint.

The chimney roof slab shall be of reinforced concrete treated for water proofing and protected by a layer of acid resistant tiles laid in acid resistant mortar. Suitable personnel access door and truck entry door will be provided. A personnel access hatch in of the slab, liner access hatches, rain water drainage system, flue acid drainage, bird screens or louvers on the ventilation openings shall also be provided.

There will be structural steel stairways for access to platforms. Arrangement shall be provided for measuring concentration of particulate matters, Nox& Sox in the flue gas for monitoring and taking necessary measure for pollution control. It will also have necessary arrangement for electrical power supply , distribution boards, socket outlets, power and control cabling raceways system, stair and platform lighting, lightening protection and ear thing system.

Pressurized ventilation system will be provided to keep inside of chimney free from flue gas that might otherwise leak through mortar joints of brick lined flue. Stack elevator will be provided to run along inside surface of wind shield. There will be mini reinforced concrete shell circumscribing each flue above roof level. Annular cast iron chimney caps will be fixed on top of flue covering both flue lining and mini shell.

Galvanized mild steel discrete strakes will be provided over the required length of the chimney at the top, if found necessary from wind tunnel study for chimney model.

CHAPTER FOUR

CALCULATION

4.1 Calculation of efficiency for Um-dabakir power station

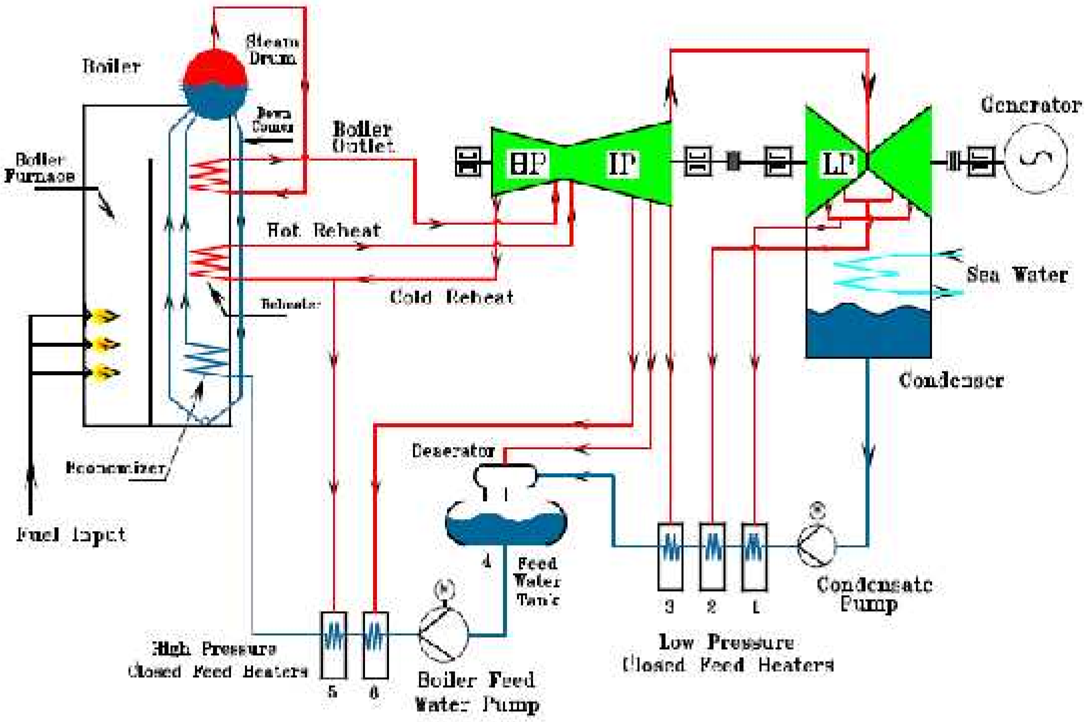


Figure (4.1) Block diagram for Um-dabakir

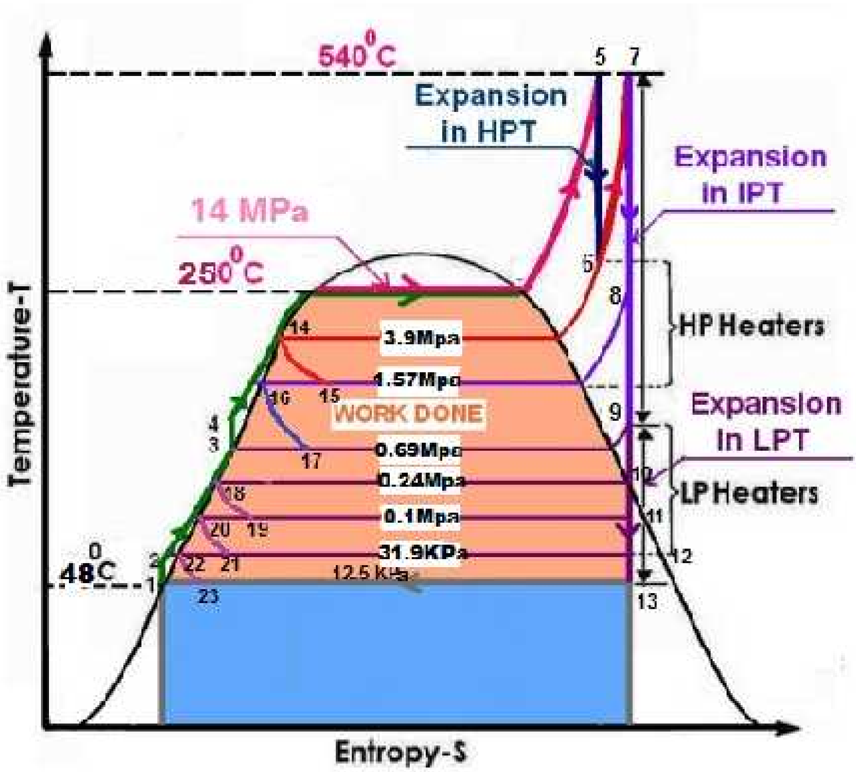


Figure (4.2)T-S diagram for Um-dabakir power station

From steam table:

$h_1 = h_f @ P_{condenser}$

$= h_f @$ 12.5 kpa = 208.87 kJ/kg

$h_2 = h_1 + Wpupm1$

$w_{pump1} = v(P_2 - P_1)$

$w_{p1} = 0.001(690-12.5) = 0.675$ kJ/kg

$h_2 = 209.553$ kJ/kg

$h_3 = h_f @$ P heater4

$h_3 = h_f @$ 0.69 Mpa

$h_3 = 694.416$ kJ/kg

$h_4 = h_3 + W_{pupm2}$

$h4 = h3 + w_{pump2}$

$w_{pump2} = v\ (P_4 - P_3)$

w_{p2}=0 .001(14000-690)= 13.31 kJ/kg

h_4= 707.726 kJ/kg

h_5= hg @ 14 Mpa and 540 °C

h_5= 3429.2 kJ/kg

$S_5=S_6$=6.844 kJ/kg.k

h_6=3119.64 kJ/kg

$h_7= h_g$ @ 3.9 Mpa and 540 °C

h_7= 3449.4 kJ/kg

$S_7=S_8= S_9=S_{10}$= 7.215 kJ/kg.k

h_8= 3330.58 kJ/kg.k

h_9= 3112.2 kJ/kg

h_{10}= 2869.32 kJ/kg

$S_{10}=S_{11}$= 7.215 kJ/kg.k

$$X11 = \frac{S11 - Sf}{Sfg}$$

$$X11 = \frac{7.215 - 1.303}{6.056} = 0.98$$

X_{11}= 0.98

$h_{11}= h_f+ X_{11} * h_{fg}$

h_{11}= 417+ 0.98*2258

h_{11}=2629.84 kJ/kg

$S_{11}=S_{12}$

$$X12 = \frac{S12 - Sf}{Sfg}$$

$$X12 = \frac{7.215 - 0.961}{6.785} = 0.92$$

X_{12}=0 .92

$h_{12}= h_f+ X_{12}*h_{fg}$

h_{12}= 294.7 + 0.92*23332.2

h_{12}= 2440.324 kJ/kg

$S_{12}=S_{13}$

$$X13 = \frac{S13 - Sf}{Sfg}$$

$$X13 = \frac{7.215 - 0.706}{7.365} = 0.88$$

X_{13}= 0.88

h_{13}= 210.25 + 0.88*2381.25

h_{13}= 2305.75 kJ/kg

h_{14}= h_{15} = h_f @ 3.9 Mpa = 1073 kJ/kg

h_{16}= h_{17} = h_f @ 1.57 Mpa = 854.4 kJ/kg

h_{18}= h_{19} = h_f @ 0.24 Mpa = 530 kJ/kg

h_{20} = h_{21} = h_f @ 0.1 Mpa = 417 kJ/kg

h_{22} = h_{23} = h_f @ 31.9 kpa = 294.7 kJ/kg

h_{24} = h_f @ 55 °C = 230.2 kJ/kg

h_{25}= h_f@ 80 °C = 334.9 kJ/kg

h_{26}= h_f @ 105 °C= 439.86 kJ/kg

h_{27}= h_f @ 130 °C = 546 kJ/kg

h_{28} = h_f @ 170°C = 719.22 kJ/kg

h_{29}= h_f @ 195 °C = 830 kJ/kg

h_{30} = h_f @ 250 °C = 1085.598 kJ/kg

Table of Enthalpy values (4.1)

State	Position	Enthalpy h [kJ/kg]
1	Feed water from condenser to condenser extraction pump	208.87 [kJ/kg]
2	Feed water from condenser extraction pump to heater1	209.553 [kJ/kg]
3	Open feed water heater	694.416 [kJ/kg]
4	From open feed water heater to boiler feed pump	707.726 [kJ/kg]
5	From boiler feed pump to H.P.T	3429.2 [kJ/kg]
6	Extraction in H.P.T and extraction steam on heater6	3119.64 [kJ/kg]
7	From boiler (reheat line) to I.P.T	3449.4 [kJ/kg]
8	Extraction steam on heater5	3330.58 [kJ/kg]
9	Extraction steam on heater4	3112.12 [kJ/kg]
10	Extraction steam on heater3	2869.32 [kJ/kg]
11	Extraction steam on heater2	2629.84 [kJ/kg]
12	Extraction steam on heater1	2440.324 [kJ/kg]
13	Condensate steam	2305.75 [kJ/kg]
14 ;15	Drain steam from heater6 to heater5	1073[kJ/kg]
16;17	Drain steam from heater5 to open feed water heater	854.4 [kJ/kg]
18;19	Drain steam from heater3 to heater2	530 [kJ/kg]
20;21	Drain steam from heater2 to heater1	417 [kJ/kg]
22;23	Drain steam from heater1 to condenser	294.7 [kJ/kg]
24	Feed water to heater1	230.2 [kJ/kg]
25	Feed water to heater2	334.9 [kJ/kg]
26	Feed water to heater3	439.86 [kJ/kg]
27	Feed water to open feed water heater	546 [kJ/kg]
28	Feed water to heater5	719.22 [kJ/kg]
29	Feed water to heater6	830 [kJ/kg]
30	Feed water to boiler	1095.598 [kJ/kg]

Heat balance for heaters:

Heat balance for heater6:

$h_6*m_1+h_{29}=h_{14}*m_1+h_{30}$

$3319.64*m_1 +83 = 1073*m_1 + 1095.598$

$M_1= 0.13$

Heat balance for heater5:

$h_8*m_2 + h_{28} + h_{15} = h_{16}*(m_1+m_2) + h_{29}$

$3330.58*m_2 + 719.22 + 1073 = 854.4*(0.13+m_2) + 830$

$M_2 = 0.033$

Heat balance for open feed water heater:

$h_9*m_3 + h_{17}(m_1+m_2) + h_{27} = h_{28}$

$3112.12*m_3 + 854.4*(0.13+0.033) + 546 = 719.22$

$M_3 = 0.011$

Heat balance for heater3:

$H_{10}*m_4 + h_{26}*(1-m_1-m_2-m_3) = h_{18}*m_4 + h_{27}*(1-m_1-m_2-m_3)$

$2869.32*m_4 + 439.86*(1-0.13-.033-.011) = 530*m_4 + 546*(1-0.13-0.033-0.011)$

$M_4 = 0.037$

Heat balance for heater2:

$h_{11}*m_5 + h_{25}*(1-m_1-m_2-m_3) = h_{21}*(m_4+m_5) + h_{26}*(1-m_1-m_2-m_3)$

$2629.64*m_5 + 334.9*(1-0.13-0.033-0.011)$

$= 417*(0.037+m_5) + 439.86*(1-0.13-0.033-0.011)$

$M_5 = 0.046$

Heat balance for heater1:

$h_{12}*m_6 + h_{24}*(1-m_1-m_2-m_3) = h_{22}*(m_4+m_5+m_6) + h_{25}*(1-m_1-m_2-m_3)$

$24440.324*m6 + 230.2*(1-0.13-0.033-0.011) = 294.7*(0.037+0.046+m_6)+334.9*(1-0.13-0.033-0.011)$

$M_6 = 0.052$

Calculated the energy supplied in the boiler:

$q_{add} = (h_5-h_4)+(h_7-h_6)$

$q_{add}=(3424.2-707.726)+(3449.4-3119.64)=3051.234$ kJ/kg

Calculated total work in turbines:

$W_{T1}= h_5-h_6 =3429.2-3119.64= 309.56$ kJ/kg

$W_{T2} = (1-m_1)*(h_7-h_8) = (1-0.13)*(3449.4-3330.58) =103.37$ kJ/kg

$W_{T3} = (1-m_1-m_2)*(h_8-h_9)$

$=(1-0.13-0.033)*(3330.58-3112.12)=182,85$ kJ/kg

$W_{T4} = (1-m_1-m_2-m_3)*(h_9-h_{10})$

$= (1-0.13-0.033-0.011)*(3112.12-2869.32)=200.55$kj/kg

$W_{T5} = (1-m_1-m_2-m_3-m_4)*(h_{10}-h_{11})$

$= (1-0.13-0.033-0.011-0.037)*(2869.32-2629.84) =188.95$ kJ/kg

$W_{T6} = (1-m_1-m_2-m_3-m_4-m_5)*(h_{11}-h_{12})$

$= (1-0.13-0.033-0.011-0.037-0.046)*(2629.84-2440.324)=140.81$ kJ/kg

$W_{T7} = (1-m_1-m_2-m_3-m_4-m_5-m_6)*(h_{12}-h_{13})$

$= (1-0.13-0.033-0.011-0.037-0.046-0.052)*(2440.324-2305.75)$

$=93$ kJ/kg

Total Turbine work = 1219.09 kJ/kg

$$\text{Thermal Efficiency} = \frac{\text{Total Turbine work}}{\text{Energy supplied in boiler}}$$

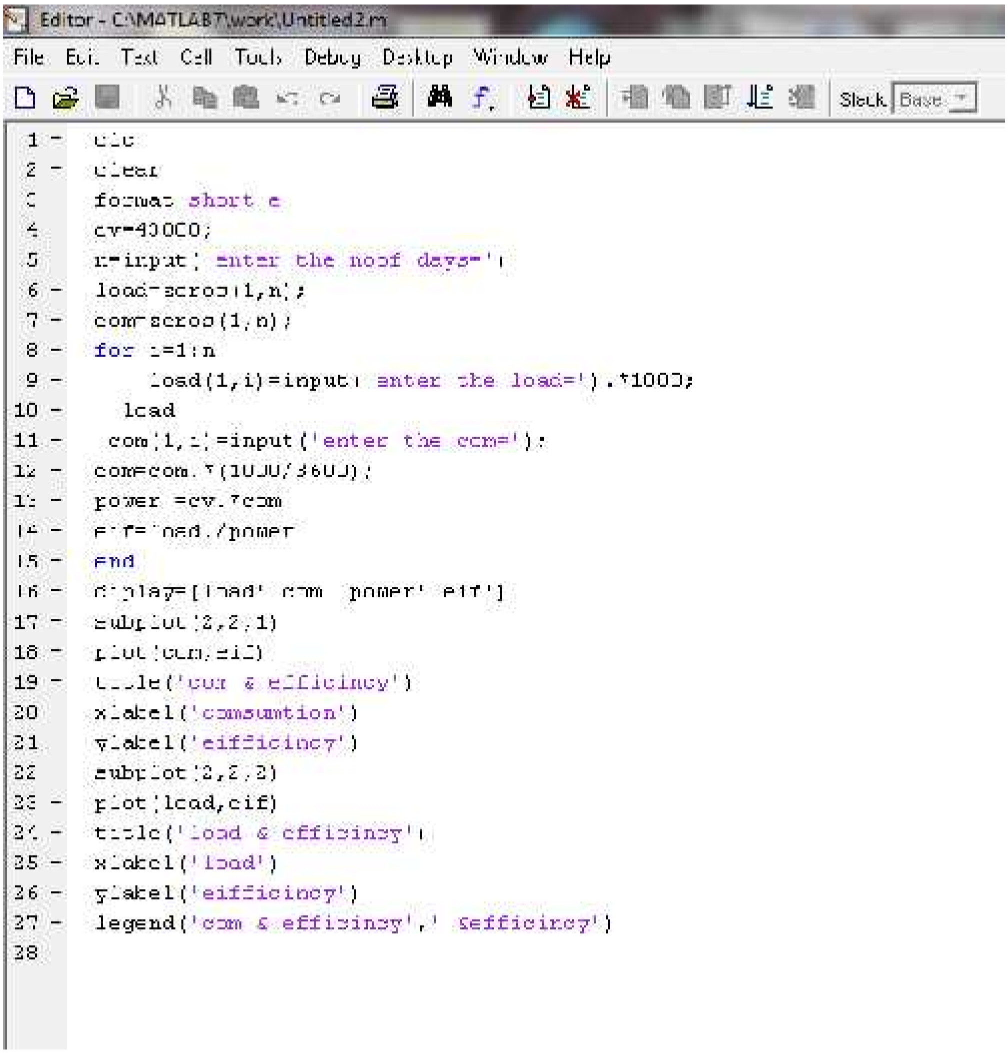
$$\text{Thermal Efficiency} = \frac{1219.09}{3051.234} = 39.9\%$$

Comparison between design efficiency and actual efficiency table (4.2)

Date	Fuel consumption Tone/hour	Calorific value of crude oil MJ/kg	Load MW	Actual efficiency= $\frac{load}{fuel\ consumption * cacalrofic\ value}$ % efficiency %	Design efficiency %
1/6/ 2014	19.98	43	75	31.43	39.90
2/6/2014	24.90	43	103	34.63	39.90
3/6/2014	20.33	43	87	35.83	39.90
10/6/2014	23.39	43	98	35.07	39.90
12/6/2014	24.03	43	102	35.35	39.90
13/6/2014	24.11	43	101	35.07	39.90

4.2 MATLAB Program:

We made a script file for MATLAB program through it we can enter the fuel consumption and load after that it calculates the efficiency



```
clc
clear
format short e
cv=40000;
n=input('enter the noof days=')
load=zeros(1,n);
com=zeros(1,n);
for i=1:n
    load(1,i)=input('enter the load=').*1000;
  load
 com(1,i)=input('enter the com=');
com=com.*(1000/3600);
power =cv.*com
eif=load./power
end
display=[load' com' power' eif']
subplot(2,2,1)
plot(com,eif)
title('com & efficincy')
xlabel('consumtion')
ylabel('eifficincy')
subplot(2,2,2)
plot(load,eif)
title('load & efficincy')
xlabel('load')
ylabel('eifficincy')
legend('com & efficincy',' &efficincy')
```

CHAPTER FIVE

CONCULATION

5.1 Results:

* According to the obtained results in chapter four the efficiency was 39.9%. as an actual efficiency.
* from our last field visit to Um-Dabakir power plant station in White Nile, the efficiency obtained in this station is considered to be the highest among all other steam power plants in Sudan.

5.2 Recommendation:

We recommend for the students to conduct field visits to Um-Dabakir power plant station for its developed equipments and it is the recent station in Sudan

We recommend the use of other programs for the calculation of the efficiency other than MATLAB

We recommend the use of another fuel because crude oil has many disadvantages despite the low cost.

To facilitate the procedures for the students when they conduct any field visit, the university should have representatives in most of the vital constructions such as Um-Dabakir power plant station.

5.3 Conclusion:

To sum up, our main concern is to find the maximum efficiency of steam turbine power plant and design a computer program to calculate the efficiency, we calculated the efficiency manually and was obtained successfully. Based on real thermodynamic values which were taken from Um-Dabakir power station the efficiency was obtained.

We designed a computer program "MATLAB" which led to efficiency higher compared to the actual efficiency and this is due to the values which were taken at the designed values.

Moreover, we achieved the goals we proposed including an economical view of which we compare some fuels used in Sudan with other fuels such as natural gas and this comparison is tabulated.

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2/ Y. A. Çengel and M. A. Boles, Thermodynamic An Engineering Approach, 5th edition, McGraw-Hill, 2006.

3/ (P.K.Nag), Power plant Engineering, Third Edition copyright @ 2006.

٤/ Um-Dubakir power plant documentation @ 2005.

5/ Data collected from Um-Dbakir power station UNIT 3.

6/ American society of Mechanical Engineers code (ASME).

Appendices

Appendix 1: Request to go to Um-Dabakir station

Sudan University of Science & Technology
College of Engineering
School of:
Mechanical Engineering

جامعة السودان للعلوم والتكنولوجيا
كلية الهندسة
مدرسة الهندسة الميكانيكية

2015/3/23 م

مدير محطة أم دباكر

السلام عليكم ورحمة الله وبركاته

الموضوع :- زيارة علمية لطلاب مشروع تخرج تحت عنوان

Maximum efficiency of steam turbine

... تعاون والعلاقة المتطورة بين المؤسسات الاكاديمية والمؤسسات الصناعية ترجو
... السودان للعلوم والتكنولوجيا (كلية الهندسة — مدرسة الهندسة الميكانيكية) .
... الكريمة بالسماح لطلاب المشروع المذكورين أدناه بزيارة مؤسستكم الرائدة
... بعض المعلومات المتعلقة بموضوع بحث تخرجهم . والطلاب هم :

1- ... قحطان عبدالله غالب
2- محمد قاسم عبدالحفيظ شرف
3- ... عبدالله ...

،، وتقبلوا فائق الشكر والتقدير والاحترام ،،

23/3/2015

أ. عبدالله مختار محمد عبدالله

رئيس قسم هندسة القدرة

ppendix 2: Request to go to Bari station

Sudan University of Science & Technology
College of Engineering
School of:
Mechanical Engineering

جامعة السودان للعلوم والتكنولوجيا
كلية الهندسة
مدرسة الهندسة الميكانيكية

التاريخ : 1/6/2015 م

السيد /مدير محطة بحرى الحرارية

السلام عليكم ورحمة الله وبركاته

الموضوع : زيارة علمية لطلاب مشروع تخرج تحت عنوان

Maximum efficiency of steam turbine

في إطار التعاون والعلاقة المتطورة بين المؤسسات الاكاديمية والمؤسسات الصناعية ترجو إدارة جامعة السودان للعلوم والتكنولوجيا (كلية الهندسة – مدرسة الهندسة الميكانيكية) موافقتكم الكريمة بالسماح لطلاب المشروع المذكورين أدناه بزيارة مؤسستكم الرائدة بغرض تجميع بعض المعلومات المتعلقة بموضوع بحث تخرجهم . والطلاب هم :

1- هاني قحطان عبدالله
2 - محمد قاسم عبدالحفيظ
3- خالد عبدالله عبدالله
4- الخطيب عاطف

،، وتقبلو فائق الشكر والتقدير والاحترام ،،

3/6/2015

أ. عبدالله مختار محمد عبدالله
مشرف المشروع

0903965 912

بسم الله الرحمن الرحيم

وزارة الموارد المائية و الكهرباء

Ministry Of Water Resources Electricity

الشركة السودانية للتوليد الحراري المحدودة

إدارة الموارد البشرية

قسم التدريب

التاريخ : 2015/6/23م

النمرة : ت/خ/م

السيد/ مدير محطة الشهيد

السلام عليكم ورحمة الله وبركاته ,, ,,

الموضوع:مشروع تخرج لعدد 4 طلاب

بالاشارة للموضوع اعلاه ،نرجو التكرم بمساعدة طلاب الهندسة الميكانيكا جامعةالسودان،وذلك من اجل اكمال بحث التخرج تحت عنوان (Maximum Efficiency of Stem Turbine) ،طلاب هم :

1- هانى قحطان عبدالله.

2- محمد قاسم عبد الحفيظ.

2-خالد عبدالله عبدالله.

4- الخطيب عاطف .

وشكـــراً ,,,,

السيد/ رئيس وحدة الوردية

الرجاء التكرم بمدهم بالمعلومات المطلوبة والتي تفيدهم في مشروع

30/6/2015

م. الهادى ادم الحاج

مدير قسم التدريب

I السيد/ مدير قسم التشغيل

لعنايتكم -

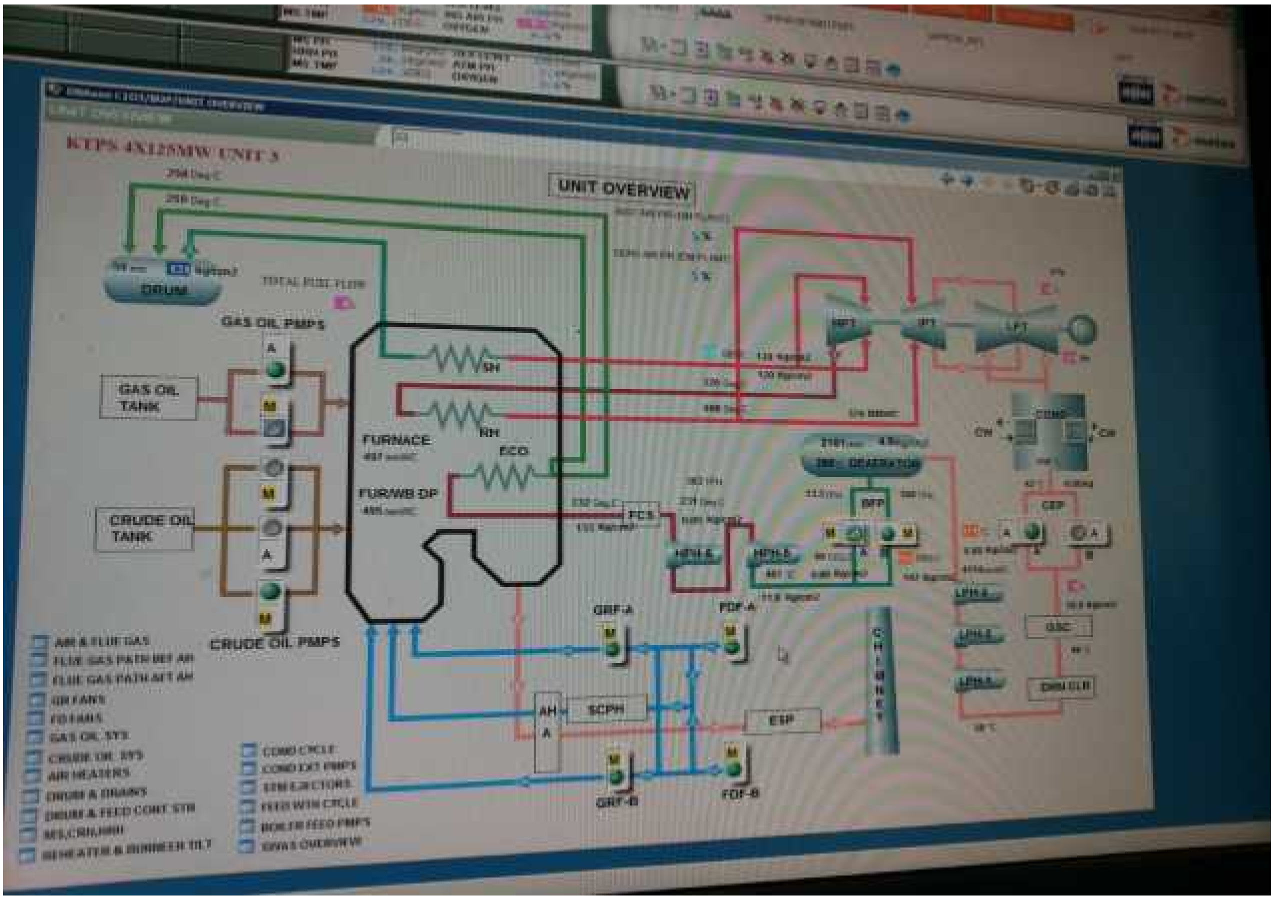
30-6-2015

عبد الباقي النعيم - التدريب

Appendix 3: a picture of steam turbine

Appendix 4: a picture of part of the plant

Appendix 5: a picture taken from a computer in central control room



Appendix 6: a picture shows the chimney