1.1. Introduction :-

Oil and gas industry is a very challenging industry with daily technologies coming in line that contribute to the sustainable exploration, production and utilization of hydrocarbon resources. It is very well documented in the international literature that conventional oil is vastly depleting and business as usual is not the trend in today's world. Demand for oil is progressively increasing and politics is playing a vital role on this strategic commodity global trade game. Best Available Technologies helps a lot in resources recovery and conservation. the industry's activities in extracting, processing and marketing fuels also accounts for 27.4% of total global primary energy use (IEA, 2011).

Energy is needed to extract resources from the ground, and to process, transform and deliver those resources to consumers. Because energy comprises a significant portion of the oil and gas industry's overall operating costs, companies already have a strong financial incentive to save energy. Using energy efficiently reduces costs along the whole supply chain, improving competitiveness and making end products more affordable for consumers. It is also a powerful environmental tool, reducing the carbon intensity of processes and therefore reducing carbon emissions to the atmosphere. This is why oil and gas companies have invested heavily over the years in more efficient technologies all along the supply chain, and plan to invest more in the future. But worldwide, opportunities still exist within the industry to make significant contributions towards reducing energy consumption and greenhouse gas emissions by taking advantage of energy efficiency improvements (IPIECA, 2013).

Energy efficiency and energy conservation are distinctly different; however, both play a role in reducing the amount of energy used. Energy efficiency is about reducing the energy intensity of a process or activity so that less energy is required to provide the same product or service. This can be achieved by introducing more efficient technologies, equipment or processes. On the other hand, whilst definitions of energy conservation differ, it is generally more related to culture, human behavior and operational procedures. It typically means using less energy by reducing use, or by eliminating unnecessary activities and energy losses, rather than using less energy to accomplish he same thing. (IPIECA, 2013).

- **Sudan Environment**:

Sudan environment is high temperature compare with other countries , it characterized with an average of 10 hrs of sun shine and solar of (3.05-7.62)KW/m^2 /day the temperature about (32-45) ,so need to keep the hydrocarbon products safety in transport and storage to control the total evaporation losses and minimize it.

Organic liquids in the petroleum industry, usually called petroleum liquids, generally are mixtures hydrocarbons having dissimilar true vapor pressures (for example, gasoline and crude oil). Organic liquids in the chemical industry, usually called volatile organic liquids, are composed of pure chemicals or mixtures of chemicals with similar true vapor pressures (for example, benzene or a mixture of isopropyl and butyl alcohols) (Hamed .Suliman 2014).

Fixed roof tanks are either freely vented or equipped with a pressure/vacuum vent. The latter allows the tanks to operate at a slight internal pressure or vacuum to prevent the release of vapors during very small changes in temperature, pressure , or liquid level.

The potential emission sources for above-ground horizontal tanks are the same as those for vertical fixed roof tanks. Emissions from underground storage tanks are associated mainly with changes in the liquid level in the tank. Losses due to changes in temperature or barometric pressure are minimal for underground tanks because the surrounding earth limits the diurnal temperature change, and changes in the barometric pressure result in only small losses.

The external floating roof design is such that evaporative losses from the stored liquid are limited to losses from the rim seal system and deck fittings (standing storage loss) and any exposed liquid on the tank walls (withdrawal loss).

Emissions from organic liquids in storage occur because of evaporative loss of the liquid during its storage and as a result of changes in the liquid level. The emission sources vary with tank design, as does the relative contribution of each type of emission source. Emissions from fixed roof tanks are a result of evaporative losses during storage (known as breathing losses or standing storage losses) and evaporative losses during filling and emptying operations (known as working losses). External and internal floating roof tanks are emission sources because of evaporative losses that occur during standing storage and withdrawal of liquid from the tank. Standing storage losses are a result of evaporative losses through rim seals, deck fittings, and/or Deck seams.

Several methods are used to control emissions from fixed roof tanks. Emissions from fixed roof tanks can be controlled by installing an internal floating roof and seals to minimize evaporation of the product being stored. The control efficiency of this method ranges from 60 to 99 percent, depending on the type of roof and seals installed and on the type of organic liquid stored.

The concept of energy conservation is closely linked to economic process if not be identical to the concept of economic industrial process completely in general, and here is intended to wasted energy set in operational productivity in refineries in the form of the cost of the actual production account with compared with the design cost for each process in terms of the amount of fuel used, and thus this comparison shows that there were flaws in the design of the stomach, and then work to reduce this cost to treat problems in all operations of the facility and to reach productivity maximum efficiency possible in terms of reducing wastage in high productivity of energy products from refineries.

When the early stages of design and construction of the refinery, taking into account the raw quality and quantity and the target production of refinery products passing through all (processes) and (Utilities) associated with each process, and the energy used for the completion of each process efficiently and calculated from the energy quantities, whether electrical or thermal .

In this research will be taken ELobeid refinery as a model to reduce the energy losses in some equipments , started with calculate energy losses in pipes ,crude oil storage tanks ,heat exchangers ,heaters, valves ,flanges and boilers, and the amount of fuel used in the burning to heat the water in the Boilers, or heaters, then compare it with the energy needed from the design data .

This comparative study investigate the problems that we intend to solve by the most economic way, and thus calculate the losses cost of each unit and then the total costs and compare them with the initial design and therefore know the weak points and recommend remedying it, and so we can find an economic process that is ideal for engineering work.

Taking into account the comparison with the original design of the refinery as well as compared to Elobeid refinery with similar products in the amount and number of units . To achieve the most accurate results and calculations .

1.2. Problem Statement:

Energy auditing is conducted for Elobied refinery to examine the energy losses in the refinery equipment (tanks,valves,flanges and pipes) in order to enhance energy efficiency

1.3. Objectives:

The objective of this research are:

1) To evaluate the energy consumption in Elobied Refinery.
2) To reduce the energy losses in CDU.
3) To reduce the operation cost in Elobeid refinery.
4) To evaluate the Emissions in the crude oil tanks.
5) To propose the solutions to reduce energy losses.

2.1. INTRODUCTION:-

- Elobied Refinery company are built in 1995 as 10000bbl/day and increase the capacity to
- ORC consist of :-(TWO Heaters-eight Heat Exchangers -Storage Tanks -4Generations -Cooling tower-4boilers).
- Its produce many products have different percentage :

Table: 2.1

Product	Percentage %
Furnace	64
Naphtha	6
Kerosene	7
Gasoil	24

- ORC have many units there are:

Table:2.2

No	Unit	Account of Equipment
1	Fired Heater	2
2	Boiler	4
3	Crude oil tanks	7
4	Products tank	13
5	Laboratory	1
6	Condenser	1
7	Stripping column	3
8	Heat exchanger	9
9	Administration building	2
10	Control room -DCS	1

FIg. 2.1 ELOBIED REFINERY

2.2. Energy audit:-

Energy audit means three interrelated issues: savings in money; environmental protection and sustainable development. Awareness of these issues is vital to the people working in intensive energy industries such as oil and gas industry.(Ali A. Rabah , ..etc).

What is an Energy Audit?

The energy audit is one of the first tasks to be performed in accomplishing an effective energy management program designed to improve the energy efficiency and reduce the energy operating costs of a facility .(Assoc. Prof. Dr. Ugur Atikol, cea).

An energy audit consists of a detailed examination of how a facility uses energy, what the facility pays for that energy, and finally, a recommended program for changes in operating practices or energy consuming equipment that will cost effectively save dollars on energy bills.

The energy auditis sometimes called an energy surveyor an energy analysis, so that it is not confused with a financial audit.

The energy audit is a positive experience with significant benefits to the facility.

The term “audit” should be avoided if it clearly produces a negative image in the mind of a particular business, organization, or individual.

Basic Components of an Energy Audit

The audit process starts by collecting information about a facility’s operation and about its past record of utility bills.

This data is then analyzed to get a picture of how the facility uses –and possibly wastes –energy, as well as to help the auditor learn what areas to examine to reduce energy costs.

Basic Components of an Energy Audit

Specific changes –called Energy Conservation Measures (ECM’s) –are identified and evaluated to determine their benefits and their cost effectiveness.

These ECM’s are assessed in terms of their costs and benefits, and an economic comparison is made to rank the various ECM’s.

Finally, an Energy Action Plan is created where certain ECM’s are selected for implementation, and the actual process of saving energy and moneybegins.

Goals of the Energy Audit Clearly identify types and costs of energy use Understand how energy is being used–and possibly wasted Identify and analyze more cost-effective ways of using energy.

-improved operational techniques

-new equipment, new processes or new technology

Perform an economic analysis on those alternatives and determine which ones are cost-effective for your business or industry

Types of Energy Audits:

a. Type I-also called walk-thruor checklist.
b. Type II-also called Mini-audit.
c. Type III-also called Maxi-audit.
d. Investment gradeaudit.
e. MasterAudit.

Type I Audit:

This audit consists ofa walk-throughinspection of afacility to identify maintenance, operational, or deficient equipment issues and to also identify areas which need further evaluation.

Type II Audit:

This audit includes performing economic calculations and may include performing monitoring/metering/testing to identify actual energy consumption and losses.

Type III Audit:

This audit includes the performance of computer modeling to determine the actual year round energy consumption.

Investment Grade Audit:

This audit includes weighing risk into the economic calculations of a type II or III energy audit. This audit can be utilized to obtain funding for the projects identified.

Master Audit:

This energy audit also contains information such as code compliance, maintenance schedule development, equipment inventories, etc.

How Do You Know Which Type of Audit to Select?

Depends on the funding available for the audit, the cost and potential of the Energy Management Opportunity, and the required accuracy for the audit information.

Depends on the type of facility, function of the facility, and processes within a facility. (Assoc. Prof. Dr. Ugur Atikol, cea).

2.3. History of Energy Audit :-

The California Air Resources Board finally released a report to the public yesterday on a series of audits looking at greenhouse gas (GHG) and other pollutant reductions in the refining sector. The audits were part of a regulation adopted in July 2011 covering the largest industrial sources of GHG emissions. Reports on other sectors (Cement, hydrogen, power, oil and gas, and mineral production) should be out later this summer. The regulation required 45 major industrial GHG sources - major meaning that they emit more than 0.5 million metric tonnes of carbon-dioxide equivalent (MMTCO2e) per year or for cement plants and refineries, more than 0.25 MMTCO2e per year – to report the following in December 2011.

- An audit of fuel and energy consumption, and GHG, criteria pollutants, and toxic air contaminant (TAC) emissions.
- A list of all potential energy efficiency improvements for equipment, processes, and systems.

Although most refineries report that they have done energy efficiency audits in the past, what is notable about this regulation is that the audits track conventional and toxic air pollutants in addition to carbon and energy, and that results are being shared with the public. Not everything is publicly released – the report notes that some projects were identified as "not implementing" and it appears that the public may never know the full extent of what these projects are or how great the benefits would be if they were implemented.

According to the audit report, over the last few years California refineries have reduced 2.2 MMTCO2e per year and have the opportunity to reduce at least 0.6 MMTCO2e more in the coming years. If it wasn't clear before, that major emitters can make substantial GHG reductions to meet our AB 32 climate goals, these audits prove it. We can also expect a 365 ton per year (TPY) reduction in NOx emissions and an 88 TPY reduction in particulate matter (PM) from these measures going forward if they are fully implemented. This is significant given that all of the major refineries in California are in areas that fail to meet federal clean air standards – every ton reduced of the two major air pollutants, NOx and PM counts.

The twelve major refineries that submitted audits account for roughly 30 percent of all industrial GHG emissions (34 MMTCO2e per year of a total of 111 MMTCO2e from all major sources reporting in 2009). Collectively they came up with more than 400 energy efficiency improvement measures including things like boiler upgrades, optimizing electrical equipment and pumps, improving maintenance, replacing old heat exchangers, and adding insulation. All of the measures cost a total of $2.6 billion in up front investments but save an average of $200 million per year. (Ernst Worrell and Christina Galitsky,2005)

Although dozens of local, state and federal regulations address refinery emissions, the sector continues to emit toxic air contaminants in large quantities. The public audit report does not include data on how much TAC emissions have been reduced due to energy efficiency improvements, but one would guess there could be a significant co-benefit of TAC reductions.

Energy management systems Many companies have developed and implemented formal energy management systems that seek to incorporate efficiency improvements and emissions reductions into routine business operations. A consistent standard for energy management systems is now available from the International Organization for Standardization (ISO) as ISO 50001, which prescribes the key elements required for effective energy management and efficiency improvements. Elements include a corporate energy policy, a baseline for energy use, improvement goals and action plans, energy reviews and routine evaluation of progress. (IPIECA, 2013).

- Energy management systems have been in place for several years in various segments of the industry. Examples include:

● Exxon Mobil’s Global Energy Management System (GEMS), targeting refinery operations and chemical plants;

● Petrobras’ Energy Efficiency Programme for refining, cogeneration and heating systems;

● Repsol’s Energy Management Systems in refining and marketing segments including distribution and fuel stations.

Because of the success they bring, energy management systems may become more common throughout the industry in the next 10 years. IPIECA has developed specific guidance on applying the concepts of ISO 50001 specifically for the oil and gas sector, to facilitate the use and effectiveness of energy management systems across the industry (IPIECA, 2013b).

2.4 Benchmarking tools:-

Another management tool to facilitate energy efficiency is benchmarking. Consistent metrics can be used to evaluate performance within a facility and also compare energy efficiency between facilities. They can be the basis for setting goals, identifying energy reduction projects and tracking progress.

However, defining relevant energy performance metrics in the oil and gas industry is not a straightforward endeavour. Every refinery and every oil and gas field is unique. In the refining sector, each refinery has its own unique characteristics, shaped by the markets it serves, the local environmental requirements and the types of feedstocks used to make the final product. Each refinery is essentially a collection of individual process units, each designed and tuned to produce particular refined products.

To address these challenges, the refining sector has developed modular energy performance indexes which take into account the different levels of complexity between refineries. (IPIECA, 2013).

2.5 Oil refining:-

Oil refining is an energy-intensive activity, accounting for about half of all the energy consumed by the oil and gas industry as a whole. And factors such as more stringent oil product standards , Benchmarking indices have become standard in the refining industry as a tool to monitor and drive energy efficiency improvements and compare performance between refineries. As a result, the average energy intensity of the refining industry segment has fallen by 13% since 1980 in OECD countries, according to IEA data.(IPIECA 2013).

2.6.1 Methods are used to control emissions from fixed roof Tanks:

Vapor balancing is another means of emission control. Vapor balancing is probably most common in the filling of tanks at gasoline stations. As the storage tank is filled, the vapors expelled from the storage tank are directed to the emptying gasoline tanker truck. The truck then transports the vapors to a centralized station where a vapor recovery or control system is used to control emissions Vapor.(hamed suliman 2014).

- balancing can have control efficiencies as high as 90 to 98 percent if the vapors are subjected to vapor recovery or control. If the truck vents the vapor to the atmosphere instead of to a recovery or control system, no control is achieved.
- Vapor recovery systems collect emissions from storage vessels and convert them to liquid product. Several vapor recovery procedures may be used, including

vapor/liquid absorption, vapor compression, vapor cooling, vapor/solid adsorption, or a combination of these. The overall control efficiencies of vapor recovery systems are as high as 90 to 98 percent, depending on the methods used, the design of the unit, the composition of vapors recovered, and the mechanical condition of the system.

Floating Roof Tanks:

- Total emissions from floating roof tanks are the sum of withdrawal losses and standing storage losses. Withdrawal losses occur as the liquid level, and thus the floating roof, is lowered. Some liquid remains on the inner tank wall surface and evaporates.

- **Standing storage losses from floating roof:**

tanks include rim seal and deck fitting losses, and for internal floating roof tanks also include deck seam losses for constructions other than welded decks. Other potential standing storage loss mechanisms include breathing losses as a result of temperature and pressure changes.

Rim seal losses can occur through many complex mechanisms, but for external floating roof tanks, the majority of rim seal vapor losses have been found to be wind induced. No dominant wind loss mechanism has been identified for internal floating roof or domed external floating roof tank rim seal losses. Losses can also occur due to permeation of the rim seal material by the vapor or via a wicking effect of the liquid, but permeation of the rim seal material generally does not occur if the correct seal fabric is used.

The deck fitting losses from floating roof tanks can be explained by the same mechanisms as the rim seal losses. However, the relative contribution of each mechanism is not known. The deck fitting losses identified in this section account for the combined effect of all of the mechanisms.

Numerous fittings pass through or are attached to floating roof decks to accommodate structural support components or allow for operational functions.

The most common components that require openings in the deck are:

- Access hatches
- Gauge-floats
- Gauge-hatch/sample ports
- Deck drains

- Deck legs
- Guide pole
- Rim vent

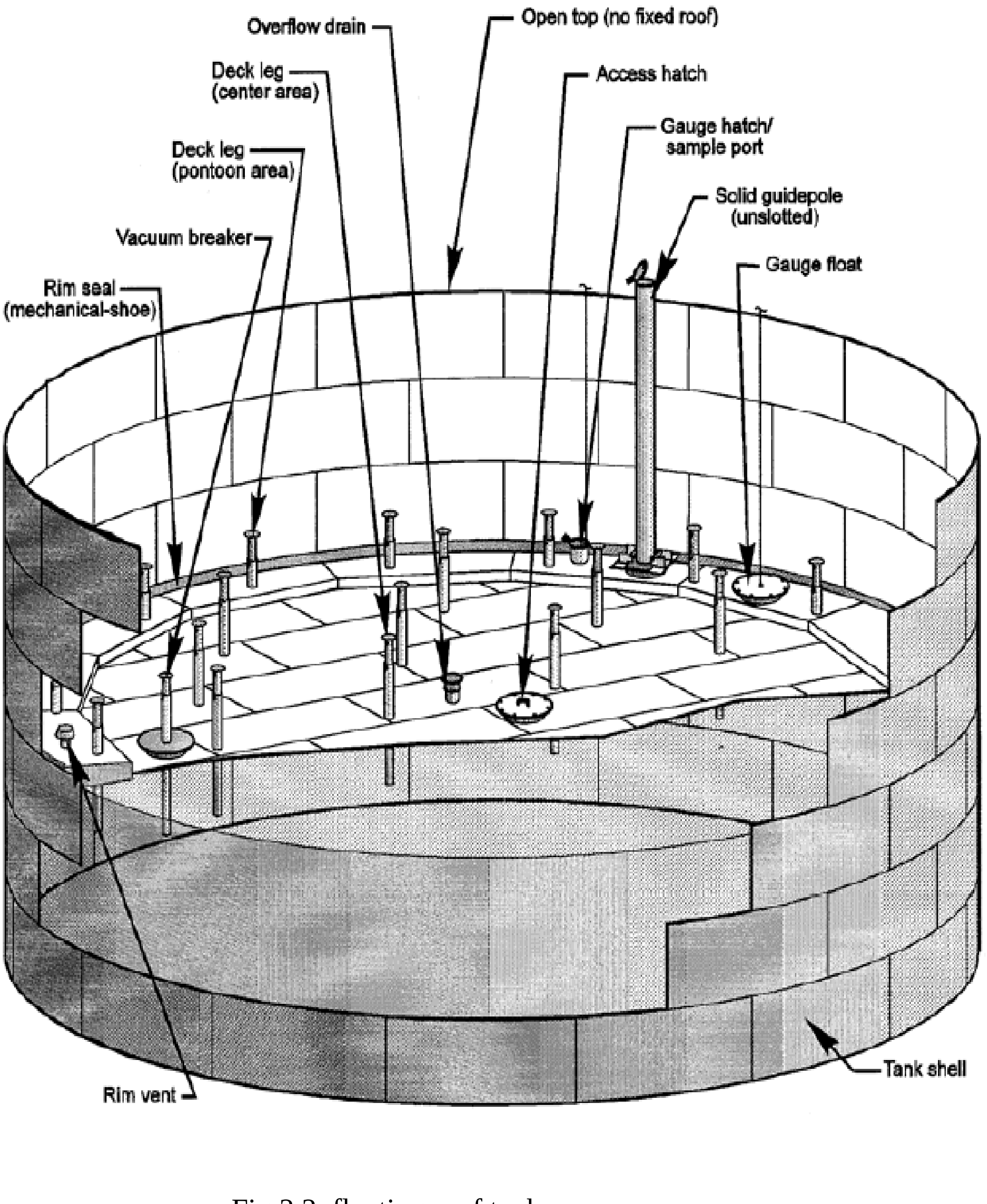


Fig:2.2. floating roof tank

Fig:2.3. floating roof tank

2.6.1.1 Emission Estimation Procedures:

- The following slides presents the emission estimation procedures for fixed roof, external floating roof, domed external floating roof, and internal floating roof tanks. These procedures are valid for all petroleum liquids, pure volatile organic liquids, and chemical mixtures with similar true vapor pressures: It is important to note that in all the emission estimation procedures the physical properties of The vapor do not include the noncondensibles (e. g., air) in the gas but only refer to the condensable components of the stored liquid. To aid in the emission estimation procedures, a list of variables with their corresponding definitions was developed and is presented in Table. (hamed suliman 2014).
- gallon per each square feet from the liquid surface during summer time per year (0.05m3/0.092m2),and 10 gallons (0.038m3) during winter season.

2.6.2 VALVES AND FLANGES:(numbering)

Definitions:

For the purpose of this rule:

(1) A Valve is defined as any device that regulates the flow of fluid in a piping system by means of an external actuator acting to permit or block passage of fluid including the attached flange and the flange seal.

(2) A Flange is defined as a projecting rim on a pipe or piping component used to attach it to another piping detail.(M.wahbi,2016)

The principal functions of valves cover:-

1) **Starting and stopping flow**

This is a major applied service of the valves. The most suitable type for this service is the gate valve. When open its seating design allows fluid to move in a straight line with minimum restriction and minimum pressure drop across the valve.

2) **Regulating or throttling the flow**

Most suitable type is the globe or angle valve. Here the seating design develops change of direction to fluid flow, hence increasing restriction to flow. The valve design allows closer regulation; usually the valve can be set from 0 to 100% open. In practice it is not common to find this valve in size greater than 12 inch. This is because of the difficulty in closing & opening larger valves against pressure

3) **Preventing back flow**

Checks valves are designed to perform this job. They are usually found in two basic types i.e. swing / lift. Forward flow opens the valve and gravity/back flow closes it to prevent reverse flow. Generally the swing type is used with gate valves, while the lift type is used with globe valves. Check valves are found fixed on pumps discharge close to the pump outlet

4) **Relieving the pressure**

Boilers and pressurized vessels are exposed to the risk of explosion against extreme pressure build up. Safety and relief valves are fixed on such vessels to open automatically at the incidents of risky pressure. The valves are set to open at known pressure values far below the explosive limits and slightly above the operating pressure Generally relief valves are fixed on liquid vessels and safety valves on gas vessels.

2.6.2.1 Types of valves:

1) Gate Valve
2) Globe valve
3) Check valve
4) Plug valve
5) Ball valve
6) Slide valve
7) Needle valve
8) Angle valve
9) Butterfly valve
10) Safety valve
11) Steam trap valve
12) Fire hydrant valve

Types of valve that used in ORC:

1- Gate Valve

Widely used in industry since they are efficient in fully open and fully shut the flow .

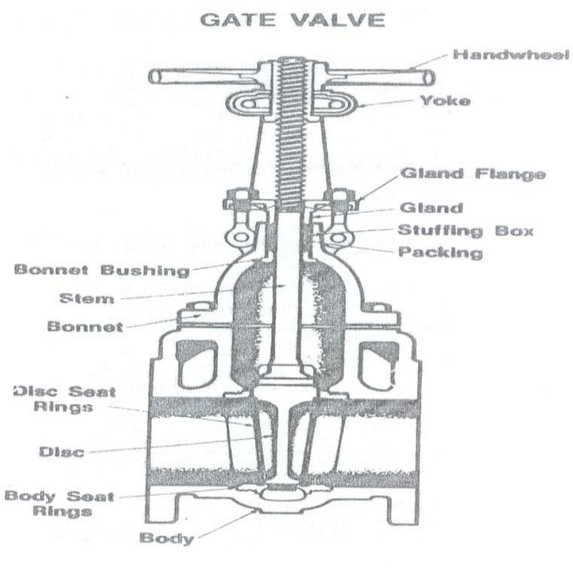


Fig.2.4. Gate Valve

- The fluid flow in straight line across the valve seating with the minimum resistance The opening element is a wedged disc actuated by stem-screw and hand wheel.
- The disc moves up & down at right angle to the flow and seats against two trapped seat faces when shutting off the flow

- Gate valves are suitable for service of infrequent valve operation where the disc is kept either fully open or fully closed e.g. isolation but not for throttling
- Close regulation by gate valve is almost impossible. Velocity of the flow against partially open position causes vibration / chattering and consequently damages to valve seating in addition to erosion of the disc
- The stem comes into rising & non-rising configuration. in rising –stem valve , a rising condition indicates open position
- In practice, the gate valve requires more turns and more work to open it fully and unlike to globe & angle valves, the amount of flow is not proportional to the number of wheel turns.

2-Globe / Angle Valves

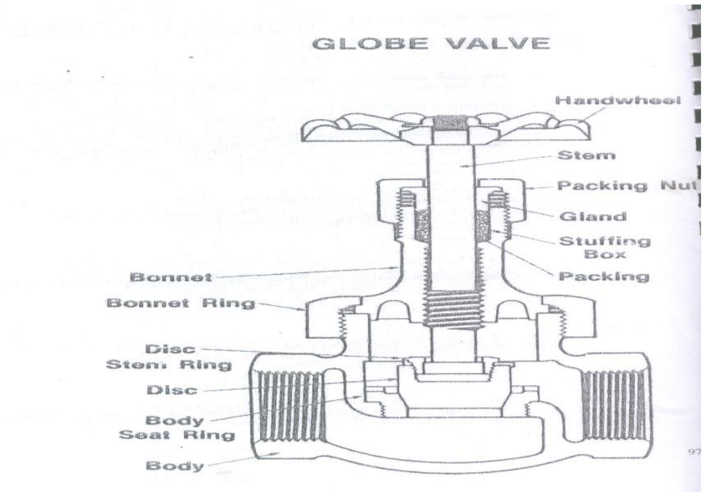


Fig 2.5.globe valve

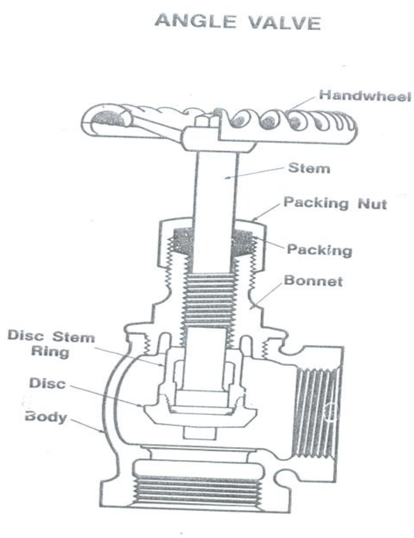


Fig 2.6. angle valve

3-Check Valves

They are also called non-return valves. They contribute the following types:

3.1-**Piston Check Valve** :

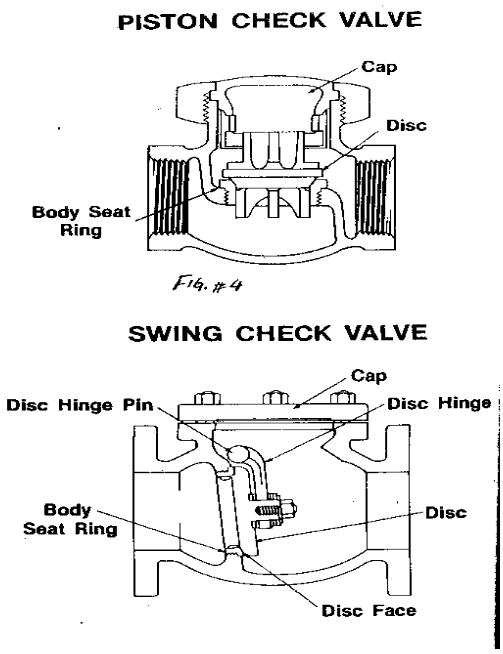


Fig..2.7. check valve

- It depends on gravity on its operation. At forwards flow, the fluid lifts the piston from its seat ,through the guides to open During back flow gravity and the reverse flow seat the piston, thus stopping the reverse flow.
- It has relatively higher pressure drop

3.2- **Ball Check Valve:** similar to piston type with the guided piston being replaced by a ball. Recommended in vertical piping.

3.3- **Swing Check Valve** (see fig # 4): the operating element is a disc hinged at the top and swing at lower end. It seats against a mechanical seat in tilted bridge opening. *The disc swings freely from the fully open position to fully close.* It offers less resistance to flow, a property makes it used for pressure services especially on liquid lines. On forwards flow the disc swings open in proportion to the amount of flow, while it swings closed seated on the reverse flow, thus preventing back flow

The flow in both gate and swing check valve is in straight line and without restriction at the seats. Because of this similarity, the valves are recommended for combination in appliance

3.4- Basic Lift Check Valve

The operating disc is seated on a horizontal bridge wall. The disc is equipped with a short guide and free to move vertically up and down.

On forward flow the disc moves up to open and it drops seated by gravity to prevent reverse back flow

Recommended for steam/air/gas/water piping

Fig # 5 shows two design configurations suitable for vertical & horizontal piping systems

3.5- Stop-Check or Non-return Valves

Functional on boilers connected to a common same header. They automatically prevent back flow from the header into the shut down boiler. By doing so, the valve provides safe isolation of boilers under maintenance or inspection

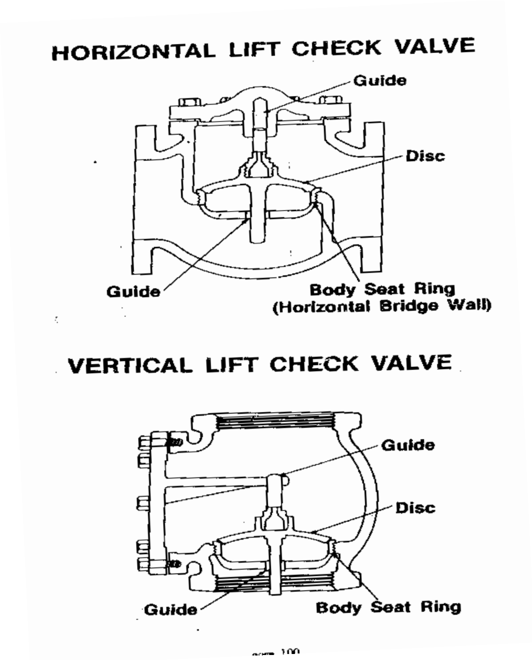


Fig.2.8. horizontal/vertical check valves

4- Needle Valves

They are designed to give fine control of flow in small diameter piping. The operating element is a sharp pointed conical disc of needle shape matching the seat. They come in globe and angle types constructed from bronze& steel. They are used in air / water /oil / gas /light fuel / fuel oil. They are mostly applied in pneumatic control systems. The threads of the stem are much finer so that fine adjustment of the flow is achievable

5-Safety Valves:

5-1- General Informations

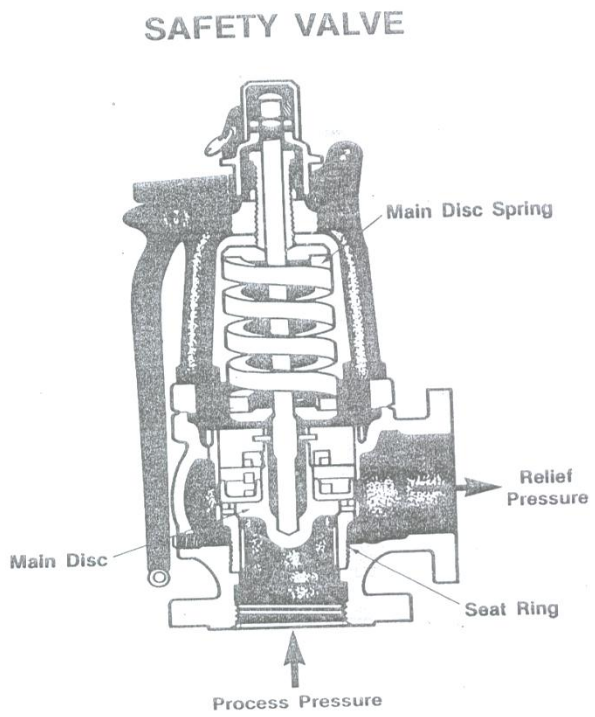


Fig.2.9. safety valve

Process vessels and pipeline can stand only limited amount of design pressure. When exceeded, they will be exposed to damages and explosion

- To prevent this hazardous situation from happening, relief or safety valves are fixed on equipment to protect them from over pressure increments
- These valves are spring loaded, set at specific pressure. when the pressure inside the equipment reaches the set value ,the valve open to release excess pressure thus relieving the equipment. The valves are designed to open automatically at their set pressure
- Safety valve is a nomenclature given for valves working on compressible fluids e.g. steam/air/gas, while relief valve is designated for incompressible fluids e.g. water & liquids
- In equipment operation there exist two pressure limits worth consideration i.e.

a) **The operating pressure**:

this the normal safe pressure as per process requirements. To keep smooth operation conditions, the operators work to monitor the pressure at this value. At some faulty operational conditions, the pressure inside the vessel exceeds the allowable limit. with the continuity of the fault shoots rapidly, the pressure shoots rapidly to reach explosive damaging levels

b) Design Pressure:

This maximum pressure value the equipment can stand before explosion. The value of this pressure is usually high above the operating pressure e.g. if the operating pressure is 20 psi, the design pressure may be as high as 150 psi

- to prevent faults in operation from damaging equipment, safety /relief valves are fixed and designed to open before explosion occurs

6- Ball Valves

The operating element is a ball with a hole at the center. When the hole comes in line with the pipe, the valve opens. When the solid part comes in line with the pipe, the valve closes. Similar to plug valve, it is quick operated. It is usually made from hard plastic and used in chemicals piping

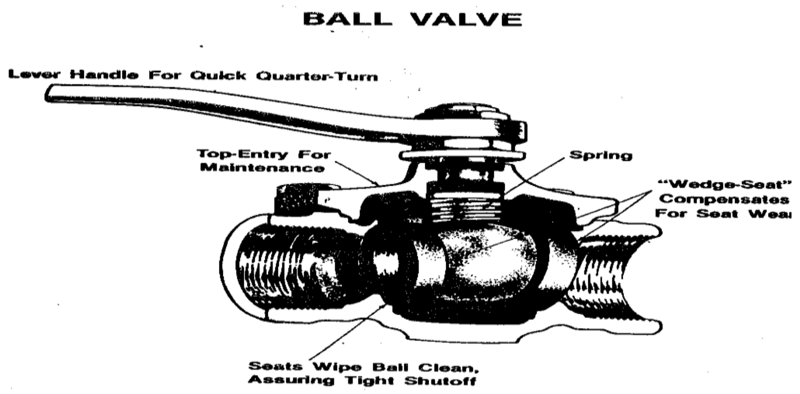


Fig.2.10. ball valve

2.6.3 Boilers:

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or a gas (steam). The steam or hot water under pressure is then usable for transferring the heat to a process.

- **BOILER TYPES**:

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

(1) Fire tube "fire in tube".

(2) Water tube or "water in tube" Common types of fire tube boilers are scotch marine, firebox,

Steam Distribution Systems

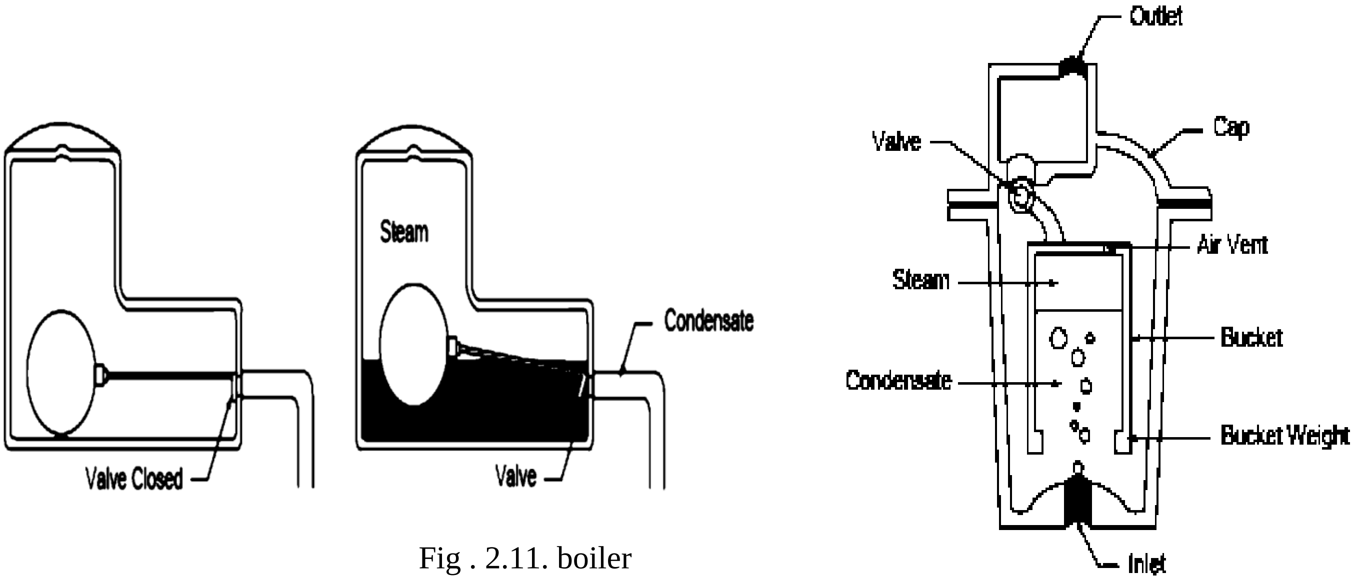


Fig . 2.11. boiler

2.6.4 Heaters (Furnaces)

- Fired heaters or furnaces are used extensively in the process industry. All furnaces have a fire-box or combustion space where a fuel is burned, and a stack through which flue gases are discharged to the atmosphere.

- **Type of Heaters:**

  Most modern heaters are built with two distinct heating sections:

  1- a radiation section which can receive heat directly from the flame.

  2- Convection section which recovers heat from the hot gases travelling to the stack

- **Names of heaters are not standardized but the types can be called**:

  a) Large box-type
  b) Separate –convection (Lummus)
  c) Down-convection
  d) Straight – up (Born)

e) A tram ((Kellogg)
f) Circular (Deflorez)
g) Large isoflow (petrochem)
h) Small isoflow (petrochem)
i) Equiflux (UOP)
j) Double – upfired (UOP)
k) Radiant wall (selas)

- ## Heat transfer means

Conduction: In a solid, the flow of heat by conduction is the result of the transfer of vibration energy from one molecule to the next, and in fluids it occurs in addition as a result of the transfer of kinetic energy. (Hussein Mahmoud,2016)

Convection: Heat transfer by convection is attributable to macroscopic motion of a fluid and is thus confined to liquids and gases.

Radiation: All materials radiate thermal energy in the form of electromagnetic waves. When radiation falls on a surface it may be reflected, transmitted, or absorbed.

- ## Combustion

i. What is combustion?

Combustion is a chemical reaction between a combustible material and oxygen, as a result of which various combustion products are, formed (one of them being flue gas)

Exothermic reactions: Reactions in which heat is produced are called exothermic reactions

$$\text{Fuel + oxygen} \longrightarrow \text{flue gas + heat}$$

➢ **Combustion conditions**

i. **Ignition energy**: the combustible mixture that meets this condition must be ignited. Initiating a combustion reaction requires ignition energy. If only a small amount of heat is required, a spark from a sparkplug can suffice.

ii. **Explosion limit**: in the gas phase fuel and oxygen must be thoroughly mixed. The mixing ratio of fuel and oxygen must be within the explosion limits;

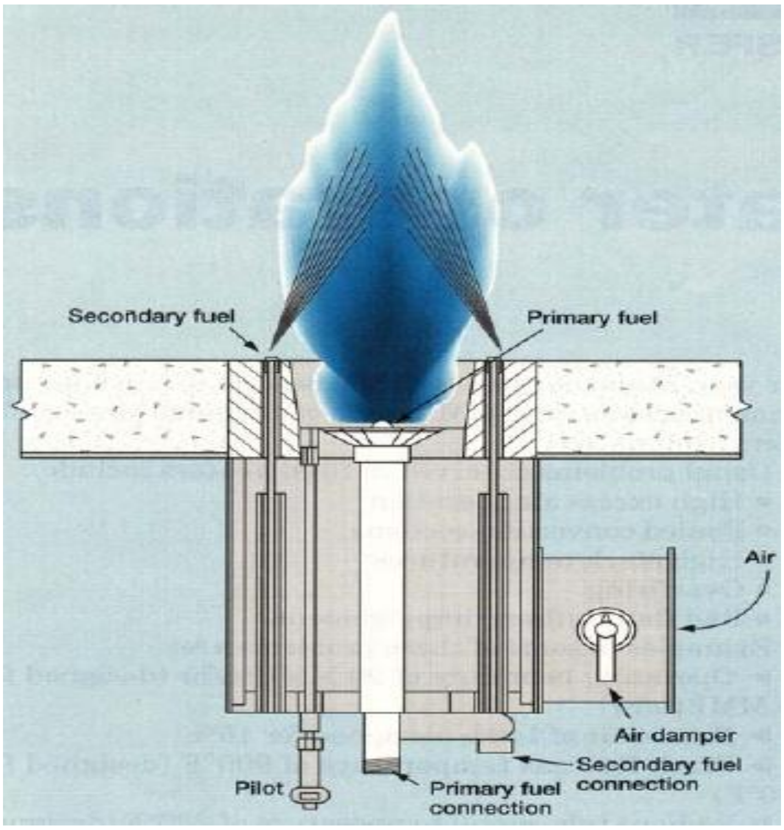


Fig .2.12. flame shape

- **A flame**: is 'the visible part of an exothermic reaction between fuel and oxygen'. Flame is characterized by:
  - I. the emission of light;
  - II. the prevalence of temperatures higher than 1100ºC;
  - III. Oxidation of carbon, hydrogen and sulphur .
  - IV. The continuation of the initiated reaction.
- **The flame speed**: is defined as the speed with which the flame front propagates.
- **Flame colour:** The colour of the flame is dependent, among other things, on the carbon/hydrogen ratio.

- Red-orange to yellow for liquid fuel;
- Yellow to blue for gaseous fuels.

- **Adiabatic flame temperature:** The adiabatic flame temperature is determined by the amount of heat released per kilogram of fuel and also by the amount and composition of the combustion products formed per kilogram of fuel.

➢ Appearance of the Firebox and Flames

- Bright and clear firebox means more than enough oxygen.
- Hazy long and the flames with licking, yellow and smoky in firebox mean not enough oxygen.
- Flame color depends on fuel composition. Gas often burns blue, but heavy fuel oil burns yellow

❖ Combustion air requirement

Theoretical air/ air requirement: is the amount of air per kilogram of fuel which contains just enough oxygen to burn all of the fuel.

Oxygen Starvation

If you try to operate a fired heater with too little combustion air to starve the burners of oxygen to low rate in the firebox, then you will likely cause “afterburn” or secondary combustion in the stack, you will not be able to operate on automatic temperature control, and may even destroy the equipment altogether.

Afterburning:

The products of incomplete combustion of the fuel, and in more severe cases even the unburned fuel itself, flow with the flue gas up through the convective section and up the stack. A certain amount of air leaks in through the convective section and stack from outside the heater. When these hot, combustible hydrocarbons in the form of unburned fuel mix with the extra air that is leaking in from the environment, reignition is liable to occur.

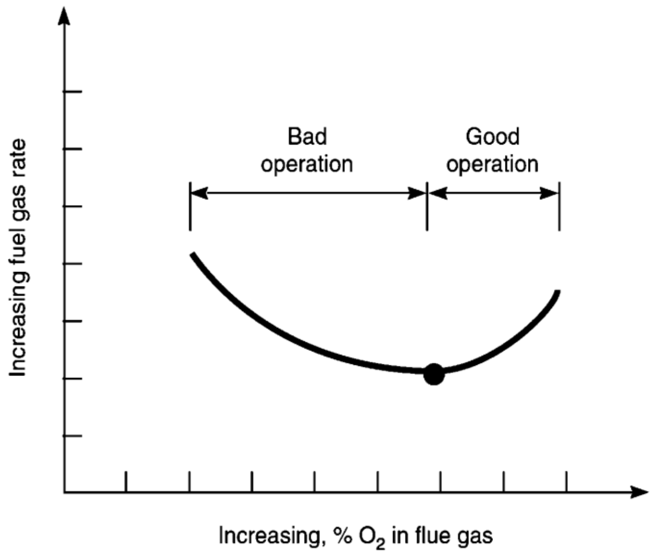
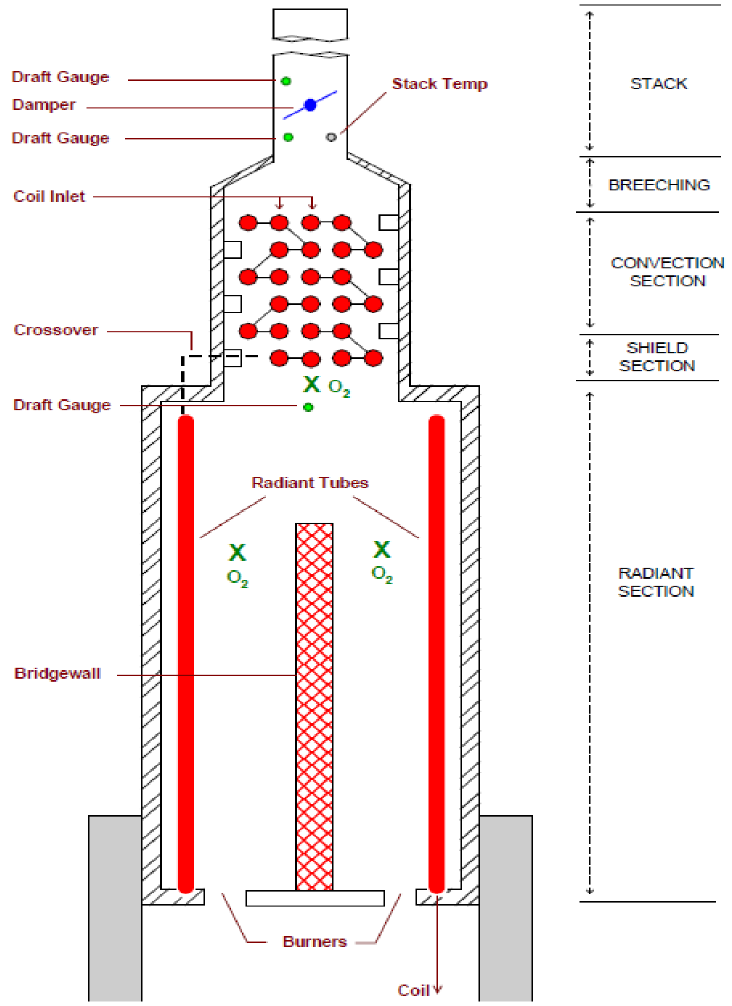


Fig .2.13. **Oxygen Starvation**



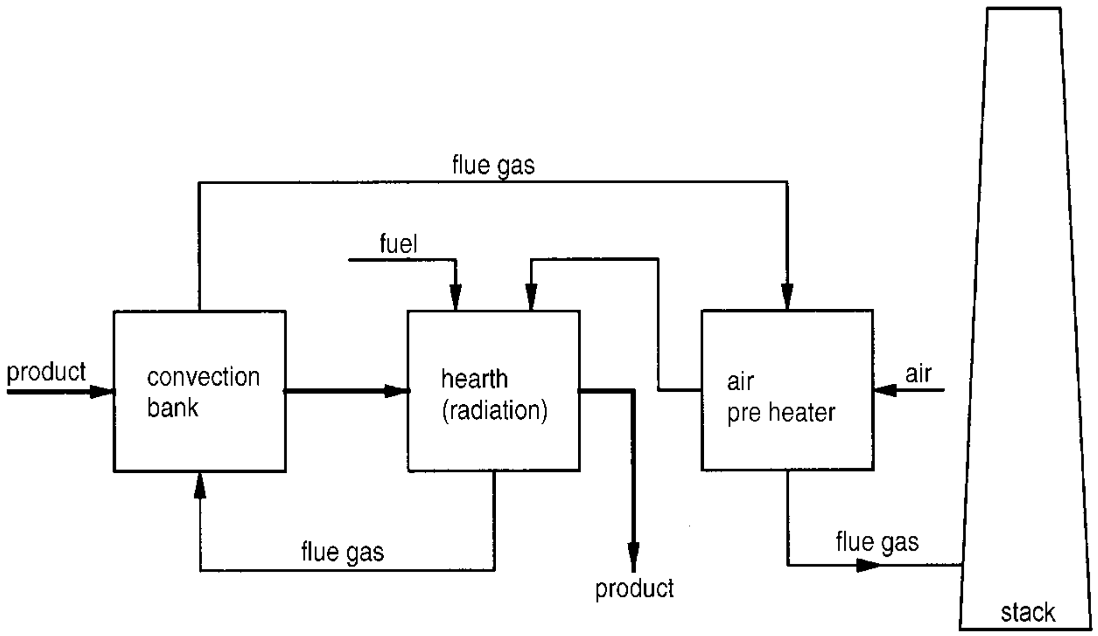


Fig .2 .14. construction of furnace and operation

Furnace type

I. horizontal BOX furnaces;

II. Vertical furnaces.

1.1 Horizontal BOX furnace

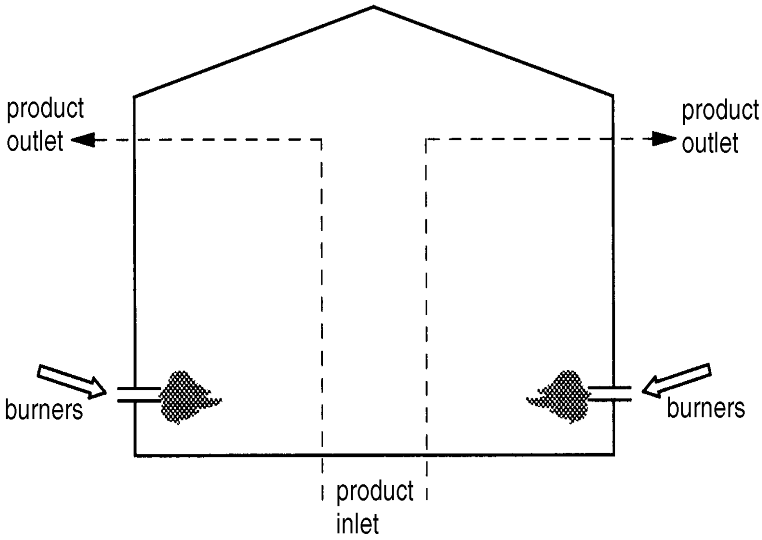


***Fig. 2.15.*Horizontal BOX furnaces with radiant cell**

Vertical furnace:

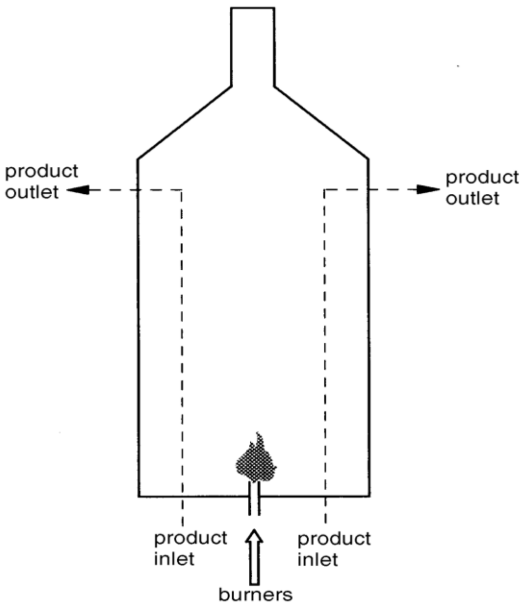


Fig ***.2.*16.Vertical furnace with radiant cell**

Draft System :

The function of draft in a combustion system is to exhaust the products of combustion into the atmosphere.

Correct Draft:

Stack dampers and secondary air registers affect the draft and both adjustments are related.

Excessive draft, either positive pressure or negative pressure, can lead to severe problems in the convection section.

Natural Draft:

It is the draft produced by a chimney alone. It is caused by the difference in density between the column of hot gas inside the chimney and column of outside air of the same height and cross section.

Mechanical Draft:

It is draft artificially produced by fans

Induced Draft:

An induced-draft fan draws enough draft for flow into the furnace, causing the products of combustion to discharge to atmosphere.

Forced Draft:

The Forced draft system uses a fan to deliver the air to the furnace, forcing combustion products to flow through the unit and up the stack.

Draft Readings:

Draft readings are a comparison of two pressures taken at the same elevation and are traditionally quoted in inches of water gauge. To make sense of a set of draft readings for a furnace, you must first normalize the data.

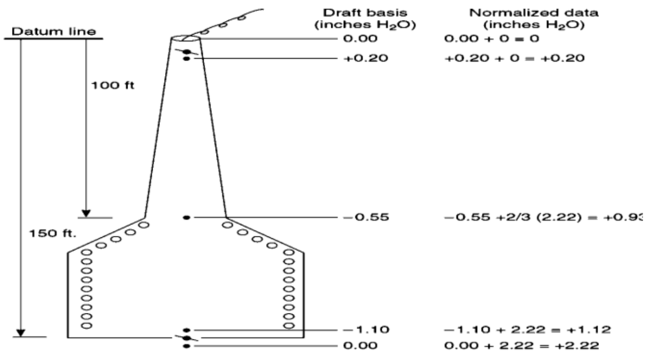


Fig.2.17. Draft reading

The air register and the stack damper are used together as a team to optimize the heater draft. Our aim in balancing the draft for a natural draft or a balanced-draft heater is to maintain a small negative pressure of − 0.1 in of water, just below the shock tubes.

If we operate with a positive pressure in the firebox the hot flue gases will leak outward. This damages the roof arch supports and the steel structure so as to shorten the life of the heater. Flame impingement of the upper radiant tubes may also result from positive pressures.

We adjust the draft with the stack damper and maintain the combustion-air level by adjusting the air registers to accommodate the adjustments made on the stack damper.

The flue gases must be able to leave the furnace. This can be monitored by adjusting the position of the slides to minimum. It is also possible to control the flue gases by monitoring the flow of air. In any case, air cannot enter if the flue gas is not being discharged. If a draught control device is used, exceeding a maximum pressure can lead to dangerous situations.

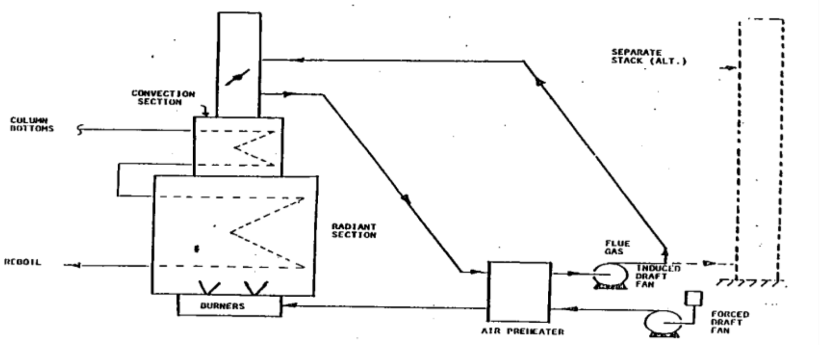


Fig .2.18. Typical fired heater flow scheme air preheater

- **Furnace efficiency**

Furnace efficiency or total furnace efficiency is the ratio of heat usefully absorbed and total heat supplied.

Efficiency = heated usefully absorbed by heated medium/ total heat supplied

There is another way to determine total efficiency: by subtracting all losses from a value of 100%.

In this calculation, the following losses are taken into account:

I. **stack losses;**
II. **radiation losses;**
III. **Residual losses**.

Total efficiency can also be determined using figure 37. To do this, we utilize the measured percentage by volume of O_2 and the flue-gas temperature. The graph in figure 2 is based on various values for air-fuel ratio, and average values for the outside-air temperature, and radiation losses. Different lines can be constructed for different air-fuel ratios. Given: percentage by volume of O_2 = 5.7, and flue-gas temperature = 328°C.

Total efficiency can be read as follows:

I. move perpendicularly upward from the flue-gas temperature as far as the slanting line of the O_2 Percentage measured;
II. From the intersection, move horizontally leftward. Read the total-efficiency value on the left-hand vertical axis.

2.7 Energy Conservation in Refineries of COSMO Oil (2006):

COSMO oil Refineries (Sakai Refinery, Sakaide Refinery, Yokkaichi Refinery, Chiba Refinery) applied procedures to reduce energy losses.

2.7.1 Process Modification

Table:2.3

Equipment	Energy	Procedure
Steam Line Vacuum Ejector Flare	Steam Saving Steam Saving Save loss gas	Improve process consumption Replacement, Use low press. steam. Flare Gas Recovery system.
Heat Exchanger Furnace Pump & Compressor Motor Tower Internal	Fuel Saving Fuel Saving Save Electric Power Save Electric Power Low pressure drop	Install new Heat Exchangers, Remodel Network. Introduce APH(Air Pre-Heater) and O2% control system. Replacement of burner type.

		Replacement, Impeller cut. Inverter control, Pole change motor. Replacement to Packing from Tray type.

- QC Activity:-

Effective plant operation by QC Activity:

O2% control : Furnace

Reflux ratio Control : Fractionators

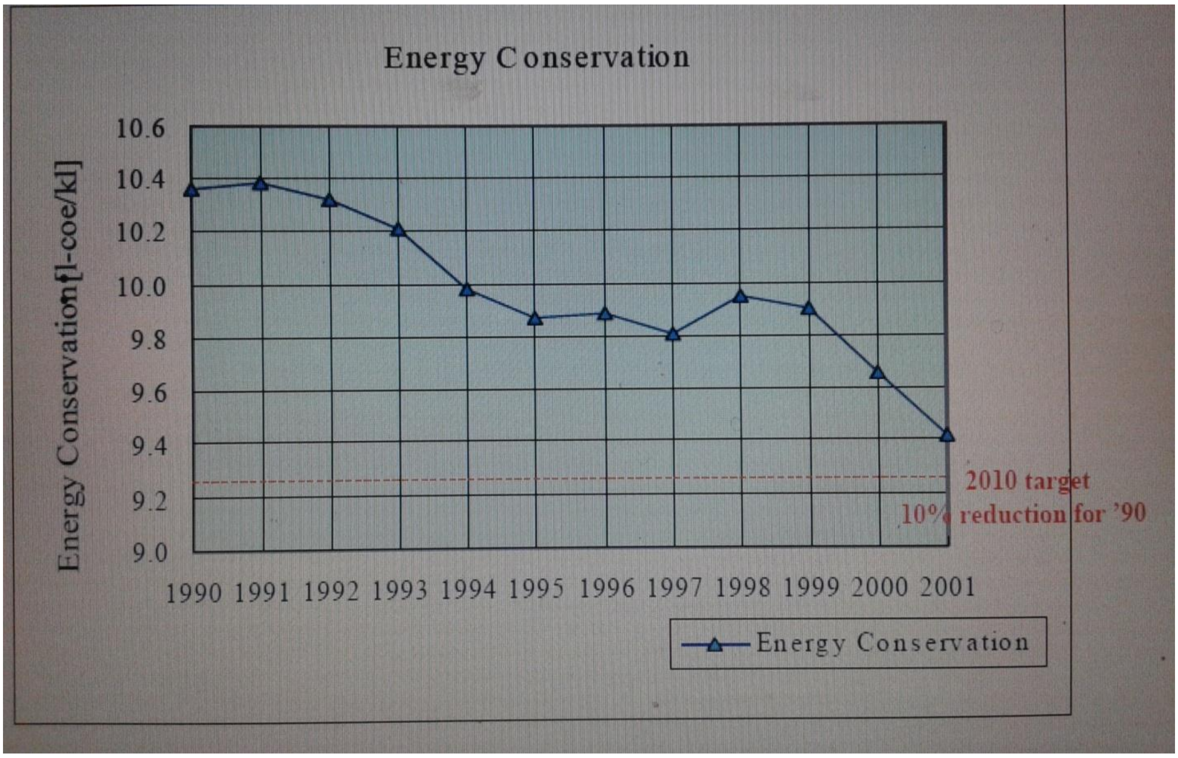


Fig.2.19. Trend of Energy Conservation in Cosmo

2.7.2. ORC Energy Audit Project Draft Final Report(2015):

In April, 2015, the general directorate for energy affairs in the Ministry of Petroleum and Gas signed an agreement with Energy Research Center of the University of Khartoum to implement energy audit study for El-Obayid Refinery.

Table:2.4.Potential saving in preheat train:

Utility	Existig	New	Savins	Savins%	Dollar savings
Cooling water (ton/yr)	826507	337269	489238	59	39139
Fuel for heater (ton/yr)	8002.26	5344.37	2657.89	33	835816
	Total USD savings				874955

Table:2.5. Summary of potential savings in insulation:

Item	MMBTU/yr	Toe /yr	Savings $/yr23
Bare pipes	3091	78	3091
Flanges	8310	208	8310
Valves	6280	157	6280
Total	**17681**	**443**	**17681**

2.7.3. G. A. R. rassoul and Tahseen hameed khlaif (September 2009):

In order to reduce the losses due to evaporation in the stored crude oil and minimizing the decrease in °API many affecting parameters were studied (i.e. Different storage system, namely batch system with different types of storage tanks under different temperatures and:or different pressures). Continuous circulation storage system was also studied. It was found that increasing pressure of the inert gas from 1 bar to 8 bar over the surface of the crude oil will decrease the percentage losses due to evaporation by (0.016%) and decrease the change of °API by (0.9) during 96 hours storage time. Similarly using covering by surfactant (potassium oleate) or using polymer (polyurethane foam) decreases the percentage evaporation losses compared with uncovered surface of the blend crude oil. In each surfactants and polymers the layer thickness was (1.0, 1.5, 2.0, 2.5, 3.0 cm), and increasing the thickness of the surfactant to 2.5 cm or of the polymer to 3 cm was found to be best required thickness. Surfactant gave lower percentage evaporation losses than polymer, for fixed roof tank (i.e. 0.299%, 0.383%) for 120 hours evaporation time. Different processed storage tanks namely (fixed roof, external moving roof, fixed and internal moving) were studied and fixed and moving roof was the best in reducing evaporation losses (0.453%) for 120 hours. In continuous circulation for proposed continuous storage system, the percentage evaporation losses for covered with surfactant, covered with polymer, and uncovered surface of blend crude oil were (0.328%), (0.378%), and (0.45%) respectively at 24 °C for 96 hours evaporation time.

3.1 Total Losses From Fixed Roof Tanks:

- The following equations, provided to estimate standing storage and working loss emissions, apply to tanks with vertical cylindrical shells and fixed roofs. These tanks must be substantially liquid- and vapor-tight and must operate approximately at atmospheric pressure.

Total losses from fixed roof tanks are equal to the sum of the standing storage loss and working loss:

$$\mathbf{LT = LS + LW \ldots\ldots\ldots\ldots..(3\text{-}1)}$$

- LT = LS + LW
- where:
- LT = total losses, lb/yr
- LS = standing storage losses, lb/yr, see Equation
- LW = working losses, lb/yr,
- Standing Storage Loss
- The standing storage loss, LS, refers to the loss of stock vapors as a result of tank vapor space breathing.

$$\mathbf{LS = 365\ VV\ WV\ KE\ KS \ldots\ldots\ldots\ldots\ldots\ldots..(3\text{-}2)}$$

- where:
- LS = standing storage loss, lb/yr
- VV = vapor space volume, ft3, see Equation
- WV = stock vapor density, lb/ft3
- KE = vapor space expansion factor, dimensionless
- KS = vented vapor saturation factor, dimensionless
- 365 = constant, the number of daily events in a year, (year)-1

Tank Vapor Space Volume, VV - The tank vapor space volume is calculated using the following equation:

$$\mathbf{Vv=(\frac{\pi}{4} D^2)Hvo\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3\text{-}3)}$$

where:

VV = vapor space volume, ft3

D = tank diameter, ft, see Equation 1-13 for horizontal tanks

HVO = vapor space outage, ft

Vapor Space Expansion Factor, KE

The calculation of the vapor space expansion factor, KE, depends upon the properties of the liquid

in the tank and the breather vent settings. If the liquid stock has a true vapor pressure greater than 0.1 psia, or if the breather vent settings are higher than the typical range of ±0.03 psig, see Equation.

- If the liquid stored in the fixed roof tank has a true vapor pressure less than 0.1 psia and the tank breather vent settings are ±0.03 psig, use either Equation

If the tank location and tank color and condition are known, KE is calculated using the following

equation:

$$\boldsymbol{KE = 0.0018 \Delta Tv = 0.0018\ [0.72\ (TXA\text{-}TAN\ ) + 0.028\alpha}\ \ldots\ldots\ldots\mathbf{(3\text{-}4)}$$

where:

KE = vapor space expansion factor, dimensionless

Δ TV = daily vapor temperature range, °R

TAX = daily maximum ambient temperature, °R

TAN = daily minimum ambient temperature, °R

α = tank paint solar absorptance, dimensionless

I = daily total solar insolation on a horizontal surface, Btu/(ft2 day)

0.0018 = constant, (°R)-1

0.72 = constant, dimensionless

0.028 = constant, (°R ft2 day)/Btu

If the tank location is unknown, a value of KE can be calculated using typical meteorological

conditions for the lower 48 states. The typical value for daily solar insolation is 1,370 Btu/(ft2 day), the daily range of ambient temperature is 21°R, the daily minimum ambient temperature is 473.5 °R, and the tank paint solar absorptance is 0.17 for white paint in good condition. Substituting these values into Equation 1-5 results in a value of 0.04.

$$\boldsymbol{LW = NHLX\ (\tfrac{\pi}{4})D\ KNKPWVKB}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\boldsymbol{(3\text{-}5)}$$

where:

LW = working loss, lb/yr

N = number of turnovers per year, (year)-1

HLX = maximum liquid height, ft

D = diameter, ft

KN = working loss turnover (saturation) factor, dimensionless;

for turnovers > 36, KN = (180 + N)/6N

for turnovers ≤ 36, KN = 1

KP = working loss product factor, dimensionless

for crude oils KP = 0.75

for all other organic liquids, KP = 1

WV = vapor density, lb/ft3,

KB = vent setting correction factor, dimensionless

for open vents and for a vent setting range up to ± 0.03 psig, KB = 1

$$\mathbf{KE}=\frac{\Delta TV}{TLA}+\frac{\Delta Pv-\Delta PB}{PA-PVA}>0\text{……………….}(3\text{-}6)$$

where:

Δ TV = daily vapor temperature range, °R;

Δ PV = daily vapor pressure range, psi;

Δ PB = breather vent pressure setting range, psi;

PA = atmospheric pressure, psia

PVA = vapor pressure at daily average liquid surface temperature, psia;

TLA = daily average liquid surface temperature °R;

- The daily vapor temperature range, Δ TV , Is calculated using the following equation:

$$\Delta TV = 0.72\ \Delta TA + 0.028\ \alpha\ I \text{ ……………………….}(.3\text{-}7)$$

where:

Δ TV = daily vapor temperature range, °R

Δ TA = daily ambient temperature range, °R;

α = tank paint solar absorptance, dimensionless;

I = daily total solar insolation factor, Btu/ft2 d;

- The daily vapor pressure range, Δ PV, can be calculated using the following equation:

$$\Delta PV = PVX - PVN \text{ ……………………………………(3-8)}$$

where:

Δ PV = daily vapor pressure range, psia

PVX = vapor pressure at the daily maximum liquid surface temperature, psia;

PVN = vapor pressure at the daily minimum liquid surface temperature psia;

- The following method can be used as an alternate means of calculating Δ PV for petroleum

  liquids:

$$\Delta PV = \frac{0.50 \times B \times PV \times \Delta TV}{TLA^2} \text{ ……………………………(3-9)}$$

where:

ΔPV = daily vapor pressure range, psia

B = constant in the vapor pressure equation, °R;

PVA = vapor pressure at the daily average liquid surface temperature, psia;

TLA = daily average liquid surface temperature, °R;

ΔTV = daily vapor temperature range, °R;

- The breather vent pressure setting range, Δ PB, is calculated using the following equation:

$$\Delta PB = PBP - PBV \text{ …………………….(3-10)}$$

where:

Δ PB = breather vent pressure setting range, psig

PBP = breather vent pressure setting, psig

PBV = breather vent vacuum setting, psig

- The daily ambient temperature range, Δ TA, is calculated using the following equation:

$$\Delta TA = TAX - TAN \text{ ……………………(3-11)}$$

where:

ΔTA = daily ambient temperature range, °R

TAX = daily maximum ambient temperature, °R

TAN = daily minimum ambient temperature, °R

Vapor Space Outage:

- The vapor space outage, HVO is the height of a cylinder of tank diameter, D, whose volume is

equivalent to the vapor space volume of a fixed roof tank, including the volume under the cone or dome

roof. The vapor space outage HVO, is estimated from:

$$\mathbf{HVO = HS - HL + HRO \ldots\ldots\ldots\ldots\ldots\ldots(3\text{-}12)}$$

where:

HVO = vapor space outage, ft; use HE/2 from Equation 1-14 for horizontal tanks

HS = tank shell height, ft

HL = liquid height, ft

HRO = roof outage ft.

Notes:

- For a cone roof, the roof outage, HRO, is calculated as follows:

$$\mathbf{HRO = 1/3\ HR \ldots\ldots\ldots(3\text{-}13)}$$

where:

HRO = roof outage (or shell height equivalent to the volume contained under the roof), ft

HR = tank roof height, ft.

Vented Vapor Saturation Factor, KS:

- The vented vapor saturation factor, KS, is calculated using the following equation:

$$\mathbf{Ks = \frac{1}{1+0.053 \times PVA \times HVO} \ldots\ldots\ldots\ldots\ldots(3\text{-}14)}$$

where:

KS = vented vapor saturation factor, dimensionless

PVA = vapor pressure at daily average liquid surface temperature, psia;

HVO = vapor space outage, ft,

0.053 = constant, $(Psia - ft)^{-1}$`.

- Stock Vapor Density, WV - The density of the vapor is calculated using the following equation:

$$\mathbf{WV=\frac{MV\times PVA}{R\times TLA}} \text{ ………….(3-15)}$$

where:

WV = vapor density, lb/ft3

MV = vapor molecular weight, lb/lb-mole;

R = the ideal gas constant, 10.731 psia ft3/lb-mole °R

PVA = vapor pressure at daily average liquid surface temperature, psia;

TLA = daily average surface temperature, °R;

$$\mathbf{MV=\sum Mi\,Yi = \sum Mi\left(\frac{PXi}{PVA}\right)} \text{ ……….(3-16)}$$

where:

- PVA, total vapor pressure of the stored liquid, by Raoult's Law, is:

$$PVA=\Sigma Pxi$$

$$\boldsymbol{PVA = exp\left[A-\left(\frac{B}{TLA}\right)\right]} \text{ ………………………….(3-17)}$$

where:

exp = exponential function

A = constant in the vapor pressure equation, dimensionless

A = 12.82 - 0.9672 ln (RVP)

B = constant in the vapor pressure equation, °R

B = 7,261 - 1,216 ln (RVP)

TLA = daily average liquid surface temperature, °R

PVA = true vapor pressure Psia.

- The true vapor pressure of organic liquids at the stored liquid temperature can be estimated by

Antoine's equation:

$$\mathbf{Log\ PVA=A\text{-}\left(\frac{B}{TLA+C}\right)} \text{ …………(3-18)}$$

where:

A = constant in vapor pressure equation

B = constant in vapor pressure equation

C = constant in vapor pressure equation

TLA = daily average liquid surface temperature, °C

PVA = vapor pressure at average liquid surface temperature, mm Hg .

- If the daily average liquid surface temperature, TLA, is unknown, it is calculated using the

  following equation:

$$\mathbf{TLA=0.44TAA + 0.56TB + 0.0079\ \alpha\ I \ldots\ldots\ldots(3\text{-}19)}$$

where:

TLA = daily average liquid surface temperature, °R

TAA = daily average ambient temperature, °R;

TB = liquid bulk temperature, °R;

α = tank paint solar absorptance, dimensionless;

I = daily total solar insolation factor, Btu/(ft2 day);

- The daily average ambient temperature, TAA, is calculated using the following equation:

$$\boldsymbol{TAA=\left(\frac{TAX+TAN}{2}\right)\ldots\ldots\ldots\ldots\ldots(3\text{-}20)}$$

where:

TAA = daily average ambient temperature, °R

TAX = daily maximum ambient temperature, °R

TAN = daily minimum ambient temperature, °R

- The liquid bulk temperature, TB, is calculated using the following equation:

$$\mathbf{TB = TAA + 6\alpha - 1 \ldots\ldots\ldots\ldots..(3\text{-}21)}$$

where:

TB = liquid bulk temperature, °R

TAA = daily average ambient temperature, °R,

α = tank paint solar absorptance, dimensionless;

- Working Loss:-

The working loss, LW, refers to the loss of stock vapors as a result of tank filling or emptying

operations. Fixed roof tank working losses can be estimated from:

$$LW= 0.0010MVPVA\ Q\ KN\ KP \ldots\ldots\ldots\ldots\ldots(3\text{-}22)$$

where:

LW = working loss, lb/yr

MV = vapor molecular weight, lb/lb-mole;

PVA = vapor pressure at daily average liquid surface temperature, psia;

Q = annual net throughput (tank capacity [bbl] times annual turnover rate), bbl/yr

KN = working loss turnover (saturation) factor, dimensionless;

for turnovers >36, KN = (180 + N)/6N

for turnovers ≤36, KN = 1

N = number of turnovers per year, dimensionless:

$$N=\frac{5.614Q}{VLX} \ldots\ldots\ldots\ldots\ldots(3\text{-}23)$$

where:

VLX = tank maximum liquid volume, ft3

$$VLX=\frac{\pi}{4}D\ H\ LX \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3\text{-}24)$$

where:

D = diameter, ft

HLX = maximum liquid height, ft

KP = working loss product factor, dimensionless

for crude oils KP = 0.75

for all other organic liquids, KP = 1

- By assuming the temperature to be 60°F (520°R), and adding the vent setting correction factor,

KB, the result is Equation 1-35. The vent setting correction factor accounts for any reduction in emissions due to the condensation of vapors prior to the opening of the vent. This correction factor will only affect

the calculation if the vent settings are greater than ±0.03 psig.

$$\textbf{Lw = NHLX} \left(\frac{\pi}{4}\right) D^2 \textbf{KN KP WV KB} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\textbf{(3-25)}$$

where:

LW = working loss, lb/yr

N = number of turnovers per year, (year)-1

HLX = maximum liquid height, ft

D = diameter, ft

KN = working loss turnover (saturation) factor, dimensionless;

for turnovers > 36, KN = (180 + N)/6N

for turnovers ≤ 36, KN = 1

KP = working loss product factor, dimensionless

for crude oils KP = 0.75

for all other organic liquids, KP = 1

WV = vapor density, lb/ft3,

KB = vent setting correction factor, dimensionless

for open vents and for a vent setting range up to ± 0.03 psig, KB = 1

- Vent Setting Correction Factor

When the breather vent settings are greater than the typical values of ± 0.03 psig, and the

condition expressed in Equation 1-36 is met, a vent setting correction factor, KB, must be determined

using Equation 1-37. This value of KB will be used in Equation 1-35 to calculate working losses

When:

$$\textbf{KN} = \left(\frac{Pbp+PA}{PI+PA}\right) > 1.0 \ldots\ldots\ldots\ldots\textbf{(3-26)}$$

Then:

$$\textbf{KB} = \left(\frac{\frac{PI+PA}{KN}-PVA}{PBP+PA-PVA}\right) \ldots\ldots\ldots\ldots\ldots\textbf{(3-27)}$$

where:

KB = vent setting correction factor, dimensionless

PI = pressure of the vapor space at normal operating conditions, psig

PI is an actual pressure reading (the gauge pressure). If the tank is held at atmospheric

pressure (not under a vacuum or held at a steady pressure) PI would be 0.

PA = atmospheric pressure, psia

KN = working loss turnover (saturation) factor (dimensionless)

for turnovers > 36, KN = (180 + N)/6N

for turnovers ≤ 36, KN = 1

PVA = vapor pressure at the daily average liquid surface temperature, psia;

PBP = breather vent pressure setting, psig.

3.2 Heat losses in uninsulated pipes:-

lt=Z*C*EL*0.9 …………..(3-28)

lt≡total cost losses per .

Z≡ $length\ of\ pipe\ per$ ft.

C≡ $price.$

EL≡ $heat\ losses\ btu\ /\ hr.$

0.9≡ $factor.$

3.3 Estimated BTU losses for valve and flanges:-

Ct=Sv*Oy*C ……………..(3-29)

Sv=Vus-Vis ……………..(3-30)

Ct≡ $total\ cost\ for\ yearly\ saving.$

Sv≡ $total\ btu\ saving\ per\ year.$

Oy≡ $operating\ hour\ per\ year.$

C≡ $cost\ per\ million\ btu.$

Vus≡ $value\ @temp\ in\ unisollated\ pipe\ per\ btu\ /\ hr.$

Vis≡ $value\ @temp\ in\ isollated\ pipe\ per\ btu\ /\ hr.$

3.4. Boilers:-

Boiler Efficiency:

Boiler efficiency is a valuable tool to track system performance, to identify problems, and to determine the effectiveness of system alterations and evaluate potential savings. There two method of boiler efficiency

1. ASME Direct Method
2. Indirect Method (Combustion Model)

- **Energy balance**:

HEAT INPUT = HEAT OUT PUT + LOSS

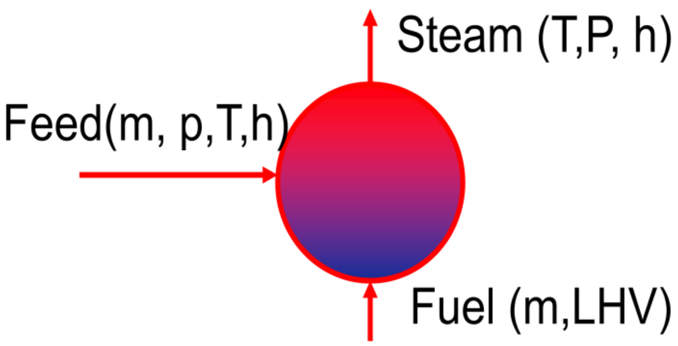
- Efficiency

$$Q_i = Q_o + Q_{loss} \quad \text{........ (3-31)}$$

$$\eta = \frac{Q_o}{Q_i} \quad \text{......... (3-32)}$$

Mass balance

Mass in = Mass out + Accumulation + loss .... (3-33)



Ƞ = Total heat content of steam / Heat of Combustion

= Sensible heat + Latent heat + Super heat / Fuel consumption * Calorific value …………(3-34)

3.5. heat losses in furnace:

- Heater efficiency =

Heat absorbed by crude oil + Heat absorbed by steam / fuel consumption * calorific value ….(3-35)

3.6. Design of heat exchanger:

I. Calculation of caloric temperature

$$r = \frac{\Delta t_c}{\Delta t_h} = \frac{T_2 - t_1}{T_1 - t_2} \qquad (3\text{-}36)$$

Energy balance:

$$Q_g = Q_k = \dot{m}_k C_k (t_2 - t_1) = \dot{m}_g C_g (T_1 - T_2) \qquad (3\text{-}37)$$

Calculation of heat transfer area and tube numbers:

$$F_T = \frac{\frac{\sqrt{R^2+1}\ln(1-S)}{1-RS}}{\frac{(R-1)\ln\left(2 - S\left(R + 1 - \sqrt{(R^2)+1}\right)\right)}{2 - S\left(R + 1 + \sqrt{(R^2)+1}\right)}} \qquad (3\text{-}38)$$

$$R = \frac{T_1 - T_2}{t_2 - t_1}$$

$$LMTD = \frac{(T_2 - T_1) - (t_2 - t_1)}{\ln\left(\frac{T_2 - T_1}{t_2 - t_1}\right)}$$

Determining the heat transfer area (‘*A*’):

$$A = \frac{Q}{U_{assm} LMTD \times F_T} = \frac{\dot{m}_g C_g (T_1 - T_2)}{U_{assm} \times LMTD \times F_T} \qquad (3\text{-}39)$$

Calculating no. of tubes (n_t):

$$n_t = \frac{A}{\pi d_o L_t} \qquad (3\text{-}40)$$

Check for fluid velocity:

$$\mathrm{Re} = \frac{4 \dot{m}_k (n_p / n_t)}{\pi d_i \mu} \qquad (3\text{-}41)$$

Determination of heat transfer co-efficient:

$$j_H = \frac{h_i d_i}{k}\left(\frac{\mu_k C_k}{k_k}\right)^{-1/3}\left(\frac{\mu}{\mu_w}\right)^{-0.14} \qquad (3\text{-}42)$$

Shell side heat transfer co-efficient (*hₒ*):

$$D_e = \frac{4\left(P_T^2 - \frac{\pi}{4}d_o^2\right)}{\pi d_o} \;,\; a_s = \frac{CBD_S}{P_T} \quad j_H = \frac{h_o D_e}{k_g}\left(\frac{\mu_g C_g}{k_g}\right)^{-1/3}\left(\frac{\mu}{\mu_w}\right)^{-0.14} \qquad (3\text{-}43)$$

Overall heat transfer co-efficient (Uo cal ,):

$$U_{o,cal} = \left[\frac{1}{h_o} + R_{dg} + \frac{A_o}{A_i}\left(\frac{d_0 - d_i}{2k_w}\right) + \frac{A_o}{A_i}\left(\frac{1}{h_i}\right) + \frac{A_o}{A_i}R_{dk}\right]^{-1} \qquad (3\text{-}44)$$

$$\frac{U_{o,cal} - U_{o,assm}}{U_{o,assm}} < 30\% \qquad (3\text{-}45)$$

4.1. Calculate the Energy losses in storage tank:

Used the equation (3-1)-(3-2)-(3-22)

Table:.4.1.

Symbol	type	Value	symbal	type	value
Q	Crude	3160572	KE		0.041
	l.residue	973129	Wv		0.04743
	Gas oil	385453	Mv		26.3
	Kerosene	108273	Pva	Crude	0.07
	diesel	108273		l.residue	0.0002
	naphtha	81913		Gas oil	2.7
Kp	crude	0.75		Kerosene	0.029
	product	1		diesel	0.029
KN	N>36	0.167		naphtha	2.7
	N<36	1		l.residue(43)	0.07

4.2. Calculate the Energy losses in pipe:

used the equation (3-28)

Before Distillation:

Table :4.5.

Type	length (m)	Length (ft)	Diameter (in)	fluid Pressue (psia)	Heat Loss per 100 of Uninsulated line(MMBtu/yr)	heat loss Mmbtu/y
Crude	7	22.966	4	150	850	195.211
Crude	7	22.966	4	150	850	195.211
Crude	200	656.168	4	150	850	557742.8
Gasoil	42	137.8	4	150	850	1171.3

Distillation:

Table:4.6.

Type		length (m)	Length (ft)	Diameter (in)	fluid Pressure (psia)	Heat Loss per 100 of Uninsullated line(MMBtu/yr)	heat loss MMBtu/yr
Gasoil in	In	120	393.7	2	150	480	1889.76
Gasoil out	Out	50	164.04	2	150	480	787.392
Kerosene	In	20	65.62	2	150	480	314.976
kerosene	Out	50	164.04	2	150	480	787.392
L. Naphtha	In	120	393.7	2	150	480	1889.76
L.Naphtha	Out	120	393.7	2	150	480	g1889.76
H. Naphtha	In	24	78.74	6	150	1195	940.943
H.Naphtha	Out	50	164.04	6	150	1195	1960.278

Efficiency:

=Total MMBtu/yr*0.9*2.5 = **(1281970.762$)**

4.3. Calculate The Energy losses in valves:

Used equation number (3-29),(3-30)

Heat exchangers area:

Table:4.7

Fluid	Size(in)	Ts	account	Btu/hr/unit
Crude	4	415	6	5918
	6	415	6	8477
	8	415	1	11460
H. naphtha	4	172.5	2	1529
kerosene	4	221	2	1529
Gas oil	4	318	4	3383
Residue	6	455	8	13320
Total			29	45616

Boiler area:

Table:4.8.

Fluid	Size(in)	Ts	account	Btu/hr/unit
Crude	1	415	17	1423
	1.5	415	3	2846
	6	415	1	8477
Steam	1	700	10	3819
	2	700	1	7638
	6	700	5	23042
Total			37	47245

CDU area:

Table:4.9.

Fluid	Size(in)	Ts	account	Btu/hr/unit
l. naphtha	1	172.5	4	737
	2	172.5	1	737
	3	172.5	4	2443
	4	172.5	1	1529
	6	172.5	10	2158
H. naphtha	1	210	8	368
	2	210	3	737
	4	210	3	1529
kerosene	1	221	8	368
	2	221	3	737
	3	221	3	1105
	4	221	4	1529
Gas oil	1	318	8	814
	2	318	3	1629
	3	318	2	2443
	4	318	7	3383
	6	318	2	4813
Residue	4	455	1	5918
	6	455	5	8477
Steam	1	700	5	3819
	1.25	700	2	3819
	2	700	8	7638
Total			99	57098

Heaters area:

Table:4.10.

Fluid	Size(in)	Ts	account	Btu/hr/unit
Crude	1	415	14	1423
	1.5	415	19	2846
	2	415	22	2846
	3	415	6	4269
	4	415	5	5918
	8	415	1	26849
Steam	1	700	9	3819
	2	700	2	7638
	3	700	1	11457
	4	700	2	16021
Total			81	83086

Total losses in all valves are:

Table:4.11.

equipment	Account	Btu/hr/unit	Losses/$
H.X	29	45616	998990400
CDU	99	57098	1250446200
heater	81	83086	1819583400
Boiler	37	47245	1034665500
Total	246	233045	5103685500

4.4. Calculate The Energy losses in flanges:

- Used equation number (3-29),(3-30)

Heat exchangers area:

Table:4.12.

Fluid	Size(in)	Ts	account	Btu/hr/unit
Crude	4	415	15	5918
	6	415	7	8477
	8	415	3	11460
H. naphtha	4	210	2	1529
kerosene	4	221	2	1529
Gas oil	4	318	2	3383
Residue	6	455	21	13320
	8	455	5	9284
Total			57	54900

Boiler area:

Table:4.13.

Fluid	Size(in)	Ts	account	Btu/hr/unit
Steam	2	415	2	2846

CDU area:

Table:4.14.

Fluid	Size(in)	Ts	account	Btu/hr/unit
Crude	8	415	5	11460
L. naphtha	1	172	7	368
	2	172	6	737
	4	172	19	1529
	6	172	7	2158
	8	172	4	2443

H. naphtha	2	210	3	737
	4	210	4	1529
	6	210	6	2158
kerosene	4	221	10	1539
Gas oil	4	318	5	3383
	6	318	8	4813
Residue	4	455	3	9284
	6	455	8	13320
Steam	2	700	1	7638
	4	700	1	16021
Total			97	79117

Heaters area:

Table:4.15.

Fluid	Size(in)	Ts	account	Btu/hr/unit
Crude	1	415	4	1423
	2	415	9	2846
	4	415	8	5918
	6	415	7	8477
Steam	1	700	4	3641
	2	700	14	7638
	4	700	3	16021
	6	700	4	48063
Total			53	94027

- **Total losses in all flanges are**:

Table:4.16.

equipment	Account	Btu/hr/unit	Losses/$
H.X	57	54900	1202310000
CDU	97	79117	1732662300
heater	53	94027	2059191300
Boiler	2	2846	62327400
Total	209	230890	5056491000

4.5. Calculate The efficiency of heaters:

Table:4.17.

Type of fuel	Sudanese crude (Blend)	Fuel consumption	539.1 kg/ hr
Density @ 15°C	0.8756 kg/l	Crude charge	45152kg/ hr
API ° @ 15°C	30.1	Steam quantity	1875 kg/ hr
Calorific Value	10800 k Cal/kg	Crude inlet temp	255 °C
Steam inlet temp	169 °C	Crude outlet temp	370 °C
pressure	10.62 bar	pressure	10.62 bar
Steam outlet temp	280 °C	All burners online	

- **Used equation number (3-35)**

Heat of Combustion= fuel consumption * calorific value

=539.1*10800=5822280 cal/hr

Heat absorbed by crude oil = 45152 (370 -255) *0.73 = 3790510.4 K cal /hr

Heat absorbed by super heat steam = 1875*(280 – 169) *0.48 = 99900 K cal/hr

η = 3890410/ 5822280 = 66.8%

4.6. Calculate the efficiency of boilers:

Table:4.18.

Type of fuel	Sudanese crude (Blend)	Fuel consumption	140 kg/ hr
Density @ 15°C	0.8756 kg/l	Boiler feed water	2080 kg/ hr
API ° @ 15°C	30.1	Boiler feed water, temp	37°C
Calorific Value	10800 k Cal/kg	Steam from boiler, temp	169°C
- Steam from boiler, press	4.83 bar		

- **Used equation number (3-34)**

Heat of Combustion= fuel consumption * calorific value

=140*10800=1512000 cal/hr

Total heat content of steam= Sensible heat + Latent heat + Super heat

=2080((100-37)*1+539+(169-100)*0.48)=

=1321049.6

η =1321049.6/1512000=0.87

Summary:

The total losses are:

Table:4.19.

equipment	Btu/hr/unit	Losses/$
pipe	7569764.783	1732662300
valve	233045	5103685500
flanges	230890	5056491000
Total	8033700	11892838800

4.1.7. calculation design heat exchanger :

Used the equation (3.36)-(3.45)

Table:4.20

TYPE	M	T_{in}	T_{out}
Residue	194304	390	339
Crude	133608	304	353

Shell side ≡ Residue tube side ≡ Crude

Table:4.21.

ρ_R	46.4262	ρ_C	51.9557
μ_R	1.2970	μ_C	2.0316
P_R	45	P_C	235
S_R	0.57	S_C	0.48
C_R	0.7636	C_C	0.5803
fouling	0.005	fouling	0.005

Solution:

Table: 4.22

Q_R	3366652	n_t	400 tube
A	= 1897.8	R_E	6659.8
J_H	42	J_H	110
H_I	111.789	H_O	176.29

U_{OCAL}=32

(45-32)/45=28%

5.1 Conclusion:

In this research a data from Elobied refinery has been used to calculate the losses for fixed roof ,unisolated valves, flanges and pipes, in addition the efficiency for furnace and boiler , the losses are reached it are :

I. Fixed tank =68666716 ib/yr =171666791$
II. Unisolated valve =233042 btu/hr/unit =5103685500$
III. Unisolated flanges =230890 btu/hr/unit =5056491000$
IV. Unisolated pipes =7569764.783 btu/hr/unit =1732662300$
V. Heater efficiency =66%
VI. Boiler efficiency =87.4%

5.2 Recommendation:

The recommendation of this research are:

1) It is recommended to use a floating tank for storing naphtha and crude oil to reduce energy losses due to emission.
2) To reduce the cost of storage an internal floating tank may be used to store gasoline.
3) Coated pipes, valves and flanges should be used to reduce energy losses.
4) Apply forced draft and induced draft for heaters to reduce oil consumption which use to ignite a flame; this process increases the efficiency about (3-6%).
5) This work can be extending to calculate the consumption of electric in the refinery and make design to floating roof tank.

Appendix A:

Table A-1: Specific gravity of crude oil and products

Type	SG
Crude Oil	0.877
Long residue	0.901
Diesel	0.846
Gas Oil	0.835
kerosene	0.783
Gasoline	0.75

Table A.2: Calorific values

Type	HCV, BTU/lb	HCV, BTU/tonne
Crude Oil	18404	40580820
Long residue	18010	39712050
Diesel	18017	39727485
Gas Oil	19200	42336000
kerosene	19800	43659000
Gasoline	20500	45202500

Appendix B:

Table: ORC Storage Tanks Capacities

Tank NO.	TYPE	S.G	Capacity m^3
TK 11	Crude Oil	0.877	5000
TK 12	Crude Oil	0.877	5000
TK 13	Crude Oil	0.877	5000
TK 14	Crude Oil	0.877	3000
TK 15	Crude Oil	0.877	5000
TK16	Crude Oil	0.877	5000
TK17	Crude Oil	0.877	5000
TK 61	Long residue	0.901	5000
TK 62	Long residue	0.901	5000
TK 63	Long residue	0.901	5000
TK 64	Diesel	0.846	3000
TK 51	Gas Oil	0.835	600
TK 52	Gas Oil	0.835	600
TK 53	Gas Oil	0.835	5000
TK 41	Gas Oil	0.783	600
TK 42	kerosene	0.783	600
TK 43	Diesel	0.846	600
TK 31	naphtha	0.716	600
TK 32	naphtha	0.716	600
TK 33	naphtha	0.716	600
TK 71	water	1.0	600
TK 72	water	1.0	600
TK 21	Slops	0.820	180
TK 22	Slops	0.820	180