Sudan University of Science & Technology

College of petroleum Engineering

Department of Transportation & Refining

Study of using fuel oil as furnace oil instead of crude oil in El-Obied Refinery

دراسة استخدام وقود الفيرنست المنتج كوقود فرن بديلا عن الخام في مصفاة الأبيض

Project submitted in partial fulfillment of the requirement for the Bachelor of Engineering (Honors) Degree in Transportation and Refining Engineering

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الإستهلال

قال تعالى:

" وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ ۚ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ "

سورة هود الاية (88)

Dedication

We dedicate this project to our parents for the love and support they have provided throughout our entire life, they have been there for every decision we have made and help our dreams become reality, to our friends and families for their help and encouragement. We also dedicate this project to **Mr. Mohamed Osman** and **Eng. Mosab Mohamed.**

Acknowledgment

Thankfulness and appreciation for Allah as always before and after. Without the encouragement and support of some people this thesis would have not been feasible.

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Abstract

The main objective in the refining petroleum industry is to achieve economic and environmental purposes as possible by producing specification products with attention to economic aspects. In ORC (EL-Obied Refinery Company) there are losses in availability products and profit benefit by burning crude oil as furnace fuel.

In the past years there's bovines change in the crude oil prices, the price has risen more than fuel oil (long residue). So, this project studies the ability of replacement crude oil by using fuel oil(products) from distillation unit.

The project includes the comparing between the existing(old) fuel system and new fuel system, properties of fuel oil as fuel, environmental impact for both system, cost estimation and profit predict from using fuel oil.

Key words: crude oil, fuel oil, existing fuel system, new fuel system

التجريد

من أهم أهداف عمليات تكرير النفط هي تحقيق المكاسب الإقتصادية مع الحفاظ على البيئة في نفس الوقت, عبر إنتاج مواد ذات عائد اقتصادي دون ان يكون لها تأثير على البيئة. في شركة مصفاة الأبيض يتم فقد منتجات ذات قيمة وفوائد ربحيه عندما يتم استخدام خام النفط كوقود لفرن التسخين.في السنوات الماضية لوحظ ان تغير اسعار خام النفط تزايدت بزياده وصلت الى%. لذلك يختص هذا المشروع بدراسة إمكانية استبدال خام النفط بزيت الوقود(الفيرنست) المنتج من عمليات التقطير.

تتضمن الدراسة, آلية عمل نظام الوقود الحالي والجديد ,خصائص استخدام زيت الوقود (الفيرنست) كوقود احتراق, الأثر البيئي لكلا النظامين, تقدير التكلفة والربحية المتوقعةعند استخدام زيت الوقود(الفيرنست).

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Introduction

1.1 Introduction

Elobeid Refinery Company (ORC), is a company wholly owned by the Sudanese government since1996.

The refinery stands as an evidence for the good decision, planning, acting and the close follow –up of the official authorities to reach the target. And this target is what the political and technical authorities in the ministry of energy and mining had challenged on it.

The refinery designed to process 10,000 barrel/day (452,000 t/y), then developed to reach 15,000 barrel/day (679,150 t/y) since DE bottle-necking the crude heaters by adding to the preheat train three heat exchangers and two fuel oil pumps.

The main products are Fuel oil (63%), Gas oil (24%), Naphtha (6%) &Kerosene (7%).

1.2 Problem statement:

The burning of crude oil that used as furnace fuel has problem because it contains a large quantities of valuable products.

1.3 Objectives:

- Determine the ability of replace crude oil by fuel oil
- Determine the amount of fuel oil used.
- Replace the old system by new system.
- Determine the cost of the new system.
- Compare the air emissions of both systems.

1.4 Scope of this study:

The scope of this project is to study of using fuel oil as refinery fuel instead of crude oil in El-Obied refinery.

Chapter 2
Literature review

Literature review

2.1 Introduction:

A large variety of opportunities exist within petroleum refineries to reduce energy consumption while maintaining or enhancing the productivity of the plant. Studies in the petroleum refining have demonstrated the existence of a substantial potential for energy efficiency improvement. Major areas for energy efficiency improvement are utilities, fired heaters, process optimization, heat exchangers, motor and motor applications.

In the current period of high energy costs, economics still dictates how much energy a plant changes can conserve from change in equipment and/or type of fuel used. Simultaneously changes shall conduct with minimum capital investment.

2.2 Refinery fuel system:

Fuel gas and residual fuel are the most commonly used fuels in the refinery. Other refinery products of low monetary value, such as heavy pitch residues, tars, FCCU decanted oil, vacuum tower bottoms from certain crudes, lube extracts, and waxes are also used as fuel in the refinery itself. The majority of these materials would be difficult to blend in a commercial fuel of acceptable specifications because of high viscosity, chemical aggressiveness, high contaminant level (sulfur, metals, etc.), and associated environmental problems in their use. Gaseous streams diverted to the refinery as fuel are those gases that cannot be processed to saleable products economically. These include H2, CH4, C2H6, and frequently C3 and C4 gases. In a refinery of average complexity, approximately two thirds of refinery fuel requirements may come from refinery gases. The rest of the fuel requirement is made up from a natural gas supply, if available, or residual fuel oil produced in the refinery. In many refineries, both gaseous and liquid fuels are used simultaneously. Furnaces and boilers are equipped with combination burners, suitable for both gas and oil firing. Exception to this are certain refinery units, such as cat reforming, where only gas firing is permissible because of the need for precise temperature control. Furnaces that are operated when no gaseous fuel is available as during refinery start up must be equipped with oil burning capability.

Burning fuel provides the necessary heat. The refinery fuel system includes facilities for the collection, preparation, and distribution of fuel to users.The aim of the fuel oil system design is that operational changes to one furnace will not cause fluctuation of supply to another
portion of the refinery. (Sommer, 1973)

2.3 The existing fuel oil system:

EL-Obied Refinery has fuel system designed to supply heaters and boilers, the fuel system receives crude oil from the crude charge pumps discharge line. The purpose of refinery fuel system is to enhance constant and regular supply of oil to burners of steam boilers and heaters. The system includes: storage tank, pumps and heating system.

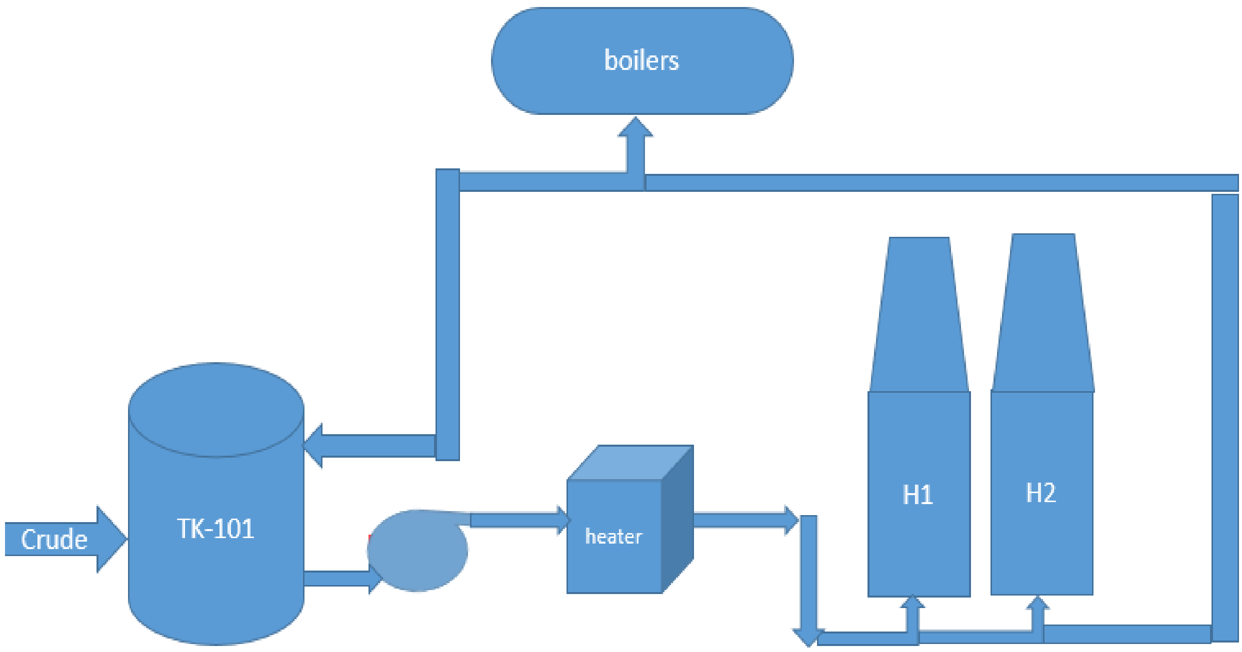

Figure (2-1): simplified sketch of the refinery fuel system

2.4 Alternatives fuels:

Fuel gas and residual fuel are the most commonly used fuels in the refinery. In our case there is no fuel gas available, therefore the fuel oil can be the only available alternative refinery fuel.

Heavy fuel oils are blended products based on the residues from various refinery distillation and cracking processes.

They consist of aromatic, aliphatic and naphthenic hydrocarbons, typically having carbon numbers from C_{20}toC_{50}, together with asphaltenes and smaller amount of heterocyclic compounds containing Sulphur, nitrogen and oxygen. They also contain organic-metallic compounds, the most important of these trace metals is vanadium. (Groups, 1998)

The high flash point, good storage stability, and potential energy value make residual fuel a relatively safe and economical energy source.

2.4.1 Types of fuel oils:

The various types of fuels are available for firing in boilers, furnaces and other combustion equipment's. The selection of right type of fuel depends on various factors such as availability, storage, handling, pollution and landed cost of fuel.

- Biodiesel:
  Sold in percentage mixture with No.2 home heating oil as a heating fuel or bio heat.
- Jet fuel (type A):
  Basically Kerosene, or filtered No.1 oil cleaned up to higher specifications including very fine filtering and a water removal step.
- Kerosene:
  Is No.1oil which has been filtered to clean it up. Sold at ridiculously higher prices in stores as "lamp oil" this material may have deodorants or fragrances added. The traditional name for kerosene is "coal oil".
- Diesel fuel:

Used in diesel powered vehicles and some other engines, is basically No.2 home heating oil.

- Home heating oil:

  Also referred to as No.2 fuel oil or by some writers as Regular fuel oil.

- Fuel oil No.3:

  It is a distillate fuel oil that is not in wide use.

- Fuel oil No.4 or (bunker oil):

  It produced by blending distillate along with residual fuel oils such No.2 and No.5. Is used in large stationary engines, power plants and very large commercial boilers. (GiobeCore, n.d.)

♦ Two types of fuel oils are commonly used in Sudan these: (Ali A. Rabah, 2013)

  ▪ heavy fuel oil produced in Elobied refinery
  ▪ heavy cocker gas oil of Khartoum refinery

2.4.2 Classification of fuel oil:

In general, fuel oil is classified in six classes numbered 1 through 6, according to its boiling point, composition and purpose.

- fuel oil No.1:

  Similar to kerosene. It is the fraction that boils off right after gasoline.

- fuel oil No.2:

  This is the diesel fuel that trucks and cars run on, leading to the name "road diesel".

- fuel oil No.3:

  This is a distillate fuel oil and is rarely used.

- fuel oil No.4:

  This fuel oil usually a blend of distillate and residual fuels oil, such as No.2 and No.6; sometimes it is just a heavy distillate (diesel distillate or residual fuel oil).

- fuel oil No.5:

It is a mixture of 75% to 80% of No.6 and 25% to 20% of No.2.

- fuel oil No.6:

  This oil is called residual fuel oil (RFO)or heavy fuel oil (HFO). It is the remainder of crude oil after gasoline and distillate fuel oils have been extract through distillation. It fuels thermal power station or robust engines.

2.4.3 Advantages of using heavy fuel as fuel oil:

- ✓ Fuel oil can be burned to smokeless combustion without sparks.
- ✓ Fires can be started and stopped instantly as required.
- ✓ High calorific value with low consumption rate
- ✓ Price lower than traditional energy sources.
- ✓ Low settling point.
- ✓ High flash pint and good storage stability.

2.4.4 Disadvantages of using heavy fuel as fuel oil:

- ☒ Toxicity:

  The toxicity of a heavy fuel oil depends on the toxicity of the individual stocks from which it is blended, represented in: CARCINOGENICITY
- ☒ Fire risk is increased
- ☒ Under certain conditions, the vapor from fuel oil forms an explosive mixture with air.
- ☒ All fuel oil burners make an objectionable roaring sound.
- ☒ Auxiliary apparatus is necessary to start an oil fire or to maintain it or both.
- ☒ Fuel oil has a tendency to leak through valves and joints in the system. (GiobeCore, n.d.)

2.5 Crude oil:

It is a liquid mix of hydrocarbons. found in certain rock strata, it's possible to extract this liquid and then refine it so that it can be used as a fuel. Kerosene, gasoline, and oil come from petroleum.

2.5.1 Classification of crude oil:

- Paraffinic –the ratio of paraffinic hydrocarbons is high compared to aromatics and naphthenic. as **Nile Blend**
- Naphthenic –the ratios of naphthenic and aromatics hydrocarbons are relatively higher than in paraffinic crudes.
- Asphaltic –contain relatively a large amount of poly nuclear aromatics, a high asphaltic content & less paraffin's

2.5.2 Disadvantages of crude oil:

- ☒ Combustion contributes dangerous gasses to the environment:

  Petroleum, when it is combusted, generates high levels of carbon dioxide. Methane and other greenhouses gases can be produced as well depending on how the petroleum has been refinery.

- ☒ Petroleum is a finite resource:

  Petroleum is a fossil oil, so it is a resource that has limitation. We do keep finding new deposits of petroleum to exploit, which provides new reserves for us to stockpile, but at some point those reserves may run out.

- ☒ The refinement process of petroleum can be toxic:

  Petroleum on its own can be lethal to all forms of life in some way. At just 0.4 %concentration levels, it is lethal to fish. The benzene that is present in crude oil and fuels refined from it, is known **carcinogen**. Exposure to petroleum lowers white blood cell count in humans, which makes them more susceptible to illnesses.

- ☒ Petroleum can be a trigger for acid rain:

  When petroleum combusts, it creates a high temperature impact with the surrounding air. That causes the nitrogen in the atmosphere to oxidize. nitrous oxide, when combined with the sulfur content that is found in petroleum, can combine with atmospheric moisture to create acid rain. When it falls, acid rain can create acidic waters in lakes, ponds and rivers.

- ☒ Petroleum transportation isn't 100% safe:

  Business Insider reports that more than 9 million gallons of petroleum have spilled from US transportation networks from 2010-2016. More than 1,300 total spills occurred during that period, which equates to one spill every 2 days. More than 73,000 miles of pipeline transport petroleum every day, plus more is transported by tankers and trains.
- ☒ It is a commodity that is exploited for political purposes:

  The value of petroleum makes it a resource that every side of the political rainbow attempts to exploit. Nations go to war over petroleum resources. Terrorists attempt to sabotage petroleum networks. Dictators can take control over a nation's resources, amass billions or trillions in funds, and then use that value to violently suppress people. (Vasa-Sideris, n.d.)

2.6 Furnace

Fired heater is a device used to heat up chemicals or chemicals mixtures. It's classified as direct fired or indirect fired. Direct- fired furnace can be identified by the amount of volume, the combustion gases occupy inside the furnace. Fired heater can be also classified as natural, induced, forced, or balanced draft. Fired heaters are used in many processes, including distillation, reactor processes, olefin production, and hydro cracking. The primary means of heat transfer in a fired heater are radiant heat transfer and conviction and consist essentially of a battery of pipes or tubes that pass through a fire box.

2.6.1 Furnace Applications and Theory of Operation:

A furnace that is, a fired heater is a device used to heat up chemicals or chemical mixtures. Fired heaters transfer heat generated by the combustion of natural gas, ethane, propane, or fuel oil. Furnaces consist essentially of a battery of pipes or tubes that pass through a firebox. These tubes run along the inside walls and roof of a furnace. The heat released by the burners is transferred through the tubes and into the process fluid. The fluid remains in the furnace just long enough to reach operating conditions before exiting and being pumped to the processing unit. Furnaces are used in crude processing, cracking, olefins production, and many other processes. Furnaces heat up raw materials so that they can produce products such as gasoline, oil, kerosene, chemicals, plastic, and rubber. The chemical-processing industry uses a variety of fired heater designs. These elaborate furnace systems can be complicated and equipped with the latest technology.

2.6.2 Furnace Types:

First, furnaces can be classified by several features: type of draft, number of fireboxes, number of passes, volume occupied by combustion gases, and shape.

- **Draft**:

Furnace draft can be natural, forced, induced, or balanced. In a natural-draft furnace, buoyancy forces induce draft as the hot air rises through the stack and creates a negative pressure inside the firebox. This pressure is lower than normal atmospheric pressure. Forced-draft furnaces use a fan to push fresh air to burners for combustion. Forced draft is used in furnaces that preheat the combustion air to reduce fuel requirements. In an induced-draft furnace, a fan located below the stack pulls air up through the firebox and out the stack. Balanced-draft furnaces require two fans: one inducing flow out the stack and one providing positive pressure to the burners. shows a balanced-draft furnace.

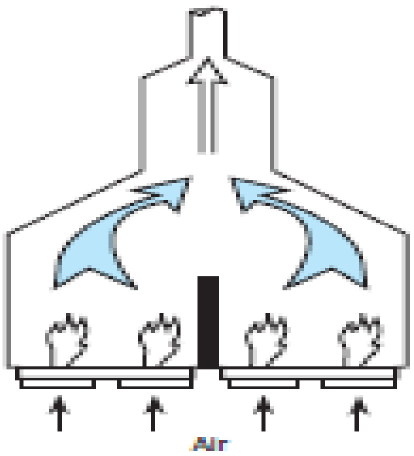

Figure (2-2): Natural-Draft furnace

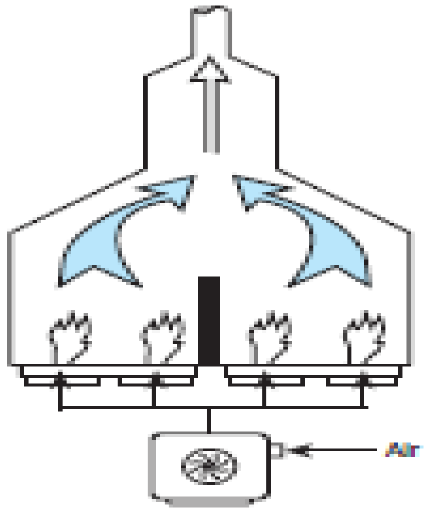

Figure (2-3): Forced-Draft furnace

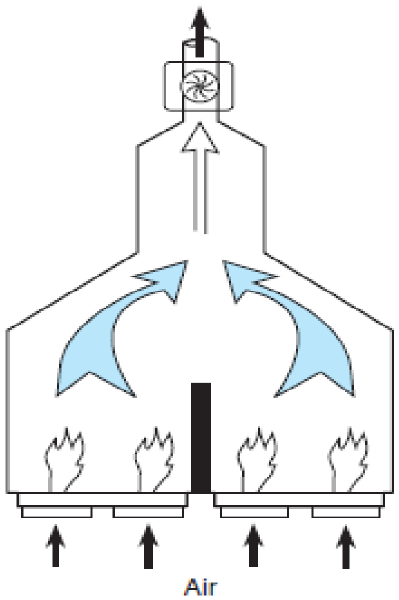

Figure (2-4): Induced-Draft furnace

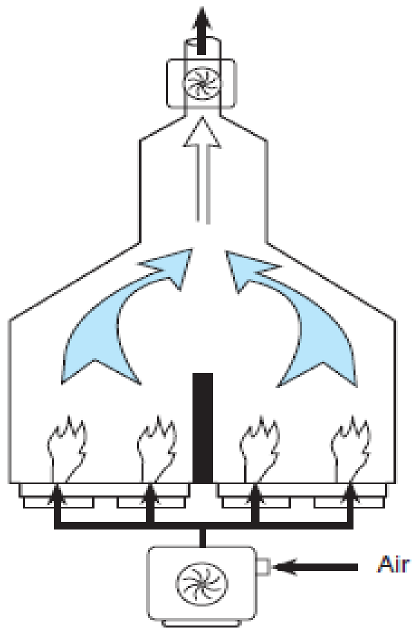

Figure (2-5): Balanced-Draft furnace

- Number of Fireboxes:

  A furnace can have one or two fireboxes. A double-firebox furnace has a center wall that divides two combustion chambers. Hot gases leaving the two chambers meet in a common convection section.

- Number of Passes:

  The charge—that is, flow—entering a furnace is often split into two or more flows called passes. These passes usually are referred to as the east, west, north, or south pass. As the names suggest, each goes to a specific section of the furnace before they all enter a common discharge header. Furnace operators balance the flow rate of these passes equally before starting the furnace. Balanced fluid flow is critical during furnace operation. Another critical factor to be considered is the composition of the charge. The components that make up the charge must remain consistent throughout the duration of the run or variations in operating conditions will occur. This could involve pressure, temperature, flow, and analytical variations to both the charge and furnace operation.

Second, Direct Fired and Indirect Fired:

Furnaces are classified as direct fired or indirect fired. The class is based on the volume occupied by combustion gases. In direct-fired furnaces, the combustion gases typically fill the interior. Direct-fired furnaces heat process streams such as heavy hydrocarbons, glycol, water, and molten salts. Cabin, cylindrical, box, and A-frame furnaces are direct fired. Fire-tube heaters are indirect fired. They contain the combustion gases in tubes that occupy a small percentage of the overall volume of the heater. The heated tubes run through a shell that contains the heated medium. A fire-tube heater resembles a multi pass, shell-and-tube heat exchanger. This type of heater is composed of a shell and a series of steel tubes designed to transfer heat through the combustion chamber (tube) and into the horizontal fire tubes. Exhaust fumes exit through a chamber similar to an exchanger head and pass safely out of the boiler. The water level in the boiler shell is maintained above the tubes to protect them from overheating. The term fire tube comes from the way the boiler is constructed. A fire-tube heater consists of the boiler shell, fire tubes, combustion tube, burner, feed water inlet, steam outlet, combustion gas exhaust port, and tube sheet.

2.6.3 Basic Components of a Furnace:

Fired heaters come in a variety of shapes and sizes. They have different tube arrangements and feed inlets and burn different types of fuels and have different burner designs. All furnaces do, however, have certain things in common: firebox, radiant tubes or coils, convection tubes, damper and stack, refractory lining, burners and air registers, fuel system, instruments, and induced- or forced-draft fans.

- Firebox and Refractory Layer:

  The section in a furnace that contains the burners and open flames is called the firebox.

- Radiant and Convection Tubes:

  The tubes located along the walls of the firebox are called the radiant tubes or coils. Radiant tubes receive direct heat from the burners. These tubes operate at high temperatures and are constructed of high-alloy steels.

  Convection tubes are located in the roof of the furnace and are not indirect contact with burner flames. Hot gases transfer heat through the metal tubes and into the charge. Convection tubes usually are horizontal and are equipped with fins to increase efficiency.

- Air pre heaters:

  are often used to heat air before it enters a furnace at the burners. Air tubes are typically located in the stack or convection section that allow outside air to be brought in by a compressor or blower and gradually warmed up before mixing with fuel at the burner.

- Soot Blower:

  Soot blowers are devices found in the convection section of process heaters. Soot blowing is required when the efficiency of the convection section decreases.

- Stack Damper:

  Combustion gases leave the furnace through the stack and are dispersed into the atmosphere at a height to ensure against any immediate deleterious effect such as carbon monoxide poisoning.

- Burners and Air Registers:

Burners can be arranged on the floor or the lower walls of the firebox. There are several types of burners. Oil burners set the proportion of fuel and air and mix them by atomizing the fuel with high-pressure steam or air. (Thomas, 2011)

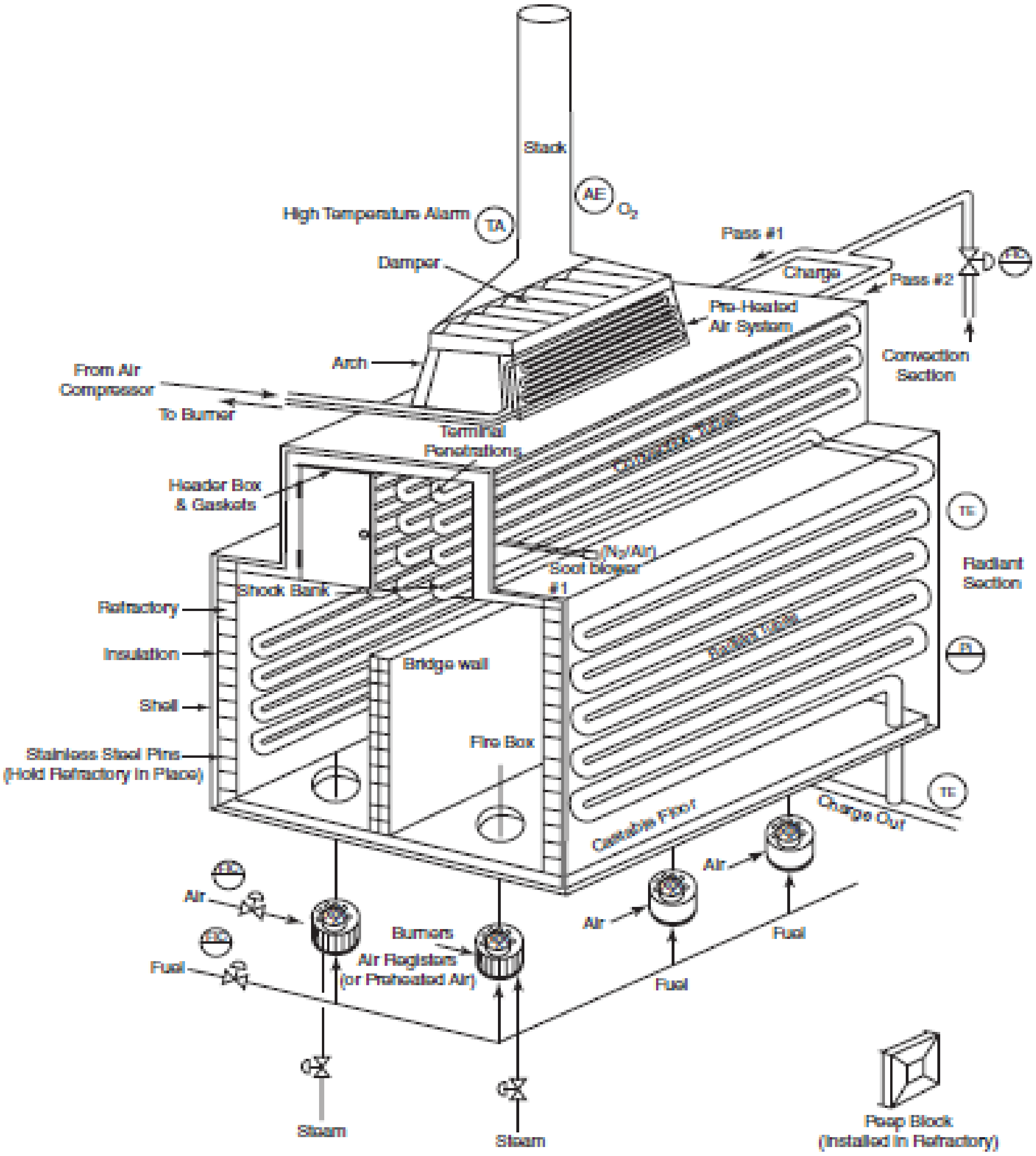

Figure (2-6): components of furnace

2.7 Heat Transfer:

The primary means of heat transfer in a fired heater are radiant heat transfer and convection however, heat must pass through the walls by conduction to be absorbed by the flowing fluid. In the fired furnace, the flame on the burner is the radiant heat source. Radiant heat transfer takes place primarily in the firebox.

Tubes located in the firebox are referred to as radiant coils or tubes. The tubes transfer heat to the fluid by conduction. In a fired furnace, radiant heat is emitted from the combustion of natural gas or light oil. As the radiant heat travels from the bottom of the furnace, contacting the tubes or passing in the furnace, and then continues to the top, heat is transferred to the surrounding air. This process initiates the convective heat transfer process that causes the lighter air and hot combustion gases to rise above the radiant heat source. The top of the furnace is referred to as the convection section because most of the heat it receives is by convection. (Thomas, 2011)

2.8 Combustion:

Combustion is a rapid chemical reaction that occurs when the proper amounts of fuel and oxygen (O2) come into contact with an ignition source and release heat and light. Furnaces use this principle to provide heat. Complete combustion occurs when reactants are ignited in the correct proportions. Incomplete combustion occurs in a fired furnace when not enough oxygen exists to completely convert all of the fuel to water and carbon dioxide. Many furnaces use natural gas or methane (CH4) as fuel for the burners. Methane (CH4) reacts with O2 to form carbon dioxide (CO2) and water (H2O):

$$CH_4+2O_2 \rightarrow CO_2+2H_2O$$

Incomplete combustion may result in the production of carbon monoxide. The chemical processing industry also uses ethane, propane, and light oils for fuel. illustrates the basic components of the fire triangle or fire tetrahedron. Another common combustion reaction with oxygen is:

$$C_3H_8+5O_2 \rightarrow 3CO_2+4H_2O.$$

Propane and oxygen form similar products to methane and oxygen.

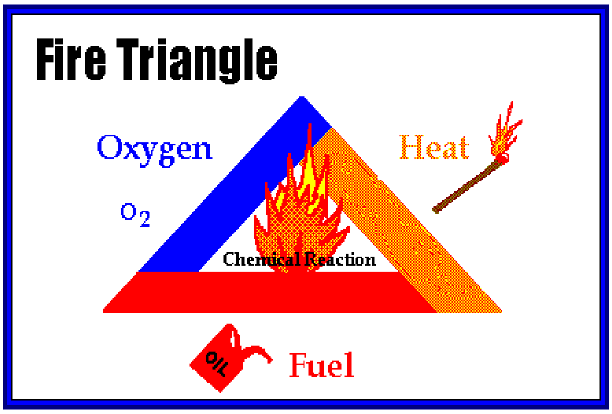

Figure (2-7): fire triangle

2.9 Fuel Heat Value:

Different fuels release different amounts of heat energy as they are burned. The heat energy released, referred to as the heat value, is measured in British thermal units per cubic foot. The British thermal unit (Btu)is a measurement of heat energy. One Btu is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Hydrogen has the lowest fuel heat value (274 Btu/foot3), whereas natural gas, or methane, has a heat value of 909 Btu/foot3. Charts are available that list the heating values of fuels used in furnaces. It is important to realize that the more Buts a fuel gives off; the more oxygen is required for combustion. (Thomas, 2011)

Chapter 3
Methodology

Methodology

3.1 Introduction:

This chapter is focuses on the fuel system of refinery heaters. The whole frame of the study touches the efforts for energy conservation by reducing the consumption of valuable oils to reduce the operating cost.

It includes; description of the existing system, criteria of field operation, fuel properties, the cost of fuel consumed, comparison, proposals, cost estimation, and economical analysis.

We use Excel Program to calculate efficiency of existing system and the quantity of new fuel. And HYSYS to simulates the both systems.

3.2 Furnace efficiency:

There are two methods to calculate efficiency: -

l- Direct method:

$$e = \frac{\text{heat absorb by crude+heat absorb by steam}}{\text{fuel consumption }*\text{calorific value}} *100 \quad (3\text{-}1)$$

2- Indirect method:

$$e = \frac{(\text{LHV}+\text{Ha}+\text{Hf})-\text{Qs}-\text{Qr}}{(\text{LHV}+\text{Ha}+\text{Hf})} * 100 \quad (3\text{-}2)$$

E=Net thermal efficiency.

LHV=Lower heating value of fuel (BTU/LB).

Ha=Heat input in form of sensible heat of air (BTU/LB).

HF=Heat input in form of sensible heat of fuel (BTU/LB).

QF=Heat stack losses (BTU/LB).

QF=Radiation heat losses (BTU/ LB).

This research focus on direct method to calculate efficiency and new fuel consumption.

3.2.1 The old system efficiency:

To determine the efficiency of furnace you have to know some information. This information's includes (heat absorbed by crude oil, heat absorbed by steam and the total heat of combustion). Before efficiency calculations these variables must be calculated.

Firstly, the heat of combustion must be determined:

Heat of combustion=crude(fuel)consumption*LHV of crude(fuel)

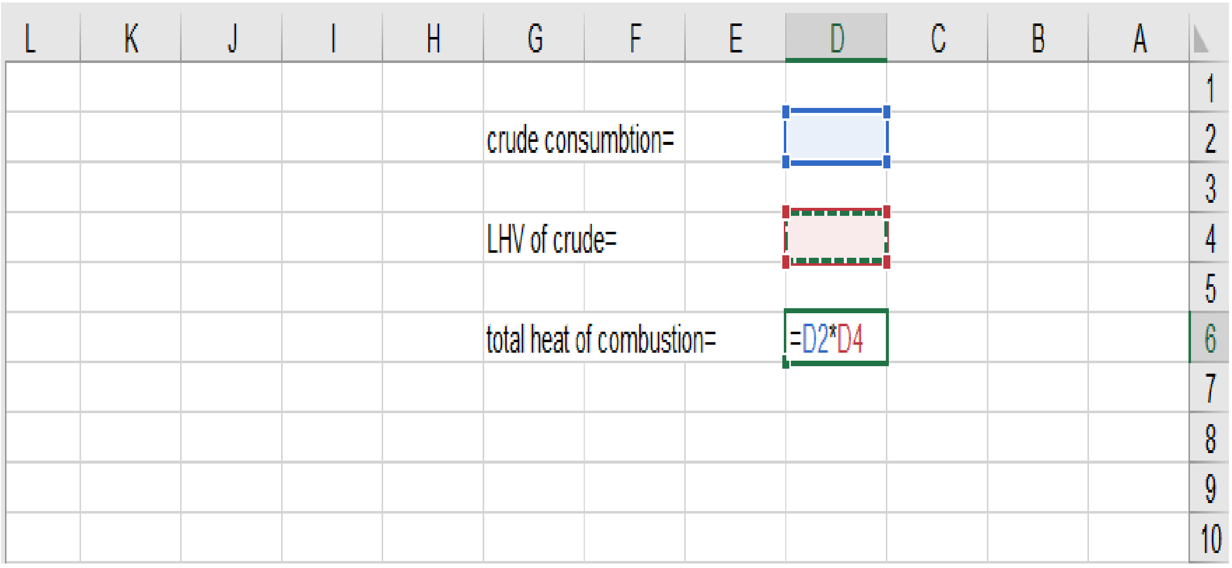

Figure (3-1): total heat of combustion

The next step is determining heat absorbed by crude oil(feed).

Heat absorbed by crude oil(feed)=crude oil(feed)to heater*$\triangle$T*Cpcrude

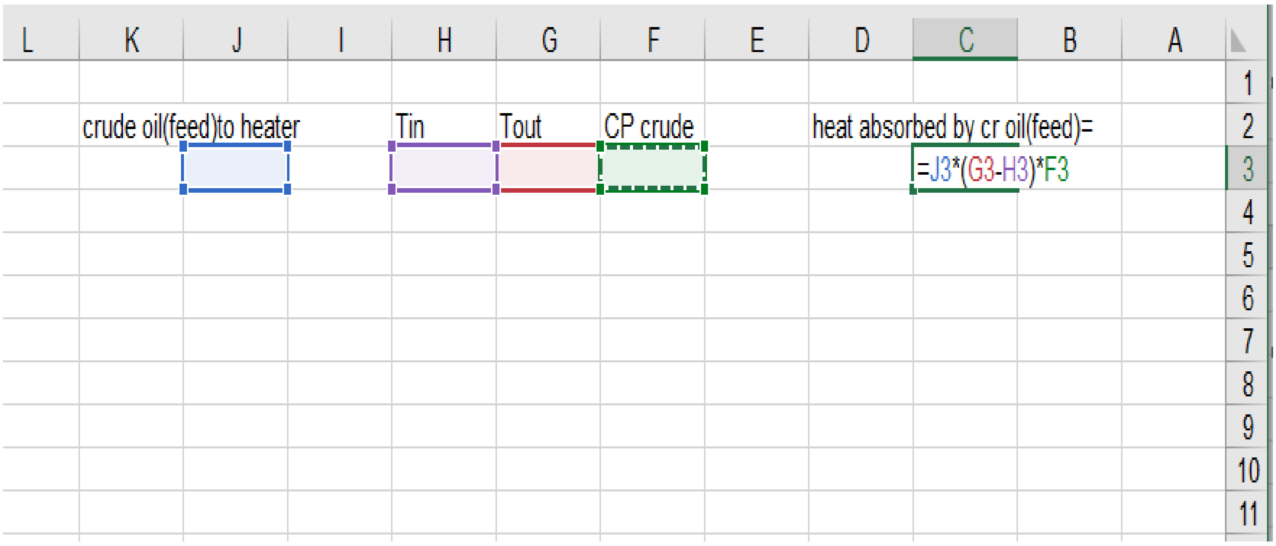

Figure (3-2): heat absorbed by crude oil

Finally, the heat absorbed by superheated steam has been calculated.

Heat absorbed by superheated steam=steam to heater*ΔT*CPw

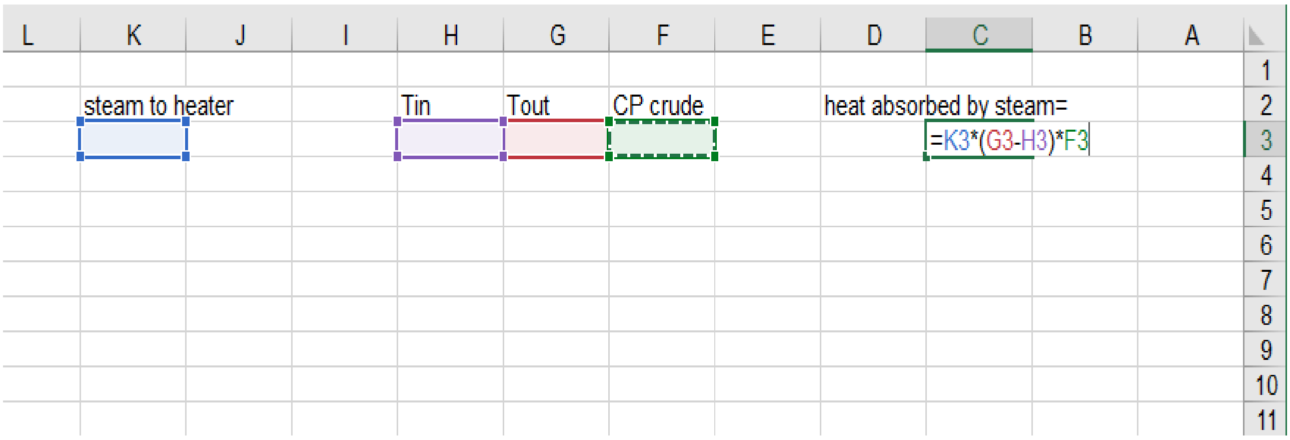

Figure (3-3): heat absorb by superheated steam.

So the data finally being ready to calculate efficiency.

3.2.2 The new system efficiency and fuel consumption:

The efficiency of the new system is equal to the efficiency of existing(old)system, that mean we want to determine the new fuel consumption.

Total heat of combustion(crude)=Total heat of combustion (fuel oil)

$$\text{Fuel oil consumption} = \frac{total\ heat\ of\ combustion}{LHV(fuel\ oil)}$$

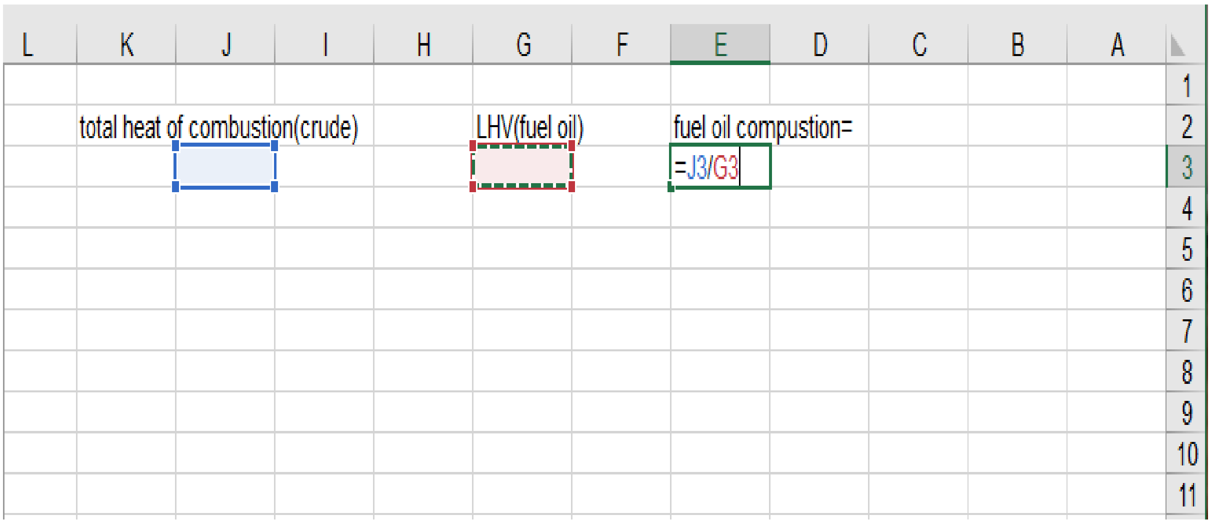

Figure (3-4): fuel oil consumption

3.3 Aspen HYSYS:

Aspen HYSYS is the market-leading process modeling solution that provide large economic benefits throughout the process engineering lifecycle. It brings the power of process simulation and optimization to your desktop, and delivers a unique combination of modeling technology and ease of use. Aspen HYSYS enables companies to bring new plants and design to market faster and optimize production for greater margins. (Journal, June 2010)

Aspen HYSYS benefits:

- ✓ Improve engineering design and operation.
- ✓ Improve energy efficiency
- ✓ Reduce capital cost

3.3.1 The existing system(old):

The existing system has been simulated in HYSYS by the following procedure: Open Aspen HYSYS, and select "Petroleum Assays", search for " Nile Blend" then the "Properties Environment" been OK.

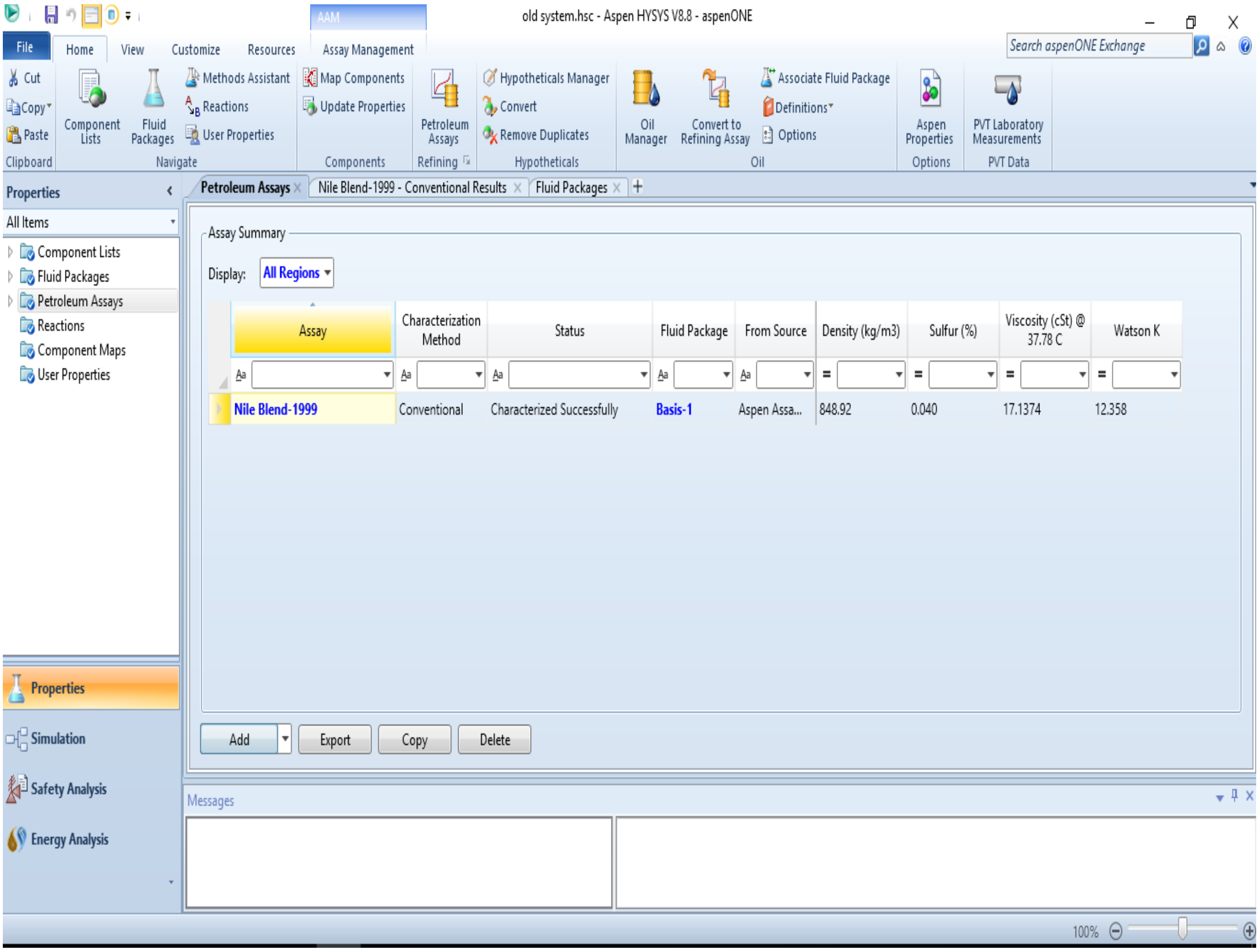

Figure (3-5): petroleum assay

Then go to "Simulation Environment", and inter the data for the crude oil(feed), crude oil(fuel), air conditions and equipment.

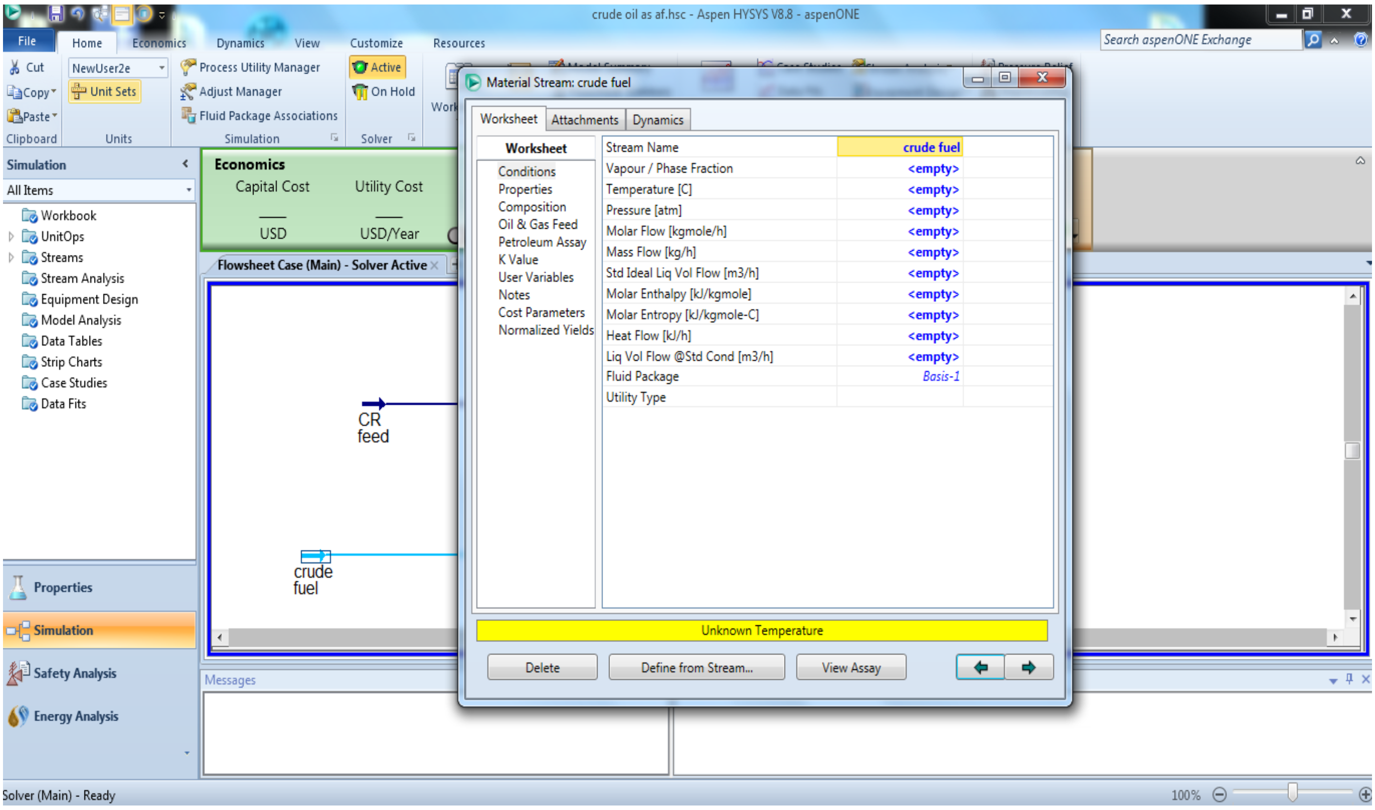

Figure (3-6): crude oil fuel conditions

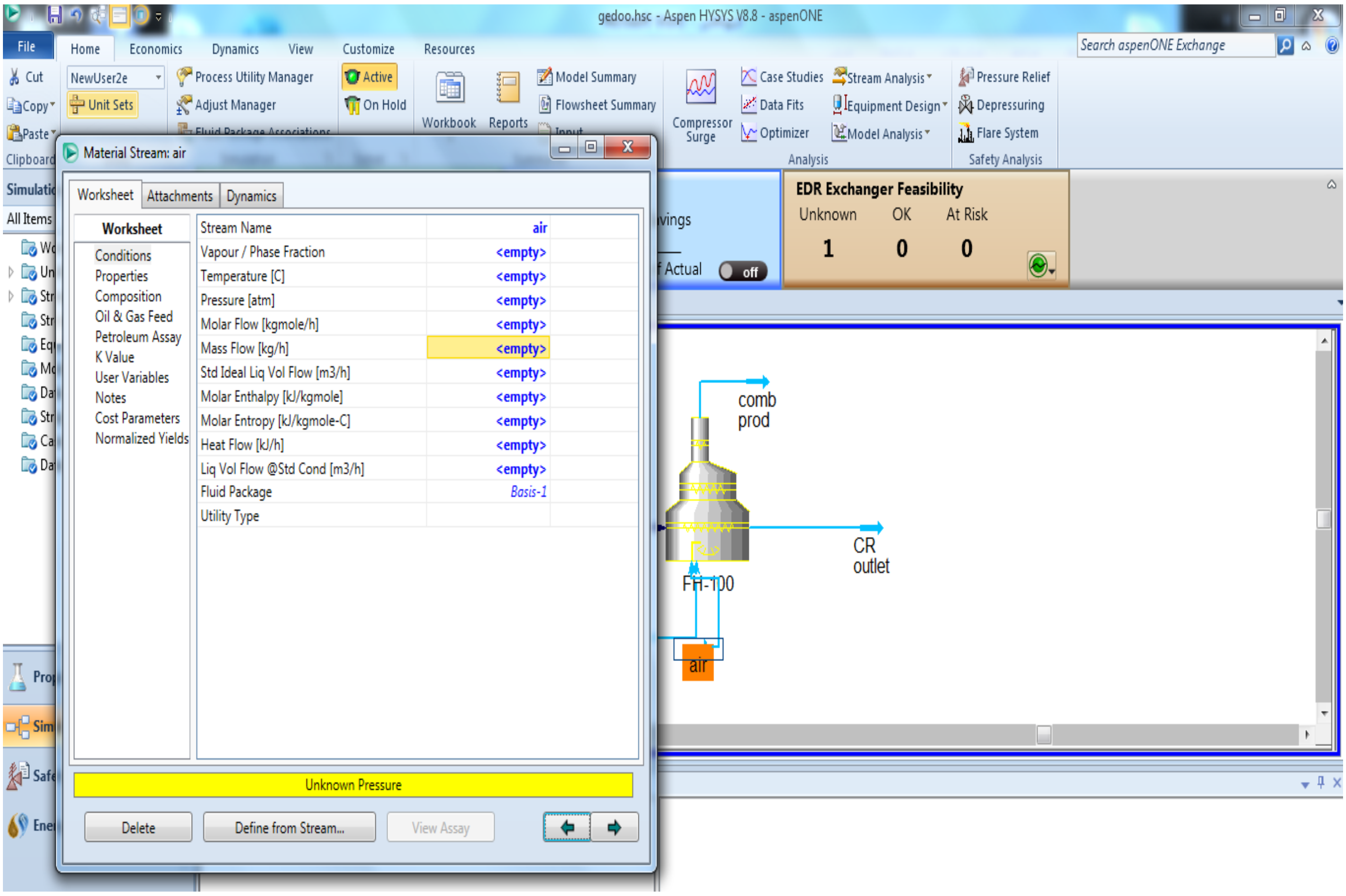

Figure (3-7): air conditions

Finally, enter the data efficiency and excess air for "Simplified Furnace"

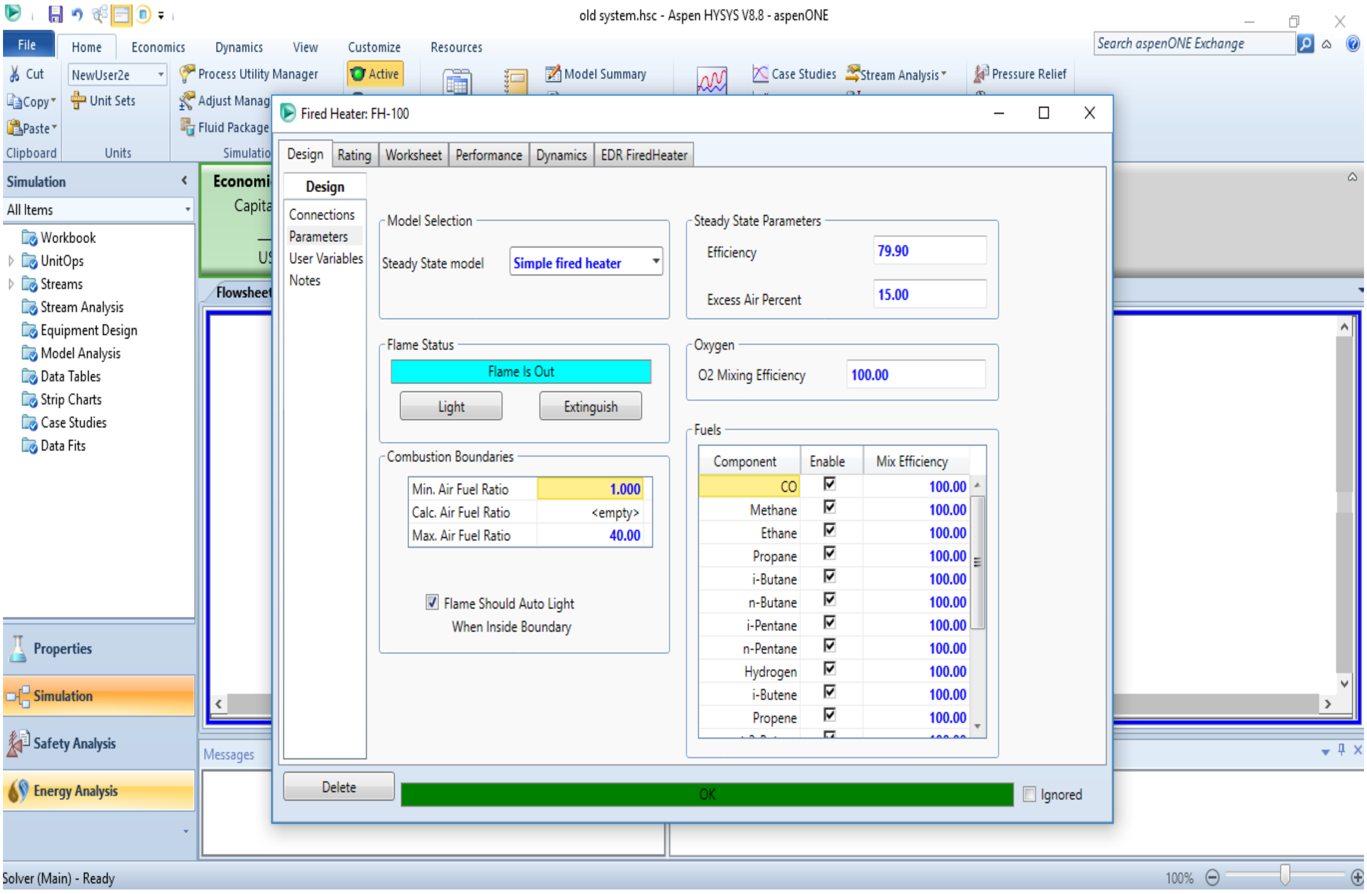

Figure (3-8): simplified furnace data

If there is no error, Then the simulation of the old fuel system been completely.

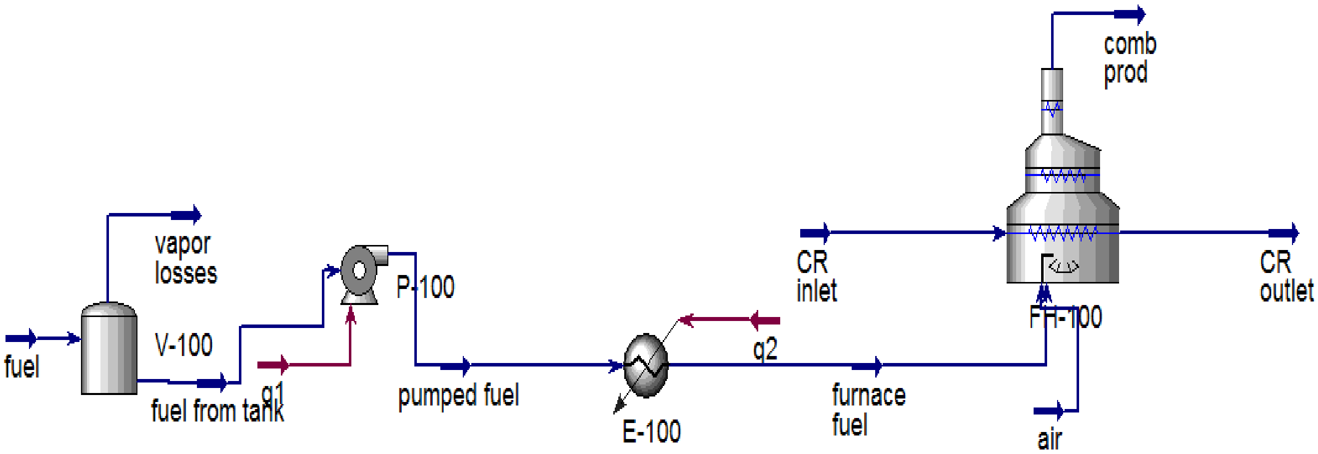

Figure (3-9): The Existing fuel system flow sheet.

3.3.2 The proposal of new fuel system:

When used the fuel oil, new equipment's had been required. The fuel oil enters the tank, and leave through pump to heater at 120-150 psig. The fuel oil delivers to heaters at 130^{0}C and at approximate pressure of 100psig for control and atomize.

Firstly, select Nile Blend and fuel oil assay, enter the data of the fuel oil, crude oil(feed) and air conditions.

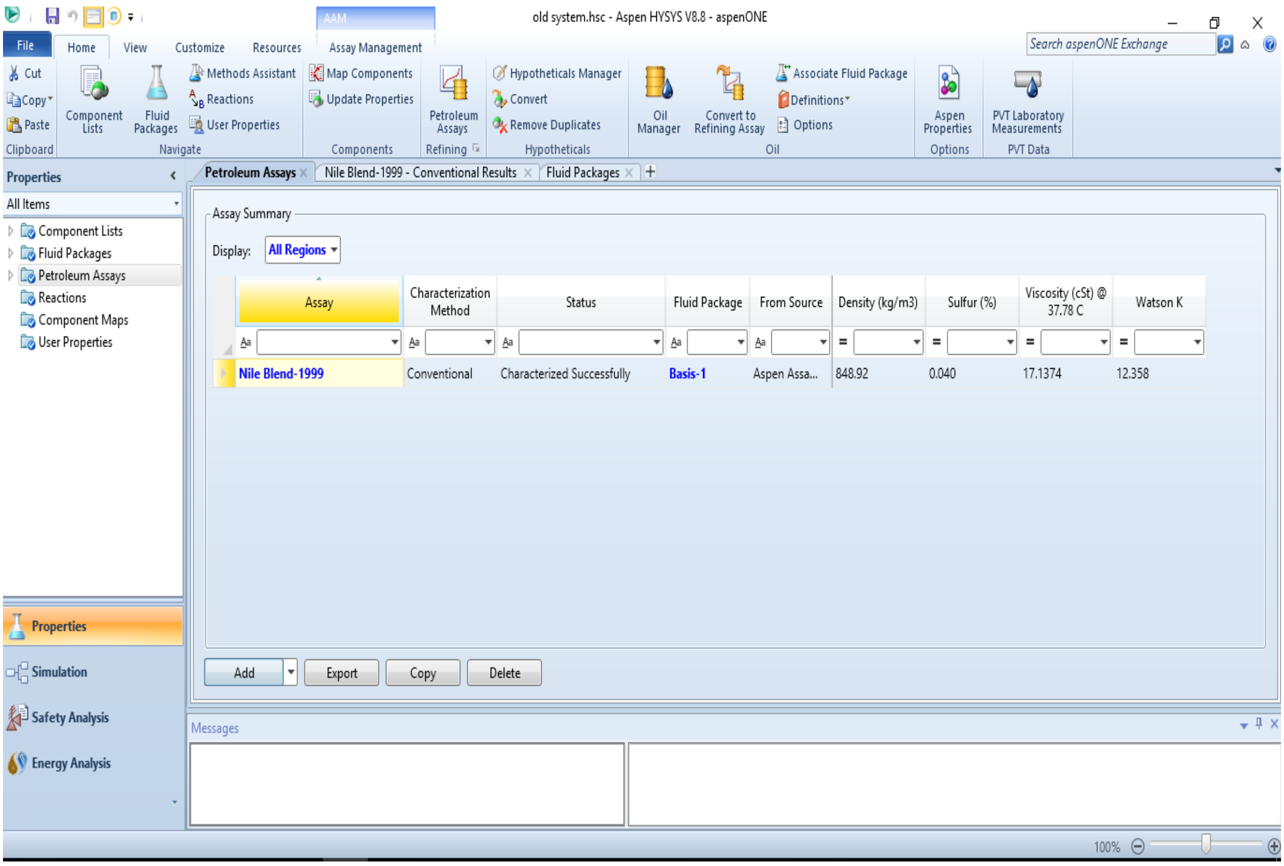

Figure (3-10): Nile Blend from petroleum assay

Secondly, enter the data of fuel oil stream and air condition, then select furnace and enter the data for "Simplified Furnace"

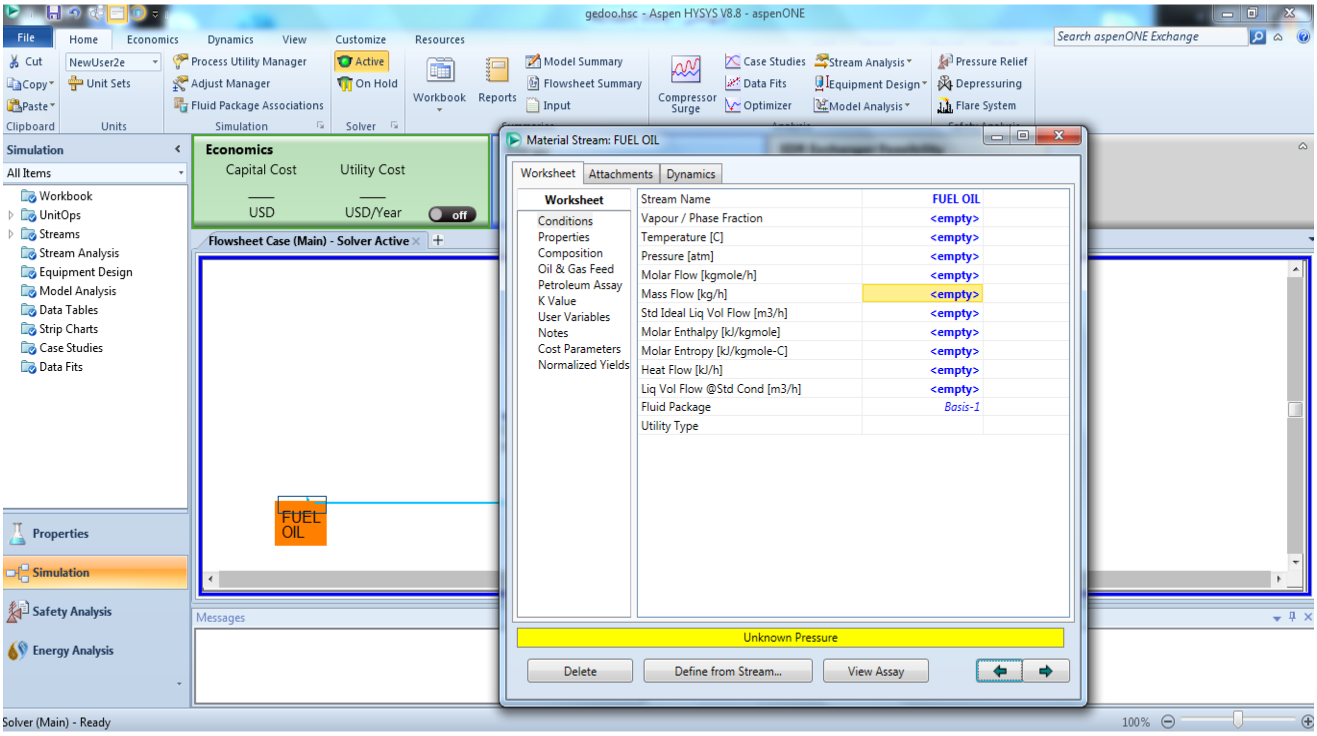

Figure (3-11): fuel oil condition

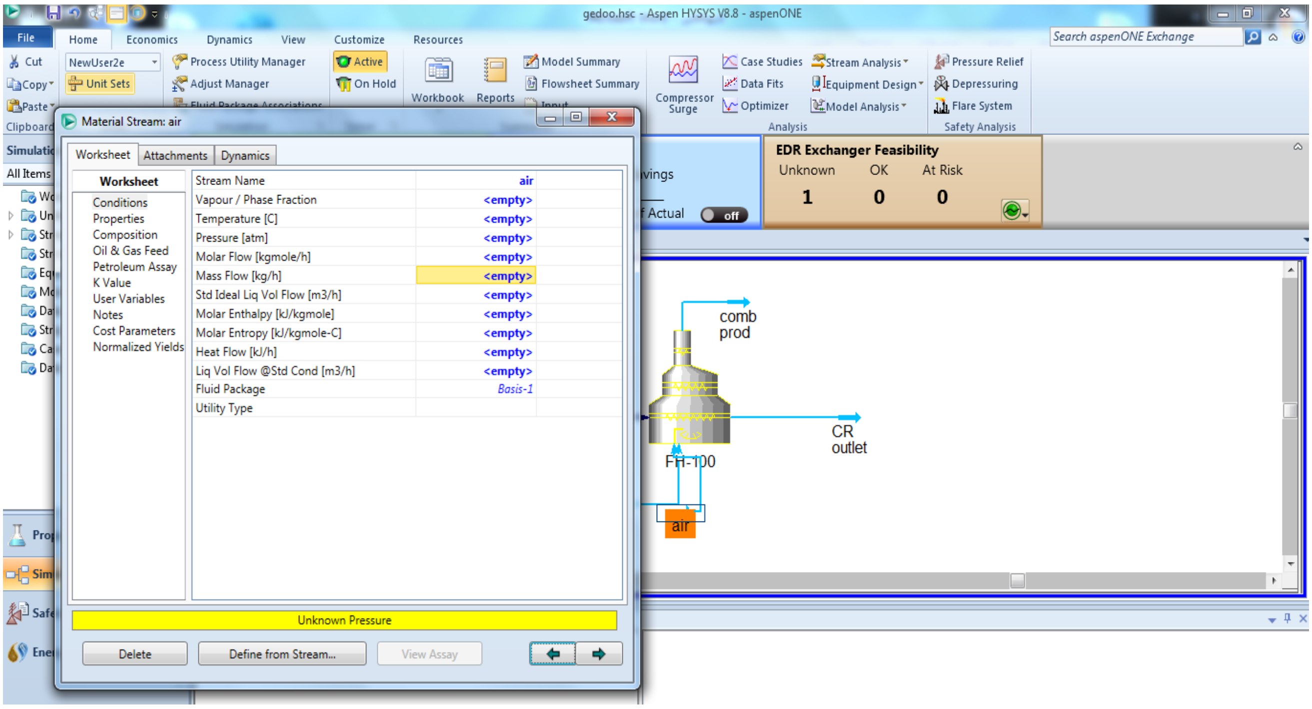

Figure (3-12): air conditions

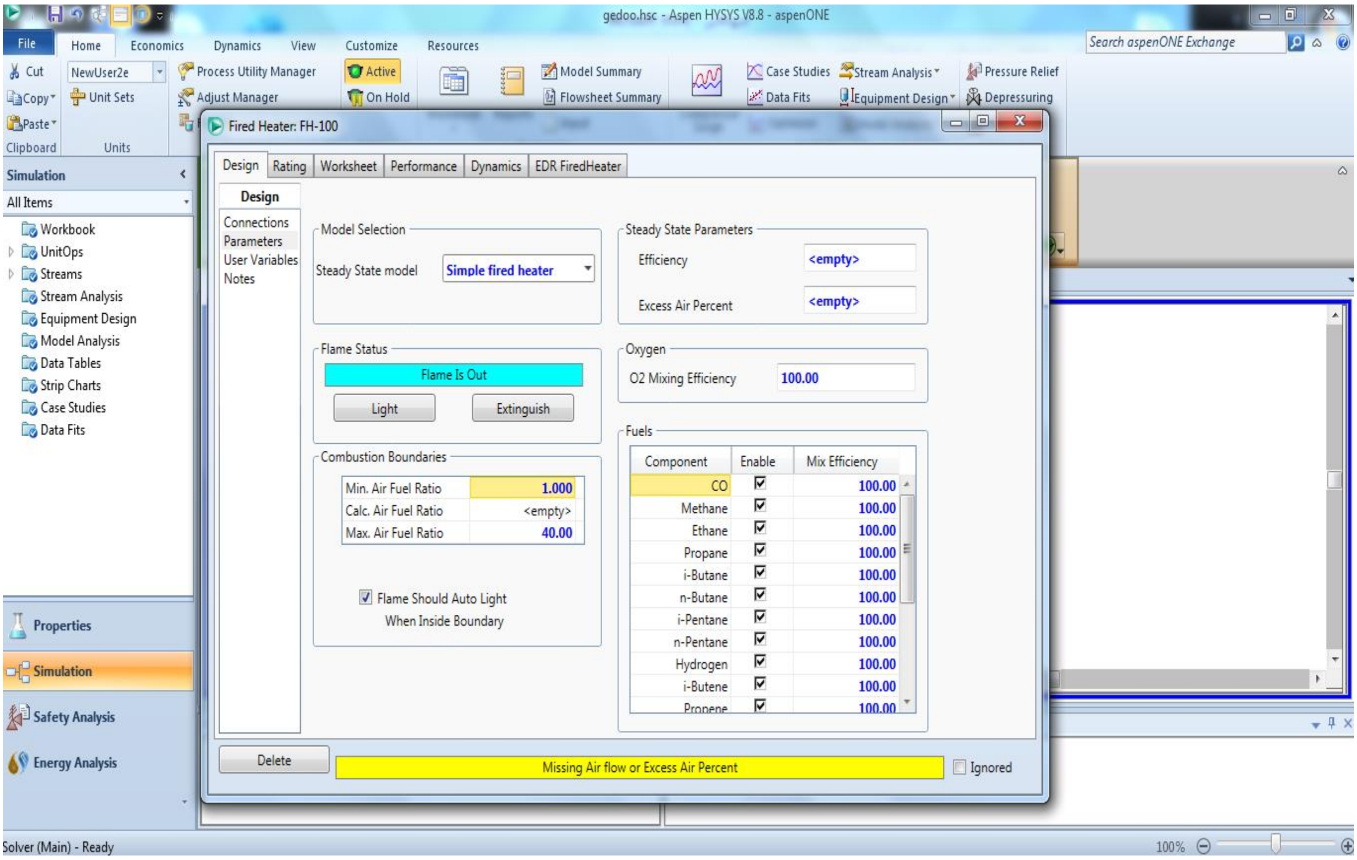

Figure (3-13): "Simplified Furnace" data

If no error, the simulation been completely.

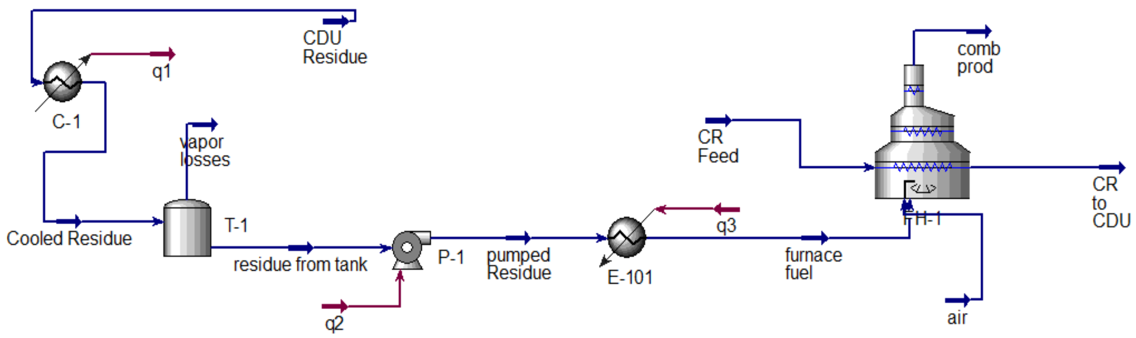

Figure (3-14): new fuel system flow sheet

3.4 The economics of using fuel oil:

In a free enterprise system, the primary motive for individuals investing in a business is to make a profit. Thus, the managers of manufacturing facilities must base their business decisions primarily upon profit, or the business does not continue to prosper. Business decisions are also influenced by laws being enforced by regulatory agencies.

Basis of the study:

- The refinery will keep running for 330 days/year.
- The study based on average throughput of the refinery (10000 bbl/d).
- The prices of crude oil and products based on the average of international prices netted back to the refinery for the first quarter 2018.

Cost study:

3.4.1 For the existing system:

Total cost

$$= total\frac{fuel(crude)cost}{day}$$

$$+ (cost\ of\ heating.soot\ blowing.and\ additional\ operation\ and\ maintenece\ cost)$$

Total fuel cost / day = Crude consumption * Crude cost/ton

3.4.2 For the new system:

3.4.2.1 total cost:

$$\text{Total cost} = \frac{\text{total fuel cost}}{\text{day + (cost of heating.soot blowing.and maintenance cost)}}$$

Total fuel cost / day = fuel oil consumption * fuel oil cost/ton

3.4.2.2 Total investment cost of using fuel oil:

Total investment cost of using fuel oil = summation of the new equipment and installations costs.

3.4.2.3 Economic analysis:

To procedure the economic analysis we must calculate:

- **Effective operating cost:**

The net savings in operating cost = total costs of existing system–total costs of new system

- **Payback period:**

We take the investment period 10 years.

$$\text{Payback period} = \frac{\text{Total investment cost \$}}{\text{Cash flow (USD)}}$$

- **Project profitability index:**

We take the investment period 10 years.

$$\text{profitability index} = \frac{\text{Total of NPV}}{\text{Total investment cost}}$$

- **Opportunity cost:**

Crude cost:

The crude oil cost = quantity of crude (ton/year) * crude price ($/ton)

Crude processing fees:

The processing fees = quantity of crude (ton/year) * crude processing fees **(**$/ton**)**

$$\text{Total crude cost (\$/year)} = \text{crude oil cost} + \text{processing fees}$$

Products selling (sale revenue):

The total price of each product = product quantity(ton/day) * product price ($/ton)

The total products return (sale revenue) $/year = naphtha total sales $/year +kerosene total sales $/year +gas oil total sales $/year +fuel oil total sales $/year

$$\text{The profit (\$/year)} = \text{Total products return} - \text{Total crude cost}$$

3.4.2.4 The hidden costs of heavy oil:

If we consider other factors such as ease of handling, toxicity, environmental impacts and plant maintenance costs, heavy oils fail to compete with other fuels, there are trade-offs and hidden costs that actually reduce the advantages of heavy oils.

- Sulphur and vanadium are present in high concentrations in heavy oil and require the addition of special chemicals to reduce the corrosion effects.
- Oil pumping – increased energy costs associated with continual circulation of the oil in the storage tanks to maintain viscosity.
- Soot blowing of heater tubes – the build-up of soot on the fire side of the boiler reduces heat transfer to the boiler and must be removed daily to maintain efficiency with steam or compressed air and regular manual soot removal must be conducted.
- Dirty fuel leads to dirty machinery, then soot removal and general additional maintenance cost is required.

Chapter 4
Results and Discussions

Results and Discussions

4.1 RESULTS:

4.1.1 old system result

- **old system simulation results:**

  The old system has been simulated in hysys simulation.

The data used are:

Table (1): existing(old) fuel system data

Name	Data used	Value
Crude data	Nile blend from hysys	
Fuel of furnace	Nile blend from hysys	
Tank		
Volume	Operation data	8.5 m^3
Pump		
outlet pressure	Operation data	130 psig
Heater		
Inlet temperature	Operation data	120^{o}F
Out let temperature	Operation data	200^{o}F
Out let pressure	Operation data	114.7 psia
Furnace		
Air stream		
Temperature	Operation data	113^{o}F
Pressure	Operation data	36.74 psia
Mass flow rate	Operation data	661.4 lb/hr
Oxygen composition	Operation data	0.21
Nitrogen composition	Operation data	0.79
Crude stream		

Inlet temperature	Operation data	460°F
Inlet pressure	Operation data	139.7 psia
Inlet mass flow	Operation data	10,000 bbl/day
Fuel stream		
Inlet temperature	Operation data	200°F
Inlet pressure	Operation data	114.7 psia
Mass flow rate	Operation data	3031 bbl/day

The result out of the furnace are shown in the table:

Table (2): outlet of existing(old) system

Parameter	**VALUE**
Crude out let temperature	630°F
combustion (stack) temperature	900.7°

The stack greenhouse gases composition at 900.7 °F are:

Table (3): stack GHG composition

Nitrogen	0.5433
Carbon mono oxide	0
Oxygen	0.0469
Carbon dioxide	0.0482

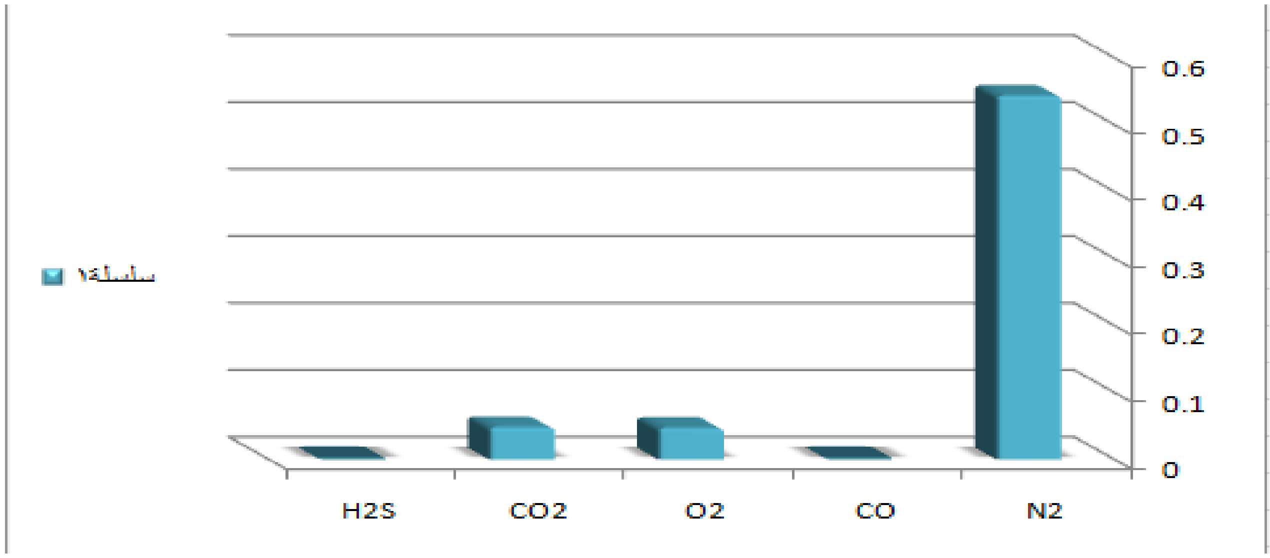

Figure (4-1) show the composition of greenhouse gases at 900.7^{o}

The data used are:

Table (4): properties of crude and steam

Component	data	unit
crude oil to heater	58333.33	**kg/hr**
Toc	427	**C**
Tinc	147	**C**
Cp of crude	0.73	
steam to heater	60.8333	**kg/hr**
Tos	471	**C**
Tin s	83	**C**
Cp of water	0.48	
crude consumption	1375	**kg/hr**
LHV of crude	10860	**k cal/kg**
LHV of fuel	9600	**k cal/kg**

The result from excel sheet are shown in picture below:

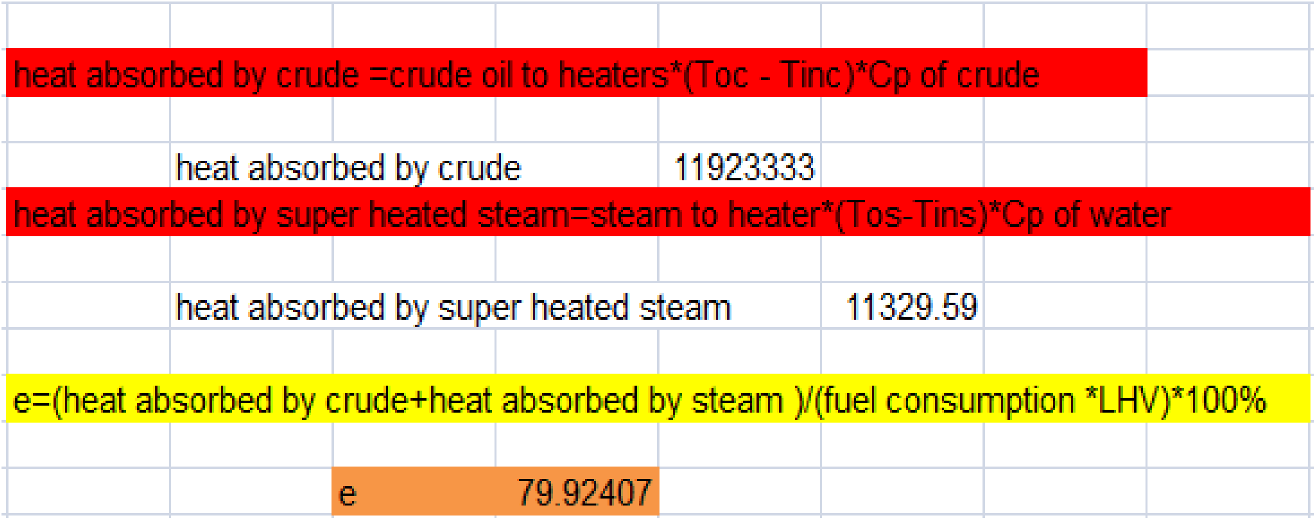

Figure (4-2): calculation of efficiency

4.1.1.2 cost calculation:

Table (5): operating cost of existing(old)system

Parameter	**Value**	**Unit**
Fuel consumption	33.0	Ton/day
Price of crude	62.8	$/barrel
Fuel price /ton	424	$/ton
Total fuel cost /day	13992	$/day
Cost of heating , soot blowing , and additional operating and maintenance cost	0	$/day
Total cost	**13992**	**$/day**

4.1.2 new system results:

4.1.2.1 the fuel oil consumption result from excel sheet:

fuel oil consumption =(total heat of combustion)/ LHV of fuel oil
total heat of combustion =crude consumption *LHV of crude

total heatof combustion	14932500
fuel oil consumption	1555.469

Figure (4-3): calculation of fuel oil consumption

4.1.2.2 new system simulation results:

The data used are:

Table (6): new fuel system data

Name	Data used	Value
Crude data	Nile blend from hysys	
Fuel of furnace	El-Obied Residue assay	
Tank		
Volume	Operation data	10 m^3
Pump		
outlet pressure	Operation data	130 psig
Heater		
Inlet temperature	Operation data	108.4^{o}C
Outlet temperature	Operation data	130^{o}C
Out let pressure	Operation data	114.7 psia
Furnace		
Air stream		
Temperature	Operation data	113^{o}F

Pressure	Operation data	36.74 psia
Mass flow rate	Operation data	661.4 lb/hr
Oxygen composition	Operation data	0.21
Nitrogen composition	Operation data	0.79
Crude stream		
Inlet temperature	Operation data	460^{o}F
Inlet pressure	Operation data	139.7 psia
Inlet mass flow	Operation data	10,000 bbl/day
Fuel stream		
Inlet temperature	Operation data	130^{o}C
Inlet pressure	Operation data	114.7 psia
Mass flow rate	Operation data	3430 bbl/day

The results of new system simulation are shown in the table below:

Table (7): outlet of new fuel system

Parameter	**Value**
Crude out let temperature	652^o F
Combustion (stack) tempeture1	1035^o F

The stack greenhouse gases composition at 1035 °F are:

Table (8): stack GHG compositions

Nitrogen	0.5822
Carbon mono oxide	0
Oxygen	0.0318
Carbon dioxide	0.0556
Hydrogen sulfide	0.0031

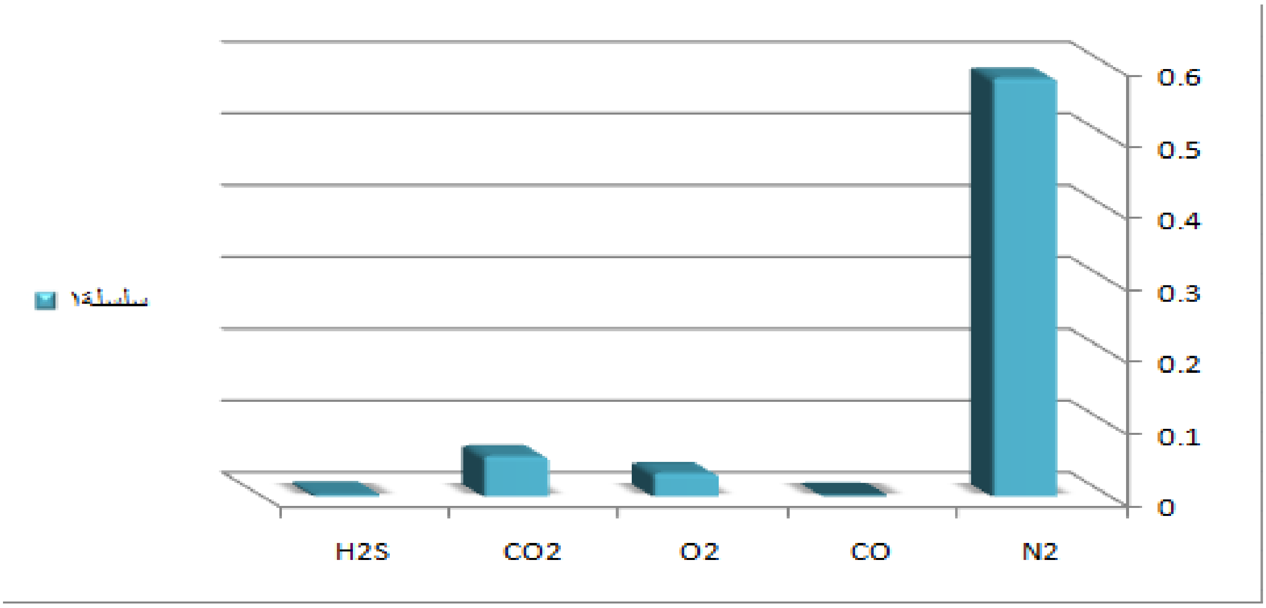

Figure (4-4) show the composition of greenhouse gases at 1035°F

4.1.2.3The new system cost calculations:

Operation costs:

Table (9): operating cost of new system

Parameter	**Value**	**Unit**
Fuel consumption	37.33	Ton/day
Price of fuel oil	56.74	$/barrel
Fuel price /ton	369	$/ton
Total fuel cost /day	13775	$/day

Cost of heating , soot blowing , and additional operating and maintenance cost	43	$/day
Total cost	**13818**	**$/day**

New Equipment and Installations:

Table (10): new equipment and installation cost

Item	Description	Estimated cost, $	
		Crude	**Fuel oil**
Tank	Day tank ,welded, carbon steel , 10m^3	0.0	60,500
Pump	2 gear pumps (8GPM ,VSM , EX.P)	0.0	25,000
Soot blowers	Soot blowing	0.0	15,000
Pipes	Connections ,fittings , insulations	0.0	10,000
installation	Installations of new equipment (fitting, welding , fabricating)	0.0	7,000
construction	Foundation , land preparing ,trenches	0.0	8,600
Instruments and control	Cables ,PLC'S, level control valve	0.0	30,000
Heaters	Electrical heaters	0.0	20,500
Meters	Carolos meters	0.0	15,000
Filters	5.0 micron filter	0.0	3,000
Viscometer	Viscosity meter	0.0	3,500
Safety service and tools	Fire fighting, guards, alarm devices , ….etc	0.0	11,000
Others	Engineering supervision ,services ,…etc	0.0	6,300
Total cost		0.0	**215,400**

4.1.3 Economic analysis:

4.1.3.1-effictive operating cost:

Table (11): net savings in operating cost

Fuel	Quantity /day	Price /unit	subtotal	heating	Total
Crude oil	33 ton	424	13992$/d	Exist	13992$
Residual oil	37.33ton	369	13775$/d	43$	13818$
Difference					174$/d

4.1.3.2-payback period:

Cash flow=net savings in operating cost * the refinery operating days (330 days/year)

Table (12): payback period of cash flow

Year	Cash flow (USD)
1	**57420**
2	**57420**
3	**57420**
4	**57420**
5	**57420**
6	**57420**
7	**57420**
8	**57420**
9	**57420**
10	**57420**

Total investment cost =215400$

Payback period = (215400/57420) =3.75 years

4.1.3.3-project profitability index:

using 15%as interest rate for 10 years

Table (13): project profitability index of cash flow

Year	Cash flow	Rate 15%0	Net present vale (NPV)
1	**57420**	**0.869**	**49955**
2	**57420**	**0.756**	**43410**
3	**57420**	**0.658**	**37782**
4	**57420**	**0.572**	**32844**
5	**57420**	**0.497**	**28538**
6	**57420**	**0.432**	**24805**
7	**57420**	**0.367**	**21590**
8	**57420**	**0.327**	**18776**
9	**57420**	**0.284**	**16307**
10	**57420**	**0.247**	**14183**
Total of NPV			**288191**

Profitability index=288191/215400= 1.34 (>1.0)

That means the investment is profitable**.**

4.1.3.4 opportunity cost:

Crude price:

Table (14): crude oil prices

CRUDE	Qty ton/day	Qty ton /year	Price $/ton	Total /$
Nile blend	33	10890	424	4,617,360

Crude processing fees (0.645 $/bbl):

Table (15): crude oil processing fees

Crude	Qty ton /day	Qty ton/year	Price $/ton	Total /$
Nile blend	**33**	**10890**	**4.626**	**50,378**

Total crude cost =4,617,360+50,378 **= 4,667,738 $/year**

Product return (sale revenue):

Table (16): product return (sale revenue)

Crude	Qty ton/day	Qty ton /year	Price $/ton	Total /$
Naphtha	1.71	564	501	282,714
Kerosene	1.76	581	583	338,606
Gas oil	7.22	2383	583	1,389,056
Fuel oil	22.31	7362	369	2,716,689
Total	**33**	**10890**		**4,727,065**

Total products return (sale revenue) =**4,727,065 $/year**

Profit = 4,727,065 – 4,667,738 = **59,327 $/year**

4.2 discussion:

The results shown that when we use the fuel oil as furnace fuel it will give outlet crude oil feed temperature higher than using of crude oil as furnace fuel. That means fuel oil has high heating efficiency. And can replace the crude oil.

The stack temperature of new system higher than the stack temperature of the old one. That means the combustion products of the new system, when we use fuel oil is higher.

Also the results shown that the **GHG** (greenhouse gases) emissions in the new system has slightly increased.

From the economic analysis and costs estimations we find that the new system is profitable and the operating costs of the new system is lower than existing system.

Chapter 5
Conclusions and recommendations

Conclusions and recommendations

5.1 Conclusions:

In this project, the used of fuel oil as furnace fuel examined using excel sheets. The results show that the operation cost of fuel oil most economical than used crude oil and the revenue from processing the quantities of crude oil fuel has profitability value. From Aspen HYSYS simulation result show that the heat efficiency of fuel oil is higher than crude oil fuel.

5.2 Recommendation:

- Redesign the furnace to comet the new variables and make a cost estimate.
- Clarify the required treatments and make a cost estimate.
- Make a study to determine the effect of excess air in the combustion process

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