American Journal of Quantum Chemistry and Molecular Spectroscopy
2018; 2(2): 18-30
http://www.sciencepublishinggroup.com/j/ajqcms
doi: 10.11648/j.ajqcms.20180202.11

Evaluation of the Efficiency of the Combustion Furnace of the Delayed Coking Unit by Manipulating the Parameters that Affect the Furnace Efficiency

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To cite this article:
Mahmoud Adam Hassan Salih, Ahmed Abd Alazeem Mohammed, Basil Yousif Khalifa, Fatima Omar Elamin, Nihad Omer Hassan. Evaluation of the Efficiency of the Combustion Furnace of the Delayed Coking Unit by Manipulating the Parameters that Affect the Furnace Efficiency. *American Journal of Quantum Chemistry and Molecular Spectroscopy*. Vol. 2, No. 2, 2018, pp. 18-30.
doi: 10.11648/j.ajqcms.20180202.11

Received: August 13, 2018; **Accepted**: September 17, 2018; **Published**: October 19, 2018

Abstract: Furnaces and fired heaters provide the energy associated with running hydrocarbon processes and chemical plants. they are required to maximize heat delivery of the process-side feed while minimizing fuel consumption, as well as Maximize heat delivery with varying fuel quality, and Minimize heater structural wear which caused by operation. Furthermore, minimize stack emissions and Maximize safety integrity levels. In this study the suitable and best way to gain high efficiency of the furnace has been determined by manipulating the parameters that affect in efficiency of the furnace which is represented in: The effect of excess air and stack temperature on furnace efficiency, the effect of preheating the inlet air on furnace efficiency, and the effect of nitrogen to oxygen ratio in combustion air on the efficiency. Aspen exchanger design and rating (EDR) was used to design fired heater and the results were used in aspen HYSYS to determine the effect of these parameters consequently obtaining the best effective way for high efficiency which represent in reducing the percent of nitrogen. This study also includes controlling and monitoring three major parameters: (Fuel gas/fuel oil pressure, Excess air and Furnace draft fan), and using excel sheets for estimating the Cost of the furnace.

Keywords: Furnace, Efficiency, Excess Air, Stack Temperature, Heat Loss

1. Introduction

Fula crude oil is one of the types of crude oil in Sudan, one of its characteristics it contains high percentage of asphalt as well as high density and viscosity that is why delayed coking unit (DCU) has been stablished in Khartoum refinery company, this unit works on removal of asphalt from the crude hence reduce its viscosity and its density therefore high percentage of the desired products in Sudan market can be produced. In addition, delayed coking unit upgrades material called bottoms from the atmospheric or vacuum distillation column into higher-value products. With delayed coking, two or more large reactors, called coke drums, are used to hold, or delay, the heated feedstock while the cracking takes place. Coke is deposited in the coke drum as a solid. This solid coke builds up in the coke drum and is removed by hydraulically cutting the coke using water. The yield of coke from the delayed coking process ranges from about 18 to 30 percent by weight of the feedstock residual oil [1]. Delayed coking unit consist of various numbers of primary facilities such as coke drums, fractionator, pumps as well as furnace.

1.1. Furnace

Fired heater is a device used to heat up chemicals or chemical mixtures. It's classified as direct fired or indirect fired. Direct-fired furnaces 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 hydrocracking. The primary means of heat transfer in a fired heater are radiant heat transfer and convection and consist essentially of a battery of pipes or tubes that pass through a firebox [2]. In general, a Fired Heater can be divided into three zones:

(i) Radiant zone
(ii) Convective zone
(iii) Economizer zone

1.2. Furnace Efficiency

Running furnaces efficiently is a major operating concern because two thirds of a plant's fuel budget is needed for furnace fuel cost. Furnace efficiency is linked to environmental regulations that stipulate a clean operation. Most furnaces use fuel gas or fuel oil. Natural gas burns cleaner and more efficiently than oil [2].

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

$$Efficiency = \frac{heated\ usefully\ absorbed\ by\ heated\ medium}{\text{total heat supplie}} * 100 \quad (1)$$

1.3. Combustion Reaction

The combustion reaction in the burner model of the Fired Heater performs pure hydrocarbon (CxHy) combustion calculations only. The extent of the combustion depends on the availability of oxygen which is usually governed by the air to fuel ratio. Air to fuel ratio (AF) is defined as follows:

$$AF = \frac{\left(\frac{Mass\ of\ flow\ O2}{\sum Mass\ of\ luw\ fuel}\right)}{Mass\ ratio\ of\ o2\ in\ air} \quad (2)$$

1.4. Problem Statement

Reduction in the operation efficiency compare to design efficiency and increase in heat losses.

1.5. Objectives

1. Determine furnace efficiency.
2. Investigate different parameters that affect in thermal efficiency: -
   (a) The effect of excess air and stack temperature on furnace efficiency.
   (b) The effect of preheating the inlet air on furnace efficiency.
   (c) The effect of nitrogen to oxygen ratio in combustion air on the efficiency.
3. Furnace control.
4. Furnace cost.

1.6. Scope of this Study

The scope of this project is to give detailed study for efficiency of the furnace in delayed coking unit (DCU), control of furnace and cost of furnace.

2. Heat Transfer

Fired Heater heat transfer calculations are based on energy balances for each zone. The shell side of the Fired Heater contains five holdups:

(a) three in the radiant zone
(b) a convective zone
(c) an economizer zone

For the tube side, each individual stream passing through the respective zones is considered as a single holdup. Major heat terms underlying the Fired Heater model are illustrated in the figure below.

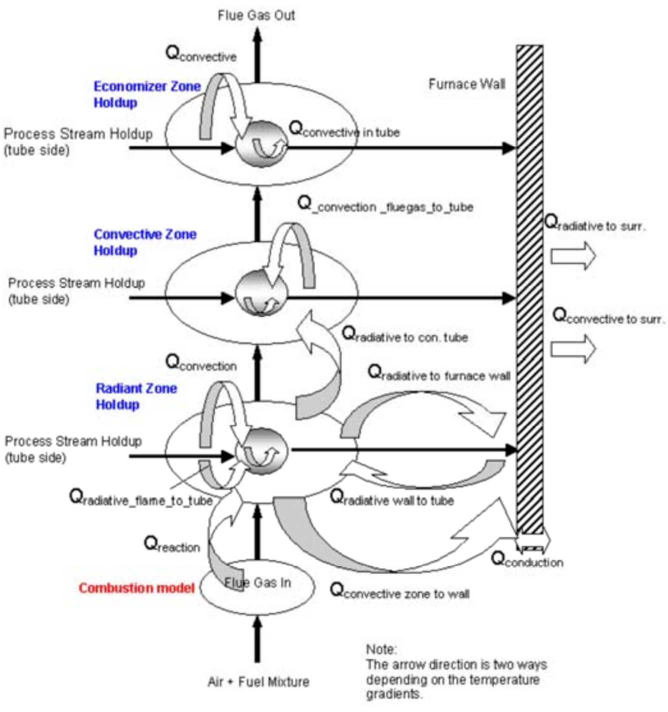


Figure 1. *Major heat terms underlying the Fired Heater model.*

The heat terms related to the tubeside are illustrated in the figure below.

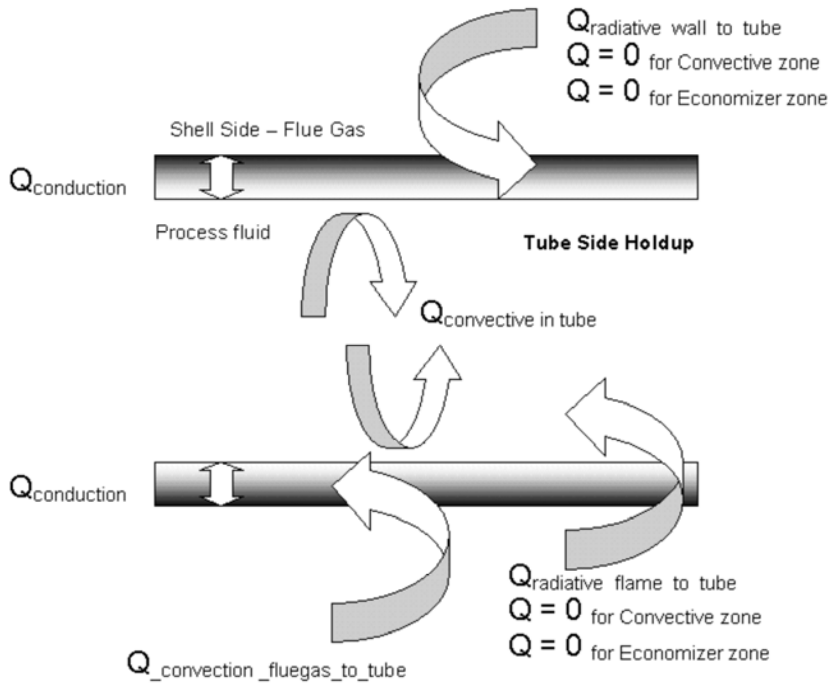


Figure 2. *The heat terms related to the tubeside.*

Taking Radiant zone as an envelope, the following energy balance equation applies:

$$\frac{d(M_{rad}H_{rad})}{dt} + \frac{d(M_{RPFTube}H_{RPFTube})in}{dt} = (M_{RPF}H_{RPF})_{in} - (M_{RPF}H_{RPF})_{out} + (M_{FG}H_{FG})_{in} - (M_{FG}H_{FG})_{out} - Q_{red\ wall\ to\ tube} - Q_{red\ wall\ sur} - Q_{con\ wall\ sur} + Q_{rad\ wall\ tube} - Q_{con\ to\ wall} + Q_{reaction} \quad (3)$$

Where:

$$\frac{d(M_{rad}H_{rad})}{dt} = energy\ accmulation\ in\ radiant\ zone\ holdup$$

Radiant Heat Transfer

For a hot object in a large room, the radiant energy emitted is given as:

$$Q_{convective} = UA(T_2 - T_1) \quad (4)$$

T1 = temperature of hot surface 1, K

T2 = temperature of hot surface 2, K

Convective Heat Transfer

The convective heat transfer taking part between a fluid and a metal is given in the following:

$$Q_{convective} = UA(T_1 - T_2) \quad (5)$$

where:

U = overall heat transfer coefficient, W/m2K

A = area exposed to convective heat transfer, m2

T1 = temperature of hot surface 1, K

T2 = temperature of surface 2, K [14].

The U actually varies with flow according to the following flow-U relationship if this Flow Scaled method is used:

$$U_{used} = U_{specified}\left(\frac{\text{Mass flow at time t}}{\text{Reference Mass flow}}\right)^{0.8} \quad (6)$$

where:

Uspecified = U value at steady state design conditions [14].

The ratio of mass flow at time t to reference mass flow is also known as flow scaled factor. The minimum flow scaled factor is the lowest value, which the ratio is anticipated at low flow region. For the Fired Heater operation, the minimum flow scaled factor can be expressed only as a positive value. For example, if the minimum flow scaled factor is +0.001(0.1%), when this mass flow ratio is achieved, the Uused stays as a constant value. Therefore,

$$U_{used} = U_{specified}(0.001)^{0.8} \quad (7)$$

Conductive Heat Transfer

Conductive heat transfer in a solid surface is given as:

$$Q_{convective} = -KA\frac{(T_1 - T_2)}{\Delta t} \quad (8)$$

where:

k = thermal conductivity of the solid material, W/mK

= thickness of the solid material, m

A = area exposed to conductive heat transfer, m2

T1 = temperature of inner solid surface 1, K

T2 = temperature of outer solid surface 2, K [4].

2.1. Heating Values

Heating value of fuel (units of KJ/kg or Mj/kg are traditionally used to quantify maximum amount of heat that can be generated by combustion with air at standard condition (STP) ($25C°$and $101.3\ kpa$). The amount of heat release from combustion of the fuel will depend on the phase of water in the product. If water is in gas phase in the product, the value of total heat denoted as the lower heating value (LHV) [14].

2.2. Excess Air

The terms excess air and excess oxygen are commonly used to define combustion. They can be used synonymously but have different units of measurements. The percentage of excess air is the amount of air above the stoichiometric requirement for complete combustion. The excess oxygen is the amount of oxygen in the incoming air not used during combustion and is related to percentage excess air., additional air beyond the theoretical "perfect ratio" needs to be added to the combustion process—this is referred to as "excess air." [8].

3. Furnace Efficiency

There are two methods to calculate efficiency: -

(a) Direct method: -

$$e = \frac{heat\ absorb\ by\ crude + heat\ absorb\ by\ steam}{fuel\ compustion * calorific\ value} * 100\% \quad (9)$$

(b) Indirect method: -

$$e = \frac{(LHV + Ha + Hf) - Qs - Qr}{(LHV + Ha + Hf)} * 100\% \quad (10)$$

e= Net thermal efficiency.

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

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

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

Q_s=Heat stack losses(BTU/LB).

Q_r=Radiation heat losses ($BTU/\ LB$).

This research focus on indirect method as a source of high accuracy because all loses (stack losses, radiation losses) are taken into account..

$$Weight = (volume\ fraction * molecular\ weight).$$

$$Heating\ value = (net.heating\ value * weight)$$

$$Stoichiometric\ oxygen = (oxygen\ from\ combustion\ reaction * volume\ fraction).$$

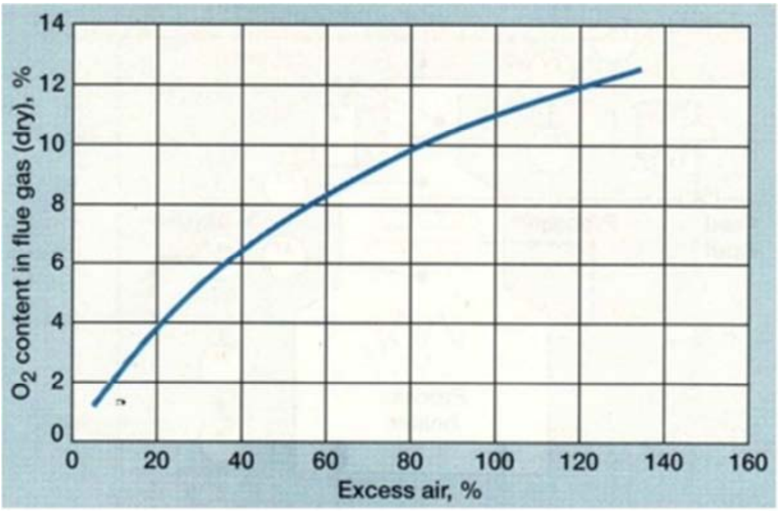


Figure 3. *Relation between excess air % and oxygen% in flue gas [11].*

$$-Actual\ oxygen\ required = Stoichiometric\ oxygen + (excess\ air * Stoichiometric\ oxygen).$$

$$-\ Actual\ air\ required = actual\ oxygen\ required * (^{100}/_{21}).$$

- Estimate stack component (CO_2, H_2O, SO_2, O_2, N_2).

$$-Amount\ of\ CO_2\ in\ flue\ gas = (total\ formed + CO_2\ reported\ as\ fuel).$$

$$-Amount\ of\ H_2O\ in\ flue\ gas = (total\ formed + H_2O\ reported\ as\ fuel).$$

$$-Amount\ of\ SO_2 in\ flue\ gas = (total\ formed + SO_2\ reported\ as\ fuel).$$

$$-Amount\ of\ O_2\ in\ flue\ gas = (actual\ O_2\ supplied - actual\ O_2\ used\ during\ combustion).$$

$$-Amount\ of\ N_2\ in\ flue\ gas\ =\ (79\%of\ moles\ of\ air\ +N_2\ reported\ as\ fuel).$$

3.1. Lower Heating Value

$$LHV = \frac{\Sigma\ heating\ value}{\Sigma\ weight\ of\ component\ of\ fuel} \tag{11}$$

3.2. Stack Losses

1. $(amount\ of\ stack\ component\ *molecular\ weight)$.
2. $(result\ from\ (1)\ /\ amount\ of\ fuel\ enter\ the\ furnace)$.
3. $result\ from\ (2)\ *\ enthalpy\ for\ each\ stack\ component)$.
4. $summation\ of\ all\ result\ in\ (3)$.

3.3. Radiation Losses

The radiation heat losses were determined by multiplying heat input fuel (LHV)by the radiation losses expressed as percentage Therefore, $radiation\ heat\ losses\ =\ (1\% + 3\%)/2 = 2\%\ of\ heat\ input(LHV)$.

3.4. Sensible Heat Correction for Combustion of Air (H_a)

$$H_a = lb\ of\ air\ /\ lb\ of\ fuel * Cp_{air} * (T_t - T_d) \tag{12}$$

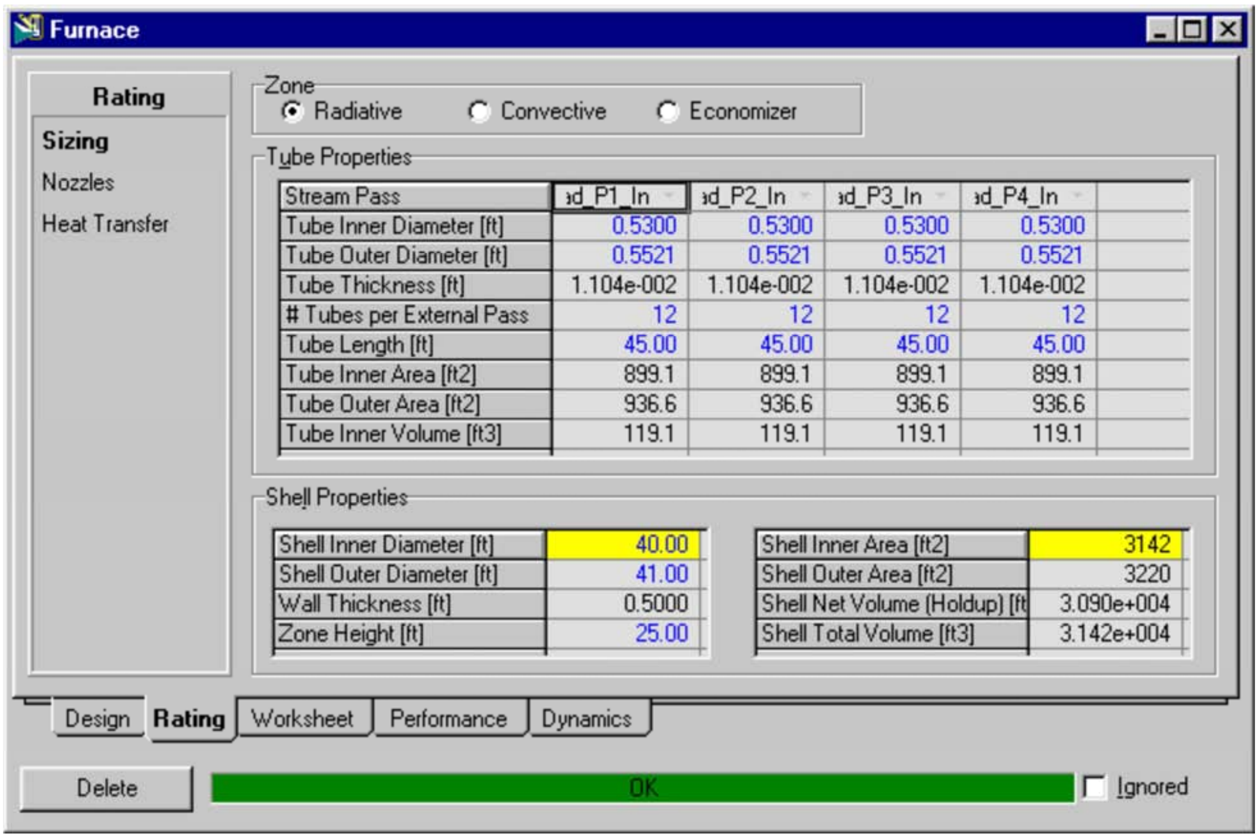
T_t = combustion air temperature.

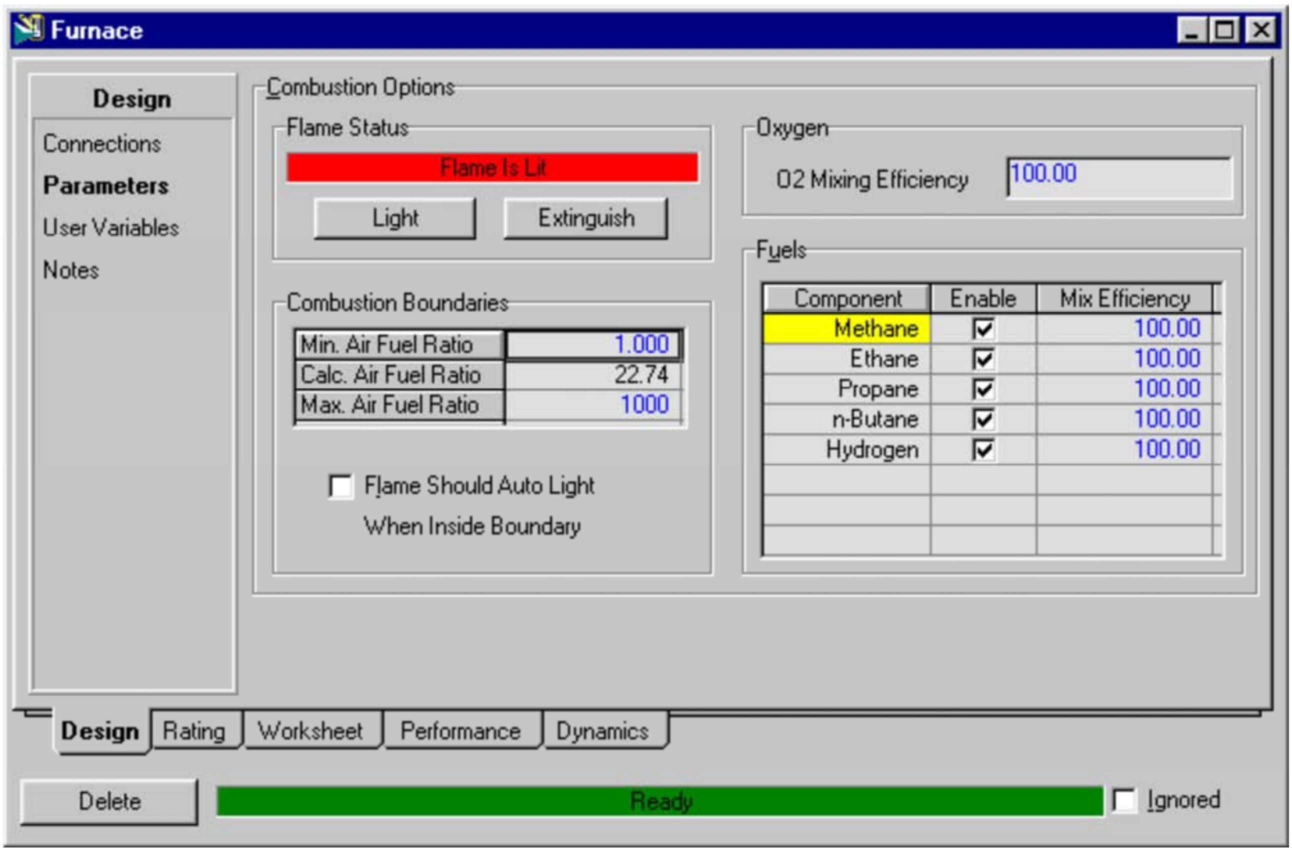
T_d = datum temperature (60°f).

3.5. Sensible Heat Correction for Fuel (H_f)

$$H_f = C_{Pfuel} *(Tt - Td) \quad (13).$$

4. HYSYS Simulation




Furnace
Design
Connections
Parameters
User Variables
Notes
Combustion Options
Flame Status
Flame Is Lit
Light
Extinguish
Oxygen
O2 Mixing Efficiency
100.00
Fuels
Component
Enable
Mix Efficiency
Methane
100.00
Ethane
100.00
Propane
100.00
n-Butane
100.00
Hydrogen
100.00
Combustion Boundaries
Min. Air Fuel Ratio
1.000
Calc. Air Fuel Ratio
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Max. Air Fuel Ratio
1000
Flame Should Auto Light
When Inside Boundary
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Worksheet
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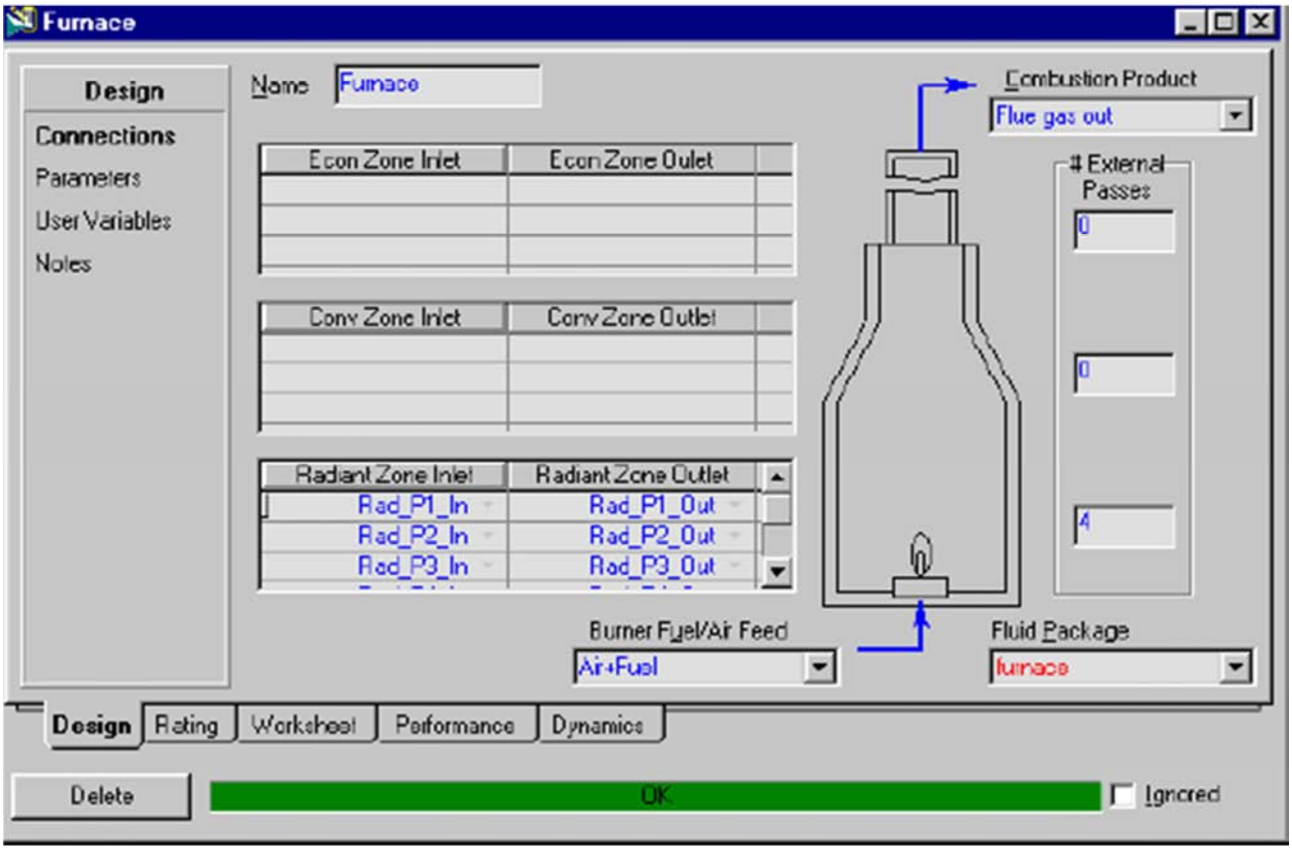
Dynamics
Delete
Ready
Ignored


Furnace
Design
Connections
Parameters
User Variables
Notes
Name
Furnace
Combustion Product
Flue gas out
Econ Zone Inlet
Econ Zone Oulet
External Passes
0
Conv Zone Inlet
Conv Zone Outlet
0
Radiant Zone Inlet
Radiant Zone Outlet
Rad_P1_In
Rad_P1_Out
Rad_P2_In
Rad_P2_Out
Rad_P3_In
Rad_P3_Out
4
Burner Fuel/Air Feed
Air+Fuel
Fluid Package
furnace
Design
Rating
Worksheet
Performance
Dynamics
Delete
OK
Ignored

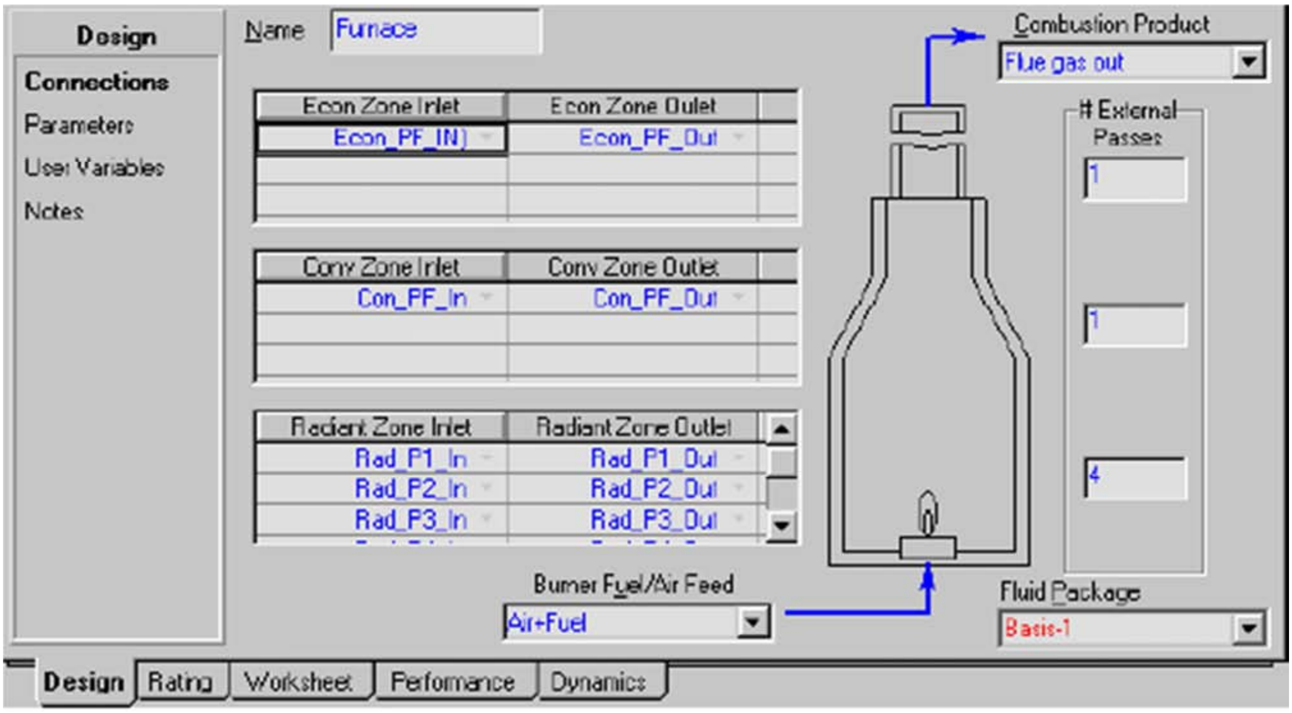


Figure 4. Simulation.

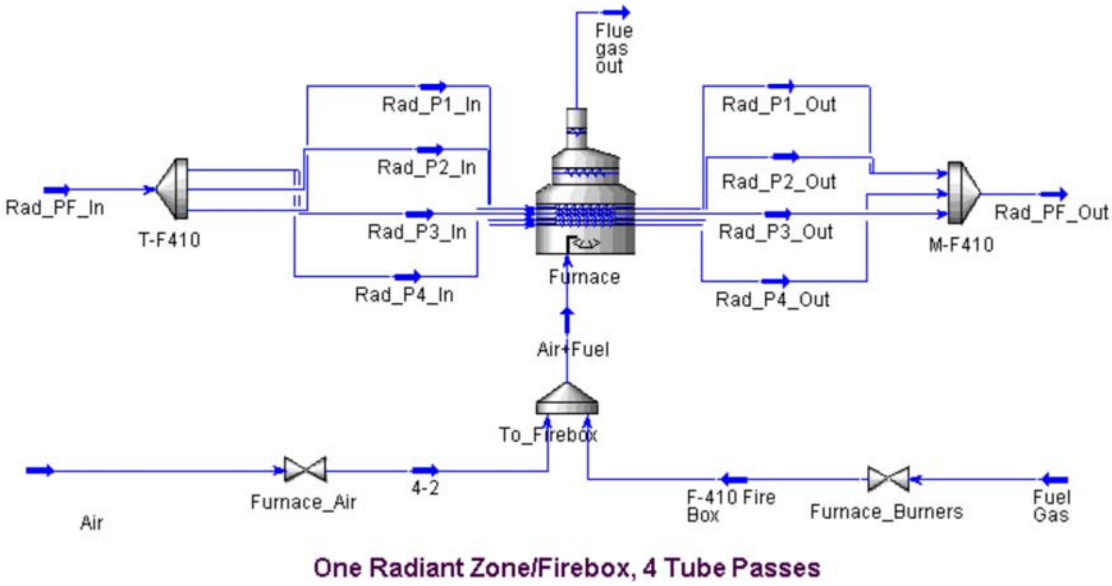


Figure 5. Process flowsheet.

5. Cost Estimation

Cost estimation is required for any industrial process and determination of the necessary investment is an important part of plant design project.

Cost estimation include the determination of:

1. Fixed cost (Capital cost, Installation cost, Transportation).
2. Operation cost:
   (a) Utilities (electricity, fuel gas, compress air).
   (b) Operator Labor.
   (c) Maintenance Labor.
   (d) Depreciation.

5.1. Cost Estimation Calculations

5.1.1. Fixed Cost

The capital cost in Delayed Coking Unite furnace in Khartoum Refinery Company estimated by the manufacture company [15].

$$Total\ fixed\ cost = capital\ cost + installation\ cost + transportation \tag{14}$$

$$Installation\ Cost = 0.4 * capital\ cost \tag{15}$$

$$Transportation = 0.05 * capital\ cost \quad (16)$$

5.1.2. Operation Cost

$$Depreciation = (capital\ cost * 0.9)/anticipated\ life \quad (17)$$

$$Est.Downtime\ hr = no.days * 24\ hr \quad (18)$$

$$Est.Operating\ hr = no.days * 24\ hr \quad (19)$$

$$Total\ Available\ Hours/\ Year = est.downtime + est.operation \quad (20)$$

$$Operator\ Labor = hr/furn/yr * price\ of\ hr * no.operater \quad (21)$$

$$Maintenance\ Labor = hrs/furn/yr * price\ of\ hr * no.operater \quad (22)$$

5.2. Utilities

$$Electricity = full\ load\ KW * Price\ of\ KW \quad (23)$$

$$Fuel\ gas = lb/hr * price\ of\ lb \quad (24)$$

$$Comp\ air = lb/hr * price\ of\ lb \quad (25)$$

$$Annual\ Furnace\ Operating\ Cost = Depreciation + electricity\ annual\ cost + fuel\ gas\ annual\ cost + compressed\ air\ annual\ cost + Operator\ Labor + Maintenance\ Labor \quad (26)$$

$$Total\ cost = operation\ cost + fixed\ cost \quad (27)$$

6. Results and Discussions

6.1. Results

6.1.1. Excel Results

These contain two type of result (furnace efficiency**,** the effect of stack temperature and excess air on thermal efficiency).

6.1.2. Furnace Efficiency Result

The data we use to calculate efficiency is (combustion sheet and combustion reaction)

Table 1. *Combustion work sheet.*

Component of fuel	Vol. fraction $mole/hr$	Net heating value BTU/Lb
Methane	49.67	21500
Hydrogen	9.48	51600
Ethane	19.57	20420
Ethylene	3.12	20290
Propane	5.11	19930
Propylene	3.09	19690
Butane	1.93	19670
Butylene	0.92	19420
Pentane	0.84	19500
Nitrogen	1.38	0
Carbone monoxide	2.44	4345
Carbone dioxide	2.43	0
Hydrogen sulfide	0.0036	6550
Total	99.9836	

Table 2. *Combustion reaction.*

Reaction	Moles of oxygen require
$H_2 + 0.5O_2 \rightarrow H_2O$	0.5
$CO + 0.5O_2 \rightarrow CO_2$	0.5
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	2
$C_2H_6 + 3.5O_2 \rightarrow 2CO_2 + 3H_2O$	3.5
$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$	2
$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$	5
$C_3H_6 + 4.5O_2 \rightarrow 3CO_2 + 3H_2O$	4.5
$C_4H_{10} + 6.5O_2 \rightarrow 4CO_2 + 5H_2O$	6.5
$C_4H_8 + 6O_2 \rightarrow 4CO_2 + 4H_2O$	6
$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$	8
$C_6H_{14} + 9.5O_2 \rightarrow 6CO_2 + 7H_2O$	9.5
$S + O_2 \rightarrow SO_2$	1
$H_2S + 1.5O_2 \rightarrow SO_2 + H_2O$	1.5

- From these data the thermal efficiency of DCU furnace in Khartoum refinery = 86.43%.

6.1.3. Effect of Stack Temperature and Excess Air on Thermal Efficiency

The effect of stack temperature has been examined and excess air on thermal efficiency and the results were found as shown in figure below.

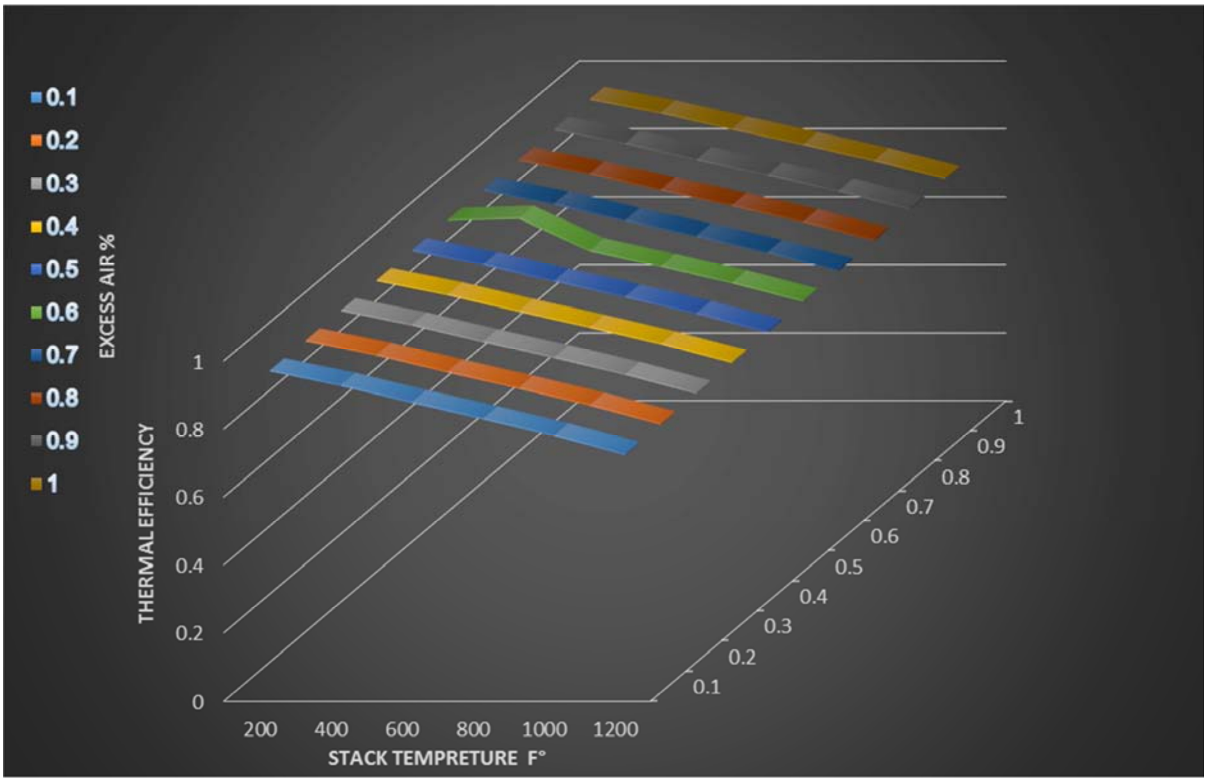


Figure 6. *Effect of excess air and stack temperature on efficiency.*

6.1.4. Aspen HYSYS Simulation Results

Table 3. *EDR data [11].*

Process data:-	
1-stream	
Total mass flow rate	125 T/Hr
Inlet temperature	270°C
Out let temperature	320°C
Inlet vapor mass fraction	3%
Out let vapor mass fraction	40%
Flue gas:-	
Inlet temperature to convection section	290°C
Ambient temperature	33.1°C
Injection steam:-	
Mass flow rate	360 kg/Hr
Pressure	2.5 Mpa
Temperature	420°C
Firebox:-	
Fire heater type	Twin box
Tube row layout	Refectory baked
Fire box dimension:-	
Height	13700 mm
Length	18834 mm
Width	16530 mm
Evaluation of floor firebox	2550 mm
Evaluation of top fire box	13700 mm
Burner details:-	
Burner location	Bottom
Type of burner	Flat flame
No. of burner	98
Burner diameter	100 mm
Main tube rows:-	
Process steam in firebox	4
Tube passes	4
Evaluation of main tube in firebox	Horizontal
Tube straight length	18420 mm

Process data:-				
Height of lowest tube above firebox		500 mm		
Tube to wall clearance		200 mm		
Tube –U bend location		Inside firebox		
Tube lay out angle		U-shell		
Flow direction in first tube		Up flow		
Tube location:-				
Tube location	Main	main	Main	Main
No. of tube per pass	12	6	4	2
Tube material	316L	316L	316L	316L
Pipe schedule	80	80	80	80
Tube outside diameter(mm)	114.3	168.28	219.08	273.05
Tube wall thickness (mm)	8.56	10.97	12.7	15.09
Tube Spacing(mm)	203.2	304.8	406.4	508
Gas of take:-				
Flue gas off take width (mm)		2800		
Flue gas off take length (mm)		40430		
External diameter (m^2)		3070		
Convection bank:-				
Process stream in bank	2		2	
Stream inflow form	Bank2		Inlet	
Stream out flow	Firebox		Bank1	
Tube No. used in bank	1		1	
Tube alienation in bank	Horizontal		Horizontal	
Flue gas flow direction	Up		Up	
Duct width(mm)	1553		1553	
Duct other side(mm)	1553		1553	
Tube length(mm)	15700		15700	
Gas flow:-				
Stack diameter at bottom		3070		
Stack diameter at top		2800		
Height to bottom of stack		14903		
Height to top of stack		55217		
Height of damper in stack		14903		

Table 4. *Inlet stream parameter.*

Item	**Unit**	**Design thermal load**		
Calculated thermal load	Kw	4755	682	25754
Name		Crude	steam	Heater feed
Flow	Kg/hr	123010	9650	162294
Inlet pressure	Mpa	0.9	1.25	2.85
Outlet pressure	Mpa	0.57	1.15	0.65
Inlet temperature	°C	270	191	366
Outlet temperature	°C	320	300	500

6.1.5. Cost Estimation Results

Table 5. *Cost estimation data.*

Capital Cost	**1301300** $
Est. Downtime day	30 day
Est. Operating day	335 day
Anticipated life	20 $year$
Throughput	162300 ton/hr
Electricity full load	20397000 kw
Electricity price	0.13 $\$/kw\ hr$
Fuel gas full load	2280.7 lb/hr
Fuel gas price	0.06 $\$/lb$
Compressed air full load	39630.5 lb/hr
Compressed air price	0.003$\$/lb$
Number of furnace operator labor hour per year	8760 hr
Price of hour for operator labor	1.3$\$/hr$
Number of operator labor	67 man
Number of furnace maintenance labor hour per year	8760 hr
Price of hour for maintenance labor	1.6$
Number of maintenance labor	19 man

	A–C	D	E	F	G	H	I
1	cost estimation						
3						Annual	
4					Unit	Cost	unit
5	[All figures in US $]						
7	Capital Cost			1301300	$		
8	Installation cost			520520	$		
9	Transportation			65065			
10	Total Fixed Cos			1886885			
12	Anticipated life			20	Yrs		
14	Depreciation(straight line)					58558.5	$
16	Total Available Hours/ Year			8760	Hrs		
17	Est. Downtime (Repairs / Mt			720	Hrs		
18	Est. Operating Hrs			8040	Hrs		
20	Throughput			162300	Ton / Hr		
21	Utilities						
22		Full Load Kw		$ / Kwhr			
23	Electricity	20397000		0.13		2651610	$
24		lb/hr		$ / Lb			
25	Fuel Gas	2280.7		0.06		1100209.68	$
26	Comp Air	39630.5		0.003		955887.66	$
28	Operator Labor	Hrs/Furn/Yr	$ / Hr	no.operater			
29		8760	1.3	67		762996	$
30	Maintenance Labor	Hrs/Furn/Yr	$ / Hr	no.operater			
31		8760	1.6	19		266304	$
32	Annual Furnace Operating Cost					5795565.84	$
33	Total cost					7682450.84	$

Figure 7. *Cost estimation results.*

6.2. Discussions

The furnace efficiency has been put under light in this research as one of the important facilities in the refinery and for the fact that its consume a huge amount of fuel so huge amount of cost. The efficiency of DCU furnace in Khartoum refinery has been calculated using indirect method.

The results show that furnace efficiency is about 86.43%. which indicates the furnace efficiency obtained according to use heat exchanger in the top of the furnace to deliver heat from the stack gases to preheat air that enters the furnace.

Inlet air preheats result show that thermal efficiency has been increased with increasing of air temperature.

The effect of excess air and stack temperature on thermal efficiency shows that the thermal efficiency has been reduced according to increase in excess air and stack temperature and vice versa. Increasing the fraction of the oxygen in the inlet air will lead to increase in thermal efficiency based on the fact that nitrogen absorb heat hence decease thermal efficiency.

Furnace Control:

Process Side – Fluid heated inside the tubes must be controlled for efficient heat transfer and to minimize tube fouling and coking. Flow distribution at the inlet is very important. All fluid passes should have an equal amount of fluid flowing through the tubes. In most liquid or fouling services, it is important to have an individual pass flow controller to avoid flow imbalances due to coking or localized overheating. Another variation is to use feed forward control. Any load change in the feed minimizes the outlet feed temperature variation [13].

Fluid flowing through the tubes should have an adequate pressure drop in the fired heater to ensure good fluid distribution in a multiple- pass heater.

Firing Controls – Two major parameters that should be controlled and monitored are:

-Fuel gas/fuel oil pressure.

-Furnace draft.

Furnace Draft – Flue gas analysis is the single most powerful tool available to maximize combustion efficiency. One improved control scheme automatically controls oxygen in the flue gas by varying the furnace draft [13].

Control schemes have been installed in balanced draft systems to more accurately control excess air and draft. Some of these schemes involve controlling the air/fuel ratio. Several problems have been experienced in measuring the fuel and air flow rate accurately.

Closing the stack damper reduces the furnace draft. To adjust excess air, the stack damper must be adjusted in conjunction with the air registers. A step-by-step procedure to adjust the draft and excess air in balance draft furnaces is shown in Figure (4-6).

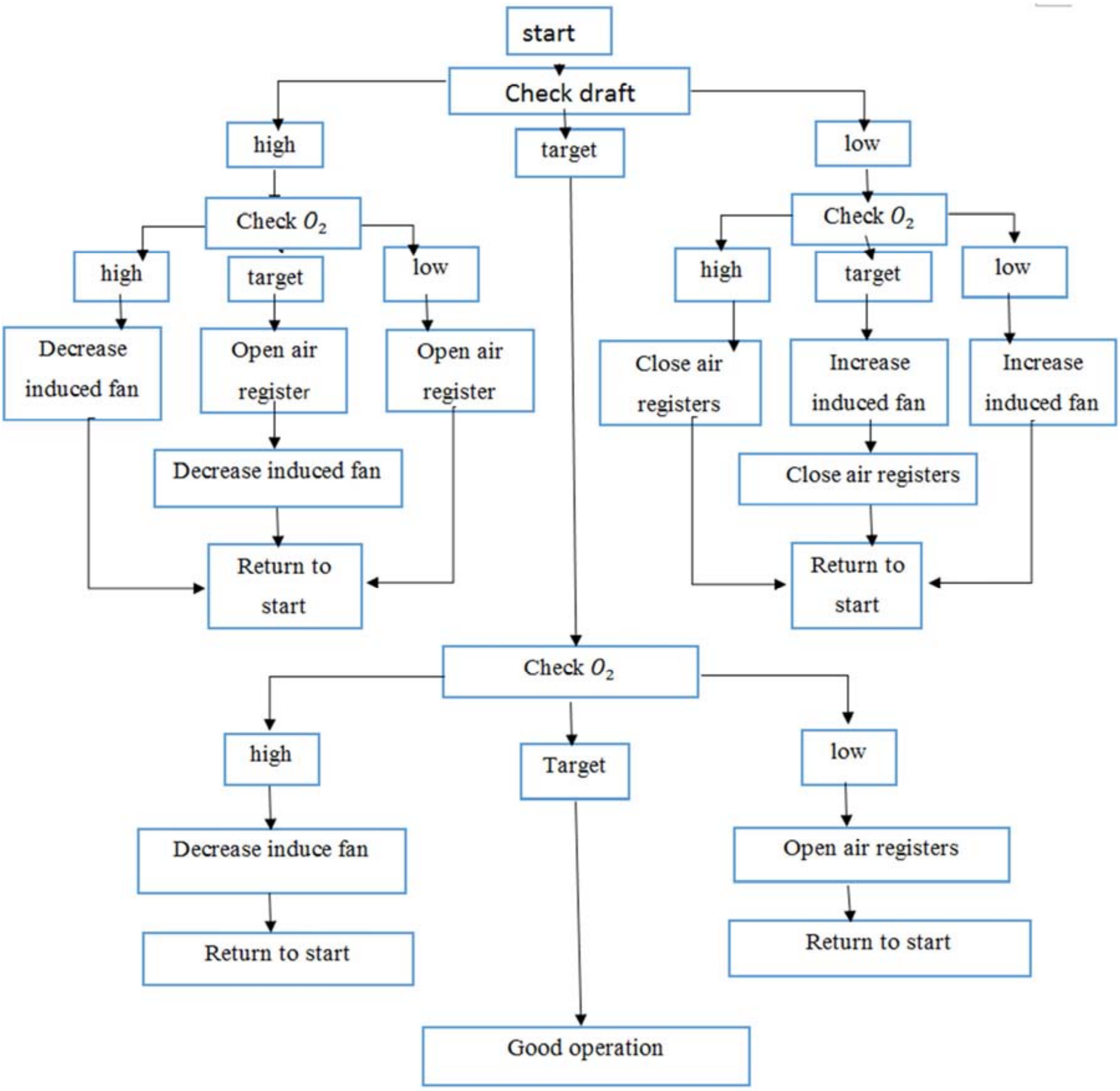


Figure 8. *Draft control.*

7. Conclusions

In this research the parameters that affect in furnace efficiency (excess air / stack temperature are examined using equations and excel sheets. The results show that increasing in stack temperate at constant excess air will lead to reverse proportion with the efficiency of the furnace and vice versa. Furthermore, the result of oxygen percentage in air and preheated air from Aspen HYSYS simulation software and EDR 'aspen exchanger design and rating') of DCU both provides direct proportion with the efficiency. In addition, cost of furnace has been estimated by excel sheets as well as controlling different parameters that affect in operation.

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