Effect of air combustion preheater on furnace efficiency by using refinery simulator

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Ministry of oil\BOTI

Abstract:

One of the basic crude oil refining steps is the heat up to high temperature about 370^0 C, which is done in the furnace. The balance between fuel and air required to combustion provide an economical and efficient heating.

In this research operating data of heating up the furnace are collected by using an interactive simulator of Drilling System Company (ORTIS) which gives a flexibility of operation cannot be obtained in real furnace, these data are related to find the operation paths under different control system of manual, automatic and working automatic without pre-heating are used .

Using of combustion air preheater, by exchanging heat with the flue gases, leading to increase furnace heating efficiency from 85% to 93% also the fuel supplied to the burners is more less than working without preheater.

As the simulator used in this research very closed to real operating system of furnace which cover all the variables of furnace inside temperatures, excess air analyzer, and fuel gas control and inside pressure control.

The using of interactive simulator is very useful in stating the right operating conditions. The use of pre-heating of combustion air is best economical method to reach heating the crude oil to the required temperature with minimum fuel gas consumption, which directly affects the efficiencies of the furnace in each case.

الخلاصة:

احدى اهم الخطوات الرئيسيه في عمليات تصفية النفط الخام هي تسخينه الى درجات حرارة عالية بحدود ٣٧٠ درجة سيليزيه والتي تتم بواسطة الافران.

ان عملية الموازنة بين كمية الوقود والهواء المستهلك في عملية الاحتراق تجعل عملية الاحماء كفوءة وفعالة ومجدية اقتصاديا .

في هذا البحث تم اخذ المعطيات الخاصة باحماء الفرن من خلال استخدام المشبه الخاص بعمليات التصفية (مشبه شركة drilling system) والذي يعطي مرونة كبيرة لايمكن الحصول عليها في الافران الحقيقية .

ان استخدام معيدة الغليان واعادة التسخين بغازات الاحتراق الصاعدة تؤدي الى زيادة كفاءة الافران من ٨٥% الى ٩٣%وكذلك كمية الوقود المجهز للمشاعل اقل بكثير من الكمية المستخدمة في حالة عدم وجود معيدة الغليان.

ان استخدام المشبه في هذا البحث متقارب جدا مع الظروف التشغيلية الحقيقية للافران والذي يغطي كل المتغيرات الداخليه للافران من درجة حرارة , الهواء الزائد , المحللات ,مسيطرات الاوقود ومسيطرات ضغط الوقود .

يعد استخدام جهاز المشبه في هذا البحث من الامور المهمة جدا والمفيدة في اختيار افضل الظروف التشغيليه والحصول على اعلى كفاءة.

كما يعد استخدام معيدة تسخين هواء الاحتراق الداخل للفرن مجدي اقتصاديا حيث يقلل كمية الوقود المستهلك الى اقل كمية ممكنه مع اعطاء اعلى كفاءة لاحماء الفرن.

Introduction:

A furnace is equipment used to supply heat in higher temperatures to different types of materials, such as melting of metals, boiling of liquids, and crude oil heating in refineries. Furnaces, in essence, are a kind of heat exchanger that transfer the thermal energy obtained from burning fossil fuels in a closed space to a process liquid which in coils or locked up pipe flows. (Esmaeil masoui, 2011).

Thermal efficiency of process heating equipment, such as furnaces, ovens, heaters, and kilns is the ratio of heat delivered to a material and heat supplied to the heating equipment. (Hassan al-Haj Ibrahim, 2013).

The heating efficiency of the furnace is calculated from the operation data collected in different cases by using furnace simulator and real operation of the Dora Refinery in of Middle Refinery Company in Baghdad. The properties and composition of fuel gas and air are assumed to be same in all cases, the operation cases differ in the manner of control and the use of air preheating cycle or not.

Oil Refinery Training Interactive Simulator (ORTIS) of Drilling Systems (UK Company) is used to operate and control the heating steps of Crude Distillation Unit (CDU), where the data are used to calculate and compare the efficiency of the furnace. ORTIS is designed on the basis of actual data of oil refinery processes.(simulation, ORTIS 5000, 2010, UK).

The furnace in interest is a box type equipped with 8 gas burners, and the quantity of fuel gas flow supply, as read by pressure controller (PIC-3), is cascade controlled with the crude outlet temperature by the temperature controller TIC-1 in automatic state. (Drilling system simulator manual, 2010).

Galitsky & Worrel by controlling variables such as percentage of excess air and amount of oxygen in outgoing gasses showed and assessed importance of performance increase of used energy in furnaces and its relation to decrease of operational cost and amount of pollution. By these methods, up to 18% saving in furnace energy consumption could be achieved (Galitsky & Worrel, 2011)

Blasiak Wlodzimierz and Weihong Yang shows different characteristics compared to combustion in normal atmosphere known as high temperature air combustion (Hi TAC),to developed an experimentally verify mathematical model (numerical calculation of a single jet fuel in (Hi TAC) that saving cost of (10-30)% can often be achieved .(Blasiak& Weihong, 2008)

The aim of this work is to obtain the efficient operating conditions for heating up of refinery furnace, and to find the effect of combustion air reboiler on furnace efficiency and fuel consumption.

Simulation:

Oil Refinery Training Interactive Simulator (ORTIS) of Drilling Systems (UK Company) is used to operate and control the heating steps of Crude Distillation Unit (CDU), where the data are used to calculate and compare the efficiency of the furnace. As shown in figure (1) ORTIS is designed on the basis of actual data of oil refinery processes.

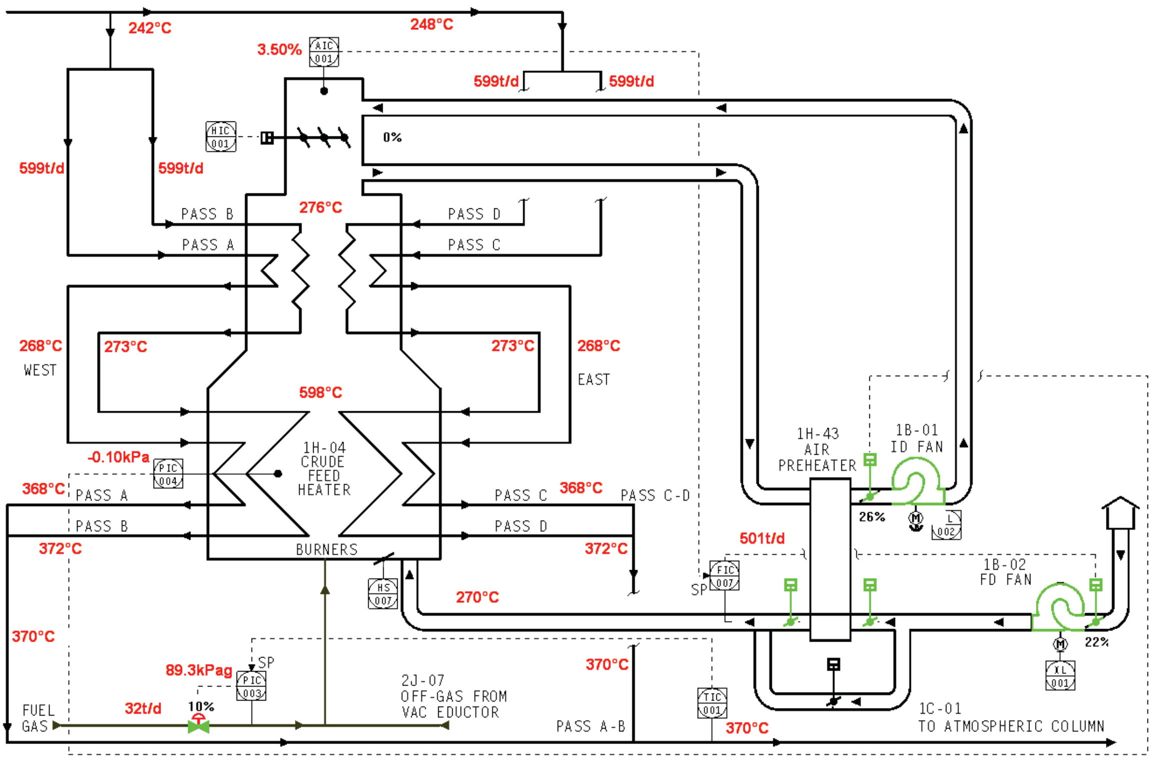


Fig. (1) Simulation of furnace.

The crude oil enters to at the top of the furnace with four passes at the convection region where the furnace temperature indicated by(TI- 30), then flow in the radiation area where the temperature of the furnace read by (TI- 31), at the end the heated crude out of the furnace as one stream to the distillation column . (Drilling system simulator manual, 2010)

Results and discussion:

Three types of operation to start warming up the furnace, Automatic control, Manual control, and operation with no preheating to combustion air, the following relations were obtained:

1-Relation between Fuel and Temperature change

Figures (2, 3) show the relation between fuel gas supply and two regions inside the furnace, (radiation and convection regions).

The increase of radiation and convection temperature changed in a linear relation and it's appear the achievement of higher temperature with less fuel can done by preheating the combustion air.

Since the hot air carrying energy to the combustion with less fuel due to the nature of control system.

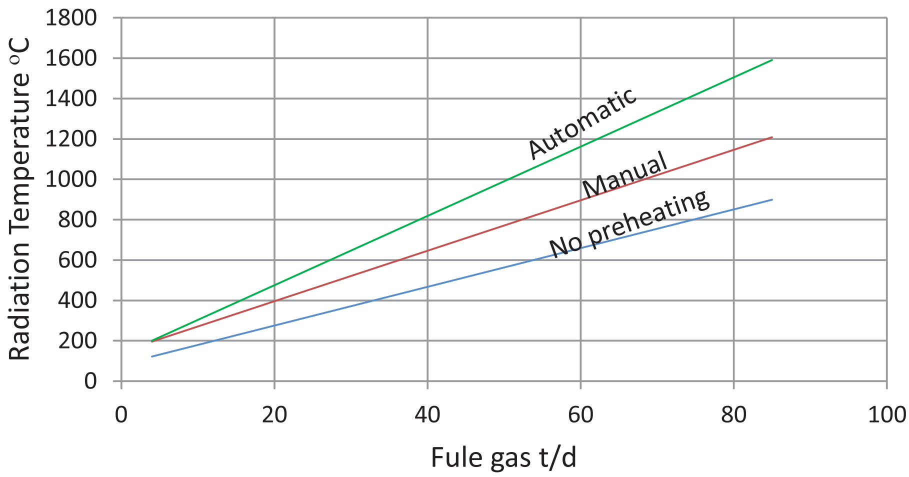


Fig.(2) Change of radiation temperature with fule.

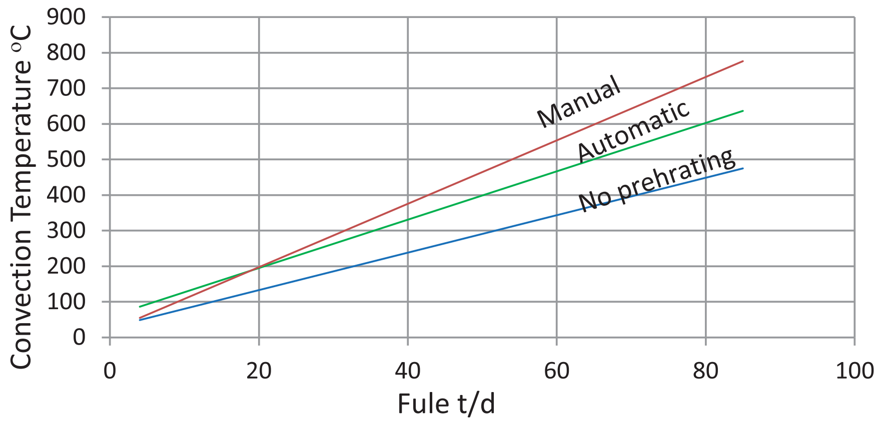


Fig.(3) Change of Convection Temperature with Fule.

2-Relation of radiation and convection changing temperature

To study the changes of heat distribution inside the furnaces radiation area temperature and convection area temperature of startup the furnace to steady state point, is shown in figure(4),it's obvious there is linear increasing between these two areas inside the furnace.

It shows the linear smoothly increasing in all operating systems ,they have the same behavior ,normally due to the increasing of radiation temperature followed by increasing of convection temperature according to heat transfer laws ,which means that the furnace heating up operation is as designed and the

Combustion is stable.

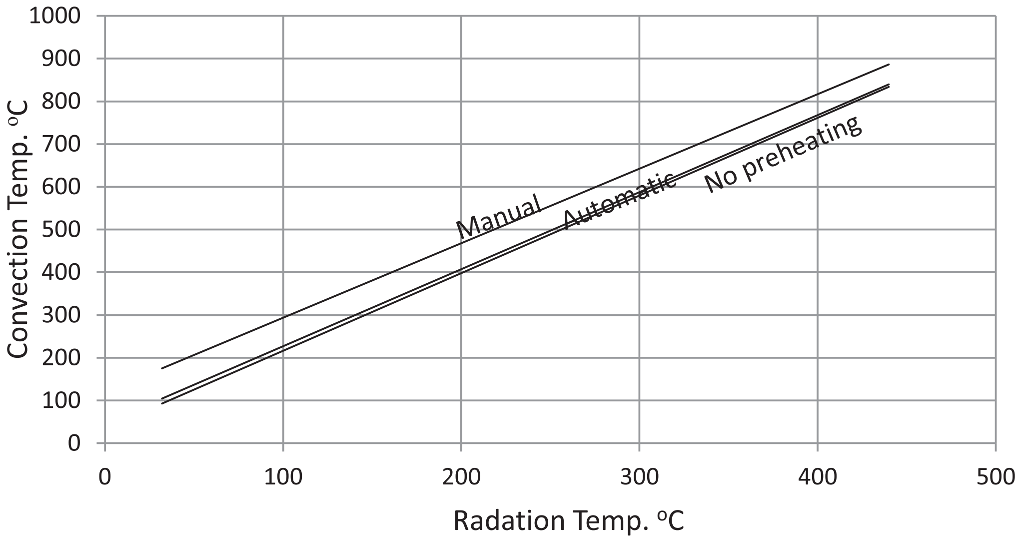


Fig.(4) Changing of convection with radiation temperature.

3-The Effect of fuel supply on crude heating

With the three operation methods the effect of increasing crude temperature to the design point at start up varied polynomial with the fuel supply as shown in Figure(5).

The temperature of crude with preheating minimizing the combustion fuel due to the energy saving done by the preheater and the operating system used in heating up process.

The smoothly increasing of the temperatures in the figure (5) is due to the active control of the furnace system.

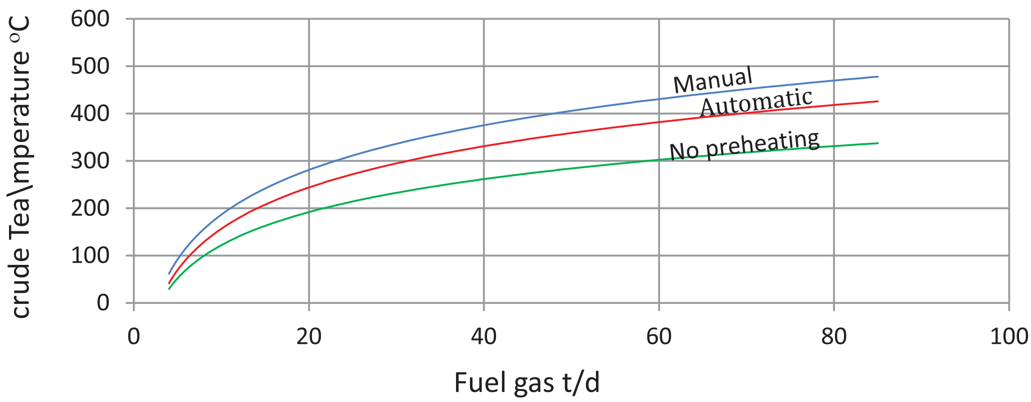


Fig.(5)Crude temperature increasing.

Furnace efficiency calculation:

The heating efficiency of the furnace is calculated from the operation data collected in different cases by using furnace simulator and real operation of the Dora Refinery in of Middle Refinery Company in Baghdad. The properties and composition of fuel gas and air are assumed to be same in all cases, the operation cases differ in the manner of control and the use of air preheating cycle or not.

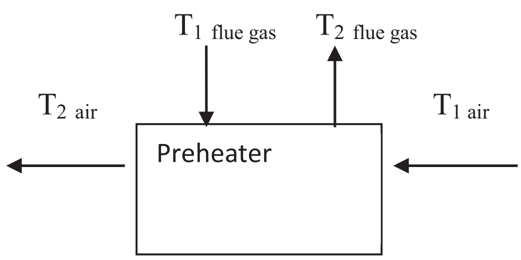
Sample of efficiency calculations:

Case (3):

Fuel gas = 42 t\d

Excess air = 2%

Forced air IN = 700 t\d



From heat balance on preheater calculate the temperature of flue gases out of furnace.

$Q_{forced\ air} = Q_{flue\ gases}$

$MC_p(T_2-T_1)_{air} = MC_p(T_1-T_2)_{flue\ gas}$

$O_{2req} = 222.522*1.2$

O_{2req} = 267.026 mole\hr

Air $_{req}$=267.026*(100/21)

Air $_{req}$= 1271.55 mole\hr *29

Air $_{req}$=36875.074 lb\hr

Flue gases out= fuel gas IN+ combustion air IN

Flue gases out= 36875.074+3857

Flue gases out = 40732.07 lb\hr

Forced air=700 t\d

Forced air= 64283.33 lb\hr

T_2=139.5C^0

$$\eta=\frac{LHV-Qs-Qr}{LHV}*100$$

Total heat input = (total heating value\fuel gas)

Total heat input (LHV) = 27017.812

Qr: expressed as percentage (2.5-4) % of heat input

Assume radiation heat losses =2.5%

Qr=675.445

Qs: determined from a summation of the heat content of the flue gas components at the exit flue gas temperature.

Qs= 1243.85

$$\eta=\frac{LHV-Qs-Qr}{LHV}*100$$

η = 93.6%

Table. (1): The efficiency results obtained from the calculation as following:

case	operation	% excess air	Fuel gas t/d	Efficiency
1 Sim	Auto	2	52	83.38
2 Sim	Man	3	42	93.6
3 Sim	Man	2	42	93.9
4 Sim	Auto	2	85	82.3
5 Dura	Auto	3	915	85.7

Conclusion:

1- The relations investigated showed the furnace heating affective parameters. They are studied during heating up stage under different control and operating technique (auto and manual). These relations show the ability of raising furnace temperature smoothly by controlling the variables in both operating cases of automatic or manual. And the effect of using pre-heating of combustion air by exchange with the flue gases drawn by induce fun ID which is found reducing the quantity of fuel gas required for heating, as compared with the actual values from Dora refinery furnace.

2- Using of combustion air preheater ,by exchanging heat with the flue gases , leading to increase furnace heating efficiency from 85% to 93% also the fuel supplied to the burners is more less than working without preheater

3- It is clear that the use of simulator in operating the furnace gives the possibility of trying different operation system comparing to the actual furnace, it is not possible to try or investigate many variables due to the nature of working conditions and limited ability of repeating the stat up and shut down of such unit.

Abbreviations:

AIC=analyzer indicator control

Auto=automatic

FD-fan=forced air fan

FIC=flow indicator control

ID-fan=in deduced air fan

LHV =Total heat input

PIC= pressure indicator control

TIC=temperature indicator control

Man=manual

Sim=simulator

η = efficiency

Q_r =radiation heat losses

Qs= stack heat losses

T=temperature

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