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# Feasibility of Furnace H-701 Energy Recovery in Sarkhoun and Qeshm Gas Refinery Using the Heat Exchanger

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**Abstract:** The aim of this study is the investigation and thermal analysis relating to emissions of the flue-furnace H-701 of Sarkhoun and Qeshm Gas Refinery in Bandarabbas (IRAN) and thermal load has been calculated. Then Study of the combustion process and calculation of required combustion air and the heating of air In order to increase its enthalpy using energy combustion gases is done by designing Heat Exchanger. This method helps to optimization of energy consumption and reduction of energy losses and prevents the increase in environment air and will help to cleanliness of the environment. Using this method efficiency of furnace will be increased by 8.63%.

**Keywords:** Energy recovery, furnace, heat exchanger, optimization of energy consumption, preheating combustion air

## INTRODUCTION

Nowadays non-renewable state of fossil fuels on the one hand and high rate of energy from the other hand has made Statesmen and researchers to take action toward optimization of energy consumption. Furnaces in oil and gas industries are the most widely used fossil energy equipment which their removal from these industries is impossible. In fact, Furnace is a Unit in which heat from the fuel in insulated chamber to the process fluid that is in the pipes is transferred. The main task of furnace is supplying Specific heat for the process fluid in high temperatures. Furnaces have different types which Furnace with direct flame is the most commonly used. In these Furnaces, Heat through fuel combustion is created by Burners inside the furnace and transfers to the process fluid .The furnaces are composed of three parts:

- Combustion chamber
- Division pipes of transport and radiation section
- Chimney

To increase the efficiency of furnaces and optimization of energy consumption in Furnace many ways are recommended that include:

- Control of excess combustion air
- Identify and fix leaks in the furnace
- Preheating of combustion air
- Fix the fracture and cracks in walls and firebricks (Rockwell Automation, 2007)

One way to optimize the energy consumption is the use of thermal energy of exhaust gases of the furnace Chimney. Nowadays this energy is used for applications such as preheating combustion air, heating process fluid, preheating boiler feed water, heating used water (Rockwell Automation, 2007). Preheating combustion air with regard to regional climate of the region and physical condition of Sorkhoun and Qeshm Gas Refinery is the proposed ways of exploiting this thermal energy which will save in fuel consumption.

Reza *et al*. (2006) examined the effects of different methods of optimizing energy on the important environmental factor in furnaces, namely the pollutant gases produced by the combustion reaction.

In other research, Mojtaba *et al*. (2001) investigated the effects of energy recovery system on the thermal efficiency and the specific consumption of reheating furnaces of Mobarakeh Steel Company.

The purpose of this study is to optimize the energy consumption and increase the efficiency of furnace H-701 in the unit 700 of Sarkhoon and Qeshm Gas Refinery by using the off-gas energy. First the emission of off-gas from the chimney of furnace H-701 is analyzed and its heat load is calculated. Then a heat exchanger is designed to use the energy. In this heat exchanger which can be installed on the chimney, the off-gas from the chimney is located in the vicinity of the combustion air and exchanges the heat and preheats the combustion air in the furnace. Finally the increasing rate of furnace efficiency is calculated using the recovery system.

## MATERIALS AND METHODS

**Case study (unit 700 of Sorkhoun and Qeshm Gas Refinery):** One of the most valuable products of Sorkhoun and Qeshm Gas Refinery is produced gas

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Table 1: The composition of the natural gas used to fuel according to molar % (data sheets for H-701)

| $CH_4$ | $C_2H_6$ | $CSH_8$ | i-$C_4H_{10}$ | n$C_4H_{10}$ | i-$C_5H_{12}$ | n-$C_5H_{12}$ | $C_6$ | $C_7$ | $C_8$ | $N_2$ | $Co_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 77.39 | 9.64 | 5.13 | 1.14 | 1.7 | 0.43 | 0.59 | 0.35 | 0.19 | 0.04 | 2.79 | 0.61 |

Table 2: Thermodynamic properties of natural gas (Yunus and Michael, 1998)

| LHV | Molecular mass | Temperature | Δh | Z. (Brown *et al*., 1948) |
|---|---|---|---|---|
| 47 MW | 21.54 Kg/K mol | 45°C | -79499.25 Kj/k mol | 0.99 |

liquids. These gas liquids contain light weight materials which remain liquid only in high pressure situations and low temperature hence cause problems in transmission and distribution in form of Gas liquids. Therefore, before the presentation of Gas liquids, separation of light hydrocarbon should be implemented In order to limit the vapor pressure so that they can be transmitted through the pipeline. These hydrocarbons include methane-ethane-propane-isobutene-normal butane. Consolidation of gas liquids is accomplished through reduction of Pressure and distillation process.

This unit includes the following devices:

- Tank of inlet separation
- Two furnaces
- Tower of ethane sensitization (Deethaniser) and butan desensitization (Debutanizer)
- Collection tank (Energy audit reports from Sarkhoun and Qeshm Gas Refinery)

**Introduction of furnace H-701 unit 700:** Furnace H-701 The, subject of this study has the Reboiler role of the Deethanizer tower of Unit. 700. This Furnace is a Cylindrical Type With an internal diameter of 4.9 and 44 m height from ground level and has two radiation and moving parts. Furnace lining is made of lightweight insulating concrete with a thickness of 203 mm. internal diameter of Chimney 1.48 m and its height is 96 m. furnace includes 4 burner which are located in bottom of the Furnace and each of them produce 2.9 MW heat in normal conditions. The process fluid enters the furnace with Debbie 31.94 kg/s under pressure and temperature 2400 kpa, 225 c, respectively and after heat absorption with 1980 kpa pressure and 296°C temperature goes out. Fuel required for burners of Natural gas furnace is fuel gas with 15% excess air for combustion .Convection of that in LHV state is 47 and by burning with excess air, 1.16 MW Heat is generated which 0.97 MW of its amount is absorbed by the process fluid and the rest is wasted. Temperature of the Chimney exhaust gases Chimney gas is 340°C (Data sheets for H-701).

In Table 1 you can find the composition of the natural gas used to fuel according to Molar % and in the Table 2 you can see Thermodynamic Properties of Natural Gas.

**Calculation of thermal load of exhaust gases from chimney:** Taking into account the composition of natural gas and 15% excess air and energy Audit Report, Complete combustion reaction is as follows:

Table 3: The amount of changes in the enthalpy of exhaust gases from the chimney at temperature (340°C) (data sheets for H-701) (Yunus and Michael, 1998)

| Compound | The molar | Mole (%) | Δh the enthalpy (kj/k mol) |
|---|---|---|---|
| $CO_2$ | 1.330 | 8.9 | -379986.9 |
| $N_2$ | 10.730 | 69.9 | 9285.9 |
| $O_2$ | 0.377 | 2.5 | 9664.6 |
| $H_2O$ | 2.790 | 18.4 | -230849.5 |

$$1\ (\text{fuel}) + 2.83\ (o_2 + 3.76\ N_2 + 0.175\ H_2O) \rightarrow 1.33CO_2 + 10.73\ N_2 + 0.3770_2 + 2.79\ H_2O \quad (1)$$

Flame temperature, adiabatic is 2082.341°C (Yunus and Michael, 1998) Af (ratio of air to fuel) = 18.47.

In Table 3 you can see the amount of changes in the enthalpy of exhaust gases from the chimney at temperature (340°C)

Considering that Composition of exhaust gases from the Chimney is Z = 0.99, they Show the ideal gas behavior. Molecular mass of the compound is 27.6 $\frac{kg}{K\ mol}$ and its density is 0.5431 kg/m$^{3.}$

If we cool the exhaust gases of the temperature of 340 to150°C (Sulfuric acid dew point) the amount of released heat is (What is a Recuperate and Why is it Important, www.chpcentermw.org):

$$Q = \int_{T_1}^{T_2} mcpdt = \int_{T_1}^{T_2} m(a + bT + cT^2 + dT3)dt \quad (2)$$

$$Q = -990.742\ KW$$

If we cool the exhaust gases of the temperature of 340 to 150°C (Sulfuric acid dew point) the amount of released heat.

Amount of fuel consumed by each Burner would be 221.5 kg/h.

The amount of combustion air is 16495 kg/m$^3$ (Data sheets for H-701).

**Calculation the enthalpy of combustion air (at ~25°C):**. The amount of combustion air Debbie 16495 kg/h, which Containing molecular mass of 28.45 kj/ (K mol) and Z = 0.993. Behavior of This compound is in the Form of an ideal gas. By establishing equilibrium the energy of combustion air and exhaust gases from Chimney and regardless of all waste, Combustion air can be heated to a temperature of 230°C. To increase

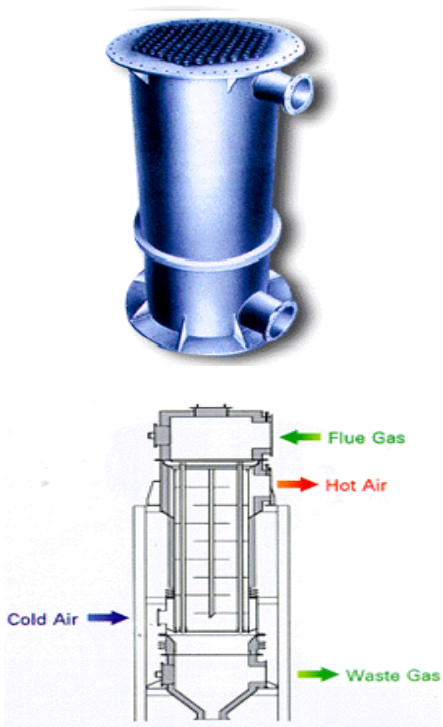


Fig. 1: Recuperator

Table 4: Composition of combustion air and enthalpy changes (data sheets for H-701) (Yunus and Michael, 1998)

| Compound | The amount of mole | Molar percentage | The amount of enthalpy Δh (kj/kmol) |
|---|---|---|---|
| $O_2$ | 2.830 | 20.26 | 2277 |
| $N_2$ | 10.640 | 76.20 | 2240 |
| $H_2O$ | 0.495 | 3.55 | -23222.5 |

Table 5: Physical and thermodynamic properties of combustion air and chimney emissions (exhaust gases from the chimney) (Ernest, 1964)

| Cool fluid | Hot fluid |
|---|---|
| $\dot{m}c = 32746.41\ \frac{lb}{hr}$ | $\dot{m}h = 34286.112\ \frac{lb}{hr}$ |
| $T_{1s} = 77°F$ | $T_{1s} = 644°F$ |
| $T_{2s} = 466°F$ | $T_{2s} = 302°F$ |
| $T_{cs} = 127.5°C$ | $T_{ns}\ 245°C$ |
| $k = 0.018\frac{Btu}{hr\ Ft^2°F}$ | $k = 0.0225\frac{Btu}{hr\ Ft^2°F}$ |
| $CP = 0.25\frac{Btu}{lb°F}$ | $CP = 0.277\frac{Btu}{lb°F}$ |
| $\rho = 0.0541\frac{lb}{ft^3}$ | $\rho = 0.0405\frac{lb}{ft^3}$ |
| $\mu = 0.0221$ cpoise | $\mu = 0.0241$ cpoise |
| **Cool fluid (tube)** | **Hot fluid (shell)** |
| V = 11 m/s [2] | Ds = 50 in |
| ID = 0.75 in | $Rd_2 = 0.005$ [2] |
| N = 2220 | $\Delta Ps = \frac{F*G^2t*Ds(N+1)}{5.22\times10^{10}\times de\times s} =$ 6.9 Psi |
| $Rd_1 = 0.002$ [2] | F = 0.002 [2] |
| $\Delta P_t = \frac{F*G^2t*L*n}{5.22\times10^{10}\times ID\times S} = 0.129Psi$ | |
| F = 0.0035 [2] | |

the efficiency of industrial furnaces several methods have been suggested. Among the methods mentioned in the introduction according to the requirements and capabilities of Furnace H-701 and Features of the region best practice to enhance its efficiency is preheating of Combustion air using energy exhaust gases from the Chimney to prevent the loss of energy and increase of environmental temperature. Way to achieve this goal is application of heat exchanger so that Heat exchange can be occurred between the exhaust gases from the Chimney and combustion air. In Table 4 you can see the Composition of combustion air and enthalpy changes.

**Heat exchanger design:** Based on the above calculations a heat exchanger should be deigned which heat the Temperature of the combustion air from 25 to 230°C up and get this heat from the exhaust gases for the chimney. This type of heat exchanger or recuperator is of flue tube type with transport mechanism containing lot of tubes. Type of its structure is shell and tube (What is a Recuperator and why is it important, www.chpcentermw.org).

You can find in the Fig. 1 the recuperator and in Table 5 you can see physical and thermodynamic properties of combustion air and Chimney emissions.

This recuperator is used for industrial furnaces and this model can be installed in a small space (Chimney) (Type Orrecuperator, www.jp.alstom.com).

Real length by calculating the allowable Pressure drop in tube and shell is 12 ft. Valid.

## RESULTS AND DISCUSSION

Industrial furnaces with the task of the process fluid heating have a special place in industry and are the major consumers of fossil fuels. Discussion, review and control of their performance lead to a great help to maintain and sustain non-Renewable energy of country.

The amount of fuel enthalpy and Combustion air in current situation of Furnace i.e., fuel temperature of 45°C and combustion air with temperatures of 25°C entering the combustion chamber is equal to $\Delta h_1 = -199260.605\frac{kg}{kmol}$ (Table 4) In the present circumstances that Combustion air is heated to a temperature of 230°C Enthalpy changes of fuel and air combustion are:

$$\Delta h_2 = -114435\frac{kg}{kmol}$$

$$\Delta h = \Delta h_2 = \Delta h_1 = 84825.61\frac{kg}{kmol} \quad (3)$$

As it can be seen With heating the air, the amount of Enthalpy for every kilo mol of fuel is increased to $84825.61\frac{kg}{kmol}$.With this approach which does not cause any changes in Furnace operation in other words we want that process fluid with the same mentioned Mass flow, temperature and pressure enters in to the Furnace the with the same conditions rise in

temperature. So the amount of heat energy that process fluid can get is assumed to be constant. So according to Enthalpy increase for maintaining the amount of heat energy we reduce the amount of fuel efficiency Furnace in current conditions:

$\eta_1 = \frac{9700}{11600}$, $\eta_1 = 83.62\%$, $\eta_2 = \frac{9700+968.75}{11600}$, $\eta_2 = 91.97\%$

With preheating of combustion air efficiency of Furnace is increased by 8.63%:

$$LHV = 47\frac{Mj}{kg}$$

So Amount of fuel saved per hour is $m = 74.21\frac{kg}{hr}$ = 8430609.98 $m^3$/year.

Approximately 650 ton/year in terms of Fuel mole is saved. Assuming fixed trend of furnace function in The amount of air saving is occurred too.

## CONCLUSION

Furnace H-701 of Sorkhoun and Qeshm gas refinery is one of the largest consumers of energy of this big industrial Unit. With the designed heat exchanger in this study by which we preheat the combustion air Energy consumption can be optimized and Furnace efficiency will be increased. The results of this study showed that using this method, the furnace efficiency increases by 8.635% and 74.21 kg/h fuel can be saved. Therefore we can save 650 tons of energy annually by applying this optimization method in Sarkhoon and Qeshm Gas Refinery.

By reducing the amount of combustion air the amount of heat energy required for air heating is reduced too. With This method there would be a great help to the optimization of energy consumption and reduction of fossil fuel consumption and environmental investment in heat exchanger leading to Reduction in the amount of fuel is reversible in a short time. Recommended due to the limited resource in industries that are the studies Energy recovery can be done by installing Recuperator; the resulting savings will be.

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## NOMENCLATURE

$\rho$ = Density
$\Delta h$ = Enthalpy changes
$y_i$ = The amount of molar
$T_1$, $T_2$ = Hot fluid temperature
$t_1$, $t_2$ = Cold fluid temperature
$t_c$ = The average temperature of the cold fluid
$T_h$ = The average temperature of the hot fluid
$\mu$ = Viscosity
K = The heat transfer coefficient
Cp = Specific heat capacity
Rd = Scaling factor
$\Delta P$ = Pressure drop

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