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WASTE HEAT RECOVERY IN INDUSTRIES: ALTERNATIVE WAY TO REDUCTION OF THERMAL POLLUTION

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Abstract*-Waste heat is a sufficient amount of heat which is generated in a process by combustion of fuel or any chemical reaction, but the heat is emitted in the environment to increase machine's efficiency as well as long life of it. Due to emission of sufficient amount of heat to environment, it causes environment pollution as well as thermal pollution. Firstly, the paper deals with feasibility of waste heat in industries and also reduction of that amount of heat which is dumped into environment even though it can be utilized economically. The paper also discusses about a case study of a blast furnace of BSRMand identifies the amount of waste heat through chimney exit and shows that how much heat can be recovered further without disturbing the operation of entire furnace process. The flue gas(waste gas) emitting from chimney from a blastfurnace contains a significant amount of heat. Finally,how the waste heat can be utilized for re-use economically has also been notified shortly in this paper.*

Keyword: waste heat, flue gas, thermal pollution, heat loss.

1. INTRODUCTION

Waste heat is a heat that is generated due to fuel combustion or chemical reaction. It is normally released into the environment, even though it may still be used. Recovery of waste heat has become very important from environmental, economicpoints of view. Recovery of waste heat has a direct effect on the efficiency of the process. This is reflected by reduction in utility consumption and costs as well as process cost. It also reduces pollution, equipment size, auxiliary energy consumption[1].It is estimated that somewhere between 20 to 50% of industrial energy input is lost as waste heat in the form of hot exhaust gases, cooling water, and heat lost from hot equipment surfaces and heated products. As the industrial sector continues efforts to improve its energy efficiency, recovering waste heat losses provides an attractive opportunity for an emissionfree and lesscostly energy resource.Large quantity of hot flue gases is generated from boilers, kilns, ovens and furnaces. If some of this waste heat could be recovered, a considerable amount of fuel could be saved. The energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered by adopting necessary measures as outlined in this study.To evaluate the idea, if a recovery process is set for waste heat, then this heat can be reused if heat is needed for another section like space heating, water preheating, combustion air preheating, boiler feedwater preheatingetc. [2–3].So, it is said that, if we reuse waste heat as thermal energy for different purposes it will be beneficial as well as efficient for any industry to save from extra cost of utilizing waste heat.The aim of this study is to analyze the quality and quantity of waste heat for a furnace in industries considering a case of blast furnace in BSRM and to take a decision on how much waste heat can be recycled to increase the efficiency of furnace system.

2. WASTE HEAT TEMPARATURE QUANTITYANDQUALITY

The waste heat temperature is a key factor for determining waste heat recovery feasibility. Waste heat temperatures can vary significantly, with cooling water returns having low temperatures around 40-90°C and glass melting furnaces having flue gas temperatures above 1,320°C. In order to enable heat transfer and recovery, it is necessary that the waste heat source temperature is higher than the heat sink temperature. Moreover, the magnitude of the temperature difference between the heat source and sink is an important determinant of waste heat's utility or "quality". The source and sink temperature difference influences a) rate at which heat is transferred per unit surface area of heat exchanger,b)the maximum theoretical efficiency of converting thermal from the heat source to another form of energy (i.e., mechanical or electrical), and c) the efficient thermal storage.Depending upon the type of process, waste heat can be rejected at virtually any temperature from that of chilled cooling water to high temperature waste gases from an industrial furnace or kiln. Usually higher the temperature, higher the quality and more cost effective is the heat recovery. In any study of waste heat recovery, with high temperature heat recovery, a cascade system of waste heat recovery may be practiced to ensure that the maximum amount of heat is recovered at the highest potential. An example of this technique of waste heat recovery would be where the high temperature stage was used for air pre-heating and the low temperature stage used for process feed water heating or steam raising.Waste heat quality are categorized dividing temperature ranges into i)low ii) medium and iii) high quality of waste heat sources. (Considering the case in this study,low temperature sources is not mentioned here) as follows[3]:

Table 01:Waste heat sources

Temp Range	Example Sources	Temp (°C)
High (>650˚C)	Nickel refining furnace	1370-1650
	Steel electric arc furnace	1370-1650
	Zink refining furnace	760-1100
	Copperrefinaryfurnace	760-815
	Hydrogen plants	650-1000
	Open hearth furnace	650-700
	Glass melting furnace	1000-1550
	Fume incinerators	650-1450
	Steel heating furnace	925-1050
Medium (230-650˚C)	Steam boiler exhaust	230-480
	Gas turbine exhaust	370-540
	Dying and baking oven	230-600
	Catalytic crackers	425-650
	Annealing Furnace cooling system	425-650

Heat in flue gas and vapor steams release higher temperature and the waste heat in waste gas(flue gas) is recoverable enough.Convectional and radiation heat loss from exterior of equipment can be used for low grade temperature like space heating or room heating.Understanding the process is essential for development of waste heat utilization system. This can be accomplished by reviewing the process flow sheets, layout diagrams, piping isometrics, electrical and instrumentation cable ducting etc. Detail review of these documents will help in identifying:a) Sources and uses of waste heatb) Upset conditions occurring in the plant due to heat recoveryc) Availability of spaced) Any other constraint, such as dew point occurring in equipment etc.[2–3].

3.TECHNICAL DESCRIPTION OF A BLAST FURNACE: A CASE STUDY OF BSRM

The blast furnace is a pusher type furnace. It is designed to reheat cold billets loaded on one or two rows before rolling. It will be operated with natural gas, light fuel oil and heavy fuel oil. From them, natural gas and light fuel oil is considered as primary fuel and heavy fuel as secondary oil. The furnace is divied into 3 sections, preheating; heating; and soaking zone. It has 24 burners and 4 heating zones. They are operated with specific fuel in order of necessity. It’s charging temperature is about 20˚C and discharging temperature is 1100-1200˚C.It’s peak capacity is about 110 ton/hour. To recover fraction of waste heat, a recuperative zone with bottom recirculating system by which the high temperature waste gas from heating zone is fed into preheating zone. Combustion air is suitably preheated in order to decrease specific fuel consumption. The chimney is built 30m long to avoid moisture and other particles which is harmful for entire furnace process.

4. WASTE HEAT ANALYSIS OF BLAST FURNACE

The furnace is named after blast furnace or dual fuel furnace. Two types of fuels are used to operate this blast furnace. They are oil and natural gas. The oils are of two types. They are HFO oil and LDO oil. After completing all performs of this furnace, the flue gas (waste gas) contains a high amount of heat which is another source of thermal energy if it is recycled. To utilize this amount of heat, the chemical components of flue gas are given below and also to have a faithful amount of heat, some practical facts are also analysed. Main chemical components of flue gas for a blast furnace[4] are: water vapor, nitrogen (typical contents 75-80%), carbon dioxide (typical contents 7-15%), carbon monoxide and hydrogen (CO, H_2) due to incomplete combustion (typical contents 50-150 ppm), oxygen (O_2) due to excess of air (typical contents 2-8%), nitrogen oxides NO_X (NO + NO_2) due to N_2 and O_2 combination at high temperatures (typical contents <100ppm.), sulphur dioxide (typical contents <200ppm.), unburned hydrocarbons and ashes. Typical sulfur content in HFO and LDO is accordingly 0.1-4.5% (maximum) [5-6] and 1.2-1.8% (maximum) [7] and this sulfur content is important becausein order to avoid corrosion due to condensation of sulfur oxide gases, temperature of the waste gas is kept above sulfuric acid dew point temperature. It is recorded that, for 5% sulfur content in flue gas the sulfuric acid dew point temperature is 150˚C. So, at an average 150˚C, the flue gas should be released in environment to avoid the harm of corrosion on furnace operation.The observed furnace releases waste heat at chimney exitas an amount of average above 300˚C which is of medium temperature waste heat sources. So it is said that if the amount of waste heat in chimney exit is kept at an average150˚C,it is sufficient to avoid corrosion of sulfur content and the operation of entire furnace process will not be affected and rest 150˚C or more than it can be recovered for any process where such kind of amount of heat is required. Such as: boiling of water, refrigeration process, room pre-heating etc. The waste gas analysis graph of BSRM for 2 days is given in Fig. 1:

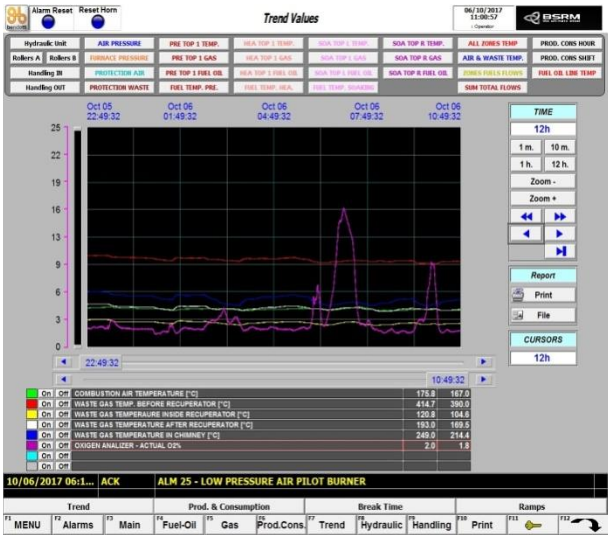

Figure.1: waste gas analysis graph of BSRM

From the above graph, it is noticed that the waste gas temperature before recuperator is 414.7˚C and inside the recuperator is 120.8˚C. After the exit of recuperator the temperature is 193˚C. From the record, it is said that, the recoverd heat by recuperator is around 221˚C Which is poor enough and the rest heat is released which is of huge in amount. At chimney exit, the temperature is slightly increased due to exhaust fan and is recorded as around 250˚C.the entire temperatures are recorded when the furnace process is on. So, it is said that after recovery of waste heat which is used for furnace pre-heating zone, at an amount of average 300˚C is released at chimney exit which can be considered also as waste heat.

5. MATHEMATICAL CALCULATION

To justify the idea of recovery of waste heat, we considered two facts:(1) if waste heat temperature at chimney exit is 300˚C and (2) if waste heat temperature at chimney exit is 150˚C.The calculation will provide a clear concept of how much heat can be recovered from chimney exit as discussed earlier. Considering Adiabatic process, The power of chimney fan is as follows**:**

$$P = \frac{\gamma Q p1}{\gamma - 1}\left[\left(\frac{p2}{p1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] \qquad (1)$$

Q= volumetric flow of waste gas
= 0.011 Nm^3/s

γ =1.3 [assume]

<u>When waste heat temperature =300˚C</u>

Pressure beforeexhaust fan =p_1=9 bar(assume)

Pressure after exhaust fan=p_2=10 bar(assume)

Therefore, power of exhaust fan,P_1 = 1069.57 W.

<u>When the temperature of released waste heat =150˚C</u>

The new pressure at chimney exit, $p_2^{/}=p_2+h\rho g$
=10.0023 bar

Pressure before chimney fan, p_1=9 bar

<u>From techniquel data of furnace of BSRM</u>

The height of chimney,h =30meter

At 150˚C, the density of flue gas can be considered ρ=0.8 kg/m^3[8]

From equation (1)
Power of chimney fan, P_2=1071.9=1072W

<u>Recovered heat calculation</u>

Mass flow rate,m =3 kg/h (considering HFO fuel oil)

Specific heat of HFO,s= 2.0934kJ/kg.k [8]

$\Delta\theta=\theta 1-\theta 2$=300˚C-150˚C=150K

Recovered heat (per hour),$Q^{/}=m \times s \times \Delta\theta$
=942.03 kJ/h

From above calculation, we can say that the power of exhaust fan will not be so much increased due to 150˚temparature heat release. The recovered amount of heat will be 942 kJ for every hour which is efficient enough to recycle for further use.

6. RESULT OF THIS CASE STUDY

The overall experiment leads to let us get a decision that, at an average 900kj heat per hour can be saved and the environment will also be saved from CO_2 emission and also from thermal pollution. Though the calculation is based on one fuel type. For LDO, the amount will also be nearly about HFO.

7. CONCLUSION

Waste heat recovery is an excellent concept that is evaluated for decades. It is another source of renewable energy that significantly will contribute to our efficient energy conversion process like mechanical or electrical. The study focuses on waste heat quality, feasibility and its faithful usage. The proposed mathematical analysis of whole system can vary according to conditions, quality of waste heat temperature. The waste heat energy is another potential energy source in developing country like Bangladesh. In BSRM, Chittagong, it is observed above that amount of waste heat is in large amount at 200-300˚C after overall process completion. If the waste heat recovery of chimney exit is executed successfully, the waste heat may be a great source of another energy in many industries in Bangladesh

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8.ACKOWLEDGEMENT

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10.NOMENCLATURE

Symbol	**Meaning**	**Unit**
P	Power	(W)
p	Preassure	N / m^2
γ	Heat capacity ratio	dimensionless
Q	Volumetric flow of waste gas	(Nm^3/s)
m	Mass flow rate	(Kg/h)
s	Specific heat	(kJ/kg-k)
$\Delta\Theta$	Temperature difference	(k)
ρ	density	(Kg/m^3)
g	gravity	(m/s^2)
$Q^{/}$	Amount of heat	(kJ)
h	Height of chimney	(m)