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WASTE HEAT THERMAL STORAGE SYSTEM A WAY TO RENEWABLE ENERGY

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Abstract

Different equipment of industries discharge heat which is of no use for this process but are required for other process if that amount of heat can be stored or recovered efficiently without malfunctioning of given process. That amount of heat is not ignorable and causes a great problem to environment. That heat is named waste heat". If such amount of heat is stored somehow and can be used for further uses where thermal energy is needed , can be designated as renewable energy and don't have green -house effect also. To evaluate the purpose, the paper looks forward to notify the amount of waste heat in different sectors of industries and provides an idea on waste heat thermal storage system that is a better solution for this problem which is environment-friendly and efficient enough. Firstly, the research deals with background of waste heat, it's meaning, and feasibility. To execute the research, an ideal model for different qualities of waste heat, a thermal storage according to temperature level are designed and their different uses for other processes are monitored where heat is needed. Furthermore, a case study of BSRM and a simulation is performed to ensure the feasibility of waste heat storage for low temperature using ANSYS software version 16.2. The result provides us with sufficient information that the waste heat is good enough after storage.

Keywords: Waste heat, Thermal storage materials, HTF, Water

1. Introduction

When heat is used to conduct a thermal process, then the whole of it is not consumed which results in loss of thermal energy, this unconsumed heat is called waste heat . Storage of waste heat has an effective impact on economic and environmental point of view. This system helps to reduce process cost, utility consumption as well as CO_2 emission. Furthermore equipment size can also be minimized here [1]. Between 20-50% on energy input is lost as waste gas. The form of waste heat are hot exhaust gas from furnace, boiler, kiln, ovens, cooling water, heat lost from heat surface of different equipment As the industries are focusing on increasing energy efficiency, recovery or storage of waste heat can be a great solution. But the drawback of recovery of waste heat is ,it has to be reused immediately whether it is necessary or not for any other process. To overcome the limitation, storage system can be a better solution. Storage of waste heat leads to save consumption of primary fuel as well as helps to increase efficiency [2-3]. Though 100% waste heat can not stored , at a reasonable percentage it can be saved that will be practical in use which is discussed in this paper.Thermal energy can be stored at temperatures from -40°C to more than 400°C as sensible heat, latent heat and chemical energy (i.e. thermo-chemical energy storage) using chemical reactions. The storage period can be day or month. So it is said that , if we can store waste heat as thermal energy for thermal storage, it will be beneficial as well as efficient to any industry to save from extra cost of utilizing waste heat. The data indicate that waste heat can be stored from low temperature to high temperature effectively. To evaluate the storage material, we focused on some properties heat storage capacity, operating temperature as well as the type of heat transfer fluid(HTF) and availability with low cost[4-5].Developing efficient and inexpensive energy storage device is as important as developing new source of energy. Thermal storage can be defined as the effective storage of thermal energy at high or low temparatures. The another aim of this study is to establish a proposed model which can be automatically controlled for thermal storage system. If needed the storage will supply extra heat for another process otherwise this heat will return back to thermal source. That means, this automation will help the industries not to think about what to do if heat loss is increased or decreased. This automation is both effective and digitalized.

2. Waste Heat Temperature & Quality

The waste heat temperature is a key factor to determine waste heat feasibility. Waste heat temperatures can vary significantly, with cooling water returns having low temperatures around 100- 200°F and glass melting furnaces having flue temperatures above 2,400°F. In order to enable heat transfer and storage, 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) the 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).& 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. Waste heat quality are categorized dividing temperature ranges into i)low ii) medium and iii) high . Heat in flue gas & vapor steams releases higher temperature wheather heat in vapor steams as latent heat is recoverable. 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 heat b) Upset conditions occurring in the plant due to heat recovery c) Availability of space d) Any other constraint, such as dew point occurring in an equipment etc. Quality of waste heat sources are provided in table 03 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
	Copper furnace	900-1090
	Hydrogen plants	650-980
	Open hearth furnace	650-700
	Glass melting furnace	1000-1500
	Fume incinerators	650-1450
	Steel heating	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
	Annelling Furnace Cooling System	425-650
Low (<230˚C)	Cool water Furnace doors	32-55
	Wielding machines	32-88
	Hot process liquids	32-232

The table given above shows that how much waste heat can be stored in different quality and temperature. In furnace process, maximum heat is lost that is noteworthy. The hot process fluids also release heat in environment which is sufficient for any small heating process. To evaluate the feasibility of waste heat, a case study in BSRM leads to sufficient information about waste heat. The study reveals that at at about more than 100˚C heat can be recovered or stored for further purpose.In figure 01, a waste gas graph analysis of BSRM is provided to realize the practical amount of waste heat in industries of developing country like Bangladesh.

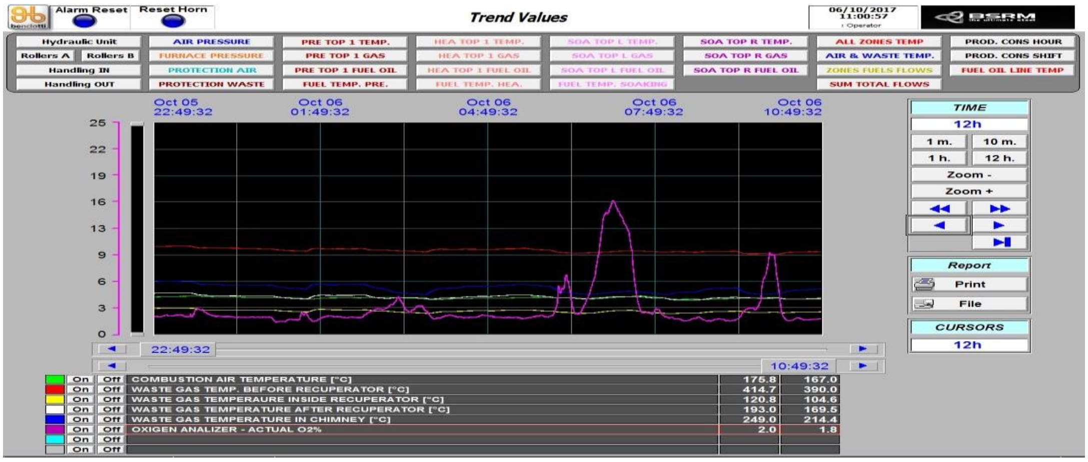


Figure 01: waste gas analysis graph of BSRM

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 about 300˚C .From the record, it is said that,the recoverd heat by recuperator is around 150˚C and the the entire temperatures are recorded when the furnace process is on. At chimney exit, the temperature is slightly increased due to exhaust fan and is recorded as 250˚C. So, it is said that after recovery of waste heat which is used for furnace pre-heating zone, at an amount of more than 200˚C is released at chimney exit which can be considered also as waste heat. In environment, for avoiding corrosion effect of sulpher content, it is estimated that at 5% sulpher content the discharge heat temparature should be 150˚C as it is the dew point temperature of 5%sulpher content. In spite of this, near about 100˚C can be saved or stored for any heating process After identifying source of waste heat and the possible use of it, the next step is to select suitable heat storage system and equipments to recover and utilise the recovered heat.[2-3]

3. Choice of Thermal energy storage

Thermal energy storage (TES) is a technology that stores thermal energy by heating or cooling a storage medium so that the stored energy can be used at a later time for heating and cooling applications and power generation. TES systems are used particularly in buildings and industrial processes. There are three kinds of TES systems, namely: 1) sensible heat storage that is based on storing thermal energy by heating or cooling a liquid or solid storage medium (e.g. water, sand, molten salts, rocks), with water being the cheapest option; 2)latent heat storage using phase change materials or PCMs (e.g. from a solid state into a liquid state); and 3)thermo-chemical storage (TCS) using chemical reactions to store and release thermal energy. The familiarization with different thermal storages, efficiency and cost comparison are provided below in table 02.

Table 02:Different Types of Storages

Name of storages	Capacity kWh/t	Efficiency (%)	storage period	cost(€/kwh)
Sensible (hot water)	10-50	50-90	d/m	0.1-10
PCM	50-150	75-90	h/m	10-50
Chemical reactions	120-250	75-100	h/d	8-100

The above data say that sensible heat storage is more inexpensive than any other storage[5] This energy is stored or extracted by heating or cooling a liquid or a solid,which does not change its phase during the process. The materials include like water, heat transfer oils or inorganic molten salts and solid like rocks,refractory. For choosing a storage material, we have to look forward its high specific heat(Cp), low thermal conductivity(>0.3w/m-k), high boiling point than waste heat temperature, suitable HTF for heat transfer. According to heat capacity, water has the highest specific heat (4200J/kg-k),compared to other substances. It can store more heat per unit of weight. It is non-toxic and in many countries available free of charge or at low cost[7] But it is suitable only for those waste heat temperature below 100˚C .For low temparature(30-90˚C) waste heat, water can be selected as thermal storage. Performance of a THS is characterized by storage capacity, heat input and out put rates while charging and discharging and storage efficiency. The storage capacity of an SHS is given by $Qs=V\rho c\Delta T$ where m is mass, v volume, c is specific heat ,ρ is density and ΔT =max temp. difference of medium[6]Some assumptions can be considered for this storage design:

- Steady flow device
- Shell and tube type
- Mass flow rate of each fluid is constant
- No change in velocity, kinetic and potential energy.
- Axial heat conduction is negligible
- Outer surfaces of storage are thermally insulated , no heat transfer will occur between storage wall and environment.

4. Block diagram of proposed storage system and simulation of thermal storage

The proposed automated storage system is presented here using block diagram. As practical implementation is time consuming and costly, so a proposed block diagram is given below :

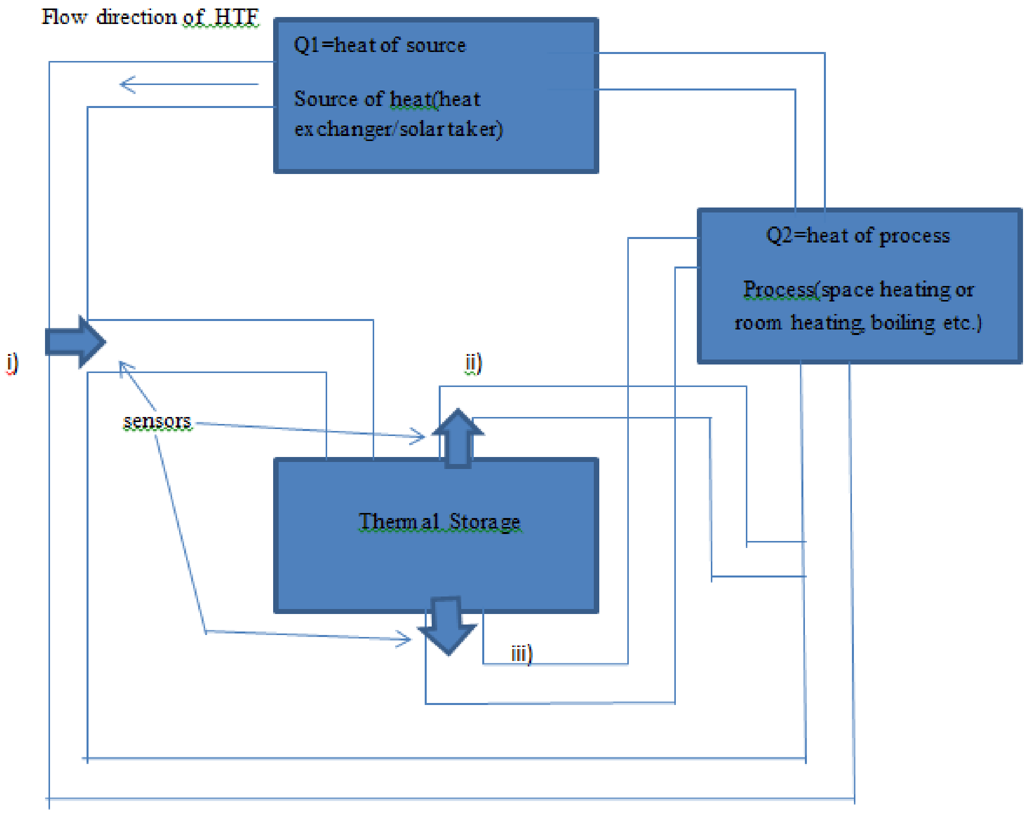


Figure 02: Automation of Thermal storage

Here, Q1= supplied heat from thermal source and Q2=process heat required for the entire process.

i) If Q1> Q2, the required heat for process will be   supplied and waste heat will go to thermal storage

ii) If Q1<Q2, the stored heat will go directly to the process for the supply of rest heat

iii) If Q1=0, only the heat between thermal storage and process will exchange

iv) If Q1=Q2, no heat will go to thermal storage.(not shown in block diagram)

The automation is controlled by sensor.

The interior and exterior storage design is given below:

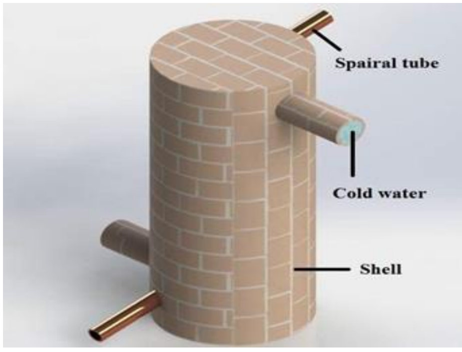


Figure 03: Thermal storage

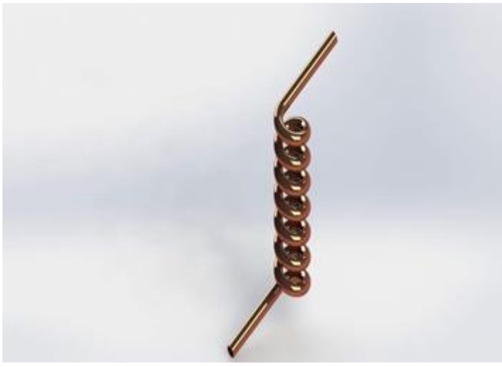
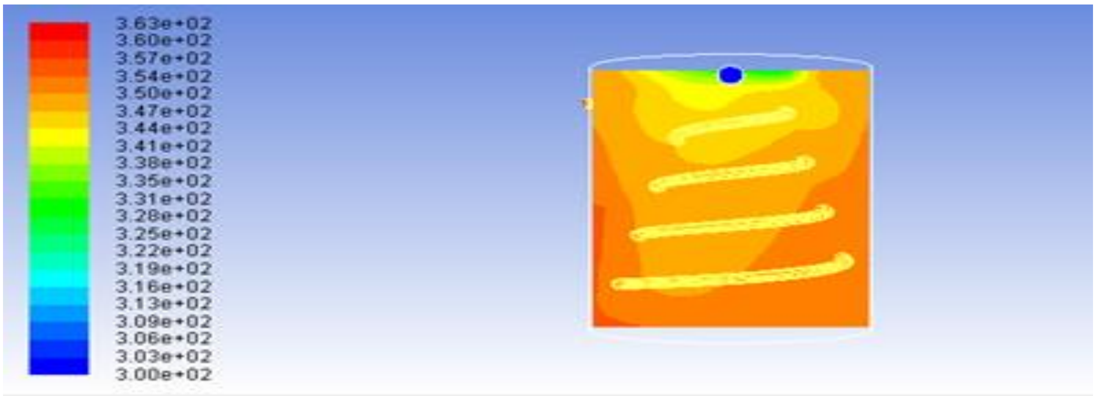


Figure 04: Copper spiral tube

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          Static Temperature                     (k)
---------------------------- --------------------
                   cold_out            353.27115
                    cold_in                  300
                     hot_in                  363
                    hot_out            350.39899
     ---------------- --------------------
                        Net                  363
 zone-surface: cannot create surface from sliding interface zone.
:ing empty surface.
 zone-surface: cannot create surface from sliding interface zone.
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Figure 05: Analysis of waste heat via Ansys

The storage design is given above where the storage wall is thermally insulated. For insulation , thermal insulation with good insulation property like fiber glass can be used .For heat transfer in storage material , we have to choose a pipe with best thermal conduction and cost effective enough. For this purpose , copper tube can be a better choice. The spiral shape of copper tube is chosen here because HTF should flow slowly to maintain heat quality. HTF will be flown slowly (steady state) so that the quality of heat is not decreased. While the heat is reused ,some amount of heat will be absorbed via cold water. This process is maintained carefully so that by any how the temperature of storage wall will not rise.

5.Result and Discussion

The above simulation provides us a clear idea that, while using a water as storage , for 90˚C(363k), we got 77˚C(350k) in hot outlet. We also use water for heat transfer fluid (HTF). So , the cold water which will transfer heat , inlet temperature is 27˚C and outlet 80˚C. The temperature rise of cold outlet is because due to waste heat . So we can say that , the loss of waste heat after storage in hot outlet is not too much, 13˚C. which was perfect enough to reuse for further heating process. Besides, as the simulation software was a trial version, the mesh analysis is not so perfect. From that we can say that, the result will be much better than that. The constraints are here the diameter of copper tube, it's shape, storage material, thermal insulation of storage system which are variables. By changing any one of this variable considering cost and time, the simulation result will be more efficient.

6. Conclusion

Waste heat storage 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 storage which is automated. The proposed design of whole system can vary according to conditions,quality of waste heat temperature & as well asthermal storage materials. The waste heat energy is another potential energy source in developing country like Bangladesh. In a study,in BSRM,Chittagong, it is observed that amount of waste heat is in large amount at 300-350˚C after overall process completion. If the model is executed successfully, the waste heat may be a great source of another energy in Bangladesh. It is noticible that the model is designed focusing on the cost and availability which can be used universally for any country.

7.Acknowledgement

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