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Heat Energy Recovery System

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Energy demands in today's world have increased and the main area of concerns is that approximately 90% of world's oil reserves are expected to be depleted within two generations. We are trying to build a technological system where the by-product of conventional fuel *i.e.,* exhaust heat of fuel, will be converted into another form so that it can further be used again. Mainly, recovery of heat energy is our prime motive. According to our motive, we are going to recover the heat of the hot exhaust gases from chimneys of factories which usually dissipate into the atmosphere and thus that exhaust heat left unused. So, we are making a water storing tank *i.e.,* water jacket that will surround the chimney through which heat from hot exhaust gases will come in contact with water present in water jacket. Through the process of conduction, heat transfer will take place. Therefore, due to heat, the temperature of the water will increase to a very high extent, and hot water can be used in boilers as a pre-heater for household or commercial purposes. Furthermore, global warming will also be controlled if we start implementing this technology at a huge scale.

Keywords: Chimneys; Conduction; Exhaust; Heat Recovery; Temperature; Water Jacket

I. Introduction

The majority of energy production from conventional and renewable resources is lost to the atmosphere due to onsite (equipment inefficiency and losses due to waste heat) and offsite (cable and transformers losses), which sums to be around 66% loss in electricity value [1-2]. The waste heat of different degrees could be found in final products of a certain process or as a by-product of industry such as from the exhaust producing from steel-making, glass making factories, etc. (Table 1). Heat is that amount of energy flowing from one body to another spontaneously due to their temperature difference or by means other than work or transfer of matter. Heat energy flows from an object of high temperature to an object with a lower temperature. It will never do the reverse until and unless any external force is applied.

In this project, we concentrated an approach towards the recovery *i.e.,* Recovery of waste heat. Approximately, there is a 30-50% heat energy loss in the form of heat dissipation *i.e.,* by cooling system and exhaust systems. This lost heat may contain heat energy and kinetic energy, which could be further employed for some applications. Extraction of heat energy is a somewhat easy process but recovering energy from an existing system to an extent that it can be used for useful work is difficult. Energy demands are increasing day by day and need a strong solution. No one thought over it for

many years. So here we are introducing our Heat Energy Recovery System, which will use exhaust gases from chimneys of factories and use this waste energy again in another form. Our project is designed in such a way that it is durable and efficient with very low service requirement [3].

Concept of Waste Heat Recovery

Waste Heat Recovery means to utilize the heat energy in a better desired way which is expelled or exhausted to the atmosphere. This wasted heat energy can be recovered by coupling some secondary auxiliaries such as water jacket in electric chimneys to extract heat from exhaust gases generated by industries. This reduces wastage and improves efficient utilization of fuel *i.e.,* resources. The lost heat may be utilized for further energy requirements.

Table 1. Waste Exhaust Heat of Various Furnaces

Types of Device	Temperature, °C
Nickel Refining furnace	1370-1650
Aluminum Refining Furnace	650-760
Zinc Refining Furnace	760-1100
Copper Refining Furnace	760-815
Steel Refining Furnace	925-1050
Copper Reverberatory Furnace	900-1100
Open Hearth Furnace	650-700
Cement Kiln (Dry process)	620-730
Glass Melting Furnace	1000-1550
Hydrogen plants	650-1000
Solid Waste Incinerators	650-1000
Fume Incinerators	650-1450

II. Objective

According to the United States Department of Energy, up to 50 percent of the energy from all fuels burned in the U.S. ends up in the atmosphere as waste heat. Research indicates that recovery of the waste energy from industrial facilities could fulfill up to 20 percent of total domestic electricity demand and simultaneously effect a 20 percent reduction in greenhouse gas emissions. Waste heat is a heat which is generated by a way of fuel combustion or chemical reaction and then dumped into the environment, even though it could still be reused for some useful and economic purpose. A large amount of hot flue gases is generated from boilers, glass factory, sugar factory, furnaces etc. The energy lost in waste gases cannot be fully recovered. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved [4]. Imagine if this waste heat can be recovered and adopted successfully there will be a revolutionary change in the world in terms of energy reusability. However, as per our analysis, much of the heat could be recovered and losses are minimized. So, the objective of our project is to establish a system which is strong enough to tackle present issues on a recovery of heat energy and efficient enough to make all facts into fiction.

III. Material Required

1. Water tank (at inlet and outlet)
2. Water jacket (around the chimney)
3. Motor
4. Piping system

IV. Construction

A schematic is designed to understand it in a better way (Fig. 1). Brick and cement made chimneys have low conduction ability. These materials nowadays have become obsolete and are no longer used for making chimneys. Modern chimneys are too way different from old chimneys. Water tank surrounds the chimney up to 80% of its height. High output is achieved at the storing end. This design is based on modern chimneys, which are now used everywhere and are called as "Electric Chimneys". Electric chimneys are the chimneys which are held high in length, can work up to 24 hours, and it is best suited for our project to provide the output as per we planned [5].

The following standards and assumptions were taken to complete our research.

1. Thermal conductivity of chimney= 379 W/m K
2. Thickness of chimney= 0.25 m
3. Inlet exhaust gas temperature= 70 °C
4. Temperature of water before process= 20 °C
5. Mass flow rate= 1 kg/s
6. Specific heat at constant pressure= 4.180 KJ/Kg·K
7. Density of air= 2.017 kg/m^3
8. Velocity of inside air= 1 m/s
9. Height of chimney=6 m
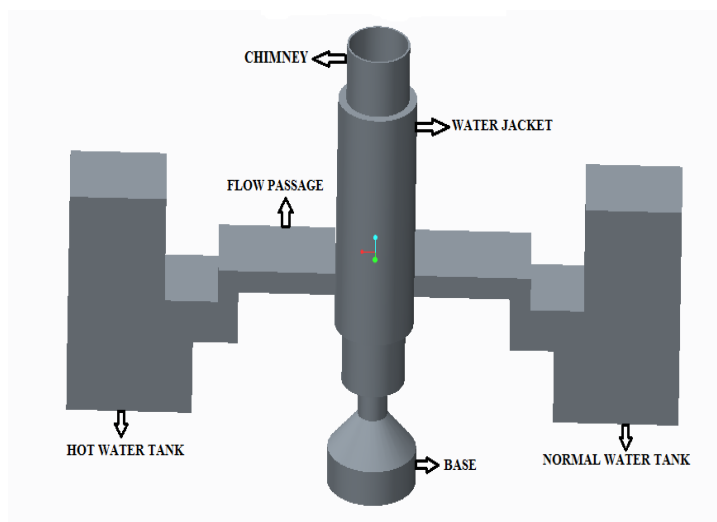10. Dynamic viscosity of air=0.0000182 m^2/s.

Fig. 1. Schematic of Actual Model

V. Code Methodology

In this project, we use 'C' program to create our code. We made our code to calculate the desired output temperature at the water jacket. Standards values are kept in mind while defining the code. All the standards are pre-defined and the actual output is obtained (Fig. 2). Following is the code used in our project.

```c
#include<stdio.h>
int main()
{
        float
a1=0.19625,a2=4.56,dt=45,k=379,dx=0.25,h,ql,x,m=1,cp=4180,rho_air=2.017,v=1,l=6,u
=0.00001182,w,Pr=0.730,b=0.4,n,g,re;
        printf("Q=h.Am.(dt)        Q=-K.Am(dt/dx)\n\n");
        printf("h.Am.(dt)=K.Am(dt/dx)     (NEGLECT THE NEGATIVE)\n\n");
        printf("d=0.75 meter\nAm=(A0-Ai)/ln(A0/Ai)\nRo=0.75 m\nRi=0.5 m\n");
        printf("dt=(70-25)==>45\nK=379 w/mk\ndx=10*10^-3\n\n");
        h=(k)/(dx);
        printf("Convective heat transfer h=%f watt/m.sq.-K\n\n",h);
        printf("Q(loss)=h.A.dt\n");
        ql=h*a1*6*dt;
        printf("Heat loss Q(loss)=%f Joule\n\n",ql);
        printf("m=1\ncp=4.18*10^3 J/kg-K\nt=(70-x)\n");
        x=70-(ql/(m*cp));
        printf("Temperature of water jacket==>%f celcius\n\n",x);
        printf("Outlet temperature of air t=%f\n\n",(70-x));
        printf("rho_air=2.017 kg/m.cube\nVelocity of air v=1 m/sec.\nL=6
meter\nDyanamic viscosity u=1.182*10^-5 \n");
        w=(rho_air*v*l)/u;
        printf("Reynold number without water jacket=%f   (Turbulent)\n\n",w);
        printf("Nu=h.L/k\nNu=(0.0233)*Re^0.8*Pr^0.4\n");
        n=(h*l)/k;
        g=n/(0.023*pow(Pr,b));
        re=pow(g,1.25);
        printf("Reynold number with water jacket=%f   (Turbulent)\n\n",re);
        return(0);
}
```

```
Q=h.Am.(dt)          Q=-K.Am(dt/dx)

h.Am.(dt)=K.Am(dt/dx)       (NEGLECT THE NEGATIVE)

d=0.75 meter
Am=(A0-Ai)/ln(A0/Ai)
Ro=0.75 m
Ri=0.5 m
dt=(70-25)==>45
K=379 w/mk
dx=10*10^-3

Convective heat transfer h=1516.000000 watt/m.sq.-K

Q(loss)=h.A.dt
Heat loss Q(loss)=80329.054688 Joule

m=1
cp=4.18*10^3 J/kg-K
t=(70-x)
Temperature of water jacket==>50.782524 celcius

Outlet temperature of air t=19.217476

rho_air=2.017 kg/m.cube
Velocity of air v=1 m/sec.
L=6 meter
Dyanamic viscosity u=1.182*10^-5
Reynold number without water jacket=1023857.812500   (Turbulent)

Nu=h.L/k
Nu=(0.0233)*Re^0.8*Pr^0.4
Reynold number with water jacket=6941.331543   (Turbulent)
```

Fig. 2. Output of code

I. Working

      The working of our project is very simple, *i.e.,* various factories such as glass factory, boilers, sugar factory, furnaces, etc. produce flue gases into the atmosphere through chimneys. So, we are setting up a water jacket surrounding the chimney which will be full of water. After setting up, the waste exhaust flue gases are made to flow through the heat exchanger unit. The temperature of flue gases at the exhaust is initially very high. Due to the flow of hot gases through a heat exchanger, there is an increase in temperature of water which is circulated from feed pump via the heat exchanger to water jacket. Water gets heated and gains temperature through conduction from hot exhaust gases, *i.e.,* waste heat is recovered and the flue gases are exhausted at reduced temperature [6-8]. The temperature of exhaust gases is considerably reduced; this also helps to control global warming. Due to recovery of energy, there will be a considerable reduction in fuel (such as CNG, LPG and other primary fuels) required to heat the water. Also, after that lukewarm or somewhat hot water is transferred to tank through motor which is transferred to household and commercial applications. It can also be used in boilers to work as a pre-heater in household, where it can be used for various purposes such as bathing, washing utensils and clothes, etc.

II. Applications

1. Waste heat of medium (120-650 °C) and high (>650 °C) temperature could be used for the generation of electricity or mechanical work via different capturing processes [9-11].
2. Waste heat recovery system can also be used to fulfill refrigeration requirements of a trailer (for example): The configuration is easy as only a waste heat recovery boiler with absorption cooler is required. Furthermore, only low pressures and temperatures needed to be handled.
3. Hot water can also be used for medical purposes such as sterilization of medical equipment. It can be used in household for washing clothes and bathing, and commercially it can be used in the same factories as a pre-heater which will also help in increasing its efficiency [12].
4. Usage of primary fuels will be reduced over a large extent.
5. Due to reduced exhaust gas temperature, it helps in lowering global warming.

III. Results Obtained

The proposed design of a plant layout has been analyzed. It's identified that the potential in cement, glass and automobile factories for generation of exhaust heat is the maximum.

As per calculations and research conducted, only reference standard values of all the materials are used as a sample and following results are obtained.

1. Temperature of water before entering in the water jacket = **25°C.**
2. Minimum temperature of exhaust gases entering in the chimney = **70°C.**
3. Rise in temperature exhaust gas comes in contact with water jacket = **50°C**
4. Reynolds's number for exhaust gases without using water jacket comes out to be = 10238.812500. [**TURBULENT FLOW**]
5. Reynolds's number for exhaust gases when the water jacket is used, comes out to be = 6941.331543. [**TURBULENT FLOW**]

NOTE: Value of Reynolds's number remains turbulent even when heat is extracted from exhaust gases by using a water jacket. Waste heat is successfully recovered, and our prime motto is achieved. Also, due to success of this research, various global warming gases will be greatly reduced.

IV. Conclusion and Future Scope

The waste heat energy of flue gases through chimney is recovered. This recovered heat can be utilized to generate *i.e.,* to heat the water and this water can be further used for pretreatment and conservation of various processes. Heat exchanger acts as a basic recovery device. In this application, there is an efficient utilization of heat *i.e.,* heat recovery. The approach of review of this research is towards the heat recovery technique and simple implementation for various systems in day to day life. These techniques have proven better, beneficial and eco-friendly. It is also a way and hope of energy saving.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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