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Utilization of waste heat generated from thermal power plants

Narendra Kushwah and S.K. Mahajan✉

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Abstract

The present paper describes the main features of waste heat recovery. Waste heat is heat, which is generated in a process by 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. The energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and loss minimized by adopting various measures as outlined in this paper.

Keywords: *Duct, Dumped, Slagging*

Introduction

The present communication deals with the utilization of waste heat generated from thermal power plants. Waste heat is the heat that is generated in a process by way of fuel combustion or chemical reaction (Gordon, 2001) which is then dumped in to the environment and not reused for useful and economic purpose. Boilers, Klins, oven and furnace are such examples which generate large quantity of hot flue gases. The energy lost in waste gases can not be fully recovered. Hence in the present investigation and attempt has been made to describe some of the methods which are useful to utilize waste heat generated from various sources. Some of the commercial equipmentswhich can be used to recover waste heat for others applications are Recuperator, Regenerator, Economizer, Heat wheels, Heat pipe and Waste heat recovery boiler (Nag.,1987 and Kumar, 2008).In order to evaluate the potential for waste heat recovery determination of heat quality and heat quantity are necessary. In this connection waste heat can be recovered by the mechanical equipment for different industrial processes.

Methodology for Waste Heat Recovery

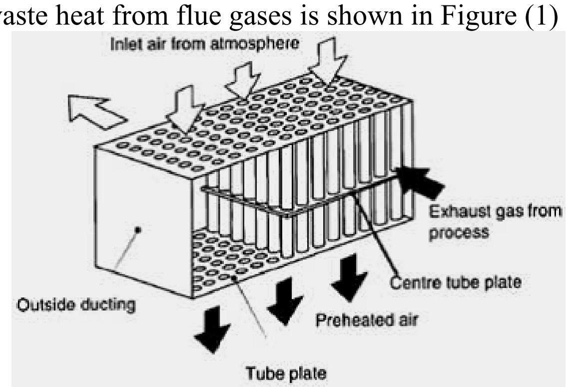
This section describes the various commercial equipments that can be used to recover waste heat for other application.

Author's Address

Mechanical Engg. Department, J.I.T, Borawan, Khargone
Former Professor of Botany, Govt. P.G. College, Khargone (M.P.)-451001

Recuperator

In a recuperator, heat exchange takes place between the flue gases and the air through metallic or ceramic walls. Duct or tubes carry the air for combustion to be pre-heated, the other side contains the waste heat stream. A recuperator for recovering waste heat from flue gases is shown in Figure (1)



Waste heat recovery using Recuperator

Regenerator (Fig. 2)

The Regeneration which is preferable for large capacities has been very widely used in glass and steel melting furnaces. Important relations exist between the size of the regenerator, time between reversals, thickness of brick, conductivity of brick and heat storage ratio of the brick.

In a regenerator, the time between the reversals is an important aspect. Long periods would mean higher thermal storage and hence higher cost. Also long periods of reversal result in lower average temperature of preheat and consequently reduce fuel economy.

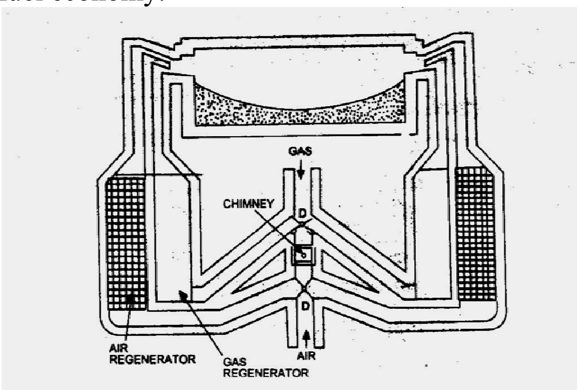


Fig. 2. Regenerator

Accumulation of dust and slagging on the surfaces reduce efficiency of the heat transfer as the furnace becomes old. Heat losses from the walls of the regenerator and air in leaks during the gas period and out-leaks during air period also reduces the heat transfer.

Heat Pipe (Fig. 3)

A heat pipe can transfer up to 100 times more thermal energy than copper, the best known conductor (Kumar, 1985). In other words, heat pipe is a thermal energy absorbing and transferring system and have no moving parts and hence require minimum maintenance.

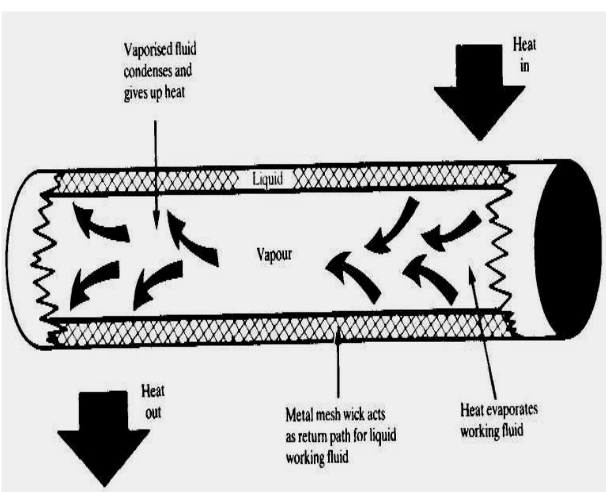


Fig. 3 : Heat Pipe

The Heat Pipe comprises of three elements – a sealed container, a capillary wick structure and a working fluid. The capillary wick structure is integrally fabricated into the interior surface of the container tube and sealed under vacuum. Thermal energy applied to the external surface of the heat pipe is in equilibrium with its own vapor as the container tube is sealed under vacuum. Thermal energy applied to the external surface of the heat pipe causes the working fluid near the surface to evaporate instantaneously. Vapor thus formed absorbs the latent heat of vaporization and this part of the heat pipe becomes an evaporator region. The vapor then travels to the other end of the pipe where the thermal energy is removed causing the vapor to condense into liquid again, thereby giving up the latent heat of the condensation. This part of the heat pipe works as the condenser region. The condensed liquid then flows back to the evaporated region.

Waste Heat Boilers (Fig. 4)

Waste heat boilers are ordinarily water tube boilers (Yadav ,2003) in which the hot exhaust gases from gas turbines, incinerators, etc., pass over a number of parallel tubes containing water. The water is vaporized in the tubes and collected in a steam drum from which it is drawn off for use as heating or processing steam.

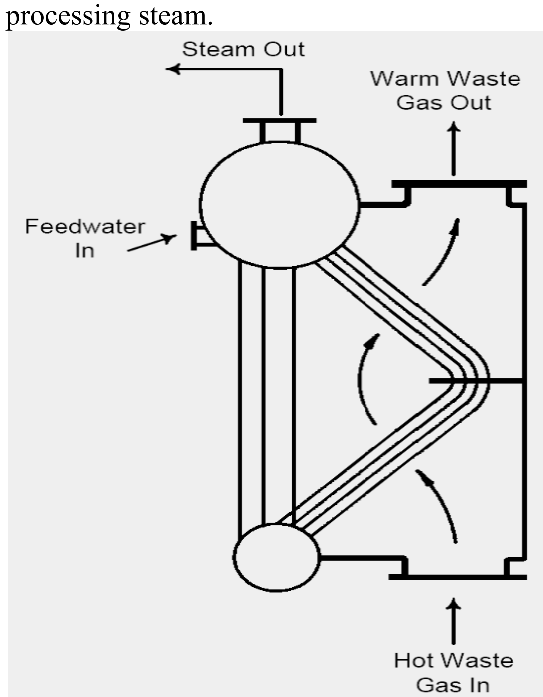


Fig. 4: Two-Pass Water Tube Waste Heat Recovery Boiler

Because the exhaust gases are usually in the medium temperature range and in order to conserve space, a more compact boiler can be produced if the water tubes are finned in order to increase the effective heat transfer (Kumar, 1985) area on the gas side. The pressure at which the steam is generated and the rate of steam production depends on the temperature of waste heat. The pressure of a pure vapor in the presence of its liquid is a function of the temperature of the liquid from which it is evaporated. The steam tables tabulate this relationship between saturation pressure and temperature. If the waste heat in the exhaust gases is insufficient for generating the required amount of process steam, auxiliary burners which burn fuel in the waste heat boiler or an after-burner in the exhaust gases flue are added. Waste heat boilers are built in capacities from 25 m^3 almost 30,000 m^3 / min. of exhaust gas.

Results and Discussion

This section explains how to evaluate the potential for waste heat recovery along with examples.

Determining the waste heat quality

When recovering the waste heat, the quality of waste heat must be considered first.

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, it is absolutely necessary that there should be some use for the recovered heat. Typical examples of use would be preheating of combustion air, space heating, or pre-heating boiler feed water or process water. 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 generation.

Quality, potential and their uses

In considering the potential for heat recovery, it is useful to note all the possibilities, and grade the waste heat in terms of potential value as shown in the Table 1.

Table 1: Waste source and quality

S.No.	Source	Quality
1.	Heat in flue gases.	The higher the temperature, the greater the potential value for heat recovery
2.	Heat in vapour streams.	As above but when condensed, latent heat also recoverable.
3	Convective and radiant heat lost from exterior of equipment	Low grade – if collected may be used for space heating or air preheats.
4.	Heat losses in cooling water.	Low grade – useful gains if heat is exchanged with incoming fresh water.
5.	Heat losses in providing chilled water or in the disposal of chilled water.	a) High grade if it can be utilized to reduce demand for refrigeration. b) Low grade if refrigeration unit used as a form of heat pump.
6.	Heat stored in products leaving the process	Quality depends upon temperature.
7.	Heat in gaseous and liquid effluents leaving process.	Poor if heavily contaminated and thus requiring alloy heat exchanger.

Recovery potential for different industrial processes

Waste heat can be recovered from various industrial processes. A distinction is made between high, medium and low temperatures of waste heat.

Table 2 gives the temperatures of waste gases from industrial process equipment in high temperature range. All these results from direct fuel fired processes.

Table 2 Typical waste heat temperature at high temperature range from various sources

Types of Device	Temperature, °C
Nickel refining furnace	1370 –1650
Aluminium refining furnace	650-760
Zinc refining furnace	760-1100
Copper refining furnace	760- 815
Steel heating furnaces	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

Table 3 gives the temperatures of waste gases from industrial process equipment in the medium temperature range. Most of waste heat in this temperature range comes from the exhaust of directly fired process units.

Table 3 Typical waste heat temperature at medium temperature range from various sources

Type of Device	Temperature, °C
Steam boiler exhausts	230-480
Gas turbine exhausts	370-540
Reciprocating engine exhausts	315-600
Reciprocating engine exhausts (turbo charged)	230- 370
Heat treating furnaces	425 - 650
Drying and baking ovens	230 - 600
Catalytic crackers	425 - 650
Annealing furnace cooling systems	425 - 650

Table 4 lists some heat sources in the low temperature range. In this range it is usually not practical to extract work from the source, though steam production may not be completely excluded if there is a need for low-pressure steam. Low temperature waste heat may be useful in a supplementary way for preheating purposes.

Table 4 Typical waste heat temperature at low temperature range from various sources

Source	Temperature, °C
Process steam condensate	55-88
Cooling water from:	
Furnace doors	32-55
Bearings	32-88
Welding machines	32-88
Injection molding machines	32-88
Annealing furnaces	66-230
Forming dies	27-88
Air compressors	27-50
Pumps	27-88
Internal combustion engines	66-120
Air conditioning and refrigeration condensers	32-43
Liquid still condensers	32-88
Drying, baking and curing ovens	93-230
Hot processed liquids	32-232
Hot processed solids	93-232

Determining the Waste Heat Quantity

In any heat recovery situation it is essential to know the amount of heat recoverable and also its usage.

The total heat that could be recovered can be calculated using this formula:

$$Q = V \times \rho \times C_p \times \Delta T$$

Where,
Q is the heat content in kcal.
V is the flow rate of the substance in m^3/hr.
ρ is the density of the floe gas in kg/m^3.
Cp is the specific heat of the substance in kCal/kg°C.
ΔT is temperature difference in °C

Conclusion

Heat recovery technology is an excellent tool to conserve energy. The waste heat recovery brings in related economic benefits for the local community and would lead to sustainable economy and industrial growth in the region. The waste heat recovery activity would be able to replace electricity generated by grid-connected power plant thus saving further exploitation and depletion of natural resources – coal, or else increasing its availability to other important process.
The electricity generated from the waste heat recovery would help to reduce carbon dioxide emission and other associated pollution at thermal power plants. By placing waste heat recovery power plants in heavy industries which are generating huge amount of waste heat, we can reduce 10-12 % of Global Warming effect. This will helpful for Nation too. This project can be treated as the efficient method of utilization of waste gases for production of electrical energy and one can hope that the “Waste Heat Recovery” will play even great roll in industrial development of twenty first century.

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