WASTE HEAT RECOVERY POWER PLANTS IN CEMENT INDUSTRY

S K Gupta / S K Kaul

Holtec Consulting Private Ltd., Gurgaon, India

ABSTRACT

In a cement plant, nearly 35% heat is lost, primarily from the preheater and cooler waste gases. This corresponds to around 70 to 75 MW of thermal energy. This energy can be tapped by installing a **Waste Heat Recovery Power Plant (WHRPP).**

Size of WHRPP is influenced by the moisture content present in raw material and fuel (coal). Even after considering heat for drying-off nominal moisture content, around 30 kwh/ t clinker of power can still be generated by WHRPP, i.e. say, 7.5 MW for a 6,000 tpd plant.

The cost of installation of WHRPP is around Rs. 10 crores per MW, and the operating cost is less than Rs. 0.5/ unit (excluding interest & depreciation).

For a 6000 tpd plant, around 70,000 t/annum of CO_2 can be reduced. Installation of WHRPP also reduces carbon dioxide generation.

Based on the experience of the cement/ captive power plants, this paper deals with the various issues involved in decision-making, as well as in implementation of WHRPP in cement industry.

1. INTRODUCTION

1.1 Energy crisis on one hand, and increase in generation of CO_2 on other hand, are the two major issues, which are being discussed worldwide, these days. In addition, due to the perpetual increase in energy prices, one has to think of ways & means of conserving depleting fossil fuels/ reducing generation of CO_2. All possible means of saving energy, which otherwise, went un-arrested/ un-used in the energy intensive industries, hence, are being explored.

1.2 In cement industry, energy corresponds to the major cost head of operating expenses. An appreciable amount of energy can be conserved by optimizing the plant operation, and by recovering waste heat from the preheater and cooler gases. This saved energy can be converted into electrical energy, by installing waste heat recovery boilers/ turbine.

1.3 This paper deals with the various aspects of installing **WASTE HEAT RECOVERY POWER PLANTS (WHRPP),** in cement industry.

2. WASTE HEAT SOURCES AND THEIR POTENTIAL

2.1 Heat Balance

01 In the process of clinkerisation, it is seen, that around 55% of the total heat input, is only utilised for clinkerisation. Waste gases account for around 35% of total heat input.

Heat balance (per kg. of clinker) for a typical cement plant, is depicted in **Table - 1** :

Description	5-Stage Preheater		6-Stage Preheater	
	Kcal / Kg	**%**	**Kcal / Kg**	**%**
Theoretical heat requirement	410	52.1	410	53.5
Exhaust gas heat (preheater)	163	20.8	148	19.4
Exhaust air heat (grate cooler)	116	14.7	116	15.1
Radiation heat loss (preheater, kiln, cooler)	76	9.6	71	9.2
Heat in discharged clinker	21	2.6	21	2.7
TOTAL	**786**	**100**	**766**	**100**
Heat input from fuel fired, viz coal	734	-	714	-

Table - 1: Heat Balance for a Typical Cement Plant

02 The waste heat potential derived from heat balance of a typical 6000 tpd cement plant, in terms of thermal energy (in MW), is as given in **Table - 2** :

Description	**5-Stage Pre-heater**	**6-Stage Pre-heater**
Total power input	213 MW	207 MW
Power used in clinkerisation	111 MW	111 MW
Power lost	102 MW	96 MW
- Pre-heater gases	- 44 MW	- 40 MW
- Cooler gases	- 31 MW	- 31 MW
- Radiation	- 21 MW	- 19 MW
- Clinker heat	- 6 MW	- 6 MW

Table - 2 : Waste Heat Potential in terms of Thermal Energy

Thus, 70 MW of thermal energy is available for exploitation, in various ways.

2.2 The various avenues for the exploitation of this available waste heat energy are :

- Drying of raw material(s) and coal
- Generation of electricity
- Heating of equipment/storage hoppers to facilitate easy handling of sticky material(s)
- Heating of building(s) in cold countries
- Heating of water
- Generation of steam for oil handling installation and driving some auxiliaries
- Air conditioning/deep freezing by adsorption process
- Scavenging air for bag filters

Principally, direct utilization of the waste heat for drying of raw material and coal, yields the maximum efficiency, and should be given the first preference. However, even after meeting the nominal drying requirement, substantial heat is available in waste gases. Electricity generation from surplus waste heat is the next preferred option, out of the above-mentioned avenues.

Generation of electricity by using waste heat of exhaust gases, has been discussed further, in this paper.

3. SIZING OF WASTE HEAT POWER GENERATION SYSTEM

3.1 As mentioned above, normally, the first priority for utilization of the waste heat is, for the drying of raw materials and coal, since the efficiency of energy conversion system, from thermal to electricity, like in WHRPP, is as low as 18 to 20% (conversion losses are very high). Second priority is given to the power generation.

Though, incorporation WHRPP, increases complexity of the system, to some extent, it is still worth considering, as power is generated at much lower cost, than that available from Grid.

As a broad criteria, at places where un-interrupted power supply is available at cheaper rates, it may not be economical to install WHRPP. Places where electricity rates are high, or there are frequent power interruptions, use of WHRPP is very lucrative.

3.2 Moisture in raw materials has an important influence on the sizing of the power generation plant. This fact is depicted in **Fig -1**. It shows that the waste heat recovery power plant is sized based on the different moisture conditions in raw material / coal i.e. the outlet gas temp from waste heat recovery system is decided, so as to cater to the moisture drying requirement.

The moisture content in the raw material increases during rainy season. Quantum of moisture, and the duration, varies from place to place. The sizing of WHRPP plant can be done for any of the following conditions:

01 **Fig - 1(a)** shows WHRPP matched to minimum moisture content in raw material. It can, therefore, run on full load only, during the extremely dry season. Whenever moisture is more than min. value, power generation would need to be curtailed, so that waste heat is first utilized for drying.

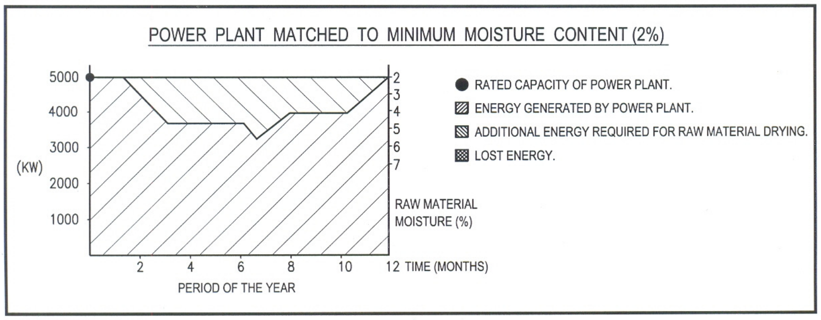

Fig - 1 (a) : Power Plant Matched to Minimum Moisture Content (2%)

02 **Fig - 1(b)** shows the WHRPP matched to the average moisture conditions. The investment cost in this case, shall be relatively lower but the plant will not be able to recover the full amount of waste heat during dry season. Also, during extremely wet season, plant will have to be run at reduced capacity.

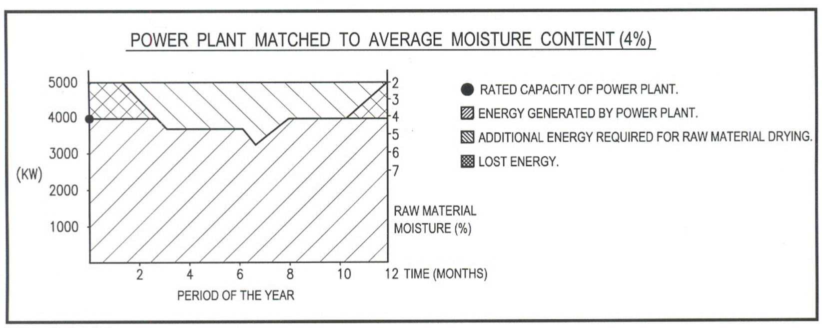

Fig -1(b) : Power Plant Matched to Average Moisture Content (4%)

03 **Fig - 1(c)** shows WHRPP matched to maximum moisture content. Though investment will be lowest, a considerable heat shall be lost in dry and semi-dry seasons.

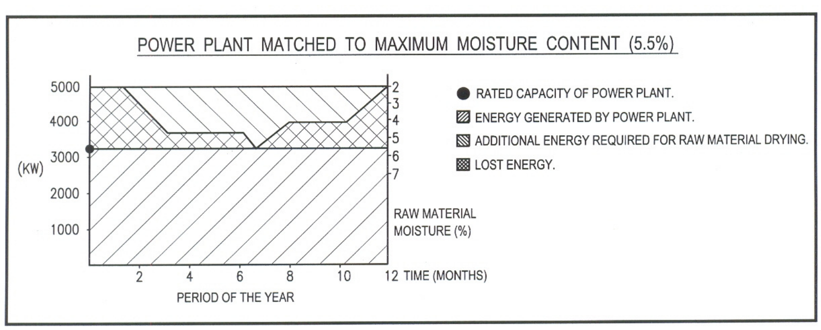

Fig -1(c) : Power Plant Matched to Maximum Moisture Content (5.5%)

3.3 A techno-economic study of the above three alternatives for a particular plant, would decide the size of the WHRPP. The technology and system selection for WHRPP should be flexible, so that it is able to meet the fluctuating heat requirement for the raw material/ coal drying, depending upon the varying moisture content in the raw material/ coal.

Besides the techno-economic study, weightage must be given to the fact that a size of WHRPP, which can be self sufficient for running the main clinkerisation unit on its own, shall provide a steady and un-interrupted kiln operation.

3.4 As shown in **Fig - 2**, as a rule of thumb, around 30 kwh of electricity can be generated per tonne of clinker, from a 5-stage preheater kiln, by utilising the waste heat of exhaust gases from Preheater & Grate Cooler. It is based on the normal operating conditions, and partly, accounting waste heat for drying-up of moisture in the raw material and coal (av. moisture).

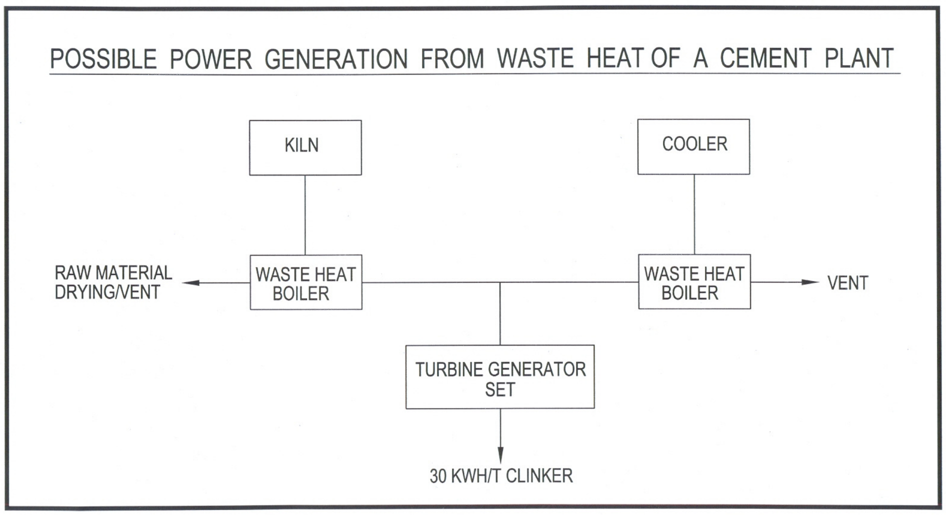

Fig - 2 : Possible Power Generation from Waste Heat of a Cement Plant

Based on the above, amount of power which may be generated for the standard sizes of plants, is :

- 4500 tpd :: 5.6 MW
- 6000 tpd :: 7.5 MW
- 10,000 tpd :: 12.5 MW

4. <u>CARBON DIOXIDE REDUCTION BY WHRPP</u>

With installation of WHRPP, the requirement of the power from captive power or utility grid, is reduced. Thus, WHRPP can reduce about 70,000 tons of CO_2 emission per annum, for a 6000 tpd plant.

There are a lot of incentives, in the form of **Carbon Credits**, to reduce carbon foot-print, in almost all the countries, which can be earned by installing WHRPP.

5. BROAD SYSTEM CONCEPT OF WASTE HEAT RECOVERY POWER PLANT

5.1 Working Cycle

Most of the WHRPP supplied in the industry, employ **Rankine Steam Cycle,** as depicted in **Fig - 3**. The technology is well established. The gases from the preheater and cooler are passed through the boiler to generate steam. The steam drives the turbine for generation of electricity. The exhaust steam from turbine, is cooled through air / water cooled condenser, and recycled back to the boiler.

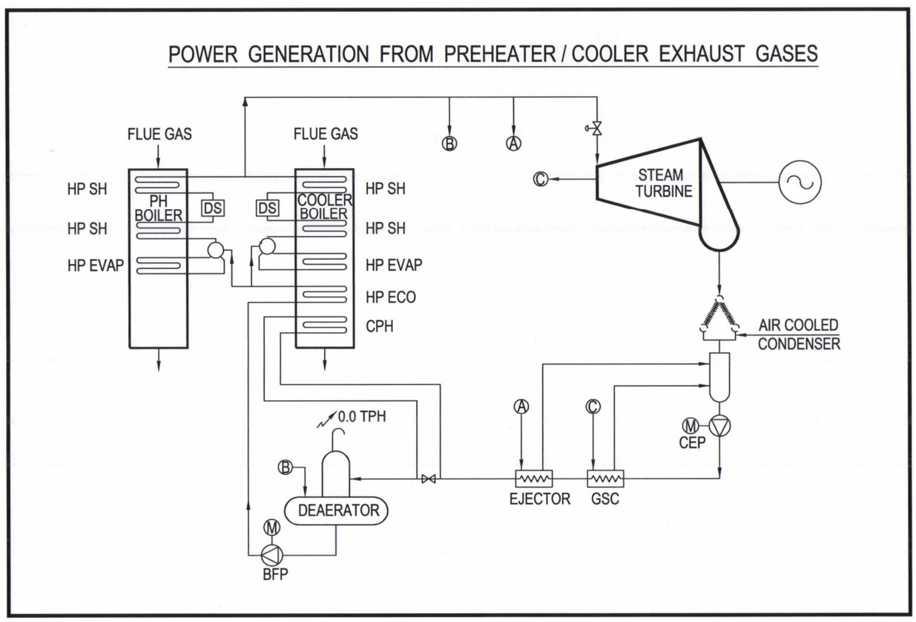

Fig - 3 : Power Generation from Preheaer/ Cooler Exhaust Gases

Organic Rankine Cycle - is another technology, which can be adopted. In this cycle, organic fluid is used as the working fluid, which exchanges heat, and is vaporized by the flue gases from the cooler. The organic vapor then, expands in the Turbine, condenses, and then, is recycled. Since Organic cycle is suitable for the clean gases, it as such, can be used only for the cooler EP exhaust gases only.

5.2 Considerations for Installation of WHRPP

01. In the PH gases, dust load is high, and is sticky. In cooler, is very abrasive. Proper care hence, has to be taken for selection of the various equipment especially, dust dislodging system, dampers, velocity profile in boiler, wear liners, configuration of the boiler, turbine and condenser etc.

02. While introducing WHRPP, the additional pressure drop is there in the system. PH and cooler fans hence, have to be sized accordingly.

03. In actual practice, the kiln performance may vary from time to time, resulting in fluctuating exhaust gas conditions. As such, the waste heat boiler and the connected turbine generator set, should be suitably designed/selected, to take care-of such fluctuations.

6. SOME REFERENCES

References of some of the projects under implementation, are given in **Table - 3** below:

Sn	Cement Plant Capacity (tpd)	No. of Boilers		WHR Capacity (MW)
		Preheater	Cooler	
1	1 x 6500	2	1	6.7
2.	1 x 4500	2	1	7.2
3.	1 x 7000	2	1	7.3
4.	1 x 5000 + 1 x 10,000	1	2	10.0
5.	1 x 11,000	2	1	10.8
6.	1 x 3000 + 1 x 4000 + 1 x 5100	4	3	12.0
7.	1 x 8200	2	1	12.5
8.	4 x 3500 + 1 x 5000	3	3	13.2
9.	1 x 10,000	2	1	13.5
10.	1 x 6000 + 1 x 11,000	3	2	15.2

Note: 1. Project cost is approx. Rs. 10 crores per MW.
2. Operating cost, excluding interest & depreciation, is Rs. 0.5/ Kwh

Table - 3: Project References

7. CONCLUSION

Cement Industry being a power intensive industry, one has to think in terms of energy optimisation and savings. **Waste Heat Recovery Power Plants**, contribute significantly, to the electrical energy saving (to the tune of 25%).

The reduction in CO_2 emission, makes it environmental friendly.

Installation of the waste heat recovery plant has to be tackled as a system approach, rather than considering cement plant and WHRPP operations, independently.

The **Waste Heat Recovery Technology,** as any other technology, is in an incessant phase, and many more innovations, in terms of equipment and applications, may be expected in future.