Cogeneration of Power Utilising Waste Heat in Cement Manufacture: Technological Perspectives

Summary

In the dry process cement plants nearly 40 percent of the total heat input is rejected as waste heat from exist gases of preheater and grate cooler. This waste heat can be effectively utilized for electric power generation. Cogeneration of power besides mitigating the problem of power shortage also helps in energy conservation as well as reducing green house gas emissions.

Cogeneration systems have been successfully operating in cement plants in India, China and South-east asian countries. In existing plans cogeneration technologies based on bottoming cycles have potential to generate upto 25-30 percent of the power requirement of a plant. However, the Indian cement industry is yet to make a beginning in this direction due to existence of various technical and financial constraints.

The paper discusses about the various technologies and schemes for cogeneration, recent developments and evaluation of these technologies/ schemes. It also highlights the various technical considerations which should be studies in depth for design of heat exchanger and the cogeneration scheme for installation of cogeneration system in a cement plant. Further, a case study recently carried out by NCB in a 1.2 million tonne per annum capacity dry process cement plant for techno-economic viability is also presented.

1. Introduction

The rising energy cost in cement manufacture has spurred developmental efforts towards more effective energy conservation measures. Of late, to contain energy cost as well as make cement manufacture more and more environmentally benign, waste energy management, adopting cogeneration system based on waste heat recovery, is gaining importance. Such a development assumes considerable significance and potential in Indian cement industry in order to achieve cost economy and environmental compatibility.

2. Technology status of Indian Cement Industry

The Indian cement industry has been keeping pace with new technology and there has been an all round Upgradation of technology in all sections of production. The introduction of precalciner technology had made it possible to increase the installed capacity of the plants to a great extent and single kilns of more than 7000 tpd capacity are in operation in India at present. In addition, vertical roller mills for limestone and coal grinding as well as for clinker and slag grinding, roller presses for limestone, clinker and slag grinding, 6-stage preheaters and air beam technology for grate cooler, improve instrumentation, expert systems, use of high grade fuel in place of low grade fuel etc. has enabled drastic reduction in energy consumption and increased productivity. The consumption of thermal energy of 680-700 kCal/kg clinker in pyroprocessing and electrical energy of 70-75 kWh/t of cement for modern cement plants are comparable to world's best levels of energy performance. However, the Indian cement industry is yet to make a beginning for the adoption of cogeneration technology due to existence of various technical and financial barriers.

3. Cogeneration Scenario Overseas

Cogeneration systems are well established in cement industry the world over with Japan, China and South-east asian countries taking the lead in this development. In Japan alone, there are about 33 cogeneration units with a generating capacity of about 200 MW, which is about 25 percent of the power requirement of these units. Most of the large cement plants in China too are equipped with cogeneration units generating 22 to 36 kWh/ t power sufficient for 25-30% of the total power requirement. The power so generated is considered enough to operate kiln section on a sustained basis. In south east asian region, even plants with less than 200 tpd capacity have viable cogeneration systems contributing to energy efficiency and pollution control.

4. Scope for cogeneration in Indian Cement Plants

The studies carried out by NCB in a large number of cement plants have indicated the following scenario:

4.1 Waste Heat Availability

In the dry process plants, nearly 40 percent of the total heat input is rejected as waste heat from the exist gases of preheater and cooler. The quantity of heat lost from preheater exist gases ranges from 180 to 250 kCal/ kg clinker at a temperature range of 300 to 400^{o}C. In addition, 80 to 130 kCal/ kg clinker heat is lost at a temperature range of 200 to 300^{o}C from exist gases of grate cooler. These waste heats have various applications such as drying of raw materials, coal/ lignite, slag, preheating air required for coal combustion and cogeneration. In most of the plants part of the waste heat is utilized for drying of raw material and coal, but even after covering the need for drying energy in most of the cases, there is still waste heat available which can be utilized for electrical power generation.

4.2 Potential for Cogeneration

Cogeneration technologies based on bottoming cycle appear to be an attractive proposition for Indian cement plants and have the potential to generate upto 25-30 percent of the power requirement of a one million tonne capacity plant. Combined cycle cogeneration using a coal based thermal power plant is also worth considering with grid power cut/ failure being so frequent ad its mitigation is very desirable. A 3000 tpd plant with reheater exist gas temperature of 350-400^{o}C has a potential to generate about 4.5 MW power by conventional type waste heat boiler with steam turbine. The potential for cogeneration of power could be increased further through supplementary firing.

NCB study of 20 cement plants indicates cogeneration potential ranging from 3.0 to 5.5 MW in different plants depending upon availability of gases and number of PH stages, temperature of gases, use of gases for drying of raw material and coal etc. (Table 1).

	Plant Detail	Ph exist Gas		Cooler Exit Gas		Cogen. Poten. Mw
		Flow (Nm^3/ Hr)	Temp (^{o}C)	Flow (Nm^3/ Hr)	Temp (^{o}C)	
A	3000 TPD, 4ST (SP) 4500 TPD, 5ST (PC)	186000 350000	415 320	258000 250000	250 250	4.6 5.5
B	33000 TPD, 4ST (PC)	289167	360	129245	230	4.5
C	3000 TPD, 4ST (SP)	194000	350	276800	220	4.0
D	3300 TPD, 6ST (PC)	187800	295	232800	245	3.2
E	3300 TPD, 6ST (PC)	233750	300	165000	250	3.2
F	2x2800 TPD, 6ST (PC)	170000	300	130000	250	4.4
G	2x1700 TPD, 5ST (PC)	157000	320	120000	250	4.2
H	3300 TPD, 4 ST (PC)	148000	390	154000	290	4.2
I	2250 TPD, 5ST (PC)	148000	378	149000	260	3.2
J	2500 TPD, 4ST (PC)	172400	365	120000	230	3.0
K	2225 TPD, 5ST (PC)	88000	300	142000	220	3.4
L	2225 TPD, 5ST (PC)	88000	300	142000	220	
M	3250 TPD, 6ST (PC)	225000	295	240000	230	3.5
N	3000 TPD, 4ST (PC)	210000	360	180000	220	3.7
O	3700 TPD, 4ST (PC)	151000	280	373000	220	3.2
P	2000 TPD, 5ST (PC)	183000	330	210000	240	3.4

Studies further indicate that there exists about 160 MW of cogeneration potential in about 40 cement plants having a minimum installed capacity of 1 million tonne per annum.

4.3 Reduction of Green House Gas Emissions

The cement manufacture is a high temperature sintering process involving chemical reaction. The limestone ($CaCO_3$) decomposes into CaO and CO_2 during this process resulting in release of CO_2 into the atmosphere. It is estimated that one tonne of $CaCO_3$ release 0.44 tonne of CO_2. Further, the coal is used as a fuel in cement manufacture and use of coal results in discharge of CO_2 to the atmosphere to the tune of about 2.2 tonnes CO_2 per tonne of coal. Further, the captive diesel and thermal power stations also contribute to generation of green house gas emissions. It is worth mentioning that every MWh generated in coal based thermal power plant results in release of about 1.12 tonnes of CO_2 emission. The emission of CO_2 from Indian cement industry is estimated to be about 97.4 million tonnes in the year 1999-2000. The cogeneration potential of 160 MW is expected to be about 97.4 million tonnes in the year 1999-2000. The cogeneration potential of 160 MW is expected to reduce the GHG emission by about 1.5 million tonnes CO_2 per year (a total of 30 million tonnes in its life cycle of 20 years).

5. Barriers in adoption of cogeneration technology

The main constraints identified for non-adoption of the technology by Indian cement industry can be broadly classified into three main categories, viz.

- Technical barriers
- Financial barriers and
- Institutional barriers

The details under each category are as under:

Technical/ Technological Barriers

- Non availability of proven technology indigenously.
- Design of waste heat recovery boiler suitable to withstand high dust load in the waste gases.
- High performance risk due to lack of demonstration.

Financial Barriers

- Large capital requirement and financial constraints.
- Viability remains to be established.
- High cost of technology and access to funds.
- Depressed cement marketing scenario.

Institutional Barriers

- Lack of incentives for adoption of technology.
- Lack of capacity building efforts resulting in lack of operating experience and confidence level.

Nevertheless, the Indian cement industry is quite keen to adopt the cogeneration systems to achieve the national objectives of energy conservation and pollution control.

6. Technical consideration for cogeneration schemes

The various considerations for the design of appropriate cogeneration scheme for a particular plant will need in-depth study of the following technical details:

6.1 Availability of Waste Heat for Cogeneration

The heat available for recovery entirely depends on the design of the cement plant and its configuration. The pyroprocess system design itself plays a crucial role. The parameters that are important are plant capacity, heat consumption, type of system such as preheater kiln or precalciner kiln, either with one string or two strings of preheater, number of stages of preheater (4,5 or 6 stages) and type of clinker cooler. Next aspect is the drying and grinding system utilized for raw materials and fuel. Some of the crucial parameters are the quantity of material to be ground their moisture content, their grindability, type of grinding system etc.

6.2 Location of Waste heat Boiler

Another factor that could be important is the location of heat recovery unit in the process circuit, namely before or after process fan, in the down-comer at an elevated position or at ground level, and before or after the pollution control device such as electrostatic precipitator or a bag filter. These could play a role in estimating the heat that could be recovered as well as in the design and layout of plant.

Further, various options are available for recovery of heat from cooler excess air. Some of them are as follows; (i) incorporating a waste heat recovery unit before the cooler pollution control device (ii) incorporating the recovery unit after the pollution control device and before/after the cooler ID fan (iii) pre-circulating a part of the cooler outlet excess air that is being let out to atmosphere back to cooler air fans, and (iv) including an auxiliary furnace with an extra fuel firing and utilising this hot air for combustion to enhance the recovered heat.

These various options have different merits and they have to be thoroughly evaluated before finalizing any system.

6.3 Suitability of Waste Heat Recovery Boiler

The waste gases from preheater and cooler exhaust contain high dust concentrations. While the dust concentration in PH gases can be upto 100-120 gm/Nm^3, it can be of the order of 60-70 gm/Nm^3, in the grate cooler exhaust. Accordingly the waste heat recovery boiler should be able to withstand high dust loads. Moreover, the operating conditions in cement plants require design of waste heat recovery boilers which should be able to withstand the problems of heavy coating formation, as the raw meal dust tends to adhere to the heat exchanging surfaces, resulting in drastic reduction of capacity and the wear of tubes due to coarse clinker particles. As such, the characterization of the dust in the waste gases with regard to particle size, stickiness, abrasiveness should be studied in detail for evaluation of the suitability/ design of the waste heat recovery boiler.

6.4 Maximum Flue Gas Temperature

There is a limit at the upper scale of the temperature of the waste gases for cement plant application as the flue gases contain dust comprising alkalies and salts. These components make the dust sticky and aggressive at temperatures more than 600^{o}C which is considered as the highest gas temperature for steam production. The material used for waste heat boiler tubes and plates is also not too expensive if the gas temperature is less than 600^{o}C.

6.5 Quantity of Heat Recovery

Ideally, higher the temperature of the gases, the better the heat transfer efficiency, as the gases at higher temperatures can be cooled down to a much lower temperature in the waste heat recovery boiler. For example, in one particular application, the gases with 600^{o}C, can be cooled down to approximately 150^{o}C whereas gases with 330^{o}C can be only be cooled down to 195^{o}C. Keeping the minimum temperature difference between the gas temperature and water temperature – 20K, power generation in MW and gas outlet temperature at the end of the heat exchanger is shown in Fig.1. The critical parameters such as steam flow rate, pressure and superheat gas outlet temperature are to be optimized for each plant in order to achieve maximum power generation.

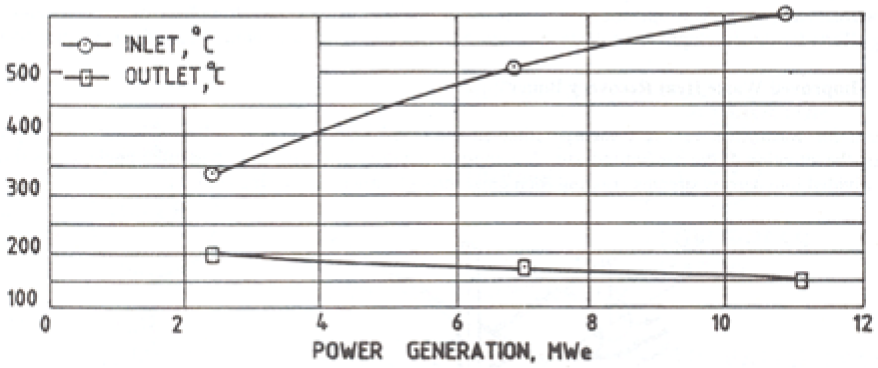

Fig. 1: Relationship between Power Generation and Gas Temperature

6.6 Type of Boilers, Turbine and Condensers

Waste heat boilers are typically huge rectangular boxes containing economiser, evaporator and superheater coils. Since low grade heat recovery is only possible in a cement plant, boilers are of large surface area. The source of heat being from dusty gases, only plain tubes or tubes with fans of low frequency can be provided in the coils. Normally plain tubes are used for preheater gases and finned tubes are used for cooler exhaust gases. Sometimes supplementary firing is also needed for additional steam generation. Depending on the space availability, horizontal or vertical configuration is adopted for a boiler. Same constraint also determines the water/ steam circulating system used for a unit i.e. natural or forced/ assisted circulation.

In the conventional rankine cycle plants steam generated from recovered waste heat is typically applied as an injection to a back pressure or condensing type turbine.

The condenser may be water cooled or air cooled type. The selection will depend upon the type of scheme adopted and availability of required quantity of water nearby/ in the plant.

6.7 Dedusting Arrangement

The heat exchangers for exhaust gas are often exposed to heavy coating formation as the raw meal dust tends to adhere to the heat-exchanging surface. The dust that settles on the heat transfer surfaces reduces the area available and reduces heat transfer coefficients and hence the rate of transfer. So, using a proper dust removal system becomes essential. To avoid this, the heat exchangers are normally designed with straight tubes which are continuously or periodically cleaned by steam or air soot blowers, sonic waves, mechanical hammering/ rapping or steel shot dispersion. Of these methods the latter two have proved to be most effective.

6.8 Availability of Water

Water used for waste heat boiler should be of high level of purity. This is achieved by using a demineraliser unit in the boiler circuit. Depending upon the condition of water sometimes a separate or integral condensate preheating system is also required. A stem drum and a deaerator alongwith a low pressure and a high pressure dosing system complete the circuit.

7. Recent Developments

Keeping in view the difficult operating conditions for the cogeneration system in cement plants with regards to high dust loads, characteristics of dust e.g. stickiness, abrasiveness, low temperature of exhaust gases, fluctuations in gas temperatures, stability of kiln operations etc., various machinery manufacturers/ suppliers have been continuously making efforts for the development of the technology. Some of the recent developments are discussed hereunder:

7.1 Improved Waste Heat Recovery Boiler

A system for waste heat recovery incorporating an improved heat exchanger called 'Thermowir' is presently engaging the attention of the cement industry. It comprises parallel plates fixed at a particular angle to gas flow. Gas flow is divided into narrow streams crossing each other through structural packing (Fig.2).

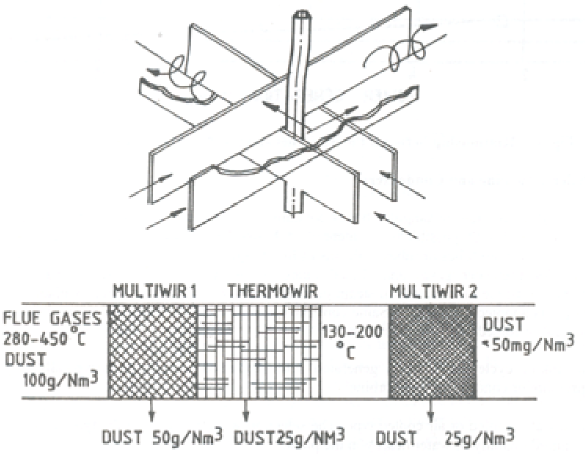

Fig. 2: Improved Waste Heat Recovery Boiler

As a result, the steams induce rotational motion in each other. The solid particles are thrown from centre of the channel to the walls due to centrifugal force. The heat transfer tube is placed exactly in the middle of the channel so that it remains almost dust free. Steam is produced in the tubes of the boiler by transfer of heat from flue gases. The other advantages of this system as compared to conventional heat exchangers/ boilers are higher efficiency and removal of 60% of the dust from the gases, thus reducing load on the existing ESP. However, this system is yet to be demonstrated on full scale set up for which efforts are presently underway.

7.2 Modified Rankine Cycle Systems

The Rankine cycle has also been improvised using binary fluid of ammonia and water as the working fluid in place of only water for improving the overall efficiency of conventional systems. This system is called 'Kalina Cycle' (Fig.3). In this system efficiency gains of upto 50% for low temperature heat sources (200-280^{o}C) and upto 20% for higher temperature heat sources have been claimed as compared to conventional Rankine cycle based power plants. Kalina cycle takes advantage of the ability of ammonia-water mixture at any given pressure to boil or condense at a 'Variable' temperature. Moreover, conventional axial flow turbines can be used in these plants as molecular weights of ammonia and water are almost similar. Further, the turbines used may be smaller in size and hence less costly as back pressure turbines can be used as condensing turbines.

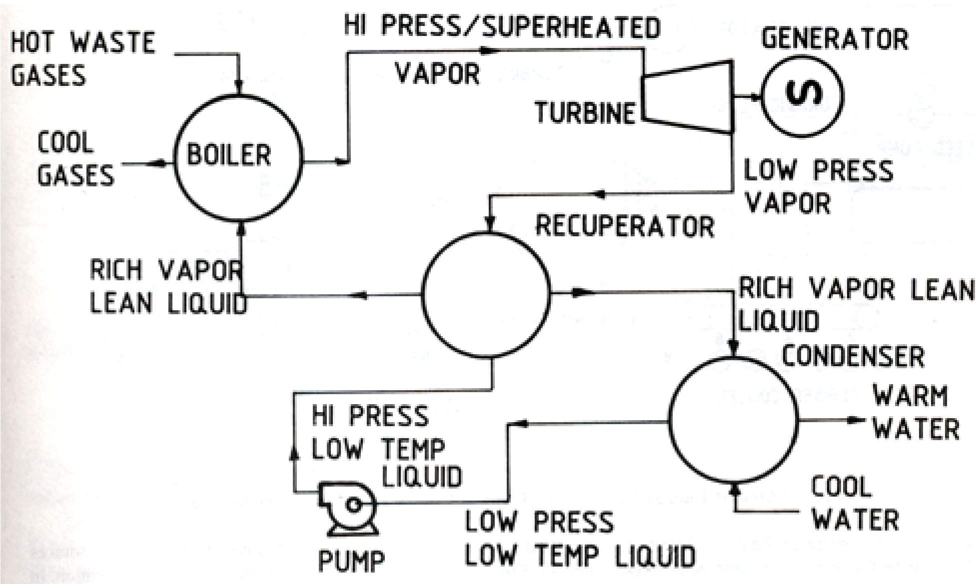

Fig. 3: Modified Rankine Cycle Power Plant

7.3 Organic Rankine Cycle

The need to replace the conventional steam cycle in the heat recovery systems of the cement has led to the introduction of the organic Rankine cycle to the industry. The fundamental principle of the organic Rankine cycle of one such system called Ormat Energy Converter (OEC) is that the working fluid driving the turbine is an organic fluid rather than steam. The organic fluid has a much lower boiling point than water, so that much lower temperature heat sources can generate organic vapor which then expands into a turbine, condenses and is recycled. The organic turbine is back pressure type and operates at low revolutions, and are consequently highly reliable, requiring minimal maintenance.

The OEC system for cement plant low temperature waste heat, such as for clinker cooler exhaust air (which are typically in the range of 220^{o}C to 300^{o}C or for 6 stage preheater gases which are typically just below 300^{o}C) is shown in Fig. 4. The exhaust air/ gases of each waste heat source enter into a waste heat recovery oil heater where they exchange heat with thermo-oil. The heated thermo-oil from each heat exchanger flows into a common thermo-oil loop into the vaporizer or a single ormat energy converter (OEC) where it exchanges heat with the organic working fluid of the OEC. The high pressure vapor of the organic fluid expands as it passes through the OEC turbine and is then condensed by air cooled condensers and recycled by a cycle pump. The cooled thermo-oil is similarly and is then condensed by air cooled condensers and recycled by a cycle pump. The cooled thermo-oil is similarly recycled. A 1.5 MW cogeneration plant based on this system has been installed at the Lengfurt plant of Heidelberger Cement, Germany utilising heat from clinker cooler exhaust.

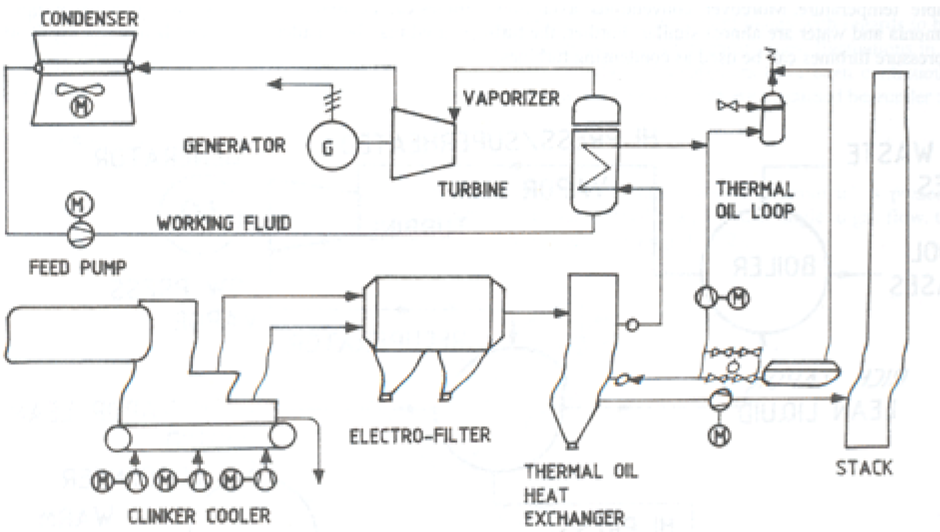

Fig. 4: Ormat Energy Converter : Clinker Cooler Heat Recovery System

In case of 4 or 5 stage preheater, exhaust gas temperatures of 350-400^oC may be typical. For such heat sources combined with the lower temperature clinker air, ORMAT proposes to use combined cycle of application. In the basic configuration (Fig 5), there are two independent heat transfer loops. The first will be from the preheater gases heat recovery unit and its vapor will enter the high pressure “topping” turbine. It will exhaust at positive pressure into vaporizer of the low pressure “bottoming” organic turbine. The thermo-oil heated by the clinker cooler of heat exchanger will enter the preheater of the OEC. The two turbines are on a single shaft and have a single generator.

Besides above, the conventional Rankine cycle based cogeneration systems being offered by manufacturers/ suppliers from Japan etc. have also been improvised particularly with regard to removal of dust which adheres to the tubes/ heat exchange surfaces of the boiler resulting in reduced efficiency of the waste heat boiler.

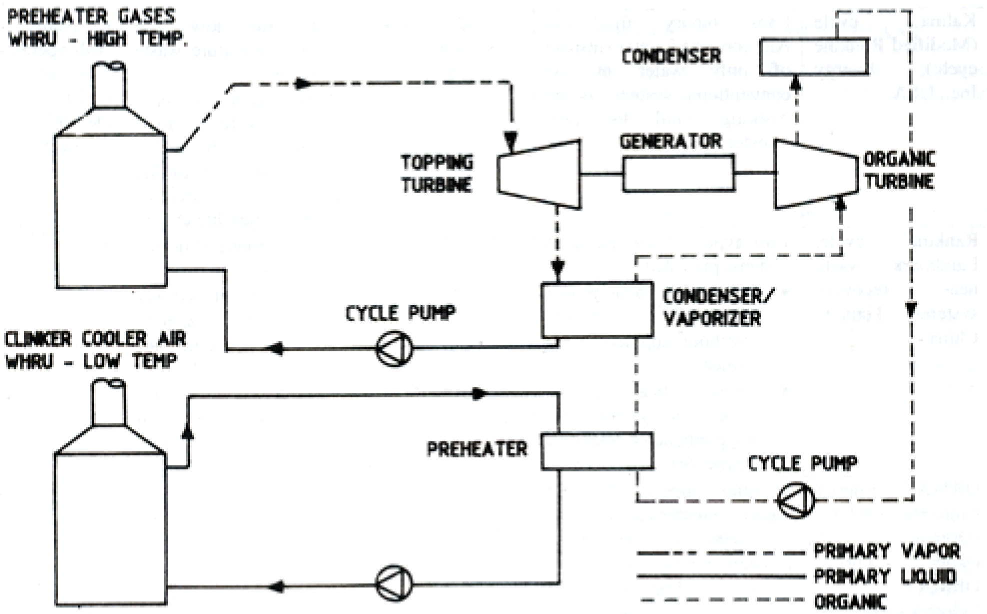

Fig. 5: Ormat Combined Cycle for Cement Waste Heat

The salient features of the technologies being offered by various manufactures/ suppliers, indicative cost of installation per MW, merits and the plants already installed by them are given in Table 2.

Table 2
Salient Features of Various Cogeneration Technologies

Technology, Manufacturer & Country	Salient Features	Installation Cost/ MW (Indicative)	Merits	No. of Plants Installed
Thermowir system (Rankine cycle), Caldyn, Germany	Comprises parallel plates fixed at particular angle to gas flow dividing it into narrow streams and inducing rotational motion thus throwing solid particles from centre to the walls. Steam is produced within the tubes employing heat in flue gases	1.1-1.4 million US$	▪ Removing 60% (48-60 gm/NM^3) dust from gases reducing load on existing ESP ▪ Reduction of CO_2 by 40 million kg per year for 4.5 MW plant ▪ Higher efficiency than conventional system	One pilot project of 2.5 MW capacity under installation/ commissioning at M/s Shree Cement, Beawar in India
Kalina cycle (Modified Rankine cycle). Energy Inc. USA	Uses binary fluid of Ammonia and water (instead of only water in the conventional system) as the working fluid for heat transfer	1.2-2.0 million US$	▪ Suitable for low and medium temperature waste heat sources ▪ Efficiency gains of upto 50% for low temperature heat sources (200-280^oC) and upto 20% for higher temperature heat sources as compared to rankine cycle.	6 plants (4 with operating experience, 2 under engg. Design? In Japan/ USA
Rankine cycle, Landmark waste heat recovery systems, Tianzin, China	Two types of cogeneration systems provided: ▪ Pure waste heat power generation system (without supplementary boiler) ▪ Waste heat power generation system (with supplementary boiler in sequence)	1.3-1.5 million US$	▪ No modification required in kiln system. ▪ 22-35 kWh/t of clinker power generation capacity (without supplementary fired system) ▪ No possibility of shut down due to kiln stoppage (with supplementary fired system)	44 kiln systems. (Total 240 MW installed capacity) in China
ORMAT Energy Converter (OEC) (Organic rankine cycle – ORC), ORMAT Industries Ltd., Tel Aviv, Israel	Thermal energy of heat source transferred to OEC by heat transfer fluid flowing through the OEC vaporizer. The vaporized OEC working fluid drives the special turbine coupled to the generator. Turbine exhaust vapor flows through condenser and is recycled. ORC of the OEC driving the turbine is organic fluid rather	1.8-2.4 million US$	▪ Improved technology and environmental friendly ▪ Factory integrated for rapid, easy installation ▪ Highly reliable, requires less maintenance, high average availability ▪ Uses air cooled condenser, no water required	1.5 MW power plant installed (for clinker cooler exhaust) at the lengfurt plant of Heideberger Cement AG, Germany

	than steam which has a much lower boiling point than water.			
Rankine cycle, Mitsubishi Heavy Industries, Japan	Utilities waste heat boiler for generation of steam which drives the turbine and generator. Steam cycle used for relatively high temperature PH exhaust gases, hot water flash cycle for medium temperature exhaust gases of cooler	1.3-1.5 million US$	▪ Technology operating in a number of plants	5 cement plants with 72.8 MW cogeneration capacity (50% installation in Japan)
Rankine cycle, Kawasaki Heavy Industries Ltd., Japan	The system uses steam power cycle for recovery of waste heat and dedusting of boiler tubes is achieved through improvised rapping mechanism	1.3-1.5 million US$	▪ Technology operating in a number of plants	In 16 kiln systems (42% share in Japan)

8. Techno-Economic Evaluation in a 1.2 MTPA Dry Process Cement Plant

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Preliminary techno-economic analysis for estimation of cogeneration potential, project cost and the payback period for a typical 1.2 mtpa dry process plant having 4 stage preheater and calciner, carried out by NCB indicated the following:

8.1 Availability of Waste Heat

The heat balance of the kiln indicates a total heat input of 797.5 kCal/kg clinker from coal combustion as given in Table3.

	Input	kCal/kg Clinker	Output	kCal/kg Clinker
1.	Heat of coal combustion	797.50	Heat of reaction	410.00
2.	Sensible heat of coal	2.52	Sensible heat in PH gases	224.14
3.	Sensible heat in kiln feed	25.00	Sensible heat of dust in exit gases	6.56
4.	Sensible heat in primary air	0.22	Sensible heat in cooler exhaust air	122.90
5.	Sensible heat from cooling air	12.02	Heat for evaporation of moisture	0.38
6.	Sensible heat in coal conveying air	2.28	Sensible heat in clinker leaving cooler	19.98
			Radiation losses and convection losses	33.36
			Unaccountable losses	22.22
	Total Heat Input	**839.54**	**Total Heat Output**	**839.54**

The sensible heat in preheater exhaust gases is 224.14 kCal/kg clinker while sensible heat in cooler exhaust air is 122.90 kCal/kg clinker. The heat balance indicates the following sensible heat availability and recovery potential:

Waste Heat From Cooler Vent Air

From the cooler exhaust, 182588 Nm^3/hr air at 310^oC is vented to atmosphere. Sensible heat in cooler vent air and clinker dust load released to atmosphere works out to $16.57x10^6$ kCal/hr.

Waste Heat from Preheater Gases

About 238900 Nm^3/hr gases at 410^oC with $32.5x10^6$ kCal/hr heat are released from the preheater. Out of it about $5.5x10^6$ kCal/hr is utilized in coal mill for drying coal during grinding. The details of waste heat utilization for raw material and coal drying are given below:

	Coal Mill	Temp ^oC	Sensible Heat kCal/hr
-	Inlet	390	$5.5x10^6$
-	Outlet	85-90	$0.9x10^6$
	Raw Mill		
-	Inlet	255	$24X10^6$
-	Outlet	105	$8.6x10^6$

It is therefore estimated that a total of $26x10^6$ kCal/hr (equivalent to 30 MWe) is being wasted.

8.3 Waste Heat Recovery for Cogeneration of Power

The thermal energy availability and power generation potential have been worked out as follows:

Thermal Energy from Cooler Vent Air

Cooler vent air flow rate			:	182588 Nm^3/hr
Temperature at Waste heat boiler	-	Inlet	:	300^oC
	-	Outlet	:	230^oC
Total heat recoverable from cooler vent air including dust load			:	$4x10^6$ kCal/hr

Due to low temperature of gases, the cooler vent air heat is proposed to be utilized only for generation of saturated steam or preheat the water.

Thermal Energy from Preheater Gases

Preheater gases will be drawn after the coal mill tapping point so that hot gas supply to coal mill is not disturbed.

Gas flow after preheater fan	:	238920Nm^3/hr at 403^oC
Gas flow through coal mill	:	43493 Nm^3/hr at 380^oC
Remaining gas flow through Waste heat boiler	:	195427 Nm^3/hr at 390^oC
Temperature at outlet of Waste heat boiler	:	260^oC
Sensible heat recovered from gas and dust in waste heat boiler	:	$8.8x10^6$ kCal/hr

8.3 Power Generation Potential

The power generation potential in this case works out as given in Table 4.

Location / System		Qty of Gases Nm3/hr	Waste Heat Boiler Working Temp, ^oC		Gross Power Gen. MW
			Inlet	Outlet	
I.	Preheater Exhaust	195427*	390	260	4.0
II.	Cooler Exhaust	182588	300	230	

* Out of Total PH exhaust gas of 238920 NM^3/hr at 410°C, 43493 NM^3/hr at 390°C used in coal mill (Moisture 9-12%) and waste heat boiler exhaust can be used for raw material drying which can be upgraded in heat content by hot air generator for raw mill (VRM) application, if required.

The schematic diagram of the proposed cogeneration system is shown in Figure 6.

8.4 Economic Evaluation

The estimated cost of the cogeneration project has been worked out to be about Rs 2600 lakhs. The economic evaluation indicates a payback period of 3 years and 6 months which is quite attractive for a favourable decision for the implementation of the scheme.

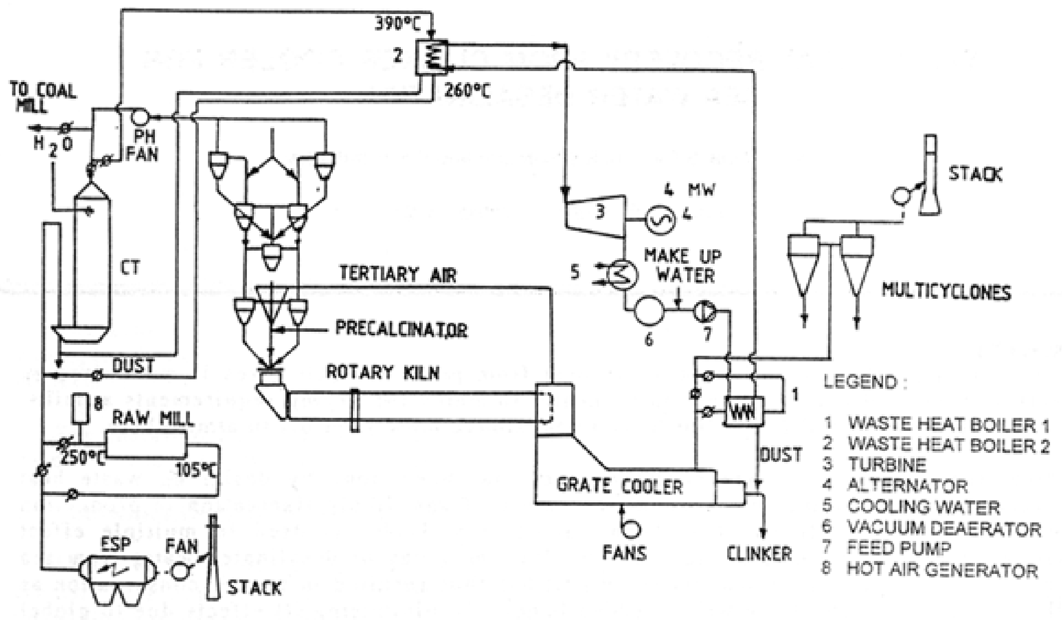

Fig. 6: Flow Sheet for Waste Heat Recovery System

9. NCB's Technological Support

NCB has been in the forefront to promote this development is in a position to provide technological support to cement plants interested in setting up systems for cogeneration of power. Keeping in view the large potential for cogeneration in the various cement plants and its impact on the energy conservation and environmental pollution including global warming, the Ministry of Commerce and Industry, Gove. Of India has identified NCB as a nodal agency for evaluation of various available cogeneration technologies and to make policy recommendations for the adoption of appropriate technology for cogeneration in Indian cement Industry. Efforts are also being made by NCB for securing fund support from the financial institutions e.g. Global Environment Facility (GEF) etc. for the installation of a full scale demonstration plant of cogeneration in a large size cement plant.

10 Conclusions

Cogeneration of power today has emerged as a proven and effective energy conservation measure. In view of the rising energy cost together with power shortages, it is imperative that Indian cement industry adopts cogeneration systems sooner than later to make itself more competitive as well as eco-friendly through such developments. There are about 40 large size cement plants in the country having production capacity of one mtpa and above which are ideally suited for adoption of cogeneration systems. NCB backed by its expertise is in a position to provide a comprehensive technological and industrial support to the industry for the techno-economic evaluation and implementation of cogeneration projects.

Acknowledgement

The authors have freely drawn upon completed R&D work, status reports of NCB and some of the unpublished work in NCB. This paper is being published with the permission of the Director General, NCB.

Reference book:

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Cement and Building Materials
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