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Fuel Enhancement of Waste Heat Recovery Power Plant in Cement Industry

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ABSTRACT

The low temperature unused gases from Air Quenching Chamber (AQC) and Suspension Pre-heater (SP) of cement plant are utilized to generate electric power. The fuel enhancement is a new technology that improves economy by using coal energy as input source to Waste Heat Recovery Power Plant (WHRPP) during kiln stoppage. Few minor modification in waste heat recovery is needed which include modification of boilers, addition of coal dosing system in WHRPP and comparative study for ash removing system and coal pulverizing system.
By introducing this scheme of fuel enhancement at WHRPP in cement industry; ensures improved economy of Bestway cement Ltd. This modification will help to reduce electricity dependency on utility grid and can contribute 16 MWh in present energy crises of country. This technical solution will reduce country's overall fossil fuel consumption.
KEYWORDS: Air Quenching chamber, Waste Heat Recovery Power Plant (WHRPP), Suspension Pre-heater.

1. INTRODUCTION

There are 29 cement plants in Pakistan producing about 44 million tons of cement annually. The majority of cement plants in country electricity from of utility grid while only few plants contain captive power plants which are fossil fuel based. The cement sector is one of the most energy consuming industries [1]. Fuel enhancement WHRPP basically consists of three main systems: coal mill, WHRPP and coal dosing system.

Bestway Cement Plant is located at district Chakwal of Punjab province, Pakistan. There are two lines of dry cement production with capacity of 5300 ton/day/ line. At present about 370,000 MWh of electricity is purchased from utility grid by Bestway per annum.

In cement plant, approximately 90% of total energy is used as heat energy in the clinker calcinations progression. Out of total heat expended in the clinker calcinations development, more than 35 present of heat is discharged as unused heat to the surroundings without consumption, consequently, a great deal of energy is wasted [2]. Bestway inaugurated a 16 MW Waste Heat Recovery Power Plant at its Chakwal (Pakistan) location in September, 2009. This plant is capable of fulfilling approximately 28% of the electricity requirements. The WHRPP generate 101,760 MWh of gross electricity per annum and displace 101,760 MWh of net electricity.

Coal is world's rich and widely spread fossil fuel with reserves for all types estimated to be about 990 billion tons, enough for 150 years at current consumption [3]. Coal fuels 42% of global electricity production, and is likely to remain a key component of the fuel mix for power generation to meet electricity demand. Coal generated electricity is considered as cheap power compared to petroleum products or natural gas [3-5]. The proven efficiency of coal is 32% to 42% which is better when compared to other fuels [6]. Also raw coal stock in coal yard is about 35,000 tons to 40,000 tons which can generate electric power and will contribute to national grid. By introducing new technology of fuel enhancement at WHRPP in cement industry, improved economy of Bestway cement Ltd (plant). This modification will help out to reduced electricity dependency on utility grid and generate cheap electricity by coal as compared to oil (diesel, furnace oil), natural gas and utility grid. This technical solution reduced country's overall fossil fuel utilization. Consequently improved security and improved the country balance of cost.

2. MATERIAL AND METHODS

I. Modeling Of WHRPP with Coal Dosing System

Cement manufacturing process consumes large amounts of energy [4]. The rotary kiln is heated with pulverized coal, oil or gas; each of these fuels has different burning characteristics and heat transfers. Coal is used widely due to its comparatively low cost. Coal fuel is fed at kiln main and pre-calciner (PC) for calcinations process of cement and electrical energy is used to run all type of electrical load like motors, heaters, electrostatic precipitator

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and lighting load etc. The exhausted hot gas energy from cement plant and coal dosing system is utilized to run the electric power generation system.

In Bestway cement Ltd, a Waste Heat Recovery (WHR) captive power plant is installed to effectively utilize the waste heat and generate electric power. The gas exit from (AQC) and (SP) in cement production [7]. The WHR power generation is 16MW when both kiln lines are operational. The plant includes installation of 4 WHR boilers of which two at the pre-heater stage and two at clinker cooler stage plus a turbine and a generator. The steam from SP boiler and AQC boiler is fed to steam turbine generator to produce electric power. Due to energy crisis, mostly kiln one line remains shutdown. When one line is shutdown, output of WHRPP is half of total generation. However, we will take full output from existing power plant through proposed coal dosing as shown in figure 1.

The scheme will generate power by using coal through coal dosing system in cement plant. The produced electricity will displace electricity purchased from utility grid. The major equipment specifications are shown in table 1

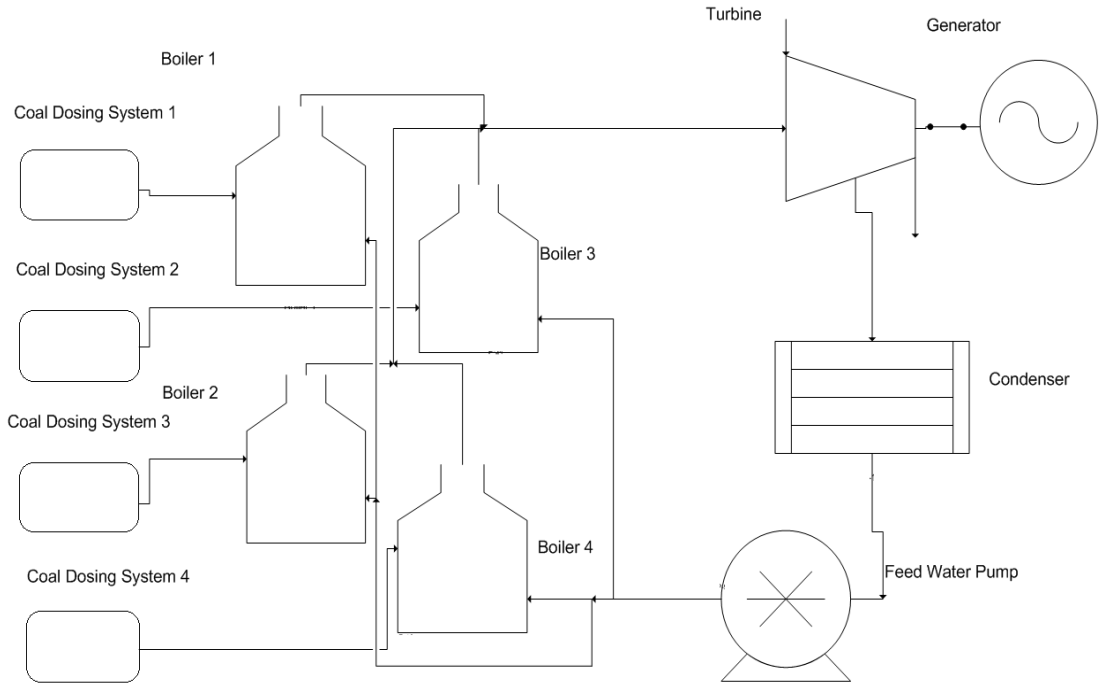

Figure 1: Power plant run by coal

II. TECHNICAL BARRIER ANALYSIS/METHODOLOGY

The basic technical barrier analysis in fuel enhancement of waste heat recovery power plant are following.

1. MODIFICATION OF BOILERS
2. COAL DOSING SYSTEM
3. ASH REMOVING SYSTEM
4. COAL PULVERIZING

Modification Of Boilers

The capacity of AQC boiler is 14 tons steam/hr. At BCL site 1MW power is generated by 4 tons of steam; 1,870 kWh per Ton of Coal or 0.9 kWh per Pound of Coal [8]. According to above reference 64 tonns of steam produce 16MW power by using 8 tonns of coal.

So 1 tonn steam =1/4=0.25MW
For 14 tons steam = 14x0.25 =3.5MW
Flame length for 2MW =2.7m [9]
For 3.5MW flame length will be 4725mm

The distance between water tubes and gases inlet point is 2520mm. The selected burning gun for coal feeding flame is 4725mm so the length of burning gun tip to super heater water tubes is 7245mm.

Table 1: Technical Specification of major equipment

Steam Turbine: • Multi stage mixed pressure condensing turbine • Output power 16.5MW • Rotational Speed 3000rpm • Inlet steam pressure 1.53Mpa • Inlet steam temperature 324ºC • Exhaust steam pressure 0.956Mpa • Inlet steam flow 77.2T	**Generator:** • Three phase Ac synchronous generator • Output power 16.5MW • Rotational speed 3000 rpm • Output voltage 6.3K V
SP Boiler: • Steam pressure and temperature (superheated outlet) 1.63Mpa, 321 ºC • Exhaust gas temperature (inlet 335 ºC and outlet 223 ºC) • Exhaust gas flow from each SP waste heat exchanger 306000 Nm3/hr • Steam output 24 tonns/hr	**AQC Boiler:** • Steam pressure and temperature (superheated outlet) 1.63 MPa, 345ºC • Exhaust gas temperature (inlet 360ºC and outlet 101 ºC) • Exhaust gas flow from each AQC waste heat exchanger 189100 Nm/hr • Steam output 14 tonns/hr

The flame should finish 2000mm before the super heater tubes because direct flame is destructive and may damage the tubes. Therefore, the total length from tubes to burning tip is 9245mm. So the modified length is 6725mm and width is 3700mm as shown in figure 2

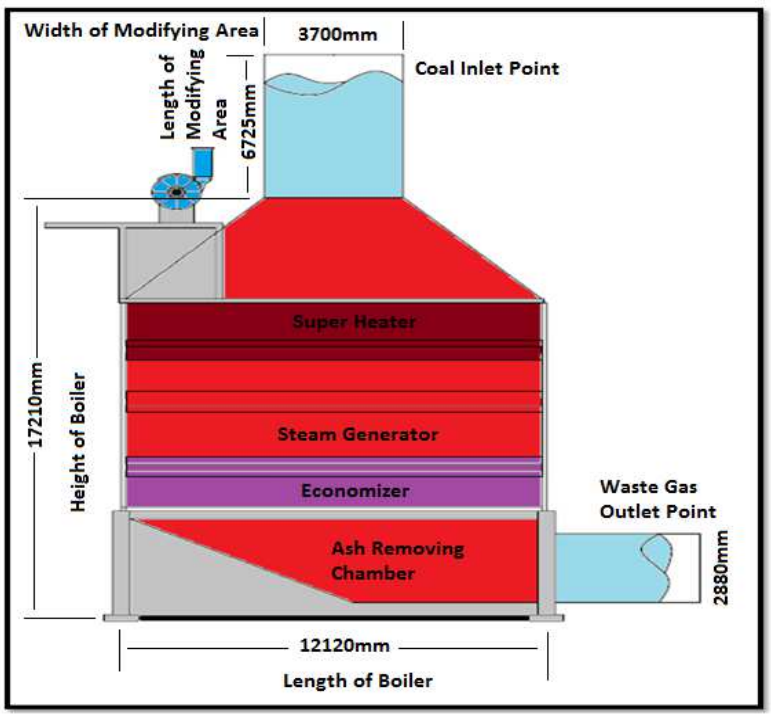

Figure 2: AQC Boiler after modification

SP boiler capacity is 24 tons of steam. 1 equal to 0.25MW and 24x0.25=6MW

So the flame length for 6MW will be 8100mm

The distance between water tubes and gases inlet point from side wall is 5300mm. The selected burning gun for coal feeding the flame is 8100mm. so the length of burning gun tip to super heater water tubes is 13400mm. and the flame should finish 2000mm before the super heater tubes. Therefore, the total length from tubes to burning tip is 15,400 mm .The modified length is 10100mm and width is 5588mm as shown in figure 3.

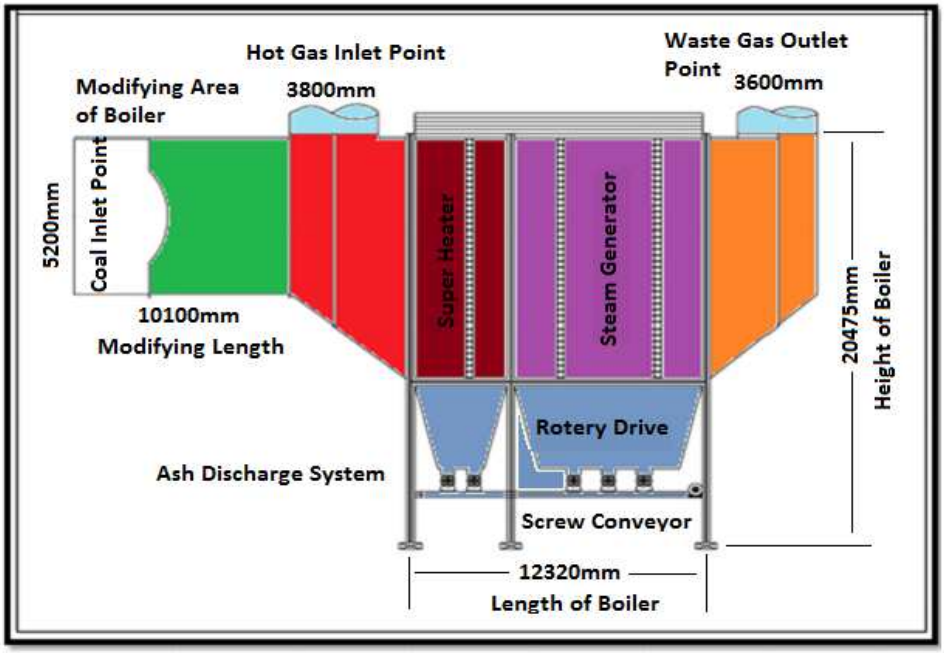

Figure 3: SP boiler after modification

Coal Dosing System

The proposed system consists of Coal, Coal Bin, flow meter, Blower and fuel Burning Gun.

Coal is being used as fuel in system to generate heat energy. Flow meter will work as transportation of coal to blower in collaboration/accordance with measuring system installed with flow meter. Capacity of flow meter is 2.5 tons/h.

It is used to transport coal to burning gun. Blower will transfer 2.2 tons/hour coal to burning gun. So the capacity of selected blower is 29.22 KW

We select multi-fuel burner for proposed system because whenever cement plant will stall the heat source for WHRPP will also stop then coal will burn in boiler and maintain the temperature. When cement plant is planned to shut down for maintenance then power plant also stops. After power plant maintenance, it will not run on direct coal fuel. For initial temperature, light up the boiler by furnace oil or gas through Multi-fuel burner which burns fuel (coal, furnace oil and gas) in boiler. This burner can control the fuel to produce heat energy for boiler according to heat requirement.

Figure 4: Multi-fuel burner [10].

Fuel adjustment is required to control temperature in boiler. Burner for proposed system has capacity of 2.5 tons/h for each system and selected burner is multi-fuel burner made of Pillard Company as shown in figure 4. Multi-fuel burners are available in different range 0.5 t/h to 16 t/hr [10].

Ash Removing System

Ash removing method will use the rotary and conveyors which are already used for dust removal from boilers.

Dust come in AQC and SP boilers with hot gases from Cement plant. Raw mill feed to kiln 291 tons/ day and after processing clinker production got 5300 tons/day. According to feed production should be 9400 tons/day so the efficiency of the plant with respect to raw material feed is 56.6 % and returning material (waste) before clinker production is 43.4 % (4100 tons/day), efficiency of electrostatic precipitator EP is 90 % in which 3690 tons/day is collected and 410 tons/day pass through EP. Pre-duster efficiency is also 90%; 369 tons/day is collected and 41 tons/day is passed which come into WHR Boilers so the waste dust particles 1.708 tons/hr which is already removed from boilers through conveyors.

Standard Coal ash range is 6.2% to 11.0% after coal burning [11-12] and in boiler maximum 8.8 tons/hr coal will be used. Therefore, maximum ash will be 0.968 tons/hr which is low as compared to waste material.

Existing dust removal components are broad range ash handling systems. These systems will be applied to ash handling for boilers bottom ash removal and also ash removal from all downstream ash accumulation points.

Coal Pulverizing

WHR power plant installed capacity is 16MW. Energy as coal is calculated by 1,870 kWh per Ton of Coal or 0.9 kWh per Pound of Coal [8] i.e. 8.8 tons/h maximum. At plant site there are four (4) boilers. Therefore, for one boiler maximum coal requirement is 2.2 tons/hr.

The rotary kiln is heated with pulverized coal. Coal is used widely due to low cost as compared to oil and gas. The raw coal is simultaneously pulverized, dried out and evenly distributed to the coal burners. Hot air or flue gases transfer the pulverized fuel to the burner and reduce the moisture in the coal.

III. ELECTRIC POWER INTEGRATION

Operation of Power Plant

The coal mill grinds the raw coal which runs the cement plant and the waste gases from the plant goes to heat exchanger where these run the turbine and generator to produce electricity . When cement plant is stalled due to technical reasons or planned shut down; WHRPP also stops .The proposed coal dosing system will automatically turns on. Coal dosing system will get grind coal from existing coal mill as shown below in figure 5.

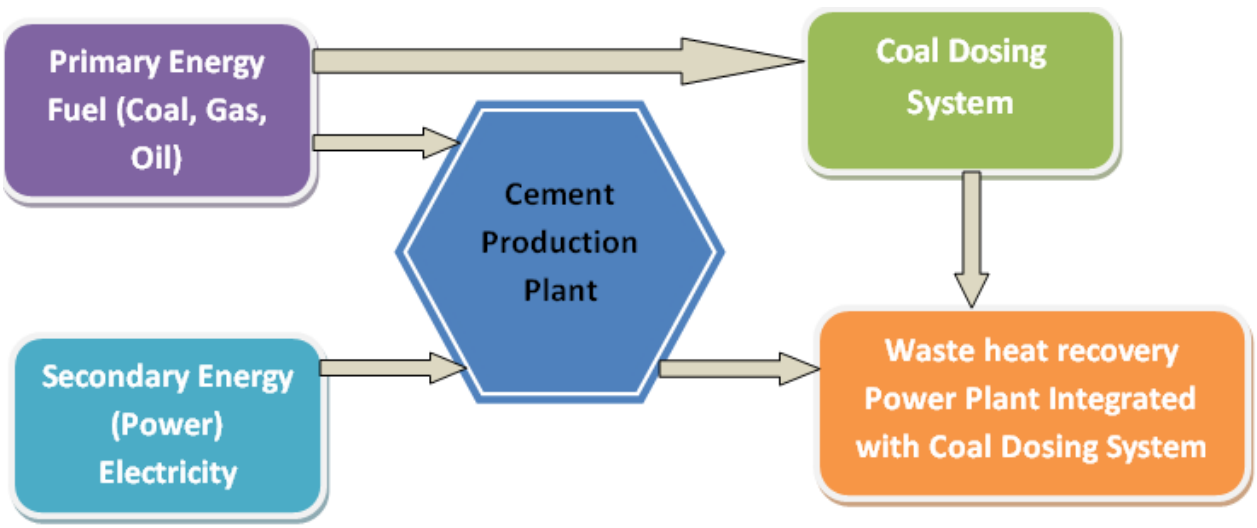

Figure 5: Operation of plant

Typical Operation Data of Whrpp and Power Generation by Coal

Table 2 discusses operational status of power purchased from WAPDA, power generated by WHRPP and Coal and also power displaced by WAPDA.

Table 2: Typical Operation data of WHRPP

Plant status	Power import from WAPDA	Power generated (plant site)		Power displaced from WAPDA
		WHRPP	Coal	
Cement plant in running condition	52 MWh	Nil	Nil	Nil
Cement plant and WHRPP in running condition	36MWh	16MWh	Nil	16MWh
Only one line operational	10MWh	8MWh	8MWh	16MWh
Cement plant install condition	Nil	Nil	16MWh	16MWh

3. RESULTS AND DISCUSSION

Cost Analysis of Fuel Enhancement in Waste Heat Recovery Power Plant

Coal mill and waste heat recovery power plant are essential requirement at project site and the coal dosing system is proposed. The estimated cost for proposed project is calculated in table 3.

Table 3: Analysis of power generation by coal

Power Generation by Coal	
Power house capacity	16 MWh
Power house Generation per day	384 MWh
Power house Generation for 100 days	38400 MWh
O&M Cost in Rs. (Overall)	
Net Maintenance & Operational Cost	312367964.4
Cost Per KWH	8.1345824
Saving	
Utility average rate	17.5 Rs./KWh
Generation by Coal	8.1345824 Rs/KWh
Saving per unit	9.3654176 Rs./KWh
Saving for 100 days	81033580 Rs.
Payback Period	
Proposed system capital price	66,350,000 Rs.
Savings	81033580 Rs.
Total payback period	0.8187964 Years

Price Comparison of Different Available Energy Resources

The electricity generation by the coal is cheap as compared to other fossil fuel and Utility grid as shown in figure 6.

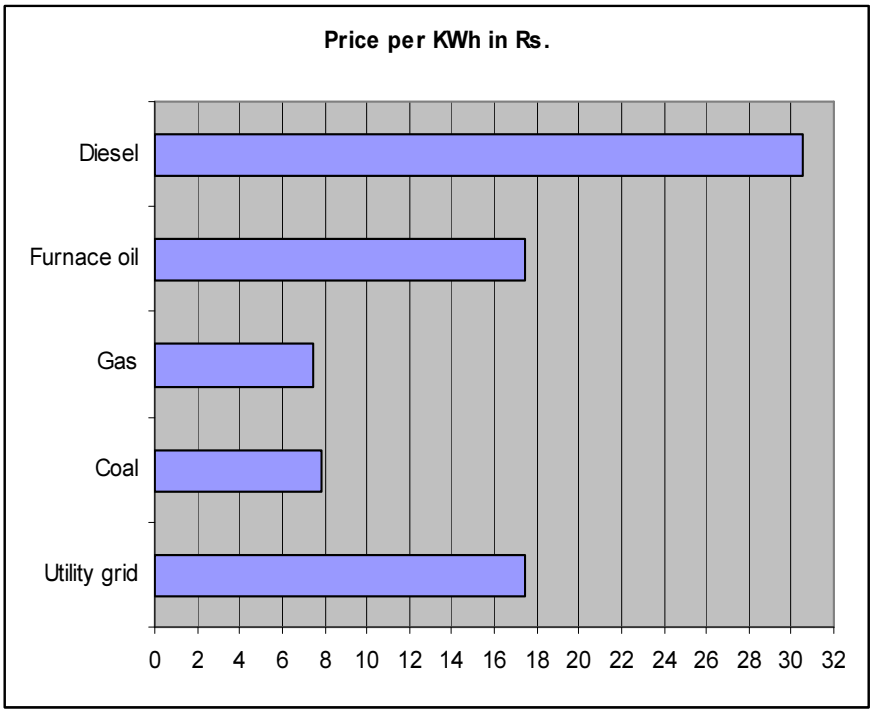

Figure 6: Comparison of price per KWh

4. Conclusion

The fuel enhancement is a new technology that converts coal energy into electrical energy in cement plant by modifying the WHR boilers which can run independently i.e. without cement plant waste heat.

Coal (fuel) energy integration is one of the most important approaches in cement industry where WHRPP is installed. This kind of energy concept will be applied with WHRPP. The uninterrupted power production could be gained by using coal dosing system at WHRPP instead of waste hot gases and also improving energy efficiency of cement industries reducing reliance on national grid.

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