FUEL ENHANCEMENT OF WASTE HEAT RECOVERY POWER PLANT IN CEMENT INDUSTRY

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(248-FET/MSEE/F10)

This dissertation is submitted to Faculty of Engineering and Technology, International Islamic University Islamabad Pakistan for partial fulfilment of the degree of MS **Electronic Engineering** with specialization in **Power Electronics and Renewable Energy Technologies** at the Department of Electronic Engineering

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Certificate of Approval

This is to certify that the work contained in this thesis entitled, **"Fuel Enhancement of Waste Recovery Power Plant in Cement Industry"** was carried out by **Muhammad Imran Khan, Registration # 248-FET/MSEE/F10**, it is fully adequate in scope and quality, for the degree of MS (Electronics Engineering).

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بسم الله الرحمن الرحيم

In The Name of Allah (SWT) The Most Beneficent and The Most

Merciful

DECLARATION

I certify that research work titled "Fuel Enhancement of Waste Heat Recovery Power Plant In Cement Industry" is my own work and has not been presented elsewhere for assessment. Moreover, the material taken from other sources has also been acknowledged properly.

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There is no way, no words, to express my love and gratitude, May Allah helps us in following the true spirit & principles of Islam written down in the Holy Quran and Sunnah (Aameen).

Abstract

In this thesis, A research case study is made on a fuel enhancement in waste heat recovery power plant (WHRPP) is Already installed at Bestway cement industry Chakwal, Pakistan. Which effectively recycle the low temperature unused gases from Air Quenching Chamber (AQC) and Suspension Pre-heater (SP) of cement plant to generate electric power? The fuel enhancement is a new technology that improves the economics by using coal energy as input source to the WHRPP. Only small modification in waste heat recovery is needed which include modification of boilers, addition of coal dosing system in WHRPP, conduction of comparative study for ash removing system and coal pulverizing system.

The WHRPP totally depends on cement plant operation, when cement plant is stopped due to technical reason or planed shut down, effectively electric power generation is stopped and contribution to utility and energy dependency cost reduction is also stopped. For continuous contribution to utility and minimizing the dependency, the coal dosing (firing) system is installed, which is used for dosing coal in heat exchangers (boilers) to generate steam, boiler will be fed steam to steam turbine generator to produce power in existing plant. The studies are conducted based on modified WHRPP. It is found that for 100day expected power generation is 38,400 MWh, power displaced 16MW by WAPDA at hourly bases. Existing Dust collecting system capable for dust amount of 1.708 tons/hrs, which is suitable for required modified WHRPP transportation of 0.968 tons/hrs of coal ash.

High and rising energy and fossil fuel prices are strong drivers for new research and feasible technical solutions. Cement industries are highly energy intensive industries; these industries are looking thoroughly for solutions to reduce their dependence on

energy costs. The technical solution to minimize energy costs and contribute in present energy crisis of Pakistan is discussed in this thesis.

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 from WAPDA, contributed 16MWh in present energy crises of Pakistan, and generate cheap electricity by coal as compared to oil (diesel, furnace), natural gas and WAPDA. This technical solution reduced Pakistan's overall fossil fuel utilization. Consequently improved security and improved the country balance of cost.

Contents

Table of Figures

CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION AND BACKGROUND

There are 29 cement plants in Pakistan producing about 44 million tons of cement annually [1]. The majority of cements plants in Pakistan buy electricity from WAPDA grid although only a few plants contain captive power plants which are based on fossil fuel.

The cement industry is one of the recorded energy consuming industry.[2] The calcinations procedure of clinker is the most energy intensive in cement production because waste gases with temperature lower than 400 °C emitted from the clinker cooler and pre-heater respectively at the kiln inlet and backend. The heat which is lost is about more than 30% of thermal consumption for clinker production [3], [4], which means that large amount of energy is wasted. By recovering the waste heat for power generation will reduce both energy consumption for cement and particularly including electricity and fuel consumption for in-house power station.

Bestway inaugurated its 16 MW Waste Heat Recovery Power Plant at its district Chakwal location in September 2009. This plant is capable of fulfilling approximately 28% of the electricity requirements of the Chakwal location and must result in reducing more than 35,000 tons of Carbon Dioxide discharge per annum. This Waste Heat Recovery Power Plant is the first of its type in the cement manufacturing company of Pakistan. As Waste Heat Recovery Power production use no fuel so no hothouse gas discharge in the procedure. Meanwhile, the dust discharge and temperature of released flue gas is more lowered which have a positive impact on the atmosphere. The Plant has facilitated to extensively minimize its dependence on exterior source of power.

Bestway's Waste Heat Recovery plant conform to the CDM (Clean Development Mechanism) methodology and has been effectively recorded by UNFCCC (United Nations Framework Convention on Climate Change).BCL contain imported electricity from WAPDA grid delineated with the government before the scheme implementation and will import electricity which cannot meet from the Project activity from WAPDA grid. So, the related electric power system is WAPDA grid.

The electricity generated through the WHRPP decreases reliance on grid electricity consequently helping to stabilize the grid in the region. This must contribute to lowering blackouts and brownouts practiced by further grid users and help to increase the financial performance of other businesses coupled to the grid. The electricity produced through the plant displaces grid electricity mostly produced by fossil-fuel burning power plants. It will help to decrease overall fossil fuel consumption by improving energy security and country's balance of costs.

In Bestway Cement limited there are two production lines of dry cement with capability of 5350 ton/day/line. Recently about 370,000 MWh of electric power purchased from WAPDA is used in Bestway per annum. The Project generates 105,600 MWh of gross electricity per annum and displaces 105,600 MWh of total electric power that would then to be bring in from WAPDA grid.

1.2 ELECTRICITY GENERATION BY WASTE HEAT RECOVERY POWER PLANT

The waste gas erasing from Suspension Pre-heater (SP) at kiln inlet side and Air Quenching Chamber (AQC) as shown in figure 1.1 were about 390 °due to which there was more chances for heat loss in the clinker production.

The WHR power station was installed and started providing electric power to grid in 2009. To get waste heat from clinker progression AQC and SP waste heat boilers were installed at surviving production lines to generate super-heated steam for the steam turbine that is mechanically coupled with the generator.

- AQC waste heat exchanger is installed at the kiln outlet that consists of two heat exchangers to make best use of waste heat recovery from the clinker coolers and give the surety of being safe working of the generator. SP boiler is installed at the kiln backend. The steam generated from SP boiler along with the steam from AQC boiler is put into the turbine together.

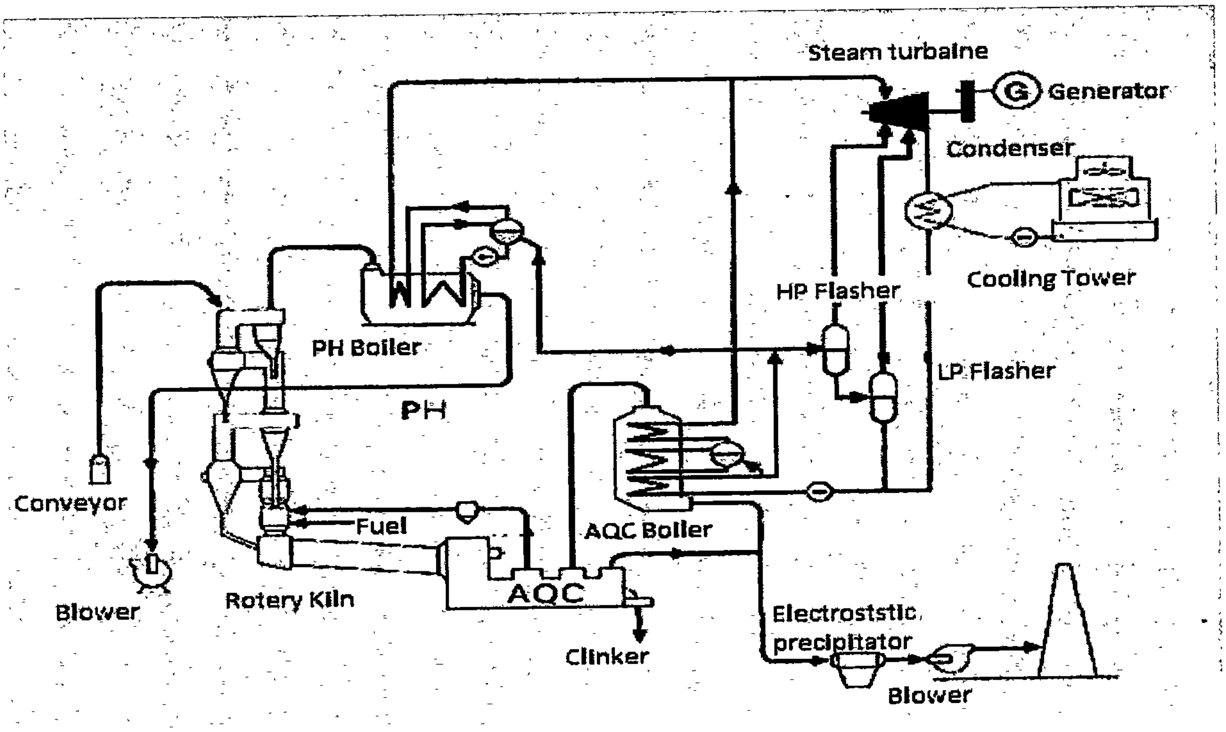

Figure 1-1 **waste heat recovery power plant at cement plant [5].**

1.3 ELECTRICITY GENERATION BY COAL

Coal is present in great amounts in the world and broadly distributed fossil fuel with assets for all types of coal that is expected to be about 990 billion tons sufficient for 150 years if we look at current consumption [28]. Coal is used as fuel for 42% of global electricity production and is expected to continue as important component as the fuel mix for power generation to meet electric power demand particularly in developing countries. To maximize the effectiveness of coal used in power generation; coal is grinded into powdered form due to which the surface area increases and permits it to burn more swiftly. Powdered coal is blown into the combustion chamber, which is a part of boiler, where it is burnt at very high temperature as shown in figure.1.2. Water present in the tubes of boiler is converted to steam due to hot gases.

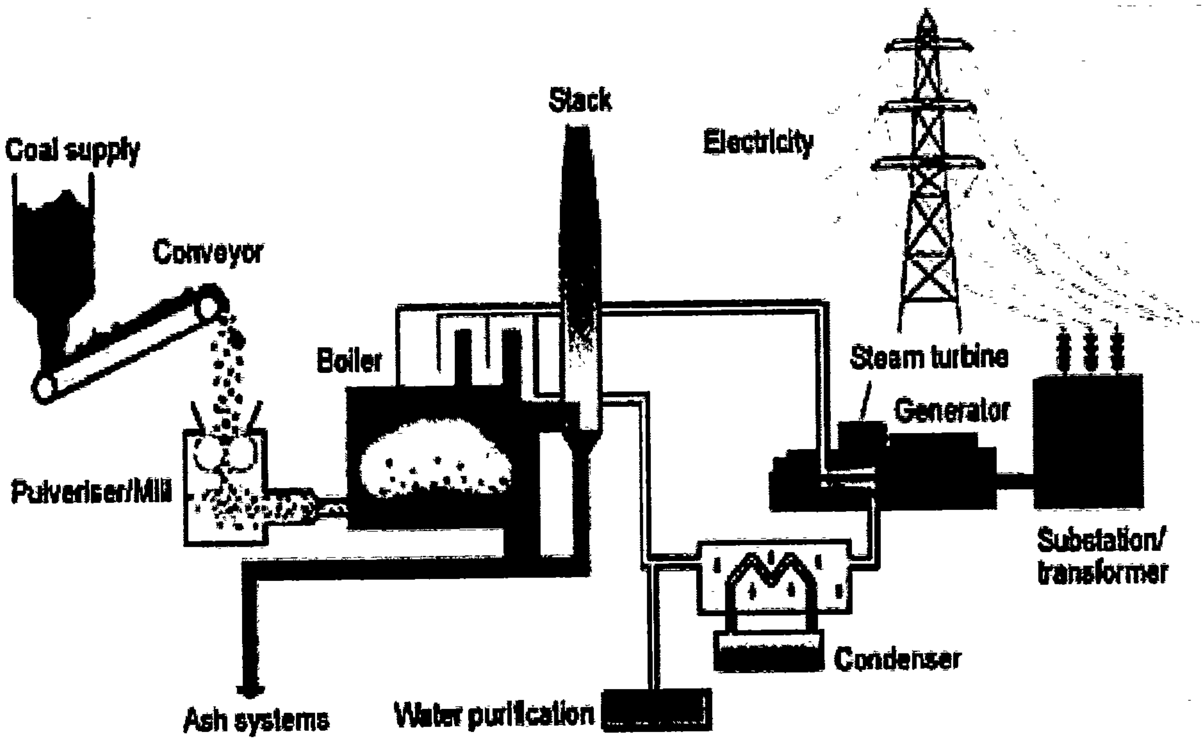

Figure 1-2 Electricity generation by Coal [6].

The steam produced by the boiler is of very high pressure and is delivered into a turbine that contains thousands of propeller-like blades. The steam drives these blades which rotates the turbine shaft high speed. A generator is installed at other end of the turbine shaft. Electric Power is generated when shaft rotate rapidly in a strong magnetic field. After passing through the turbine, steam is again condensed and returned to the boiler to be heated again.

1.4 MOTIVATION

In these days Pakistan is facing intense energy crisis. Electricity shortage is high affecting cement sector which is one of the major consumers of energy. Coal generated electricity is considered cheap power when compared to petroleum products or natural gas [7], [8]. There are ways to generate electricity from Waste Heat Recovery Power

Plant which is already working in Bestway cement limited. WHRPP totally depend on cement plant. It is beneficial to keep WHRPP running even at times when cement plant stalls due to any technical problem or planned shutdown. The proposed modification in the existing plant by inletting the coal in heat exchanger to produce heat will run the power plant independently. The selection of coal as fuel in heat exchanger has two advantages; first it is available in extra quantity at plant site and second it is cheapest fuel.

1.5 PROBLEM STATEMENT

Whenever cement plant stalls due to any electrical, mechanical or production problem Waste Heat Recovery Power Plant (WHRPP) will also stop functioning i.e. WHRPP depends totally on cement plant.

- ✓ Planned shutdown could be 1-2 weeks or up to 1 month
- ✓ Stoppage due to technical issues could be 1-2 or takes 4 hours depending on problem type. During stoppage plant temperature automatically decreases from set level and requires 2 to 3 hours to reach to desired temperature set level again adding 2 or three extra hours into stoppage time.
- ✓ The main problem is cement plant shut down and WHRPP also stops working because it totally depends on cement plant. Power generation also stops since this generated electricity is used by cement plant itself.

1.6 PROPOSED SOLUTION

- Minimizing the drawbacks of plant shut down WHRPP Plant will go through the modification in the existing plant by inletting the coal in heat exchanger to produce heat which will run the power plant continuously.

- We are not receiving as much power as we need because we are generating it by WHRPP. Moreover when plant stops the power generation will not stop. Hence the generated power transfers to utility.
- When the cement plant will shut down the proposed system will start automatically through interlocking. The generated power from coal will fulfil the small power requirements of cement plant and utility.
- Coal generated electricity is cheap when compared to petroleum products or natural gas.
- There are other benefits to use coal as fuel for heat generation and electric power generation, such as the proven efficiency of coal is 32% - 42% better than other fuels [9]. Coal is definitely flammable and creates high energy upon combustion which helps in the generation of large amounts of electric power. The coal at plant side is available in extra quantity. On daily usage average 25-30 days coal is being stored in coal yard. So no extra charges required for the transportation of coal to generate electric power.
- A comparative study has been conducted about coal fuel with alternate petroleum fuels which is used for electrical power generation. The self generated power per unit rate with other petroleum fuel and utility has also been compared.

1.7 RESEARCH METHODOLOGY

✓ For minimizing the drawbacks of plant shut down WHRPP will be upgraded. The up gradations would be consisting on coal dosing inlet, blower for coal transfer from inlet to the burning chamber.

- ✓ In the upgraded system, coal will be transferred to the burning chamber through blower from a separate inlet which is specifically developed for this purpose.
- ✓ Coal dosing start automatically as the power plant stops working. The coal inlet to the burning chamber will be measured according to the required temperature.
- ✓ The reason for developing/installing new unit is to provide power supply to grid system.

CHAPTER 2. LITERATURE REVIEW

2.1 WASTE HEAT RECOVERY AND POWER GENERATION

Waste heat recovery for generating electric power is a method in which waste heat is captured by any specified industrial procedure and uses that heat to generate electric poweras shown in figure 2.1.

Lot of energy intensive industrial processes such as cement making, steel and iron making, glass industries, pulp industries and paper industries ;all release very hot gases or steam which can be recaptured and used to generate electric power [10].

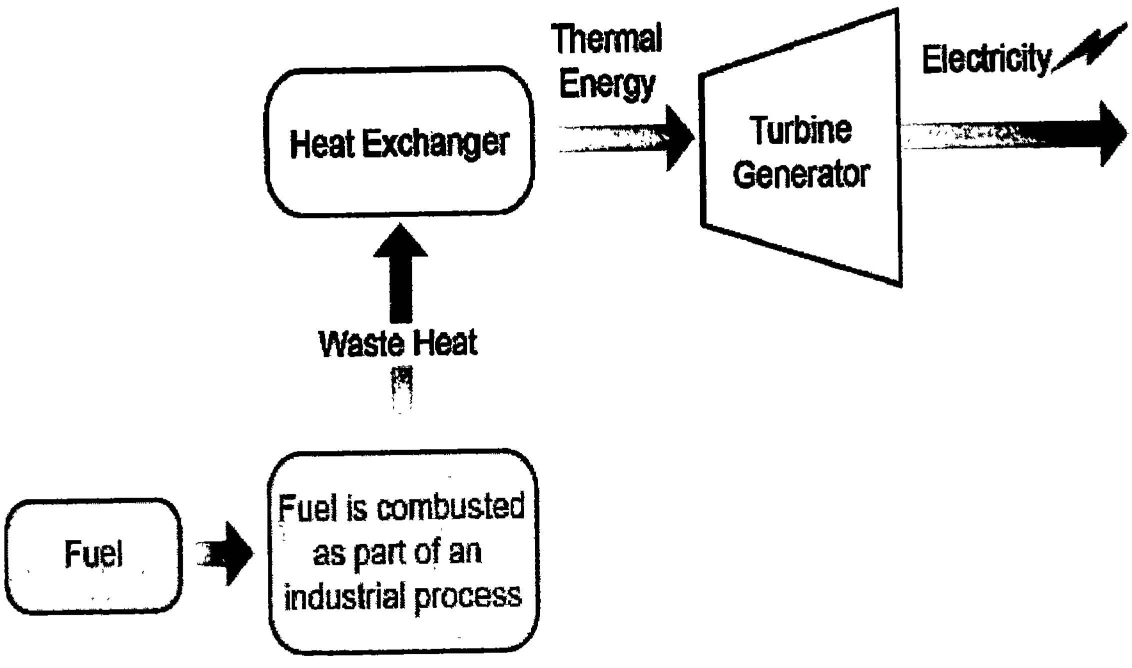

Figure 2-1 Waste Heatto PowerGeneration [10].

2.2 WASTE HEAT CLASSIFICATIONS WITH RESPECT TO TEMPERATURE

Steam generated by waste heat is classified on the basis of temperature. Generally high-energy intensive industries release high temperature hot gases. Steam can be classified on the basis of temperature into three main types i.e. high temperature, medium temperature and low temperature [11], [12]. A brief explanation of these temperature ranges and their sources is as following.

2.2.1 High Temperature (Above 1200 ^{o}F)

The source of such hot exhaust gases could be from furnaces (such as Steel electric arc, Steel heating, Aluminium or Copper reverberatory, Glass liquefy), Hydrogen plants and coke ovens.

2.2.2 Medium Temperature (500 to 1200 ^{o}F)

The source of this temperature gases could be prime mover exhaust streams such as gas turbine or reciprocating engine. Other source could be ovens (for drying baking or curing) and cement kiln lay down in this temperature range of exhaust gases.

2.2.3 Low Temperature (Below 500 ^{o}F)

The sources of this temperature range exhaust gases could be boilers, ethylene furnaces, steam condensate, low temperature ovens and hot process liquids or solids.

2.3 WHRPP CLASSIFICATION WITH RESPECT TO TECHNOLOGIES

The power plant can also be classified into different categories on the basis of different technologies which use for power generation from waste heat.

2.3.1 Steam Rankine Cycle (SRC)

Using heat to generate steam in the waste heat boiler is most usually used system for the generation of electric power from waste heat, which then runs the steam turbine, which then operates generator.

Waste heat recovery boiler and steam turbine work thermodynamically as a Rankine Cycle, as shown in Figure 2.2In the steam Rankine cycle, firstly the working fluid water is pushed to higher pressure before entering to a heat recovery boiler. The water is converted to steam by the hot gases and then expanded to lower temperature and pressure in a turbine which generates mechanical power that is enough to drive an electric generator. At vacuum conditions the low-pressure steam is exhausted to a condenser where heat is eliminated by condensing the vapor back into liquid. The condense form of water from the condenser is then returned to the pump and the cycle continues [13].

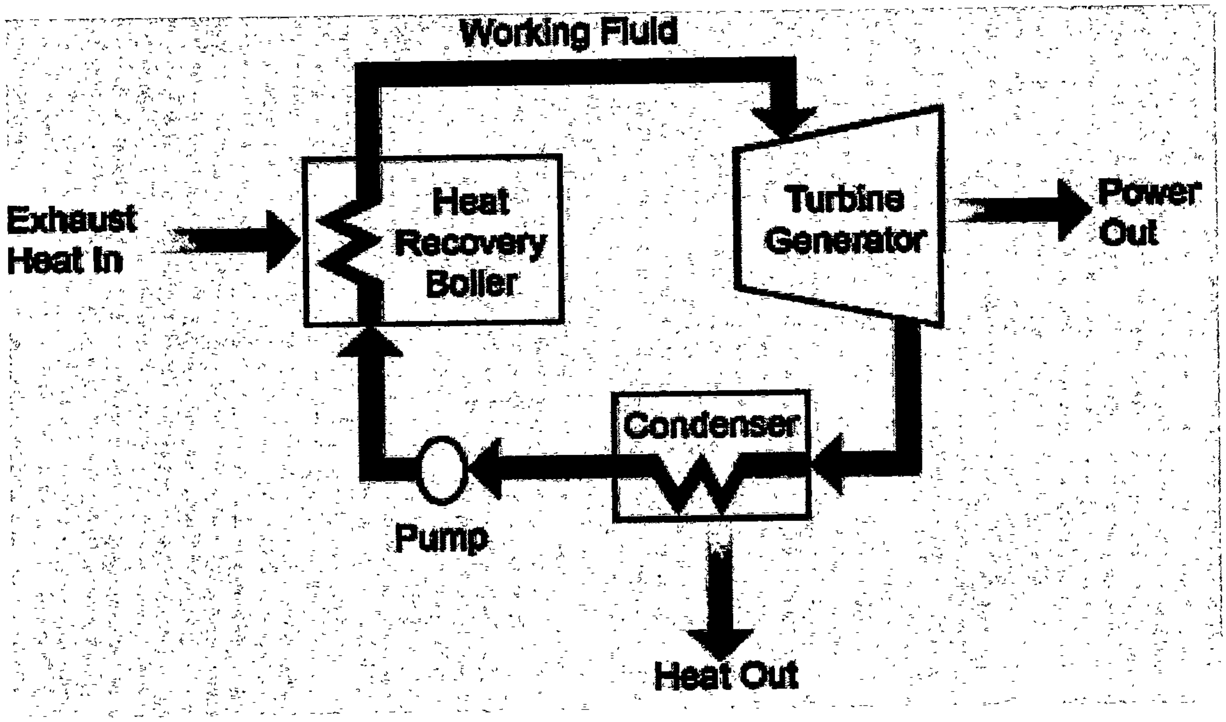

Figure 2-2 **Simple Rankine Cycle Heat Engine [14].**

2.3.2 Organic Rankine Cycles (ORC)

In ORC heat engines several working fluids having improved efficiencies at lower heat source temperatures are used. In ORCs working fluid is used which have low boiling point, high vapour pressure, high molecular mass, and high mass flow as compared to water. Collectively, these factors enable high efficiency of turbine than in an SRC. ORCs can be used for waste heat sources as low as 300 °F, however steam systems are limited to heat sources more than 500 °F. ORCs have generally been used to generate electric power in geothermal power plants as given in Figure 2-3 and further newly in tubes of compressor heat recovery applications [14].

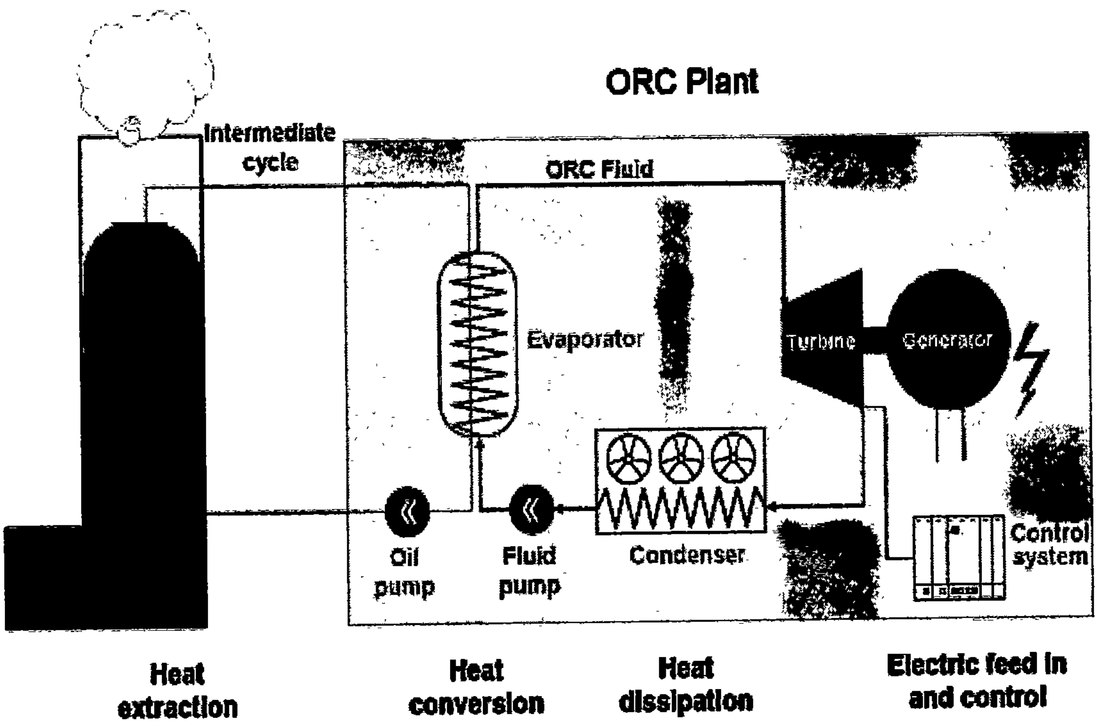

Figure 2-3 **Organic rankine cycle process [14].**

2.3.3 Kalina Cycle

It is other type of Rankine cycle, in which a solution of water and ammonia is used as the working fluid, and allows for a more efficient energy withdrawal from the heat source. The Kalina cycle has working temperature range from 200 °F to 1,000 °F and is 15-25 percent more efficient than ORCs at the similar temperature level. Kalina cycle systems are becoming more famous abroad in geothermal power plants, where the hot fluid is very often below 300 °F [2], [15].

2.4 WASTE HEAT POWER AT CEMENT PLANT

In cement industries, approximately 90% of whole energy is utilized by heat energy in the clinker calcinations procedure. From the total heat which was consumed in the clinker calcinations procedure, greater than 35% of heat is discharge as waste heat to the atmosphere deprived of being used. Thus, large amounts of heat energy is unused, causing serious contamination in the work place [16].

The Quzhai Cement 9000kW Waste Heat Recovery plan includes erection of a waste heat scheme at the Quzhai Cement plant close to Luquan City, Hebei China. It has two dry procedure rotary kiln cement making two lines of 2500 tons/day)

The main purpose of the scheme is to consume waste heat from the cement making lines, which was emitted in the air, for the generation of the electric power that was used on-site as shown in figure 2-4. The power generated by the scheme has displaced electric power that was provided by the North China Power network. The project is contributing to the further effective utilization of energy at the cement factory and reduces dependence on exhaustible fossil fuel.

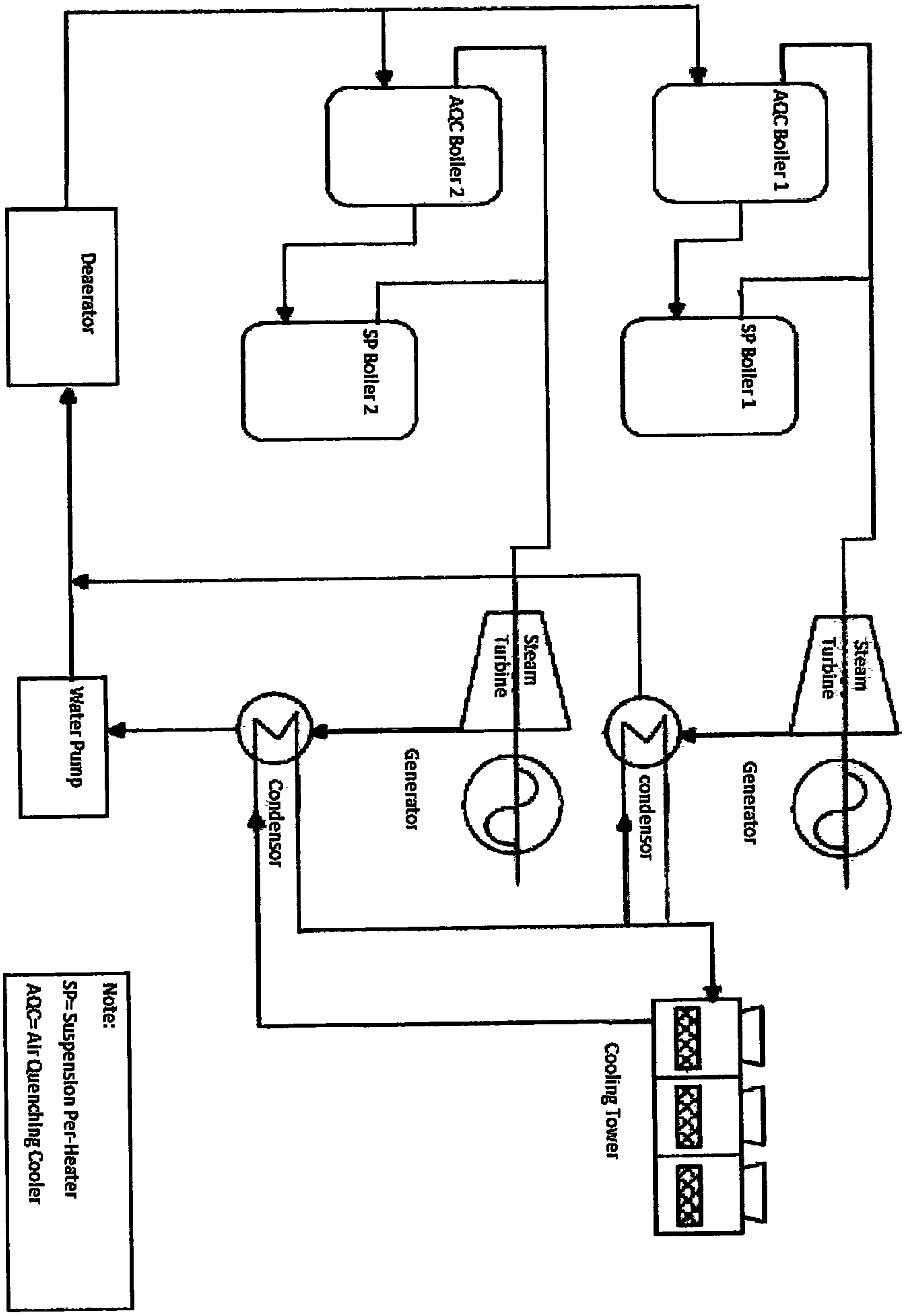

Figure 2-4 Waste heat recovery process [16].

2.5 COAL AND ITS TYPES

Coal is classified into four general categories [17]. as discussed below

2.5.1 Anthracite

Anthracite is best quality of coal with the highest carbon substance, involving 86% to 98%, and a heat rate of approximately 15,000 BTUs-per-pound. Most commonly related with house heating, found typically in 11 north eastern countries in Pennsylvania.

2.5.2 Bituminous

Bituminous coal is used commonly to produce electric power and build coke for the steel production. Bituminous coal has carbon substance which ranges from 45% to 86% carbon and a heat rate of 10,500 to 15,500 BTUs-per-pound.

2.5.3 Sub bituminous

This type of coal contains 35-45% carbon substance and a heat rate between 8,300 and 13,000 BTUs-per-pound. Assets of this type of coal are situated mostly in a half-dozen Western states and Alaska. Assist heat rate is low, this coal normally has a low sulphur content than remaining types, which is a cause of motivation because its burning process is clean.

2.5.4 Lignite

It is a low quality coal, which contain lowest carbon substance i.e. 25-35%, and a heat rate ranging between 4,000 and 8,300 BTUs-per-pound. It is also known as brown coal and mostly involved in the generation of electric power.

2.6 COAL FIRED POWER PLANT

Coal-fired power generation processes are described below. The basic method either running the plant by oil or by gas is identical. All major components are shown in figure 4-5.

2.6.1 Coal deliver

From coal yard, coal is sent to crushers and then conveyors getthem ready and sends coal to funnel-shaped hopper at the power plant. Then coal is transferred and is trodden to small number in mass.

2.6.2 Coal grind

Now these small masses of coal are poured into coal mill grinder. After grinding it is converted into powdered form. This powdered form of coal is then taken into the boilers by the help of hot air.

2.6.3 Boiler

The boilers contain kilo-meters of long tubes filled by water. When the coal comes into the boiler, it immediately catches fire and burn with great strength. The internal temperature of boiler may rise up to 1,300° C. Then tube water converts to vapours.

2.6.4 Precipitators and chimney

When the coal burns, it releases gases (CO_2, SO_2, and NO) and slag. The gases then ventilated out through chimney. Air filters which are larger in size are known as electrostatic precipitators which remove almost all the coal dust prior releasing into the air. The denser dust particles are collected at the base of boiler is also emitted by rotory. Toxic waste controlling equipment is installed to minimize the emission of fumes into the air.

2.6.5 Turbine and generator

The steam from the boiler falls on the blades of the turbine due to which the turbine rotates. Rotation of blades depends upon the steam pressure. The turbine is coupled with generator by the help of a shaft. By the principle of electromagnetic induction electric power is produced in generator as the turbine turns.

2.6.6 Condenser and water cooling method

The used steam leaves the turbines and goes through cool tubes present in the condenser. The used steam is again converted into water by the help of the condenser. Then this water is again sent to the water tubes present in the boiler for the repetition of the boiling process. Meanwhile water is filled in the condenser by some reservoir to keep it cool. The water in the condenser exchanges its coolness with the hotness of tube water and makes tube water cool and then release the hot water from the plant.

2.6.7 Water distillation

Water distillation plant is installed for minimizing the corrosion of boiler tubes. Water is purified by the plants so that it can be used in the boiler tubes. Rest of the contaminated water is also recycled and is throw out to land streams.

2.6.8 Ash removing system

Ash taken from the boilers through rotory and conveyers is removed from the plant and dragged to discarding areas. Fly ash is use in manufacturing of cement.

2.6.9 Transformer and transmission lines

For the transmission purposes Transformers are used as step up and step down the voltage of the electric power which is produced by the power plant. After that transmission lines transmit the electric power to the substations from the power plant.

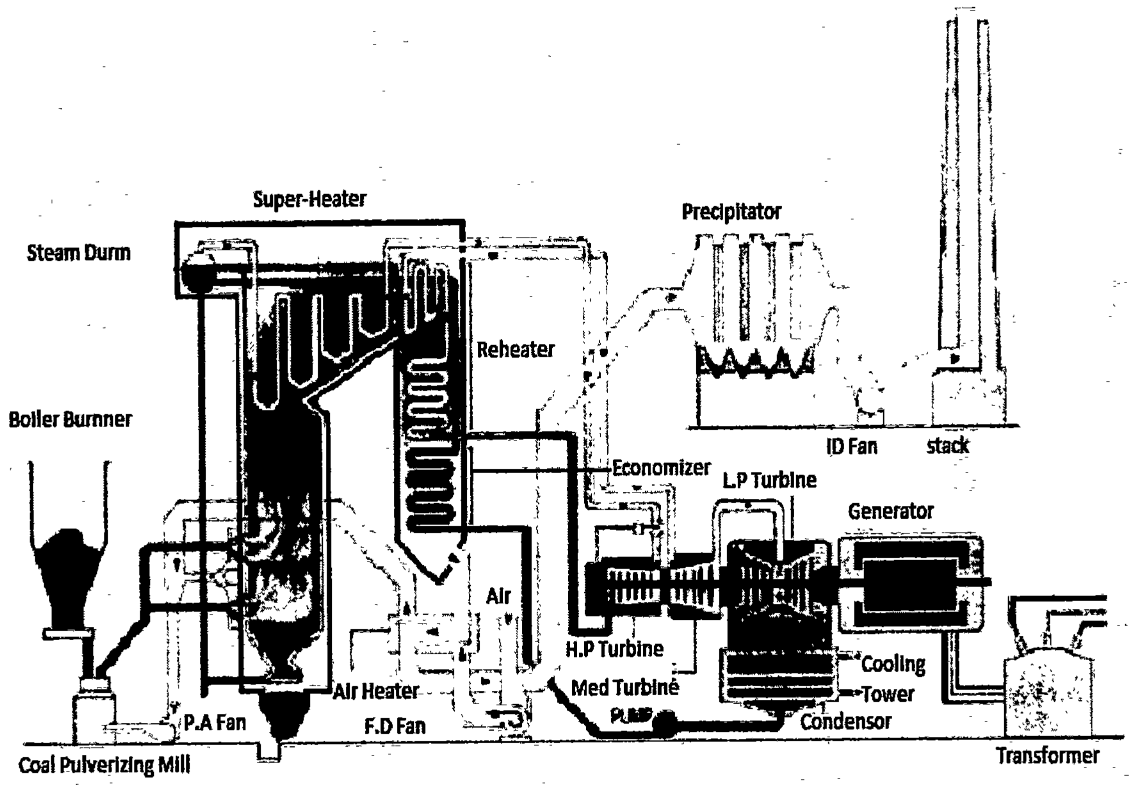

Figure 2-5 Component of coal power plant [18].

2.7 MODIFICATION IN BOILER

In his paper [19]. present different boiler modification schemes that can be implemented used to raise steam temperature, working steam pressure, economizer surface region, addition of superheater surface area, upgrading OFA systems, and steam production from variety of fuels, including fossil fuels (coal, oil, natural gas), biomass fuels (sawdust, bark, hog fuel, clarifier sludge, farming by products etc,), and/or waste fuels (tire derived fuel, production and demolition garbage, municipal waste, reject derived fuel, etc.) Idea is to produce more power in low cost.

2.8 BLOWERS

Blowers are used to provide air for airing and for running the industrial procedures. Pressure is generated by the blowers so that air can move against the resistance.

By the way of movement of the air we can differentiate among fans, blowers and compressors. As stated by American Society of Mechanical Engineers (ASME), the fans blowers and compressors can be defined by finding out definite ratio of the discharge pressure over the suction pressure.

While selecting the blower we must keep in mind the following terms like efficiency of blower, pressure of the air, volume flow rate, type of material handled and space limitations [20].

2.8.1 Types of blower

There are two types of blowers which are used in industry widely

1. Centrifugal blowers
2. Positive displacement blowers

Blowers can obtain the pressure which is very much higher than that of fans, as high as 1.20 kg/cm^2.They are also used to produce negative pressures for industrial vacuum systems. The centrifugal blower and the positive displacement blower are two main types of blowers, which are described below.

1. **Centrifugal blowers:**

Centrifugal blowers resembles to centrifugal pumps than to the fans. The impeller is normally gear-driven and revolves as quickly as 15,000 rpm. Air is accelerated through each impeller in multi-stage blower while in single-stage blower air does not have to take many turns, which makes it more efficient.

Centrifugal blowers normally work against pressures from 0.35 to 0.70 kg/cm^2, but it can also obtain greater pressures.

2. **Positive-displacement blowers:**

Positive movement blowers contain rotors, which grab the air and drive it through casing. If the system pressure varies, a constant volume of air is delivered by the blowers. They can create sufficient pressure up to 1.25 kg/cm^2. They run in slower speed than that of centrifugal blowers e.g. 3,600 rpm.

2.9 FUEL BURNER

There are different types of burners like Gas Burner, Oil Burner, Coal Burner, Wood Burner, and Process Gas Burner for several purposes and in several areas, which depends on fuel supply and the purpose of the burner.

- DS Burner for Bituminous Coal
- RS Burner for Lignite
- DST Burner for all Pre-dried Pulverized Fuels
- ADS Burner – Oil / Gas
- SG Burner – BFG

DS Burners were used in direct firing systems for nearly all kinds of pulverized solid fuel qualities. The DS Burner is the first of its kind enabling the controlled ignition and staged combustion process. It represents the basis model for the development of the other types of burners. Due to its excellent flame stability, the DS Burner shown in Figure 2-6 (a) comes up with a control range of 1: 3.8 where as normal coal burners are limited to 1: 2. The burner is suitable for individual combustion air supply as well as wind box arrangements.

RS Burner designed for lignite burning in boilers shown in Figure 2-6 (b). In comparison to usual jet burners, RS Burner is focused on stable fuel ignition at the burner tip. This principle came from DS Burner and designed by HPE.

The DST Burner developed on the basis of the DS Burner concept for use in indirect firing systems. This burner type is the right one for all kinds of pre-dried pulverized fuels. These burners have a considerable turndown rate of up to 1:17 and are thus ideal in supporting flexibility issues. DST Burners shown in Figure 2-6 (c) can be used for atmospheric operation or in pressurized systems.

ADS Burners shown in Figure 2-6 (d) are used with industrial boilers and utility steam generators. They are designed as single and for multi-fuel operation. ADS Burners are available for the front wall, opposed installation or as bottom burners; they are also used as start-up burners in utility units.

SG Burners shown in Figure 2-6 (e) are used for low calorific fuel like Blast Furnace Gas (BFG / BOFG), multi fuel applications like COG, NG and oil. For best combustion performance, fuel and air flows are also influenced by swirlers and other devices [21].

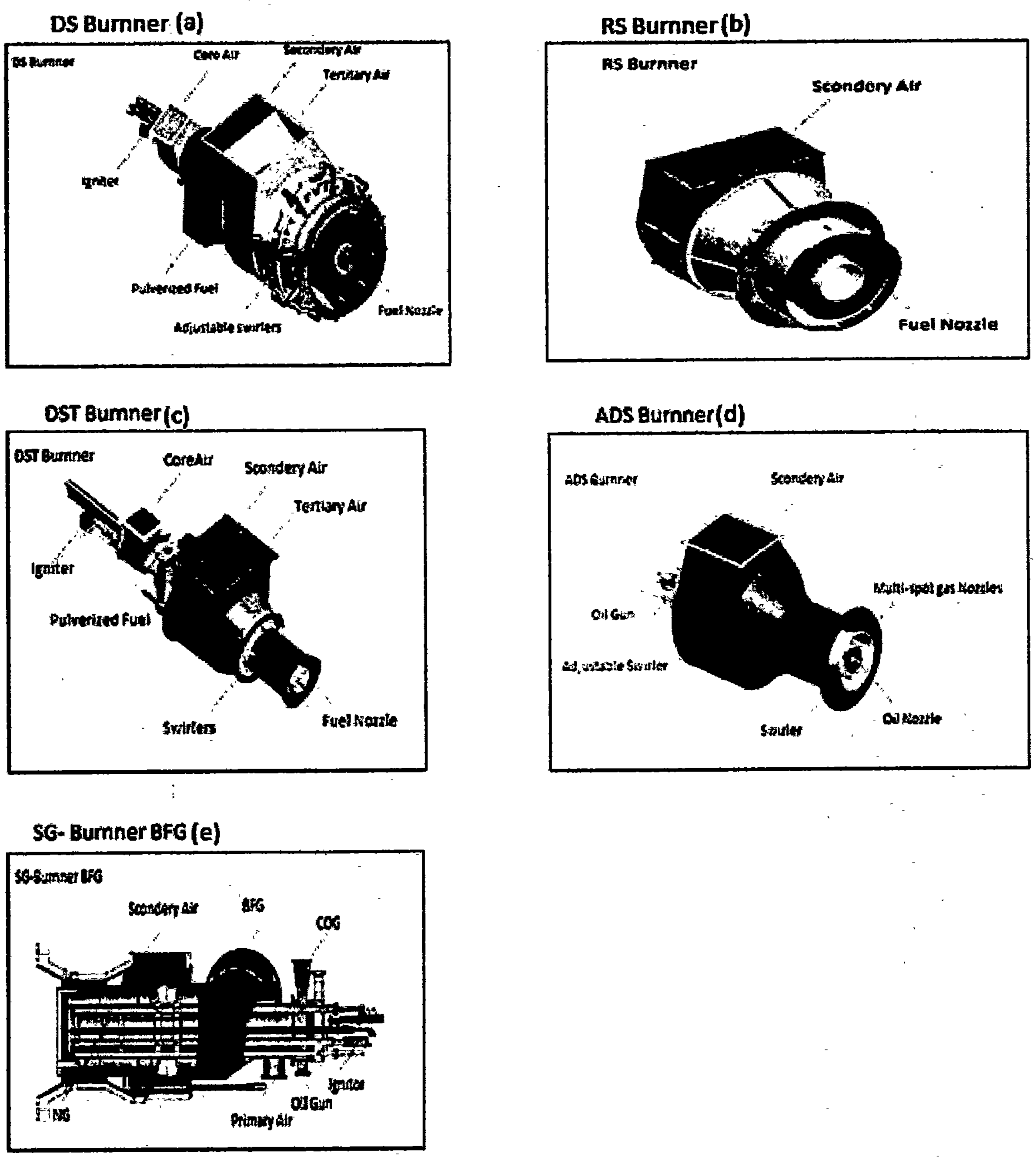

Figure 2-6 **Different types of fuel burner** [21].

2.10 DIMENSIONS OF THE FLAME OF BURNER

Ahead of selecting the fuel supply, the dimensions of the combustion compartment have to be checked which is to be shared with the selected burner, to make sure they are related to those of the test boiler used to test the burners. For this test, the figure 2-7 under must be used, in which with ingoing the thermal productivity or the fuel release on the X axis; examine the diameter of the combustion section on the upper axis and the length of the section on the Y axis. The selection is confirmed by the boiler and the burner will be attached to walls within the tolerance range. Below is a graph through which flame length is derived

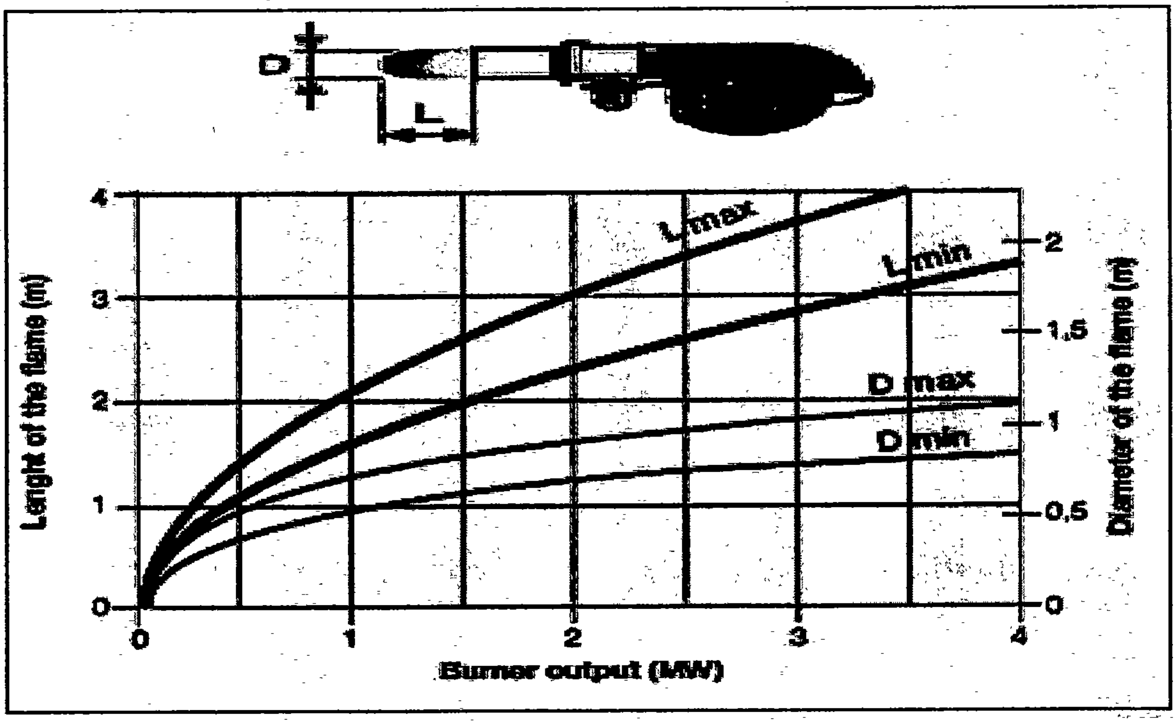

Figure 2-7 Flame length [22].

According to above graph

If Burner thermal output is 2000 KW.

Flame length according to graph L max, L min respectively (maximum and minimum) flame range so average Flame Length is L_{flame} (m) is 2.7 m (medium value)

Flame diameter according to graph D max, D min respectively (maximum and minimum) flame range so average Flame diameter D_{flame} (m) is 0.8 m (medium value).

CHAPTER 3. PLANT INTRODUCTION

3.1 INTERDUCTION OF BCL CEMENT PLANT

Bestway Cement Plant is located at district Chakwal, Punjab province, Pakistan. BCL is contains two dry clinker production lines and the capacity of each line is 5350 tons/day.

Cement manufacturing process consumes large amounts of energy, fuel and Electrical energy. The rotary kilns are 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 feed 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 MV and LT motors, heaters. Electrostatic precipitator and lighting load etc.

3.2 PLANT COMPOSITION

Plant consists upon different sections according to work process and each part is explained individually below. Major sections are shown in figure 3-1 that is kiln, pre-heater, pre-calciner, clinker cooler and raw mill silo.

3.2.1 Quarrying and Crushing

Mostly the raw materials required are obtained from the quarrying by mining. Crushing is necessary to reduce the quarried materials to a size suitable for grinding. The size of crushed material generally ranges to about 25mm by roller mills.

3.2.2 Stockpiling

When the raw materials are highly variable in composition then it is very essential to even out the variations in composition by stockpiling. The blending beds called mix beds are longitudinal or circular. The longitudinal stockpile had been reported to give a better blending efficiency. A blending bed is not necessary if the materials are of uniform composition suitable for the burning process. Here the incoming material is deposited in the layers of one or more variable raw materials. A blending bed consists of two stocks piles one of which is being built up, while the other is being reclaimed and passed on to the grinding unit.

3.2.3 Grinding of Raw Material

The pre homogenized parent mix is delivered to the feed bins of the raw mills by the reclaimer beds. The necessary correcting compounds are also stored in feed bins. Raw meal samples are taken from the discharge end of the mills before going to the continuous homogenizing silos. The periodic samples so collected are dispatched to the laboratory and analysed. Computer actuates the weighing feeders to carry out necessary adjustments in respect of correcting materials.

3.2.4 Homogenisation of Raw Meal

The raw meal is pumped in to blending silos where it is subjected to homogenise to confirm that kiln feed is of uniform chemical structure; perquisite for the effective working of the kiln and for good quality clinker.

3.2.5 Coal mill (Grinding of coal)

Coal is used widely due to its comparatively low cost. Pulverized Coal feed at kiln and PC for calcinations process of cement for making pulverized coal equipped with coal mill capacity of 40tons/hr to raw coal mill.

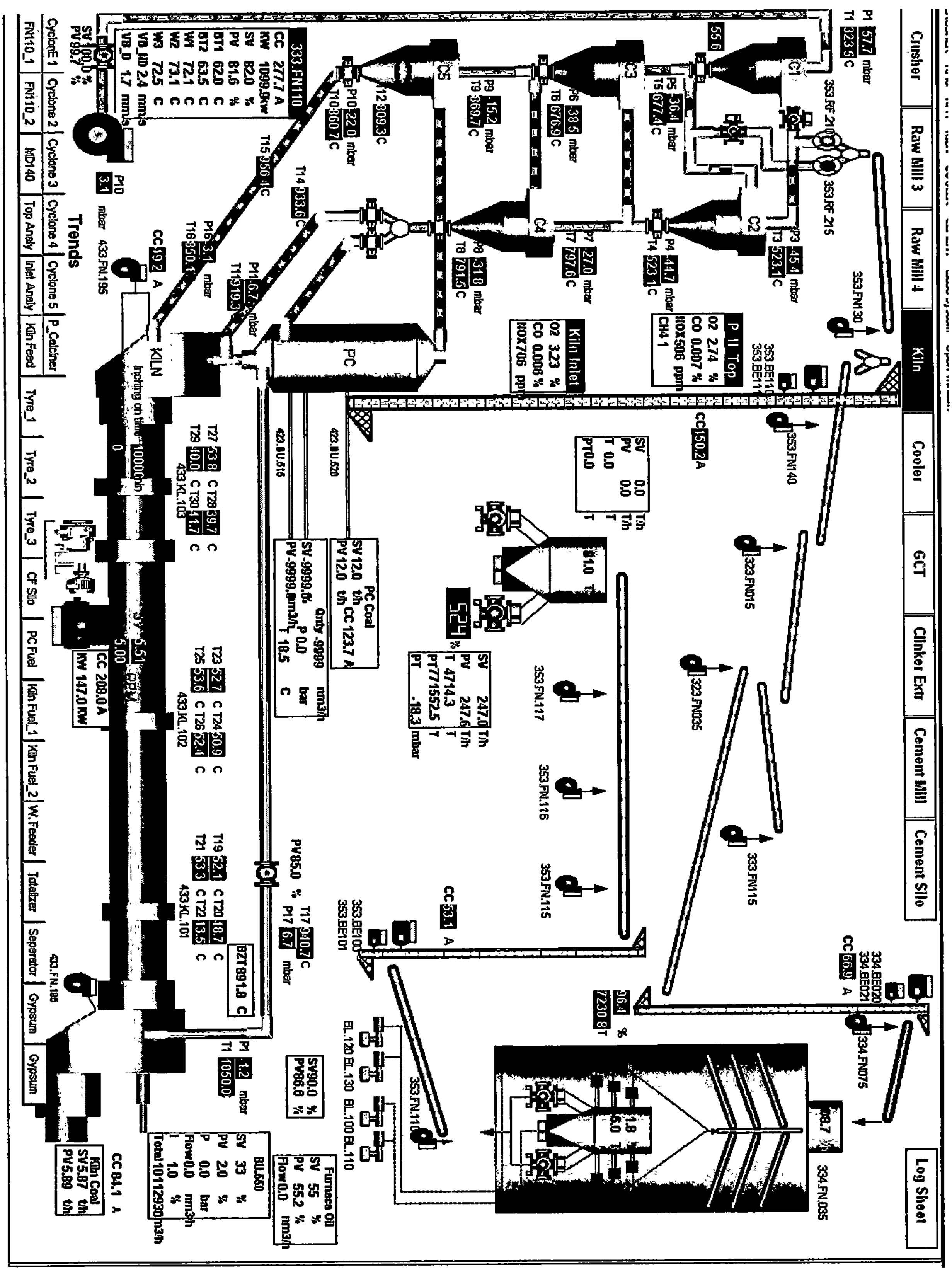

Figure 3-1 **Cement operation PLC view of plant site (Bestway Cement Ltd,)**

3.2.6 Fuel dosing system

Coal, oil and gas fuel feed at kiln main and Pre-calciner for calcination process of cement; a dosing system is equipped at plant.

3.2.7 Rotary Kilns

Rotary kiln are indeed large rotating furnace 4.5 meters outer diameter and 4.3 inner diameter and 72 meter long made of steel plates welded together into a sturdy construction and kiln entire interior is lined with refractory bricks. The rotary kiln is supported by girth tires around the circumference at several points and kiln slowly rotate at 1 to 5 rpm by a gear drive motor to expedite a continuous flow of material through kiln by incident having a slope of 3-4 degree.

Clinker is discharged red hot from the lower and of the kiln and transformed to clinker cooler to lower the clinker temperature.

3.2.8 Suspension Preheated

TH-16438

Raw meal is conveyed to the top of preheated tower, which contains five-cyclone stage. The raw material falls by gravity through each into reconnected cyclone and the hot gases from the kiln pass through the cyclones and heat the raw meal to approximately 300-900°c.The hot raw meal from the bottom cyclone partially calcinated (20-40%) leaves the preheated tower at about 300-900 ^{0}c and enter the rotary kiln for further heating and sintering into clinker.

3.2.9 Clinker Hydraulic Cooler

On leaving the hottest zone the clinker cools to about 1000-1200 °c. Then air is quenched as it leaves the kiln and the quality of clinker is improved. Air is forced through a bed of clinker on a hydraulic which conveys the clinker forward and the air used to cool the clinker becomes highly heated and is used as a secondary and tertiary air in the kilns.

The grate cooler desires more air which is essential for burning .The extra air needs to be vented to the atmosphere, thus causing considerable heat loss. Excess air from the grate cooler is deducted by gravel bed filter and used to dry the moisture in the raw material stage or coal, for heating fuel oil, or for generating electricity.

3.2.10 Storage of Clinker

The temperature of the clinker after leaving the coolers is brought down to a level suitable for handling and subsequent milling clinkers is stored either in open yards or in silos so as to avoid dust.

3.2.11 Cement Mill (Grinding of clinker)

The final stage in the manufacture of cement lies in grinding the clinker to a very fine grey powder with 0-6% of gypsum or anhydrite that powder is called cement and stored in silos.

3.2.12 Cement silo (Storage) and packing plant

Cement ground from the cement mill is stored in silos and these silos are either of concrete or steel structures .The capacity of these silos is 11000 x 8= 88000 tons. Cement is loaded in trucks through rotary packer.

3.3 WASTE HEAT RECOVERY POWER GENERATION:

3.3.1 Introduction

In cement industry, approximately 90% of total energy is used as heat energy in progression of clinker calcinations. The entire heat used in progression of clinker calcinations and nearly 35% of heat is quitted as waste heat to the surroundings without being used, hence, a excessive deal of energy is wasted [16].

In Bestway cement limited a waste heat recovery (WHR) Captive power plant is fitted to use the waste heat in a proper manner and generate Electric Power. The waste gases exit from suspension pre-heater (SP) and air Quench chamber (AQC) in cement production. The WHR power generation is 16MW when both kiln lines are in operation. The power plant contains 4 WHR boilers from which two are at the pre-heater stage and two are at clinker cooler stage one turbine and one generator. The steam from SP Boiler and AQC Boiler is fed to steam turbine generator to produced electric power. Due to energy crisis mostly kiln one lines remain shut off during last year's. When one line remains shut off due to any reason then output of WHRPP is half of total generation.

3.4 MAJOR EQUIPMENT OF WHRPP

Major equipment of Waste Heat Recovery Power Plant are shown in figure 3.2

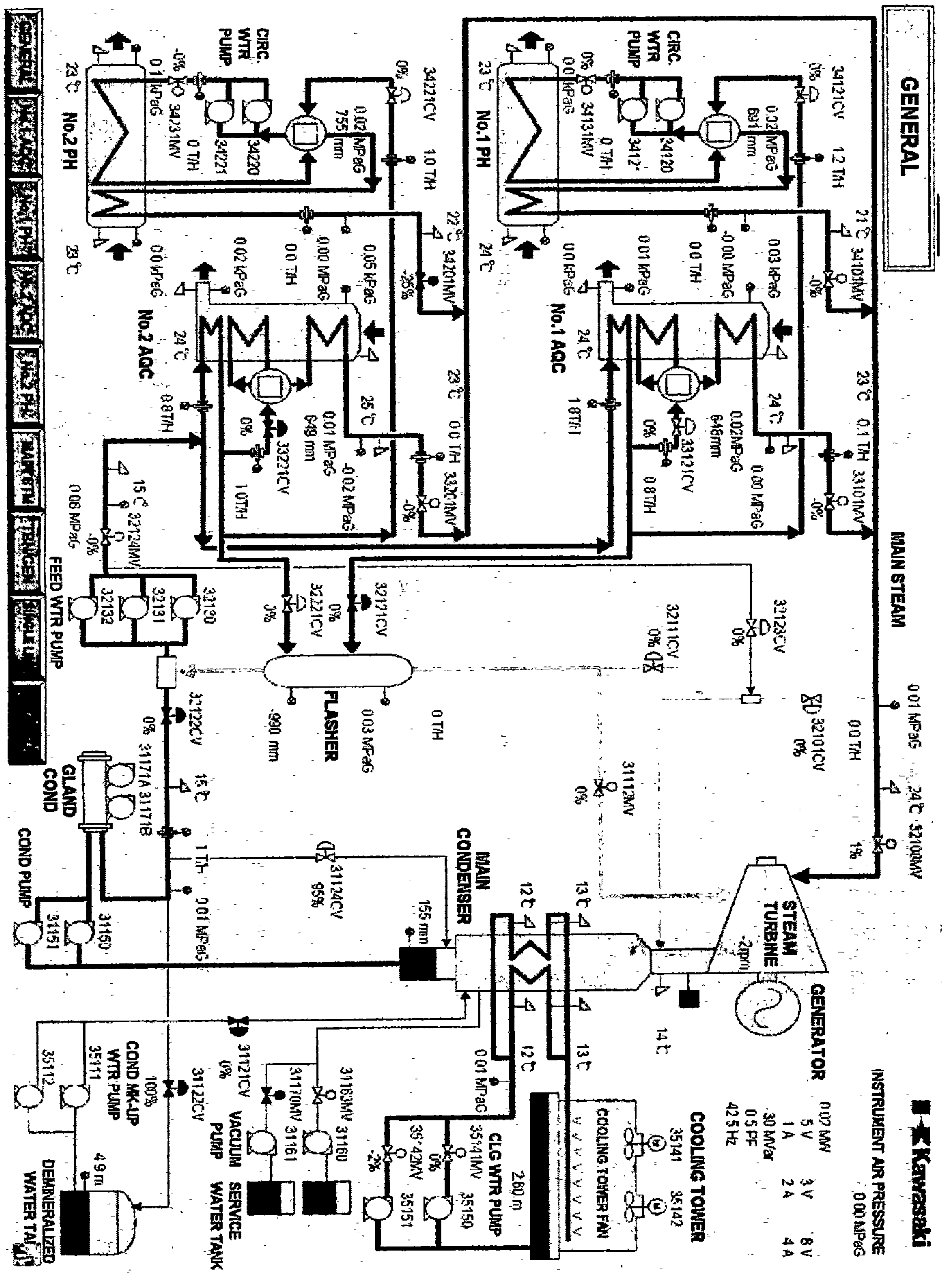

Figure 3-2 Waste Heat Recovery Power Generation at plant site (Bestway Cement Ltd.)

3.4.1 Air Quench Chamber Boiler

Boilers are of two types, water tube boiler and fire tube boiler. AQC boilers are water tube boiler containing three stages one of them is economizer, second is steam generator and third is super heater. Economizer takes water from feed water pump and economizes it. Economized water transfer in steam generator tank. Steam generator produces steam. This steam is made super steam by super heater and which goes to turbine. The Specification of AQC boilers shown in table 1.

Specifications of AQC boilers installed at plant

Type	KAWASAKI type Natural Circulation
Quantity	**2**
Location	**Outdoor**
Feed water temperature (at Economizer Inlet)	76 °C
Steam pressure (at Superheated outlet)	1.63 MPa
Steam temperature (at Superheated outlet)	345 °C
Feed water temperature (at Economizer Outlet)	198 °C
Feed water flow (at Economizer inlet)	45.5 Ton/hr
Exhaust gas temperature (at inlet)	360°C
Exhaust gas flow from each AQC Waste Heat Exchanger	189,100 Nm^3/hr
Exhaust gas temperature (at outlet)	101°C
Evaporation	14tons/hr

Table 1 Specifications of AQC boilers (Bestway Cement Ltd.)

3.4.2 Suspension Pre-heater Boiler

SP boilers are also water tube boilers. It contains two stages; steam generator and second is super heater. Steam generators take economized water from economizer and make steam and super steam by super heater. The specification of SP boiler is shown in table 2.

Specifications of SP boilers installed at plant

Type	KAWASAKI Natural Circulation
Quantity	**2**
Location	**Outdoor**
Steam pressure (at Superheated outlet)	1.63 MPa
Steam temperature (at Superheated outlet)	321°C
Feed water temperature (at Economizer Outlet)	198 °C
Feed water flow (at Economizer inlet)	24.1Ton/hr
Exhaust gas temperature (at inlet)	335°C
Exhaust gas temperature (at outlet)	223°C
Exhaust gas flow from each AQC Waste Heat Exchanger	306,000 Nm^3/hr

Table 2 Specifications of SP boilers (Bestway Cement Ltd.)

3.4.3 Steam Turbine

Turbine produces mechanical power by using super heated steam which is generated by AQC boiler and SP boiler. The specification of steam turbine shown in table 3.

Specification of Steam turbine installed at plant

Type	Multi stage mixed pressure condensing turbine
Quantity	1
Rated output(at generator terminal)	16,550KW
Guaranteed output (at generator terminal)	14,900 kW
Revolution	3,000 rpm
Main steam condition at steam turbine inlet Inlet steam pressure	1.53 MPa
Inlet steam temperature	324°C
Inlet steam flow	77.2 T/H
Exhaust steam pressure	0.956 MPa

Table 3 **Specification of Steam turbine** (Bestway Cement Ltd.)

3.4.4 Generator

Generator is mechanically coupled with steam turbine and convert mechanical energy into electrical energy. The specification of generator shown in table 4.

Generator specifications installed at plant

Type	Three phase, AC synchronous generator Horizontal shaft, totally enclosed, self ventilated, revolving field (indoor use) for suitable parallel operation
Quantity	1
Rating	16MW
Capacity	19,470KVA
Time rating	Continuous
No. of pole	2
Rotation speed	3,000 rpm
Voltage	6,300 V
Frequency	50 Hz
Power factor	0.85 Lag

Table 4 Specifications of Generator (Bestway Cement Ltd.)

3.4.5 Condenser, Cooling tower and feed water pump

Steam is condensed in condenser after turbine Evaporation. Cooling tower take hot water from condenser and make it cool. Recycled water, which take from condensate pump and hot water/saturated steam take from flasher feed to economizer via feed water pump.

3.4.6 Flasher

Recirculation of hot water/saturated steam between economizer and flasher via feed water pump.

3.4.7 Circulation water pump

Circulation water pump eject hot water from economizer and feed to steam generator.

3.4.8 Pre-duster

Hot gases come from AQC and SP in both boilers also carrying dust particles. To remove these dust particles and prevent them to enter in AQC Boiler, pre duster is used ahead of AQC Boilers as shown in figure 3-3.

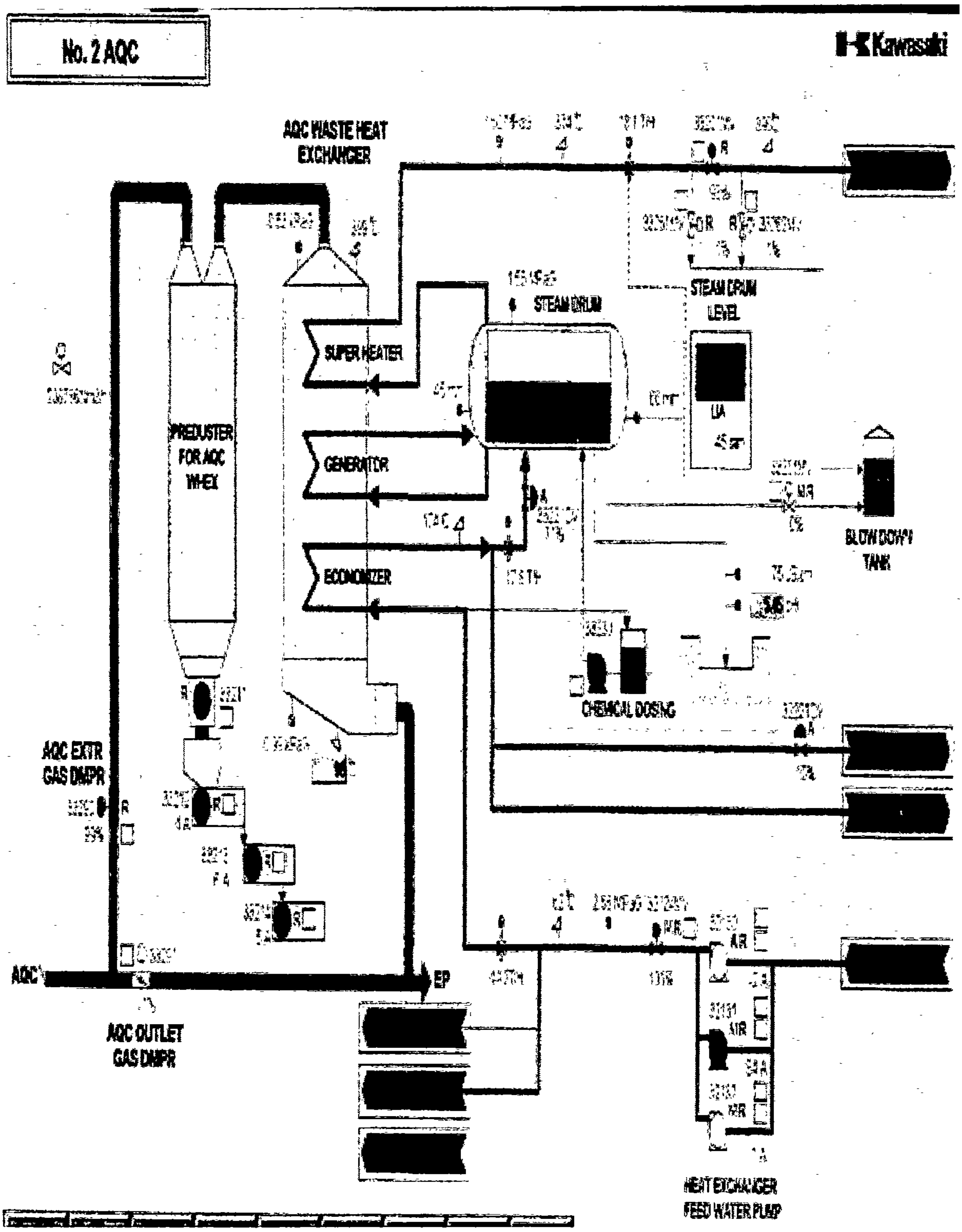

Figure 3-3 AQC waste heat boiler and pre-duster with dust removal(Bestway Cement Ltd)

3.4.9 Vibrators

To remove minor dust particle which can harm the tubes of boiler, vibrators are used inside the boiler.

3.4.10 Rotary and Conveyer

To catch and remove dust which falls on the bottom of boiler, Rotary and dust conveyer are used. Rotary is used to exit only dust as shown in figure 3-4.

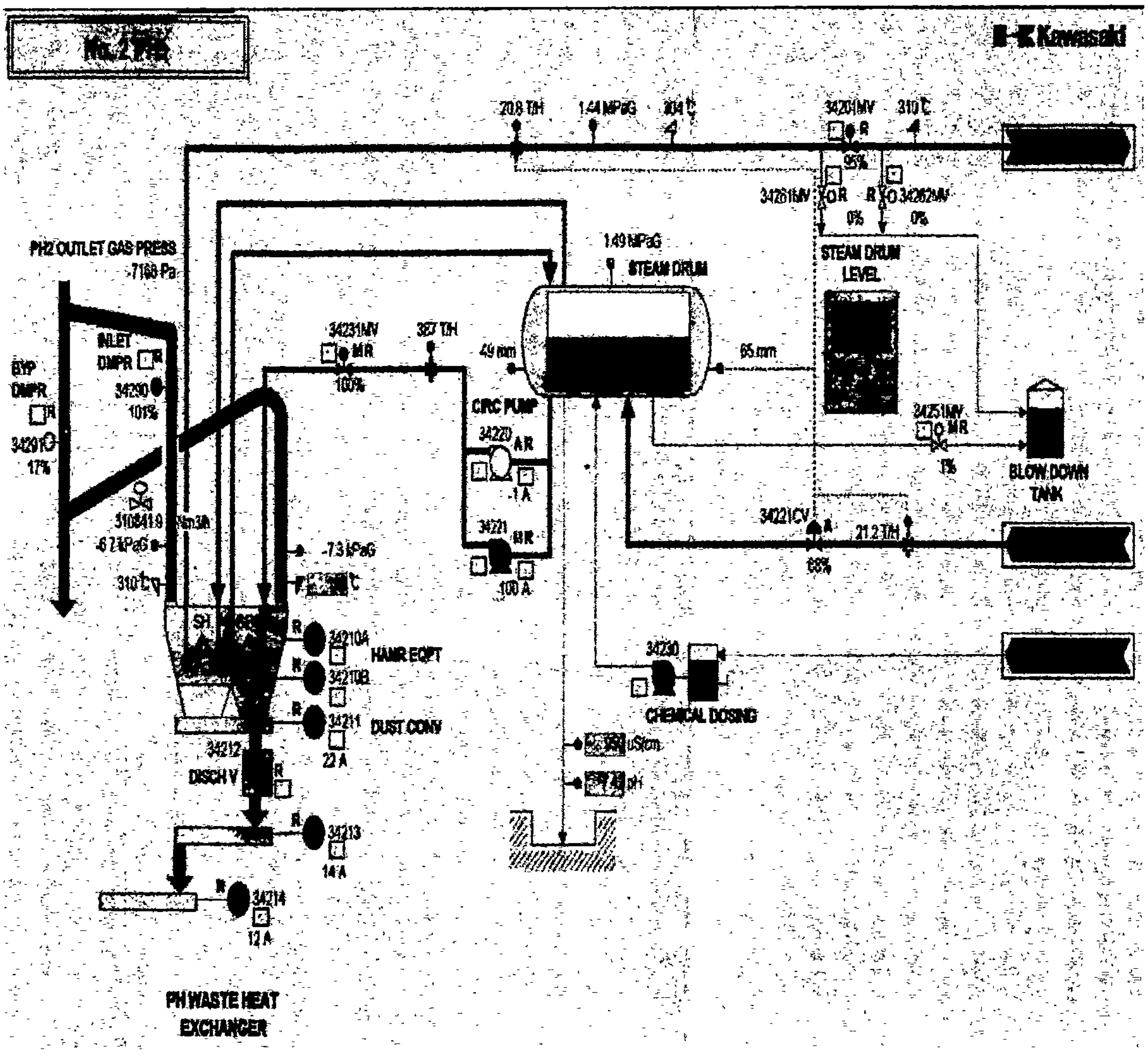

Figure 3-4 **SP waste heat boiler with vibrator and dust removal(Bestway Cement Ltd).**

3.5 STATISTICS OF WHR PLANT

Electrically installed capacity of cement plant is 53MW and full operation load is 52MW so around 370,000 MWh of electricity imported from WAPDA grid is used up by Bestway yearly. The WHRPP generate 105600 MWh of electricity per annum. The electricity produced by the waste heat power plant is displacing electricity produced by fossil fuel power plants on the grid. This can help Pakistan to reduce its overall fossil fuel consumption, thus improving energy security and improving the country's balance of payments.

CHAPTER 4. MODIFICATION OF BOILER

4.1 EXISTING BOILER

The existing WHR power plant contains four (4) water tubes boiler two (2) of them installed at Air Quench Chamber (AQC) and other two (2) are installed at suspension pre-heater (SP). The dust particles, which come with waste hot gases, are harmful for water tubes. These dusts particles are removed from water tubes by vibrators and dust fall down at the bottom of boiler. Rotary is used to put out the dust from boiler's chamber without leakage of hot gases. Conveyors shift the dust in dust yard.

4.1.1 AQC Boiler

AQC boilers consist of economizer, steam generator and super heater. The boiler water tubes are mounted respectively as super heater, steam generator and economizer in horizontal condition shown in figure 4-1 and dimensions of AQC boilers shown in table 5.Also water tube dimensions shown in table 6.

AQC boiler Dimensions diagram before modification

Title	Size
The length of object	12120 mm.
The width of object	3920 mm.
The height of object	17210mm.
The diameter of gas inlet point	3700mm.
The diameter of gas outlet point	2880mm.

Table 5 **AQC boiler Dimensions diagram before modification(Bestway Cement Ltd).**

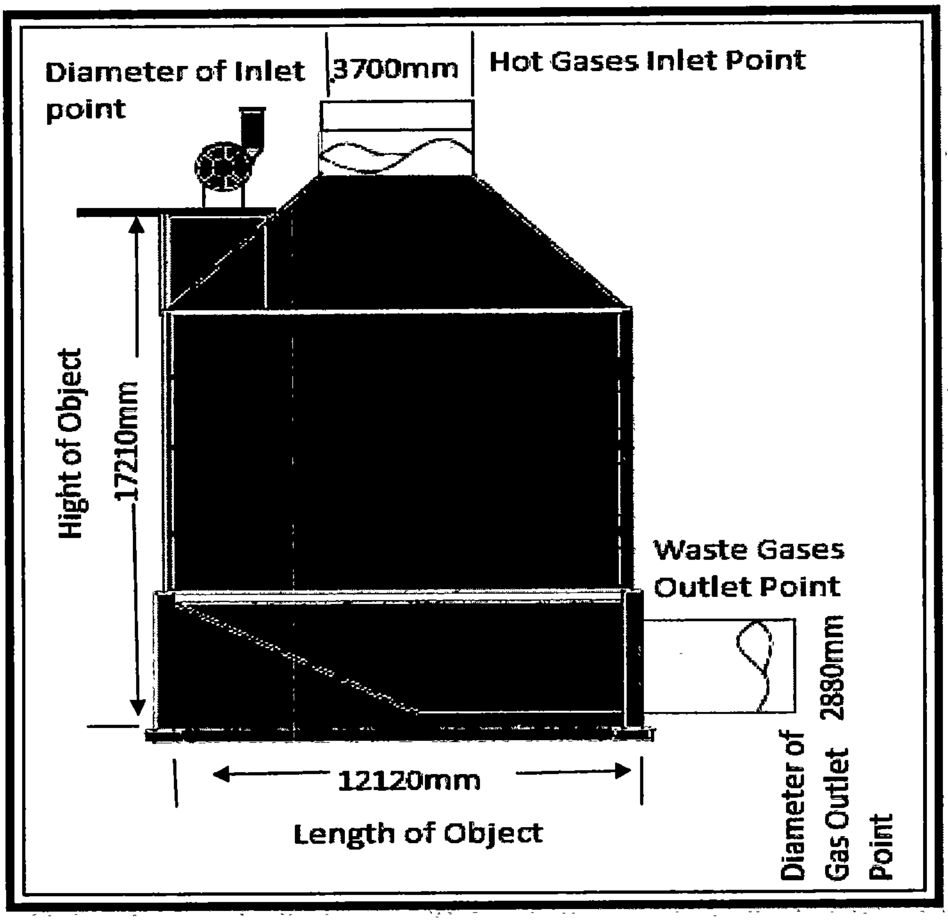

Figure 4-1 **AQC boiler Dimensions diagram before modification(Bestway Cement Ltd).**

Size of water both boilers.

Height	4900 mm,
Width	4430mm
Length	12mm
Distance between water tubes and boiler internal wall	20 mm

Table 6 **Water tube dimensions (Bestway Cement Ltd).**

4.1.2 SP Boiler.

Suspension pre-heater boilers consist of steam generator and super heater. Economized water is taken from AQC boiler. In SP boiler water tubes are mounted respectively as super heater and steam generator in vertically condition. Dust removing system is also shown in figure 4-2 consisting of rotaries and screw conveyor, dimensions are shown in table-7

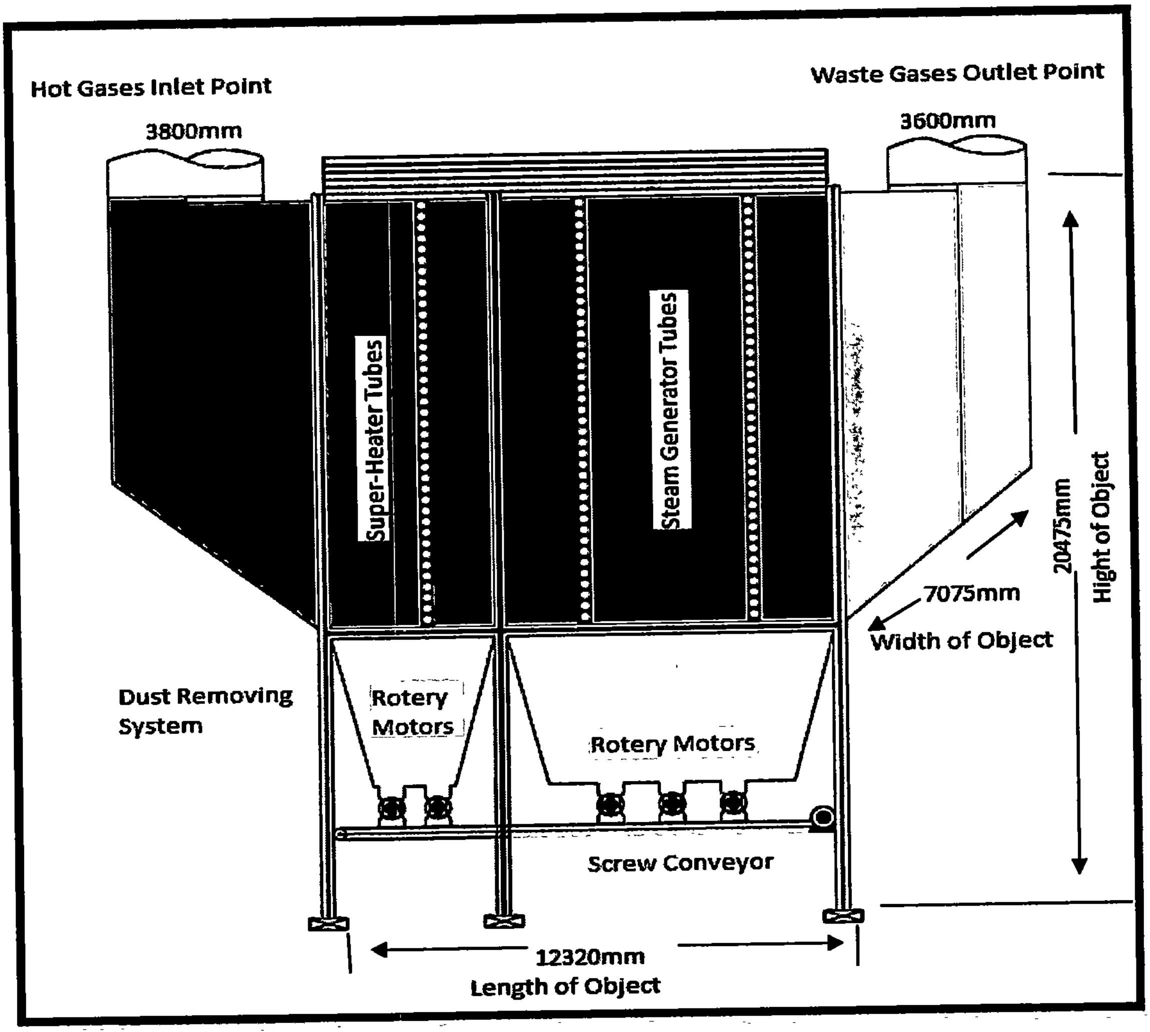

Figure 4-2 SP Boiler Before Modification(Bestway Cement Ltd).

SP boiler Dimensions diagram before modification

The length of object	12320 mm
The width of object	7050 mm.
The height of object	20475mm.
The diameter of gas inlet point	3800mm.
The diameter of gas outlet point	3400mm.

Table 7 SP boiler Dimensions diagram before modification(Bestway Cement Ltd).

4.2 MODIFIED BOILERS

For fuel enhancement in waste heat recovery power plant there is need to modify boilers at gas inlet points. Then we can feed coal as fuel in boiler.

4.2.1 MODIFIED DIAGRAM OF AQC BOILER:

The capacity of AQC boiler is 14 ton steam/hr. 1,870 kWh per Ton of Coal or 0.9 kWh per Pound of Coal [23]. Accordingly 64 tons of steam produces 16 MW power by using 8 tons of coal.

0.5 tons of coal= 4 tons of steam= 1MW Electricity

1 ton steam=1/4=0.25 MW

For 14 tons steam= 14x0.25 =3.5 MW

Flame length for 2MW=2.7m

For 3.5 MW flame length will be 4725mm

The distance between water tubes and gases inlet point is 2520mm. selected burning gun for coal feeding flame is 4725mm. so the length of burning gun tip to super heater water tubes is 7245mm. The flame should finish 2000mm before the super heater tubes, because direct flame is harmful 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 4-3.

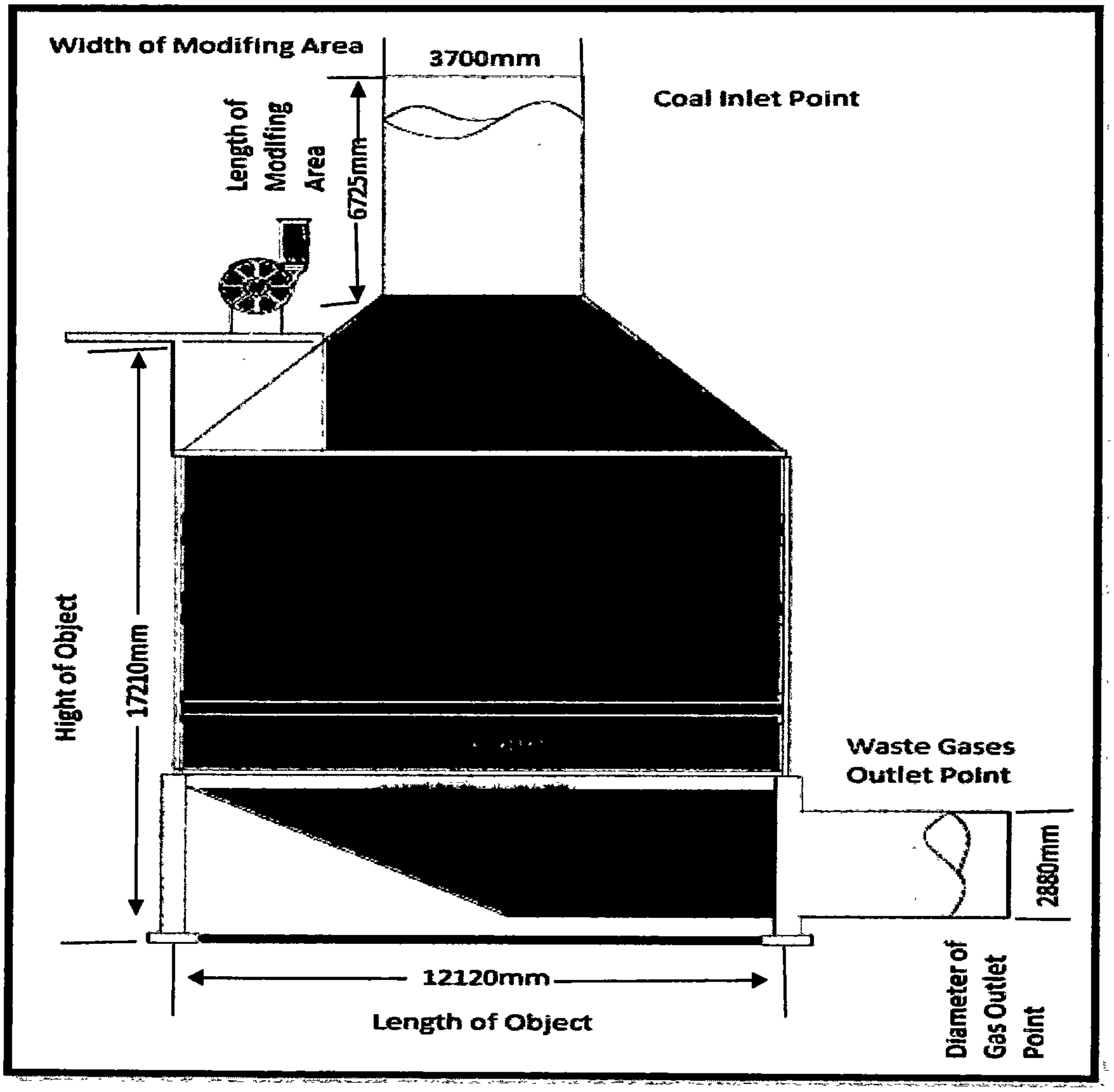

Figure 4-3 **AQC Boiler after modification.(Bestway Cement Ltd).**

4.2.2 MODIFIED DIAGRAM OF SP BOILERS

SP boiler capacity is 24 tons of steam.1 ton steam is equal to ¼ =0.25 MW and 24x0.25=6 MW

So the flame length for 6MW will be 8100mm

The distance between water tubes and gases inlet point from sidewall is 5300mm. Selected burning gun for coal feeding the flame is 8100mm. so the length of burning gun tipto super heater water tubes is 13400mm. The flam should finish 2000mm before the super heater tubes because direct flame is harmful and may damage the tubes. Therefore, the total length from tubes to burning tip is 15400 mm. So the modified length is 10,100mm and width is 5588mm and as shown in figure 4-4.

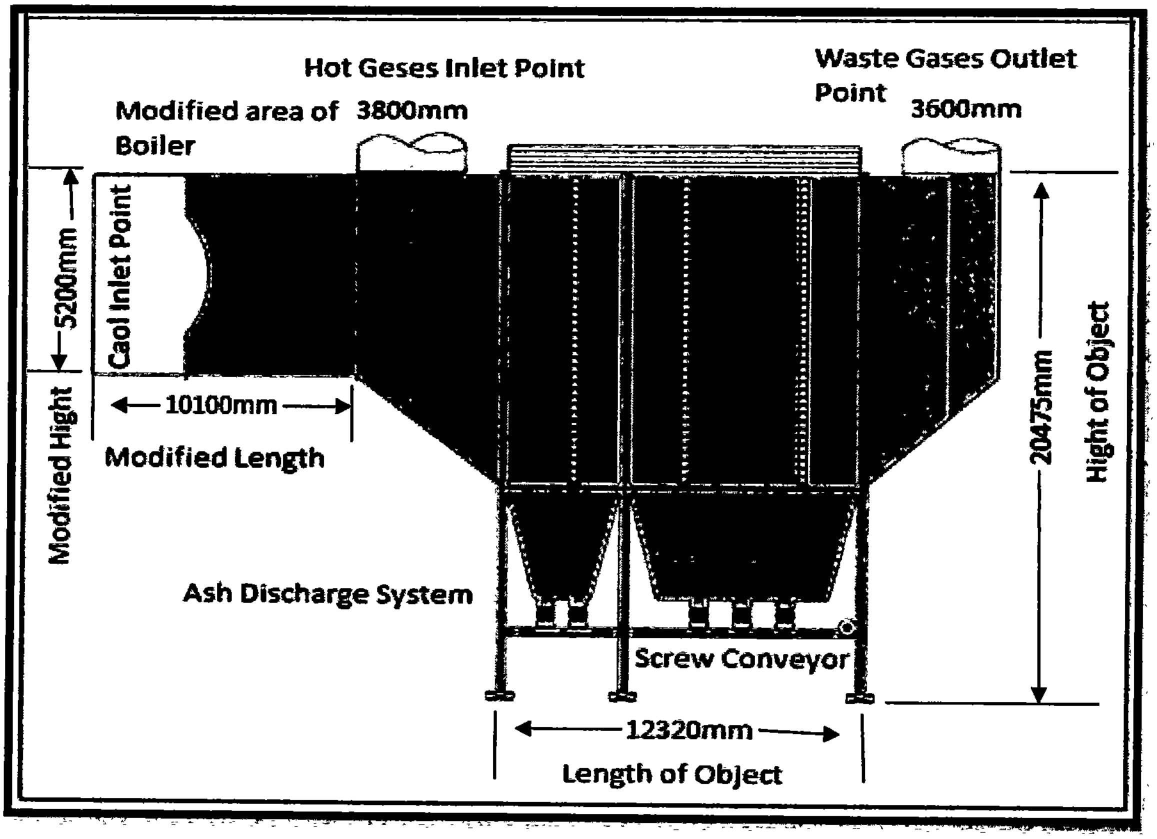

Figure 4-4 SP Boiler after Modification(Bestway Cement Ltd).

4.2.3 Proposed System for Coal-Dosing

This system shown in figure 4-5will work during the time when kiln is not working and no heat source is coming from kiln. The proposed system consists of following equipment; Coal, Coal Bin, flow meter, Blower and Burning Gun.

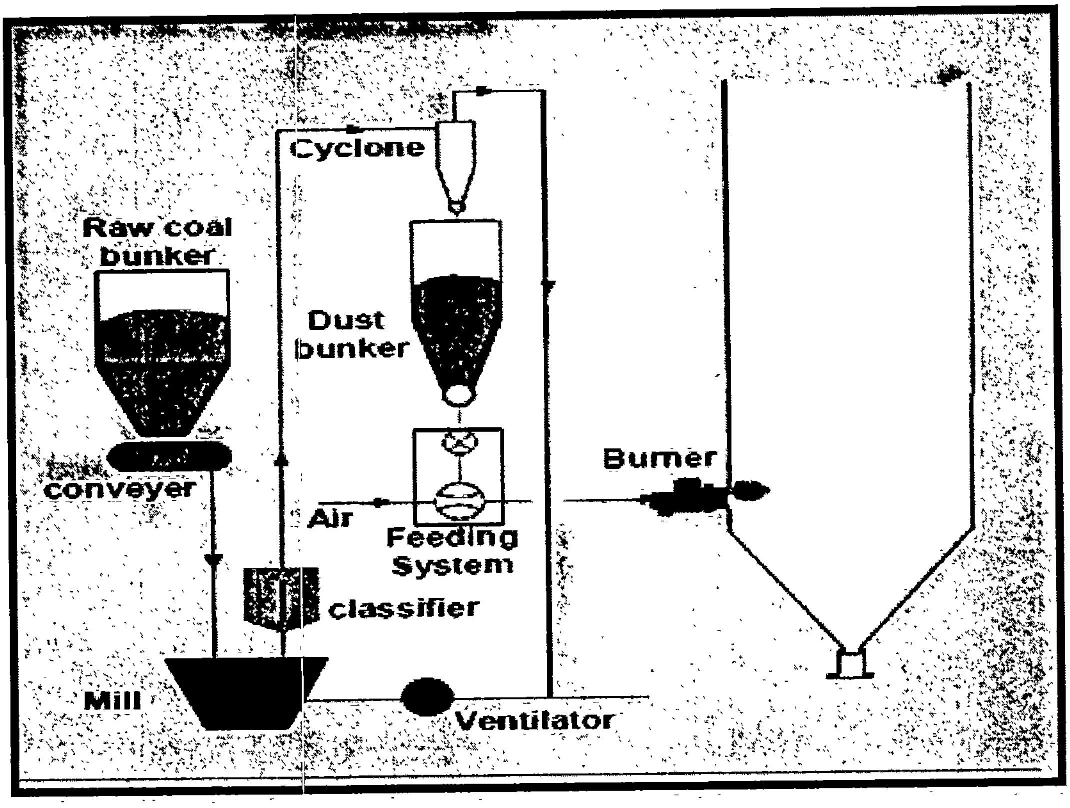

Figure 4-5 **Proposed coal dosing(Bestway Cement Ltd).**

- **Coal**

Coal is being used as fuel in system to generate heat energy.

- **Coal flow meter**

Flow meter will work as transportation of coal for fuel to blower. This will be with collaboration/accordance of a measuring system installed with flow meter. Capacity of flow meter is maximum 3 tons/h.

- **Blower**

It is used to transport coal to burning gun. Blower will transfer maximum 3 tons/hour coal to burning gun. So the capacity of blower is

Formula

HP = CFM x PSF / 33000 x Efficiency of blower.

Flow rate (CMF) = cubic feet per mint.

Pressure (PSF) = pounds per square foot.

33000 = conversion factor.

HP = horsepower.

HP = 106.14x9744/ 33000x.8

HP =39.17 = 29.22 KW

- **Burner**

We select multi-fuel burner for proposed system because when cement plant will stop due to any reason, the heat source for waste heat recovery plant will also stop then immediately coal will burn in boiler and maintain the temperature. When cement plant already in stall condition as planned shutdown for maintenance purpose or due to technical reason. After power plant maintenance, when it start it will not run on direct coal fuel. For initial temperature light up the boiler at furnace oil or gas; Multi-fuel burner 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. Fuel adjustment is required to control temperature in boiler. Burner for proposed system is capacity of 2.2t/h .For each system and selected burner is multi-fuel burner by made of pillard company as shown in figure 4-6.Multi-fuel burners are available in different range 0.5t/h to 16t/hrs[24].

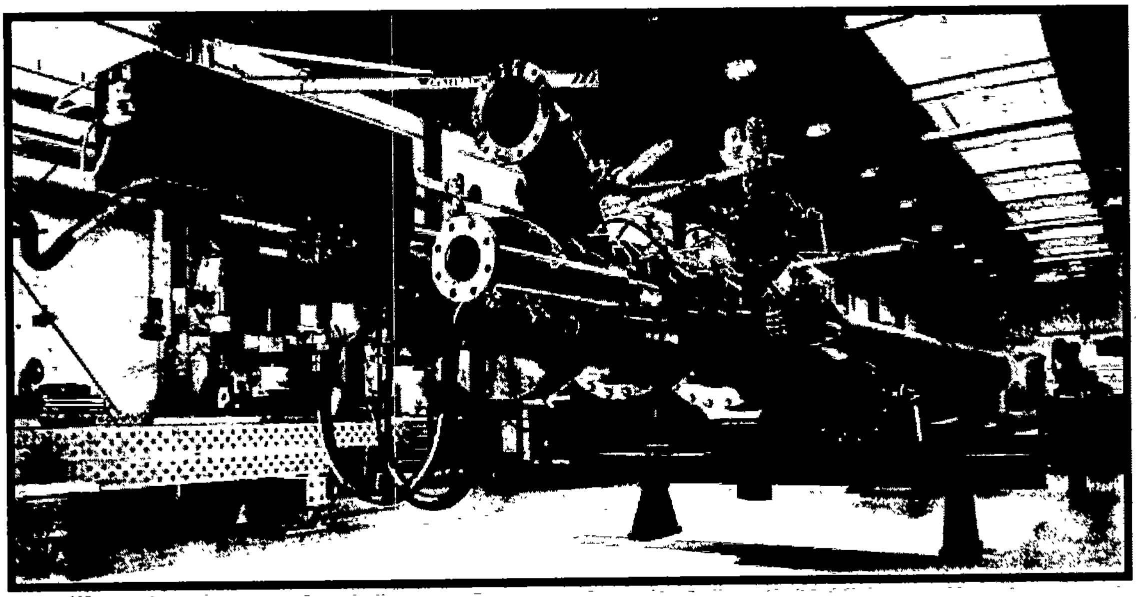

Figure 4-6 Multi-fuel burner [24]

4.2.4 Ash removing system

Ash removing method will use the rotary and conveyors which are already used for dust removing from boilers. Comparative study is below.

- **Rotary and Screw conveyors**

Dust come in AQC and SP boilers with hot gases from Cement plant; raw mill feed to kiln 391 ton per day after process clinker production got 5300 tons/day. According to feed production should 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) returning of waste material conduct through electrostatic precipitator, efficiency of EP is 90 % in which 3690 tons/day collected and 410 tons/day pass through EP. Pre-duster efficiency is also 90% .So in pre-duster 369 tons/day is collected and 41 tons/day is passed which come into WHR Boilers. The waste dust particles 1.708 tons/hrs which are already removed from boilers through conveyors. Standard Coal ash range is 6.2% to11.0% after coal burned [26-27]. in boiler maximum 8.8 tons/hrs coal will be used .Therefore, maximum ash will be 1.408 tons/hrs which is low as compared to waste material.

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

4.2.5 Coal pulverizing:

1. **Coal required for dosing in boiler**

WHR power plant installed capacity is 16MW. Equally, energy as coal is calculated by given reference.1,870 kWh per Ton of Coal or 0.9 kWh per Pound of [23] i.e.8.8tons/h Maximum and at plant site there are four (4) boilers. Therefore, for one boiler coal requirement is maximum 3 ton/hr.

2. **Raw Coal is stock at plant site**

The rotary kiln is heated with pulverized coal. Coal is used widely due to low cost as compared to oil and gas. Raw coal is stocked in coal yard about 35,000tones to 40,000tones. Fine (pulverized) coal is stocked about 120tones in fine coal bin every time.

Figure 4-7 Coal at plant site(Bestway Cement Ltd).

3. **Pulverizing of coal in coal mill**

At plant, site roller mill is already installed for coal pulverizing. This is burnt in kiln to produce cement. The coal mill production capacity is 40tons/hrs and electrical load capacity is 1.2MW. The raw coal is pulverized in the mills, then dehydrated and uniformly distributed to the coal burners. Hot air or gases transfer the grinded fuel to the burner and minimize the wetness in the coal.

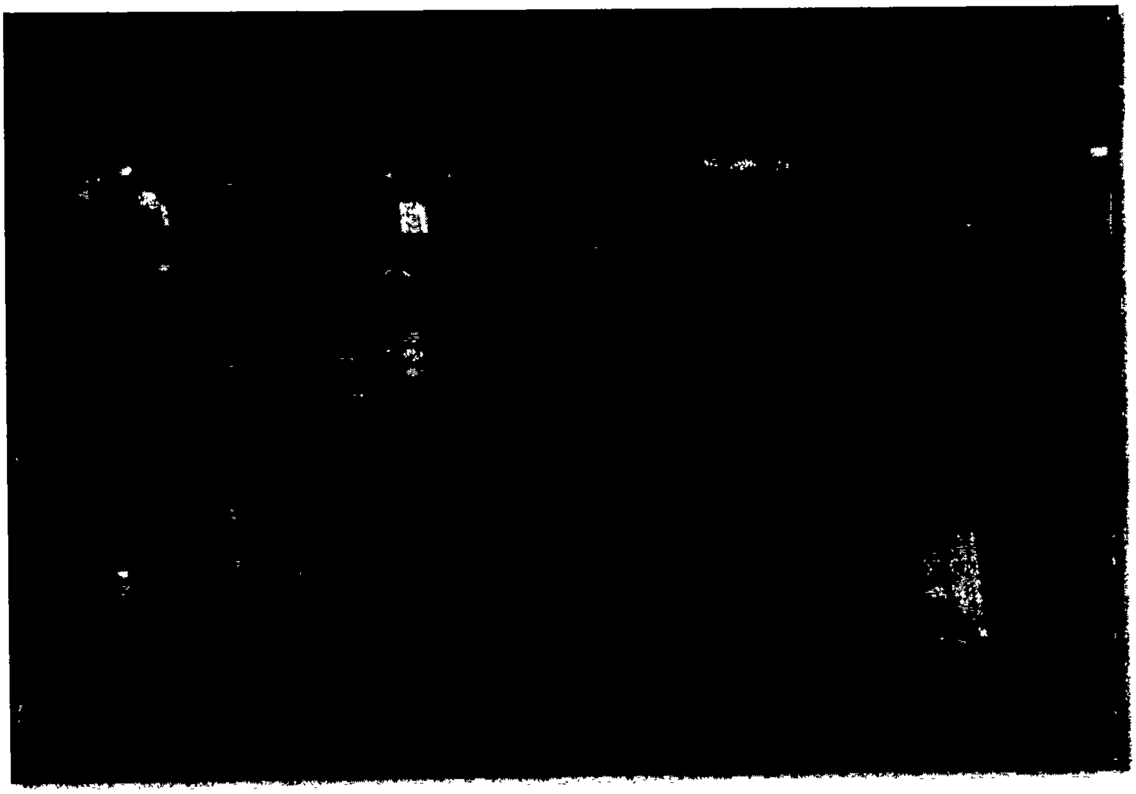

Figure 4-8 **Existing coal mill at plant site(Bestway Cement Ltd).**

4.3 IMPACTS' OF MODIFICATION OF BOILERS:

If we don't modify the boilers the direct flame hitting the water tubes may damage tubes but if we modify it the flame disappears before reaching near to the water tubes because we increased the distance between water tubes and burning gun.

If we try to dose the coal without modification most of the coal falls down without burning and it go waste but when we will modify the exchanger all coal will be burned without wastage.

If we don't modify the exchanger it will be a loss of coal and also decrease the efficiency of the system but if we modify it there will be no fall of coal and similarly there will be no loss and also efficiency of the system will not decrease.

CHAPTER 5. RESULTS AND DISCUSIONS

1. To make the result of our proposed system we have to compare the cost or price/unit of electricity with WAPDA P.P.U of electricity. Comparison also can be enhanced by using other fuels in place of coal.

2. Main aim of our working is to reduce the cost of energy which we acquire in coal dosing system. By virtue of this proposed system our energy cost comes down at 8.1 PKR. This is comparably less than WAPDA consumer energy price which is currently 8.93 PKR. Here it is necessary to mention that proposed system energy cost can be lowered by using more imported coal, which is purified by decreased sulpher contents and also ash percentage is in controlled range.

5.1 COMPARATIVE OPERATION OF WHRPP:

The figure 5.1 shows coal mill grinds the raw coal which runs the cement plant. The waste gases from the plant go to heat exchanger where waste gases run the turbine and runs generator to produce electricity. When cement plant stops due to technical reasons or plant shuts down WHRPP also stops then proposed coal dosing system will automatically turns on. Coal dosing system will get grind coal from existing coal mill.

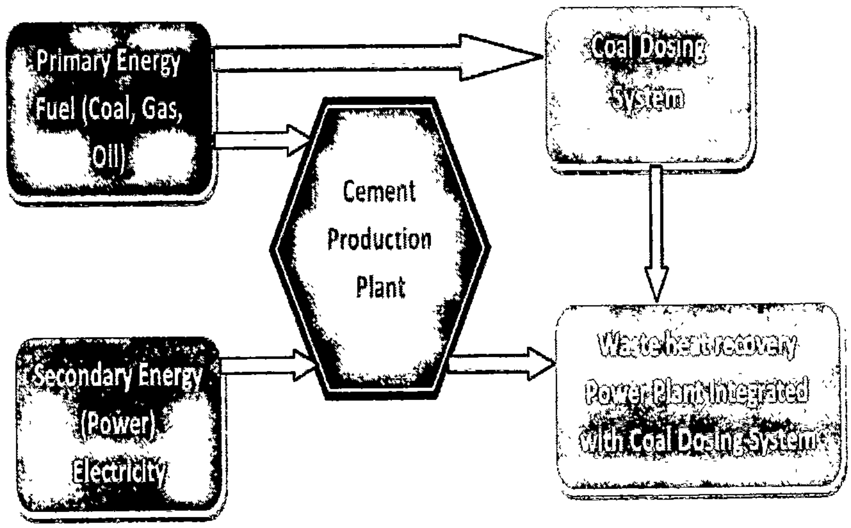

Figure 5-1 **Cement plant with waste heat recovery power plant**

Typical Operation data of WHRPP and power generation by coal in Bestway cement plant

Plant status	Power import from WAPDA	Power generated by WHRPP	Power Generate by coal	Power displace by WAPDA
cement plant in running condition	52 MWh	Nil	Nil	Nil
cement plant and WHRPP in running condition	36MWh	16MWh	Nil	16MWh
only one line in working	36MWh	8MWh	8MWh	16MWh
cement plant in stop condition	Nil	Nil	16MWh	16MWh

Table 8 Typical Operation data of WHRPP and power generation by coal in Bestway cement plant.

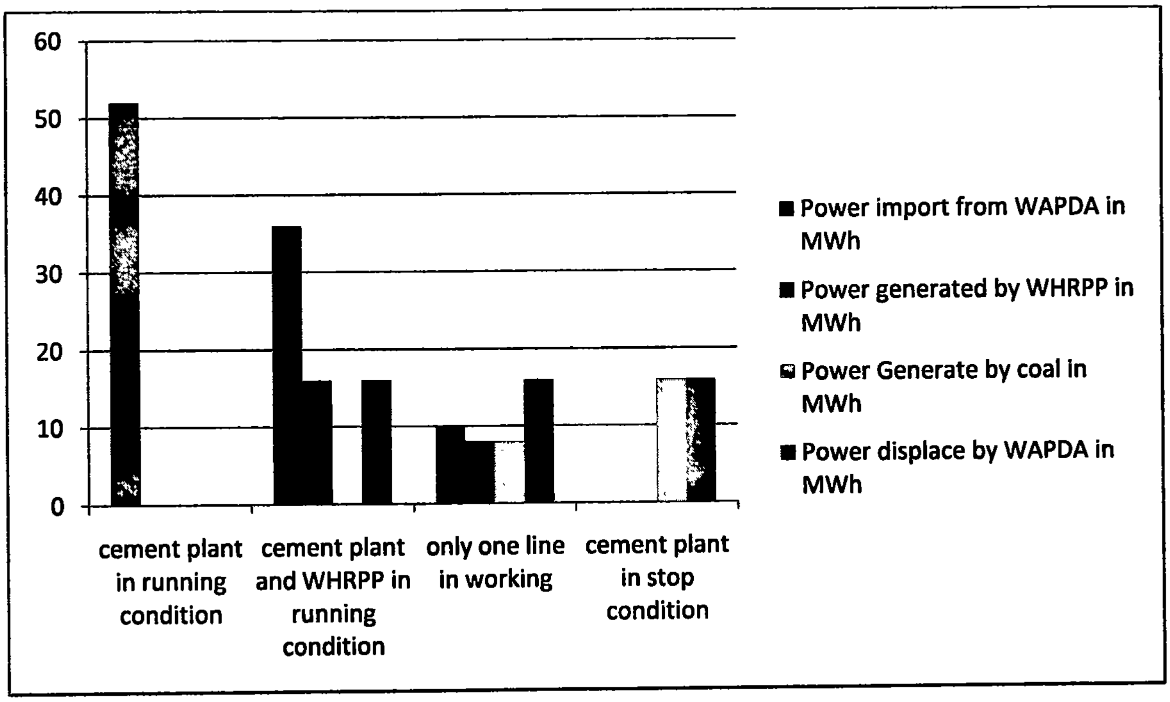

Figure 5-2 Typical Operation data of WHRPP and power generation by coal in Bestway cement plant.

5.2 COST ANALYSIS OF FUEL ENHANCEMENT IN WASTE HEAT RECOVERY POWER PLANT.

Fuel enhancement waste heat recovery power plant basically consist of three main system, coal mill, waste heat recovery power plant and coal dosing system. Coal mill and waste heat recovery power plant always exist at project site and the coal dosing system is proposed. The estimated cost for proposed project is calculated.

Coal Mill

Capital Cost			
Equipment Name	**Source**	**Price**	
Coal mill include lubrication and hydraulic unit	BCL	141525000	Rs.
Belts conveyer and weigh scale	BCL	91800000	Rs.
Bucket elevator	BCL	34425000	Rs.
Raw and Fine coal bins	BCL	26775000	Rs.
Bag filter material and dust collection	BCL	30600000	Rs.
Hot air fan nd System fan	BCL	57375000	Rs.
Total Capital Cost of Coal Mill	BCL	382500000	Rs.
Maintenance Cost			
at the rate of 2% of Capital cost / year	Calculation	7650000	Rs.
Maintenance cost per day	Calculation	20958.90411	Rs.
Maintenace cost per hour	Calculation	873.2876712	Rs.
Maintenance cost for 5 hours in a day	Calculation	4366.438356	Rs.
Maintenace cost for 100 days	Calculation	436643.8356	Rs.
Operation Cost			
Coal mill energy consumption for 5 hours / day	Calculation		
Capicity 40 ton / hours	Calculation		
Running load / day	Calculation	1.2	MW/Hours
Running Hours 5 hours / day	Calculation	6	MW/day
MW converted into KWH	Calculation	6000	KWH/day
WAPDA rate at off peak is Rs.	Calculation	17.5	Rs.
Running cost per day	Calculation	105000	Rs.
Running cost of 100 days	Calculation	10500000	Rs.
O & M Cost	Calculation	10936643.84	Rs.

Table 9 **Calculation and observation of coal mill section(Bestway Cement Ltd).**

Waste Heat Recovery Power Plant		
Equipment name	**Source**	**Price**
PH waste heat boiler	BCL	494900000
AQC waste heat boiler	BCL	227250000
Steam turbine with its accessories and generator	BCL	247450000
DCS	BCL	101000000
Electrical and instrument equipment	BCL	121200000
Auxiliary	BCL	237350000
Total capital cost	BCL	1429150000
Operational and maintenance cost of waste heat recovery		
Maintenance Cost		
Maintenance cost (maintenance cost @ 2% of capital cost per year)	Calculation	28583000
Maintenance cost (maintenance cost @ 2% of capital cost for 1 day)	Calculation	78309.58904
Maintenance cost (maintenance cost @ 2% of capital cost for 100 days)	Calculation	7830958.904
Operational Cost		
Operation cost (fuel consumption)	BCL	295680000
Cost of per ton coal	Proposal activity	14000
Coal consumption per hour 8.8 ton	Calculation	123200
Coal consumption per day	Calculation	2956800
Coal consumption per 100 day	Calculation	295680000
Total Operational and maintenance cost	Calculation	303510958.9

Table 10 **Calculation and observation of coal WHRPP section (Bestway Cement Ltd).**

Table 11 **Calculation and observation of coal dosing section (Bestway Cement Ltd).**

Power Generation by Coal

Power house Generation per day	384 MWH
Power house Generation for 100 days	38400 MWH
Power generation MWH to KWH	38400000 KHW

O&M Cost (Overall)

Operational Cost of Coal Mill	4476000 Rs.
Maintenance cost of WHRPP	7830958.904 Rs.
Operational Cost of WHRPP	295680000 Rs.
Maintenance cost of Coal Dosing Sys	363561.6438 Rs.
Operational Cost of Coal Dosing Sys	3580800 Rs.
Sum of All Maintenance & Operational Cost	312367964.4 Rs.
Cost Per KWH	8.1345824 Rs.

Saving

Generatio by Coal	8.1345824 Rs/KWh
Saving per unit	9.3654176 Rs/KWh
Saving for 100 days	359632035.6 Rs.

Payback period

Proposed system capital prise	66,350,000
Saving	359632035.6
Total pay back period	0.184494131

Table 12 **Analysis of power generation by coal (Bestway Cement Ltd).**

5.3 COMPARISON OF PRICE PER KWH OF DIFFERENT AVAILABLE ENERGY RESOURCES.

The comparison of price per KWh of different available energy resources is as under:

Price Comparison of Different Available Energy Resources		
Energy Resources	Source	Price per KWH
WAPDA	(water and power development authority)	17.5
Coal	Proposed at bestway cement Ltd. Chakwal	8.1
Gas	(saphair Electric power MurridkaySheikhupura) Ghadoon Power Plant (Ghadoontextile) Ghadoon industrial state topi sawabi	7.71 7.5
Oil (furnace)	(saphair Electric power MurridkaySheikhupura) Ghadoon Power Plant (Ghadoontextile) Ghadoon industrial state topi sawabi	17 18
Oil (diesel)	(saphair Electric power MurridkaySheikhupura) Ghadoon Power Plant (Ghadoontextile) Ghadoon industrial stste topi sawabi	31 30

Table 13 The comparison of price per KWh of different available energy resources is as under

The comparison of price per KWh of different available energy resources is as under

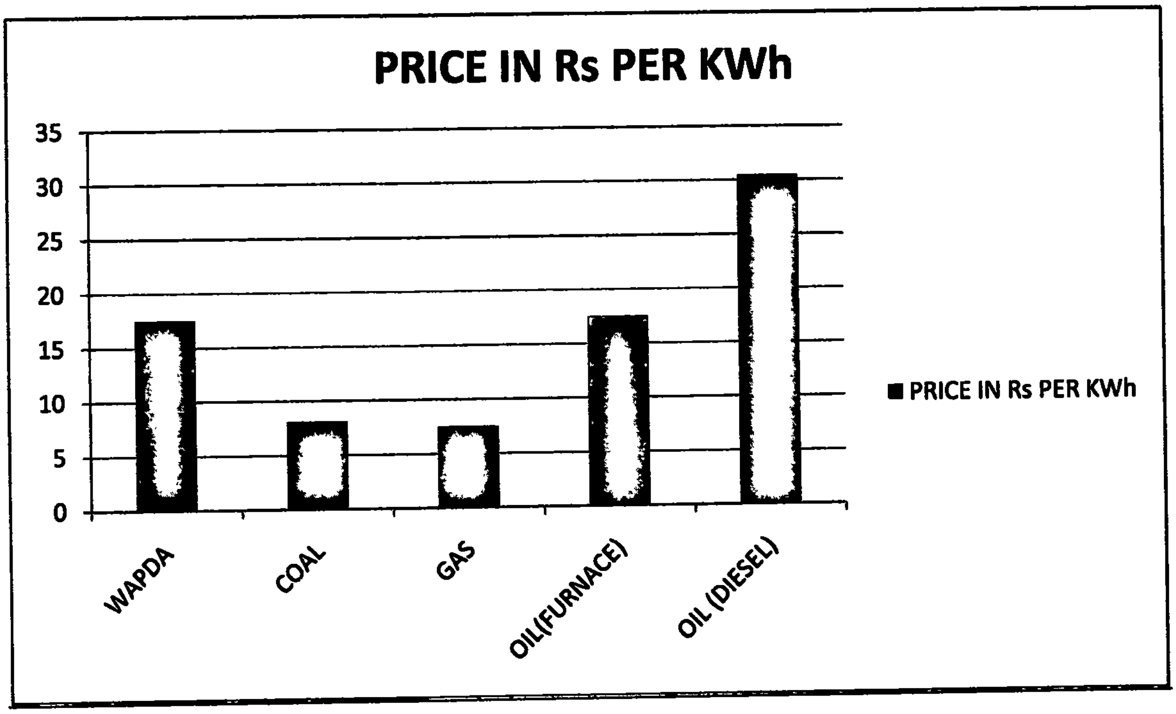

Figure 5-3 **comparison of price per KWh of Different Available Energy Resources**

5.4 CONCLUSION

Fuel enhancement in waste heat recovery power plant project at Bestway cement limited Chakwal in chakwal city is studied. The fuel enhancement is a new technology that changes the project economics of converting coal energy into electrical energy instead of cement plant waste heat by modifying the waste heat recovery boilers.

Coal (fuel) energy integration is one of the most important approaches in any cement industries where WHRPP is installed. This kind of energy concept will be applied with WHRPP. The continuously output power production could be gained by using coal dosing system at WHRPP instead of waste hot gases. By using above method improving energy efficiency of cement industries and minimizing dependence on national grid (WAPDA).

The analysis is conducted which is based on using the methodology of coal dosing system. It is clear that electricity generation by the coal is cheap as compared to other fossil fuel and WAPDA. Also expected for 100 days power generation is 38400 MWh and the project will displace an amount of 100 days power presently drawn from the national grid (WAPDA).

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