To Analyze The Thermal Loses in a Steam Power Plant

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Last, but not the least, we would like to thank our friends for their encouragement and help which they gave us to overcome the difficulties at various stages of our project work.

DEDICATION

It is our deepest gratitude and warmest affection that we dedicate our project to our beloved parents who always pray for us, our teachers who has been a constant source of encouragement, knowledge and inspiration and our friends.who cooperated with us till its successful completion

ABSTRACT

As the demand for electricity is increasing day by day. coal is cheaper and available in large quantities compared to other fuels. The world has no option but to opt for thermal power generation. The rapid increase in global electricity demand has led to a significant increase in the size of power plants and the number of generating units. Sasol Synfuel a South African company, conducted a study on the operational efficiency of a coal-fired boiler in Secunda Mpumalanga province. The analysis of coal samples using the CHNS technique revealed that the coal quality significantly affects the boiler's performance. The study also collected data on temperature and output steam pressure changes during the boiler's operation. The results suggest that the coal used for firing the boilers is suitable and can be improved through regular maintenance and replacement of ageing heat transfer tubes. Increasing efficiency can save energy resources in power plants. Energy efficiency represents a cost-effective approach to increasing profitability, increasing competitiveness, and improving environmental performance. The basic principle of a steam power plant is that it works on a modified rankine cycle. It depends on the type of boiler used in the power plant (water tube boiler,fire tube boiler, etc.). Palvaraized coal is used as a combustion process to give two types of heating values (higher heat value HHV and lover heat value LHV).HHV is the value in which impurities are included, and LHV is the value in which no impurities are included. HHV is always greater than LHV. The boiler uses this calorific value (LHV), which converts water into high-pressure steam. This steam is allowed from the boiler at a specific pressure, which further passes to the super heater region, where it flows through the duct system and strikes the turbine blade. Once the turbine starts, it is connected to the generator to produce electricity.

Balochistan University of Engineering and Technology Khuzdar

Certificate

Department Of Mechanical Engineering

This is certify that the work present in the thesis on " **To Analyze The Thermal Loses in a Steam Power Plant** " is entirely written by the following students under the supervision of Asst. Prof. Javid Iqbal The results obtained by us have not been submitted to any other university or institute, either in part or in full, for the award of any other degree.

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Chapter 1

Introduction

1.1. Background

Pulverised coal-fired power plants are the most widely used coal evaporator technology, with 90% of all coal-fired plants operating with high operational efficiency. The coal test is a crucial process in the production of power from steam turbo generators, which produce a combined power of 600 megawatts. The process involves a combination of thermal and physicochemical explanatory strategies to determine the gas composition of the fuel.[11]

The basic composition of coal fuel is determined using the CHNS natural analyzer, which determines the rate-essential composition of carbon, hydrogen, nitrogen, and sulfur. The oxygen content in the coal tests is determined by a percentage. The dampness of the coal test substance and unstable matter can be obtained by increasing the temperature. In this case, the coal tests are placed one at a time in a warm gravimetric analyzer (TGA), calibrated to operate at an increased temperature of 10°C after each decrease from 25°C. This ensures that the coal test mass is freed at 100–107 °C and the volatiles are completely freed at 800-850°C, preventing any further damage to the coal.Coal fuel for utilisation and exchange is assessed.[14]

utilising different standard strategies, all inclusive. These created standard strategies for coal assessment and utilised broadly and globally; a few of these Testing strategies incorporate British Standard Institution(BSI), the German Organisation for Institutionalisation(Commotion), the Universal Association for Standardisationsation (ISO), and the American Society for Testingand Materials (ASTM), etc. ISO and ASTM are themost broadly utilized coal testing and assessment strategies. In this ponder, be that as it may, the testing strategy utilized toassess the characteristics of the coal tests forCombustion is the ISO, which is encouraged and clarified in the strategy area. [2]

The evaluation of coal fuel is widely used using various standard methods, including ISO and ASTM. ISO and ASTM are the most widely used methods for coal testing and evaluation, with ISO being the primary testing method for combustion samples.[14]

1.2 World Energy Resources

1. **Oil energy**: energy is produced when the ancient remains of pressurized plants and animals (i.e. crude oil) is refined into petroleum and combusted in oil-fired power plants. The process creates steam which turns a turbine and spins a generator to produce electricity.[2]

2. **Coal energy**: The heat produced by the combustion of the coal is used to convert water into high-pressure steam, which drives a turbine, which produces electricity.[11]

3. **Gas energy**: Gas is a fossil fuel which can be used to generate electricity. By burning gas, we create Heat. which powers a turbine. The rotation of this turbine spins a generator which creates electricity.[19]

4. **Nuclear energy**: Nuclear energy is the energy in the nucleus, or core, of an atom. Nuclear energy can be used to create electricity, but it must first be released from the atom.[13]

5. **Hydropower energy**: Hydropower, or hydroelectric power, is a renewable source of energy that generates power by using a dam or diversion structure to alter the natural flow of a river or other body of water.[12]

6. **Geothermal energy**: The word geothermal comes from the Greek words geo (earth) and therme (heat). energy is a renewable energy source because heat is continuously produced inside the earth. People use geothermal heat for bathing, for heating buildings, and for generating electricity.[13]

7. **Wind energy**: the process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity.[16]

8. **Solar energy**: Solar energy is heat and radiant light from the Sun that can be harnessed with technologies such as solar power (which is used to generate electricity) and solar thermal energy (which is used for applications such as water heating.[15]

9. **Biofuel Energy**: Biofuels are a class of renewable energy derived from living materials. The most common biofuels are corn ethanol, biodiesel, and biogas from organic byproducts. Energy from renewable resources puts less strain on the limited supply of fossil fuels, which are considered nonrenewable resources.[19]

10. **Tidal energy**: Tidal energy is a renewable energy powered by the natural rise and fall of ocean tides and currents.[20]

11. **Wave energy** : Wave energy is a form of renewable energy that can be harnessed from the motion of the waves.[5]

1.3 Steam Power plant Boiler

The basic principle of a steam power plant is that it works on a modified rankine cycle. It depends on the type of boiler used in the power plant (water tube boiler,fire tube boiler, etc.). Palvaraized coal is used as a combustion process to give two types of heating values (higher heat value HHV and lover heat value LHV).HHV is the value in which impurities are included, and LHV is the value in which no impurities are included. HHV is always greater than LHV. The boiler uses this calorific value (LHV), which converts water into high-pressure steam. This steam is allowed from the boiler at a specific pressure, which further passes to the super heater region, where it flows through the duct system and strikes the turbine blade. Once the turbine starts, it is connected to the generator to produce electricity. [2]

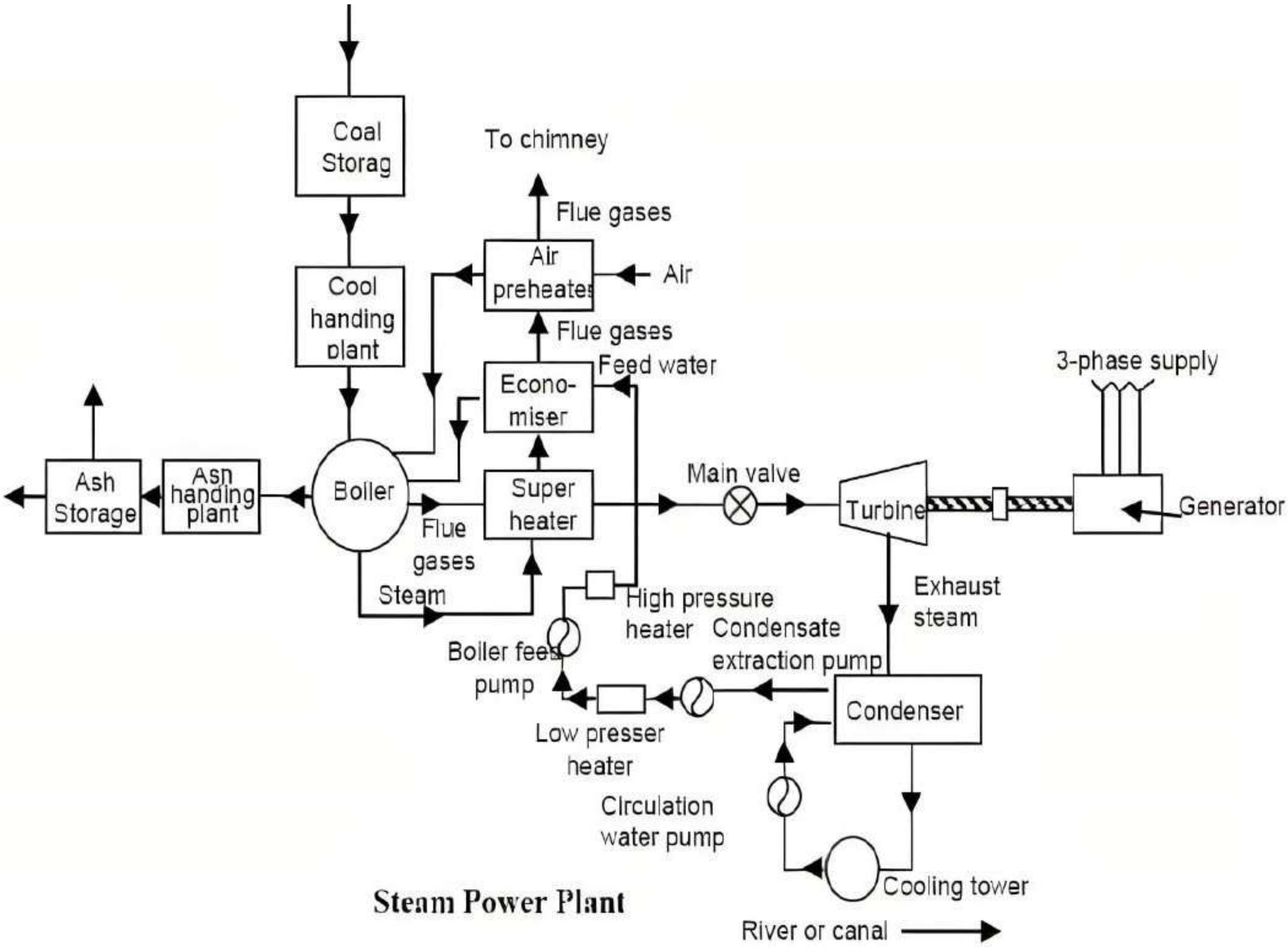


Figure 1.1 steam power plant [2]

1.4 Main components of steam power plant

1. Burner.
2. Economizer.
3. Air Preheater.
4. Turbine.
5. Boiler.
6. Generator.
7. Condenser.
8. Super Heater.

1.Burner

The heat required for a steam boiler to turn water into steam is provided by burners. Typically, a hob needs to maximise combustion efficiency while minimizing extra air. The burner, which permits heat to be forced into the steam boiler system, is regarded as an industrial blowtorch.[2]

2.Economizer

In steam power plants, economizers are frequently used to collect waste heat from flue gas or boiler stack gases and transfer it to the boiler feed water .By increasing the boiler feed water's temperature, this lowers the energy input required, which in turn lowers the firing rates required for the boiler's rated output.[11]

3. Air Preheater

In essence, air pre-heaters are heat-exchangers that are mounted in the boiler's gas duct exit flus. By reclaiming heat from the boiler flue gas, the air preheater improves the boiler's thermal efficiency by lowering the amount of useful heat lost in the flue gas.[19]

4. Boiler

A boiler is a component of a standard steam power plant that consists of a furnace for burning fuel, surfaces for transferring heat from the combustion products to the water, and an area for collecting steam. A fossil fuel or, in certain setups, waste fuels are burned in the furnace of a typical boiler.[2]

5. Generator

The boiler, generator, and steam turbine, along with additional auxiliaries, make up a steam power plant. High-pressure and high-temperature steam are produced by the boiler. Heat energy from steam is transformed into mechanical energy by the steam turbine. Electric power is then produced by the generator from the mechanical energy.[20]

6. condenser

A surface condenser or steam condenser may be a water-cooled shell and tube warm exchanger utilised to condensate the depleted steam from the steam turbine in warm control stations. The steam is changed over from a vaporous to a fluid state at a weight level below the barometrical weight.[2]

7 Super heater

A super heater could be a vital part of the evaporator framework that's utilised to extend the general effectiveness of a warm control plant. More particularly, it could be a gadget that changes damp steam (immersed steam) into dry steam, as dry steam contains more warm vitality.[11]

1.5 Rankine Cycle

The Rankine cycle is an idealized thermodynamic cycle portraying the method by which certain warm motors, such as steam turbines or responding steam motors, permit mechanical work to be extracted from a liquid because it moves between a warm source and warm sink. The Rankine cycle is named after William John Macquorn Rankine, a Scottish polymath teacher at Glasgow College.Warm vitality is provided to the framework through an evaporator, where the working liquid (usually water) is changed over to a high-weight vaporous state (steam) in order to turn a turbine. After passing over the turbine, the liquid is permitted to condense back into a fluid state as it squanders warm vitality, which was rejected some time ago and returned to the kettle, completing the cycle. Grinding misfortunes all through the framework are regularly dismissed for the reason of disentangling calculations, as such misfortunes are ordinarily much less noteworthy than thermodynamic misfortunes, particularly in bigger frameworks.[11]

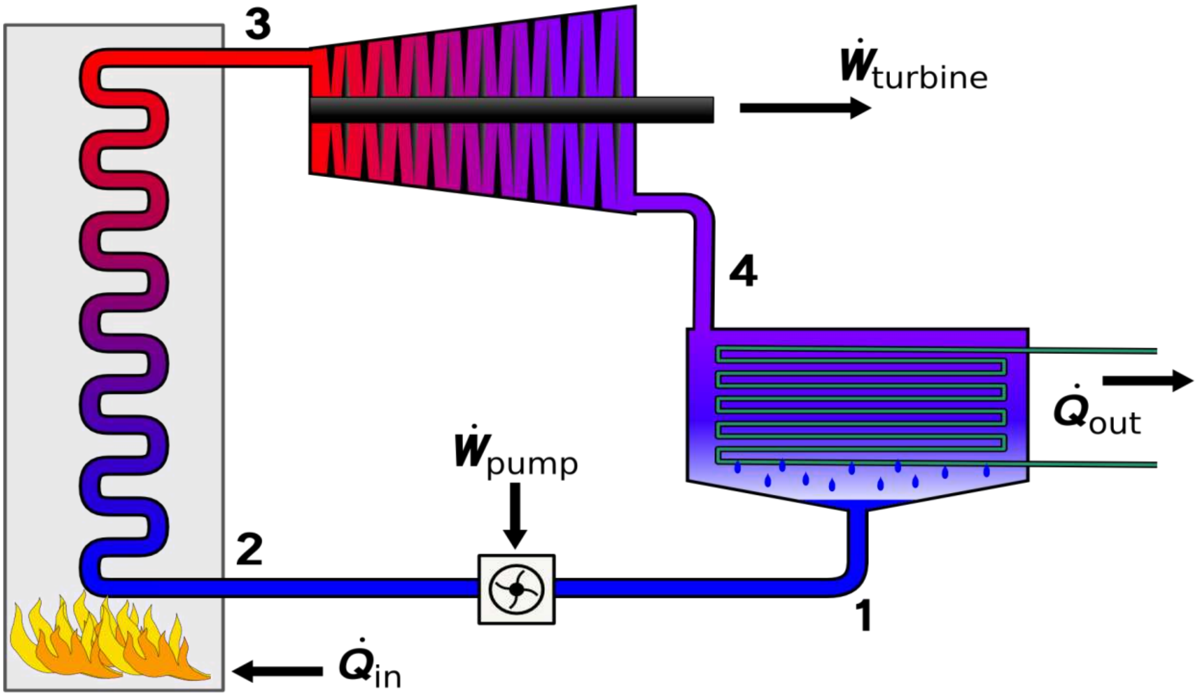


Fig 2.Physical layout of the Rankine cycle [11]

Problem statement

A boiler is used to produce high pressure steam. Coal is used for combustable processes. But most of the coal contains moisture, volatile matter, ash,and inherent moisture. These imperfections reduce the higher heat value (HHV) and the lower heat value (LHV). It also contains hydrogen, which reacts with oxygen in water molecules. which also reduces the overall efficiency of the boiler. The biggest boiler loss is dry flow gases, which are escaping through the chimney. At least 5% to 9% of losses occur due to the dry flow of gas. This gas depends on the actual air supplied to the boiler. We will reduce the dry flue gases of the boiler and the moisture inside the coal sample.

Objective

- To calculate Dry flue gas loss.
- To calculate the heat loss due to evaporation of water formed due to hydrogen in fuel.
- To calculate heat loss due to moisture present in fuel
- To Calculate the amount of energy released during the combustion of Coal (GCV)
- To calculate Net calorific value of coal (NCV)
- To calculate fixed carbon ratio in coal.

1.5 Project scope

A steam power plant's boiler plays a crucial role in power generation. It converts water into steam, which drives the turbines. Key aspects for analysis include efficiency, fuel type, boiler design, and environmental impact. Factors such as temperature, pressure, and heat transfer efficiency influence overall performance. Regular maintenance is vital to ensure optimal functioning and safety.[19]

The scope of analyzing a steam power plant boiler encompasses a comprehensive study of its design, operation, and performance. This includes evaluating efficiency improvements, exploring advanced materials for enhanced durability, assessing environmental impact mitigation strategies, and investigating innovative technologies for cleaner energy production. Additionally, examining the integration of digital monitoring and control systems can be part of the scope to optimize plant operation and maintenance. Researching sustainable fuel options and considering the economic feasibility of implementing new technologies also expands the scope of analysis.[19]

The waste heat goes to the generator. this increases the refrigerant pressure and is converted to high steam pressure. The pressure from the generator outlet to the expansion remains constant, but the temperature is decreasing. In the expansion valve, pressure is decreasing, and temperature is also decreasing. This low temperature passes to the evaporator, where the convection process takes place. The things inside the evaporater cool down after some time. This cycle repeats itself again and again to achieve the required.[9]

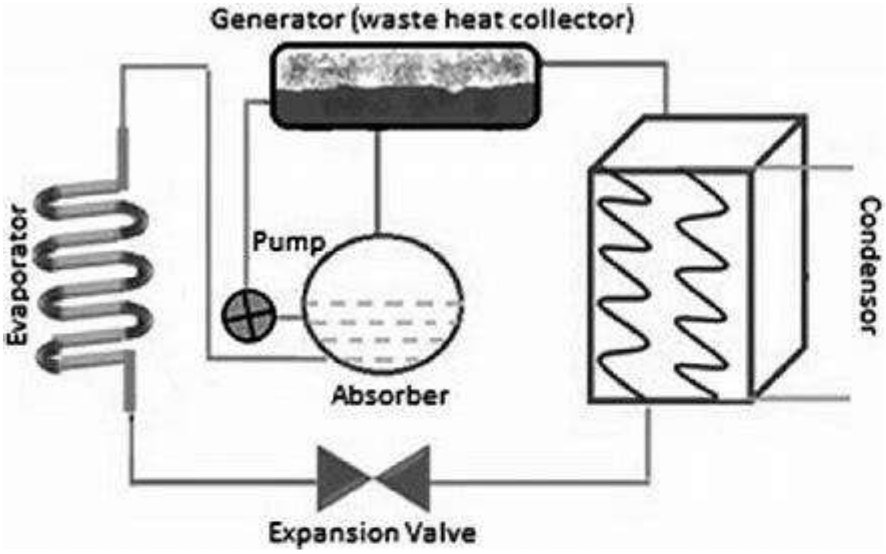


Fig 3.Vapour absorption cycle [9]

1.6 Application

The production of power is the main use. Utilizing steam turbines, thermal energy from burning nuclear reactors or fossil fuels (coal, natural gas, or oil) is transformed into mechanical energy, which is subsequently utilized to produce electricity.

Steam from power plants is often utilized in various industrial processes, such as in manufacturing, chemical production, and food processing. It can provide heat or be used to drive machinery.

Power plant steam can be utilized to district heating systems, which distribute the steam to neighboring residential and business areas for hot water and space heating.

Desalination procedures can be powered by steam, which is created by heating saltwater and then condensing it to produce fresh water.

Certain power plants are built for cogeneration, which produces useful heat and electricity at the same time. This is particularly effective in settings like some industrial facilities where heat and electricity are required.

Steam is crucial in various stages of oil refining processes, including crude oil distillation and other refining operations.

In chemical plants, steam is frequently used for various processes like distillation and reactions. It functions as an effective and adaptable heat transfer medium.

In carbon capture technologies, steam is utilized in procedures to absorb and retain carbon dioxide emissions from power plants.

Biomass or municipal solid waste can be burned in steam power plants, which helps produce renewable energy.

The pulp and paper industry uses a lot of steam for things like pulping and drying paper.

Chapter 2

2.1.Literature review

A G Vinchurkar et al.(2014) Growing demand for coal in thermal power plants, which is the main source of electricity generation India is depleting very fast so it is desirable that we have such optimal technologies which can reduce energy losses of coal boilers and improves its energy efficiency. It creates an impact production and optimization of energy sources. A method for calculating the energy efficiency of boilers. This article discusses the loss method and loss optimization. Also energy efficiency[11] . the possibilities of the boiler for its improvement and the functional instructions of the engineers are discussed to maximize boiler efficiency. Boiler efficiency increases by 1% for every 20 degrees Celsius of tube temperature drop. Each 6 ºC increase in the temperature of the feed water of the boiler with waste heat recovery would give approx. Saving fuel in the boiler 1%. If the flue gas temperature is reduced by 22 ºC during heat recovery, the fuel saving is approximately 1%. to reach. Each millimeter thickness of the soot coating increases the temperature of the stack by about 55 °C. Depository 3 mm of soot can increase fuel consumption by 2.5%. 1 mm thick scale (deposit) on top. the water side could increase fuel consumption by 5-8 percent. Minimize radiation, convection and neglected losses. Enable automatic blowing control. Adjustable speed for blowers, blowers and pumps. Minimize additional energy consumption. Optimization of specific oil consumption. Optimizing the specific consumption of coal. Maintain proper terminal conditions.Ensuring accurate instruments. Good maintenance practices.[11]

Muhammad Saeed Ullah1 et al (2019),It was determined from the discussion above that SRG, LKR, SLG, and THR are bituminous class II coals. The best gas coals are these ones.They have a long, bright flame when burning, and after distillation, they go through a phase called intumescences when gas is released freely.[20]

Even though THR coal has the lowest sulfur content—1.9%—there is still a stage in the coal liquefaction process where sulfur must be removed using Claus's process. MCH is a class (1) bituminous coal that burns with a very long, very bright, smoky flame. Because of this, it is primarily used for firing reverberator furnaces and similar equipment. Due to their ability to burn freely, they are also occasionally used as house coals. But they don't work well for steam rising, and they don't cake well, which makes them completely unusable for making coke. KTL are bituminous coals classified as class 4, with a moisture content of only 4%. Since KTL has the lowest moisture content of the six samples, it can be used for coal gasification, which requires coal with a low moisture content. Since they are caking coals, carbonization may employ them.[19]

A.Ariunaa1 et al (2015), 1.According to Russian classification, the samples' degree of coalescence could be ranked as follows: Baganuur (B2)<Naryn sukhait (G). According to the ASTM D388 standard, this result indicates that Baganuur coal belongs to the lignite A type and Naryn sukhait coal to the high volatile bituminous B type coals. Due in part to its higher melting temperature[13]

2. Naryn Sukhait coal ash has higher silicate and melting modules than Baganuur coal, which results in an acidic medium, lower hydraulic, and lower pyroxene modules.

3.Thermogravimetric analysis results validate that Baganuur lignite has low thermal stability and that its thermal breakdown happens at a lower temperature than that of Naryn sukhait coal.

4. The higher char yield of Naryn sukhait bituminous coal when compared to Baganuur lignite validates the higher thermal stability of Naryn sukhait coal.

5. The results demonstrate intense thermal decomposition, with 53.3% of the organic mass of Baganuur lignite converting to gaseous and volatile compounds during carbonization.[13]

Bai Kamara et al.(2023) results of the CHNS analyzer show that coal (sample B) consists of about 62% carbon, 43% oxygen, 3% hydrogen, 1.5% nitrogen, and 0.19% sulfur. Such an elemental composition shows that a uniform and efficient combustion would take place inside the fire chamber of the boiler on the surface of the burners, because it consists of more than 55% of combustible substances, i.e. coal and hydrogen, even more. the percentage of oxygen contained also allows uniform and efficient combustion. Sulfur is also flammable and at the same time time causes tube corrosion problems, a smaller percentage of that causes minor or insignificant boiler tube corrosion problems. Based on this, we can summarize The elemental composition of coal ensures uniform and efficient combustion during boiler firing and minimal corrosion problems of boiler tubes.[19]

Proximate analysis (moisture content, ash content, mineral substances, volatile substances, fixed carbon content) effect on boiler efficiency. Results of experimental TGA and ISO coal (sample B) final analysis calculations Table 2 of this study showed that coal prepd approximately 1.4% moisture, 25% ash, 22% volatiles, 27% minerals and 52% solid carbon. Moisture and ash content are non-combustible components with a combined percentage of approx 26.4% Combustible parts are e.g solid carbon and its volatiles with a total percentage of about 74%. It has been observed since the year the result is that the combustible components of sample B are almost three times greater than the non-combustible components indicating that. . During measurement effectiveness of coal chemical properties daily collection of data during boiler operation 30 days during boiler operation showed that temperatures and pressure values of steam generation obtained during operation of coal-fired boilers were almost stable during the data collection period, suggesting minimal coal-based effects. properties during boiler operation.[2]

Ravinuthala Ajay Kumar et al.(2020),600 MW Steam Efficiency Analysis power plant is considered. The efficiency of boiler, turbine and condenser is calculated as mentioned above. The values are given in the table. The efficiency of the turbine shows better heat use where boiler exergy efficiency shows losses. Condenser pressure drops are large, the system can supported by some basic cycle (binary power cycle) arrangement of heat recovery available Boiler, turbine and condenser are the three main ones components of a thermal power plant. Because depends on the overall efficiency of the thermal power plant effectiveness of these three components.[20]

Xiao-jun Ning et al.(2019),In this study, the effect of coal ash on carbon content structure and flammability of different earth materials coals were studied and the following conclusions can be drawn according to the results. (1) If the content of volatile substances in the soil carbons were solid, there was a negative linear relationship between the crystalline heights of the carbon structures ash content of coal and ground coal. (2) Values of AD/AG, AS/AG, ASL/AG gradually increased with the ash content of pulverized coal; in addition the carbon structure of coal gradually began to change order and degree of graphitization of soil material carbon gradually increased. (3) Thermogravimetric analysis showed that the combustion efficiency of PL anthracite was worse than t he other. four bituminous coals. If bituminous coal and anthracite mixed in a ratio of 4:6, the ash content of the ground coal increased, which reduces the contact area. coal, as a result of which the flammability of ground coal gradually decreased.[3]

Craig J. Donahue et al.(2009),The moisture content of most samples appears to be lower than expected. There may be several explanations for this score The supplier may have intentionally or unintentionally dried the samples before sending them to the customer.In addition, frictional heat generated during coal grinding the sample in the mortar may have caused moisture a loss Results of volatile matter and fixed carbon of the samples follows the expected trend. That is, starting from anthracite, content of volatile substances in the case of bitumen, lignite, peat should increase and fixed carbon should decrease.

The ash content of all samples is within the expected range of the development organization and is a source of technical standards materials, products, systems and services. This average is based on determining the mass of 69 students % S in sample 7 using the Eschka method.[6]

Devendra Raut et al. (2021),A theoretical design of a solar powered VARS combined with PCM-based latent heat was presented to store energy, it is useful to make a preliminary design using some realistic assumptions and approximations. The obtained values can be used for detailed design and measurement of the parts. Analytical design of each component is important and useful for detailed design. Component size varies linearly with cooling capacity and the amount of PCM required varies linearly with cooling power on different slopes.[5]

Ahmet Fevzi Savaş et al. (2022),This study examined the surface heat losses of a steam boiler that was used for 17 years in a textile industry company's distillation process. A thermal camera and an infrared thermometer were used to measure the temperatures in various boiler parts, and an effort was made to identify any areas that had inadequate or missing insulation. In this direction, the main area for improvement was identified by creating a heat loss graph and utilizing a Pareto diagram. The Pareto diagram showed that the front and back covers had reached dangerously high temperatures. It was suggested that insulating jackets and pads be used to cover surfaces that are heated to high temperatures. It was estimated that the insulation would save 8kW of heat per hour by comparing the heat losses before and after the improvement. The estimated payback period for the insulation investment is as short as three months.[20]

Heat energy loss can be avoided and efficiency can be increased by insulating the boiler's non-insulated sections and replacing any old insulation in areas with inadequate insulation. Since insulation is simple to use, saves significant amounts of energy, and pays for itself quickly, it is one of the topics that is mainly and extensively covered in energy recovery studies. Insulation lowers the amount of heat loss, saving fuel and money. When considering the situation more broadly, it is evident that insulation not only lowers energy use but also safeguards the environment.[9]

TU Taliding1 et al. (2021),Based on the findings of the proximate analysis, which was done to ascertain the values of volatile matter (VM), fixed carbon (FC), moisture content (MC), and ash content (Ash). The moisture content (MC) value obtained ranges from 3.65% to 8.42%, suggesting that the coal seam next to the roof has a higher MC value than the coal seam next to the floor.[19] The range of ash content (Ash) generated is 5.59% to 64.96%; samples BNH01-PL02 and BNH02-PL02 have high Ash content (Ash) values exceeding 15%.While samples BNH01 PL01 and BNH02-PL01 have low ash contents (Ash) of less than 8%, this indicates In contrast to the distribution of moisture content (MC) values, the value of ash content (Ash) is greater in the coal seam adjacent to the floor than in the coal seam adjacent to the roof. The resulting volatile matter (VM) value is 17.69% - 62.83%; the BNH01-PL01 sample had the highest volatile matter value (VM), while the BNH02-PL02 sample had the lowest volatile matter value (VM). This distribution of VM values is consistent with the moisture content value (MC) distribution, which indicates a greater value of volatile matter (VM) in the coal seam adjacent to the roof than in the coal seam adjacent to the floor. There is no variation in the specific and systematic fixed carbon value (FC) in the coal seam vertically, as evidenced by the fixed carbon value (FC) produced, which ranges from 13.70% to 46.76%. The BNH02-PL01 sample has the highest fixed carbon value (FC).[17]

1Surface Science Western et .al(2010),The use of regression and the adaptive network-based fuzzy inference system (ANFIS) to model and predict gross calorific value (GCV) is proposed. The prediction operations are performed on 635 experimental data sets. The correlations between GCV and coal analysis indicate that higher levels of vitrinite and inertinite in coal can lead to higher GCV, while increases in mineral matter and liptinite contents can lead to lower GCV. The correlation coefficient (R2) between the prediction value and the modeling data When using the ANFIS method for modeling and prediction, R2 is 0.96, whereas the experimental value of GCV for the nonlinear regression is 0.83.[20]

The findings demonstrated the successful use of coal petrography analysis (macerals) as a predictor of GCV. Regression and ANFIS models were compared, and it was discovered that the performance of the former is superior. As a result, it can be applied to GCV estimation with effectiveness.[19]

Yinglin Wen et al (2016), The drying processes of both raw and moisturized coal can be divided into four stages: the relative fast decreasing rate stage, the short constant rate stage, the increasing rate stage, and the relatively slow decreasing rate stage. The maximum drying rate of raw lignite is significantly lower than that of moisturized coal due to the more complex moisture forms present in the former.[11]

[The average pore diameter of dewatered raw lignite and dewatered moisturized coal reaches its maximum at drying temperatures of 393 and 413 K, respectively. In comparison to raw coal, the Deff of moistened coal increases when it is dried. Furthermore, for the process of drying raw and moisturized coal, the Deff of the comparatively slow .Four stages can be distinguished in the drying processes of both raw and moisturized coal: the increasing rate stage, the short constant rate stage, the relatively fast decreasing rate stage, and the relatively slow decreasing rate stage. Because the moisture forms in raw lignite are more complex than those in moisturized coal, the maximum drying rate of raw lignite is much lower. At drying temperatures of 393 and 413 K, respectively, the average pore diameter of dewatered raw lignite and dewatered moisturized coal reaches its maximum. When moistened coal is dried, its Deff increases relative to raw coal. Additionally, for the raw and moisturized coal drying process, the Deff of the relatively slow.[4]

Pilatowsky et al (2013, The findings demonstrated that, in semi-tropical climates, the monomethylamine–water combination is a good option for solar absorption refrigeration systems operating at moderate evaporator temperatures (5 to 10 C). The theoretical COPSARS values have been computed with a reasonable FSOL for milk cooling applications. In Mexico's rural areas, a typical daily milk production can be cooled by using high efficiency evacuated tube collectors operating at a moderate temperature, which also reduces the solar collector area and produces the necessary heating load. [16]

Adil Qadeer et al (2020),To study the system's performance, a prototype model was created.

The results clearly show that Pakistan has access to solar energy and that the country's climate is suitable for a solar absorption cooling system.

- The generator's fluid flow rate of 0.05 kg/s allowed the system to reach its maximum COP of 0.64.The experimentally determined heat transfer rates for the generator and evaporator were 3.15 and 1.55 kWh, respectively.

The potential of the solar absorption cooling system for cooling applications is confirmed by the experimental results and the economic analysis. The maximum COP of the system can be attained with the maximum radiation and ambient temperature. [15]

Summary of Literature Review

Growing demand for coal in thermal power plants, which is the main source of electricity generation. India is depleting very fast so it is desirable that we have such optimal technologies which can reduce energy losses of coal boilers and improves its energy efficiency. It creates an impact production and optimization of energy sources. A method for calculating the energy efficiency of boilers. This article discusses the loss method and loss optimization .Steam power plants are widely utilized throughout the world for electricity generation, and coal is often used to fuel these plant. 600 MW Steam Efficiency Analysis power plant is considered. The efficiency of boiler, turbine and condenser is calculated as mentioned above. The values are given in the table. The efficiency of the turbine shows better heat use where boiler exergy efficiency shows losses. Condenser pressure drops are large, the system can supported by some basic cycle (binary power cycle) arrangement of heat recovery available Boiler, turbine and condenser are the three main ones components of a thermal power plant. Because depends on the overall efficiency of the thermal power plant effectiveness of these three components

The operational efficiency of a coal-fired boiler is strongly dependent on the type of coal fuel used for firing the boiler. These coal samples were analyzed using the CHNS technique to determine their percentage elemental composition (Carbon, Hydrogen, Nitrogen, Sulphur).

Fixed carbon is the solid combustible material that remains after loss of moisture and volatile matter minus the ash that remains after combustion is complete.

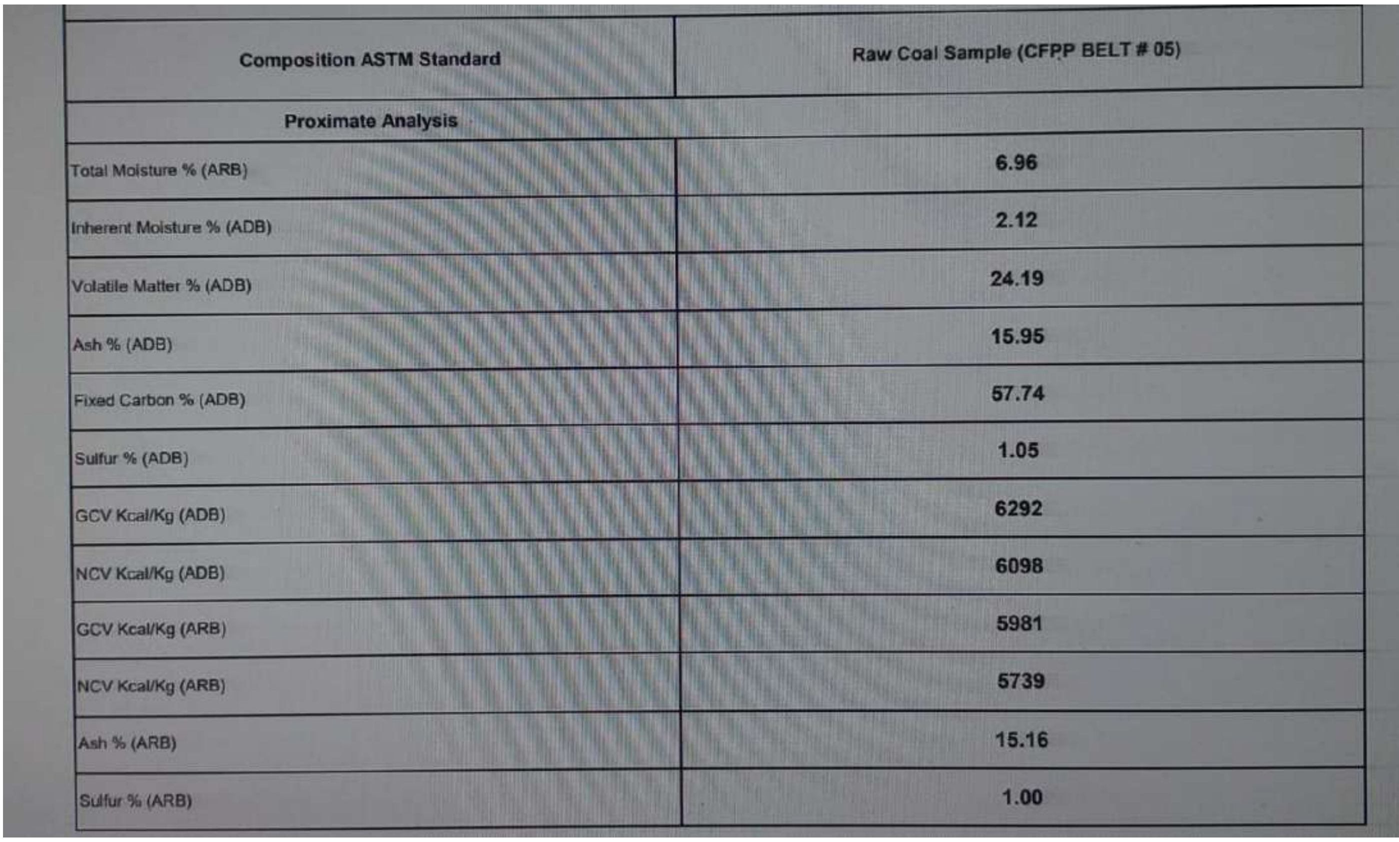
Heating value is defined as the amount of heat evolved when a unit weight of the fuel is burnt completely know as gross calorific value (GCV).

- **Chapter 3**

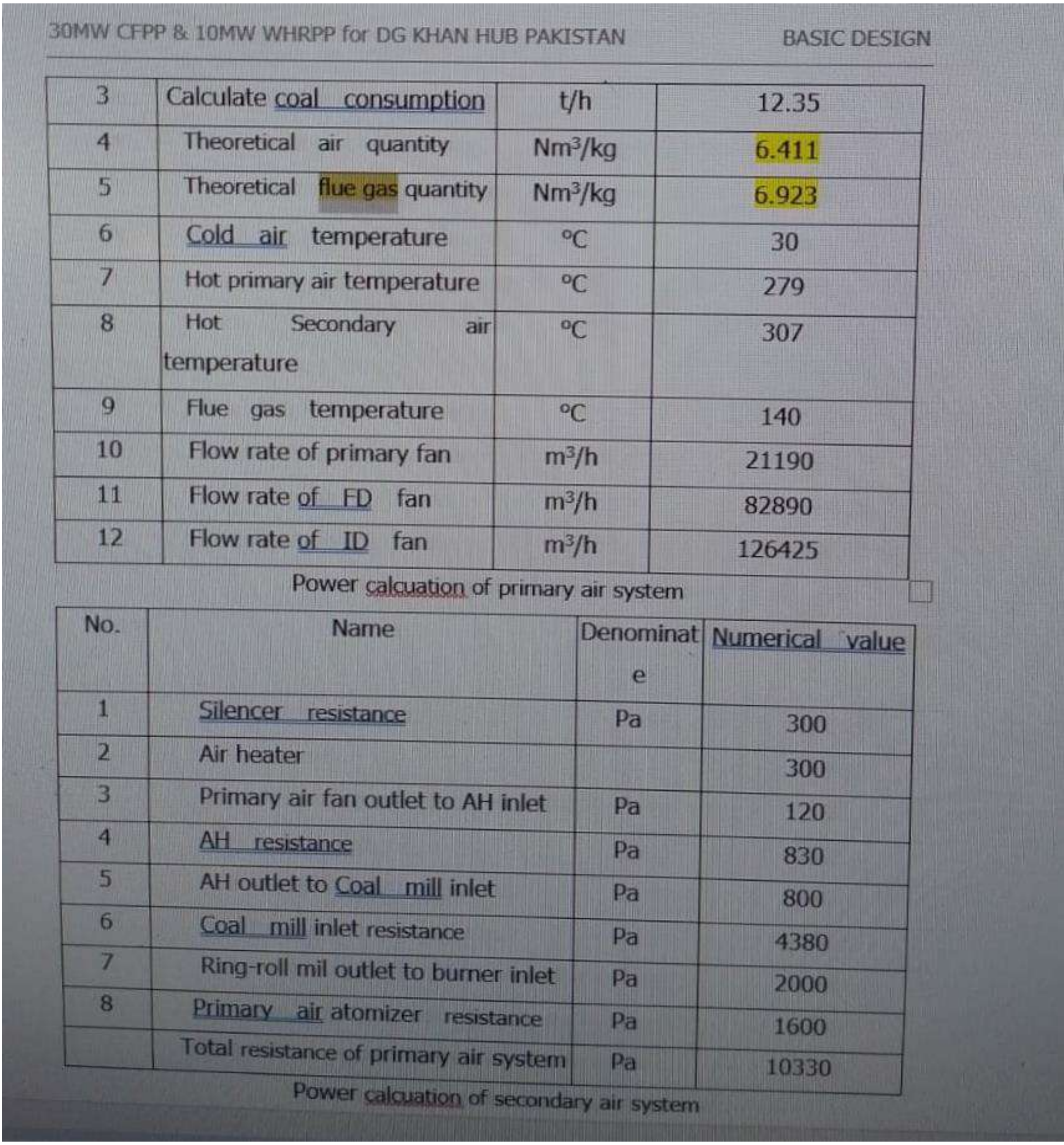
3.1.Methodology

The DATA WE COLLECT FROM THE DG CEMENT POWER PLANT

Data table 3.1.1



Composition ASTM Standard	Raw Coal Sample (CFPP BELT # 05)
Proximate Analysis	
Total Moisture % (ARB)	6.96
Inherent Moisture % (ADB)	2.12
Volatile Matter % (ADB)	24.19
Ash % (ADB)	15.95
Fixed Carbon % (ADB)	57.74
Sulfur % (ADB)	1.05
GCV Kcal/Kg (ADB)	6292
NCV Kcal/Kg (ADB)	6098
GCV Kcal/Kg (ARB)	5981
NCV Kcal/Kg (ARB)	5739
Ash % (ARB)	15.16
Sulfur % (ARB)	1.00



30MW CFPP & 10MW WHRPP for DG KHAN HUB PAKISTAN BASIC DESIGN

3	Calculate coal consumption	t/h	12.35
4	Theoretical air quantity	Nm³/kg	6.411
5	Theoretical flue gas quantity	Nm³/kg	6.923
6	Cold air temperature	°C	30
7	Hot primary air temperature	°C	279
8	Hot Secondary air temperature	°C	307
9	Flue gas temperature	°C	140
10	Flow rate of primary fan	m³/h	21190
11	Flow rate of FD fan	m³/h	82890
12	Flow rate of ID fan	m³/h	126425

Power calcuation of primary air system

No.	Name	Denominate	Numerical value
1	Silencer resistance	Pa	300
2	Air heater		300
3	Primary air fan outlet to AH inlet	Pa	120
4	AH resistance	Pa	830
5	AH outlet to Coal mill inlet	Pa	800
6	Coal mill inlet resistance	Pa	4380
7	Ring-roll mil outlet to burner inlet	Pa	2000
8	Primary air atomizer resistance	Pa	1600
	Total resistance of primary air system	Pa	10330

Power calcuation of secondary air system

Exhaust gases temperature of chimmny	**137◦C**

Table 3.1

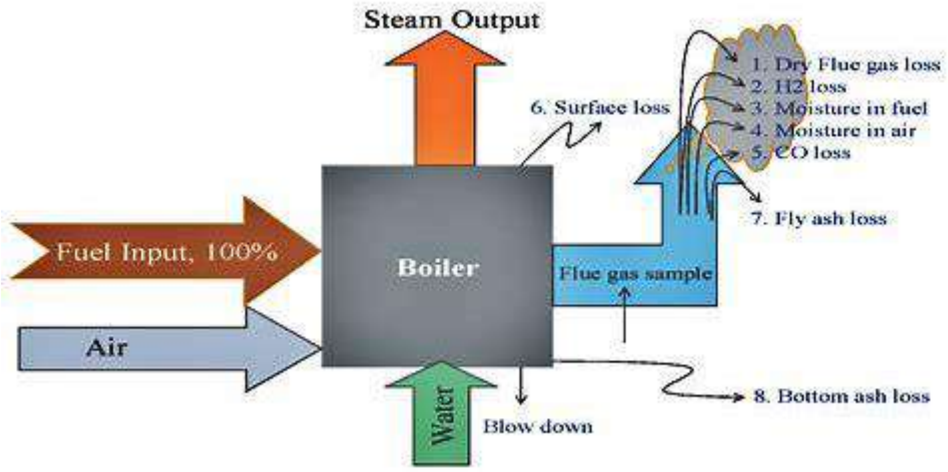


Fig 3.1 Steam power plant [11]

Analytical methods

Analytical methods in mathematics involve using techniques such as calculus, algebra, and logic to analyze and solve problems. These methods often rely on precise reasoning and mathematical structures to derive conclusions or solutions. Calculus, for example, is a powerful analytical tool for studying functions and their behavior, while algebraic methods help manipulate equations and expressions to uncover relationships. Overall, analytical methods provide a systematic approach to understanding and solving mathematical problem. [18]

1 Dry Flue Gas Loss

This loss occurs due to heat carried away by the flue gases to the atmosphere through the chimney. This loss constitutes the largest portion of the boiler losses and is dependent on.[11]

- Quantity of dry flue gases.
- Exit temperature of flue gases at Air pre heater (APH) outlet.
- Mean specific heat of flue gases.

This loss in mainly dependent on amount of excess air supplied to the boiler over the theoretical air and exit flue gas temperature at APH outlet. Any change in excess air quantity by 5% causes 1% change in dry flue gas loss.

Heat loss due to dry flue gas which is the greatest boiler loss and can be calculated by the following formula.

$$L\% = \frac{(M.cp(tf - ta))}{GCV\ of\ Fuel} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [11]$$

M=Mass of flue gases

Cp = Specific heat of flue gas Kcal/Kg

Tf = Flue gas temperature at APH outlet ◦C

Ta = Atmospheric temperature ◦C

$$L\% = \frac{(M.cp(tf - ta))}{GCV\ ofFuel} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

The given data that we collect from the industry

M=6.96KG/KG

Cp =0.45 Kcal/kg

Tf = 157 at air preheater outlet temperature

Ta=30 Atmospheric temperature

Now puts this data in the given equtionm

$$L\% = \frac{(6.96 * 0.45(157 - 30))}{5981} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [11]$$

$$L\% = \frac{(6.96.0.45(127))}{5981} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

$$L\% = \frac{(6.96 * 58.5)}{5981} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

$$L\% = \frac{(407.16)}{5981} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

$$L\% = 0.0681 * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

L%=6.81

We get the result after simplification

L%1=6.81…………(a)

Key Referance loss is equal to

L%1=4.79

Loss difference between key refrence and industry is equal to=2.02

This loss actually depends on the actal air supplied to the boiler.

TABLE3.2 [11]

Serial No	COMPARISION	Percentage loss of dry flue gases
1	KEY REFERANCE	4.79
2	DG CEMENT	6.79

2) Heat Loss Due to Evaporation of Water Formed Due to H_2 in Fuel.

This loss occurs as a result of hydrogen burning, which forms water when it reacts with oxygen in the air.

This loss happens because the water absorbs the heat energy produced in the boiler, turning it into steam.

The amount of hydrogen in the fuel determines how much is lost. All that is lost is the latent heat needed to turn water into steam. This is one way to calculate the loss:[11]

L%2 = $$\frac{9H_2.(584+Cp(Tf-Ta))}{GCV\ of\ fuel} * 100$$ ………………….[11]

Where H_2= Kg of hydrogen per Kg of fuel.

Cp = Specific heat of flue gas Kcal/Kg

Tf = Flue gas temperature at APH outlet oC

Ta = Atmospheric temperature oC

584= latent heat corresponding to water vapour of fuel.

Using the above equation to calculate the percentage loss due to evaporation of water formed due to hydrogen in fuel.

Now the data of the industry is given by

Where H_2=5.4% Kg of hydrogen per Kg of fuel.

Cp = o.45 Specific heat of flue gas Kcal/Kg

Tf = 157cFlue gas temperature at APH outlet oC

Ta =30 Atmospheric temperature oC

GCV=5981 0f Bituminous coal kcal/kg

Now putting the above value

L%2 = $$\frac{9H_2.(584+Cp(Tf-Ta)}{GCV\ of\ fuel} * 100$$ ………………….2[11]

%L2 = $$\frac{9*0.054.(584+0.45(130)}{5981} * 100$$ ………………….2

$$\%L2 = \frac{9*0.054.(584+58.5)}{5981} * 100 \ldots\ldots\ldots\ldots 2$$

$$\%L2 = \frac{9*0.054.(584+0.45(157-30)}{5981} * 100 \ldots\ldots\ldots\ldots 2$$

$$\%L2 = \frac{9*0.054.(642.5)}{5981} * 100 \ldots\ldots\ldots\ldots 2$$

$$\%L2 = \frac{9*34.695)}{5981} * 100 \ldots\ldots\ldots\ldots 2$$

$$\%L2 = \frac{(312.255)}{5981} * 100 \ldots\ldots\ldots\ldots 2$$

$$\%L2 = 0.052207 * 100 \ldots\ldots\ldots\ldots 2$$

%L2=5.2%

This loss is occur when hydrogen react with oxygen to from water molecules which causes to reduce the overall efficiency of the boiler.

So 5.2% loss is occur in the boiler that we collect the data.

Key reference loss is 3.9%

Table 3.3[11]

Comparesion	Percentage Due H_2 in Fuel
Key reference	3.9%
Dg cement	5.20%

Heat Loss Due to Moisture Present in Fuel

The moisture in the air is the cause of the loss. The air's humidity is the cause of the loss. Moisture turns into vapour when it absorbs heat from the combustion chamber or furnace. This heat needs to be included as a boiler loss because it travels up the stack. Since the boiler receives hot air from the air pre heater, this loss is minimal. This is one way to calculate the loss:[11]

$$\%L3=\frac{M.(584+Cp(Tf-Ta)}{GCV\ of\ fuel}*100 \ldots\ldots\ldots\ldots[11]$$

Where M = Kg of moisture per Kg of fuel

Cp = Specific heat of flue gas Kcal/Kg

Tf = Flue gas temperature at APH outlet oC

Ta = Atmospheric temperature oC

584= latent heat corresponding to water vapour of fuel

Now the given data of the industry is given by

Where M =6.96 Kg of moisture per Kg of fuel

Cp =0.45 Specific heat of flue gas Kcal/Kg

Tf = 157cFlue gas temperature at APH outlet oC

Ta =30c Atmospheric temperature oC

Putting the given value in the eqution

$$\%L2=\frac{0.0696*(584+0.45(157-30)}{5981}*100 \ldots\ldots\ldots\ldots 2$$

$$\%L2=\frac{0.0696(584+0.45(130)}{5981}*100 \ldots\ldots\ldots\ldots 2$$

$$\%L2=\frac{0.0696.(584+58.5)}{5981}*100 \ldots\ldots\ldots\ldots 2$$

$$\%L2=\frac{0.0696.(642.5)}{5981}*100 \ldots\ldots\ldots\ldots 2$$

$$\%L2=\frac{44.718)}{5981}*100 \ldots\ldots\ldots\ldots 2$$

$$\%L2=0.0074*100 \ldots\ldots\ldots\ldots 2$$

%L2=0.74%

Table 3.4[11]

Comparison	Percentage Loss Moisture in Fuel
Key reference	0.20%
Dg cement	0.74%

To Find Gross Calorific Value And Net Calorific Value

Ultimate Analysis

The ultimate analysis is the method used to determine the percentage proportion of the major chemical elements (organic substances) present within the coal sample these elements include carbon, nitrogen, hydrogen, sulphur, and carbonate contents. Oxygen within the coal substance is obtained by difference (i.e., subtracting the total percentages of carbon,hydrogen, nitrogen, and sulphur from 100).

Ultimate analysis results are used for combustion calculation, it provides information on the combustible and noncombustible substances within the coal sample used in

calculating the combustible air needed, flue gases, and

hydrogen combustion losses [12].

The results in this research of the coal samples are on as received and air dried basis

$\text{HHV of coal}=(8080C+34500(-O/8)+22400S)*1/100\ \text{Cal/kg}$……………………….[14]

Where C, H, O, and S represent the percentage of the coal Carbon, Hydrogen, Oxygen, and Sulphur contents respectively.

The coal calorific value is affected by the moisture it contains, i.e., the more moisture in the coal fuel the lesser its calorific value.

Now we use this equation to find the value of the GCV and NCV of bituminous coal

Key reference value of the different element ratio in bituminous coal is given by

$C=70\%$, $H=4.7\%$, $O=22.2\%$, $S=0.3\%$

PUT this value in the equation

$\text{HHV of coal}=(8080*70+34500(4.7-22.2/8)+22400*0.3)*1/100\ \text{kCal/kg}$……………………….3

$\text{HHV of coal}=(8080*70+34500(4.7-22.2/8)+6720)*1/100\ \text{kCal/kg}$

$\text{HHV of coal}=(8080*70+34500(1.925)+6720)*1/100\ \text{KCal/kg}$

$\text{HHV of coal}=(8080*70+34500(1.925)+6720)*1/100\ \text{kCal/kg}$

$\text{HHV of coal}=(8080*70+34500(1.925)+6720)*1/100\ \text{KCal/kg}$

$\text{HHV of coal}=(8080*70+34500(1.925)+6720)*1/100\ \text{KCal/kg}$

HHV of coal=(8080*70+66412.5+6720)*1/100 KCal/kg

HHV of coal=(6468.125)*1/100 KCal/kg

HHV of coal=6468.125 kCal/kg

Now we find the NCV of the bituminous coal.using the given formula

NCV of coal=(HHV-52.83H) Kcal/kg………………….[14]

Put the given value

NCV of coal=(6468.125-52.83*4.7) kcal/kg

NCV of coal=(6468.125-248.301) kcal/kg

NCV of coal=6219.824 Kcal/kg

Key reference HHV value and NCV is given by

$\text{HHV} = 6468.125 \text{ cal/kg}$

$\text{NCV} = 6219.824 \text{ cal/kg}$

The data that we 0btain from the industry

HHV=5981 cal/kg

NCV=5739 cal/kg

There is to much difference in HHV and the NCV of the key reference and the industry.

Table 3.5 [11]

COMPARISION	GCV VALVE OF COAL kcal/kg	NCV VALVE OF COAL Kcal/Kg
KEY REFERANCE	6468.125	6219.824.635
DG CEMENT	5981	5739

Proximate analysis

Proximate analysis results provide information on the inorganic matter the coal contains including moisture content, volatile matter, fixed carbon contents, and ash (i.e., inorganic material left after all the combustible matter has been burned off).

The fixed carbon(FC) content is obtained by difference. The coal ignition in the boiler furnace is proportional to the volatile matter

i.e., the higher the volatile matter the easier the coal ignition.

Fixed carbon is the main flammable substance for heat generation within coal

The equation used to find the FC content

FC = [100- (Moisture+ Ash +Volatile matter)]%........[5]

The data we obtain from the industry is given by

Moisture=6.96

Ash =15.95

Volatile Matter=24.19

FC = [100- (6.96+ 15.95 +24.19)]%

FC = [100- (47.1)]%

FC = 52.9%

Table 3.6 [10]

Comparison	Fixed Carbon
Key Reference	71%
Dg Cement	52.9%

Chapter 4

4.1 Result and Discussion

Comparison of Gross Calorific Value of Bituminous Coal

A higher Gross Calorific Value (GCV) of bituminous coal indicates a greater energy content per unit of weight.

Energy Efficiency: Higher GCV means more energy is released during combustion, leading to increased efficiency in power generation or other industrial processes.

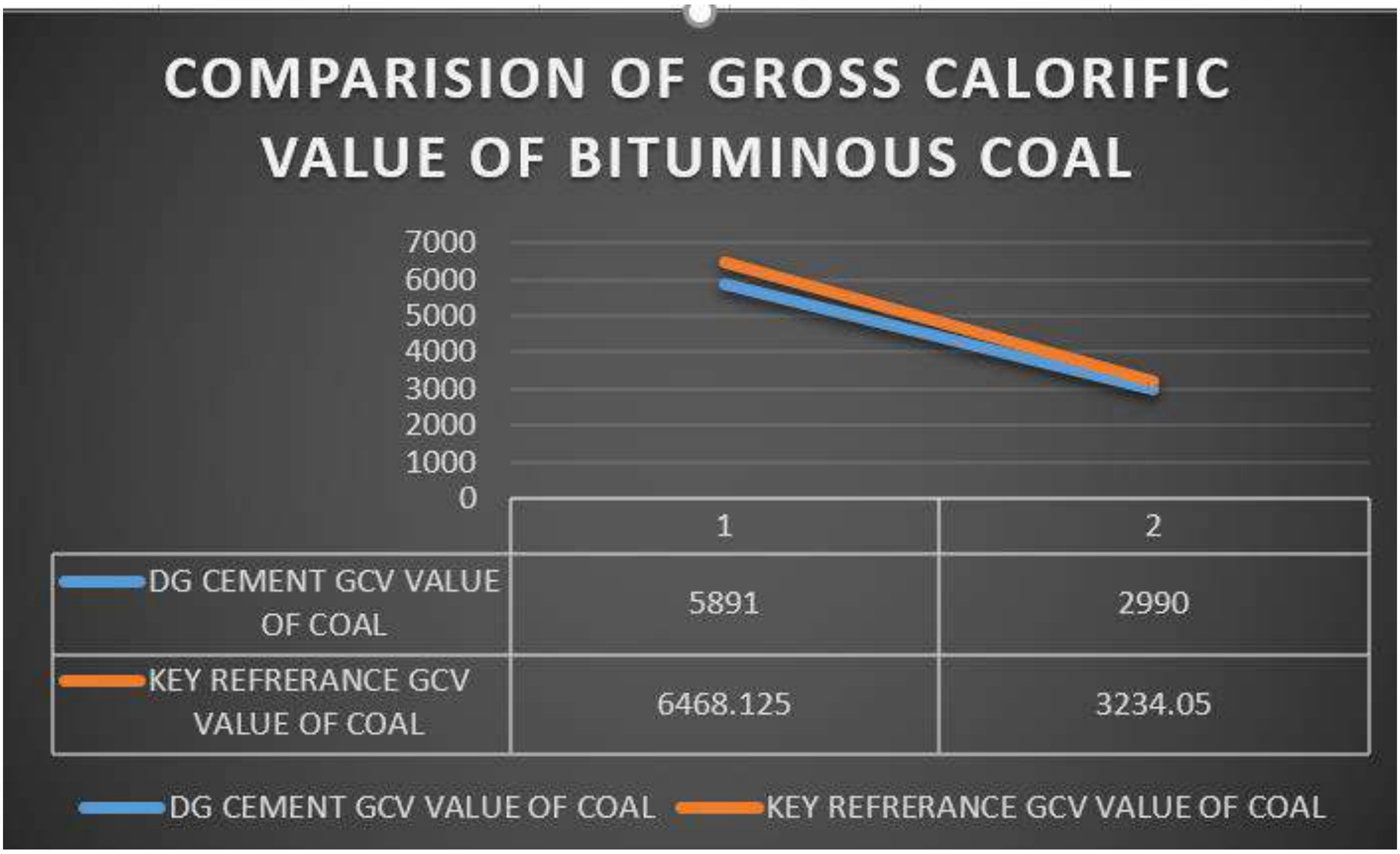
Reduced Emissions: With a higher GCV, less coal is required to produce the same amount of energy, resulting in lower emissions of pollutants such as carbon dioxide (CO2), sulfur dioxide (SO2), and nitrogen oxides (NOx) per unit of energy generated.

Cost-effectiveness: Since less coal is needed for the same energy output, higher GCV can contribute to cost savings in terms of transportation, storage, and overall fuel consumption.

Space Utilization: Higher GCV allows for the generation of more energy in a smaller space, which can be crucial in settings where space is limited, like industrial facilities or power plants.

Reduced Ash Content: Bituminous coal with higher GCV often has lower ash content, minimizing the waste generated during combustion and easing the burden on ash disposal.

It's worth noting that while higher GCV is generally advantageous, other factors like ash content, moisture content, and sulfur content also play roles in determining the suitability of coal for specific applications.



	1	2
DG CEMENT GCV VALUE OF COAL	5891	2990
KEY REFRERANCE GCV VALUE OF COAL	6468.125	3234.05

Graph 4.1 Comparison Of GCV Value[10]

Net Calorific Value of Bituminous COAL

When calculating the energy content of bituminous coal, the net calorific value (NCV) takes into account the energy needed to evaporate the water that is produced during combustion. Here are some advantages to taking NCV into account:

Realistic Energy Output: By taking into consideration the latent heat of vaporization of water vapor produced during the process, NCV offers a more accurate measurement of the actual energy released during combustion.

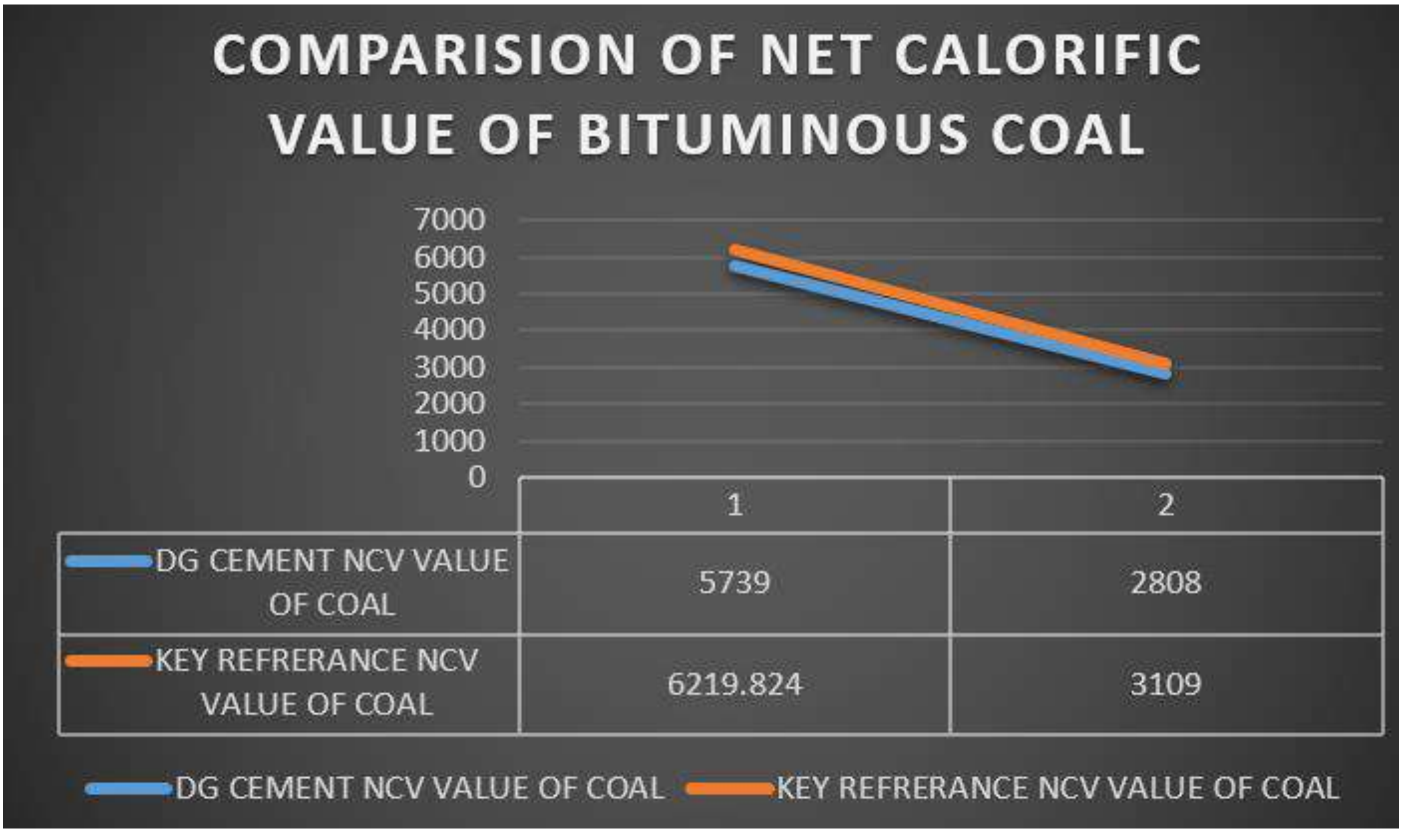
Practical Efficiency: NCV is especially important in applications (like power generation) where combustion releases water vapor. Because it more accurately depicts usable energy, the practical efficiency of energy conversion processes can be evaluated more effectively.

Precise Energy Comparisons: Because NCV takes into account the energy required to turn water into vapour, it offers a more precise foundation for comparison when comparing various fuels or evaluating energy efficiency.

Process Optimisation: By taking into consideration the energy losses related to water vaporisation, an understanding of the NCV aids in process optimisation in industrial settings, resulting in more productive and economical operations.

Emission Calculations: NCV is essential for precise computations of emissions per unit of usable energy, supporting both emission standard compliance and environmental impact assessments.

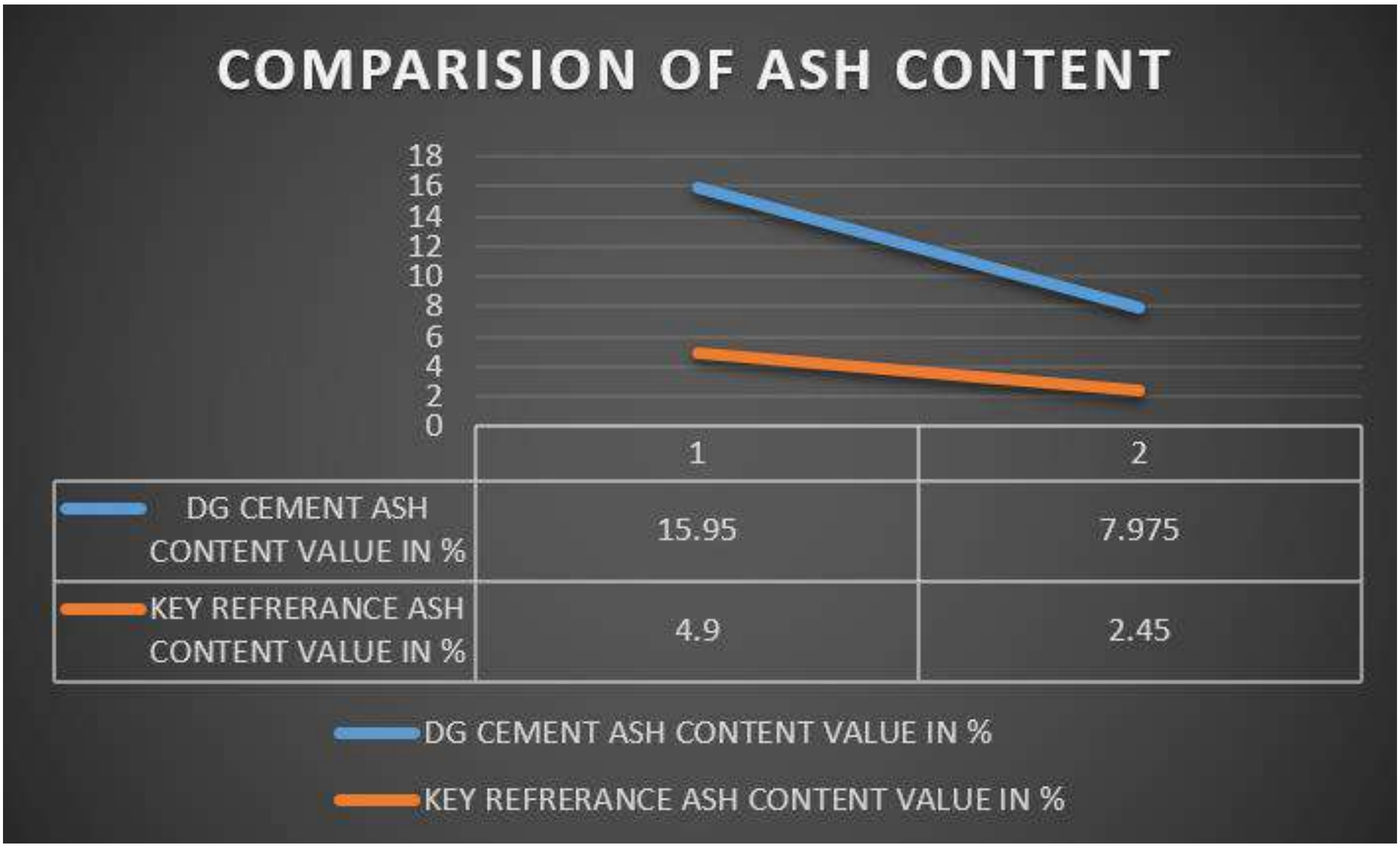
Although GCV is frequently employed for broad comparisons, NCV is particularly useful in situations where a sizable amount of the combustion byproduct is water vapour.



Graph 4.2 Comparison Of NCV Value[10]

Comparison Of Ash Content

A "coal beneficiation" or "coal washing" system is a device that is frequently used in coal-fired boilers to reduce the amount of ash and increase the calorific value. In order to prepare the coal for burning, contaminants, such as ash, must be removed. Improving the coal's quality is the main objective in order to increase its combustion efficiency. This is a quick rundown of how coal beneficiation operates: Techniques for Physical Separation: Different physical techniques are used to extract impurities from coal according to variations in density, size, and form. Screening, dense medium separation, and gravity separation are typical methods. Chemical Treatment: Impurities in the coal may be broken down or modified using certain chemical methods. Depending on the precise contaminants present, these procedures may change.Air bubbles are used in flotation, a different method for selectively separating contaminants from coal particles.Coal can have its calorific value increased by reducing its ash content through the use of coal beneficiation. Consequently, this improves the boiler's combustion process's efficiency. Remember that the particulars of the coal being processed and the required quality for burning may influence the choice of beneficiation technique.



Graph 4.3Comparision of Ash Content[10]

One of the key factors affecting coal's quality and burning properties is the correlation between the amount of ash and carbon in the material. The inorganic residue left over after burning coal is known as the ash content, and it is inversely correlated with the carbon content. The carbon concentration tends to decrease with increasing ash content, and vice versa. When considering the generation of energy and its effects on the environment, this link is important. Elevated levels of ash indicate a reduced calorific value and a rise in impurities, which can impact the effectiveness of burning coal and extracting energy. On the other hand, increased carbon content increases the amount of energy released during burning. Industries that use coal to generate energy must comprehend this relationship in order to choose coal types that meet their efficiency and environmental objectives. Additionally, It provides guidance for initiatives to lessen the negative environmental effects of emissions and ash disposal.

Comparison of carbon

The benefits of bituminous coal's high carbon content are numerous.

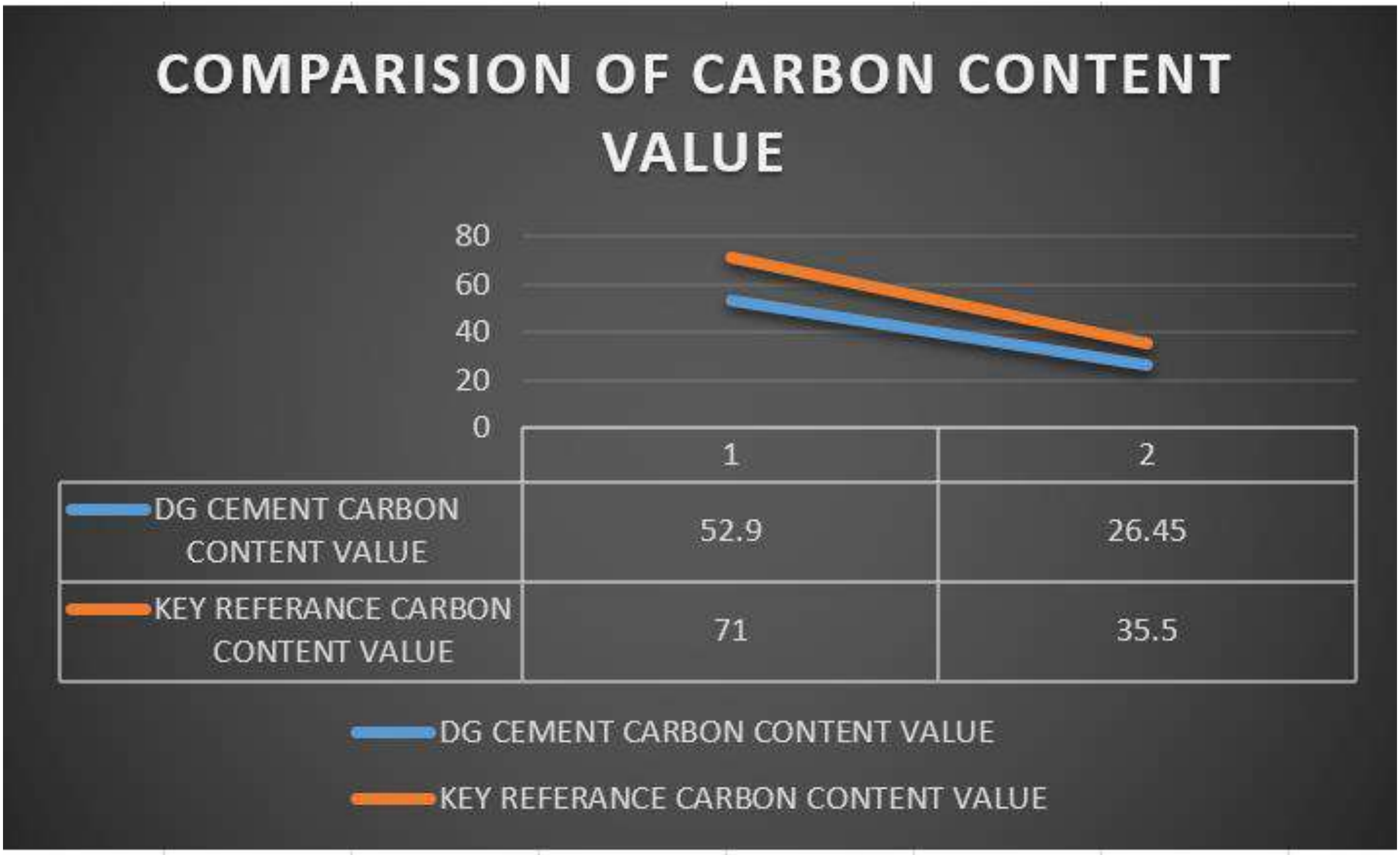
1. The energy content Burning bituminous coal with a high carbon content releases more energy, making it a valuable fuel for heating and power generation.

2**. Effective Combustion**: A higher carbon content facilitates more efficient combustion, which improves the generation and use of heat.

3. **Production Utilisation**: Because it can produce high temperatures, bituminous coal with elevated carbon levels is frequently used in industrial processes like the production of steel.

4. **Diminished Impurities**: Higher carbon content is usually linked to lower concentrations of impurities such as ash and sulphur, which enhances overall combustion efficiency and lessens environmental impact.

5**. Versatility**: Bituminous coal's high carbon content increases its adaptability, making it ideal for a range of uses, such as the manufacture of coke and as a raw material in specific chemical processes.



Graph 4.4 COMPARISION OF CARBON CONTENT VALUE[10]

Chapter 5

5.1 Conclusion

In Conclusion, this thesis has explored the complex field of thermal analysis, with bituminous coal as its main focus. A careful examination of the coal's thermal characteristics, such as its ash content, calorific value, and pyrolysis behaviour, has provided important information about how suitable it is for different uses. The empirical results have practical implications for industries dependent on bituminous coal, in addition to adding to our understanding of the resource.

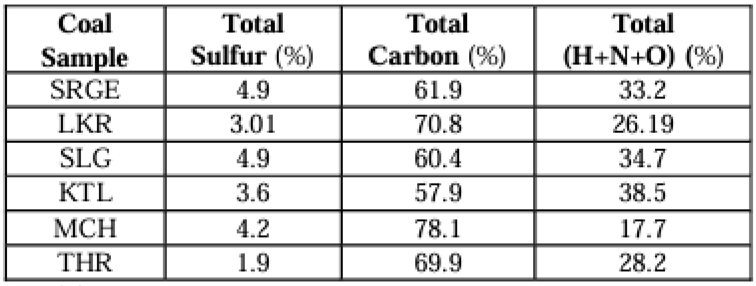
An examination of the thermal behaviour of coal, including how it reacts to changes in temperature and releases volatile substances when it pyrolyzes, provides vital information for both energy production and environmental concerns. The calorific value and ash content that are disclosed are important factors to consider when assessing the effectiveness and environmental consequences of using bituminous coal as a fuel source.

Nevertheless, it is imperative to recognise the intrinsic constraints of this research, including the particular attributes of the bituminous coal sample and possible discrepancies among various sources. In order to ensure a more thorough understanding of bituminous coal types' thermal characteristics, this creates opportunities for future research to examine a wider range of them.

The more we learn about the application of thermal analysis to bituminous coal, the more obvious the consequences are for industrial processes, environmental sustainability, and energy production. This thesis serves as a catalyst for ongoing research endeavours, in addition to consolidating current knowledge in this particular domain. Because bituminous coal is a dynamic energy resource, research into it must continue in order to improve our knowledge and direct the development of more effective and clean technologies related to thermal analysis.

5.2 Suggestions

1. The ash content of Tharparkar coal is 4.9, whereas that of the coal used in DG cement power-plant is 15.9. This indicates that Tharparkar coal is significantly more efficient than the coal used in DG cement power-plant because, as we all know, the less ash a coal contains, the more efficiency it can provide.Likewise, when comparing the corban contents of the coal used in DG cement power-plant and the coal from Tharparkar, the corban content of the former is 69.9, while the corban content of the latter is 52.9.This shows that the Tharparkar coal gives more heat than the coal used in DG cement Power-plant because the corban content is the key component that produces heat.



Coal Sample	**Total Sulfur** (%)	**Total Carbon** (%)	**Total (H+N+O)** (%)
SRGE	4.9	61.9	33.2
LKR	3.01	70.8	26.19
SLG	4.9	60.4	34.7
KTL	3.6	57.9	38.5
MCH	4.2	78.1	17.7
THR	1.9	69.9	28.2

Table 3: The results of the ultimate analysis of the coal. [10]

Waste heat utilization

We observed the Continuous flow of heat from the chimney which was wasted into the soundings of the Steam Power-plant at DG cement power-plant So it's recommended to use this heat for the vapor absorption cycle explained below:

It is possible to use a methodical approach to utilise the 137°C waste heat from a power plant for a vapour absorption cycle. To start, use a heat exchanger to collect the waste heat that is at a high temperature. Direct this heat then towards a vapour absorption system, where a water-based refrigerant interacts with an appropriate absorbent (like lithium bromide) to produce vapour.Vapour is produced as a result of the absorbent's absorption during the transfer of waste heat. The thermal energy in this vapour can then be used to power a generator or a turbine, producing electricity. Through the integration of the vapour absorption cycle into the power plant's operations, it is possible to maximise resource utilisation and reduce environmental impact while improving overall efficiency. For maximum efficiency and energy recovery from the waste heat stream, the system must be regularly monitored and optimised.

Particulate matter, carbon dioxide (CO2), nitrogen oxides (NOx), Sulphur dioxide (SO2), and other pollutants can be released when bituminous coal is burned. Changes that can be made to lessen these effects include

*__Flue Gas Desulphurization (FGD)__: By removing Sulphur compounds from the flue gas and capturing them, FGD systems can be added to reduce emissions of Sulphur dioxide.

2**. SCR, or selective catalytic reduction**: SCR systems can be used to catalytically convert nitrogen oxide (NOx) into nitrogen and water Vapour, thereby reducing NOx emissions.

3**. Module Matter Management**: Particulate matter in the flue gas can be collected and eliminated by installing fabric filters or electrostatic precipitators.

4. **Improvements in Efficiency**: By lowering the amount of coal required and the amount of emissions produced per unit of energy produced, improving combustion technologies and equipment can improve the overall efficiency of burning coal.

5**. Capturing and Storing Carbon (CCS)**: Carbon dioxide emissions can be captured and stored by cutting-edge technologies like CCS to lessen their impact on climate change.

6**. Combining Biomass Fire**: One way to cut greenhouse gas emissions and diversify your energy sources is to co-fire coal and biomass.

7. ***Cleaner Coal Technologies**:* Studies into cleaner coal technologies, like integrated gasification combined cycle (IGCC) and fluidized bed combustion, have the potential to improve coal-burning efficiency and minimise environmental impact.

With these changes, the environmental issues brought on by bituminous coal burning will be addressed, and cleaner, more sustainable energy practices will be encouraged.

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