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ABSTRACT

Escalating apprehension about the harmful effects of widespread use of conventional fossil fuels in industry, has led to vast amounts of effort and capital being directed towards researching and developing sustainable alternative energy sources. One of the most promising and abundant of these sources is alternative fuels.

This project analyzes the scope of liquid alternative fuels as a replacement for conventional fuels, in comparison to other alternatives as well as gasoline. Recommendations are made on improving methods of alternative fuels generation and storage. Industrial boilers encompass the category of boilers used in industrial, processing, mining, and refining or any other industry to provide steam, hot water, and/or electricity. Industrial boiler systems are used for heating with hot water or steam in industrial process applications. Industrial boilers are located at facilities in the food, paper, chemicals, refining, and primary metals industries. There is no precise regulatory definition or specific size requirement for an industrial boiler. An industrial boiler is typically defined by its common function – a boiler that provides heat in the form of hot water or steam for co-located industrial process applications. This industrial boiler category does not include electric utility boilers as these do not provide the same service.

CHAPTER 1

INTRODUCTION ABOUT COMPANY

1.1 COMPANY NAME

Alka Earth Tech Equipment

1.2 COMPANY LOCATION

390- Dediyasan G.I.D.C-II,
Mehsana-384002 (N.G.)
(GUJARAT)

1.3 COMPANY OVERVIEW

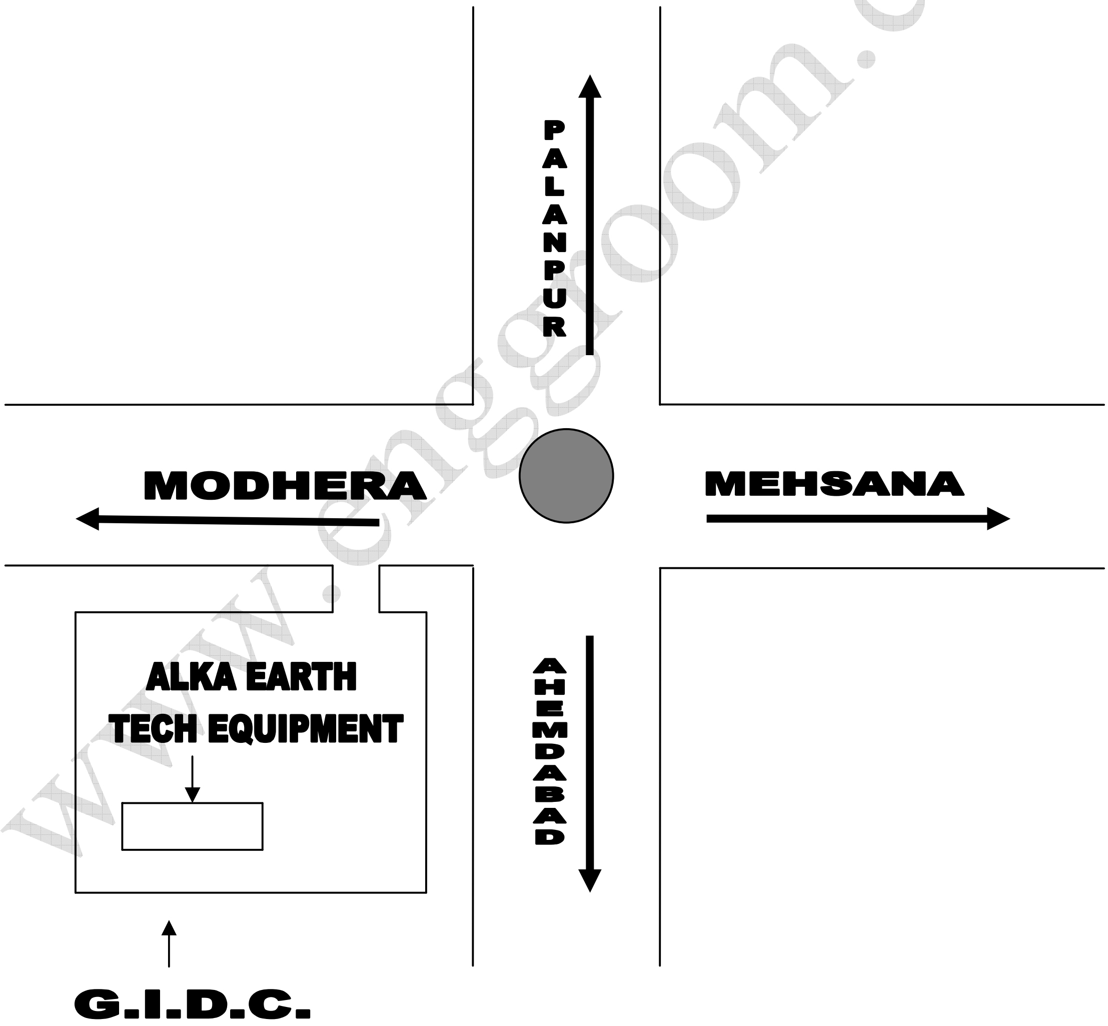
The company had initial of about 1 crore in plant. It was a pioneer small-scale industry in production of road construction machines and equipment that spare parts set in north Gujarat.

The company currently is well setup and is able to manufacture the road construction machines and equipment that spares parts sets its own.

1.4 HISTORY

In the year 1985 Mr. Alpesh Prajapati Started his industrial activities & Introduce the road construction machines set successfully and manufactured.

1.5 PLANT LOCATION



1.6 COMPANY PRODUCTS

They manufacture a wide collection of road construction machines and equipment that spare parts & all types of fabrication & machinery job works & repairers.

- Road construction machines
- Paver machine
- Bitumen Pressure Distributor
- Dram Mixers
- Pugmin machine

1.6.1 Road construction machine

- We offer Road Construction Machines that finds application in various construction industries. This equipment is manufactured using high grade raw material and superior quality machines.

- The products are highly appreciated among our clients for their superior quality and durability.

- Our product range includes Wet Mix Plant, Mechanical Brooms, Mobile Wet Mix Plant, Bitumen Tank, Drum Mix Asphalt Plant, Bitumen Pressure Distributor, Fog Seal, Chips Spreader, Mini Drum Mix Plant (15-20TPH) Mobile unit, Wet Mix Paver and Bitumen Boiler.

1.6.2 Wet Mix Plant

Fig.1.1

We provide our clients a precisely engineered range of Wet Mix Plant, which is fortified with a plug mill mixing unit, feeding system and water tank. Designed using sophisticated technology, wet mix plant is known to provide outstanding performance even under harsh working conditions. These are fuel efficient and offered in various specifications to fulfill different requirements of clients.

1.6.3 Drum Mix Asphalt Plant

Fig.1.2

- Our clients can avail from us Drum Mix Asphalt Plant that adheres to the international quality standards. Made using high grade raw material these plants are highly efficient and have longer durability. Also available with us is automatic drum mix plants.
- These are designed as per the specifications provided by our clients. Available at market leading price, these plants are designed and developed for the International market.
- We have wide range of products in drum mix asphalt plant. We have range of DM 25 to DM 60

1.6.4 Stationery Wet Mix Plant

Fig.1.3

- We design and fabricate a wide range of Mobile Wet Mix Plant that is made using high quality raw materials.

- Designed for mobility with capacity of 60 tons to 250 tons per hour. Easy to commission, these wet mix plants can be put in to operation with shortest time.

1.6.5 Bitumen Tank

Fig.1.4

- We offer Bitumen Tank, which is completely insulated so as to minimize the heat loss. The inside of the tank is heated by "U" shape heating tube that is fitted with an automatic burner of desired capacity.

- The fuel tank supplies the fuel for the burner. Also, on top of the bitumen tank the manhole is provided for inspection and charging of bitumen. We manufacture Bitumen Tank up to 2500 diameters.

1.6.6 Bitumen Pressure Distributor

Fig.1.5

- We offer our clients a highly functional range of Bitumen Pressure Distributor (Capacity up to 7000 Ltr). These bitumen pressure distributors are used for applying a uniform coating of hot Bitumen on specified surface in set quantity and are fitted with unique Pressure Cleaning System (PCS).

CHAPTER-2

DISCRIPTION OF IDP

2.1 Problem Summery

- **IDP Statement :-**

"SUGGESTING GAS AS AN ALTERNATIVE FUEL IN PLACE OF DIESEL/COAL FOR REDUCING POLLUTION AND INCREASING FUEL EFFICIENCY AND ECONOMY OF THE PLANT."

2.2 Problem Detail & Description:-

Recently, we go to visit Alka earth tech equipment industries we meet Alpesh Prajapati, he gives us permission , we discuss to Alpesh bhai he gives information for industries , their company boiler, Paver Machine, Bitumen pressure distributor , Drum mixers etc. Some instrument used in products lath machine, drilling machine, Bending machine etc. used in this product

We find to improve in boiler, boiler work on fuel diesel & coal, production speed is very slow and add in this boiler is produce much pollution production expenses is very higher and production time is taken a high. It is affect on the totally production of the company.

If We applied to new method " Suggesting gas like alternatives fuel in place of diesel /coal for reducing pollution of increasing fuel economy. the plant" boiler is produce low pollution and we save to production expenses is low and time taken by work is low. By apply this method so, production increase in this process. and pollution is decrease.

2.3 Bitumen tank

Fig.2.1

In alka industry for melting asphalt the convectional fuel is used in boiler shown in the figure. here this boiler create high pollution and noise pollution.

We offer Bitumen Boiler which suitable for asphalt jointing, setting and roofing.

2.4 DETAIL DISCRIPTION OF IDP

IDP Statement:-

"SUGGESTING GAS AS FUEL IN PLACE IN DISEL / COAL FOR REDUCING POLLUTION AND INCREASING FUEL EFFICIENCY AND ECONOMICAL THE PLANT.

" REPLACEMENT OF GAS BOILER IN PLACE OF CONVENTIONAL BOILER"

Figure 2.2 LPG Boiler

As shown in figure we use LPG Gas boiler in place of conventional boiler. In Gas boiler we use the alternative fuels like LPG, CNG etc. So pollution is decrease by this boiler and efficiency of this boiler is increase and also cost of alternative fuels is decrease than conventional fuels.

Most of the LPG available in the market is utilized in the residential sector. There are almost no limitations for LPG use in the industrial sector but a limited number of industries use this fuel. The prospects for increased consumption in the other sectors, especially the industrial sector, remain very limited.

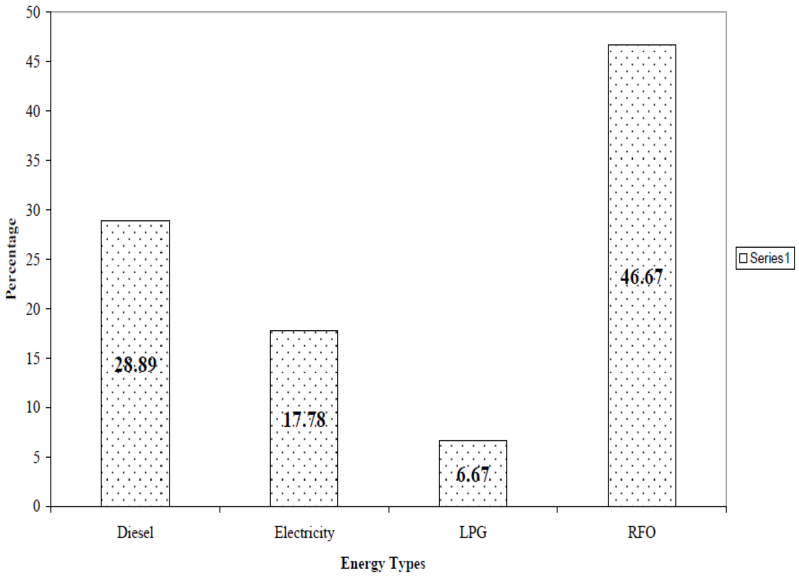
Almost no data were available on LP Gas used in the industrial sector. No conclusions are possible on industrial applications of LPG and policy; this is a research gap. It is against this background that this study was carried out to explore the potential of LPG as a viable energy resource for our industries. This study aims to examine the factors that are particularly catalytic in the deployment of LPG as industrial fuel with the aim of providing some insights for industries that have plans to promote the use of gas as fuel in the country.

The distribution of industrial industries of the 45 industrial industries surveyed (55.6 percent) were located in the heavy industrial area (26.7 percent) in the light industrial area, and the remaining (17.8 percent) located in areas outside these two main industrial areas.

Ninety five percent of the large sized industries were cited in the heavy industrial area, while the remaining 5 percent were sited in the light industrial area. None of the small industries were located in the heavy industrial area. 53.3 percent of the medium sized industries were located in the light industrial area, 26.7 percent in the heavy industrial area, while 20 percent were sited outside the light and heavy industrial areas. However, 50 percent forming the majority of the small industries, were located outside these two main industrial areas, while the remaining 50 percent were distributed in the light and heavy industrial areas as 30.0 and 20.0 percent, respectively.

- **Main Energy Sources Used by Industry Sub-sectors:-**

Industry is an important part of the economy and energy is a vital input into the Industry. In fact, every Industry plant uses at least one type of energy in their production process.



Source: Authors' Field Survey-November, 2006

GRAPH-1

Graph-1 depicts the main energy sources being used by the industrial sub-sectors. The most highly used fuel is Residual Fluid Oil (46.67 percent), whilst the least utilized fuel is LPG (6.67 percent). 28.89 percent of the industrial interviewed use diesel, while the remaining 17.78 percent uses electricity. Most of the industries (91.1 percent) use the energy for process heating, 4.4 percent for process drying, and the remaining 4.4 percent for machine drive. 95.2 percent of the industries that use RFO as main fuel use it to generate heat, while the rest of the 4.8 percent is for process drying. According to the survey results, 100 percent of the industries that use diesel are for process heating. 66.7 percent of the industries that use LPG as main fuel are for process heating, while 33.3 percent is for process drying. However, the industries that use LPG as substitute fuels or alternative fuels use it to drive machines and start ignition in addition to the process heating and drying. Reasons assigned for the choice of a particular energy source included the design of their boilers and furnaces (40 per cent), its comparatively low price (33.3 per cent) and the readily availability of the energy (26.7 per cent). The distribution is as shown in table

- **Distribution of Gas users across the various Industries :-**

Of the industries identified to be using LPG as their energy source, 12.5 percent are in the food and beverage industry, another 12.5 percent belong to the chemical industry, 25.0 percent in the textile industry, 37.5 percent in the metal industry, and the remaining 12.5 percent in the paper and petroleum industry. Results show that LPG users are found in almost all the industrial sub-sectors.

Generally, 87.5 percent of all the industries using the gas are large sized companies, with only 12.5 percent being small sized companies. Within the large sized industries, 65 percent of the respondents were not using the gas, while the remaining 35 percent were using the gas. None of the medium sized industries were using the gas. However, one representing 12.5 percent of the small sized industries were identified as using the gas. The distribution is as shown in the table 7.0

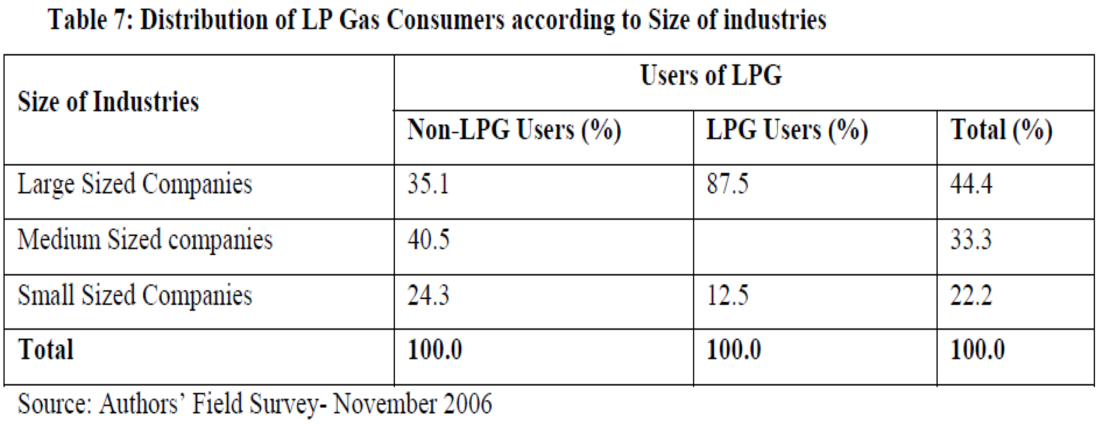
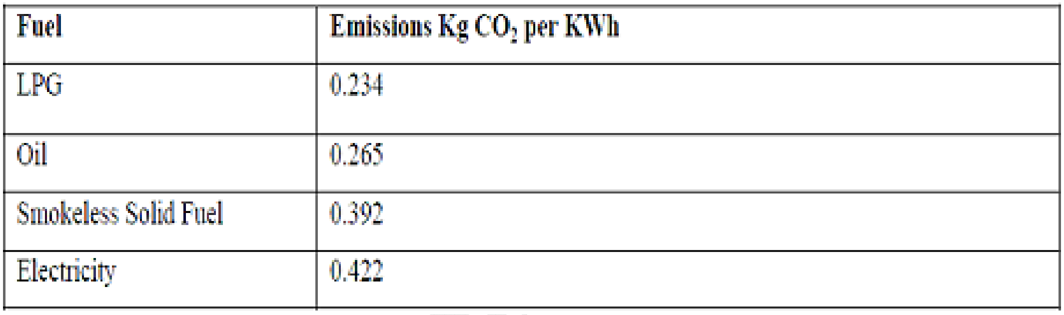


Table 7: Distribution of LP Gas Consumers according to Size of industries

Size of Industries	Users of LPG		
	Non-LPG Users (%)	LPG Users (%)	Total (%)
Large Sized Companies	35.1	87.5	44.4
Medium Sized companies	40.5		33.3
Small Sized Companies	24.3	12.5	22.2
Total	**100.0**	**100.0**	**100.0**

Source: Authors' Field Survey- November 2006

TABLE -3.2



Fuel	Emissions Kg CO_2 per KWh
LPG	0.234
Oil	0.265
Smokeless Solid Fuel	0.392
Electricity	0.422

Table -3.3 Alternative fuels CO_2 Emission

Emissions from energy production and consumption play a major role in air pollution. From table 9.0, it can be shown that the contribution of LPG to global greenhouse gas emission is relatively small. It can be calculated that these fuels emit more CO2 than LPG; as follows: oil emits 13.2 percent more CO2 than LPG, smokeless solid fuel emits 67 percent more CO2 than LPG, and electricity emits 80 percent more CO2 than LPG.

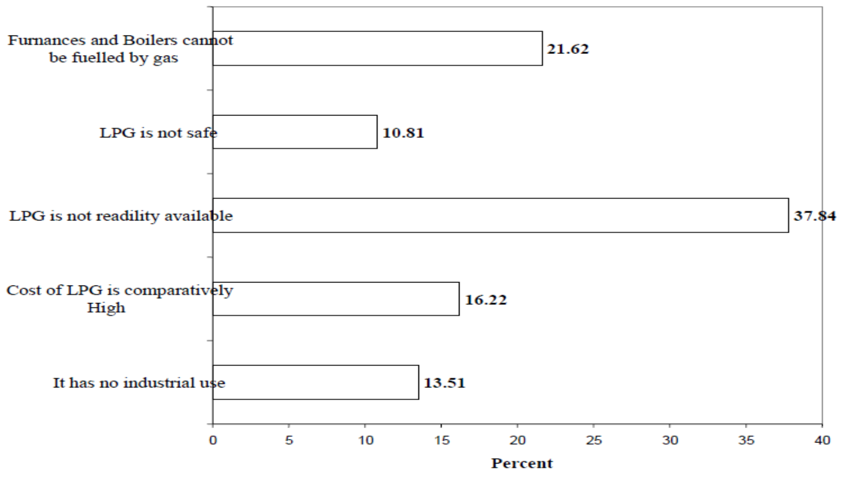
Though the figures shown, distances that pollutant gases travel means that pollution is an international problem. Because energy use patterns translate into greenhouse gas emissions, the industrial sector stands as one of the country's environmental culprits. Hence, greater LPG use means projected reduction in carbon dioxide emissions. It is

becoming clear that efforts to reduce Green House Gas (GHG) emissions must increase conversion to lower-carbon energy sources.

- **Reasons for Non-Utilization of LPG:-**

LPG has demonstrated health and environmental benefits compared to other conventional fuels, but the rationales for using LPG-fired units have met serious challenges, especially in the industrial sector. Respondents outlined some of the reasons for none-use of the gas as unavailability of the gas, inability of their furnaces and boilers to be fuelled by the gas, comparatively high cost of the gas, and the fear of the gas catching fire (safety issues). The distribution is as shown in graph-2:

Figure 2a: Reasons for non-use of LPG



Source: Authors' Field Survey-November, 2006

GRAPH-2

CHAPTER-3 BOILER FUELS

BOILER FUELS:-

Many different solid, liquid, and gaseous fuels are fired in boilers. Sometimes, combinations of fuels are used to reduce emissions or improve boiler performance. Fuels commonly fired in boilers include fossil, biomass, and RDFs as well as other types of fuels and fuel combinations. Coal, petroleum-based oils, and natural gas are fossil fuels commonly fired in ICI boilers. However, other forms of solid, liquid, or gaseous fuel derived from these fossil fuels are sometimes included in this category. One of these fuels, which is referred to as tire-derived fuel (TDF), consists of shredded vehicle tires. Another boiler fuel is referred to as biomass. Biomass is renewable organic matter. Examples of biomass include fast-growing trees and plants, wood and wood waste, agricultural crops and residue, aquatic plants and algae, animal wastes, and organic municipal and industrial wastes.

RDF is a potentially valuable energy source. It consists of MSW that has been processed using size reduction and material recovery techniques to eliminate materials such as aluminum, steel, glass, plastic, and rock. Common types of fuels fired in boilers are listed in Table 5.1 with key properties provided in Table 5.2. Additional information about some of the more common fuels is presented in the remainder of this section.

- **Coal:-**

Coal is a brown-to-black combustible, sedimentary rocklike material composed primarily of consolidated and chemically altered plant material that grew in prehistoric forests.1 The chemical composition of coal varies from one location to another, depending on the vegetation from which it was formed and the environmental conditions (such as temperature and pressure) to which the formation was exposed. In addition to its major chemical constituents of carbon, hydrogen, nitrogen, and oxygen, coal also contains some water and impurities of which ash, mercury, and sulfur are major concerns from an emissions viewpoint.

Table 3.1. Fuels fired in boilers to generate hot water or steam

Fuel	Description
By-product/waste	Any liquid or gaseous substance produced at chemical manufacturing plants or petroleum refineries (except natural gas, distillate oil, or residual oil) and combusted in a steam generating unit for heat recovery or for disposal.[2]
Biomass	Organic matter that is used as fuel is called biomass;[3] biomass is a nonfossil fuel that includes materials such as wood, bagasse, nut hulls, rice hulls, corncobs, coffee grounds, and tobacco stems
Coal	Coal is a brown-to-black combustible sedimentary rocklike material composed principally of consolidated and chemically altered plant material that grew in prehistoric forests;[1] it includes all solid fuel classified as anthracite, bituminous, subbituminous, or lignite coal, coal refuse, or petroleum coke.[2]
Coal refuse	Waste products of coal mining, physical coal cleaning, and coal preparation operations containing coal, matrix material, clay, and other organic and inorganic materials.[4]
Distillate oil	Fuel oils that contain 0.05 wt % nitrogen or less and comply with the specifications for fuel oil Nos. 1 and 2 as defined in ASTM D 396 (Refs. 2 and 5).
Municipal-type solid waste and RDF	Refuse, more than 50% of which is waste containing a mixture of paper, wood, yard waste, food wastes, plastics, leather, rubber, and other noncombustible materials such as metal, glass, and rock, which are usually removed prior to combustion.[2]
Natural gas	A naturally occurring mixture of hydrocarbon gases found in geologic formations beneath the earth's surface, of which the principal constituent is methane, or LP gas as defined in ASTM D 1835 (Refs. 2 and 6).
Oil	Crude oil or petroleum or a liquid fuel derived from crude oil or petroleum, including distillate and residual oil.[2]
Propane	Propane is a heavy gaseous fossil fuel processed from crude petroleum and natural gas.[6]
Residual oil	Crude oil and fuel oil Nos. 1 and 2 that have nitrogen content greater than 0.05 wt %, and all fuel oil Nos. 4, 5, and 6 as defined in ASTM D 396 (Refs. 2 and 5).
Solvent-derived fuel	Any solid, liquid, or gaseous fuel derived from solid fuel for the purpose of creating useful heat and includes, but is not limited to, solvent-refined coal, liquefied coal, and gasified coal.[4]
Very low sulfur oil	Oil that contains no more than 0.5 wt % sulfur and that, when combusted without SO_2 emission control, has a SO_2 emissions rate equal to or less than 215 ng/J (0.5 lb/MBtu) heat output.[2]
Wood	Wood, wood residue, bark, or any derivative fuel or residue thereof, in any form, including, but not limited to, sawdust, sanderdust, wood chips, scraps, slabs, millings, shavings, and processed pellets made from wood or other forest products.[2]
Wood residue	Bark, sawdust, slabs, chips, shavings, mill trim, and other wood products derived from wood processing and forest management operations.[7]

TABLE-5.1

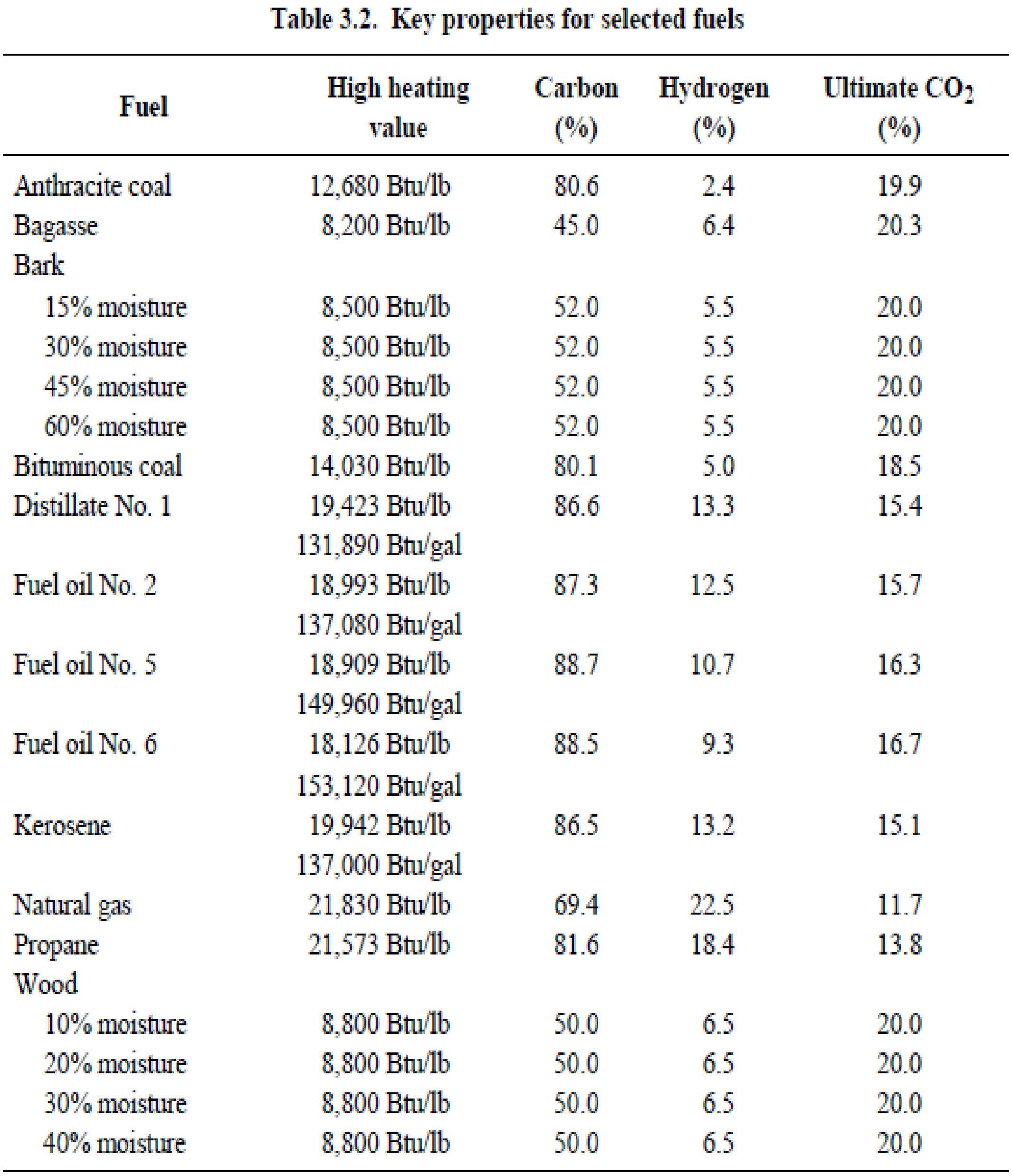


Table 3.2. Key properties for selected fuels

Fuel	High heating value	Carbon (%)	Hydrogen (%)	Ultimate CO_2 (%)
Anthracite coal	12,680 Btu/lb	80.6	2.4	19.9
Bagasse	8,200 Btu/lb	45.0	6.4	20.3
Bark				
15% moisture	8,500 Btu/lb	52.0	5.5	20.0
30% moisture	8,500 Btu/lb	52.0	5.5	20.0
45% moisture	8,500 Btu/lb	52.0	5.5	20.0
60% moisture	8,500 Btu/lb	52.0	5.5	20.0
Bituminous coal	14,030 Btu/lb	80.1	5.0	18.5
Distillate No. 1	19,423 Btu/lb 131,890 Btu/gal	86.6	13.3	15.4
Fuel oil No. 2	18,993 Btu/lb 137,080 Btu/gal	87.3	12.5	15.7
Fuel oil No. 5	18,909 Btu/lb 149,960 Btu/gal	88.7	10.7	16.3
Fuel oil No. 6	18,126 Btu/lb 153,120 Btu/gal	88.5	9.3	16.7
Kerosene	19,942 Btu/lb 137,000 Btu/gal	86.5	13.2	15.1
Natural gas	21,830 Btu/lb	69.4	22.5	11.7
Propane	21,573 Btu/lb	81.6	18.4	13.8
Wood				
10% moisture	8,800 Btu/lb	50.0	6.5	20.0
20% moisture	8,800 Btu/lb	50.0	6.5	20.0
30% moisture	8,800 Btu/lb	50.0	6.5	20.0
40% moisture	8,800 Btu/lb	50.0	6.5	20.0

TABLE-5.2

A number of physical and chemical properties influence the coal selection process. These properties are determined by laboratory analysis of representative coal samples using test methods established by The American Society for Testing and Materials (ASTM). Important coal properties include

- moisture;
- proximate analysis (fixed carbon, volatile matter, ash);
- ultimate analysis (carbon, hydrogen, nitrogen, oxygen, sulfur, and chlorine);
- gross caloric value (as received and on a dry basis);
- mineral matter in coal (ash, major and minor elements, fusibility of ash, trace elements, mercury, fluorine, arsenic, selenium, and sulfur in ash);
- petrographic analysis;
- grindability;
- free-swelling index;
- CO2;
- forms of sulfur (pyritic, sulfate, organic); and ash abrasiveness.

- **Lignite**

Lignite is the lowest ranking coal with a heating value of 8,300 Btu/lb or less and a moisture content as high as 35%.10 Depending on the caloric value, lignitic coals are subdivided into the two classes Shown in Table 5.3. Lignitic coals have a high content of volatile matter, which makes them relatively easy to ignite, especially when the combustion air is preheated. Because lignite has a relatively low sulfur content, it emits low amounts of SO2.

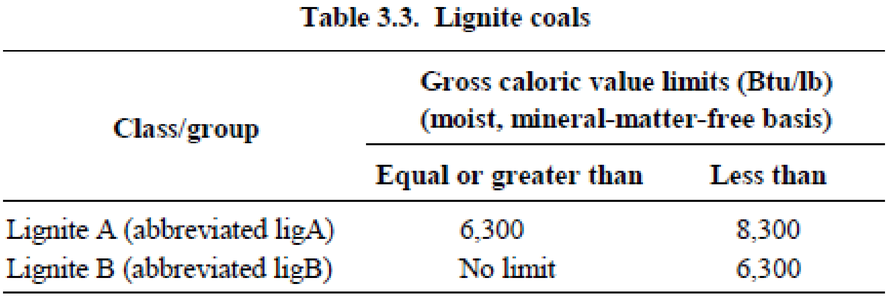


Table 3.3. Lignite coals

Class/group	Gross caloric value limits (Btu/lb) (moist, mineral-matter-free basis)	
	Equal or greater than	Less than
Lignite A (abbreviated ligA)	6,300	8,300
Lignite B (abbreviated ligB)	No limit	6,300

TABLE-5.3

- **Subbituminous**

Subbituminous coals, which have a heating value between 8,300 and 11,500 Btu/lb, have a higher heating value than lignitic coals. They also have less ash and burn cleaner than lignitic coals, but the moisture content is relatively high, usually between 15 and 30%. Subbituminous coals are subdivided into three classes based on the caloric values listed in Table 5.4. The sulfur content of most subbituminous coal is low, generally less than 1%. Because the sulfur content is low, many power plants have changed to subbituminous coal to limit SO2 emissions. Low sulfur coals, which are mined in Montana and Wyoming, are relatively low in cost. Combustion of subbituminous coal results in reduced NOx emissions, but generally exhibits high fouling and slagging ash characteristics. Burning subbituminous coal in a boiler that was designed for a different class of coal may require changes in the boiler design or operation to optimize performance.

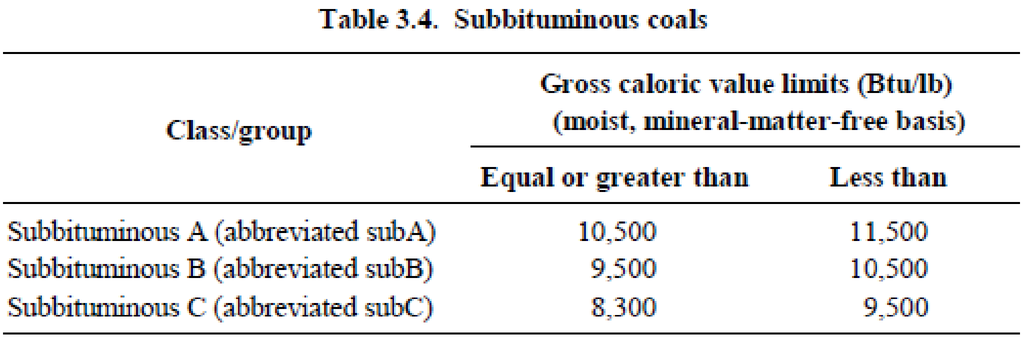


Table 3.4. Subbituminous coals

Class/group	Gross caloric value limits (Btu/lb) (moist, mineral-matter-free basis)	
	Equal or greater than	Less than
Subbituminous A (abbreviated subA)	10,500	11,500
Subbituminous B (abbreviated subB)	9,500	10,500
Subbituminous C (abbreviated subC)	8,300	9,500

TABLE-5.4

- **Bituminous**

Bituminous coals are used routinely by electric utilities and in some industrial applications to fire steam-generating boilers even though their sulfur content can be relatively high. Compared to lignitic and subbituminous coals, the heating value of bituminous coals range between 10,500 and 14,000 Btu/lb. This higher heating value and its relatively high volatile matter enable bituminous coals to burn easily when fired as PC. Bituminous coals are subdivided into the following groups in Table 5.5 based on fixed carbon, volatile matter, or gross caloric limits.

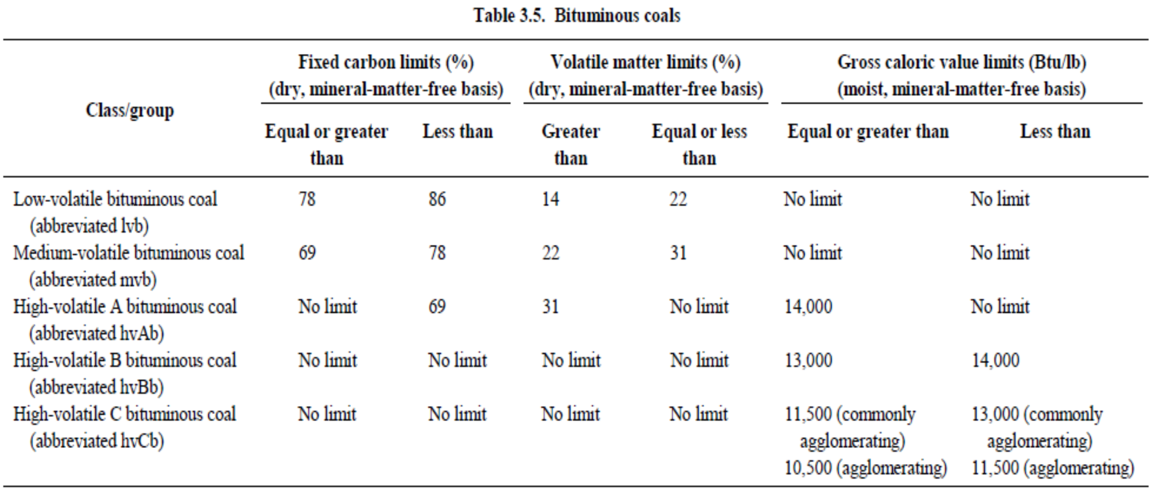


Table 3.5. Bituminous coals

Class/group	Fixed carbon limits (%) (dry, mineral-matter-free basis)		Volatile matter limits (%) (dry, mineral-matter-free basis)		Gross caloric value limits (Btu/lb) (moist, mineral-matter-free basis)	
	Equal or greater than	Less than	Greater than	Equal or less than	Equal or greater than	Less than
Low-volatile bituminous coal (abbreviated lvb)	78	86	14	22	No limit	No limit
Medium-volatile bituminous coal (abbreviated mvb)	69	78	22	31	No limit	No limit
High-volatile A bituminous coal (abbreviated hvAb)	No limit	69	31	No limit	14,000	No limit
High-volatile B bituminous coal (abbreviated hvBb)	No limit	No limit	No limit	No limit	13,000	14,000
High-volatile C bituminous coal (abbreviated hvCb)	No limit	No limit	No limit	No limit	11,500 (commonly agglomerating) 10,500 (agglomerating)	13,000 (commonly agglomerating) 11,500 (agglomerating)

TABLE-5.5

- **Anthracite**

  As a fuel, anthracitic coals are the highest ranking with fixed carbon contents ranging from 86 to 98%. In addition to their high carbon content, they have a moisture content that is only about 3% and a heating value that can be as high as 15,000 Btu/lb. Anthracitic coals are characterized as slow-burning fuels that are low in sulfur and volatile matter. These coals are used mostly to make coke for metallurgical processes.10 Anthracitic coals are subdivided into the following groups in Table 5.6 based on their fixed carbon and volatile matter content.

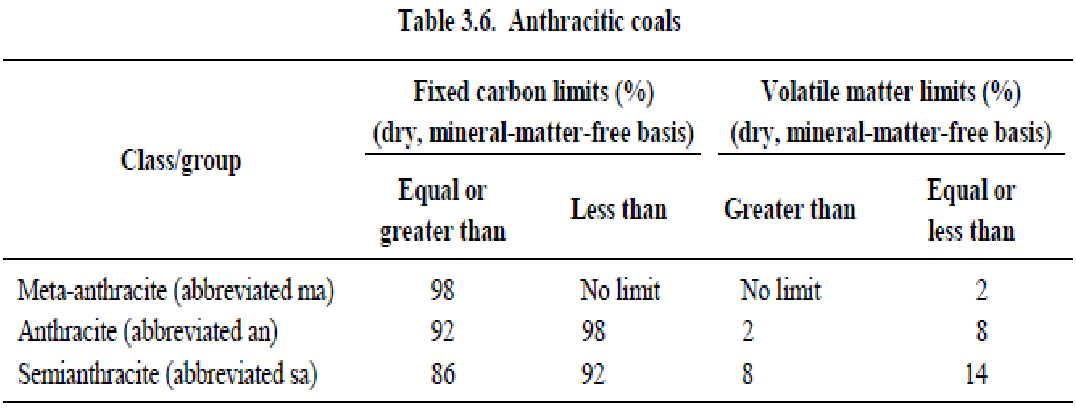


Table 3.6. Anthracitic coals

Class/group	Fixed carbon limits (%) (dry, mineral-matter-free basis)		Volatile matter limits (%) (dry, mineral-matter-free basis)	
	Equal or greater than	Less than	Greater than	Equal or less than
Meta-anthracite (abbreviated ma)	98	No limit	No limit	2
Anthracite (abbreviated an)	92	98	2	8
Semianthracite (abbreviated sa)	86	92	8	14

TABLE-5.6

If the quality of coal from a particular location does not meet the applicable fuel specification, it can be processed in different ways to upgrade its quality. Operations such as washing, drying, sizing, and blending of coals from different sources are techniques that may be used to produce acceptable coal, but other methods that involve separation of foreign materials such as slate and pyrites from the coal may be necessary. Although one or more of these methods may produce coal with the desired quality, special equipment may be required to perform the operations.

- **Fuel Oil**

Petroleum is a naturally occurring black liquid found floating on subterranean lakes of saltwater and located beneath dome-shaped nonporous rock formations. These deposits consist of natural gas, crude oil, and saltwater separated into layers by virtue of their difference in specific gravity. When a well is drilled through the rock formation, natural gas flows to the surface where it is either burned or transported by pipeline to a processing facility. Depending on the pressure, the crude oil either flows to the surface or is removed by pumping. Once above ground, the crude oil is transported by pipeline, truck, rail, barge, or ship to a refinery. At the refinery, the crude oil is processed into any number of petroleumbased products, including fuel oils.

Fuel oils burned in boilers include the heavier petroleum products that are less volatile than gasoline. They are divided into two classes, distillate and residual. Distillate oils are lighter than residual oils with a consistency between kerosene and lubricating oil. They have a low viscosity and are typically sediment- and ash-free. Because distillate oils are relatively clean fuels, they are used primarily for home heating and industrial applications where low ash and low sulfur are important. Smaller amounts of distillate oil are used in steam generation applications as a startup or supplemental fuel for certain solid-fuel combustion processes. Residual oils are products that remain after the more volatile hydrocarbons have been extracted. Residual oils, which are highly viscous, are usually free from moisture and sediment after processing. Some of the heavier residual oils must be heated to make the fuel easier to handle and burn. Sometimes, distillate and residual oils are blended to create a mixture with proportions that meet a desired fuel specification. As a liquid, fuel oils are relatively easy to handle and burn. In most oil burners, the oil is atomized with air, steam, or pressure to enhance combustion. The characteristics of atomized oil approximate those of natural gas. The heating value of fuel oil is derived primarily from its two major constituents, hydrogen and carbon. Most fuel oils have a hydrogen content that ranges between 10 and 14%, and a carbon content that ranges between 86 and 90%.18 Heating values for fuel oils are expressed in units of either British thermal unit per pound (Btu/lb) or per gallon (Btu/gal) at 60°F. Complete combustion of 1 lb of carbon yields a gross heat of 14,500 Btu.19 Hydrogen has a very high heating value compared to carbon; but it is a very lightweight gas, so the heating value of 1 ft3 of hydrogen is low compared to other gaseous fuels. Heating values for commercial fuel oils vary from approximately 17,500 to nearly 20,000 Btu/lb.18 Other constituents in fuel oils include nitrogen, sulfur, ash, and impurities such as moisture and sediment. Compared to coal, the nitrogen and ash contents of most fuel oils are very low. Residual oils tend to have higher nitrogen contents than distillate oils. A standard specification for five grades of fuel oil intended for use in different types of fuel oilburning equipment under various climatic and operating conditions has been developed by the ASTM. Requirements in this specification cover both distillate and residual oils. fuel oil Grade No. 2 is considered a premium steam-generating fuel because its cleanliness and ease of handling are often used to justify its relatively high cost. The cost of Grade No. 6 fuel oil is relatively low, but heating of the fuel is required to facilitate handling and burning. Sulfur found in fuel oil is very undesirable. Its products of combustion are very acidic and can cause corrosion in economizers, air heaters, induced draft fans, flue gas ducts, and stacks. The sulfur content of fuel oil can vary from a low of 0.01% for Grade No. 1 to as high as 3.5% for Grade No. 6 , During combustion, some of the sulfur accumulates in the ash, but most is discharged with the flue gas into the atmosphere. If uncontrolled SO2 emissions exceed established limits, it may be necessary to switch to a lower sulfur oil or install SO2 scrubbers to meet applicable emissions standards.

- **Natural Gas**

Natural gas is a colorless hydrocarbon fuel consisting primarily of methane (CH_4) and ethane (C_2H_6), its two principle combustible components. It is typically found under the earth surface is porous rock and shale formations or above crude oil deposits located beneath dome shaped nonporous rock formations. When a well is drilled through the formation, natural gas, which is under pressure, flows to the surface where it is either burned or transported by pipeline to a processing facility. This characteristic makes natural gas a very desirable boiler fuel because it can be piped directly into the boiler. In addition to its ease of distribution, use of natural-gas-fired boilers requires a relatively small boiler space, and the overall plant design is typically compact and simple. With a heating value of about 1,000 Btu/ft3 under standard conditions of 60°F at atmospheric pressure and low excess-air requirements that contribute to high efficiency, natural gas is perhaps very close to an ideal fuel. When natural gas at the well head contains sulfur-bearing alcohols and phenols (mercaptans) and a high percentage of hydrogen sulfide, it is referred to as sour gas. By removing the objectionable constituents, sour gas can be converted to sweet gas. Sweet gas is required for distribution in pipelines to avoid corrosion problems caused by exposure to hydrogen sulfide. Removal of sulfur from the gas also eliminates the possibility of SO_2 emissions during combustion. From an emissions viewpoint, natural gas is an excellent fuel choice. Although natural gas from some sources contains noncombustible gases such as nitrogen and carbon dioxide, it is practically free from solid residue. Because it is free of ash and mixes easily with air, combustion is usually complete without objectionable smoke or soot. The only significant problem with using natural gas as a fuel for boilers is related to its chemical composition. Natural gas has a relatively high hydrogen content (greater than 20% by weight) compared to other fossil fuels such as oil and coal.

Table 3.7. Fuel oil grades established by ASTM

Fuel oil	Description
Grade No. 1	Distillate fuel for use in domestic and small industrial burners. This grade is particularly adapted to vaporizing burners in which the oil is converted to a vapor by contact with a heated surface or by radiation or where storage conditions require low-pour-point fuel. High volatility is necessary to ensure that evaporation proceeds with a minimum of residue. The maximum allowable sulfur content is 0.5% by mass. The maximum allowable ash content is not specified.
Grade No. 2	Distillate fuel that is heavier than Grade No. 1. It is intended for use in atomizing burners that spray the oil into a combustion chamber where the tiny droplets burn while in suspension. This grade of fuel oil is used in most domestic burners and in many medium-capacity commercial-industrial burners where its ease of handling and ready availability sometimes justify its higher cost over residual fuels. The maximum allowable sulfur content is 0.5% by mass. The maximum allowable ash content is not specified.
Grade No. 4 (light)	Heavy distillate fuel or distillate/residual fuel blend used in commercial/industrial burners equipped for this viscosity range. This grade of fuel oil is intended for use both in pressure-atomizing commercial-industrial burners not requiring higher cost distillates and in burners equipped to atomize oils of higher viscosity. Its permissible viscosity range allows it to be pumped and atomized at relatively low storage temperatures. The maximum allowable sulfur content is not specified. The maximum allowable ash content is 0.05% by mass.
Grade No. 4	Heavy distillate fuel or distillate/residual fuel blend used in commercial/industrial burners equipped for this viscosity range. This grade of fuel oil is intended for use in burners equipped with devices that atomize oils of higher viscosity than domestic burners can handle. Its permissible viscosity range allows it to be pumped and atomized at relatively low storage temperatures. Thus, in all but extremely cold weather it requires no preheating for handling. The maximum allowable sulfur content is not specified. The maximum allowable ash content is 0.10% by mass.
Grade No. 5 (light)	Residual fuel oil of intermediate viscosity intended for use in industrial burners capable of handling fuel more viscous than Grade No. 4 without preheating. Preheating may be necessary in some equipment for proper atomization and in colder climates for handling. The maximum allowable sulfur content is not specified. The maximum allowable ash content is 0.15% by mass.
Grade No. 5 (heavy)	Residual fuel oil used in industrial burners with an increased viscosity and boiling range compared to Grade No. 5 (light). Preheating may be necessary in some types of equipment for proper atomization and in colder climates for handling. The maximum allowable sulfur content is not specified. The maximum allowable ash content is 0.15% by mass.
Grade No. 6	Residual fuel oil used in industrial burners with an increased viscosity and boiling range compared to Grade No. 5 (heavy). Preheating is required for handling and proper atomization. Extra equipment and maintenance required to handle this fuel usually preclude its use in smaller installations where cleanliness and ease of handling are important. The maximum allowable sulfur content and the maximum allowable ash content are not specified.

TABLE-5.7

During combustion, the hydrogen in natural gas combines with oxygen to form water vapor. As discussed in Sect., formation of relatively large quantities of water vapor translates to lower boiler efficiency. Like natural gas, other types of gases can also be used as fuels for boilers, but their processing costs generally make them too expensive for most large-scale applications. By-product substitutes for natural gas include producer gas, coke-oven gas, water gas, and blast-furnace gas derived from coal, refinery gas and oil gas derived from oil, and liquefied petroleum (LP) gas, including propane and butane, derived from either natural gas or oil.

- **Biomass**

Biomass is a nonfossil fuel suitable for steam generation in boilers. It is derived from plant material including wood, bagasse, nut hulls, rice hulls, corncobs, coffee grounds, and tobacco stems. Use of these by-product materials as fuel can be cost-effective especially when it solves a waste disposal problem. Wood is a complex vegetable tissue composed principally of cellulose. Most wood burned in boilers is a by-product from manufacturing operations such as sawmills, paper mills, and factories that manufacture

wood products. By-products from these operations may take the form of bark, sawdust, sanderdust, chips, scraps, slabs, millings, shavings, and processed pellets made from wood or other forest products. Care must be used when burning fine wood dust because under certain conditions it can ignite quickly. Depending on the species and moisture content, the heating value of wood varies over a wide range. Although certain types of wood are more suitable for steam production, sufficient supplies of the fuel may not always be available. In these situations, it may be necessary to burn supplementary fuels along with the wood to meet the total steam demand. Bagasse is a by-product fuel produced when the juice is removed from cane in a sugar mill. Although its heating value can be as high as 8,000 to 9,000 Btu/lb, combustion of bagasse is only feasible in certain parts of the United States where sugar cane is processed. When bagasse is burned, it is usually supplemented with auxiliary fuels.

Other biomass fuels include

- nut hulls with a heating value of about 7,700 Btu/lb,
- rice hulls with a heating value between 5,200 and 6,500 Btu/lb,
- corncobs with a heating value between 7,500 to 8,300 Btu/lb,

- **Refuse-Derived Fuel**

Residential, commercial, and industrial solid waste that is transported to a landfill for disposal can be burned as a fuel in waste-to-energy boilers. MSW that contains mixtures of paper, wood, yard wastes, food wastes, plastics, leather, and rubber can have characteristics similar to wood. Use of MSW as a fuel can be accomplished by burning the as-received material, called mass burning; but processing is often required before it can be burned effectively. When MSW is processed using size-reduction and material recovery techniques designed to shred the waste and remove noncombustible materials, it is called RDF. The highly variable nature of MSW presents challenges in designing a combustion system that can accommodate this high-ash, low-sulfur fuel.

- **Other Fuels**

Heavy residuals from petroleum-cracking processes yield a solid residue that is suitable for use as a fuel for boilers. Solid fuels derived from oil include delayed coke, fluid coke, and petroleum pitch. Some cokes produced by the delayed coking process are easy to pulverize and burn in boilers. Fluid cokes can also be pulverized and burned in boilers or burned in a cyclone furnace or a fluidized bed, but all three of these methods may require supplemental fuel to aid start-up. Petroleum pitch yields fuel with varying characteristics. Low-melting-point pitches can be heated and burned like heavy oil. Those with higher melting points must be pulverized or crushed and then burned. Coal tar pitch is the residue resulting from the distillation and refining of coal tar. Although it can be used as a boiler fuel, it is somewhat difficult to handle. At ambient temperature, it is a solid that can be pulverized before it is delivered to the boiler. At about 300°F, it becomes a liquid and can be burned like oil. Because of its low ash content, use of coal tar pitch is sometimes preferable to coal. Pulp mill sludge can be used as a fuel for boilers, but it must be dried before it can be effectively burned. This fuel typically has an ash content of approximately 10%. Sludges from deinking processes are less suitable because they have less heating value and significantly more ash. Unless sludge from the deinking process is dried before it enters the boiler, the combination of high moisture content and low heating value make it difficult to burn. Burning sludge with a high-moisture content in stoker-fired boilers presents some significant problems because removal of the moisture results in a lower combustion chamber temperature. For this reason, sludge is generally burned in stoker-fired boilers in combination with another fuel such as bark.

- **Fixed Fuels**

Environmental concerns about SO2 and PM emissions from combustion of bituminous coals have led to the development of coal cleaning techniques known as beneficiation.18 These techniques involve removal of sulfur and mineral matter from coal prior to combustion. To achieve the cleaning level needed to meet sulfur standards, the form of the solid coal must first be altered. Most advanced cleaning processes use water as the separation medium and involve grinding the coal to fine particle size. Grinding allows pyritic sulfur and other minerals that are dispersed throughout the coal to be more easily separated from the coal. After these materials are removed, the fine, clean coal product must be dried, pelletized, or reconstituted into a coal-water slurry, which can be handled like oil prior to combustion in a boiler. Coal-water slurries have potential as fuel oil substitutes in some combustion applications. Typical bituminous coal slurries contain approximately 70% PC, 29% water and 1% chemical additives. Slurries prepared from coals, which have been deep cleaned, can contain coal with finer particle sizes and a lower solids content (50 to 60%). Although coal-water slurries are produced from fine PC and are handled and fired like No. 6 fuel oil, they burn somewhat differently. Burners suitable for coal-water slurry combustion are often specially designed to accommodate the unique properties of the slurry. Viscosity and flow characteristics can affect the way the fuel is atomized and can increase wear and deterioration of piping and burner components. Oil-water slurries can be used as fuel with combustion performance similar to residual oils. These liquid-fuel emulsions are composed of micron-size oil droplets dispersed in water. Although the heating value, ash content, and viscosity of oil-water slurries are similar to residual oil, they have a relatively high sulfur content.

❖ Fuel analysis

The fuel components are usually divided into ash, moisture and other constituents. The different analyses such as physical, proximate and ultimate analyses concentrate on these other constituents.

❖ Physical analysis:

A physical analysis describes the fuel components in terms of their quantities. It is particularly used to calculate the calorific value. The composition of bagasse is usually expressed in terms of its fibre, brix and moisture content. For the purpose of analysing bagasse as a boiler fuel, it is important to separate the fibre component into vegetable fibre and ash. Coal can similarly be separated into dry, ash free coal, ash and moisture. Typical analyses of bagasse and coal are given in Table 5.8.

❖ Proximate analysis:

The proximate analysis defines that part of the fuel that gasifies below 750°C, called the volatiles, in relation to the fixed carbon. It provides an indication of its combustion properties especially the combustion stability. This property is particularly important for coal and is used to a lesser.

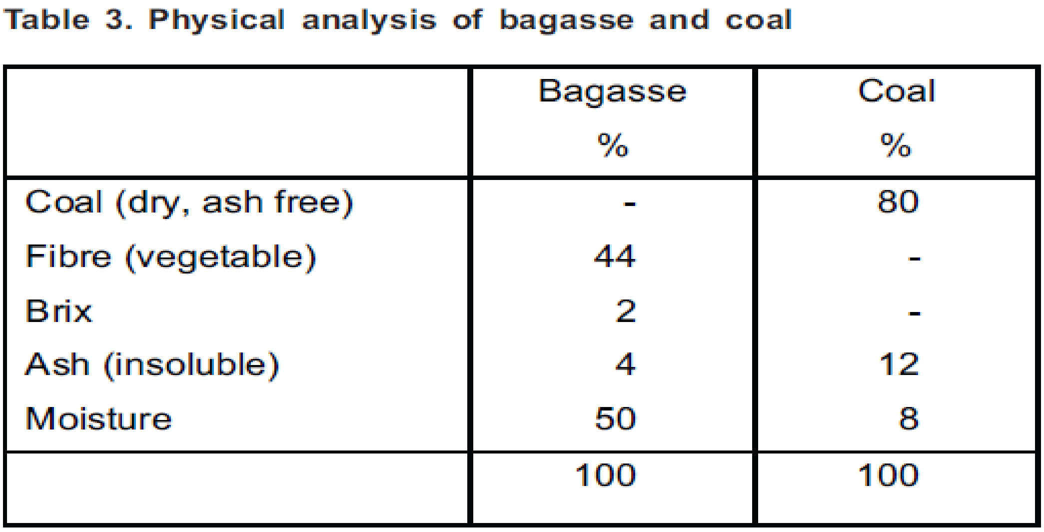


Table 3. Physical analysis of bagasse and coal

	Bagasse %	Coal %
Coal (dry, ash free)	-	80
Fibre (vegetable)	44	-
Brix	2	-
Ash (insoluble)	4	12
Moisture	50	8
	100	100

TABLE-5.8

- **Ultimate analysis**.

The ultimate analysis is the analysis of the fuel into its basic chemical elements. This analysis is used to obtain the theoretical air needed for combustion based on the stoichiometric equations of the various elements. It also provides a means to determine the quantity and composition of the flue gases. Finally, it forms the corner stone in the calculation of the boiler efficiency using the 'loss method'

- **Combustion Losses**

Combustion efficiency is a measure of the chemical energy available in fuel that is liberated by the combustion process. Quantifying combustion efficiency involves determining

- losses from unburned carbon in the flue gas (CO),
- losses from unburned carbon in the solid residue (bottom ash and fly ash), and
- losses from unburned hydrocarbons (UHCs) in the flue gases.

In its simplest form, combustion efficiency can be computed using the following equation:
Combustion efficiency = 100 . (unburned-fuel losses) .
Under perfect combustion conditions, the following phenomena can occur.

- Carbon in hydrocarbon fuel combines with oxygen in the combustion air to form CO2.
- Hydrogen in the fuel combines with oxygen in the combustion air to form water vapor.

Achieving complete combustion requires precise proportioning of the fuel-air mixture. Incomplete combustion due to an imbalance in the fuel-to-air ratio can result in significant energy loss that translates to decreased combustion efficiency. When insufficient combustion air (oxygen) is available for complete fuel combustion, some of the carbon remains unburned. Incomplete combustion can result in the formation of CO and carbon-laden PM known as soot. If no additional air is made available to complete the combustion process, two forms of energy are wasted. Heat is lost from the system as hot CO gas or soot particles leaving the stack, and energy is not extracted from the unburned or partially burned carbon. Air supplied to a boiler in excess of that required for complete fuel combustion (excess air beyond stoichiometric conditions) is also detrimental to efficiency. The efficiency reduction results from excess air entering the boiler at ambient temperature and exiting the system at the stack temperature.

❖ Boiler Losses

Boiler efficiency is a function of boiler losses and combustion losses. It can be characterized as the amount of heat captured by the boiler and transferred to the water, divided by the heat that was input.

The heat that was not transferred to the water manifests itself in a number of losses that include

- flue-gas losses,
- radiant heat losses,
- blowdown losses, and
- Unaccounted losses.

Flue-gas losses are often the primary cause for reduced boiler efficiency. Energy is wasted whenever heated flue gas is carried out of the boiler and up the stack. Flue-gas temperature is related to boiler load. In general, as boiler load increases, the flue-gas temperature increases. Hotter flue-gas temperatures increase flue-gas losses. Installation of equipment to recover some of this heat can have a beneficial effect on efficiency, but removing too much heat can cause problems such as corrosionespecially when water condenses on boiler equipment. Corrosion of internal boiler components made from certain types of steel, such as carbon steel, can occur at locations where water condenses and combines with other constituents in the flue gas to form acids. Use of stainless steel or other alloys is sometimes required to avoid these corrosion problems. For most boiler systems, there is a practical limit that dictates the minimum flue-gas temperature.

Air in excess of that required for complete fuel combustion represents a major flue-gas loss. Because the fuel supplies energy required to increase the temperature of excess air, controlling the amount of air that is supplied to a boiler has a direct impact on boiler efficiency. The loss is a function of the amount of excess air that passes through the boiler and the temperature of the excess air that discharges from the stack. Energy required to raise the temperature of excess air is wasted because it is not used to heat water. If the water vapour content of the excess air is high, even more energy is required

to superheat the water vapour. Although combustion of any fuel results in some degree of flue-gas loss, solid fuels require more excess air for complete combustion than do gaseous fuels. Although combustion with insufficient air decreases combustion efficiency, it is a very effective technique for reducing NOx formation. A lower flame temperature associated with incomplete combustion decreases the amount of thermal NOx that forms. Selection of a low-emission boiler and combustion equipment often requires a compromise between efficiency and NOx formation. For greatest efficiency, a boiler should be fitted with proper combustion equipment, including a control system that is capable of adjusting the fuel-air mixture so that little or no CO and soot are produced. Additional air that is required to complete the combustion process is sometimes provided in stages. Staged combustion is a NOx control technique based on the fact that combustion at either very low or very high excess air levels results in reduced NOx formation. By mixing air and fuel at two or more locations inside a boiler, it is possible to create zones with high and low excess air levels. Air that is injected into a boiler at different points or stages in the combustion process is known as staged combustion air (SCA).. New boilers and combustion equipment that are well-designed are capable of achieving both high efficiency and low NOx formation. However, for existing boilers, changes in firing profile may change the absorption profile, temperature profile, and carbon burnout of a boiler, thereby affecting boiler efficiency. The reaction of hydrogen atoms in fuel with oxygen molecules in air produces heat and water vapor. When the water vapor leaves the stack, it reduces the available energy by carrying away the associated latent heat of vaporization. Reducing the temperature of the flue gas as a means of lowering the heat loss is an effective way to conserve energy, but it can lead to serious corrosion problems. Because natural gas has a relatively high hydrogen content when compared to coal, this form of heat loss is higher for naturalgas- fired boilers than for comparable size coal-fired boilers.

Moisture in fuel represents another form of heat loss. Like the phenomenon just described, the water vapor leaving the stack reduces the available energy by carrying away the associated latent heat of vaporization. As water vapor from the fuel is superheated, additional heat loss is experienced. The wasted energy from this form of heat loss can be significant for solid fuels but tends to be less for gaseous fuels, which usually have a lower moisture content. Radiant heat loss consists of both radiant and convection heat losses from the outer surfaces of a boiler, which are typically above ambient temperature. These losses do not vary significantly in magnitude with boiler load because the outer surface temperature of the boiler remains essentially constant while in operation. However, these losses as a percentage of boiler output get worse whenever the load diminishes. Two ways to reduce radiant heat loss include adding thermal insulation to outer boiler surfaces and operating the boiler at the lowest temperature consistent with system and boiler manufacturer requirements. Buildup of soluble salts and accumulation of other solids in the water passages of a boiler can impede heat transfer and eventually restrict flow through boiler passages. Use of chemicals that impedescaling and regular blowdowns can help control this problem, but the hot water and solid particles that discharge during a blowdown represent wasted energy. Installing a heat recovery system can reduce boiler losses due to blowdowns. By using chemicals to control scaling, it may be possible to reduce the blowdown rate. Note that blowdown heat recovery equipment is usually cost-effective only for systems that use continuous rather than intermittent blowdown. A relatively small but important form of heat loss is characterized as unaccounted losses. These losses, which are not related to the combustion process, are associated with cyclic rather than continuous boiler operations. They include prepurge and postpurge losses, natural-draft losses, and off-line shell losses. Prepurge and postpurge losses involve forcing air through the boiler to remove unburned combustibles before startup and after shutdown. When this operation is performed, the flowing air removes some thermal energy from the boiler. Similar to purging losses, natural-draft losses occur when the boiler is shut off and air circulates naturally through the boiler. Off-line shell losses are radiant heat losses that occur after the boiler is shut off. Firetube boilers typically have off-line shell losses much less than comparable size watertube boilers because the shell temperature of a firetube boiler is more of a function of the water temperature than the combustion gas temperature. Heating systems for commercial buildings typically exhibit a wide range of heating demands throughout the heating season. To minimize unaccounted heat losses associated with cyclic operation, there may be advantages in selecting multiple boilers instead of one or two large boilers. In this approach, at least some of the smaller units operate more or less continuously

❖ CONTROLLING AIR POLLUTANT EMISSIONS

The most relevant pollutants that are expected to be emitted from the wood-fired boilers. They can be grouped by similar causes or controlling factors such that the feasible control mechanisms for one "surrogate" pollutant may be applied to all members of the group.. The surrogate groupings are carbon monoxide (CO) or total hydrocarbon (as an indicator of good combustion practices or as a surrogate for products of incomplete combustion), particulate matter (P) as a surrogate for metals and dioxin/furans, oxides of nitrogen (NO_x), and sulfur dioxide (S) for acid gases including SO_3 and HCl.

➢ Carbon-Monoxide

Carbon-monoxide emissions are controlled by employing “good combustion practices” (time-temperature-turbulence). These practices include operational and incinerator design elements to control the amount and distribution of excess air in the flue gas to ensure that there is enough oxygen present for complete combustion. The design of modern efficient boilers is such that there is adequate turbulence in the flue gas to ensure good-mixing, a high-temperature zone (1600-1800 0F) to complete burnout, and a long enough residence time at the high temperature (one or two seconds). Even a welldesigned and operated wood-fired boiler could have more than 100 ppm (hourly rolling average) CO in its stack gas. The lower the CO concentration, the more effective and complete is the combustion process. The feed to the combustor is controlled to minimize fuel spikes that lead to fuel-rich firing. Good combustion practices also limit PCDD/PCDF emissions exiting the boiler. This is accomplished by maintaining firing conditions that destroy PCDD/PCDFs founds in the fuel and by destroying PCDD/PCDF precursors that may be formed from the combustion of other chlorinated organic compounds (for in-depth analyses, a separate report is attached for your additional information.

Particulate Matter and Toxic Metals

The same mechanisms control particulate matter, as well as toxic metals. Unlike organics, metals are not destroyed during combustion. All of the metals fed into a combustion device are conserved, thus partition into one or more of the places:

- The bottom of the combustion device with the ash
- The bottom of the scrubber with the scrubber ash
- The bottom of the particulate control system with the fly ash
- The air when they are emitted from the stack.

Most metals, especially those that enter the system as solid waste, end up in the bottom ash. The fundamental principles that influence the behavior of metals in combustion devices are discussed here. Metals behavior in combustion is complex and follow one of the three pathways:

- Remain with the waste as a solid
- Become entrained in the gas stream
- Vaporize

In the first pathway, the metals remain with the waste throughout the entire process and end up as residuals or bottom ash. This is the pathway of least resistance. In the second pathway, the metal is entrained into the gas stream. If the waste is solid waste, theamount that becomes entrained depends on many variables such as the velocity of the combustion gas. The higher the velocity, the more likely the particles are to be swept into the gas stream. The degree to which this particle entrained occurs depends on the size of the particles in the solid waste and how those particles behave as the organics burn - whether they break up and form friable, dusty particles that can easily become entrained, weather they stay with the residuals. The smaller particulate tends to become entrained, although the particles are still relatively large (i.e., 10 microns in size and larger). Particles in this size range are generally relatively easy to remove from the gas stream, downstream in the process. Since they are easily controlled, these entrained particles are not the ones of most concern in metal emissions. The third, and most important, pathway is the vaporization route. Some toxic metals are volatile and have a significant vapor pressure. In the hot, burning environment of the combustion device, a portion of the metals in the waste vaporizes, changing from a liquid or solid state to a gas. This process depends on the temperature and on the chemical environment. A nonvolatile metal vaporizes if the metal comes into contact with another species and reacts to form a volatile compound. If chlorine or other halogens are present in the local surroundings, for example, the metals may undergo a chemical reaction and form chlorides, which are typically more volatile than the oxides of the metals. Those metal chlorides will subsequently vaporize. The hot combustion gas stream cools as it exits the combustion chamber, causing vaporized metal to condense into particulate matter. The vaporized metal can condense in one of the two ways: homogeneously or heterogeneously. In homogeneous condensation, gas forms tiny fume particles, all by itself, in the tens-of-angstrom size range. These particles stay this size only briefly, very quickly growing to larger particle (typically 0.1 to 0.5 □m) by colliding with each other and coagulating, as well as by condensing with other vapor. Unfortunately, most types of air pollution control equipment (APCE) are least effective in this submicron size range. In heterogeneous condensation, the vapors condense onto the surfaces of existing particles, such as condensed fume or entrained fly ash. Heterogeneous condensation occur on whatever surface area is most prominent.

➢ **Nitrogen Oxides (NOx)**

Nitric oxide (NO) is a product of waste-wood-fuel combustion. It is a Class B toxic air pollutant under Chapter 173-460 WAC. It will slowly oxidize to nitrogen dioxide (NO2). NO is the predominant oxide of nitrogen from combustion process; NO2 will be generated at approximately 5% of the quantity of NO generated. Nitrogen oxides contribute to gross atmospheric effects such as haze and smog. Relative to other fuel sources, most of the NOX emissions from waste-wood-fired boilers originate from the nitrogen that is part of the chemistry of the wood. Nitrogen that is part of the chemistry of the fuel is called "fuel-bound nitrogen." Combustion in waste-woodfired boilers is done at a relatively low temperature. For example, the average temperature in the burning fuel mass in a waste-wood-fired boiler might be around 1,500 oF. In a natural gas or fuel oil-fired boiler, the flame temperature might be 2,000 oF or higher. NOX formation from atmospheric nitrogen is very temperaturedependent. Relatively little oxidation of atmospheric nitrogen takes place below about 1,700 oF. Formation of NOX from the fuel-bound nitrogen takes place by a relatively complex chemical pathway, is sensitive to oxygen concentration in the combustion zone, and nonlinearly related to temperature. NOX emissions are more controllable to the extent that the oxygen concentration and temperature in the combustion zone are evenly distributed and controlled.

In waste-wood burning, the NOX formation process is complex, and can shift from oxidation to reduction and back again depending on the spot-temperatures and oxygen concentration in the fuel mass. However, as an approximation, the equilibrium for each NOX species based on using NH3 as the SNCR promoter for NOX reduction is

- NH3 + 3 N2O =4 N2 + 3 H2O
- NH3 + 6 NO =5 N2 + 6 H2O
- 8 NH3 + 6 NO2 =7 N2 + 12 H2O

Nitrogen oxide emissions are controlled by limiting their formation in the incinerator using staged combustion or applying selective noncatalytic reduction to reduce the NOx content in the flue gas. Staged combustion is accomplished by splitting up the introduction of combustion air into the boiler so that areas of fuel-rich and fuel-lean firing are established. This will lower the peak flame temperatures and limit the amount of oxygen available to react with nitrogen in the air at peak temperature. The introduction of additional secondary air downstream in the boiler will ensure complete combustion and minimize CO formation. Generally, staged combustion is effective in reducing Nox formation due to air-nitrogen conversion, but is not very effective for conversion of fuelbound nitrogen to NOx.

The NOx present in the flue gas can be reduced by employing either a selective catalytic or noncatalytic reducing process. The selective catalytic reduction (SCR) process utilizes ammonia injection upstream of a catalytic reactor, at about 600-650 0F, to reduce NOx to nitrogen. Selective catalytic reduction has been applied to a wide range of combustion sources where 80-85% NOx reduction has been demonstrated. Selective noncatalytic reduction (SNCR) reduces flue gas NOx through a reaction with ammonia in a temperature range of 1700-1900 0F. The ammonia may be supplied as anhydrous ammonia, aqueous ammonia, or urea. At flue gas temperature above 1900 0F, the oxidation of ammonia to NOx increases and SNCR can actually result in an increase in overall NOx. At temperatures below about 1700 0F, NOx reduction falls off and ammonia breakthrough increases, leading to the potential for a visible ammonium-chloride plume.

- **Sulphur Dioxide and Hydrogen Chloride**

High sulfur content coal or oil burning would cause significant SO2 emission. Sulfur can be a constituent of wood-waste, particularly of sludge from the pulp and paper wastewater treatment plant. If sludge is burned along with wood, sulfur will oxidize to sulfur dioxide (SO2) and sulfur trioxide (SO3). All sulfur oxides have deleterious atmospheric effects. They are active participants in the generation of smog, and contribute to tree damage as elements of acid rain. Less than 5% of the sulfur oxide will be SO3. It is the less desirable sulfur oxide compound. It is readily soluble in water andwill form sulfuric acid, which is highly corrosive. Sulfuric acid mist is a Class B toxic air pollutant under Chapter 173-460 WAC.

When a chlorine-containing organic compound (organic chlorine) is burned, the chlorine will combine with hydrogen from water produced by burning material to generate hydrogen chloride (HCl). HCl is soluble in water and will readily form hydrochloric acid. As with SO3, HCl is readily soluble in water. It forms highly corrosive hydrochloric acid. As an air pollutant constituent, it can contribute to acid rain. It is a Class B toxic air pollutant under Chapter 173-460 WAC.

Gas as fuel has following ADVANTAGES:

- ✓ Easy installation.
- ✓ Require less space.
- ✓ Reliable and less maintenance.
- ✓ As no Ash is generated, No Ash disposal problems.
- ✓ Efficiency: Minimum 80%
- ✓ Low pollution
- ✓ High efficiency
- ✓ High production cost

DISADVANTAGE OF CONVENTIONAL FUEL:

- **Cost of oil**
- **Storage of oil**
- **Maintenance**
- **Product Life**
- **Sizing**
- **Costing**

❖ REFERENCE:-

Website

- Website www.google.com
- Website www.wikipedia.com
- Website www.naptune-india.com
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Book

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CHAPTER - 04 CONCLUSION

❖ CONCLUSION:

- we studied the various technicalities and the experimental procedures carried out by the various companies and their respective research and development departments in depth which do provide a ray of hope. The practical implementation being's dependency on oil reserves and their rising costs and there by stabilize the economy for the small industry and hence make the environment pollution free which is the ultimate goal. The efficient burning of fuel reduces the CO2 emissions and renders the boiler environmentally safe and user friendly. Overall toxic emissions will drop due to better overall boiler efficiency.

Finally we got opportunity to interect ourself with industries thought Project-I subject and we can able to enhance our knowledge of Mechanical Engineering in various aspect.