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POWER STATIONS AND THE ENVIRONMENT

IBRAHIM S. AL-MUTAZ

Chemical Engineering Department
College of Engineering
King Saud University
P. O. Box 800
Riyadh 11421, Saudi Arabia

ABSTRACT

The estimated total electric power consumed worldwide was 8.2 x 10E12 Watt. 16% of this figure was consumed in the third world countries with an average consumption rate of 500 kW per person every year according to the 1980 statistics. In those power stations, about 15,000 million tons of carbon dioxide was produced annually. About 50% of sulfur dioxide present in the atmosphere comes from power stations. 750 MW power station produces about 9000 pounds of nitrogen oxides per hour.

This massive amount of pollutants emitted to the atmosphere every hour must be controlled to protect the environment while maintaining the same production and efficiency of the station. In general, nitrogen oxides, sulfur dioxide and particulate are emitted in the fuel combustion processes. The level at which hydrocarbons and carbon monoxide emitted is determined by the combustion completeness. Also the presence of sulfur dioxide in the flue gases depends on the sulfur content of the fuel. So the combustion process and the type of the fuel used play an important role in controlling the amount of pollutants emitted from power stations.

This paper will throw some light on the effect of the power station on the environment. A simple discussion of the possible controlling techniques will be presented as well as the impact of those controlling processes on the power station itself. The main purpose of building these stations was for the convenience of humen by utilizing the produced electricity. So it is required that these power stations will not deteriorate the environment and harm people.

INTRODUCTION

Consumption of electricity is increasing rapidly every year. Figure 1 shows the projected world growth of electrical generating capacity through 2010. In Saudi Arabia, the total generated power was 1173 MW in 1975 which was increased to 10704 MW in 1983, i.e. by a factor 812% (1). This growth is continued every year to provide electricity for 1709 cities and villages in the country.

During the power generation large amounts of fuel are burnt to produce

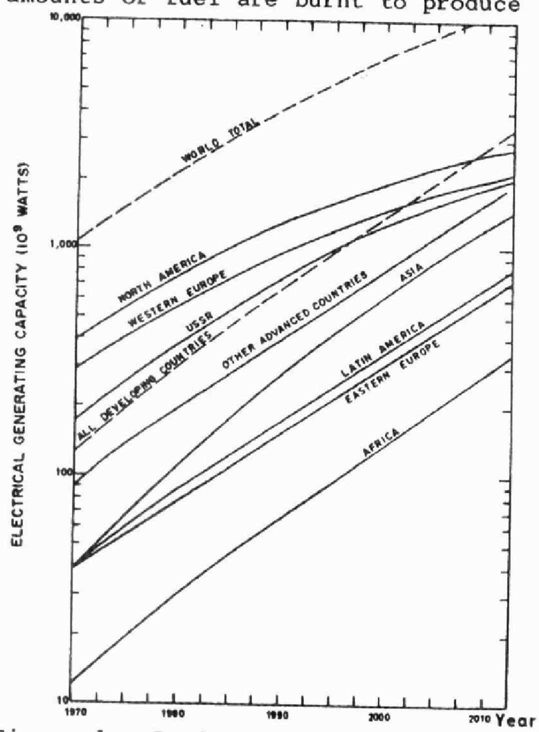

Figure 1 - Projected growth of electrical generating capacity(3).

the necessary heat which is indirectly derived from the electric generators. As a result of the increase in the production of electricity, more and more fuel is consumed. In table 1, the fuel consumptions in all Saudi power stations is listed for the period of 1977 to 1983. Fuel oil is more widely used in the recent year, usually grade six, so called Buncker C. The sulphur content of this fuel is 1.6% by weight.

The combustion of these massive amount of fuel oil, natrual gas and deisel in the power stations yields large quantities of flue gases such as unburnt hydrocarbons, carbon monoxide, nitrogen oxides and sulphur compounds. These gases have serious impacts on the environment and harm mankind when they present at high concentrations. However, to minimize the emissions of such pollutants to the atmosphere, better combustion must be achieved and pollution control devices had to be installed. In the following discussisons power plants that use fossil fuels, only fuel oil, natural gas and deisel, are considered. Plants using coal and nuclear energy have not been discussed since they do not exist in Saudi Arabia. Also these plants are not commonly used in the world nowadays.

Table 1

Total Fuel Consumption in Saudi Power Stations

Type of fuel

Year	Diesel (Liter)	Fuel oil (Liter)	Natural Gas (Btu)
1977	1089521577	490348131	18037617
1978	1685449250	556361639	18265386
1979	2117734668	879081975	34310112
1980	2490944391	1448731820	30306463
1981	2870583124	2263436042	188702884
1982	3652011006	2554255092	199220175
1983	3640583264	3838552963	181325692

Source: Ref.(1)

Btu (British thermal unit) is the quantity of heat required to raise the temperature of 1 lb of water 1°F at or near its point of maximum density. Btu Equivalent : 25,000,000 per ton; 150,000,000 per 1000 gal. 0.252 Btu = KCal.

SOURCES OF POLLUTION

The main source of pollution at the electric power station is the combustion of fuel in the furnaces. Some pollutants may be emitted from other minor sources such as boilers, gas turbines, generators, cooling water, and fuel transportation. Power station accounts for more than 4% of the total atmospheric pollution(2). About 70% of sulphur dioxide in the atmosphere are from the electric power stations.

POLLUTANTS EMITTED FROM POWER PLANTS

In the case of incomplete combustion, unburt hydrocarbons and carbon monoxides are emitted basically. While at the stoichiometric ratio of fuel and air more amount of nitrogen oxides are formed. Usually excess air is used, so carbon monoxide, partially burnet hydrocarbons and nitrogen oxides are still produced. The emission of sulphur compounds is due to the presence of sulphur in the fuel.

The rate at which pollutants are emitted from a power plant depneds on the type, quality, and quantity of fuel burnt. It is also effected by the design of the furnace and the combustion system(3). Average emission rates from conventional power plant are listed in table 2.

Table 2

Average rate of emission of pollutants from electric power plants

Pollutant	Fuel oil lb/1000 gal	Natural gas lb/10^6 ft^3
Nitrogen dioxide	104	390
Sulphur dioxide	175S*	0.4
Sulphur trioxide	2.5S	negligible
Carbon monoxide	0.04	negligible
Hc's(as methane)	3.20	negligible
Formaldehyde	0.60	1
Particulate	10(1-E)**	15

Source: Ref.(3)

* S is percentage sulphur in the fuel
** E is the efficiency of the precipitator expressed as decimal.

Sulphur Oxides: Emission of sulphur compounds in general depends on the sulphur content of the fuel. Combustion of natural gas yields negligible amount of sulphur oxides since it has almost no sulphur. When fuel oil of 3.5% sulphur is burnt in 15% excess air, about 2000 ppm of sulphur dioxide is formed(4). So the United States Environmental Protection Agency, EPA, forced all power stations in USA to use a fuel with sulphur content of no more than 1% by weight.

erwise emission control devices be installed to reduce the ced sulphur dioxide concentration the allowable limit. The maximum itted limit for the presence of hur dioxide is 0.03 ppm (80 g/m^3) n annual rate.

Nitrogen Oxides: Nitrogen oxides mainly formed by oxidation of spheric nitrogen at high tempera- . They are also formed by partial ustion of nitrogenous compounds ained in the fuel. The amount of ogen oxides formed depends on ating temperature, air to fuel o, heat of combustion and the ing rate. In the fuel oil power it, about 450 ppm of nitrogen oxi- are emitted(5). The allowable con- ration of these gases in the osphere is 0.05 ppm.

Carbon Monoxide: Limited amount of bon monoxide are emitted from the er plants; 0.04 lb of carbon mono- e is emitted from the combustion of 0 gal of fuel oil. Negligible unt of carbon monoxide is formed in natural gas operating power plant. s is because high air to fuel ratio used in the burners. So almost all bon monoxides are oxidized to car- dioxides a less harmful gas. rly 15 million tons of carbon oxide are emitted from the power nts(6).

Hydrocarbons: Like carbon mono- e, the emission of hydrocarbons ends on the amount of air used. ce excess air is used in power sta- n, low concentration of hydrocar- s are formed. About 0.006 ton/ r of hydrocarbons are emitted from power plants. The allowable con- ntration of these gases in the osphere is 0.24 ppm (16 μg/ L^3) three hours.

Particulates: There are 32 million s of particulates in the atmos- ere, 4.1 million tons are emitted om the power stations. Almost 15 unds of different particulates are rmed by the combustion of 1 million bic feet of natural gas and 10 unds from every 1000 gal of fuel l. However, electrostatic precipita- ons, cyclons, filters and other vanced mechanical separators are le to reduce particulate con- ntration to the desirable level.

THODS OF POLLUTION CONTROL

Sulphur compounds mainly sulphur ioxides are the most dangerous pollu- ants emitted from power plants foll- wed by nitrogen oxides. Hydrocarbons nd carbon monoxides are formed in mall amounts. Particulates are easily kept within the allowable limit by preciptation and/or separation in mechanical control devices.

Since nitrogen oxides are formed at high temperature, the reduction of combustion temperature tends to lower nitrogen oxides concentrations. Also the recirculation of the flue gas gives the same result. A suitable catalyst can be used to reduce nitro- gen oxides to their elements, nitrogen and oxygen.

Sulphur pollution is minimized by using low sulphur fuel, or by removing the sulphur from the fuel, at combus- tion or from the flue gases. Low sul- phur fuel is hardly found. Removal of sulphur from the fuel is not econo- mically feasible. Usually the flue gases are desulphurized. The following methods are widely used to reduce emissions at power stations.

1- High Stacks (For the dilution of pollutants in the higher atmosphere levels).

2- Flue Gas Recirculation, FGR:

Recirculation of parts of the flue gas, about 10-15%, lowers the com- bustion temperature, hence the nitrogen oxides concentration. Table 3 shows the effect of FGR on the concentration of nitrogen oxi- des.

Table 3

Effect of FGR on Nitrogen Oxides Emissions
(Natural gas firing, 7.5% excess air)

FGR, %	% reduction in NO_x
0	0
10	68
23	76
33	80
37	81

Source: Ref. (4)

3- Staged Combustion

In this method, incomplete com- bustion takes place with 85 to 95% of the required excess air in the first combustion stage. The remain- ing amounts are then supplied in the second combustion stage. Nearly 25% reduction in the nitro- gen oxide concentration was observed by staged combustion.

4- Purification of Flue Gas

4.1 Removal of Sulphur Dioxide by Lime Stone:

It involves the reaction of sulphur dioxide with limestone, calcium carbonate. This method has corrosion, errosion and solid wastes problems. It also requires high operation and maintenance cost.

4.2 Removal of Sulphur Dioxide by Magnesium Oxide:

In this process, magnesium oxide can be recovered from the solid waste and reused. Sulphuric acid and elemental sulphur could also be produced. These advantages make this method more practical than the limestone process.

4.3 Catalytic Oxidation/Reduction:

Certain catalysts are used to oxidize the sulphur dioxide to trioxide which is then absorbed by sulphuric acid. Reduction of nitrogen oxides to nitrogen and oxygen also used as a control process for nitrogen oxide emissions.

4.4 Wellman-Lord Method:

This method was used for controlling sulphur dioxide emission since 1972(7). Its operation is based on the following reaction

$$SO_2 + Na_2SO_3 \text{ ——— } 2NaHSO_3$$

This reaction is reversible. It is possible to form sodium sulfite or decompose it according to the prevailing conditions.

4.5 Other Methods

Sulphur dioxide can also be removed from the flue gas by converting it to sulphuric acid and/or elemental sulphur. It may be absorbed by double alkali materials.

CONCLUSIONS

Due to the increase in the electric power consumptions, additional power stations must be built and/or expanding the capacity of the existing ones. This leads to burning of more acounts of fuel which emitted massive amount of pollutants in the atmosphere.

Fuels used in Saudi power plants are natural gas and fuel oil, grade six (Buncker C). Sulphur dioxide and nitrogen oxides are emitted in large quantities from those plants. Emission of carbon monoxide, hydrocarbons and particulates are not significant.

Nitrogen oxide can be controlled by controlling the combustion process, air-fuel ratio and the furnace design. Their emission can be minimized by reducing the combustion temperature either by FGR or by staged combustion or by similar processes. Sulphur oxide emissions are reduced significantly by using low sulphur fuel. The usage of any desulphurization process must be justified by a feasible study against the production of low sulphur fuel or the use of natural gas.

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