STUDY ON THE REDUCTION OF SO2 EMISSIONS IN COAL-FIRED POWER UNITS

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Abstract: This paper presents the harmful effects produced by SO_2 resulting from the burning of fossil fuels (coal, natural gas, fuel oil), on the environment, human health, soil, buildings and constructions, but also outlines the possiblities of reduction of SO_2 emissions by applying the technology of burning in fluidized layer.

It also summerizes the main causes that lead to the appearance of acid rains, fog formation, smog, and other harmful effects of such emmisons in the environment

Keywords: emissions, acid, technology, pollution, SO2.

1. IMPACT OF THE ENERGY SECTOR ON THE ENVIRONMENT

In Romania, the energy sector has contributed as a major factor of environmental degradation through the development of power plants on lower coal. Pollution in this sector can be caused by the process of primary energy production, transmission, conversion and consumption. The energy sector contributes to the emission into the atmosphere of significant amounts of sulphur dioxide (SO2), carbon monoxide (CO), carbon dioxide (CO2), nitrogen oxides (NOx), fine particles, as well as to the discharge of waste water [1], [2].

The reduction of the impact of the energy systems on the environment and the implementation of the norms stipulated in this field imposed by the European Union regulations, will be achieved through: rehabilitation and modernization works, greening of the slag and ash heaps, continuous monitoring of the environmental quality in the area of the major energy objectives, rehabilitation of polluted soils and their reintroduction into the agricultural circuit, reduction of pollutant emissions to refineries and minimization of losses, ecological recovery of some oil production and processing areas by reducing the risks in such operations.

The specific measures to be adopted for the protection of the environment are as follows:

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- making investments in the area of environmental protection;
- compliance of thermal power plants with the conditions imposed by Directive 2001/80/EC on the limitation of emissions into the air of certain pollutants (SO2, NOx and dust) from large combustion plants, Directive 96/61/EC on integrated pollution prevention and control and Directive 99/31/EC on the landfilling of industrial waste;
- stepping up the use of the flexible mechanisms provided for in the Kyoto Protocol and directive 2003/87/EC on co2 emissions trading.

The energy sector, on the entire production - transport - distribution - consumption chain, produces approximately 90% of the polluting emissions in Romania. The main pollutants resulting from the combustion of fossil fuels with an impact on the air are dusts (ashes, coal particles, slag, earth, soot, etc.); sulphur oxides (SO2 and SO3); nitrogen oxides (NO and NO2); carbon oxides; tars; hydrocarbon; organic acids, etc.

2. EFFECTS OF POLLUTION BY SULPHUR OXIDES

Sulfur oxides have harmful action on the human body, on overall biological environemnt as well as on metal and stone constructions.

The most significant damage caused by SO_2 to plants happens during the day, when the photosynthetic activity is maximum, the phytotoxic action of SO_2 consisting in the destruction of chlorophyll [4], [7].

Sulphur dioxide (SO_2), produced mainly by coal combustion (but also present as result of other proccesses, for example in diesel engine emissions), combines with water in the atmosphere and causes acid rains that destroy vegetation and affect buildings.

Sulfur oxides have a direct action on plants, contributing to the modification of water and soil. Sulfur oxides, together with nitrogen oxides, are considered the main causes of acid rains, rains that can cause destruction of forests over large areas.

The harmful effect of sulphur dioxide on the vegetation is greatly amplified by its synergism with nitrogen dioxide (NO_2).

Depending on the concentration and the period of exposure sulfur dioxide has various effects on human health. Exposure to a high concentration of sulfur dioxide over a short period of time can cause severe respiratory difficulties. Especially it affects people with asthma, children, elderly and people with chronic respiratory diseases [1].

Fig.1. Effects of SO_2 on vegetables

Sulfur dioxide visibly affects many plant species (figure 1), the negative effect on their structure and tissues is discernible by naked eye.

Some of the most sensitive plants are pine, vegetables, red and black acorns, white ash, alfalfa, blackberries.

In the atmosphere, it contributes to the acidification of precipitations, with toxic effects on vegetation and soil (figure 2). The increase in the concentration of sulfur dioxide accelerates the corrosion of metals, due to the formation of acids. Sulfur oxides can erode stone, masonry, paints, fibers, paper, leather and electrical componentsc [2].

Fig.2. Effects produced by SO_2

The pollution affects soil by changing the pH, the degree of saturation of the bases and the humus content (figure 3). Sulphur dioxide SO_2 and Sulphur trioxide SO_3, in addition to other harmful effects, they contribute to excessive acidification of the soil, slow dehydration and carbonization of dead organic substances and reducing the nutritional resources of microorganisms in the soil.

Fig.3. Soil affected by SO_2

By accumulating pollutants in the soil, acidification of the trophic complex occurs, weakening of the microbial activity, reduction of the supply of mineral substances, decomposition into primary elements by disappearance of clay as binding factor, the latter effect being also amplified after strong rains.

In the cultivated plants, lead, zinc, cadmium, copper, iron, etc., can appear either by root absorption or transferred through the leaves [3].

3. SOME CONSIDERATIONS ABOUT BURNING COAL IN A FLUIDIZED LAYER

A fluidized layer is a biphasic system in which a gas, evenly distributed using a distribution grill (grate or insufflation nozzles) is expelled from the bottom up, through a mass (bed) of solid particles, so that they float in the gas current and are in a permanent agitation (figure 4). The components are: 1 - air chamber, 2 - grate 3 - heat exchanger, 4 - primary air, 5 - coal flow, 6 - limestone dust, 7 - starting burner, 8 - fluidized layer, 9 - ash cooler, 10 - secondary air, 11 - screen pipes, 12 - flue gas exhaust channel, 13 - ash discharge.

The behavior of this biphasic medium, in which solid particles can move relative to each other, is similar to that of a boiling liquid, hence the name is sometimes known as kettle layer.

Inside the fluidized layer, which reaches the height of (3-4) m, the coal particles are kept in a chaotic movement, collide with each other, as well as with the walls of the pipes of the heat exchanger or of the firebox. As a result of these collisions, the ash layer formed after burning at the surface of the particles is shaken, thus facilitating the access of oxygen to the reaction surface, which greatly assists with the increase of the burning speed of the particles, as well as the increase of the convection coefficient of the gases to the walls of the heat exchanger pipes [5], [6].

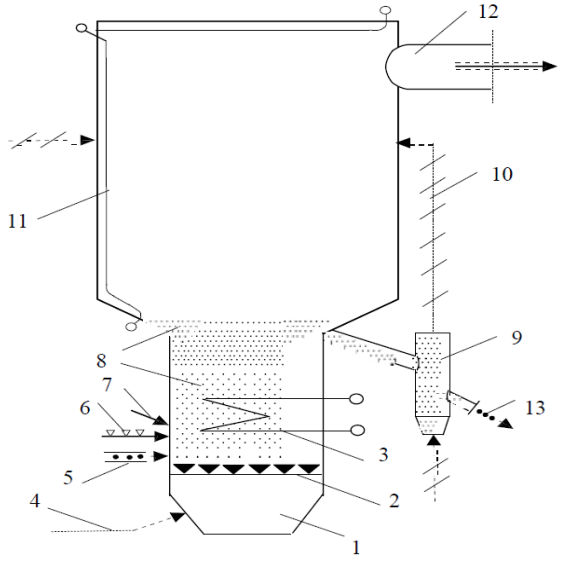

Fig. 4. The scheme of an outbreak with a stationary fluidized layer

In principle, the process consists of burning the particles of activated charcoal, in an oxidizing current, distinguishing two limit situations, determined by the value of the air insufflation rate:

- burning in stationary or dense fluidized layer (BSF);
- burning in circulating fluidized layer (BCF).

There is also a process of desulphurization of flue gases, carried out in two stages. At the first stage, calcium carbonate calcination occurs (1):

$$CaCO_3 \rightarrow CaO + CO_2 - 183kJ/mol \quad (1)$$

And in the second stage, the sulphation of calcium oxide takes place based on the following two reactions (2), (3):

$$2SO_2 + O_2 \rightarrow 2SO_3 \quad (2)$$

$$CaO + SO_3 \rightarrow CaSO_4 \quad (3)$$

These reactions may also be presented in the form of:

$$2CaO + 2SO_2 + O_2 \rightarrow 2CaSO_4 + 486\ kJ/mol \quad (4)$$

The reaction (4) of sulphation of calcium oxide is exothermic. Industrial practice has shown that by dosing limestone in the ratio Ca/S = 2.5 ÷ 3.5, the problem of simultaneous desulphurization of the flue gases was partially solved, the degree of desulphurization reached being about 50% in the best case [3].

The temperature control in the fluidized layer can no longer be ensured only by providing an immersed gas-water heat exchanger, but it is necessary to resort to a substoichiometric combustion, simultaneously with gray recirculation. This leds to the emergence of solid fuels combustion plants in circulating fluidized layer (Figure 5.).

4. SCHEME OF A FIREBOX WITH A CIRCULATING FLUIDIZED BED

The diagram of a hearth with circulating fluidized bed shown in figure 5 contains the following elements: 1 – air chamber, 2 – grill, 3 – primary air, 4 – coal, 5 – calcium carbonate, 6 – starting burner, 7 – heat exchanger heat, 8 - screen pipes, 9 - cyclone, 10 - flue gas exhaust channel, 11 and 13 - channel for ash return to the hearth, 12 - regulating valve, 14 - external heat exchanger for ash cooling, 15 – ash grate, 16 – secondary air, 17 – ash discharge channel, 18 – secondary air.

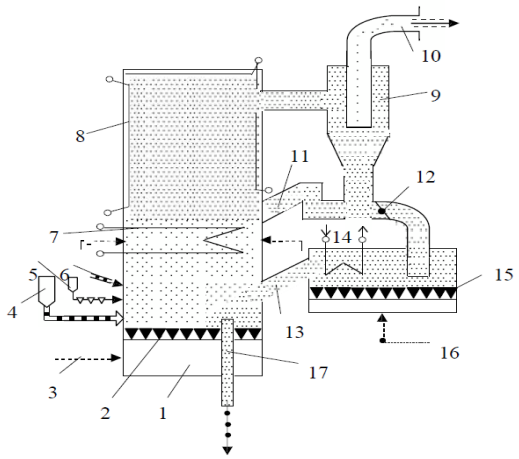

Fig.5. Scheme of an outbreak with circulating fluidized layer

a. The possibility of using various qualities of coal, from the inferior to the superior, of coal mixtures or even of household or other waste. Ignition and combustion stability is high, and unburnt losses do not exceed (1 ÷ 2) %. Coal burning is self-thermal, i.e. without hydrocarbon support, for lignites with Hi > 5000 kJ/kg, even at partial loads.

b. The polluting emissions are minimal, due to the possibility of advanced desulphurization (up to about 80 ÷ 85%) of the flue gases with the help of absorbent substances ($CaCO_3$, CaO, $CaCO_3$ MgCO3) and the blocking of the thermal mechanism for the production of nitrogen oxides as a result of the relatively low temperature in the focus (below 900^0C);

c. The preparation of coal is summary and is done by simply crushing it.

The dimensions of the coal granules (φ = 0 ÷ 20mm) for the BCF are much larger than in the case of the BSF for which the φ = (0 ÷ 7) mm, or in the case of sprayed combustion when φ 0.1 mm. Therefore, an important energy saving is made when

grinding coal, but also decreases the investment and operating expenses related to the non-existence of coal mills.

The flue gases, cleaned of dust, are relaxed in the gas turbine, after which they are cooled in the economizer, preheating the boiler water supply. To comply with the rules on the maximum concentration of dust at emission into the atmosphere, before being discharged onto the stack, the gases are again dedusted, either by using an electrostatic precipitator or by running them through filter bags made of textile materials [6].

5. CONCLUSIONS

The main component of fog is the substance formed by sulfur particles, along with varous quantities of nitrogen-containing substances, which in some areas may equal the amount of sulfur. Other components include graphite in the form of fine ash or organic aerosols.

The main reactants in a process of photochemical smog formation are nitrogen oxide and unburned hydrocarbons, which are emitted into the air as pollutants, from internal combustion engines and from other sources.

Land, vegetation and stretces of water are the surfaces on which the acid deposits accumulate. Acid rain is a form of pollution of both water and air. Acids in the air, produced by power plants and other sources, fall on earth in various surface areas.

The main effect of air pollutants on metals is surface corrosion, which leads to material loss on the surface and alteration of the electrical qualities of metals.

The effects of pollutants on humans are an important problem, because after several seriousincidents, air pollution can have a significant effect on health, especially on children, the elderly or sick people.

Sulfur dioxide visibly affects many plant species, the negative effect on their structure and tissues being noticeable by naked eye. In humans and animals, even in lower concentrations, it causes irritation of the respiratory system, and, in higher concentrations it causes bronchial spasm. Also, sulfur dioxide causes disorders of carbohydrate metabolism and enzymatic processes.

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