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Strategies for emission reduction from thermal power plants

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Abstract

Major polluters of man's environment are thermal power stations (TPS) and power plants, which discharge into the atmosphere the basic product of carbon fuel combustion, CO_2, which results in a build-up of the greenhouse effect and global warm-up of our planet's climate. This paper is intended to show that the way to attain environmental safety of the TPS and to abide by the decisions of the Kyoto Protocol lies in raising the efficiency of the heat power stations and reducing their fuel consumption by using nonconventional thermal cycles. Certain equations have been derived to define the quantitative interrelationship between the growth of efficiency of the TPS, decrease in fuel consumption and reduction of discharge of dust, fuel combustion gases, and heat into the environment. New ideas and new technological approaches that result in raising the efficiency of the TPS are briefly covered: magneto-hydrodynamic resonance, the Kalina cycle, and utilizing the ambient heat by using, as the working medium, low-boiling substances.
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1. Introduction

Major polluters of man's environment are thermal power stations (TPS) and power plants. The international conference on ecology held in Kyoto in December 1997 (Text of the Kyoto Protocol, 1997), in which 170 countries took part, proposed as a solution to the vital problem of preventing this planet's thermal death to reduce by 5.2% (in reference to the level of the year 1990) the discharge of harmful gases and aerosols, and heat into the atmosphere. It should be added here that coal-fueled TPS, in addition to ashes and smoke, discharge into the environment a complete spectrum of hazardous chemical elements, including uranium and thorium.

In the autumn of 1999 the next conference of the kind stated that no positive changes had taken place in the world's environmental situation during the preceding 2 years, and that the governments of the developed countries had not taken any effective steps to improve the situation. The International Conference held in 2001 arrived at a similar conclusion.

The way to solving the problems formulated in the Kyoto Protocol can be found in new technological approaches and in new ideas that can cardinally solve the problem of raising the efficiency of TPS. Such approaches and ideas are available today. The mission to be performed by today's technological community lies in their practical development and in bringing them into commercial practice.

1.1. Fuel-fired plants: the leading suppliers of dust, gases and heat into the atmosphere

The growth of well being of human society, improvement of the quality of life, and the very existence of mankind are impossible without power consumption and, consequently, without consumption of fuel and fuel-energy resources (FER). Output of electric power in the world reached, in 1985, 9.643 T W h (Statistical collection, 1986), having resulted in consumption of 751 million tonnes of coal, 615 million tonnes of oil, and 686 million tonnes of gas. It should be noted that annual production of electric power resulted in consumption, on the average, of 2 Gigatonnes of conventional fuel (Lukin, 1991). In 1990, at the beginning of its disintegration, the Soviet Union produced 1.726 T W h of electric power. The structure of the output of electric power at the time looked as follows (Troitsky, 1991):

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	Installed capacity (%)	Power generation (%)	Planned increase by 2010 (%)
Thermal power station (TPS)	64.5	74.6	50–55
Hydroelectric power stations (HyPS)	19.6	14.6	15
Nuclear power stations (NPS)	15.9	10.8	25

Comparison of the share (%) of individual industries in the environmental pollution (Richter et al., 1991) helps to point out to the main areas of activity aimed at improving the ecological situation:

	USSR	FRG
Heat power industry	27.0	17.6
Ferrous metallurgy	24.3	15.8
Automobiles	13.3	14.1
Chemical industry	1.3	0.9
Other industries	No data	19.1

Power consumption is a measure of the progress of human society, but in today's environmental situation on the globe priority should be given not to the absolute amount of power consumption, but rather to its 'quality', that is to the consumption of fuel-energy resources (FER) per head of population. Let us compare the levels of FER consumption in 1991 in some countries (Lukin, 1991):

	Japan	FRG	USSR	USA
FER consumption, tonness per head	4.1	6.0	8.0	11.0

In the period from 1976 to 1991 the USSR's fuel and energy engineering complex had kept discharging into the atmosphere alone up to 250 Mt a year (Lukin, 1991), or 12.5% of the amount of conventional fuel used for electric power production, while in 1981 all the fuel-fired plants in the USSR (Lukin, 1991) discharged into the atmosphere (million tonnes): CO_2-200; SO_2-150; hydrocarbons-50; aerosols-250. The share of heat-and-power engineering in this pollution amounted to 50% for SO_2, 30–35% for NO_x, and 35% for aerosols. Besides, the heat-and-power engineering consumed up to 1% of the atmospheric oxygen, replacing it by CO_2, which increased the greenhouse effect.

Taking into account the fact that from 1991 till 2002 the technology of electric power production in the FSU countries had not been improved, there is no reason to believe that for the past 12 years the environmental characteristics of the operating fuel-fired plants had improved. The environmental situation on our planet in recent years has not changed for the better. Otherwise, there would have been no Kyoto Protocol of 1997 (Text of the Kyoto Protocol, 1997).

To be more objective in this assertion we shall now turn to the data published by the GAO on June 20, 2002 (General Accounting Office, USA, 2002). Electric power stations of the USA that began operating before 1972 discharged in 2000, 59% of the sulfur dioxide, 47% of the nitrogen oxides, and 42% of the carbondioxide of the total discharge by the fuel-fired plants in 2000, while having produced only 42% of the total electricity. Let us resort to simple calculations to show the correlation between gaseous discharge from the newer and the older power stations in reference to the electricity produced by said stations.

To do so we shall use simple logic: if the older power stations produced 42% of the electric power obtained, the newer ones produced (100–42)% = 58%; if the older stations discharged into the atmosphere 59% of the SO_2, the newer ones discharged (100–59)% = 41%. And so on for each of the gaseous discharges. Then for 1% of the power produced by the older stations they discharge 59/42 = 1.41% of the SO_2, and so on. Let us list the resulting 'gaseous discharge-power produced' ratios:

Power stations	Discharge per 1% of the electricity produced		
	SO_2 (%)	NO_x (%)	CO_2 (%)
Older	1.41	1.12	1.00
Newer	0.71	0.91	1.00

It is worth noting that the discharge of SO_2 and NO_x by the newer stations is lower than that by the older ones. Discharge of CO_2 is, however, comparable, which can be explained by the very nature of the system employed for producing heat energy. Since it is carbon-containing fuel that is oxidized in combustion, the product of the process naturally turns out to be CO_2.

Nearly 75% of the power plants that began operating before 1972 are reported by the GAO (General Accounting Office, USA, 2002) to have discharged, in 2000, the amount of hazardous gases comparable with or even exceeding the limits set by the Environmental Protection Agency air quality standards, already specially extended for some of the power stations. As the GAO report says, these 'additional' emissions exceed even the extended limits for certain stations by 34% in the total SO_2, and by 60% in the total NO_x produced by the older stations. Besides, 99 percent of the 'additional' SO_2 and 91 percent of the 'additional' NO_x were discharged by the plants using coal as their basic fuel.

It is hoped that the data cited at the beginning of this paper on pollution of the environment by power stations in 1985–1990 do not look hopelessly outdated after reading the 2002 GAO USA report. Moreover, it is quite obvious that for the last 20 years there have been found no radical ways to reduce the discharge of CO_2 and heat, which are a principal cause of the build-up of the greenhouse effect and the global climate warm-up of our planet.

Low-potential thermal discharges from TPS by the middle of the 21st century, in comparison with figures for 1983, will grow 20–30 times, proportionally to the growth of electric power production (Melentev, 1983). Up to 15% of the overall thermal power of TPS is lost with the gases discharged, and up to 52%-with the water cooling the condenser. Thermal power

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