UNITED NATIONS

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Economic and Social Council

Distr.
RESTRICTED

ENERGY/WP.2/GE.1/R.1/Add.4
4 July 1994

ENGLISH
Original: RUSSIAN

ECONOMIC COMMISSION FOR EUROPE

COMMITTEE ON ENERGY

Working Party on Electric Power

Meeting of Experts on Electric Power Generation and the Environment
Fourth session, 29 and 30 September 1994
Item 9 of the provisional agenda

AN ENVIRONMENTAL APPRAISAL OF COMBINED-CYCLE POWER PLANTS

(Transmitted by the Government of the Russian Federation)*

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* In accordance with the decision of the Meeting of Experts at its third session, held in October 1993 (ENERGY/WP.2/GE.1/6, para.11 (ii)).

GE.94-31907 (E)

G.G. Olkhovsky and P.A. Verezinets

AN ENVIRONMENTAL APPRAISAL OF COMBINED-CYCLE POWER PLANTS

The use of combined-cycle technology makes it possible, on the one hand, to reduce fuel consumption, and consequently the products of combustion and on the other to lower the concentration of harmful substances in the products of combustion.

Binary combined-cycle plants equipped with high temperature gas turbines use 25-30% less natural gas than conventional power plants. Furthermore, the concentration of nitrogen oxides can be lowered to 15-25 mg/m^3 (15% 0_2) in gas-turbine plants; such values have already been achieved by Western and American firms.

New values for maximum permissible emissions of nitrogen oxides (mg/m^3 0_2 = 15%) in gas-turbine plant exhaust gases have recently been adopted:

Date of entry into operation of gas-turbine plant	Fuel used	
	Natural gas	Liquid fuel
Before 1.1.95	150	150
After 1.1.95	50	100

When nitrogen-oxide concentration standards are met downstream of the gas-turbine unit and of the steam-turbine unit boilers, total nitrogen oxide emission from a binary combined-cycle plant are no less than 35% lower than total emissions from a steam-power plant boiler.

When gas-turbine units are retrofitted to gas-and-oil fired steam-power plants, emissions of pollutants are greater than in binary combined-cycle plants but lower than in the original plants. Retrofitting a 300-MW unit with a Mashproekt GTG-110 gas-turbine unit, the exhaust gases from which are dischared into the steam-turbine boiler, yields a fuel saving of 9%. In independent operation of the steam turbine with oil firing, specific discharges of nitrogen oxides amount to 0.93 kg/MWh. Combined-cycle operation reduces specific NO_x emissions by 20%.

When concentrations stipulated in the standards are observed, the environmental indicators for coal-burning power plants are significantly worse than those for plants using natural gas or liquid fuel. Further improvement of the environmental friendliness of coal-burning plants will entail less economic operation, a rise in capital outlays and an increase in the cost of electric power.

In combined-cycle plants, in contrast to coal-fired steam-turbine plants, the efficiency stemming from the thermodynamics of the process is linked to the environmental acceptability of the plant, because of the need to guarantee reliable operation of the gas turbine. Indeed, the working medium of the gas turbine has to meet appreciably more severe standards than would be required for environmental protection alone.

Thermodynamically, the most efficient combined-cycle plants are those incorporating coal gasification. Here fuel savings may amount to 10-20% over traditional coal combustion technology. The product gas obtained during coal gasification must satisfy the following requirements:

Solid particle content below 4 mg/kg;

Absence of solid particles measuring more than 10 μm;

SO_x concentration to comply with environmental protection requirements; scrubbing technology makes it possible to remove up to 98-99% of the sulphur;

Absence of heavy metals, alkali metals and halogens.

Notwithstanding these strict requirements, a number of technologies for the complete scrubbing of product gas have already been developed.

Compliance with the NO_x - concentration standards is ensured thanks to the technology used to burn the gas in the combustion chamber of the gas-turbine.

In this way, environmental indicators for combined-cycle plants with coal gasification can be brought close to those for combined-cycle plants using natural gas.

In a project implemented in Russia under the State scientific and technological programme, the following indicators were achieved from a combined-cycle gas-turbine plant using coal gasification in a dust and gas stream with oxygen blast:

Concentration of solid particles in exhaust gases	1.5 mg/m^3
Concentration of sulphur oxides in exhaust gases	80 mg/m^3
Concentration of nitrogen oxides in exhaust gases (15% O_2)	50 mg/m^3

Ash is removed from the plant as granulated slag, a product which can be used in road construction and civil engineering.

The acidic gases (hydrogen sulphide, etc.) are converted into commercial-grade lump sulphur, which is in short supply in the chemical industry. Optimization of this technology is scheduled to begin in the late 1990s.

It should be pointed out that a consumable material - limestone or lime - is used in scrubbing stack gas at conventional power plants, so that the by-products of such stations include not ash and slag, but also gypsum. It is hard to find a use for the gypsum because it is of poor quality and abundant.

Environmental indicators for combined-cycle plants with presurged coal-firing (in a fluidized bed or a circulating fluidized bed) are lower than for combined-cycle plants using coal gasification. However, they are substantially higher than in plants using traditional combustion technology.

A comparison of various indicators for different technologies (per kilowatt-hour) appears below.

Indicator	Power plant			
	Pulverized coal	Combined-cycle using a fluidized bed	Combined-cycle using coal gasification	Combined-cycle using natural gas
1. Efficiency, %	42	43	46	52
2. Fuel consumption, g	340	335	310	140
3. Consumption of limestone, g	13	25	-	-
4. Emissions				
CO_2, g	830	810	760	380
SO_2, mg	600	585	150	-
NO_2, mg	600	585	300	350
Ash, g	34	62	31 (slag)	-
Gypsum, g	20		4 (sulphur)	-

In combined-cycle plants the proportion of total capacity attributable to the steam turbine ranges from 80% (in a combined-cycle plant feeding the gas from the gas turbine into the boiler) to 30% (for a binary combined-cycle plant). This reduces liquid waste formation during preparation of make-up water in the steam and water circuit is 25 and 70% respectively per megawatt.

Moreover, the reduction in consumption of circulating water roughly halves thermal pollution of the cooling water discharge pond or evaporation from the cooling towers.

The data cited above provide convincing proof of the substantial advantages of combined-cycle plants using coal gasification. In view of the fact that coal will be the dominant fuel used for electric power generation in the near and distant future, major attention should be devoted to this technology.
