CLEAN COAL TECHNOLOGY

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Summary

Clean Coal Technologies (CCTs) are those which facilitate the use of coal in an environmentally satisfactory and economically viable way. A basic idea for the CCTs is to develop more thermally efficient systems so that less coal is used to generate the same amount of power, together with improved techniques for flue gas cleaning, effluent treatment, and residue use or disposal.

Some CCTs have already seen commercial application in industrialized countries. Advanced electric power generation systems that generate electricity with greater efficiency and fewer environmental consequences are undergoing development in many countries. These technologies are:

- Pulverized coal combustion (PCC) with supercritical steam cycles, together with flue gas cleaning units;
- Atmospheric pressure fluidized bed combustion in both bubbling (BFBC) and circulating (CFBC) beds;
- Pressurized fluidized bed combustion (PFBC) systems;
- Integrated gasification combined cycle (IGCC) plants;
- Combined heat and power (CHP) units where the (subcritical) steam turbine is designed to produce both power and useful heat for process or district heating.

The various technologies are at different stages of development, and are applicable to units of different size. Variations in coal quality/properties affect the economics of the technologies differently.

1. Introduction

Coal's role in energy use is primarily as a source of electricity generation and in key industries, such as steel, cement, and chemicals. The vast majority of existing coal-based power plants around the world are based on pulverized coal combustion (PCC) technology linked to a conventional steam cycle.

The technology is well-proven, reliable and, in general, produces electricity at a competitive cost. Coal, however, emits a great amount of CO_2 into the atmosphere, causing global atmospheric warming along with SO_x, NO_x, particulates, and solid residues.

This is why coal-fired power plants have been required to reduce such emissions. In addition, serious local pollution by coal dust, soot, particulate, and ash has been experienced especially in developing countries, necessitating countermeasures.

Therefore, cost-effective environmental control devices to control sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM) have been developed and/or being adopted by in many countries.

Table 1 shows the current emission standards (mg/m^3) for particulate, SO_2, and NO_x for new coal-fired plants.

Some limits on trace emissions, such as volatile organic compounds (VOC), other organics (polycyclic aromatic hydrocarbons, furans, and dioxins), other hydrogen halides, and heavy metals species (Hg, Cd) have attracted interest recently in many countries.

Country	**Particulates**	**SO_2**	**NO_x**
Australia	80-280 τ	–	535-860 τ
Austria	50-280	200-550	200-660
Belgium	50	250-2000	200-650
Canada	145 τ	740 τ	490-740 τ
China, mainland	200-500	+ ε	670
China, Taiwan	50-500	570-1430	515-1025
Czech Republic	100-150	500-2500	650-1100
Denmark	55	400-2000	200-650
Finland	380-620	30-540	135-405
France	50-100	400-3400	650-1300
Germany	50-150	400-2000	200-500
India	150-350	–	–
Italy	50	400-2000	200-650
Japan	30-300	+	205-980
Netherlands	20-50	200-700	100-500
Poland	190-3700	540-1755	95-460
Spain	50-500	400-2000	650-1300
Sweden	35-50 τ	160-270	135-540 τ
Switzerland	55-160	430-2145	215-860
Turkey	140-200	430-1875	800-1690
United Kingdom	50 (25**)	400-2000 (200-300**)	650-1300 (60-270**)
USA	37-123	740-1480	220
UNECE		400-2000	
EC	30	200-850++ 200#	300 200#
World Bank¶	50	2000	750

* emission standards are converted to mg/m^3 on dry flue gas at 6%O_2 and standard temperature and pressure (0ºC (273 K), 101.3 kPa)
τ guidelines
\+ plant specific standards set
ε for plants built after 1 July 1997, the following standards also apply: 2100 mg/m^3 for plants using <1% sulfur coal: 1200 mg/m^3 for plants using >1% sulfur coal
¶ proposed standards
** achievable emission levels to be taken into account for plants built after 1995
++ for plants 100-300 MWth linear decrease (-3.3P + 1175, where P = plant size in MWth)
\# for plants greater than 300 MWth

Table 1. Emission standards (mg/m^3*) for particulates, SO_2, and NO_x for new coal-fired plants (>100 MWth) [Stuart C. Mitchell (1997)]

Clean coal technologies (CCTs) are those which facilitate the use of coal in an environmentally satisfactory and economically viable way. They comply with various regulations covering emissions, effluents, and residues. A basic approach to the CCTs is to develop more thermally efficient systems so that less coal is used to generate the same amount of power, together with improved techniques for flue gas cleaning, effluent treatment, and the use or disposal of residues. Some of the CCTs have already found commercial application in industrialized countries. Advanced electric power generation systems that generate electricity with greater efficiency and fewer environmental consequences are undergoing development in many countries. These technologies are:

- Pulverized coal combustion (PCC) with supercritical steam cycles, together with flue gas cleaning units;
- Atmospheric pressure fluidized bed combustion in both bubbling (BFBC) and circulating (CFBC) beds;
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The various technologies are at different stages of development, and are applicable to units of different size. Variations in coal quality/properties affect the economics of the technologies differently. Efforts will be made to reduce the concentrations of coal gas pollutants to levels that satisfy current emission requirements using wet flue gas treatment technologies for PCC and a part of atmospheric FBC. For combined cycle power systems, it is generally considered to be cheaper and less energy intensive to clean a smaller volume of gas pollutants prior to expansion in the gas turbine.

2. PCC with flue gas cleaning units

2.1 Introduction

Most of the world's coal-fired power generation capacity comes from PCC units. PCC units have been built to match steam turbines that have outputs between 50 and 1300 MWe. In order to take advantage of the economies of scale, most new units are installed at over 300 MWe, but there are relatively few really large ones with outputs from a single boiler/turbine combination of over 700 MWe. The subcritical PCC units are widely perceived as a well-proven and reliable technology. However, thermal efficiencies of most utility boilers are modest in the subcritical condition. Units with subcritical boilers tend to have somewhat higher emissions of SO_x, NO_x and particulate per kWh than units with supercritical boilers because they are less efficient and hence generate less kWh per unit of coal input. To improve the plant performance, the introduction of supercritical or ultrasupercritical steam conditions and the use of emission control devices is necessary.

2.2 Potential of supercritical boilers

The overall thermal efficiency of older and smaller units burning, possibly, poor-quality coals can be as low as 30%. The main route to higher efficiency is through increased steam temperatures and pressures. Increasing the main and reheat steam temperatures by

20 K improves efficiency by about 1.2% (0.5% points), and increasing the main steam pressure by 1 MPa improves efficiency by 0.1–0.3% (approximately 0.1% points). The average efficiency of larger existing plants with subcritical steam burning relatively higher quality coals is in the region of 35–36%. New plants with supercritical boilers and turbines can now achieve overall thermal efficiencies in the 43–45% range. It is currently envisaged that advanced PCC units with an efficiency of 48% (LHV) might be in operation by 2005 with over 50% (LHV) possible by 2015. One of the driving forces currently encouraging the use of more efficient power plants is environmental concern in many countries, and the declared goal of most OECD governments to reduce CO_2 emissions to 1990 levels by the year 2000. This is a goal that leaves power generators with many unsolved problems, but increasing the thermal efficiency of converting coal to power is one of the less expensive ways of reducing CO_2 emissions.

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Biographical Sketch

Yoshihiko Ninomiya graduated from Nagoya University, Japan with his Dr. of Engineering. He studied kinetics of the conversion of NO to N_2 during the oxidation of iron particles by NO in the Department of Chemical Engineering at the University of Cambridge from 1990 to 1991 as a visiting scholar supported by the Japan Society for the Promotion of Science and the Royal Society. He is Associate Professor of Applied Chemistry at Chubu University. He has over 15 years of research experience in fields of coal gasification, ash melting behavior, NO_x and SO_x control from coal combustion. He is a member of the Society of Chemical Engineers, Japan and has authored, or co-authored 50 publications.

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