U.S. AND CHINESE EXPERTS PERSPECTIVES ON IGCC TECHNOLOGY FOR CHINESE ELECTRIC POWER INDUSTRY

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Introduction

Although China is a very large and populous nation, and has one of the longest known histories in the world, it has only lately begun to seek its place among modern industrial nations. This move, precipitated by the government's relatively recently adopted strategic goals of economic development, societal reform and promotion of engagement with other industrial nations, has brought to the fore the serious situation in which the Chinese electric power industry finds itself. Owing to the advanced average age of generation facilities and the technology used in them, serious expansion and modernization of this industry needs to take place, and soon, if it is to support the rapid industrial development already taking place in China.

While China does have some oil and gas, coal constitutes its largest indigenous energy supply, by far. Coal has been mined and utilized for years in China. It is used directly to provide heat for homes, businesses and in industrial applications, and used to raise steam for the generation of electricity. The presently dominant coal utilization methods are characterized by low or marginal efficiencies and an almost universal lack of pollution control equipment. Because there is so much of it, coal is destined to be China's predominant source of thermal energy for decades to come.

Realizing these things — the rapidly increasing demand for more electric power than China presently can produce, the need to raise coal utilization efficiencies, and the corresponding need to preserve the environment — the Chinese government moved to commission several official working organizations to tackle these problems. Pursuing IGCC, the leading team includes three

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commissions, three ministries and an IGCC expert group to accelerate the move to adopt these new technologies.

In their search for technologies that would provide efficiency and improved environmental performance both in the near and long term, these groups centered their attention on the integrated gasification combined-cycle (IGCC) technologies that have spawned a number of large power generation facilities which are now in operation in the United States and Europe. These installations typically utilize one of several species of coal gasifier that produces fuel for a gas turbine/generator which, in combination with a steam turbine/generator, forms the basis of a combined cycle power generation section.

As a means of obtaining up-to-date input on the IGCC technologies themselves, electric generation practice, and environmental requirements, these empowered groups invited experts in IGCC technology from China and from the United States to meet in Beijing for study and discussions.

Following this meeting, the participants accepted assignments to prepare ten papers — five each from China and the United States — each dealing with some different aspect of China's energy industry and ways to most efficiently and timely provide the additional, clean power generation that China needs. These papers were prepared, reviewed, cross-edited by all participants, and combined in a document presented in both Chinese and English, entitled *The United States of America and the People's Republic of China Experts Report on Integrated Gasification Combined - Cycle Technology (IGCC)* which was issued in December, 1996. This report illustrates that there may now be a confluence between China's needs and a desire in the US to propagate the clean coal technologies throughout the world. This confluence of interests and motives between China and the US has all of the elements of a classical "win – win" situation.

In parallel with these efforts, the Chinese have completed pre-feasibility and engineering studies for a 200 – 400 MW IGCC demonstration power plant to feature United States technology, and the plan is to have this plant well on the way to completion by the year 2000.

The Power Picture in China

The Chinese electric industry has made large advances in terms of capacity and generation since 1980. The installed capacity has grown from 65,870 MW in 1980 to 210,000 MW in 1995. During this same time interval, annual generation increased from 300.6 billion kWh to 1,000

billion kWh.

New capacity installation during the "ninth 5 years plan," between 1996 and 2000, will be at an annual rate of 16,000 MW, reaching a total installed capacity of 300,000 MW (227,900 MW thermal) by 2000 year-end. Annual production is expected to reach 1,400 billion kWh (1,130 billion kWh thermal) by that time. By the end of the year 2000, China will have increased both its generation capacity and its annual production of power since 1980 by a factor of four.

Presently, the average coal-fired generation efficiency in China is about 30 percent LHV (410 g/kWh). During the "ninth 5 years plan," new units will be at or larger than 300 MW in size and will utilize high-efficiency technologies. This is expected to lift the average "fleet" efficiency to 32 percent LHV (380 g/kWh) by the year 2000 and to 34 percent LHV (360 g/kWh) by 2010.

Under the current "5 years plan," 33,000 MW of smaller, low-efficiency units will be retired and replaced by larger, high-efficiency units. At the same time, 40,000 MW of existing units will be refurbished and 60,000 MW of new coal-fired power plants will be constructed.

The Basic Energy Picture in China

Coal constitutes 90 percent of the fossil energy resources in China, where oil and natural gas resources are relatively scarce. Coal provides 70 percent of primary energy production in China today, and is expected to continue at this level for the next 30 to 50 years. Hydropower provides much of the balance.

From 1949 to 1993, annual raw coal production rose from 32 million tons (Mt) to 1,194.7 Mt, an increase of greater than 3,600 percent. Crude oil, 120 thousand tons (kt) to 145.2 Mt, some 121,000 percent. Natural gas production increased from 7 million to 16.95 billion cubic meters, an increase of some 242,000 percent. Total primary energy production reached 1,112.63 million tons of coal equivalent (Mtce) — ranking third in the world. The annual average growth rate of overall energy production has been 9.1 percent.

Chinese coal reserves total about one trillion tons, of which about 30 percent are proven reserves. All coal ranks are represented in China: lignite, 13 percent; subbituminous and bituminous, 75 percent; anthracite, 12 percent.

Seventy-six percent of power is generated by the burning of coal, which accounts for 30 percent

of the total of coal produced. Another 33 percent of the coal produced provides 75 percent of fuel and power in other industrial sectors, 60 percent of chemical and fertilizer raw material is coal derived, as is 80 percent of fuel consumed in the household sector, accounting for another 20 percent of coal produced. Eight percent of coal produced is used in the metallurgical industry sector for coke and power production.

Environmental Quality Issues in China

Coal-fired power generation consumed 325 million tons (Mt) of standard coal in 1995. This will rise to 430 Mt in the year 2000. Unless desulfurization is vigorously pursued, the industry will put 6.25 million tons of SO_2 per year into the atmosphere by the end of 2000. This would have a profound effect upon the population for years to come.

Chinese coal is also relatively high in ash. Its sulfur content increases with the depth from which it is mined. Although the average sulfur content of the coal burned in China is 1 percent, the resulting environmental impact is serious because of the very large amounts of this coal consumed. Approximately 23 percent of all Chinese coal is washed. Of the coal used for power generation, 11.28 percent is washed. A high coal ash content wastes transportation resources, reduces utilization efficiency and complicates end-use.

Of those efforts toward environmental protection that have been done, particulates removal has been the most successful. Because of its relatively low sulfur content, control of SO_2 has not been a priority in the past. In 1994, 14.14 million tons of particulates and 18.25 million tons of SO_2 were produced. In fact, Shenyang, Xi'an and Beijing are listed as 2nd, 7th, and 8th, respectively in terms of the highest airborne SO_2 in the world according to the United Nations. By the year 2000, annual SO_2 emissions may reach 30 million tons without adoption of appropriate control technologies.

IGCC units typically trap all of the generated particulates, 99 percent of the sulfur and 90 percent of the generated NO_x. The features that produce these results are integral parts of the operating unit and thus are included in the overall efficiency numbers. Further, high efficiencies are associated with less coal consumption per unit of produced electricity, and thus necessarily release correspondingly less of the so-called greenhouse gas, CO_2, to the atmosphere.

China's energy consumption, 70 percent of it driven by coal, has resulted in serious air pollution, including particulates, acid rain area expansion, and large CO_2 emissions. In the cities of the

north, particulate concentrations are 4-6 times higher than the maximum permissible level as declared by the World Health Organization. In one-fourth of the cities in north China, SO_2 emissions are 3 times the national standard. China is the third largest emitter of CO_2 in the world as a result of its large coal consumption. With the projected increase in coal consumption, these pollutant levels will only increase without control.

IGCC Development in the US

The US leads the world in terms of clean coal utilization technologies even though it has abundant supplies of oil and gas available either indigenous or readily available. In fact, at the present time in the US, there is near economic parity between coal, oil, and natural gas. The aggressive development of coal technologies in the US arises out of the experience of an OPEC embargo during the 1970s, large employment in the US in the coal industry, and the need to exercise tight control over polluting emissions.

The heart of the combined-cycle portion of the IGCC is the large stationary utility gas turbine. The US has had the lead from the beginning in development of these machines, mainly because they were derived originally from aircraft turbine engines. Today, the development of gas turbines is centered around increasing combustion temperatures which translates directly into higher engine efficiency. The "F" and the more recent "H" turbine technologies were developed in the US with the participation of the US Department of Energy's Advanced Turbine Systems team. Several of the industrial leaders in the pursuit of higher turbine efficiency effort and in the manufacture of a wide range of gas turbines for electric generation are US-based, such as General Electric.

In the mid-1980s, the US government kicked off the Clean Coal Technology (CCT) demonstration program to be funded to several billions of dollars over a period of several years, and to be administered by the US Department of Energy. The purpose of this program has been to stimulate the development of efficient and environmentally friendly ways to utilize coal. Now near its end, the CCT program has been responsible, in part, for several commercial-scale CCT plants, including Tampa Electric Company's Polk Power Station Unit 1, Public Service of Indiana's Wabash River project, and Sierra Pacific's Piñon Pine project at its Tracy Station.

The large commercial projects now in operation in the US are in place even though both oil and natural gas are cost competitive on a generated kWh basis with coal. These technologies become more attractive as coal becomes more available and less costly than oil or natural gas, as in the

case in China. The US is home to several of the IGCC technology developers, including Texaco, Destec, Kellogg, etc.

IGCC in China

China has considerable experience with coal gasification, which is widely used in the production of feedstock streams for the chemical and fertilizer industries. Also, there are numerous combined-cycle units generating electricity in the coastal areas. Unfortunately, these technologies have yet to be combined in China.

IGCC is the most mature, efficient, environmentally sound, and cost-competitive of the world's emerging coal-utilization technologies. There were at least 5 IGCC units sized between 250 and 300 MW either under construction or in operation in the US and Europe in 1996. Current IGCC efficiency is at least 10 percent better than all coal-fired, conventional power plants now under construction, and the "H" class turbine technology promises to raise thermal efficiencies as high as 50 percent after the year 2000.

The investment cost for IGCC has been comparable with current, and lower than that for projected, near-term, conventional pulverized coal (PC) power plant costs. It also has great potential for further decreases in first cost, making it even more attractive as an alternative to conventional technology.

With the immediate need for addition and upgrading of the existing Chinese electric power industry amounting to more than 10,000 MW per year over the next several years, the market for IGCC technology in China appears bright indeed. This is particularly so considering that, by its nature, the IGCC plant lends itself to phased, or progressive operation, i.e., one can begin with a gas turbine/generator, and run this in simple-cycle while other elements of the finished plant are being assembled. The steam turbine/generator can then be added for combined-cycle operation and, finally, the gasification section providing the full IGCC configuration. And there are other workable combinations and permutations of this arrangement, lending a great deal of flexibility, rapid commencement of power production, and early generation of cash flow.

It is important for China to build and place a large-scale IGCC electric generation facility into operation at an early date. Once in place and in operation, such a plant will provide ongoing evidence of the efficacy of the IGCC coal-to-clean power configuration, and serve as a testing-

bed for developments that could be of particular benefit to China's situation.

The early commissioning of an IGCC facility in China will assist China's machinery manufacturers to develop some portions of the technology for themselves, thus leveraging the monies available into more electric generation for each dollar spent.

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