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Design and Fabrication of Gasification Combined Cycle in Power Plant

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Abstract--- *These days the major source of electricity in our country is produced from thermal power i.e from coal. The vast resources of coal we have are not of high carbon content .The form of coal primarily mined in India is lignite which has less carbon content. We are not being able to maximize the output from the power plants using these coals only because of the inferior quality of coal. As a result there occurs much wastage of these valuable resources.*

Keywords--- *Power Plant, Gasification Combined, Design and Fabrication.*

I. INTRODUCTION

Integrated gasification combined cycle provides a suitable solution to this problem. In this process coal is converted into fuel gas which in turn is used for generating electricity. The efficiency by this process is much higher than the convential process. This paper aims at the basic

- Design
- Technical performance
- Emissions
- Relative Merits of IGCC over Conventional PC Fired Technology.
- Investment Costs.
- Environment concerns
- Commercial availability of the technology

In a developing country like India the financial resources should be aimed at such future Technology. Already experimental project has undergone but needs a much better and wide application of this technology.

1. IGCC Technology

Coal gasification is a process that converts solid coal into a synthetic gas composed mainly of carbon monoxide and hydrogen. Coal can be gasified in various ways by properly controlling the mix of coal, oxygen, and steam within the gasifier. There are also several options for controlling the flow of coal in the gasification section (e.g., fixed-bed, fluidized-bed, and entrained-flow systems; see following figure). Most gasification processes being demonstrated use oxygen as the oxidizing medium.

IGCC, like PFBC, combines both steam and gas turbines ("combined cycle"). Depending on the level of integration of the various processes (see second figure below), IGCC may achieve 40 to 42 percent efficiency.

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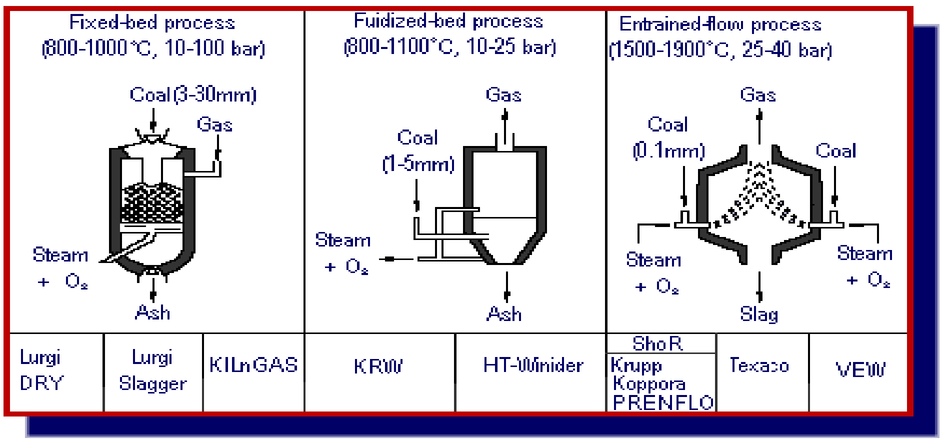
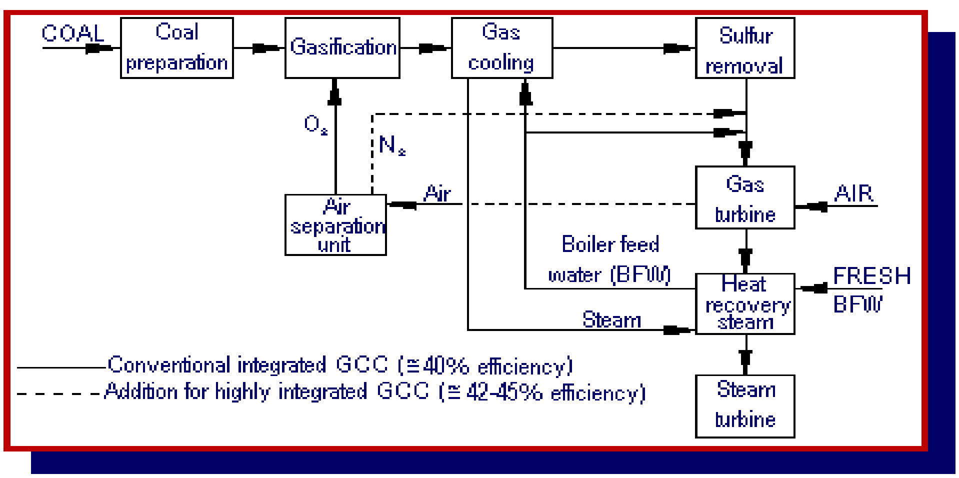
The fuel gas leaving the gasifier must be cleaned (to very high levels of removal efficiencies) of sulfur compounds and particulates. Cleanup occurs after the gas has been cooled, which reduces overall plant efficiency and increases capital costs, or under high pressure and temperature (hot-gas cleanup), which has higher efficiency. However, hot-gas cleanup technologies are in the early demonstration stage.

$C + {}^{1}/_{2} O_2$ gasification◊ CO

$C + H_2O$ gasification◊ $CO + H_2$



This shows the main three coal gasification processes: Left: fixed bed, center: fluidized-bed, and right: entrained flow.



Highly Integrated Gasification Power Plant Configuration

This figure shows a typical IGCC process flow. Plant efficiency can be improved further by: injecting the nitrogen from the air separation unit into the fuel gas prior to the gas turbine and utilizing air from the gas turbine/compressor in the air separation unit (see dotted lines).

After the fuel gas has been cleaned, it is burned and expands in a gas turbine. Steam is generated and superheated in both the gasifier and the heat recovery unit downstream from the gas turbine. The fuel gas is then directed through a steam turbine to produce electricity.

II. IGCC PROCESS

The IGCC process is shown in Figure . It consists of an air-blown, pressurised fluidised bed gasifier that is fed with coal from an integrated drying process. The feed coal is pressurised in a lock hopper system and then fed into dryer where it is mixed with the hot gas leaving the gasifier. The heat in the gas is used to dry the coal whilst the evaporation of the water from the coal cools the gas without the need for expensive heat exchangers. The coal dryer is smaller and cheaper to build than conventional coal dryers because it operates under pressure.

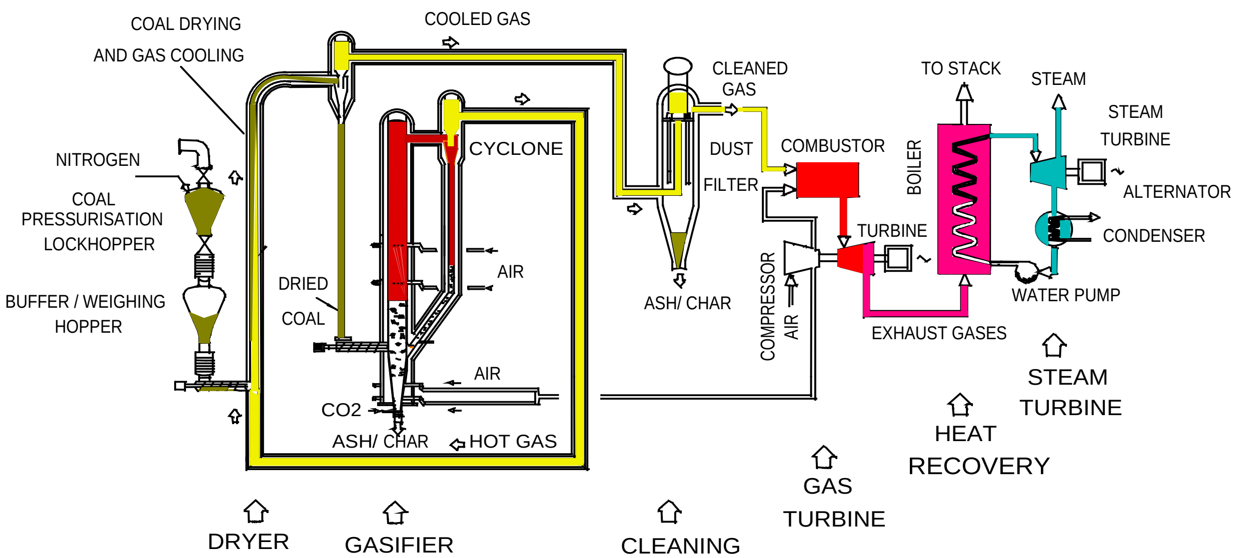


Figure 1: Diagram of the IGCC Process

The air for gasification is extracted from the gas turbine compressor then compressed again before being fed into the gasifier at 25 bar pressure. The gasifier operates at about 900°C which is below the melting point of the coal ash. Unconverted carbon and ash is removed from the bottom of the gasifier and also from the ceramic filter. This waste char material is burnt in an auxiliary boiler to recover as much as possible of the energy from the coal. The final ash product is then similar to that from a conventional brown coal boiler.

Dust emissions from the process are very low because of the very effective ceramic filters that remove the dust from the coal gas before combustion. The filters are reverse pulse cleaned on-line. In the IGCC process the filters operate at about 300°C which is much lower than in some IGCC processes.

Coals containing high levels of sulphur require additional action to absorb the sulphur containing gases before they reach the gas turbine where it will form SO_2 in the turbine combustors. The sulphur can be absorbed in the gasifier by adding limestone or dolomite with the coal and the sulphur becomes incorporated into the ash. The sulphur compounds can also be absorbed in a separate fluid bed system that uses a sorbent that is regenerated in another bed and then re-used.

Nitrogen compounds in the coal are partially converted into ammonia in the gasifier. This ammonia will form NOx in the gas turbine combustors. The ammonia can be absorbed from the fuel gas and converted to fertiliser as a by-product and the NOx levels from the gas turbine can be reduced to quite low levels.

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The water vapour from the coal becomes part of the product gas. This reduces the heating value of the gas but it can still be burnt in commercially available gas turbines fitted with appropriate burners and gas control equipment. The added moisture in the fuel gas has the beneficial effect of increasing the power produced by the turbine and thus reducing the cost of electricity produced by the plant.

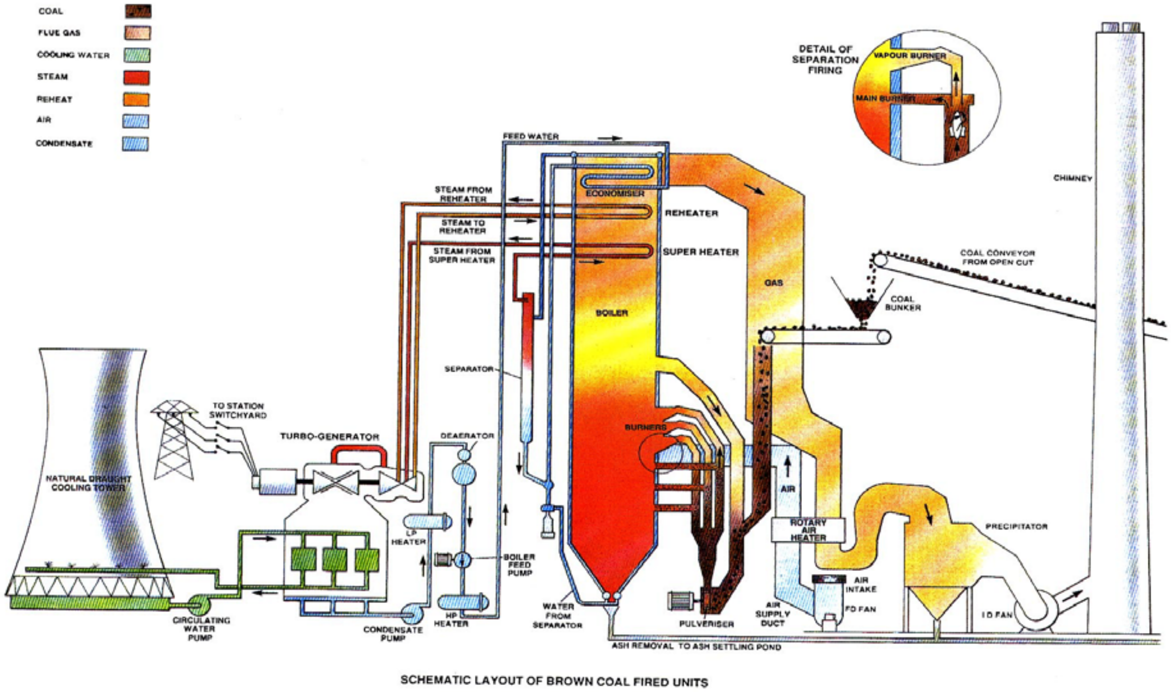

Figure 2: Schematic Layout of Brown Coal-Fired Power Station

III. Technical Performance Of An IGCC Power Plant

The IDGCC process has much higher energy conversion efficiency than conventional steam power plant. For Latrobe Valley coal the conversion efficiency of coal to electricity sent out is predicted to be 38 - 41%, based on the higher heating value (HHV) of the coal. This compares with 28% for the most recent steam power plant in the Latrobe Valley, about 35% for a black coal fired steam power plant and about 38 - 41% for black coal fired IGCC plant.

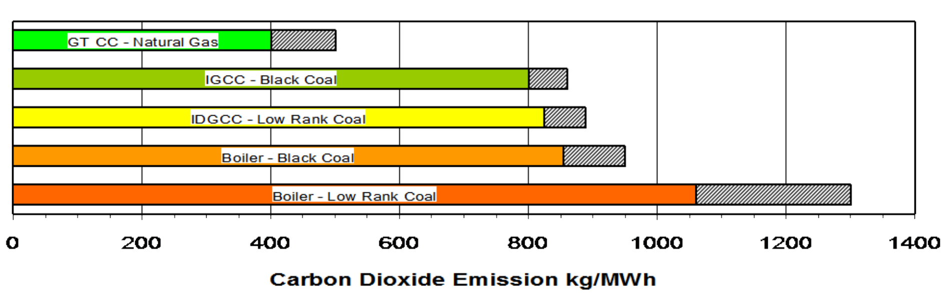

Figure 3: Typical Ranges of CO2 Emissions for Different Fuels and Technologies

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This substantial increase in efficiency leads to a corresponding reduction in emissions of CO2 as shown in Figure 3. The CO2 emission rate for a brown coal fired plant is reduced from 1160 kg/MWh for a steam power plant to 850 kg/MWh for the IDGCC plant. This is lower than the rate for conventional black coal plant and only slightly higher than a black coal IGCC. This means that low rank coals can be considered equally with higher rank coals for power generation when considering their impact on greenhouse gas emission rates. The shaded part of the bars in Figure 3 represents the effect of a range of plant efficiencies and coal composition.

Simulations of a number of process configurations have been performed using commercial software such as ASPEN and GTPRO. A typical configuration for a 125 MW scale plant has a thermal conversion efficiency for Latrobe Valley coal to electricity sent out of 37.9% based on the HHV of the coal, as shown in Table 2.

Table 1: Predicted Data for Victorian Brown Coal 125 MW-Scale IDGCC

Gas Turbine Model: GE 6FA

Input:		**Product Gas:**	
Raw Coal Flow Rate (t/h)	93.1	Gas Heating Value (Net MJ/kg)	4.0
Coal Moisture (% w.b.)	50.0		
Coal ash content (% db)	5.0	Gas Composition (vol %)	
Gross Dry Specific Energy (MJ/kg)	26.3	CO	15.0
Output:		H_2	13.5
Gas Turbine Output (MW)	87.4	CH_4	2.2
Steam Turbine Output (MW)	51.8	CO_2	9.0
Power used in Station (MW)	12.3	H_2O	25.0
Electricity Sent Out (MW)	127.0	N_2 + Ar	34.7
Net Efficiency on HHV	37.9 %	Trace gases	0.6
Net Efficiency on LHV	43.2 %	Total	100.0
CO_2 Emissions (kg/MWh)	889		

IV. SynGas Characteristics

Composition of the syngas depends on the fuel as well as on the gasification process. The typical characteristics of the SynGas as generated from different fuels at some of the IGCC projects are presented below.

	Project						
	PSI Wabash	**Tampa Polk**	**El Dorado**	**Shell Pernis**	**Sierra Pacific**	**IBIL**	**Schwarze Pumpe**
Fuel	Coal	Coal	Pet Coke/ Waste Oil	Vacuum Residue	Coal	Lignite	*
H	24.8	27.0	35.4	34.4	14.5	12.7	61.9
CO	39.5	35.6	45.0	35.1	23.5	15.3	26.2
CH_4	1.5	0.1	0.0	0.3	1.3	3.4	6.9
CO_2	9.3	12.6	17.1	30.0	5.6	11.1	2.8
N_2+Air	2.3	6.8	2.1	0.2	49.3	46.0	1.8
H_2O	22.7	18.7	0.4	--	5.7	11.5	--
LHV, KJ/M^3	8350	7960	9535	8235	5000	4530	12500
T_{fuel}, ^oC	300	371	121	98	538	549	38
Oxidant	O_2	O_2	O_2	O_2	Air	Air	O_2

* Lignite/Oil Slurry with Waste Plastic & Waste Oil

V. GAS CLEAN-UP SYSTEM

The typical steps for Gas Clean-up System aim at particulate removal, sulfur removal and NOx removal. This is achieved as follows:

Particulate Removal: Combination of Cyclone Filters & Ceramic candle Filters

SOx & NOx removal: Combination of steam/water washing and removing the sulfur compounds for recovery of sulfur as a salable product.

Hot Gas Clean-Up technology is currently under demonstration phase and various demonstrations have not been successful so far. Wet scrubbing technology, though with a lower efficiency, still remains the preferred option for gas clean-up systems in IGCC.

Sulfur Removal

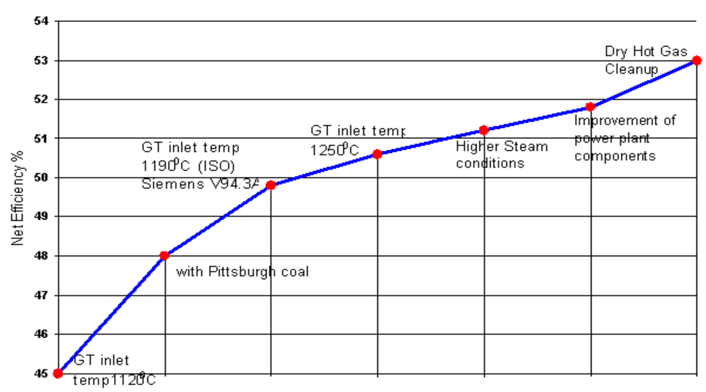
Sulfur from the hot fuel gas is captured by reducing it to H2S, COS, CS2 etc. The current sulfur removal systems employ zinc based regenerative sorbents (zinc ferrite, zinc titanate etc.) Such zinc based sorbents have been demonstrated at temperatures upto 650 0C. Sulfur is also removed by addition of limestone in the gasifier. This is commonly adopted in air-blown fluidised bed gasifiers. In fact, in the case of Air Blown Gasifiers, sulfur is captured in the gasifier bed itself (above 90%) because of addition of limestone. The sulfur captured in the bed is removed with ash.

VI. RELATIVE MERITS OF IGCC OVER CONVENTIONAL PC FIRED TECHNOLOGY

Potential for higher efficiencies

Recent advances in the Gas Turbine technologies have presented great potential towards much higher gas turbine efficiencies. Increasing the firing temperatures and utilizing materials that withstand higher temperatures can increase the efficiency of gas turbine. Continuous developments have been taking place in the newer materials of construction thus consequent higher gas turbine performance. At present the efficiency of gas turbines is in the range of 45-50% which is projected to go upto 60% with the development of H-technology by GE. The advances in gas turbines would improve the overall efficiency of IGCC plant.

Expected Improvements of IGCC Power Plant Efficiency



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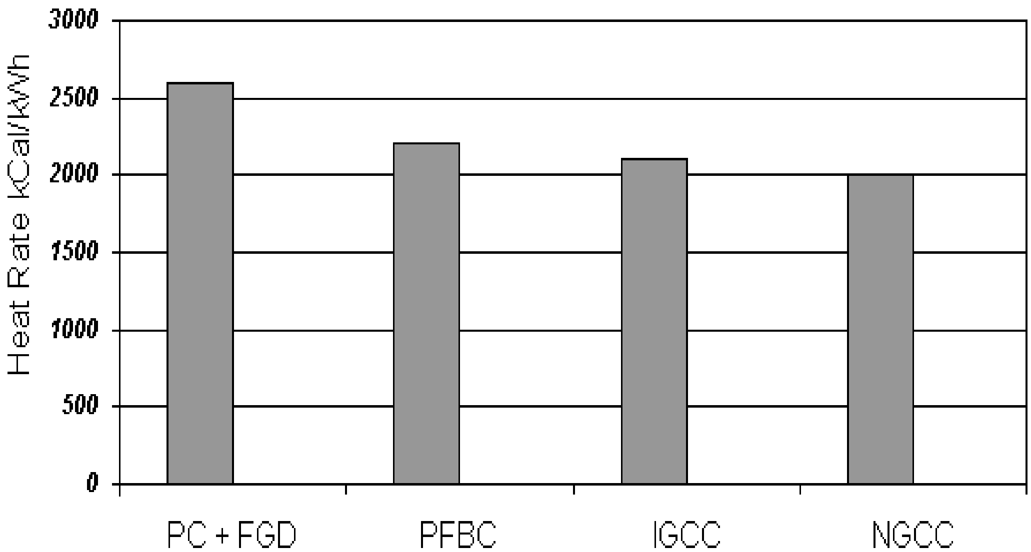
Lower Heat Rates & Increased Output

The heat rates of the plants based on IGCC technology are projected to be around 2100 kCal/kWh compared to the heat rates values of around 2500 kCal/kWh for the conventional PC fired plants.



VII. FLEXIBILITY TO ACCEPT A WIDE RANGE OF FUELS

IGCC technology has been proven for a variety of fuels, particularly heavy oils, heavy oil residues, petcokes, and bituminous coals in different parts of the globe. In fact the same gasifiers can handle different types of fuels.

Environment Friendly Technology

IGCC is an environmentally benign technology. The emission levels in terms of NOx, SOx and particulate from an IGCC plant have been demonstrated to be much lower when compared to the emission levels from a conventional PC fired steam plant. **In fact, no additional equipment is required to meet the environment standards.**

VIII. INVESTMENT COSTS

The costs for the IGCC based plants as reported are noted to be somewhat variable, depending on economy of scale, local labor costs, and applicable engineering standards. Further, gasification costs usually are estimated in combination with the downstream processing equipment necessary for delivery of a syngas suitable for conversion to the designed end product.

Accordingly, gasification investment costs are best addressed on a project specific basis. The typical project costs as reported for different demonstration/commercial projects are as below:

Comparison of IGCC investment costs with other new technologies.

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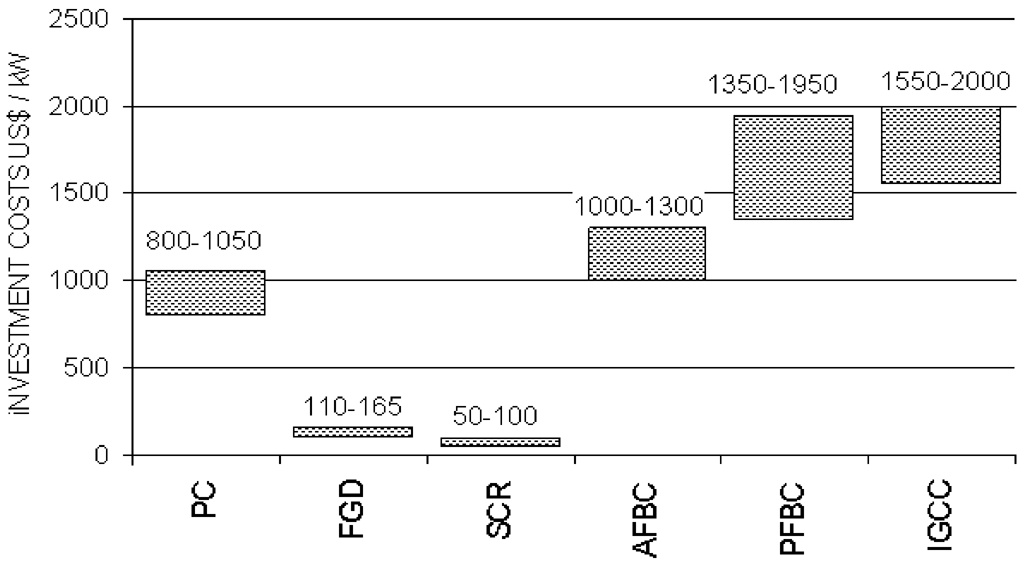

IX. IGCC PERFORMANCE

IGCC plants can achieve up to 45 percent efficiency, greater than 99 percent SO2 removal, and NOx below 50 PPM.

X. STATUS OF IGCC TECHNOLOGY

The technology level for each individual system component of IGCC i.e. gasification block, gas clean-up system and power block have already been established and proven in practice at commercial level. Integrating these individual technologies for the electricity generation is the concept of IGCC. To demonstrate IGCC technology at the commercial level, a number of projects have been in demonstration/operation stage. The fact that the IGCC technology has reached maturity stage,

XI. OPERATIONAL FEEDBACK

Typical problems that have been encountered in various projects relate to the following areas:

Gas Turbine Combustors: GT combustor design has been altered to handle low BTU gas with high mass flow due to problems encountered in gas turbines.

Hot Gas Clean-up System: Breakage of ceramic candle filters & stress corrosion cracking in heat exchangers has also been reported.

XII. IGCC TIME FOR CONSTRUCTION

Time for construction is expected to be similar to PC with wet FGD. However, phased construction (building of the gas turbine first, followed by the gasifier) can improve the economics of the IGCC plant by producing power as soon as the gas turbine is constructed.

XIII. IGCC COMMERCIAL AVAILABILITY

The following key topics describe the commercial conditions under which integrated gasification combined-cycle technology is available today.

IGCC Technology Readiness

IGCC is in the demonstration phase. After the completion of the 100 MW IGCC demonstration at Cool Water, California, in the United States (5-year program completed in 1989), a number of other demonstration projects have entered the design or demonstration phase in Europe and North America.

Most of these projects use entrained gasifiers (e.g., Texaco, Dow, and Shell technologies). The following table provides more detail information on five key IGCC projects (Wabash River, Rampa, Buggenum, Pinon Pine and Puertollano). During the late 1990s, three IGCC plants utilizing petroleum coke have been put in operation in Italy. The results of these demonstration projects will be critical for assessing further the feasibility of these technologies for developing countries.

XIV. IGCC COSTS

IGCC cost projections range from US$1,200 to 1,400/kW; 10 to 30 percent higher than for pulverized-coal with wet scrubbers. IGCC technology may be the technology of choice when high SO2 removal (e.g., 99 percent or higher) and low-NOx emissions (below 100 ppm) are required.

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