ECONO-POWER INTERNATIONAL CORPORATION

ANALYSIS OF AIR-BLOWN GASIFICATION AND SULFUR REMOVAL FOR A VARIETY OF COALS FOR INDUSTRIAL AND POWER APPLICATIONS

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ABSTRACT

Air-blown gasification and single-step sulfur removal systems have used a variety of international coals. There are significant opportunities in the US and elsewhere to use this technology for repowering natural gas power plants, smaller coal-fired power plants and industrial power and cogeneration plants. The fixed bed gasifier and single step gas clean up plant provides economical usage of coal to syngas production for use in medium to large industrial gas turbines. The system is basically shop fabricated with a minimum of field fabrication, minimizing construction time and risk for the gasification island. For larger size plants, clean coal power will offer heat rates that are competitive with natural gas while utilizing existing or reasonably available steam turbines and cooling circuits. Past focus of air-blown gasification has been on the project configuration of the gasification and sulfur removal systems. As the technology is applied in more installations, it is important to evaluate this technology on a wider variety of coals. This technology would provide for Integrated Coal Gasification Combined Cycle (IGCC) plants for even smaller sized industrial plants and offer environmental options to environmental issues on older coal plants. Mercury removal to below detectable levels is possible and economic. These plants can effectively provide coal-based syngas at stable prices well below natural gas.

This paper will explore the technical, environmental and economic aspects of using a variety of US and common import coals with air-blown gasification technology. The paper will also make a summary comparison of air-blown gasification and O_2-blown gasification.

INTRODUCTION AND A BRIEF HISTORY OF COAL GASIFICATION

It is rather ironic to be writing about gasification as coal's answer to the energy problems of the Western World, when it has been around for so long. If we try to define what type of gasifier has been most proven in the Western World we will have to say that it is the horizontal retort. For the whole of the 19th century and well into the twentieth century for village to town to city it supplied heating and lighting to the homes, the factories and the streets.

It did so because coal was the dominant energy source in those days and, although coal was burned in fireplaces and furnaces, it did not have the convenience and ease of distribution of a gas. The coming of oil and later of natural gas largely took that dependence away and the science of gasification waned until the 1930s when Germany began to develop better methods of gasification to provide, not just gas for heating and lighting, but a starting point for the synthesis of liquid fuels. And so the Lurgi and Winkler gasifiers were born and they worked to fuel the political ambitions of the political leaders to supply the German forces with fuel made from coal.

After WWII, a new phenomenon developed in the world, the use of sanctions to try to force change on an unpopular type of government and once again the Lurgi gasifier came to commercial prominence. Using the same science as the Germans and improving it, the government of South Africa was able to withstand outside pressure for many years. Once again coal had come to the rescue.

While this was going on, the Western World, and especially the United States, was becoming more and more dependant on crude oil until they developed into a situation where they became dependant on small foreign countries, with large oil reserves to maintain economic growth and life style. When a consortium of these small countries demanded more money for their oil, the then President of the US decided it was time to look for alternatives. As in many previous times, the most attractive alternative was coal.

That decision of President Nixon started the research and the developments that led to the availability of some of the technologies we have today. It may not have been a very satisfying task for those who worked on it because as often as not when we thought we were to move forward on gasification, those small countries changed their attitude and the lower cost of oil made gasification economically unattractive. This is no longer the case, the spectacular growth of China and with it a new, large demand for crude oil and natural gas, has pushed the price beyond anything dreamed of when President Nixon created Project Independence; and hence the new buzz word is once again coal gasification.

THE GASIFIERS

It may also be ironic that China, who many blame for the high cost of oil prompted the drive to find ways of using coal efficiently and kindly to the environment, are the world's greatest users of coal gasification. Throughout China, coal, coke and anthracite are being converted to fuel gas and synthesis gas in many hundreds of gasifiers. These are mostly fixed bed gasifiers that operate in much the same way as the retorts of the 19^{th} century did.

The Chinese largely use anthracite or coke in order to avoid the production of tar but one type of gasifier, used primarily to make fuel gas, does produce tar of a quality that can be sold in China. It is this gasifier design, which EPIC is developing and which we will compare economically, technologically and in complexity with the gasifiers that have arisen, like the Phoenix from the ashes, to save the Western World from economic ruin.

The oldest and most proven type, the fixed bed gasifier, the second oldest the fluidized bed gasifier and the newest, developed to use coal, after many years of operation in refineries and chemical plants, the entrained flow gasifier.

Fixed Bed Gasifiers

Lurgi Dry Bottom - In the 1930s, the Lurgi Company introduced a fixed bed gasifier that throughout the 1939-1944 World War played a major part in converting coal to synthesis gas to processes that produced liquid fuels for the German war machine. After the war a large number of these gasifiers, installed at Sasolburg in South African, were the basis by which half the liquid fuels used in that country were produced during the embargo resulting from their apartheid policies. While use in syngas applications required the units to be operated on 95% pure O_2, in most of these installations, the Lurgi design included air blown gasifiers to provide the fuel gas for a gas turbine and heat recovery system, much as is today proposed as an "Integrated Coal Gasification Combined Cycle" (IGCC). The basic Lurgi gasifier is shown in Figure 1 below.

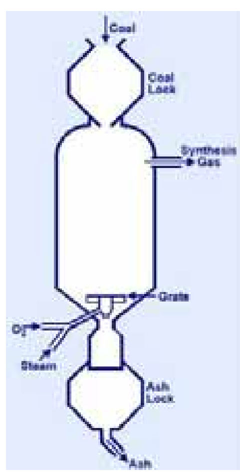

Figure 1 – Lurgi Fixed-Bed Gasifier[1]

Like all fixed bed gasifiers, the Lurgi gasifier operates with the coal flowing counter to the gas that is produced. In this way heat in the gas is transferred to the coal as the gas rises to the exit. As a result the gas temperature at the exit is low enough that it is not necessary to consider the use of a heat recovery system. It also means that it is not necessary to dry the coal, as the hot exiting gas will drive off any moisture from the coal before it enters the gasification zone. The typical gas composition is 17% CO, 39% H_2, 32% CO_2, 0.5% N_2, 10.5% CH_4 and 0.8% C_xH_y with a HHV of 298 BTU/SCF (LHV of 268 BTU/SCF).

The hot gas rising through the upper part of the coal also drives off much of the volatile matter in the coal as tar and aromatic oil. This can result in the tar being very heavy and difficult to handle. This problem has been solved in the EPIC gasifier design by allowing only 40 to 50 per cent of the gas produced in the lower stage to pass through the upper stage (as further discussed below). In this way, not only is the tar produced much lighter but more of the volatile matter in the coal passes into the lower stage of the gasifier where it is converted into syngas. This makes it much easier to collect the tar and re-inject it into the lower stage where it is also turned into syngas.

EPIC 2ST-3.6 - In the lower part of the EPIC two-stage gasifier, producer gas reactions take place between carbon in the coal and oxygen in the air to provide a hot gas, which is, predominantly, carbon monoxide and nitrogen. This hot gas rises through the middle level, where some level of hydro-gasification takes place, producing methane, and certain shift reactions take place producing hydrogen and carbon dioxide from carbon monoxide and steam in the gas. In the upper levels the heat causes some pyrolysis of the coal that releases oils and tars and finally dries out any water that was in the coal.

The use of coke ovens over the years has provided the experience necessary to maximize the carbon content in the char while removing no more than is necessary of the volatile matter. In this way a more or less smokeless char can be produced and lesser problems created in disposing of the tars and oil produced. See Figure 2 below for the EPIC two-stage gasifier:

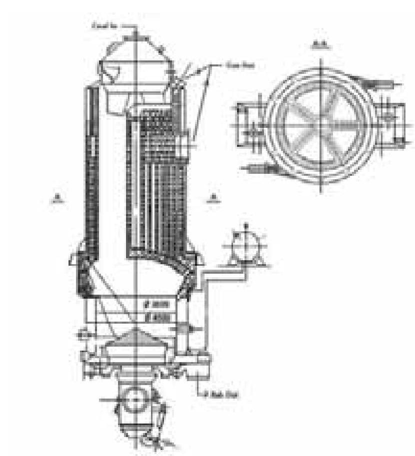

Figure 2 – EPIC 2-stage Fixed Bed Gasifier[2]

A framework of refractory bricks are built in the upper part of the two-stage that provides 5 large vertical passages through which the coal travels and narrower passages through which some of the gas produced in the lower stage feeds to a lower outlet. The rest of the gas rises through the coal and exits through the top. The gasifier internals are long lasting. The picture below (Figure 3) shows a typical gasifier after ten (10) years of continuous operation.

Figure 3 – EPIC Gasifier Internal Refractory[2]

By adjusting the relative amounts of gas exiting the upper and lower levels the amount and quality of the oils and tars can be controlled so that the tar is relatively light and can be easily separated from the gas.

In all gasifiers there will be a quantity of hydrogen sulfide produced, which is proportional to the sulfur content of the coal. The efficiency of conversion of the coal to clean gas is about 80-83%, but will depend on the amount of sulfur and ash that has to be removed. The typical gas composition using PRB coal is 30.6% CO, 14.6% H_2, 4.0% CO_2, 44.8% N_2 and 6.0% CH_4 with a HHV of 207 BTU/SCF (LHV of 196 BTU/SCF).

Although there is a small loss of efficiency due to the heat lost in the removed ash, the major effect of ash content is its relationship to the output of the gasifier. Typically it is best if the ash content of the coal is no more than 10 to 12% but it can go as high as 18% without adversely affecting the performance of the gasifier.

Entrained Flow Gasifiers

For large IGCC plants, entrained flow gasifiers are currently preferred because of their high capacity. All entrained flow gasifiers are O_2-blown, requiring the installation of an air separation plant as part of the plant. To provide normally required power plant availability, a spare gasifier will normally be required, significantly adding to the cost of the plant. The air separation plant and spare gasifier train also adds complexity for operations and maintenance.

The entrained flow gasifier converts pulverized coal to gas, at a high temperature, in an oxygen atmosphere by the partial oxidation of the carbon in the coal to carbon monoxide, freeing the hydrogen in the coal and converting a small percentage of the carbon to carbon dioxide, depending on the efficiency of the process.

Shell - The most efficient entrained flow gasifier is that developed by the Shell Company from their partial oxidation process, used extensively on refineries and chemical plants for the production of hydrogen from feeds ranging from refinery bottoms to natural gas (See Figure 4 below). The majority of these units were fitted with heat recovery steam generation equipment that made their overall efficiency over 90% when the value of the steam was taken onto account.

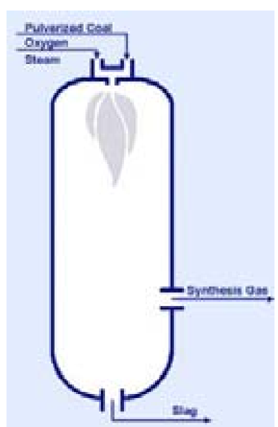

Figure 4 – Shell Entrained Flow Gasifier[1]

To add coal to the gasifier, Shell decided to blow the coal into the gasifier with nitrogen gas, although they did consider using product gas.

Gasification takes place at a temperature of about 2,700^{O}F and produces a gas consisting of approximately 65% carbon monoxide, 25% hydrogen, 4% carbon dioxide and 6% nitrogen with a HHV of 291 BTU/SCF (LHV of 257 BTU/SCF).

A green field commercial power plant of 250 MW using a single Shell gasifier was built in Buggenheim, Holland and has operated satisfactorily for a number of years.

GE (formerly Chevron Texaco) - The second entrained flow gasifier to operate on coal was developed by Texaco from their partial oxidation process. The philosophy of the Texaco partial oxidation system design was essentially one of simplicity (see Figure 5 below). To keep cost to a minimum, no attempt was made to recover heat from the exiting gases and cooling was achieved by spraying water into a tower into which the gases passed.

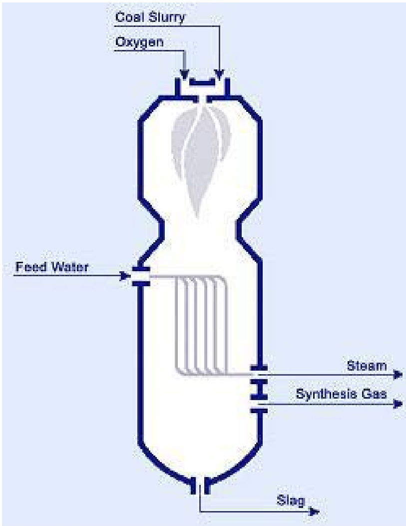

Figure 5 – GE Entrained Flow Gasifier[1]

When the reactor was converted to the use of coal, water was chosen as the transfer medium for the pulverized coal using dirty water recovered from the cooling vessel as the source.

The gasifier also operates at a temperature of 2,700^{O}F, and produces more hydrogen and less carbon monoxide and a higher carbon dioxide concentration. The gas produced consists of approximately 50% CO, 35% H_2, 14% CO_2 and 1% N_2 with a HHV of 275 BTU/SCF (LHV of 247 BTU/SCF).

A demonstration unit of the gasifier was built at Cool Water in California and has operated since 1984 and a repowering unit has operated satisfactorily in Tampa with support from D.O.E. The design passed to Chevron when that company took over Texaco and was sold to General Electric in 2004.

Conoco Phillips (formerly Dow-Destec and Global Energy) - As a means of solving the complexity of the heat recovery process, Dow Chemical Company developed a two-stage version of the entrained flow gasifier. This design consisted of a first stage horizontal vessel and a vertical second stage vessel situated above the first stage (see Figure 6 below).

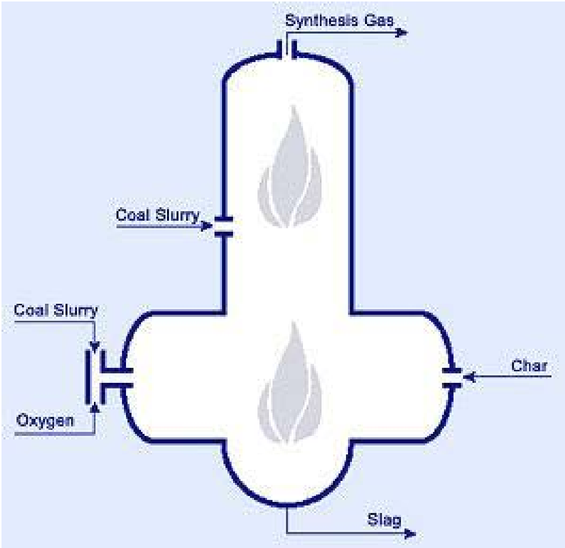

Figure 6 – E-Gas Entrained Flow Gasifier[1]

Part of the coal to be gasified is injected as water slurry into the first stage, which also operates at 2,700^{O}F. The hot product gas from the first stage flows upwards into the second stage. There the rest of the coal, again as a water slurry, is injected and is gasified while at the same time the hot gas is cooled by providing the heat needed for gasification. This allows a fire tube boiler to be used as a heat recovery steam generator. The composition of the product gas (sub-bituminous coal) is approximately 43% CO, 33% H_2, 20% CO_2, 2% inerts (N_2) and 2% CH_4 with a HHV of 266 BTU/SCF (LHV of 247 BTU/SCF).

This process was used in a repowering installation at Wabash, which has operated satisfactorily on coal and petroleum coke for a number of years. Conoco/Phillips is now actively promoting the technology after the 2004 acquisition from Global Energy.

SULFUR REMOVAL SYSTEMS

There are many systems for removing hydrogen sulfide from gas but they can be divided into 3 broad groups. In the first group are such materials as iron oxide and activated carbon, both of which capture the sulfur and then release it in the presence of oxygen. They are, however, only suitable for treating small quantities of gas.

The most used systems are those in which the hydrogen sulfide is dissolved in a liquid and then recovered due to a change in pressure or temperature. In most cases these processes must be linked to a second process, normally the Claus Process, which converts about 50% of the recovered hydrogen sulfide to sulfur dioxide, which is then mixed with the rest before passing the mixture over a catalyst to produce elemental sulfur and water.

There are a number of other processes in which the solvent carries a compound that chemically combines with the sulfur to form an intermediate compound that releases the sulfur in the presence of oxygen. Such a process is the Stretford Process. This process relies on the fact that in the presence of a mixture of sodium carbonate and sodium bicarbonate, hydrogen sulfide reacts with sodium carbonate to form sodium hydrosulfide and sodium bicarbonate and that further contact with oxygen releases the sulfur as sulfur/water foam.

This takes place in a packed column from which the solvent passes into a reaction vessel where air provides oxygen to free the sulfur as a water/sulfur foam. This foam floats to the surface of the vessel where it flows over a weir into a collection tray and thence to a vessel where the contained water is evaporated and the sulfur is melted.

Unfortunately this process initially occurred extremely slowly the reaction was accelerated up to a commercial rate by the addition initially of sodium salts of anthraquinone disulfonic acid (ADA) and later by the addition of sodium vanadate. This process was adopted in China more than twenty years ago and renamed by them as the ADA process. The scientist working with the process came to the conclusion that it should be possible to speed up the reactions by the use of a catalyst and a search began.

After some time two materials were found that allowed the quantity of ADA and sodium vanadate to be reduced. One was an extract of lignin and the other a compound given the name of PDS for which the process was renamed the PDS Process.

Work continued and some ten years ago a catalyst was finally discovered that permitted the reaction to proceed by the use of the catalyst alone. This catalyst known as 888 has largely replaced the PDS compound and has now been used in most ammonia and urea plants for the last ten years. This is the process chosen by EPIC to reduce the sulfur content of the gas produced by its gasification system to parts per million.

EPIC has chosen this process for a number of reasons. First for its inherent safety since at no time is the hydrogen sulfide concentration higher than that in the raw gas exiting the gasification unit and once the raw gas enters the absorber tower of the process it only exists as sodium hydrosulfide or as elemental sulfur. Secondly the process takes place in a single train and involves only simple vessels and pumps.

The EPIC 888 Sulfur Removal System - The process uses an aqueous solution of sodium carbonate and sodium bicarbonate in suitable proportions to give the solution a pH of between 8.5 and 9.5. The process is based on the principle that hydrogen sulfide is absorbed into the solution by changing the balance of carbonate to bicarbonate and by converting the carbonate and the hydrogen sulfide into sodium hydrosulfide and sodium bicarbonate.

The process has a major advantage over other clean up processes in that the gas is cleaned and the sulfur recovered in a single plant. Most other processes that remove hydrogen sulfide from gas use a second process which burns about half of the hydrogen sulfide to form sulfur dioxide. The latter and the former are reacted over a catalyst to produce elemental sulfur and water. The EPIC system uses a special catalyst to stimulate the above reactions and at the same time remove other trace sulfur compounds.

A typical process treating about 1,000,000 cubic feet per hour of gas will use from 10,000 to 14,000 cubic feet per hour of solvent, depending on the sulfur content of the gas. The resulting clean coal gas can achieve over 99.5% efficiency, depending upon the coal, and the gas may then be passed over a polishing bed when emissions regulations require a lower value. Figure 7 shows an overall flow chart of the process.

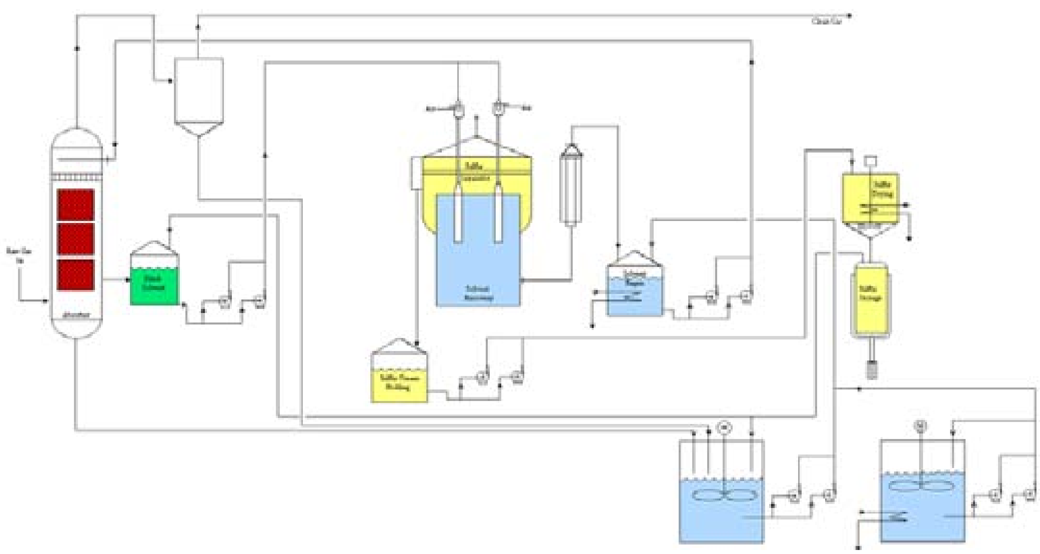

Figure 7 - Simplified Version of the Process Flowchart[2]

Raw gas from the gasification section is passed into a packed wash tower in counter current flow relative to the solvent. Clean gas leaves the top of the tower and the sulfur-rich solvent passes to a heated degassing vessel where residual gas is driven off and mixed with the clean gas stream. The solvent is then passed to an aeration vessel where air is added before entering a liquid filter where oxidation reactions take place resulting in the separation of the sulfur as a cream on the surface of the vessel. The solvent exits from the bottom of the filter and is recycled. The sulfur cream is skimmed from the top and passes into a sulfur-polishing vessel where it is heated to drive off any remaining solvent. The sulfur, now molten, flows downward into a second vessel and into a tray where it solidifies. The only vent stream from the process is the 'used' air from the aeration vessel.

The wash tower portion of the system can operate at elevated pressures (such as those required for gas turbine combustors), which reduces the vessel size of the absorber tower. Many of the additional vessels and items, such as pumps, will be skid mounted, facilitating the modularity of the system. The process has been used extensively in small and medium sized ammonia and urea plants for a number of years and is ideally suited to clean up gas to a quality satisfactory to any gas turbines which the EPIC syngas could use.

COAL FOR GASIFIERS

O_2-Blown gasifiers typically prefer bituminous and lower volatile coal. In most gasification systems, sulfur content of the coal is only a design consideration for the sulfur removal system and not an operating limitation on the gasifier.

The composition of coal and some of its physical properties have important influences on the gasification process. Young coals such as Lignite and sub-bituminous coal generally contain a high percentage of moisture and oxygen while old coal, such as bituminous coals and anthracite tend to become sticky as they are heated. As a result, in the entrained flow gasifier the coal must be dried because, if the water enters the gasifier, some of it will react with CO to form hydrogen and CO_2. On the other hand, moisture content has no effect on the gasification process in the fixed bed gasifier because the hot gas leaving the gasifier dries the coal as it enters the gasifier.

Since oxygen takes place in the gasification process coals containing more oxygen will need less oxygen or air to be added. For example, an E-gas gasifier system requires 2,220 tons per day of O_2 for sub-bituminous coal, 2,330 tons per day of O_2 for bituminous coal and 2,540 tons per day of O_2 for pet coke[3]. The oxygen in coals is particularly important in air-blown gasification as any oxygen in the coal will reduce the amount of air required for the gasification reaction and thereby reduce the resulting nitrogen in the syngas.

For fixed bed gasifiers, the coal is fed into the system in lumps, rather than being pulverized and slurried; hence considerations for handling must be made. The ash content of the coal is important as higher ash can impact the overall throughput of the gasifier. A major consideration for fixed-fed gasifiers is the swelling nature of the coal. If the swelling nature of the coal is high, mechanical means must be included to break up any larger masses in lower temperature areas (top part) of the gasifier. The other major consideration is the ash fusion temperatures. If the gasifier is not a slagging-type (like the BGL discussed above), the slag cannot be allowed to form or the grate will be impacted, causing major disruption in the gasification process.

Provided that the design of the gasifier is such that volatile matter can be easily handled without the formation of heavy tars, higher volatile content of the coal is desirable as the tars produced can be recycled into the gasification zone and increase the overall gasification efficiency. The EPIC 2ST-3.6 gasification system makes specific allowance for the volatile removal in the top (2^{nd}) stage.

MERCURY CONTROL WITH GASIFICATION

Mercury in varying minute concentrations is contained in almost all coals. As the US is now under federally mandated mercury reductions, increased emphasis and much research is being applied to controlling mercury from the use of coal.

In a conventional coal boiler, essentially all of the mercury in the coal is released in the combustion process and the large flue gas volumes as a result of the combustion process requires very large mercury treatment and/or capture systems. Some of the systems are in full-scale demonstrations but other technologies are being offered.

Mercury control from coal gasification represents a significantly easier and considerably more economical alternative to flue gas control systems. The primary reason is that mercury control is applied to the syngas before it is burned, resulting in a significant volumetric reduction from handling flue gas.

For entrained flow systems, essentially all of the mercury in the coal will be present in the syngas. Since syngas volume is considerably less than flue gas, mercury removal systems greater than 90% can be relatively easily applied to the syngas stream.

For fixed bed gasifiers, the mercury task is easier because the counter flow heat transfer between the coal and the syngas cools the gas considerably before it leaves the gasifier. Tests were carried out at the Westfield Research Station of British gas on a Lurgi gasifier there, which showed that the majority of the mercury was found in the quench liquid used to cool the gas and separate the tars, etc. The existence of mercury in the gas was checked using neutron activation, which can detect mercury down to a level of 3 parts per billion. In a test using a Pittsburgh #8 coal, which contained 0.56 ppm mercury, the scrubbing water was found to contain 0.49 ppm but the detection system showed that the mercury content of the syngas was less than the lowest detection limit of 3 parts per billion.

It is not surprising that this should happen since the scrubbing water temperature is no more than 100 F and the boiling point of mercury is 675 F that any mercury will condense out in the scrubbing water. In the EPIC system, the gas is not only scrubbed in the gasification unit but it late passes through a packed column containing a water based solvent as it enters the sulfur removal system.

In spite of this, to provide mercury removal to below detectable levels, EPIC also has made provisions to install an activated carbon bed after the sulfur removal system. This installation, where required, will add only minimal capital cost (less than $5 per kW for a large system) and the carbon utilization rates are so low that virtually no operating costs will be associated with mercury removal. A typical vessel configuration is shown in Figure 8 below:

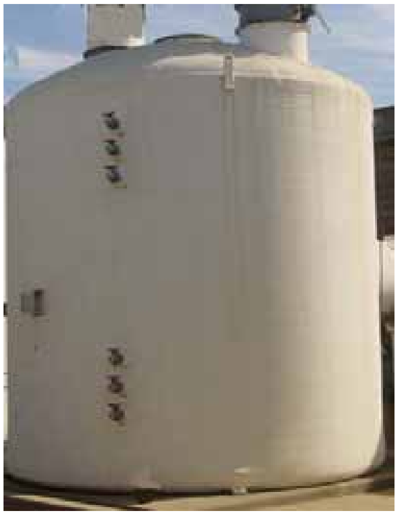

Figure 8 – Sample Carbon Vessel for Hg Removal[6]

Mercury control and the associated potential enviro-economic benefits in the form of mercury credits may be a significant contributing factor to a major shift to coal gasification as the preferred method for future power generation.

IGCC COMPARISONS

Oxygen-blown technology requires an associated air separation plant, which increases capital and operating costs for these facilities. These systems are all oxygen-blown systems and operate at much higher temperatures and pressures than the EPIC air-blown system.

In addition to increased size, and higher capital and operating costs, the larger systems are basically single-train systems. These gasifier systems are significantly larger than the EPIC system and represent an investment greater than $400 million in order to compete economically. In cases where high reliability or availability is required, the gasification plant must be doubled or tripled for redundancy, significantly adding to capital costs. There is no indication that any of these companies are considering conversion of their technology in order to compete for opportunities in users of less than 250MW.

Harvard University performed a study "Deploying IGCC in This Decade with 3 Party Covenant Financing", published in July 2004, in which the major gasification technologies were compared as to capital, operating and other comparative cost. Note that EPIC has added a 6th column that provides EPIC's comparison for an equivalent sized plant (Figure 9 below). EPIC IGCC plant will provide greater reliability with multiple units and the inherent redundancy created. Additionally, the EPIC system does not require an air separation plant, which accounts for a major portion of the capital cost differences.

Gasification Technology Comparison

* Harvard IGCC Report 2004	IGCC 4* ConocoPhillips	IGCC 5* Texaco Q	IGCC 6* Texaco HR	IGCC 7* Shell	IGCC 8 EPIC
Design and Construction:					
Plant Size (MW)	550	550	550	550	550
Output per single Gasifier	275	275	275	275	15.7
Total No. Of Gasifiers	3	3	3	3	37
No. Of Operating Gasifiers	2	2	2	2	35
No. Of Spare Gasifiers	1	1	1	1	2
Total Plant Cost - EPC ($/kW)	$1,300	$1,270	$1,450	$1,620	$1,100
Operation:					
Fuel Cost ($/mmBtu)	$1.24	$1.24	$1.24	$1.24	$1.24
Plant Efficiency (%)	40%	36%	39%	41%	38%
Heat Rate (BTU/kWh HHV)	8550	9450	8750	8370	9000
Plant Capacity Factor (%)	0.85	0.85	0.85	0.85	0.98
Annual Generation (MWh)	4095300	4095300	4095300	4095300	4,721,600
Financing:					
Pre-tax WACC	11.9%	11.9%	11.9%	11.9%	11.9%
Estimated Cost of Energy:					
O&M (cent/kWh)	0.80	0.80	0.80	0.80	0.70
Fuel (cent/kWh)	1.06	1.17	1.09	1.04	1.19
Capital (cent/kWh)	2.74	2.68	3.06	3.42	2.32
Cost of Energy (cent/kWh)	4.60	4.65	4.94	5.25	4.21

Figure 9 – IGCC Economic Comparisons

As a comparison of EPIC Air-blown IGCC with the two major US O_2-blown IGCC plants, the following Figure 10 is presented. The comparison is based upon a nominal 250 MW plant, based upon a GE Frame 7FA gas turbine in combined cycle.

	TECO-Polk[4]	**Wabash Coal**[5]	**Wabash Pet Coke**[5]	**E-Gas PRB**[7]	**EPIC PRB**[2]
Plant Output (MWe)	250	252	252	Same	263
Heat Rate – BTU/kWH – HHV	9,650	8,600	8,493	9,553	8,800

Figure 10 – IGCC Performance Comparisons

TECO-Polk heat rate increases to over 10,000 BTU/kWH LHV when the gasification and/or air separation outage generation is replaced by liquid fuel. The large auxiliary load for the air separation plant is greater than the gasification auxiliary and syngas compression requirements for the air-blown system.

The EPIC air-blown system for IGCC will require several gasification trains. While the number of such trains is high, the low pressure and lack of the need for an air separation plant result in a significant capital cost reduction for an equivalent gasification plant for a large IGCC. The larger number of gasification trains offers another significant benefit for plant operation, essentially 100% gasification system availability. Forced outage on even a couple of air-blown gasification trains will not have a significant adverse affect on the overall plant. Gasification availability in excess of 95% is easily attainable.

AIR-BLOWN SYNGAS ANALYSIS WITH VARIOUS US COALS

One of the goals of this paper is to provide some general syngas properties when common US and import coals are gasified in air-blown gasification. As was indicated above, higher oxygen containing coals result in higher syngas heat values. The moisture in the coal will be driven off in the upper stage of the gasifier and will be recovered in subsequent wet scrubbing loops. On some high moisture coal, the EPIC system may actually produce small amounts of water. Lower moisture coals will only require minimal water makeup for the gasification reaction.

The flowing Figure 11 provides the general air-blown syngas characteristics with the general coals as shown:

	PRB	Utah	US-SW	US- MW	WVa LS	WVa HS	Colombia
# Coal per 100 MMBTU Syngas (Tons)	6.89	4.68	5.65	5.8	4.74	4.81	4.95
CO	30.6	28.2	29.4	28.7	28.2	28.3	28.3
H2	14.6	11.9	14.4	12.9	11.1	11.4	13.1
N2	44.8	52.3	47.7	50.5	53.8	53.0	50.2
CO_2	4.1	3.2	3.5	3.3	3.0	3.1	3.3
CH4*	6.0	4.4	5.0	4.6	3.9	4.2	4.2
SO_2 #/MMBTU **	0.011	0.02	0.03	0.081	0.019	0.048	0.018
HHV BTU/#	3270	2684	3034	2832	2549	2620	2830
HHV BTU/SCF	208.3	176	193	183	168	172	183
LHV BTU/SCF	196	166	182	173	159	163	172

* Includes CxHy
** When burned and without EPIC H2S Polishing System

Figure 11 – Air-Blown Syngas from Common US and Import Coals

CONCLUSIONS

There are many types of gasification systems, some with considerable operating experience. The larger O_2-blown systems have generally evolved from oil residual gasification systems and represent large capital commitments. Redundant gasification capacity is necessary to achieve annual operating availability above 85%. The IGCC configuration requires an air separation plant, further increasing the gasification plant complexity.

Air-blown gasification has been proven in many installations and the syngas modifications in boilers and/or gas turbines is similar to that required for O_2-blown systems. The lower capital cost, high availability and excellent plant heat rates make air-blown gasification an excellent choice for base-load IGCC plants. The modular nature of air-blown gasification plants also allows application for relatively small industrial plants for cogeneration, boilers, kilns, process furnaces, etc. Mercury removal is easily (and relatively cheaply) accomplished with air-blown gasification.

The ability to use most US and import coals offers a broad US opportunity for air-blown gasification for industrial and utility refueling, new IGCC construction and IGCC repowering and retrofit of existing coal stations. Air-blown gasification represents a viable coal-based solution for new power or cogeneration or to replace current natural gas use in power, cogeneration and industrial fuel applications.

Sources of artwork or information:

1. DOE-NETL – Coal Gasification – Gasifiers – Description
2. EPIC Internal Documents and Performance Models
3. http://www.coptechnologysolutions.com/egas/tech_specs
4. DOE-FE-0469 – TECO Polk Project Performance Summary
5. DOE-FE-0448 – Wabash River Project Performance Summary
6. Photo courtesy of US Filter
7. “Deploying IGCC in This Decade with 3Party Covenant Financing” – Rosenberg, Alpers & Walker – Harvard University John F. Kennedy School of Government – May 2005 Revision

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