SECTION 8. EVALUATION OF PROMISING PROCESSES FOR PRODUCING OTHER GASES

At least two gases, other than pipeline gas and fuel gas, are of industrial interest. One of these is a hot raw gas that could be used for gas turbine fuel; the other is a high temperature, high pressure producer gas which could be used to reduce iron oxide in the steam-iron process for hydrogen production.

A. Gas Turbine Fuel

A hot raw producer gas suitable for use in gas turbines could be produced efficiently at 150 psig by an airblown pressurized fixed-bed gasifier.

The cost of compressing producer gas from atmospheric pressure to 150 psig is estimated to be 25 cents per MM Btu in the gas compressed. This cost, when added to the cost of a cold clean fuel gas suitable for compression, as produced from a Wellman-Galusha producer, gives a gas cost of 62 cents per MM Btu at turbine inlet pressure. This cost would be too high to be widely competitive with natural gas. However, a hot raw gas produced in a pressure gasifier would be competitive. Such a gas could be produced at a temperature of 1100 F by a Lurgi generator blown with air instead of oxygen.(62)

1. Basis for Evaluation: As a basis for economic evaluation of a gas turbine fuel producer, a 3.7 meter ID Lurgi gasifier has been used without a spare. It is assumed that Pittsburgh seam coal can be fed directly to this gasifier without pretreatment or ash recycle. It has also been assumed that a simple hot gas multiclone dust removal unit will be adequate to dedust the raw gas for use in a gas turbine.

A simplified process scheme for the system is shown in Figure 8-1. The economic evaluation of this gas producer follows the same guide lines as established for the pipeline gas plant insofar as cost of labor, maintenance, fixed charges, and utilities are concerned.

2. Procedure for Evaluation: During the initial screening of promising processes, heat and material balances were derived from the information presented by Lurgi for airblown fixed-bed operation at approximately 150 psig.(63) The results of these heat and material balances show that 0.88 lb of steam per pound of coal, and 3.1 lb of air per pound of coal are required as gasifier raw materials.

The gas yield is 72 scf per pound of coal, with the following analysis: 14.6 percent CO_2, 22.3 percent H_2, 14.0 percent CO, 3.5 percent CH_4, 44.6 percent N_2, 0.5 percent NH_3, and 0.5 percent H_2S. This gas has a heat potential, including heating value of gas and tar, plus sensible heat, of 171 Btu/scf; this is equivalent to a 91 percent thermal efficiency for heat in the gas compared to gross heating value of the coal.

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(62) See Process 37, Table 3-1, and Appendix 3.5.

(63) See Section 5 B.4 and Appendix 5.6.

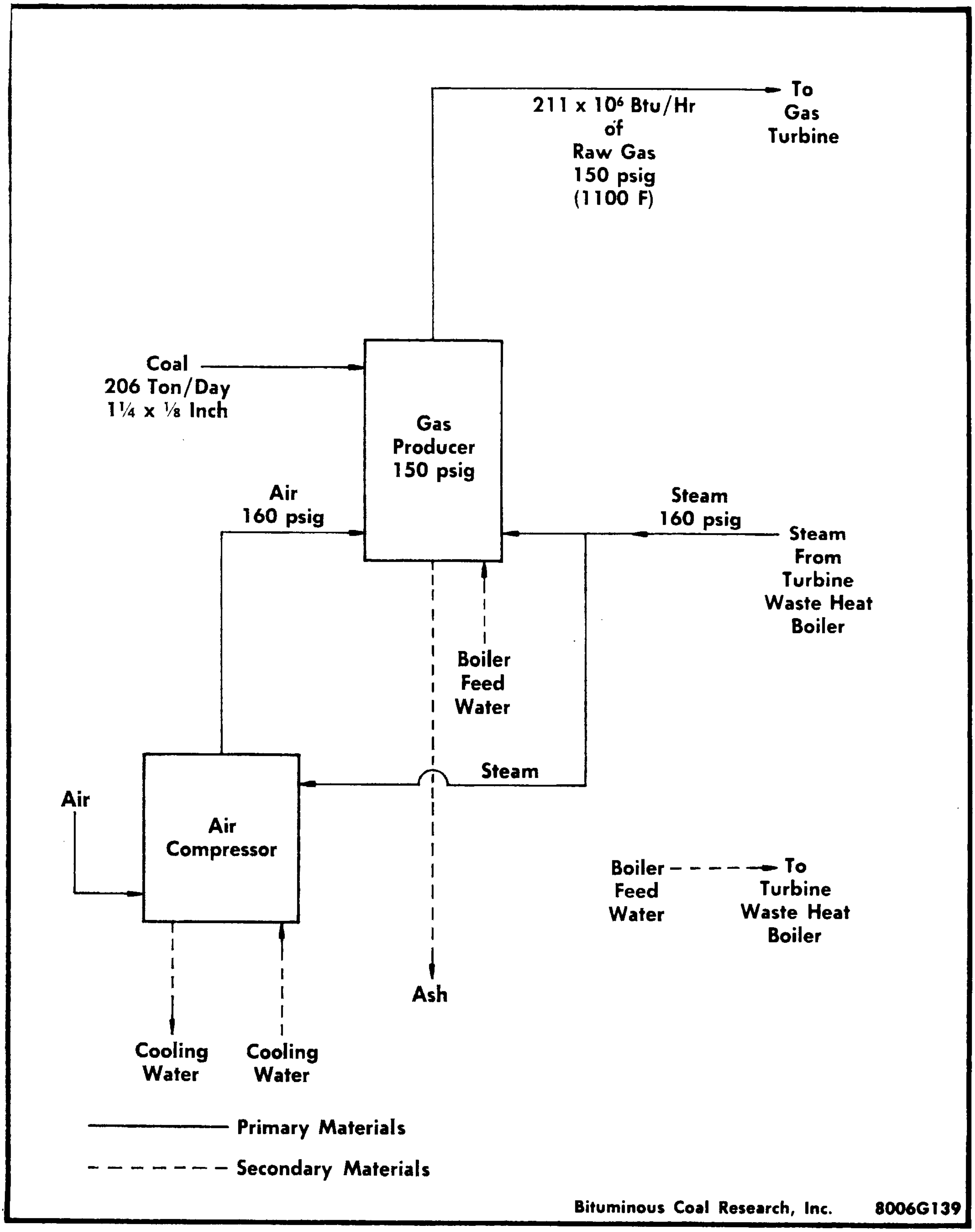

Figure 8-1 Simplified Process Scheme for Production of 150 psig Gas Turbine Fuel Using the Airblown Lurgi Gas Producer

The capacity of a single 12.1 ft ID airblown gasifier was given by Lurgi as 1.23 MM scfh. This, along with the gas yield and efficiency, gives a capacity of 8.6 tons per hour of coal, or 206 tons per day, for such a size gasifier. These data, and costs previously supplied by Lurgi, were used for the economic evaluation of this gasifier for production of gas turbine fuel.

Assuming that the air compressor is a steam turbine driven centrifugal unit, the steam required at 160 psig--the same steam pressure as is required for the gasifier--would be 48,800 lb per hour. The Lurgi gasifier requires 15,100 lb per hour of steam, but it produces in its own jacket 4,900 lb per hour of steam so that a net of 10,200 lb per hour of steam is required in addition to that for the air compressor.

If the hot gas from the Lurgi gasifier is to be used directly in the turbine, the exhaust gases from the turbine would contain twice as much heat as would be required to generate the 59,000 lb per hour of total steam needed for the gasifier feed and the air compressor steam turbine. It is therefore assumed that steam will be available from the gas turbine waste heat boiler at 160 psig in sufficient amount to feed the Lurgi gasifier and the air compressor steam turbine, so that no additional coal is required for this steam generation. The cost of the waste heat boiler for generating the steam, as well as the cost of any regenerators for turbine air preheating, would be included as part of the gas turbine cost and is not a subject of this cost study.

The cost of boiler feed water to the steam turbine waste heat boiler is chargeable to this process and is calculated from the amount of steam used in the gasifier, plus the amount of blow-down from the boiler; this boiler feed water is assumed to be five percent of the boiler capacity. In addition, circulating cooling water is required for the condenser for the steam turbine drive and the compressor intercoolers, so that a total circulating cooling water requirement of 3,000 gal/min is needed for this unit. Also, 25 gal/min of once-through fresh water is charged for ash sluicing.

It is assumed that 50 kw of power is required for the gasifier and its process auxiliaries and another 50 kw is required for the coal handling equipment and lighting and instruments.

Labor requirements are three men per shift to furnish the necessary operating supervision of the gasification and compression system, the coal conveying and charging system, and ash discharging and miscellaneous operations.

The investment cost of a 10 atm Lurgi gasifier and its accessory coal and ash hoppers, dust removal equipment, and valves and controls, delivered in the United States, is estimated at $1.15 million. The air compression and coal handling systems have been estimated at $200,000 and $100,000, respectively, making a total equipment cost of $1.45 million. It is expected that this equipment could be installed and suitably housed and piped for approximately $1 million, giving a complete cost of $2.5 million.

3. Results and Discussion: The cost study of a 150 psig hot gas producer shows that with coal at $4 per ton, the fuel gas cost will be 54.5 cents per MM Btu. (See Table 8-1.) If a 20 percent efficiency is assumed for the gas turbine, the producer gas will contribute about 1 cent per kwh to the total cost of power from the turbine. On top of this 1 cent per kwh, the fixed charges,

TABLE 8-1. COST SUMMARY FOR 150 PSIG GAS TURBINE FUEL FROM COAL BASED ON AIRBLOWN LURGI GAS PRODUCER

	Dollars/Year
1. Operating Costs	
Fuel, 206 tons/day at $4/ton	286,000
Water, softened 18,300 lb/hr x 30¢/M gal	5,500
Water, circulating 3,000 gal/min x 2¢/M gal	30,000
Water, fresh 25 gal/min x 10¢/M gal	1,200
Power, 100 kw at 1¢/kwh	8,300
Labor, 9 men/day at $2.75/hr	72,300
Plus 10% supervision and 60% overhead	55,000
	458,300
2. Capital Based Charges	
Maintenance at 5%/yr of $2.5 x 10^6	125,000
Fixed charges at 15%/yr of $2.5 x 10^6	375,000
	500,000
3. Total Costs	958,300

Heating value of hot gas output 211 x 10^6 Btu/hr for a gas turbine with 20 percent efficiency, fuel cost = 1.0¢/kwh

4. Total Costs	Cents/MM Btu
For $4/ton coal	54.5
For $8/ton coal	70.9
For $12/ton coal	87.3

operating labor, and maintenance for the turbine and its associated regenerators and waste heat boilers must, of course, be added.

It is possible that a Lurgi generator gas turbine combination might be located remote from a source of coal. The chart in Figure 8-2 shows the effect of delivered coal cost and the effect of varying the annual fixed charges on the investment in the gasifier and accessories. For annual fixed charges higher than 15 percent, the cost of gas at 150 psig from a single Lurgi airblown gasifier is probably not competitive with natural gas.

The investment cost of $2,500,000 for an airblown Lurgi gas producer complete and installed for use with a gas turbine was derived from cost data for a standard Lurgi synthesis gas generation unit. Such a standard unit includes gas quenching and waste heat boiler equipment which would probably not be required for a gas turbine installation.

Assuming that a simple multiclone installation would be adequate to dedust the Lurgi gas for a gas turbine, the basic cost of the gasification system could be reduced from $1,150,000 to $800,000. The total gasification system would then cost $800,000, plus $200,000 for the air compression and $100,000 for the coal handling equipment, for a total equipment cost of $1,100,000, and complete installed cost, including piping and buildings, of approximately $2;000,000.

If these reductions in investment cost can be realized, the total investment cost would be lowered by $500,000 as indicated and the cost of gas to the gas turbine would be lowered by 5.5 cents per MM Btu.

It is interesting to note that the relatively high investment cost for fixed-bed pressure gasification, causes a substantial increase in gas cost as the annual fixed charge rate goes up. This is contrary to the results obtained for atmospheric fuel gas producers, where relatively low fixed investment cost results in only a small increase in gas cost as annual fixed charges increase. The pressure gasification unit, and accessories required to cope with high operating pressure obviously are substantially more expensive for a given gas capacity than an atmospheric unit.

4. Conclusions: For the utility type of cost accounting which might be compatible with the 15 percent annual fixed charges, the cost of generating power through a gas turbine installation using gas turbine fuel from an airblown Lurgi could possibly compete with natural gas in those places where natural gas is expensive.

These costs for an airblown Lurgi gasifier are based on the cost given by Lurgi for production of synthesis gas. A more detailed study of these costs is required for the manufacture of producer gas; such a study should lead to a considerable cost reduction.

No attempt at optimizing the operating pressure has been made. Operation of the gasifier at higher pressure, e.g., 450 psi, should lead to a greatly increased capacity, and thus, reduced investment cost per unit of gas production. The energy in the gas produced at the higher pressure could be utilized in an expansion turbine if a gas turbine at 150 psi operating pressure is to be used.

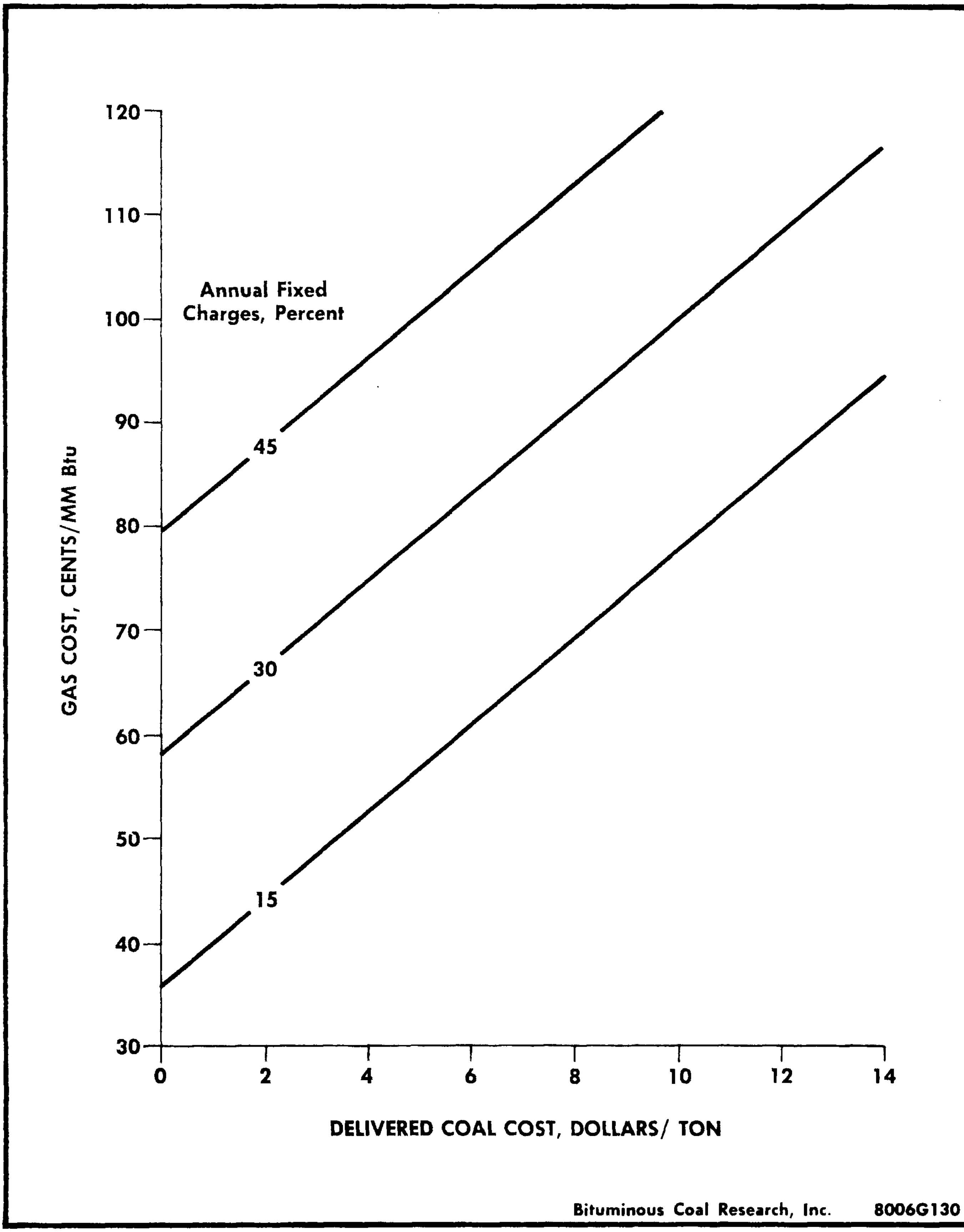

Figure 8-2 Effect of Coal Costs on Cost of 150 psig Gas Turbine Fuel from Coal Based on Airblown Lurgi Gas Producer

B. Steam-iron Reduction Gas

A hot raw producer gas may be suitable for iron oxide reduction which, in turn, could be used to produce hydrogen needed for the hydrogasification of coal; such a gas is required at approximately 1500 psig. The residual char from the hydrogasification of coal could be used as the feed material for the gas producer.

1. Basis for Evaluation: A 1500 psi gas producer has been evaluated at a capacity sufficient to supply producer gas for the reduction of the iron oxide circulating in a steam-iron system of such size to supply sufficient hydrogen for the hydrogasification of coal to make 250 MM scfd pipeline gas. Such a producer (64) requires 5160 tons per day of char from the hydrogasification unit. The composition of the gas from this producer is optimum at a 2000 F exit gas temperature; at this temperature, the formation of methane is substantially reduced. Methane is an unwanted material in this process; it is not used for reducing iron oxide and thus is wasted energy.

A two-stage combination of a pressurized Ruhrgas cyclone, blown with air, and a fluidized bed has been assumed as the best unit for producing the 1500 psi producer gas.(65) A simplified process scheme for the integrated system is shown in Figure 8-3.

The raw gas from this two-stage gasifier is sent to the steam-iron process unit at 1500 F after waste heat has been recovered by cooling the gas from 2000 to 1500 F.

The capacity of the gasifier is assumed to be proportional to the square root of the absolute operating pressure. In an atmospheric Ruhrgas gasifier with a 6.5 ft ID cyclone (66) the capacity is 130 tons per day of fuel with 20 percent ash.

2. Procedure for Evaluation: Operating costs have been determined by calculating the operating requirements and the capital investment requirements for the high-pressure gas producer. The fuel is char at 5160 tons per day on a dry ash-free basis, and is assigned a gross heating value of 15,140 Btu/lb. On the basis of 27 MM Btu per ton of coal at $4 per ton, the cost of the daf char is $4.49 per ton. Air to the gas producer is heated from 250 F at the compressor outlet to 1400 F by an air preheater requiring 525 tons per day of coal at $4 per ton.

Assuming that steam is available at 600 psig and 750 F for the air compressor drive turbines, the steam requirement for air compressors is 1,660,000 lb per hour. However, the waste heat available from the hot raw gas is equivalent

(64) See Process 46, Table 3-2, and Appendix 3.5.

(65) See Section 5 B.3 and Appendix 5.5.

(66) See Process 35, Table 3-1, and Appendix 3.5.

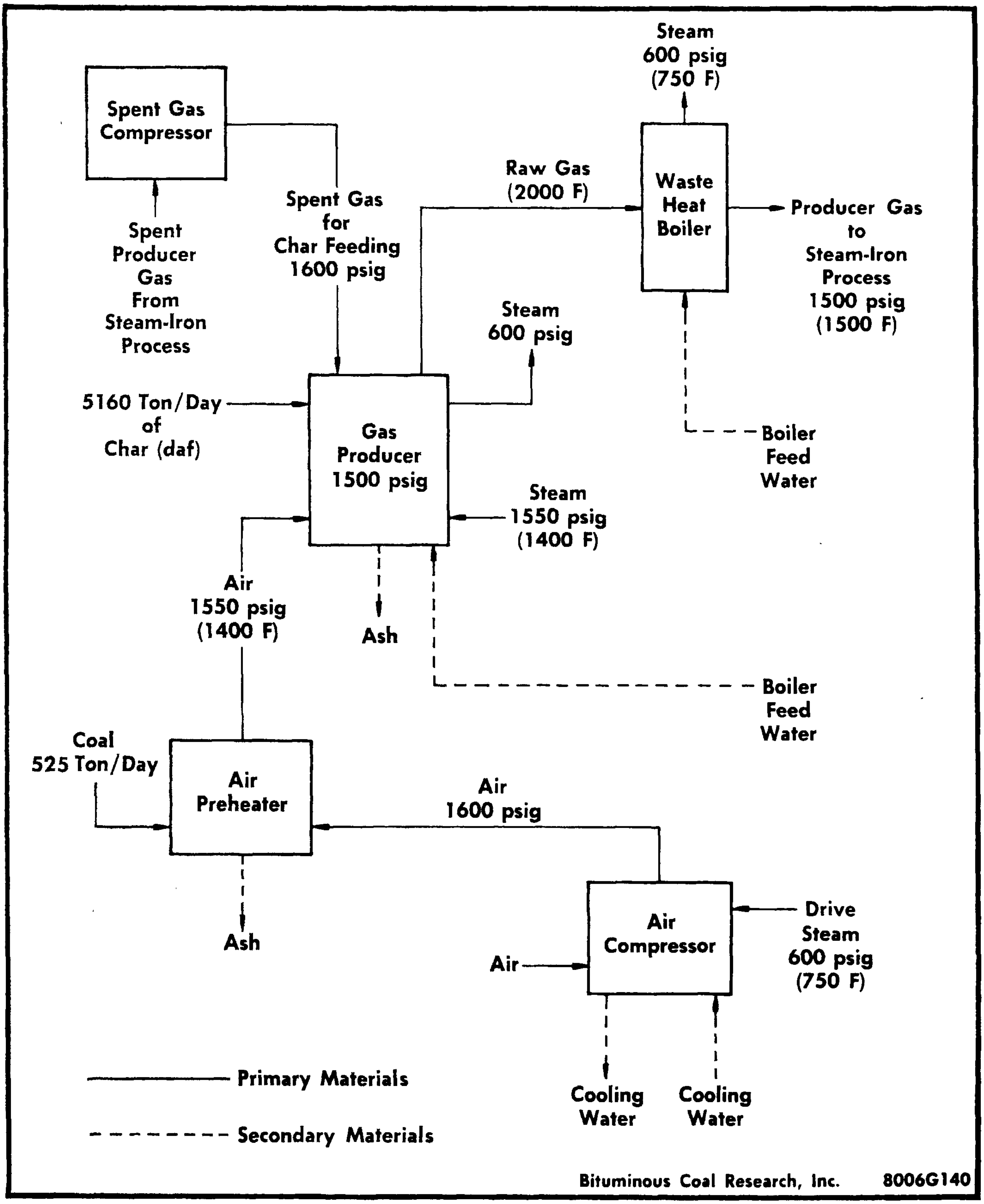

Figure 8-3 Simplified Process Scheme for Production of 1500 psig Steam-Iron Reduction Gas Using the Two-stage Fluidized Super-pressure Gas Producer

to 167,000 lb per hour of 600 psig 750 F steam, and another 7000 lb per hour of 600 psig 750 F steam is required for the compressors to furnish gas for feeding char into the gasifier. The char carrier gas is assumed to be spent producer gas and both char and spent gas are assumed to be available at 1300 psig. Finally, 65,000 lb per hour of 600 psig steam is produced by the gasifier jacket, so that a net quantity of 1,435,000 lb per hour of 600 psig steam is required. This steam is charged at 30 cents per M lb, which is the value estimated for this amount of steam from a large steam generating facility, as established in the pipeline gas plant studies.

In addition to the drive steam, high pressure process steam is required at 1500 psig; this amounts to 280,000 lb per hour. This steam is charged at 50 cents per M lb, which is the same value used in the pipeline gas plant evaluations.

Circulating cooling water requirements for the compressors are estimated at 115,000 gal/min. Fresh water required for ash quenching is estimated at 5000 gal/min, and boiler feed water required for makeup to the gasifier jacket at 130 gal/min. In addition, 90 percent of the 280,000 lb per hour of process steam is charged for as boiler feed water, since the 50 cents per M lb charge for process steam includes only 10 percent boiler feed water makeup cost. Power is estimated to be 1250 kw for miscellaneous items of equipment, pumps, lighting, and instruments for this system.

Operating labor requirements of 12 men per day for control room operation, compressors, and coal charging, and slag handling are assumed. One laboratory assistant and one helper per day bring the total number of men per day to 14.

The gas producer system, including five gasifiers, waste heat boilers, char feeding, and ash quenching equipment, cost approximately $8.6 million, erected. The compression systems for air and spent producer gas cost approximately $3.2 million, erected, and the air preheating system, $200,000, erected. No allowance for the offsite facilities, such as laboratories, administration buildings, fences, roads, etc., is made. Lastly, the estimate is made based on all utilities, plus char at 1300 psig, being available at the gas producer structure.

3. Results and Discussion: As shown in Table 8-2, the total cost of producer gas from a 1500 psig two-stage airblown gas producer operating on char is 38.5 cents per MM Btu of hot 1500 psig gas. This cost may be used as the reduction gas cost for the steam-iron process, which, in turn, will be used to furnish hydrogen for a hydrogasification system making methane.

Without knowing the economics of the entire system, from producer gas all the way through methane, it is difficult to derive any economic evaluation for hydrogen production from such producer gas, and, in turn, methane production from the hydrogen.

The costs which have been derived are approximate. For example, the utility costs have been calculated in such a way that, in an integrated plant, including the high pressure gas producer, these costs could possibly be lowered. Also, the gas producers have been estimated as two-stage units with the upper stage being a fluidized bed, and as stated, the increase in capacity due to the increased pressure has been estimated from the square root of the absolute

TABLE 8-2. COST SUMMARY FOR 1500 PSIG HOT STEAM-IRON REDUCTION GAS BASED ON TWO-STAGE FLUIDIZED SUPER-PRESSURE GAS PRODUCER

	Dollars/Year
1. Operating Costs	
Char, 5,160 ton/day at $4.49/ton	8,035,000
Preheat coal, 525 ton/day at $4/ton	729,000
Drive steam, 1,435 M lb/hr at 30¢/M lb	3,585,000
Process steam, 280 M lb/hr at 50¢/M lb	1,167,000
Water, demineralized, boiler feed, 38,000 gal/hr at 50¢/M gal	158,000
Water, circulating, 115,000 gal/min at 2¢/M gal	1,150,000
Power, 1,250 kw at 1¢/kwh	104,000
Labor, 14 men/day at $2.75/hr	112,000
Plus 10% supervision and 60% overhead	85,000
	15,125,000
2. Capital Based Charges	
Maintenance at 5%/yr of $12 x 10^6	600,000
Fixed charges at 15%/yr of $12 x 10^6	1,800,000
	2,400,000
3. Total Costs	17,525,000

4. Total Costs

Cents/M scf hot gas	5.76

5. Total Costs

Cents/MM Btu hot gas	38.5

pressure. The gasification investment could be somewhat lower if the increase in capacity with pressure went up faster than that which has been approximated by this procedure. In any case, no gasifier prices at 100 atm are available, so that the investment shown here is derived from an order of magnitude estimate.

4. Conclusions: Conclusions concerning the production of producer gas at 1500 psig can only be made when the unit is integrated into an overall system producing methane as a final product. It can be seen, however, that the producer gas at 100 atm, costing 38.5 cents per MM Btu is much less costly than gas produced at atmospheric pressure and then compressed to 100 atm. The 38.5 cents per MM Btu cost of producer gas at 1500 psig, compared to the cost of producer gas at 150 psig of 54.5 cents per MM Btu, shows the advantage of a large capacity system in reducing costs, and also shows the advantage of increased operating pressure for increasing production in a gasifier.