SECTION 7. EVALUATION OF FUEL GAS PROCESSES AS PROJECTED TO FULL-SCALE COMMERCIAL OPERATION

Two processes were selected for evaluation as projected for full-scale production of fuel gas; they are the Wellman-Galusha Gas Producer and the IFE Gas Producer.

A. Basis for Evaluations

The primary basis for the evaluation of fuel gas production equipment is the capacity, which was chosen as approximately 100 MM Btu per hour of product gas. This capacity is obtainable in units slightly larger than existing commercial fixed-bed atmospheric gas producers. A second basis for evaluation was the ability to handle highly caking, highly swelling bituminous coal, such as Pittsburgh seam coal. Such a coal has not been used commercially in fixed-bed gas producers, and because of this, presently available commercial equipment would have to be demonstrated on Pittsburgh seam coal.

The methods used for economic evaluation of a small fuel gas producer are substantially different from those used for evaluation of gasifiers for use in a large pipeline gas plant. The pipeline gas plant is self-sufficient. It generates its own steam and electricity, softens and demineralizes its own water as required, and has its own cooling water system. Fuel gas producers, on the other hand, are usually auxiliaries to a larger plant, and are supplied with all utilities on an assumed cost basis. Coal is assumed to be received by rail in a size suitable for direct use.

The equipment involved in a gas producer plant is relatively simple. The coal charging system is inexpensive because the unit is operated at substantially atmospheric pressure. The ash discharging is likewise relatively simple. The product gas is either sent directly to a burner as hot raw gas, or it is cooled and cleaned by direct contact scrubbers and electrostatic precipitators for later use. The cold clean gas is delivered at 2 psig, to allow adequate pressure for piping to the burner.

In the present study, the costs of both cold clean and hot raw fuel gases have been evaluated. No spare gas producer units have been provided.

1. Wellman-Galusha Gas Producer (Process 32): Discussions and correspondence with the McDowell-Wellman Engineering Company provided data for an economic appraisal of a producer in service operating on bituminous coal.(60)

This gas producer has not been demonstrated on Pittsburgh seam coal; however, a unit has been operated on Lower Cedar Grove seam coal from West Virginia. According to McDowell-Wellman, only minor modifications would be necessary to make the producer suitable for operation on Pittsburgh seam coal.

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(60) See Process 32, Table 3-1, and Appendix 3.5.

The cold clean gas production capacity of a standard 10 ft ID generator is 76 MM Btu per hour of gross heating value gas; the hot raw gas capacity is 90 MM Btu per hour. There is no apparent reason why a Wellman-Galusha gasifier could not be engineered with a sufficient capacity to produce 100 MM Btu per hour of either type of gas. However, to date the economic incentive for this redesign work has not been provided.

In the present cost evaluation, a Wellman-Galusha unit of sufficient size to produce 100 MM Btu per hour of gas has been assumed. Simplified process schemes for the production of hot raw and of cold clean fuel gas are shown in Figures 7-1 and 7-2, respectively.

2. IFE Two-stage Gas Producer (Process 33): The International Furnace Equipment Company, Ltd., Birmingham, England, has supplied the basic economics for their two-stage gas producer.(61)

The IFE producer is specifically designed for low-caking high volatile fuels; but, because of its special two-stage design for maximum recovery of uncracked tars and oils, it cannot operate on caking coal.

In this two-stage gas producer, the volatile materials are removed in a relatively cold, approximately 300 F, gas stream off the top of the producer. Most of the gas from the producer is taken off at approximately 950 F at an intermediate point in the fuel bed before the gas has a chance to come in contact with the undevolatilized coal. Simplified process schemes for the production of hot raw and cold clean fuel gas are shown in Figures 7-3 and 7-4, respectively.

The IFE Two-stage Gas Producer suffers from two drawbacks in the production of 100 MM Btu per hour of fuel gas. The first of these is that the largest size unit available, a 10 ft ID unit, produces only 59 MM Btu per hour of hot gas. This small capacity makes it relatively difficult to enlarge to a unit producing 100 MM Btu per hour; therefore, two producers have been quoted by IFE for a plant of this capacity. To offset this drawback, the present evaluation has been based on two units operating at normal capacity with a combined production of 118 MM Btu per hour of hot raw gas.

A second drawback is that because of the two-stage design, the producer is considerably more expensive than a single-stage producer. This added expense is supposedly offset by an increased efficiency for the production of hot raw gas; however this has not been found to be the case since the Wellman-Galusha Gasifier has approximately the same hot raw gas efficiency in a single-stage unit, as an IFE unit has in a two-stage unit. This second drawback could be offset whenever hot raw gas is required with higher quality than can be supplied by the Wellman-Galusha producer. The IFE producer does give a hot raw gas which is essentially free of cracked tar residue, so that it will not plug pipes and burner nozzles and will not be as likely to contaminate the materials over which it is being burned, such as molten glass.

(61) See Process 33, Table 3-1, and Appendix 3.5.

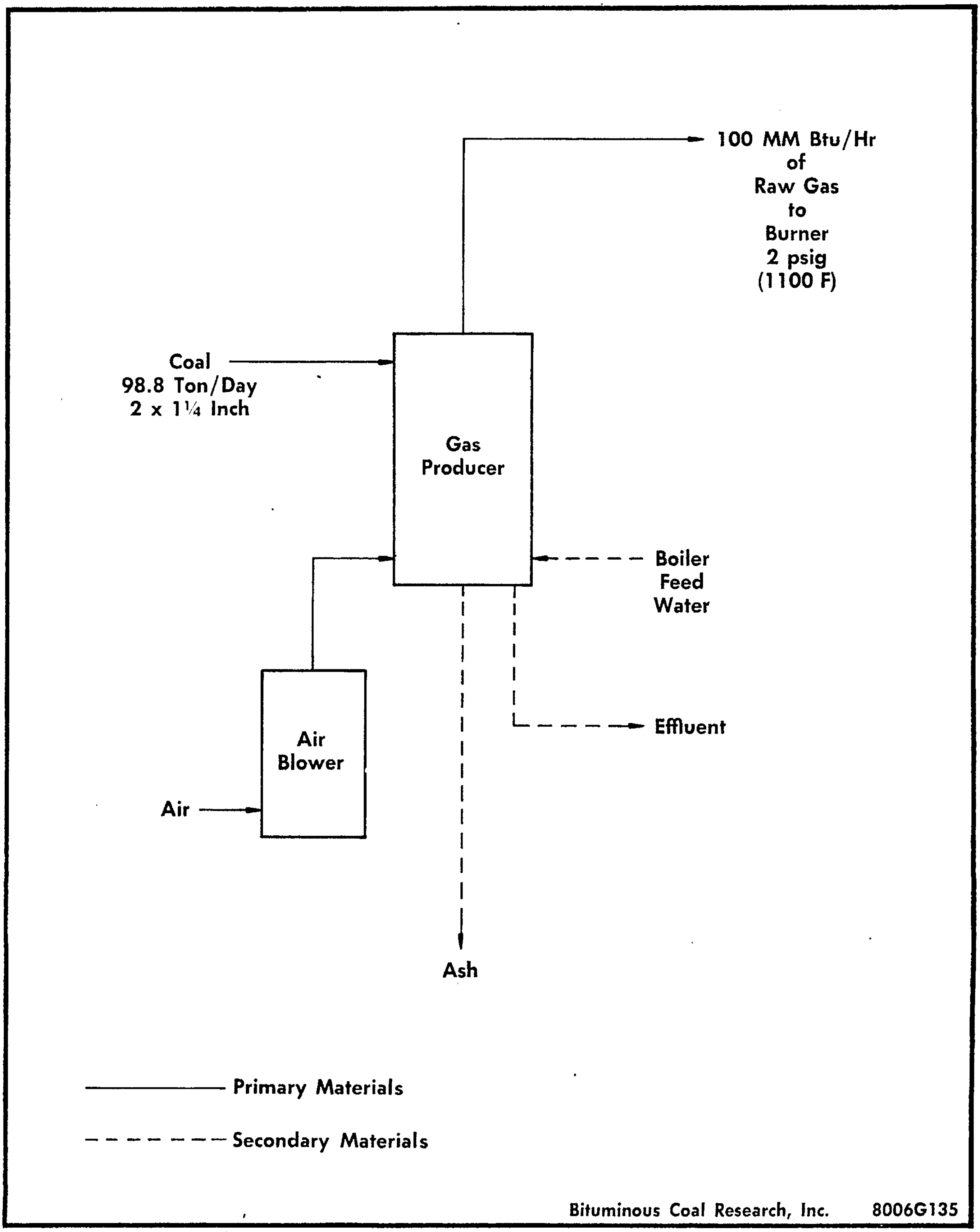

Figure 7-1 Simplified Process Scheme for Hot Raw Fuel Gas Production Using the Wellman-Galusha Gas Producer

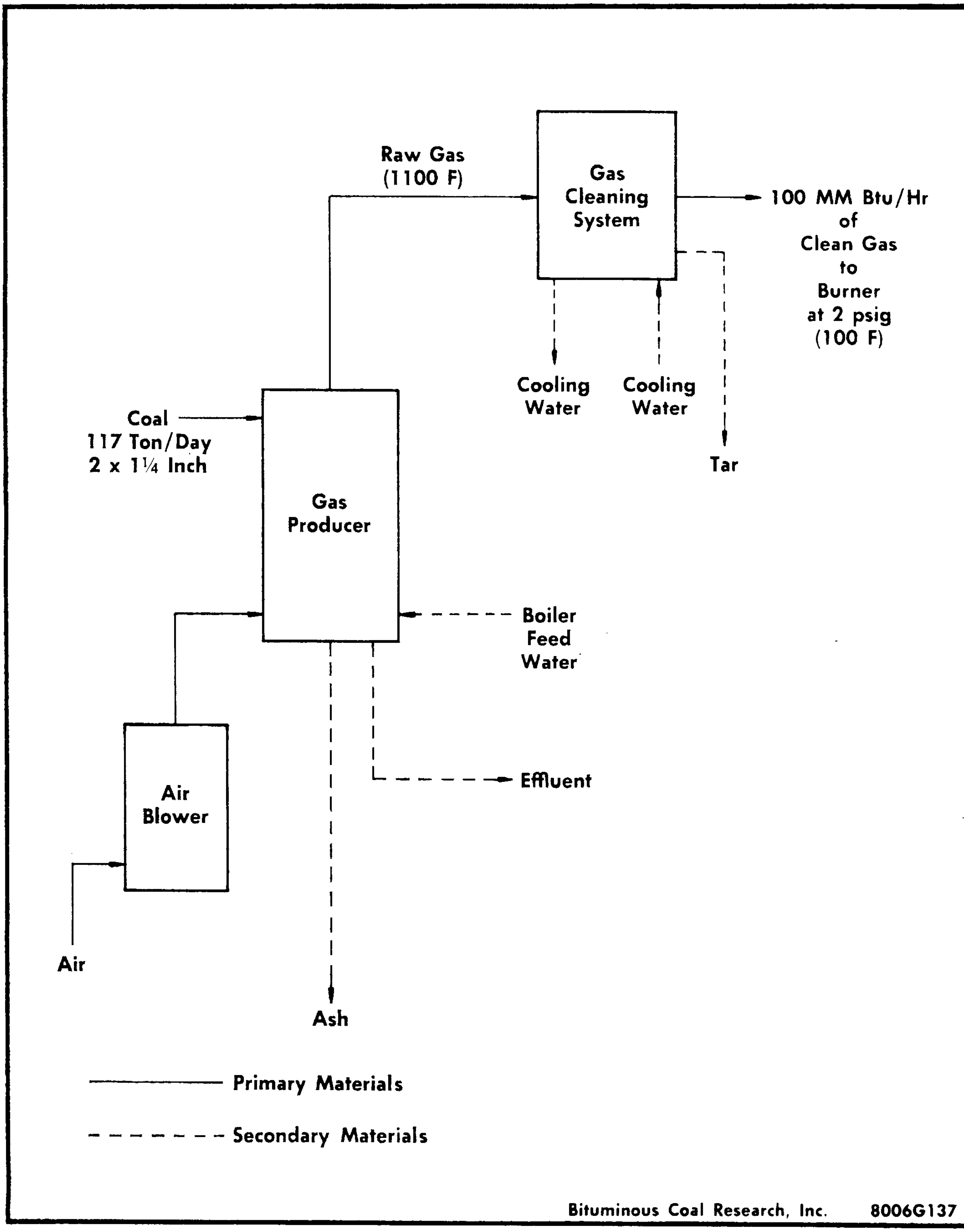

Figure 7-2 Simplified Process Scheme for Cold, Clean Fuel Gas Production Using the Wellman-Galusha Gas Producer

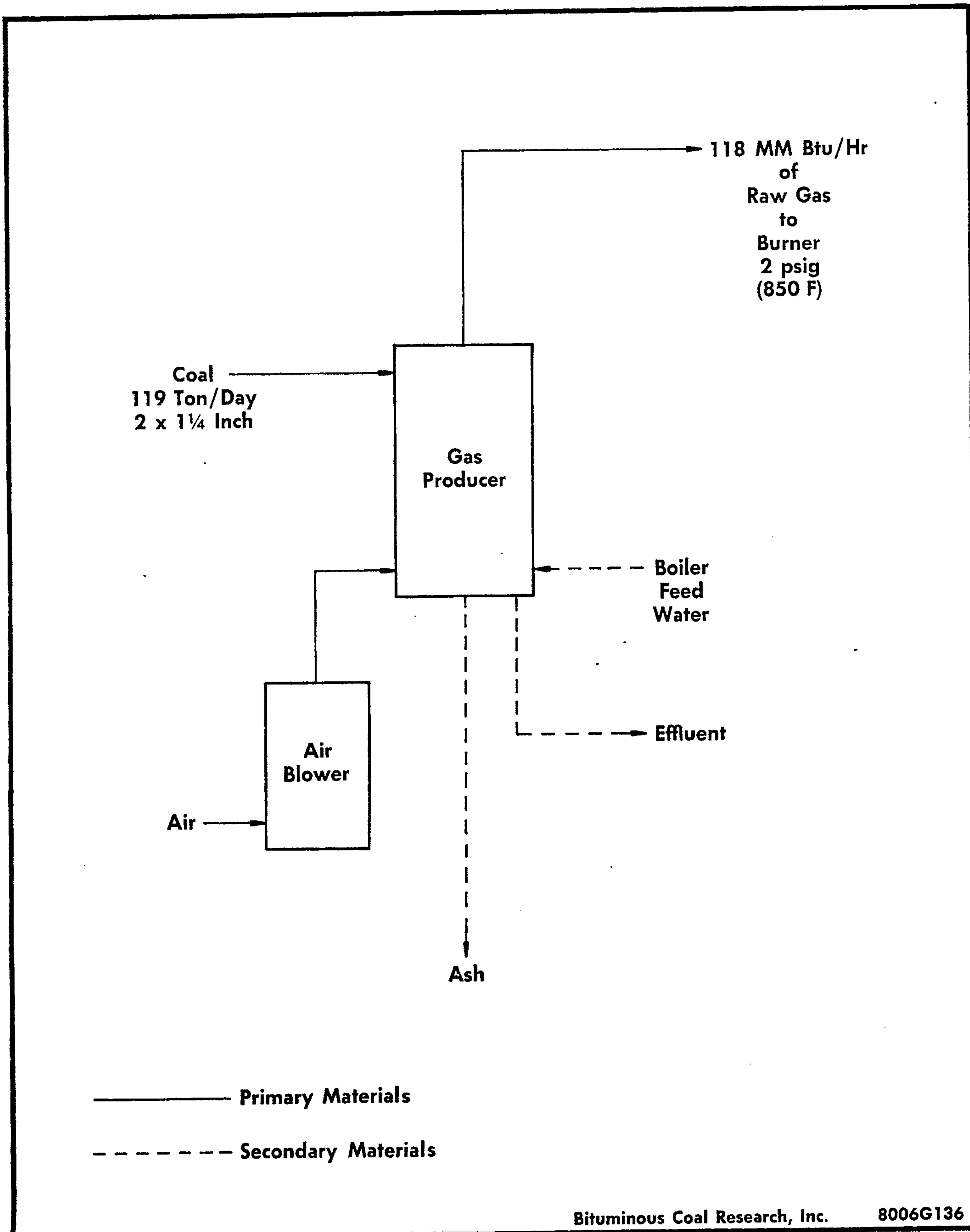

Figure 7-3 Simplified Process Scheme for Hot Raw Fuel Gas Production Using the IFE Two-stage Gas Producer

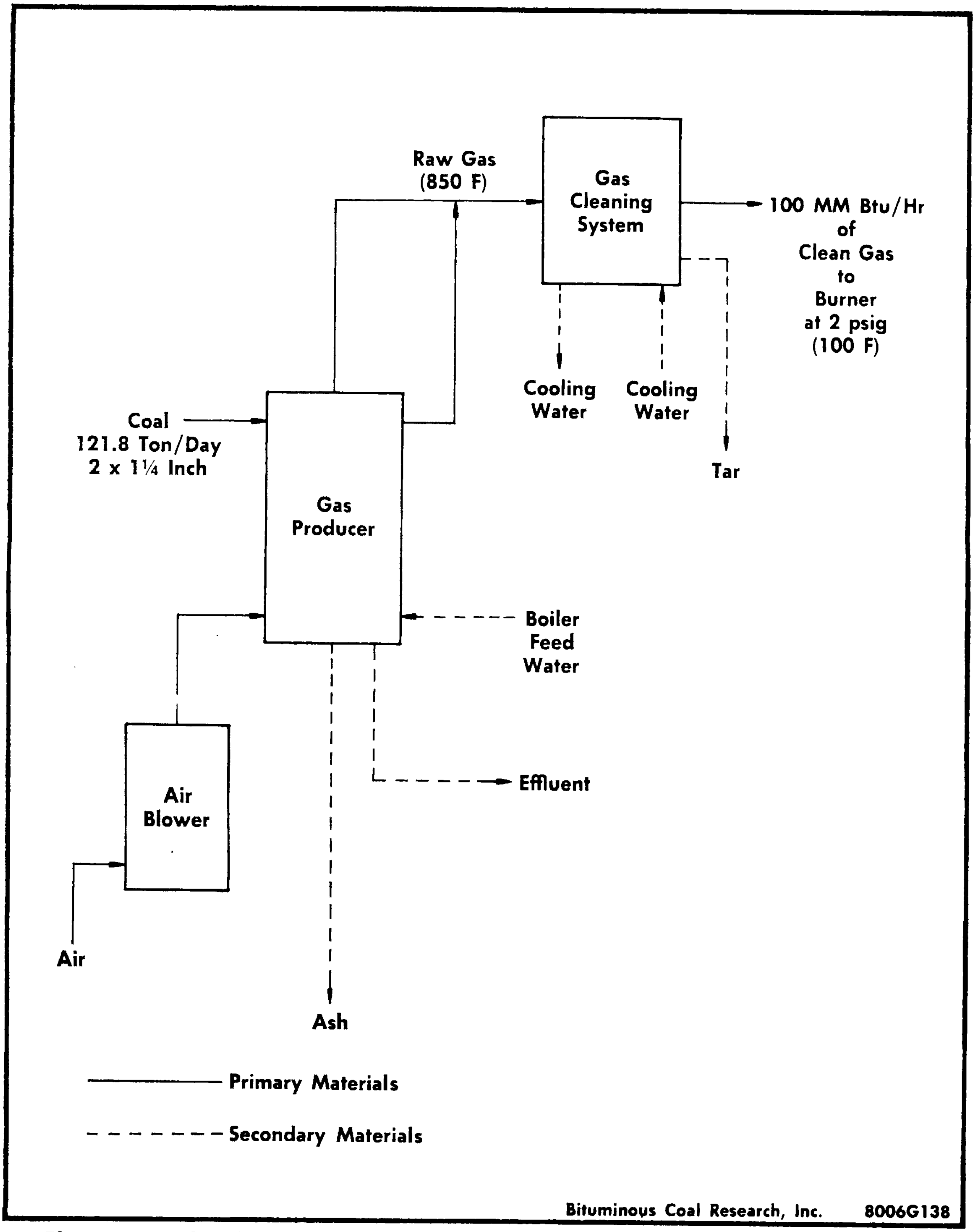

Figure 7-4 Simplified Process Scheme for Cold, Clean Fuel Gas Production Using the IFE Two-stage Gas Producer

B. Procedure for Evaluations

The production of fuel gas in an atmospheric pressure gas producer is simple compared to the production of 1000 psig pipeline gas. The latitude for fuel gas heating value is rather wide, and the specific composition of the fuel gas with respect to hydrogen, carbon monoxide, and methane is not of particular importance to the user. For these reasons, the procedure followed in this study for evaluating and comparing fuel gas producing units is not nearly as detailed as that for pipeline gas producing units.

Data from the suppliers of gas producers were reviewed for consistency and completeness, then directly converted into costs, and tabulated for comparison.

Fuel requirements for the Wellman-Galusha unit received from McDowell-Wellman Engineering were based on the performance of the Wellman-Galusha Gas Producer on Lower Cedar Grove seam coal from West Virginia. This coal has a slightly higher heating value than the Pittsburgh seam coal used as a basis for the present study. The gasification efficiency with the Lower Cedar Grove seam coal was 90 percent, from coal gross heating value to hot gas heating value, including tar, oil, and gas sensible heat. This same efficiency of 90 percent was applied to Pittsburgh seam coal to obtain the fuel requirements for the production of 100 MM Btu per hour of hot raw gas.

From an approximate heat balance and a review of the data from McDowell-Wellman, a representative cold clean gas efficiency for bituminous coal of 76 percent was determined as the basis for calculating the fuel requirement for production of 100 MM Btu per hour of cold clean gas. The difference between 90 percent efficiency for hot raw gas and 76 percent efficiency for cold clean gas production is approximately accounted for by the 6.6 percent of the coal heating value in the tars and oils removed from the gas, plus the 7.4 percent of the coal heating value lost in sensible heat as the gas is cooled.

The efficiency of the IFE Two-stage Gas Producer was given by IFE as 88 percent from coal to hot raw gas. This gas contains more tar than the Wellman-Galusha gas, since the tar is produced at a lower temperature and is not subject to thermal cracking. Also, the total gas is produced at a lower temperature. Of the 88 percent of the heating value of the coal in the hot gas, approximately 5 percent is sensible heat, and approximately 10 percent is the heating value of tars and oils. Thus, the heating value of the cold clean gas is only about 73 percent of the heat in the coal feed. This forms the basis for calculating fuel requirements for the hot raw gas and cold clean gas production in the IFE Two-stage Producer.

Water requirements for the Wellman-Galusha Gas Producer were stated by McDowell-Wellman as being 1,450 gallons per ton of coal for the producer jacket. This water is heated to a maximum of 180 F on leaving the jacket. Because scaling could be a problem if the water is not properly treated, this water has been assumed to be softened water. Some of this water evaporates into the air blown into the gas producer, thus furnishing water vapor for the gas production process. The remaining water is assumed to be discarded hot.

Cold clean gas production in a Wellman-Galusha unit requires, in addition to the water for the jacket, another 11,800 gallons per ton of coal of circulating cooling water for cooling the hot raw gas to ambient temperature and for condensing the tars and oils. Losses and evaporation of the circulating cooling water also require a makeup of 360 gallons per ton of coal.

The cost summary furnished by the International Furnace Equipment Company, Ltd., shows that for the production of 118 MM Btu per hour of hot raw gas the two IFE Two-stage Gas Producers require 96,000 gallons per day of water for the gasifier jackets. It has been assumed that the amount of circulating cooling water required for the production of cold clean gas is a function of the amount of sensible heat in this gas, and it has been calculated as being approximately 68 percent of the circulating cooling water required by the Wellman-Galusha cold clean gas production system. In addition to the circulating cooling water, makeup water of 47,000 gallons per day is required to replace cooling water evaporation and other losses.

A summary of the process data for the production of hot raw and of cold clean gas by the two systems is given in Table 7-1.

TABLE 7-1. SUMMARY OF PROCESS DATA FOR PRODUCTION OF FUEL GAS

		IFE Two-stage		Wellman-Galusha	
		Hot Raw	Cold Clean	Hot Raw	Cold Clean
Producer Input	Units				
Fuel	ton/day				
Coal		119	121.8	98.8	117
Char		-	-	-	-
Process Water	M gal/day	11.4	11.7	9.5	11.2
Steam	M lb/hr	-	-	-	-
Air	MM scf/day	8.3	8.5	7.8	9.2
Output					
Gas	MM Btu/hr	118	100	100	100
	MM scf/day	13.5	13.7	12.3	14.5

Power requirements of 18 kwh per ton of fuel for the hot raw gas unit and 50 kwh per ton of fuel for the cold clean gas unit have been used by McDowell-Wellman. International Furnace Equipment indicated costs for 13 kw per ton of fuel for hot raw gas production. In the present evaluation, electric power requirements of 37 kw per ton of fuel for cold clean gas production in the IFE units have been based on figures proportional to the requirements for the Wellman-Galusha system.

Labor costs have been calculated by assuming the appropriate number of men per shift for the operation of the gasifiers and coal charging and ash handling equipment, and when applicable, the gas cooling and cleaning equipment. Discussions with McDowell-Wellman led to the assumption of one-half man per shift for the Wellman-Galusha hot gas producer and auxiliary equipment, including coal and ash handling. This, of course, assumes that the producer is located adjacent to facilities requiring the other half of the operator's time. When making hot gas, the two IFE producers require one man per shift for operation, according to the International Furnace Equipment quotation. For cold clean gas production, one half of an operator's time has been added for each producer to allow for gas cooling and cleaning equipment.

Credit has been allowed for the tar and oil obtained in production of cold clean gas. This credit has been allowed at a rate proportional to the heating value of the coal. From the overall efficiencies of the two systems it has been determined that approximately 6.6 percent of the heating value in the coal fed to the process is recovered as tar in the Wellman-Galusha cold clean gas producer, and that approximately 10 percent is recovered as tar in the IFE cold clean gas producer. The production costs have been credited accordingly.

Investment costs have been estimated from approximate cost information given by McDowell-Wellman and by IFE. The estimates include equipment for conveying coal into the coal hoppers located above the gas producer, the coal charging equipment to the producer, the producer itself, the ash discharging equipment, the gas cleaning and cooling equipment such as direct contact scrubbers and electrostatic precipitators, where required, and instruments for the normal control of the gas producers, plus piping, duct work, air blowers, gas boosters where necessary, and the structures for supporting the equipment and housing the instruments and controls.

C. Results and Discussions

The cost data for producing fuel gas by the various methods have been tabulated in Tables 7-2 to 7-5, inclusive. They show the Wellman-Galusha and IFE costs for both hot raw and cold clean gas.

In general, the basis used for calculation of these costs is compatible with that used for the pipeline gas producing units; that is, 347 days per year operation, 15 percent per year fixed charges, basic wage rate of $2.75 per hour plus 10 percent of basic labor for supervision, and 60 percent on the basic labor and supervision for payroll overhead. A maintenance charge of 5 percent per year of total fixed investment has been used; this is somewhat higher than that used for the pipeline gas production plants. However, the plants producing pipeline gas have many low maintenance units, such as air separation plants, cooling towers, and administration and laboratory facilities, so that the maintenance rate for fuel gas generating equipment alone has been assumed to be slightly higher than the average rate for a plant producing pipeline gas. The 5 percent per year maintenance includes the necessary supervision and overhead on maintenance labor.

TABLE 7-2. COST SUMMARY FOR PRODUCTION OF 100 MM BTU/HR OF HOT RAW FUEL GAS (1100 F) FROM COAL BASED ON THE WELLMAN-GALUSHA GAS PRODUCER

	Dollars/Year
1. Operating Costs	
Fuel, 98.8 ton/day at $4/ton	137,200
Water, softened 143,300 gal/day at 30¢/M gal	14,900
Power, 75 kw at 1¢/kwh	6,200
Labor, 1.5 men/day at $2.75/hr	12,000
Plus 10% supervision and 60% overhead	9,200
Credits	None
Sub-Total	179,500
2. Capital Based Charges	
Maintenance at 5%/yr of $194,000	9,700
Fixed charges at 15%/yr of $194,000	29,100
Sub-Total	38,800
3. Total Costs	218,300

4. Total Costs	Cents/MM Btu
For $4/ton coal	26.3
For $8/ton coal	42.7
For $12/ton coal	59.2

TABLE 7-3. COST SUMMARY FOR PRODUCTION OF 100 MM BTU/HR OF COLD CLEAN FUEL GAS FROM COAL BASED ON THE WELLMAN-GALUSHA GAS PRODUCER

	Dollars/Year
1. Operating Costs	
Fuel, 117 ton/day at $4/ton	162,400
Water, softened 212,300 gal/day at 30¢/M gal	22,100
Water circulating, 960 gal/min at 2¢/M gal	9,600
Power, 210 kw at 1¢/kwh	17,500
Labor, 3 men/day at $2.75/hr	24,100
Plus 10% supervision and 60% overhead	18,400
Tar credits - 6.6% of fuel value at 15¢/MM Btu	(10,700)
Sub-Total	243,400
2. Capital Based Charges	
Maintenance at 5%/yr of $318,000	15,900
Fixed charges at 15%/yr of $318,000	47,700
Sub-Total	63,600
3. Total Costs	307,000

4. Total Costs	Cents/MM Btu
For $4/ton coal	36.9
For $8/ton coal	55.1
For $12/ton coal	73.4

TABLE 7-4. COST SUMMARY FOR PRODUCTION OF 118 MM BTU/HR OF HOT RAW FUEL GAS (850 F) FROM COAL BASED ON THE IFE TWO-STAGE GAS PRODUCER

	Dollars/Year
1. Operating Costs	
Fuel, 119 ton/day at $4/ton	165,300
Water, softened 96,000 gal/day at 30¢/M gal	10,000
Power, 55 kw at 1¢/kwh	4,600
Labor, 3 men/day at $2.75/hr	24,100
Plus 10% supervision and 60% overhead	18,400
Credits	None
Sub-Total	222,400
2. Capital Based Charges	
Maintenance at 5%/yr of $450,000	22,500
Fixed charges at 15%/yr of $450,000	67,500
Sub-Total	90,000
3. Total Costs	312,400

4. Total Costs	Cents/MM Btu
For $4/ton coal	31.8
For $8/ton coal	48.6
For $12/ton coal	65.5

TABLE 7-5. COST SUMMARY FOR PRODUCTION OF 100 MM BTU/HR OF COLD CLEAN FUEL GAS FROM COAL BASED ON THE IFE TWO-STAGE GAS PRODUCER

	Dollars/Year
1. Operating Costs	
Fuel, 121.8 ton/day at $4/ton	169,000
Water, softened 143 M gal/day at 30¢/M gal	14,900
Water, circulating, 680 gal/min at 2¢/M gal	6,800
Power, 190 kw at 1¢/kwh	15,800
Labor, 4.5 men/day at $2.75/hr	36,200
Plus 10% supervision and 60% overhead	27,600
Tar credits - 10% of fuel value at 15¢/MM Btu	(16,900)
Sub-Total	263,400
2. Capital Based Charges	
Maintenance at 5%/yr of $522,000	26,100
Fixed charges at 15%/yr of $522,000	78,300
Sub-Total	104,400
3. Total Costs	367,800

4. Total Costs	Cents/MM Btu
For $4/ton coal	44.1
For $8/ton coal	62.5
For $12/ton coal	80.8

Since the coal for the gas producers is used in relatively small quantities of approximately 100 tons per day, the basic coal cost of $4.00 per ton would probably not apply to most installations; thus gas costs have also been calculated for coal at $8.00 per ton and at $12.00 per ton. These higher coal costs are also indicated because of the coal size that gas producers require (such as 2 x 1-1/4 inch) and because of the cost of transporting the coal from the mine to the producer.

The overall results of the cost study of fuel gas producing units are presented as a bar graph in Figure 7-5. This bar graph is divided: one part shows the costs for hot raw gas, and the other shows the costs for cold clean gas. Comparisons between the two gas producers is for $4.00 per ton, $8.00 per ton, and $12.00 per ton coal. The total cost of gas, represented by the height of the bar, is divided into fuel costs, utility and labor costs, and capital based charges.

It is interesting to note the small portion of the gas cost represented by capital-based charges for the Wellman-Galusha hot gas producer. This indicates that there is relatively little to be gained from development work to reduce the investment costs of atmospheric fixed-bed hot raw gas producers. When cold gas production is considered, and gas cooling and cleaning add to the capital charges portion of the total gas cost, capital charges are still less than the fuel cost, even for $4.00 per ton coal.

Variations in gas cost from the Wellman-Galusha gas producer only are shown in Figure 7-6; gas cost is shown as a function of coal cost delivered and as a function of annual fixed charges. Industrial companies interested in using a fuel gas producer rather than natural gas can determine the cost of the fuel gas for various annual fixed charge rates. For most nonutility companies, 15 percent per year is too low an annual fixed charge, so that costs for 30 percent and 45 percent annual fixed charges have also been shown.

D. Conclusions

It can be concluded from the results of this study that the Wellman-Galusha producer is the most economical fixed-bed atmospheric gasification unit available for processes that can use hot raw producer gas. It may also be concluded that even with coal at $8.00 to $10.00 a ton and fixed charges of 45 percent, the hot raw gas cost is quite likely to be competitive or substantially cheaper than natural gas in some locations. The economic potential for further development of the fixed-bed atmospheric hot raw gas producer is small since the charges based on the capital for such a unit are a minor part of the total gas cost.

For processes requiring long operating periods without interruption for cleaning of gas mains, equipment for gas cleaning is required in addition to the producer. This increases capital investment and operating cost. The smallest cost increase has been found for hot clean gas from the IFE Two-stage Producer which is followed by the cost of cold clean gas from the Wellman-Galusha producer. In view of the limitations of the IFE producer in handling caking coals, a low cost two-stage producer able to gasify caking coals may find useful markets that are not open gas from coal at this time.

A demonstration of the use of Pittsburgh seam bituminous coal in a fixed-bed atmospheric gas producer, such as the Wellman-Galusha, appears worthwhile.

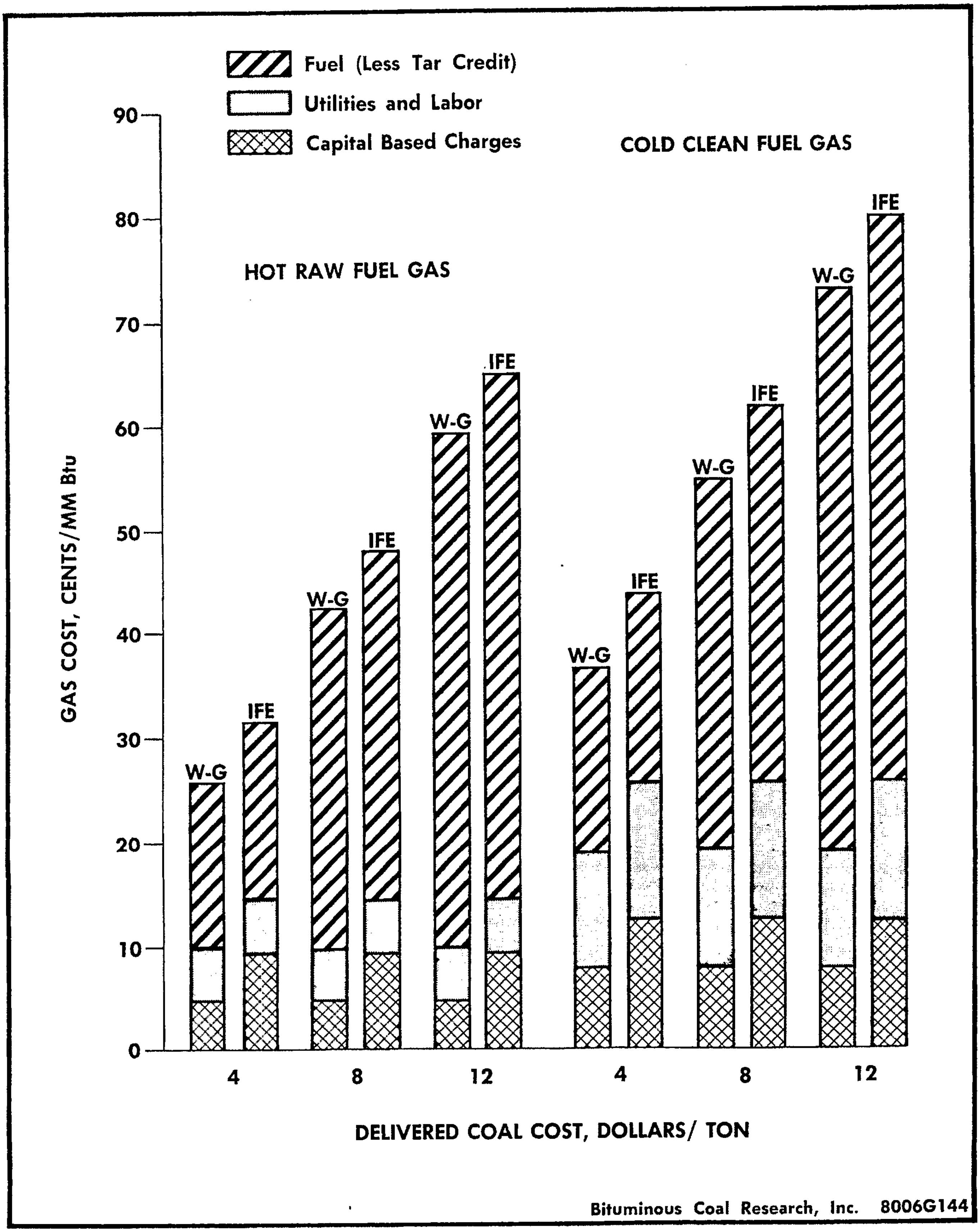

Figure 7-5 Effect of Coal Cost on Costs of Fuel Gas from Coal by the Wellman-Galusha and the IFE Gas Producers

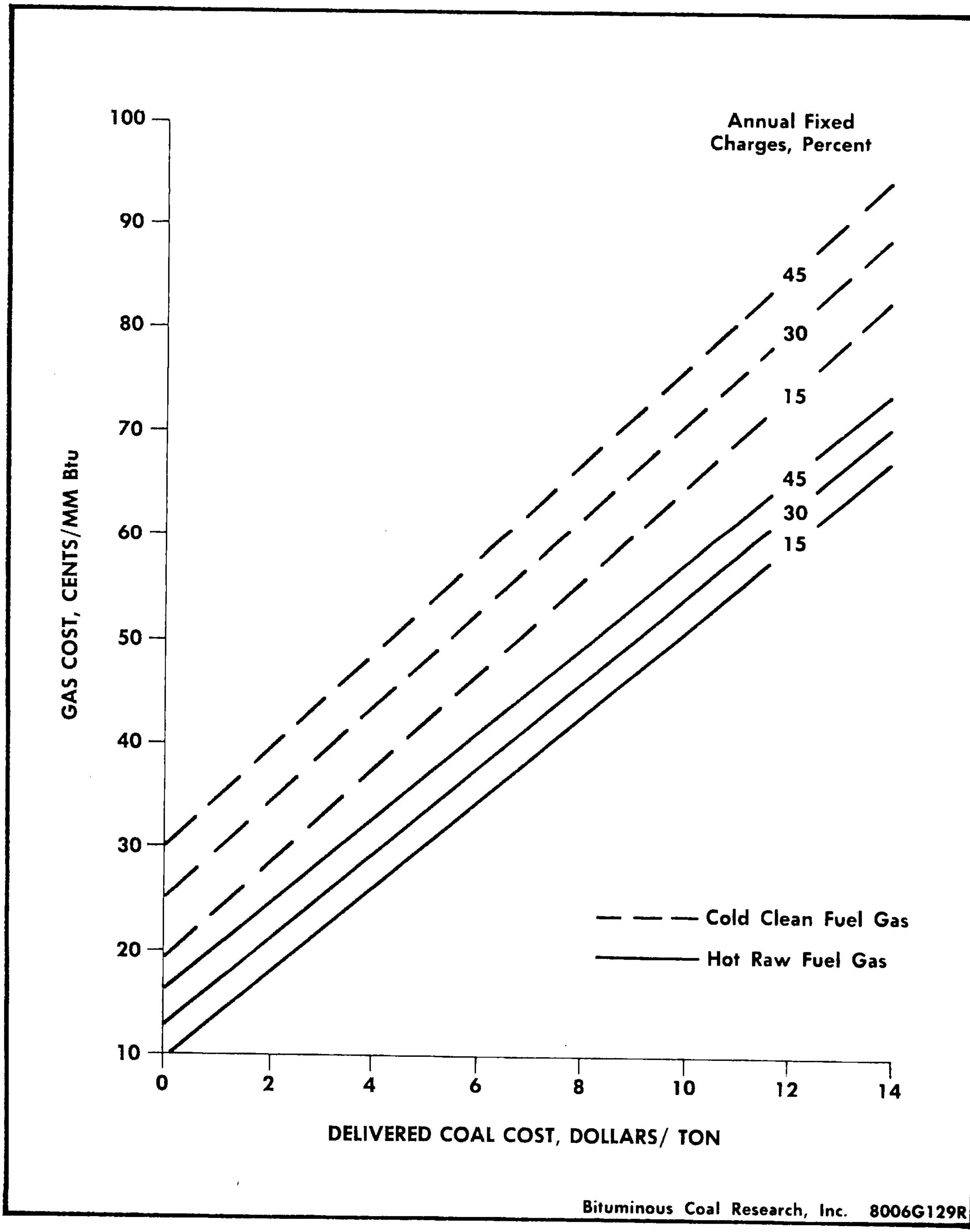

Figure 7-6 Effect of Coal Cost on Cost of 100 MM Btu/hr of Fuel Gas from Wellman-Galusha Gas Producer