Nov. 12, 1963 D. E. SEVERSON ETAL 3,110,578

GASIFICATION PROCESS FOR THE PRODUCTION OF SYNTHESIS GASES

Filed Aug. 16, 1961 3 Sheets-Sheet 1

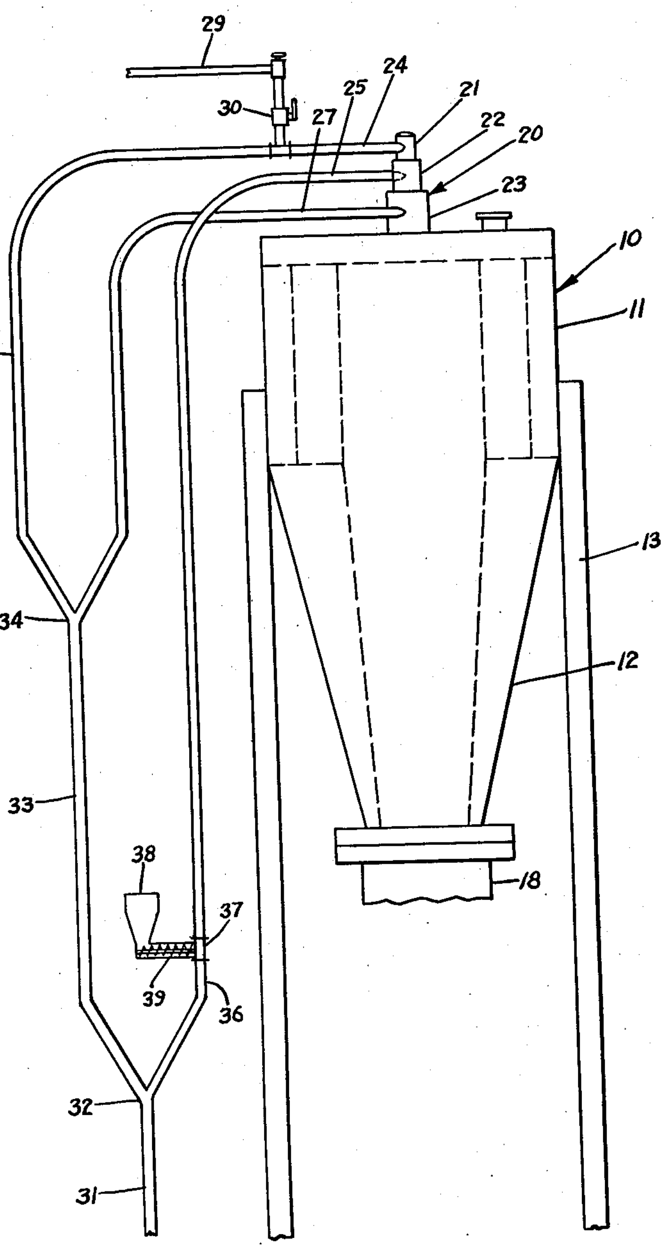

FIG. 1

INVENTORS
DONALD E. SEVERSON
BY DAVID S. GLEASON
Moore, White & Burd
ATTORNEYS

GASIFICATION PROCESS FOR THE PRODUCTION OF SYNTHESIS GASES

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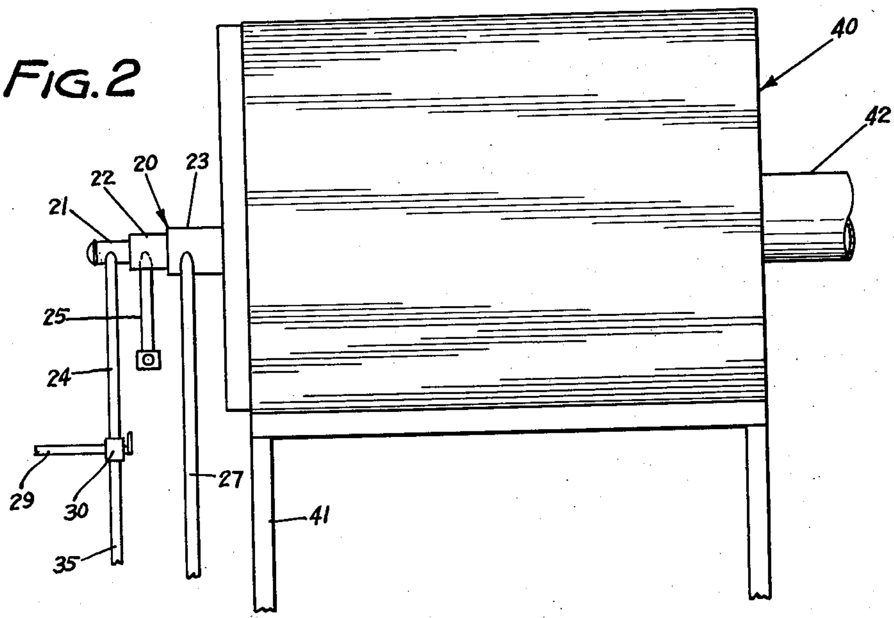
FIG. 2



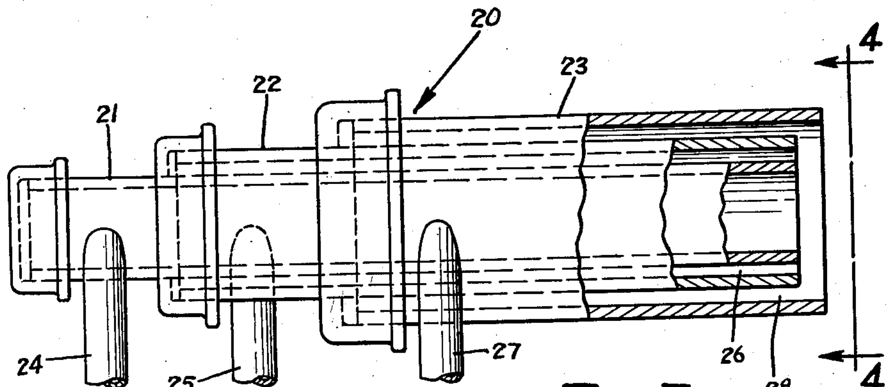


FIG. 3

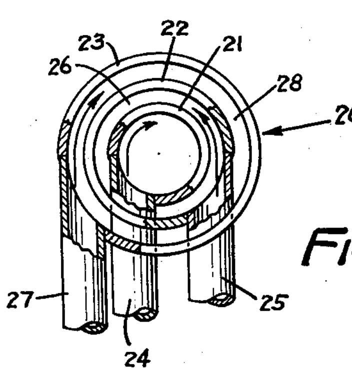


FIG. 4

INVENTORS
DONALD E. SEVERSON
BY DAVID S. GLEASON
Moore, White & Bird
ATTORNEYS

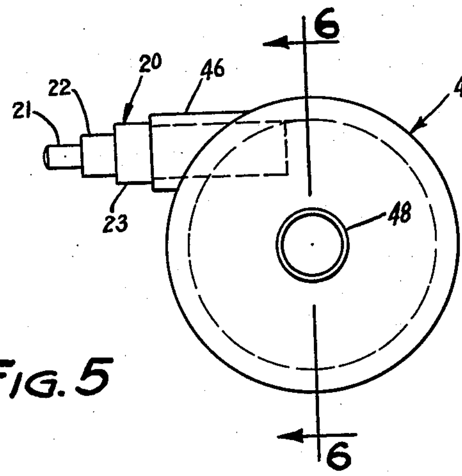


FIG. 5

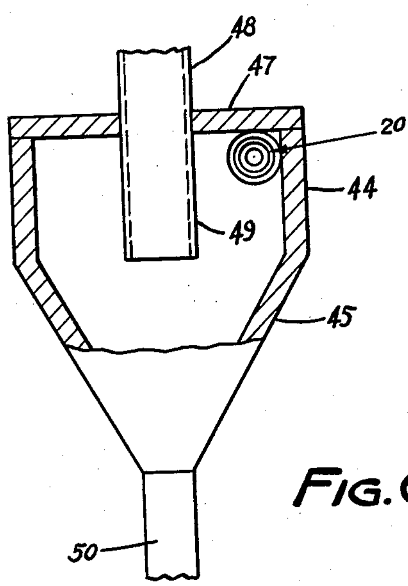


FIG. 6

INVENTORS
DONALD E. SEVERSON
BY DAVID S. GLEASON
Moore, White & Bird
ATTORNEYS

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GASIFICATION PROCESS FOR THE PRODUCTION OF SYNTHESIS GASES

Donald E. Severson, Grand Forks, N. Dak., and David S. Gleason, St. Paul, Minn., assignors to The State University and The School of Mines, also known as the University of North Dakota, Grand Forks, N. Dak., an establishment of North Dakota, and Great Northern Railways Company, St. Paul, Minn., a corporation of Minnesota

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9 Claims. (Cl. 48—203)

This invention relates to the production of synthesis gases. More particularly the invention relates to the production at near atmospheric pressures of synthesis gases by the incomplete combustion of powdered lignite or other carbonaceous fuel. The process of the present invention provides a greatly simplified and economical and efficient method of producing synthesis gases for use in chemical processes, reducing gases susbtantially free of tar for use in metallurgical processes and similar operations employing substantial quantities of synthesis or reducing gases. The process is characterized as a one step process in which gasification is accomplished in a single chemical step rather than in an exothermic reaction followed by an endothermic reaction.

Broadly stated, the process of the present invention comprises the steps of suspending a pulverized carbonaceous fuel in a stream of air, or oxygen, or oxygen-enriched air, or steam and introducing this combustible mixture into an atmospheric burner in which it is further mixed with secondary air or oxygen or oxygen-enriched air or steam, the total oxygen present being less than that theoretically required for complete combustion of the fuel. In the burner a partial oxidation takes place in a stable flame front extending into a refractory lined combustion chamber. The combustible fuel is thus converted to a gas containing carbon monoxide and hydrogen.

The invention is illustrated in the accompanying drawings wherein the same numerals designate corresponding parts and in which:

FIGURE 1 is a side elevation of a vertical form of furnace in which the gasification process of the present invention may be carried out;

FIGURE 2 is a side elevation of a horizontal furnace which may be used to carry out the gasification process;

FIGURE 3 is an enlarged detail elevation, partly broken away and partly in section, of the burner structure which may be utilized in either the horizontal or the vertical furnaces;

FIGURE 4 is a section on the line 4—4 of FIGURE 3 and in the direction of the arrows;

FIGURE 5 is a top plan view of another form of furnace which may be used to carry out the gasification process; and

FIGURE 6 is a vertical elevation in section of the furnace of FIGURE 5 on the line 6—6 of FIGURE 5 and in the direction of the arrows.

Referring to the drawings, the vertical furnace **10** shown in FIGURE 1 comprises a generally cylindrical upper housing portion **11** and a generally conical tapering lower portion **12**. The furnace is suitably supported, as by means of legs **13**. The lower end of the furnace is flanged and is joined to a flanged connector duct **18** which functions to convey the gas produced in the furnace to its situs of use.

The top wall of the furnace **10** is fitted with a burner, indicated generally at **20**, centrally located and directed downwardly into the furnace. The burner **20** comprises generally an inner tube **21**, an intermediate tube **22**, and an outer tube **23** concentrically arranged and desirably

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of such diameters and spacing that the cross-sectional areas of the inner tube and the inner annulus and outer annulus are about equal. The tubes are closed at one end and open at the other.

Each of the burner tubes is fitted near its closed end with a tangential feed tube. A tube **24** for the feeding of fluid fuel or air or the like communicates tangentially with inner burner tube **21**. The fluid fed tangentially through tube **24** into tube **21** flows generally in a spiral pattern flow through the tube **21** and out into the combustion zone forward of the open end of the burner. A solid fuel feed tube **25** intersects intermediate tube **22** tangentially, but on the side opposite from feed tube **24**. The solid fuel entrained in air flows tangentially into the annulus **26** between the outer wall of tube **21** and the inner wall of tube **22** and flows in a spiral flow pattern, opposite in direction from the spiral flow of the air in inner tube **21**, through the annulus and out into the burning zone. Feed tube **24** is used primarily for the introduction of air, oxygen or steam to the furnace but may be used to introduce preheating gaseous fuel.

An air feed inlet tube **27** intersects the outer burner tube **23** tangentially on the same side as feed tube **24**, and on the opposite side from solid fuel inlet tube **25**, with the result that air flows tangentially into the annulus **28** between the outer wall of tube **22** and the inner wall of tube **23** and flows in a spiral flow through the annulus to the burning zone. The spiral flow in the inner tube **21** and the outer annulus **28** is in one direction. The spiral flow in the intermediate inner annulus **26** is in the opposite direction.

In the illustrated system fuel gas such as natural gas, methane, propane, butane, water gas or the like may be fed from a gas supply source to a pipe **29** through a valve **30** into feed tube **24** to preheat the furnace. Air, or other oxygen source, under low pressure, is introduced into tube **31** from whence it flows through one arm of a Y connector **32**, tube **33**, one arm of a Y connector **34** and tube **35** to the inlet feed pipe **24**. Gaseous fuel is admixed with air for introduction through the feed pipe **24** to preheat the furnace and assist in initially igniting the solid fuel stream. Thereafter the gas may be turned off, or may be continued as a supplemental fuel source, as needed. The preheating fuel may just as well be introduced through any of the other feed tubes or the furnace may be preheated by a separate burner.

Air from tube **31** flows through the other arm of Y connector **32** through pipe **36** to a T connector **37** into the solid fuel feed pipe **25**. The finely divided solid fuel is fed from a hopper **38** through a screw conveyor **39** (illustrated schematically) to the T connector **37** where the solid fuel is forced into and entrained in the air flow for transport to the burner and the combustion zone. Air from pipe **33** flows through the other arm of Y connector **34** into the air feed pipe **27**.

In the horizontal form of furnace **40**, shown in FIGURE 2, the furnace is generally rectangular. The same burner structure, indicated generally at **20**, is disposed in one end wall of the furnace on a horizontal axis. The horizontal furnace is supported on legs **41**. The air and fuel flows are as already described. The combustion chambers within both vertical and horizontal furnaces are lined with refractory material such as fire brick or the like. A duct **42** in the end wall of furnace **40** opposite from the burner conveys the gases produced in the furnace to the point of use.

The furnace illustrated in FIGURES 5 and 6 is constructed in the form of a cyclone separator to remove unburned solids or other residues directly from the combustion chamber. This form of furnace, indicated generally at **43**, includes an upper cylindrical portion **44** and a lower conical portion 45. A burner unit 20, as already described in detail with respect to the vertical and horizontal forms of furnace illustrated in FIGURES 1 and 2, respectively, is fitted in a tangential sleeve 46 in the upper portion of the furnace housing adjacent the top 47. A gas discharge duct 48 intersects the top 47 of the furnace for discharge of synthesis gas from the furnace. The lower end 49 of the duct 48 may extend into the combustion chamber to function as a baffle to prevent short-circuiting of the gas stream and insure separation of residual materials from the gases produced in the furnace. The walls of lower conical portion 45 of the furnace housing 43 converge to a discharge 50 for the removal of slag, unburned combustibles and other residual material from the gas stream.

In the operation of the cyclone form of furnace, solid fuel and oxygen-containing gas are introduced into the combustion chamber in the usual manner. Because the burner enters the combustion chamber of the furnace tangential to the cylindrical wall, the flame front is directed against and around the arcuate wall of the combustion chamber in a circular path. The interior of the furnace functions both as a combustion chamber and as cyclone separator to remove any slag formed or unburned combustible or other residual materials from the gas stream. The separating function takes place directly in the combustion chamber, eliminating the need for separate separator means where solids-free synthesis gas is desired.

In the operation of the illustrated form of burner within any of the furnaces, the inner tube 21 and the outer annulus 28 are supplied with air tangentially so as to induce a clockwise rotation when viewed from the combustion zone end of the burner, as shown in FIGURE 4. The inner annulus 26 is tangentially fed with a suspension of finely divided lignite or other solid fuel entrained in air so as to induce a counterclockwise rotation, when viewed in the same manner. The directions of rotation is not critical so long as they are opposite.

The opposing rotation causes turbulent mixing of the air with the solid fuel so as to promote rapid combustion. The total air supply is divided among the three inlets 24, 25 and 27. The volume of air to any one inlet is not critical, but it is desirable that the air be about equally proportioned among them. The shape of the flame is controlled to some extent by the volume of air to the outer annulus 28. The gas inlet tube 29 or a similar inlet to any of the other feed tubes to the burner or to the combustion chamber may be utilized for the introduction of oxygen for air enrichment, or steam for increased hydrogen yields (as for ammonia synthesis), as well as for the introduction of preheat gas. The gaseous fuel is normally used only for the purpose of preheating the furnace and initiating combustion of the solid lignite fuel.

The solid fuel feed is finely divided for easy entrainment. Particle size is not critical. Pulverized lignite used in the process of the present invention has been of a screen analysis typical of commercial pulverizer output and varies between about 2% to about 30% retained on a 200 mesh screen. The pulverized fuel is pushed into the airstream from a low pressure blower which sweeps it along in suspension into the inner annulus 26 of the burner. Lignite with moisture content from about 5 to about 35% after pulverization has been successfully converted by the present process. Total oxygen feed has ranged from about 30 to about 90% of that theoretically required for complete combustion of the solid fuel. The best conversions are obtained in the range from about 40 to about 70% of theoretical oxygen rate. Other finely divided solid carbonaceous fuels which may be converted according to the process of the present invention include high volatile (31% or more (bituminous coals and sub-bituminous and brown coals.

The invention is further described with reference to the following examples. The examples are illustrative only and do not constitute limitations on the invention.

EXAMPLE 1

In a typical run, a dried lignite containing 12.2% moisture, 13.2% ash, 35.0% volatile matter and 39.6% fixed carbon and with a heating value on this basis of 8,830 B.t.u. per pound was pulverized for use. The cumulative lignite screen analysis showed 0.4% retained on 100 mesh screen, 11% on 200 mesh screen and 41% on 325 mesh screen. Air was admitted to the burner at a rate of 113 cubic feet per minute (measured at 32° F. and 1 atmosphere) as measured at an orifice in the air blower line. This air corresponded to 53.0% of the air theoretically required for complete combustion of the lignite and was substantially uniformly distributed to the three inlets of the burner. The combustion chamber was preheated for two hours by burning natural gas through the center pipe of the burner at a rate of about 8 cubic feet per minute. A gas torch was used to light the burner. Lignite was then admitted to the inner annulus in air suspension at a rate of 159 pounds per hour and after ignition of the lignite stream the gas was shut off and only air was admitted through the center pipe of the burner. A continuous sample of gas was withdrawn by a vacuum pump through a filter packed with fiberglass and through a dessicant into a gas chromatograph. The average gas analysis was 14.8% carbon monoxide, 4.7% hydrogen, 13.9% carbon dioxide, 0.0% oxygen, 0.1% methane and 66.5% nitrogen. The gas yield was 148 standard cubic feet per minute of dry gas corresponding to 62 pound moles of carbon monoxide plus hydrogen per ton of dry lignite. Solid residue was collected at a rate of 10.5 pounds per hour and upon analysis was found to contain 45.0% ash. Thus, the unburned combustible loss was 5.77 pounds per hour or 4.1% of the total combustible matter fired. A thermocouple located at the exit from the combustion chamber indicated an average temperature of 1730° F. A tar content of less than 0.005 grain per cubic foot of gas was measured by passing the gas stream through a cold trap.

EXAMPLES 2–6

A number of other runs were made following generally the procedures described in Example 1. These runs exhibit the ranges of conditions which result in effective gasification of lignite. The results are summarized in the table:

Table I

Example No.	2	3	4	5	6
Lignite feed rate, lb./hr.	94.7	121.3	34.6	100.4	126.5
Lignite moisture, percent	12.1	12.7	12.1	12.7	28.6
Percent theoretical O_2	87.2	33.2	60.9	46.6	65.5
Percent unburned combustible	1.2	64.0	4.5	12.8	8.2
Exit temperature, °F	1,990	1,600	1,520	1,785	1,640
Gas analysis (Orsat):					
Percent CO_2	14.0	12.6	14.1	12.0	13.2
Percent O_2	0.0	0.0	0.0	0.7	0.6
Percent CO	6.6	13.9	12.3	14.3	12.4
Percent H_2	5.8	12.2	6.0	9.1	7.9
Percent CH_4	0.0	0.6	0.1	0.2	0.0
Percent N_2	73.6	60.7	67.5	63.7	65.9

EXAMPLES 7–11

In order to illustrate the conversion of other solid carbonaceous fuels than lignite, the enrichment of air with oxygen and the addition of steam to the process, a number of further runs were made. In each instance the procedures described in detail in Example 1 were generally followed. In Example 7, Wyoming sub-bituminous coal was used as the solid fuel. In Example 8, high volatile Illinois bituminous coal was used. In Example 9, steam at the rate of 40.4 pounds per hour and at 30 pounds' pressure was introduced along with air.

In Example 10, 14.2% of the total oxygen introduced was pure oxygen. The remainder of the oxygen was supplied by air. The total oxygen was 45.6% of the amount theoretically required for complete combustion. In Example 11, 34.5% of the total oxygen introduced was pure oxygen. The remainder of the oxygen was supplied by air. The total oxygen was 42.3% of the amount theoretically required for complete combustion. The results of these further runs are summarized in the table:

Table II

Example No.	7	8	9	10	11
Fuel	Sub-bituminous	Bituminous	Lignite	Lignite	Lignite
Fuel feed rate, lb./hr.	97.8	85.3	98.8	87.5	87.8
Fuel moisture, percent	18.4	8.0	16.8	10.1	10.1
Percent theoretical O_2	50.4	52.4	47.9 (Steam added)	45.6 (Oxygen enriched)	42.3 (Oxygen enriched)
Percent unburned	3.2	7.1	8.4	7.1	4.4
Exit temperature, ° F.	1,615	2,080	1,605	1,450	1,545
Gas analysis (Orsat):					
Percent CO_2	12.9	9.5	14.7	12.0	10.5
Percent O_2	0.0	0.0	0.0	0.0	0.0
Percent CO	12.8	11.5	11.8	17.8	24.6
Percent H_2	8.2	3.7	8.2	9.2	10.1
Percent CH_4	0.2	0.0	0.1	0.3	0.2
Percent N_2	65.9	75.3	65.2	60.7	54.6

One exemplary metallurgical process in which the gasification process of the present invention is adapted for use is the process for the magnetic roasting of semi-taconite ores which is described in United States Patent 2,945,755, issued on July 19, 1960, to the University of Minnesota.

It is apparent that many modifications and variations of this invention as hereinbefore set forth may be made without departing from the spirit and scope thereof. The specific embodiments described are given by way of example only and the invention is limited only by the terms of the appended claims.

We claim:

1. A method of producing a substantially tar-free mixture of combustible and reducing gases comprised predominantly of

(*a*) nitrogen

on a dry gas basis and including

(*b*) carbon dioxide

(*c*) carbon monoxide and

(*d*) hydrogen,

which method comprises

(1) entraining a solid carbonaceous fuel in air as a combustible mixture,

(*a*) said carbonaceous fuel containing at least its natural non-aqueous volatile constituents,

(2) ejecting all of said combustible mixture of entrained solid fuel and said entraining air into a combustion zone

(*a*) in a turbulent flow pattern,

(3) ejecting additional air into said combustion zone

(*a*) in a turbulent flow pattern opposite to the turbulent flow pattern of the combustible mixture of fuel and entraining air, and

(4) burning said solid fuel

(*a*) at substantially atmospheric pressure

(*b*) in intimate contact with air

(i) present in total amount (including said entraining air) less than that theoretically required for complete combustion of said solid fuel.

2. A method according to claim 1 further characterized in that said air is present in amount from about 30 percent to about 90 percent of that theoretically required for complete combustion of the solid fuel.

3. A method according to claim 2 further characterized in that said air is present in amount from about 40 percent to about 70 percent of that theoretically required for complete combustion of the solid fuel.

4. A method according to claim 1 further characterized in that said solid fuel is ejected into the combustion zone in a turbulent spiral flow pattern and part of the air for partial combustion of the solid fuel is ejected into the combustion zone in a spiral flow pattern concentric with and in the same longitudinal direction as the turbulent spiral flow of solid fuel entrained in air but in the opposite spiral direction.

5. A method according to claim 1 further characterized in that part of the air for partial combustion of the solid fuel is ejected into the combustion zone in two spiral flow streams, one of said spiral flow air streams surrounding the turbulent spiral flow stream of solid fuel in air and the other of said spiral flow air streams being surrounded by said turbulent spiral flow fuel stream, all of said stream flows being concentric and in the same longitudinal direction, said spiral air stream flows being in opposite spiral direction from said turbulent spiral flow fuel stream.

6. A method according to claim 1 further characterized in that said solid fuel is a coal selected from the group consisting of high volatile bituminous coals, sub-bituminous coals and lignite.

7. A method according to claim 6 further characterized in that said solid fuel is lignite.

8. A method of producing substantially tar-free a mixture of gases comprised predominantly of nitrogen and carbon dioxide on a dry gas basis and including carbon monoxide and hydrogen, which method comprises burning a finely divided solid carbonaceous fuel at near-atmospheric pressure in intimate contact with air present in amount to supply from about 30% to about 90% of the oxygen theoretically required for complete combustion of the solid fuel, said solid fuel being entrained in air and ejected into the zone of combustion in a turbulent spiral flow pattern, part of the air for partial combustion of said solid fuel being ejected into the combustion zone in two spiral flow streams, one of said spiral flow air streams surrounding the turbulent spiral flow stream of solid fuel in air and the other of said spiral flow air streams being surrounded by said turbulent spiral flow solid fuel in air stream, all of said stream flows being concentric and in the same longitudinal direction, said spiral flow air streams being in opposite spiral direction from said spiral flow fuel stream.

9. A method according to claim 8 further characterized in that said solid fuel is lignite of between about 5% and 35% moisture content and the total amount of said air is sufficient to supply from about 40% to about 70% of the oxygen theoretically required for complete combustion of the lignite.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,110,578 November 12, 1963

Donald E. Severson et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, lines 5 and 6 and lines 16 and 17, and in the heading to the printed specification, lines 8 and 9, for "Great Northern Railways Company", each occurrence, read -- Great Northern Railway Company --; column 4, Table 1, under Example No. 5 fourth line thereof, for "12.8" read -- 13.8 --.

Signed and sealed this 19th day of May 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents

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