Oct. 12, 1965 E. W. HENDERSON 3,211,532

CARBON BLACK FURNACE

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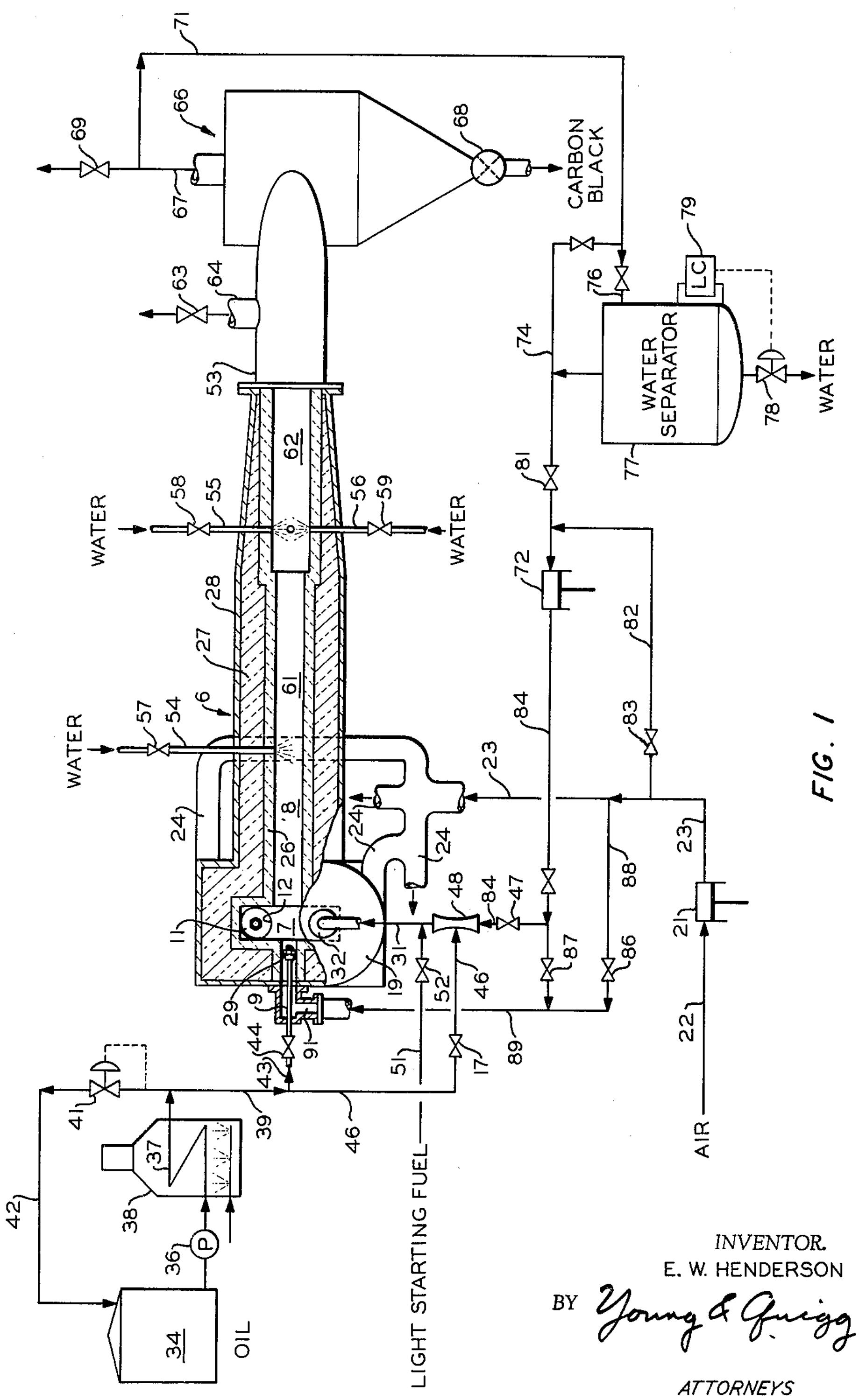

FIG. 1

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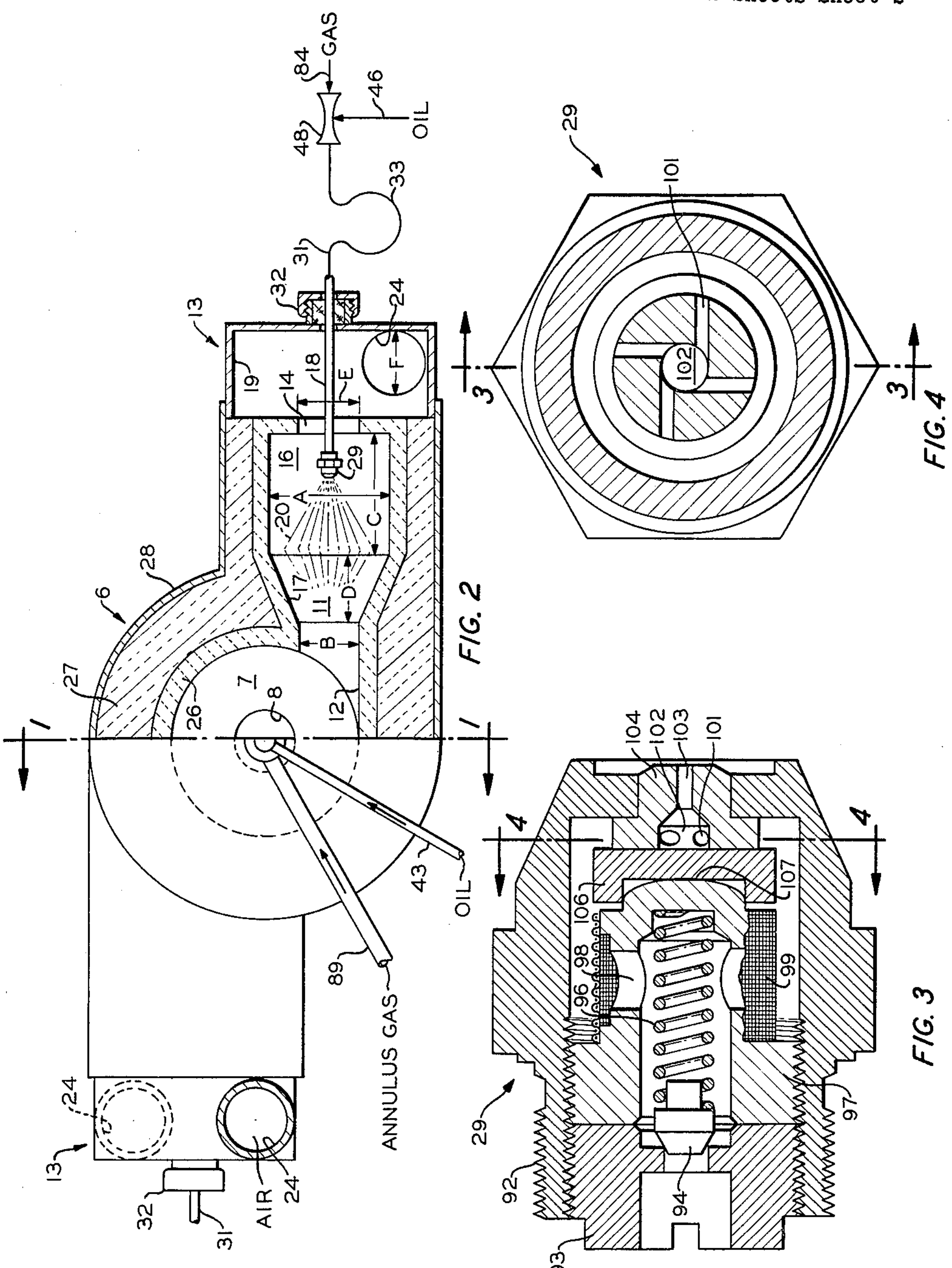

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CARBON BLACK FURNACE

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8 Claims. (Cl. 23—259.5)

This invention relates to improvements in carbon black furnaces and processes of operating the same. In one aspect it relates to such furnaces and processes as applied to the use of a heavy residual hydrocarbon oil of API gravity less than 15, especially when the oil is a heavy residual aromatic tar hydrocarbon oil having a Bureau of Mines Correlation Index (BMCI) of 85 to about 160, when such oil is used as a fuel to produce hot combustion gases which pyrolyze a portion of such oil to form carbon black. The expression heavy residual hydrocarbon oil, when used in the present specification in the field of making carbon black by a furnace process, is defined as an essentially hydrocarbon oil having a distillation range under atmospheric pressure, or corrected to atmospheric pressure, with a 10 percent distilled point of at least 550° F., and at least 10 percent of which will not distill at atmospheric pressure without cracking.

In the prior art, as represented by U.S. Patent 2,961,300 to R. E. Dollinger of November 22, 1960, it is old to have a carbon black furnace comprising in combination a first cylindrical chamber of greater diameter than length and a second cylindrical coaxial chamber of less diameter communicating therewith, said second chamber being of greater length than diameter, a hydrocarbon injector being disposed to discharge a stream of hydrocarbons predominantly axially into said first chamber and therethrough into said second chamber, and to have at least one generally cylindrical oil burner chamber having an axial outlet communicating with said first chamber predominantly tangent to the cylindrical inner wall thereof. However, in said prior art when using a heavy residual hydrocarbon oil of API gravity less than 15, or especially a heavy residual aromatic tar hydrocarbon oil having a BMCI of 85 to about 160, as the fuel to the tangentially disposed oil burner chamber, a rapid deposition of carbonaceous and tarry material occurs in the oil burner chamber which reduces the length of time that the carbon black-forming reaction can continue without shutting down the furnace and cleaning out the deposit. This shutting down and cleaning out is quite expensive in that the furnace cannot produce carbon black while being cleaned out and that considerable time of the operators is lost in cleaning out the furnace. In said Dollinger patent in column 5, lines 19–24, and column 6, Table I, it will be noted that while a heavy residual aromatic tar hydrocarbon oil having an API gravity of about 1 and a BMCI of about 122, designated as S–2 tar, is employed as an axial feedstock, a light distillate less-aromatic hydrocarbon oil of an API gravity of about 20 and a BMCI of about 80 is employed as the tangential fuel.

The present invention is the discovery that heavy residual hydrocarbon oil of API gravity less than 15, even heavy residual aromatic tar hydrocarbon oil having a BMCI of 85 to about 160, can be employed as the tangential fuel as well as the axial feedstock in such a furnace without rapid deposit of carbonaceous material if the central portion of the tangential combustion chamber is enlarged, especially if the tangential fuel is atomized into said enlarged portion of the tangential combustion section by injecting gas under pressure into said tangential fuel, said gas under pressure being either air or an inert gas, but preferably an inert gas comprising the combustion gases formed in the carbon black-producing process. Such combustion gases consist mainly of mixtures of carbon

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dioxide, carbon monoxide, nitrogen and water vapor, although minor proportions of hydrogen, methane, acetylene and other hydrocarbons in trace quantities may be present and may be used as formed, although it is preferred to separate such water as may be readily condensed by cooling to a temperature as little above atmospheric temperature as may be convenient.

One object of the present invention is to provide a new and useful carbon black furnace.

Another object is to provide new methods of operating a carbon black furnace.

Another object is to provide a carbon black furnace and method of operating the same which will permit the use of heavy residual hydrocarbon oil of API gravity less than 15, such as a heavy residual aromatic tar hydrocarbon oil of API gravity less than 15 and having a BMCI of 85 to about 160, as both the axial feedstock to be converted to carbon black and as the tangential fuel to produce the hot combustion gases which pyrolyze the axial feedstock into carbon black.

Another object is to provide a suitable tangential burner for burning such heavy oil without substantial carbon deposits in said burner.

Another object is to provide means for utilizing such heavy oil with gas pressure so that it will burn in such a tangential burner with even less tendency to deposit carbonaceous material.

Numerous other objects and advantages will be apparent to those skilled in the art upon reading the accompanying specification, claims and drawings.

In the drawings:

FIGURE 1 is an elevational view of a carbon black furnace embodying the present invention with parts broken away to show details of construction.

FIGURE 2 is an end view of the furnace of FIGURE 1 with parts broken away to show the details of construction.

FIGURE 3 is a cross-sectional view of one type of oil spray nozzle which may be employed as either the axial or tangential oil nozzles in the furnace of FIGURES 1 and 2.

FIGURE 4 is a cross section of FIGURE 3 taken along the line 4—4 looking in the direction indicated.

It will be noted that FIGURE 3 is a cross section taken along the line 3—3 of FIGURE 4 looking in the direction indicated, and the carbon black furnace portion of FIGURE 1 is taken along the line 1—1 of FIGURE 2 looking in the direction indicated, except for a part of **19** not broken away.

The furnace and process of the present invention permits the substitution of cheaper heavy oil for the more expensive light distillate oil used in tangential firing in the prior art and thus accomplishes large savings in cost for a large carbon black plant.

In FIGURE 1 a carbon black furnace, generally designated as **6**, comprises in combination a first cylindrical chamber **7** of greater diameter than length and a second cylindrical coaxial chamber **8** of from ½ to ¼ the diameter of said first chamber (shown as ⅓ the diameter of said first chamber) communicating therewith. Said second chamber **8** is of greater length than diameter. A hydrocarbon injector **9** is disposed to discharge a stream of hydrocarbons predominantly axially into said first chamber **7** and therethrough into said second chamber **8**. At least one generally cylindrical oil burner chamber **11** is provided having an axial outlet **12** communicating with said first chamber **7** predominantly tangential to the cylindrical inner wall thereof.

As shown in FIGURE 2, the oil burner chamber **11** is formed with its outlet **12** of a diameter "B" from ½ to 1½ times the diameter of said second chamber **8** (shown as about the same diameter), said oil burner chamber **11** comprising in combination, in axial communication in series, means generally designated as **13** for supplying air under pressure, an inlet **14**, a combustion section **16**, a reducing section **17** and said outlet **12**.

The combustion section **16** has a length "C" at least as great as its diameter and a diameter "A" from 1½ to 3 times the diameter "B" of said outlet **12** (shown as about twice the diameter), and a liquid hydrocarbon injector **18** is disposed in said combustion section **16** to discharge a stream **20** of hydrocarbon predominantly axially thereof towards said outlet **12**. Obviously, the spray nozzle **29** of injector **18** should be located adjacent the inlet **14** of the chamber of combustion section **16** to enable the combustion shown by dotted lines **20** in FIGURE 2 to occur as shown in said figure. The dimensions "A," "B" and "C" are critical, but the dimensions "D" and "E" are not critical, as the length "D" of reducing section **17** may be of any length permitting converging flow of gases, from combustion section **16** through outlet **12** into chamber **7**, and the diameter "E" of inlet **14** may range anywhere between the diameter "A" of combustion section **16** and about half the diameter of "B" outlet **12**, preferably about ¾ the diameter of "B". Inlet **14** (when used) merely tends to increase the turbulence and completeness of burning of hydrocarbon **20** in combustion section **16**. The diameter "A" should be at least 1¼ times the axial length of the precombustion chamber **7**.

The means **13** for supplying air under pressure may be any such means known in the prior art, but preferably comprises a cylindrical wind box **19**, preferably of at least as great diameter as said combustion section **16**, and compression means comprising a compressor **21** (lower part of FIGURE 1) having an intake conduit **22** communicating with the atmosphere and an outlet conduit **23** connected to at least one air supply conduit **24** of about the same diameter "F" as said outlet **12** connected in communication with said wind box **19** predominantly tangent to its inner cylindrical wall.

While not essential to the practice of the invention, certain details of construction are shown in FIGURE 2. The carbon black furnace **6** could be built entirely of refractory material, but to reduce the cost is preferably constructed with an inner refractory ceramic lining **26**, intermediate heat-insulating lining **27** and an outer metal casing **28**. The tangential oil injector **18** may be provided with a nozzle **29** (shown in greater detail in FIGURES 3 and 4), and the pipe **31** leading to injector **18** may be mounted in a stuffing box **32** to provide axial adjustment of nozzle **29** in combustion section **16**, movement for which is provided by flexible section **33** of conduit **31**.

As shown in FIGURE 1, a single source **34** of oil may be employed, said oil being pumped by pump **36** through coil **37** of preheater **38** into oil spray line **39**. As a safety measure, line **39** may be provided with a relief valve **41** and a recycle line **42** so that if a predetermined maximum pressure is reached in line **39** some of the oil and the pressure will be relieved through line **42** back to tank **34**. The oil in line **39** passes through line **43** and valve **44** into axial injector **9**. Axial injector **9** may be a simple pipe but preferably is provided with a nozzle **29** of the type shown in FIGURES 3 and 4.

The oil in line **39** also passes through line **46** and valve **17** and line **31** into tangential injector **18**.

While valve **47** may remain closed so that oil from line **46** is passed through line **31** into tangential oil injector **18** merely under pump pressure **36** as controlled by relief valve **41**, it is preferred to pass the oil through line **46** into the throat of a gas-powered, venturi-type oil eductor **48**, supplied with gas under a pressure of 25 to 500 p.s.i.g., more preferably 25 to 150 p.s.i.g., for example preferably about 75 p.s.i.g., with valve **47** open.

It is not believed necessary to show the details of the gas-powered oil eductor **48**, as such eductors are well known in the prior art, and any one of the same gives substantially the same results.

As the heavy oil employed is somewhat difficult to ignite, it is customary to start with a starting fuel, such as gasoline, injected through line **51** and valve **52**. After the combustion section **16** of the tangential burner **11** is heated, valve **52** is closed and valve **17** opened to supply heavy oil to the hydrocarbon injector **18**.

While it is only necessary to have one tangential burner **11** discharging through outlet **12** into the first cylindrical chamber **7**, known as the precombustion chamber, it is preferable for steady operation to have two tangential burners **11** spaced 180° apart, as shown in FIGURE 2. Of course, more than two burners could be used. While it is possible to operate with only one tangential air inlet **24** in wind box **19**, it is preferable to have two such tangential inlets to each wind box **19**, as shown in FIGURE 2. Of course, more than two tangential inlets could be used.

It is preferred to quench the hot smoke coming from the second cylindrical chamber **8**, often known as the reaction section, by injecting a spray of water into the same through pipe **54**, controlled by valve **57** as a primary quench, and if necessary, injecting further water sprays as a secondary quench through pipes **55** and **56** controlled by valves **58** and **59**, respectively. The portions **61** and **62** downstream of the first quench **54** are often known as the quench section of the furnace.

When starting the furnace, valve **63** in branch line **64** may be open to by-pass the hot combustion gases which are warming up the furnace, but as soon as the oil from line **43** is injected through axial injector **9** upon opening valve **44**, then valve **63** is closed and the smoke in pipe **53** passes into any conventional system known to the prior art for separating carbon black solids from the combustion gases suspending the same. For purposes of illustration, a simple cyclone separator generally designated as **66** is shown as this conventional separating means, the smoke entering tangentially from pipe **53** and the combustion gases, known as off-gas, passing upwardly through pipe **67** while the solid particles of carbon black, separated from the gas by centrifugal force and gravity, pass downwardly out through the conventional star valve **68**.

While the major portion of the off-gas passes through valve **69** to the atmosphere, at least a portion of these combustion gases pass through line **71**, either directly to a compressor **72** through line **74** or preferably through line **76** and water separator **77** to said compressor **72**. These combustion gases from line **76** contain a large proportion of water vapor. As water separator **77** is not very much above atmospheric temperature and may contain suitable baffles (not shown), a large proportion of the water vapor condenses to form water and is removed through valve **78** in response to liquid level control **79**, thus avoiding water entering compressor **72** or being recycled to the carbon black furnace where it would have a dampening effect on the process.

Compressor **72** may compress the gases to a pressure of 25 to 500 p.s.i.g., preferably 25 to 150 p.s.i.g., and most preferably to about 75 p.s.i.g. The gases compressed can be combustion gas from line **74** or **76** when valve **81** is open and/or air from lines **23** and **82** when valve **83** is open. The gas compressed by compressor **72** travels through line **84** and valve **47** when used to educt oil from line **46** into eductor **48** and into tangential hydrocarbon injector **18** through line **31**.

Sometimes some difficulty is experienced with carbon deposits around the axial hydrocarbon injector **9**. While not essential to the invention, valves **86** and/or **87** may be opened to permit air from lines **23** and **88**, or gas from line **84**, respectively, to pass through line **89** into the annular space **91** around injector **9** to reduce the tendency for deposits to form in said annular space **91**.

While the injection may be practiced with ordinary injector pipes **9** and **18**, it is obviously preferable to have some sort of nozzle **29** on their ends which will provide a suitable spray. While any type of spray head known to the prior art may be employed as nozzle **29**, in FIGURES 3 and 4 are shown the preferred nozzle, which nozzle was not invented by the present applicant but merely selected for use from the prior art. Nozzle **29** has threads **92** for connection with pipes **9** or **18**; however, any other connection means may be used. A valve seat **93** and spring-closed check valve **94** is biased against said seat by helical compression spring **96**. The spring retainer **97** contains openings **98** for the passage of oil therethrough. Although not essential, it is desirable to surround openings **98** with a cylindrical screen **99** in order to prevent the passage of foreign matter into the small diameter feed passages **101**, which preferably lead tangentially into chamber **102** and thence through orifice **103** in the spray nipple **104** in order to provide a more perfect spray. Plate **106** and spherical surface **107** merely allow for minor self-adjustment of parts to minimize leakage.

While the present invention is directed to an apparatus and process for cleanly burning a heavy residual aromatic tar hydrocarbon oil of API gravity less than 15, having a BMCI of 85 to about 160, in the tangential burners of a carbon black furnace of the general type disclosed in said Dollinger patent, it is obvious that other cleaner burning and more easily combustible oils can be employed as both the axial feedstock injected at **9** and the tangential fuel injected at **18**. However, such cleaner burning oils are not as valuable in making carbon black because their BMCI is generally below 85, and generally the higher the BMCI the higher the yield of carbon black is per gallon of oil, and the higher is the quality of the carbon black produced.

Therefore, from a standpoint of economic, it is preferred to use liquid feedstocks having a BMCI of at least 85 and more preferably over 110. The formula used is as follows:

$$\mathrm{BMCI}=\left(\frac{876}{460+\mathrm{F}}+\frac{670}{131.5+\mathrm{API}}-4.568\right)100$$

wherein "F" is the boiling point in degrees Fahrenheit at the 50 percent recovery distillation and "API" is the American Petroleum Institute gravity at 60° F. It is preferred that the API gravity should be as low as possible at least less than 15.

As an example of one preferred residual feedstock employed, a normally liquid hydrocarbon having a hydrogen-to-carbon atomic ratio below 1.5 and preferably in the range of 0.75 to 1.25, a mean molecular weight above 140 and preferably from 225 to 550, an API gravity less than 10, and a low Conradson carbon residue which, however, may be in excess of 1.5 weight percent or even in excess of 3 weight percent, but not more than 15 and preferably not more than 10 weight percent, is suitable in the practice of this invention. However, any heavy hydrocarbon oil of API gravity less than 15 may be employed in the invention. However, a heavy residual aromatic tar hydrocarbon oil of API gravity less than 15 having a BMCI of 85 to 160 is preferred. The feedstock should be essentially a hydrocarbon oil. However, any small oxygen or nitrogen content appears to only reduce the yield and not affect the quality of the carbon black. Sulfur is not objectionable so far as carbon black quality is concerned, but large amounts can cause corrosion in the equipment, so for commercial purposes the sulfur content should be less than 3 and preferably less than 1 weight percent. Said liquid hydrocarbon feedstock may be a petroleum residual oil or a coal tar residual oil, synthetic tars from catalytic or thermal cracking, cracked residues, or vacuum still tarry residuums.

The use of a large diameter combustion space **16** gives

ample room for the complete combustion of the liquid hydrocarbon spray before it reaches the walls of the combustion chamber so that substantial carbon deposits will not occur therein, while the reducing section **17** and outlet **12** allows the air to turn the flame away from the walls of the tangential burner and restores the original velocity to produce a sufficient tangential velocity to move the combustion gases to the cylindrical wall as they enter the precombustion chamber **7**. When employed, the further addition of gas **84** to pressure and atomize the oil emerging from hydrocarbon injector **18** gives a finer and faster burning mist of oil, with an increase in turbulence, to produce more rapid and complete combustion without deposit of carbonaceous material on the inner walls of combustion section **16**, reducing section **11**, outlet **12**, first chamber **7**, and second chamber **8**.

While specific embodiments of the invention have been discussed in the specification and shown in the drawings for illustrative purposes, the invention is not limited thereto.

Having described my invention, I claim:

1. In a carbon black furnace comprising in combination a first cylindrical chamber of greater diameter than length and a second cylindrical coaxial chamber of from ½ to ¼ the diameter of said first chamber communicating therewith, said second chamber being of greater length than diameter, a hydrocarbon injector disposed to discharge a stream of hydrocarbons predominantly axially into said first chamber and therethrough into said second chamber, and at least one generally cylindrical oil burner chamber having an axial outlet communicating with said first chamber predominantly tangent to the cylindrical inner wall thereof;

the improvement characterized by forming said oil burner chamber with its said outlet of a diameter from ½ to 1½ times the diameter of said second chamber;

said oil burner chamber comprising in combination, in axial communication in series, means for supplying air under pressure, an inlet, a combustion section, a reducing section, and said outlet;

said combustion section having a length at least as great as its diameter, and a diameter from 1½ to 3 times the diameter of said outlet and at least 1¼ times the axial length of said first cylindrical chamber; and

a liquid hydrocarbon injector disposed in said combustion section to discharge a stream of hydrocarbon from a point adjacent said inlet thereof predominantly axially thereof toward said outlet.

2. The combination of claim **1** in which the means for supplying air under pressure comprises a cylindrical wind box of at least as great diameter as said combustion section, and air compression means comprising at least one air supply conduit of about the same diameter as said outlet connected in communication with said wind box predominantly tangent to its inner cylindrical wall.

3. The combination of claim **1** with means to supply under pressure the same heavy residual hydrocarbon oil to both said hydrocarbon injector and said liquid hydrocarbon injector.

4. The combination of claim **1** in which the inlet of said oil burner chamber comprises a diaphragm with an orifice of about ¾ the diameter of said outlet.

5. The combination of claim **1** in which there is a means for introducing gas under a high pressure of 25 to 500 p.s.i.g. into said liquid hydrocarbon injector for atomizing said liquid hydrocarbon being injected into said combustion section.

6. The combination of claim **5** in which the inlet of said oil burner chamber comprises a diaphragm with an orifice of about ¾ the diameter of said outlet.

7. The combination of claim **5** in which said carbon black furnace includes means to separate the carbon black formed from the combustion gases, and means for compressing at least a portion of said combustion gases to a pressure of 25 to 500 p.s.i.g. and supplying them to said gas introducing means as said gas for atomizing said liquid hydrocarbon.

8. The combination of claim 7 with means to supply under pressure the same heavy residual hydrocarbon oil to both said hydrocarbon injector and said liquid hydrocarbon injector.

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