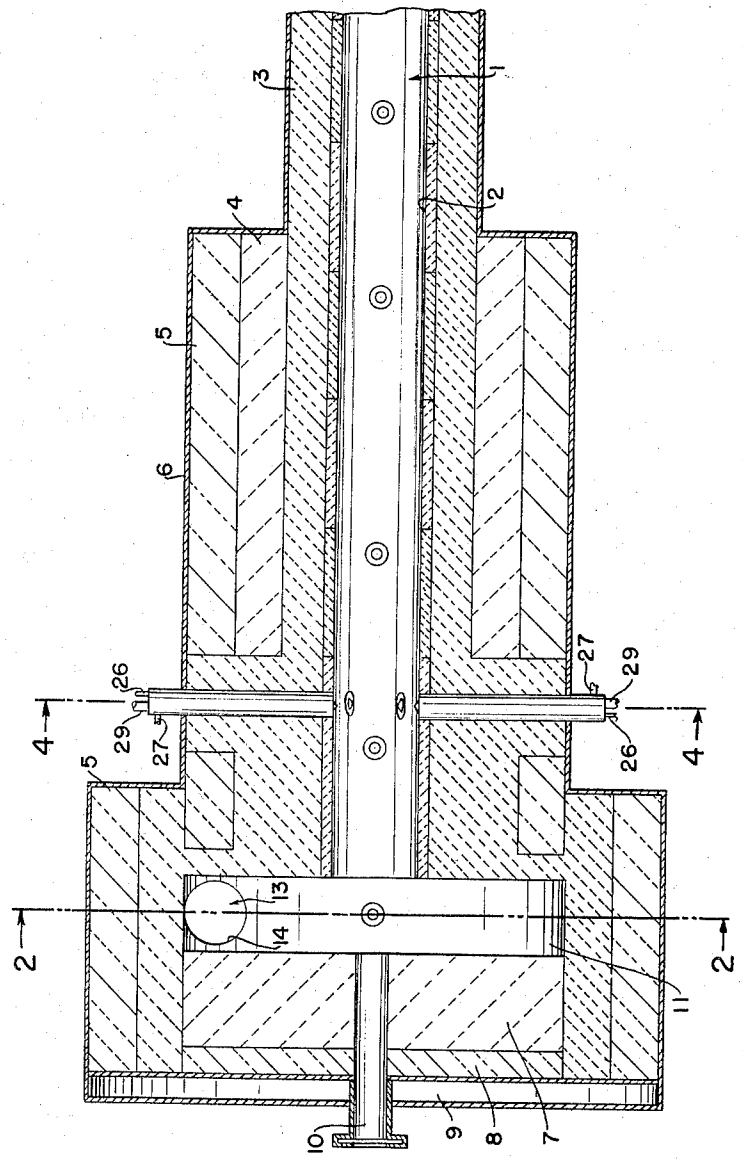
Dec. 22, 1959 G. L. HELLER 2,918,353

PROCESS AND APPARATUS FOR MANUFACTURE OF CARBON BLACK

Filed July 11, 1957

2 Sheets-Sheet 1

FIG. 1



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Filed July 11, 1957 2 Sheets-Sheet 2

FIG. 2

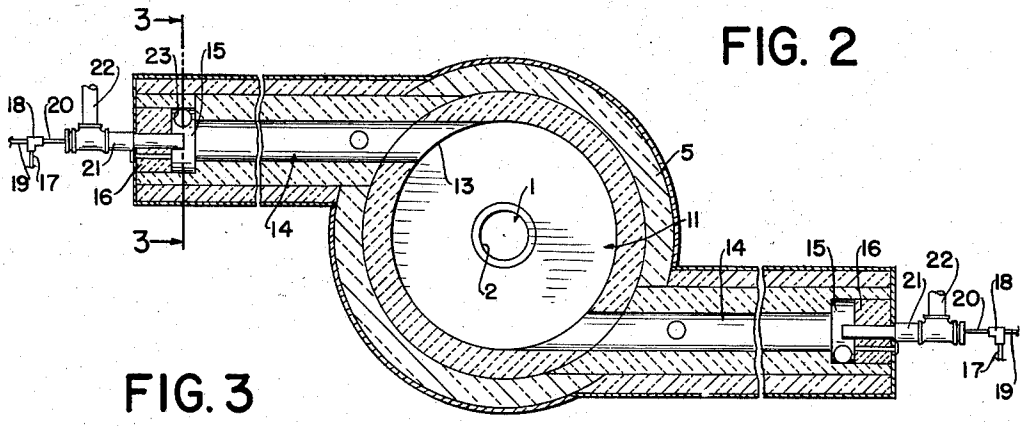


FIG. 3

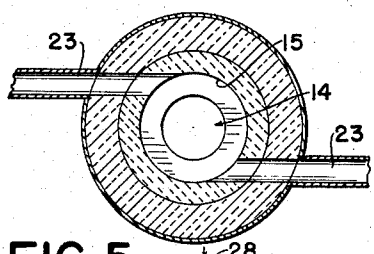


FIG. 4

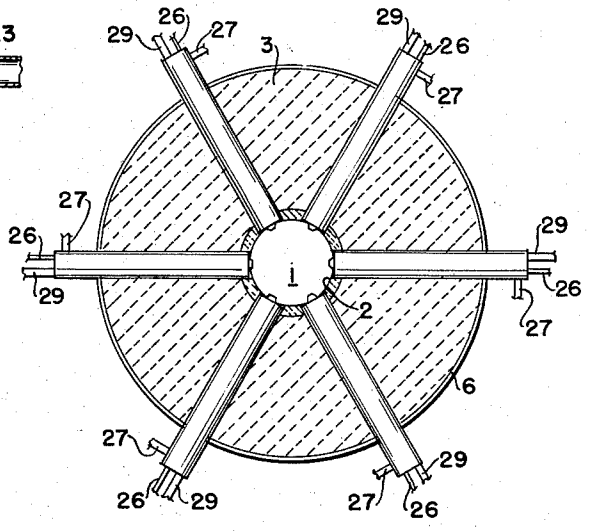
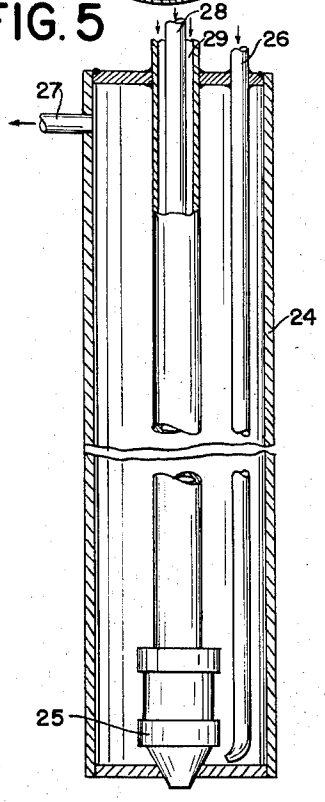


FIG. 5



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2,918,353

PROCESS AND APPARATUS FOR MANUFACTURE OF CARBON BLACK

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Application July 11, 1957, Serial No. 671,163

9 Claims. (Cl. 23—209.4)

This invention relates to the production of carbon black from hydrocarbons by dispersing the hydrocarbon in a stream of hot blast flame gases at a temperature above that at which the hydrocarbon is decomposed, whereby the hydrocarbon is decomposed by heat absorbed from the hot gases to form carbon black in gaseous suspension.

The invention is especially adapted to operations of that type in which the hydrocarbon to be decomposed, herein referred to as hydrocarbon make, is separately and forcefully injected as an atomized liquid spray directly into, and almost instantly mixed with, a separately generated stream of hot blast flame gases passing through an elongated, heat-insulated reaction chamber.

Operations of that general type have previously been proposed. For instance, in my Patent No. 2,659,662 there is described and claimed a process in which the stream of blast flame gases is generated by blasting a combustible mixture of a hydrocarbon fuel and an oxygen-containing gas at high velocity into one end of a reaction chamber of cylindrical cross-sections in a direction tangential to the inner cylindrical wall of the chamber, and burning the mixture as it enters the chamber to form hot blast flame gases swirling at tremendous velocities as they pass along a helical path longitudinally through the chamber, and the hydrocarbon make is injected substantially radially into the chamber at a zone downstream from the zone of injection of the combustible mixture.

The present invention relates more particularly to improvements in processes of that general type.

In order to generate heat at a sufficiently rapid rate and to produce the blast flame gases at adequate temperature and in sufficient volume to impart the required velocity to the resultant swirling gas stream, it has been necessary to inject the combustible mixture into the chamber at extraordinarily high velocities and to effect the combustion at a very rapid rate. Where the hydrocarbon fuel has been injected in gaseous state, this has generally been satisfactorily accomplished, but has, nevertheless, imposed certain undesirable limitations upon operating and load conditions. Where it has been attempted to use normally liquid fuel by injecting it as a liquid spray into the reaction chamber, those difficulties have been greatly increased and also, serious difficulties have been experienced due to coke formation and deposition on the chamber wall.

Under present conditions, gaseous fuel, e.g. natural gas, or liquid fuels readily convertible to vapors, are frequently not economically available and the use of liquid fuels, often heavy petroleum residues, is becoming increasingly urgent.

It is a primary object of the present invention to provide a process, of the type described, adapted to the use of such liquid fuels without coking of the chamber walls and without loss in yield or quality of the resultant carbon black and to provide apparatus adapted to the carrying out of the new process.

These and other advantages are attained by my present

invention, as will appear from the following description thereof.

In accordance with my present process, the hot blast flame gases are separately generated outside of the reaction chamber and directed at high velocity into one end of the reaction chamber in a direction substantially tangential to the inner wall thereof, thus forming the swirling stream of hot gases, previously described. The temperature, volume, composition and velocities of the hot gases thus supplied to the reaction chamber may be accurately controlled and regulated to produce optimum reaction conditions within the reaction chamber.

In operations of this type, whereby the hydrocarbon make streams are injected directly into the swirling stream of hot gases so that the liquid make streams are quickly shattered and mixed with the hot gases, I have found it particularly advantageous that the combustion of the fuel be substantially complete before the hot gases come into contact with the hydrocarbon make. This has been found materially to influence the characteristics and quality of the resultant carbon black. The yield is also increased, apparently due to better control of robber side-reactions. In accordance with the present invention, such substantially complete combustion is readily obtained independently of other operating conditions, thus providing greater flexibility of the unit.

In order to supply the hot gases to the reaction chamber at sufficiently high velocity to effect the necessary swirling when injected into the reaction chamber, I generate these gases in one or more elongated combustion tunnels of relatively small cross-sectional area, e.g. of a diameter not exceeding one-fourth of its length, by injecting the fuel oil spray and an oxygen-containing gas, e.g. air, into the outer end of the tunnel. Under such combustion conditions, and especially where a heavy residuum petroleum product is used as the fuel, coke would normally be rapidly formed on the inner walls of the tunnel disrupting operation.

An important aspect of my present invention is my method and means of avoiding such deposition of coke. This I accomplish by injecting the fuel oil spray axially into the tunnel and simultaneously develop within the tunnel, along the side walls thereof, a helically flowing, shielding layer of the oxygen-containing gas. Advantageously, I also inject into the outer end of the combustion tunnel a sheath of air contiguous to, and surrounding, the oil spray, all as hereinafter more fully described.

For this generation of the hot combustion gases, my improved apparatus, as previously noted, is provided with one or more elongated combustion tunnels or chambers. These tunnels extend substantially tangentially from near the upstream end of the reaction chamber, the longitudinal axis of each combustion tunnel lying in a plane substantially perpendicular to the longitudinal axis of the reaction chamber. These tunnels are of substantially uniform, cylindrical section throughout their length, except for a substantial increase in diameter at their outer ends to provide space for the tangential injection of the air streams. The inner ends of these combustion tunnels are in unobstructed communication with the reaction chamber. The outer ends of the tunnels are closed.

The enlarged outer end of the combustion tunnel is provided with one or more air inlets entering the tunnel in a direction substantially tangential to the inner wall of larger diameter zone. Each combustion tunnel is also provided at its outer end with an axially positioned fuel injector terminating in an atomizing nozzle in the enlarged zone end of the tunnel, advantageously in the plane of the tangential air inlets, and adapted to inject the fuel in a finely atomized condition. Advantageously,

the spray nozzle is shrouded by an annular coaxially arranged air inlet.

The hydrocarbon make is injected radially into the reaction chamber in a zone thereof downstream from the zone of introduction of the hot blast flame gases. The zone of introduction of the hydrocarbon make and that portion downstream therefrom should be of substantial uniform cross-section and substantially unobstructed. That zone of the chamber at the introduction of the hot combustion gases is with advantage of substantially increased diameter for facilitating the flow of the hot combustion gases thereto from the combustion tunnels.

The invention will be further described and illustrated with reference to the accompanying drawings which represent conventionally and somewhat diagrammatically the presently preferred form of apparatus for carrying out the process and of which

Fig. 1 is a longitudinal sectional view,

Fig. 2 is a transverse sectional view along line **2**—**2** of Fig. 1,

Fig. 3 is a transverse sectional view along line **3**—**3** of Fig. 2,

Fig. 4 is a transverse sectional view along line **4**—**4** of Fig. 1, and

Fig. 5 is a longitudinal sectional view of a hydrocarbon make injection assembly which has been used with advantage, somewhat enlarged for clarity.

Referring more particularly to Fig. 1 of the drawings, an elongated cylinder reaction chamber is represented at **1** delineated by highly refractory furnace lining **2** surrounded by layers of heat-insulating materials **3**, **4** and **5**, all encased in a metal casing **6**. The right-hand end of the reaction chamber leads to conventional cooling and collecting means, which need not here be described. The upstream end of the chamber is closed by heat refractory and insulating walls **7** and **8**, the outer side of this end wall being encased by water jacket **9**. Port **10**, extending axially through the end wall, is provided for observing conditions within the chamber.

The extreme upstream end of the reaction chamber is of substantially increased diameter as indicated at **11**, to provide an enlarged zone for the combustion of any residual combustible matter present in the entering combustion gases, and just downstream therefrom, there is provided a plurality of symmetrically arranged, radially positioned hydrocarbon make injection assemblies, shown in greater detail in Figs. 4 and 5 of the drawings.

The separately generated hot combustion gases enter the upstream end of the reaction chamber, in the zone thereof of increased diameter, in a direction substantially tangential to the inner walls of said zone as indicated at **13**. That portion of the apparatus by which these hot gases are generated is represented by Figs. 2 and 3 of the drawings.

Referring to Fig. 2, two symmetrically positioned, elongated combustion tunnels are shown at **14**, each opening at its downstream end tangentially into the enlarged section **11** of the reaction chamber at **13**. Each of these combustion tunnels is somewhat enlarged in diameter at its outer end, as indicated at **15**, and the upstream end of the enlarged section **15** is closed by refractory end wall **16**.

In the apparatus shown in Fig. 2, fuel oil under pressure, and advantageously preheated somewhat to improve fluidity and atomization thereof, is passed through tube **17** to mixing chamber **18** where it is mixed with an atomizing gas, for instance air or steam, passed to the mixing chamber through line **19**. Mixed oil and gas pass from the mixing chamber through line **20**, which passes axially through end wall **16**, into the enlarged zone **15** of the combustion tunnel terminating in said zone in a suitable nozzle adapted to inject the oil-gas mixture into the chamber in the form of a fine spray.

Instead of the arrangement shown for premixing the fuel oil and atomizing gas, a two-fluid atomizing nozzle such as shown in Fig. 5 may be used to which the oil and atomizing gas are separately passed to the nozzle as well-known in the art. However, I have usually found that the premixed arrangement shown in Fig. 2 of the drawing provides a more satisfactory atomization of the oil.

The injection tube **20** and the nozzle at the inner end thereof are surrounded by coaxially positioned tube **21** to provide an annular conduit for the introduction of a shroud of air about the atomized stream of fuel oil, the air being supplied to tube **21** from any suitable source, such as the conduit **22**.

As more clearly shown in Fig. 3, air is passed tangentially into zone **15** of the combustion tunnel through conduits **23**. In the apparatus illustrated, two of the air conduits **23** are provided, as this arrangement has usually been found more satisfactory. However, only one such conduit need be provided and even more than two may be used if desired.

Also, while the particular apparatus shown in the drawings comprises two such combustion tunnels, it will be understood that a greater number, or even a single tunnel, may be used within the scope of the invention.

Various types of atomizing assemblies may be used for injecting the hydrocarbon make into the reaction chamber. I have usually found the two-fluid type atomizer best suited for this purpose. Due to the high temperature of the furnace wall at the zone of make injection, it is generally desirable to thermally shield the oil stream as it passes through the furnace wall to prevent coking of the oil lines.

An atomizing assembly well adapted to this purpose is represented in Fig. 5 and comprises a generally cylindrical outer jacket **24** closed at each end and of sufficient length to project through and outwardly beyond the chamber wall. Atomizing nozzle **25** projects through the inner end of the jacket and is sealed therein to prevent leakage into the furnace of cooling fluid, e.g. water, discharged into the inner end of the jacket through conduit **26** and which passes from the outer end of the jacket through conduit **27**. Atomizing gas, such as steam, or air, is passed to the nozzle through conduit **28** and the hydrocarbon make in liquid form is passed to the nozzle through the annular conduit **29**.

Atomizing assemblies of the type just described may also be used with advantage for the atomizing of the fuel oil. However, when used for that purpose, the water cooling is usually unnecessary. In any event, for best results, means should be provided, as previously described, for shrouding the atomized stream of fuel oil with an annular stream of air.

In operation in accordance with my process, a finely atomized stream of fuel oil is axially injected, into each of the elongated combustion tunnels at their outer zone of enlarged diameter. The fuel oil spray nozzle may with advantage terminate substantially flush with the inner surface of end wall **16** or may project somewhat into the chamber, generally not more than 3–4 inches. Preferably, this spray nozzle should terminate at approximately the plane of the axes of the air inlet conduits **23**.

Where a relatively heavy viscous fuel oil is being used, it is frequently advantageous to preheat the oil sufficiently to permit substantially complete, uniformly fine atomization, usually to a temperature of about 400°–450° F. Higher temperatures, up to about 600° F., may be used. The oil may be supplied, under a relatively low pressure, say within the range of about 2 to 10 pounds per square inch. I have, with advantage, used either saturated steam or preheated steam as the atomizing gas. Steam temperatures of about 210–300° F. have been found satisfactory. Air is preferred as the atomizing gas and where air is so used, it may, with advantage, be preheated so as to promote atomization of the oil and should be at a pressure not less than about 40 pounds per square inch. The

optimum proportion of atomizing gas used will vary over a considerable range, depending largely upon the nature of the fuel oil.

The primary source of air for combustion is that supplied tangentially through conduits **23**. The proportion of air thus introduced may be varied somewhat, as subsequently herein illustrated, but the total air, that is air supplied through conduits **23** and that supplied through conduit **22** should be somewhat in excess of that required to effect complete combustion of the fuel oil supplied to that tunnel.

One advantage of my invention is that the combustion air supplied through conduits **22** and **23** is, with advantage, supplied under a relatively low pressure, not exceeding atmospheric pressure by more than two pounds per square inch, thus making it possible to supply the air by means of relatively inexpensive commercial centrifugal blowers, avoiding the cost of air compressor equipment.

The air introduced through conduit **23** follows a substantially helical path, forming a gently rotating layer of air, along the wall of the combustion tunnel until it finally becomes mixed with the atomized fuel oil. The coaxially introduced air aids in directing the oil spray down through the spiraling outer layer of air, preventing oil droplets from being picked up by the swirling air stream and thrown by centrifugal force against the chamber wall, with resultant coking thereon. It also serves to fill in the lower pressure region adjacent the axis of the chamber and to increase turbulence along the wall of the chamber at the zone where the coaxial air spreads out and impinges upon the outer, helical stream of air. This action further assists in preventing the formation of coke on the walls of the combustion tunnel. Also, the coaxial air stream aids in preventing excessive heating of the atomizing nozzle.

A further important requirement of this invention is that combustion of the fuel oil must be complete, or almost completed, before the gases pass from the combustion tunnels. The helically flowing layer of air along the tunnel walls has been found to inhibit the deposition of coke within the tunnel. But, unless the tunnel is of sufficient length to permit substantially complete combustion before the gases leave the tunnel, rapid coking of the reaction chamber wall will result. I have found that, to avoid such coking in the reaction chamber, combustion must be at least 90% complete before the hot gases leave the respective tunnels. In order to accomplish this under practical operating conditions, these tunnels should be at least about three feet in length and preferably about four feet long. Where the combustion is carried to this extent in the combustion tunnel, it may be completed in the upstream, enlarged end of the reaction chamber without deposition of coke therein and before coming into contact with the hydrocarbon make.

By reason of this arrangement, it is possible to use, without difficulty, as the fuel in my process relatively inexpensive and generally inferior end products of petroleum refining, e.g. heavy fuel or bunker oils, which have not heretofore been usable as the fuel in operations of this type because of excessive coking and degradation of the carbon black product.

As previously noted, a two-fluid spray nozzle similar to that shown in Fig. 5 of the drawings may be used for atomizing the fuel oil. However, I have, in most instances, found it more advantageous to use a spray assembly of the type indicated in Fig. 2 of the drawings in which the fuel oil and gas are premixed before being passed to the combustion tunel, as this arrangement has been found to result in a more satisfactory spray pattern whether the atomizing gas be air or steam. In any case, it is usually desirable to filter the fuel oil before passing it to the mixing chamber or spray nozzle, in order to minimize the possibility of plugging.

The process of the invention will be further illustrated by the following specific examples of operations carried out in apparatus substantially as represented in the drawing.

In the particular apparatus employed in these illustrative runs, the main portion of the reaction chamber was 8 inches I.D. and about 7 feet long and the enlarged upstream portion thereof was 3 feet I.D. and 7 inches in longitudinal dimension. The hot gases were generated in two blast tunnels symmetrically positioned as shown in the drawing, the main portion of which was 6 inches I.D. and about 4 feet long, the enlarged outer portion of the tunnel being 10 inches in diameter and 4 inches in longitudinal dimension. The fuel oil was injected through a ¼-inch tube after being premixed with compressed air, said tube being tipped by a conventional type spray nozzle and the tube and nozzle were surrounded by an annular stream of air passed to the combustion chamber through a 1½ inch I.D. tube. The hydrocarbon make was injected through six symmetrically positioned two-fluid spray assemblies as shown in the drawing positioned with their axes in a common plane 16 inches downstream from the enlarged portion of the reaction chamber.

Further operating data is set forth in the following tabulation:

Run No.	1	2	3
Blast Data:			
Air, Tangential, cu. ft./hr.	40,000	39,500	39,500.
Air, Axial around Sprays, cu. ft./hr.	None	500	500.
Fuel Oil Rate, gals./hr.	20	20	20.
Fuel Oil Temp. ° F.	250	350	Normal.
Atomizing Gas	Steam	Air	Air.
Pressure, lbs./sq. in.	90	40	40.
Temperature, ° F.	670	Normal	425.
Position of Spray Nozzle, Inches in from inlet end.	¾	3½	3½.
Make Data:			
Oil Rate, gals./hr.	50	52	54.
Atomizing Fluid	Saturated Steam.	Saturated Steam.	Saturated Steam.
Press., lbs./sq. in.	90	50	50.
Yield Data:			
Based on Total Oil, lbs./gal.	2.59	2.87	2.29.
Based on Make Oil, lbs./gal.	3.62	3.97	3.14.
Colloidal Data:			
Color, ABC	129	124	116.
Oil Absorption, gals./100 lbs.	17.2	15.4	15.2.

The foregoing blast and make data is for the entire operation, the tangential air being equally distributed between the four tangential inlets **23**, the axial air and fuel oil equally distributed between the two combustion chambers **14**, and the make equally distributed between the six make injectors.

It will, of course, be understood that the invention is not restricted to the particular dimensions and proportions just noted but includes apparatus and the use thereof of various capacities, sizes and proportions within the scope of the appended claims. The diameter of the main body of the combustion tunnels may, for instance, be varied from about 4 inches to about one foot I.D., depending upon their length.

Though my invention is of particular utility where it is necessary or desirable to use a heavy petroleum residue as the fuel, and advantage of particular note is its flexibility as to the type of fuel oil used. It is adapted to the use of any type of liquid oil or residuum. The fuel oil used in the foregoing runs was a heavy petroleum residuum marketed as No. 6 fuel oil and having the following characteristics:

Index of refraction	1.576
A.P.I. gravity	18.0
Asphaltenes, percent	8.0
Viscosity:	
SSU at 100° F.	4500
SSU at 210° F.	245

The ratio of axially injected air, when used, to the tangentially injected air may be varied over a considerable range. For instance, I have with advantage injected air

in annular streams surrounding the fuel oil sprays in quantities as high as one-third of the total air charged to the combustion chambers.

I claim:

1. In the process for producing carbon black by decomposing hydrocarbons whereby the hydrocarbon to be decomposed is separately injected as a liquid spray directly into a stream of hot blast flame gases passing at high velocity in a helical path through an elongated, heat-insulated reaction chamber and is rapidly mixed therewith and is decomposed by heat absorbed from the hot gases to form carbon black in suspension, the suspension being withdrawn from the downstream end of said chamber and the carbon black separated and collected, the steps of separately burning a fluid fuel and an oxygen-containing gas by injecting the fuel substantially axially into one end of a cylindrical combustion chamber of greater length than diameter, while directing air substantially tangentially into said end of the combustion chamber, and thereby mixing the fuel and air and burning the fuel to at least 90% complete combustion as it passes through the combustion chamber to produce a hot, high-velocity gas stream substantially free from unconsumed fuel and delivering said stream of hot gases tangentially into the upstream end of the reaction chamber.

2. The process of claim 1 in which there is simultaneously passed into the combustion chamber an annular stream of air coaxial with the fuel stream.

3. The process of claim 1 in which the air is directed tangentially into the combustion chamber at a superatmospheric pressure of about two pounds per square inch.

4. The process of claim 1 where the fuel is a highly viscous petroleum residue and is preheated to a temperature of 400–600° F. before being injected into the combustion chamber.

5. Apparatus for producing carbon black comprising an elongated, heat-insulated reaction chamber of cylindrical cross-section adapted to be connected at its downstream end to a cooling and collecting system, at least one elongated substantially cylindrical combustion chamber opening at one end tangentially into the upstream end of said reaction chamber, and comprising an outer portion of a length less than its diameter, closed at its upstream end and in open communication at its downstream end with a coaxially positioned, unrestricted portion of substantially uniform cross-sectional area having a diameter less than the diameter of said outer portion and of a length greater than its diameter, means for injecting at least one stream of air tangentially into said enlarged outer portion of the combustion chamber, a fuel injector extending substantially coaxially into the outer end of the combustion chamber and discharging into the said outer portion of the combustion chamber intermediate the length thereof, means for injecting hydrocarbon make substantially radially into the reaction chamber near the upstream end thereof but downstream from the entrance of the combustion chamber thereto.

6. The apparatus of claim 5 in which there is provided in the upstream end of the combustion chamber an annular air inlet surrounding the fuel injector.

7. The apparatus of claim 5 in which there are two combustion chambers symmetrically positioned with respect to the reaction chamber.

8. The apparatus of claim 5 in which each combustion chamber is provided at its outer end with at least two tangential air inlets symmetrically positioned with respect to the enlarged zone of the combustion chamber.

9. The apparatus of claim 5 in which the combustion chamber is from 3 to 4 feet in length and not more than about one foot in diameter.

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