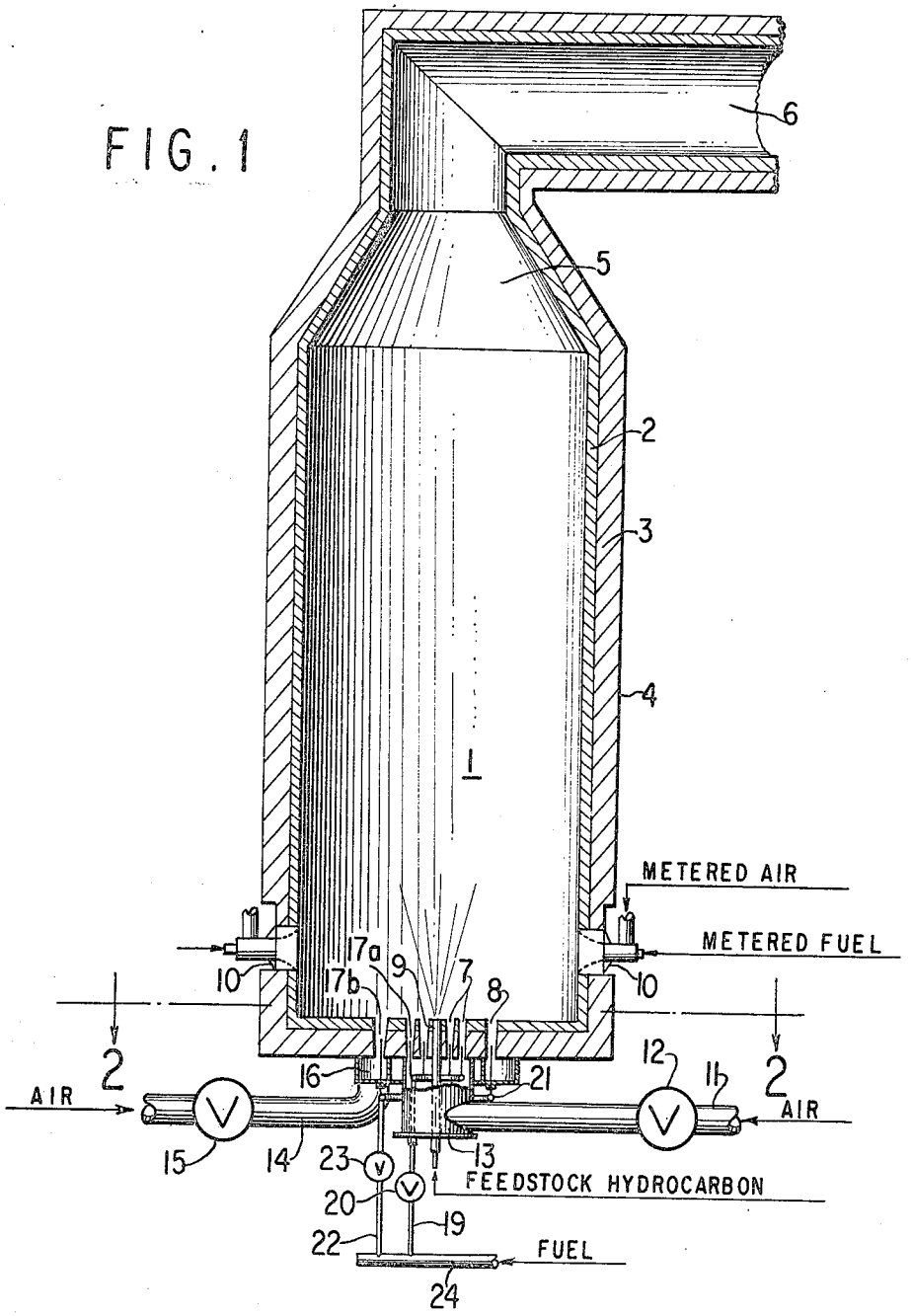
Jan. 20, 1970 C. L. DE LAND 3,490,870

METHOD AND APPARATUS FOR THE PRODUCTION OF CARBON BLACK

Filed Aug 9, 1967 3 Sheets-Sheet 1

FIG. 1



METHOD AND APPARATUS FOR THE PRODUCTION OF CARBON BLACK

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FIG. 2

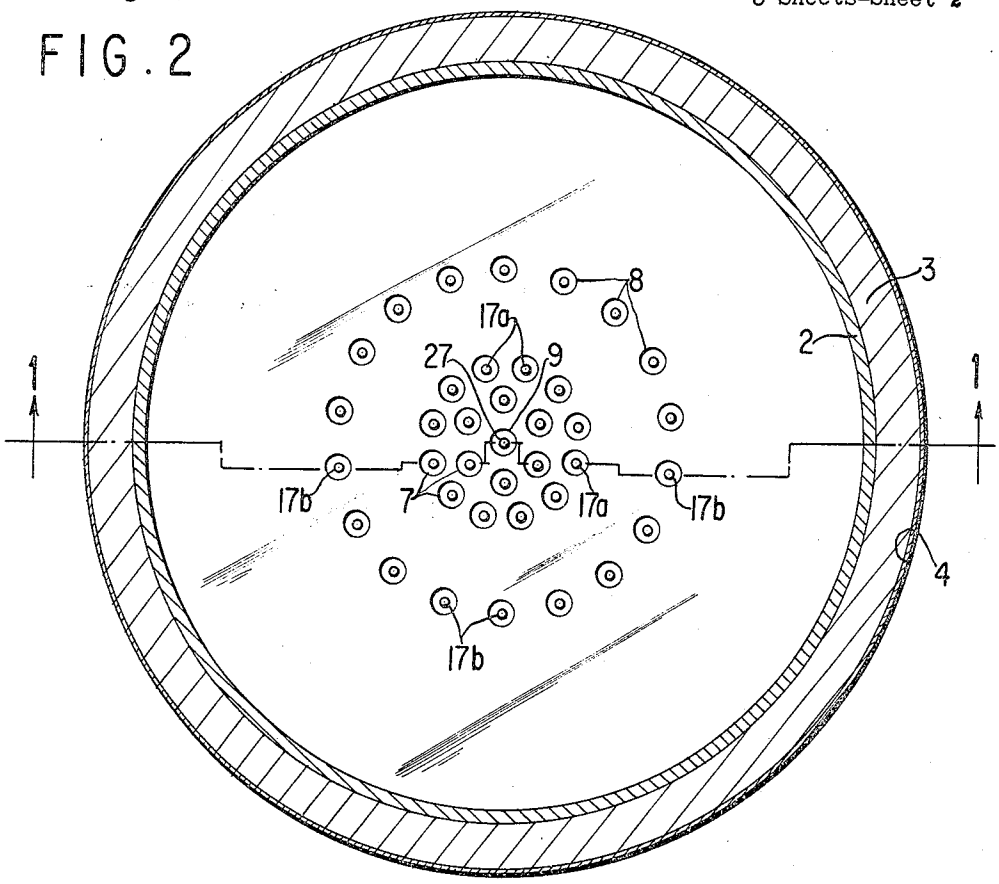
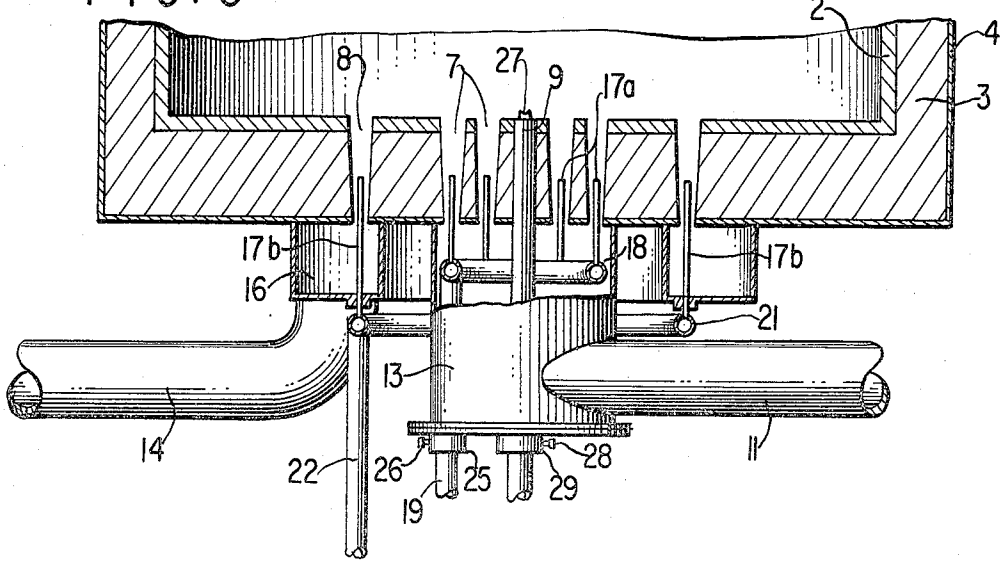


FIG. 3



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METHOD AND APPARATUS FOR THE PRODUCTION OF CARBON BLACK

Filed Aug 9, 1967 3 Sheets-Sheet 3

FIG. 7

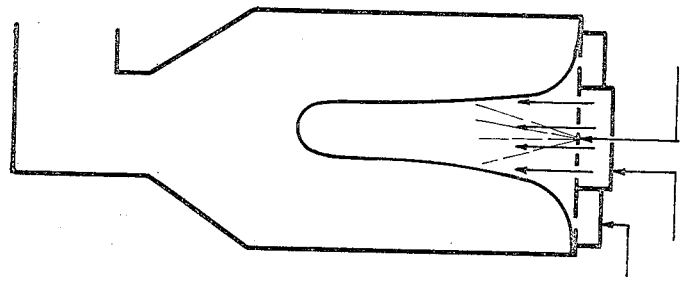


FIG. 6

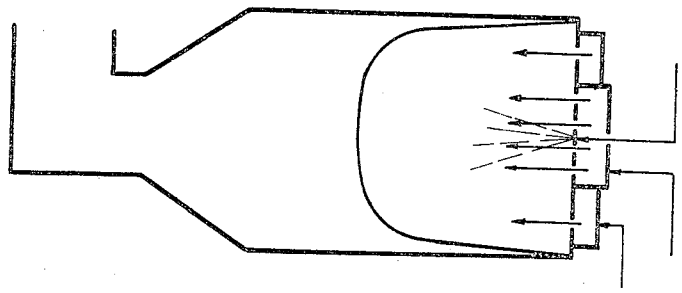


FIG. 5

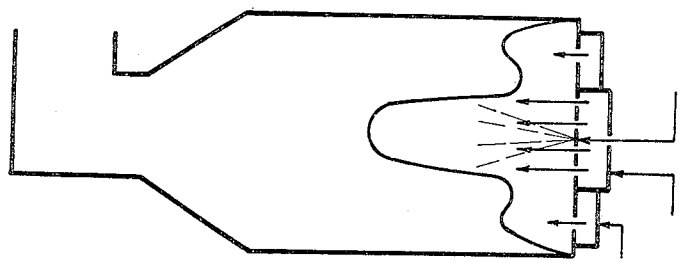
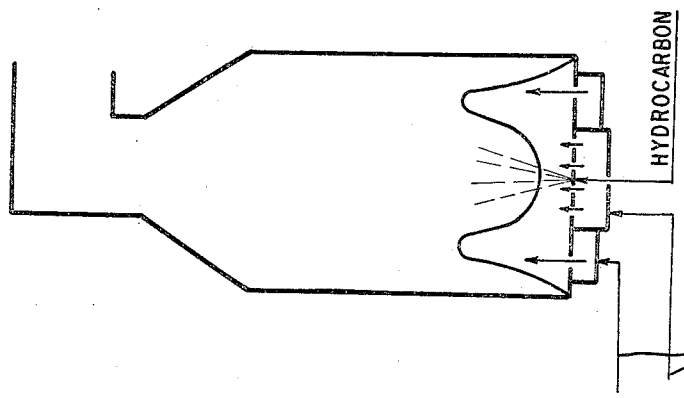


FIG. 4



United States Patent Office 3,490,870
Patented Jan. 20, 1970

3,490,870

METHOD AND APPARATUS FOR THE PRODUCTION OF CARBON BLACK

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Int. Cl. C09c 1/50; C01b 31/02; B01j 1/00
U.S. Cl. 23—209.4 16 Claims

ABSTRACT OF THE DISCLOSURE

Hot combustion gases are mixed with hydrocarbon make in an unconfined, localized region of a furnace chamber to achieve partial but incomplete thermal decomposition of hydrocarbons to carbon black. Additional combustion gas is mixed with the partially reacted hydrocarbon-combustible gas mixture outside said localized region of substantially complete conversion. In a vertically elongated chamber in which hydrocarbon is injected axially upward into the furnace chamber, primary and secondary ducts are positioned in the lower end of the chamber for regulating the velocity, temperature and atmosphere of the combustion gases within different regions of the chamber.

BACKGROUND OF INVENTION

Most commercial carbon blacks are currently produced by thermal decomposition of normally nongaseous hydrocarbons, such as petroleum residues or creosote oils by mixing hydrocarbon inside a furnace chamber with hot combustion gases produced by burning a fuel with air. Partial combustion of the hydrocarbon often results, but is generally controlled to provide maximum yield of carbon black.

The processing conditions required often differ substantially depending upon the particular grade of carbon black desired. Several grades of carbon black may be manufactured by one particular furnace process by adjustment, within feasible limits, of such factors as reaction time, combustion gas atmospheres, ratios of reactants, etc. The variety of commercial grades has, nevertheless, become so diversified as to require a multitude of furnace types and size.

In prior art processes, control over mixing of the hydrocarbon make with hot combustion gases has been essentially restricted to variation of the hydrocarbon input rate and the rate at which the total quantity of hot combustion gases is introduced into the furnace chamber. Since a certain minimum quantity of hot combustion gases must be mixed with the hydrocarbon make to effect substantially complete thermal decomposition thereof, prior processes have heretofore been restricted in the manner in which mixing may be accomplished to achieve maximum regulation of carbon black properties so as to allow production of a broad range of carbon black grades while optimizing quality and cost considerations.

A number of processes have been developed recently whereby carbon blacks are produced by thermally decomposing a feed stock hydrocarbon within the upper regions of a vertically elongated furnace chamber containing combustion gases. Carbon black is formed by thermal decomposition of the hydrocarbon make by absorption of heat from the combustion gases. A "blanket" consisting mainly of carbon black, combustion gases and gaseous products of thermal decomposition of the hydrocarbon make exists in the upper section of the furnace chamber during the carbon-forming reaction. In vertical furnaces such as those shown in U.S. Patents Nos. 2,597,772 and 2,779,665, combustion gases, or components

thereof, are introduced into the chamber and are directed uniformly upward over the entire cross-section of the chamber. In vertical furnaces such as that shown in U.S. Patent No. 3,301,639, the combustion gases are directed toward only one particular region of the furnace chamber with relation to the feed stock hydrocarbon as it enters the chamber. Although suitable for making certain grades of carbon black, these furnaces have been relatively inflexible with respect to making a broad range of carbon black grades, while optimizing both quality and economics, because of the inability to regulate the velocity, composition and temperature of different regions of the atmosphere within the furnace chamber. This is a particular problem with respect to the lower end of the chamber wherein contact between feed stock hydrocarbon and hot combustion gases is first initiated.

Considerable difficulty has been experienced with such furnaces when employing preheated air for combustion of the fuel. The inside walls of the furnace become so overheated that the refractory fails very quickly. This is particularly disadvantageous since the use of preheated air provides several important benefits, such as increased production rate and yield of carbon black. If the problem of refractory failure was to be overcome in such operations employing preheated air, it would ordinarily be necessary to employ a ratio of free oxygen to fuel in the combustion mixture that is too high to permit economical production of carbon black.

In certain prior processes, an "intermediate chamber" has been employed for partial reaction of the hydrocarbon before complete conversion within a main reaction chamber. The "intermediate chamber" interconnects axially with the main reaction chamber of the furnace and provides a confined zone within which a portion of hot combustion gases are mixed for reaction with the hydrocarbon make prior to being discharged into the center core of a spiraling second portion of hot combustion gases contained within the main reaction chamber. While this arrangement permits increased flexibility in the furnace process, it has not been entirely satisfactory due to inherent restrictive limitations in the process and desirable features with respect to the construction and operation of the furnace.

SUMMARY OF INVENTION

It is, therefore, an object of this invention to provide an improved method and apparatus for the manufacture of a broad range of grades of carbon black product. It is another object of this invention to provide a vertical furnace having improved flexibility of operation for the manufacture of carbon black.

It is another object to provide an improved apparatus and method for producing, at high rates and yields, a variety of commercial grades of carbon black.

It is a further object of the present invention to provide a vertical furnace apparatus and process utilizing preheated air for formation of combustible fuel mixed mixtures wherein refractory overheating is substantially reduced or eliminated.

These and other objects are accomplished by means of the present invention, which will be hereinafter described in detail, the novel features of which are set forth in the appended claims.

In accordance with the present invention, a metered stream of non-gaseous hydrocarbon make is projected in the form of a vapor or spray into an unconfined, localized region near one end of an elongated, unobstructed furnace chamber. The hot combustion gases employed for the decomposition of the hydrocarbon make are introduced into the furnace in two separate portions. One portion is introduced through primary ducts positioned so as to direct the combustion gases into the localized

region for thorough and intimate mixture with the hydrocarbon make. The quantity of combustion gases introduced through the primary ducts is such that partial but incomplete conversion of the hydrocarbons into carbon black occurs in the localized region.

A predetermined quantity of combustion gases is also introduced through secondary ducts positioned so that the gases are directed around and substantially out of contact with the hydrocarbon make in the aforementioned localized region of the chamber. As the preformed mixture of partially reacted by hydrocarbon make and hot combustion gases issues from the unconfined, localized region, it mixes with the combustion gases from the secondary ducts, and thermal decomposition of the hydrocarbon make into carbon black is essentially completed within the confines of the furnace chamber outside the bounds of the unconfined, localized region of initial mixing between the hydrocarbon make and the combustion gases from the primary ducts.

The primary and secondary ducts are independently supplied with combustion gases so that they may be used either separately or simultaneously. Particular advantages have been found in the simultaneous use of both the primary and secondary ducts. The velocity and composition of the combustion gases provided at the primary and secondary ducts can be independently controlled, providing greatly increased flexibility of process conditions over those obtainable in previously available furnaces. Mixing and recation of the hydrocarbon with hot combustion gases is thus controllable to an unusual degree, thereby providing the capability of altering the properties of the carbon black product. For example, the velocity of the combustion gases directed into the unconfined, localized region of mixing may be varied without altering the total combustion gas input rate. Alternately, if desired, the total input rate can be easily varied.

Furthermore, since the composition of the first and second portions of hot combustion gases can be independently varied, the atmosphere within the unconfined, localized region of mixing can be made more oxidizing or reducing, if desired, while maintaining a different atmosphere within those regions of the furnace chamber in which carbon formation is to be completed.

The independent control over velocity and composition of the primary and secondary portions of the combustion gas input is particularly advantageous when producing carbon black in vertical furnaces using preheated air for the formation of fuel mixtures that are burned to produce the hot combustion gases for decomposition. Regulation of the temperature profile across the furnace chamber is more easily accomplished, thus permitting the protection of the refractory lining thereof from overheating.

In another embodiment of the present invention, the combustion gas flow may be caused to follow a spiral pattern. Thus, completion of the thermal decomposition may be accomplished within a specific region of the reaction chamber, such as the center core of a spiraling body of hot combustion gases, or may be carried out across the whole of the cross-section of the chamber, thereby utilizing as much of the available reaction space as possible to provide maximum production from the single furnace design.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be hereinafter further described and explained with reference to the accompanying drawings in which:

FIGURE 1 is a sectional side view of a cylindrical, vertically disposed furnace in accordance with the present invention and taken along the line **1—1** of FIGURE 2;

FIGURE 2 is an enlarged cross-sectional view of the furnace taken along the line **2—2** of FIGURE 1;

FIGURE 3 is an enlarged sectional view of the bottom end of the furnace shown in FIGURE 1;

FIGURES 4, 5, 6 and 7 are somewhat diagrammatic representations of velocity profiles that may be established across the furnace chamber when introducing hot combustion gases therein in accordance with the present invention.

DETAILED DESCRIPTION OF INVENTION

In the embodiment illustrated in FIGURE 1, a cylindrical, unobstructed, vertically elongated furnace chamber **1** is bounded by a refractory layer **2**. The refractory is covered by a layer of thermal insulation **3**, which is, in turn, surrounded and supported externally by metal shell **4**. Effluent reaction products from chamber **1** are discharged through frusto-conical top section **5** into breeching **6** as a carbon black-flue gas aerosol that passes to a cooler and a carbon black collection system, not shown, of conventional design. Combustion gases may be fed into the chamber through primary ducts **7** and secondary ducts **8** that extend through the floor of the furnace. Hydrocarbon make is injected into the chamber by means of an injector assembly **9**.

It is also within the scope of the present invention to apply combustion gases to furnace chamber **1** through tertiary ducts **10** positioned in the side wall of the furnace to provide a spiraling motion to the atmosphere within the furnace chamber. The spiraling effect within the atmosphere of the furnace chamber can advantageously be produced by means of a burner arrangement such as that disclosed in U.S. Patent 3,301,639.

As shown in FIGURE 2, primary ducts **7** are arranged as a cluster about hydrocarbon injector **9** so that the duct outlets are proximal to the hydrocarbon injector. Secondary ducts **8**, on the other hand, are arranged in a ring spaced away from the cluster of primary ducts **7** so that the outlets of the secondary ducts are more distal from the hydrocarbon injector than are the outlets of primary ducts **7**.

Independent air and fuel supply systems are provided for the primary and secondary ducts. As shown in FIGURE 1, an air line **11** having conjunctive shut-off and regulating means **12** supplies a flow of air to primary bustle **13** that intercommunicates commonly with all primary ducts **7**. Another air line **14**, having conjunctive shut-off and regulating means **15**, is employed for controlling the flow of air to secondary bustle **16**, which interconnects commonly with all secondary ducts **8**. A fluid fuel, such as natural gas, is supplied to the primary and secondary ducts, independently, by means of injectors **17***a* and **17***b*, respectively. Primary injectors **17***a* extend axially upward into primary ducts **7** from ring manifold **18**, see FIG. 3, to which fuel is supplied by means of conduit **19** having a conventional, conjunctive shut-off and regulating means **20** for controlling the flow of fuel to the primary ducts. Secondary injectors **17***b* are similarly arranged within secondary ducts **8** and supplied with fuel from ring manifold **21**. Fuel is supplied to ring manifold **21** by means of supply conduit **22**, which has a conventional, conjunctive shut-off and regulating means **23** for controlling the flow of fuel to secondary ducts **8**. Fuel is supplied to conduits **19** and **22** from a main supply line **24**.

With particular reference to FIGURE 3, can be seen that the fuel supply assembly for primary ducts **7** can be moved up and down by sliding conduit **19** through guide **25** to provide positioning of the injector tips and in primary ducts **7** for the desired mixing of the fuel with air prior to ignition thereof. Once positioned, the tips can be secured in location by tightening lock screw **26** to secure conduit **19** within the guide. Similarly, the injector tips in secondary ducts **8** may be vertically adjusted and located by movement of the jet-manifold-supply conduit assembly within a similar guide having a lock screw, not shown.

The vertical location of hydrocarbon feedstock injector tip **27** is shown flush with the furnace floor. If desired, however, the tip may be raised or lowered by moving the entire atomizer assembly up and down through guide **29**.

The assembly is then locked in place with screw **28** after the tip has been positioned in the desired location.

The metering and control means for the air and fuel streams fed to the primary and secondary ducts may be any suitable, conventional apparatus and technique that provide an essentially constant flow rate, while affording means for changing the flow rate or shutting off the flow entirely when desired. An orifice, for example, may be used for metering, while a valve may be employed for altering the rate of flow and for shutting off the flow. Likewise, any suitable, conventionally available means may be employed for supplying a constant though variable flow of feedstock hydrocarbon to the atomizer tip. A variable speed metering pump, for example, can be employed. Suitable commercially available feedstock injectors for either vaporized or liquid hydrocarbons are well known to those skilled in the art, and consequently, need not be described in detail herein. The injector should, however, provide a discharge pattern that will fall in a localized region of the furnace chamber as the hydrocarbon make enters the chamber in an upward direction from an axial injection at a point.

After mixing of the fuel and air within primary and secondary ducts **7** and **8**, the combustion gases are fed into the bottom of furnace chamber **1** and combustion of the mixture is initiated therein so that the hot gaseous effluent from the ducts is directed upwardly into the chamber essentially coaxially with respect to the spray of hydrocarbon make droplets. The gases discharged from primary ducts **7** are directed into the hydrocarbon oil spray for initial mixing between the hot combustion gases and the hydrocarbon make in an unconfined, localized region of initial mixing essentially along the center line of the furnace. Gases from secondary ducts **8** are directed in such a manner as to surround the unconfined, localized region of initial mixing.

One portion of hot combustion gases, at controlled velocity, is directed from clustered primary ducts **7** into the spray of hydrocarbon droplets from atomizer tip **27** for mixture therewith to effect partial thermal decomposition of the hydrocarbon make into carbon black. Concurrently, another portion of the hot combusion gases is injected into the furnace chamber, at controlled velocity from the ring of secondary ducts **8**. Mixing of the combustion gases from secondary ducts **8** with the partially decomposed hydrocarbon make occurs outside the unconfined, localized region in which the hydrocarbon make and hot combustion gases from primary ducts **7** are first mixed. Final thermal decomposition of the hydrocarbon, therefore, occurs essentially across the entire cross-section of furnace chamber **1**.

While the primary and secondary ducts have been illustrated as comprising a series of individual ducts positioned around the center of the furnace floor, it will be readily appreciated by those skilled in the art that the provision of more than one primary and secondary duct is not essential to the apparatus and process herein described. More specifically, it will be apparent that one enlarged primary duct could be used in the furnace of FIGURE 1. In like fashion, the secondary duct could also be a singular annular duct surrounding the primary duct instead of a series of individual ducts. It will further be appreciated that when a series of secondary ducts are employed, they may be arranged in any number of suitable patterns. A particularly advantageous pattern is a symmetrical one around the one or more primary ducts in the manner illustrated in the drawings.

When using preheated air with the furnace in accordance with this invention, the air supply lines and bustles may be lined internally with refractory insulation to prevent heat loss to the atmosphere, while also avoiding damage to the metal from which the supply lines and bustles will normally be constructed. Fuel injectors and the conjunctive manifolds may be designed to impart sufficient flowing velocity to the fluid fuel to prevent coking of the fuel within these conduits by minimizing heat transfer from the hot air to the fuel within the confines of the conduits.

As previously indicated, the furnace illustrated in FIGURES 1–3 can be used to produce carbon black while introducing all of the hot combustion gases either through the clustered primary ducts **7** alone or through the outer ring of secondary ducts **8** alone. The furnace can be successfully operated in this manner in order to produce a particular grade of carbon black not requiring fine control over the velocity, temperature and composition conditions existing in various regions of the furnace chamber. The present invention, permits close control over velocity, temperature and composition of different regions of the lower end of the furnace in such a manner as to influence the manner of mixing the hydrocarbon make with the hot combustion gases. This control is obtainable by introducing the combustion gases into the furnace from both the inner cluster of primary ducts and the outer ring of secondary ducts, the velocity, composition and consequently the temperature of the combustion gases being subject to independent control and variation in the manner heretofore described.

Many carbon black properties, especially fineness, are strongly influenced by the intensity of mixing that occurs between feed stock spray and the hot combustion gases. Since the intensity of mixing can depend greatly upon the degree of turbulence in the mixing pattern, control over the velocity of gases directed into the spray of hydrocarbon make droplets can, therefore, provide a carbon black property-control feature not available when the velocity of combustion gases directed into the furnace is not subject to independently controllable variation. If all of the hot combustion gases were introduced into the furnace through the center cluster of primary ducts **7**, turbulence in the hydrocarbon-hot gas mixing zone would be primarily dependent upon the input rates of the combustion gases and feed stock hydrocarbon. At a fixed temperature, turbulence in the hot gas-hydrocarbon mixing zone could, in this instance, only be changed by altering either the total combustion gas input rate or the feed stock hydrocarbon input rate. Considerable change in carbon black properties could not be effected without drastically altering either or both of these rates. Furthermore, the extent to which the properties of the carbon black product could be varied would be subject to restrictive limitations due to the desire for optimizing production rate and the economics thereof.

Increasing the feed stock input rate in order to produce substantially coarser carbon blacks, for example, may cause a residual stain on the black due to limited contact time or insufficient total heat for complete thermal decomposition of the feed stock. Furthermore, the turbulence produced within the furnace chamber may be too high to allow formation of carbon black particles having the desired coarseness. If, on the other hand, reduced feed stock input rates were employed for producing substantially finer blacks, lower production rates and poor economics would result. If the total combustion gas input rate were reduced in order to produce a coarser black, excessive staining of the black would occur since there would be insufficient heat for thorough decomposition of the feed stock hydrocarbon. Also, any reduction in feed stock input rate to correct this problem would necessarily result in a decreased production rate. The extent to which the total combustion gas input rate could be increased to raise the fineness value of the carbon black is limited by the normally fixed capacity of the collection system employed for separation and recovery of the carbon black product.

If, on the other hand, all of the combustion gases were introduced through secondary ducts **8**, no intense mixing with the spray of hydrocarbon droplets could be accomplished, since the ducts are spaced too far from the

spray pattern to effect a localized zone of turbulence. Even with ideal optimization of the feed stock, only relatively coarse carbon black products can be produced under these circumstances.

While all of the combustion gases can, therefore, be introduced either through the clustered primary ducts **7** or through the ring of secondary ducts **8**, the variety of grades of carbon black produced in this manner is extremely limited in comparison with the flexibility obtainable by dividing the total combustion gas input between the primary and secondary ducts. Whereas at fixed input rates of feed stock and combustion gases, coarser blacks can readily be produced by using only the outer ring of secondary ducts, while finer degrees of carbon black products can be produced by feeding increased amounts of combustion gases through the center cluster of primary ducts at increasing rates. Accordingly, blacks can be produced over a broad particle size range, while optimizing quality and yield, by dividing the hot combustion gases between the primary and secondary ducts.

In operation, the proportion of hot combustion gases provided to the furnace chamber through the primary and secondary ducts may vary considerably. The proportioning will, of course, depend upon the grade of black being produced. As previously indicated, finer blacks will be made by employing a higher percentage of hot combustion gases through the primary ducts, while coarser blacks will be made by introducing a greater percentage of the hot combustion gases through the secondary ducts.

It is sometimes desirable to impart a spinning motion to the atmosphere within the furnace chamber in order to improve mixing of the partially decomposed hydrocarbons with the portion of hot combustion gases introduced from the secondary ducts. Spinning of the atmosphere may be induced and maintained by introducing a portion of the hot combustion gas tangentially into the furnace chamber. This can be accomplished by means of wall burners **10** in accordance with various methods obvious to those skilled in the art, such as that described in U.S. Patent 3,301,639.

In the operation of the disclosed furnace, the feed stock hydrocarbon is injected axially upward into the furnace chamber at an essentially constant rate. Combustion gases are directed into the spray at a specific, constant rate from the cluster of primary ducts so that mixing of the hydrocarbon and hot gases occurs in a localized, unconfined region in the lower, central section of the furnace chamber. The hydrocarbon make continues to rise upwardly while being partially decomposed by the hot gases supplied from the primary ducts. The partially decomposed hydrocarbons subsequently mixes with the portion of hot combustion gases introduced into the furnace at a specific constant rate from the secondary ducts. Complete and final thermal decomposition of the feed stock hydrocarbon occurs principally in the upper regions of the furnace chamber above the unconfined, localized zone of initial mixing. In this upper region, a "blanket" exists, comprising thermally decomposing hydrocarbon, carbon black product, gaseous products of thermal decomposition, combustion gases, and other products of reaction between the aforementioned reactants. The height at which the bottom of the blanket exists above the floor of the furnace may be regulated by adjusting the suction pressure on the furnace outlets, the entering velocity of the hydrocarbon make and the velocity of the combustion gases entering the furnace chamber. The height at which the blanket is desirably maintained above the furnace floor will depend upon the particular grade of carbon black being produced. Spinning of the atmosphere within the furnace chamber also helps to maintain the bottom of the blanket at a given level, and downward circulation of the reaction products is thereby reduced. The blanket also serves to surround the heat release zone where a substantial length of the furnace chamber, thus protecting the furnace walls from direct contact with the hot combustion gases and shielding the walls from radiation with a very dense black cloud.

In a previously "vertical" type furnace, use of preheated air has been very troublesome if not impossible because of the destructive effects of intense localized heat, both radiant and conductive, in the lower end of the furnace chamber. Temperatures not tolerated by the refractory were encountered unless the ratio of free oxygen to fuel in the combustion mixture was so high as to interfere with the economic production of carbon black. The present, preheated air, e.g. 600–1500° F., can be employed, for example, by supplying a fuel-rich combustion mixture to the cluster of primary burners while supplying an oxygen-rich mixture to the ring of secondary burners, thus protecting the refractory wall of the chamber by developing relatively cooler flames and gases by burning the mixture introduced from the ring of secondary burners. The flame and gases produced by the mixture introduced from the center cluster of primary burners will be much hotter, but are confined generally to the center of the furnace chamber. Commingling of the gases introduced of both the primary and secondary ducts occurs in the upper regions of the furnace chamber, providing an atmosphere that is not excessively oxidizing for economical production of carbon black, yet is properly proportioned from a standpoint of ingredients to provide desirable carbon black properties.

While the decomposition temperature is subject to considerable variation depending upon the type of carbon black being produced, temperatures generally between about 1600° F. and about 3000° F. are employed in carbon black manufacturing operations. Temperature may be controlled by the rate at which hot combustion gases are introduced into the chamber and by regulation of the temperature of the combustion gases themselves. The temperature of the combustion gases can be controlled, within limits, by adjusting the ratio of air to fuel in the combustible mixture. The higher the air/fuel ratio above the stochiometric amount, the lower the resultant combustion gas temperature. The air/fuel ratio, however, will ordinarily be varied somewhat depending upon the type of carbon black being produced, as is the case with the total combustion gas input rate and the proportions introduced through the primary and secondary ducts.

The present invention provides means for controlling the atmosphere of the combustion gases directed into the localized region of initial mixing while maintaining the atmosphere of the blanket substantially the same as it would exist in a furnace having no independent control over the various portions of the combustion gases. For example, an air/natural gas ratio of 10/1 on a volume basis might be employed at the primary ducts, while a ratio of 16/1 is employed at the secondary ducts. These ratios could be reversed or modified in order to supply more or less heat and a different atmosphere for partially decomposing the feed stock hydrocarbon within the unconfined, localized region, while maintaining a selected input ratio to establish a desired velocity condition in the mixing zone. The actual air/fuel ratio employed will be dependent upon the atmosphere and heat/release requirements in the localized mixing zone and in the blanket for any particular grade of carbon black product.

The structure of the carbon black product is another property that can be controlled by variation of the air to fuel ratio in the mixture burned to produce hot combustion gases for mixture with the hydrocarbon make in the unconfined, localized region of the furnace chamber. Generally speaking, employment of an oxidizing atmosphere within the localized region is conductive to structure formation, while employment of a reducing atmosphere has a depressing effect upon structure development.

Although the invention has been herein described with reference to hot combustion gases generated in burner ports located in the furnace floor, it will be appreciated that the burner ports may be located in another part of the

furnace or that the hot combustion gases may be produced externally of the furnace in a separate generator. Furthermore, various arrangements of burners other than the clusters and rings illustrated may be employed for introducing the two portions of the combustion gas into the furnace chamber. Likewise, it would be possible to provide three or more separate and independently controlled means for injecting combustion gases into the furnace chamber.

The atomizer tip employed may be of a single fluid variety, which casts a somewhat cone pattern of droplets that intercepts the flow of hot combustion gases discharged from the primary ducts. Alternately, multifluid atomizers and atomizers that cast a hollow cone of droplets may be employed. Furthermore, a cluster of tips may be used instead of employing a single tip. The atomizer tip, and the conduit that supplies the feed stock hydrocarbon to it, may be protected from heat by means of a water jacket or any other suitable means well known to those skilled in the art.

FIGURES 4–7 are somewhat general representations, not to scale, of linear velocity profiles that may be produced in the furnace of the present invention. The arrows leading into the furnace chamber are sized to different lengths to represent relative velocities through the primary and secondary ducts. The curvilinear line across the chamber represents the type of linear velocity profile that could be detected by means of a lateral pitot traverse across the lower end of the furnace chamber.

In FIGURE 4, combustion gases are being introduced into the furnace chamber at a greater rate through the outer ring of burners than through the central cluster. The velocity is, therefore, much lower in the center of the furnace cross-section than above the secondary ducts. Accordingly, mixing of the feedstock hydrocarbon with hot combustion gases would not be as intense in the localized region above the primary ducts as it would be in FIGURE 5, in which the hot combustion gases are introduced at a much greater rate through the primary ducts than through the outer ring of secondary ducts. In FIGURE 6, the combustion gas input rate is more nearly balanced between the primary and secondary ducts, so as to be essentially in accord with the process described in U.S. Patent 2,779,665 stipulating that a uniform velocity should be imparted to the combustion gases across the entire cross-section of the furnace. In FIGURE 7, all of the combustion gas is being introduced through the center cluster of primary ducts to create a very intense mixing pattern in the localized mixing zone by imparting the highest velocity possible to the combustion gases within that region.

In order to more fully illustrate the beneficial results obtainable by means of the present invention, a series of runs was conducted in a furnace substantially as depicted in FIGURES 1–3 hereof. The inside diameter of the cylindrical furnace chamber was 6 feet 6 inches over a height of 7 feet 9 inches. The frusto-conical top section of the furnace chamber tapered to an outlet diameter of 2 feet 9 inches over a distance of 2 feet 6 inches. The feedstock hydrocarbon atomizer assembly was inserted upwardly through the floor of the furnace through a hole located on the center line of the furnace chamber and was provided with a single atomizer tip having a ¼ inch I.D. x ⅛ inch long orifice which cast a solid cone pattern of feedstock hydrocarbon droplets at an angle of about 20°. Saturated steam at 100 p.s.i.g. was used as an atomizing fluid, being mixed with the hydrocarbon in an eductor prior to atomization. The atomizer tip and its supply conduit were protected from overheating by means of a water jacket. The atomizer tip was positioned 4 inches above the furnace floor.

The primary and secondary ducts were located in the furnace floor and were arranged, as shown in the drawings, to direct the combustion gases upwardly. No side burners were employed. Each duct had a length of 9 inches, an inlet diameter of 2 inches, and an outlet diameter of 3 inches. The tips of the fuel jets were positioned 3 inches inside of each duct, measured from the inlet end thereof. One set of 6 primary ducts was equispaced in a cluster around an 8 inch circle having the atomizer tip as its center. A second set of 6 secondary ducts was equispaced in an outer ring around a 2 foot 8 inch circle having the atomizer tip as its center.

The first three runs were conducted to demonstrate the alteration in carbon black properties obtainable by altering the location at which hot combustion gases are introduced into the furnace at constant input rates. In Run 1, all of the combustion gases were introduced into the furnace through the center cluster of primary ducts. In Run 3, all of the combustion gases were introduced into the furnace through the outer ring of secondary ducts. In Run 2, half of the combustion gases were introduced through the primary ducts, while the other half was introduced through the secondary ducts. The hot combustion gases were produced by burning a mixture of air and natural gas. Operating conditions and the results of the runs are shown in Table I.

TABLE I

	Condition							Property of Carbon Black		
	Center Cluster			Outside Ring						
	Air, s.c.f.h.	Gas, s.c.f.h.	Air/Gas Ratio	Air, s.c.f.h.	Gas, s.c.f.h.	Air/Gas Ratio	Feedstock Hydrocarbon, g.p.h. (60° F.)	Tinting Strength, percent FF Black	Stiff Paste Oil Absorption, gal./100 lbs.	Iodine Adsorption, ASTM
Run 1	45,000	3,750	12/1				70	75	13.1	33
Run 2	22,500	1,875	12/1	22,500	1,875	12/1	70	58	12.6	23
Run 3				45,000	3,750	12/1	70	45	6.3	16

Particle size of the carbon black is reflected by the tinting strength. The higher the tinting strength percentage, the finer the black. It can be seen that the region of the furnace chamber into which the hot combustion gases were directed had a considerable influence on the resultant particle size of the carbon black. When all of the hot combustion gases were introduced directly into the spray pattern through the primary ducts, the particle size was smallest, and the carbon black structure, as reflected by the oil absorption value, was highest. On the other hand, when all of the combustion gases were introduced through the secondary ducts, the black was considerably coarser and had a much lower structure. When the gas input was split between the primary and secondary ducts, the tinting strength value of the resultant black was about intermediate between the values resulting from Runs 1 and 3, although the oil absorption value was only slightly lowered. No alkali metals were employed for controlling the structure of the carbon blacks during their formation.

Another series of runs was carried out to demonstrate that shifting the proportion of combustion gases introduced through the cluster of primary ducts can significantly alter the properties of the carbon black, irrespective of the air/fuel ratio employed in the combustible mixture. In Runs 4 and 5, the hydrocarbon make and overall combustion gas input rates were the same. The combustion gas input was split evenly between the primary and secondary ducts in Run 4. The proportion was changed in Run 5 to provide 67% of the input through the primary ducts and 33% input through the secondary ducts. The

air/fuel ratio to each set of ducts was maintained the same in Runs 4 and 5.

In Runs 6 and 7, the air load to each set of ducts was the same as in Run 4, but the fuel mixtures were changed to provide progressively leaner ratios in the mixtures. The results are set forth in Table II.

TABLE II

	Condition							Property of Carbon Black		
	Center Cluster			Outside Ring						
	Air, s.c.f.h.	Gas, s.c.f.h.	Air/Gas Ratio	Air, s.c.f.h.	Gas, s.c.f.h.	Air/Gas Ratio	Feedstock Hydrocarbon, g.p.h. (60° F.)	Tinting Strength, percent FF Black	Stiff Paste Oil Absorption, gal./100 lbs.	Iodine Adsorption, ASTM
Run 4	22,500	1,500	15/1	22,500	1,500	15/1	70	65	12.4	28
Run 5	30,000	2,000	15/1	15,000	1,000	15/1	70	74	13.6	41
Run 6	22,500	1,250	18/1	22,500	1,250	18/1	70	63	12.9	32
Run 7	22,500	1,070	21/1	22,500	1,070	21/1	70	62	13.2	31

From the results shown in Table II, it can be seen that the carbon black produced in Run 5 had significantly higher tinting strength and oil absorption values than the carbon black of Run 4. The only essential difference in operating conditions was the rate proportioning to the gases introduced into the furnace through the primary and secondary ducts. Although the properties of the black produced in Runs 6 and 7 are somewhat different from those produced in Run 4, the properties were not as significantly altered as in Run 5, thus substantiating the fact that the hot combustion gas input rate into the spray of hydrocarbon droplets has an influence on the properties of the carbon black product.

In each of the foregoing runs, the furnace temperature was maintained in the range of about 2000° F. to about 2500° F. The feedstock hydrocarbon employed for producing carbon black was a high molecular weight, highly aromatic residue from a petroleum cracking operation, which had the properties and composition as shown below.

Analysis of feedstock hydrocarbon

API gravity	.2
Viscosity:	
SSU @ 130° F.	594
SSU @ 210° F.	67
Molecular weight	295
BMCI	123
Index of refraction	1.648
Wt. percent sulfur	1.060
Wt. percent ash	.003
Wt. percent benzene insolubles	.039
Wt. percent asphaltenes	.50
UOP K factor	10.0
Avg. B.P., ° F.	790
Specific gravity	1.0744
Lt./gal.	8.949

Ultimate analysis

	Weight percent
Carbon	89.94
Hydrogen	8.29
Sulphur	1.03
Ash	1.03
Other	0.71

Sodium (Na), 2.0 p.p.m.
Potassium (K), 0.0 p.p.m.

By submitting great flexibility in the composition, velocity and temperature of the combustion gases introduced into the furnace chamber and the degree of turbulence with which said combustion gases are mixed with the hydrocarbon make, the present invention provides a distinct advantage over the prior art permitting the production of a great variety of grades of carbon black product in a manner not heretofore possible. While the invention has been described herein with respect to particular embodiments thereof, it will be appreciated by those skilled in the art that various changes and modifications can be made without departing from the scope of the invention as hereinafter claimed.

Therefore, I claim:

1. Apparatus for the production of carbon black by the thermal decomposition of a fluid hydrocarbon comprising:

(a) a heat insulated, unobstructed, vertically elongated furnace chamber;

(b) means for injecting a fluid hydrocarbon axially upwardly into an unconfined, localized region of the chamber;

(c) at least one primary duct for directing hot combustion gases essentially upward and directly into contact with the fluid hydrocarbon;

(d) at least one secondary duct in the lower end of the chamber for directing combsution components essentially upward and around said localized region of the chamber;

(e) first supply means for furnishing combustion gases to said primary duct;

(f) second supply means for furnishing combustion gases to said secondary duct, said second means being operable independently of said first means;

(g) means for removing effluent material from the furnace chamber; and

(h) control means for independently regulating the flow velocity of the combustion gases furnished through said first and second supply means, whereby the velocity, temperature and composition of the atmosphere within the different regions of the furnace chamber may be controlled and regulated, thus permitting flexibility in the operation of the furnace for the manufacture of a variety of grades of carbon black product.

2. The apparatus of claim 1 in which the primary and secondary ducts are arranged so that the combustion components discharged therefrom are both directed to the furnace chamber co-axially with respect to the fluid hydrocarbon.

3. The apparatus of claim 2 in which the primary duct is located near the center of the furnace floor and the secondary duct is located more remotely therefrom.

4. The apparatus of claim 3 in which the primary duct comprises a series of ducts arranged as a cluster near the center of the furnace floor.

5. The apparatus of claim 3 in which the secondary duct comprises a series of ducts located distally from and arranged in a symmetrical pattern around the center of the furnace floor.

6. The apparatus of claim 1 and including at least one tertiary duct for injecting combustion components tangentially into the furnace chamber so as to impart a spin to the gaseous atmosphere within the chamber.

7. The apparatus of claim 1 in which said first and second supply means for furnishing combustion gases to the primary and secondary ducts each comprise a bustle for conveying a flow of air into the primary duct, and at least one injector for conveying a flow of fluid fuel into said duct.

8. The apparatus of claim 7 and including an air supply conduit with an air flow regulator for controlling the flow of air to each said air bustle, and a fluid fuel supply conduit with a fuel flow regulator for controlling the flow of fuel to the fuel injectors.

9. A process for producing carbon black by the thermal decomposition of normally nongaseous hydrocarbons by contact with hot combustion gases comprising:

(a) injecting a stream of hydrocarbon at a predetermined, essentially constant rate into an unconfined, localized region near one end of an elongated, unobstructed furnace chamber;

(b) passing a first predetermined portion of said hot combustion gases into the localized region of the furnace chamber where it makes direct contact and is thoroughly and intimately mixed with said hydrocarbons, the quantity of hot combustion gases in said first portion being sufficient to effect partial but incomplete conversion of said hydrocarbons into carbon black within the localized region of the furnace chamber;

(c) simultaneously passing a second portion of said combustion gases to said end of the elongated, unobstructed furnace chamber in the space around the localized region in which partial conversion of hydrocarbons takes place, said second portion being introduced at an essentially constant rate that differs from the rate at which said first portion is introduced, said second portion and the partially reacted hydrocarbon-combustion gas mixture thereafter mixing within the furnace chamber so as to substantially complete the conversion of said hydrocarbons into carbon black;

(d) removing said combustion gases and the gaseous products of the thermal decomposition of said hydrocarbons from the other end of said furnace chamber as effluent gases, together with carbon black product; and

(e) thereafter separating and recovering the carbon black from the effluent gases.

10. The process of claim 9 in which the hydrocarbons are injected axially into the furnace chamber and said first and second portions of hot combustion gases are likewise directed substantially axially into said furnace chamber.

11. The process of claim 10 in which the hydrocarbon is injected into the furnace as an atomized spray of liquid droplets.

12. The process of claim 9 in which the hydrocarbon is injected upwardly into a vertically elongated furnace chamber as an atomized spray of liquid droplets, and final thermal decomposition of the hydrocarbon occurs in the upper regions of the furnace chamber above the unconfined-localized mixing zone.

13. The process of claim 9 in which said first and second portions of hot combustion gas are each independently produced by the combustion of separately formed mixtures of fluid fuel and a free oxygen-containing gas, the proportion of oxidant to fuel being independently adjustable for each portion of said hot combustion gas.

14. The process of claim 9 in which the comparative velocities of the first and second portions of the combustion gases introduced into said furnace chamber are significantly different.

15. The process of claim 13 and including the preheating of the free-oxygen containing gas to a temperature of from about 600° F. to about 1500° F. prior to admixture with the fuel.

16. The process of claim 15 in which the first portion of combustion gases is a fuel-rich combustion mixture and the second portion is an oxygen-rich combustion mixture, whereby the relatively cooler second portion of combustion gases serve to protect the walls of the furnace chamber from the hotter combustion gases introduced into the localized region of the furnace chamber.

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