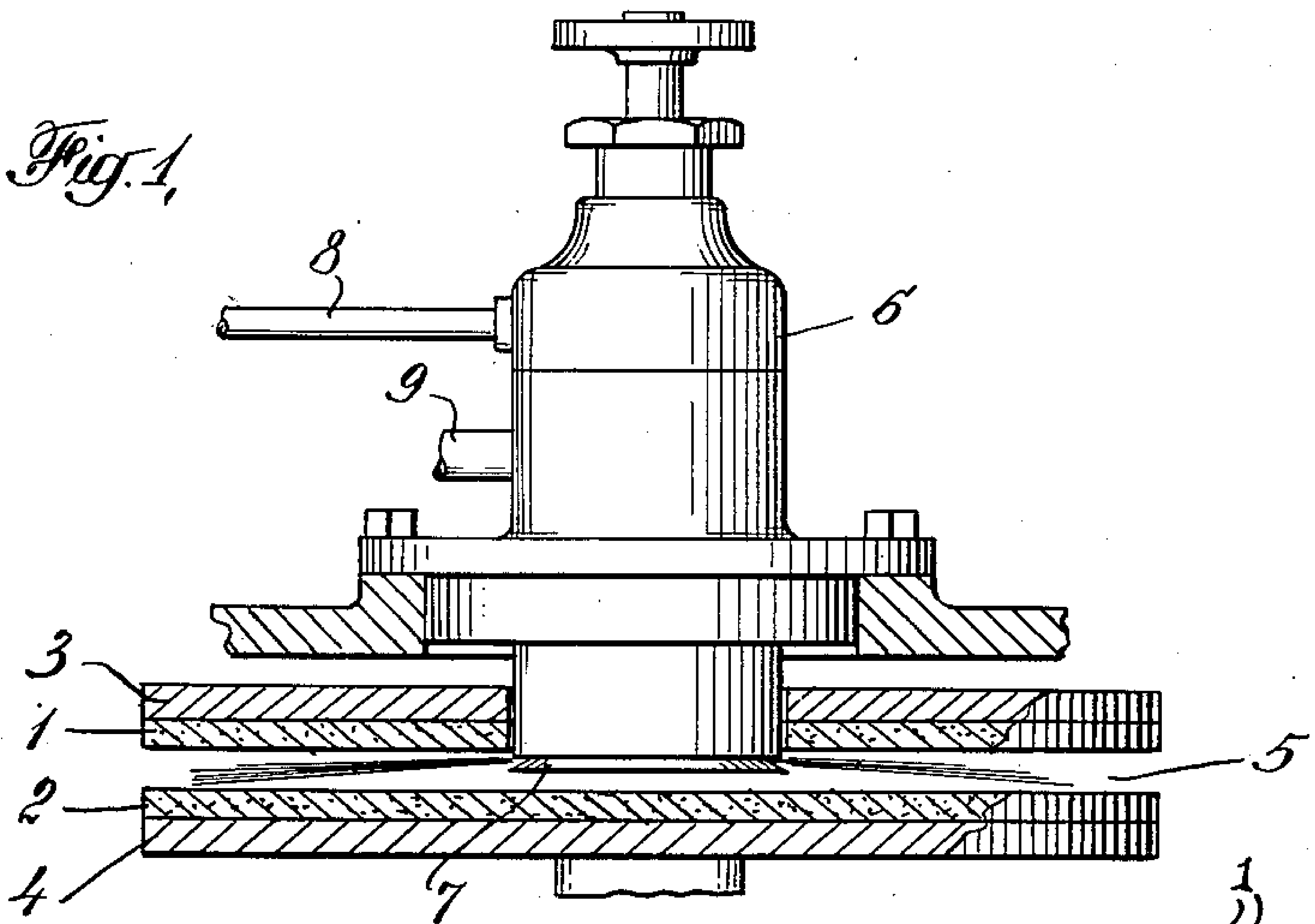
Oct. 14, 1941. E. TAYLOR 2,259,010

APPARATUS FOR COMBUSTION OF FLUID FUEL

Filed May 24, 1939 2 Sheets-Sheet 1

Fig. 1.



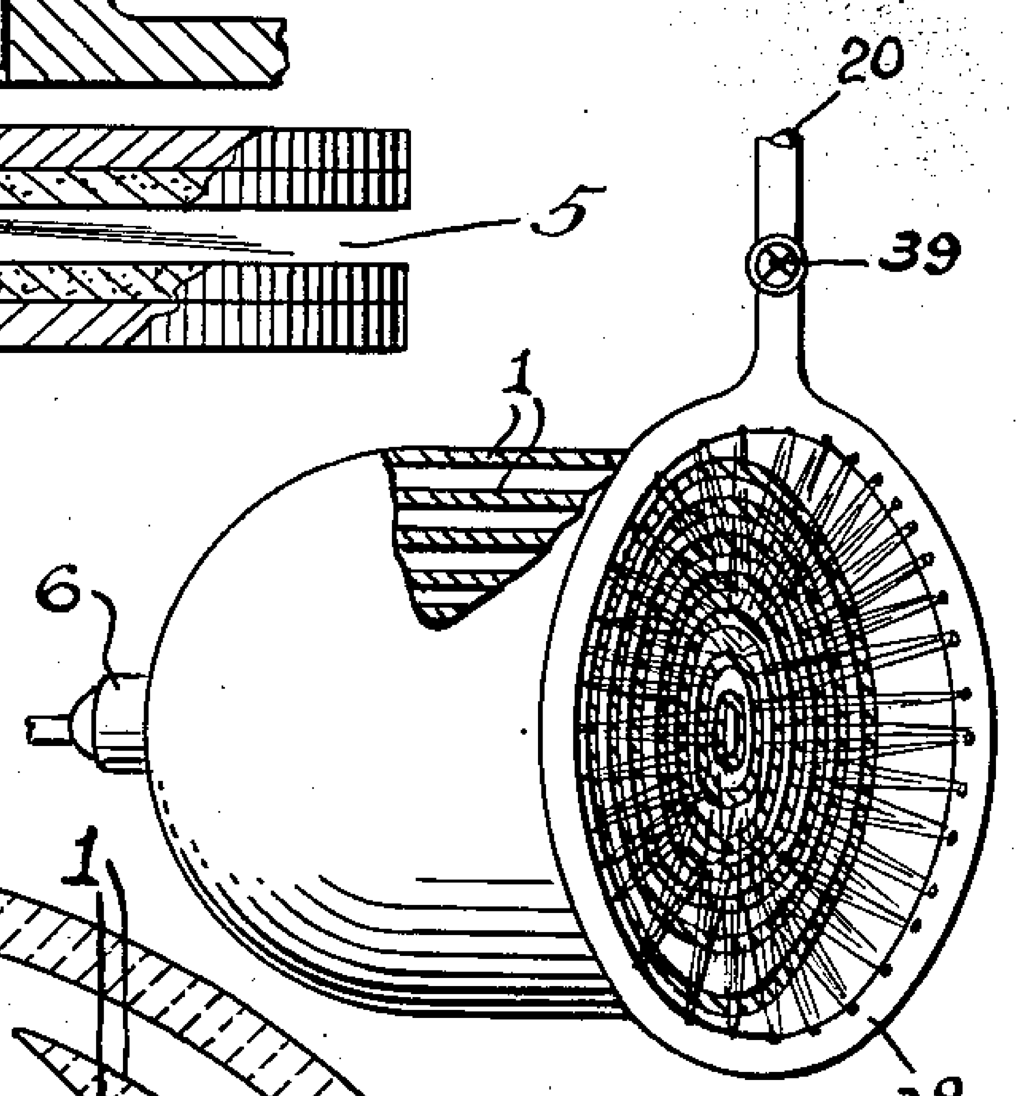
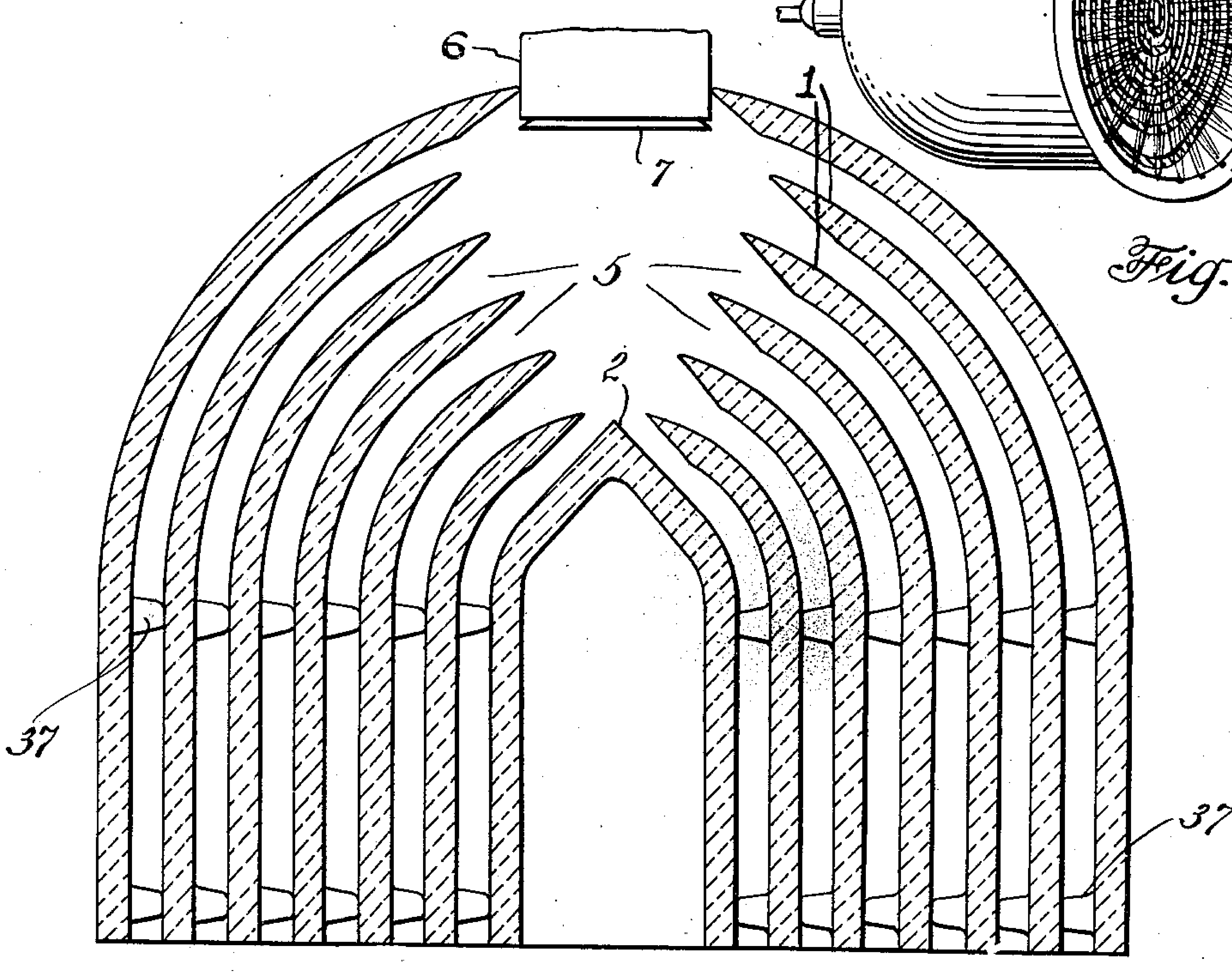


Fig. 4.

Fig. 3.



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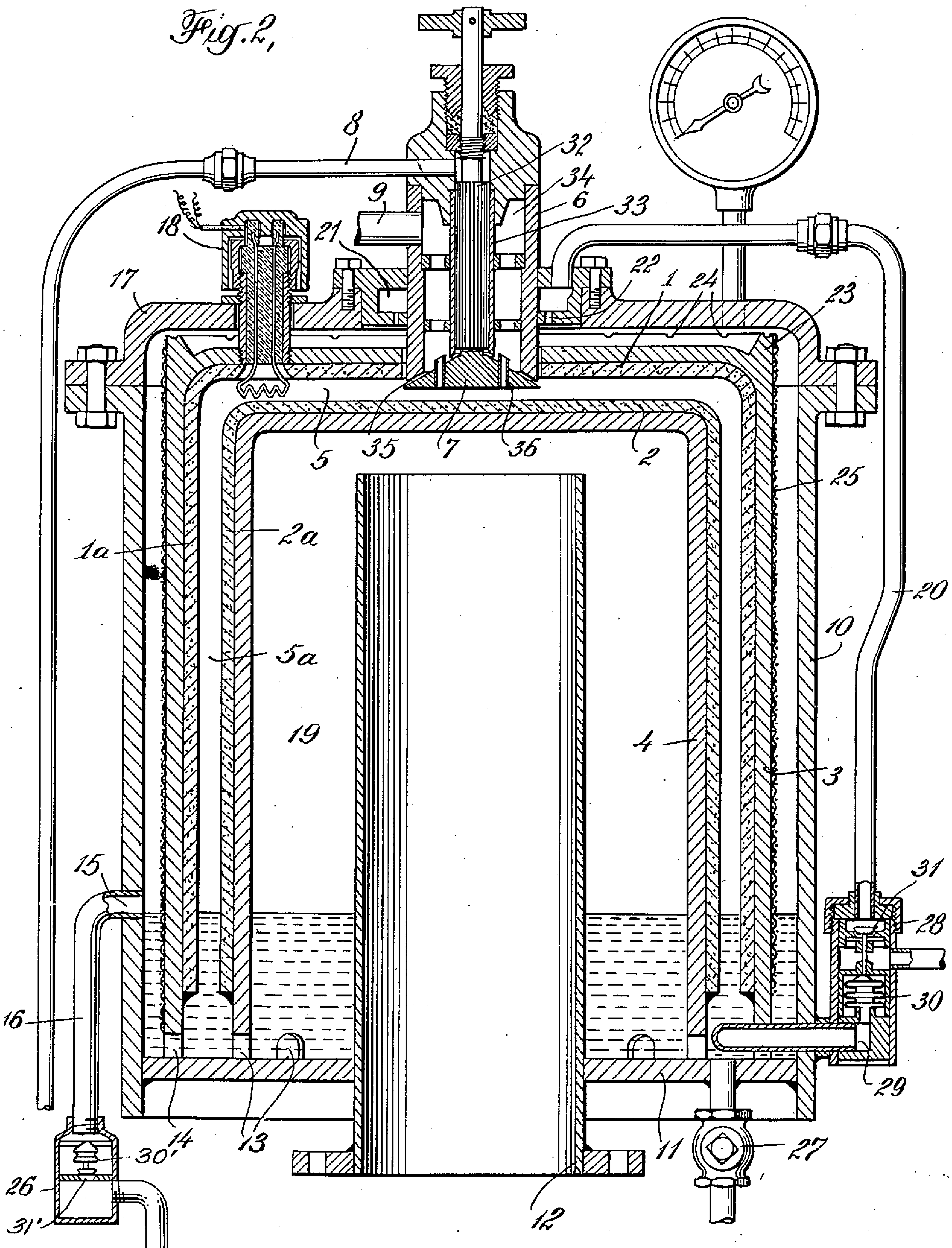
Filed May 24, 1939 2 Sheets-Sheet 2

Fig. 2,



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Patented Oct. 14, 1941 2,259,010

UNITED STATES PATENT OFFICE

2,259,010

APPARATUS FOR COMBUSTION OF FLUID FUEL

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Application May 24, 1939, Serial No. 275,462

7 Claims. (Cl. 60—45)

This invention relates to an apparatus for producing substantially complete combustion of a fluid fuel. More particularly the invention relates to an improved process and apparatus for the burning of a gaseous or liquid combustible material commingled with a combustion-supporting medium to produce a heat-conveying pressure fluid medium, which contains products of complete combustion but substantially no products of incomplete combustion, and which further contains substantially all of the heat developed by the substantially complete combustion of the fuel; and in a particularly advantageous embodiment of the invention to a highly efficient method and means for producing such a heat-conveying pressure fluid medium containing in addition a volatilized condensable gas and having a temperature substantially less than the combustion temperature, but still containing in a potentially available form substantially all of the heat units produced during the complete combustion of the fuel. The heat-conveying pressure fluid medium of the last mentioned preferred embodiment may with particular advantage be employed directly in an improved heat-radiating system or to operate prime movers for the production of power as described and claimed in my co-pending applications for Letters Patent, Serial Nos. 275,464 and 275,465, filed of even date herewith. The phrase "heat-conveying pressure fluid medium" as used herein and in the claims refers to a gaseous medium which is capable of conveying heat and of being maintained under pressure, which is capable of and may be used for performing useful work by the release of its heat or by being expanded to a lower pressure, and which further may have associated therewith varying proportions of liquid vapor. For example, if a hydrocarbon fuel is burned in air in the normal way, the resulting mixture contains excess air, nitrogen, carbon dioxide, carbon monoxide and water vapor. Such a mixture, as do products resulting from the burning of other types of fuel, falls within the designation, "heat-conveying pressure fluid medium," as well as such a mixture to which has been added a vaporized condensable liquid, for example steam. In the latter case the gas or mixture of gases may carry a quantity of water vapor substantially in excess of that required to saturate the gas. Water is the most satisfactory volatile liquid medium, although other liquids having suitable properties may be employed. Since water is one of the products of combustion of most fuels, the cyclic return of a single condensed liquid component, after utilization of the mixed gases, is possible when water is the liquid which is vaporized and added to the products of combustion.

The present invention provides a method and apparatus of improved construction adapted to accelerate and complete the combustion of a fluid fuel in a manner and to an extent which results in markedly increased efficiencies, as well as more economic consumption of fuel than has been possible in the methods heretofore employed, and which additionally provides products of combustion capable of directly performing useful work to a degree not possible with the previously employed methods.

Numerous methods have in the past been proposed for accelerating the combustion of gaseous and liquid fuels and for inducing a more complete combustion of such fuels. For example, the use of catalyzing materials variously disposed in combustion chambers has been suggested. Such suggestions have included the incorporation of the catalyst in the walls of variously shaped fire boxes and combustion chambers, or its deposition in porous refractory materials through which a gaseous fuel and air can be passed and burned, or against which a fuel and air mixture can be impinged. Substances most frequently suggested as catalytic agents are freshly deposited and finely divided metals, such as platinum and palladium, or metallic oxides, such as copper, nickel, lead, cobalt, chromium, thorium and uranium oxides. The effectiveness of such metals and oxides in promoting and catalyzing surface combustion is well known, but it is equally well known that few if any of such proposed methods have been successful in avoiding the presence of incompletely burned materials such as carbon monoxide in the products of combustion.

It is the primary object of the present invention to effect the complete combustion of a fluid fuel, thus producing a heat-conveying pressure fluid medium, containing the substantially complete amount of heat theoretically available from the complete combustion of the fuel in a form which is directly available for various useful purposes. I have found that this may be accomplished by injecting and passing, at a pressure in excess of atmospheric pressure, an intimate mixture of a fluid fuel and a combustion-supporting medium, preferably an oxygen-containing gas, between a plurality of closely spaced heated contact surfaces of refractory material. The combustion or oxidation of the fuel occurs primarily at these contact surfaces and results in what is commonly referred to as "flameless combustion." The referred to closely spaced surfaces are so constituted and disposed in accordance with my invention that their areas increase outwardly from the point of injection of the fuel, at a rate substantially in excess of a linear rate. By such an arrangement the mixture of fuel and oxygen-containing gas, which is rapidly expanding in volume and increasing in speed, is given ample opportunity to be in contact with the heated surfaces at which the major portion of the combustion occurs. By virtue of such a rapid increase outwardly of the areas of the contact surfaces, the volume of the space between the surfaces, outwardly from the point of injection of the fuel, increases at a rate in excess of the rate of increase in speed and volume of the combustible mixture. I am thus able to effect the referred to substantially complete combustion, i. e., burning to completion the oxidizable constituents of the fuel, by virtue of the just described novel arrangement of contact surfaces, as a result of which the heated and rapidly expanding gases and fuel are permitted to be in contact with the said heated surfaces for a period of time sufficient to insure complete oxidation. Such an arrangement does not offer resistance to or build up back pressure against the said expansion, or permit any substantial convection currents to be set up whereby products of combustion are circulated in the combustion zone to reduce the availability of the hot contact surfaces to unoxidized material.

An important advantage of burning a fuel and directly using the products of combustion or passing them through a volatile liquid medium before use at a lower temperature, is that the fuel is being utilized at what is commonly referred to as its "higher heating value"; that is, an appreciable part of the heat of combustion normally lost through the flue as latent heat employed in transforming the water of combustion into steam is made use of. Due primarily to failure to achieve substantially complete combustion, however, previously proposed systems based on this principle have been unsuccessful. This is in part due to deleterious effects of products of incomplete combustion, such as carbon monoxide, hydrogen, free carbon and sooty material, and unburned entrained fuel. My invention avoids the formation of products of incomplete combustion and provides a method whereby a fuel may be utilized at its "higher heating value." An additional advantage of the invention resides in the fact that if desired, excess air may be used in the combustion without introducing a loss in heat efficiency. A further important advantage of my invention, in part due to the completeness of combustion, is the absence of corrosion of the various surfaces with which the products of combustion come in contact.

Improved apparatus, adapted to generate the described heat-conveying pressure fluid medium in accordance with such a process, is included within the scope of the present invention, and will be described with reference to the accompanying drawings, which will serve to illustrate alternative forms of generator made in accordance with my invention.

In the drawings, wherein like reference numerals indicate corresponding elements:

Figure 1 is an elevational diagrammatic view, part in elevation and part in section, of an apparatus for producing complete combustion in accordance with my invention.

Figure 2 is an axial section of a generator adapted to produce a heat-conveying pressure fluid medium comprising a mixture of hot gases and a volatilized condensable liquid.

Figure 3 is an axial section of an alternative form of generator made in accordance with my invention.

Figure 4 is a diagrammatic representation of the form of generator illustrated in Figure 3, which further illustrates one method of introducing a volatile liquid into the products of combustion emanating from the plurality of combustion zones of the generator.

The process and apparatus of the invention are effective to produce complete combustion of many different types of fluid fuels, provided only that they be gaseous or liquid at normal temperatures. It is to be understood that the phrase "fluid fuel," as used herein and in the claims, has such a connotation. Any gas or mixture of gases, for example, which is capable of combustion when admixed with a gas containing a proportion of oxygen appropriate to support combustion, may be employed.

In burning a fluid fuel between the contact surfaces of my invention, complete combustion may be achieved by the use of the theoretical amount of a combustion-supporting medium, for example air, required to effect the oxidation of the components of the fuel. In actual practice in the operation of my process, I find it advantageous to use a small excess of air, for example 1 to 10%, in order to lower the working temperature of the heat-conveying pressure fluid medium produced. For example, in burning a certain liquid fuel between contact surfaces of the type described, a maximum temperature of approximately 3800° F. could be attained. In order to insure that the contact surfaces would not be harmed by such a high temperature, an excess of approximately 10% of air over the theoretically required amount was introduced, and the temperature of the resulting fluid medium reduced to approximately 2500° to 2700° F.

A simple and effective form of apparatus for carrying out the process of my invention is illustrated diagrammatically in Figure 1. Substantially flat parallel plates of refractory material 1 and 2, which may have incorporated therein a catalytic material, such as for example an oxide of chromium, are backed or supported by plates 3 and 4 of a suitable material, such as for example heat-resistant steel or other suitable alloy. In the embodiment here illustrated, plates 1 and 2 are circular and define a narrow flat zone 5, into which projects through an opening in the upper contact surface the delivery end of an appropriately supported fuel atomizing head 6, here shown in elevation, of any appropriate design adapted to spray an intimate mixture of a fluid fuel and air radially outwardly between the contact surfaces. Such a fuel injection device, particularly when a liquid fuel is employed, is preferably of the type containing an adjustable conical head 7 and will be described in greater detail below in connection with the apparatus illustrated in Figure 2.

In operating an apparatus of the type illustrated, the fuel and air or other combustion supporting medium, at a pressure in excess of atmospheric pressure, are supplied to the atomizer through inlet pipes 8 and 9 respectively. The thoroughly admixed, and in the case of a liquid fuel, atomized mixture of fuel and air is sprayed outwardly from the delivery end of the atomizer in a disc-like sheet substantially parallel to the contact surfaces. The mixture is ignited by a suitable means, such as, for example, a hot wire. The mixture of hot gases expanding rapidly with a consequent increase in speed comes into contact with the combustion-accelerating surfaces whose areas are increasing outwardly from the center at an even more rapid rate, and is completely oxidized at the said surfaces. In the injection of an atomized liquid fuel mixture between such parallel plates, it is of particular advantage to employ an atomizing fuel head such as is described and claimed in my co-pending application for Letters Patent, Serial No. 275,463, filed of even date herewith, and wherein a portion of the air is introduced through ports in the base of the conical head of the atomizer. Such an expedient results in important advantages as hereinafter more fully explained. The expanded heated gases arriving at the periphery of the circular contact surfaces contain carbon dioxide, water vapor, and the inert constituents of the combustion-supporting medium, which in the case of air is primarily nitrogen. The gaseous products are free of unoxidized fuel, carbon, or carbon monoxide.

A heat-conveying pressure fluid medium which contains a volatilized condensable liquid, which is substantially free of products of incomplete combustion, and which has a temperature lower than the combustion temperature, produced in accordance with a preferred embodiment of my invention is of particular utility. The temperature of such a fluid medium may readily be controlled to any desired value and is most frequently utilized between about 200° F. and 800° F., depending on the particular use to which it is to be put, for example in heat-radiating systems or in operating prime mover engine assemblies.

A generator for producing such a fluid medium having a temperature lower than the combustion temperature, but in which substantially all of the heat is retained, will now be described with reference to Figure 2 of the drawings. As there illustrated, an outer cylindrical wall 10 is supported by an annular plate 11 adjacent the bottom thereof preferably welded thereto. This bottom plate is in turn supported by the down-comer pipe 12 whose outer wall is advantageously welded to the inner peripheral edge of the bottom annular plate. Mounted on the bottom plate 11 and positioned concentrically between the down-comer pipe and the outer shell are spaced inverted cup-shaped shells 3 and 4. These may be made of any suitable material capable of withstanding temperature differentials such as, for example, steel or appropriate alloy materials. The annular spaces defined by the outer shell 10 and intermediate shell 3, intermediate shell 3 and inner shell 4, and inner shell 4 and down-comer pipe 12 are interconnected by means of a series of peripherally spaced openings or ports 13 and 14 adjacent the bottom plate 11. Depending on the desired capacity of the apparatus, additional ports may be provided above the bottom of the shells, but below the liquid level. These openings permit the free flow of liquid between the various chambers, the common depth in the chambers being determined by an overflow outlet 15 in the exterior cylindrical wall, to which is attached waste pipe 16. The adjacent opposite walls of the cup-shaped shells 3 and 4 are covered by narrowly spaced linings 1 and 1a, and 2 and 2a respectively of refractory material, which define an area 5 similar to that shown in Figure 1 and an annular cylindrical space 5a. The said refractory material may with advantage have incorporated therein a combustion-catalyzing substance, for example an oxide of chromium. Releasably attached to the upper edge of outer cylinder 10 is a circular plate 17, forming with the cylinder and bottom plate a closed vertical container. Through the center of closure plate 17 passes and is secured a fuel injection device 6. The fuel injection device here illustrated is an atomizer suitable for injecting an atomized mixture of oil or other liquid fuel and a combustion-supporting medium such as air into the combustion zone 5. The nozzle or delivery end of the atomizer projects through the center of shell 3 and lining plate 1' into zone 5 defined by the closely spaced plates 1 and 2, which provide the contact combustion surfaces. The atomizer should be so positioned with respect to the contact surfaces that the fuel mixture will be sprayed radially outwardly from the nozzle at an elevation approximately equidistant from the two plates. Extending through the top closure plate 17, the intermediate plate 3 and the contact surface 1 into the zone 5 is an ignition mechanism 18 for initially igniting the fuel-air mixture. A hot wire type of mechanism is preferred particularly when a liquid fuel is employed, but ignition may also be effected by means of a jump-spark device. In a generator of this type the fuel is substantially completely burned by the time it has reached the periphery of plates 1 and 2. As a precautionary measure, however, I prefer that the annular passage 5a, by means of which the hot gases are removed, be defined by closely spaced concentric cylindrical plates of refractory material in which may also be incorporated a catalytic material. The hot gases are partially cooled by being passed through a continuously replenished standing body of volatile liquid, for example water, in which the plates 1a and 2a are immersed. The hot gases pass from the annular space 5a through ports 13. The partially cooled gases together with superheated steam pass upwardly through space 19 and are removed from the generator by means of pipe 12. Water is continuously supplied to the generator through pipe 20, and may be introduced at the top of the generator through an annular chamber 21 having downwardly discharging openings 22. The outer cup-shaped shell 3 is provided around its upper end with an upwardly extending peripheral flange 23. The water introduced through openings 22 passes across the top of the shell 3 and overflows through a series of peripherally-spaced notches 24. Exteriorly of the outer wall of the shell 3 is preferably attached a cylindrical screen 25 for distributing the water overflowing through notches 24 over the surface of the cylinder. The water added to the system in this manner attains an equal level in the various chambers at the bottom of the generator by passing through the peripherally-spaced ports 14 and 13. The common depth of the water in the various annular spaces is determined by an overflow outlet 15 connected with pipe 16 provided with valve 26. The apparatus may be emptied when not in use through outlet pipe 27. The supply of water to the generator through pipe 20 is automatically regulated by a thermostatic valve 28, set in accordance with the desired temperature of the gas-steam mixture to be generated. This valve may be secured outside and near the bottom of the outer wall of the generator. The valve may be of any standard construction suitable to effect the desired control of the inlet water responsively to the temperature of the water in the bottom of the generator. As here illustrated, the valve comprises a chamber 29 for a thermostatic fluid connected to a Sylphon bellows 30 and having an attachment extending through the exterior wall 10 at a point below the water level in the generator. The Sylphon bellows operates a valve 31 which controls the passage of water from the water inlet pipe to pipe 20. Other types of thermostatic valves may of course be used. The above referred to valve 26 situated in the overflow pipe is a steam trap and may have a structure similar to that of valve 28, except that it opens and permits the passage of water when exposed to lower temperatures. A Sylphon bellows 30' opens the valve 31' to permit the exit of overflowing water but not the escape of the hotter gases.

The fuel atomizing head 6, illustrated in Figure 2, is described and claimed in my referred to copending application, Serial No. 275,463, and possesses special advantage when used in connection with the present invention in cases where a liquid fuel is employed. As illustrated, the atomizer comprises an exteriorly fluted cylinder or rod 32 which is longitudinally and slidably movable in a tubular housing 33. Liquid fuel introduced through pipe 8 passes through the grooves of the fluted cylinder 32 to the surface of a conical block 7 depending from the bottom of said fluted member. Air or other combustion-supporting gas is introduced through connection 9 into an annular chamber 34 defined by the housing 33 and the outer cylindrical housing. Both of these cylindrical members are bevelled at their lower ends, the inner bevelled member being adapted to form an oil-tight closure with cone 7 when the said cone and central mechanism is raised by means of the threaded connection fixed to the upper end of the fluted member. During operation the cone is adjusted to a position with respect to the bevelled edge of cylindrical housing 33 such that a desired amount of oil is permitted to flow radially outwardly over the surface of the cone. This oil, together with air introduced into annular chamber 34 through pipe 9, passes through the annular bevelled exit 35, and atomizes the oil as it passes therethrough, and particularly as it reaches the sharp peripheral edge of the cone, thus delivering into the combustion chamber an atomized mixture of fuel and combustion-supporting medium. In the particularly advantageous form of atomizer here illustrated, there is in addition a series of concentrically spaced ports 36, which pass through the cone substantially parallel to the axis thereof. Each of these ports has an upwardly extending portion which extends into the air space 34, permitting the liquid fuel to flow across the surface of the cone without entering the ports. In such a device a portion of the air passes through the ports 36 and thence radially outwardly past the surface of the base of the cone, being diverted in this direction by the opposing plate 2. When this additional air reaches the periphery of the cone and the atomized mixture being discharged therefrom, an increased degree of atomization is produced. The air passing through these ports results in the further important advantage that the first point of contact between the fuel and the contact surface is extended radially outwardly, thus preventing the possibility of the deposition of carbon on the coolest portion of the plate substantially directly beneath the atomizing head. A portion of the air passing through the beveled exit remains above the oil spray, thus delivering the fuel to the contact surfaces between two layers of combustion-supporting gas. The conical block in the atomizer here illustrated has an angle of 120° which, with the arrangement as shown, is appropriate to produce a flat disc-like sheet of atomized fuel and air between the contact surfaces 1 and 2. A conical angle of approximately 120° gives best results when such a disc-like sheet is desired. In generators in which the two closely spaced contact surfaces assume a dome-shaped or conical structure, the combustible mixture being injected at the apex, angles somewhat less than 120° are advantageously employed. A conical angle of 90° to 100°, as hereinafter more fully explained, produces a globular injection which is particularly desirable in certain types of generator.

Figure 3 of the drawings illustrates an alternative embodiment of my invention suitable for producing a heat-conveying pressure fluid medium which may also contain a volatile condensable liquid. An apparatus such as that here shown possesses a greatly increased capacity and may be used to effect a rapid complete combustion of fuel at a rate greater than is possible in an apparatus of the type illustrated by Figure 2. In accordance with this embodiment a plurality of superimposed coaxially aligned closely spaced substantially bell-shaped surfaces 1 and 2 provide a plurality of substantially bell-shaped passages 5. These contact surfaces are with advantage made of refractory material, having incorporated therein a combustion-catalyzing substance such as for example an oxide of chromium. These surfaces may be supported by blocks 37, spaced at appropriate points in the annular passages between the concentrically placed surfaces. The tops of the bell-shaped surfaces, other than the innermost surface 2, are provided with coaxially aligned openings preferably having progressively smaller diameters approaching the inner surface. Such an arrangement of plates and openings defines a well, and particularly when the openings are progressively smaller a tapering well, which makes possible an equal distribution of the combustible mixture in the passages 5 between the contact surfaces. An intimate mixture of fuel and a combustion-supporting medium is injected into the passages. It will be noted that the areas of the contact surfaces adjacent the opening at the top increase outwardly therefrom at a rate in excess of a linear rate. Although the rate of increase is not as great as in an apparatus such as that shown in Figure 1, it is, nevertheless, sufficient to permit the hot gases to expand freely without the creation of a back pressure. The fuel injection device may be of any suitable type capable of injecting an intimate mixture of the fuel and air into the space between the openings at the top of the plates. When a liquid fuel is used, an atomizer of the type illustrated in Figure 2 and more fully in my co-pending application, Serial No. 275,463, wherein the conical block 7 has an angle of 90°, is particularly suitable.

An important advantage of a generator such as that illustrated in Figure 3 is that its use is not restricted to a vertical position as illustrated in Figure 3, but it may be used equally well in a horizontal position illustrated in Figure 4. Regardless of its position, the hot products of combustion emerging from the outer ends of the annular passages 5 may be brought in contact with a volatile liquid medium to reduce the temperature of the products of combustion and convert a portion of their sensible heat to latent heat in any appropriate manner, for example by spraying the volatile liquid across the path of the products of combustion. In this way the oxidizing mixture which has been maintained between the plates until complete combustion has been attained is combined with superheated steam, in the case where water is the volatile liquid, at any desired temperature, said temperature being regulated by the amount of water brought in contact with the hot gases. In Figure 4 is diagrammatically illustrated one method of introducing a liquid, for example water, into the products of complete combustion emanating from between the plates 1 of a generator of the type illustrated in Figure 3. In this particular method of operation water supplied through pipe 29 is sprayed inwardly from a circular ring 38 across the path of the hot products of combustion. The amount of water, and thus indirectly the temperature of the combined hot gases and steam, may be controlled by the regulation of a valve 39. In the event that a generator of this type is used in a vertical position, an arrangement similar to that illustrated in Figure 2 may be employed to pass the hot products of combustion into and through a continuously renewed standing body of water.

The oxidation of the fuel according to my invention may be accelerated and perfected to a degree sufficient to yield a gaseous product substantially free of products of incomplete combustion by contact with surfaces of refractory material. I prefer, however, to incorporate in the refractory material a high melting oxidation-catalyzing material such as for example an oxide of a heavier metal. I have found that a particularly effective composition is one containing equal parts by weight of kaolin, a hydrated aluminum silicate having a melting point above 3100° F., and chromic oxide having a softening point above 3800° F. Such a mixture will have a melting point above 3500° F. Inasmuch as operating temperatures in generators operated in accordance with my invention are maintained at approximately 2500° F. with 3000° F. a maximum, a mixture such as that described is of particular advantage. My invention, however, contemplates the use of other catalytic metallic oxides. Certain oxides, for example Fe_2O_3, having excellent catalytic properties are of limited utility due to their relatively low melting or softening points.

The distance between the contact surfaces in the generators of my invention may vary somewhat, the lower limit being determined largely by practical considerations such as the necessity in generators of the type illustrated in Figures 1 and 2, of arranging the injection mechanism to inject the fuel between the plates, and the upper limit being such that convection currents are substantially completely eliminated. In practice I have found that a distance of about ¼ to ⅜ inch produces the most satisfactory results.

The catalytic plates are preferably supported by metallic plates having the same configuration. Any metal or alloy capable of withstanding high temperatures and pressures is suitable for this purpose. A high grade steel or alloy steel will in most cases prove satisfactory. The cup-shaped members 3 and 4, in an apparatus such as is illustrated in Figure 2, are not subjected to as high temperatures as the corresponding plates in the apparatus illustrated in Figure 1, due to the cooling effect of the water and the mixture of products of combustion and steam which are in contact with the outer surfaces of the said plates. Other heat-resistant alloys, for example the various cobalt alloys, or copper alloys, may also be used for this purpose.

The present invention, which has been described in its preferred embodiment as passing the hot products of combustion into and through a standing body of water, may also be operated by subjecting the hot products of combustion to contact with the water in other ways. For example, as was described with reference to the apparatus of Figure 3, as illustrated in Fig. 4 the water may be sprayed into the expanding hot gases to accomplish the same purpose. A further method involves the passage of the hot gases into a packed tower, through which is circulated a continuously renewed supply of water.

As will be apparent from the above description the heat-conveying pressure fluid medium produced by a generator of the type shown in Figure 2 may be regulated to any desired temperature and pressure, these two properties being completely independent of each other. Thus my process will produce a gas-stream mixture for delivery to a heating system for example, having a pressure of 5 pounds and a temperature which may range from 200° F. to 1000° F. as desired. Similarly the pressure of the gas-steam mixture as delivered may vary over wide limits, for example from 1 to 10 pounds, as commonly used in heating systems up to several hundred pounds when the mixture is to be used to drive an engine. The temperature of the emerging gas-steam mixture when a fixed proportion of air is employed is determined largely by the rate at which water is introduced into the generator. The pressure on the other hand is dependent only on the pressure under which the fuel and air are supplied to and taken from the generator.

I claim:

1. A generator adapted to produce a heat-conveying pressure fluid medium by effecting the substantially complete combustion of a fluid fuel which comprises coaxially aligned closely spaced members having bell-shaped portions, the adjacent surfaces of which have incorporated therein a catalytic material, said bell-shaped members providing between them a continuously open space for combustion of the fluid fuel and conduction of products of combustion, and means for injecting a combustible fuel mixture into said open space at substantially the center thereof, whereby said mixture expands freely between and in contact with the said adjacent surfaces radially outwardly from the point of injection, the injection of the combustible fuel mixture being in a direction substantially parallel to the confining walls of said open space so that contact of the combustible fuel mixture with said confining walls is primarily by said free expansion of the fuel mixture and so that there is no appreciable deflection of the fuel mixture by said confining walls until combustion of the fuel mixture has been initiated.

2. A generator adapted to produce a heat-conveying pressure fluid medium by effecting the substantially complete combustion of a fluid fuel, said fluid medium having a temperature lower than the combustion temperature and containing a volatilized condensable liquid, which comprises coaxially aligned closely spaced members having bell-shaped portions, the adjacent surfaces of

which have incorporated therein a catalytic material, said bell-shaped members providing between them a continuously open space for combustion of the fluid fuel and conduction of products of combustion, means for injecting a combustible fuel mixture into said open space at substantially the center thereof, whereby said mixture expands freely between and in contact with the said adjacent surfaces radially outwardly from the point of injection, and means for subjecting a volatile liquid medium to contact with the said products of combustion, thereby to cause by vaporization a lowering of the temperature of the products of combustion, the injection of the combustible fuel mixture being in a direction substantially parallel to the confining walls of said open space so that contact of the combustible fuel mixture with said confining walls is primarily by said free expansion of the fuel mixture and so that there is no appreciable deflection of the fuel mixture by said confining walls until combustion of the fuel mixture has been initiated.

3. A generator adapted to produce a heat-conveying pressure fluid medium by effecting the substantially complete combustion of a fluid fuel, said fluid medium having a temperature lower than the combustion temperature and containing a volatilized condensable liquid, which comprises a plurality of superimposed coaxially aligned closely spaced members having bell-shaped portions, the adjacent surfaces of which have incorporated therein a catalytic material, said bell-shaped members providing between them continuously open spaces for combustion of the fluid fuel and conduction of products of combustion, the said open spaces being interconnected through coaxially aligned openings in the said bell-shaped portions at substantially the center thereof, means for injecting a combustible fuel mixture into said open spaces through the said coaxially aligned openings, whereby said mixture expands freely between and in contact with the said adjacent surfaces radially outwardly from the point of injection, and means for subjecting a volatile liquid medium to contact with the said products of combustion, thereby to cause by vaporization a lowering of the temperature of the products of combustion.

4. A generator adapted to produce a heat-conveying pressure fluid medium by effecting the substantially complete combustion of a fluid fuel, said fluid medium having a temperature lower than the combustion temperature and containing a volatilized condensable liquid, which comprises coaxially aligned closely spaced vertically disposed members having bell-shaped portions, the adjacent surfaces of which have incorporated therein a catalytic material, said bell-shaped members providing between them a continuously open space for combustion of the fluid fuel and conduction of products of combustion and means for injecting a combustible fuel mixture into said open space at substantially the center thereof, whereby said mixture expands freely between and in contact with the said adjacent surfaces radially outwardly from the point of injection, the lower ends of the said members being immersed in a body of a volatile liquid, thereby to cause by vaporization during the passage of the products of combustion therethrough a lowering of the temperature of such products, the injection of the combustible fuel mixture being in a direction substantially parallel to the confining walls of said open space so that contact of the combustible fuel mixture with said confining walls is primarily by said free expansion of the fuel mixture and so that there is no appreciable deflection of the fuel mixture by said confining walls until combustion of the fuel mixture has been initiated.

5. A generator adapted to produce a heat-conveying pressure fluid medium by effecting the substantially complete combustion of a fluid fuel, said fluid medium having a temperature lower than the combustion temperature and containing a volatilized condensable liquid, which comprises a closed vertical substantially cylindrical container, coaxially aligned closely spaced vertically disposed members having bell-shaped portions within and spaced from the walls and top of said vertical container and supported on the bottom thereof, the adjacent surfaces of the said bell-shaped portions having incorporated therein a catalytic material, said bell shaped portions providing between them a continuously open space for combustion of the fluid fuel and conduction of products of combustion, means for injecting a combustible fuel mixture into said open space at substantially the center thereof whereby said mixture expands freely between and in contact with the said adjacent surfaces radially outwardly from the point of injection, means for removing the heat-conveying pressure fluid medium from the cylindrical container, means for introducing a volatile liquid into the lower portion of the cylindrical container, and communicating passages in the said members near the bottom thereof providing interconnection between the said members, the pressure fluid removal means and the volatile liquid introduction means.

6. A generator adapted to produce a heat-conveying pressure fluid medium by effecting the substantially complete combustion of a liquid fuel, said fluid medium having a temperature lower than the combustion temperature and containing a volatilized condensable liquid, which comprises a closed vertical substantially cylindrical container, coaxially aligned inverted closely spaced cup-shaped members within and spaced from the walls and top of said vertical container and supported on the bottom thereof, the top portions of said cup-shaped members being two closely spaced substantially flat parallel plates whose opposing surfaces are contact surfaces of a refractory material having incorporated therein a combustion-catalyzing substance, the upper of said plates being provided with an opening situated at the approximate center thereof, a liquid fuel atomizing head passing through the top of said cylindrical container and through the opening in the upper plate and capable of injecting radially outwardly between the contact surfaces an atomized mixture of the fuel and a combustion-supporting medium, a substantially centrally located vertical down-comer pipe supported by the bottom of the vertical container and extending upwardly within said container, communicating passages in each of said cup-shaped members near the bottom thereof providing interconnection between the annular spaces defined by the outer cylinder wall, the cup-shaped members and the wall of the down-comer pipe, and means for introducing a volatile liquid into the vertical cylindrical container.

7. A generator adapted to produce a heat-conveying pressure fluid medium by effecting the substantially complete combustion of a liquid fuel, said fluid medium having a temperature lower than the combustion temperature and con-

taining a volatilized condensable liquid, which comprises a closed vertical substantially cylindrical container, coaxially aligned inverted closely spaced cup-shaped members within and spaced from the walls and top of said vertical container and supported on the bottom thereof, the top portions of said cup-shaped members being two closely spaced substantially flat parallel plates whose opposing surfaces are contact surfaces of a refractory material having chromic oxide incorporated therein, the upper of said plates being provided with an opening situated at the approximate center thereof, a liquid fuel atomizing head passing through the top of said cylindrical container and through the opening in the upper plate and capable of injecting radially outwardly between the contact surfaces an atomized mixture of the fuel and a combustion-supporting medium, a substantially centrally located vertical down-comer pipe supported by the bottom of the vertical container and extending upwardly within said container, communicating peripherally spaced passages in each of said cup-shaped members near the bottom thereof providing interconnection between the annular spaces defined by the outer cylinder wall, the cup-shaped members and the wall of the down-comer pipe, means for introducing a volatile liquid through the top of the closed vertical container and for causing the liquid to flow exteriorly of the outer cup-shaped member, automatic control means for admitting the volatile liquid at a rate dependent on the temperature of the liquid in the bottom of the container, and means for limiting the maximum volume of the liquid present in the container.

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