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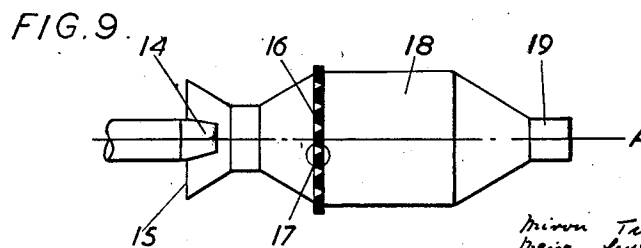
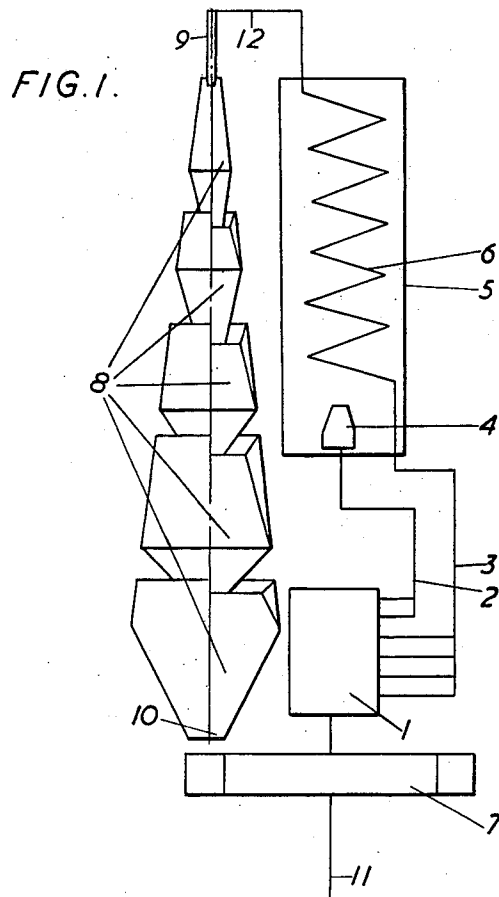
M. TUVAL ETAL

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METHOD AND APPARATUS FOR THE COMBUSTION OF FUEL

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3 Sheets-Sheet 1



Inventors
Miron Tuval and
Meir Levy
By Michael S. Stoker

Attorney

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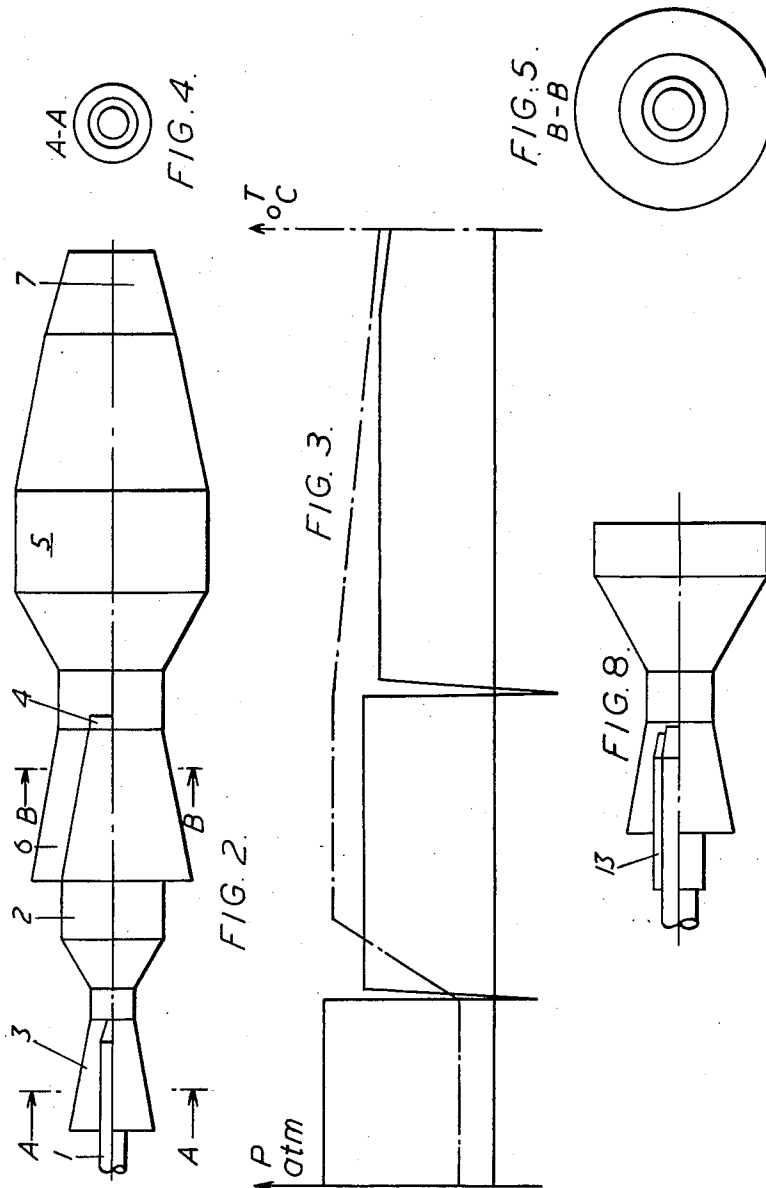
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METHOD AND APPARATUS FOR THE COMBUSTION OF FUEL

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3 Sheets-Sheet 2



Inventors
Miron Tuval and
Meir Levy
By Michael S. Striker
Attorney

Feb. 26, 1963

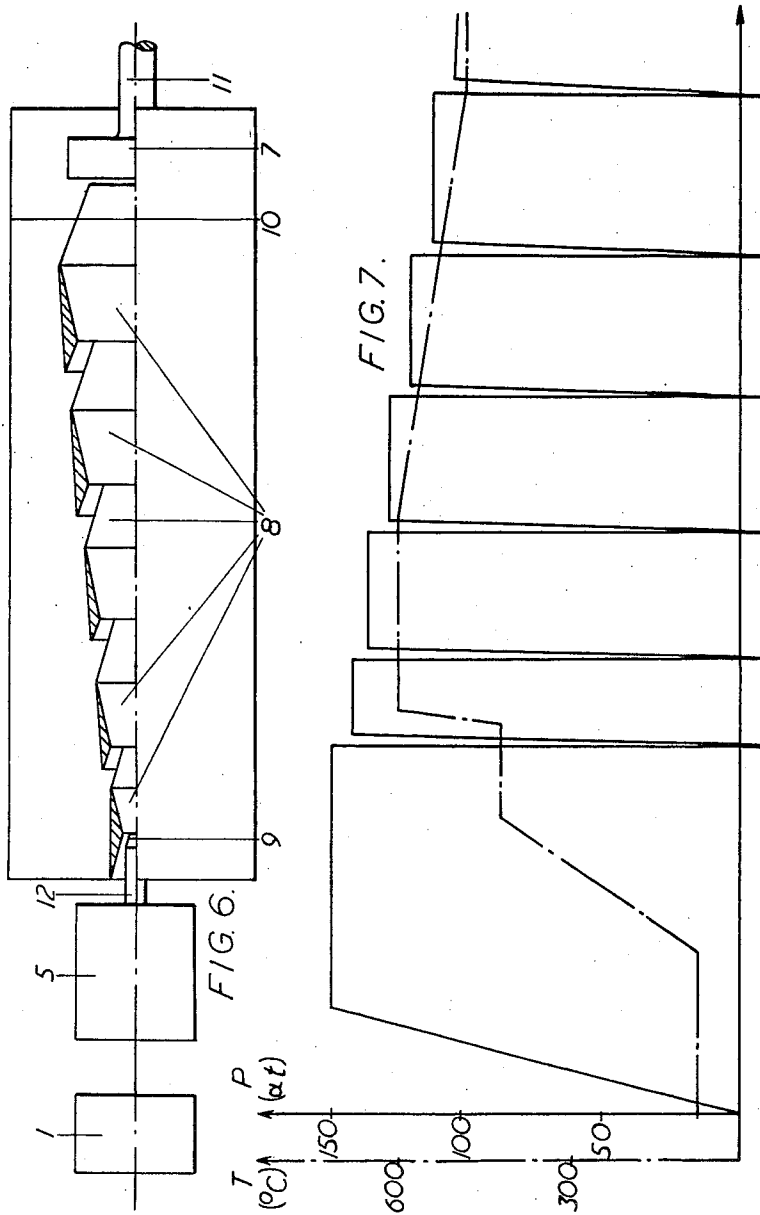
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METHOD AND APPARATUS FOR THE COMBUSTION OF FUEL

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3 Sheets-Sheet 3



Inventors
Miron Tuval and
Meir Levy
By Michael S. Storker
Attorney

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METHOD AND APPARATUS FOR THE COMBUSTION OF FUEL

Miron Tuval, 19 Louis Marshall St., Tel Aviv, Israel, and Meir Levy, Ahad Ha'am St. 12, Ramat Gan, Israel
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This invention relates to a method for producing gaseous products of combustion and an apparatus for carrying out said method.

Conventional internal combustion engines are relatively inefficient. The construction of the commonly used motor of motor-cars is quite complicated and such motor has a high ratio of weight per horsepower, as well as many moving parts which are liable to wear. A substantial part of the power produced is intentionally dissipated by means of the mandatory cooling system, without being utilized for any useful purpose. As to the conventional combustion turbo-engine, compressed air from an air compressor is introduced under pressure into its combustion chamber, while fuel is injected into said compressed air, the combustion of the air-fuel mixture being achieved by means of a spark produced by an electric spark plug.

Due to the inherent natural properties of the gaseous media, it is difficult and uneconomical to obtain high compression ratios by means of such air-compressor as used with the conventional turbo-engine.

In order to obtain high efficiencies by means of such turbo-engine, the combustion of the air-fuel mixture has to take place at a high temperature, usually in the region of 650–1100° C. and at a relatively low pressure, in the order of 6–8 atm., said pressure being of course lower than that exerted by the air-compressor used for introducing the compressed air, as otherwise back-firing would result.

This high temperature, as well as the relatively low air-pressure, constitute drawbacks. Furthermore, such an air compressor for introducing the air necessary for combustion of the air-fuel mixture, is a cumbersome and relatively inefficient device which, in itself, is a disadvantage which should, if possible be obviated.

An object of the present invention is to provide a novel method for producing gas by combustion, and a novel apparatus for this purpose, which apparatus, unlike the conventional apparatus, does not require the provision of an air compressor.

Another object is to provide an apparatus, in which the combustion of the air-fuel mixture, or mixtures, takes place in successive zones in the combustion chamber.

According to the invention, the method for producing gas by combustion, comprises in combination the steps of introducing under pressure at least partially gasified fuel through suitable inlet means into a combustion chamber wherein combustion of said fuel takes place, after ignition, in a number of successive zones, said combustion taking place due to the introduction of outside air in predetermined quantities into each zone through suitable inlet means, said air being drawn into said zones by the suction effect created by the flow under pressure of the fuel into the first zone and thence the combustion products successively into the other zones, the predominantly gaseous products of combustion leaving the last zone at elevated temperature and at an elevated total pressure.

The apparatus for carrying out the method according to the invention, comprises a single or multiple zone combustion chamber, in combination with means for pre-heating and, preferably, at least partially cracking, fluid or solid fuel or fuel mixtures, means for introducing

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under pressure said fuel or fuel mixture through suitable inlet means into the first zone of said combustion chamber, suitable formed openings being provided for the passage of the combustion products from the first zone to the next and to successive zones in the case of a multiple zone combustion chamber, inlet means being provided in each zone for the introduction of outside air thereinto (due to the suction effect created by the flow of the fuel and admixture of combustion products), and for ignition, a suitable exit being provided in the last zone for the predominantly gaseous combustion products.

By means of the novel apparatus, the necessity for the provision of an air compressor for introducing air into the combustion chamber is obviated. Furthermore, the operational characteristics of this novel apparatus are superior to the conventional constructions hitherto used, as in this novel apparatus the combustion takes place at a higher pressure, and as for an identical efficiency, as compared with conventional internal combustion engines, inclusive modern gas turbo engines, a lower temperature may be used.

This reduction in temperature, for identical or superior efficiency is of considerable economical significance, since much cheaper materials may be used in the construction of the apparatus according to the invention, in comparison with the special alloys required for the construction of conventional high efficiency turbo engines.

The apparatus for carrying out the method according to the invention is illustrated, by way of example only, in the accompanying drawings, in which:

FIGURE 1 is a schematical view of the apparatus,

FIGURE 2 is a schematic fragmentary cross-sectional view of a double zone combustion-chamber,

FIGURE 3 is a diagram showing the temperature and pressure at each corresponding zone of FIGURE 2,

FIGURE 4 is a schematic cross-section through A'—A" of FIGURE 2,

FIGURE 5 is a schematic cross-section through B'—B" of FIGURE 2,

FIGURE 6 is a schematic partial cross-sectional view of an apparatus incorporating a quintuple-zone combustion chamber,

FIGURE 7 is a diagram showing the temperature and pressure at each corresponding zone of FIGURE 6,

FIGURE 8 is a schematic fragmentary cross-section view through an inlet into any zone of the combustion chamber providing for additional air and/or fuel and/or gaseous components, and

FIGURE 9 shows a combustion zone, according to the invention, wherein a grid is located.

With reference to the drawings, the apparatus comprises, in general, the components as shown in FIGURE 1.

Said apparatus comprises—a distributor pump or compressor 1, actuated by suitable means as for example the motor-shaft 11 actuated by means of the turbine 7, which forces fuel, coming from a source not shown, through pipes 2 and 3 in predetermined quantities and desired rates of flow into a heater 5; fuel flowing through pipe 2 being introduced through a nozzle 4 and burned in said heater 5, so as to heat the fuel flowing through the coil 6. The fuel passing through the heating chamber 5 is heated to a predetermined temperature, depending on its quality, inherent properties and the like and also on the properties of the multiple combustion chamber 3 wherein it is burned. In a preferential embodiment of the invention, the fuel is heated to such a temperature, as to undergo at least partial cracking and gasification while passing through the coil 6, as thereby the energy which may be derived from it is increased. Furthermore, said heating is carried to such extent, that

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the fuel introduced under pressure by means of pipe 3 leaves said heating chamber 5 and enters the combustion chamber 8 at a predetermined pressure depending on the construction of said combustion chamber. The fuel heated in the heating chamber 5 leaves through pipe 12 and is introduced into the multiple-stage combustion chamber through nozzle 9, the combustion in said combustion chamber taking place in a manner to be explained in connection with FIGURE 2. The combustion products leave said combustion chamber through opening 10, their energy being converted into other desired forms of energy by suitable means, as for example by means of turbine 7.

In FIGURE 2, 1 is a nozzle through which preheated fuel with an admixture of gaseous components is introduced into the first stage 2 of the combustion chamber. By injecting this fuel-mixture at relatively high pressure and temperature, air, necessary for the combustion of said fuel, is introduced through the opening 3 by means of suction due to said introduction of the combustible mixture. This opening is of suitable size and form, calculated to introduce by suction such a quantity of air from outside, as to cause the combustion of a predetermined portion of the fuel introduced through nozzle 1. The design of said opening or openings 3 is well known to anybody versed in the elements of fluid dynamics. In a preferred embodiment of the invention, said openings 3 are given the forms of venturis. The simultaneous introduction of the preheated fuel-mixture and introduction of the sucked-in air brings about the spontaneous combustion of such part of the fuel mixture, as will be proportional to the amount of air introduced. By this partial combustion of the fuel, gaseous products of combustion are produced, which leave the opening 4 of the first zone of the chamber at a velocity which is a function of the amounts of fuel and air, temperature and pressure. The gaseous mixture leaving through 4 enters the second zone of the combustion chamber 5. Here also, an opening or openings 6 are arranged around said opening 4, in such a manner that said gaseous mixture brings about the introduction of further predetermined quantities of air from outside by suction through said opening 6. This opening is given any suitable form and dimension; preferably a venturi may be used.

It is selfunderstood that the relative dimensions of the various stages of the chamber and of the corresponding openings for the introduction of air are such, as to provide for the combustion of predetermined portions of the introduced fuel, taking into account the change of volume by combustion, change of pressure and of temperature, and to provide for practically complete combustion of the whole of the combustible components up to the end of the last stage. The gaseous mixture leaving through 7 is made to impinge on a turbine or other suitable arrangement and its inherent thermal and kinetic energy is thus utilised.

In FIGURE 3 there are shown the corresponding temperatures and pressures, corresponding on each point of the respective curves to the point vertically above at the axis of the apparatus described in FIGURE 2.

FIGURE 6 shows an apparatus incorporating a five-zone combustion chamber. By way of example only, details of data for one possible construction of such apparatus are given. The fuel or fuel mixture, preferably an initially liquid hydrocarbon mixture known under the trade designation of "mazuth" or medium fuel oil is pumped under pressure by means of a pump 1 and passed through a preheater 5, where it attains a temperature of about 450° C., this temperature being the temperature at which this particular fuel undergoes partial cracking without any undesirable coking taking place. The fuel mixture leaves the preheater through pipe 12 and is introduced through a suitable nozzle or nozzle-arrangement, as described in connection with FIGURE 2, into the first stage of the five-zone combustion chamber 8.

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FIGURE 7 gives the temperatures and pressures corresponding to the apparatus described in FIGURE 6.

In this example, the fuel is introduced into the first zone of the five-zone combustion chamber at a temperature of about 450° C. and at a pressure of about 150 atmospheres, the pressure and the temperature at each zone are shown on the corresponding diagram given in FIGURE 7. The predominantly gaseous mixture leaving the exit of the last zone leaves at a pressure of about 65 atm. and at a temperature of about 600° C. Calculations have shown, that a theoretical efficiency of about 60% can be obtained from this particular construction.

Experiments carried out have shown that the expected and calculated suction effect is obtained, resulting in the introduction of the required quantities of air into each zone.

For some constructions it might be preferable to introduce into one or more zones of the multiple-zone combustion chamber, additional quantities of air, fuel or a mixture of both.

For some specific uses, the introduction of a certain quantity of water is desirable, so as to obtain a higher thermal efficiency.

In FIGURE 8 there is shown, by way of example only, a construction which provides for the possibility of introducing the desired quantities of fuel and/or air, and/or other gases, or gaseous mixtures.

The construction is identical with the one described in detail in connection with FIGURE 2, an additional pipe 13 being provided for introduction of said components. Other modes of injection of the aforementioned additional substances may be resorted to.

It is selfunderstood that the hot gaseous mixture leaving the turbine may be utilised for preheating or heating the fuel mixture to be introduced into the combustion chamber and/or for heating the air due to be sucked into said chamber.

It is clearly understood that the thrust of the hot, predominantly gaseous, mixture leaving through the exit of the last stage of the combustion chamber can be utilised as such for the purpose of propulsion.

Although in the aforementioned there have been described constructions in which the preheated fuel, coming from the pressure pump after having been passed through the heating unit, is introduced into the first zone of the multiple-zone combustion chamber, and passes on through the successive zones, part of said fuel undergoing combustion in each zone, it is within the scope of the invention to resort to such constructions wherein injection of predetermined quantities of fuel simultaneously into more than one zone may be resorted to.

Experiments have shown that the provision of a suitable grid or netting, located either at the inlet of the thus equipped zone, or at a location as shown in FIG. 9, which is a schematic cross-section of one zone of a combustion chamber, equipped with such grid, said grid or netting being substantially vertical to the direction of the axis A as shown in this figure.

The combustion zone 18 shown in this figure has an inlet 14, through which there are introduced the fuel mixture, and if this zone is not the first one, also combustion products from previous zone or zones; an inlet 15, through which air is sucked in, as above explained, a grid 16, having preferably conical holes 17, as shown; and an outlet 19. This grid constitutes a resistance for the flow of the gaseous mixture in a backward direction. Thus improved flow characteristics are attained, improving the efficiency of the apparatus.

The gaseous, or at least partially gaseous mixture entering the combustion chamber, as well as the mixtures passing from one stage to the next one, have a component of velocity in the direction of the flow. As the mixture is ignited in the respective zone, its volume is increased and the gaseous mixture flows in the direction of least resistance. As there is already a flow at a certain velocity

through these holes in the grid, the gaseous mixture is thus made to continue in its direction of flow, as desired.

Furthermore it has been found that whenever only gaseous fuel is used, such as propane, butane, similar mixtures of producer gas or the like, same may be used with or without preheating. After introduction under pressure into the first stage, all the effects described are obtained.

It is clearly within the scope of the invention to use any suitable mixture of gaseous and/or liquid and/or solid fuel after suitable preheating, whenever required.

It has been found, that whenever fuel-oil is heated to a relatively low temperature, such as about 250° C., same may be introduced in at least partially gaseous state into the first zone under pressure, resulting in the predicted and above described characteristics of the combustion chamber. It was found, that due to the relatively low temperatures throughout the combustion chamber, ignition is necessary at least in the first, but often also in the second and even third zone.

Although we have described our invention with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example, and that numerous changes in the details of construction, and the combination and arrangement of parts, may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

We claim:

1. A method for producing energy by combustion, comprising, in combination, the steps of preheating a liquid fuel; introducing the preheated fuel under pressure through a nozzle into a combustion chamber communicating with the outside air so that ambient air is sucked into said combustion chamber to form with a part of said fuel a combustible mixture; effecting ignition of said mixture to produce combustion gas; guiding the remaining fuel and said combustion gas into another combustion chamber of greater volume communicating with the outside air and introducing said fuel and gas into said other combustion chamber at a point of substantially minimum pressure therein so that air is sucked into said other combustion chamber and forms with at least a part of said remaining fuel a combustible mixture which is ignited by said combustion gas to form a greater volume of combustion gas; and guiding said greater volume of combustion gas out of said other combustion chamber at a temperature and kinetic energy greater than the temperature and kinetic energy of the introduced fuel.

2. A method for producing energy by combustion, comprising, in combination, the steps of preheating a liquid fuel to at least partly crack the same; introducing the preheated fuel under pressure through a nozzle into a combustion chamber communicating with the outside air so that ambient air is sucked into said combustion chamber to form with a part of said fuel a combustible mixture; effecting ignition of said mixture by spontaneous combustion to produce combustion gas; guiding the remaining fuel and said combustion gas into another combustion chamber of greater volume communicating with the outside air and introducing said fuel and gas into said other combustion chamber at a point of substantially minimum pressure therein so that ambient air is sucked into said other combustion chamber and forms with at least a part of said remaining fuel a combustible mixture which is ignited by said combustion gas to form a greater volume of combustion gas; and guiding said greater volume of combustion gas out of said other combustion chamber at a temperature and kinetic energy greater than the temperature and kinetic energy of the introduced fuel.

3. An apparatus for producing energy by combustion, comprising, in combination, a series of successive combustion chambers, each having an outlet opening at one end and an inlet opening venturi configuration at the other end thereof, said openings of each chamber being of substantially smaller transverse section than an intermediate

portion thereof, said ends with said outlet openings extending into said inlet openings of the next successive combustion chambers to the throat of said venturi configuration thereof and forming in the said chamber annular air inlets, the volume of each chamber being greater than the volume of the preceding chamber; nozzle means located in the inlet opening of the first combustion chamber and forming an annular air inlet in the same; preheating means for preheating a fuel; means for supplying the preheated fuel under pressure to said nozzle means so that fuel is introduced into said first combustion chamber at a predetermined velocity whereby ambient air is sucked through said annular inlet of the same into the same to form a combustible mixture in said first combustion chamber; and means for effecting ignition of the mixture in said first combustion chamber whereby combustion gas and fuel passes through the outlet opening of the same into the next successive combustion chamber at a predetermined velocity to suck ambient air through said inlet of the same whereby an additional amount of a combustible mixture is formed which is ignited by said combustion gas and passes through the outlet of said next successive combustion chamber into the next following successive combustion chamber until the combustion gas produced by all the introduced fuel passes through the outlet of the last combustion chamber.

4. An apparatus for producing energy by combustion, comprising, in combination, a series of successive combustion chambers, each having an outlet opening at one end and an inlet opening of venturi configuration at the other end thereof, said ends with said outlet openings extending into said inlet openings of the next successive combustion chambers to the throat of said venturi configuration thereof and forming in the said chamber annular air inlets, the volume of each chamber being greater than the volume of the preceding chamber, and the openings of each chamber being of substantially smaller transverse section than an intermediate portion thereof; nozzle means located in the inlet opening of the first combustion chamber and forming an annular air inlet in the same; a grid located in said first combustion chamber and extending transverse to the same between said inlet and outlet openings and opposite said nozzle means to reduce back pressure, said grid having perforations wider on the side of said grid facing said nozzle and inlet than on the side of said grid facing the outlet of said first combustion chamber; preheating means for preheating a fuel; means for supplying the preheated fuel under pressure to said nozzle means so that fuel is introduced into said first combustion chamber at a predetermined velocity whereby ambient air is sucked through said annular inlet of the same into the same to form a combustible mixture in said first combustion chamber; and means for effecting ignition of the mixture in said first combustion chamber whereby combustion gas and fuel passes through the outlet opening of the same into the next successive combustion chamber at a predetermined velocity to suck ambient air through said inlet of the same whereby an additional amount of a combustible mixture is formed which is ignited by said combustion gas and passes through the outlet of said next successive combustion chamber into the next following successive combustion chamber until the combustion gas produced by all the introduced fuel passes through the outlet of the last combustion chamber.

5. In an apparatus for burning fuel to obtain energy therefrom, in combination, a series of enclosures each of which forms a combustion chamber in its interior, each enclosure having at one end an opening forming an inlet of venturi configuration and at its opposite end a tubular outlet of smaller cross section than an intermediate portion of said enclosure extending with substantial clearance into the inlet of the next following enclosure to the throat of said venturi configuration thereof so that at the inlet of each except the first of said enclosures there is a free space between said inlet and the tubular outlet

of the preceding enclosure, and said enclosures being of successive larger size from the first to the last enclosure; and means cooperating with the first enclosure at the inlet thereof for introducing a combustible fuel into the same and for igniting the fuel in said first enclosure, whereby the combustion products from the first enclosure flow automatically into the next enclosure sucking ambient air in through the free space at the inlet of the second enclosure to provide automatic combustion in said second enclosure and so on throughout the series of enclosures.

6. Apparatus for producing energy by combustion, comprising, in combination, first and second elongated combustion chambers in axial alignment, each having an inlet opening of venturi configuration at one end and an outlet opening at the other end thereof, said openings of each chamber being of substantially smaller transverse dimension than the largest transverse dimension of said chamber, said second chamber having a greater volume than said first chamber, and the outlet opening of said first chamber located in the inlet opening of said second chamber at the throat of said venturi configuration thereof; means located in the inlet opening of said first chamber for injecting a predetermined amount of fluid fuel under pressure into said first chamber and forming in said inlet opening of said first chamber a passage through which ambient air may be sucked into said first chamber in an amount less than that required for complete combustion of the fuel therein; and means for igniting part of the fuel in said first chamber so that combustion gas at a temperature and kinetic energy greater than the temperature and kinetic energy of the introduced fuel is produced and said combustion gas and the remainder of the fuel is ejected from the outlet opening of said first chamber into said second chamber through the inlet opening of said second chamber, said outlet opening end of said first chamber forming in the inlet opening of said second chamber a passage through which ambient air may be sucked into said second chamber in an amount sufficient for complete combustion of the remainder of the fuel in said second chamber, said remainder of the fuel being spontaneously ignited by the combustion gas from said first chamber so that additional combustion gas at a temperature and kinetic energy greater than the temperature and kinetic energy of the fuel introduced into said second chamber is produced and is ejected with the combustion gas received from said first chamber from the outlet opening of said second chamber.

7. Apparatus for producing energy by combustion, comprising, in combination, a plurality of elongated combustion chambers in axial alignment including a first and last chamber and at least one intermediate chamber, each of said chambers having an inlet opening of venturi configuration at one end and an outlet opening at the other end thereof, the openings of each chamber being of substantially smaller transverse dimension than the largest transverse dimension of said chamber, said chambers being of successively increasing volume from said first to said last chamber, the outlet openings of said first and said intermediate chamber being located in the inlet openings of their next succeeding chambers, respectively, at the throat of said venturi configuration thereof; means located in the inlet opening of said first

chamber for injecting a predetermined amount of fluid fuel under pressure into said first chamber and forming in said inlet opening of said first chamber a passage through which ambient air may be sucked into said first chamber in an amount less than that required for complete combustion of the fuel therein; and means for igniting part of the fuel in said first chamber so that combustion gas at a temperature and kinetic energy greater than the temperature and kinetic energy of the introduced fuel is produced and said combustion gas and the remainder of the fuel is ejected from the outlet opening of said first chamber into said intermediate chamber through the inlet opening of said intermediate chamber, said outlet opening end of said first chamber forming in the inlet opening of said intermediate chamber a passage through which ambient air may be sucked into said intermediate chamber in an amount less than that required for complete combustion of the remainder of the fuel therein, a part of the remainder of the fuel being spontaneously ignited by the combustion gas from said first chamber so that additional combustion gas at a temperature and kinetic energy greater than the temperature and kinetic energy of the fuel introduced into said intermediate chamber is produced and is ejected from the outlet opening of said chamber into the inlet opening of the next succeeding chamber, said last chamber receiving the accumulated combustion gas and the last remainder of the fuel from the next preceding chamber through the outlet opening of the next preceding chamber located in the inlet opening of said last chamber, said outlet opening end of said next preceding chamber forming in the inlet opening of said last chamber a passage through which ambient air may be sucked into said last chamber in an amount sufficient for complete combustion of the last remainder of the fuel in said last chamber, said last remainder of the fuel being spontaneously ignited by the combustion gas from said next preceding chamber so that additional combustion gas at a temperature and kinetic energy greater than the temperature and kinetic energy of the fuel received in said last chamber is produced and is ejected with the combustion gas received from said next preceding chamber from the outlet opening of said last chamber.

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