Sept. 20, 1966 J. D. NESBITT 3,273,623

SELF-STABILIZING COMBUSTION APPARATUS

Original Filed April 11, 1961 4 Sheets-Sheet 1

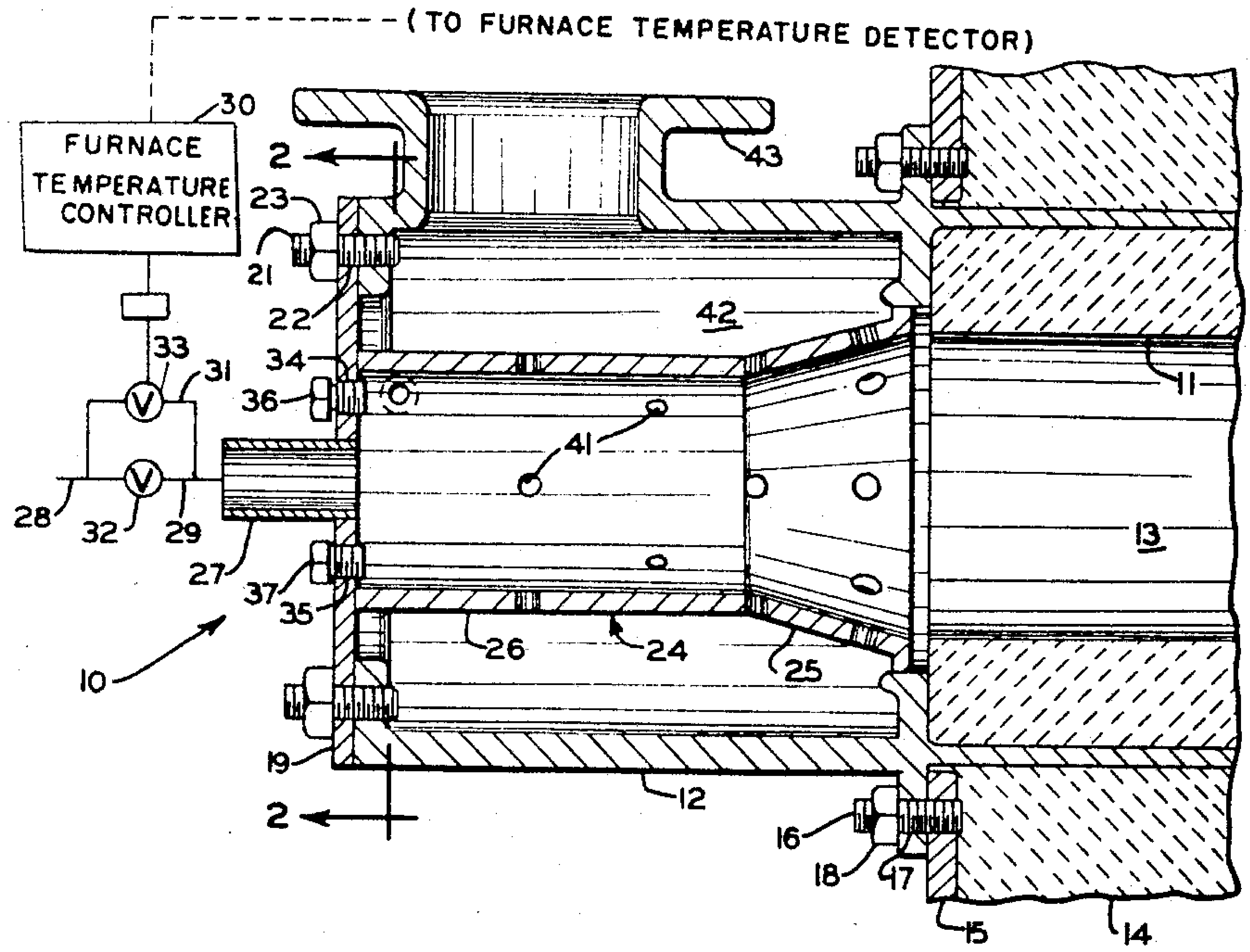

Fig. 1.

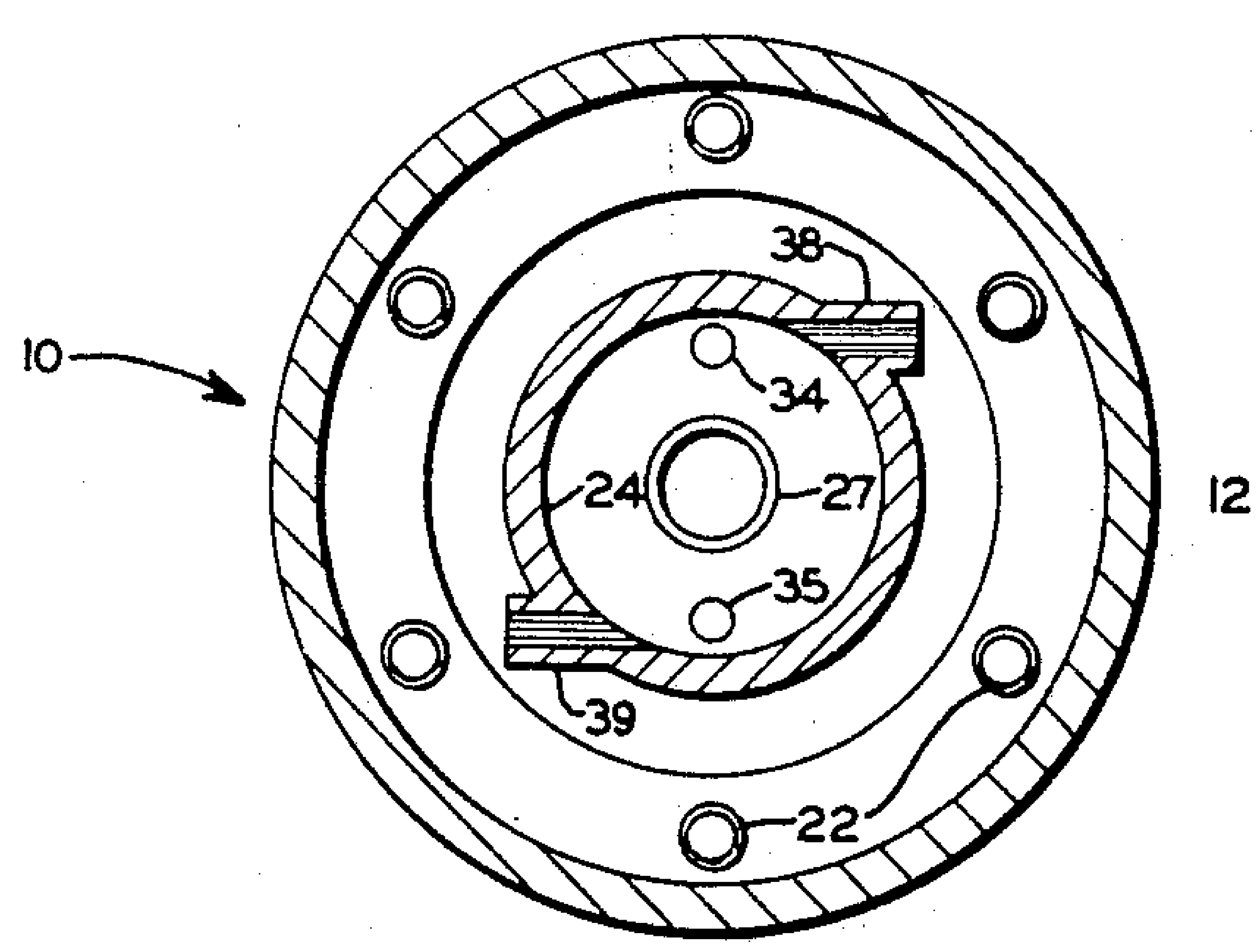

Fig. 2.

INVENTOR.
JOHN D. NESBITT
BY
Alfred L. Patmore, Jr.
ATTORNEY

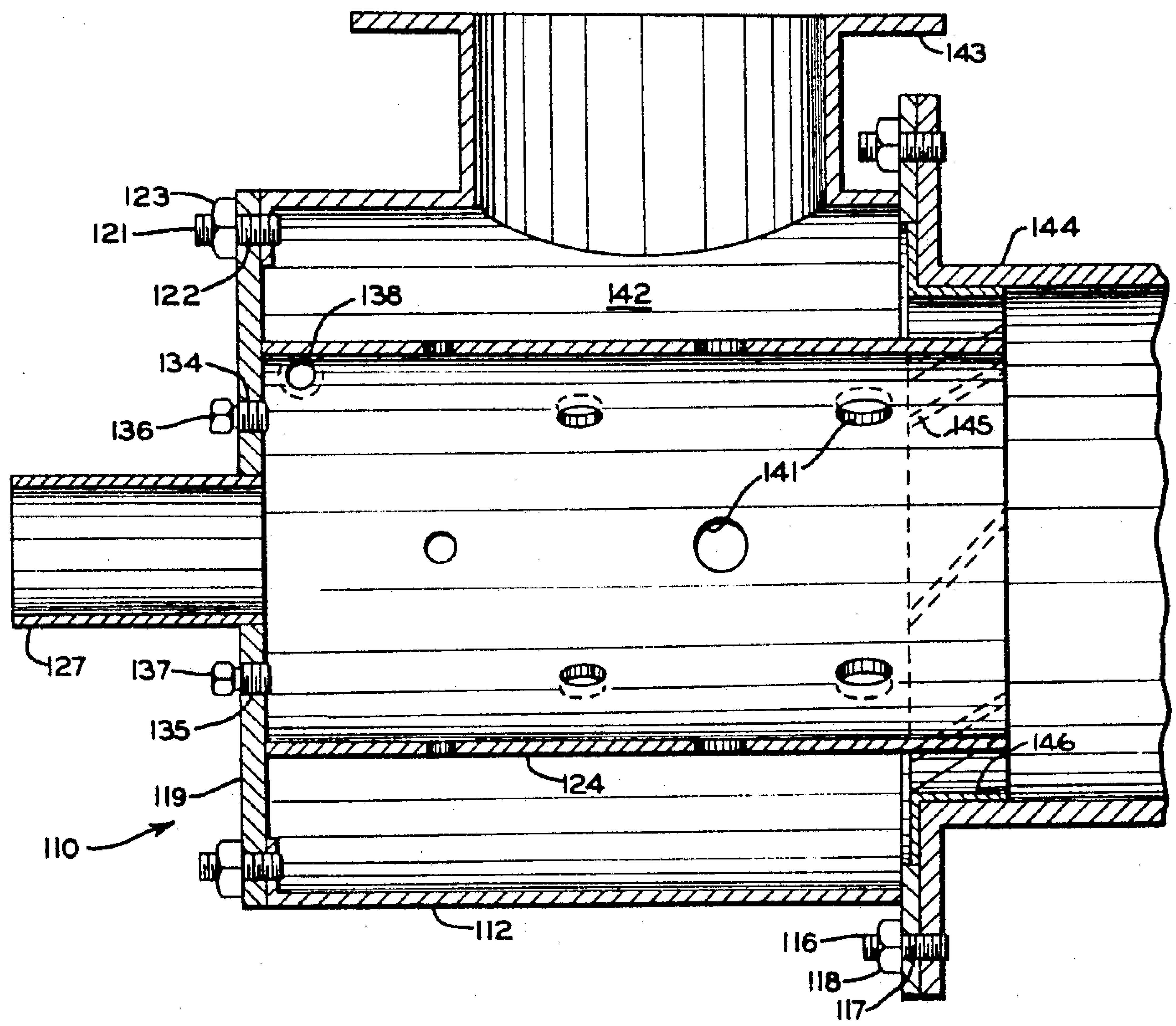

Fig. 3.

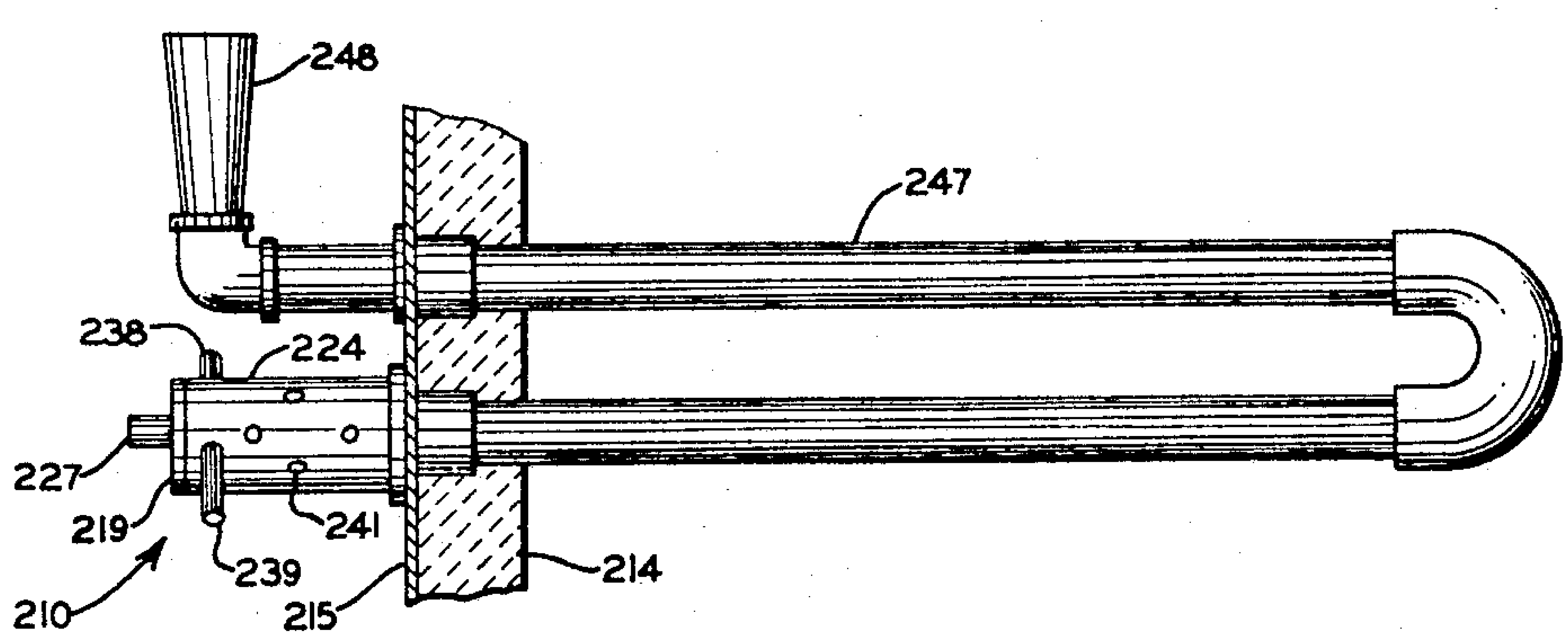

Fig. 4.

INVENTOR.
JOHN D. NESBITT

BY

Alfred L. Patmore, Jr.

ATTORNEY

SELF-STABILIZING COMBUSTION APPARATUS

Original Filed April 11, 1961 4 Sheets-Sheet 3

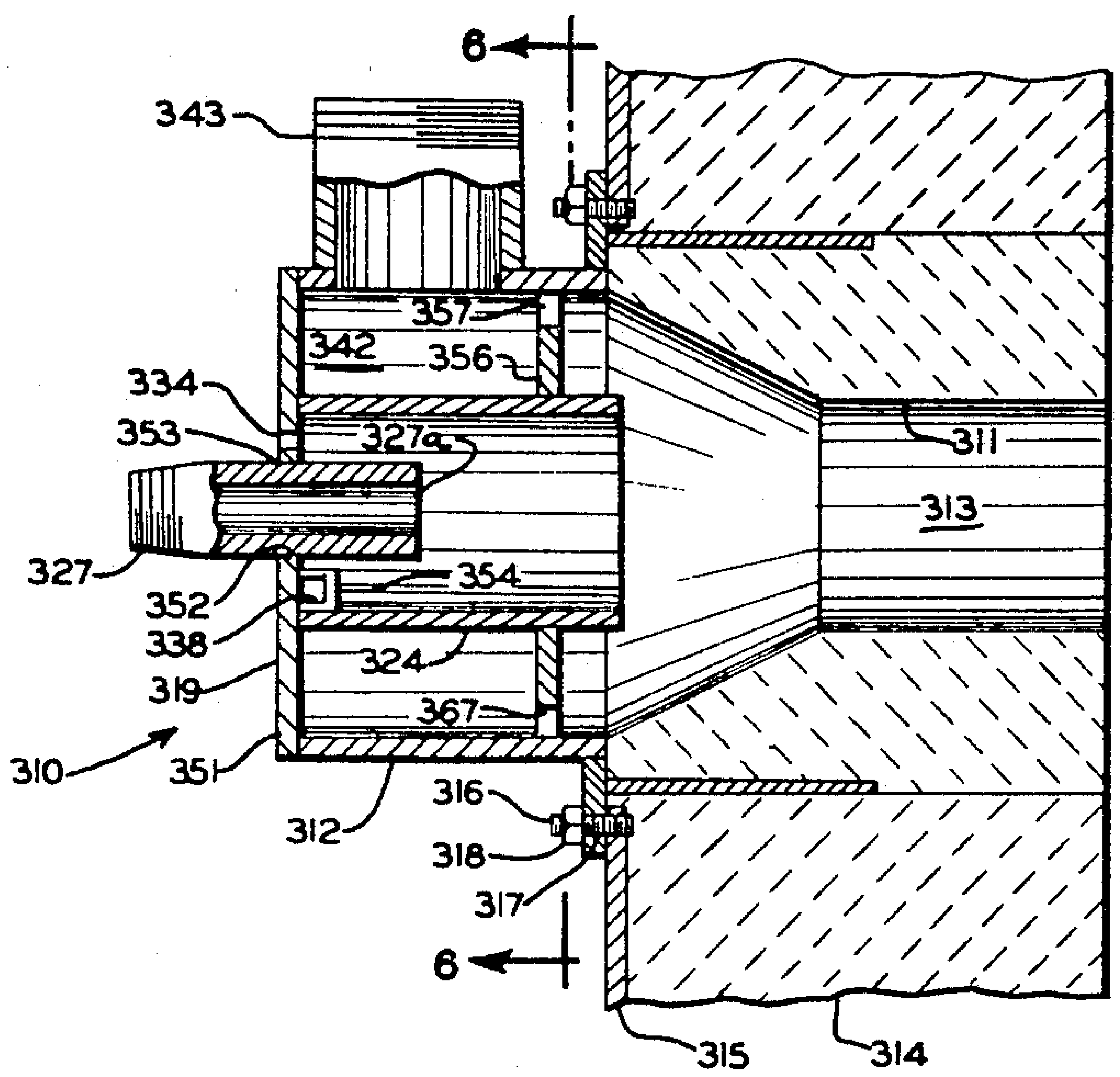

Fig. 5.

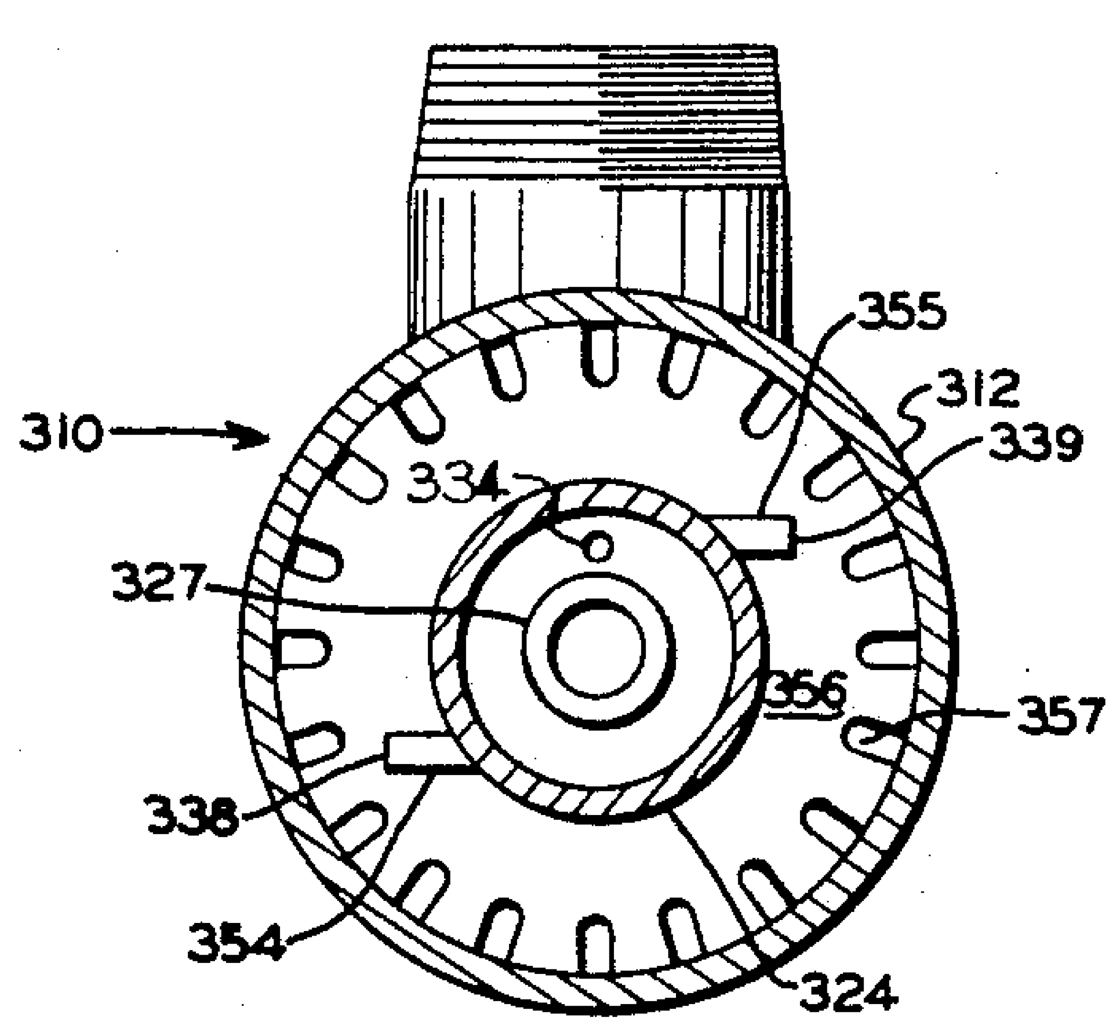

Fig. 6.

INVENTOR.
JOHN D. NESBITT
BY
Alfred L. Patmore, Jr.
ATTORNEY

SELF-STABILIZING COMBUSTION APPARATUS

Original Filed April 11, 1961 4 Sheets-Sheet 4

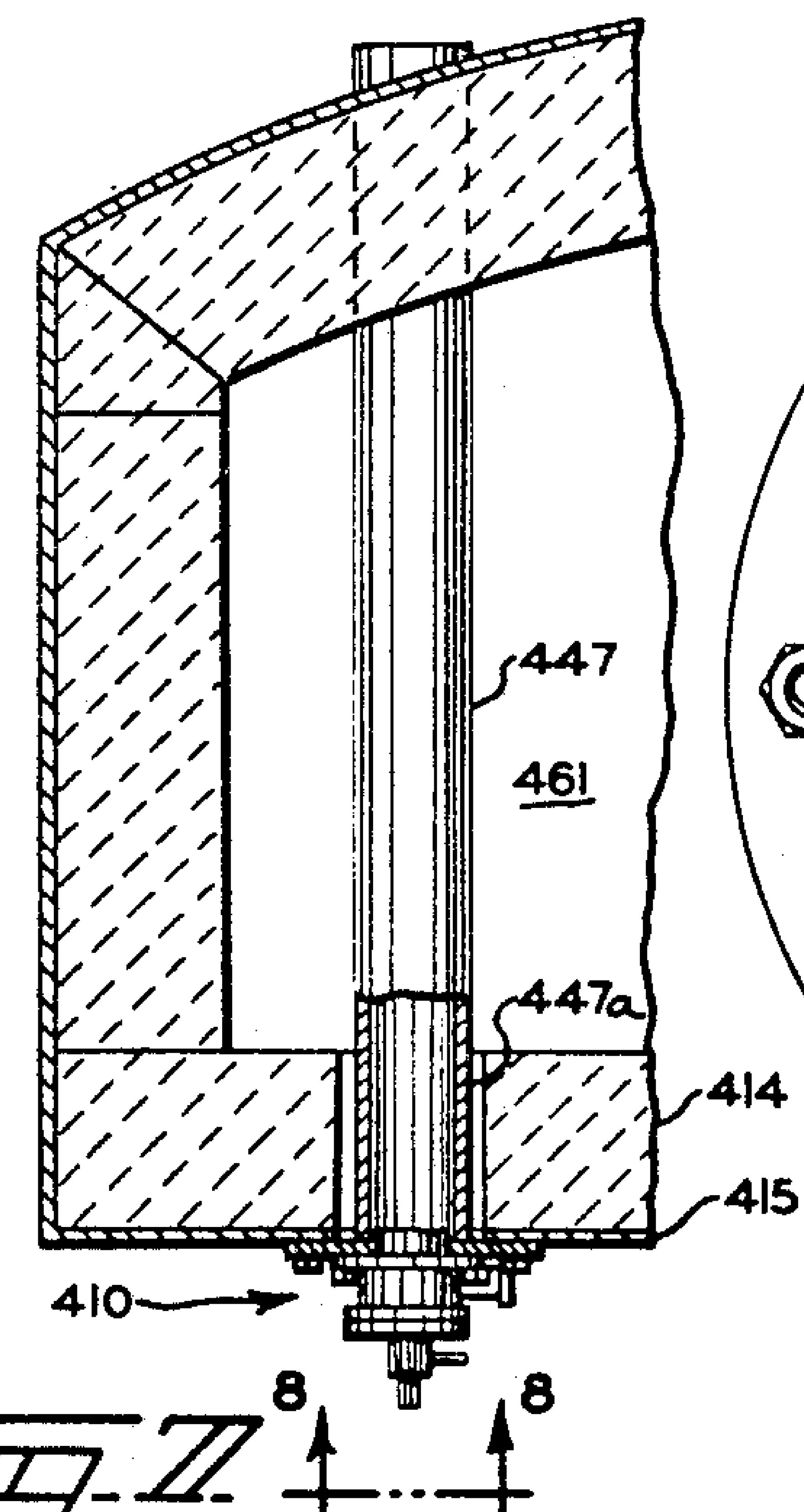

FIG. 7.

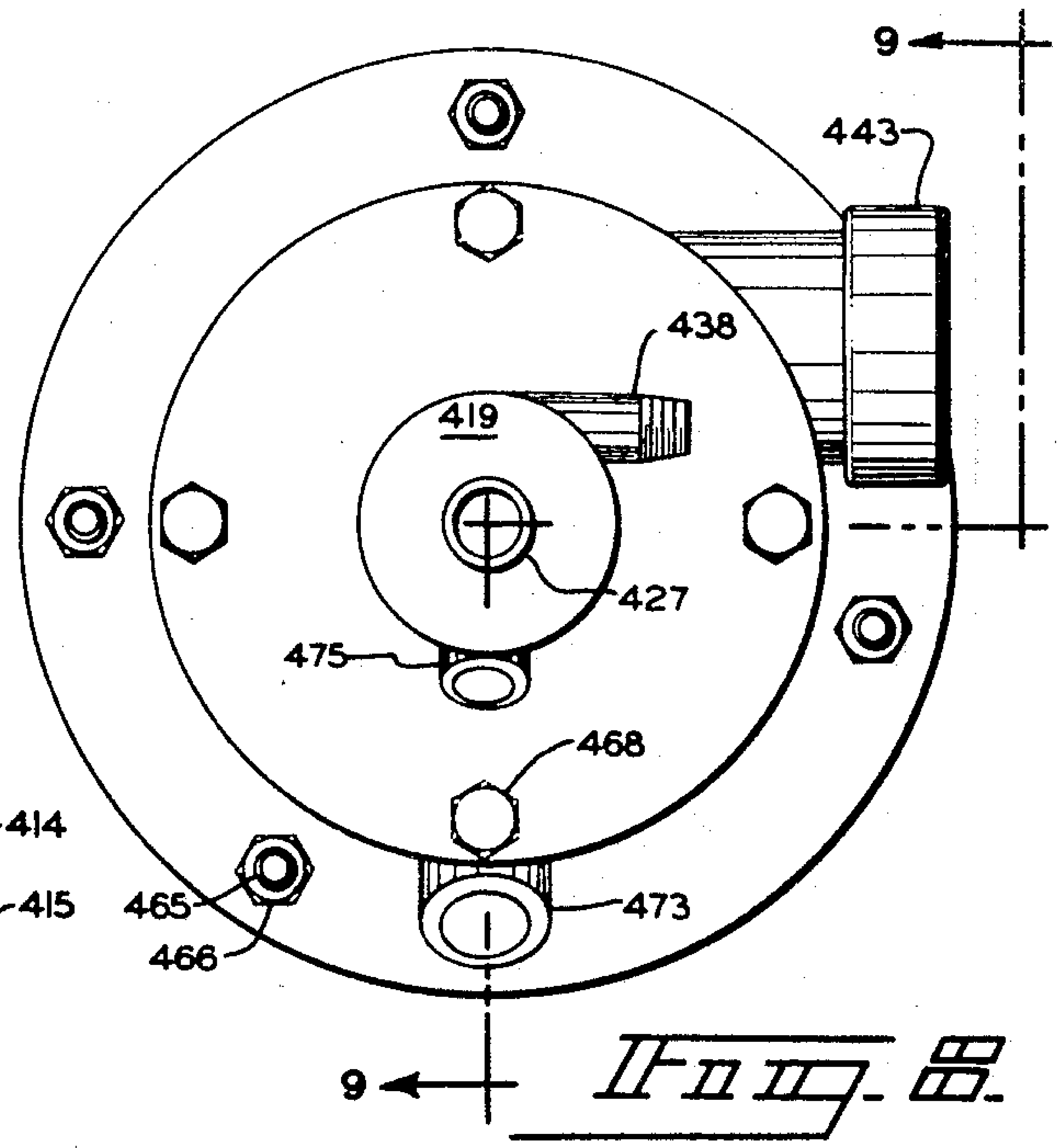

FIG. 8.

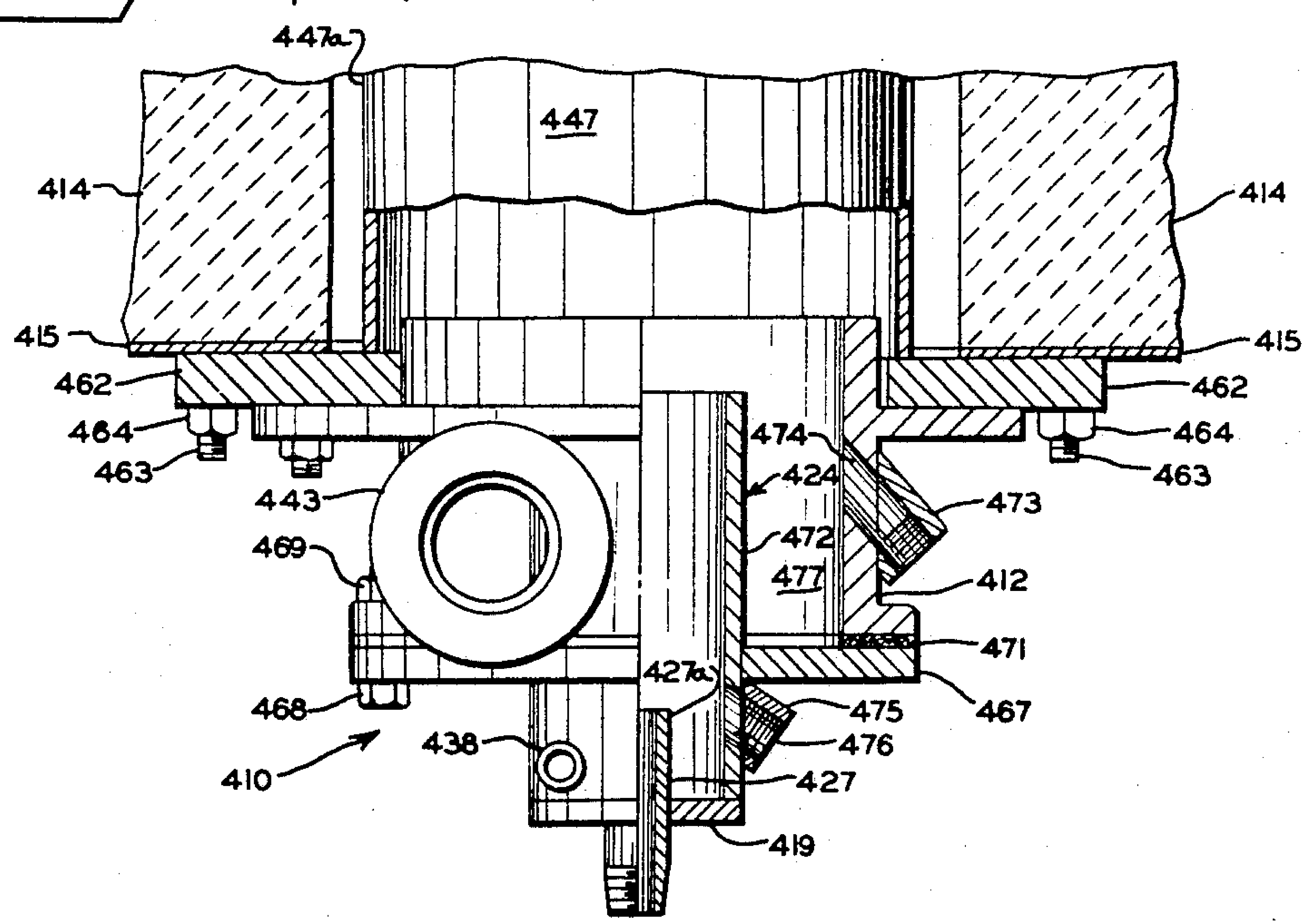

FIG. 9.

INVENTOR.
JOHN D. NESBITT
BY
Alfred L. Patmore, Jr.
ATTORNEY

3,273,623
Patented Sept. 20, 1966

3,273,623

SELF-STABILIZING COMBUSTION APPARATUS

John D. Nesbitt, Toledo, Ohio, assignor to Midland-Ross Corporation, Toledo, Ohio, a corporation of Ohio

Application June 7, 1965, Ser. No. 473,267, now Patent No. 3,244,219, dated Apr. 5, 1966, which is a division of application Ser. No. 102,316, Apr. 11, 1961. Divided and this application Nov. 3, 1965, Ser. No. 516,818
2 Claims. (Cl. 158—7)

This is a division of application Serial No. 473,267, filed June 7, 1965, now Patent No. 3,244,219 issued April 5, 1966, which in turn is a division of application Serial No. 102,316, filed April 11, 1961 now Patent No. 3,187,799 issued June 8, 1965, which in turn is a continuation in part of application Serial No. 808,161 filed April 22, 1959, now abandoned.

This invention relates to a system for stabilizing the combustible reaction of streams of fuel and air in various types of combustion apparatus. More particularly, the invention relates to apparatus for making various types of combustion equipment self-stabilizing.

The stabilization of the combustible reactions promoted by various types of industrial combustion apparatus is frequently accomplished by means of a separate combustion system, normally of the pre-mix type, used as a piloting system. The use of a separate piloting system to provide flame stability for a principal combustion system has a number of undesirable features among which are the complication of the structure of the burners of the principal combustion system to make them suitable to receive a pilot burner, complication of the piping required to pipe the overall system, and, in the case of a pre-mix piloting system, certain well recognized safety hazards.

It is, therefore an object of my invention to overcome the dependency of prior art combustion systems on separate piloting systems for proper flame stability. It is a further object of this invention to accomplish the aforesaid object by providing self-stabilizing combustion apparatus.

For further consideration of what I believe to be novel and my invention, attention is directed to the preferred form of my invention as disclosed in the following portion of the specification, the appended claims, and the accompanying drawing.

FIG. 1 illustrates an elevational view, in section, of a burner embodying the present invention.

FIG. 2 illustrates a view taken on line 2—2 of FIG. 1.

FIG. 3 illustrates an elevational view, in section of a burner embodying the present invention, the burner being specifically adapted to fire into an immersion heating tube.

FIG. 4 illustrates an elevational view of a radiant heating tube of the hairpin type having a burner embodying the present invention.

FIG. 5 illustrates an elevational view, in section, of an alternative burner construction embodying the present invention.

FIG. 6 illustrates a view taken on line 6—6 of FIG. 5.

FIG. 7 illustrates an elevational view, partially in section, of a single pass radiant tube having a burner of alternative construction embody the present invention.

FIG. 8 illustrates a view of the burner of FIG. 7 taken on line 8—8.

FIG. 9 illustrates a view taken on line 9—9 of FIG. 8.

Referring in more detail to the drawing and in particular to FIGS. 1 and 2 a burner **10** is shown thereat installed in a furnace wall. A typical application for this burner is in a low temperature tempering furnace. Burner **10** comprises a tunnel block **11** attached to burner

body **12**. Tunnel block **11** is a refractory composition and square configuration with a cylindrical tunnel chamber **13** extending longitudinally therethrough. The burner body **12** which is generally made of cast steel, is adapted to be installed in a refractory lined furnace wall **14**. Burner body **12** is attached to metallic casing **15** of furnace wall **14** by means of studs **16** affixed to casing **15** and extending through holes **17** in burner body **12**. Nuts **18** threaded on studs **16** securely hold the burner body to the casing, and the studs are so positioned that the body is properly aligned with respect to cylindrical tunnel chamber **13**.

Burner body **12** has backplate **19** attached thereto by means of studs **21** affixed to body **12** and extending through holes **22** in plate **19**. Nuts **23** threaded on studs **21** securely hold the backplate to the burner body.

Disposed within the burner body **12** is wall means forming a substantially cylindrical combustion chamber **24**, axially aligned with tunnel chamber **13** and welded to backplate **19**. Combustion chamber **24** has an outwardly expanding or tapered section **25** at its exit end for approximately ⅓ of the total chamber length. The tapered section expands from the cylindrical portion **26** of chamber **24** to approximately the internal diameter of tunnel chamber **13**. The tapered section is used merely to provide smooth expansion of the gases from cylindrical portion **26** to the tunnel chamber. In a larger capacity burner, the same burner body **12** can be used with a larger cylindrical combustion chamber equal in diameter to the tunnel chamber diameter and having no tapered portion. For example, the combustion chamber **124** of the burner in FIG. 3 is shown as a straight cylindrical casting.

A fuel pipe **27** is welded to backplate **19** flush with the inside face thereof and in substantially axial alignment with combustion chamber **24** and tunnel chamber **13**. Pipe **27** is supplied fuel from a source, not shown, through lines **28**, **29** and **31** the latter two lines containing valves **32** and **33** respectively. Backplate **19** is also provided with two tapped holes **34** and **35** into which pipe plugs **36** and **37** are inserted. Holes **34** and **35** are located equidistant from the axis of an within the combustion chamber when the latter is welded to the backplate. The burner can be ignited through one of the holes **34** and **35** by an electric or fuel torch. As will be explained later, the combustion chamber will normally be under positive pressure, and unless the burner is ignited at throttled air flow, it may be difficult to ignite because of outflow through the hole. For gaseous fuel operation, the preferred form of ignition will normally be an electric spark inserted into one of the holes **34** and **35** in place of pipe plug **36** or **37**.

A commercially available flame rod safety device may be placed in the other of the holes **34** and **35** in place of pipe plug **36** or **37** to shut off a valve in line **28** should the flame in combustion chamber **24** become extinguished.

Air inlet pipes **38** and **39**, FIG. 2, are welded tangent to the internal diameter of combustion chamber **24** adjacent backplate **19**. Pipes **38** and **39** are directed perpendicularly to the axis of chamber **24** and are normally spaced from the backplate **19** a short distance such as ⅜" to ½" and, as shown in FIG. 2, they are spaced 180° apart and attached to the combustion chamber in a manner to introduce the air in the same direction, in this case counterclockwise. Inlet pipes **38** and **39** are shown entering combustion chamber **24** adjacent holes **34** and **35** in backplate **19**. They are shown in this manner for convenience and could be located spaced 90° from their present location, or under some circumstances it may be desirable to supply four inlet pipes 90° apart. Inlet pipes **38** and **39** must be long enough in relation to their internal diameter to provide a straight air flow path. A length to inside diameter ratio of at least 2 to 1 has proven satisfactory. By virtue of the perpendicular disposition of inlet pipes **38** and **39** with respect to the axis of chamber **24** the air admitted therethrough will have substantially no component of motion parallel to the axis of chamber **24**.

Additional air is admitted to combustion chamber **24** by a plurality of apertures **41** in the chamber wall means downstream of the tangential air inlet pipes **38** and **39**. The size and location of apertures **41** are such as to maintain combustion of the fuel stream in combustion chamber **24** at a maximum rate without flame quenching. A convenient pattern for spacing apertures **41** to obtain radial entry of air is in a plurality of axially spaced circumferential stages. The burner of FIG. 1 shows four of these stages downstream of the tangential air inlet pipes **38** and **39**. The first three stages are in cylindrical portion **26** of the combustion chamber, and each stage contains four apertures circumferentially spaced 90° apart. The fourth stage is located in outwardly tapered section **25**, and it contains eight apertures circumferentially spaced 45° apart.

Air entering each aperture **41** will produce a back eddy current which will promote stable burning with maximum mixing. As previously stated, the size and spacing of apertures **41** is such as to maintain combustion at the maximum possible rate without flame quenching. Flame quenching is indicated by the presence of intermediate combustion products. The presence of intermediate combustion products can be qualitatively detected, even in extremely minute quantities, by the characteristic pungent odor of the aldehydes formed. Once flame quenching is known to exist by the detection of aldehyde odors, the extent of the flame quenching can be evaluated quantitatively by measurement of carbon monoxide content in the combustion gases. In this manner, the optimum aperture arrangement can be accurately determined for burners of different capacity.

The space between burner body **12** and combustion chamber **24** defines an annular air chamber **42**. Air is supplied to this chamber by a blower and piping, not shown, to flange portion **43** of burner body **13**. Air is then properly distributed between tangential air inlet pipes **38** and **39** and radial apertures **41** by their relative areas.

In excess air operation of the burner, a small percentage of the total air supplied to air chamber **42** is introduced to combustion chamber **24** through tangential air inlet pipes **38** and **39** to form a spinning air stream circumposing an axially flowing fuel stream emitted to the chamber through fuel pipe **27**. The combustible mixture of fuel and air formed at the interface of the spinning air stream and the axially flowing fuel stream is ignited through one of the apertures **34** and **35** in backplate **19** to establish a spinning, slow mixing, stable flame adjacent the gas nozzle. This spinning flame, in effect, establishes an extremely stable pilot for the balance of the fuel and air.

The preferred amount of air emitted through the tangential air inlet pipes is approximately 5–7.5%, with 4–10% of the total air being acceptable. If too little of the total air is admitted to the tangential air inlet pipes, for example, less than 4%, the air will pull out in a parabola along the gas stream to produce an unstable flame which will finally quench as the spin air is further decreased. When too much of the total air is admitted tangentially, over approximately 10%, a back eddy or vortex is created which causes carbon to build up on the backplate which results in the flame rod and ignition means inserted through holes **34** and **35** in the backplate becoming inoperative, and the general maintenance of the burner is greatly increased.

The preferred air pressure drop is 1.5 to 3.5″ W.C. with operation at approximately 2″ W.C. being standard. Increasing the pressure beyond 3.5″ W.C. results in flame quenching and the consequent production of aldehydes.

Fuel is supplied to fuel pipe **27** at 0 to 1″ W.C. pressure. Under normal excess air operation the air flow is maintained constant, and the fuel is cut back as heat demand decreases. Because of the extremely wide range of excess air that may be used, any of the common control systems may be used. With the valve arrangement of FIG. 1, a simple high-low control system can be used. When the burner is firing at full capacity, both valves **32** and **33** will be open to supply fuel from line **28** through lines **29** and **31**. When heat demand decreases, a simple temperature controller, not shown, can be used to close valve **33**, and only a small percentage of maximum fuel flow, for example, 3 to 5% will be supplied from line **28** through line **29** and open valve **32**. A proportional or modulating control system can also be used wherein one of the valves **32** and **33** would be a motor driven valve throttled by a temperature controller an amount which is proportional to the deviation between set point or desired furnace temperature and actual furnace temperature.

Excess air burners of this type can be commonly built with capacities ranging from 300,000 to 3,000,000 B.t.u./hr. with a corresponding turndown ratio (maxium to minimum fuel flow) of from 30/1 to 100/1. The prior patent art indicates that the heating capacity of luminous or long flame burners ranges up to approximately a maximum of 70,000 B.t.u. per hour per cubic foot of combustion space; whereas, the burner of the present invention has a heating capacity of 1,000,000 B.t.u. per hour per cubic foot of combustion space.

Burner **110**, shown in FIG. 3, is a modification of burner **10** and is particularly designed for heating immersion tubes. The similarity of elements of the embodiments of FIGS. 3 through 9 to the embodiment of FIGS. 1 and 2 is indicated by identifying them with a three digit numeral whose last two digits are the same as the two digits of the numeral used to identify the corresponding element of the embodiment of FIGS. 1 and 2.

In heating sealed immersion tubes, it is desirable to compromise between the rapid mixing, high capacity burner **10** of FIG. 1 and the prior art long flame burner. If burner **10** were used without modification for this application, a hot spot would result adjacent the point where the burner is joined to the tube because combustion is rapid and is completed close to the exit of the combustion chamber even when firing at maximum capacity. It is desirable to complete combustion uniformly along the length of the tube so that the tube becomes uniformly heated.

Burner **110** of FIG. 3 is shown attached to immersion tube **144** in the same manner as burner **10** is attached to metallic furnace casing **15**. The basic difference between the two burners is that the air supplied to combustion chamber **24** through radial apertures **41** in burner **10** is supplied in the burner **110** of FIG. 3 in part to the combustion chamber **124** through apertures **141** and in part directly to immersion tube **144** through spin vanes **145** circumposing the combustion chamber adjacent its outlet end.

Spin vanes **145** are attached to flange member **146** over which immersion tube **144** is slipped for mounting to burner body **112**. Spin vanes **145** thus occupy the annular space between flange member **146** and combustion chamber **124**. Vanes **145** are attached to flange member **146** at some angle, shown nominally as 45°, to the axis of flange member **146** and combustion chamber **124** to cause the air to spin a desired amount. The spacing between vanes is designed to proportion the ratio of aperture **141** area to the effective annular area of the spin vane assembly to thus proportion the ratio of air admitted radially to the combustion chamber and the amount admitted to immersion tube **144** through spin vanes **145**.

Spin vanes **145** impart a spiral motion to the air passing through them into immersion tube **144** so that this air spins around the axially flowing fuel and products of combustion stream issuing from combustion chamber **124**, and the spinning air also travels axially down tube **144**. The spiralling air tends to produce a slow mixing long flame which travels the length of the immersion tube. The spiraling air eliminates hot spots and produces a uniform temperature distribution over the length of the immersion tube by the combined effect of lengthening the flame and providing a spiralling layer of air adjacent the inside wall of the tube through which the heat must pass. The amount of air which passes through the spin vanes is normally regulated at 70–75% of the total air.

FIG. 4 shows another modification of the burner adapted to fire into a commonly used hair-pin type radiant tube **247**. Burner **210** is the same as burner **110** of FIG. 3 having a spin vane assembly, except that a burner body **112** or air housing is not placed around the combination chamber **224**. Air is supplied to one of the tangential air inlet pipes **239** under pressure to provide a spinning, slow mixing, stable flame at the point of entry of the fuel through pipe **227** to combustion chamber **224**. An eductor **248** is coupled to the exhaust end of radiant tube **247** to produce a draft or suction through the tube to cause air at atmospheric pressure to flow into combustion chamber **224** through radial apertures **241** and through the spin vanes into tube **247**. The draft also pulls in the fuel through pipe **227** which is in substantially axial alignment to combustion chamber **224**. Additional air is drawn into tangentially air inlet **238** as the firing rate is increased by increasing the draft produced by eductor **248**; this air adds to the spinning air admitted under pressure to air inlet **239**. Burner **210** products a long flame in radiant tube **247**, and it operates in essentially the same manner as burenr **110** except that the air is drawn into the burner by an eductor at the exhaust end of the tube instead of being supplied under pressure to the burner.

The burner **310** illustrated in FIGS. 5 and 6 may be contracted to burner **10** of FIGS. 1 and 2 by the fact that it is essentially a long-flame burner. Such a burner, which may be operated on either the excess air principle or as a proportioning burner, or on some combination of the two, is well suited for heating relatively high temperature furnace chambers (say over 1200° F.) where there is little danger of quenching a long flame. The burner **310** comprises tunnel block **311** attached to burner body **312** which is shown constructed of a weldment but which may also be constructed, at least partially, of castings in the same manner as the burner of FIGS. 1 and 2. Burner body **312** is attached to metallic casing **315** of furnace wall **314** by means of studs **316** affixed to casing **315** and extending through holes **317** in burner body **312**. Nuts **318** threaded on studs **316** securely hold the burner body to the casing, and the studs are so positioned that the body is properly aligned with respect to cylindrical tunnel chamber **313**.

Burner body **312** has backplate **319** attached thereto by means of continuous weld **351**. Disposed within burner body **312** are wall means forming a substantially cylindrical combustion chamber **324** axially aligned with tunnel chamber **313** and welded to backplate **319**. A fuel inlet pipe **327** is inserted through an aperture **352** in backplate **319** and is affixed in place by continuous weld **353** in such a manner that the outlet end **327***a* of fuel inlet **327** is for reasons which are to be indicated later, located at a distance somewhat downstream, with respect to the direction of fuel flow from backplate **319**. Pipe **327** is in substantially axial alignment with combustion chamber **324**.

A portion of the combustion air, preferably from 4–10% of the amount required for stoichiometric combustion of the fuel stream added through inlet **327**, is admitted tangentially to combustion chamber **324** from annular air chamber **342**, defined by burner body **312** and combustion chamber **324**, by means of air inlet conduits **338** and **339**. Conduits **338** and **339** are defined on three sides by channel-shaped members **354** and **355**, which are adapted to be inserted in milled slots (not shown) in the end of combustion chamber **324** and on the fourth side by a portion of backplate **319**. Air inlet conduit **338** and **339** must be located very closely adjacent backplate **319**, a feature which will inhere in the illustrated mode of construction, and the axis thereof must be perpendicular to the axis of combustion chamber **324**.

Burner **310** differs primarily from burner **10** in that only a very small portion of the required combustion air is added to combustion chamber **324** whereas all of the required combustion air is added to combustion chamber **24** of FIG. 1. Thus burner **310** of FIGS. 5 and 6 incorporates the spin stabilizing feature of burner **10** of FIGS. 1 and 2 but it does not utilized the radial addition of the main or secondary air stream. In burner **310** of the main air stream is combined with the unburned fuel stream passing from combustion chamber **324** in a region downstream thereof, i.e., in tunnel **313**. This is accomplished by mounting body **312** to furnace casing **315** in such a fashion that annular chamber **342** is in fluid communication with tunnel block **313**. Thus, air will pass from chamber **342** into tunnel block **313** circumposing the fuel flowing from combustion chamber **324**. To provide for rapid mixing (and hence rapid combustion) in tunnel block **313** of the air stream from chamber **342** and the fuelstream from tube **327** an orifice plate **356** is inserted in the annular space defined by the inside diameter of burner body **312** and the outside diameter of combustion chamber **324**. The high degree turbulence imparted to the air stream by virtue of sudden re-expansion occurring downstream of orifice plate **356** greatly increases the rate of intermixing of the fuel and air stream in tunnel **313** over the rate of intermixing which would occur through natural turbulence.

Although it would be possible to construct orifice plate **356** as a simple annular plate attached either to the inner surface of burner body **312** or, preferably, to the outer surface of combustion chamber **324** (i.e., with an inner diameter slightly greater than the outer diameter of chamber **324** and an outer diameter substantially less than the inner diameter of burner body **312**) it is preferred to use a more complex construction for reasons to be explained later. The more complex construction comprises an annular plate which would substantially block the annular space between burned body **312** and combustion tube but for a plurality of radial slots **357** formed around the outer periphery thereof. Such a construction, as has been found by experimentation, reduces to a minimum the suction imposed on the outlet end of chamber **324** by the turbulent motion of the air stream downstream thereof. An excessive suction in this region will undesirably tend to draw the flame front from its stabilized position within combustion chamber **324**.

The fact that there are conditions downstream of combustion chamber **324** which may create a slight suction or negative pressure therein, whereas combustion chamber **24** of burner **10** of FIGS. 1 and 2 normally operates at positive pressure by virtue of the staged radial admission of secondary air through ports **41**, leads to another important structural distinction between burner **10** and burner **310**. In burner **10** the end of fuel pipe **27** terminates flush with the inner surface of backplate **19** whereas the fuel inlet pipe **327** of burner **310** terminates at a point somewhat downstream, with respect to the direction of fuel flow, from backplate **319**. The extended fuel inlet construction of burner **310** functions in the following manner to overcome the tendency of flame front to drift away from the backplate under the influence of downstream suction conditions; the stream of rapidly spinning air, which is added to combustion chamber **324** through tangential air inlet conduits **338** and **339**, forms a vortex with a concomitant vortex suction effect immediately downstream of the outlet end 327a of fuel inlet pipe 327; the vortex suction in the region of outlet end 327a tends to divert an outer annular layer of the fuel stream passing therefrom and causes the diverted portion to flow, in reverse in an annular layer immediately outside of the extended portion of inlet 327, toward backplate 319; the diverted portion of the fuel stream mixes with the spinning air stream to form a spinning combustible mixture adjacent backplate 319; the spinning combustible mixture can be readily ignited by holding a torch or match to small port 334 because of the fact that flame will pass therethrough since combustion chamber 324 is under suction; the spinning combustable mixture, when once ignited, will continue to burn forming a spinning highly stable flame front which will serve to stabilize the main combustible reaction between the uncombusted fuel stream passing from combustion chamber 324 and the main air stream passing through slotted orifice plate 356. Thus, burner 310 of FIGS. 5 and 6, like burner 10 of FIGS. 1 and 2 and burners 110 and 210 of FIGS. 3 and 4 is self-stabilizing.

FIGS. 7–9 illustrate a radiant tube burner 410 embodying the self-stabilizing feature of burners 10, 110, 210 and 310. Radiant tube burner 410 differs from the radiant tube burner 210 in function, by virtue of the fact that it is specifically suited to fire a single-pass radiant tube whereas burner 210 is primarily suited to fire a radiant tube with a plurality of passes such as the illustrated "hairpin" tube. Radiant tube burner 410 differs further from burner 210 in hat it, like the immersion tube burner 110, is specifically adapted to be fired under pressure.

The combustion of a fuel stream within a narrow elongate radiant heating tube may be achieved either according to the principle of pre-mix combustion or according to the principle of diffusion combustion or according to some combination of the principles of pre-mix combustion and diffusion combustion. Pre-mix combustion, by definition, is the combustion of a stream of homogeneously mixed fuel and air, normally mixed in approximately stoichiometric proportions. Diffusion combustion, on the other hand, is the combustion of the combustible mixture of fuel and air which occurs by diffusion at the interface of contiguously flowing streams of fuel and air. Pre-mix combustion is normally characterized by a flame which is relatively short and highly stable whereas diffusion combustion is characterized by a flame which is quite long and relatively unstable. Some prior artisans have found it expenditious to offset these relative merits and demerits of pre-mix and diffusion combustion by combining these combustion principles into a combustion technique known as partial pre-mix partial diffusion. An example of this technique is described in U.S. Patent 2,873,798 to Knight which discloses a radiant tube burner of the diffusion type piloted by a cluster of pre-mix pilot burners.

Simple diffusion combustion has long been widely recognized as an ideal combustion technique for multiple-pass radiant tube elements which are commonly constructed in the shape of a U or a W. In such radiant tubes there is normally available a relatively large combustion volume when compared to the combustion volume available in single-pass radiant tubes, the additional volume being obtained in the additional passes of the multiple pass tube which greatly increase the length to diameter (L/D) ratio of the tube. Because of the greater L/D ratio of a multiple-pass radiant tube, the extremely long flame characteristic of a diffusion burner is not only tolerable but is even desirable in that it promotes more uniform heat release from all portions of the radiant tube surface. Consequently, pre-mix combustion is commonly employed only to a limited extent in prior art multiple pass radiant tube firing systems and usually only as an expedient to overcome the poor flame stability characteristic of prior art diffusion burners.

Certain industrial furnace designs are, however, because of space limitations or other factors, not readily suited to being heated by a bank of multiple pass radiant tubes. Such furnaces can be conveniently heated only by a plurality of single-pass radiant tubes. Examples of such a furnace are described in U.S. Patent 2,822,798 and 2,849,220. The single pass radiant tubes used to heat such furnaces are characterized by a relatively small length to diameter ratio when contrasted with the length to diameter ratios of multiple pass radiant tubes. Because of the small length to diameter ratio of single pass radiant tubes, it has heretofore not been practicable to fire such radiant tubes with conventional diffusion burners due to the excessive flame length characteristic of prior art diffusion burners. Accordingly it has been the practice of prior artisans to fire such single pass radiant tubes with partial diffusion, partial pre-mix burners using a much higher degree of pre-mix combustion than was needed for mere stabilization of the diffusion combustion flame.

The use of pre-mix combustion in any radiant tube firing system creates numerous problems many of which become especially severe in single pass radiant tube firing systems which, heretofore, have required a very high degree of pre-mix combustion to obtain proper flame length control. First, the use of any degree of pre-mix combustion greatly complicates the construction of the burner and its piping system, factors which add considerably to the cost of the firing system. Secondly, the use of pre-mix combustion, with its concomitant rapid rate of heat release, tends to overheat the entrance portion of the radiant tube immediately downstream of the burner. This problem can be quite severe by virtue of the fact that this portion of the radiant tube is normally surrounded by the thick refractory material with which the furnace is lined, such refractory tending to retard heat transfer from the shielded portion of the radiant tube.

Burner 410 of FIGS. 7–9 is shown attached to single-pass radiant heating tube 447 which passes through, and is adapted to deliver heat to, furnace chamber 461 which is defined by wall means 414 of refractory construction backed up by metallic casing plate 415. Radiant tube 447 is disposed vertically in chamber 461 and is supported on annular retaining plate 462 which is attached to casing plate 415 by means of studs 463 and nuts 464. Burner 410 is mounted in coaxial fluid communication with radiant tube 447 by attaching it to annular retaining plate 462, as by means of studs 465 and nuts 466. Burner 410 comprises burner body 412 and a backplate 467 affixed thereto by means of bolts 468 and nuts 469 with a gasket 471 inserted between burner body 412 and backplate 467 to seal the joint therebetween. Extending through a hole in backplate 467 is a combustion chamber 424 formed by cylindrical wall 472 and backplate 419, it being noted that combustion chamber 424 ought to be substantially coaxial with burner body 412. Extending through a hole in backplate 419 and terminating at a point somewhat downstream (with respect to the direction of fuel flow therethrough) is a fuel inlet pipe 427 which is in substantially axial alignment with combustion chamber 424.

A stream of air comprising 4–10% of the amount of air required for stoichiometric combustion of the stream of fuel flowing through fuel inlet pipe 427 is added tangentially to combustion chamber 424 by means of air inlet pipe 438. Air inlet pipe 438 is located upstream of the outlet end 427a of fuel inlet tube 427 and is disposed with its axis prependicular to the axis of combustion chamber 424 so that the stream of air which passes into combustion chamber 424 has substantially no component of motion parallel to the axis of combustion chamber 424. A spinning stable ring of flame can be obtained adjacent backplate 419 of burner 410 in the same manner that a stable ring of flame is obtained adjacent backplate 319 of burner **310** except that, in the case of burner **410**, the flame front can sometimes be caused to shift from a region adjacent backplate **419** to a region adjacent the outlet end of combustion tube **424** due to suction on combustion tube caused by tangential admission of main air to burner body **412**. The shifting of the flame front in this fashion has not been found to be particularly undesirable and the flame front will normally recede to a region adjacent the backplate when the suction on combustion tube **424** is reduced as the rate of admission of main air to burner body **412** is reduced on normal turn-down. The only noteworthy aspect of the shifting flame front phenomenon is that, in instances where flame monitoring is desired, it is necessary to monitor at a point downstream of combustion chamber **424**. This may be accomplished by inserting a conventional flame detecting rod (not shown) through fragmentary pipe coupling **473** attached to burner body **412** coaxially with aperture **474** and being disposed with its axis adapted to intersect the axis of combustion chamber **424** at a point downstream thereof.

Ignition of the flame stabilizing ring in combustion chamber may be accomplished by means of a spark plug (not shown) inserted through fragmentary pipe coupling **475** attached to combustion chamber **424** coaxially with aperture **476** and being disposed with its axis adapted to intercept the axis of fuel inlet pipe **427** at a point downstream thereof.

The main stream of combustion air for combusting the unburned portion of the fuel stream emerging from combustion chamber **424** is added tangentially by means of air inlet connection **443** to the annulus **477** formed between the outside diameter of combustion chamber **424** and the inside diameter of burner body **412**. It is especially important in a burner adapted for firing a single pass radiant tube that air inlet connection be disposed with its axis substantially prependicular to the axis of combustion chamber **424**. Such a construction imparts a very rapid tight spinning motion to the stream of main combustion air as contrasted to the lazier spiraling motion inparted to the stream of main air by turning vanes **145** of burner **110**. Due to the relatively high vortex suction effect with an associated high degree of turbulence at the axis of a tightly spinning air stream the fuel stream flowing along the axis will tend to mix very rapidly with the spinning air stream. The mixing occurring in this fashion will proceed in a pattern starting from the axis outwardly to the inner periphery of radiant tube **447**. Thus, the extreme outer layer of the spinning air stream will retain its autonomy for a sufficiently long period to provide for effective high convective cooling of firing end portion **447***a* of radiant tube **447** which is shielded by a portion of refractory wall **414** and which, because of the limited ability of refractory wall **414** to absorb heat therefrom, is a portion particularly susceptible of being overheated.

In constructing burner **410** it is important to pay careful attention to the size of annulus **477** so that it is neither too large or too small. I have found that the optimum annulus size is one that will impart a pressure drop of 4–5 in W.C. to the stream of spinning air flowing therethrough when air is being added at the maximum desired

rate. A smaller annulus will impart a higher pressure drop to the air stream and this will undersirably tend to dampen the spinning motion of the air stream. A larger annulus will impart a lower pressure drop to the air stream and this will undesirably reduce the rate of mixing of the spinning air stream and the axially flowing fuel stream.

The best modes known to me to carry out this invention have been described in terms sufficiently full, clear, concise, and exact as to enable any person skilled in the art to practice the invention. However, it is to be understood that various modifications of the above will be readily apparent to a skilled artisan without departing from the scope of the invention which is defined only by the appended claims.

I claim:

1. Self-stabilizing burner apparatus comprising, in combination: wall means including a backplate forming a substantially cylindrical combustion chamber having an inlet end and an exit end; wall means forming a burner body circumposing said combustion chamber and forming an annular chamber therewith; a refractory tunnel block having a tunnel in fluid communication with said combustion chamber and said annular chamber; a fuel inlet pipe for delivering a stream of fuel substantially axially to said combustion chamber, said pipe having an outlet end disposed within said combustion chamber at a point somewhat downstream from the backplate thereof; an air inlet connection for delivering a stream of air to said annular chamber; air inlet conduit means extending from said combustion chamber to said annular chamber for delivering a portion of said stream of air from said annular chamber to said combustion chamber for combusting a portion of said stream of fuel, said air inlet conduit means being disposed tangentially to said combustion chamber and perpendicularly to the axis thereof and being disposed upstream from the outlet end of said fuel inlet pipe; and a restricted orifice disposed within said annular chamber being adapted to restrict the flow of the remaining portion of the stream of air from said annular chamber to said tunnel, thereby causing the remaining portion of the air stream and the uncombusted portion of the stream of fuel to mix rapidly in said tunnel.

2. Apparatus according to claim **1** wherein said orifice comprises an annular plate having a plurality of radial slots disposed around the outer periphery thereof.

References Cited by the Examiner

UNITED STATES PATENTS

2,673,726	3/1954	Oldenkamp.	
2,787,318	4/1957	Wolfersperger	158—1.5
2,806,517	9/1957	TeNuyl	158—1.5 X
2,952,307	9/1960	Schramm et al.	158—7
3,030,773	4/1962	Johnson	158—28 X

FOREIGN PATENTS

1,033,539	4/1953	France.
255,080	9/1929	Great Britain.

FREDERICK L. MATTESON, Jr., *Primary Examiner.*

ROBERT A. DUA, *Assistant Examiner.*