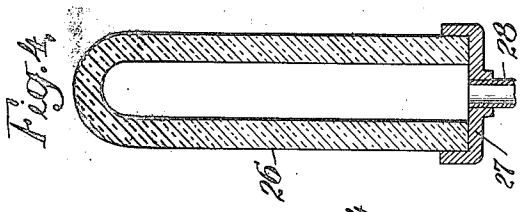
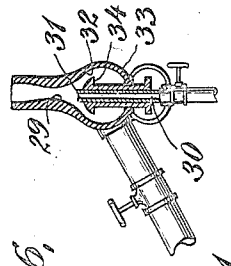
W. A. BONE, J. W. WILSON & C. D. McCOURT.

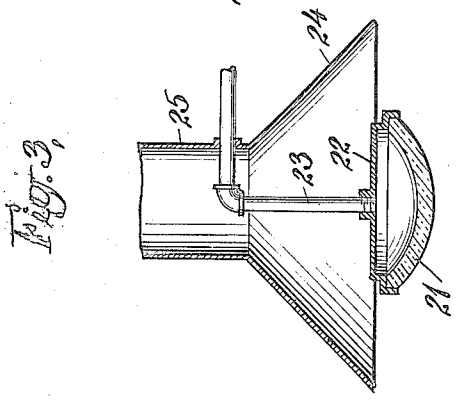
PROCESS OF BURNING GASES.

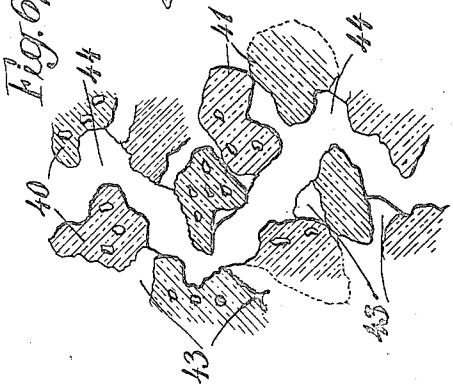
APPLICATION FILED JULY 11, 1912. RENEWED SEPT. 8, 1916.

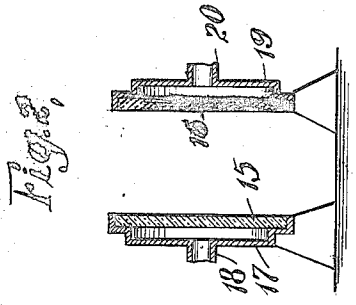
1,222,922. Patented Apr. 17, 1917.

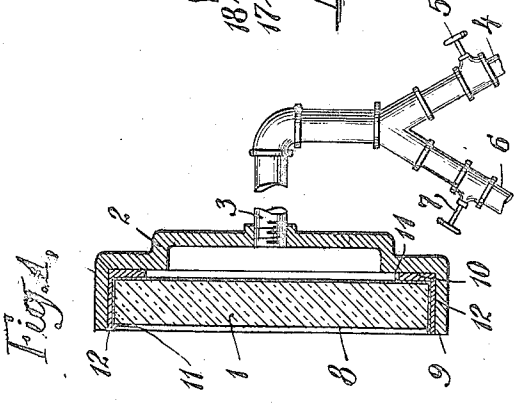














WITNESSES

Jessie B. Kay

Charles Eberhart.

INVENTORS

William Cutter Bone

James Wilson Wilson

BY Cyril Douglas McCourt

Duncan & Duncan ATTORNEYS

UNITED STATES PATENT OFFICE.

WILLIAM ARTHUR BONE AND JAMES WILLIAM WILSON, OF LEEDS, AND CYRIL DOUGLAS McCOURT, OF LONDON, ENGLAND, ASSIGNORS TO RADIANT HEATING LIMITED, OF LONDON, ENGLAND, A BRITISH CORPORATION.

PROCESS OF BURNING GASES.

1,222,922. Specification of Letters Patent. Patented Apr. 17, 1917.

Application filed July 11, 1912, Serial No. 708,852. Renewed September 8, 1916. Serial No. 119,139.

To all whom it may concern:

Be it known that we, WILLIAM ARTHUR BONE, of Leeds, in the county of York, England, JAMES WILLIAM WILSON, of Armley, Leeds, in said county, and CYRIL DOUGLAS McCOURT, of 45 Braxted Park, Streatham Common, London, S. W., England, subjects of the King of Great Britain, have made certain new and useful Improvements Relating to Processes of Burning Gases, of which the following is a specification taken in connection with the accompanying drawing, which forms part of this application, which is based upon and contains subject-matter taken from our copending United States application, Serial No. 586,058, filed October 8, 1910.

This invention relates to processes of utilizing the accelerating influence of the incandescent surface of a highly porous refractory diaphragm upon the combustion of a suitable explosive mixture of gaseous fuel and air fed in large volume through the diaphragm toward its heated outer surface, so that a large proportion of the potential energy of the fuel is liberated as radiant energy from the incandescent surface so as to be available in connection with many industrial gas heating operations. When an explosive mixture of coal gas and air, for instance, in their combining proportions or with air in slight excess thereof is passed at suitable velocity through the pores or interstices of a suitable porous refractory diaphragm into its incandescent surface layer a many fold accelerated and substantially flameless combustion of the gas takes place within the interstices, pores or parts of the incandescent diaphragm layer which are more or less impregnated or in contact with the gaseous mixture; and energy thus developed in large amounts by this intensified, complete and efficient combustion is absorbed by the adjacent surface layer of the diaphragm and maintains it in a state of incandescence, thus securing a very convenient and efficient source of radiant energy. This highly accelerated or intensified surface combustion seems to be due to the emission of charged corpuscles or electrons from such incandescent solids, and the consequent formation of layers of electrified or ionized gas in which the chemical changes incident to combustion proceed with extraordinary rapidity. It has been demonstrated that the incandescent solid plays an active and important part in the combustion of the explosive gaseous mixture under these conditions, the particles of the incandescent solid apparently forming a composite system with the adjacent molecules of the combining gases, so that such combustion complex acts in a manner very different from what occurs in normal flame combustion. For example it has been proved that the presence of water vapor certainly accelerates, if it is not essential to, the normal flame combustion of carbon monoxid in air or oxygen, whereas the presence of even a small quantity of water vapor such as will saturate the gases at 18° C. greatly retards the surface combustion of an explosive mixture of carbon monoxid and oxygen in contact with heated fire clay surfaces. Another thing which indicates the distinctive and qualitative difference between such surface combustion and normal flame combustion is the fact, that in ordinary combustion methane and other hydrocarbons have much greater affinity for oxygen than either hydrogen or carbon monoxid; while in surface combustion these selective affinities are completely reversed, apparently because of the controlling action of the heated solid particles on the manner of combustion.

This invention is adapted for the combustion of a large variety of combustible gaseous material, as for example blast furnace gas, producer gas, water gas, which may be carbureted, coke oven gas, coal gas, petrol air gas and similar hydrocarbon gas and other combustible vapors, natural gas and mixtures thereof, all of which are hereinafter referred to as combustible gases, although the temperature attainable in any particular case will naturally depend upon the calorific intensity of the gaseous material employed. The combustible gas is combined with air or other available supporter of combustion preferably in substantially the combining proportions or with a slight excess or deficiency of air, although the proportions of the constituent gaseous materials may vary considerably and still secure an explosive gaseous mixture, such as is capable of explosive combustion or inflammation, possibly under conditions of increased pressure and temperature.

In the illustrative forms of apparatus for

carrying out this invention shown in the drawings in a somewhat diagrammatic way,

Figure 1 is a vertical central section through a form of diaphragm apparatus.

Fig. 2 is a similar view through a pair of opposed diaphragms.

Fig. 3 is a similar view showing an inverted convex diaphragm in connection with a hood and flue.

Fig. 4 shows in section a tubular diaphragm unit.

Fig. 5 is a diagrammatic view showing a magnified section of the diaphragm structure; and

Fig. 6 is a similar view showing diagrammatically one of the channels in such porous diaphragms.

The porous refractory diaphragm may be given any suitable shape so as to have the desired form of incandescent outer surface from which the heat is transmitted. In the illustrative form of diaphragm unit shown in Fig. 1 the permeable or porous diaphragm 1 may be in the form of a flat plate of sufficiently refractory material preferably formed of agglomerated or united particles or grains of substantially uniform size so as to form tortuous channels for the passage of the explosive gaseous mixture through the diaphragm. The diaphragm which may be an inch or so thick may be mounted in any desired way, as for instance, by being supported in a suitable casing 2 of iron or other suitable material which may be formed with a suitable recess behind the diaphragm communicating with the injecting pipe 3 for the explosive gaseous mixture which for example may be formed by forcing the combustible gas through the inlet pipe 6 in the desired amounts controlled by the gas valve 7 while air is similarly supplied under the desired pressure through the air inlet pipe 4 to the extent determined by the adjustment of the air valve 5. In order to keep the edge of the diaphragm cool it is desirable to minimize the discharge of gas from this part of the outer or discharge surface 8 of the diaphragm in any suitable way, as for instance applying a suitable impervious coating 11 to the edge and adjacent inner face of the diaphragm. A suitable impervious coating for this purpose may be formed of a mixture of finely ground burned fireclay and sodium silicate which may be applied in moistened condition and then warmed sufficiently to cause setting of this cement-like material which forms a hard material somewhat like Portland cement or limestone. Plaster of Paris or other impervious cement-like material may also be used for this impervious coating or the desired part of the diaphragm may be rendered impervious by a suitable glaze formed during its manufacture. The diaphragm is preferably mounted within a suitable seat 10 in the casing of such shape as to substantially conform to the edge of the diaphragm which is preferably located so as to be protected by the edge or flange 9 of the casing. Any suitable cement or luting material may be used to hold the diaphragm within the casing, as for instance, fireclay or preferably a mixture of finely ground burned fireclay and sodium silicate which may be caused to set by suitable warming, or other suitable cementitious material, such as plaster of Paris, asbestos paste, or whitelead compositions may be used. Such porous refractory mediums when in the form of coherent diaphragms may be arranged horizontally, vertically or at any desired angle and the hot outer surface may be either the upper or lower surface. Several diaphragms may be arranged in any desired way to supply heat to various parts of an object and for grilling or toasting purposes, for instance, two diaphragms may be arranged opposite each other. As indicated in Fig. 2 the incandescent diaphragms 15 and 16 are placed at any suitable distance apart so as to heat both sides of the article placed between them. The diaphragm 15 may be mounted within a suitable casing 17 connecting with the injecting pipe 18 and formed with a suitably connected support, if desired. The opposing diaphragm 16 may be mounted in a similar support 19 having the injecting pipe 20.

In some cases instead of using plain diaphragms many other special forms or contours suited to special purposes may be used, such, for example, as the dome-shaped or convex diaphragm shown in Fig. 3. In this case the porous refractory diaphragm 21 is shown mounted in inverted position in the iron or other suitable casing 22 so as to have the outer hot surface of the diaphragm pointed downward so as to be suitable, for instance for heating a room when mounted in its upper portion or for heating or evaporating liquids or other material placed beneath the diaphragm. As indicated, the diaphragm and its connected casing may in this instance be conveniently supported by the injecting pipe 23 for explosive gaseous mixture, and if desired a suitable hood 24 may be mounted in connection with the diaphragm so as to carry off the products of combustion therefrom in connection with a suitable flue, such as 25. A form of tubular diaphragm 26 is shown in Fig. 4 as mounted within a suitable casing or support 27 of iron or other suitable material so that the explosive gaseous mixture supplied to the diaphragm through the injecting pipe 28 maintains the outer surface of the porous diaphragm in incandescent condition. The explosive gaseous mixture may be formed and fed to any such refractory diaphragms which are sufficiently porous by a suitable injector device in which either the combusti-

ble or combustion supporting constituent may be under pressure and be discharged with sufficient velocity to draw in and mix the other component of the explosive mixture and feed the same with sufficient pressure through the diaphragm. In Fig. 4 the injector device may as indicated comprise the curved injector throat 29 with which the injector nozzle 31 coöperates so as to draw in additional gaseous material through the annular passage 32 the size of which may be regulated by adjusting the position of the valve 34 threaded or otherwise adjustably mounted on the nozzle, for instance. The supporting casing 33 communicating with a suitably valved supply pipe may be used to connect the injector throat with the pipe 30 communicating with the nozzle so as to allow the entrance of air or other gaseous supporter of combustion around the nozzle when the combustible gas is discharged therefrom at a velocity pressure of a few pounds per square inch which is sufficient to produce a pressure behind the diaphragm of an eighth or a quarter of an inch of water or more. The valve in the gas supply pipe may be used to regulate the amount of gas discharged from the injecting nozzle and the valve indicated in the air supply pipe may regulate the amount of air drawn in.

These refractory diaphragms of a high and quite uniform degree of porosity may be manufactured in a number of ways, as for instance, by suitably uniting refractory porous granules of substantially uniform size so as to give a high degree of porosity and permeability to the diaphragm which is penetrated by tortuous gas passages formed by the network of spaces or interstices between the refractory particles or grains of which the diaphragms are made up. Porous fireclay is a satisfactory material for such diaphragms and may be readily crushed or ground in any desired way into particles or grains of the desired size. The granules for making any particular class of diaphragms are substantially uniformly sized, that is, for instance, the granules passing a sieve having 30 meshes to the linear inch are selected and freed from objectionable fine material by separating therefrom all particles which will pass a 50 mesh sieve. Another size of granules useful for such diaphragms for less explosive gaseous mixtures are those passing a 16 mesh sieve and retained by a 32 mesh sieve. Still larger sized granules, such as are suitable for making diaphragms which may be generally used for burning coal gas and illuminating gas are those passing an 8 mesh sieve and retained by a 16 mesh sieve. These porous granules may be united in any desired way preferably by means which will not destroy or undesirably impair the porosity of each of the granules. This may be accomplished by the use of suitable binding agents, such as incorporating with the granules a small percentage of feldspar or a mixture of feldspar with a little fluorspar to the extent of ten per cent. or so of the granules. Such binding material in dry finely powdered form may be incorporated with the granules by first wetting them and then thoroughly stirring them with the dry binding material which thereby coats the particles which may then be immediately molded while in this moistened condition. The molded diaphragms are then burned at a high temperature in a suitable pottery kiln or other furnace so that the temperature is carried considerably beyond the fusing point of the binding material and this causes the binding material to unite or fuse together the adjacent points of the rough porous granules while the binding material is sufficiently absorbed into the body of the granules to leave them with rough unglazed surfaces so as not to undesirably minimize their porosity. The diaphragms are formed by being burned at calcining temperatures greatly in excess of their working temperatures so that at all working temperatures the particles are firmly and sufficiently rigidly held in position. For instance, diaphragms may be burned at temperatures of 1300 to 1400 degrees C. and operated at temperatures of 800 or 900 degrees C. with good results. It is also desirable to carefully mold these diaphragms so as to prevent the destruction of the tortuous passages which naturally form between the rough granules and for this reason moistened material is preferably only compacted very slightly as with an ordinary rolling pin in molding the diaphragms and it is for some purposes even better to merely remove the surplus material into the diaphragm molds so as to prevent any possibility of crushing the particles or undesirably packing them. It is also desirable to remove the surface of the baked diaphragms where the particles have become alined as by being in contact with the smooth mold surface and this may be done in any desired way as with a rasp before they are used. For some purposes also it is not desirable to use as the discharge or outer active surface of the diaphragms the surface which has been in contact with the mold, but to use this surface for the inner surface through which the gas enters. In this way diaphragms may be formed of extremely high and uniform porosity, the degree of porosity, that is, the proportion of porous cavities and spaces between the particles or granules being as high as 50 per cent. or so in some cases. For some special purposes it is sometimes desirable to form the diaphragms with outer discharge sur-

faces of coarser particles and with bodies or inner layers of finer particles which can of course be conveniently effected when molding the moist material.

The substantially uniform size of the granules and the tortuous nature of the gas passages between them are desirable in highly permeable diaphragms suitable for operation under low gas pressures. The size of the granules and consequent size of gas passages and permeability of diaphragms of this character should be so chosen as to give the proper operation with the particular kind of gas with which they are to be used, the size of granules being in all cases small enough so that together with the tortuous character of the gas passages and the greatly increased cooling effect due to the impinging action and rough surfaces of the granules forming these passages, flashback through the diaphragm passages is greatly minimized and practically eliminated under operating conditions with the particular explosive gaseous mixtures used. Diaphragms an inch and a quarter or so thick may be formed in this way of porous fireclay granules of between one-eighth and one-sixteenth inch mesh, which give good results with explosive coal gas and air mixtures supplied under pressures of about one-eighth of an inch of water, and such diaphragms may burn as much as 75 cubic feet or so of coal gas or 400 to 500 cubic feet of explosive coal gas and air mixture per hour for every square foot of diaphragm surface, thus maintaining the outer heated surface of the diaphragm at a temperature of about 850° C. or so under freely radiating conditions. A diaphragm similarly formed of granules of substantially sixteen-mesh size will burn a similar amount of explosive coal gas mixture, but requires somewhat higher pressures, about one-quarter inch or so for the same diaphragm thickness. More explosive or inflammable gaseous mixtures such as those comprising water gas containing somewhat larger proportions of hydrogen require a considerably finer diaphragm to effectively suppress backflashing or quick backfiring therethrough, and for such explosive gaseous mixtures the diaphragm may be formed of granules as fine as about 30 or 50 mesh or even of still finer granules of between 50 and 100 mesh size in the case of more inflammable water gas mixtures.

The action of such porous refractory diaphragms in effecting the accelerated surface combustion of explosive mixtures can be understood by reference to Fig. 5 which diagrammatically illustrates the diaphragm structure on a greatly magnified scale. The outer granules or particles 40 of porous refractory material are the ones maintained in a highly heated or incandescent condition by the combustion of the explosive gaseous mixtures injected against them so as to maintain them in this highly heated condition in which they can radiate heat to each other and from the exposed outer surface of the diaphragm. As may be seen by reference to the portion of these granules within the plane of this section the granules not only have rough outer surfaces, but have internal pores such as 42 communicating in many instances with the outer surfaces to form cavities which the gases may readily penetrate. These particles and the similar inner particles 41 are firmly united, but have relatively large cavities or interstices, so that the entire diaphragm is formed with a net work or concatenation of these communicating spaces or channels. Fig. 6 illustrates diagrammatically the character of one of these tortuous gas passages or channels 44 through a diaphragm of this character, the section being taken along the irregular line following the greatest cross-section of this particular channel through the porous particles. These same factors promote the surface combustion action occurring in the hot outer layer of the diaphragm several granules thick. The explosive gases are here brought into impingement with the rough incandescent surfaces of the granules so that penetration and contact with the gas is greatly promoted and highly accelerated combustion takes place much more effectively than would be possible in the case of a dense porcelain plate, for example, drilled with separate small holes.

For the proper operation of these diaphragms it seems desirable or necessary to have sufficiently free radiation or dissipation of the heat from the incandescent outer diaphragm layer to prevent the accumulation of heat in this layer to such an extent that it can undesirably heat by conduction the rearward layers of the diaphragm and thus cause the zone of surface combustion of the explosive gases to slowly and progressively move back away from the outer surface. This back heating action occurs when, for example, two coal gas diaphragms are arranged with their incandescent surfaces close together, or when a refractory non-conducting plate or the like is moved against or close to a hot diaphragm, and may also take place when excessive amounts of the gaseous mixtures are being burned in the diaphragm so that the heat developed exceeds that which can be properly dissipated from the radiating diaphragm surface at the relatively moderate incandescent temperatures at which it seems preferable to operate these diaphragms. When such back heating takes place the outer diaphragm surface actually frequently cools off after the combustion zone or incandescent layer has moved backward into the diaphragm, and instead of a substantially uniform incandes-

cent surface darker spots appear and in many instances the outer surface cools below a bright heat when the combustion layer has retreated some distance. When this slow retrogression or penetration of the hot combustion zone through the diaphragm occurs the explosive gases in the diaphragm chamber may become ignited, and it is of course desirable to quickly correct this undesirable action as by shutting off the gas supply and cooling the diaphragm or by considerably increasing the proportion of air mixed with the combustible gas supplied so that normal conditions are restored. Then the relatively freer radiation of heat from the incandescent diaphragm surface should be insured so as to radiate the heat as fast as it is generated by surface combustion, and prevent the progressive accumulation of heat and rise of temperature in the incandescent surface layer which undesirably heats the adjacent material and initiates such backheating. In normal operation of such refractory diaphragm the explosive gaseous mixture continues to burn with accelerated surface combustion in the incandescent surface layer and this combustion may be definitely localized and maintained at the desired intensity by regulating the supply of explosive gases and the amount of heat radiation as by increasing or diminishing the freedom of radiation, so as to insure equilibrium and counteract any unbalancing tendencies in the heating system. This back heating action is distinct from the ordinary backflashing or quick backfiring of explosive gaseous mixtures in tubes, such backfiring action being suppressed or eliminated in diaphragm operation by the greatly increased cooling effect on the gases of the small granules and the relatively large surface of the tortuous gas passages therethrough. For instance, in the coal gas diaphragms referred to having granules of between one-eighth and one-sixteenth inch mesh, the passages are of appreciable size and the porosity is so great that the total area of the passages through the diaphragm is in the neighborhood of 30 to 60 square inches for each square foot of diaphragm surface. But nevertheless, no backfiring occurs with a properly made diaphragm of this character, and the importance of the tortuous roughened character of the gas passages in preventing backflashing can be appreciated from the fact that only as much gas will pass through a square foot diaphragm of this character as will issue from an orifice or nozzle about one-quarter or one-half inch in diameter under equal pressures. In gradually shutting off the gas supply to diaphragms of this character the speed of the explosive mixture passing through the tortuous channels of the diaphragm is gradually reduced to zero, but the cooling action of the diaphragm structure is such as to prevent backflashing of the explosive gases in contact with the incandescent outer face of the diaphragm even under these conditions; and such diaphragms may be regularly operated when the speed of the explosive gases through the diaphragms is much less than the normal speed of backflashing of the mixtures.

It is of course understood that many other refractory substances such as magnesia, bauxite, ganister, preferably those having a sufficiently porous character may be used to form the granules which may be united in many ways to form porous diaphragms of this character. Various firebrick compositions have proved highly desirable, especially the more porous refractory materials of this character.

Having described these inventions in connection with a number of illustrative embodiments, arrangements, proportions, materials, pressures, conditions, processes and orders of steps, to the details of which disclosure the inventions are not, of course, to be limited, what is claimed as new and what is desired to be secured by Letters Patent is set forth in the appended claims.

1. The process of burning explosive gaseous mixtures which consists in causing the mixture to flow with a velocity less than the normal speed of back-firing of the mixture through tortuous passages of a porous refractory diaphragm to a highly heated surface layer thereof, effecting combustion of the mixture within said highly heated surface layer of the diaphragm, and preventing backflashing by the cooling action of portions of the diaphragm through which the mixture flows on its way to the combustion zone, whereby the combustion is localized within the surface layer of the diaphram and such surface layer is maintained in a state of incandescence.

2. The process of burning explosive gaseous mixtures which consists in causing the mixture to flow with a velocity less than the normal speed of back-firing through tortuous passages of a porous refractory diaphragm to a highly heated surface layer thereof, effecting combustion of the mixture within said highly heated surface layer of the diaphragm, preventing backflashing by the cooling action of portions of the diaphragm through which the mixture flows on its way to the combustion zone, and permitting heat to radiate freely from said highly heated surface layer of the diaphragm, whereby the combustion is localized within the surface layer of the diaphragm and such surface layer is maintained in a state of incandescence.

3. The process of burning explosive gaseous mixtures which consists in causing the mixture to flow with a velocity less than the normal speed of back-firing of the mixture

through tortuous irregular sectioned passages of a porous refractory diaphragm to a highly heated surface layer thereof, effecting combustion of the mixture within said highly heated surface layer of the diaphragm, and preventing backflashing by causing the mixture as it advances through the diaphragm to impinge on the walls of the tortuous passages of the diaphragm, whereby the combustion is localized within the surface layer of the diaphragm and such surface layer is maintained in a state of incandescence.

4. The process of burning gaseous fuel which consists in combining the gaseous fuel with a gaseous supporter of combustion in proportions to form an explosive gaseous mixture, causing the mixture to flow with a velocity less than the normal speed of back-firing of the mixture through a porous refractory diaphragm to a highly heated surface layer thereof, effecting combustion of the mixture within said highly heated surface layer of the diaphragm, and preventing backflashing by the cooling action of portions of the diaphragm through which the mixture flows on its way to the combustion zone, whereby the combustion is localized within the surface layer of the diaphragm and such surface layer is maintained in a state of incandescence.

5. The process of burning explosive gaseous mixtures which consists in causing the mixture to flow with a velocity less than the normal speed of back-firing through a porous refractory diaphragm to a highly heated surface layer thereof, effecting accelerated surface combustion of the mixture within said highly heated surface layer of the diaphragm, and preventing backflashing by the cooling action of portions of the diaphragm through which the mixture flows on its way to the combustion zone, whereby the combustion is localized within the surface layer of the diaphragm and such surface layer is maintained in a state of incandescence.

WILLIAM ARTHUR BONE.
JAMES WILLIAM WILSON.
CYRIL DOUGLAS McCOURT.

Witnesses:
M. G. SPALDING,
CHARLES E. TAYLOR.