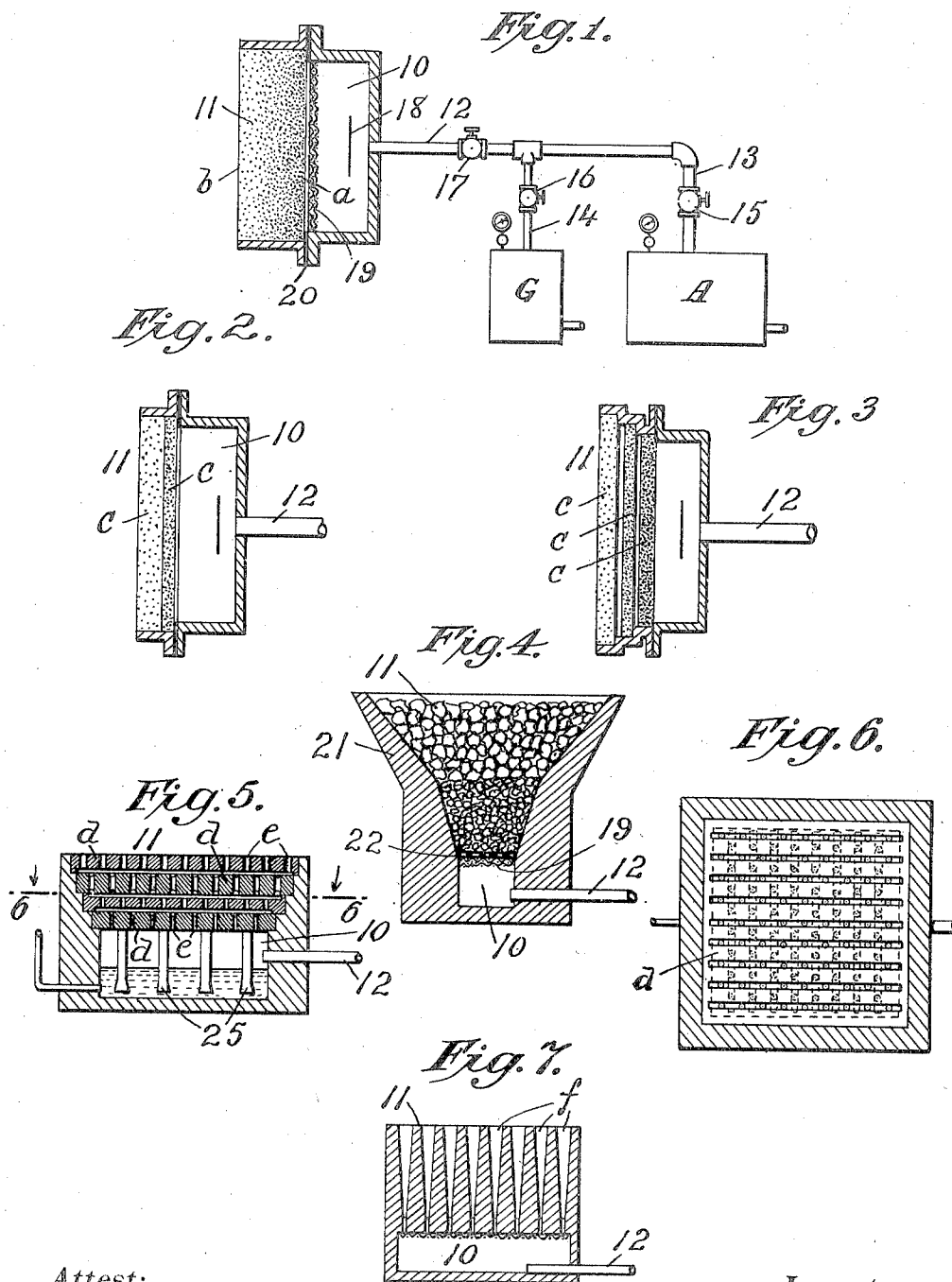


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 APPARATUS FOR BURNING EXPLOSIVE GASEOUS MIXTURES.
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UNITED STATES PATENT OFFICE.

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APPARATUS FOR BURNING EXPLOSIVE GASEOUS MIXTURES.

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To all whom it may concern:

Be it known that I, CHARLES E. LUCKE, a citizen of the United States, residing at New York city, in the county of New York and State of New York, have invented certain new and useful Improvements in Apparatus for Burning Explosive Gaseous Mixtures, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

This invention relates to apparatus for burning explosive gaseous mixtures continuously, or non-explosively, as distinguished from non-continuous or intermittent combustion of such mixtures. The object of the invention is to provide an efficient apparatus for burning explosive gaseous mixtures by causing the mixture to move with a velocity greater than the rate of propagation of inflammation through the mixture so as to prevent back flash, and then rapidly reducing the flow velocity to the rate of propagation of inflammation and preventing dissipation of the mixture or diffusion with other gas, and burning the mixture at the surface or zone where the velocity equals the rate of propagation of inflammation. The invention aims to provide an apparatus of this kind which shall be adaptable to a great variety of uses, and shall be safe in operation, and which will permit of a large variation in supply pressure of the explosive mixture without substantial change in location of the combustion zone, and which shall have a high capacity for the space occupied and shall be highly efficient.

To these ends, I provide a porous and permeable combustion bed or diaphragm and means for causing the gaseous mixture to enter the diaphragm and flow there-through with an initial velocity greater than the rate of propagation of inflammation through the mixture, as by maintaining a supply of the explosive mixture against one side of the diaphragm under a suitable pressure; and I make the diaphragm of greater flow area, that is, with a greater aggregate cross-section of its passages or pores, toward the discharge side than toward the inlet side; and this result is secured in accordance with one feature of the present invention by making the diaphragm of increasing permeability in the direction from its inlet side or face to its discharge side, that is, the

aggregate cross-section of the passages or pores of the diaphragm for a given cross-sectional area is greater toward the outlet side than toward the inlet side of the diaphragm. The increase in permeability of the diaphragm may be a gradual increase or an increase in one or more steps; and the diaphragm may be of any suitable construction to provide intercommunicating or expanding passages or passages which are both intercommunicating and expanding, and may be of any suitable refractory material, that is, material which will withstand the degree of heat to which it is subjected in the use of the apparatus.

In the accompanying drawings I have shown a simple form of apparatus made in accordance with the invention and modifications thereof. In said drawings:

Figure 1 shows partly in section a simple form of apparatus made in accordance with the invention.

Figs. 2, 3, 4, 5, 6 and 7 show modified forms of apparatus.

Referring first to Fig. 1, 10 represents a gas chamber one wall of which is formed by a porous and permeable diaphragm 11. The explosive gaseous mixture is supplied to the chamber 10 through a supply pipe 12 from a suitable source adapted to maintain the required pressure in the chamber 10. Any suitable means may be provided for supplying the explosive mixture. The simple means shown comprises a tank A for the air or other combustion supporting gas and a tank G for the fuel gas, from which tanks pipes 13 and 14 respectively lead to the pipe 12, said pipes 13 and 14 being controlled by valves 15 and 16 respectively. A controlling valve 17 may also be provided in the pipe 12. The supply of fuel gas and combustion supporting gas may be maintained in the respective tanks by any suitable means. A baffle plate 18 in the gas chamber 10 serves to prevent the stream of mixture from the pipe 12 from impinging directly against the diaphragm 11 and insures a more even pressure of the mixture on the diaphragm.

The diaphragm 11 is of gradually increasing permeability from its inlet side or inner face *a* to its outer face or side *b*, and the diaphragm intended to be shown in this figure is one having intercommunicating

passages. It may be of any suitable character and formed in any suitable way from suitable refractory material, as by bonding together, in a mold or otherwise, broken or
5 other granular refractory material, or by molding a plastic mass to which has been added particles or pieces of matter which on being heated will disappear, or generate a gas or vapor, and leave a suitable porous
10 and permeable structure. In the operation of the apparatus, the proportionate amounts of fuel gas and air or other combustion supporting gas flowing from the tanks G and A through the pipe 12 into the gas chamber
15 10 will be controlled by the valves 15 and 16 so that the mixture entering the chamber 10 will contain the fuel gas and combustion supporting gas in proportions to form an explosive mixture, and the amount
20 of mixture entering the chamber will be controlled by the valve 17 or by the valves 15 and 16 so as to maintain a pressure within the chamber sufficient to cause the gaseous mixture passing from the chamber
25 through the diaphragm 11 to flow through the passages at the inner or inlet side of the diaphragm with a velocity greater than the rate of propagation of inflammation through the mixture. As the gas advances through
30 the diaphragm its velocity will be quickly reduced, and, being ignited, it will burn at the surface or zone where the velocity equals the rate of propagation of inflammation. This surface or zone of combustion will locate within the diaphragm a greater or less
35 distance from the outer face thereof or at the outer face, according to the character of the explosive mixture and according to the gas pressure maintained in the chamber 10 and the thickness and permeability of the
40 diaphragm. The proper proportions of fuel gas and air or other combustion supporting gas, that is, proportions such according to the nature of the constituents
45 that the gaseous mixture entering the chamber 10 shall have the property of self-propagation of inflammation and shall be of suitable strength or richness within the limits within which the mixture will have the
50 property of self-propagation of inflammation, and the proper supply of the mixture to the chamber to maintain the necessary or desired pressure therein, may be readily determined by experiment. The pressure of
55 the fuel gas and of the air or other combustion supporting gas in the tanks G and A respectively must, of course, be kept sufficient to maintain the desired pressure in the gas chamber 10.
60 Increase in the supply of mixture to the chamber 10 and increase in the pressure maintained in said chamber will cause the flame cap or combustion zone to advance toward the outer face *b* of the diaphragm,
65 and decrease in the supply or pressure in

the chamber 10 will result in the combustion zone moving backward toward the inner face of the diaphragm; but so long as sufficient pressure is maintained in the chamber 10 to cause the mixture to move
70 through the passages adjacent the inner face of the diaphragm with a velocity greater than the rate of propagation of inflammation and to cause the combustion zone to be located at such a point beyond
75 the inner face of the diaphragm that the inner face does not become heated to a degree sufficient to cause ignition of the mixture, back flash and ignition of the mixture in the chamber 10 will be prevented. As a
80 safe-guard against ignition of the mixture in the chamber 10, however, during normal operation, and to prevent such ignition when the gas pressure is reduced in shutting down or from any other cause, a flame-
85 interrupting, cooling screen or partition 19 of one or more layers of fine wire gauze or other suitable flame interrupting screen or partition may be provided in the chamber
90 10 adjacent to the inner face of the diaphragm. This flame interrupting screen is shown in Fig. 1 as set slightly away from the face of the diaphragm so as to avoid its becoming heated by contact therewith. It
95 is not always necessary, however, that the flame interrupting screen, if provided, be set away from the face of the diaphragm, but it may set close thereagainst, and, furthermore, if the pores or passages in the innermost portion or layer of the dia-
100 phragm adjacent its inner face are sufficiently small this portion of the diaphragm proper may itself form and serve, so long as it remains cool, as a flame interrupting screen to prevent transmission of inflammation
105 to the mixture within the chamber 10. It is desirable also when the side walls of the chamber 10 are of a material which is a good heat conductor to provide a suitable insulating joint as indicated at 20 between
110 the part of the side walls in contact with the diaphragm and the part forming the side walls proper of the chamber.

By reason of the fact that at the combustion zone the temperature in the bed is high
115 and at the supply side the temperature is comparatively low, there will be a conduction of heat through the bed toward the supply side which under some circumstances might raise the temperature of that side to
120 the temperature of ignition of the mixture, igniting the mixture in the feed chamber and interrupting the operation. It is found, however, that when the permeability of the bed is low enough, its heat conductivity low
125 enough, and the loss in pressure through the bed high enough, or the supply pressure high enough, that this does not take place.

Figs. 2 and 3 show each a part of an apparatus similar to that shown in Fig. 1 but
130

differing therefrom in having, instead of a diaphragm of gradually increasing permeability, one in which the increase in permeability is abrupt, or in one or more steps.

5 In Fig. 2 the diaphragm is shown as made up of two porous and permeable layers or plates *c* set one closely against the other, the inner plate *c* being of relatively less and the outer plate *c* of relatively greater permeability. The explosive mixture being supplied to and maintained under suitable pressure in the chamber 10, it will enter the diaphragm and flow through the passages of the inner plate *c* with a velocity greater than the rate of propagation of inflammation through the mixture; and in passing from the plate *c* into and through the outer plate *c* the mixture will lose velocity and will burn at the surface or zone within the outer plate *c* where equality is attained between the flow velocity and rate of propagation of inflammation. In Fig. 3 the diaphragm is shown as made up of three plates of porous and permeable refractory material *c*, *c*, *c*, of successively greater permeability from the innermost one outward, so that the explosive mixture, entering and flowing through the inner plate with a velocity greater than the rate of propagation of inflammation, will enter and flow through the successive plates of increasing permeability under decreasing pressure and with decreasing velocity until burned at the surface or zone where the velocity equals the rate of propagation of inflammation. The plates may be spaced slightly apart as shown in Fig. 3, but usually best results will be obtained with the plates set closely adjacent each other as in Fig. 2.

40 Fig. 4 shows a diaphragm or bed 11 formed by a mass of loose granular refractory material placed in a suitable container 21 formed with a gas chamber 10 below a grate or other suitable perforate support 22 on which the granular material rests. The granular material is in comparatively smaller pieces at the bottom of the bed and of a larger size in the upper part of the bed; or the bed might be formed of granular material of gradually increasing size from the lower part up. A flame interrupting screen 19 is shown beneath the grate 22.

The bed or diaphragm as shown in this figure is of greater cross-sectional area toward its discharge side than toward the bottom or inlet side, and this might be depended on to give the desired increase in flow area, or aggregate cross-section of the pores or passages of the bed, even though the granular material were of the same general size throughout the bed. A bed in which the increasing flow area is secured by both increase in cross-sectional area and increase in permeability is, however, sometimes most desirable. Increasing the flow

area toward the discharge side of the bed by increasing the cross-sectional area of the bed is, of course, particularly adaptable to beds or diaphragms of considerable thickness as compared to their cross-sectional area. The increase in cross-sectional area as shown in Fig. 4 is gradual, but might, obviously, be in one or more steps. So, also, a gradual increase in cross-sectional area might be uniform instead of being sharper toward the discharge side of the bed as shown in this figure.

Fig. 5 shows a porous and permeable diaphragm of increasing permeability from its inner to its outer side or face made up of a plurality of plates *d* each having more or less closely arranged perforations *e*. The aggregate capacity of the perforations of each successive plate from the inner plate outward is greater than that of the preceding plate, and they are best arranged so that the perforations in adjacent plates do not register; and the aggregate capacity of the perforations in the innermost plate will be such compared with the supply of mixture to the supply chamber 10 that the mixture will flow through the perforations in this innermost plate *d* with a velocity greater than the rate of propagation of inflammation through the mixture, and by making the perforations in this innermost plate sufficiently small this plate will act as a flame interrupting cooling screen. The plates *d* may be made of metal, but usually some other refractory material which is a poorer heat conductor and which is capable of withstanding a greater degree of heat will best be employed. If the plates are of metal, or if the innermost plate is of metal, it is desirable that some additional means be provided for preventing the inner plate from becoming too highly heated. For this purpose, I provide, as shown in this figure, the inner plate *d* with metal fingers or other suitable projections 25 which extend into contact with a body of water. The cooling, or heat absorbing, water might be arranged to circulate in contact with the conducting projections 25, but an efficient arrangement is as shown in this figure where the lower part of the chamber 10 serves as a tank in which the water into which the lower ends of the conductors 25 extend may be maintained at a suitable level by any suitable means. Such projections will not only prevent the plate from being injured by burning, but will also serve to keep the temperature of the gas passages of the inner plate and also of other plates conductively connected with the inner plate lower than it would otherwise be. They thus serve as an additional means of preventing premature ignition of the mixture by heat conducted down from the hot zone. Such water cooled heat conducting projections may also be provided advantage-

geously when the inner portion or the whole of the diaphragm is of other material than metal.

To provide communication between the 5 perforations in the successive plates, the plates are preferably made with surface grooves connecting the perforations and extending in such directions that the grooves in the meeting face of adjacent plates will 10 cross each other and thus provide passages connecting the perforations when the plates are set close against each other, and at the same time avoiding a large free or open space between adjacent plates. Fig. 6 15 shows the face of one of the plates *d* having its perforations connected by parallel grooves, and the position of the perforations and the connecting grooves in the meeting face of the plate next below are indicated by dotted lines, the grooves thus indicated being parallel grooves extending at 20 right angles to the grooves in the upper face of the plate shown.

The diaphragms shown in Figs. 1 to 5 25 have intercommunicating passages. In Fig. 7 I have shown a form of diaphragm in which there is no communication between the passages within the diaphragm, but the diaphragm is formed with a number of non-communicating passages *f* extending through 30 the diaphragm from its inner to its outer side, each of which expands or increases in cross-section in the direction from the inner to the outer side of the diaphragm. 35 These expanding or conical passages allow the gas flowing through them to expand so as to advance in increasing volume and with decreasing velocity. The best results with a bed of this character are secured when the 40 bed is formed with a comparatively large number of openings *f* each of small capacity at its inlet end; and the angle of the conical or expanding openings should be very small and the diaphragm should be of considerable 45 thickness, so that the gaseous mixture advancing through the conical openings may have its velocity sufficiently reduced within the limits of the diaphragm.

What is claimed is:

50 1. An apparatus for burning explosive

gaseous mixtures comprising in combination a porous and permeable combustion bed of greater permeability in one portion than in another, and means for causing the explosive mixture to flow through the bed in the 55 direction from the portion of lesser to the portion of greater permeability and with an initial velocity greater than the normal rate of propagation of inflammation of the mixture where it enters the bed. 60

2. An apparatus for burning explosive gaseous mixtures comprising in combination a porous and permeable diaphragm having intercommunicating passages and being of 65 increasing permeability and of increasing cross-sectional area in the direction from the inlet to the discharge side thereof, and means for maintaining a comparatively slow moving supply of the explosive mixture against the inlet side of the diaphragm under sufficient 70 pressure to cause it to enter and move through the passages at the inlet side of the diaphragm with a velocity greater than the normal rate of propagation of inflammation of the mixture where it enters the dia- 75 phragm.

3. An apparatus for burning explosive gaseous mixtures comprising in combination a gas chamber, a porous and permeable diaphragm forming the top wall of the gas 80 chamber and formed by a layer or bed of loose granular refractory material resting at the bottom on a support having gas passages therethrough, the granules at the bottom of said bed being smaller than those at 85 and near the upper face thereof, and means for maintaining a supply of the explosive mixture in said gas chamber under a pressure sufficient to cause the mixture to enter and to flow through the bed with an initial 90 velocity greater than the normal rate of propagation of inflammation of the mixture where it enters the bed.

In testimony whereof I have hereunto set my hand in the presence of two subscribing 95 witnesses.

CHARLES E. LUCKE.

Witnesses:

FRANK C. ERB,
A. L. KENT.