

W. B. EDDISON.

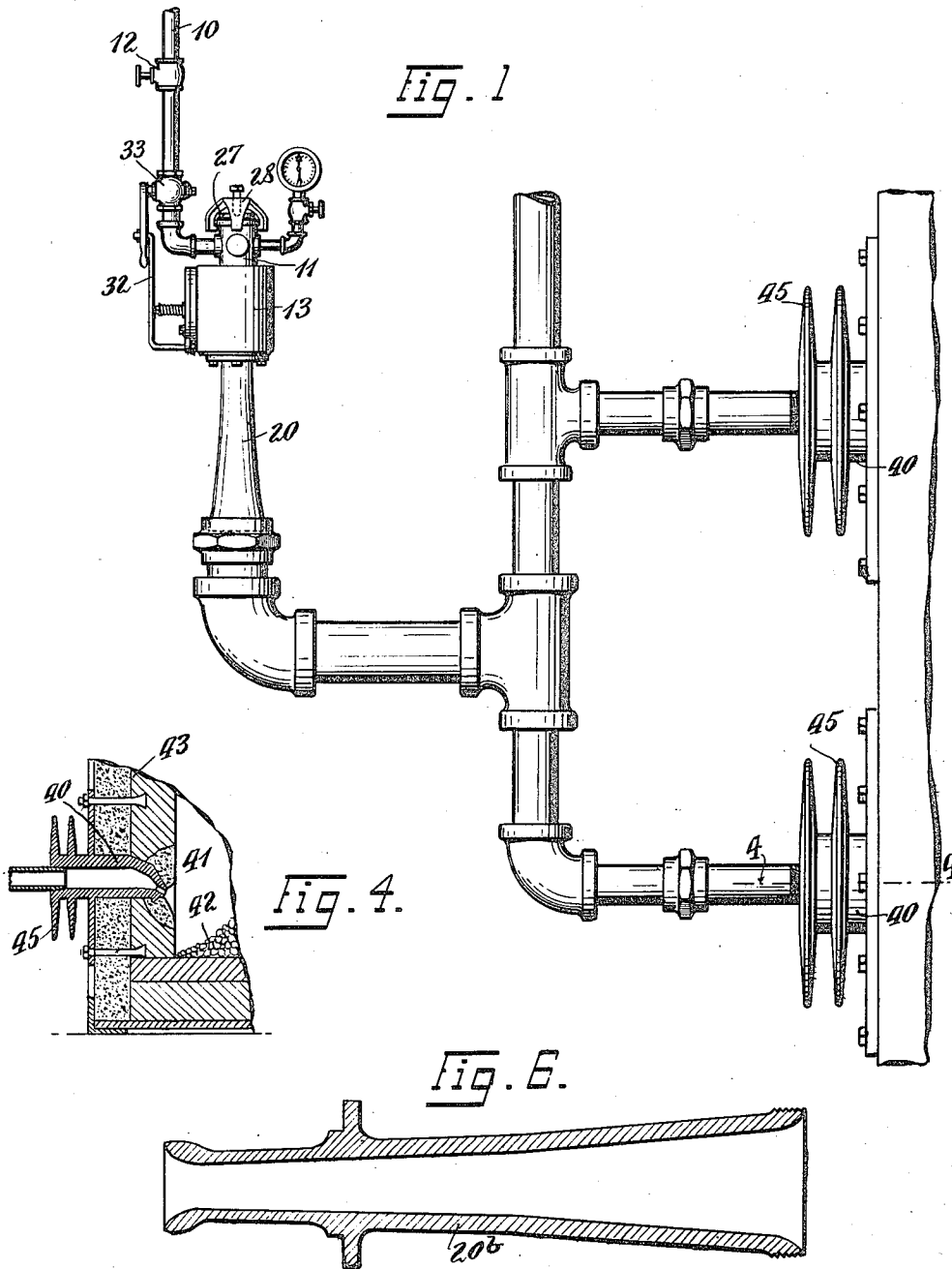
JET APPARATUS.

APPLICATION FILED JULY 2, 1917.

Patented Feb. 18, 1919.

2 SHEETS—SHEET 1.

1,295,086.



WITNESSES:
Charles A. Mathe.
Lillian R. Fox

INVENTOR:
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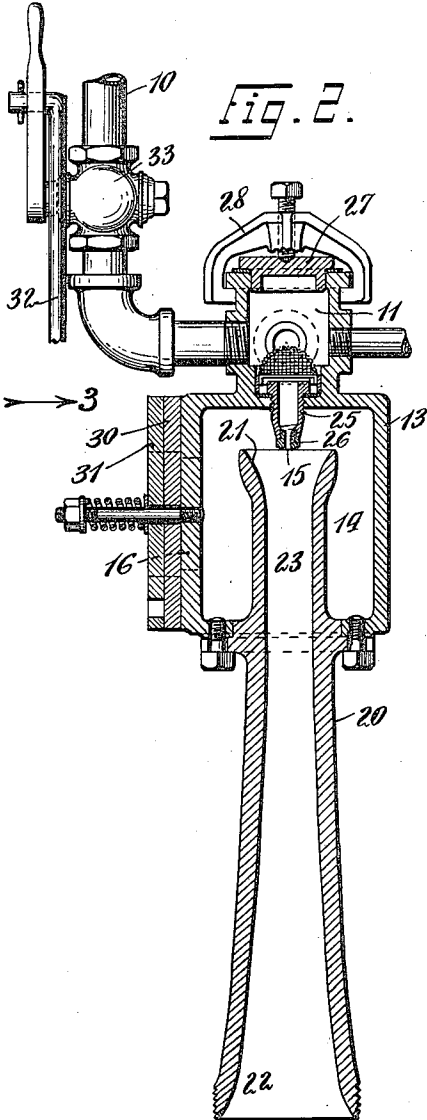
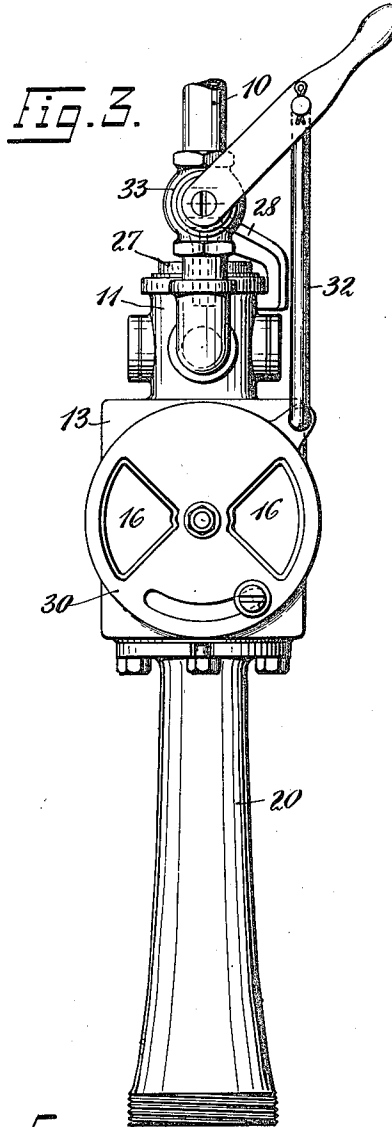
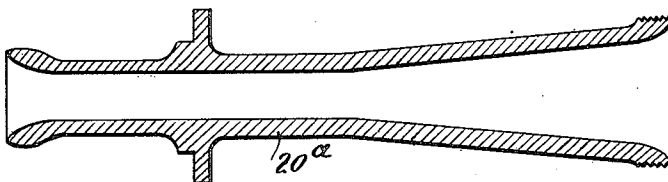


Fig. 5.



WITNESSES:

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UNITED STATES PATENT OFFICE.

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JET APPARATUS.

1,295,086.

Specification of Letters Patent.

Patented Feb. 18, 1919.

Application filed July 2, 1917. Serial No. 178,321.

To all whom it may concern:

Be it known that I, WILLIAM BARTON EDDISON, a citizen of the United States, residing at Irvington, in the county of Westchester and State of New York, have invented certain new and useful Improvements in Jet Apparatus, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

This invention relates to jet apparatus for forming and supplying a mixture of gases, and more particularly to an apparatus in which the mixture is formed and supplied under the desired pressure through the utilization of the pressure energy of a gas which forms a minor constituent of the resulting mixture.

The invention has been made especially with the idea of providing an apparatus for supplying an explosive gaseous mixture of air and fuel gas to the burner discharge orifices of a surface combustion furnace at a pressure above a predetermined minimum and in quantities variable at will and without changing the proportions of the constituent gases, that is, to meet the conditions of constant proportions, variable quantity, and exit pressure sufficient to prevent back-flashing.

The usual city or town gas requires from five to six parts by volume of air to one part of the fuel gas to form an explosive mixture containing gas and air in approximately combining proportions. The efficiency of jet mixing apparatus heretofore used for supplying under pressure a mixture of gases formed by the entraining and inducing action of a jet of gas supplied under comparatively high pressure and discharged into the entrance cone of a Venturi tube decreases as the ratio of driven gas to driving gas in the mixture increases, so that when it comes to supplying an explosive mixture of air and fuel gas by the energy of a jet of the fuel gas, the efficiency of the apparatus is low, with the result that the pressure under which such an explosive mixture can be so supplied to a surface combustion burner is so low compared to the initial gas pressure that only a very limited range of mixture supply is possible with the fuel gas supplied under the usual and most desirable high pressure distribution supply pressures of from 10 to 15 pounds.

The present invention has been made with the idea of overcoming this disadvantage and providing a jet apparatus suitable for supplying an explosive mixture of air and fuel gas to the burner discharge orifices of a surface combustion furnace which shall have a comparatively high efficiency and give a greater range of mixture supply pressure with resulting increased range of variation in the amount of mixture that may be supplied and discharged through a given area of burner discharge orifice or orifices. The invention is not, however, limited in its application to apparatus for such purpose, but is generally applicable to jet apparatus for supplying a mixture of gases formed by the energy of a jet of the gas which forms a minor constituent of the mixture, and it is also not limited in its application to conditions which call for variation in the quantity of mixture supplied under a given available pressure of the driving gas, or which call for maintenance of proportions in the mixture under variations in the quantity of mixture supplied.

Obviously the driving gas and the driven gas need not be gases of different kinds, and the expression "mixture of gases" as used herein would include a mixture of different portions of gas of the same kind but drawn from different sources.

When a jet of gas is discharged at high velocity into the entrance cone of an ordinary Venturi tube having a throat or critical cross-section of negligible length, to the entrance cone of which other gas has access, and the throat being of sufficient size for the production of a mixture containing an amount of the driven gas equal to several times that of the driving gas, the flow velocity at and near the axis of the throat is so greatly in excess of the velocity at and near its side walls as to greatly interfere with the building up of pressure in the discharge cone of the Venturi tube, and unless the discharge nozzle of the driving gas is set back a suitable distance from the entrance cone of the Venturi tube, the drawing in of the desired proportionate amount of the driven gas will not be attained. Satisfactory operation of such an apparatus, but with comparatively low efficiency, may be secured by setting the driving gas nozzle back from the Venturi throat sufficiently to permit such an amount of the driven gas to be entrained by

the open jet of the driving gas that the moving stream or jet entering the entrance cone of the venturi will contain a substantial portion of the whole proportionate amount of driven gas desired in the mixture. But even with such an arrangement, the velocity of the central portion of the stream passing from the Venturi throat into the discharge cone is so much greater than the velocity at the outer portions thereof, that the efficiency of the apparatus in changing the velocity energy of the gaseous mixture back into pressure energy is comparatively very low. The entraining or inducing efficiency is also low, and the arrangement also has other disadvantages.

To get the most efficient transformation of velocity energy into pressure energy in the expanding or discharge cone of the Venturi tube, it is necessary to have as near as possible a uniform velocity across the stream of gas at the point where such transformation begins. I have found that by suitably elongating the throat or portion of minimum cross-section of the Venturi tube of a jet mixture supply apparatus, the pressures across the stream of mixed gases may be substantially equalized, the core of the stream giving up some of its velocity to the peripheral portions, and the stream then passing from the throat into the discharge cone with the velocities of its inner and outer portions so nearly equalized that a comparatively high efficiency in transforming velocity energy of the stream into pressure energy is obtained. Furthermore, the elongated throat has the effect of increasing the entraining or driving action of the driving jet, so that the general efficiency of the apparatus in supplying under desired pressures a mixture containing a proportionate amount of entrained gas equal to several times the amount of the entraining or driving gas is very much greater than that of the ordinary jet inspiring device having a Venturi throat of negligible length. The efficiency of the apparatus varies substantially inversely as the ratio of the entrained to the entraining gas, and this ratio depends practically on the relative size of the jet nozzle to the Venturi throat cross-section, and also depends on the relative size of the orifice or orifices through which the mixture is discharged and the pressure against which the mixture is discharged.

In supplying an explosive mixture of fuel gas and air to the burners of a surface combustion furnace, it is, as before pointed out, necessary that the mixture supply pressure be maintained above a predetermined minimum in order that the mixture shall be discharged through the burner orifices with a velocity in excess of the rate of propagation of inflammation through the mixture so as to prevent back flashing, and it is desirable

that the quantity of mixture supplied may be varied at will without changing the proportions of the constituent gases. With a jet apparatus made in accordance with the present invention, an explosive mixture of fuel gas and air, that is, a mixture which with ordinary city gas should contain usually from $5\frac{1}{2}$ to 6 parts of air to one of gas, may be supplied to a surface combustion furnace at the required pressure through a comparatively wide range of quantity control with the gas supplied to the apparatus at a pressure of, say, 10 pounds, for example. In order that proportions of the constituent gases in the mixture may be maintained approximately constant under variations in quantity of mixture supplied, the entrained gas, that is, air in the particular case under consideration, should be supplied under a pressure approximately equal to the furnace pressure or the pressure against which the mixture is discharged from the burner orifices. This condition is met by drawing the air for the mixture direct from the surrounding atmosphere when the furnace pressure is approximately atmospheric pressure. Furthermore, the flow of the air into the Venturi throat and the flow of the mixture should most desirably be controlled by orifices having approximately constant coefficients of discharge, and there should be no, or substantially no, dead flow resistance between the controlling orifices. In such apparatus for supplying an explosive mixture to a surface combustion furnace the aggregate area of the discharge nozzles or burner orifices should of course bear a suitable relation to the area of the Venturi throat, that is, the area of the discharge orifice or orifices should be small enough so that the proper or necessary pressure may be built up in the mixture flowing through the pressure cone of the Venturi tube, while yet being large enough so that there may be a sufficiently low pressure and correspondingly low resistance to flow in the Venturi throat for the desired proportionate flow of air to take place. With an apparatus made in accordance with the present invention, the aggregate burner discharge orifice area may be substantially smaller than is practicable with an apparatus in which the Venturi throat is of negligible length.

By the term "surface combustion" as used herein is meant the combustion of an explosive gaseous mixture which is supplied at a velocity in excess of the rate of propagation of inflammation through the mixture so as to prevent back-flashing through the supply nozzle or orifice, the mixture being then caused to spread out with rapid increase of its stream cross-section and consequent reduction of its flow velocity, and combustion taking place in a zone or surface at which the flow velocity of the mixture is

equal to its rate of propagation of inflammation. Such surface combustion is disclosed in U. S. Letters Patent of Dr. Charles E. Lucke, among which may be mentioned
 5 No. 755,376, dated March 22, 1904, and No. 1,146,724, dated July 13, 1915. While apparatus embodying the present invention is especially adapted for supplying explosive gaseous mixture for surface combustion furnaces, yet as before pointed out the invention
 10 is not to be considered as limited to such use or such apparatus, but it is to be understood that the invention is intended for and is capable of use generally for supplying
 15 gaseous mixtures under pressure, and especially where the amount of the driven gas in the mixture is substantially in excess of the amount of the driving gas.

A full understanding of the invention can
 20 best be given by a detailed description of an approved form of apparatus embodying all the features of the invention, and such a description will now be given in connection with the accompanying drawings showing
 25 such an apparatus for supplying an explosive mixture of fuel gas and air to a surface combustion furnace, and in which—

Figure 1 is a plan view of the apparatus and of part of the furnace to which the apparatus is attached;

Fig. 2 is a sectional view on a larger scale of the jet mixing and proportioning device;

Fig. 3 is a view in elevation looking in the direction of the arrow 3 of Fig. 2;

35 Fig. 4 is a broken sectional view of a part of the furnace taken on line 4—4 of Fig. 1 and showing one of the burner tubes in section; and

Figs. 5 and 6 are sectional views of modified forms of the Venturi tube of the apparatus.

Referring to the drawings, the fuel gas which is to serve as the driving or inducing or entraining gas is supplied under a suitable pressure from a source of supply such as a high pressure distribution main, being supplied through a supply pipe 10 to a chamber 11, an adjustable restriction or valve 12 being provided in the supply pipe
 50 for controlling the supply of gas to the chamber 11 and the pressure maintained therein. The gas chamber 11 is formed in an extension of the inspirator body or casing 13 which also provides an air chamber
 55 14 separated from the gas chamber by a partition and connected therewith by a gas discharge orifice 15. Air enters the chamber 14 through inlet opening 16 and the apparatus is provided with means for closing
 60 these openings and for adjusting the effective size thereof for the purpose hereinafter explained.

The Venturi tube 20 is mounted with its entrance cone 21 opening into the air chamber 14 in position to receive the jet of gas

issuing from the gas orifice 15, and the end of the discharge or pressure cone 22 of the Venturi tube is connected to supply the mixture to the mixture discharge orifices of the burner nozzles. The entrance end of the
 70 Venturi tube most desirably extends into the air chamber to a point beyond the air inlet openings 16 so as to provide a space about the tube to insure an even flow of air into the entrance cone of the tube without other
 75 means for baffling the air to insure such even flow. The tube may be of any suitable construction, but when of the shape here shown is most desirably formed of a single casting of metal or other suitable material,
 80 and it is conveniently cast with a shouldered flange at a suitable distance from its inner end formed to set in an opening in the end wall of the body casing 13, the tube being
 85 removably secured in position as by tap bolts as shown. I find that if in casting such a tube care is taken to have a smooth core no finishing of the inner surface of the tube is necessary.

The entrance cone and the expanding portion forming the discharge or pressure cone are or may be of usual form, care being taken, however, that these parts shall be of suitable limited angles between their sides, when, as in the apparatus shown, approximately constant proportions of fuel gas and
 95 air in the mixture are to be maintained under variations in quantity of mixture delivered, and also in order that the energy of the driving gas may be most efficiently employed
 100 to supply the mixture under desired pressure. If the angle between the sides of the discharge cone of the tube is too great, an efficient transformation of velocity energy into pressure energy is not secured, and
 105 furthermore the presence of eddy currents is liable to interfere with the maintenance of constant proportions of the constituent gases in the mixture. On the other hand, too small an angle would mean an excessive
 110 length of the cone and involve excessive friction losses. An angle of 10° between the sides of the discharge cone has been found to work well under usual conditions of operation.
 115

If the included angle between the walls of the entrance cone 21 is too large, the first part of the elongated throat of the tube will not be properly filled with the entering air and eddy currents will result, interfering
 120 with the desired entraining and inducing action and with the maintaining of proportionality under variations in quantity of mixture flowing. To avoid this condition the angle between the sides of the entrance
 125 cone and the formation of the cone should for best results be such that its coefficient of discharge will be approximately constant within the working range of flow rates, and desirably this coefficient should be 100 per
 130

cent. This angle may be varied considerably without bad results but should not be so small as to cause the entering air to encounter excessive friction in reaching the throat. A comparatively short entrance is sufficient and desirable and a length equal to or even somewhat less than the diameter of the throat has been found to work well.

The Venturi tube should therefore have its entrance and discharge cones of such limited angles that the air and gas will hug the sides of the discharge cone and maintain the position of the limit of minimum jet cross-section stationary in the throat of the tube, and that the desired rise in pressure will be developed and the necessary change of velocity energy back into pressure energy effected without excessive friction losses.

The throat or portion 23 of smallest cross-section of the Venturi tube instead of being of negligible length is elongated and made of a length which is great as compared to its diameter. Without such an elongated throat the comparatively fast flowing central portion or core of the jet of gas and entrained air tends to drive through the central portion of the throat and into the pressure cone with the portions of the stream nearer the walls moving much more slowly, so that an efficient building up of pressure in the pressure cone is impossible. The elongated throat which I provide serves as a means for equalizing the flow velocity across the stream of mixture and causing the stream to enter the pressure cone with such an approximation to uniform velocity in all its parts that an efficient transformation of velocity energy into pressure energy in the pressure cone is secured. With such a throat the jet nozzle need not be so set back from the entrance cone of the tube as has been necessary with tubes having throats of negligible length. A greatly increased entraining or driving action is also secured, such increased entraining or driving efficiency being probably due to the fact that with the driving jet inclosed by the elongated throat the losses due to eddy currents which occur when the jet passes as an open jet across an intervening space from the nozzle to the Venturi tube are substantially eliminated, and that in addition to the frictional entrainment of air there is a substantial entraining or driving action due to induction. The elongated throat thus acts both as a velocity equalizing tube and as an entraining tube.

The exact length of the velocity equalizing and entraining throat of the Venturi tube may vary considerably without losing all benefits which it imparts to the apparatus, and the best length for any given throat diameter will vary somewhat according to the shape of the tube and the form, size and relative positions of other parts

and the use to be made of the apparatus. With a size Number 47 Morse twist drill nozzle which is .0785 inches in diameter, discharging gas under a pressure of 10 pounds per square inch into a Venturi tube having an entrance cone of the form shown and a throat of uniform $\frac{3}{8}$ " diameter throughout its length, that is, one having its sides parallel, as shown by Fig. 5, the nozzle being set close to the entrance end of the tube as shown, it has been found that a length of 5 inches or 8 diameters, gives the maximum amount of air passing with a substantial equalization of the flow velocity, and therefore gives the best condition for transforming the velocity energy back to the maximum pressure energy in the pressure cone without limiting the proportionate amount of air in the mixture. A shorter throat does not give such good equalization of velocities, and with increase in the length of the throat the aggregate velocity and consequently the amount of air passed decreases.

The throat need not have its sides exactly parallel. It may for example have its sides parallel for a portion of its length and then slightly divergent as shown in Fig. 2, or it may, as a further example, have its sides slightly diverging throughout its length as shown by Fig. 6. In all cases, however, the walls of the throat should extend at an angle to the tube axis substantially less than the angle to the tube axis of the walls of the discharge or pressure cone. The walls of the throat may be considered as in all cases extending at an angle to the tube axis which is substantially less than the angle to the tube axis of the walls of the pressure cone and which may vary from zero to the maximum less than the angle to the tube axis of the walls of the pressure cone. In practice I find that the angle of the walls of the throat to the tube axis should not exceed about $2\frac{1}{2}^\circ$ and the best results are secured as this angle approaches zero.

Manufacturing considerations have led to the use of a throat of the form shown in Fig. 2, the sides of which extend at zero angle to the tube axis, or which is of uniform diameter, for a portion of its length and the sides of which then diverge slightly, merging, it may be more or less abruptly, into the side walls of the pressure cone. With such a throat there may be no definite line of junction of the throat and the pressure cone. Manufacturing considerations and reliability in operation also make it more desirable to use a single throat with each jet nozzle rather than a compound throat comprising two or more throats of increasing size arranged tandem, one discharging into another. While, therefore, I do not wish in protecting the invention to be limited exactly as to the angle to the tube axis of the sides of the elongated throat, or to the use

of a single throat, I intend to claim specifically in this application apparatus having a single elongated entraining and velocity equalizing throat, the sides of which extend at zero angle to the tube axis, that is, which is of uniform diameter, throughout at least a substantial portion of its length.

The gas orifice 15 should be of such form as to give the gas jet as much velocity energy as possible, and should, therefore, have a suitably rounded entrance followed by a straight or approximately straight run of a length equal to or somewhat greater than its diameter, that is, sufficient to properly direct and form the jet. For convenience in manufacture and in order to permit ready change of the gas orifice as desired, a removable nozzle piece 25 is provided secured in position by being threaded to screw into a tapped hole in the partition between the gas chamber and the air chamber, the nozzle being provided most desirably with a removable tip 26. The wall of the gas chamber opposite the partition wall is formed with an opening through which access may be readily had for setting or removing the gas nozzle, this opening being normally closed as by means of a cap piece 27 held in place by a screw extending through a yoke 28.

The gas nozzle should for best results be set with its extreme tip end close to, and most desirably approximately in the plane of, the end of the entrance cone of the Venturi tube, as shown, so that, the nozzle orifice being of suitable relative size, the driving jet at the point of entrance into the throat will have a cross-area which is only a fractional part of the cross-area of the throat. When so set close to the end of the Venturi tube, the outside of the nozzle and of its tip should be formed so as not to interfere with the flow of air into the Venturi tube, that is, the nozzle should project sufficiently into the air chamber to permit the entrance end of the Venturi tube to be set off from the partition wall between the air and gas chambers sufficiently for free flow of air into the Venturi tube, and the nozzle should be of such external size and shape as not to interfere with such flow.

The relative size or cross-area of the nozzle orifice and of the Venturi throat will vary according to the proportions of driving and driven gases in the mixture to be produced, increase in the proportion of the driving gas requiring a larger nozzle orifice, and vice versa. For producing and supplying under suitable pressure to a surface combustion furnace an explosive mixture of air and fuel gas in the proportion of about $5\frac{1}{2}$ to 1, with the Venturi throat of the form shown in Fig. 2, the area of the throat should be from 50 to 100 times that of the nozzle orifice. The exact relative areas will be determined by other conditions and espe-

cially the aggregate burner discharge orifice area. I have found it best to use a No. 47 Morse twist drill nozzle with a Venturi tube having an elongated throat $\frac{5}{8}$ " in diameter for supplying burners having an aggregate discharge orifice area equal to about $1\frac{1}{2}$ of the area of the Venturi throat.

In an apparatus such as shown for supplying an explosive mixture of fuel gas and air, the relative size of the gas orifice will thus vary according to the character of the fuel gas to be used, the richer the gas the smaller the orifice, and vice versa. Change in mixture proportions may thus be accomplished by changing the area of the gas orifice, this being readily accomplished in the construction shown by changing the nozzle tip. Slight variations or adjustment of proportions is most conveniently effected, however, by controlling the supply of air to the air chamber 14, and for this purpose in the construction shown a shutter 30 which is adapted to open and close the air inlet openings or ports 16 has adjustably connected to it a plate 31 by which the size of the shutter openings may be varied. The ports 16 are of such size relatively to the Venturi throat that when they are fully open approximately full atmospheric pressure will be maintained in the air chamber. When, however, the plate 31 is adjusted to partly close the shutter openings, the flow of air into the air chamber is restricted and the pressure in the air chamber lowered and a smaller proportionate amount of air enters the Venturi throat with the gas. A limited adjustment of proportions may be effected by such means without substantially affecting the maintenance of proportions under variations in the amount of mixture supplied within the usual working range of the apparatus. In order to prevent back draft from the furnace chamber through the inspirator when the gas is shut off, the shutter 30 may be connected by a link 32 to the handle of a shut-off valve 33 in the supply pipe 10 so that when the gas is shut off the air inlets 16 will also be closed.

The inspiring apparatus is shown in Fig. 1 as connected to supply a plurality of burner nozzles or mixture discharge tubes 40 of an impact-jet surface combustion furnace for burning explosive gaseous mixtures according to the method of U. S. Patent No. 1,146,724, granted July 13, 1915 on an application of Dr. Charles E. Lucke. The furnace, a broken section of which is shown by Fig. 4, comprises a structure providing a furnace chamber 41 provided with a porous and permeable combustion supporting bed 42 of refractory material against which jets of the explosive mixture are directed from the nozzles 40 set in the furnace wall 43. The jet of mixture, moving with a velocity in excess of the rate of propagation of in-

flammation of the mixture, strikes against the combustion bed, the mixture being thereby deflected and caused to spread out with rapid loss of flow velocity and burning at the surface of or within the bed as described in said patent.

In order that the proportionality of the mixture may be maintained under variations in the quantity supplied, each of the burner nozzles is formed with a discharge orifice of substantially constant coefficient form, and the connecting passages between such orifices and the Venturi tube, that is, the passages through the burner nozzles and the connecting piping, are of such relatively large size that there will be no or substantially no pipe resistance to affect the flow of the mixture. The flow of air and gas into the Venturi tube and the flow of the mixture will thus be controlled according to the flow law of orifices, and whatever velocity and pressure changes take place will be according to the flow law of orifices and not by reason of pipe, bend or eddy current losses.

In the operation of the furnace, the development of back pressure resulting from the heating of the mixture in the burner nozzle through the nozzles becoming highly heated, would, in the absence of some means for compensating for the increase in back pressure, cause a change in the proportions of gas and air in the mixture, since the increase in back pressure by increasing the pressure in the expansion cone of the Venturi tube would result in a reduction of the flow velocity through the Venturi throat and a reduction in the proportionate amount of air entering the Venturi tube. Such heating of the mixture in the burner nozzle also reduces the amount of mixture flowing from the nozzle under the available pressure. Such undesirable results are best avoided by using burner nozzles having an approximately constant pressure-capacity characteristic, this characteristic of the nozzles being secured by forming the nozzles so that the walls of the discharge passage shall be prevented from becoming excessively heated in operation. Such a nozzle is more fully described in U. S. Patent No. 1,242,114, granted October 2, 1917, on an application of Richardson, Eddison and Read. This is accomplished in the burner nozzle shown in the drawings by having the nozzle formed and set in the furnace wall so that only a small portion of the end or nose of the nozzle is exposed to the furnace heat, the balance thereof being protected by the surrounding wall of poor heat conducting material, and by forming the nozzle of the body of metal of sufficient continuous mass to rapidly conduct away to the outer portions of the nozzle body or tube such heat as is absorbed by the exposed nose of the nozzle, and by forming or providing the outer end of the nozzle tube with means

for discharging the heat, such as the heat dissipating fins or plates 45.

The high efficiency of the apparatus in entraining and pressure building gives considerable latitude with regard to the aggregate burner discharge orifice area which may be employed with a given throat area of the Venturi tube. Of course the area of the burner discharge orifice must not be so great as to prevent the building up of the necessary mixture pressure for causing the required excess velocity of discharge from the nozzle, or as to unduly limit the range of quantity control, and on the other hand, the burner discharge orifice area must not be so small as to prevent sufficient pressure reduction at the Venturi throat and cause too great a resistance to flow in the throat for the desired proportionate flow of air to take place. The aggregate burner discharge orifice area will, however, always be quite definitely related to the orifice area of the gas jet nozzle, since for determining proportions in the mixture the principal governing factor within the limits imposed by a given throat size is the area of the gas nozzle orifice against the aggregate burner discharge orifice area. For example, in the apparatus the dimensions of parts of which are given on page 5, the ratio of the burner discharge orifice area to the orifice area of the gas jet nozzle is approximately 100 to 1. Increasing the size of the gas nozzle orifice or decreasing the aggregate burner orifice area increases the proportionate amount of fuel gas, or driving gas, in the mixture, and decreasing the size of the gas nozzle orifice or increasing the aggregate burner discharge orifice area decreases the richness of the mixture, or the amount of driving gas in the mixture. I have already given an example of the relative proportions which I employ in apparatus such as shown for supplying an explosive mixture of fuel gas and air to an impact-jet surface combustion furnace.

In the operation of the apparatus, the gas being under a suitable pressure and the apparatus being adjusted to secure the desired proportions for any flow rate, then the amount of mixture supplied may be varied as desired within the working limits of the apparatus simply by adjusting the gas control valve 12. With the opening and closing of the gas control valve, permitting more or less gas to flow, the air flow into the Venturi tube increases and decreases proportionately, and the final delivery pressure of the mixture to the burner orifices rises and falls correspondingly, the quantity of mixture discharged from the burner orifices thus being varied but the proportionality of the mixture being maintained approximately constant.

The term "orifice" as used in the claims is to be understood to mean an opening which

is restricted as compared to the adjacent flow passage or space and so formed as to control the flow of gas therethrough according to the typical flow law of orifices

5 ($V=C\sqrt{2gh}$), true when the pressure or head h is not too large, and an orifice having a constant coefficient, or a constant coefficient orifice, is to be understood as an orifice the coefficient of discharge of which is approxi-
10 mately constant within the normal working range of the apparatus, or for which the area of the contracted vein of the jet is itself constant. It is desirable that the co-
15 efficient of the orifices controlling the flow of air and of the mixture should be approximately 100%. It may be pointed out that the air inlet ports as varied in size by ad-
20 justment of the shutter plate 31 act as constant coefficient orifices under the low head under which the air passes therethrough.

Subject matter disclosed but not claimed herein is claimed in my co-pending applica-
25 tions Serial No. 130,887, filed November 11, 1916, and Serial No. 174,818, filed June 14, 1917.

What is claimed is:

1. Jet apparatus for supplying a mixture of gases, comprising a nozzle for discharg-
30 ing a high velocity jet of the driving gas, an elongated and smooth-walled entraining and velocity-equalizing tube into which the jet of gas is discharged, the sides of said tube being approximately parallel and the length thereof being sufficient to substantially
35 equalize the velocities across the stream, and means for transforming velocity energy of the stream of gases from said tube into pressure energy, the nozzle being so formed and so located that the cross-area of the
40 jet at the point of entrance into said tube shall be only a fractional part of the cross-area of the tube.

2. Jet apparatus for supplying a mixture of gases, comprising means for supplying one
45 of the gases under pressure to serve as the driving gas, means providing an orifice for discharging a high velocity jet of said gas, an elongated and smooth-walled entraining and velocity-equalizing tube into which the
50 jet of gas is discharged, the cross-area of said tube being many times greater than the cross-area of said orifice and the orifice being so close to the end of the tube that the jet at the point of entrance into the tube
55 will have a cross-area which is only a fractional part of the cross-area of the tube, the sides of said tube being approximately parallel and its length being equal to several times its diameter, whereby the flow veloc-
60 ity across the stream of gases is substantially equalized, and a pressure cone for transforming velocity energy of the stream of gases from said tube into pressure en-
65 ergy.

3. Jet apparatus for supplying a mixture

of gases, comprising a Venturi tube, and means providing an orifice for discharging into the Venturi tube in the direction of flow through the tube a high velocity driv-
70 ing jet of gas having at the point of entrance into the throat of the Venturi tube a cross-area which is small compared to the cross-area of the throat, the Venturi tube having between its entrance cone and its
75 pressure cone an elongated smooth-walled entraining and velocity-equalizing throat the sides of which are approximately parallel and the length of which is equal to several times its diameter, whereby the flow
80 velocity across the stream of gases is substantially equalized.

4. Jet apparatus for supplying a mixture of gases, comprising a Venturi tube, and means for directing into the Venturi tube in the direction of flow through the tube a
85 high velocity jet of gas which is to serve as the driving gas having at the point of entrance into the throat of the Venturi tube a cross-area which is small as compared to the cross-area of the throat, the Venturi
90 tube having between its entrance cone and its pressure cone a smooth-walled elongated entraining and velocity-equalizing throat the length of which is several times its di-
95 ameter and the walls of which extend at an angle to the tube axis less than the angle to the tube axis of the walls of the pressure cone, whereby the flow velocity across the stream of gases is substantially equalized.

5. Jet apparatus for supplying a mixture
100 of gases, comprising a Venturi tube, and means for discharging into the Venturi tube in the direction of flow through the tube a high velocity jet of the gas which is to serve as the driving gas having at the point of en-
105 trance into the throat of the Venturi tube a cross-area which is small as compared to the cross-area of the throat, the Venturi tube having between its entrance cone and its pressure cone a smooth-walled elongated
110 entraining and velocity-equalizing throat the walls of which extend at zero angle to the tube axis from the entrance cone for a distance which is great compared to the di-
115 ameter of the throat, whereby the flow velocity across the stream of gases is substan-
tially equalized.

6. Jet apparatus for supplying a mixture of gases, comprising a Venturi tube, and means for directing into the Venturi tube
120 in the direction of flow through the tube a high velocity jet of the gas which is to serve as the driving gas having at the point of entrance into the throat of the Venturi tube a cross-area which is small as compared to
125 the cross-area of the throat, the Venturi tube having between its entrance cone and its pressure cone a smooth walled elongated entraining and velocity-equalizing throat, the length of the throat being several times
130

its diameter and its walls extending from the entrance cone for a substantial portion of its length at zero angle to the tube axis and thereafter diverging at an angle which is less than the angle of divergence of the walls of the pressure cone, whereby the flow velocity across the stream of gases is substantially equalized.

7. Jet apparatus for supplying a mixture of gases, comprising a Venturi tube, and means for directing into the Venturi tube in the direction of flow through the tube a high velocity jet of the gas which is to serve as the driving gas having at the point of entrance into the throat of the Venturi tube a cross-area which is small as compared to the cross-area of the throat of the Venturi tube, the Venturi tube having between its entrance cone and its pressure cone a smooth-walled elongated entraining and velocity equalizing throat the length of which is several times its diameter and which is of uniform diameter throughout at least a substantial portion of its length, whereby the flow velocity across the stream of gases is substantially equalized.

8. Jet apparatus for supplying a mixture of gases, comprising a Venturi tube, and a nozzle set with its tip approximately at the plane of the end of the entrance cone of the Venturi tube to discharge a high velocity jet of the driving gas into the Venturi tube in the direction of flow through the tube, the cross-area of the nozzle orifice being small as compared to the cross-area of the throat of the Venturi tube, and the Venturi tube having between its entrance cone and its pressure cone a smooth-walled elongated entraining and velocity equalizing throat the length of which is equal to several times its diameter and the walls of which extend at an angle to the tube axis less than the angle to the tube axis of the walls of the pressure cone, whereby the flow velocity across the stream of gases is substantially equalized.

9. Jet apparatus for supplying a mixture of gases, comprising a Venturi tube, and a nozzle set to discharge a high velocity jet of the driving gas into the Venturi tube in the direction of flow through the tube, the Venturi tube having between its entrance cone and its pressure cone a smooth-walled elongated entraining and velocity-equalizing throat the length of which is equal to several times its diameter and the walls of which extend at an angle to the tube axis less than the angle to the tube axis of the walls of the pressure cone, whereby the flow velocity across the stream of gases is substantially equalized, the cross-area of said throat being many times greater than the cross-area of the nozzle orifice, and the nozzle being set with its tip so close to the end of the throat that the high velocity jet

at the point of entrance into the throat will have a cross-area which is only a fractional part of the cross-area of the throat.

10. Jet apparatus for supplying a mixture of gases, comprising means forming a supply chamber, a Venturi tube having its entrance end projecting into said chamber and provided with a short entrance cone, a nozzle extending from the chamber wall opposite the end of the Venturi tube in position to discharge a high velocity jet of gas into the Venturi tube, the cross-area of the nozzle orifice being small as compared to the cross-area of the throat of the Venturi tube and the nozzle being set with its tip so close to the end of the throat that the cross-area of the jet as it enters the throat shall be small as compared to the cross-area of the throat, means for supplying gas under pressure to said nozzle, and means providing a flow controlling orifice for supplying another gas to said chamber, the Venturi tube having between its entrance cone and its pressure cone an elongated entraining and velocity-equalizing throat the walls of which extend at an angle to the tube axis less than the angle to the tube axis of the walls of the pressure cone and the length of which is sufficient to substantially equalize the velocity across the stream of gases flowing therethrough.

11. Jet apparatus for supplying a mixture of gases in approximately constant proportions, comprising a Venturi tube, means for discharging into the entrance cone of the Venturi tube in the direction of flow through the tube a high velocity jet of the gas which is to serve as the driving gas having at the point of entrance into the throat of the Venturi tube a cross-area which is only a fractional part of the cross-area of the throat, means comprising an inlet orifice for supplying another gas to the entrance cone of the Venturi tube, means providing a flow controlling orifice for controlling the flow of the gaseous mixture received from the Venturi tube, means for varying the supply of the driving gas in order to vary the quantity of the mixture produced, and means for varying the size of said inlet orifice for varying the proportions of the gases in the mixture, the Venturi tube having between its entrance cone and its pressure cone an elongated velocity equalizing throat the length of which is equal to several times its diameter and the walls of which extend at an angle to the tube axis less than the angle to the tube axis of the walls of the pressure cone, whereby the flow velocity across the stream of gases is substantially equalized.

12. Apparatus for supplying and burning an explosive mixture of fuel gas and air in approximately constant proportions, comprising a Venturi tube, means for supply-

ing the fuel gas under pressure to serve as the driving gas, a nozzle set to discharge into the Venturi tube in the direction of flow through the tube a high velocity jet of the fuel gas having at the point of entrance into the throat of the Venturi tube a cross-area which is only a fractional part of the cross-area of the throat, an inlet orifice for supplying air to the entrance cone of the Venturi tube from a source of supply under pressure substantially equal to the pressure against which the mixture is discharged, a burner nozzle through which the mixture is discharged to be burned, said burner nozzle being formed to control the flow of the mixture according to the flow law of orifices having constant co-efficients, and a connecting passage between the orifice of the burner nozzle and the Venturi tube formed and proportioned to avoid pipe, bend and eddy losses, the Venturi tube having its entrance cone and its pressure cone of such limited angles that the air and gas will hug the sides of the tube, and having an elongated velocity-equalizing throat between its entrance cone and its pressure cone the length of which is several times its diameter and the walls of which extend at an angle to the tube axis less than the angle of the tube axis of the walls of the pressure cone, whereby the flow velocity across the stream of gases is substantially equalized.

13. Apparatus for producing and burning an explosive gaseous mixture of fuel gas and air in approximately constant proportions, comprising means providing an air chamber, a Venturi tube set with its entrance cone open to the air chamber, means for supplying the fuel gas under pressure to serve as the driving gas, a nozzle extending into the air chamber and set to discharge into the entrance end of the Venturi tube in the direction of flow through the tube a high velocity jet of the fuel gas having at the point of entrance into the throat of the Venturi tube a cross-area which is only a fractional part of the cross-area of the throat, an inlet orifice for admitting air under atmospheric pressure to the air chamber, adjusting means for varying the size of said inlet orifice to vary the

proportions of fuel gas and air in the mixture, a burner nozzle through which the mixture is discharged to be burned, said burner nozzle being formed to control the flow of the mixture according to the flow law of orifices having constant coefficients, and a connecting passage between the orifice of the burner nozzle and the Venturi tube formed and proportioned to avoid pipe, bend and eddy losses, the Venturi tube having between its entrance cone and its pressure cone an elongated velocity equalizing throat the length of which is equal to several times its diameter and the walls of which extend at an angle to the tube axis less than the angle to the tube axis of the walls of the pressure cone, whereby flow velocity across the stream of gases is substantially equalized.

14. Apparatus for producing and burning an explosive mixture of fuel gas and air, comprising means for supplying the fuel gas under pressure to serve as the driving gas, a nozzle for discharging a high velocity jet of said gas, an entraining and velocity-equalizing tube into which the jet of gas is discharged, the cross-area of said tube being many times greater than the cross-area of the nozzle orifice and the nozzle being set with its tip so close to the end of the tube that the high velocity jet at the point of entrance into the tube will have a cross-area which is only a fractional part of the cross-area of the tube, and the sides of said tube being approximately parallel and its length being sufficient to substantially equalize the velocities across the stream, a pressure cone for transforming energy of the stream of gases from said tube into pressure energy, and a burner nozzle having a restricted orifice to which the gaseous mixture is supplied from said pressure cone and through which the mixture is discharged to be burned.

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

W. BARTON EDDISON.

Witnesses:

H. F. WHITE,

JOHN H. BARTLETT, Jr.