This invention relates to the regulation of desired characteristics of heating flames, particularly flames produced by the combustion of a mixture of fuel gas and oxidizing gas, such as oxygen and acetylene, and used in seam welding operations or stationary welding operations, such as bronze welding and pressure welding, wherein the metal is brought up to the desired temperature quickly and then held at substantially that temperature for a heat soaking period. This invention also relates to apparatus for effecting such regulation. This invention particularly relates to the regulation of such flames wherein desired characteristics—such as the flame temperature, available heat, velocity of the flame jet, and rate of flame propagation, all of which affect the heating effect of the flame or rate of transfer of heat from the flame to a workpiece—are varied. Other characteristics—as the relative length of the inner cone, distance between the end of the inner cone and the surface of the work or contact area of the inner cone, and the ratio between oxygen and fuel gas in the combustible mixture (which affects the chemical activity between the flame and the material being heated)—are maintained substantially constant.

The amount of heat transferred, or B. t. u., absorbed by the workpiece, is dependent on the total available B. t. u. and the efficiency of heat transfer. The total available B. t. u. may be altered by varying the quantity or type of constituents of the flame. The efficiency of heat transfer may be altered by varying the temperature of the flame, the velocity of the flame jet, and the rate of flame propagation. To maintain the maximum effectiveness of the heating operation, it is desirable that the spacing between the blowpipe and the surface of the workpiece shall be maintained substantially constant, that the length of the inner cone of the flame shall be maintained substantially constant, that the character of the flame, i. e., neutral, oxidizing, or carburizing shall be maintained substantially constant or varied only as necessary, and, in some instances, that a blowpipe or equivalent flame producing means shall be moved across a workpiece at a substantially constant speed. Thus, an object of this invention is to provide a novel method of and apparatus for heating flame regulation, whereby the heating effect of the flame, or the amount of heat transferred to the workpiece, may be varied as desired without substantially impairing the effectiveness or facility with which the heating operation can be carried out, i. e., without changing the length of the inner cone or the separation of the blowpipe and the work or the rate of relative travel of the work.

Among other objects of this invention are to provide a novel method of controlling the rate of heat transfer from a flame to a workpiece; to provide a novel method of varying the temperature or other desired characteristics of a heating flame without varying the length of the inner cone of the flame, and without altering a desired carburizing or oxidizing effect of the flame, or without altering the chemical character of the flame from neutral, when the same is to be maintained; to provide such a method wherein the tendency for flashbacks is minimized; to provide such a method by which a surface area may be heated relatively quickly to a desired temperature and that temperature maintained without the danger of overheating the surface of the work; to provide apparatus for carrying out the above method; and to provide such apparatus which may be made substantially automatic in operation, and also may be made to respond to variations in heating conditions at the surface of the workpiece. Other objects and novel features of this invention will become apparent from the following description and accompanying drawing, in which:

Fig. 1 is a schematic illustration, partly in section, of an oxy-acetylene blowpipe, and apparatus constructed in accordance with this invention, for regulating the flame produced by the blowpipe;

Fig. 2 is a cross-section of an oxygen-air-acetylene regulator and proportioner constructed in accordance with this invention; and

Fig. 3 is a schematic illustration of constant speed strip welding apparatus, including a multi-flame oxy-acetylene blowpipe, and apparatus by which the flames produced by the blowpipe are regulated in accordance with the method of this invention.

In accordance with the method of this invention, in order to vary the heating effect of a flame, the combustible mixture forming the flame—which combustible mixture is normally formed by mixing fuel gas and an oxidizing gas having a relatively high oxygen content, preferably substantially pure oxygen—is instead formed by mixing fuel gas and an oxidizing gas mixture consisting of oxygen and oxidizing gas having a relatively low oxygen content, preferably air. The relative proportion of oxygen to air (oxygen to nitrogen) in the oxidizing gas mixture is increased when a greater heating effect is desired. At the same time, the pressure and flow of the
oxidizing gas mixture is increased proportionally, and the pressure and flow of the fuel gas is varied in accordance with the variation in oxidizing gas pressure and flow.

Also in accordance with this invention, fuel gases such as acetylene and hydrogen may be mixed with oxygen, and the pressure and flow of the acetylene regulated to vary the heating effect of the flame, the pressure and flow of oxygen being regulated in accordance with that of the acetylene. It will be evident that other fuel gases, or mixtures thereof, may be utilized, in carrying out this invention.

By the above method, the heating effect of the flame may be varied as desired, since the available heat and the temperature of the flame will vary in accordance with the relative proportion of oxygen in the oxidizing gas in accordance with the relative amount of acetylene in the fuel gas mixture, and the velocity of the flame jet will vary in accordance with the pressure of fuel gas and oxidizing gas. Not only will the length of the inner cone remain substantially constant, but also the character of the flame will remain unchanged. The latter feature is particularly important when the nature of the work requires a constant character of flame, such as carburing for certain types of welding, oxidizing for rapid heating, or neutral for other heating operations.

Apparatus for carrying out the above method and constructed in accordance with this invention, as illustrated in Fig. 1, may comprise a proportioner P for controlling the relative proportions of oxygen and air in an oxidizing gas mixture formed in a regulator R. Regulator R controls the pressure or amount of fuel gas or acetylene passing to a blowpipe B, along with the air-oxygen mixture. Regulating valves V on blowpipe B are adjusted to provide the desired initial mixture of oxygen and acetylene, or oxidizing gas and fuel gas, passing to a tip T. The initial setting of valves V is preferably maintained, since variations in temperature and heating effect of the flame are readily achieved by adjustment of proportioner P. Regulator R and proportioner P may be combined in a single casing, as in Fig. 2, in which a combined proportioner and regulator RP is illustrated.

The strip welding apparatus illustrated in Fig. 3 comprises, in general, a machine welding blowpipe M provided with a head H adapted to direct a plurality of high temperature heating flames along a welding seam on a workpiece W. The relative proportions of oxygen, acetylene, and air in the combustible mixture, forming the heating flames discharged from head H, are determined by a combined regulator and proportioner RP', which is controlled by a solenoid S. In turn, solenoid S is controlled by a photo-cell control unit C, which in turn is responsive to variations in a thermal condition of the welding seam.

The above apparatus may also be utilized in carrying out the method of this invention where-in the proportions of a fuel gas mixture are varied, and the oxygen is varied in accordance with the pressure of a fuel gas such as acetylene, as explained previously. Thus, the proportioner P of Fig. 1 may control the relative proportions of acetylene and hydrogen, for instance, while the regulator R may control the pressure and flow of oxygen in accordance with the pressure and flow of acetylene. Similarly, the combined proportioner and regulator of Fig. 2 may be supplied with acetylene, hydrogen, and oxygen; and the regulator and proportioner RP' of Fig. 3 may control the relative proportions of acetylene, hydrogen, and oxygen, to welding blowpipe M. Thus, it will be understood that oxygen and air may be replaced by acetylene and hydrogen or the like, respectively, and that acetylene or fuel gas may be replaced by other gases in the various passages, chambers, hoses, etc., of the apparatus described below.

Referring again to Fig. 1, for a more detailed description of the apparatus illustrated therein, oxygen and air are supplied through hose 5, hose 10, and hose 11, respectively, to casing 12 of the proportioner P. The oxygen flows from an inlet chamber 13 to an outlet chamber 14, such flow being controlled by a valve 15. Valve 15 is controlled by a diaphragm 16, actuated by a compression spring 17 and the differential between the pressure in oxygen outlet chamber 14 and the pressure in an air inlet chamber 18, oxygen pressure being exerted against the valve side of the diaphragm and air pressure being exerted against the opposite side of the diaphragm. The force exerted by spring 17 is adjusted by a screw 18, which may be turned down to cause spring 17 to exert a greater force against diaphragm 16 and thereby produce a higher oxygen pressure in chamber 14. This produces a corresponding increased flow of oxygen through hose 21, from chamber 14 to oxygen inlet chamber 22 of regulator R. The air pressure is normally maintained substantially constant, though, if desired, an increase or decrease in the oxygen pressure can be produced by increasing or decreasing the air pressure, due to the effect upon diaphragm 18 and consequent opening or closing of valve 18.

The air is fed from chamber 18 through a hose 23 to an air-oxygen mixing chamber 24 of regulator R. Oxygen from hose 21 passes into oxygen inlet chamber 22 and flows through a restricting orifice 25 into mixing chamber 24. From chamber 24, the oxidizing gas or air-oxygen mixture flows through a hose 26 to blowpipe B.

When the oxygen pressure in chamber 14 increases as regulated by screw 18, the oxygen pressure in chamber 22 of regulator R increases, and flow through orifice 25 proportionally increases. The resultant increasing flow of oxygen into chamber 24 causes the relative amount of oxygen therein to increase, and the proportion (and partial pressure) of oxygen in the air-oxygen mixture to increase. As the oxygen pressure (and the flow of oxygen through the orifice 25) increases, the pressure difference between the air supply line 11 and the chamber 24 decreases, reducing the flow of the air, so that a point will be reached at which very little air will be present in the chamber 24, and substantially pure oxygen will be delivered through hose 26 to blowpipe B.

When this point is reached, oxygen will back up through hose 20 and hose 26, from chamber 16 into chamber 18. As long as the oxygen pressure for passage 21 is well above the air pressure in passage 23, there will be no danger of the air pressure in the mixing chamber 24 stopping the flow of oxygen because there will still be an oxygen pressure drop across the orifice 25. This will also be the case when no air is supplied, as when the heating flame of blowpipe B is being adjusted to the desired oxy-acetylene or oxy-hydrogen fuel gas ratio by valves V at the beginning of the heating operation.

The pressure of fuel gas or acetylene flowing to the blowpipe—from an inlet hose 28 through an inlet chamber 29 in regulator R, to an outlet chamber 30 and through a hose 31 to blowpipe
The pressure of oxygen in chamber 22 is regulated in accordance with the pressure of oxygen in chamber 22. The reason the gas from the hose 28 is regulated in accordance with oxygen pressure is because in practice the fuel gas usually passes through a pressure regulator so that the fuel gas pressure is fairly constant in the system. For this purpose, a valve 32, which at all times automatically controls the flow of acetylene from chamber 28 to chamber 30, is attached to and actuated by a double diaphragm arrangement, comprising an upper diaphragm 34 and a lower diaphragm 33, the two diaphragms being connected together to move in unison. The force produced by the pressure of oxygen in chamber 22, exerted against diaphragm 33 which forms the lower wall of chamber 22, acts on open valve 32, while the force produced by the pressure of acetylene in chamber 30, exerted against diaphragm 34 which forms the upper wall of chamber 30, acts to close valve 32. Thus, the pressure and flow of acetylene is determined by the pressure and flow of oxygen, which in turn determines the pressure and flow of oxidizing gas and the proportion of oxygen in the oxidizing gas mixture.

The double diaphragm arrangement is a safety feature which assists in preventing the formation of a combustible or explosive mixture in either the oxygen or acetylene supply line, due to leakage from the other line. Vent 35 in casing 36 of the regulator provides communication between the atmosphere and the space between the diaphragms, so that if either diaphragm is ruptured, the fuel gas or oxygen, as the case may be, will escape to the atmosphere. It will be understood that the effective areas of the two diaphragms may be different, so that a change in the oxygen pressure in chamber 22 will produce a fractional proportional change in the acetylene pressure in chamber 30.

The acetylene or fuel gas and oxidizing gas mixture are mixed in the blowpipe B to form a combustible mixture, which is discharged from tip 'T' to produce a heating flame. Changes in temperature and heating effect of this flame are readily effected. Assuming that screw 10 is set for the lowest flame temperature obtainable with the setting of valves V, and it is desired to increase the heat output and effect of the flame, the screw 10 is merely turned down so that spring 17 will exert a greater force against diaphragm 18. This causes valve 15 to open to a greater extent, causes the pressure of oxygen in chamber 14 to increase, and also causes a greater amount of oxygen to flow to regulator R and the pressure in chamber 22 to increase. This results in a greater flow of oxygen through orifice 26, a displacement of air in chamber 24, an increase in the proportion of oxygen in the oxidizing gas mixture, and an increase in the pressure of the oxidizing gas mixture. At the same time, the increase in the pressure of oxygen in chamber 22 causes an increase in the pressure and flow of acetylene, with a resultant increase in the temperature and heat effect of the flame. The resultant increased rate of flame propagation is compensated by the increased velocity of the jet, due to the increased pressure of oxidizing gas and fuel gas. However, the ratio of oxygen to acetylene is kept the same, and neither the character of the flame nor the length of the inner cone of the flame will be changed. Thus, the heating effect and temperature of the flame may be varied over a wide range while maintaining the effectiveness of the heating operation. It is estimated that, by this invention, the temperature of a substantially neutral oxy-acetylene heating flame can be varied over a range extending from approximately 4000° F, to 5500° F.

Similarly, when the heating effect of the flame is regulated by varying the constituents of a fuel gas mixture, acetylene may be supplied through hose 10, hydrogen or the like through hose 11, and oxygen through hose 28. Turning down screw 18 will cause the pressure of the acetylene to increase, the relative proportion of acetylene in the fuel gas mixture to increase, and the pressure and flow of oxygen to increase. Thus, the heating effect of the flame may be increased without changing substantially the character of the flame or length of the inner cone.

The combined regulator and proportioner RP illustrated in Fig. 2, comprises a casing 29 to which an oxygen inlet pipe 48 is connected; an upper cap 41, to which an air inlet pipe 43 is connected; and a double diaphragm cap, consisting of an intermediate section 43 and a lower section 44, to which an acetylene inlet pipe 45 is connected. Oxygen passes from pipe 48 through an inlet passage 46 to a valve chamber 47, formed in casing 30. The flow of oxygen from valve chamber 47 to an oxygen chamber 48 is controlled by a valve 49, which seats against the tapered underside of an orifice 46 in a valve bushing 41. The stem of valve 49 extends through orifice 46, while bushing 41 threadedly engages casing 30, to close the upper end of valve chamber 47 and hold a sealing washer 52 against a suitable shoulder in the casing. The upper end of the stem of valve 49 is attached to a diaphragm 53, the periphery of which is clamped securely between cap 49 and cap 41 for sealing purposes. The central portion of diaphragm 53 is clamped between a pair of bearing plates 54, attached to the stem of valve 49 and provided with upturned edges to prevent rupture of the diaphragm upon flexing. Diaphragm 53 may comprise a rubber disc, as shown, or may comprise several layers of rubber or other suitable material, such as metal, synthetic rubber substitute, or canvas impregnated with rubber or the equivalent. Diaphragm 53 forms a partition between oxygen chamber 48 and an acetylene mixing chamber 55, formed principally in cap 41. Oxygen passing from chamber 48 to mixing chamber 56 through an orifice 56 in the diaphragm. Air passes into chamber 56 from inlet 42, the mixture of air and oxygen being led from chamber 56 by an outlet pipe 57, to a blowpipe or similar apparatus.

The pressure of oxygen in chamber 48 and the consequent flow of oxygen through orifice 56—which in turn determines the proportion of oxygen to air in the oxidizing gas mixture, as explained in connection with orifice 25 of the apparatus of Fig. 1—is determined by the force exerted by a relatively heavy coil spring 58 disposed in chamber 56 and bearing at its lower end against the upper diaphragm oxygen and acetylene in the combustible mixture. The resultant increased rate of flame propagation is compensated by the increased velocity of the jet, due to the increased pressure of oxidizing gas and fuel gas. However, the ratio of oxygen to acetylene is kept the same, and neither the character of the flame nor the length of the inner cone of the flame will be changed. Thus, the heating effect and temperature of the flame may be varied over a wide range while maintaining the effectiveness of the heating operation.
are proportional to the pressure and flow of oxygen. The flow of acetylene from inlet 48 to an outlet pipe 64—through an inlet passage 66 and a valve chamber 68 to a diaphragm chamber 71, and an outlet passage 89—is controlled by a valve 68, in turn connected to a double diaphragm assembly including a diaphragm 70. Oxygen pressure is exerted against diaphragm 70 in a chamber 71, formed between housing 78 and the diaphragm, the diaphragm being clamped between housing 78 and intermediate cap 43, for sealing purposes. Oxygen is led from chamber 48 to chamber 71 by a connecting passage 72, so that variations of oxygen pressure in chamber 48 will be communicated to chamber 71, and the pressure exerted against diaphragm 70 will cause the flow of acetylene to be correspondingly regulated. Acetylene valve 68 is similar to oxygen valve 48, seating against the tapered lower portion of an orifice 73 in a bushing 74 which threadedly engages lower cap 44 and clamps a gasket 75 against a shoulder formed in the cap, for sealing purposes.

Utilized principally for safety purposes, the double diaphragm arrangement includes a lower acetylene diaphragm 76, while a chamber 77, formed in intermediate cap 43 between upper oxygen diaphragm 70 and lower acetylene diaphragm 76, is vented to the atmosphere by holes 78 extending through cap 43. Should rupture of either diaphragm occur, the oxygen or acetylene, as the case may be, will be vented to the atmosphere through holes 78, instead of passing into the other line. As before, the possibility of a combustible or explosive mixture being formed in either supply line is avoided.

The upper end of chamber 67 is closed by diaphragm 76, which is clamped between intermediate cap 43 and lower cap 44. The central portions of diaphragms 70 and 76, are clamped between pairs of discs 80 and 81, respectively. The upper end of the stem of valve 69 is attached to diaphragm 76 and discs 81, while diaphragms 70 and 76 are secured together, to move in unison, by a stud 82. Also, the lower end of a spring 83 extends into a recess in bushing 74 while the upper end of the spring engages lower disc 81 at diaphragm 76.

Spring 83 compensates in part for the higher pressure at which oxygen normally is passed through the device, and for the difference in area between diaphragms 70 and 76, which difference in area is such that a change in oxygen pressure will produce a proportional but unequal change in the acetylene pressure. If desired, the area of diaphragm 76 may be made equal to or greater than the area of diaphragm 70. Also, a spring may be provided to bear against the lower end of valve 69, so that any desired relation between the oxygen pressure and the acetylene pressure may be obtained. The relative areas of diaphragms 70 and 76 and the strength of spring 83 may be varied as desired, particularly for different fuel gases.

The combined regulator and proportioner RP of Fig. 2 operates in substantially the same manner as the individual proportioner P and regulator R of Fig. 1, orifice 25 in diaphragm 84 corresponding to orifice 25 in proportioner P. Thus, tightening screw 59 causes an increase in the pressure of oxygen and relative proportion of oxygen to air in the oxidizing gas mixture, which further causes an increase in the pressure of acetylene. While the increments of pressure variation differ slightly, the principle of operation is the same. Also, when acetylene, hydrogen or the like, and oxygen are supplied through pipes 68, 70, and 48, respectively, the operation of the apparatus again corresponds to the operation of the apparatus of Fig. 1 when corresponding gases are utilized.

In the constant speed strip welding apparatus illustrated in Fig. 3, the combined proportioner and regulator RP' is similar to the combined proportioner and regulator RP of Fig. 2. Thus, oxygen, air, and acetylene are supplied thereto by hoses 69, 66, and 81, respectively. Acetylene flows to the blowpipe M through a hose 68, while the oxidizing gas mixture of oxygen and air flows to blowpipe M through a hose 66. During the welding operation, the head H and control unit C are moved at a substantially constant speed along the seam to be welded, or the work W is moved between the two at a substantially constant speed. The spacing of the head above the work and the control unit below the work are maintained substantially constant. The operation of the combined proportioner and regulator RP' is controlled by solenoid S, which is operatively connected with a spring, similar to spring 84 of the regulator and proportioner RP of Fig. 2. The amount of current passing through the solenoid S determines the pull exerted upon the core, which in turn determines the pressure of the spring and thereby causes the proportions of oxygen and air in the oxidizing gas mixture and the pressure of acetylene to vary as desired. As solenoid S is controlled by a photo-cell control unit C, responsive to thermal variations in the welding operation, the heating effect of the flame will be varied as necessary, to maintain substantially the same thermal condition at all points of the welding operation and thereby produce a uniform weld.

Photo-cell unit C comprises a photo-electric cell 90, disposed at the lower end of a tube 91 which protects the cell and also excludes thermal radiations other than those emanating from the underside of the welding seam. Photo-cell 90 is of a type responsive to variations in the radiations which reflect the thermal condition of the welding seam, and causes proportional variations in the electrical impulses passing through the photo-cell and to an amplifier 92 through wires 93. In the amplifier 92, the impulses are amplified to provide more sensitive control, the amplifier being connected with a reactor 84 by wires 85. In the reactor, the variations in impulse are imposed upon electricity passing to solenoid S through wires 86, the reactor being supplied by wires 87 from an A C supply line 88. Thus, in response to a decrease or increase in the radiations reflecting the thermal condition of the welding operation, the control unit C will cause the force exerted by solenoid S on the control spring of the combined regulator and proportioner RP' to increase or decrease, so that the heating effect of the flames discharged from head H will increase or decrease, as the case may be, to maintain substantially uniform welding conditions along the seam.

At the beginning of the welding operation, the combustible mixture preferably consists of oxygen and acetylene, valves V' being adjusted to provide heating flames having the highest temperature and greatest heating effect. After the initial portion of the seam has been heated to the desired temperature, welding takes place, thus started, the relative motion between the head H and control unit C and the workpiece W is be-
9 gun, so that the heating flames will be applied to successive portions of the seam. As the welding operation progresses, variations in the temperature and thermal condition of the weld at the point of application of the flames will be compensated for and corrected by variations in the heating effect of the flames.

Similarly, when a mixture of fuel gases rather than oxidizing gases is utilized, the combustible mixture at the beginning of the operation preferably consists of acetylene and oxygen. After the welding operation is started, and welding along the seam progresses, reductions in the heat necessary to maintain the desired thermal condition will be effected by the introduction of hydrogen into the fuel gas mixture and a decrease in the pressure and flow of acetylene and in the pressure and flow of oxygen, as controlled by solenoid S and the combined regulator and proportioner RP, in turn controlled by photo-cell unit C.

Furthermore, it will be apparent that this invention provides an efficacious and highly desirable method of and apparatus for controlling or varying characteristics of a heating flame. The method of this invention has advantages not possessed by other methods of changing the heating effect by varying the constituents of the combustible mixture. In the case of an oxy-acetylene flame, for instance, if the amount of oxygen in the combustible mixture should be decreased without varying other constituents, a neutral flame would become carburizing or an oxidizing flame would become neutral. Similarly, if the amount of acetylene is reduced sufficiently to lower the temperature and heating effect of the flame, then a neutral flame would become oxidizing or a carburizing flame would become neutral. Furthermore, if the supply of both oxygen and acetylene were reduced simultaneously without any other change in the combustible mixture, not only would the length of the inner cone be changed, but also the danger of flashbacks would be increased due to the jet velocity becoming less than the velocity of flame propagation. Flashbacks and resultant backfires sometimes result in expensive work being damaged or ruined.

Furthermore, while oxy-acetylene heating flames produced by acetylene and oxygen fuel gases have been given as specific examples in explaining this invention, it will be understood that these are only representative of many other types of heating flames and fuel gases to which this invention is applicable. Thus, the method of this invention includes regulating predetermined characteristics of a heating flame while maintaining other predetermined characteristics substantially constant, the flame being produced by a combustible mixture of fuel and oxidizing gases and at least one of the constituent gases in accordance with the pressure and flow of another of the constituent gases to increase or decrease the heating effect of the flame, the regulation of the pressure and flow of the constituent gases being such that an increase in the pressure and flow of substantially pure oxygen occurs substantially simultaneously with an increase in the pressure and flow of a fuel gas, and an increase in the pressure and flow of a fuel gas tends to increase the heating effect of the flame.

It will also be understood that the method and apparatus of this invention are useful in heating operations other than strip welding, and heating operations combined with other operations. For instance, the principles of this invention are applicable to the normalizing or softening of a relatively hard surface layer along the kerf produced by an oxygen cutting jet; the principles of this invention are applicable to the flame hardening of i.e., local heating followed by a suitable cooling or quenching step to harden the heated surface; the principles of this invention are applicable to preheating for welding, or both preheating and heating during actual welding; the principles of this invention are applicable to preheating for oxygen cutting; and the principles of this invention are applicable to many other operations involving heating, which will readily suggest themselves to those skilled in the art.

An advantage of the present invention resides in the simplicity of construction and ease of operation in being able to vary the heating effect of the blowpipe flame as desired without the mechanisms herefore required for increasing the separation between the work and the blowpipe, or changing the rate of relative travel between the work and blowpipe. This has been possible because applicant has retained the length of the inner cone of the blowpipe flame substantially constant.

What is claimed is:

1. Apparatus for regulating the heating effect of a flame produced by the combustion of fuel gas, comprising means for mixing oxidizing gas having a relatively high oxygen content and a stream of oxidizing gas having a relatively low oxygen content to form an initial mixture; means for varying the proportion of oxidizing gas having a relatively high oxygen content and varying the pressure of said oxidizing gas of high oxygen content; means in addition to the other means for throttling the flow of said initial mixture; means for simultaneously varying the pressure of fuel gas; means for throttling the flow of said fuel gas; and means for mixing said initial mixture gases with such fuel gas to form a combustible mixture, whereby the proportion of oxidizing gas having a relatively high oxygen content may be increased, the pressure of oxidizing gases may be increased, and the pressure of fuel gas may be increased simultaneously to produce an increase in the heating effect of said flame.

2. Apparatus for regulating a heating flame produced by the combustion of a fuel gas, comprising means for mixing fuel gas and an oxidizing gas mixture to form a combustible mixture; means for controlling the flow of fuel gas supplied to said mixing means in accordance with the pressure of oxidizing gas; walls forming a chamber for mixing oxidizing gas having a relatively high oxygen content and a stream of oxidizing gas having a relatively low oxygen content; one of the chamber walls having an orifice through which said oxidizing gas having a relatively high oxygen content passes into said chamber; and means for passing oxidizing gas mixture from said chamber to said means for mixing fuel gas and oxidizing gas mixture at reduced pressure.

3. Flame heating apparatus comprising a blowpipe for mixing fuel gas and oxidizing gas to provide a combustible mixture which will produce a high temperature heating flame; oxidizing gas richness regulating means having a chamber provided with walls within which air and oxygen are adapted to be mixed; a valve in said regulating means for controlling the flow of fuel gas from a fuel gas inlet to a fuel gas outlet; a wall of said chamber having an orifice through which oxygen is conducted to said mixing chamber; said regu-
11. Apparatus as defined in claim 3, in which said oxygen pressure control means comprises a valve and a diaphragm controlling said valve, movement of said diaphragm being controlled by oxygen pressure exerted against one side of said diaphragm.

5. Apparatus as defined in claim 3, wherein said diaphragm means comprises a pair of spaced diaphragms connected together to move in unison, one of said diaphragms being subject on one side to fuel gas pressure and the other of said diaphragms being of larger effective area and subject on its opposite side to oxygen pressure with the space between said diaphragms being vented to the atmosphere.

6. To a flame heating apparatus, including a blowpipe for mixing fuel gas and oxidizing gas to provide a combustible mixture, a combined oxidizing gas pressure regulator and oxygen richness proportioner having a chamber in which air and oxygen are mixed; said regulator and proportioner having a fuel gas inlet passage, a fuel gas outlet passage, an oxygen inlet passage to said mixing chamber; a valve for controlling the flow of fuel gas from the fuel gas inlet passage to the fuel gas outlet passage; a valve controlling the flow of oxygen from the oxygen inlet passage to the mixing chamber; said mixing chamber having a wall in which is an orifice leading from said oxygen inlet passage to said mixing chamber; a connection between said mixing chamber and said blowpipe; an air supply passage leading to said mixing chamber; and means for controlling said fuel gas valve and responsive to variations in pressure in said oxygen inlet passage.

7. In flame heating apparatus as defined in claim 6, means for controlling said oxygen valve including a diaphragm subject on one side to the pressure in said oxygen inlet passage and on the other side to the pressure in said mixing chamber.

8. In flame heating apparatus as defined in claim 6, wherein means for controlling said oxygen valve comprises a diaphragm and an adjustable spring acting against one side of said diaphragm, said diaphragm forming a wall between said oxygen inlet passage and said air supply passage, and said orifice leading from said oxygen inlet passage to said mixing chamber through said diaphragm.

9. A method of regulating characteristics of a flame produced principally by the combustion of acetylene, which comprises mixing acetylene and hydrogen to form a fuel gas mixture; supplying oxygen to support the combustion of such mixture; and increasing the proportion of acetylene in said fuel gas mixture and simultaneously increasing the pressure and flow of oxygen, to produce an increase in the heating effect of said flame.

10. A method of regulating the heating effect of a flame produced by the combustion of a mixture of acetylene, hydrogen, and oxygen, such method comprising varying the pressure and rate of flow effected by said pressure of a flowing stream of acetylene; regulating the pressure and flow of a stream of oxygen directly in accordance with the varied pressure of acetylene; simultaneously proportioning the flow of a stream of hydrogen inversely to and with the flow of acetylene; and mixing the acetylene with the hydrogen and with the oxygen to form said mixture.

11. A method of producing a flame having an adjustable heating effect which comprises providing a supply of diluent gas at desired supply pressure; providing supplies of combustible mixture forming gases comprising acetylene and oxygen at least one of which is under higher pressure; reducing the pressure of said one of said combustible mixture forming gases to a value equal to said diluent supply pressure while admixing said one gas with said diluent which is inert with respect to the said one gas to form an initial mixture having a desired composition; regulating the pressure of the other of said combustible mixture forming gases in accordance with said initially reduced pressure of said one combustion mixture forming gas; and admixing said other combustible mixture forming gases under the head of its regulated pressure with said initial mixture to form, when ignited, said flame.

12. A method of varying the heating effect of a flame which comprises providing a supply of diluent gas at desired supply pressure; providing supplies of combustible mixture forming gases at least one of which is under higher pressure; reducing the pressure of said one of said combustible mixture forming gases to a value equal to said diluent supply pressure while admixing said one gas with said diluent which is inert with respect to the said one gas to form an initial mixture having desired adjustable proportions; regulating the pressure of the other of said combustible mixture forming gases in accordance with said initially reduced pressure of said one gas; and finally admixing said other combustible mixture forming gas under the head of its regulated pressure with said initial mixture to form, when ignited, said flame.

13. A method of varying the heating effect of a flame which comprises supplying air at a desired pressure; supplying oxygen at a higher pressure; reducing the pressure of said oxygen and maintaining such initially reduced pressure above the air supply pressure; further reducing the pressure of said oxygen to a value equal to said air supply pressure while admixing said one gas with said diluent which is inert with respect to the said one gas to form a mixture of air and oxygen having desired proportions; regulating the pressure of a supply of fuel gas in accordance with said initially reduced pressure of oxygen alone; admixing proportioned amounts of fuel gas under the head of said regulated pressure with proportioned amounts of said mixture of air and oxygen to form, when ignited, said flame; and adjusting the degree by which said initially reduced pressure of oxygen exceeds the air supply pressure to vary the heating effect of said flame without substantially changing the proportionality between oxygen and fuel in said flame.

14. A method of varying the heating effect of
a flame which comprises providing a supply of diluent gas at a desired supply pressure; providing a supply of acetylene at a higher pressure; automatically reducing the pressure of said acetylene and maintaining such initially reduced pressure above the diluent supply pressure; further reducing the pressure of said acetylene to a value equal to said diluent supply pressure while admixing said acetylene and diluent to form an initial mixture of acetylene and diluent of desired proportions; regulating the pressure of a supply of oxygen in accordance with said initially reduced pressure of acetylene; mixing proportioned amounts of said oxygen under the head of said regulated pressure with proportioned amounts of said initial mixture to form, when ignited, said flame; and adjusting the degree by which said initially reduced pressure of acetylene exceeds said diluent pressure to vary the heating effect of said flame without substantially changing the proportionality between oxygen and acetylene in the flame.

15. The method of adjusting the heating effect of a flame supplied by a mixture of fuel gas and oxidizing gas which comprises flowing a diluent gas into one of the components of said mixture which is inert with respect to the diluent, controlling the flow of the mixture component to be diluted in response to a difference between the diluent pressure and the pressure of said one mixture component before being diluted and when the pressure of said one component is above a predetermined value, controlling the flow of the other mixture component in response to the pressure difference between it and the pressure of the mixture component to be diluted, and mixing said diluent gas with said oxidizing gas.

16. The method of adjusting the heating effect of a flame supplied by a mixture of fuel gas and oxidizing gas which comprises flowing a diluent gas into one of the components of said mixture which is inert with respect to the diluent, controlling the flow of the mixture component to be diluted in response to the difference between the diluent pressure and the pressure of said one mixture component before being diluted and when the pressure of said one component is above a predetermined value, and mixing said fuel gas with said oxidizing gas.

17. The method of changing the velocity and heating effect of a gas flame supplied by a fuel gas, a gas rich in oxygen, and a gas having a relatively low oxygen content which comprises initially adjusting the flow of the gas rich in oxygen, further controlling the flow of said gas rich in oxygen in response to the difference in pressure between it alone and the gas having a relatively low oxygen content and adjusting the flow of fuel gas in response to the pressure difference between it and said gas rich in oxygen to retain the length of the inner cone of said flame constant and the ratio of oxygen to fuel constant for one kind of fuel.

18. An apparatus for changing the velocity and heat of a gas flame nozzle while maintaining the ratio of available oxygen to fuel gas substantially constant which comprises, a line for supplying a gas having a low oxygen content, a line for supplying a gas rich in oxygen, a line for supplying fuel gas, a valve in the line rich in oxygen, means for automatically adjusting said valve in response to pressure difference between the line with relatively low oxygen content and the portion of the line rich in oxygen between the valve and the nozzle when said line rich in oxygen is above a given pressure, a valve in the fuel gas line, and means for automatically controlling said last mentioned valve in response to the pressure difference between the fuel gas line and said portion of the line rich in oxygen between the nozzle and first mentioned valve.

19. Apparatus for controlling the relative supply of a gas rich in oxygen content to a gas having a lower oxygen content, comprising a fuel supply line, a supply line for each oxidizing gas, a valve in the line rich in oxygen, a device responsive to pressure difference between said line having a low oxygen content and the portion of the line rich in oxygen adjacent but beyond the said valve when above a predetermined pressure for controlling the supply of gas rich in oxygen, and means beyond said valve for mixing the gas low in oxygen with the gas rich in oxygen prior to contact with the fuel and its supply line.

20. Apparatus for controlling the heat of a flame supplied by fuel and oxidizing gases and comprising a pair of passages for combustible mixture forming gases, a third passage for a diluent gas, a valve in one passage of said pair, a device for controlling said valve in response to the pressure difference between said valve and beyond said valve when the pressure is above a given amount and said third passage; means for mixing the gas from said one passage and said diluent to form a gaseous mixture which is non-explosive, a valve in the other passage of said pair, a device for controlling said other valve in response to the difference between the pressure in said other passage after its valve and the pressure in said one passage after its valve and before said mixing means, and blowpipe means for mixing the gases from said other passage and the mixture from said mixing means.

21. The method of operating a blowpipe to change the heating effect of the flame without substantially changing the length of the inner cone of the flame which comprises supplying two components of a fuel gas mixture to said blowpipe, diluting one of said components with a compatible diluent to form a non-explosive preliminary mixture, varying the flow of said one component, further adjusting the flow of the varied component in response to the pressure of the diluent gas flowing to the formation of said preliminary mixture, and adjusting the flow of the other component in response to pressure of the adjusted first mentioned component to maintain the ratio of oxygen to fuel substantially constant.

22. The method of operating a blowpipe to change the heating effect of the flame without substantially changing the length of the inner cone of the flame which comprises supplying two components of a fuel gas mixture to said blowpipe, diluting one of said components with a compatible diluent to form a non-explosive preliminary mixture, varying the flow of said one component, further adjusting the flow of the varied component in response to the pressure of the diluent gas flowing to the formation of said preliminary mixture, adjusting the flow of the other component in response to pressure of the adjusted first mentioned component to maintain the ratio of oxygen to fuel substantially constant, and reducing the pressure of the first mentioned component subsequent to its control of said other or second mentioned component, said diluting including mixing said diluent and first
2,416,161

mentioned component after the pressure of the first component has been reduced.

23. The method of operating a blowpipe to change the heating effect of the flame without substantially changing the length of the inner cone of the flame, which comprises supplying two unmixed components of a fuel gas mixture to said blowpipe, flowing a diluent into one of said components which is non-explosive with the diluent, controlling the flow of said diluent in response to a reduced pressure of said one of said components, controlling the flow of said one of the components with which the diluent is mixed, and controlling the flow of the other component in response to the pressure of the flowing first mentioned component with which the diluent is mixed.

24. Apparatus for changing the heating effect of the flame from a blowpipe which comprises means for supplying two components of a fuel gas mixture to a blowpipe, means for supplying a diluent gas for one of said components, a manually adjustable valve for said one of said components which valve is also automatically adjustable in response to pressure of said diluent gas being supplied, a valve for controlling the flow of the other component in response to pressure of the first mentioned component being supplied, a pressure reducing orifice through which the first mentioned component passes after it has controlled the supply of the second component, a mixing chamber with which said diluent gas supply means is connected and into which said first component also passes after being reduced in pressure by its passage through said orifice, and means for conducting the controlled mixture of diluent gas and first component as well as the controlled second component to said blowpipe.

EIBE W. DECK.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>985,896</td>
<td>Hopkins</td>
<td>Mar. 7, 1911</td>
</tr>
<tr>
<td>1,213,159</td>
<td>Dalen</td>
<td>Jan. 23, 1917</td>
</tr>
<tr>
<td>1,228,116</td>
<td>Sebille</td>
<td>Dec. 16, 1919</td>
</tr>
<tr>
<td>1,530,630</td>
<td>Baird</td>
<td>May 26, 1925</td>
</tr>
<tr>
<td>2,083,750</td>
<td>Bucknam et al.</td>
<td>Aug. 3, 1937</td>
</tr>
<tr>
<td>2,089,029</td>
<td>Bucknam et al.</td>
<td>Aug. 3, 1937</td>
</tr>
<tr>
<td>2,193,240</td>
<td>Schmidt</td>
<td>Mar. 12, 1940</td>
</tr>
<tr>
<td>2,280,029</td>
<td>Crowe</td>
<td>Apr. 14, 1942</td>
</tr>
<tr>
<td>2,186,962</td>
<td>Jones</td>
<td>Apr. 9, 1940</td>
</tr>
<tr>
<td>2,304,645</td>
<td>Mott</td>
<td>Dec. 12, 1944</td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Country</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>564,864</td>
<td>German</td>
<td>July 14, 1932</td>
</tr>
<tr>
<td>226,380</td>
<td>British</td>
<td>Feb. 20, 1930</td>
</tr>
</tbody>
</table>

Certificate of Correction


February 18, 1947.

EIBE W. DECK

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 7, line 43, for “dice” read dice; column 10, line 64, claim 2, strike out the words “at reduced pressure” and insert the same after the word “chamber” and before the semi-colon, line 61, same claim; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of May, A. D. 1947.

[SEAL]

LESLIE FRAZER,
First Assistant Commissioner of Patents.
2,410,161
mentioned component after the pressure of the first component has been reduced.

23. The method of operating a blowpipe to change the heating effect of the flame without substantially changing the length of the inner cone of the flame, which comprises supplying two unmixed components of a fuel gas mixture to said blowpipe, flowing a diluent into one of said components which is non-explosive with the diluent, controlling the flow of said diluent in response to a reduced pressure of said one of said components, controlling the flow of said one of the components with which the diluent is mixed, and controlling the flow of the other component in response to the pressure of the flowing first mentioned component with which the diluent is mixed.

24. Apparatus for changing the heating effect of the flame from a blowpipe which comprises means for supplying two components of a fuel gas mixture to a blowpipe, means for supplying a diluent gas for one of said components, a manually adjustable valve for said one of said components which valve is also automatically adjustable in response to pressure of said diluent gas being supplied, a valve for controlling the flow of the other component in response to pressure of the first mentioned component being supplied, a pressure reducing orifice through which the first mentioned component passes after it has controlled the supply of the second component, a mixing chamber with which said diluent gas supply means is connected and into which said first component also passes after being reduced in pressure by its passage through said orifice, and means for conducting the controlled mixture of diluent gas and first component as well as the controlled second component to said blowpipe.

EIBE W. DECK.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>595,896</td>
<td>Hopkins</td>
<td>Mar. 7, 1911</td>
</tr>
<tr>
<td>1,213,190</td>
<td>Dahlen</td>
<td>Jan. 23, 1917</td>
</tr>
<tr>
<td>1,225,110</td>
<td>Sebille</td>
<td>Dec. 16, 1919</td>
</tr>
<tr>
<td>1,536,650</td>
<td>Beaird</td>
<td>May 26, 1925</td>
</tr>
<tr>
<td>2,089,014</td>
<td>Bucknam et al.</td>
<td>Aug. 3, 1937</td>
</tr>
<tr>
<td>2,089,015</td>
<td>Bucknam et al.</td>
<td>Aug. 3, 1937</td>
</tr>
<tr>
<td>2,089,022</td>
<td>Jones</td>
<td>Aug. 3, 1937</td>
</tr>
<tr>
<td>1,719,998</td>
<td>McNeill</td>
<td>July 14, 1932</td>
</tr>
<tr>
<td>2,193,240</td>
<td>Schmidt</td>
<td>Mar. 12, 1940</td>
</tr>
<tr>
<td>2,280,029</td>
<td>Crowe</td>
<td>Apr. 14, 1942</td>
</tr>
<tr>
<td>2,196,992</td>
<td>Jones</td>
<td>Apr. 9, 1940</td>
</tr>
<tr>
<td>2,304,645</td>
<td>Mott</td>
<td>Dec. 12, 1944</td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Country</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>854,804</td>
<td>German</td>
<td>July 14, 1922</td>
</tr>
<tr>
<td>326,390</td>
<td>British</td>
<td>Feb. 20, 1930</td>
</tr>
</tbody>
</table>

Certificate of Correction


EIBE W. DECK

February 18, 1947.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 7, line 43, for “dice” read “disce”; column 10, line 64, claim 2, strike out the words “at reduced pressure” and insert the same after the word “chamber” and before the semi-colon, line 61, same claim; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of May, A. D. 1947.

[SEAL]

LESLEIL FRAZER,
First Assistant Commissioner of Patents.