Fig. 1. 

Fig. 2. 

Fig. 3. 

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[Signature]
URNER FOR TEMPERED FLAME OPERATION

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This invention relates to a burner for tempered flame operation for the heat treatment of work such as billets, blooms, bars and the like, particularly at low temperatures, such as in the range 300-1500° F. It is concerned especially with a burner for delivering to the work a clear substantially non-luminous flame, which flame can be tempered (i.e., its temperature controlled) over a wide range and is delivered at such velocity as to assure optimum circulation and conversion.

In such a heat treatment process it is important to be able to deliver to the work a flame which is substantially non-luminous, i.e., clear, since a luminous flame radiates more heat than a non-luminous flame and results in localized hot spots in the work having disadvantages well known to those skilled in the art. A clear or non-luminous flame delivers most of its heat to the work by convection. When adequate circulation is provided for the work is heated with optimum uniformity. It is also important to be able to temper the flame, i.e., deliver it to the work at a controlled temperature lower than the temperature produced under stoichiometric operation and close to the final work temperature.

I have devised a burner for tempered flame operation which delivers a clear non-luminous flame at various degrees of tempering through use of air in excess of stoichiometric proportions while at the same time insuring adequate circulation to promote optimum convection and uniformity of application of heat to the work. My burner may also be employed under reducing conditions, i.e., with a deficiency of air relative to stoichiometric proportions.

I provide a burner for tempered flame operation comprising a burner body having two communicating coaxial zones, a first zone of relatively small transverse dimension and a second zone of relatively great transverse dimension, generally axially directed fuel inlet means admitting fuel into the first zone in a direction to pass through the first zone into the second zone, means for controlling the quantity of fuel admitted through the fuel inlet means, first air inlet means admitting air into the first zone at the end of the first zone at which the fuel is admitted, second air inlet means admitting air into the second zone at the end of the second zone where the second zone communicates with the first zone and third air inlet means admitting air into the second zone at a location spaced from the end of the second zone where the second zone communicates with the first zone. The first and second air inlet means preferably admit air in a direction generally parallel to the direction of fuel flow through the burner and the third air inlet means admit air in a direction inwardly at an angle to the direction of fuel flow through the burner.

Preferably each of the first and second zones of burner is at the inlet thereof a generally radial wall with the first and second air inlet means constituting by series of air inlet openings through such respective radial walls, I find that for optimum operation the radial distance from the inner edge of each of the air inlet openings of the second air inlet means to the inside face of the first zone should be no greater than .336 inch. The air inlet openings of the first air inlet means should have a length to diameter ratio substantially in the range 1.16-3.00 and the air inlet openings of the second air inlet means should have a length to diameter ratio substantially in the range .83-1.20. Means should be provided for delivering air to the burner at a pressure substantially in the range 6-7 inches water column.

By burner preferably has a jacket constituting a part of the burner body generally surrounding the two communicating coaxial zones and defining an air supply manifold communicating with the first, second and third air inlet means, the manifold having an air inlet port through which air is delivered thereto.

Other details, objects and advantages of the invention will become apparent as the following description of a present preferred embodiment thereof proceeds.

In the accompanying drawings I have shown a present preferred embodiment of the invention.

FIGURE 1 is an axial cross-sectional view through a burner constructed in accordance with my invention; and FIGURES 2, 3, 4, 5 and 6 are diagrams illustrating operation of the burner shown in FIGURE 1.

Referring first to FIGURE 1, there is shown a burner for tempered flame operation which comprises a burner body designated generally by reference numeral 12 having two communicating coaxial zones 3 and 4 respectively, the first zone 3 being of relatively small transverse dimension and the second zone 4 being relatively great transverse dimension. In the form shown the zone 3 is defined by a cylindrical wall 5 and zone 4 is defined by a cylindrical wall 6. The zone 3 has a diameter substantially less than that of the zone 4 and the cylindrical wall 5 is joined to the cylindrical wall 6 by a radial wall 7 which is in radial alignment with the right-hand extremity, viewing FIGURE 1, of the zone 3 which, as will presently appear, is the outlet extremity of that zone.

The left-hand extremity of the zone 3, which is the inlet extremity of that zone, is defined by a radial wall 8. Fuel, normally gas, although oil may be used, is admitted to the burner through an axial port 9 opening into the zone 3. The fuel is delivered through a suitable conduit adapted to be connected to the burner at 10.

A jacket 11 constituting a part of the burner body 2 generally surrounds the zones 3 and 4 and defines an air supply manifold designated generally by reference numeral 12. Air is delivered to the manifold 12 through an air inlet port 13.

Air is delivered from the manifold 12 into the zone 3 through first air inlet means in the form of a series of air inlet openings 14 in the wall 8 surrounding the fuel inlet port 9. Air is delivered from the manifold 12 into the zone 4 through second air inlet means in the form of a series of air inlet openings 15 in the wall 7 surrounding the outlet extremity of the first zone. Air is delivered from the manifold 12 into the zone 4 at a location spaced from the inlet end of zone 4 through third air inlet means in the form of a series of air inlet openings 16 in the cylindrical wall 6. The openings 16 admit air in a direction inwardly at an angle to the direction of fuel flow through the burner. While the air inlet openings 16 are shown as having their axes inclined at an acute angle to the axis of the burner, the axes of the openings 16 may be at right angles to the axis of the burner. Also while in the form shown the axes of the openings 16 intersect the axis of the burner the openings may be arranged with their axes offset from the axis of the burner to create a swirl in the burner. A pilot duct is shown at 17.

For optimum operation the radial distance from the inner edge of each of the air inlet openings 15 to the inside face of the zone 3 should be no greater than .336 inch. This dimension is indicated by the letter X in FIGURE 1. The length to diameter ratio of each of the openings 14 should be substantially in the range 1.16-3.00 and the length to diameter ratio of each of the openings 15 should
be substantially in the range .83-1.20. In FIGURE 1 the length of one of the openings 15 is designated by L and the diameter by D. It is found that when the openings are thus proportioned an optimum jet effect of the air is created.

FIGURES 2, 3, 4, 5 and 6 illustrate the operation of my burner respectively with 0%, 425%, 600%, 1000% and 1500% excess air. In FIGURE 2 and air fuel are induced in stoichiometric proportions. The flame is substantially at the openings 15 which in reference to op-

eration of the burner may be referred to as the second stage air inlet openings. The openings 14 may be referred to as the first stage air inlet openings. The openings 16 may be referred to as the third stage air inlet openings. In FIGURE 2 the second and third stages and the port block 18 are filled with flame. There is no combustion in the first stage, i.e., in the zone 3.

FIGURE 3 shows the operating condition when the gas flow is reduced so that 425% excess air is supplied. It is desirable to maintain the air flow constant and con-
trol the temperature of the flame by varying the fuel in-
put. In FIGURE 3 combustion begins to occur in the first stage but it is not stabilized there. The flame front is still well established at the second stage air inlet openings 15.

FIGURE 4 shows the operating condition when the gas flow is reduced so that 1000% excess air is supplied. The flame front establishes itself at the first stage air inlet openings 14 but most of the combustion is still occurr-
ing at the second stage air inlet openings 15. In ef-
tect there are now two flame fronts established.

FIGURE 5 shows the operating condition when the gas flow is reduced so that 1500% excess air is supplied. Combustion is still occurring in the first and second stages but stabilization is occurring at the second stage air inlet openings 14. There is still some burning occurring around the second stage air inlet openings 15 but such burning is not contributing to the stabilization of the flame.

FIGURE 6 shows the operating condition when the gas flow is reduced so that 1500% excess air is supplied. There is no more flame around the second stage air in-
let openings 15 and the flame front is still well estab-
lished at the first stage air inlet openings 14. Maximum excess air for the burner would be 2500%, more or less, the flame having the general character shown in FIG-
URE 6.

Summarizing, at 0-425% excess air there is no com-
bustion in the first stage and the flame is stabilized at the second stage air inlet openings. At 425-600% excess air combustion occurs in the first and second stages but the flame front is still established at the second stage air inlet openings. At 600-1500% excess air the flame front is established at the first stage air inlet openings but combustion is still occurring in the first and second stages. At 600% the greater part of the combustion occurs at the second stage air inlet openings but at 1500% there is no combustion at the second stage air inlet openings. This transition occurs very gradually as the fuel flow is decreased. At 1500-2500% excess air the flame front is at the first stage air inlet openings and there is no com-
bustion at the second stage air inlet openings. Above about 2500% excess air (i.e., a fuel turn-down ratio of 25:1) the burner is extinguished.

Under all of the conditions illustrated the flame is clear or substantially non-luminous so that the heat is trans-
mitted to the work by convection rather than by radia-
tion, avoiding hot spots in the work. As demonstrated, the flame may be tempered over a wide range while main-
taining the flame clear and also maintaining adequate circulation to insure optimum uniformity of heat transfer to the work by convection. The burner is also adapted to operate with a deficiency of air resulting in reducing conditions in the furnace.

The length to diameter ratios of the air inlet openings 14 and 15 specified above provide for a desired jet ac-
tion promoting adequate velocity of flow through the burner and optimum convection in the furnace. The above mentioned radial distance from the inner edge of the air inlet openings 15 to the inside face of the first zone is independent of the size of the air inlet openings or the diameter of the zone 3. The jets of air from the air inlet openings 15 entrain the mixture from the first stage, lowering the pressure there. This in turn allows the gas to expand and be more readily entrained by the first stage jets when the burner is operating with an excess of air. It is the entrainment of the gas into the air jets that provides flame retention; i.e., in each stage the flame front is established in small zones surrounding the perimeters of the air jets. Beyond the mentioned critical distance for the dimension X (FIGURE 1) the entrainment of the first of the second stage jets is too small to contribute effective-
ly to the lowering of the pressure in the first stage. The dimension is independent of air inlet opening size because it is determined by the jet velocity and flow con-
ditions which in turn are determined by the pressure drop and the length to diameter ratio of the air inlet open-
ings. As the flow is made more laminar entrainment is improved. Thus the burner is capable of operation at a higher excess of air when the air pressure is reduced and the length to diameter ratio of the air inlet means of the second stage (15) is increased. Both of these changes cause the jets to become more laminar, their laminar ratio being limited. A suitable balance be-
tween excess air capacity and luminosity has been achieved in existing burners with air pressure in the range 6-7 inches water column and length to diameter ratios of the air inlet openings as above specified.

Desirably the first stage velocity should be less than 155,000 B.f.u. per square inch of cross sectional area based on the nominal capacity of the burner. If the ve-
locity is further increased the velocity of the mixture leaving the first stage exceeds the flame velocity and the flame front will not transfer from the second to the first stage when the gas is turned down. The critical velocity for the transfer may be increased by increasing the air pressure, increasing the gas pressure or decreasing the distance from the inner edge of the second stage air inlet openings 15 to the inside face of the first zone or stage 3. All of these changes increase the rate of mixing in the first stage but then the rate of gas turn down after the flame front has transferred is decreased.

While I have shown and described a present preferred embodiment of the invention it is to be distinctly un-
stood that the invention is not limited thereto but may be otherwise variously embodied within the scope of the fol-
lowing claims.

I claim:

1. A burner for tempered flame operation comprising a burner body having two communicating coaxial com-
bustion zones disposed for the passage of fuel successively therethrough, a first zone of relatively small transverse dimension and a second zone of relatively great trans-
verse dimension, said first zone having an outlet opening adjoin-
ing an inlet opening of said second zone, generally axially directed fuel inlet means disposed in an inlet opening of said first zone and admitting fuel into the first zone in a direction to pass through the first zone into the second zone, first air inlet means admitting air into the first zone adjacent said inlet means, second air inlet means admitting air into the second zone adjacent said inlet means, said air inlet means admitting air into the second zone and admitting air into the second zone said air inlet means, generally axially directed fuel inlet means disposed in an inlet opening of said first zone and admitting fuel into the first zone in a direction to pass through the first zone into the second zone, whereby the turn-down ratio of said burner is greatly increased, the operation of said burner being that as the fuel is turned down the flame generated by com-
bustion thereof progressively recedes from said second zone into said first zone.

2. A burner as claimed in claim 1 in which the first and second air inlet means admit air in a direction gen-
generally parallel to the direction of fuel flow through the burner and the third air inlet means admit air in a direction inwardly at an angle to the direction of fuel flow through the burner.

3. A burner as claimed in claim 1 in which the second zone has the inlet opening thereof defined by a generally radial wall in radial alignment with the outlet opening of the first zone with the second air inlet means constituted by a series of air inlet openings through such radial wall, the radial distance between each of such air inlet openings and an inner surface of the first zone being no greater than .336 inch.

4. The combination according to claim 1 wherein said burner is capable of a fuel turn-down ratio of about 25:1, while the volume of air supplied to said burner remains essentially constant.

5. A burner as claimed in claim 1 in which each of the first and second zone inlet openings is defined by a generally radial wall with the first and second air inlet means constituted by series of air inlet openings through such respective radial walls.

6. A burner as claimed in claim 5 in which the air inlet openings of the first air inlet means have a length to diameter ratio substantially in the range 1.16-3.00 and the air inlet openings of the second air inlet means have a length to diameter ratio substantially in the range .83-1.20.

7. A burner as claimed in claim 1 having a jacket constituting a part of the burner body generally surrounding the two communicating coaxial zones and defining an air supply manifold communicating with the first, second and third air inlet means, the manifold having an air inlet port through which air is delivered thereto.

8. A burner as claimed in claim 7 in which each of the first and second zones has at the inlet opening thereof a generally radial wall with the first and second air inlet means constituted by series of air inlet openings through such respective radial walls, the radial distance from the inner edge of each of the air inlet openings of the second air inlet means to the inside face of the first zone being no greater than .336 inch, the air inlet openings of the first air inlet means having a length to diameter ratio substantially in the range 1.16-3.00 and the air inlet openings of the second air inlet means having a length to diameter ratio substantially in the range .83-1.20.

9. A burner as claimed in claim 1 in which a port block member is secured to said burner body adjacent an outlet opening of said second zone, said member having an opening therefrom communicating with said second zone and disposed substantially co-axially therewith, said port block opening defining a combustion area.

10. The combination according to claim 9 wherein said third air inlet means are disposed at a location in said second zone closer to said port block than to said first zone.

11. The combination according to claim 10 wherein said port block opening is outwardly flaring.

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