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SUDDEN EXPANSION BURNER HAVING STEP FUEL INJECTION

Filed March 25, 1960

2 Sheets-Sheet 1

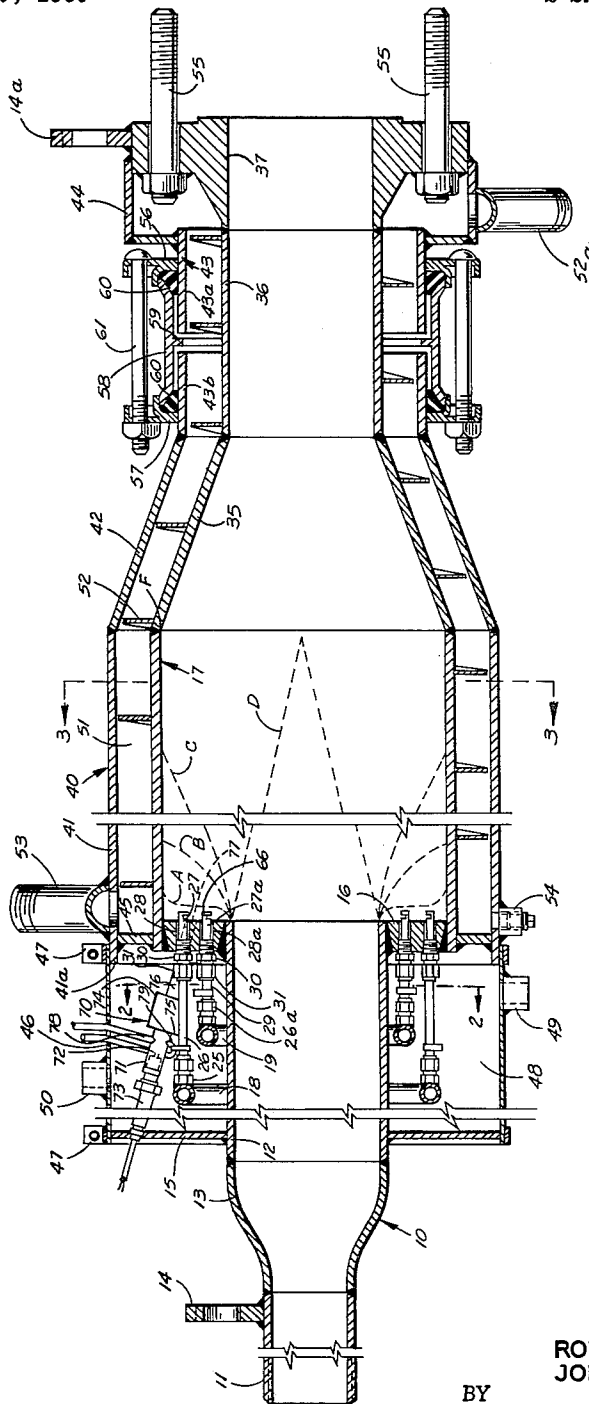


FIG. 1

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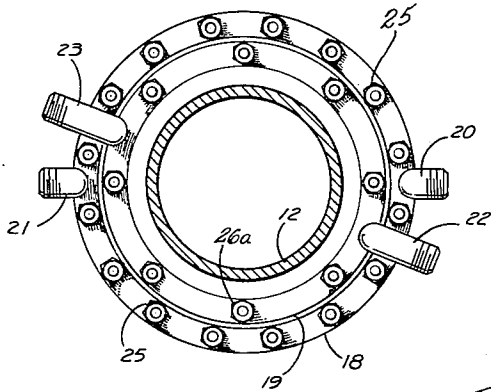


FIG. 2

FIG. 3

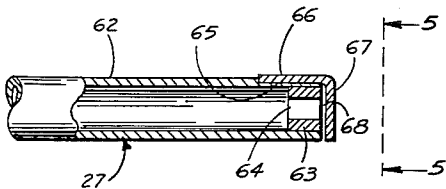
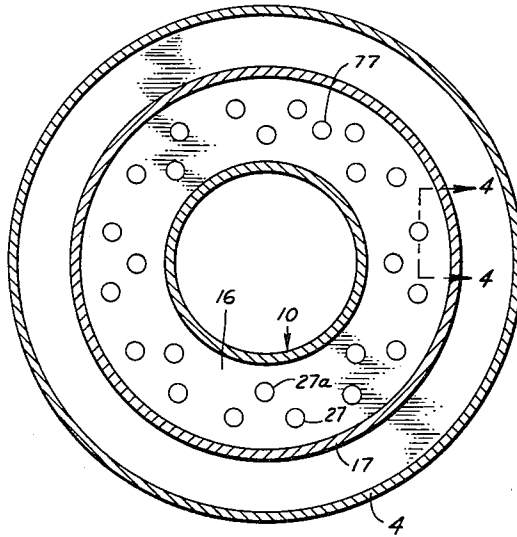


FIG. 4

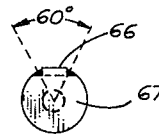


FIG. 5

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SUDDEN EXPANSION BURNER HAVING STEP FUEL INJECTION

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This invention relates to a sudden expansion burner having step fuel injection and more particularly to a sudden expansion burner in which fuel is injected at the step to provide wide stability limits.

At present, sudden expansion burners are utilized in commercial processes and test facilities where large volumes of high temperature air are required. Present types of sudden expansion burners utilize a step between smaller and larger pipe sections to provide for sudden expansion, and fuel is injected into the air flow at a location in the smaller pipe section upstream of the step. When the velocity of the air flowing in the smaller section is low, the flame front will sometimes move upstream from the step into the small section, resulting in instability of burner operation. At high velocities, the air flow in the smaller pipe section will cause burning to occur after the sudden expansion.

In the present invention, the fuel is injected into the air flow at the step so that the flame cannot move back into the smaller pipe section. Ignition is accomplished at the step by any suitable type of igniter (such as a hydrogen-air igniter) which can produce a one-shot flame or can operate continuously over short periods. The fuel injection nozzles are supported by the step and direct the fuel in vapor or gaseous form into the air leaving the smaller pipe section and entering the larger pipe section. Adjacent the step surface, a zone will exist which is too fuel rich for combustion while centrally in the larger pipe section a zone will exist having insufficient fuel for combustion. Between these two zones, there exists a zone where combustion of the fuel with the air will continually take place until all the fuel is combusted. The relative sizes and shapes of these zones will vary with fuel flow and air flow.

The larger pipe section is reduced aft of the station where complete combustion is accomplished. This reduction in size increases the velocity of the hot gases and results in turbulence which provides a good temperature profile. Generally, control of the discharge temperature is accomplished by varying the fuel flow rate to vary the overall fuel-to-air ratio. Because of the wide operating range over which flame stability can be maintained, the present invention is capable of operation over a wider discharge temperature range. No secondary air is required to obtain complete combustion as in some prior step burners, and stability results because of the shielded region of zero velocity flow adjacent the step. Various fuel-oxidant combinations can be utilized to produce high temperature gases, such as air-propane or oxygen-JP4, and these fuels can be supplied to the burner in liquid or gaseous form.

It is therefore an object of the present invention to provide a sudden expansion burner having a step at which fuel is injected into a gaseous oxidant for combustion with the oxidant.

Yet another object of the invention is to provide a sudden expansion burner having both fuel injector nozzles and an igniter located at the burner step where sudden expansion takes place.

Another object of the invention is to provide a sudden expansion burner having a flame front continually located at the burner step, said flame front being stable

2

over a wide range of fuel-oxidant flow ratio and over a large range of discharge temperature.

These and other objects of the invention not specifically set forth above will become readily apparent from the accompanying description and drawings, in which:

FIGURE 1 is a vertical section of the sudden expansion burner of the present invention showing the small and large pipe sections connected at the step.

FIGURE 2 is a transverse section along line 2—2 of FIGURE 1 showing the two fuel manifolds for the nozzles.

FIGURE 3 is a transverse section along line 3—3 of FIGURE 1 illustrating the fuel injection nozzles and the igniter port.

FIGURE 4 is an enlarged vertical section along line 4—4 of FIGURE 3 illustrating the discharge end of a fuel injection nozzle, and

FIGURE 5 is an end elevation along line 5—5 of FIGURE 4 showing the impingement plate for one of the fuel injection nozzles.

The embodiment of the invention chosen for illustration comprises a small inlet pipe section 10 having a portion 11 connected with a larger portion 12 by an expansion connection 13. A supporting bracket 14 is secured to portion 11 and a cover supporting partition 15 is secured to portion 12. The pipe section 10 introduces air or other oxidant to the burner and is connected by step 16 to the larger pipe section 17 of the burner. Two fuel manifolds 18 and 19 surround the portion 12 of the inlet section 10, the manifold 19 being smaller in diameter and closer to the step 16. Fuel is introduced into manifold 18 at two opposite locations by passages 20 and 21 and fuel is introduced to manifold 19 at two opposite locations by conduits 22 and 23. The manifold 18 carries a plurality of fittings 25 which connect with a plurality of conduits 26 leading to a plurality of fuel injector nozzles 27. In a like manner, the manifold 19 carries a plurality of fittings 26a which connect to a plurality of conduits 29 leading to a second group of fuel nozzles 27a. The nozzles 27 are each located in an opening 28 in step 16 and the openings 28 are arranged in a circular path around the step. In a similar manner, the nozzles 27a are each located in an opening 28a in the step 16 and the openings 28a are also arranged in a circular path around the step. As illustrated in FIGURE 3, the circular path defined by nozzles 27 is larger than the circular path defined by nozzles 27a and the nozzles 27 are greater in number. Each nozzle is secured by threaded fittings 30 to the step 16 and the fittings 30 are secured to fittings 31 on the connecting conduits 26 and 29.

The larger pipe section 17 connects with a tapered section 35 which in turn connects with a smaller diameter section 36 carrying an end connecting member 37. An outer jacket 40 comprises sections 41 and 42 opposite sections 17 and 35, respectively, and also comprises an expansion joint 43 and manifold 44 opposite section 36 and end member 37, respectively. The jacket 40 is supported by the manifold 44 at one end and by partition 45 at the other end. A cover 46 surrounds cover supporting partition 15 and end 41a of section 41. The cover is secured by clamps 47 in order to form a water cooling space 48 containing the manifolds 18 and 19. Cooling water is introduced to the space 48 through fitting 49 and the water is discharged from the space through fitting 50. Also, jacket 40 defines a water cooling space 51 which contains a spiral plate 52 to direct the cooling water entering from passage 52a to the opposite end of the space 51 and out of passage 53. A plug 54 is provided to drain the space 51 when desirable.

The end member 37 carries a burner supporting bracket 14a and also contains bolts 55 for attaching additional pipe sections of the size of section 36. The expansion

joint 43 comprises a portion 43a surrounded by an annular ring 56 and a portion 43b surrounded by an annular ring 57. The ends of portions 43a and 43b are spaced apart and a cover member 58 has a ring 59 extending into the space between the portions. Also, the member 58 extends between rings 56 and 57 to compress sealing material 60 against the portions 43a and 43b when the bolt 61 extending between the rings is tightened. Thus, the expansion joint 43 permits relative movement of portions 43a and 43b without leakage of fluid.

FIGURES 4 and 5 show the construction of a nozzle 27, which construction is the same as for nozzles 27a. The nozzle comprises a tube 62 which is first filled at its end with weld metal 63 and the weld metal is then drilled to contain a central opening 64. A small area 65 on the outer circumference of tube 62 is ground flat to receive and secure an extension 66 of impingement plate 67. The impingement plate is spaced slightly from the end of the tube 62 and provides a slot 68 between the plate of the tube which is closed only at extension 66. As illustrated in FIGURE 5, the extension 66 at its connection with plate 67 covers approximately 60 degrees of the total arc of tube 62 so that the slot 68 is open through an arc of approximately 300 degrees. The slot 68 of each nozzle is directed parallel to the step 16 and is located just beyond the surface of step 16 with the extension 66 at the outer side.

It is understood that the conduits 20-23, connected to the manifolds, extend through the jacket space 48 to the exterior of cover 46 and connect with a source of fuel. Two manifolds are utilized so that high manifold fuel pressure can be maintained over a wide range of fuel flow. In other words, when the fuel flow is low, one manifold can be cut off to direct all flow through the other manifold to maintain a high fuel pressure. A hydrogen-air igniter 70 of known construction comprises a smaller pipe section 71 which contains ignition points 72 of plugs 73. The smaller pipe section 71 is connected to larger pipe section 74 by step 75 and hot gases for ignition are discharged by conduit 76 into opening 77 in the step 16. Air is introduced to smaller section 71 through conduit 78 and hydrogen is introduced to the same section through passage 79. The hydrogen-air burner 70 can be utilized for one-shot ignition of the fuel discharge from the nozzles, or the ignition can be continuous over a few seconds. It is understood that the plug 73 for igniter 70 can be actuated at the same time as solenoid valves in the supply passages to manifolds 18 and 19.

In operation of the burner, air or other oxidant is introduced to the step through the smaller pipe section 10 and combustion of the air or oxidant with fuel introduced at step 16 through nozzles 27 and 27a is initiated by the igniter 70. A sheltered region of low velocity will exist adjacent step 16 and this region will be receiving fuel directly from the nozzles. A zone adjacent the step will be too rich in fuel for combustion, and the size of the zone which is too fuel rich will depend on the fuel-air ratio. For instance, at a low fuel-air ratio, the fuel rich zone will exist between step 16 and line A and the combustion zone exists on the opposite side of line A. At increased fuel-air ratio, the boundary line for the fuel rich zone will assume the position B and at high fuel-air ratio, the boundary line will assume the position C. The combustion zone commences at line A, B or C, depending on the fuel-air ratio, and continues inwardly to a location determined by the conical surface generated by line D. The zone within the conical surface is too fuel lean to support combustion. The extent to which the flame front will be positioned axially along the conical surface will be determined by the total fuel flow and the fuel-air ratio. In any event, the larger pipe section 17 is long enough so that complete combustion will take place before the fuel-air mixture reaches the station F at which the tapered section 35 commences. The tapered section 35 increases the velocity of the high temperature gases

to produce turbulence and a good temperature profile in the section 36 and in the sections adjoining end member 37 which lead to the point of use of the high temperature gases.

When vaporized propane is injected through the nozzles 27, 27a into air, stability of the flame over a large range of fuel flow rate and over-all fuel-air ratio has been obtained, resulting in a stable temperature range of discharged high temperature gases from 150 degrees to 3600 degrees. Since the fuel is not injected into the air or oxidant until it reaches the step, the resulting flame cannot move back up into the small pipe section 10 and the step 16 maintains the flame stable over wide temperature discharge ranges. It is understood that the larger pipe section 17 will be long enough so that complete combustion will occur before the gases arrive at station F. In general, the radial length of the step between the pipe sections can vary; one operative burner having a step extending between a six inch smaller pipe section and a twelve inch larger pipe section.

The end slots 68 of the nozzles extend through an arc sufficient to direct the fuel inwardly toward the incoming air and radially and somewhat outwardly around the step surface. This results in a low velocity zone adjacent the step which is too fuel rich for combustion and causes the fuel in this zone to mix with turbulent air resulting from the expansion. However, it has been determined that a few nozzles, which are open at the ends to direct fuel into the airstream and open at the sides to direct fuel around the step, will also provide a stable flame front. In other words, as long as the fuel is directed into the airstream and over the step, stability can be obtained from a variety of nozzle designs. Also, while two manifolds and two sets of nozzles are desirable, a single manifold and nozzle set can be utilized. In place of utilizing a reduced pipe section 36 at the end of the burner, the pipe section 17 could be extended over a relative long length to give a good temperature profile. Various other modifications are contemplated by those skilled in the art without departing from the spirit and scope of the invention as hereinafter defined in the appended claims.

What is claimed is:

1. A sudden expansion burner comprising:

a small pipe section connected with a supply of oxidant;

a larger pipe section downstream of the small pipe section;

a step member extending only outwardly at the end of said small pipe section connecting the end of said small pipe section with the adjacent end of the larger pipe section;

two fuel manifolds;

a plurality of nozzles supported adjacent said step member for continuously directing fuel into the oxidant emerging from said smaller pipe section and over the surface of the step member;

means for connecting each of said nozzles to one or the other of said manifolds, the nozzles connected to each manifold being arranged in a circular pattern, one circular pattern being of greater diameter than the other and having a greater number of nozzles; and

means supported adjacent said step member for igniting the fuel with the oxidant at a location downstream of said step member.

2. A sudden expansion burner comprising:

a small pipe section connected with a supply of oxidant;

a larger pipe section downstream of the small pipe section;

a step member extending only outwardly at the end of said small pipe section connecting the end of said small pipe section with the adjacent end of the larger pipe section;

nozzle means supported adjacent said step member for

5

continuously directing fuel into the oxidant emerging from said smaller pipe section and over the surface of the step member; and

means supported adjacent said step member for igniting the fuel with the oxidant at a location adjacent said step member, said nozzle means including a plurality of tubes, an impingement plate spaced slightly from the end of each tube and connected by a projection to the side of said tube, the fuel discharge slot formed between said plate and the end of said tube being discontinuous only at said projection and being oriented to direct fuel over the surface of said step member, each of said discharge slots being located at the downstream side of the surface of said step member and substantially parallel to said surface.

3. A sudden expansion burner comprising a small, substantially circular inlet pipe section connected with a supply of oxidant,

a step member extending transversely outwardly from the downstream end of said small pipe section, a larger substantially circular pipe section having its upstream end connected with the downstream side of said step member,

a plurality of fuel nozzles supported adjacent the downstream side of said step member for continuously directing fuel over the downstream surface of the step member and transversely towards the oxidant emerging from the downstream end of said smaller pipe section,

ignition means operative solely downstream of said step member and adjacent thereto for igniting the fuel with the oxidant at a location downstream of said step member, and each of said nozzles comprising a hollow open-ended tube extending substantially perpendicularly from said step member, an impingement plate spaced slightly from the open end of said tube and connected by a projection to a side of said tube in order to form a fuel discharge slot substantially parallel to the surface of said step member.

4. A sudden expansion burner as defined in claim 3 wherein the end of the tube contains a means forming a

6

restriction through which fuel is discharged against said plate.

5. A sudden expansion burner comprising a first pipe section constituting the sole supply of oxidant to the burner;

a step member extending only outwardly at the open discharge end of said first pipe section;

a second larger-in-diameter pipe section forming the combustion chamber connected at its upstream end with said step member;

a plurality of nozzles supported adjacent the step member, said nozzles having means directing fuel inwardly toward the open end of said first pipe section and substantially parallel to said step member, and

means adjacent said fuel nozzles to ignite the resultant mixture of fuel and oxidant.

6. The structure of claim 5 wherein the first pipe section is centrally arranged with respect to the step member and the fuel nozzles are arranged circumferentially about the first pipe section.

7. The structure of claim 6 wherein the step member is a wall perpendicular to the axis of the first pipe section.

8. The structure of claim 7 wherein the juncture between the larger-in-diameter pipe section and step member is substantially a right angle.

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