Un brûleur (10, 210) selon la présente invention comprend un tube extérieur (62), un tube intérieur (34) positionné de manière à se trouver à l’intérieur du tube intérieur (34), une alimentation électrique (38) couplée au tube intérieur (34), et un ergot d’allumage (70) couplé au tube extérieur (62). Un élément isolant (16) permet de séparer le brûleur d’une source (28) de gaz naturel. Cette source (28) de gaz naturel fournit du gaz naturel à une zone de combustion (45) via le tube intérieur (34). Une source d’oxygène (58) fournit en oxygène la zone de combustion (45) via un espace (144) ménagé entre les tubes intérieur et extérieur (34, 62). Une étincelle est créée entre le tube intérieur (34) et l’ergot d’allumage (70) de manière à enflammer le gaz naturel et l’oxygène pour créer une flamme (12).

A burner (10, 210) is provided in accordance with the present invention that includes an outer tube (62), an inner tube (34) positioned to be within the inner tube (34), a power supply (38) coupled to the inner tube (34), and an ignitor pin (70) coupled to the outer tube (62). An insulator (16) is provided that separates the burner (10) from a natural gas supply (28). The natural gas supply (28) provides natural gas to a combustion zone (45) through the inner tube (34). An oxygen supply (58) provides oxygen to the combustion zone (45) through a gap (144) between inner and outer tubes (34, 62). A spark is created between the inner tube (34) and the ignitor pin (70) to ignite the natural gas and oxygen to create a flame (12).
A burner (10, 210) is provided in accordance with the present invention that includes an outer tube (62), an inner tube (34) positioned to be within the inner tube (34), a power supply (38) coupled to the inner tube (34), and an ignitor pin (70) coupled to the outer tube (62). An insulator (16) is provided that separates the burner (10) from a natural gas supply (28). The natural gas supply (28) provides natural gas to a combustion zone (45) through the inner tube (34). An oxygen supply (58) provides oxygen to the combustion zone (45) through a gap (144) between inner and outer tubes (34, 62). A spark is created between the inner tube (34) and the ignitor pin (70) to ignite the natural gas and oxygen to create a flame (12).
OXYGEN-FUEL PILOT WITH INTEGRAL IGNITION

Background and Summary of the Invention

This patent application claims priority to U.S. Provisional Application Serial No. 60/066,869 filed Nov. 25, 1997 which is expressly incorporated by reference herein.

The present invention relates to industrial burners, and particularly to a small air/fuel or oxygen/fuel burner. More particularly, the present invention relates to a spark-ignition burner which can be used as a small self-sufficient burner or as a pilot ignition service for a larger burner.

Burners are frequently used in industrial environments to provide heat to various processes. For example, burners are used to provide heat to boilers, furnaces, kilns, rotary dryers, fume incinerators, pollutant-burning afterburners, and laboratory equipment. Some burners are also used as pilots that ignite larger burners.

Many burners are configured to convert air and fuel into a combustible air-and-fuel mixture which is then ignited to produce a flame for providing heat to a process.

According to the present invention, a burner assembly for combining first and second gases to produce a flame is provided. The burner assembly includes a longitudinal axis, a first gas conduit, a second gas conduit, and a spark generator. The first gas conduit includes a first end and a second end spaced apart from the first end. The first gas conduit defines a passageway extending between the first and second ends to communicate a first gas to a combustion zone. The second end defines an outlet of the first gas conduit. The second gas conduit includes a first end and a second end spaced apart from the first end. The second gas conduit defines a passageway extending between the first and second ends of the second gas conduit to communicate a second gas to the combustion zone. The second end defines an outlet of the second gas conduit. The outlet of the second gas conduit is spaced apart from the outlet of the first gas conduit along the longitudinal axis of the burner assembly.

The spark generator is coupled to the first and second gas conduits and configured to create a spark within the combustion zone to initiate combustion of the first and second gases in the combustion zone.
According to preferred embodiments of the present invention, the burner assembly is included in an apparatus for producing a flame. The apparatus includes a gas supply configured to supply a gas, the burner assembly, and an insulator. The spark generator is electric and electrically coupled to the second gas conduit and configured to create a spark within the combustion zone to initiate combustion of the gases in the combustion zone. The insulator is formed to include a passageway configured to communicate gas from the gas supply to the passageway of the second gas conduit. The insulator is positioned to electrically insulate the gas supply from the electric spark generator.

Additional features of the invention will become apparent to those skilled in the art upon consideration of the following detailed description of preferred embodiments exemplifying the best mode of carrying out the invention as presently perceived.

Brief Description of the Drawings

The detailed description particularly refers to the accompanying figures in which:

Fig. 1 is a side elevational view of a burner showing an inner fuel tube surrounded by an outer tube that is connected to an oxygen source, a natural gas supply providing natural gas that flows through an insulator into the inner tube, the inner tube being connected to a power supply, and the oxygen and natural gas mixing at a fuel-dispensing outlet;

Fig. 2 is an exploded perspective view of components of the burner and the insulator showing the position in which they are assembled to form a working burner;

Fig. 3 is a side elevational view, with portions cut away, showing the fuel-dispensing outlet of the burner where the oxygen and natural gas mix to form a narrow, uniform flame;

Fig. 4 is a cross-sectional view taken along line 4-4 of Fig. 3 showing the inner tube positioned to lie within the outer tube to create a gap therebetween;
Fig. 5 is a perspective view of an alternative embodiment of a burner including a sleeve having a movable ignition pin which permits a user to adjust a spark gap distance between the ignition pin and the inner tube;

Fig. 6 is a side elevational view, with portions cut away, of an alternative embodiment showing a bluff body at the tip of the inner tube so that air, instead of oxygen, can be mixed with the natural gas forming a less uniform flame;

Fig. 7 is a side elevational view of the present invention showing the ignition end of the burner to be contained within a ceramic block for insertion into a refractory furnace;

Fig. 8 is a side elevational view, with portions cut away, of the burner mounted within a larger burner and used as a pilot for starting the larger burner, the pilot burner being sealed and secured to the larger burner by a threaded connection between the larger burner and the burner;

Fig. 9 is a side elevational view, with portions cut away, of yet another alternative embodiment showing the burner being used as a pilot for a larger burner, the pilot including an O-ring used as a seal and a set screw for holding the pilot in place within the burner;

Fig. 10 is a side elevational view, with portions cut away, of still another alternative embodiment showing the burner as a pilot for a larger burner, the pilot including an O-ring used as a seal and the outer tube comprising machine threads for securing the pilot burner within the larger burner;

Fig. 11 is a side elevational view of an alternative embodiment showing the burner including a ceramic star insulator for supporting a portion of the weight of the inner tube to prevent the inner tube from engaging and grounding out with the ignition pin; and

Fig. 12 is an exploded perspective view of the burner of Fig. 11 showing the star insulator positioned to lie between a counter bore formed in the outer tube and a ring coupled to the inner tube.

**Detailed Description of the Drawings**

A spark-ignition burner 10 is provided to mix oxygen and natural gas in a combination zone 45 to produce a flame 12 (see Fig. 3) and is configured for use as a
burner or a pilot ignition apparatus in a larger burner. The burner 10 comprises various modular units which are easily assembled together. The first modular unit 14 comprises a fitting 20, a compression ring 22, and a connector 24, as shown in Figs. 1 and 2. An insulator 16 is positioned to be between burner 10 and a natural gas supply 28. Fuel other than natural gas may also be used in burner 10.

Insulator 16 is made of PVC plastic and includes a length 17 of about 2 inches (5 centimeters). It is within the scope of the disclosure to make the insulator of alternate materials such as MACOR or machinable glass ceramic and of a shorter or a longer length. Insulator 16 is hollow, thereby forming a passageway 26 through which fuel, for example, can flow. A fitting 18 is connected to natural gas supply 28 and gas flows into fitting 18 at natural gas inlet 30.

A second modular unit 32 comprises an inner tube 34, an ignitor clip 36, porcelain blocks 46, 48, and a connector 50. Inner tube 34 is made of stainless steel and includes two opposite ends 40, 42 and a hollow body 41 extending therebetween. An ignitor clip 36, also made of stainless steel, is coupled to inner tube 34 by, for example, welding. Ignitor clip 36 is also coupled to a power supply 38 as shown in Fig. 1.

The power supply 38 provides the ignitor clip 36 with a constant supply of current until ignition occurs. By providing ignitor clip 36 at end 40 of the inner tube 34 with current from the power supply 38, inner tube 34 is an electrical conduit charged with current. Opposite end 42 of the inner tube 34 includes the fuel-dispensing outlet 44 for the natural gas flowing therethrough that leads to a combustion zone 45. Thus, inner tube 34 is a gas conduit as well as an electrical conduit. Porcelain blocks 46, 48 surround inner tube 34 and connector 50 surrounds porcelain blocks 46, 48 as shown in Figs. 1 and 2. Porcelain blocks 46, 48 act as insulators to prevent current from running from inside tube 34 to connector 50.

Second modular unit 32 connects with first modular unit 14 as inner tube 34 is received by fitting 20, compression ring 22, and connector 24 as shown in Fig. 1. Compression ring 22 and connector 24 are tightened down around fitting 20 thereby securing end 40 of inner tube 34 within fitting 20. Because fittings 18, 20, compression ring 22, and connector 24 are made of steel, a conductive material, insulator 16 is provided to block the flow of electricity provided by power supply 38.
from flowing to natural gas supply 28 and the rest of the plant (not shown) which may contain electrically sensitive equipment (not shown).

Insulator 16 provides a physical electric separator or barrier between natural gas supply 28 and fitting 20 and the remainder of burner 10. Thus, stray voltages from power supply 38 are blocked and prevented from traveling to natural gas supply 28 by insulator 16. This provides protection to natural gas supply 28 and any electrically sensitive equipment in electrical communication with natural gas supply 28.

As shown in Fig. 1 and 2, a three-way connector 52 is provided having a first opening 54 coupled to connector 50 of the second modular part 32, a second opening 56 connected to an oxygen supply 58, and a third opening 60 connected to an outer tube 62. Thus, outer tube 62 is a gas conduit providing oxygen to combustion zone 45 and inner and outer tubes 34, 62 provide a gas conduit providing both natural gas and oxygen to combustion zone 45. Connector 50 and outer tube 62 are shown to include pipe threads 64 which provide air-tight and water-tight seals. Thus, no extra sealing measures are required to seal between connector 50 and outer tube 62.

Alternatively, the second modular unit and the outer tube may be connected to the three-way connector by an O-ring connection, silver solder, a press fit, or any other coupling method.

Outer tube 62 includes opposite ends 66, 68 and an ignition pin 70 located at end 68 as shown in Figs. 1 and 3. Ignition pin 70 is connected to ground 72. Inner tube 34 lies within outer tube 62 so that fuel dispensing outlet 44 of inner tube 34 is in close proximity of ignition pin 70 and provides a spark gap 82. Spark gap 82 is the distance between end 42 of inner tube 34 and ignition pin 70. Thus, power supply 38, connector 36, inner tube 34, and ignitor pin 70 provide an electric spark generator that creates a spark across spark gap 82 that ignites the combustion of the natural gas and oxygen within combustion zone 45.

Burner 10 includes a central axis 118. End 68 of outer tube 62 is formed to include a rim 120 defining an outlet 122 that is spaced axially outward from fuel dispensing outlet 44 of inner tube 34 along central axis 118 by a distance 124. Outlet 122 is also spaced axially outward from ignition pin 70 by a distance 126 as shown in Fig. 3. Fuel dispensing outlet 44 is spaced axially inward from ignition pin 70 by a distance 128.
Outer tube 62 includes an outer surface 130, an inner surface 132 facing away from outer surface 130, an outer diameter 133, and a radial thickness 134 measured between outer surface 130 and inner surface 132. Inner tube 34 includes an outer surface 136 facing toward inner surface 132 of outer tube 62, an inner surface 138 facing away from outer surface 136, an outer diameter 140, and a radial thickness 142 measured between outer surface 136 and inner surface 138. A radial gap 144 (measured between inner surface 132 of outer tube 62 and outer surface 136 of inner tube 34) creates a passageway 139 for oxygen to travel to combustion zone 45. Gap 144 is greater than radial thickness 134 of outer tube 62 as shown in Fig. 4. Another radial gap 146 (measured radially between fuel dispensing outlet 44 and ignition pin 70) and distance 128 create spark gap 82.

According to a preferred embodiment of the present disclosure, distance 124 is 0.422 inches (1.07 centimeters); distance 126 is 0.297 inches (0.751 centimeters); distance 128 is 0.125 inches (0.316 centimeters); outer diameter 133 is 0.587 inches (1.49 centimeters); radial thickness 134 is 0.06 inches (0.152 centimeters); outer diameter 140 is 0.1875 inches (0.474 centimeters); radial thickness 142 is 0.02 inches (0.0506 centimeters); gap 144 is 0.140 inches (0.354 centimeters); and radial gap 146 is 0.06 inches (0.152 centimeters). Many other variations of these dimensions are also within the scope of the present disclosure.

Burner 10 operates such that natural gas flowing from natural gas supply 28 enters fitting 18 at natural gas inlet 30. The gas then flows through insulator 16 and fitting 20 to inner tube 34. Oxygen from the oxygen supply 58 flows through outer tube 62 and around inner tube 34 through passageway 139 in direction 63 as indicated in Fig. 3. The inner tube 34 carries the gas and keeps it separated from the oxygen until the gas exits at end 42 into combustion zone 45. Inner tube 34 also carries, as stated before, the electrical current for the spark ignition means. Because of the close proximity of grounded ignition pin 70 and electrically charged inner tube 34, the current provided by power supply 38 and traveling through inner tube 34 jumps from inner tube 34 to ignition pin 70 to form an electrical arc within combustion zone 45. Ignition pin 70 is located near fuel-dispensing outlet 44 of inner tube 34. As the natural gas and the oxygen mix at the fuel-dispensing outlet 44, the electric arc between ignition pin 70 and inner tube 34 creates an ignition force for igniting flame 12
as shown in Fig. 3. Thus, ignitor pin 70 provides an ignitor extension to which the electrical arc jumps.

Because fuel-dispensing outlet 44 of inner tube 34 is axially inset from outlet 122 of outer tube 62, smooth laminar flow exists at outlet 122. This laminar flow produces a non-turbulent, narrow flame 12. Because flame 12 is narrow, localized hot spots are reduced at outlet 122. Thus, no turbulent "flame wash" is produced that could reduce the useful life of a burner or degrade any other surrounding material that is susceptible to high temperatures.

An alternative embodiment is provided in Fig. 5 wherein ignition pin 70 is coupled to a sleeve 74 and outer tube 76 includes an aperture or notch 78. Ignition pin 70 is movable back and forth in directions 75 through notch 78 relative to outer tube 76 between a plurality of positions. As sleeve 74 moves in direction 75 along axis 80 of outer tube 76, spark gap 82 increases or decreases. Thus, the position of ignition pin 70 relative to inner tube 34 is adjustable. Because the distance between ignition pin 70 and inner tube 34 is adjustable, spark gap 82 (see, for example, Fig. 3) is also adjustable. It is advantageous to be able to adjust the position of ignition pin 70 as a fine adjustment for setting an optimum spark gap 82 during installation and setup of the burner 10. Thus, sleeve 74 provides a portion of an adjustable electric spark generator. Although Fig. 5 illustrates an adjustable spark gap 82 through the use of a movable sleeve 74 to which the ignition pin 70 has been attached, it is within the scope of the invention to include any type of fixture apparatus for fixing movable sleeve 74 at a fixed position relative to outer tube 76 to "fine tune" the position of ignition pin 70 relative to inner tube 34.

In another alternative embodiment of the present invention, air or air with varying grades of oxygen may be used instead of pure oxygen to run through outer tube 62 as shown, for example, in Fig. 6. When air instead of oxygen is mixed with fuel from inner tube 34, a bluff body 84 may be attached to inner tube 34. A bluff body 84 creates turbulent eddies 86 formed as the air travels through passageway 139 in outer tube 62 in direction 63 and mixes with the fuel from inner tube 34 before traveling out an outlet opening 69 of outer tube 62. Because of the turbulent flow, a much less uniform flame 12 is produced.
In an alternative embodiment shown in Fig. 7, ceramic block 88 is attached to burner 10 by cementing ceramic block 88 around outer tube 62. It is often necessary to insert burner 10 into a refractory furnace (not shown) made of multiple bricks. Attaching ceramic block 88 to burner 10 allows burner 10 to be installed into the refractory furnace without the need to make additional adjustments or inlet holes to the furnace itself. The ceramic block 88 acts as one of the existing blocks or bricks already in the furnace. Because flame 12 is narrow, it does not strike block 88 which could cause undesirable high temperature to develop on block 88. Ceramic block 88 can be provided in various shapes and sizes to fit a plurality of refractory furnaces.

Burner 10 may be used alone as a small self-sufficient burner or as a pilot ignition service for a larger burner 110 as shown in Fig. 8. As shown in Fig. 8, large burner 110 includes a gas conduit 170, an oxygen-admission port 160, an oxygen-supply housing 116, and a frame 114 mounted in an inlet end of a burner block 112 provided. Further details of a burner system similar to that shown in Fig. 9 are described in U.S. Patent No. 5,458,483, the subject matter of which is expressly incorporated by reference herein. Burner 10 is mounted to burner 110 for use as a pilot burner to aid in the ignition of burner 110. Burner 110 discharges a flame 12 into a flame chamber 132 as shown in Fig. 8. Pilot burner 10 is needed, for example, when larger burner 110 is shut off frequently or perhaps at the end of each day. Many burners are self igniting in hot temperature environments (e.g. about 1200 °F, 650°C); however, if the burner is turned off so frequently that temperatures do not always remain high enough to self ignite, a pilot burner is needed. As shown in Fig. 8, pilot burner 10 is identical to burner 10 shown in Figs. 1 and 2. Pilot burner 10 is mounted to burner 110 through the use of pipe threads 64 located around outer tube 62. As stated previously, pipe threads 64 are air and water tight and, therefore, eliminate the need for an additional seal. Pilot burner 10 is shown mounted at the top of burner 110. However, it is within the scope of the invention that burner 10 may be mounted to burner 110 in any of a variety of locations.

In further alternative embodiments where burner 10 is used as a pilot burner for larger burners 110, pilot burner 10 may be attached by means other than pipe threads 64. For example, Fig. 9 shows burner 10 inserted in direction 91 and mounted to burner 110 through the use of a set screw 90 drilled through burner 110.
and into outer tube 62 of pilot burner 10. An O-ring 92 may be added around outer
tube 34 to produce an air-tight or water-tight seal. O-ring 92 provides the necessary
seal needed between the two burners 10, 110. Fig. 10 shows an alternative
embodiment where machine threads 94 are used for securing pilot burner 10 to burner
110. O-ring 92 is provided to create an air-tight and water-tight seal. In addition, the
pilot burner 10 may be cemented (not shown) into the larger burner 110 without the
use of O-ring 92 for purposes of permanently sealing the pilot burner 10 within the
larger burner 110.

Figs. 11 and 12 show another alternative burner 210 which includes a
star insulator 96 and an outer tube 262 having a counter bore 99. Star insulator 96 is
positioned to lie within outer tube 262 as shown in Fig. 11. Star insulator 96 is radially
symmetric and includes five tips 97 and a center hole 98. Inner tube 34 is positioned
to lie in center hole 98 of star insulator 96 and includes a silver soldered ring 95 that
abuts star insulator 96 to position star insulator 96 against counter bore 99 formed in
outer tube 262. Star insulator 96 is made of ceramic; however, star insulator may be
made of any insulating materials. Star insulator 96 prevents inner tube 34 from
engaging and grounding out against ignitor pin 70. In high temperatures, inner tube 34
may tend to slightly deform one way or another. Star insulator 96 supports the weight
of inner tube 34 while centering inner tube 34 within outer tube 62. Star insulator 96
may also be used in place of bluff body 84 to create turbulent eddies.

Although the invention has been described in detail with reference to
certain preferred embodiments, variations and modifications exist within the scope and
spirit of the disclosure.
CLAIMS:

1. A burner assembly for combining first and second gases to produce a flame, the burner assembly having a longitudinal axis, the burner assembly comprising
   a first gas conduit including a first end and a second end spaced apart from the first end, the first gas conduit defining a passageway extending between the first and second ends to communicate a first gas to a combustion zone, and the second end defining an outlet of the first gas conduit,
   a second gas conduit including a first end and a second end spaced apart from the first end, the second gas conduit defining a passageway extending between the first and second ends of the second gas conduit to communicate a second gas to the combustion zone, the second end defining an outlet of the second gas conduit, and the outlet of the second gas conduit being spaced apart from the outlet of the first gas conduit along the longitudinal axis of the burner assembly, and
   a spark generator coupled to the first and second gas conduits and configured to create a spark within the combustion zone to initiate combustion of the first and second gases in the combustion zone.

2. The burner assembly of claim 1, wherein the spark generator includes an ignition extension coupled to the first gas conduit and the ignition extension is positioned to lie between the outlet of the second gas conduit and the outlet of the first gas conduit along the longitudinal axis of the burner assembly.

3. The burner assembly of claim 1, wherein the first gas conduit has an outer surface facing away from the longitudinal axis, an inner surface facing toward the longitudinal axis, and a thickness measured between the outer and inner surfaces, the second gas conduit includes an outer diameter, and the thickness of the first gas conduit is less than the outer diameter of the second gas conduit.

4. The burner assembly of claim 1, wherein the first gas conduit has an outer surface facing away from the longitudinal axis, an inner surface facing toward the longitudinal axis, and a thickness measured between the outer and inner surfaces, the second gas conduit includes an outer surface facing away from the longitudinal axis and an inner surface facing toward the longitudinal axis, the second
gas conduit is positioned to lie within the first gas conduit, and the inner surface of the first gas conduit and the outer surface of the second gas conduit cooperate to define a gap therebetween having a gap length that is greater than the thickness of the first gas conduit.

5. A burner assembly for producing a flame from a gas, the burner assembly comprising:

- a gas conduit including a first end and a second end spaced apart from the first end, the gas conduit defining a passageway extending between the first and second ends to communicate a gas to a combustion zone, and the second end defining an outlet of the gas conduit and

- a spark generator configured to create a spark within the combustion zone to initiate combustion of the gas in the combustion zone, the spark generator being coupled to the gas conduit for movement relative to the outlet of the gas conduit between first and second positions.

6. The burner assembly of claim 5, wherein the gas conduit includes a first portion and a second portion spaced apart from the first portion, the first portion is formed to include an aperture and the spark generator includes an ignition extension positioned to lie within the aperture of the first portion for movement between the first and second positions.

7. The burner assembly of claim 6, wherein the spark generator further includes a power supply coupled to the second portion of the gas conduit to create an electric spark between the second portion of the gas conduit and the ignition extension.

8. The burner assembly of claim 6, wherein first portion of the gas conduit includes an end and the aperture is formed in the end of the gas conduit.

9. The burner assembly of claim 8, wherein the aperture is a notch.

10. The burner assembly of claim 6, wherein the spark generator further includes a sleeve, the ignition extension is coupled to the sleeve, and the sleeve is positioned to lie around the first portion of the gas conduit to permit movement of the ignition extension between the first and second positions.

11. An apparatus for producing a flame, the apparatus comprising:

- a gas supply configured to supply a gas,
a burner assembly including a gas conduit defining a passageway configured to conduct the gas to a combustion zone and an electric spark generator electrically coupled to the gas conduit and configured to create a spark within the combustion zone to initiate combustion of the gas in the combustion zone, and an insulator formed to include a passageway configured to communicate gas from the gas supply to the passageway of the gas conduit, the insulator being positioned to electrically insulate the gas supply from the electric spark generator.

12. The apparatus of claim 11, wherein the gas supply includes a portion positioned to lie adjacent to the insulator, the burner assembly includes a portion positioned to lie adjacent to the insulator, and the portion of the gas supply is spaced apart from the portion of the burner assembly.

13. The apparatus of claim 11, wherein the insulator includes an axis extending along the passageway, a first end coupled to gas supply, and a second end coupled to the burner assembly and spaced apart from the first end by a distance along the axis.

14. The apparatus of claim 13, wherein the distance between the first and second ends of the insulator is about 2 inches (5 centimeters).

15. An apparatus for producing a flame, the apparatus comprising a gas supply configured to supply a gas, a burner assembly including a gas conduit defining a passageway configured to conduct the gas to a combustion zone and an electric spark generator electrically coupled to the gas conduit and configured to create a spark within the combustion zone to initiate combustion of the gas in the combustion zone, and an insulator positioned to lie between the gas supply and the burner assembly to electrically insulate the gas supply from the spark generator.

16. The apparatus of claim 15, wherein the gas supply and gas conduit cooperate to define a central axis and the insulator is positioned to lie between the gas supply and the burner assembly along the central axis.

17. The apparatus of claim 15, wherein the insulator is cylindrical shaped.
18. The apparatus of claim 15, wherein the gas conduit includes a first tube, a second tube positioned to lie within the first tube, and an insulator positioned to lie between the first and second tubes to electrically insulate the first tube from the second tube.