

[54] **COMBUSTION SYSTEM FOR FLARE GAS**
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 both of N.J.

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3,092,166	6/1963	Shepherd	431/9
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[52] U.S. Cl. **431/5, 431/90, 431/202, 431/284, 431/285, 23/277 C**

[51] Int. Cl. **F23d 13/20**

[58] Field of Search 431/58, 1, 174, 202, 284, 431/285; 110/8 A; 23/277 C

[57] **ABSTRACT**

A flare gas stack has a combustion tip defining a mixing and combustion chamber of diameter greater than that of the stack; an oxygen-fuel burner of the rocket type is mounted centrally within the stack and directly beneath the chamber for projecting a stiff oxy-fuel flame vertically into the chamber; openings to atmosphere at lower part of the combustion tip provide for induction of air into the chamber.

[56] **References Cited**
UNITED STATES PATENTS

2,480,230	8/1949	Elster	23/277 C
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11 Claims, 4 Drawing Figures

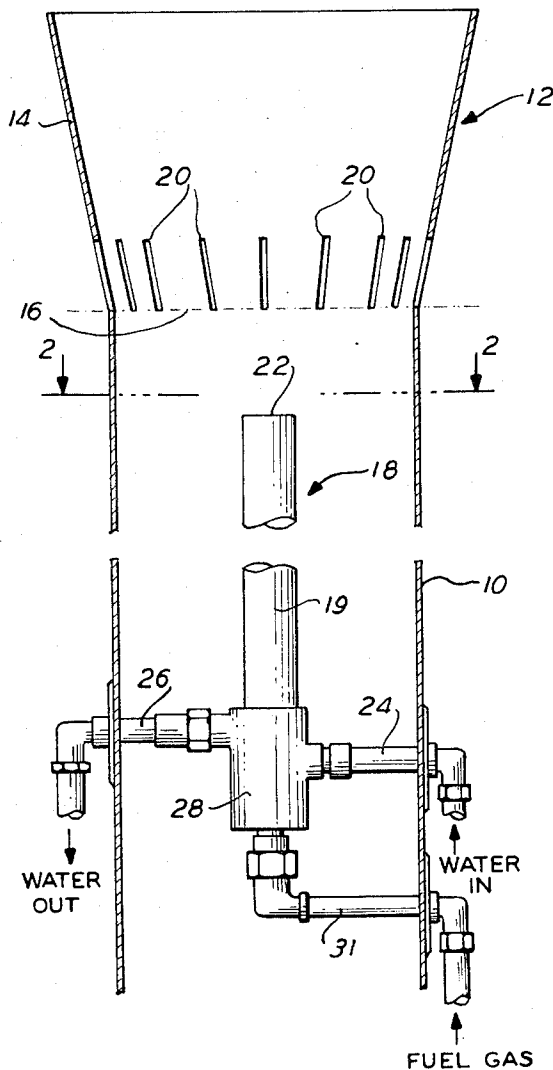


FIG. 1

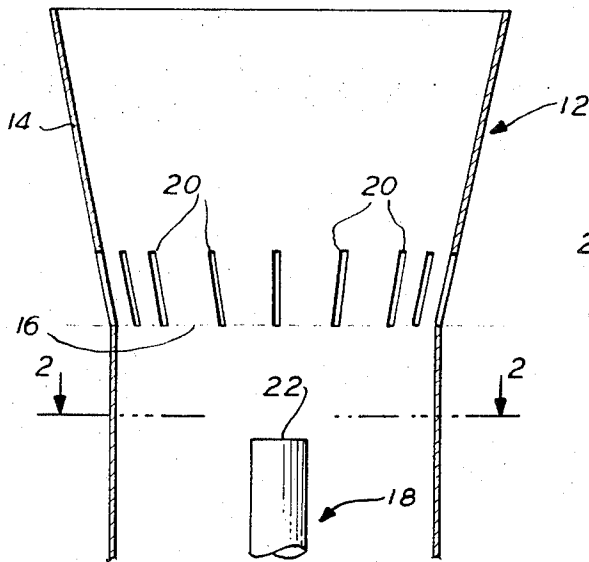


FIG. 2

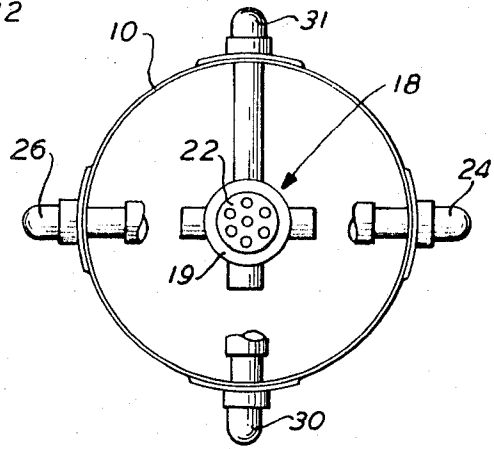


FIG. 3

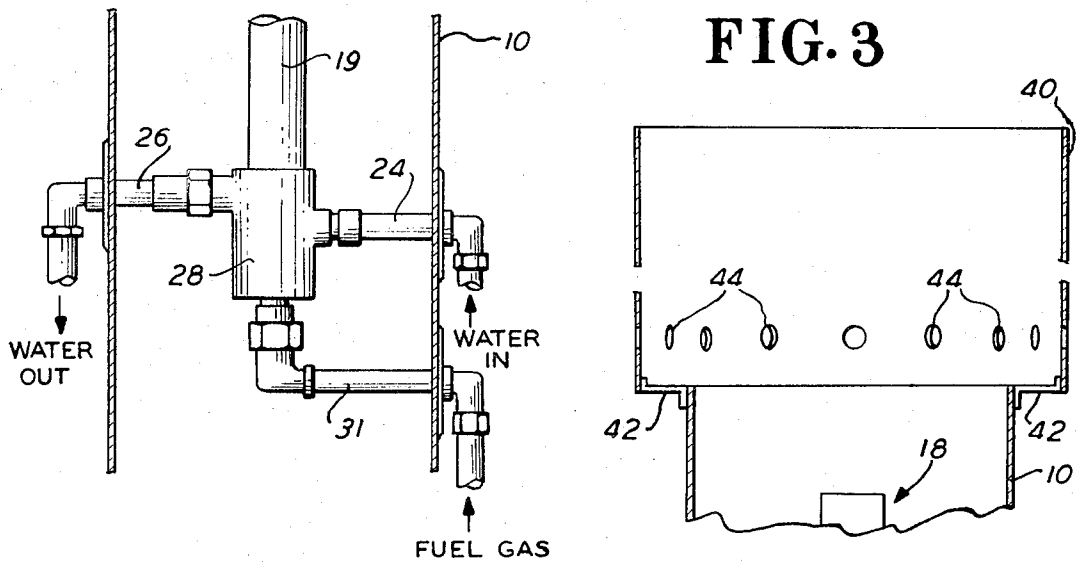
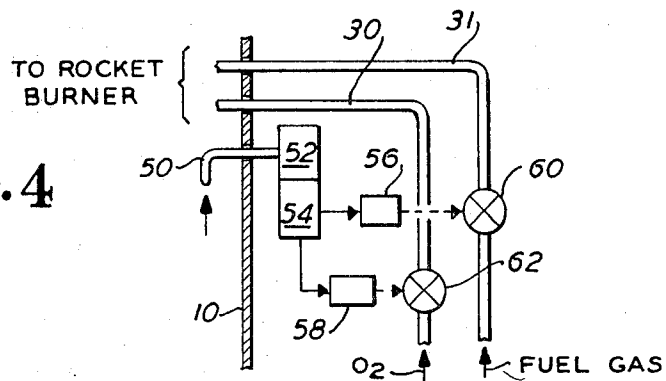


FIG. 4



COMBUSTION SYSTEM FOR FLARE GAS

BACKGROUND OF THE INVENTION

In certain industrial operations, large volumes of combustible off-gases are produced either continuously or intermittently, which must be disposed of without unduly contaminating the ambient atmosphere. Typical examples of such operations are petroleum oil refining, gas separation and distillation and the like, wherein hydrocarbon off-gases having little economic value are formed as by-products. Such off-gases are commonly disposed of by burning at the top of a high "flare stack" in an effort to minimize the effects of flame luminosity and smoke on neighboring areas. In general, the top portion or "combustion tip" of the flare stack is provided with a pilot light for ensuring continuous burning of the flare gas.

For improving combustion at the combustion tip and thereby reducing smoke emission, various methods have been proposed such as the injection of steam into the combustion tip. However, in order to be effective for smoke reduction during burning of significant volumes of flare gas, large quantities of steam are required at approximately 100 psi or higher; further, objectionable high luminosity of the flame from the combustion tip is not according to prior art literature, materially reduced by steam injection methods.

The present invention is concerned with ensuring more complete combustion of the flare gases at the stack combustion tip with significantly reduced smoke and flame luminosity that are ordinarily associated with combustion of flare gases.

SUMMARY OF THE INVENTION

In accordance with the invention, the combustion tip of a flare gas stack constitutes an enlarged chamber, either conical or cylindrical, forming in effect a continuation of the stack. The chamber is open to atmosphere at its upper end and also through peripheral openings at its lower end. For ensuring more complete combustion of the flare gases at the combustion tip with greatly decreased smoke and visible flame, an oxygen-fuel rocket type burner is located centrally of the stack immediately below the enlarged chamber so as to project a stiff oxy-fuel flame vertically upward into the chamber. This flame which exceeds in velocity that of the stack flare gas, produces high turbulence in and above the combustion tip, tending to mix the flare gases with the highly heated oxy-fuel flame and thereby accelerate combustion; further, the aspirating action of the high velocity rocket flame draws in ambient air through the peripheral openings for materially increasing available oxygen for combustion. Thus, the rocket oxy-fuel flame serves to pump additional air into the chamber and mix the combined gases therein for ensuring more complete and efficient combustion of the flare gases.

The rocket burner is adjustable for stable operation between wide limits of heat output so that uniform flare gas combustion can be obtained for different disposal rates, ranging from minimum off-gas production to emergency dumping.

A principal object of the invention therefore is an improved system for burning flare gas at a stack combustion tip, that is simple, economical and efficient.

Another object of the invention is an improved flare gas combustion system of the character described

above wherein an oxy-fuel rocket burner projects a high velocity, high temperature flame into the combustion tip for establishing a high degree of turbulence of the flare gas and mixing with adjoining air with resultant increased rate of combustion.

Another and related object is to provide an improved flare gas combustion system of the character above, wherein a very significant reduction in smoke and visible flame from the flare stack is achieved by advantageously combining an oxygen-fuel rocket burner with a flare stack combustion tip.

BRIEF DESCRIPTION OF DRAWING

FIG. 1 is a partly sectional view in elevation of the upper part of a flare gas stack with combustion tip embodying the present invention;

FIG. 2 is a view taken along the sectional line 2—2 of FIG. 1;

FIG. 3 is a section in elevation of a modified form of the combustion tip; and

FIG. 4 is a schematic illustration of an automatic control system that can be used with the invention.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring to FIG. 1, a cylindrical stack 10 for disposal of flare gas or the like, has at its top a so-called "combustion tip" 12 forming an open chamber within which at least a major part of the flare gas rising through the stack is burned; burning is completed in ambient air, generally a short distance from the combustion tip, depending on wind conditions and other factors. The flare stack is usually quite high so that the combustion gases can be more readily dissipated into ambient air by prevailing air currents.

In the form shown by FIG. 1, the combustion tip comprises a truncated conical section 14 that is in effect, an extension of the stack from a base line indicated at 16. The cone angle may be approximately 25°, and the divergent section 14 may vary in height, depending on the combustion requirements of the flare stack and the extent to which wind shielding of the burning gas is desired.

A flame projecting burner 18 using oxygen and a fuel such as natural gas, is positioned below the combustion tip referring to base line 16, and centrally of the stack for projecting a turbulent, high temperature flame vertically into the chamber 12 through the divergent section 14; thus, it is seen that the turbulent flame is projected through the throat (at base 16) of a venturi-like passage for enhancing mixing within the combustion chamber as more fully described below.

At the passage throat, the divergent section 14 is open to ambient air through suitable apertures, such as slots 20 that are peripherally spaced around the section. A strong "pumping" action of the flame induces flow of ambient air through the slots 20 into the combustion chamber, thereby providing additional oxygen for increasing combustion of the flare gases.

The oxygen-fuel burner used in the flare stack is preferably of the so-called "rocket type" disclosed in U.S. Pat. No. 3,092,166, granted June 4, 1963 to T. L. Shepherd. This type burner has characteristics that can be used to advantage for high temperature, efficient combustion of the flare gases in the combustion tip. For example, the inherent stability of the burner achieved by anchor flames, ensures continuous flame output notwithstanding variation of the fuel supply over a wide

range within a comparatively brief time. By simple valve adjustments of the oxygen and fuel gas lines, the burner flame length can be varied from about 3 ft. up to as much as 40 ft., and the heat output can be varied from about 20,000 Btu/hr. to approximately 10,000,000 Btu/hr. for a comparatively small size burner; also valve adjustment serves to control the flame temperature and its oxidizing potential by varying the oxygen-fuel ratio as desired. Thus, the ratio control which is variable over a wide range, can also provide excess amounts of oxygen in situations such as large-scale dumping of waste gases, where excess oxygen is desirable.

Another practical advantage of this rocket type burner when used in a high stack (often in cold ambient air) is that it has rapid light-off under cool conditions. That is, high burner output can be developed within a few seconds after light-off, even though the burner may be operating into a cool space or open air.

The rocket burner 18 is mounted coaxially of the stack so that the burner exhaust at 22 is positioned a short distance below the base line 16 of the combustion tip. The barrel 19 of the burner 18 is water cooled from an incoming line 24 that is connected to an annular passage in the barrel formed by concentric cylinders (not shown). The passage is connected to an outlet line 26. The breech end housing 28 of the rocket burner provides couplings for the cooling lines 24 and 26 and also for an oxygen inlet line 30 and a gas inlet line 31, FIG. 2. The pipe connections described above can serve as the mounting structure for the burner within the stack.

The flare gases are burned at the combustion tip in the following manner: assuming moderate flow of flare gas through the stack, the rocket burner is started (as described in U.S. Pat. No. 3,092,166) with the oxygen and gas line supply valves (not shown) set for a desired mixture ratio and flame velocity. The resulting comparatively high velocity, high temperature and turbulent flame not only draws a large amount of air through the venturi throat slots 20 as described above, but also creates a high degree of turbulence throughout the combustion chamber 12 as it interacts with the lower velocity flare gas rising from the stack and with the inducted air from slots 20 and ambient air drawn into the mixed gases at the upper part of the chamber. Thus, as the mixture of air and flare gas is expanded and accelerated in the diverging section 14, it is brought closer into interacting contact with the hot oxy-fuel rocket flame for ensuring rapid combustion.

This interaction is enhanced by the flow separation that takes place along the sides of the diverging section 14. The more or less separate outer streams of air tend to mix with the separating streams of flare gas rising from the stack into the diverging section so that atmospheric oxygen is available for flare gas combustion under the influence of the hot oxy-fuel flame. As the rocket flame velocity can be increased if desired to that of sound, it will be apparent that high degrees of turbulence for mixing and flame interaction can be obtained throughout a wide range of loads.

In brief, the turbulent, hot oxy-fuel flame materially raises the heat content level of the air and flare gas mixture for ensuring both active mixing and substantially complete combustion thereof; also as mentioned above the mixture ratio of the rocket burner can be adjusted as required so that the flame can have an excess of oxy-

gen where the air oxygen is insufficient for complete combustion, as for example in heavy dumping or in gas concentrations rich in hydrocarbons.

The flare gas combustion tip can also take the form shown in FIG. 3 wherein the combustion chamber is a cylindrical member 40 having a diameter greater than that of the flare stack 10. The cylinder 40 is supported on the stack by spaced brackets 42 or the like, so that the lower peripheral part of the combustion chamber is open to atmosphere. The cylinder also may have apertures 44 spaced along the periphery thereof at the lower part of the chamber for admitting ambient air to the chamber.

As in the case of FIG. 1, the rocket burner at 18 is located immediately below the combustion chamber for projecting vertically therein a turbulent, high temperature flame of velocity materially higher than that of the rising flare gas. The resulting mixing of air and flare gas and the interaction of the gas mixture is generally similar to that described above. The flare gas streams tend to separate and to mingle with the induced air streams flowing into and along the sides of the combustion chamber from the lower peripheral opening at 42 and through the lateral apertures 44. The mixture in turn interacts with the hot turbulent flame so that the heat content of the gaseous mixture is greatly increased, thereby ensuring a high rate of combustion.

The two forms of combustion tips, i.e., venturi-type and cylindrical, described herein have special applications in practice although either form is suitable for materially reducing flare gas flame length and smoke. The venturi-type tip for example, appears to be especially suitable where the flow pattern of flare gas is non-uniform.

Where the flare gas varies in flow rate within wide limits, it may be more economical to control the rocket burner feed automatically. One method of control is indicated in FIG. 4 wherein the rate of flare gas flow is sensed by a pitot-type tube 50 or the like, mounted within the stack 10 as indicated. The tube is connected to known means at 52 for converting the sensed flow rate (or pressure) to an electrical signal for example, that controls through the fuel-oxygen ratio setting means 54, valve servos 56 and 58 for operating the fuel and oxygen supply line valves 60 and 62 respectively. This type control is sufficiently responsive, combined with the inherent fast response of the rocket burner to valve adjustments, for anticipating flow of large volumes of flare gas to the combustion tip.

In practice where manual adjustment is used, the rocket burner can be operated at its low-heat setting where flare gas flow is comparatively light and intermittent; for high flow rates, the burner can be adjusted as required for either excess oxygen or exceptionally high heat output or both, as mentioned above.

The invention has demonstrated in several preliminary stack tests its capability of greatly reducing smoke associated with incomplete combustion and also greatly reducing both the length and luminosity of the flare stack flame. In one test under strong wind conditions, intermittent quantities of offgases from a methane still were burned in conventional manner in a flare stack. A long, moderate-temperature flame with some dark smoke was observed to extend approximately 30 feet horizontally from the combustion tip. When the rocket burner was started (the stack being modified to

incorporate the invention) the flame length was reduced to approximately 10 feet, and about 80% of the smoke was eliminated under the same wind conditions.

In another test wherein ethylene off-gas from the still was burned also under strong wind conditions, a flame about 40 feet in length with heavy black smoke was observed to extend horizontally from the stack when the conventional pilot light was used. When the oxy-fuel burner was started according to the invention, the flame was again reduced to about 10 feet in length, and approximately 75% of the smoke was eliminated.

Having set forth the invention in what is considered to be the best embodiment thereof, it will be understood that changes may be made in the system and apparatus as above set forth without departing from the spirit of the invention or exceeding the scope thereof as defined in the following claims.

We claim:

1. A stack combustion tip for burning flare gas comprising:

- a. an enclosure at the top of the stack forming an open-end combustion chamber for receiving flare gas rising through the stack,
- b. the combustion chamber having an enlarged cross-section with respect to the cross-section of the stack and having at its lower periphery openings to ambient air,
- c. and an oxygen-fuel burner mounted substantially centrally within the stack for projecting hot, turbulent elongated oxygen-fuel flames into the combustion chamber, said burner having a barrel portion defining an elongated burner chamber substantially centrally positioned within said stack and parallel to the longitudinal axis of said stack, a plurality of fuel passages for supplying streams of fuel, a plurality of oxygen passages for supplying streams of substantially pure oxygen, and means for cooling said burner chamber which chamber is positioned to receive said streams of fuel and oxygen supplied thereto from said fuel and oxygen passages, respectively, such that said fuel and oxygen streams are mixed and ignited in said burner chamber to produce said hot, turbulent elongated oxygen-fuel flame.

2. A stack combustion tip as specified in claim 1 wherein the oxygen-fuel burner is mounted coaxially of the stack and directly beneath the combustion chamber for projecting the flames vertically into the center of the chamber.

3. A stack combustion tip as specified in claim 2 wherein the oxygen-fuel burner projects the flames at greater velocity than that of the rising flare gas.

4. A stack combustion tip as specified in claim 1 wherein the enclosure is a frusto-conical section mounted at its small-diameter end on the stack, and the

lower periphery of the section has said openings for admitting ambient air to the chamber.

5. A stack combustion tip as specified in claim 4 wherein the frusto-conical section is joined to and forms an extension of the stack, and the openings are peripherally spaced apertures in the section wall.

6. A stack combustion tip as specified in claim 1 wherein the enclosure is an open-end cylindrical member, and the lower end of the member is annularly spaced from the stack end to form peripheral openings to ambient air.

7. A stack combustion tip as specified in claim 6 wherein the cylindrical member also has wall openings laterally spaced around the cylindrical periphery opening to ambient air.

8. In a system for burning flare gas including an oxygen-fuel burner mounted substantially centrally within a cylindrical stack through which a flare gas flows to a combustion chamber of an enlarged cross-section with respect to the cross-section of the stack, said combustion chamber having openings in its lower periphery to ambient air and said oxygen fuel burner having a plurality of fuel passages for supplying streams of fuel, a plurality of oxygen passages for supplying streams of substantially pure oxygen, a barrel portion defining an elongated burner chamber positioned substantially centrally and parallel to the longitudinal axis of said stack and means for cooling said barrel portion which portion is positioned to receive said supplied streams of fuel and oxygen, the method which comprises:

- a. discharging into the combustion chamber from the stack a turbulent flame of burning fuel gas and oxygen at a velocity higher than that of the flare gas,
- b. causing flame-induced flow of ambient air into the combustion chamber from the lower periphery thereof and along the combustion chamber sides for mixing with the rising flare gas, and
- c. directing the flame vertically and centrally of the combustion chamber for optimum mixing and interaction of the mixed gases with the flame.

9. The method as specified in claim 8 wherein the induced air is caused to flow into the lower peripheral part of the combustion chamber for upward flow in diverging directions.

10. The method as specified in claim 8 wherein the oxygen-fuel flame is projected turbulently in concentric relation to the rising flare gas from the stack and the inducted air respectively for interacting relationship in the combustion chamber.

11. The method as specified in claim 8 wherein the rate of flow of flare gas in the stack is sensed, and the supply of fuel gas and oxygen for the flame is adjusted according to the sensed flow rate.

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