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Buchanan et al.

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[45] **Jan. 7, 1975**

[54] **SEQUENTIAL COMBUSTION OF WASTE GASES**

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[73] Assignee: **Exxon Research Engineering Company,** Linden, N.J.

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[52] **U.S. Cl.** ..... **431/5,** 23/277 C, 431/202

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

[58] **Field of Search** ..... 431/5, 8, 202, 285; 23/277 C; 423/210; 239/568

[56] **References Cited**

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Assistant Examiner—William C. Anderson
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[57] **ABSTRACT**

A waste gas flare provides two separate sequential burner arrays within a combustion chamber, which is enclosed at the sides but open at the top and bottom. The lower one of the two burner arrays handles the first 25 percent of the waste gas which the flare is designed to receive. A substantial excess of air is induced in order to produce low temperature combustion. The combustion products and excess air from the lower burner array pass to an upper array which burns all the remaining waste gas (above the first 25 percent sent to the lower array). The flare is substantially smokeless without the need for steam injection at most gas rates, although at extremely low rates small quantities of steam are added. Each of the burner arrays produces, by means of slotted openings, a series of fan-shaped flames which require less steam for smokeless operation than is needed when gas is discharged from circular nozzles.

13 Claims, 3 Drawing Figures

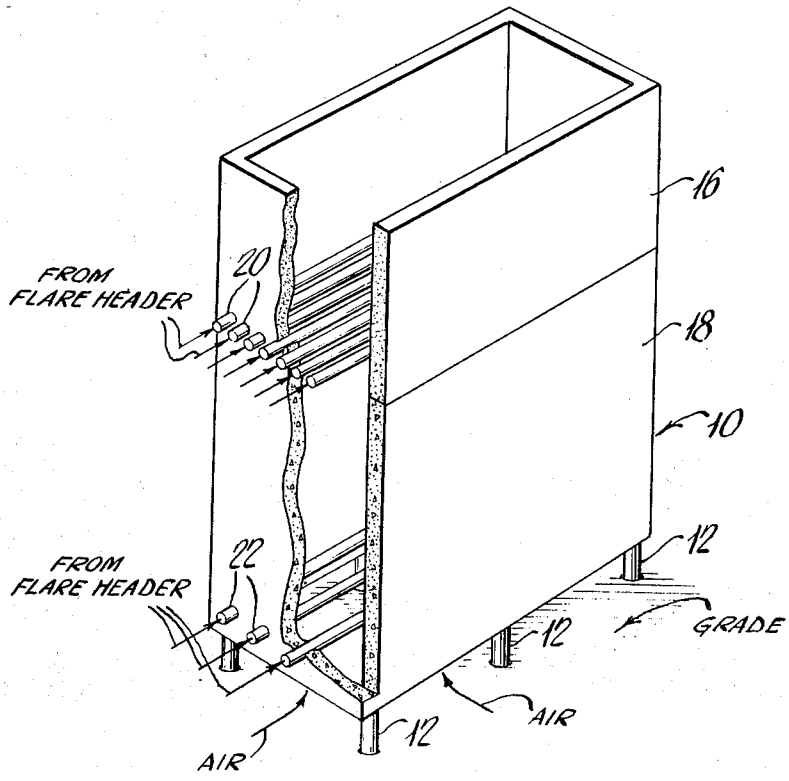


Fig. 1.

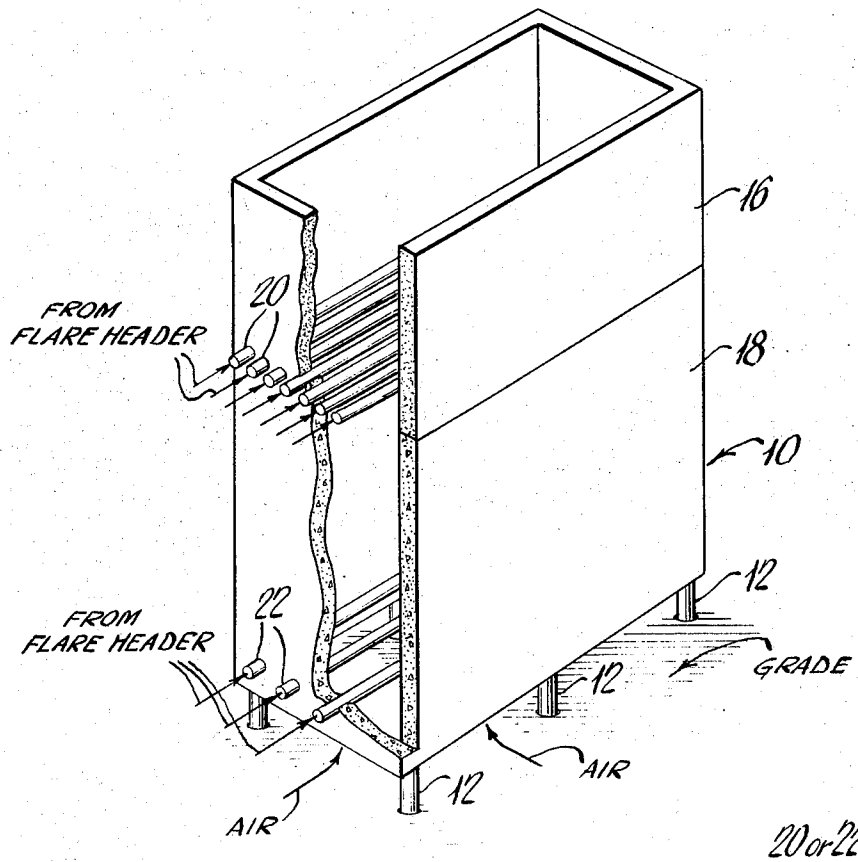

16
18
10
12
12
12
20
FROM FLARE HEADER
22
FROM FLARE HEADER
GRADE
AIR
AIR

Fig. 3.

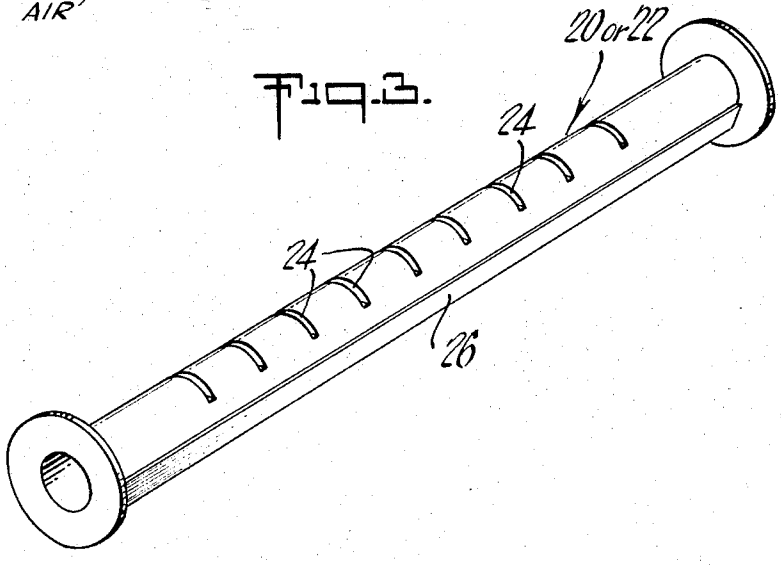
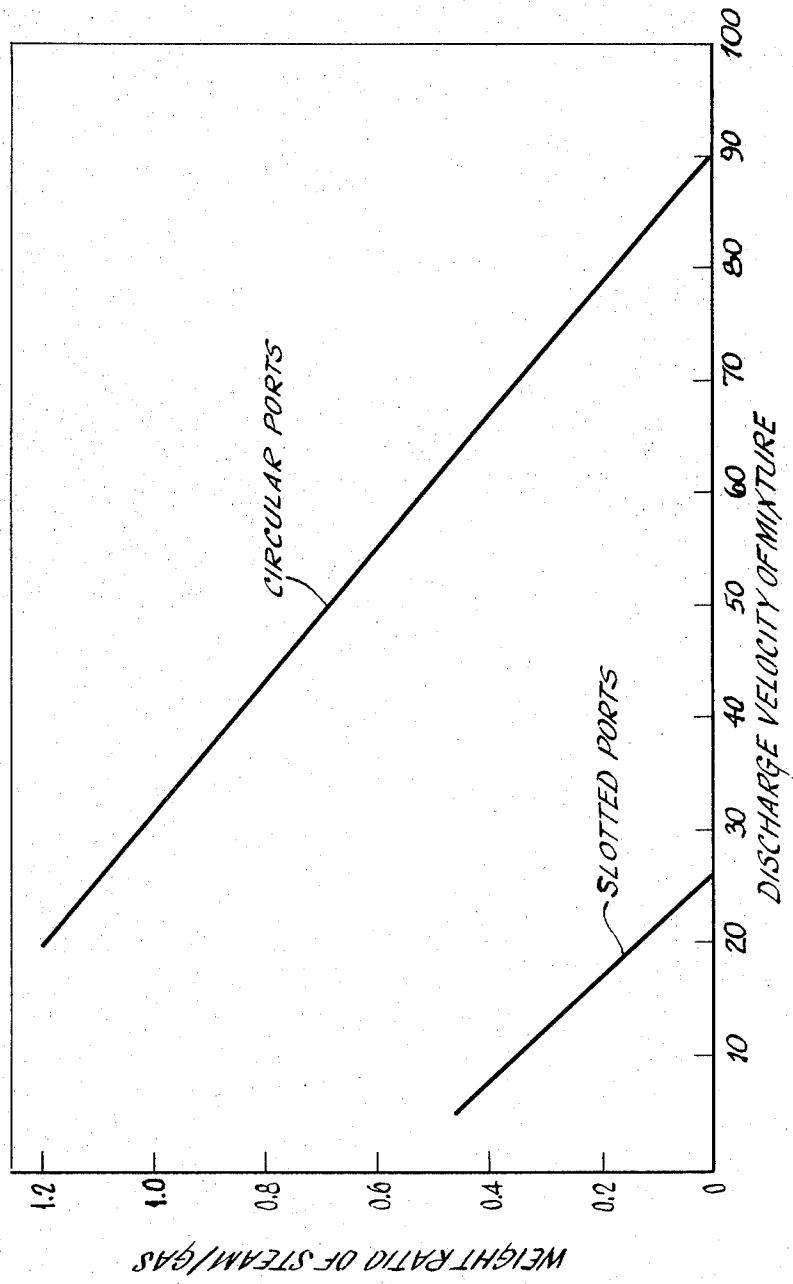

20 or 22
24
24
26

Fig.2.


CIRCULAR PORTS
SLOTTED PORTS
WEIGHT RATIO OF STEAM/GAS
DISCHARGE VELOCITY OF MIXTURE
0
0.2
0.4
0.6
0.8
1.0
1.2
10
20
30
40
50
60
70
80
90
100

SEQUENTIAL COMBUSTION OF WASTE GASES

BACKGROUND OF THE INVENTION

It is common practice in refineries and chemical plants to dispose of waste gases when it is not possible or practical to use them. Since these gases could be hazardous or contribute to air pollution, the accepted practice is to burn or "flare" them. In congested areas, elevated flares are used most commonly. The flow of waste gases tends to be irregular so that while it is usual for flares to be designed for the maximum expected load, normally they handle only a small fraction of the maximum expected load.

The gases produced by refineries and chemical plants have a wide range of compositions, some of which burn relatively cleanly, but others are inherently smoke producers. A flare must provide insofar as possible, a smokeless burning over a wide range of conditions. Flares usually operate without air premixing and produce diffusion flames, which obtain oxygen by mixing with the surrounding air. Often a relatively smoky flame will be produced due to inefficient mixing of gas and air, particularly when heavy or unsaturated hydrocarbons are in the waste gas being flared. To alleviate this, steam is introduced by any one of a number of conventional methods in order to increase turbulence and mixing, while at the same time reducing by chemical reaction the amount of carbon produced by the flame. Adding steam thus has two effects, both of which reduce luminosity and smoke.

Although proper premixing of air with the gases could eliminate smoke production, the complications, expense and inherent safety problems involved in properly mixing air and gases when the gas rate and composition are irregular have led to the operation of most flares without premixing of air with gas. Flares often operate with very low gas pressures, typically less than 1 inch of water. If high pressures were always available, design of air inspirating flares would be feasible, but since a low and variable pressure is available, steam is used to supply oxygen and to induce air into the flare tip. The prior art includes designs such as that disclosed in U.S. Pat. No. 2,506,972 of Schellentrager et al. in which a portion of the air needed for combustion is introduced near the flare tip. Air is induced by the action of steam in an inspirating venturi. Thus, the benefits of both air and steam are obtained. The stoichiometric amount of combustion air needed is not supplied by premixing since the problems—particularly noise, flash back, and overheating due to burning inside the flare tip, preclude this approach.

Since the tip of an elevated flare may well be several hundred feet above grade and since the flare must always be in service, such structures are expensive and difficult to maintain. Any damage to equipment located at the top of such flares can be very expensive to correct, especially if operations must be shutdown in order to make repairs.

Ground flares, that is, relatively short structures with burners located near grade have been disclosed in the prior art. One such design is disclosed in U.S. Pat. No. 2,971,605. A more recent commercial design is John Zink's Thermal Oxidizer Flare. Such designs are essentially ground level incinerators. The flames are confined within a structure rather than freely burning in the atmosphere as is typical of an elevated flare. The present invention is a novel improved ground flare which operates efficiently over a wide range of capability and requires significantly less steam injection.

SUMMARY OF THE INVENTION

An improved flare for burning waste gases of variable quantity and quality preferably has two sequential burner arrays which handle different amounts of waste gases. Both burner arrays are located in a combustion chamber, enclosed at the sides but open at the top and bottom. The lower burner array typically handles up to about 25 percent of the maximum expected gas rate. It is located below the upper burner array which handles the remainder of the gas. The combustion of waste gas causes large quantities of ambient air to be induced into the combustion chamber from the atmosphere by natural draft, effectively lowering the temperature and permitting relatively inexpensive materials to be used. Owing to the large quantity of excess air induced and the special design of the burner ports, it is possible to operate in an essentially smokeless manner without steam injection, except at very low gas rates, when a small amount of steam is needed. The excess gas above the first 25 percent is directed to the upper burner array. The upper array receives preheated combustion air plus combustion products from the lower burner array, thus making possible the smokeless combustion of the upper stage.

Essentially smoke-free flaring is achieved by means of this invention. The flames, being confined within the surrounding structure, are not visible and, since no smoke is produced, essentially no disturbance to the surrounding community results. In addition, the noise level resulting from operation of the flare at high loads is minimized.

The gas is released in the burner stages through ports which are constructed to produce a flat fan-shaped flame, thereby maximizing the contact between the flame surface and the surrounding air, improving the mixing substantially, reducing the smoke-forming tendency and permitting steamless operation under most conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an overall perspective view of a progressive combustion ground flare according to the present invention.

FIG. **2** shows the correlation between velocity and steam needed for smokeless burning, comparing the flat fan-shaped flame with that produced by a circular port.

FIG. **3** is a perspective view of a typical burner tube employing the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIG. **1**, a ground flare generally designated **10** according to the present invention is elevated above grade on a plurality of support piers **12**. The flare **10** consists of two distinct portions, an upper portion **16** and a lower portion **18**. The lower portion **18** operates at moderate temperatures since a large volume of air is induced through the bottom opening, about twice that required for the design maximum gas flow rate. This amount of air is about seven times more than is needed for the amount of gas burned in the lower portion **18** and the resulting combustion temperature is quite low, typically 650°F. Such a large excess of air is

contrary to normal furnace operating practice wherein high temperatures are achieved by restricting the air supply and thereby maximizing heat transfer. At low gas rates all the waste gases are fed to the lower burner array comprising a bank of tubes **22** disposed horizontally near the bottom of the lower portion **18.** Waste gases are supplied to the lower bank of tubes **22** from the flare header (not shown) under all operating conditions, but below approximately 25 percent of the maximum rate the gas is directed exclusively to the lower bank of tubes **22** by instrumentation in the flare header system.

Each of the tubes **22** as well as the tubes **20** comprising the upper bank to be discussed more completely hereinafter are provided with outlet ports **24** (see FIG. 3) which create a fan-shaped flame. The fan-shaped flame has a large surface area exposed to the air and requires significantly less steam injection in order to produce a smoke free, non-luminous flame. Thus, this flame shape has been adopted for use in this flare in order to reduce steam consumption. FIG. **2** compares the performance of fan-shaped flames and those produced by the usual round openings. In its simplest possible configuration, the fan-shaped flame may be produced by making a saw cut around one-quarter of the circumference of the tube, at the top and normal to the axis of the tubes. Alternatively, nozzles which produce such flames may be provided spaced uniformly along the tubes **22** to provide burner ports. Not only does the fan-shaped flame reduce steam required for smokeless combustion, but it has another unexpected benefit in that no flame holders are required. The large volume of air passing around the burner tubes **22** create negative pressures at the side and behind the tube which hold the flames close to the tubes and prevent blowoff, while at the same time assuring ignition at all the ports since each serves as a pilot for its neighbors. Another benefit is that the air removes heat from the burner tube sufficient to prevent weakening and the consequent failure of the tubes. A longitudinal slot in the tubes **20** or **22** has been found to be unsatisfactory since insufficient heat is removed and the tube is seriously weakened. Thus, an apparently simple circumferential saw cut has been found to perform in an unexpectedly superior manner. Heat removal from the tubes may be critical to retention of strength, thus, in an alternate embodiment, additional support may be provided for the tubes by supporting them from the bottom by an angle brace **26** as shown in FIG. **3.**

As noted above, the burning of gases in the lower bank of tubes **22** induces, due to the natural draft, a large quantity of air which mixes with the hot gases and reduces the overall temperature, thus permitting the use of inexpensive materials in the lower portion as well as producing a smokeless flare even at relatively low gas rates. It is usual with conventional flares to provide large quantities of steam, especially at low rates, in order to achieve the velocity needed to thoroughly mix air with the gas so that a smokeless flame is produced. Also the prior art includes flares which use the motive force of steam to induce air. The large opening at the base of the flare in the present invention provides an ample inlet for air to be induced without the assistance of steam.

When the gas to be flared is above 25 percent of the expected total, the excess is diverted to the upper burner array comprising a second bank of tubes **20** located in the upper portion **16.** Although two banks of tubes are preferred, it is within the scope of the invention to use more than two rows with combustion occurring progressively from the bottom to the top rows. The gas is burned after mixing with the hot combustion products from below along with the large excess of air which was induced. Combustion at the upper burning stage produces a significantly higher temperature, typically 1,800°F. Thus, additional insulation is required in the upper section **16** in order to withstand such high temperatures. The presence of preheated combustion air and the steam inherently in the combustion products from below produces a smokeless burning even at very high rates. Since all combustion takes place within the confines of the flare **10,** no flame is visible and, since no smoke is produced, the operation of the flare produces no visible disturbance to the surrounding community. In addition, combustion taking place within a confined space is significantly less noisy, reducing noise pollution to a minimum.

The upper bank of burner tubes **20** also is provided with nozzles **24** which produce fan-shaped flames, again reducing the quantity of steam which is required in order to achieve smokeless combustion, which generally requires steam only at the lowest gas rates (see FIG. **2**).

A significant advantage of the flare according to this invention is that at no time are air and fuel premixed in a confined space without combustion taking place. Thus, dangers of flash back and internal explosions are eliminated by providing a raw gas burner without premixing. Owing to the erratic variations in quantity and quality of waste gases which reach typical industrial flares, it is necessary to operate over a wide range of pressures, compositions and flow rates. In this situation, premixing of air with fuel, which is otherwise highly desirable to minimize smoke production and to assure efficient combustion, is not readily done with safety. The present invention foregoes the advantages of premixing, but achieves about the same results—producing smokeless, nonluminous, and relatively quiet burning.

Although in the preferred embodiment the first 25 percent of the waste gases are sent only to the lower burner array, it is possible to burn more than 25 percent in the lower burner while still maintaining the advantages of progressive combustion.

Although not the preferred embodiment using progressive combustion, it is feasible to construct a single stage flare using these principles since improved combustion can be obtained by using the novel slotted burner array without progressive combustion. In such a flare, the tubes would be in a single horizontal array spaced to provide at least about 50 percent excess air, preferably 100 percent or more, to achieve the best results.

The foregoing description of the preferred embodiment is by way of illustration of the invention and it is not to be construed as limiting the scope of the invention which is defined by the claims which follow.

What is claimed is:

1. A method of burning waste gases without premixing of air and gas comprising:

a. introducing a first fraction of said gases uniformly across a first combustion zone established within a hollow enclosure open at the top and bottom wherein said first fraction is burned in a large ex-

cess of air induced through the bottom opening of said enclosure into said first zone by natural draft created by combustion;

b. flowing the combustion products from said first zone upward into a second combustion zone established within said enclosure;

c. introducing the remaining fraction of said gases into said second zone wherein said remaining fraction is burned in the presence of combustion products and air from said first zone;

d. discharging the combustion products and air from said second zone through the top opening of said enclosure.

2. The method of claim **1** wherein said first fraction is all of said waste gases up to a maximum of 25 percent of the design maximum.

3. The method of claim **1** wherein said remaining fraction is the remaining portion of said gases above 25 percent of the design maximum.

4. The method of claim **1** wherein the air induced into the primary combustion zone is about seven times that required for complete combustion of the first gas fraction.

5. The method of claim **1** wherein the air flowed into said second combustion zone is about twice that required for complete combustion of the design maximum gas.

6. A ground flare for burning waste gases in a noiseless and smokeless manner without premixing of air and gas comprising:

a. a hollow structure open at the top and bottom within which combustion takes place, said structure being elevated sufficiently to permit inducing air through said bottom in excess of that needed for combustion of said waste gases;

b. first burner grid means within said structure for distributing a first fraction of said gas uniformly across the horizontal cross section of said structure;

c. second burner grid means within said structure for distributing the remainder of said gas uniformly across the horizontal cross section of said structure, said second grid disposed above said first burner grid within said structure.

7. The flare of claim **6** wherein said first fraction of gas is within the range of 0–25 percent of the design maximum.

8. The flare of claim **6** wherein said gas remainder is the remaining portion of said gases above 25 percent of the design maximum.

9. The flare of claim **6** wherein the air induced into said structure is about 100 percent of that needed for stoichiometric burning of the design maximum gas rate.

10. The flare of claim **6** wherein said first and second burner grid means each comprise a plurality of horizontal tubes disposed across the interior of said structure.

11. The flare of claim **10** wherein gas is distributed from a plurality of nozzles longitudinally spaced on said tubes and shaped to produce flat fan-shaped flames disposed normal to the axis of said tubes.

12. The flare of claim **10** wherein each of said tubes is provided with a multiplicity of longitudinally spaced narrow slots.

13. The tubes of claim **12** wherein said slots extend around one quarter of the circumference of said tubes in the upper portion thereof, thereby creating flat fan-shaped flames.

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