United States Patent [19]

Reed et al.

[11] **3,887,324**

[45] **June 3, 1975**

[54] **METHOD FOR NON-POLLUTING COMBUSTION OF WASTE GASES**

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[22] Filed: **Oct. 15, 1973**

[21] Appl. No.: **406,210**

Related U.S. Application Data

[62] Division of Ser. No. 216,659, Jan. 10, 1972, Pat. No. 3,779,689.

[52] **U.S. Cl.** **431/5;** 431/190; 431/202; 431/29; 431/90; 431/121; 431/3; 431/4

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

[58] **Field of Search** 431/3, 4, 5, 29, 30, 32, 431/60, 89, 90, 121, 202, 281, 190; 137/118

[56] **References Cited**

UNITED STATES PATENTS

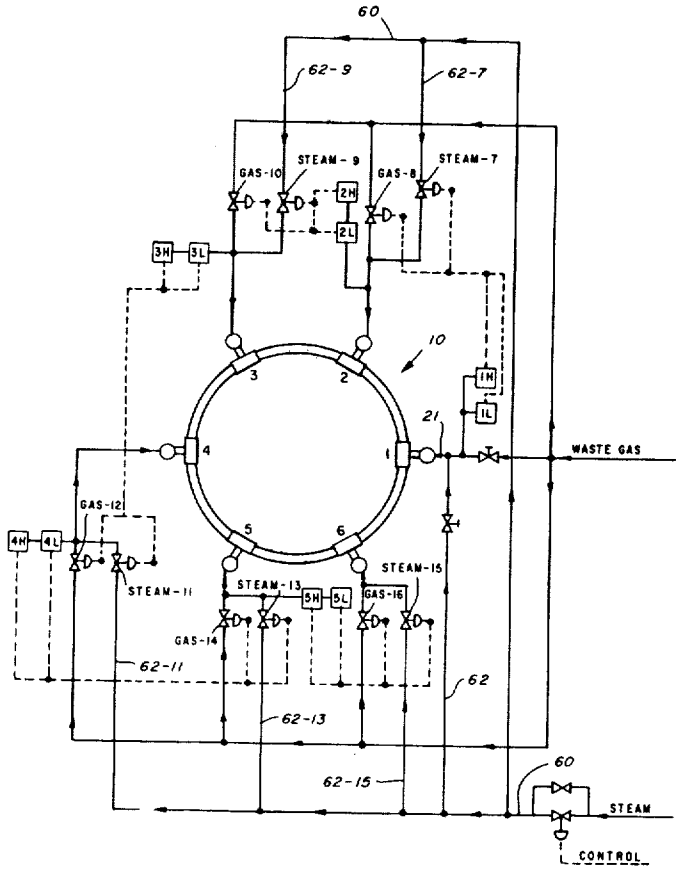
2,336,538	12/1943	Geisel et al.	431/29
2,362,045	11/1944	Bliss	431/29 X
2,390,806	12/1945	Nagel	431/90 X
3,043,366	7/1962	Wentworth	431/121 X

Primary Examiner—Charles J. Myhre
Assistant Examiner—William C. Anderson

[57] **ABSTRACT**

A non-polluting waste-gas disposal system for processing plants or other operation subject to variable quantities of waste gas for disposal. The system includes a low-level burner normally adapted to handle the usual volumes of plant waste gas, required to be disposed, without visible flame, smoke or noise pollution. An elevated flare can be used in combination to consume gases in excess of the normal capacity of the low-level flare.

6 Claims, 9 Drawing Figures



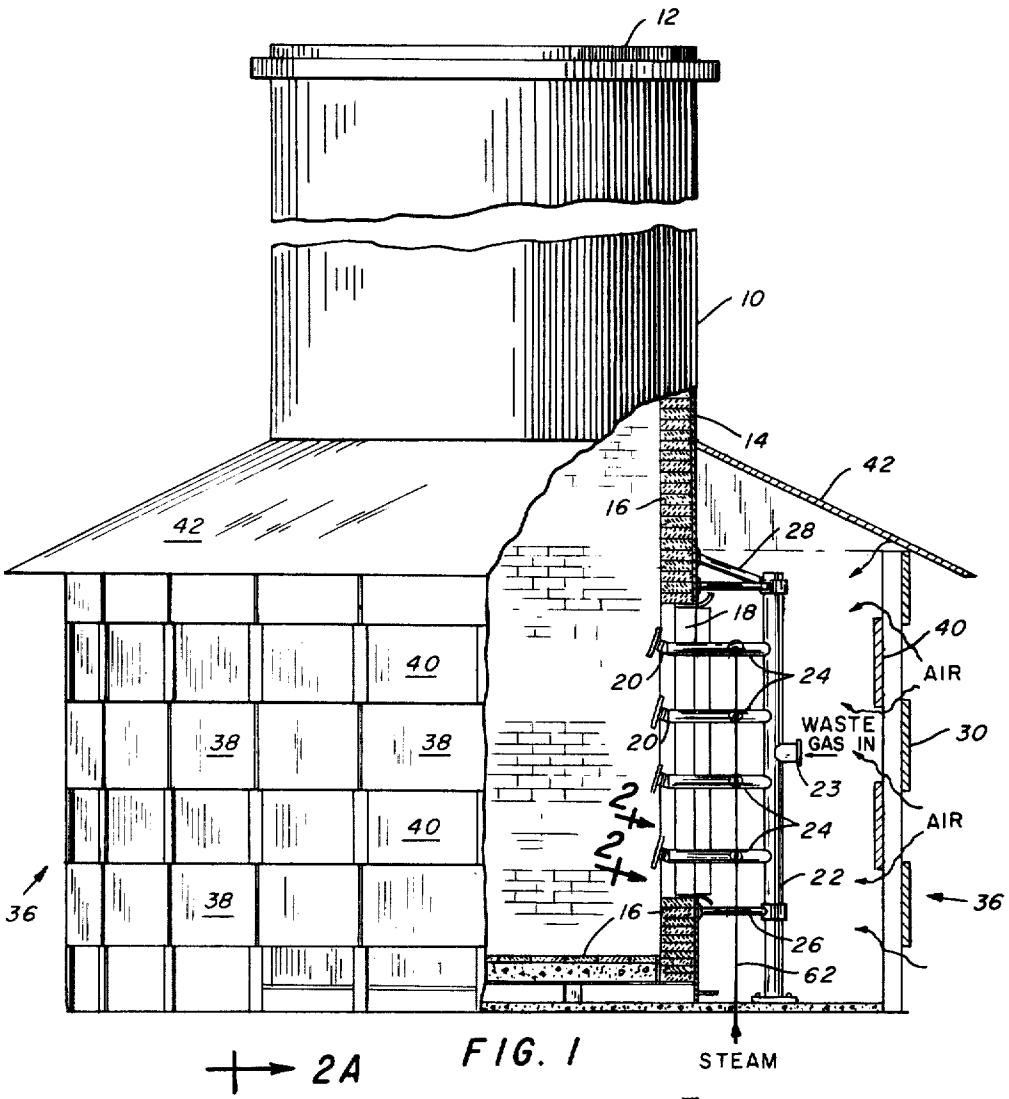


FIG. 1

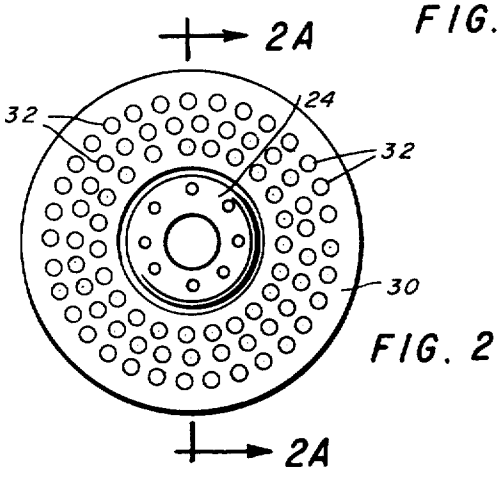


FIG. 2

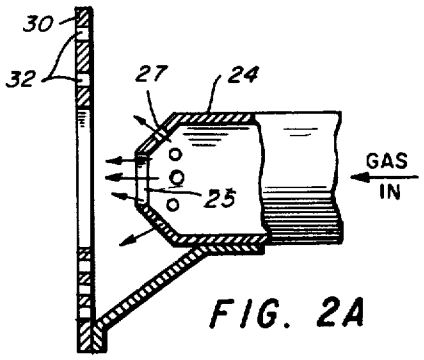


FIG. 2A

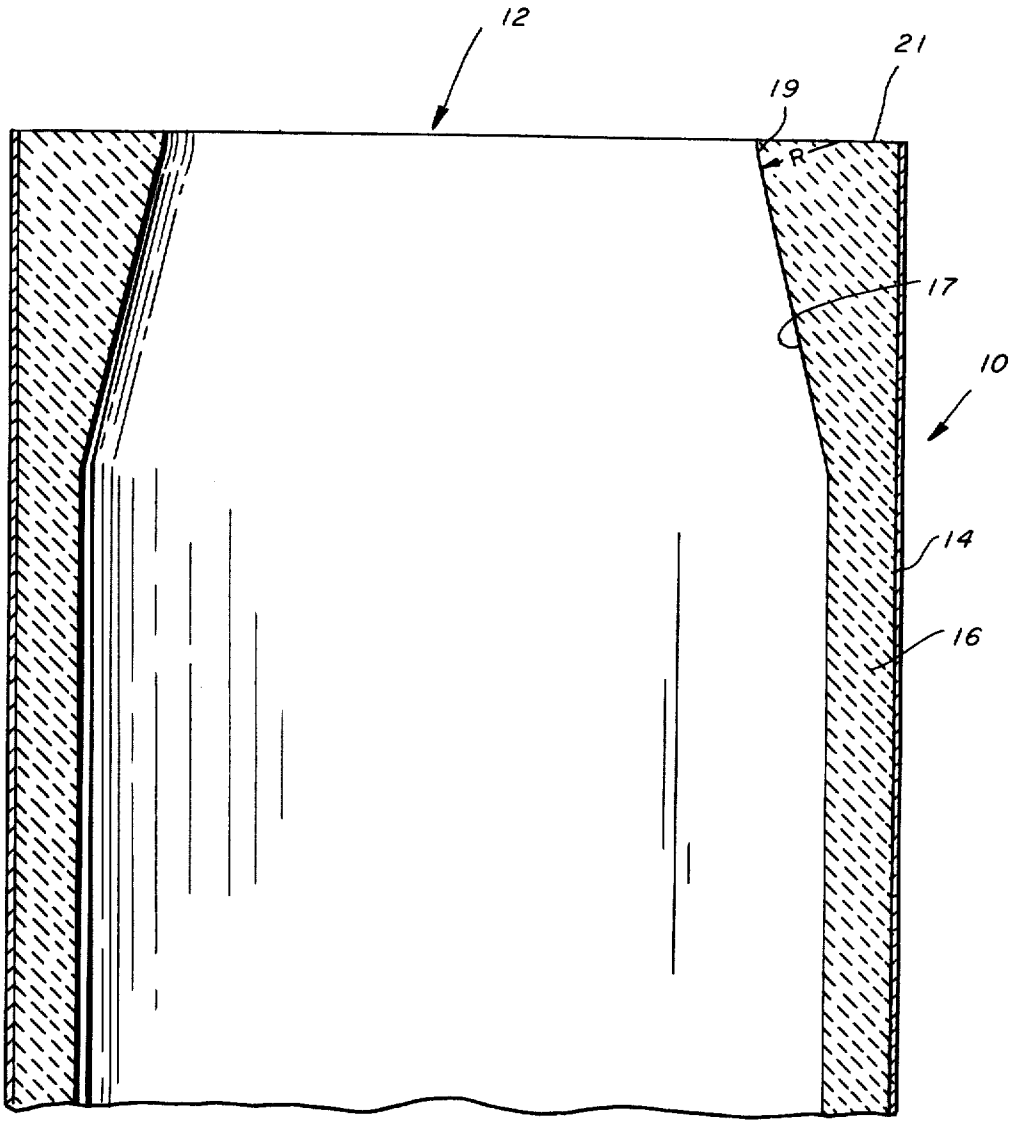


FIG. 3

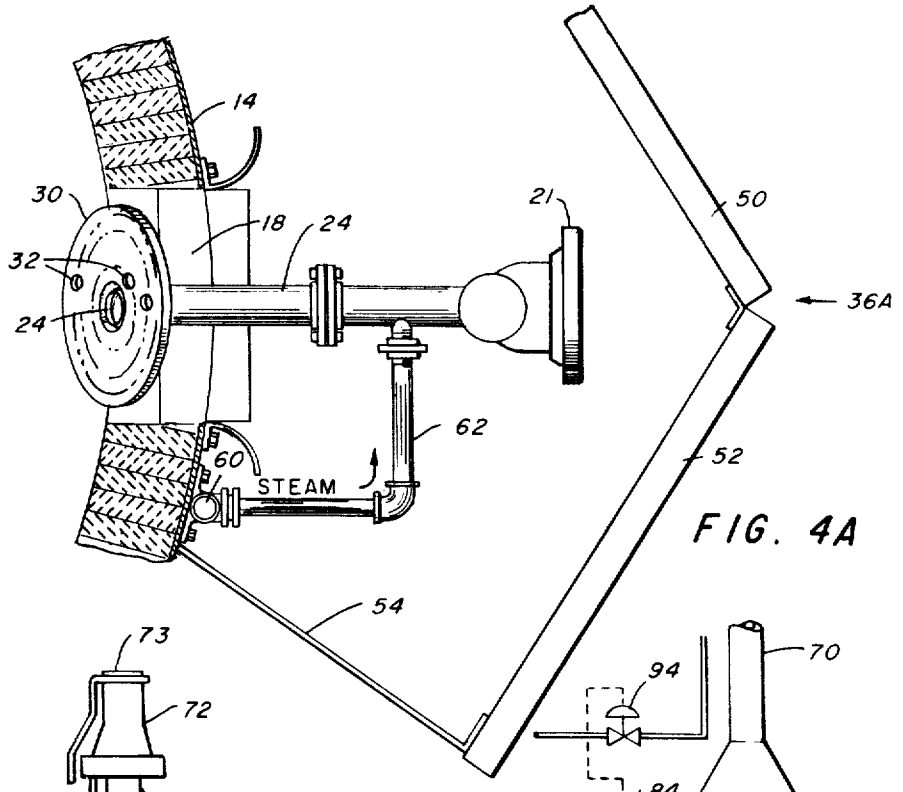


FIG. 4A

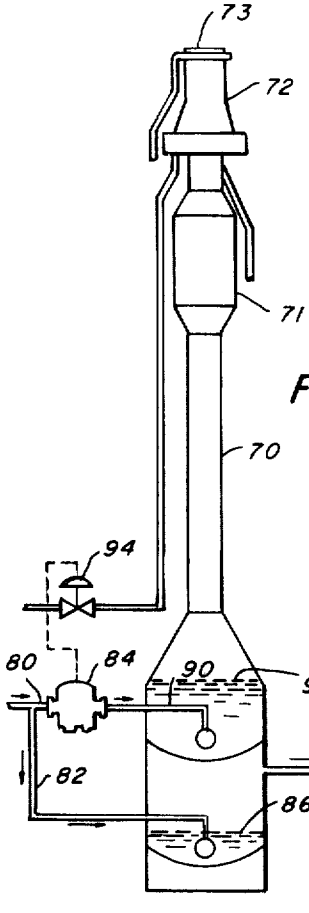


FIG. 5

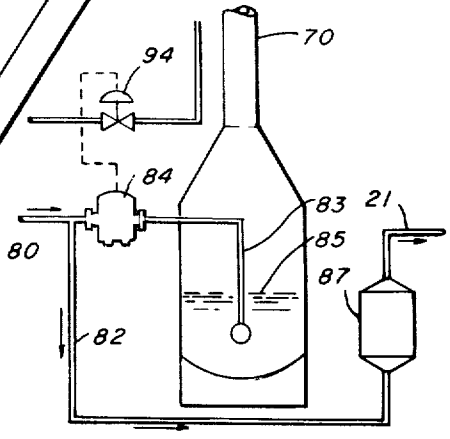


FIG. 6

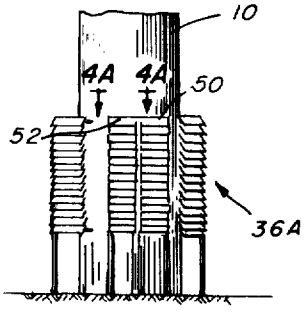


FIG. 4

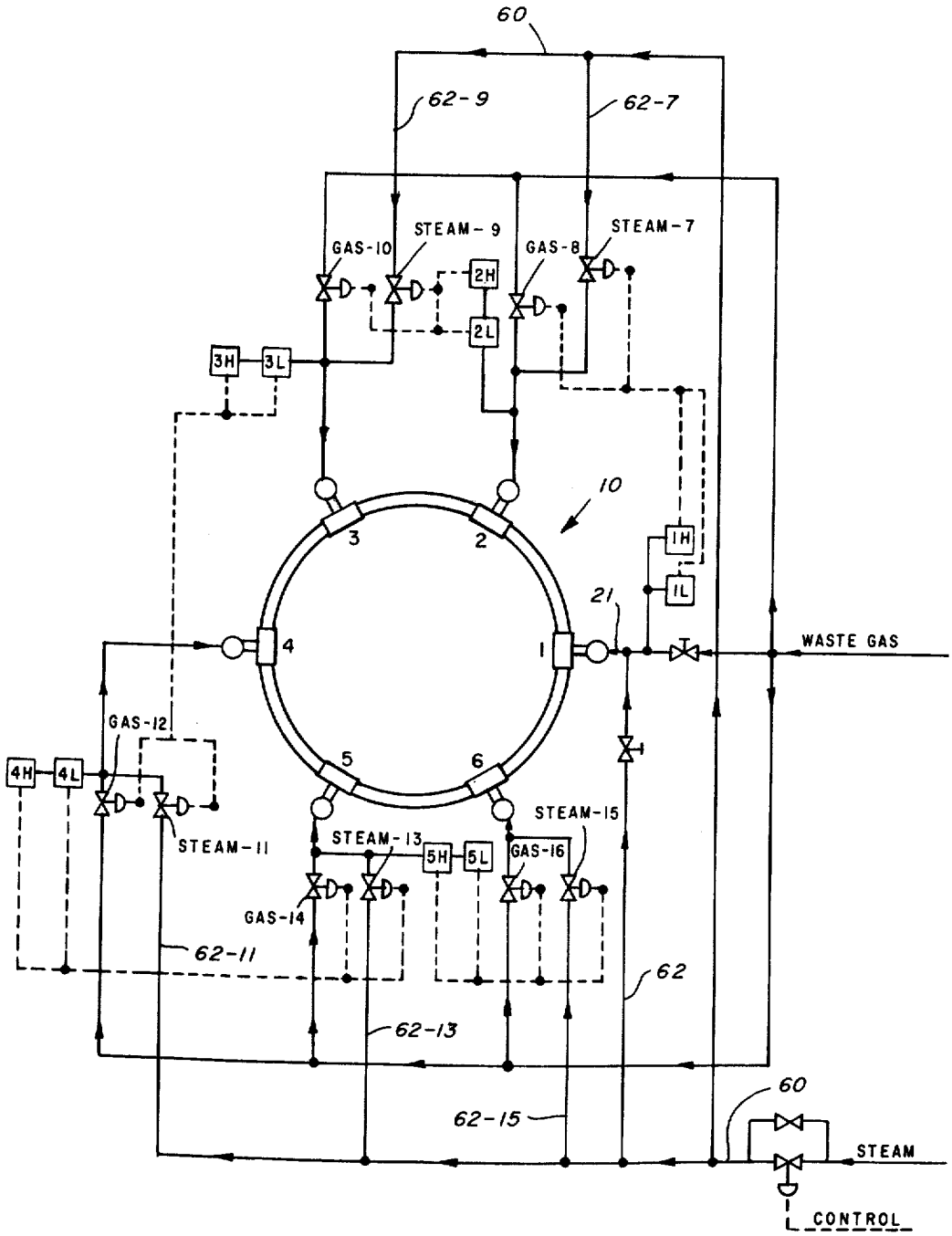

60
62-9
62-7
STEAM-9
GAS-10
GAS-8
STEAM-7
2H
2L
3H
3L
10
3
2
1H
1L
21
WASTE GAS
4
1
GAS-12
4H
4L
5
6
STEAM-15
STEAM-13
5H
5L
GAS-16
STEAM-11
GAS-14
62-11
62
62-13
60
62-15
STEAM
CONTROL

FIG. 7

METHOD FOR NON-POLLUTING COMBUSTION OF WASTE GASES

This is a division of application Ser. No. **216,659,** filed Jan. **10, 1972,** and now U.S. Pat. No. **3,779,689.**

BACKGROUND

In many crowded areas of the world it is necessary, because of existing plant operation, to dispose of waste gases by burning or oxidizing, since the waste gases normally have no other utilitarian purpose. In order to maintain a plant in its existing community location, it is becoming increasingly necessary to provide such disposal without pollution of the atmosphere and without visible flame and noise and hence provide an acceptable disposal system to the surrounding community.

In addition, many plants, such as refineries, chemical processes and the like, form, at various stages of operation, variable quantities of gases which must be disposed. For example, in many processing operations the start-up or shut-down procedures typically will involve changes in the normal quantity of disposable gas until the efficient operation of the plant is reached. For one reason or another, many processes may be upset or overloaded, hence taxing the normal disposal system beyond its efficient operation. In the fuel burning art stable burning and complete combustion for safe operation can be expected when fuel flow ranges from 2 to 100 percent of design condition. When fuel flow falls below 2 percent of design flow there is great difficulty in securing safe and stable burning in a combustion space which is at high temperature level. At a temperature level of 150° F. or lower, safe, stable and complete burning in any typical burner or combustion system is difficult and virtually impossible. Because of the many operational variables found in many process plants it is vitally necessary that there be safe, stable and complete burning of any small or large waste gas volume in addition to stringent air-pollution regulations and safety. Because of widely varying quantities, the safe and efficient disposal is burdened. Some prior artisans have devised plural burner stages which operate sequentially upon reaching a given pressure but have the disadvantage of each stage starting at zero flow and these systems do not operate efficiently and economically.

SUMMARY

It is the purpose and object of this invention to overcome the heretofore mentioned problems and provide a flare or disposal system for waste gas utilizing a low-level ground burning system which is substantially smokeless, noiseless, and non-polluting to the atmosphere. Such a low-level burner is designed to accept those quantities of gas for disposal under normal or non-normal operating conditions of the plant, and in some instances, may be used alone or in combination with an elevated flare apparatus for consumption of excess quantities of gas beyond the rated capacities of the low-level burner.

The invention further provides and is directed to a flare stack which comprises one or a plurality of substantially low-level burner areas to receive and provide efficient combustion of variable quantities of waste gas, and an upper stack for the venting of the products of combustion. The inner diameter of the upper stack being substantially unrestrictive to the flow of the products of combustion, or in any event of design to create a maximum flow velocity immediately at the point of discharge.

To abate the noise of combustion flame, the invention further provides a screen either opposite each burner area, or completely encircling the lower level burner areas as a plenum chamber to abate the noise of combustion, visual display of the flame, and to present air pressure differentials caused by wind forces.

The invention further provides a waste gas flow staging method whereby a predetermined minimum pressure can be experienced by burner stages, subsequent to the first, without starting at zero flow. As additional flow of waste gas is experienced a condition sensing means allows flow to a subsequent stage to be combined with the previous stage or stages at a predetermined pressure and flow above zero.

The above purposes, objects and other objects of the invention may be more readily obtained and understood by reference to the following drawings and descriptive matter.

DRAWINGS

DESCRIPTION OF THE VIEWS

FIG. **1** is an elevational view, partly in section, depicting a typical low-level burner of this invention.

FIG. **2** is a front view of a typical burner nozzle taken along the line **2—2** of FIG. **1.**

FIG. **2A** is a partial sectional view of the burner nozzle taken along the line **2A—2A** of FIG. **2.**

FIG. **3** is a partial sectional view of an additional embodiment.

FIG. **4** is a partial elevation of another embodiment.

FIG. **4A** is a partial top sectional view of a burner opening utilizing the screen embodiment of FIG. **4.**

FIGS. **5** and **6** are schematic descriptions generally depicting the gas disposal system of this invention.

FIG. **7** represents a schematic diagram of the flow staging for disposal of variable quantities of waste gases.

DESCRIPTION

Before explaining the present invention in details, it is to be understood that this invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not limitation.

GROUND LEVEL FLARE STACK

The embodiment shown in FIG. **1** includes a burner or flare stack **10** preferably of cylindrical shape fully opening at its upper end **12.** The stack **10** may be fabricated to any desired height such that the effluent exhaust gases are at an acceptable elevation above the surrounding terrain or community. Typically such a stack is about 18 feet in diameter and may range from 40 to 100 feet or more in height, which in the burner art is of a relatively low-level. Although the stack may be fabricated in a variety of ways typically, as shown, construction comprises an outer metallic shell **14** which is lined with a suitable refractory material **16.** Although the flare stack **10** is described as being circular it is to be understood that this is not to be limiting as other cross-sectional configuration, e.g., round, square,

rectangular or other geometrical configurations are to be inclusive of the invention. In any event in the preferred form of the apparatus the inner configuration of the stack is preferably the same throughout the vertical length than in any event not less than the internal cross-sectional area at the location of the burners **20.** The purposes for the maintaining of a substantially constant cross-sectional area throughout the length of the stack is based on the so-called 'natural-draft' or 'chimney-effect.' That is, a structure as described generates a draft as the buoyant gases rise. Such an effect is useful in producing sufficient in-flow draft of combustion supporting air through openings **18** for burning the gases. Such a draft effect is a function of both the height of the stack and the temperature of the gases. Since the internal temperature level is usually fixed, the stack height becomes critical in the establishment of sufficient draft of incoming air to support smokeless combustion of the waste gas stream. Any reduction in cross-sectional area in the vertical travel of the gases will produce an acceleration at the restriction but subtract from the draft-induced air because of the created pressure drop across the restriction. This may seriously reduce the air volume and the efficiency of the combustion process. However, additional factors enter into the design of the stack based largely upon present ecological requirements of government or other regulatory agencies. In addition, there are regulatory height restrictions and cost restrictions which must be considered. For example, it has been found that certain exit velocities from a stack must be maintained in order to have proper diffusion of pollutant products into the surrounding atmosphere to maintain a required parts-per-million (ppm) condition.

A further factor is the makeup of the combustible waste gases and its burning temperature. For combustible gases there is chemically-fixed theoretical air demand according to the nature of the gases. Flame temperature, which may exist within the stack, is governed by the quantity of air in excess of the theoretical present as the burning progresses. For example, ethylene (C_2H_4) utilizing theoretical air demand of 14.4 cubic feet/Cu.ft. of ethylene results in a temperature excess of 3,600° F. which far exceeds typical refractory endurance. A much more satisfactory temperature level is 2,000° F. which can be obtained by the admission of more than theoretical air for the burning. Two hundred fifty percent excess air or 50.5 Cu.ft/cubic ft. of ethylene will result in temperature within which standard refractories can be utilized. The exit velocity of a typical stack based on 2,000° F. is in the order of 75 feet per second. In many instances this velocity is sufficient to diffuse pollutant products, such as SO_2, into the atmosphere within required parts/million. However, if the velocity of discharge required for proper diffusion is greater than 75 feet per second and where the volume of waste or disposal gases is fixed the required velocity increase must occur by other means where structures of minimal height are necessitated by regulation, cost, or other factors. Reducing the discharge cross-sectional area as in FIG. **3** is one such means. For example, if the velocity of a given quantity of combustion gas flow at the required temperature is 75 ft./second and 100 ft./second is required for proper diffusion of pollutants, there must be a 25 ft./second acceleration. The height of a vertical furnace with substantially constant cross-sectional area vertically for burning 30,000 lbs/hour C_2H_4 is 62.68 feet which provides a flow velocity of 75 ft./second. The height necessary to achieve a discharge velocity of 100 ft./second considering total pressure drop due to acceleration (0.53 inch Water Column) plus the pressure drop (0.35 inch WC) across the burners (0.88 inch WC total) divided by a net draft effect per foot of stack height (0.00905 inch WC) calls for a stack 97.24 feet high. If a flow restriction is placed within the stack, the pressure drop to be added is approximately:

$$(\sqrt{0.3} \times 100/75)^2 - 0.3 = 0.233 \text{ inch of water (WC)}$$

At 2,000° F. the draft effect per foot of stack height is 0.0115 inch WC. Since the draft increase required is 0.233 inch WC the additional stack height necessary to provide for the added draft is:

$$0.233/.00905 = 25.41 \text{ feet}$$

The total height required being:

$$62.68 \text{ feet} + 25.41 \text{ feet} = 88.09 \text{ feet}$$

This data, however, is based on flow efficiency at the restricted area of 100 percent which in most instances is not the case. For example, a thin edged orifice such as used in metering is approximately 61 percent efficient. When the ratio of the orifice length to diameter is 1.00 a coefficient becomes 0.85, but the point at which the preferred velocity occurs is down inside the orifice and is not effective as such in promoting diffusion. Accordingly, this invention teaches that maximum velocity discharge must occur immediately as the gases flow to the atmosphere for effective pollution control. This invention teaches a stack orifice contour which will provide exit flow coefficients ranging close to 1.00 which will provide a relatively low-stack height, proper diffusion of pollutants into the atmosphere and maximum velocity of diffusion yet providing cost savings. A typical example of such a stack discharge orifice cross-section is shown in FIG. **3.** Preferably the restriction is positioned within the upper 10–15 percent of the stack height and comprises a converging wall **17** terminating with an arcuate contoured portion **19,** being defined from a radius (R) centered anywhere along the terminal stack end **21.**

BURNERS

Reference is made to FIGS. **1, 2** and **2A.** Suitably arranged at one or a plurality of peripheral locations are burner areas defined by vertical openings **18** which are adapted to receive a plurality of vertically arranged burners **20,** as shown. In one preferred embodiment the burner tip is angularly oriented slightly upwardly and inwardly, e.g., 20° radially into the interior of the stack **10.** It is to be understood that other burner arrangements which will provide efficient mixing of the waste gas and air are inclusive of the invention. Although vertically arranged burner areas **18** are shown, the invention is adaptable to a horizontally arranged opening or plurality of horizontally oriented openings in the lower portion of the stack. Combustible waste gas is supplied from supply connection **23** to each burner nozzle **20** via a manifold **22** being divided to each burner nozzle via conduits **24.** The manifold **22** may be appropriately supported by cross brace numbers **26** and **28** to the stack side wall. Each of the burner nozzle designs as shown in this preferred embodiment include a diversion plate **30,** surrounding the burner nozzle conduit **24**

and which is provided with a plurality of circular or other shaped openings **32.** The nozzle tip shown includes a central discharge orifice **25** and a plurality of angularly oriented openings **27.** The latter openings are directed toward the upstream face of plate **30** to cause intimate mixing of the waste gas with the combusting supporting air draft flowing to and through plate **30** and perforations **32.** It has been found that a burner nozzle design as shown is adaptable to provide acceptable time, temperature and turbulence to burn a wide variety of waste gas components of varying molecular weight without adjustments, without the formation of coke, carbon or other polymerized chemical deposits and with substantially complete combustion to eliminate atmospheric pollutants.

VISUAL, NOISE AND WIND SCREEN

Circumferentially surrounding the bottom of stack **10** is a screen generally designated by the numeral **36.** In this embodiment the screen includes a plurality of slightly overlapping panel members **38** and **40** which are alternately spaced vertically and horizontally of each other providing a gap for flow of combustion supporting air to the burners. In some instances a roof **42** is provided to prevent weather elements, snow, rain, etc., from interfering with the efficient operation of the burner and to define an air plenum surrounding the burner areas. The screen functions to (1) eliminate the sight of a visible flame; (2) reduce combustion noise; and (3) substantially eliminate air pressure differentials in the air plenum about the burner areas from the effect of wind.

Although in the above described embodiment a complete circumferential wind and noise screen or fence is shown it is to be understood that such a screen or fence may be segmented about each burner assembly, shown generally as **36A** in the views of FIGS. **4** and **4A**. That is, vertical wind and noise screen louvers **50** and **52** extend upward from the ground opposite each burner area and are supported to the stack outer shell **14** by brace members **54.** In some instances it is desirable to inject steam from a supply manifold **60** into conduit **62** for injection into each of the burner gas supply conduits **24** providing further assistance toward smokeless combustion of the gases to be disposed.

MODIFICATIONS

Referring now to FIGS. **5** and **6** the low-level flare or burner **10** is shown as used in combination with a high level flare **70.** Such an elevated flare stack is well known in the art including at its upper end a combustion tip **72,** as for example, shown in U.S. Pat. No. 3,539,285 and which generally includes devices to ensure ignition in areas where wind velocity may tend to extinguish the flame. It should be understood that the use of an elevated flare is but a safety addendum to the low-level stack of this invention, being useful as an emergency or secondary disposal means in the event the low-level stack is sought to operate beyond the rated design capacities. As shown in FIG. **5,** waste gases to be disposed enter through conduit **80** which is in communication with conduits **90** and **82.** Conduit **90** terminates below hydrostatic liquid level **92** while conduit **82** terminates below liquid level **86** which is of lesser level than **92.** Hence waste gas initial flow occurs through **80–82** as long as the flow pressure is greater than liquid level **86** pressure but less than liquid level **92** pressure.

When the pressure in **80** rises to a point capable of displacing the liquid level **92** pressure flow of gases is initiated in **84–90** to be discharged to atmosphere through **70** to **72–73** but this initiation of flow performs a useful service because of the 'Flow-Sensor' **84** which at the initiation of flow creates a signal to the steam valve **94** to cause opening of the steam valve in a substantially linear relationship to the volume of flow of gases from **80** through **90.** The flow sensor **84** is disclosed in U.S. Pat. No. 3,570,535 and creates a variable instrument signal, the magnitude of which is proportional to flow quantity, for transmission to **94.**

Steam admitted by the valve **94** travels to the vicinity of **73** where the steam serves to suppress smoking as is well known in the arts.

Under normal operating conditions of flow the low-level stack **10** is maintained in constant operation to its design capacities with the auxiliary high level flare operating in the event of an upset in the plant operation involving larger quantities of gas which must be disposed or in which other intermediaries or products will be required to be removed to prevent explosions or other hazards.

FIG. **6** is another alternate embodiment of the integrated flare system with like parts having like numerals from FIG. **5.** The primary difference is the elimination of the second liquid seal with waste gases passing directly through a flame or explosion arresting device **87** of a type well known to those skilled in the art, thence via conduit **21** to the particular burner area or areas. Excess gas flow through conduit **83** sufficient to overcome hydrostatic level **85** is then burned in the stack **70.**

WASTE GAS STAGING

FIG. **7** is incorporated as a part of this invention disclosure as a schematic diagram to depict the staging sequence for the burning of variable quantities of waste gas. The stack **10** depicts the circumferentially spaced burner areas designated by the numerals **1–6** and are staged in the operation as required for the particular quantity of waste gas to be disposed. Before successive burners are staged in the operation, however, there must be a pre-purging of the burners with a gas of some nature typically steam via conduits **60** and **62** to each burner area. The sequence in operation for the introduction of a gas stream and the steam are accomplished by pressure switches which are capable of emitting signals of controllable magnitude which in turn operate the sequencing valves as hereafter described. The pressure switches are shown in FIG. **7** as numbered squares (**1L—1H, 2L—2H, 3L—3H,** etc.). The "L" after each number indicates a switch which emits its signal on a given smaller pressure rise of the waste gas while "H" indicates switches which emit signal on a rise greater in pressure than the L-switch. The same is true for the operation of the steam control valves sequentially identified as "steam-**7,**" **9, 11, 13** and **15** which are used in conjunction with those valves identified as "gas-**8,**" **10,** 12, 14 and **16** respectively. In the embodiment shown the odd numbered steam valves are set to respond to the smallest emitted signal while the even numbered gas valves respond only to the greatest emitted signal. Staging of the gas is accomplished in the following manner. Burner **1** is constantly in operation. It receives

gas via conduit **21** which may be isolated by appropriate valves shown if required for any reason. Pressure switches **1L** and **1H** are in communication with conduit **21** sensing the gas pressure therein. Controllable amounts of steam via lines **60** and **62** maintain a constant injection or purge of burner **1** in the event there is no waste gas stream entering the conduit **21**. When a small volume of gas is delivered to burner **1** the pressure in the conduit **21** is not capable of energizing pressure switch **1L**. As the volume of gas increases the conduit pressure rises to a point where switch **1L** is energized, emitting a small signal adequate for opening steam-**7** valve for admission of purge via conduit **60** and **62-7** into burners located in area **2**. This pressure, however, is not adequate for the opening of gas-**8** valve until a further rise in conduit **21** pressure causes switch **1H** to emit a greater signal thus opening gas-**8** valve and burner **2** is now placed into service, there being, of course, ignition means of those types well known in the art to ignite and maintain ignition of the flame. Further increases in pressure then bring into operation pressure switches **2L** and **2H** to sequentially operate purge steam-**9** valve and gas-**10** valve to cause burner **3** to be placed into operation with the operation continuing to the other burners as the increase in waste gas flow and pressure increases. Of course as the waste gas flow decreases the sequencing procedure is reversed.

While the purpose of the purge is to prevent burner malfunction or impairment, any gas may be used for this purpose. Steam is preferred because of the favorable condition of smoke suppression, after purging, as it enters a part of the reaction during the burning process.

What is claimed is:

1. A method of burning variable quantities of waste gas comprising the steps of:

flowing a purge gas through a conduit to a first gas-air mixing and burner stage immediately prior to the flowing of said waste gas through said conduit;

flowing said waste gas through said conduit to said first burner stage;

igniting said waste gas-air mixture; and the additional steps of:

sensing a pressure or flow condition of said waste gas;

flowing a purge gas through a second gas-air mixing and burner stage responsive to an increase of said pressure or flow;

flowing said waste gas to said first and said second burner stages responsive to further increase in flow and pressure; and

igniting said waste gas-air mixture.

2. A method of burning variable quantities of waste gas comprising the steps of:

feeding a purge gas and said waste gas to a first gas-air mixing and burner stage; and

igniting said waste gas issuing therefrom;

sensing a pressure or flow condition of said waste gas;

flowing a purge gas through a second gas-air mixing and burner stage responsive to a first condition of said pressure or flow;

flowing said waste gas to said second burner stage responsive to a second condition of pressure or flow higher than said first condition; and

igniting said waste gas-air mixture.

3. A method of claim **2** including the additional steps of:

flowing a purge gas through a third gas-air mixing and burner stage responsive to a third condition of said pressure or flow higher than said second condition;

flowing said waste gas to said first, second and third burner stages responsive to a fourth condition of said pressure or flow higher than said third; and

igniting said waste gas-air mixture.

4. A method of claim **2** including the additional steps of:

flowing a purge gas through a plurality of additional gas-air mixing and burner stages responsive to a third condition of said pressure or flow higher than said second condition;

flowing said waste gas to said first, second and additional burner stages responsive to a fourth condition of said pressure or flow higher than said third; and

igniting said waste gas.

5. A method of claim **3** including the additional step of:

sequencing said steam and waste gas to additional burner stages as a function of increases in said waste gas pressure or flow.

6. A method of burning variable quantities of waste gas comprising the steps of:

sensing a pressure or flow condition of said waste gas;

flowing said gas to a first ignitable burner stage responsive to a first condition of said pressure or flow; and

flowing said gas to said first and a second ignitable burner stage responsive to a second condition of said pressure or flow higher than said first condition.

* * * * *