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Zink et al.

[11] **3,814,567**

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[54] **SMOKELESS FLARE USING LIQUID WATER PARTICLES**

[75] Inventors: **John Smith Zink; Robert D. Reed; Hershel E. Goodnight,** all of Tulsa, Okla.

[73] Assignee: **John Zink Company,** Tulsa, Okla.

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[21] Appl. No.: **228,010**

[52] **U.S. Cl.** ..... **431/4,** 23/277 C, 431/202, 431/190

[51] **Int. Cl.** **F23c 9/04**

[58] **Field of Search** ..... 431/4, 278, 190, 202, 283; 239/434, 101; 23/277 C; 261/DIG. 9

[56] **References Cited**

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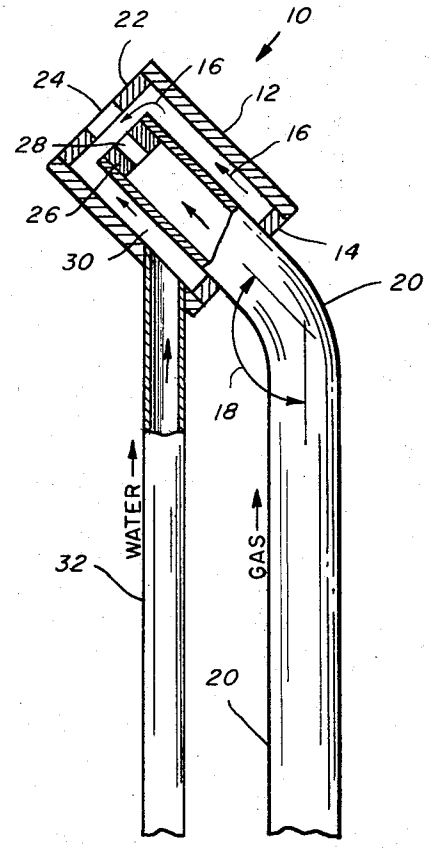
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Primary Examiner—William F. O'Dea
Assistant Examiner—William C. Anderson
Attorney, Agent, or Firm—Head & Johnson

[57] **ABSTRACT**

This disclosure describes a system for smokeless burning of hydrocarbon gases in which liquid water is used as input in place of the customary use of steam to provide the hydrogen necessary to accomplish complete smokeless combustion. A particular design of atomizer is used in which the pressure of gas provides the energy for atomizing the water into droplets of such small size that they will instantly evaporate in the flame, and provide the water vapor to reform the hydrocarbons and provide the necessary hydrogen-to-carbon ratio for smokeless combustion.

14 Claims, 5 Drawing Figures



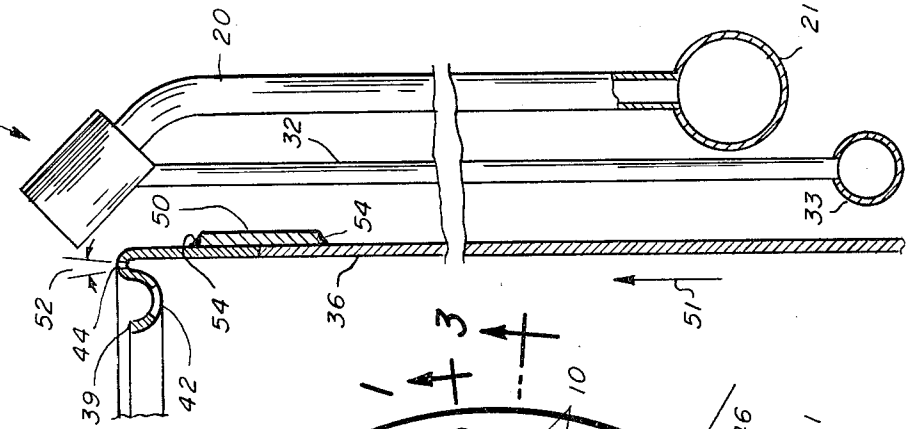


FIG. 3

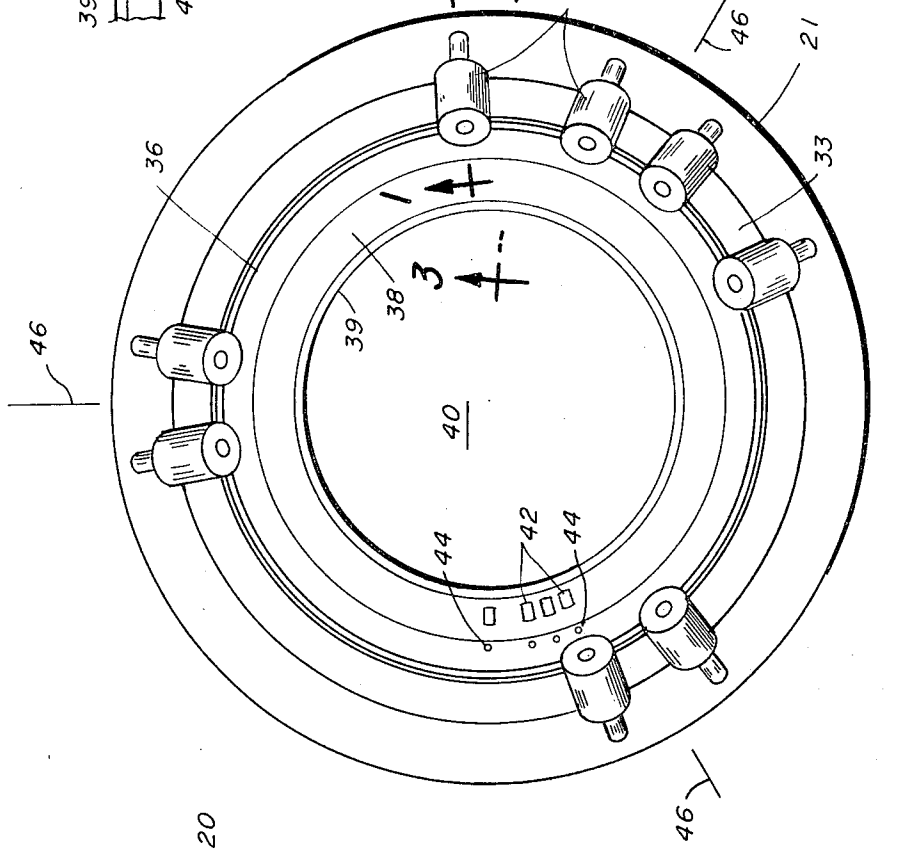


FIG. 2

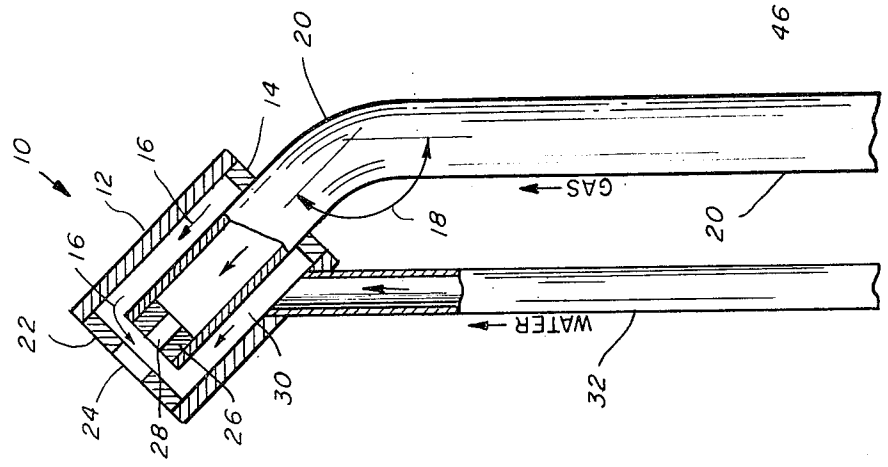


FIG. 1

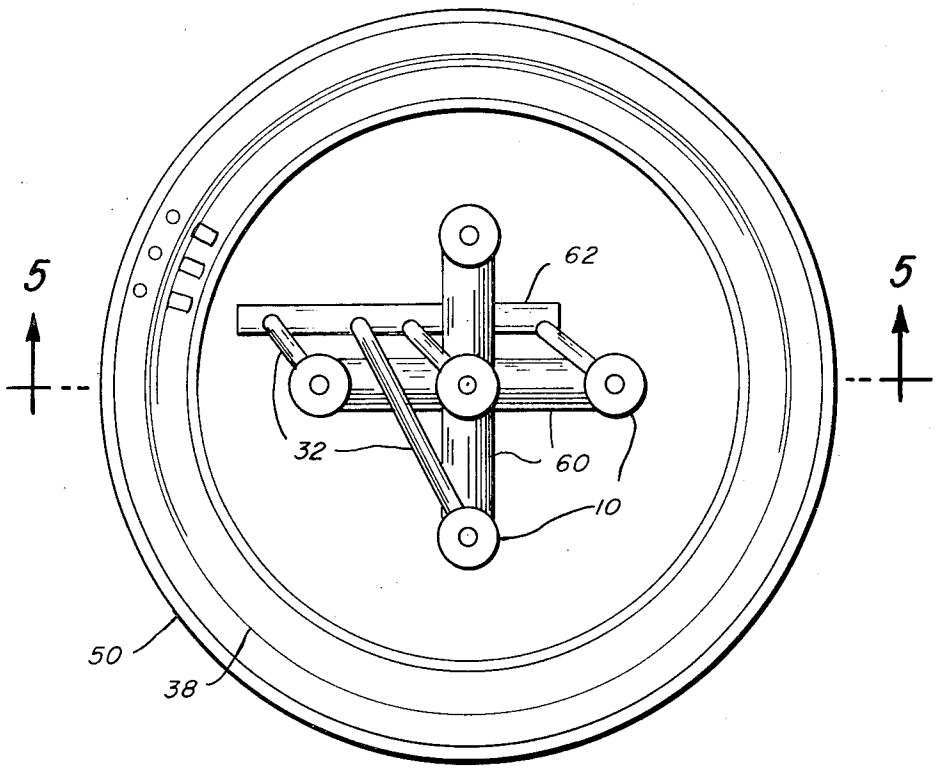

5
5
62
32
60
10
50
38

FIG. 4

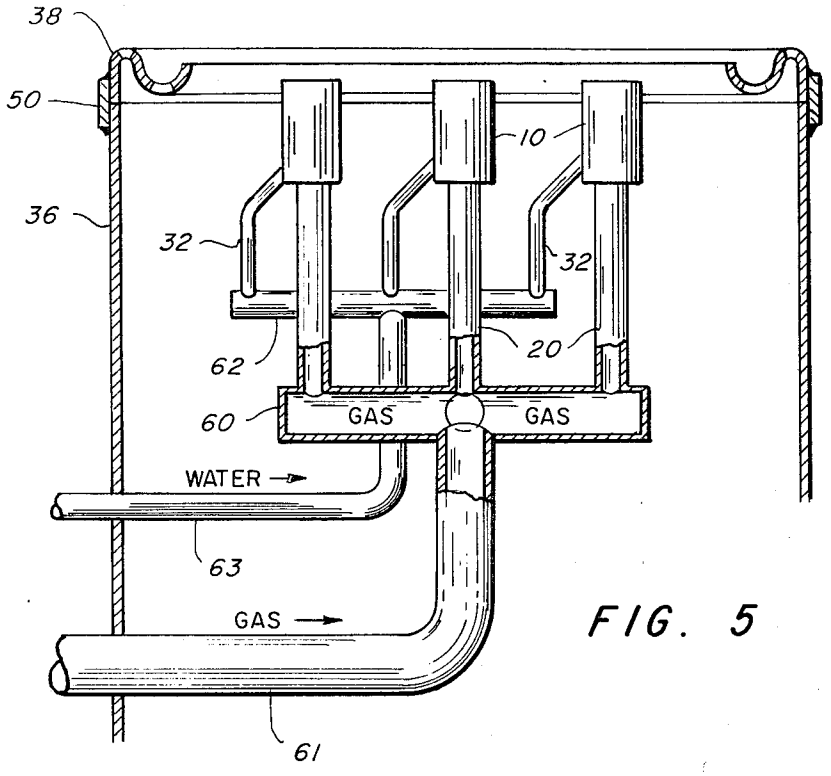

38
50
36
32
10
32
62
20
60
GAS
GAS
WATER
63
GAS
61

FIG. 5

SMOKELESS FLARE USING LIQUID WATER PARTICLES

BACKGROUND OF THE INVENTION

This invention lies in the field of the combustion of hydrocarbons which have a hydrogen-to-carbon mass ratio of less than 0.25. More particularly, this invention involves the use of water in a liquid state to reform the hydrocarbons to provide the smokeless combustion.

When the hydrogen-to-carbon weight ratio of the hydrocarbons is less than 0.25, and as gas is burned at the flare, smoke results from the burning because the hydrocarbons have dissociated to their components, hydrogen and carbon, and there is not adequate hydrogen burning to avoid escape of carbon as smoke. Thus, the art of smokeless flaring is predicated upon two factors which are:

1. Significant increase of the hydrogen-to-carbon ratio to a value of at least more than 0.25 as the gas burns; and

2. Keeping the carbon combined and avoiding free carbon in the flame.

It is well known to use steam intermixed with the hydrocarbon gas which, by reformer action, will provide increased amounts of hydrogen, which increase the hydrogen-to-carbon weight ratio to a sufficiently high value to keep the carbon combined and therefore avoid the free carbon escape from the flame which results in smoke occurring.

In order for the reforming action to occur, the water must be in vapor phase. Thus steam has been used because direct injection of sprayed liquid water has not, heretofore, shown the required proper smoke-suppressant capability.

It has been found that droplets of water from typical spray nozzles are generally larger than about 200 microns (0.0078 inch) in diameter and cannot evaporate rapidly enough to be effective in the reforming reaction. Droplets absorb heat from the flame only on their surface, and since the amount of heat required to evaporate a droplet of water depends upon its mass, the critical dimension is the ratio of the area to the mass of the droplet. The mass increases with the third power of the diameter, while the surface area increases only as the square of the diameter. Thus, as the diameter of a droplet is cut in half the surface to mass ratio doubles and at constant temperature level the evaporation rate doubles. It is therefore clear that if direct injection of water is to be satisfactory, droplets must be of a much smaller size than the 200 microns which are available from typical spray nozzles. In this invention the droplets are provided in a much smaller size than 200 microns by the use of a special atomizer, in which liquid water is used. The droplets are formed by inter-acting a high velocity gas stream with a sheet of water to provide droplets predominantly of the order of ten microns in diameter.

SUMMARY OF THE INVENTION

It is a primary object of this invention to provide a smokeless flare system for hydrocarbon gases in which the hydrogen-to-carbon weight ratio of the gas is less than 0.25.

It is a further object of this invention to provide smokeless combustion by the use of liquid water, rather than steam.

The objects of this invention are furthered and the weaknesses of the prior art systems, which utilize steam, are overcome in this invention by the use of a plurality of atomizers in which the energy of gas is used to atomize the water, to provide particles of sufficiently small size that they are instantly evaporated in the flame and provide the water vapor needed for the reforming action. These atomizers comprise a central pipe through which gas flows and which contains a first orifice at its end. A plenum surrounds this first pipe and is supported by it providing an annular space into which water is introduced by means of a second pipe. The plenum comprises a cylindrical pipe of larger diameter and carries a second orifice coaxial with the first orifice and with the first pipe. The second orifice is larger than the first orifice and is spaced appropriately in front of it. The pressure of gas in the first pipe is sufficiently larger so that critical velocity gas flow issues from the first orifice. There is a thin sheet of water immediately across the front of the first orifice, which is driven by this high velocity gas stream out through the second orifice, causing it to be broken up into extremely small particles or droplets. Thus, as soon as the mixture of particles or droplets and gas enters the already existing flare stack flame the water is rapidly evaporated.

A plurality of these atomizers is placed around the top or discharge point of the flare, which is typically circular in form, with flow from the nozzles directed generally inwardly and upwardly to the flame immediately downstream of the point of emergence of flared gases for ignition and burning thus creating the flame. A separate gas supply at pressure typically of 15 lb. gauge or more (but not so limited) is directed to the ports or orifices for gas flow in each of the plurality of atomizers to establish flow from each of the atomizers. Specific flow of gas at pressure from each of the atomizers may be equal or may be altered by port or orifice sizing as preferred; also the discharge flow direction from each of the atomizers may be altered from generally radially inward.

Additional vertical atomizers can be provided in the central region of the flare stack in case the diameter is so large that the stream of gas and water droplets cannot extend completely to the center of the stack.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects of this invention and a better understanding of the principals and details of the invention will be evident from the following description taken in conjunction with the appended drawings in which:

FIG. **1** represents in cross section the construction of the atomizer, taken along the line **1—1** of FIG. **2.**

FIG. **2** shows in plan view the arrangement of the plurality of atomizers arranged around the top of the flare stack.

FIG. **3** illustrates a vertical view taken along the line **3—3** of FIG. **2.**

FIGS. **4** and **5** show in plan and elevation a modification of FIG. **2** including the addition of a plurality of atomizers in the central region of the flare stack.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and in particular to FIG. **1,** gas is supplied through a pipe **20** which has an

orifice plate **26** with an orifice **28** centrally located in its tip. Surrounding the first pipe is a plenum which comprises a tube **12** which is supported by the first pipe at the back end **14.** This provides an annular space **30** between the pipe **20** and the pipe **12.** Liquid water is introduced through a second pipe **32** which penetrates the pipe **12** and permits the water to flow into and along the annular space **30.** There is an orifice plate **22** in the end of the plenum with an orifice **24** coaxial with the orifice **28** in the first pipe. Gas, which is separately supplied, passes through the first pipe and is supplied at a pressure sufficient to create a stream of gas issuing from the first nozzle **28** typically at critical, or sonic, velocity. Normally this would be a pressure of about 28 pounds absolute. Water flows in the direction of the arrows **16** along the annular space **30** and then radially into the orifice **24** where it is hit by the high velocity jet of gas, which drives it in a turbulent condition through the orifice **24** and causes the formation of extremely small droplets. While conventional spray jets provide droplets which are generally larger than 200 microns in diameter, this atomizer **10** has been found to produce droplets which are predominantly of the order of 10 microns in diameter. These are obviously small enough so that when they are thrown into the flame they can immediately evaporate to provide water vapor which reacts with hydrocarbons. This provides additional hydrogen to increase the hydrogen-to-carbon weight ratio to a value for which smokeless combustion can be provided.

FIG. **2** shows in plan view the top of the flare stack. This should be studied in conjunction with FIG. **3** which shows a section through the flare stack along the line 3—3 of FIG. **2.** The stack wall **36** has a tip **38** extending upwardly and held in place by means of the strip **50** welded at **54.** The tip extends inwardly to provide a plurality of orifices. There are two sets of these, a set of small orifices **44** which are directed inwardly at an angle of from 5° to 30°, and a group of larger orifices **42.** A plurality of atomizers **10** are spaced symmetrically around the circumference of the tip, and supported by manifolding pipes **21** and **33** respectively for the gas and water so that they extend over the tip of the flare stack and are directed inwardly and upwardly at an angle of approximately 20° to 80° above the horizontal. The supply of flare gas goes upwardly through the flare stack in the direction of arrow **51** and through the orifices **42** and **44** and up through the central portion of the stack **40.** Conventional pilot lights are provided at one or more positions around the stack, indicated by numeral **46,** to promptly ignite any gas which is directed through the pipes **20** or through the stack **40.**

In operation, when gas is to be flared, separately supplied gas is directed up the pipes **20** and a mixture of droplets of water and gas issue from each of the atomizers **10** and flow into a conical-shaped space over the top of the flare stack. In the flame formed as the flare gas burns there is additional hydrogen, which results from the reforming operation due to the steam which is formed by the evaporation of the droplets from the atomizer. The main body of gas coming up through the central portion **40** is directed into this atmosphere, having the excess of hydrogen, and so is burned with a smokeless flame.

When the diameter of the flare stack is very large, the streams of gas and water particles issuing from the atomizer may not reach completely across to the center of the stack. In such a case, additional atomizers can be provided as shown in FIGS. **4** and **5.** These show a plurality of vertically directed atomizers **10,** arranged in a symmetrical manner in the central portion of the stack. These are supplied with gas and water as shown and serve to provide additional hydrogen by the reforming operations of the hydrocarbons.

While a flare system could be designed in the manner shown in FIGS. **4** and **5** without the circumferential array of atomizers it would require a high density of atomizers inside of the flare stack which would seriously limit the volume capacity of the stack which could be used to supply the combustion gas. The preferred arrangement is that shown in FIG. **2** with or without the supplementary use of atomizers in the central part of the stack.

While the invention has been described with a certain degree of particularity it is manifest that many changes may be made in the details of construction and the arrangement of components. It is understood that the invention is not to be limited to the specific embodiments set forth herein by way of exemplifying the invention, but the invention is to be limited only by the scope of the attached claim or claims, including the full range of equivalency to which each element or step thereof is entitled.

What is claimed:

1. In a smokeless flare having a flare stack within which a gas stream is conducted to an outlet tip for burning thereabove, the improvement comprising:

at least one means adjacent said outlet tip for directing, into the flame of said burning gas stream, liquid water particles of size less than 200 microns, the size of said droplets being sufficiently small so that in the environment of said flame the droplets are vaporized to steam.

2. A flare of claim **1** where said means adjacent said outlet tip comprises:

a first pipe for supplying pressured gas, a first orifice means in the end of said first pipe,

a wall surrounding and spaced from said end of said first pipe to form a plenum, a second orifice in said wall coaxial with but larger than said first orifice,

means to supply liquid water to said plenum whereby said pressured gas issuing from said first orifice forms and directs said droplets into said burning gas stream.

3. A flare of claim **2** wherein the pressure of said gas is at great enough to cause atomization of water.

4. A flare of claim **2** wherein said means is located outside said flare stack tip and directed into said burning gas stream.

5. A flare of claim **2** wherein said means is located inside said flare stack and directed into said burning gas stream.

6. A flare of claim **5** wherein said means is directed downstream with said burning gas stream.

7. A method of smokelessly flaring or burning a gas stream comprising the step of:

directing particles of liquid water, of size less than 200 micron, into the flame of said burning gas stream and prior to the complete burning of said gas stream.

8. A smokeless flare system for burning hydrocarbons having a hydrogen-to-carbon weight ratio of less than 0.25, comprising:

a. atomizer means comprising:

1. first pipe means for supplying gas at a pressure great enough to atomize water;
2. first orifice means in the end of said first pipe means;
3. plenum means surrounding and supported by the end of said first pipe means, including a circular wall coaxial with said first pipe to form an annular space and second orifice means coaxial with, and larger than, and space in front of said first orifice;
4. second pipe means connected to said plenum for supplying water to said annular space;

b. flare stack means;

c. a plurality of said atomizers placed symmetrically around said flare stack at the tip thereof, and directed inwardly and upwardly over the top of said tip and into the flame of said burning gas; and

d. means to conduct the gas to be flared up said flare stack and to ignite said gas.

9. The flare system as in claim **8** in which said flare stack means includes an inwardly flaring tip at the top thereof, a plurality of orifices in said tip.

10. The flare system as in claim **8** in which said flare gas is also supplied to said first pipes, but at higher pressure.

11. The flare system as in claim **8** including a plurality of pilot lights symmetrically placed around the top of said tip.

12. The flare system as in claim **8** in which said atomizers are directed at an angle to the horizontal of 20° to 80°.

13. The flare system as in claim **8** in which the pressure of said gas in said first pipe is great enough that the velocity of gas issuing from said first orifice is substantially sonic.

14. The flare system as in claim **8** in which two sets of orifices are provided in said inwardly flaring tip, one set being directed radially inwardly at an angle of from 5° to 30°.

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