

May 30, 1967

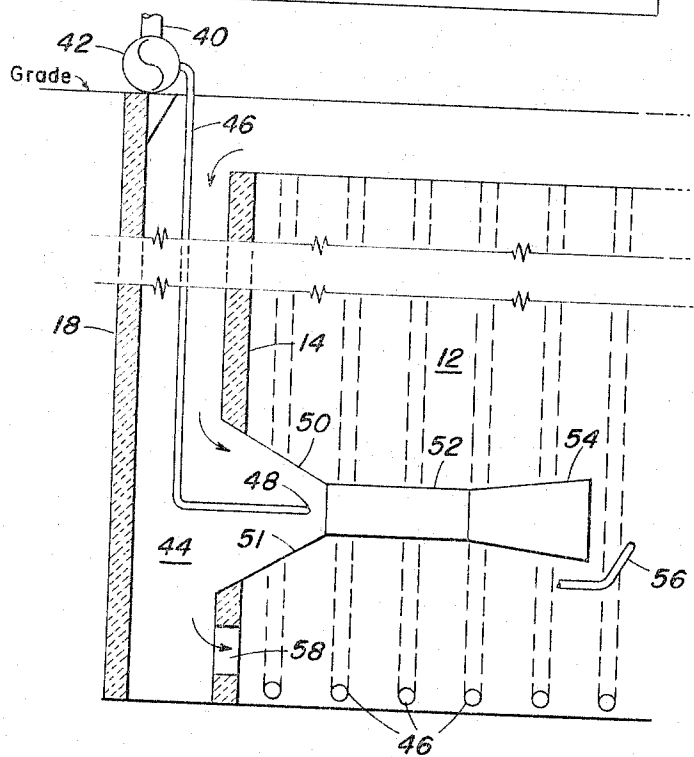
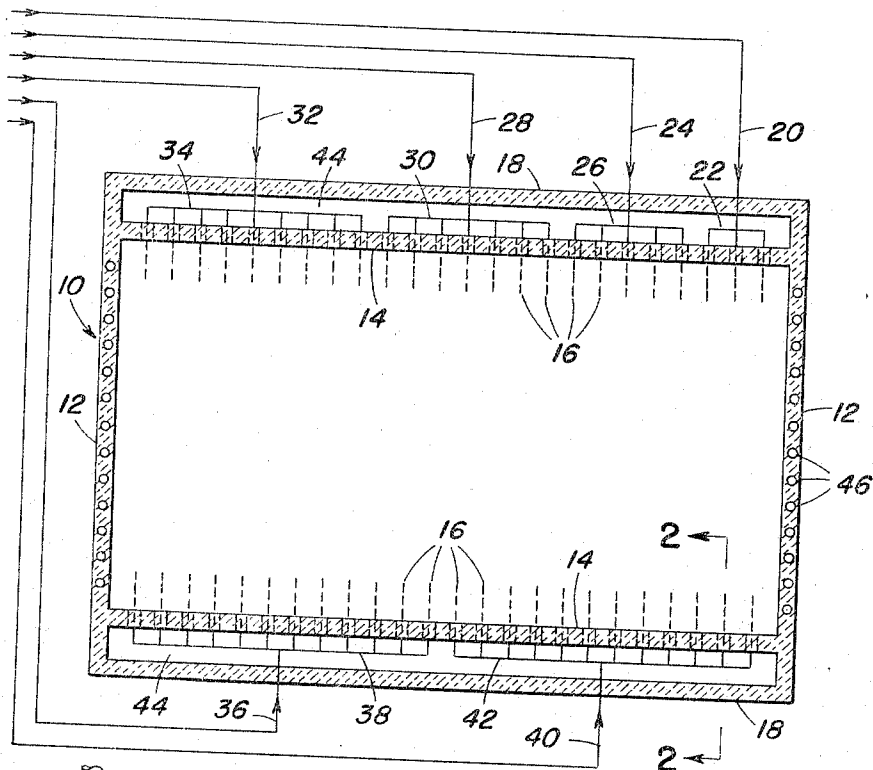
R. S. NAHAS

3,322,178

FLARE APPARATUS FOR COMBUSTIBLE GASES

Filed Aug. 12, 1965

3 Sheets-Sheet 1



INVENTOR
Robert S. Nahas
BY *Flynn, Marn*
& Jangarathis
ATTORNEYS

May 30, 1967

R. S. NAHAS

3,322,178

FLARE APPARATUS FOR COMBUSTIBLE GASES

Filed Aug. 12, 1965

3 Sheets-Sheet 2

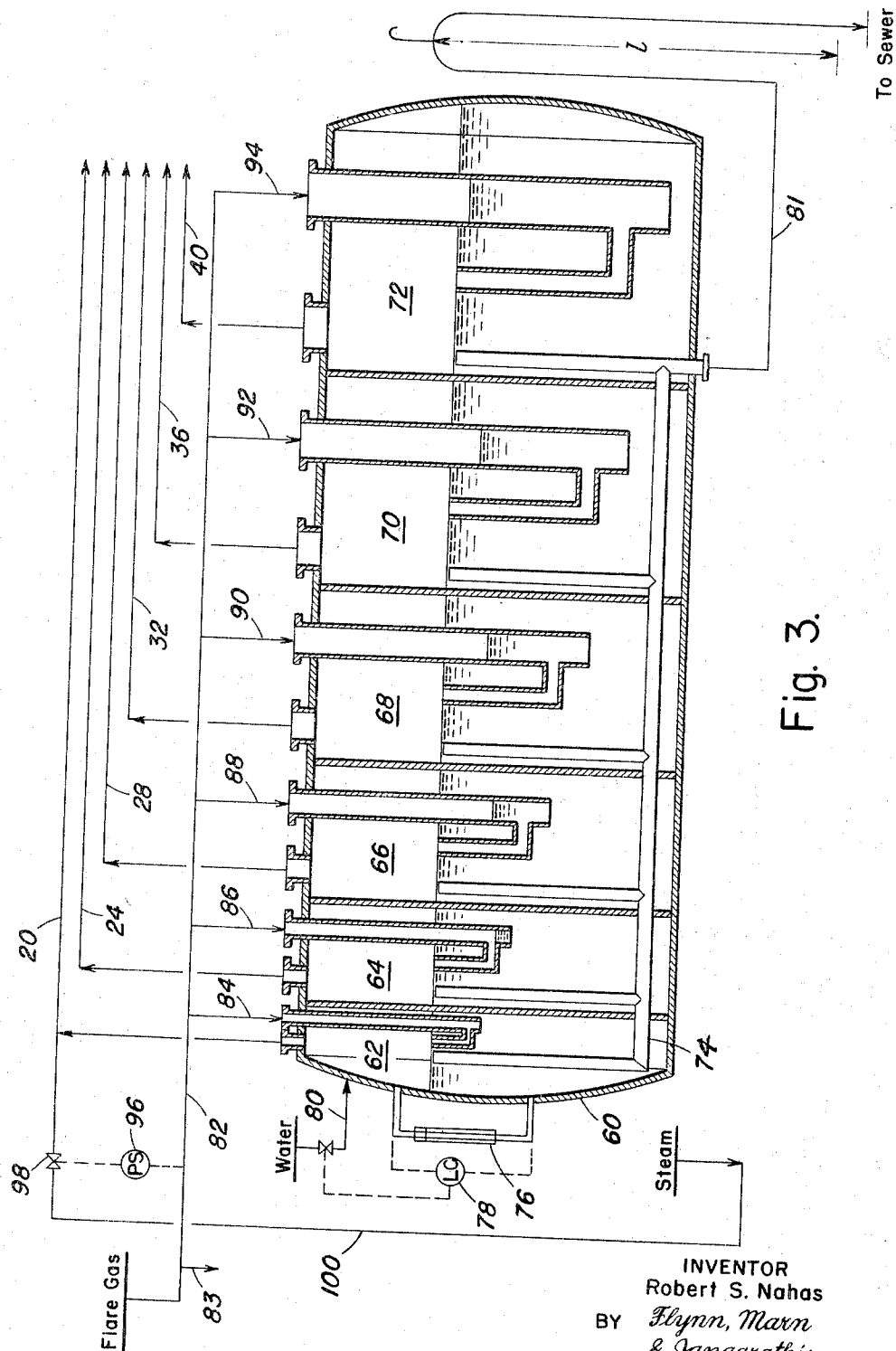


Fig. 3.

INVENTOR
Robert S. Nahas
BY *Flynn, Marx
& Jangarathis*
ATTORNEYS

May 30, 1967

R. S. NAHAS

3,322,178

FLARE APPARATUS FOR COMBUSTIBLE GASES

Filed Aug. 12, 1965

3 Sheets-Sheet 3

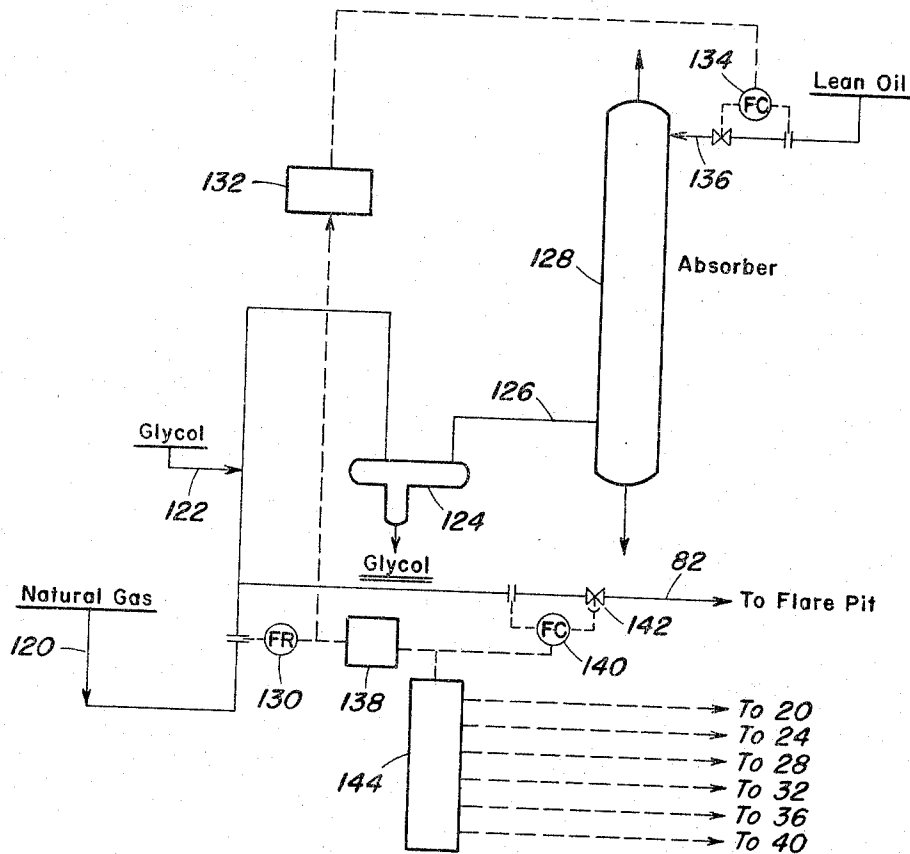


Fig. 4.

INVENTOR
Robert S. Nahas
BY *Flynn, Marn*
& *Jangarathis*
ATTORNEYS

FLARE APPARATUS FOR COMBUSTIBLE GASES
Robert S. Nahas, Englewood, N.J., assignor to The Lum-
mus Company, New York, N.Y., a corporation of Dela-
ware

Filed Aug. 12, 1965, Ser. No. 479,187
7 Claims. (Cl. 158-7)

This invention relates in general to the economical smokeless burning of refinery waste gases or chemical plant gases and, more particularly, the invention relates to the smokeless burning of flare gases over 100 percent of the design flaring load. The apparatus of the invention is applicable to substantially any sort of flare gas, and is characterized by the efficient and economic handling of 100 percent of the design flaring load without producing pollution, smoke or other problems, and has the additional advantage of being shielded from public view.

Heretofore, refinery waste gases have been burnt in a variety of different types of flares. In recent years the necessity of eliminating smoke and accomplishing the burning of these gases inconspicuously has increased to a very large degree, due to stringent governmental anti-pollution regulations. Also, elevated, luminous flares, even when smokeless, have caused complaints, particularly from residential areas near chemical plants. Many devices have been developed for eliminating smoke when flaring over a certain range of the design capacity of the flare. In other words, flares have been designed to be smokeless at relatively low flaring rates, but not at high rates which approach or reach design capacity. In most refineries or petrochemical plants, flares constitute the plant's main safety system, safety valves throughout the plant discharging thereinto. One of the most fundamental functions of flares, of course, is to provide an outlet for gross fluctuations in either process streams or in raw materials, so that the devices employed heretofore have been in most respects unsatisfactory from a pollution standpoint. For example, one device employed heretofore consists of injection means for supplying steam or water sprays around the flare flame in order to mask the smoke. The smokeless burning achieved by such injection devices has not until now operated satisfactorily over the entire flaring range. Smokeless burning can be accomplished by means by multi-jet flares, but these devices are limited to a relatively small and constant flaring load; such multi-jet flares are not practical for large flaring load designs, due to the fact that they become unwieldy and expensive under such conditions.

The most common flare in use in refineries at this time is the elevated flare. This flare consists of a flare stack which is taller than the tallest equipment in the refinery and is located at a safe distance therefrom. A water seal prevents blow-back in the main flare line from the process units caused by air backing up inside the flare header. As noted above, elevated flares can be designed with steam injection facilities at the top of the stack which mask the smoke formed when gases are flared under poor combustion conditions. Of course, such steam injection facilities substantially increase the installed cost of the elevated flare. The multi-jet flares, employed for relatively low design loads, comprise a header supplying a multitude of small (about 1 inch) jets spaced a few feet above grade. The jets are arranged in a pattern of circular or rectangular cross section, with a flue gas stack located thereabove and generally only about 30 feet high.

Burning pits are occasionally employed for flaring purposes and consist simply of a rectangular or square hole about 10 feet deep or less located in a remote area of the refinery. Gases flared in such pits almost invariably burn with a substantial quantity of smoke due to the lack of combustion air in the immediate burning area. Ground

flares with water injection are also employed to flare refinery gases, and these installations consist of three stacks in a general coaxial relation. Combustion of the flare gas occurs in the inside and intermediate stacks; the outside stack provides a shield for the flame and is generally no more than 30 feet in height. Water is sprayed through a nozzle in the immediate flame area and this masks the smoke formed. These installations are smokeless only for about 20 percent of the design flaring load.

Several schemes have been proposed for the automatic control of flaring systems. In one instance, a flare is ignited automatically in accordance with the gas pressure in the main flare header from a gas producer. The end of the flare header in this system is divided at its upper end into several laterally and upwardly extending branch pipes; the gas supplied to this flare is regulated by immersing bells which descend into sealing liquids. A second installation of the same general sort includes a flare stack ignition system. The stacks themselves are of conventional cylindrical structure, but two stacks are provided, a pilot stack being employed to provide a substantially continuous ignition means for the normal waste gases and a second, larger stack being employed to handle greater volumes. Ignition of the second stack is provided through a Venturi tube to the gas line, and means are also provided for supplying the necessary air into the Venturi.

As can be seen from the foregoing, the prior art devices suffer from the general disadvantage of accommodating only a fraction of the design flaring load smokelessly, and in many instances are both expensive to construct and to operate.

It is therefore a general object of the present invention to provide an apparatus for the flaring of refinery gases which overcomes the defects of the various prior art devices.

A further object of the present invention is to provide an apparatus for the smokeless and inconspicuous flaring of refinery gases over the entire design flaring range.

Yet another object of the present invention is to provide an apparatus for the smokeless burning of refinery gases, within very broad limits of fluctuation thereof, which is both economical to construct and to operate.

Various other objects and advantages of the present invention will become clear from the following description of several embodiments thereof, and the novel features will be particularly pointed out in connection with appended claims.

In essence, the present invention makes use of a series of Venturi burners arranged in a novel manner to produce smokeless burning of refinery flare gases over the complete range of design. Additionally, a preferred embodiment of the present invention comprises a novel method for the operation of the Venturi burners. The invention overcomes the inherent low flexibility of Venturi burners; as is well known for smokeless burning such a burner requires a fixed amount of inspired air, smoke being caused by incomplete combustion of gases. If a sufficient quantity of air can be properly mixed with the gases to be burned, no smoke will be formed. Thus, a given burner of the Venturi type is inherently designed for a specific gas rate and, as a general rule, will not operate satisfactorily at less than about 60 percent of this rate. This is because the kinetic energy of the gas leaving the jet nozzle is not sufficient to inspire the required quantity of air to produce smokeless burning. To overcome this difficulty, a substantial number of Venturi burners are required to cover the design flaring load, and in order to stay within the satisfactory operating range, a method of bringing one or more of these burners into operation, depending on the quantity of gas to be flared, has been devised.

In any particular system, the total number of burner sets and the number of burners per set must be determined by the particular requirements of the system. In the embodiment of the invention described hereinbelow, a system consisting of six sets of burners, several sets having varying number of burners, is described.

In operation, the first set of burners handles very small quantities of gas normally flared, and as more gas becomes available to be flared, more of the burner sets go into operation. The system is designed in such a manner that the second set of burners comes into operation when the flare header pressure is high enough to obtain the necessary jet velocity to aspirate the required quantity of air into the burner set. The third burner set comes into operation when the total flaring load exceeds 60 percent of the cumulative design capacity of the first three sets. The same holds true for the remaining burner sets.

In another aspect, the invention provides for a novel method of controlling the cutting-in of the burners, although this is not a necessary feature of the invention. In this preferred embodiment, however, use is made of a seal drum containing water or some other suitable liquid, which drum is provided with several compartments, one for each burner set, wherein the flow of gas to each of the burner sets is regulated by the liquid seal height for each particular set. While water is normally the liquid employed, other liquids can be used and may in some instances be necessary, as for example when the flare gases are below 0° C. The liquid level in all of the compartments is the same and is maintained by a loop seal, the height of which should be at least 200 percent of the maximum back pressure on the seal drum.

Water level is also maintained by a level controller which keeps a constant water inventory in the drum. In the case of a very small flaring load, i.e. insufficient gas pressure to drive the first burner set smokelessly, the gas velocity may be maintained by means of steam. The succeeding compartments of the water seal drum are maintained at the minimum pressure deemed necessary for satisfactory operation of the particular burner set, i.e., when two sets of burners are operating and the flaring rate is at least 60 percent of the cumulative design flaring capacity of the first three sets of burners, the water seal is blown in the third compartment and the third set of burners comes into operation. Thus, the arrangement is such that when the first burners become overloaded the next set kicks in so as to always have sufficient burners to handle the volume of gas to be flared.

A second type of control scheme for kicking in the burners employs analog control modules, and is advantageously employed in any plant having such a control system.

The burners themselves are arranged in a novel manner so as to provide secondary combustion air by means of a natural draft to the flame area to complement the primary air inspired into the burners. In the embodiment described, the burners are set out in uniform sections in a refractory wall in an open pit approximately 10 feet deep. The minimum velocity of the burners is about 10 feet per second in the throat area thereof. A natural draft is provided by the use of firebrick checker walls below the burner which carry the air to the bottom of the pit. Additionally, side walls are provided with transite pipes located therein for cooling and air inspiration purposes.

A better understanding of the invention will be gained by referring to the following detailed description of two embodiments thereof, taken in connection with the appended drawings, in which:

FIGURE 1 is a plan view of a burner installation in accordance with the invention;

FIGURE 2 is an elevation view taken along lines 2-2 of FIGURE 1;

FIGURE 3 is an elevation view, in section, of a water seal drum for controlling the flow of flare gases to the assembly illustrated in FIGURE 1; and

FIGURE 4 is a schematic flow sheet or flow diagram of an alternative method of controlling the flow of flare gases employing analog control modules, as applied in a natural gas absorption train.

With reference to FIGURE 1, the burner installation of the invention, indicated generally at 10, is seen to be rectangular in shape, with two end walls 12 and two side walls 14, the latter having a large number of burners 16 located therein a manner to be described hereinbelow with reference to FIGURE 2. As shown in FIGURE 1, the entire installation is placed substantially below grade level, and therefore retaining walls 18 are provided in spaced parallel relation to the side walls 14. This keeps all flaring out of view. Of course, the installation may be built at grade level with suitably high side walls 14 to accomplish the same end. As can be seen from the drawing, the burners 16 are provided with flare gas through six separate conduits, each conduit supplying a successively larger number of burners. It is to be emphasized, of course, that the size and number of conduits and the number of burners per conduit is dependent on the size of a given installation and the composition of the flare gas. In particular, conduit 20, of a relatively small size, supplies a header 22 supplying gas to three of the burners 16. Conduit 24 supplies header 26, which in turn feed five burners, and conduits 28, 32, 36 and 40 supply, respectively, headers 30, 34, 38 and 42 with gas. The size of the conduits 20, 24, 28, etc. is roughly proportional to the number of burners 16 supplied by each. As shown, headers 38 and 42 have the same number of burners associated therewith and may each handle about 25% of the design load.

While the side walls 14 are firebrick or other suitable refractory material, the walls 18, forming ducts 44, are of any suitable concrete composition. End walls 12 are comprised of a refractory aggregate such as vermiculite concrete, and are provided with transite asbestos piping 46 open at the bottom thereof so as to provide additional secondary combustion air.

The arrangement of individual burners within walls 14 is illustrated in FIGURE 2. As can be seen from FIGURE 2, retaining wall 18 and firewall 14 form between them a duct 44 allowing for the inspiration of air thereinto. Conduit 40 supplies header 42 which in turn supplied a plurality of burners through pipes 46 (only one shown). Pipes 46 pass down through duct 44 and terminate in a narrowed section 48 in the throat of the Venturi burner indicated generally at 50. The burner is comprised of three parts in the conventional manner; in particular, an inwardly sloping portion 51, a throat portion 52, and a flaring portion 54. A pilot ignition pipe 56 is provided to light the various sets of burners. By means of checker work openings 58 at the bottom of wall 14, additional air is inspired from duct 44 into the interior of the assembly and provides additional combustion air within the chamber. As can be seen from FIGURE 2, end wall 12 has openings at the bottom thereof for pipes 46, which by the natural draft created, provide additional secondary combustion air, as well as cooling end walls 12.

As noted in connection with FIGURE 1, gas is supplied to the six sets of burners through six separate conduits, a control system being employed to supply gas to the burners only when required. One embodiment which may be employed for such a control is illustrated in FIGURE 3. With reference to FIGURE 3, a water seal drum, indicated generally at 60, is employed and is divided into six compartments 62, 64, 66, 68, 70 and 72. As can be seen from FIGURE 3, these compartments are of gradually increasing size, as are the conduit fittings leading thereinto. Water is maintained at a given height in each compartment by means of a pipe 74 extending the length of the drum into each compartment, and terminating in

an external loop seal, indicated generally at 81. A constant inventory of water in the drum is maintained by means of a gage 76 and level controller 78 controlling water supply line 80. The height of loop seal 81, i.e. "l," should be at least 200 percent of the maximum back pressure on the seal drum to prevent water in the seal from being blown out to the sewer when flaring at the design rate.

Gas to be flared from the refinery is passed into header 82, liquids being drained therefrom in line 83. Gases in header 82 pass into six conduits of increasing diameter, 84-89, respectively, which pass into seal drum 60. Inside drum 60, these conduits descend to a gradually increasing depth below the surface of the water level therein. A branch conduit returning to the water level provides a passage for the flare gases when the seal is blown, so that the gases needn't bubble through the water. When the flare gas pressure in header 82 is quite low, it will pass into conduit 84, which terminates only a slight distance below the liquid level in compartment 62, it will blow the water seal and pass through the branch conduit into the vapor space of compartment 62 and into outlet conduit 20. In the event that gas pressure in header 82 is insufficient to blow the seal in second compartment 64, this is the only compartment of seal drum 60 which will be operative. In the event that pressure in header 82 is too low for even compartment 62, the flare will not come into operation. A controller 96 controls the valve 98 in the stream line 100, insuring a minimum nozzle velocity for the first burner set. This feature is not really necessary, however, since the amount of smoke which could be formed at such a low flaring rate would be masked by the retaining walls.

The incoming gas in conduits 84 and 86 is shown in FIGURE 3, as having sufficient pressure to blow the water seals in compartments 62 and 64, so that flare gas is passing only through conduits 20 and 24 and into the burner arrangement (FIGURE 1); the remaining conduits 88-94, have varying amounts of the water seal still intact. This might be said to represent a normal flow of flare gas.

The first burner set will burn the smallest quantity of gas and each additional set burns a progressively greater proportion of gas, and the height of the water seals in each compartment is set accordingly. A typical example of the capacity of each burner set is illustrated hereinbelow in Table I.

TABLE I

	Percent of Design Load Flared Through Venturi Burner Set	Cumulative Percent of Design Load
1st Set.....	5	5
2nd Set.....	8	13
3rd Set.....	12	25
4th Set.....	20	45
5th Set.....	25	70
6th Set.....	30	100

Before the first set of burners goes into operation, the pressure in flare header 82 must be high enough to inspire the volume of air required for premixing. The quantity of air inspired is determined by means of a force balance and from the dimensions of the Venturi throat. The area of the Venturi in relation to the area of the jet nozzle is important, because if the ratio of former to the latter is too large the effect of jet velocity will be lost. Before the second set of burners comes into operation (i.e. before the seal in compartment 64 is blown) the pressure in flare header 82 must rise to a level such that the first two sets of burners can operate at at least 60% of their cumulative capacity. As noted above, this insures smokeless burning. For the example set forth in Table I, pressure in header 82 should be $0.6 \times 13 = 8\%$ of the design flaring load. Thus, the range of operation of the first burner set is from 5-8% of the design flaring rate.

Jet nozzle velocity is given by the standard equation $v=c\sqrt{2g\Delta h}$ (1)

where

- v=gas velocity, cm./sec.;
- c=nozzle recovery factor;
- Δh =pressure drop, in cm. of fluid flowing; and
- $g=981$ cm./sec.².

If the pressure drop between flare header 82 and the burners is negligible, then the pressure drop across the nozzle is essentially equal to static pressure in the flare header. If the static pressure is h when the first burner set goes into operation (i.e. 5% of the design rate), the second set should start up when the pressure reaches $h(8/5)^2$, which is 8% of the design rate, as discussed above. The pressures at which the other burner sets come into operation, and the corresponding height of the seals in the various compartments, is calculated in a similar manner.

By maintaining a constant water level in the drum, the seal in a particular compartment will re-establish itself when the pressure in flare header 82 drops below the water seal height, and that burner set will stop flaring. Thus, the burner sets operate smokelessly under any conditions.

If, in a particular installation, the composition of the flare gas is such that hydrocarbons may condense in the seal drum, steam in line 100 may be provided to each compartment by separate conduits (not shown).

An alternative to the embodiment of FIGURE 3 is illustrated schematically in FIGURE 4, which shows, in simplified form, the front end of a natural gas absorption train. As is well known, well-head pressure of natural gas is susceptible to broad variation, but treatment facilities operate most effectively with a constant load. In recent years, analog and digital devices have been developed which can effectively control processing units for maximum efficiency at flow rates varying broadly over the design range. In the absorption of natural gas, for example, analog control modules have been developed which control the flow of lean oil to the absorber so as to maximize production up to the design capacity of the treatment plant. If the flow rate of gas exceeds this figure, of course, gas must be flared.

With reference to FIGURE 4, which is greatly simplified, natural gas in line 120 is dried with glycol added at 122 and removed in drum 124, and the dried gas is passed to absorber 128 via line 126. A flow recorder 130 passes a signal to a plurality of analog modules, indicated generally at 132, which, on the basis of this information and other signals (not indicated) from other parts of the plant, maximize the flow of lean oil by means of flow controller 134.

If design capacity is exceeded, a signal also passes from flow recorder 130 to analog module 138, which prevents a sudden increase in the gas rate to the absorber. Thus, when the feed gas rate, V_1 , increases suddenly, module 138 permits some of the gas, V_2 , to be flared for a period t_1 , during which period the liquid flow rates from the absorber trays respond to a changed lean oil rate from the top of the absorber. After t_1 has elapsed, the flare gas rate is exponentially reduced to zero with time constant t_2 . There is thus a time delay t_1 function in this controller and exponential damping (time constant t_2), which is controlled by the analog module.

While the controller 138 is thus seen to minimize flaring, potentially large volumes of gas may have to be flared and the present invention, providing smokeless burning over the entire design range, is no less important.

Controller 138 passes a signal to flow controller 140, opening valve 142 in flare gas line 82. In this embodiment of the invention, line 82 goes directly to the flare pit (FIGURES 1 and 2) and is connected directly to

each of conduits 20, 24, 28, 32, 36 and 40, each of these latter conduits being provided with a valve (not shown). A second control module 144 also receives the signal from controller 138 and is preset to open and close the valves in each of these conduits in accordance with the flow rate of gas to be flared. Of course, controller 144 can, alternatively, have its own flow recorder in conduit 82 and be independent of controller 138.

As noted above, the embodiment of FIGURE 4 is illustrative only; digital control, for example, could also be employed.

It will be understood that various other changes in the steps, materials, details and arrangements of parts, which have been hereinabove described in order to illustrate the invention, may be made by those skilled in the art within the principle and scope of the invention as defined in the appended claims.

What is claimed is:

1. A flare for combustible gases comprising:
 - a plurality of Venturi burner sets, said sets being capable of burning 100% of the design flaring load of said gas;
 - a plurality of Venturi burners in each of said sets; means for providing air to each of said burners; and control means for operating said burners, said control means being responsive to the total pressure of the gas to be flared, said means operating an additional set of burners when there is sufficient flare gas pressure to aspirate the required quantity of air into said additional set of burners and the burners already operating to effect smokeless burning of the flare gas in said burners, said sufficient flare gas pressure being a flare gas pressure that exceeds about 60% of the cumulative design capacity of the burners operating and the burners in said additional set.
2. A flare for combustible gases comprising:
 - a plurality of Venturi burner sets, said sets being capable of burning 100% of the design flaring load of said gas;
 - a plurality of Venturi burners in each of said sets; means for providing primary combustion air to each of said burners; and control means responsive to the flare gas pressure for operating said burners, said control means comprising a liquid seal drum, a plurality of compartments in said drum, the number of said compartments corresponding to the number of said burner sets;
 - a plurality of conduits, each said conduit communicating with one of said compartments and one of said burner sets;
 - means for maintaining a constant inventory of liquid within said drum and a constant level of liquid within each of said compartments; and flare gas supply means in each of said compartments, said means providing, with said liquid, pressure seals of increasing magnitude in each of said respective compartments, whereby flare gas is distributed to

one or more of said conduits depending on the pressure thereof.

3. A flare for combustible gases comprising:
 - a chamber;
 - a plurality of Venturi burner sets located within said chamber;
 - a plurality of Venturi burners in each of said sets, the amount of burners in each set being unequal;
 - means for supplying gas to be flared to each set of burners; and control means responsive to the flare gas pressure for operating each set of burners, said control means placing an additional set in operation in response to an increase in the flare gas pressure, said burner sets being placed in operation by said control means in the order of increasing number of burners.
4. A flare as claimed in claim 3 wherein said control means comprises an analog module responsive to the pressure of said gases, and valve means associated with each of said burner sets, said module acting to open said valves in seriatim at preselected gas pressures.
5. A flare as claimed in claim 3 and additionally comprising independent means for supplying a minimum pressure of gas to a first burner set, whereby burning in said first set is smokeless regardless of flare gas pressure.
6. A flare for combustible gases comprising:
 - a chamber, said chamber containing at least one double wall forming a passage therebetween;
 - a plurality of Venturi burner sets, said sets being capable of burning 100% of design flaring load of said gas;
 - a plurality of Venturi burners in each of said sets, said Venturi burners being in fluid flow communication with said passage, whereby air is introduced into said burners;
 - means for feeding gas to be flared to said burners; means connecting said passage with said chamber, whereby air is fed to said chamber; and control means to operate said burners, said control means being responsive to the total pressure of the gas to be flared, said means operating an additional set of burners when there is sufficient flare gas pressure to aspirate the required quantity of air into said additional set of burners and the burners already operating to effect smokeless burning of the flare gas in said burners.
7. The flare for combustible gases of claim 6 further comprising an additional means for introducing air into said chamber.

References Cited

UNITED STATES PATENTS

1,576,086	3/1926	Browne.	
2,311,350	2/1943	Richardson	158—7
2,453,382	11/1948	Pietsch	158—105 X
2,971,605	2/1961	Frost et al.	158—104 X

JAMES W. WESTHAVER, *Primary Examiner.*