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Reed

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[54] **FLARE SYSTEM VAPOR RECOVERY**

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[52] **U.S. Cl.** .... **431/89;** 23/277 C; 431/202
[51] **Int. Cl.²** **F23N 1/08**
[58] **Field of Search** .... 431/202, 5, 89; 23/277 C

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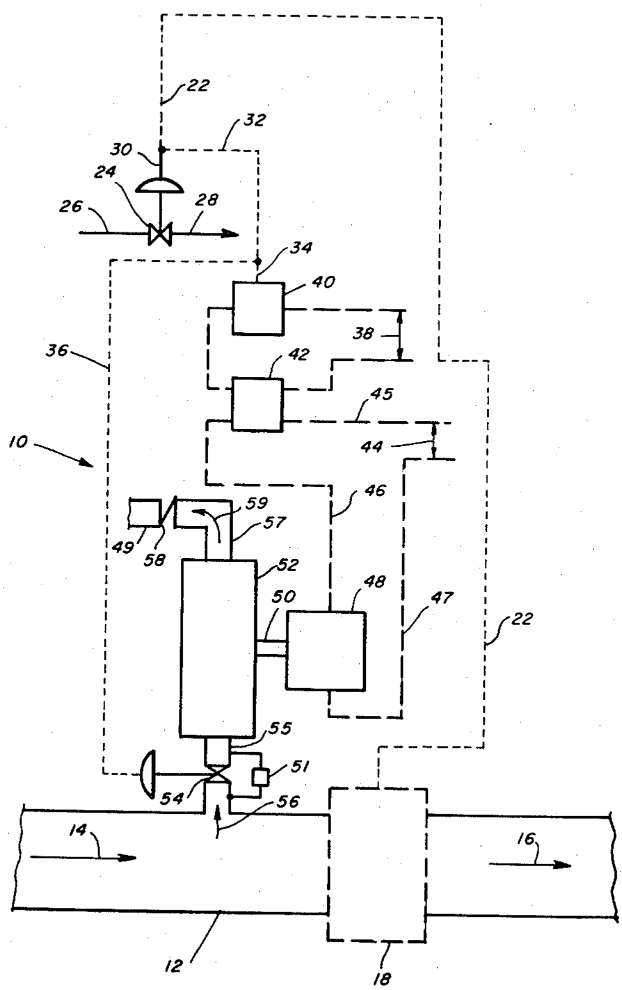
Primary Examiner—Edward G. Favors

[57] **ABSTRACT**

Means for recovery of combustible vapors from flare systems which incorporates means for sensing the pressure and flow in the flare system so that any vapors removed from the flare system for recovery and use elsewhere will not produce a condition in the flare system where there is an inflow of atmospheric air into the flare stack with a possibility of combustible mixtures being formed within the flare system.

7 Claims, 2 Drawing Figures



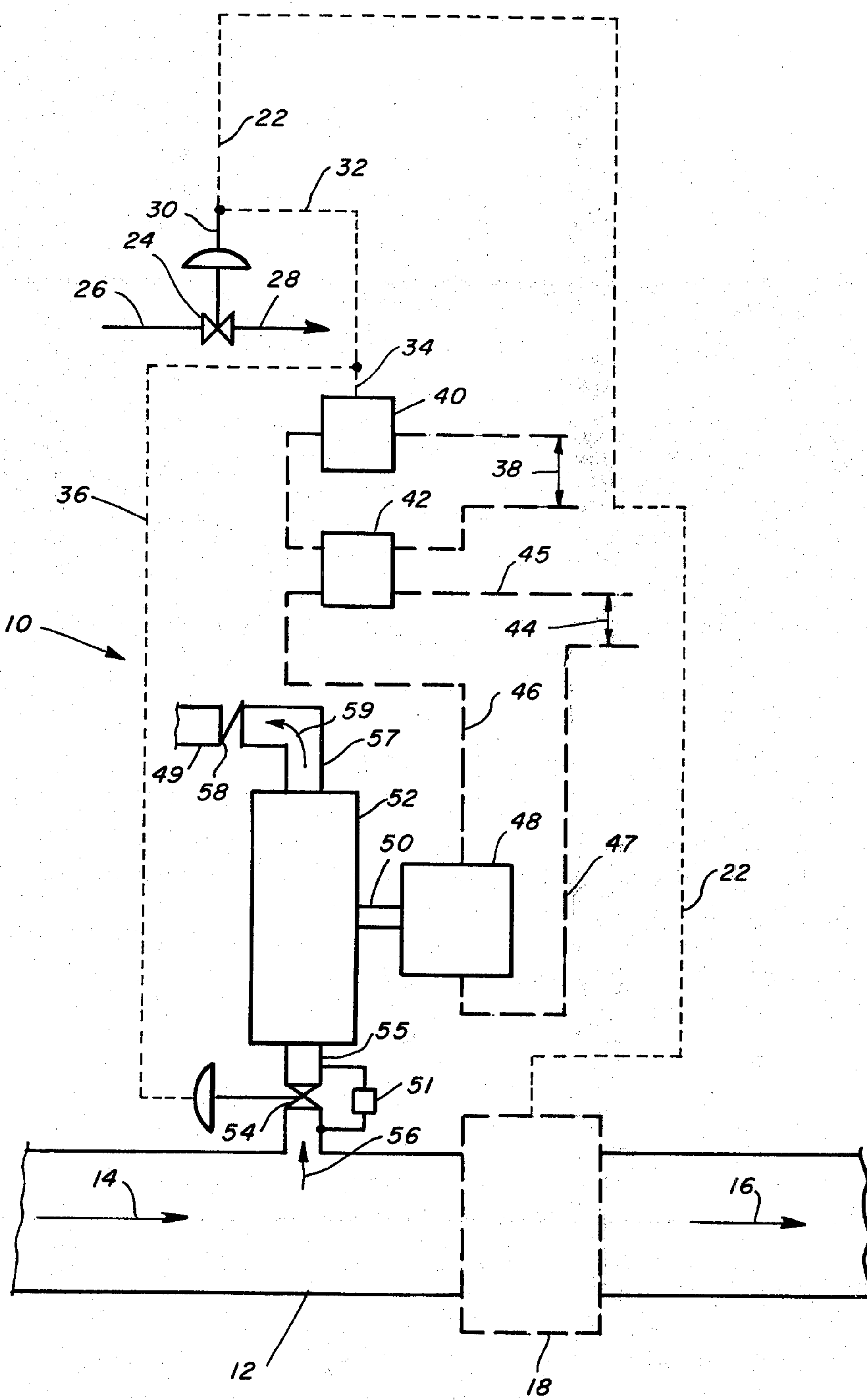

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FIG. 1

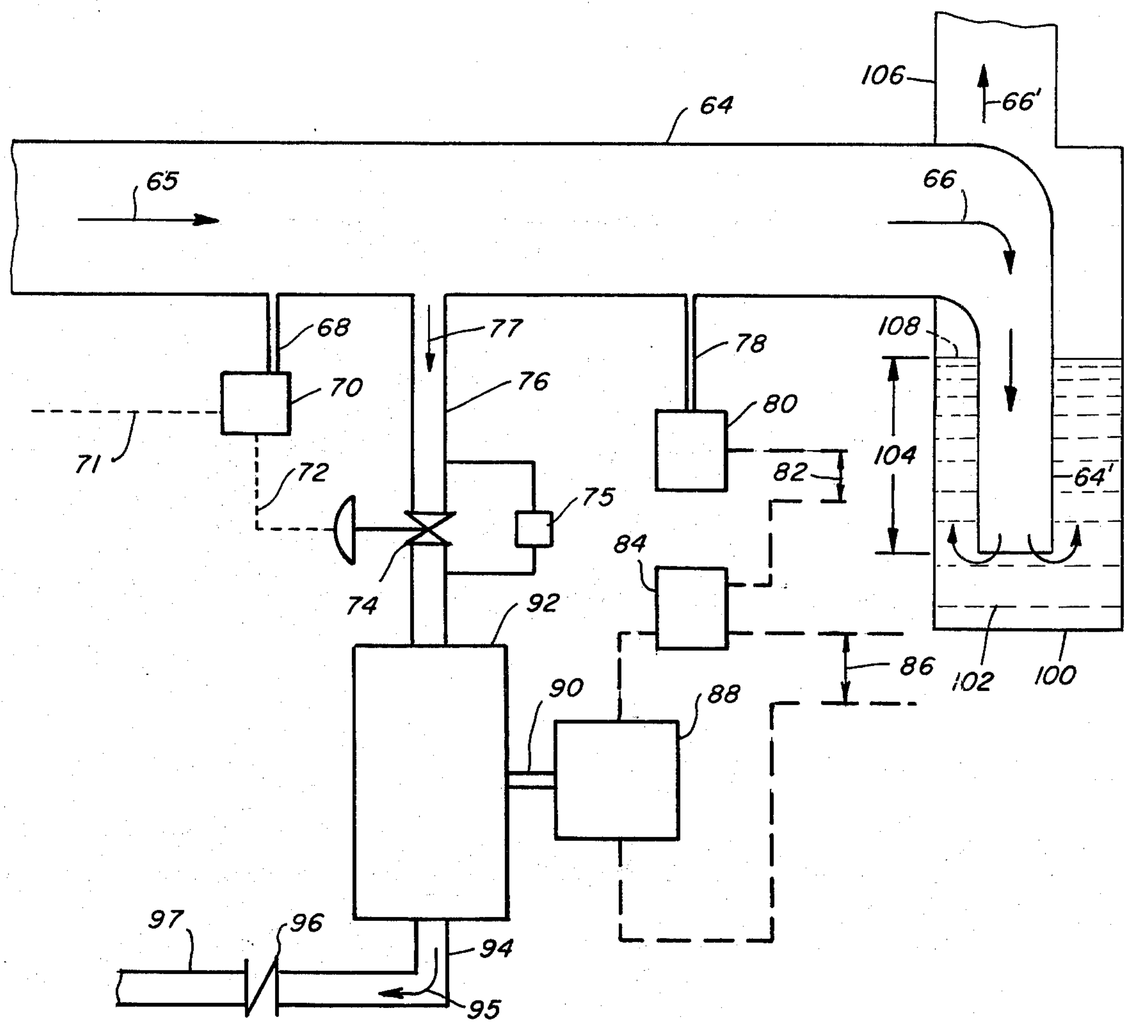
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FIG. 2

FLARE SYSTEM VAPOR RECOVERY

BACKGROUND OF THE INVENTION

In connection with the flare burning of waste process gases which are combustible and in view of existing regulations as regard to avoidance of pollution by controlling the burning to provide smoke free combustion, and further because of the great interest at the present time in the conservation of fuel, these systems have been designed to utilize as much of the flare gases or vapors as possible for other purposes, while insuring that the withdrawal of flare vapors from the flare system does not cause the inflow of atmospheric air through the flare stack and the possibility of creation of combustible or explosive gas mixtures within the flare system. Any flow through the flare stack in an amount greater than is necessary to maintain the flare stack free of air would be excess combustion, and in this case, all vapors that can be recovered for combustion elsewhere is a saving of fuel and energy.

Flared gases may be considered as "vapors" generally and thus the term vapor recovery will be applied to this condition of the removal and utilization of excess flare gas or vapors since combustibles as relieved to the flare system may be considered as being in vapor phase.

It is extremely important that in withdrawal of flared vapors from flare systems that the withdrawal is not of such a large magnitude as to cause air to be drawn back into the flare system because the volume of vapor withdrawal exceeds the volume of vapors released to the flare system from any source connected with the system.

This may be summarized in the statement that, in relation to the flare system any gas movement must be from the system that supplies the flare vapors to the flare, for discharge to atmosphere and burning as discharged. Since the flare discharge is to the atmosphere, any movement in the opposite direction would result in the presence of air within the flare system to create explosion hazards.

SUMMARY OF THE INVENTION

It is an important object of this invention to provide means for selectively withdrawing vapors from a flare system when the volume of flare vapors is greater than a selected minimum volume, necessary to maintain a continuous flow of vapor through the flare system to the flare stack, to ensure that there is no inflow of atmospheric air through the flare stack that would create a hazardous explosion condition.

It is a further object of this invention to provide control means which will sense the flow of vapors within the flare system such manner as to assure that withdrawal of vapors from the flare system through the action of compressor means, whatever the magnitude of withdrawal may be, will be in quantity such as to assure movement from the system to the flare in any case thus ensuring that, if system flow exists, it is always from the system to the flare.

These and other objects are realized and the limitations of the prior art are overcome in this invention by providing sensor means in the flare system whereby the flow of flare vapors to the flare through the flare stack and system and the pressure within the flow conduit can be used to control the withdrawal of flare vapors from the system to a compressor for use of the vapors at other locations. When the pressure and/or flow conditions are proper, means are provided for starting a compressor and for providing proportional control on the duct between the flare system and the inlet to the compressor so that the amount of flare vapors withdrawn from the flare system will be within the proper range.

The system can be used with a flare system which utilizes a water seal or with a system that does not utilize a water seal.

It is to be understood that greatest recovery of flared vapors is possible when the flare system includes a water seal between the point of vapor recovery and the flare. Pressure upstream of the water seal must rise to a condition greater than the depth of immersion of the tube pendant in the water of the seal in order to provide continuing vapor flow through the system to the flare for discharge to atmospheric pressure. Thus all vapor moving from origin in the system upstream of the seal is recoverable since the water seal will not permit vapor flow in either direction until water-displacement pressure is present either upstream or downstream of the water seal. Withdrawal of vapor, by control, is not possible until the pressure upstream of the water seal becomes substantially equal to the immersion depth of the water seal and, by control, the rate of vapor withdrawal from the flare system increases upstream of the water seal as pressure there increases beyond the pressure required for initial flow to the flare. Since initial compressor operation is not possible until pressure upstream of the seal is approximately equal to water seal immersion normally and since the compressor is the source of energy for vapor withdrawal when it is operating, no vapor can be withdrawn from the flare system when the compressor is not operating but withdrawal can continue when pressure upstream of the seal is caused to be substantially equal to water seal immersion depth or greater by virtue of vapor flow equal to vapor withdrawal upstream of the point of vapor withdrawal and the compressor is operating by virtue of pressure control means.

When no water seal forms a part of the flare system and in view of need for flow from the flare system to the flare to assure that no air will be drawn into the system by compressor operation, initial compressor operation, cannot, by control, occur until such time as flow to the flare exists in adequate quantity thus there is flare-burned loss of the quantity of vapor which moves from the system to the flare before vapor recovery can begin. As the initial compressor operation occurs, only a small quantity of vapors is withdrawn from the flare system until such time as the flare system flow increases.

All flare systems cannot include water seals for various reasons, thus two forms of the vapor recovery system are required because, as has been stated, any flare vapor movement must be from the flare system to the flare, to avoid indraft of air to the system and creation of explosion hazard. Where no water seal is present there must be a selected minimum flow of vapor to the flare before initial compressor operation for vapor recovery can begin. Vapor which moves to the flare is discharged to atmosphere for burning and is thus lost. The selected minimum flow to the flare can be in the order of 1 ½ feet/second but is not so limited when no water seal is a part of the flare system.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 represents a control system applied to a flare system which does not utilize the water seal.

FIG. 2 represents a control system applied to a flare system which does utilize a water seal.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made to the drawings and in particular to FIG. 1, in which the numeral **10** indicates generally a control system according to the present invention. A portion of the flare vapor flow system is indicated by the conduit **12**. Arrow **14** indicates the direction of flow of flare vapors within the system from sources. Arrow **16** represents the direction of flow of flare vapors to the flare stack and to the atmosphere. Dashed enclosure **18** represents a sensor system sensitive to the flow rate of gases in the conduit **12** and also sesitive to the pressure in the conduit **12.** No particular kind of sensor means are required, the only requirement being that the sensor signal output be a selected function of the pressure and flow rate. The sensors shown in U.S. Pat. Nos. **3,326,041** and **3,570,535** would be satisfactory. When the conditions of pressure and/or flow rate are proper, according to a selective consideration, a signal is applied to the signal line **22** which controls three operations. The signal goes by line **30** to control valve **24,** which initiates the flow of steam to the flare stack to initiate the proper combustion conditions. Steam enters on conduit **26** and departs on conduit **28** for the combustion region of the flare stack. This feature is common to the prior art devices.

The signal on line **22** also goes by line **32** and **34** to a pressure switch **40.** This switch receives electrical power over the leads **38** to control a starting relay or contactor **42,** which controls the power line **44** through leads **45, 46** and **47** to supply power to the driving motor **48,** through shaft connection **50** to compressor **52.** Compressor **52** is adapted to take the flare vapors from the conduit **12** through conduit **55** and valve **54** to compress them to a pressure suitable for combustion apparatus, and to deliver the compressed vapors through conduit **57** and check valve **58** in accordance with arrow **59.** Conduit **49** beyond the check valve then goes to a fuel system for combustion in various pieces of equipment. The purpose of the check valve **58** is to prevent flow of combustion gases from the fuel system connected to conduit **49** back into the compressor and into the flare conduit **12,** since this would be waste of good fuel. Consequently, the flow of vapors from the flare system **12** into the fuel combustion system **49** occurs only when conditions are right in the flare system. The flow of flare vapors to the compressor is indicated by arrow **56.**

There is a bypass around valve **54** and an orifice **51** of such size as to maintain a selected minimum flow of gas into the compressor even though the valve **54** is closed. The control valve **54** is normally closed and on signal from **18** through lead **36** the valve will open and allow additional flow of vapor from the flare system **12** as flow in **12** increases.

Reviewing the system and its operation, when the amount of flare gas **14** is such that the flow velocity and pressure are correct a minimum of signal is provided on lead **22** thence to **32, 34** and **40** that starts the compressor **52** and provides a minimum flow of vapor through the orifice **51** and into the fuel system **49.** If the vapor flow is high enough as to justify a greater flow of flare vapors from **12** to **49** than is provided by the orifice **51,** then the control on lead **36** causes the valve **54** to open because of greater signal from **22** and the amount of opening is proportionate to the amount of pressure and volume, so that as the flow **14** increases the flow **56** will increase also, leaving a selected minimum flow **16** at all times through the flare system to the stack.

The purpose of the bypass orifice **51** is to permit the sudden starting of the compressor and limiting the flow of gas at the start so as not to upset the flow conditions in the flare system, and perhaps cause the inflow of air into the stack. The valve **54** is provided for the purpose of controlling the withdrawal of flare vapors as the flow **14** increases. For example, if at a low rate of flow of flare vapors the suction to the compressor should be unrestricted as the compressor starts, this would cause abrupt withdrawal of too large a volume of vapor from the conduit **12** in accordance with the arrow **56** and a shock effect would result which would in effect reduce the pressure to the point that the compressor is shut off. The pressure would then rise because of the stoppage of the flow **56** and the compressor would start again and the same shock effects would occur. Thus, there would be a violent control cycling from on to off, etc. at a high rate, with damage to the system resulting. Consequently, the valve **54** is provided which remains closed until after the compressor has been started. The compressor has a minimum flow through the orifice **51.** The control **18** provides a proper signal through lead **36** to the valve **54** so that as the volume of flare gas increases the volume of vapors withdrawn in accordance with arrows **56** similarly increases to maintain the selected minimum **16** of flow of vapors to the stack.

Referring now to a second embodiment of this invention shown in FIG. **2** the conduit **64** carries the flare vapors in accordance with arrows **65** and **66** to the stack, for combustion. A side conduit **76** leads to valve **74** and compressor **92.** The output of the compressor goes by conduit **94** in accordance with arrow **95** through check valve **96** to conduit **97** and to the fuel system where it can be burned in boilers or other apparatus which requires fuel. There is a pressure tap **68** on conduit **64** leading to control means **70,** which permits control fluid in conduit **71** to pass through conduit **72** to the valve **74.** As in the case of FIG. **1,** there is a bypass orifice **75,** around the valve **74** which is normally closed, so that when the compressor **92** starts, the initial flow of gas in accordance with arrows **77** from the conduit **64** is limited by the orifice **75.** The later, the valve **94** take control and provides a proportional flow of vapors from the conduit **64** into the fuel system.

In FIG. **2,** although not shown, there is downstream of the arrow **66** a water seal through which all vapors must pass in their flow to the stack. The conduit **64** turns downward at **64'** and is immersed in a chamber **100** filled with water **102** to a level **108.** The chamber **100** has an upward pipe **106** which carries gases **66'** to the stack. The depth of immersion or hydrostatic level through which the gases must pass is indicated by the dimension **104.** The pressure in the conduit **64** is dictated by the depth of immersion of an entry duct into the water of the water seal. The pressure in conduit **64** at static flow condition is measured as inches of water column, according to the pressure required for displacement of the water content of the duct which is water immersed. The pressure in conduit **64** must be greater than the depth of immersion in order for flare gas to move toward the stack.

Because of the water seal, flow of air from the flare toward the system cannot occur. Therefore, any flow in relation to the flare must be toward the flare when the pressure in conduit **64** exceeds the immersion depth of the duct. In other words, with the water seal virtually the entire flow of vapors can be recovered through the route of the compressor back into the fuel system, whereas in the embodiment of FIG. **1** there must be maintained a minimum flow **16** at all times. In other words, the flow **77** of FIG. **2** can be virtually equal to the flow **65** which would means that no additional flow **66** to the stack could occur. The inflow of atmospheric air into the stack is taken care of by the water seal pressure and other control apparatus.

When the pressure in the conduit **64** approximately equals the water head in the water seal, the pressure transmitted by conduit **78** to the pressure switch **80** causes the switch **80** to deliver control power to the relay or contactor **84** being supplied through power lead **82** through the switch **80.** When the relay **84** closes, power supplied by leads **86** is then permitted to flow to the motor **88** which drives the compressor **92** through the shaft **90.** With the compressor **92** running, a minimum flow of vapor **77** from the conduit **64** flows through the conduit **76** and the orifice **75** through the compressor and conduit **94** and through the check valve **96** to the fuel system **97.** The amount of vapors flowing through the orifice **75** is small enough so that it does not radically upset pressure in the conduit **64.**

If with this minimum flow the pressure in **64** is still equal to or greater than the pressure head in the water seal, the compressor continues to run and as the pressure rises in the conduit **64** the valve **74** opens proportionately, so as to maintain a pressure in the conduit **64** equal to or slightly greater than the pressure head in the water seal. Thus, utilization of a maximum quantity of the vapors in the flare system is possible by this means without danger of having hazardous explosive conditions in the flare system due to indraft of air.

It is clear, therefore, that by the control system both in FIGS. **1** and **2** flare vapors can be salvaged from the flare system, compressed and combined with other fuel into a fuel system, without endangering the operation of the flare system. In other words, the amount of flare gases withdrawn is a function of the amount of flare gases provided to the flare system and is never more than the minimum required to keep the system operating properly and safely.

While the sensor **18** has been shown as a single unitary element it will be clear that it can comprise more than one element responsive separately to flow rate and to pressure.

Flares are used because, for safety reasons, it is at times necessary to pressure-relieve process systems where the vapors relieved are combustible to a degree which makes them valuable as fuels (hydrocarbons) or they have value because of their nature.

In the latter case ammonia, hydrogen, chlorinated hydrocarbons and others may be considered. In this case and if the flared vapors can be recovered after relief to a flare system, air pollution is further avoided but safety pressure relief is provided for by the flare system.

By far the greatest interest is in the area of fuel recovery where flared hydrocarbons are typical. Hydrocarbons are typical fuel. But useful recovery must provide for both recovery and pressure elevation on recovered vapors in order for them to be used as fuel meanwhile avoiding explosion hazard due to fuel recovery.

Recovery of flared vapors is in proportion to the speed/pressure of movement of the vapors through the flare system toward the flare where fuel value is lost through burning in the atmosphere.

If the speed of movement of flared vapors in a flare system is **1**′/second (foot per second) the volume of vapors moving flareward is **3,600** CFH (**60** CFM) per square foot of system line area. In a **20** inch system line (area = **2.96** sq ft) the volume of gases (vapor) to the flare for burning is **2,96** × 3,600 = 10,656 CFH (cubic feet per hour).

If **10,656** cubic feet per hour have calorific value at **2,000** btu/cu ft (which may be considered typical), the heat lost would be **21,312,000** btu's/hr. At today's fuel cost, this represents approximately **$26.00**/hour aside from the fact that the fuel energy is forever lost.

In the system as in FIG. **2** of our invention, virtually all of the flare line flow can be withdrawn from the flare system and used as fuel in any satisfactory manner but the system as in FIG. **1** (at **1** ½′/second flow velocity) would allow loss of **1** ½ times **10,656** CFH or **15,984** CFH before vapor recovery can be initiated. However, any flow in excess of **1** ½′/second could be recovered where now it is lost.

The flare system is designed for complete emergency relief of vapors but such a condition of emergency is rare and, in fact may never occur. Years of experience with flare systems show clearly that, for **99.9** percent of flare operating time, velocity within the flare system is maximal at **40**′/second with average velocity in the order of from **10** to **20** feet per second when pressure relief is required.

Relieved vapor movement through the flare system does not occur constantly but does occur, as a weighted estimate, approximately **8**% of the operating time for the flare where operating time may be considered as the time the flare is ready to accept burn/flared vapors. Average flare line velocity may vary considerably but **10**′/second is a reasonable assumption. Maximum vapor recovery in any case is according to compressor capacity when vapor relief to the flare system is occuring.

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 waste vapor flare system, a vapor recovery system comprising:

a. conduit means for the flow of flare vapors from a source thereof to a flare stack where the vapors are expelled to the atmosphere and burned;

b. sensor means connected to said conduit means for sensing the pressure and/or flow rate of said flare vapors in said conduit means, and means to generate a sensor signal which is a selected function of the said pressure and/or flow rate;

c. motor means driving compressor means, the compressor inlet connected to said conduit means through normally closed first valve means, the compressor outlet connected through check valve means to a fuel using system; and

d. first control means responsive to said sensor signal to start said compressor; and

e. second control means responsive to said sensor signal to control the opening of said first valve means.

2. The system as in claim **1** including bypass conduit means connected around said first valve means to pass a selected minimum vapor flow from said conduit means to said compressor inlet when said compressor is running.

3. The system as in claim **1** including delay means in the control means of said first valve means and means responsive to said delay means to delay the opening of said first valve means until after said flow of vapors from a source thereof is adequate for additional flow to said compressor when said compressor is running.

4. The system as in claim **1** in which said first valve means is a proportional valve means.

5. The system as in claim **1** including means responsive to said sensor signal to initiate and control steam flow to the combustion area of said flare if said flare operation requires said steam for avoidance of air pollution.

6. The system as in claim **1** including in said first and second control means, means to ensure that the flow rate to said stack never falls below a minimum selected value.

7. In a waste vapor flare system having a water seal, a vapor recovery system, comprising:

a. conduit means for the flow of flare vapors from a source thereof to a flare stack where the vapors are expelled to the atmosphere and burned;

b. sensor means connected to said conduit means for sensing the pressure of said flare vapors in said conduit means, and means to generate a sensor signal which is selected function of said pressure;

c. motor means driving compressor means, the compressor inlet connected to said conduit means through normally closed first valve means, the compressor outlet connected through check valve means to a fuel using system;

d. first control means responsive to said sensor signal to start said compressor; and

e. second control means responsive to said sensor signal to control the opening of said first valve means.

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