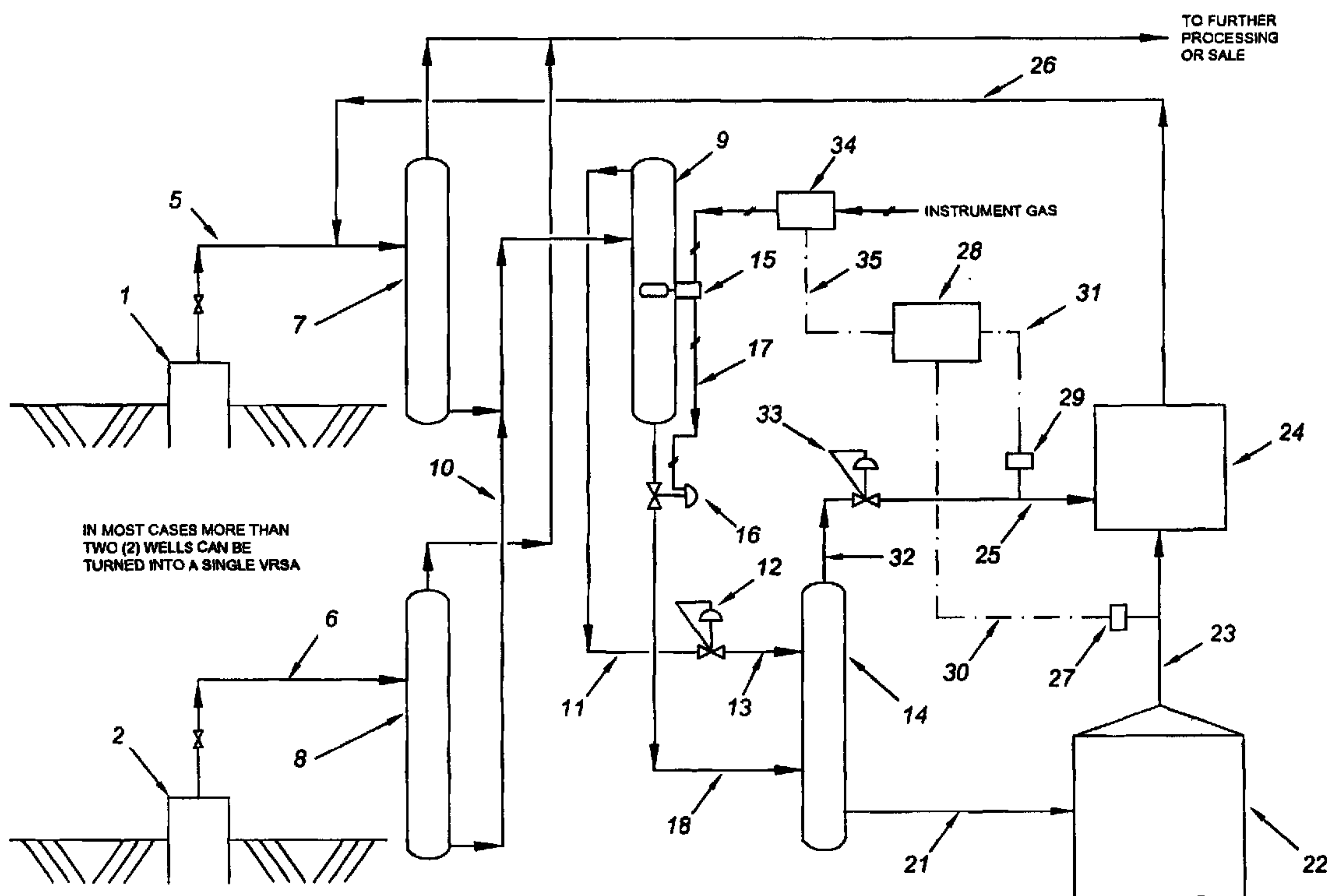




(22) Date de dépôt/Filing Date: 2009/03/06  
 (41) Mise à la disp. pub./Open to Public Insp.: 2009/09/06  
 (45) Date de délivrance/Issue Date: 2015/11/24  
 (30) Priorité/Priority: 2008/03/06 (US12/043,685)

(51) Cl.Int./Int.Cl. *C10G 5/06* (2006.01),  
*C10L 3/10* (2006.01), *E21B 43/34* (2006.01),  
*F04B 25/00* (2006.01), *F25J 3/00* (2006.01)  
 (72) Inventeurs/Inventors:  
 HEATH, RODNEY T., US;  
 HEATH, FORREST D., US;  
 HEATH, GARY, US  
 (73) Propriétaires/Owners:  
 HEATH, RODNEY T., US;  
 HEATH, FORREST D., US;  
 HEATH, GARY, US  
 (74) Agent: UREN, JOHN RUSSELL

(54) Titre : DISPOSITIF DE RECUPERATION DE LA PHASE GAZEUSE CONTENANT UN BOUCHON  
 D'HYDROCARBURE LIQUIDE  
 (54) Title: LIQUID HYDROCARBON SLUG CONTAINING VAPOR RECOVERY SYSTEM



(57) Abrégé/Abstract:

A liquid hydrocarbon slug-containing vessel for incorporation into a system integrating a low-pressure separator with a vapor recovery process system, and a method for regulating the temperature of a gas to be compressed by a two stage compressor so as to prevent liquification of the gas and to prevent over-heating of the compressor.

**LIQUID HYDROCARBON SLUG CONTAINING VAPOR RECOVERY SYSTEM**

**ABSTRACT OF THE DISCLOSURE**

5           A liquid hydrocarbon slug-containing vessel for incorporation into a system integrating a low-  
pressure separator with a vapor recovery process system, and a method for regulating the  
temperature of a gas to be compressed by a two stage compressor so as to prevent liquification of  
the gas and to prevent over-heating of the compressor.

10

15

20

25

30

35

40

## PATENT APPLICATION

5

## LIQUID HYDROCARBON SLUG CONTAINING VAPOR RECOVERY SYSTEM

BACKGROUND OF THE INVENTIONField of the Invention (Technical Field):

10 **[0001]** The present invention relates to a stand-alone, liquid hydrocarbon slug-containing vapor recovery process system for application on natural gas well pads having either single or multiple wells.

Background Art:

15

**[0002]** Natural gas production units can be can be integrated with the components (e.g., engine, emissions separator, circulating pump, educator, compressor, and controls) of a vapor recovery process system (referred to herein as a "VRSA"). In such an integrated system, a vessel can be incorporated to contain a liquid hydrocarbon slug to relieve the VRSA from having to handle vapors derived from liquid hydrocarbons beyond its instant capacity to do so. Such a slug-containing vessel operates at the flowing line pressure and captures a liquid hydrocarbon slug upstream of the high pressure separator. Such an integrated system requires a slug-containing vessel for each well that produces liquid hydrocarbon slugs greater than the instant capacity of the VRSA.

25

**[0003]** However, because many of the applications of a VRSA are on well pads that have several natural gas wells, and the wells are already equipped with production units of various designs, a design is needed for a stand-alone, slug-containing VRSA that (limited only by the gas capacity of the compressor) could recover all the hydrocarbon vapors from the liquids produced by multiple wells on a well pad.

30

**[0004]** Note that where the discussion herein refers to a number of publications by author(s) and year of publication, that, due to recent publication dates, certain publications are not to be considered as prior art vis-à-vis the present invention. Discussion of such publications herein is given for more complete background and is not to be construed as an admission that such publications are prior art for patentability determination purposes.

40

5

BRIEF SUMMARY OF THE INVENTION

**[0005A]** According to one aspect of the invention there is provided a method for operating a compressor comprising: providing a compressor comprising a first stage and second stage; gases emanating from said first and second stages; connecting an outlet of the first stage through a cooling coil immersed within produced liquid hydrocarbons such that the gases from the first stage of compression are cooled to no less than 170 degrees Fahrenheit by the produced liquid hydrocarbons via conduction thereto; and connecting an inlet of the first stage to a heating source, wherein the heating source is immersed within the produced liquid hydrocarbons such that the produced liquid hydrocarbons simultaneously heat gases entering the inlet of the first stage and cool the compressed gases exiting from the first stage of compression.

20

25

30

35

40

**[0006A]** According to a further aspect of the invention, there is provided a method for operating a compressor comprising: providing a compressor comprising a first stage and second stage with gases emanating from said first and second stages; connecting an outlet of the first stage through a cooling coil immersed within produced liquid hydrocarbons which have been removed from a well in their liquid state such that the gases from the first stage of compression are cooled by the produced liquid hydrocarbons via conduction thereto; and connecting an inlet of the first stage to a heating source, wherein the heating source is immersed within the produced liquid hydrocarbons such that the produced liquid hydrocarbons simultaneously heat gases entering the inlet of the first stage and cool the gases exiting from the first stage of compression.

5

10

15

20

25

30

35

40

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

**[0015]** The accompanying drawings, which are incorporated into and form a part of the specification, illustrate one or more embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating one or more preferred embodiments of the invention and are not to be construed as limiting the invention.

**[0016]** Fig. 1 is a flow diagram of a stand-alone, slug containing VRSA of an embodiment of the present invention;

**[0017]** Fig. 2 is a schematic of a configuration of the intermediate pressure slug containing vessel of an embodiment of the present invention; and

**[0018]** Fig. 3 is a schematic showing the operation of pipe coils of an embodiment of the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

**[0019]** An embodiment of the present invention provides for a vessel and system, for use with a vapor recovery process system (a "VRSA"), for containing a liquid hydrocarbon slug for those instances where the VRSA does not have the capacity to handle vapors, derived from liquid hydrocarbons, above a given amount.

**[0020]** As used herein, the words "a", "an", and "the" mean one or more. The same number labels in the figures are used consistently throughout for better understanding although such consistent use of numbering does not imply restriction to one embodiment.

**[0021]** Turning to the figures, Fig. 1 is a flow diagram of an embodiment of the stand-alone, slug-containing VRSA of the present invention. One or more natural gas wells may produce a liquid hydrocarbon slug that could exceed the capacity of VRSA 24 to handle the instantaneous volume of vapors created by the liquid hydrocarbon slug. In the embodiment illustrated in Fig. 1, natural gas wells 1 and 2 are in communication with high pressure separators 7 and 8 via well flow lines 5 and 6. High pressure separators 7 and 8 separate the produced natural gas from the produced liquids and may stand alone or be a part of a production unit. Liquids collected in high pressure separators 7 and 8 are transferred via dump line 10 to intermediate pressure liquid slug-containing vessel 9. Gases that evolve from the liquids being dumped into intermediate pressure slug containing vessel 9 are transferred to the inlet of backpressure regulator 12 via flow line 11.

**[0022]** Gases and/or liquids exiting backpressure regulator 12 are transferred into low pressure separator 14 (which, in this embodiment, is heated) via flow line 13 (the complete operation of backpressure regulator 12 is further illustrated in Fig. 2).

**[0023]** Liquid level control 15 sends a pressure signal through tubing line 17 to open motor valve 16 and transfers produced liquids from intermediate pressure slug containing vessel 9 through line 18 into low pressure separator 14. Line 21 transfers produced liquids from low pressure separator 14 into

storage tank **22**. Line **23** transfers gases evolved from the liquids in storage tank **22** into the emissions separator (not shown) of VRSA **24**.

**[0024]** Line **32** transfers the gases from low pressure separator **14** to the inlet of backpressure valve **33**. Line **25** transfers the gases exiting back pressure valve **33** into the emissions separator (not shown) of VRSA **24**. Line **26** preferably transfers the gases collected and compressed by VRSA **24** to the inlet of one of the high pressure separators. Transducer **27** measures the pressure in storage tank **22**. Transducer **29** measures the pressure in emissions separator (not shown) of VRSA **24**. Electrical line **30** connects transducer **27** to programmable logic controller ("PLC") **28**. Electrical line **31** connects transducer **29** to PLC **28**. I/P transducer (converting current input to pressure output) **34** may be installed to control the pressure signal either upstream of liquid level control **15** (as shown) or downstream of liquid level control **15** on tubing line **17**. Electrical line **35** connects PLC **28** to I/P transducer **34**. Tubing line **36** (see Fig. 2) carries a controlled pressure signal from I/P transducer **34** to the supply gas inlet of liquid level control **15**.

**[0025]** Fig. 2 is a schematic of a configuration of an embodiment of intermediate pressure slug containing vessel **9**. Intermediate pressure vessel **9** is illustrated as a horizontal vessel (the preferred design) with liquid accumulator section **42** (a first boot) and gas dome **43** (a second boot).

**[0026]** Liquid accumulator section **42** extends downwardly from the bottom of intermediate pressure slug-containing vessel **9**, through the top of low pressure separator **14** and into heated liquid contained in low pressure separator **14**. Liquid accumulator section **42** contains liquid level control **15** and internal dump line **37** which extends downwardly from outlet connection **48** located at the top of intermediate pressure vessel **9** to a distance (e.g., approximately 2 inches) from the bottom of liquid accumulator section **42**. Gas dome **43** extends upwardly a distance (e.g., approximately two feet) above the top of intermediate pressure vessel **9**. Gas dome **43** has inlet connection **47** connected to line **10**. Line **10** transfers the produced liquids from the high pressure separators to intermediate pressure slug containing vessel **9**. Internally, gas dome **43** has line **44** which extends downwardly from outlet connection **46** to terminate at point **50**. In a most preferred embodiment, point **50** is approximately four inches below inlet connection **47** and approximately four inches above the top of intermediate pressure slug containing vessel **9**. The outlet of connection **46** is connected by line **11** to the inlet of back pressure regulator **12**. Back pressure regulator **12** senses, through tubing line **38**, the gas pressure contained in intermediate pressure slug containing vessel **9**.

**[0027]** The specific operation of intermediate pressure slug containing vessel **9** is as follows. The operation of intermediate pressure slug containing vessel **9** begins when produced liquids are dumped

from high pressure separators 7 and 8 into intermediate pressure slug containing vessel 9. The pressure in intermediate pressure slug containing vessel 9 is controlled by backpressure regulator 12 to maintain an intermediate pressure of, for example, from approximately 75 to 150 psig between the operating pressure of high pressure separators 7 and 8 and low pressure separator 14. The pressure settings of backpressure regulators 12 and 33 are determined by the lowest expected flowing line pressure in the high pressure separators. The change of pressure between the high pressure separators and intermediate pressure slug containing vessel 9 causes entrained gases and some liquid flashing to occur in intermediate pressure slug containing vessel 9.

**[0028]** As soon as the gas pressure in intermediate pressure slug containing vessel 9 reaches the set pressure of back pressure regulator 12, gas will begin to flow through back pressure regulator 12 into low pressure separator 14. The produced liquids entering intermediate pressure slug containing vessel 9 will fall to the bottom and begin filling liquid accumulator section 42.

**[0029]** If the output through electric line 35 from PLC 28 to I/P transducer 34 (such transducers convert current input to a proportional pressure output) shows that VRSA 24 can handle the vapors generated by the liquids entering intermediate pressure slug containing vessel 9, liquid level control 15 will open dump valve 16, and through lines 37, 49, and 18, cause the produced liquids to flow into low pressure separator 14.

**[0030]** If the volume of vapors from the produced liquids entering intermediate pressure vessel 9 begin to overload the vapor capacity of VRSA 24, PLC 28 will send a signal to I/P transducer 34 to begin closing dump valve 16. As long as the volume of produced liquids entering intermediate pressure slug containing vessel 9 continue to generate enough vapors to overload the capacity of VRSA 24, PLC 28 through I/P transducer 34 will continue to close dump valve 16.

**[0031]** Keeping dump valve 16 closed will cause intermediate pressure slug containing vessel 9 to begin filling with produced liquids. Intermediate pressure slug containing vessel 9 preferably has several barrels of fluid capacity and is designed to store excess produced liquids so they can be dumped over an extended period of time to match the vapor capacity of VRSA 24. In case of a mechanical failure or other unexpected occurrence, line 44 is designed to prevent overfilling of intermediate pressure slug containing vessel 9. Anytime bottom 50 of line 44 becomes covered with produced liquids, the produced liquids will flow with the released vapors through lines 44, 11, and 13 and back pressure valve 12 into low pressure separator 14. Produced liquids flowing through back pressure valve 12 would be an upset operating condition.

**[0032]** Referring again to Fig. 2, low pressure separator **14**, can be either two or three-phased. Low pressure separator **14** has fire tube **39** to provide heat to the system. The bottom end of emission separator **45** (a component of VRSA **24**) is immersed in the heated liquids contained in low pressure separator **14**. Also, two pipe coils **40** and **41** are immersed in the liquids contained in low pressure separator **14**. As required to control the temperature of control gas entering the emissions separator or the stages of compression, additional coils could be installed in the low-pressure separator.

**[0033]** Fig. 3 is a schematic illustrating the operation of pipe coils **40** and **41**. As previously described, both pipe coils **40** and **41** are immersed in the produced liquids contained in low pressure separator **14**. The purpose of pipe coils **40** and **41** is to control the gas discharge temperature of both stages of two-stage compressor **51**. Controlling the gas discharge temperatures of two-stage compressor **51** provides successful operation of VRSA **24**. If the gas discharge temperature is too low (below, for example, 170 degrees Fahrenheit after the first stage of compression), condensation of the collected vapors could occur in the first stage compressor cylinder and lead to rapid mechanical failure of the compressor. If the discharge gas temperature is too high (for example, 300 degrees Fahrenheit or above after the second stage of compression), mechanical failure of the compressor could also occur.

**[0034]** Referring again to Fig. 3, pipe coil **40** is a heating coil immersed in the produced liquids contained in low pressure separator **14**. Pipe coil **40** is designed to heat, if necessary, the collected vapors exiting emission separator **45** prior to the vapors entering first compression stage **62** of two-stage compressor **51**. Flow line **53** splits at point **54** into flow lines **55** and **56**. Flow line **55** connects from point **54** to one inlet port **57** of three-way valve **52** (commonly referred to as a splitter valve). Flow line **56** connects from point **54** to inlet **64** of heating coil **40**. Flow line **65** connects from outlet connection **66** of heating coil **40** to a second inlet port **58** of three-way valve **52**. Flow line **60** connects from common port **59** of three-way valve **52** to inlet port **61** of first stage of compressor **51**. Component **63** may be either a transducer utilized to control an I/P or a throttling indirect acting thermostat (as temperature falls, output increases) that senses the temperature of the discharge gas exiting the first stage of compression **62**. Instrument gas supply line **64** is illustrated leading to component **63**. Tubing line **68** carries the output signal from component **63** (in this embodiment, a throttling thermostat) to the diaphragm of three-way valve **52**.

**[0035]** As previously described, to prevent condensation of the collected vapors, it is necessary to maintain the temperature of the gas exiting first compression stage **62** at approximately 170 degrees Fahrenheit or above. If thermostat or transducer **63** senses that the discharge gas temperature in flow line **67** is too cool, it will send a pressure signal to first three-way valve **52** to begin closing the gas flow between inlet port **57** and common port **59**. Decreasing the proportion of the gas flow between ports **57**

and 59 will cause the balance of the gas flowing through line 53 to flow through heating coil 40 where it collects heat prior to entering port 58 of three-way valve 52. In three-way valve 52, the cool gas from port 57 will mix with the heated gas from port 58 to maintain an adequate temperature of the gas entering at inlet port 61 the first stage of compression 62 to provide the desired gas discharge temperature of approximately 170 degrees Fahrenheit or above in flow line 67. Under most operating conditions, it is anticipated that, because of compression, the temperature of the discharge gas in flow line 67 will be in the range of about 200 degrees Fahrenheit; therefore, heating coil 40 will only be required to provide heat to the gas in flow line 60 when very cold ambient temperatures are encountered.

[0036] Cooling coil 41 is immersed in the produced fluids contained in low pressure separator 14. Cooling coil 41 uses the fluids in low pressure separator 14 as a heat sink to cool, when required, the hot gases exiting from first stage of compression 62 before the hot gases enter the second stage of compression 69. As previously described to prevent damage to compressor 51, it is necessary to keep the maximum temperature of the gas exiting the second stage of compression 69 of compressor 51 below approximately 300 degrees Fahrenheit. Cooling coil 41 mirrors the operation of heating coil 40. The only change is that component 70 (a thermostat or transducer and I/P) which senses the temperature of the gas in discharge flow line 26 is direct acting (as temperature rises, output increases) and the action of second three-way valve 73 becomes the reverse of the action of first three-way valve 52. The gas flowing from port 74 to port 75 is hot. The gas flowing from port 76 to port 75 is cooled. Component 70 (which again, is a thermostat or transducer and I/P) opens and closes three-way valve 73 to maintain the desired temperature of approximately 270 degrees Fahrenheit in discharge flow line 26. Flow line 26 preferably transfers the collected and compressed vapors to the inlet of one of the high pressure separators. Unlike prior art systems, embodiments of the present invention thus provide the ability to accurately control the temperature of gas entering and passing through the compressor regardless of what the ambient temperature is or even if the ambient temperature fluctuates over a large range.

[0037] By pre-heating the gas flowing into the inlet to the first stage of the compression, the gas is maintained in a gaseous state. By cooling the gas after compression by the first stage, the gas is allowed to enter the second stage of compression at a temperature low enough to ensure that damage to the compressor does not occur because of excess gas temperature during compression of the gas in the second stage of the compressor. Thus, embodiments of the present invention not only ensure that the gas is maintained at a temperature that prevents condensation and/or liquification of the gas, but also maintains the gas at a temperature low enough to prevent thermal damage to the compressor.

**[0038]** The present invention not only provides more desirable results than prior art systems, but also provides desirable results using less energy because the heat transferred from the hot gas to the produced liquid decreases the amount of fuel, gas, or other energy source required to maintain the produced liquids at the desired bath temperature.

**[0039]** The preceding examples can be repeated with similar success by substituting the generically or specifically described components and/or operating conditions of this invention for those used in the preceding examples.

**[0040]** Although the invention has been described in detail with particular reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover all such modifications and equivalents.

**THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:**

5

1. A method for operating a compressor comprising: providing a compressor comprising a first stage and second stage; gases emanating from said first and second stages; connecting an outlet of the first stage through a cooling coil immersed within produced liquid hydrocarbons such that the gases from the first stage of compression are cooled to no less than 170 degrees Fahrenheit by the produced liquid hydrocarbons via conduction thereto; and connecting an inlet of the first stage to a heating source, wherein the heating source is immersed within the produced liquid hydrocarbons such that the produced liquid hydrocarbons simultaneously heat gases entering the inlet of the first stage and cool the compressed gases exiting from the first stage of compression.
2. The method of claim 1 wherein the cooling coil maintains a temperature range for a gas passing through the compressor at a temperature sufficient to prevent thermal damage from occurring to the compressor.
3. The method of claim 1 wherein heat for the heating source is generated, at least in part, by the first stage.
4. The method of claim 1 wherein the heating source and the cooling coil are contained within a single unit.
5. The method of claim 1 wherein the heating source maintains a temperature range for a gas passing through and/or entering the compressor at a temperature sufficient to prevent condensation and/or liquefaction of the gas in the compressor.

30

35

6. The method of claim 5 wherein the cooling coil maintains the temperature range at a point below that which causes thermal damage to occur to the compressor.

5 7. The method of claim 1 further comprising contacting a lower end of an emissions separator with the produced liquid hydrocarbons.

8. A method for operating a compressor comprising: providing a compressor comprising a first stage and second stage with gases emanating from said first and second stages; connecting an outlet of  
10 the first stage through a cooling coil immersed within produced liquid hydrocarbons which have been removed from a well in their liquid state such that the gases from the first stage of compression are cooled by the produced liquid hydrocarbons via conduction thereto; and connecting an inlet of the first stage to a heating source, wherein the heating source is immersed  
15 within the produced liquid hydrocarbons such that the produced liquid hydrocarbons simultaneously heat gases entering the inlet of the first stage and cool the gases exiting from the first stage of compression.

9. The method of claim 8 wherein heat for the heating source is generated, at least in part, by the first stage.

20

10. The method of claim 8 wherein the heating source and the cooling coil are contained within a single unit.

25

30

35

5 11. The method of claim 10 wherein the heating source maintains a temperature range for a gas passing through and/or entering the compressor at a temperature sufficient to prevent condensation and/or liquefaction of the gas in the compressor.

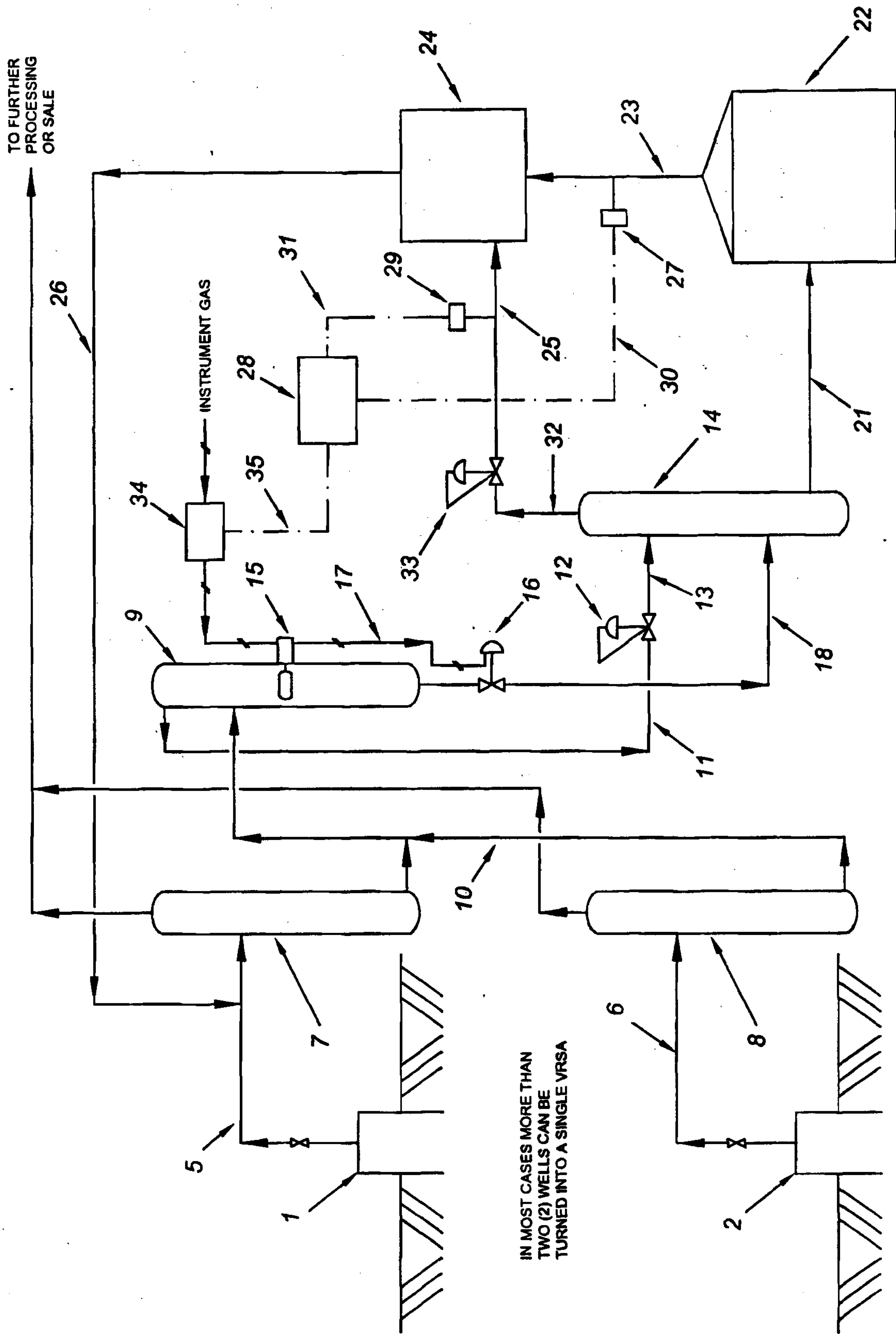
12. The method of claim 10 wherein the cooling coil maintains the temperature range at a point below that which causes thermal damage to occur to the compressor.

10 13. The method of claim 8 further comprising contacting a lower end of an emissions separator with the produced liquid hydrocarbons.

15

20

25



IN MOST CASES MORE THAN TWO (2) WELLS CAN BE TURNED INTO A SINGLE VRSA

Fig. 1

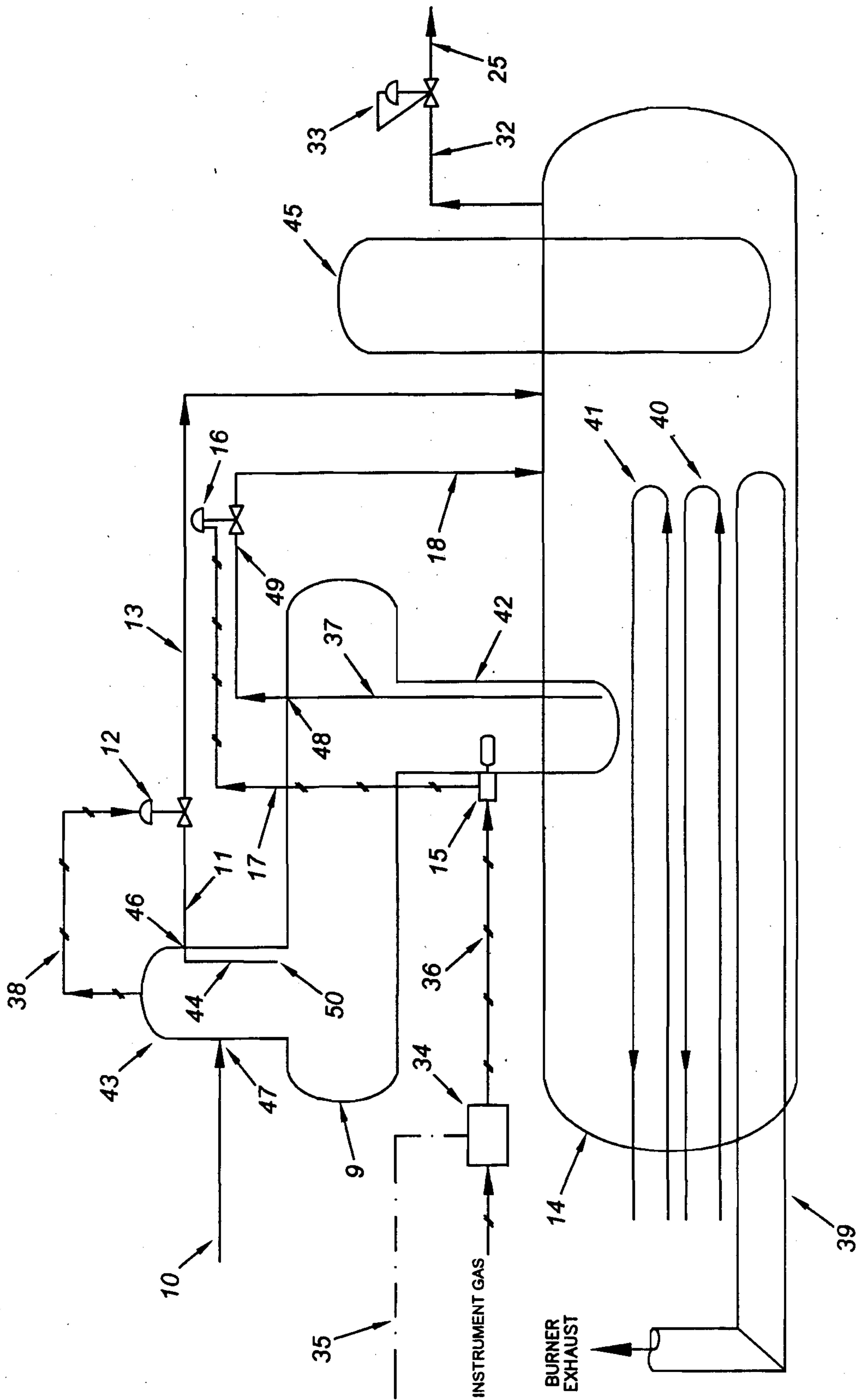
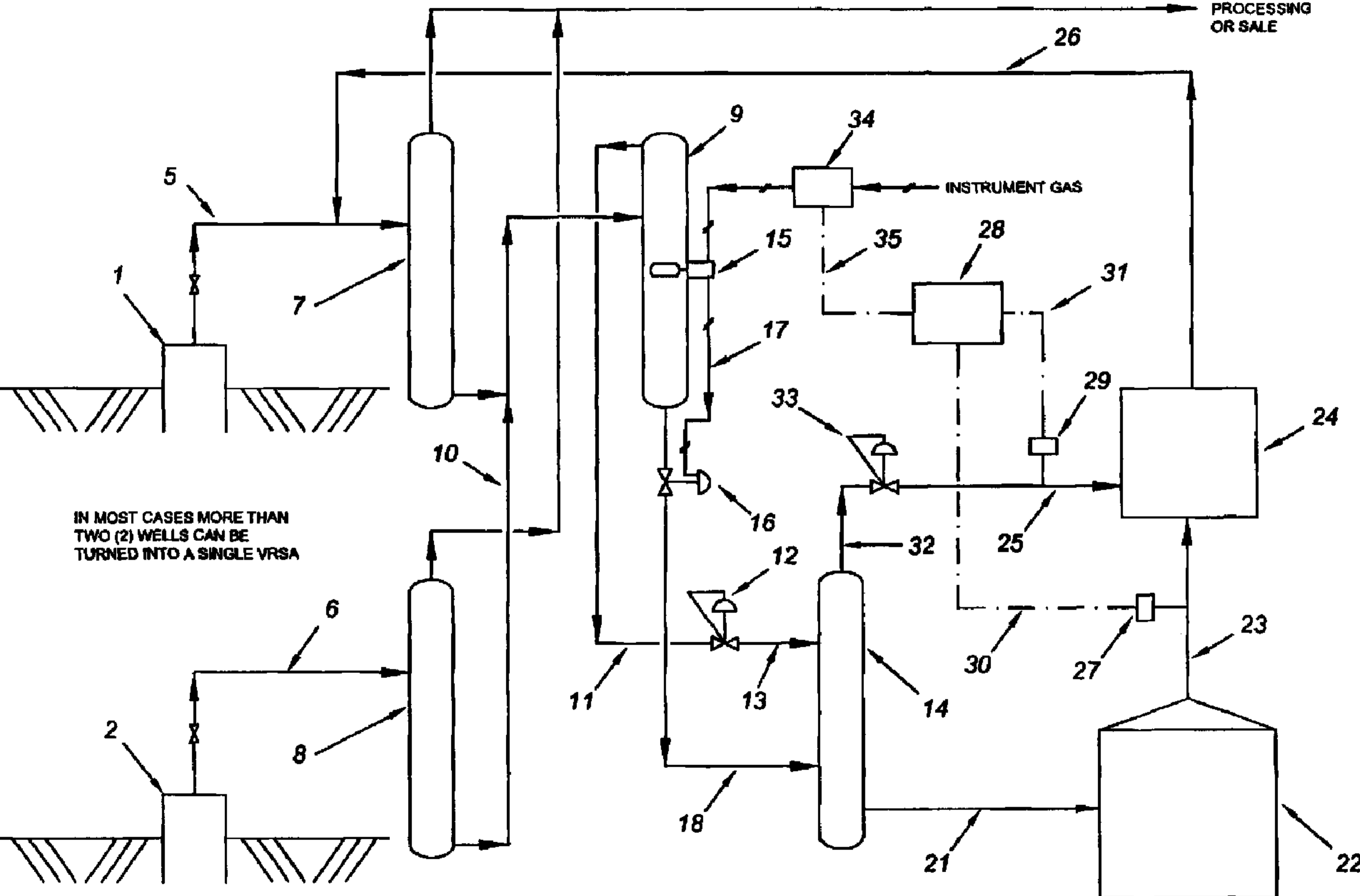


Fig. 2



TO FURTHER  
PROCESSING  
OR SALE



IN MOST CASES MORE THAN  
TWO (2) WELLS CAN BE  
TURNED INTO A SINGLE VRSA