United States Patent

[11] 3,572,047

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[21] Appl. No. **804,921**
[22] Filed **Mar. 6, 1969**
[45] Patented **Mar. 23, 1971**
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[54] **ANTICAVITATION AND REFRIGERATION SYSTEM AND METHOD**
14 Claims, 1 Drawing Fig.

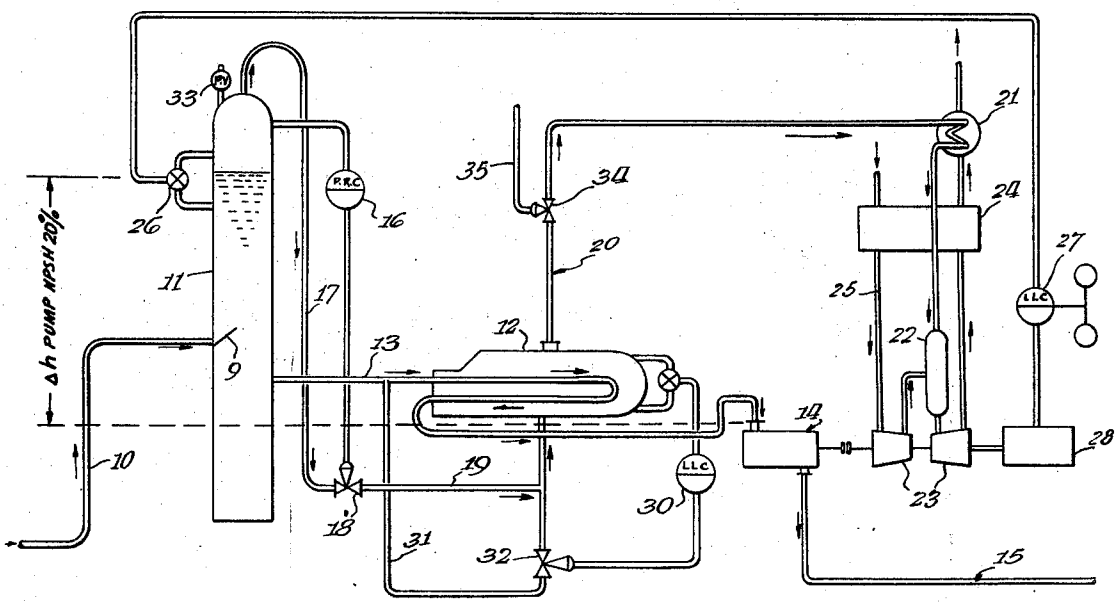
[52] **U.S. Cl.** **62/45,** 62/53, 62/55, 62/49
[51] **Int. Cl.** **F17c 7/02,** F17d 1/14
[50] **Field of Search** 62/45, 51, 53, 55

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ABSTRACT: In a cryogen-pumping system, the formation of vapor due to heat leak, especially, causes cavitation in the pump. A separator is provided to separate the cryogen vapor from the liquid. Then the vapor is expanded in a heat exchanger to subcool the cryogen liquid upstream of the pump.



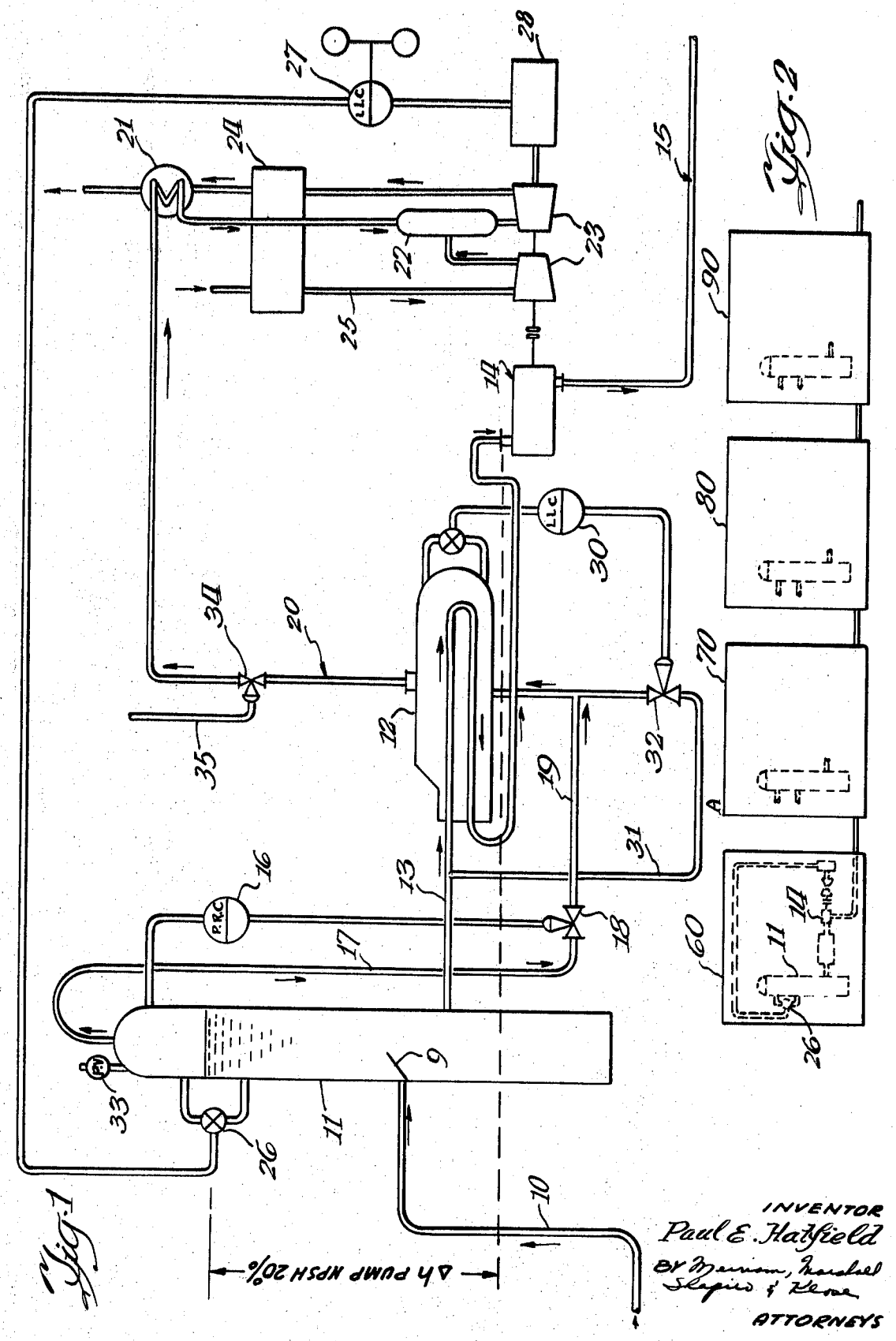

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Fig. 1

Fig. 2

ANTICAVITATION AND REFRIGERATION SYSTEM AND METHOD

In pumping fluids in the cryogenic range, heat leaking into the fluid being pumped is an ever-present problem. With a heat leak, a two phase, i.e. liquid-vapor condition can occur. Moreover, if the fluid is in the super-critical range or beyond the critical pressure for a particular fluid, any pressure loss that develops that reduces the fluid pressure below the critical pressure will also cause a two-phase system, providing that the initial temperature of the fluid is at a level to cause a two-phase condition at below the critical pressure. Systems which permit the establishment of a two-phase or alternating liquid-vapor condition are undesirable in that cavitation of the pumping mechanisms used in transporting the fluids occurs. Cavitation can severely damage most of the pumping mechanisms presently available for pumping cryogens.

The present invention is concerned with minimizing the problem of cavitation associated with pumping mechanisms utilized in the transporting of liquefied normally gaseous materials such as liquefied petroleum gases. The instant invention is also adapted for any pumping system subject to a two-phase, liquid-vapor condition or for pumping cryogenic fluids at their points of delivery.

The system of the instant invention relates to releasing vapors which occur in the liquefied cryogen due possibly to a heat leak into the system or a pressure loss. This release of vapors is completed upstream of a pumping station and is accomplished by passing the fluid being transported through a vessel where the velocity of the fluid being transported is substantially reduced such that the vapors will float out of the liquid phase of the fluid. In the case of fuels, the collected vapors can be utilized to supply part or all of the energy required for the driver of the pumping device, e.g. turbine; otherwise, the vapors can be collected, compressed, expanded and, following a heat exchange with the liquid portion of the fluid or material being transported, the vaporous portion can be delivered to a point of delivery to a user.

Other advantages of the invention and the description of the invention itself will become apparent from the following detailed description in which:

FIG. 1 shows a schematic view of the flow diagram of the system of the present invention; and

FIG. 2 illustrates a master station and additional stations located downstream of the master station.

Referring to the drawing, the material being transported in pipeline 10 passes into vessel 11 where the velocity of the fluid is substantially reduced thereby allowing vapor bubbles in the fluid to float upward to the surface of the liquid cryogen. Deflector plate 9 assists in the separation of the vapor and liquid by directing the vapor bubbles upward in vessel 11. Following separation of the liquid and vapor, the liquid portion of the fluid being transported passes from vessel 11 through line 13 into the tube side of heat exchanger or economizer 12 where it is cooled prior to passing to pumping mechanism 14 where this liquid portion is pumped on through pipeline 15.

The vaporous portion of the fluid collects at the top of vessel 11, where it increases in pressure until pressure-sensing device 16 operates thereby permitting the vaporous portion to pass under pressure through line 17 and expansion valve 18. As the vapor portion passes through valve 18, its temperature is substantially reduced so that a liquid fraction and vapor fraction pass through line 19 into the shell side of exchanger 12 where an indirect heat exchange occurs with the liquid portion passing through the tube side of the exchanger. The heat exchange occurring in exchanger or economizer 12 serves to vaporize some of the liquid fraction located in the shell side of exchanger 12. The vapors which collect in the shell side exit from exchanger 12 through line 20.

As is shown in the drawing, in those instances where the fluid being transported is a fuel, e.g., methane, propane, butane, the vaporous material in the shell side of exchanger 12 will pass through line 20 to fuel heater 21 and then to combustion chamber 22 of gas turbine 23 which is utilized to drive

pump mechanism 14. Turbine 23 utilizes heat exchanger 24 where exhaust gases from turbine 23 are employed to preheat the combustion air entering the combustion chamber through line 25.

If the vaporous portion which is expanded to the shell side of exchanger 12 is insufficient to supply the amount of material required to pass into line 20, control 30 will sense a reduction of liquid level in exchanger 12, which causes the activation of valve 32 whereby some of the liquid portion, which normally would pass through line 13 into the tube side of exchanger 12, is passed through expansion valve 32 and is flashed into the shell side of the exchanger.

As the liquid level in vessel 11 varies, level-sensing indicator 26 will be actuated, which actuation will be sensed by liquid control indicator 27 which sends an impulse to turbine regulator 28 causing turbine 23 to speed up or slow down depending upon what is necessary to keep the liquid level constant in vessel 11.

Vessel 11 must be of sufficient vertical height to maintain a hydraulic head in excess of that of the normal positive suction head (NPSH) required for pumping mechanism 14. Height level indicator 26 is set dependent upon the suction head requirements of pump 14. The liquid level height is adjusted so that it is equal to the normal positive suction head and additionally is adjusted to have a NPSH of about 10—20 percent greater than required by pumping mechanism 14 to take into account the pressure drop losses which occur between vessel 11 and pump mechanism 14. Of course, vessel 11 must also be designed to have a height higher than the liquid level to provide sufficient space for the collecting of the vaporous portion.

Further, vessel 11 has a pressure valve 33 which will be activated in the event the pressure built up by the vapor portion of the fluid being transported exceeds a desired pressure.

As shown in FIG. 2, there are illustrated a plurality of stations 70, 80 and 90 located downstream of master station 60. Each of these downstream stations will comprise the elements which make up the master station 60, e.g., heat exchanger, pump, turbine and regulating means, and will be operated in a manner corresponding to the operation of master station 60. Like station 60, each of the downstream stations will include a facility like vessel 11 whose liquid level can be controlled in the same manner as described previously with respect to controlling the liquid level in vessel 11 by the liquid level sensing indicator 26. Setting the liquid level control indicator 26 in master station 60 will cause the regulation of the other stations downstream of station 60, for a change in speed of pump 14 will cause a corresponding change in the rate of flow in the pipeline to the downstream stations.

In a series of pumping stations such as seen in FIG. 2, station 60 would be considered the "master" station and set the general flow rate level of the entire pipeline system. Any changes of the rate of flow from station 60 would cause a corresponding change of the pumping rates of the downstream stations e.g., 70, 80, 90, detected by liquid indicator 26 on vessel 11 at each station.

Additionally, injections or extractions of the pumped fluid can be made between stations with the downstream pumping station of the system automatically detecting this flow change again by means of level indicator 26 and controller 27, thereby making the entire pipeline system self-regulating.

The instant invention has been described where the fluid passing through the pipeline system is a fuel. However, in those instances where the fluid being pumped is not a fuel but some other material e.g., liquid oxygen, ammonia, nitrogen, the vapors which are shown as entering line 20 and then into the turbine will instead be directed by valve means 34 to go to a user through line 35. If desired, the vapors in line 35 may also be returned to the original conditions of the pipeline by reliquefying the vapor by the conventional means of compression, expansion cooling and reinjecting the liquefied material into the pipeline at 10.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

I claim:

1. The method of minimizing cavitation associated with pumping devices employed in pumping liquefied normally gaseous materials, said method including the steps of:
- reducing the velocity of the material being pumped prior to entry of said materials into said pumping device;
- separating the vapor portion of said material from said liquid portion thereof;
- expanding said vapor portion to permit it to enter a heat exchange means to cool said liquid portion;
- passing said liquid portion through the said heat exchange means whereby said liquid portion is cooled in an indirect heat exchange with said vapor portion;
- exiting at least a fraction of said vapor portion from said heat exchange means as a vapor following heat exchange with said liquid portion; and
- passing said cooled liquid portion to said pumping device.

2. The method of minimizing cavitation associated with pumping devices employed in pumping liquefied normally gaseous materials, said method including the steps of:
- reducing the velocity of the material being pumped prior to entry of said material into said pumping device;
- separating the vapor portion of said material from said liquid portion thereof;
- expanding said vapor portion to permit it to enter the shell side of a shell and tube heat exchange means to cool said liquid portion;
- passing said liquid portion through the tube side of said heat exchange means whereby said liquid portion is cooled in an indirect heat exchange with said vapor portion;
- exiting at least a fraction of said vapor portion from said heat exchange means as a vapor following heat exchange with said liquid portion; and
- passing said cooled liquid portion to said pumping device.

3. The method of claim 2 further including the steps of delivering said vapor portion of said material which exits from said shell side of said heat exchange means as a source of fuel for a means for driving said pump device.

4. The method of claim 3 further including the step of regulating the supply of vapor to said pump driving means.

5. The method of claim 3 further including the step of regulating the vapor portion admitted to said heat exchange means.

6. The method of claim 3 further including the step of deflecting vapor bubbles in said material upwardly to assist in the separating of said material into a liquid portion and vapor portion.

7. A system for minimizing cavitation associated with pumping devices employed in pumping liquefied materials, said system comprising:
- means for reducing the velocity of the material being pumped whereby said material separates into a vapor portion and a liquid portion;
- conduit means for delivering said liquid portion to a heat exchanger;
- means for expansion of said vapor portion into said heat exchanger to permit an indirect heat exchange to occur between said liquid portion and vapor portions in said exchanger; and
- conduit means for delivering said liquid portion to said pumping device following the exit of said liquid portion from said exchanger.

8. A system for minimizing cavitation associated with pumping devices employed in pumping liquefied normally gaseous materials, said system comprising:
- means for reducing the velocity of the material being pumped whereby said material separates into a vapor portion and a liquid portion;
- conduit means for delivering said liquid portion to the tube side of a heat exchanger;
- means for expansion of said vapor portion into the shell side of said heat exchanger to permit an indirect heat exchange to occur between said liquid portion and vapor portions which are in said exchanger; and
- conduit means for delivering said liquid portion to said pumping device following the exit of said liquid portion from said exchanger.

9. A system in accordance with claim 8 further including a driving means for said pump device and conduit means for delivering said vapor portion as it exits from said shell side of said heat exchanger to said drive means.

10. A system in accordance with claim 9 further including means for bypassing part of said liquid portion to the shell side of said heat exchanger and expansion means for expanding said liquid portion prior to its entering into said shell side of said heat exchanger.

11. A system in accordance with claim 10 further including means for regulating the vapor portion to be delivered to said pump driving means.

12. A system for minimizing cavitation associated with pumping devices employed in pumping liquefied normally gaseous materials, said system comprising:
- means for reducing the velocity of the fluid being pumped including a storage facility, whereby said material is separated into a vapor portion and a liquid portion;
- conduit means for delivering said liquid portion to the tube side of a shell and tube heat exchanger;
- means for expansion of said vapor portion into the shell side of said heat exchanger to permit an indirect heat exchange to occur between said liquid portion and vapor portion which are in said exchanger;
- conduit means for delivering said liquid portion to said pumping device following the exit of said liquid portion from said exchanger;
- a drive means for said pump device and conduit means for delivering said vapor portion as it exits from said shell side of said heat exchanger to said drive means;
- means for bypassing part of said liquid portion to the shell side of said heat exchanger and expansion means for expanding said liquid portion prior to its entry into said shell side of said heat exchanger; and
- means for regulating the vapor portion to be delivered to said pump driving means.

13. A system in accordance with claim 12 further including a baffle means for deflecting said material as it enters into said storage facility; said baffle means arranged to permit vapor bubble in said fluid to be directed in an upwardly direction.

14. A system for minimizing cavitation associated with pumping devices employed in pumping liquefied materials in a pipeline said system comprising:
- a plurality of pumping stations including a master station and at least one station downstream of said master station;
- a vessel for receiving and reducing the velocity of the material being pumped into said master station whereby said material separates into a vapor portion and a liquid portion;
- conduit means for delivering said liquid portion to a heat exchanger;
- means for expansion of said vapor portion into said heat exchanger to permit an indirect heat exchange to occur between said liquid portion and vapor portions in said exchanger;
- conduit means for delivering said liquid portion to said pumping device following the exit of said liquid portion from said exchanger;
- means for regulating the liquid portion level in said vessel; and
- conduit means for receiving said liquid portion following the exit of said liquid portion from said pumping device and delivering at least a portion of said liquid portion to said downstream station, said downstream station including:

a vessel for receiving and reducing the velocity of the material being pumped into said downstream station whereby said material separates into a vapor portion and a liquid portion;

conduit means for delivering said liquid portion to a heat exchanger;

means for expansion of said vapor portion into said heat exchanger to permit an indirect heat exchange to occur between said liquid portion and vapor portions in said exchanger;

conduit means for delivering said liquid portion to said pumping device following the exit of said liquid portion from said exchanger; and

means for regulating the liquid portion level in said vessel.