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FLOW CONTROL

Filed Nov. 3, 1966

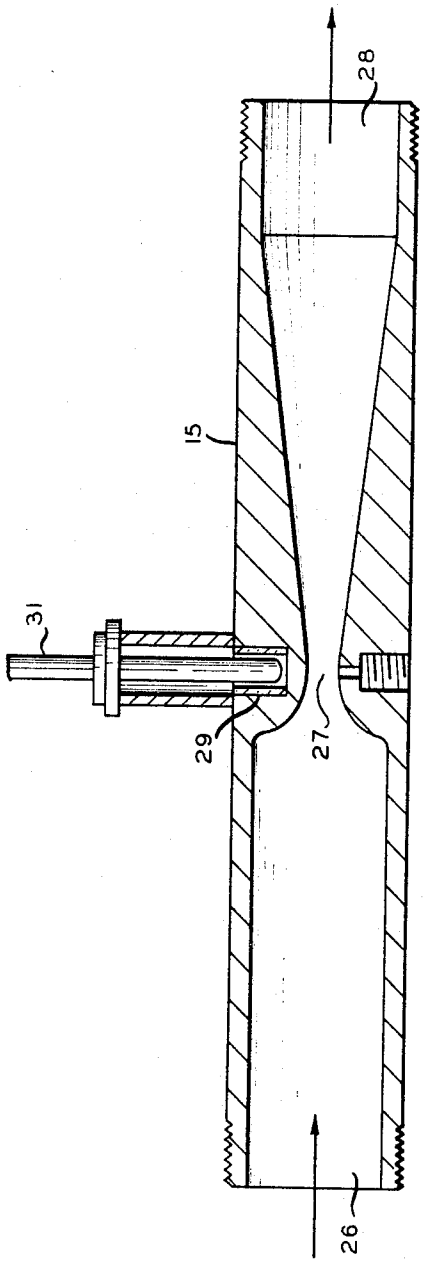


FIG. 3

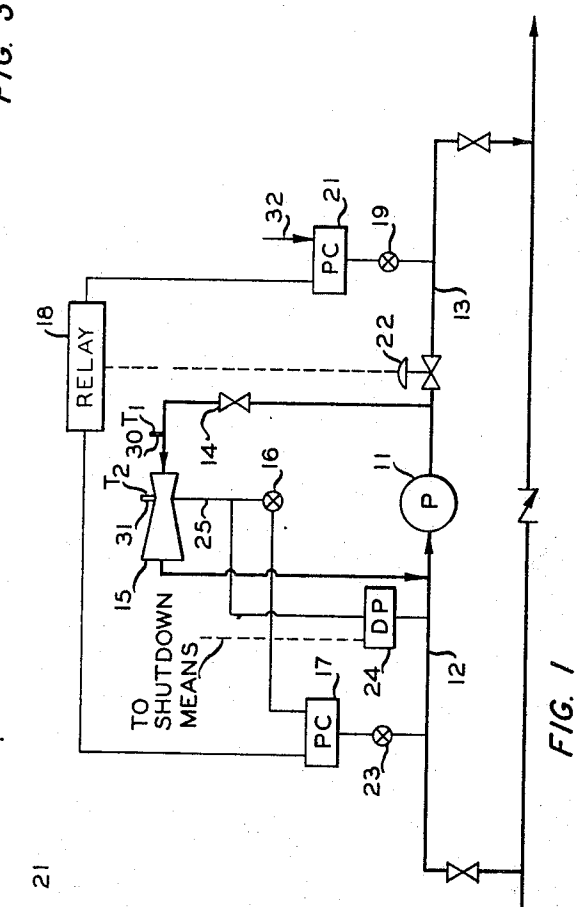


FIG. 1

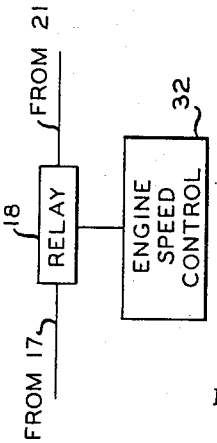


FIG. 2

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FLOW CONTROL

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ABSTRACT OF THE DISCLOSURE

A method for controlling the suction pressure of a pump transporting liquid wherein the vapor pressure of the transported liquid is determined and the suction pressure of the pump is controlled in response to the determined vapor pressure so as to maintain the suction pressure at a value above the determined vapor pressure which will prevent vaporization in the pump. Apparatus for controlling the suction pressure of the pump includes means to determine the vapor pressure of a liquid being transported through the pump and means to control the suction pressure of the pump in response to the vapor pressure determination.

This invention relates to flow control. In one aspect the invention relates to method and apparatus for controlling flow through a pump. In another aspect the invention relates to controlling the suction pressure of a pump.

The transportation of liquid and liquefied products in the petroleum industry by long distance pipelines is widespread. Because of the pressure drop along the pipeline due to friction between the liquid and the pipe, it is necessary to utilize pump or booster stations positioned along the line at intervals of approximately 25 to 75 miles in order to boost the pressure from station to station along the line. In the operation of such stations, it is desirable to prevent vaporization of the material being pumped. Previously, particularly at unattended pump stations, it has been necessary to maintain a pressure in the pump suction high enough to prevent vaporization of the most volatile products. This necessitates pumping the less volatile products at an unnecessarily high suction pressure, thus reducing the efficiency of the operation. I have found that by changing the pipeline pump suction pressure when the vapor pressure of the product changes, it is possible to prevent vaporization of the more volatile products, and to permit the less volatile products to be pumped at lower pressures.

An object of the invention is to improve the efficiency of operation of a products pipeline.

Another object of the invention is to prevent vaporization of the more volatile products and permit pumping all products at the lowest practical pump suction pressure.

A further object of the invention is to prevent vaporization in a pump.

Other aspects, objects, and the advantages of the invention are apparent in the written description, the drawing, and the claims.

According to the invention, there is provided method to control the suction pressure of a pump transporting liquid, in response to the vapor pressure of the liquid being pumped to prevent vaporization in the pump. In a preferred embodiment of the invention, the vapor pressure of the liquid being pumped is determined by withdrawing a small liquid stream from the discharge of the pump, passing it through a vapor pressure measuring zone where the vapor pressure is measured, and then returning it to the suction of the pump. A vapor pressure signal responsive to the vapor pressure measured in the zone is produced and the suction pressure of the pump is controlled responsive to this vapor pressure signal.

Further, according to the invention, there is provided apparatus for controlling the suction pressure of a pump transporting liquid, comprising means to determine the vapor pressure of the liquid being transported through the pump and means to control the suction pressure of the pump in response to the determined vapor pressure at a value above the determined vapor pressure sufficient to prevent vaporization in the pump.

FIGURE 1 is a schematic diagram of a suction pressure control system for a pump powered by a constant speed motor.

FIGURE 2 is a schematic diagram of a suction pressure control system for a pump powered by a variable speed engine.

FIGURE 3 is a typical flow nozzle in cross-section.

In FIGURE 1, pump **11** is provided with suction **12** and discharge **13**. A small stream of liquid is piped from discharge **13** through flow controller **14** into flow nozzle **15**. After passing through flow nozzle **15**, the stream is then piped to suction **12**. Flow nozzle **15** is constructed in such a manner that the liquid stream passing into it is restricted in such a manner that the velocity of the stream is sufficiently high so as to reduce the pressure in flow nozzle **15** to the equilibrium vapor pressure of the liquid stream at the flowing temperature thereof. In operation, the object is to attain a throat pressure which is equal to or slightly below the flowing vapor pressure of the pipeline stream. Theoretically, it is only necessary to pass enough product through flow nozzle **15** to just reach the flowing vapor pressure. However, in order to be sure vaporization is occurring, a little extra flow is passed through flow nozzle **15**. The vaporization which results produces a refrigeration effect which super cools the small stream and thus lowers the flowing vapor pressure of the small stream. In operation, advantage can be taken of this refrigeration in order to determine the required flow rate. In one installation, flow controller **14** was adjusted until there was about a 6° F. temperature drop from thermometer **30** to thermometer **31**. Such a temperature drop indicates that vaporization is occurring within flow nozzle **15**. Since vaporization is occurring in the pressure of both liquid and vapor phases, the pressure in the nozzle is therefore the vapor pressure of the liquid.

Because of the vaporization occurring within flow nozzle **15**, bubbles are formed and these bubbles do not immediately close and disappear when the pressure increases as the stream passing through it exits. Therefore, the piping between flow nozzle **15** and suction **12** should be be large enough to keep the friction loss low and insure proper return of the liquid stream to the pump suction, thereby allowing proper vaporization in flow nozzle **15**.

Vapor pressure transmitter **16** communicates by means of pipe **25** with flow nozzle **15** and measures the pressure of the liquid passing through flow nozzle **15**, produces a corresponding vapor pressure signal, and transmits this vapor pressure signal to suction pressure controller **17**. The vapor pressure signal transmitted by vapor pressure transmitter **16** comprises the measured pressure in flow nozzle **15** plus a pressure constant comprising a correction for the temperature drop between thermometers **30** and **31** and a pressure allowance for the pipeline pump NPSH (net positive suction head) requirement. This vapor pressure signal is used as the set point, or desired pump suction pressure, in suction pressure controller **17**. Suction pressure transmitter **23** measures the pressure in suction **12**, produces a corresponding suction pressure signal, and transmits the suction pressure signal to suction pressure controller **17**. Suction pressure controller **17** compares the vapor pressure signal received from vapor pressure transmitter **16** with the suction pressure signal received from suction pressure transmitter **23** and sends a suction pres-

sure control signal responsive to this comparion to low select relay **18** to cause the actual suction pressure to achieve its set point valve. As the suction pressure increases with respect to the set point value, the value of the suction pressure control signal increases. Discharge pressure transmitter **19** measures the pressure of discharge **13**, produces a corresponding discharge pressure signal, and transmits this discharge pressure signal to discharge pressure controller **21**. A set point is mechanically introduced into discharge pressure controller **21** by mechanical means **32**. The discharge pressure signal is compared with the set point or desired value of pressure which is the maximum allowable pressure at which this point in the pipeline can be operated. Discharge pressure controller **21** then sends a discharge pressure control signal responsive to this comparison to low select relay **18** to cause the actual discharge pressure to achieve its set point value. As the pressure of discharge **13** increases, the value of the discharge pressure control signal decreases.

In low select relay **18**, the lower in value of the pressure signals received from controllers **17** and **21** is selected and passed therethrough to diaphram control valve **22**, an air to open valve, whereby the throughput of pump **11** is regulated responsive to the pressure of discharge **13** or responsive to the vapor pressure-suction pressure relationship, depending upon which is the limiting condition in the operation of this pumping system. The suction pressure control signal is the signal which is normally selected by low select relay **18** to control the pump throughput. However, the discharge pressure control becomes controlling at any time it is lower than the suction pressure control signal. In the system illustrated, the signals produced and transmitted, by transmitters **16**, **19**, and **23** and by controllers **17** and **21**, are pneumatic pressure signals.

Low select relay **18** can be substituted with a high select relay wherein the higher of the two signals received is transmitted to open or close valve **22**; however, the signals produced by transmitters **16**, **19**, and **23** and controllers **17** and **21** must be reversed in value and air to open valve **22** must be substituted with an air to close valve so that the system operates in harmony.

Differential pressure controller **24**, i.e., a differential pressure switch, is in communication with pipe **25** and suction **12** to protect against an instrument failure in pressure transmitters **16** or **23** or suction pressure controller **17**, and operates to shut off the pump power means when the positive differential between the pressure in suction **12** and the pressure in pipe **25** is too small. A suitable instrument for this function can be a Differential Pressure Cell, Model 199, made by Barton Instrument Corp., Monterey Park, Calif.

Pressure transmitters **16**, **19**, and **23** can be Ashcroft, Model 1260, made by Manning, Maxwell & Moore, Stratford, Conn. Pressure controllers **17** and **21** can be those made by Taylor Instrument Companies, Rochester, New York, and described in their catalog as 402RF0151 and 402RF0051, respectively. Low select relay **18** can be a Taylor, Type SK11359, made by Taylor Instrument Companies, Rochester, N.Y.

In FIGURE 2, the same numbers and descriptions apply as employed in FIGURE 1. FIGURE 2 illustrates the pump suction pressure control system when the means employed for driving the pump comprises a variable speed engine. In low select relay **18**, the lower in value of the pressure signals received from controllers **17** and **21** is selected and passed therethrough to pump engine speed control means **32** whereby the throughput of pump **11** is controlled.

In FIGURE 3, a cross section of flow nozzle **15** is shown. The small liquid stream withdrawn from discharge **13**, as shown in FIGURE 1, enters the flow nozzle through inlet **26**. The velocity of the stream is sufficiently high so as to reduce the pressure in throat **27** to the equalibrium vapor pressure of the liquid stream at the

flowing temperature thereof. The stream then exits through outlet **28** and is returned to suction **12**, as shown in FIGURE 1.

Thermometer **31** is inserted in well **29** and the temperature in throat **27** is thereby measured.

Although the apparatus described above includes pneumatic instrumentation, electrical, hydraulic, or any combination of these three can be used. If desired, controller **14** can be operated responsive to measured values of temperature to maintain a desired temperature differential between thermometers **30** and **31**.

Reasonable variation and modification are possible within the scope of the invention, which sets forth method and apparatus for flow control including controlling flow through a pump and controlling the suction pressure of a pump in response to the vapor pressure of the liquid being pumped to prevent vaporization in the pump.

What is claimed is:

1. A method for controlling the suction pressure of a pump transporting liquid, comprising:
- withdrawing a small liquid stream from the discharge of said pump into and through a vapor pressure measuring zone, and returning said stream to the suction of said pump;
- measuring said vapor pressure of said liquid stream in said zone;
- producing a vapor pressure signal responsive to said vapor pressure measured in said zone; and
- controlling the suction pressure of said pump in response to said vapor pressure so as to maintain said suction pressure at a value above said vapor pressure to prevent vaporization in said pump.

2. The method of claim **1** wherein, in said vapor pressure measuring zone, said liquid stream is passed through a flow nozzle whereby, within said flow nozzle, the velocity of said stream is sufficiently high to reduce the pressure existing in said flow nozzle to the equilibrium vapor pressure of said liquid stream at the flowing temperature thereof.

3. The method claim **1** including:
- controlling the flow of said small liquid stream to a value which produces partial vaporization of said stream in said vapor pressure measuring zone.

4. The method of claim **1** including:
- measuring said suction pressure and producing a suction pressure signal representation thereof;
- producing a suction pressure control signal responsive to said vapor pressure signal and said suction pressure signal;
- measuring the pump discharge pressure and producing a discharge pressure control signal representation thereof;
- selecting the lower valve of said suction pressure control signal and said discharge pressure control signal; and
- controlling the throughput of said pump responsive to said lower value.

5. The method of claim **1** including:
- measuring said suction pressure and producing a suction pressure signal representation thereof;
- producing a suction pressure control signal responsive to said vapor pressure signal and said suction pressure signal;
- measuring the pump discharge pressure and producing a discharge pressure control signal representation thereof;
- selecting the higher value of said suction pressure control signal and said discharge pressure control signal; and
- controlling the throughput of said pump responsive to said higher value.

6. An apparatus for controlling the suction pressure of a pump transporting liquid, comprising:
- a pump;
- a flow nozzle capable of restricting a liquid stream

whereby, within said flow nozzle, the velocity of said liquid stream is sufficiently high to reduce the pressure existing within said flow nozzle to the equilibrium vapor pressure of said liquid stream at the flowing temperature thereof;

conduit means to withdraw a small liquid stream from the discharge of said pump into and through said flow nozzle and return said stream from said flow nozzle to the suction of said pump;

flow control means in said conduit means used to withdraw said stream from said discharge into said flow nozzle;

means to measure the temperature of said small liquid stream withdrawn from said discharge of said pump;

means to measure the temperature of said stream flowing through said flow nozzle; and including:

means to produce a vapor pressure signal responsive to said equilibrium vapor pressure; and

means to control said suction pressure of said pump responsive to said vapor pressure signal.

7. The apparatus of claim **6** wherein said means to control said suction pressure of said pump responsive to said vapor pressure signal comprises:

a suction pressure transmitter in communication with said suction of said pump;

a suction pressure controller in communication with said vapor pressure transmitter and said suction pressure transmitter;

a differential pressure control means in communication with the input to said nozzle pressure transmitter and said suction of said pump;

a discharge pressure controller;

a discharge pressure transmitter in communication with said discharge of said pump and said discharge pressure controller; and

a low select relay in communication with said suction pressure controller, said discharge pressure controller, and means to control the throughput of said pump.

8. The apparatus of claim **7** wherein said means to control the throughput of said pump comprises:

a nozzle pressure transmitter in communication with said flow nozzle; and

said means to control said suction pressure of said pump responsive to said vapor pressure signal comprises:

a suction pressure transmitter in communication with said suction of said pump;

a suction pressure controller in communication with said vapor pressure transmitter and said suction pressure transmitter;

a differential pressure control means in communication with the input to said nozzle pressure transmitter and said suction of said pump;

a discharge pressure controller;

a discharge pressure transmitter in communication with said discharge of said pump and said discharge pressure controller; and

a high select relay in communication with said suction pressure controller, said discharge pressure controller, and means to control the throughput of said pump.

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