Jan. 24, 1967 C. H. THAW 3,299,815

MULTISTAGE, TURBINE DRIVEN BOOSTER PUMP SYSTEM

Filed June 17, 1965 2 Sheets-Sheet 1

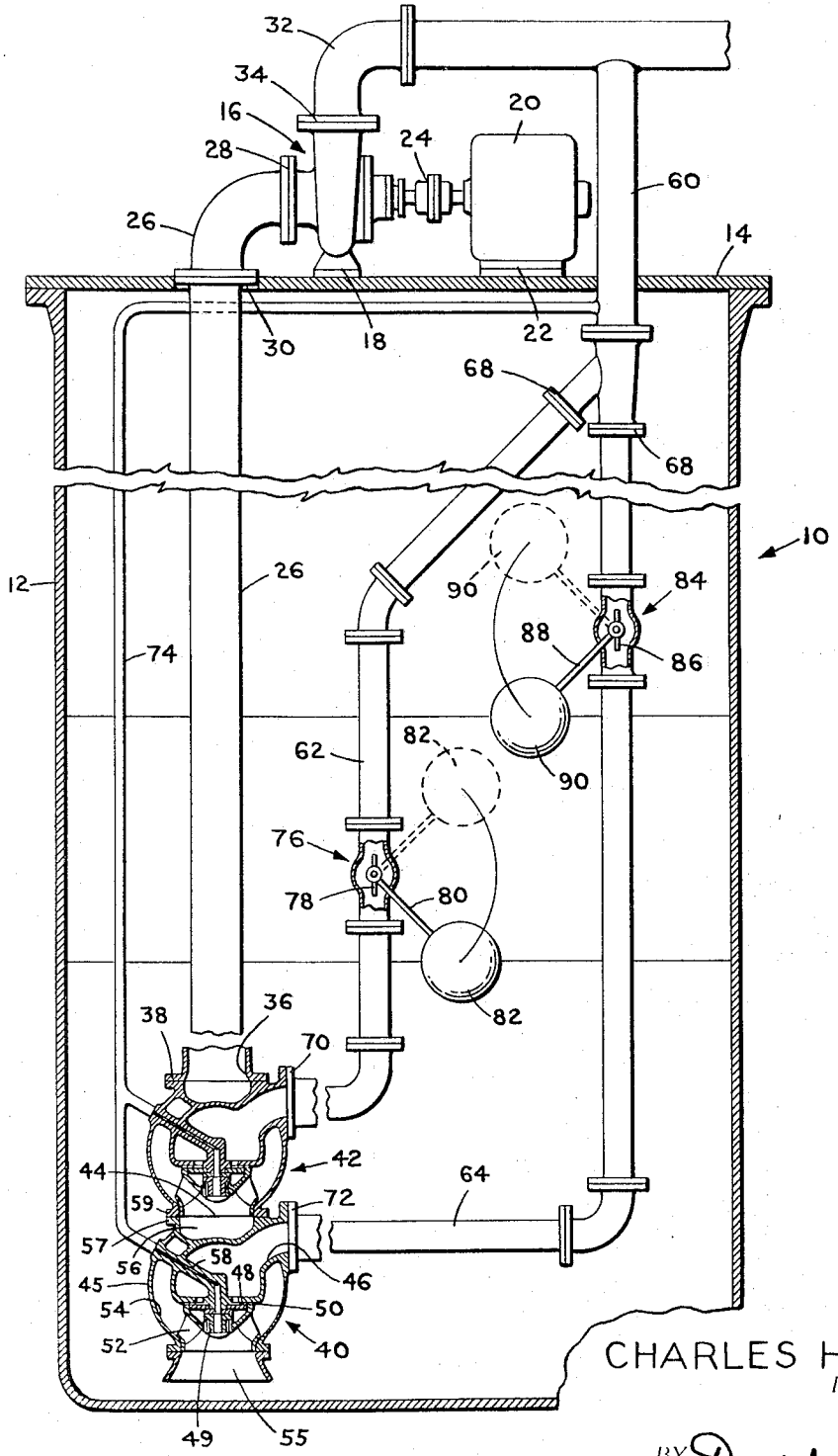


FIG. 1

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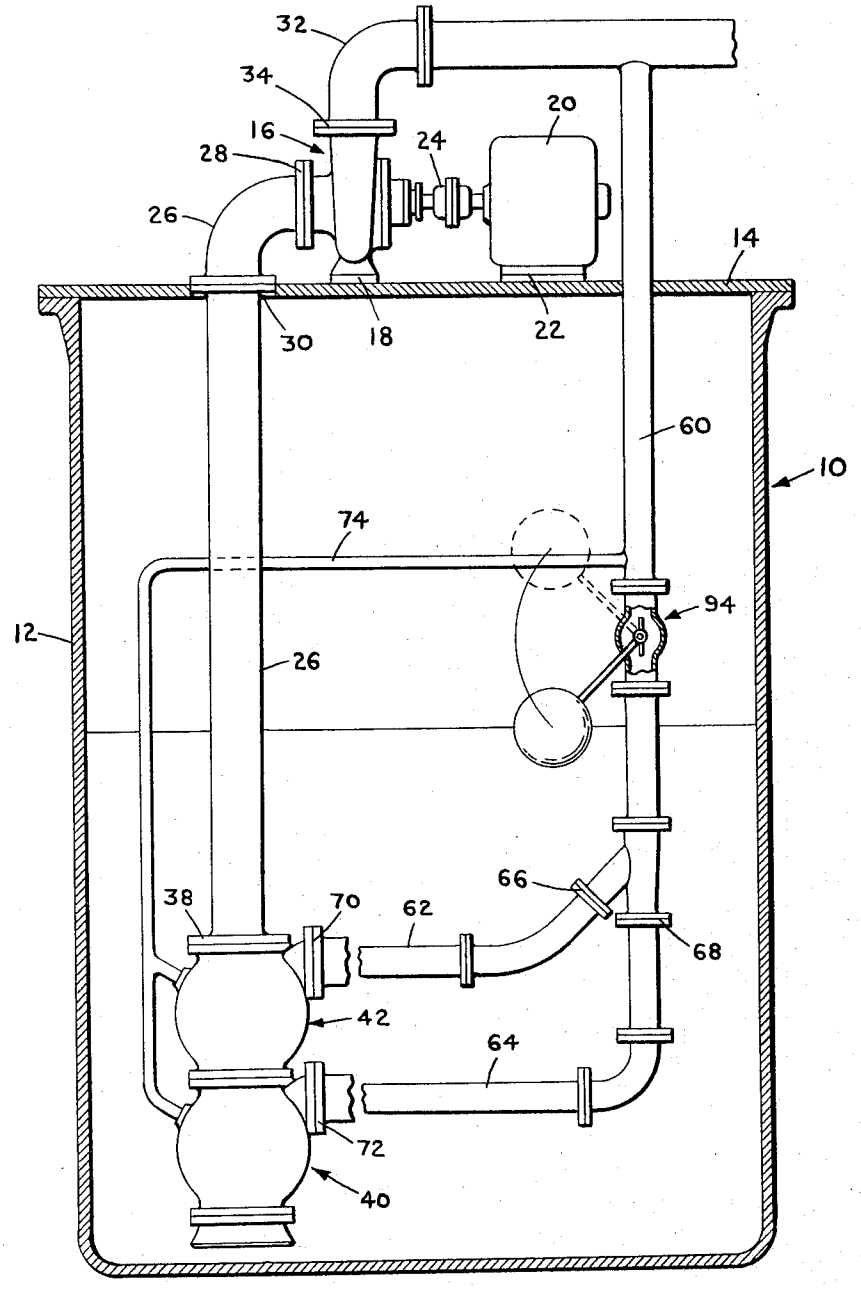


FIG. 2

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MULTISTAGE, TURBINE DRIVEN BOOSTER PUMP SYSTEM

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7 Claims. (Cl. 103—5)

This invention relates to new and improved method and apparatus for pumping liquids and, more particularly, to new and improved method and apparatus for pumping highly volatile liquids without the danger of cavitation and liquid vaporization.

It is an object of this invention to provide new and improved apparatus for the pumping of highly volatile liquids from relatively deep containers which include main pump means positioned above the said liquids, and first and second stage, series connected, independently driven booster pumps located within said containers and driven by pumped liquid bypassed from said main pump.

Another object of the invention is the provision of apparatus as above wherein said first stage booster pump is adapted to operate at much lower speeds than said second stage booster pump while delivering the same quantity of pumped liquid.

Another object of this invention is the provision of apparatus as above wherein said second stage booster pump is adapted to operate with a much higher discharge head than said first stage booster pump, whereby said second stage booster pump can operate at much higher speeds than have heretofore been possible in the pumping of volatile liquids without danger of cavitation and liquid vaporization.

Another object of this invention is the provision of apparatus as above including control means to independently control the operation of said first and second stage booster pumps in response to the level of a highly volatile liquid within a relatively deep container, whereby each booster pump may be operated only at the precise time, and pumping rate, commensurate with the level of the said liquid within the said container and necessary to prevent cavitation and liquid vaporization, to thus avoid the unnecessary dissipation of energy in the unnecessary operation of the said booster pumps, and insure maximum pumping efficiency of the said apparatus.

Another object of the invention is the provision of apparatus comprising first and second stage booster pumps as above which include similarly sized casings and pump inlet and outlet means, whereby said first and second stage booster pumps may be conveniently and economically connected in series without requiring the provision of transition duct means therebetween.

Another object of the invention is the provision of apparatus as above which make possible the utilization of main pump components of smaller size and higher operational speeds without danger of cavitation and liquid vaporization.

Another object of the invention in the provision of a new and improved method for pumping highly volatile liquids from relatively deep containers without cavitation or liquid vaporization, which includes the utilization of first and second stage, series connected, independently driven booster pumps which are adapted to pump the same quantities of liquid while operating at different speeds and discharge heads within said liquid for supplying the latter to a main pump located above said liquid.

A further object of the invention is the provision of apparatus as above which are of particularly economical and durable design, construction, and method of operation, whereby costs of fabrication, installation, operation, and maintenance thereof are minimized, and long periods

of satisfactory, trouble-free operation thereof are assured.

In a herein disclosed preferred embodiment, the apparatus of the invention consists of a pumping system which comprises relatively deep container means for holding a highly volatile liquid, main pump means positioned atop said container means and driven by constant speed drive means, and first and second stage, series connected booster pump means located within said liquid and connected to the inlet conduit of said main pump means for supplying liquid thereto. The said first and second stage booster pump means are contained in similarly sized casing means having similarly sized inlet and outlet means to facilitate the in-series installation thereof, but are designed to run at different speeds and with different discharge heads while pumping the same quantities of liquid. Means are provided to bypass a portion of the pressurized, pumped liquid from the outlet of said main pump means for the supply thereof as a driving liquid to said first and second stage booster pump means, and container liquid level responsive valve means are provided in said bypass means to independently control the supply of driving liquid to said first and second stage booster pump means to insure maximum economy in the operation thereof while preventing cavitation and liquid vaporization during the operation of the pumping system.

The above and other objects and advantages of my invention are believed made clear by the following detailed description thereof taken in conjunction with the accompanying drawing wherein:

FIGURE 1 is a diagrammatic view of a first embodiment of a pumping system constructed in accordance with the teachings of the invention, and includes portions cut away for purposes of illustration, and

FIGURE 2 is a diagrammatic view of a second embodiment of a pumping system constructed in accordance with the teachings of the invention, and includes portions cut away for purposes of illustration.

Referring now to FIGURE 1, a container of the nature particularly adapted to contain fluids of high volatility in the liquid states thereof, as for example liquid propane, is generally indicated at **10**, and comprises a cup-like body portion **12** with a cover member **14** attached over the open, upper end thereof in any convenient, readily removable manner. The container **10** preferably includes non-illustrated vent valve means to prevent excessive vaporization and escape of the liquid propane therefrom, while at the same time maintaining the pressure within the said container within acceptable safety limits. A main centrifugal pump, of the generally conventional construction well known in this art, is generally indicated at **16**, and is supported as shown atop the said cover member by pump support legs **18** extending therebetween.

A constant speed drive motor of conventional construction, as for example an electric motor, is generally indicated at **20** and is supported as shown atop the cover member **14** adjacent the said main centrifugal pump by motor support legs **22** extending therebetween. The drive motor **20** is drivingly connected to the main centrifugal pump **16**, in generally conventional manner, by drive coupling means **24** connected therebetween.

An inlet conduit **26** is connected to the inlet of the main centrifugal pump **16** as indicated at **28** and extends therefrom a shown, through the cover member **14** as indicated at **30**, to the lower portion of the container **10**. A supply conduit **32** is connected to the outlet of the main centrifugal pump **16**, as indicated at **34**, and extends therefrom to any suitable point of utilization or storage of the liquid pumped by the said main centrifugal pump from the container **10**.

The inlet conduit **26** terminates as shown in an open ended portion, as indicated at **36**, and includes an attach-

ment flange member 38 secured thereto in any convenient manner.

First and second stage, series connected booster pumps are indicated generally at 40 and 42, respectively, with the outlet side of the second stage booster pump 42 being connected as shown to the attachment flange member 38 in any convenient manner, to enable the said booster pump to discharge into the inlet conduit 26 of the main centrifugal pump 16, and the outlet side of the first stage booster pump 40 being connected in any convenient manner to the inlet side of said second stage booster pump, as indicated at 44, to enable the said first stage booster pump to discharge into the inlet of said second stage booster pump.

The said first and second stage booster pumps do not, per se, form part of this invention, but are each preferably of the nature of the turbine driven, centrifugal pumps described in detail in the copending application of Walter K. Jekat et al., Serial No. 434,774, filed February 24, 1965, and assigned to the assignee hereof. Thus, reference may be had to the said copending application for a detailed description of the construction and manner of operation of the said first and second stage booster pumps.

Briefly described, however, each of the said booster pumps, as for example, first stage booster pump 40, comprises a pump casing 45 which includes a driving liquid inlet passage 46 formed therein as shown. A circular array of radial flow, turbine nozzles 48 are supported at the end of the said driving liquid passage, and a combined turbine and centrifugal pump rotor assembly 49, which includes a stage of radial flow turbine vanes 50 and a stage of centrifugal pump impeller vanes 52 attached thereto as shown, is rotatably supported from the said casing below the said driving liquid inlet passage. A liquid passage 54, having an inlet 55, is formed in the pump casing 45 and surrounds the respective stages of radial flow turbine 50 and centrifugal pump impeller vanes 52. Thus may be readily understood whereby the supply of driving liquid to the stage of turbine vanes 50, through driving liquid inlet passage 46 and turbine nozzles 48, will result in driven rotation of the combined turbine and centrifugal pump rotor assembly 49 as the said driving liquid flows through the said turbine stage, and attendant pumping of liquid from within the container 10 through liquid passage 54 by the centrifugal pump impeller vanes 52 to the outlet of the booster pump 40 as indicated at 56. After passing through the said turbine stage, the driving liquid will mix with the liquid in liquid passage 54 and be pumped therewith to the said booster pump outlet. A lubricating liquid supply passage 58 extends as shown through the pump casing 45 for conveying lubricating liquid to the fully floating bearings of the rotating, combined turbine and centrifugal pump rotor assembly 49.

As made clear by the drawings, each of the first and second stage booster pumps 40 and 42 are of vertical inlet and outlet design, and each have the same attachment flange dimensions, as indicated at 57 and 59, respectively, whereby may be readily appreciated that the said booster pumps are ideally suited for simple, and economical in-series stage installations of the depicted nature without requiring the use of transition duct means therebetween.

A bypass conduit 60, and branch conduits 62 and 64 which are connected thereto as indicated at 66 and 68, respectively, extend as shown from the supply conduit 32 to the respective inlets of the booster pumps 40 and 42 and are connected thereto as indicated at 70 and 72, respectively. Thus, a portion of the liquid pumped by the main centrifugal pump 16 from the container 10 to the supply conduit 32 may be bypassed from the latter for the supply therefrom as a driving liquid through bypass conduit 60 and branch conduits 62 and 64, to the respective booster pumps 40 and 42 to result in the drive of the latter. A bearing lubricant supply conduit 74 extends as shown from the bypass conduit 60 to the respective lubricating liquid supply passages formed in the casings of the booster pumps, whereby a portion of the pumped liquid bypassed from supply conduit 32 through bypass conduit 60 may in turn be bypassed from the latter through the bearing lubricant supply conduit 74 and supplied therefrom to the respective fully floating bearing assemblies of the booster pumps 40 and 42 for the lubrication thereof. Alternatively, the bearing lubricant supply conduit 74 and bearing lubricant supply passages 58 may be eliminated, and pre-lubricated and sealed ball bearings utilized to rotatably support the combined turbine and centrifugal pump rotor assemblies 49 in lieu of the bearings of the fully floating type discussed above.

A float controlled valve assembly is generally indicated at 76 and is positioned as shown in the branch conduit 62 to control the supply of driving liquid therethrough to the second stage booster pump 42. The said valve assembly comprises a valve member 78 which is rotatably positioned in the branch conduit 62, in any convenient manner, and a valve operating arm 80 extending from the said valve member 78 with a float 82 attached to the remote extremity thereof. Thus may be readily understood whereby the level of liquid in container 10 will act upon the float 82 to close the valve 76 and shut off the supply of driving liquid to the second stage booster pump 42 whenever the level of the liquid in the said container is well above the said valve.

A valve assembly generally indicated at 84 is similarly positioned in the branch conduit 64 and similarly comprises a valve member 86, a valve operating arm 88, and a float 90, whereby a level of liquid in the container 10 well above the valve assembly 84 will result in the latter shutting off the supply of driving liquid to the first stage booster pump 40 through the conduit 64.

In a typical application of the pumping system of the invention, as for example in the pumping of a highly volatile liquid such as propane from a substantially liquid-full container 10, the first stage booster pump 40 is designed to deliver the same quantity of pumped liquid as the second stage booster pump 42 while operating at a lower rotational speed than the latter and with a lower discharge head. The second stage booster pump 42 takes advantage of the increased pressure at the inlet thereof, due of course to the operation of the first stage booster pump 40, and can thus operate at a much higher speed without the danger of cavitation and liquid vaporization occurring in the highly volatile, liquid propane being pumped by the system. Thus, the discharge head of the second stage booster pump 42 is much higher than the discharge head of te first stage booster pump 40.

Although, the said first and second stage booster pumps are designed to deliver the same quantities of pumped liquid while operating at different rotational speeds and with different discharge heads, the design sizes of the respective internal components thereof, namely the turbine nozzles, turbine vanes, and centrifugal pump impeller vanes, are chosen to enable the housing of the combined turbine and centrifugal pump rotor assemblies of each of the pumps in the same size casing to provide the advantageous in-series stage installation characteristics referred to hereinabove. Thus is believed made clear that the pumping system of the invention enables the rotation of each of the pump rotor assembly of the main centrifugal pump 16, and the pump rotor assemblies of the respective booster pumps 40 and 42, at its own most economical speed, despite the fact that only one constant speed drive motor 20 is provided.

The propane pumping operation of the pumping system of the invention, including first and second stage booster pumps 40 and 42 designed as discussed above, is then commenced by the energization of the constant speed, electric drive motor 20, which results in rotation of the pump impeller of the main centrifugal pump 16 by virtue of the drive coupling 24 connected therebetween.

At this point, since the container **10** is substantially full of liquid propane, the said main centrifugal pump is fully capable of pumping the liquid propane from the said container to the supply conduit **32** on its own without assistance from either or both of the said first and second stage booster pumps. It is to this effect that valve assemblies **76** and **84** are both designed to be in the closed positions thereof with the container **10** substantially full of liquid propane, whereby the said valve assemblies will prevent the bypassing of any of the pumped propane from the supply conduit **32** to either of the first or second stage booster pumps to prevent the unnecessary operation of the said booster pumps, with attendant unnecessary energy dissipation, and thus insure maximum overall pumping system efficiency.

Operation of the pumping system of the invention continues in this manner, with only main centrifugal pump **16** operating, until such time as the level of propane within the container **10** falls sufficiently to result in the partial opening of float controlled valve assembly **84**, whereby a portion of the pumped propane will be bypassed from the supply conduit **32** and flowed as a driving liquid, through conduits **60** and **64**, to the driving liquid passage **46** of the first stage booster pump **40** to commence operation of the latter.

At this point, second stage booster pump **42** will remain inoperative due to the fact that the float controlled valve assembly **76** remains closed, whereby the system will now operate with the first stage booster pump **40** functioning to pump liquid propane from the bottom of the container **10**, intermix it with the liquid propane supplied thereto as driving liquid through conduit **64**, and supply the resultant liquid propane stream to the inlet conduit **26** of the main centrifugal pump **16** through the still inoperative second stage booster pump **42** connected therebetween. In this regard it is to be clearly understood that the supply of lubricating liquid to the fully floating bearings of the first and second stage booster pump **40** and **42** through the lubricating liquid supply conduit **74** and respective lubricating liquid supply passages **58** is constant once operation of main centrifugal pump **16** is commenced, whereby the fully floating, combined turbine and centrifugal pump rotor assembly **49** of second stage booster pump **42** will present no significant resistance to the flow of pumped liquid from the first stage booster pump **40** therethrough, but rather, will rotate freely as the said pumped liquid flows through the liquid passage **54** of the said second stage booster pump.

Since, at this point, only limited operation of first stage booster pump **40** is required to maintain operation of the pumping system of my invention and prevent cavitation or vaporization of the highly volatile liquid propane being pumped thereby, it may be readily appreciated that the said pumping system automatically compensates for this condition by continuing to maintain the second stage booster pump **42** inoperative, and permitting only the limited operation of first stage booster pump **40** commensurate with the partially open position of float controlled valve assembly **84**.

As the propane level in container **10** continues to drop, the float controlled valve assembly **84** will assume the fully open position thereof, whereby the first stage booster pump **40** will be operating at design speed thereof to boost the liquid propane from the bottom of the tank to the inlet of the main centrifugal pump **16** through the still inoperative second stage booster pump **42**.

Operation of the pumping system of the invention continues in this manner until the level of propane within the container **10** falls sufficiently to result in float controlled valve assembly **76** starting to open, whereby a portion of the pumped propane which is bypassed from supply conduit **32** through bypass conduit **60** will be supplied from the latter through branch conduit **62** as a driving liquid to the driving liquid passage **46** of the second stage booster pump **42** to this commence operation of the said second stage booster pump. Thus, the operation of the pumping system will now entail the operation of both main centrifugal pump **16** and first stage booster pump **40** at the respective design speeds thereof, and the operation of second stage booster pump **42** at less than the design speed thereof, whereby overall pumping system efficiency is maintained at a maximum while cavitation and vaporization of the highly volatile liquid propane is concurrently prevented.

When the propane level in the container **10** has dropped sufficiently so that both of the float controlled valve assemblies **76** and **84**, respectively, have assumed the fully opened positions thereof, each of the main centrifugal pump **16** and the respective first and second stage booster pumps **40** and **42** will be operating at the design speeds thereof to complete the pumping of the remaining propane from the container **10**. Thus, maximum pumping capacity is provided only when needed, that is to say only when the amount of propane remaining in the container **10** has assumed a relatively low level to create conditions most conducive to cavitation and propane vaporization during the pumping thereof from the said container. Non-illustrated control means, as for example those in the nature of a float controlled shut-off switch, are of course provided to discontinue operation of the pumping system of the invention by shutting off electric drive motor **20** when the level of the liquid propane in the container **10** has fallen so low as to make further pumping thereof from the said container impracticable.

Thus is believed made clear whereby the pumping system of the invention provides a superior pumping arrangement which is particularly adaptable to the pumping from relatively deep containers of highly volatile liquids like propane which have bad cavitation characteristics. In addition, it is believed made clear that the respective float controlled valve assemblies enable the operation of the respective first and second stage booster pumps only at the precise times, and flow rates, commensurate with the level of liquid propane in the container and necessary to prevent cavitation and vaporization of the liquid propane during the pumping thereof. This is to say that the said first and second stage booster pumps are operated only when necessary, whereby the unnecessary dissipation of energy in the operation thereof is avoided, and maximum overall pumping system efficiency assured.

It is further believed made clear that the first and second stage booster pumps **40** and **42** will insure the supply at all times of a net positive suction head to the main centrifugal pump **16** sufficient to avoid cavitation and liquid vaporization regardless of the level of liquid propane in the container **10**, whereby the rotational components of the said main pump may be of smaller size and higher operational speeds than have heretofore been possible in the pumping of highly volatile liquids with bad cavitation characteristics, to thus result in significant economies in the costs of fabrication, operation and maintenance of the said main pump.

Referring now to the embodiment of FIGURE 2, the same may readily be seen to be essentially similar to the embodiment of FIGURE 1 with the exception that float controlled valve assemblies **76** and **84** are eliminated from the branch conduits **62** and **64**, respectively, and replaced by a single float controlled valve assembly **94**, of the same construction, which is positioned instead as shown in the bypass conduit **60**. To this effect, the said bypass conduit is lengthened to enable the placement of the said valve assembly at a position well within the interior of container **10**.

Operation of the embodiment of FIGURE 2 is similar to the operation of the embodiment of FIGURE 1 in most respects with the exception of the sequence of operation of the respective first and second stage booster pumps **40** and **42**.

Thus, in the embodiment of FIGURE 2, the said booster pumps will always operate concurrently, once

valve assembly **94** commences to open upon a sufficient drop in the level of propane within the container **10**. The said first and second stage booster pumps **40** and **42** are again designed, however, to operate at different speeds and with different discharge heads while pumping the same quantities of liquid as described in detail hereinabove.

Thus, although the pumping system of the embodiment of FIGURE 2 will not be quite as efficient as the pumping system of the embodiment of FIGURE 1, the former is somewhat more simple than the latter in that only one valve assembly is required therein.

For use under conditions in which the container **10** does not contain sufficient liquid propane to enable the main centrifugal pump **16** to pump the liquid propane therefrom on its own, non-illustrated priming means would of course be provided and may comprise, for example, a source of liquid propane under sufficient pressure which may be temporarily communicated to bypass conduit **60**, as through suitable valve means, and function as a driving liquid for one or both of the first and second stage booster pumps **40** and **42** (depending upon the respective positions of float controlled valve assemblies **76** and **84**) to enable the operation of the said booster pumps to prime the main centrifugal pump **16**. Such condition might arise, for example, as a result of an interruption in the pumping operation after more than half of the liquid propane had been pumped from the container **10**, whereby the said main centrifugal pump would be incapable of re-starting the pumping operation on its own without assistance from priming means.

It will be understood that the invention is not to be limited to the specific construction or arrangement of parts shown but that they may be widely modified within the invention defined by the claims.

What is claimed is:

1. A pumping system for the pumping of a liquid with bad cavitation characteristics comprising:

(a) a container for the liquid to be pumped;

(b) main pump means disposed above the liquid to be pumped;

(c) a first stage turbine driven booster pump means of the rotary type disposed below the main pump means;

(d) the inlet of the first stage turbine driven booster pump means disposed in the liquid to be pumped;

(e) second stage turbine driven booster pump means of the rotary type disposed below the main pump means connected in series with the first stage turbine driven booster pump means;

(f) the outlet of the second stage turbine driven booster pump means connected to the main pump means to supply liquid to be pumped thereto;

(g) by-pass conduit means comprising:

(1) a main by-pass conduit extending from the main pump;

(2) a first branch conduit connecting the main by-pass conduit to the inlet of the first stage booster pump means;

(3) a second branch conduit extending from the main by-pass conduit to the inlet of the second stage booster pump means;

(h) control valve means cooperatively associated with the by-pass conduit means and responsive to the level of the liquid to be pumped within the container therefor to control the flow of the liquid by-passed from the main pump means to drive the first and the second stage booster pump means; and

(i) the first and the second stage booster pump means constructed and arranged to operate at different speeds and with different discharge heads while pumping the same quantities of liquid to prevent cavitation and liquid vaporization of the liquid pumped.

2. The combination claimed in claim **1** wherein the control valve means comprise:

(a) first valve means cooperatively associated with the first branch conduit;

(b) second valve means cooperatively associated with the second branch conduit; and

(c) the first and second valve means constructed and arranged to control the flow of the first and the second stage booster pump means respectively to independently drive the first and the second stage booster pump means.

3. The combination claimed in claim **2** wherein the first valve means are operable to open before the second valve means as the level of the liquid with the container falls.

4. The combination claimed in **2** wherein:

(a) each of the first stage booster pump means and the second stage booster pump means comprise bearing means of the fully floating type;

(b) means to supply to the bearing means a portion of the pumped liquid by-passed from the main pump means to lubricate the bearing means.

5. A pumping system for the pumping of liquids with bad cavitation characteristics comprising:

(a) a deep container for the liquid to be pumped;

(b) a centrifugal pump disposed above the level of the liquid in the container;

(c) drive means for driving the centrifugal pump;

(d) a first stage turbine driven booster pump of the rotary type disposed below the centrifugal pump;

(e) the inlet of the first stage booster pump disposed in the liquid adjacent the bottom of the container;

(f) a second stage turbine driven booster pump of the rotary type connected in series with the first stage booster pump and disposed below the centrifugal pump;

(g) the outlet of the second stage booster pump connected to the inlet of the main centrifugal pump to supply pumped liquid thereto;

(h) the first and the second stage booster pumps constructed to operate at different speeds and with different discharge heads while pumping the same quantity of liquid;

(i) a by-pass conduit extending from the outlet of the main centrifugal pump to by-pass a portion of the liquid pumped thereby;

(j) a first and a second branch conduit extending from the by-pass conduit to the inlets of the first and the second stage booster pumps respectively to independently supply the by-passed portion of the pumped liquid to the first and second stage booster pumps as a driving liquid thereto; and

(k) a first and a second valve means each responsive to the level of the liquid within the container cooperatively associated with the first and the second branch conduit respectively to control the flow of the the driving liquid to the first and the second booster pump means.

6. The combination claimed in claim **5** wherein:

(a) each of the first and the second stage booster pumps comprise casing means of substantially the same size; and

(b) the outlet of the first stage booster pump is connected directly to the inlet of the second stage booster pump.

7. A pumping system for the pumping of a liquid with bad cavitation characteristics comprising:

(a) main pump means disposed above a supply of the liquid to be pumped;

(b) first stage booster pump means of the turbine driven rotary type disposed below the main pump means;

(c) the inlet of said first stage booster pump means disposed in the liquid to be pumped;

(d) second stage booster pump means of the turbine driven rotary type connected in series with said first stage booster pump means;

(e) the outlet of said second stage booster pump means connected to the inlet of said main pump means to supply pumped liquid thereto;

(f) means to independently drive said first and second stage booster pump means comprising:

separate by-pass conduit means from the outlet of said main pump to the inlet of each of said first and second stage booster pump means;

(g) control means responsive to the level of the liquid to be pumped cooperatively associated with said by-pass conduit means to control the supply of driving liquid pumped therethrough to the respective inlets of said first and second stage turbine driven booster pumps;

(h) said first and second stage booster pump means being constructed and arranged to operate at different speeds and with different discharge heads while pumping the same quantities of liquid to prevent cavitation and liquid vaporization of the liquid to be pumped.

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