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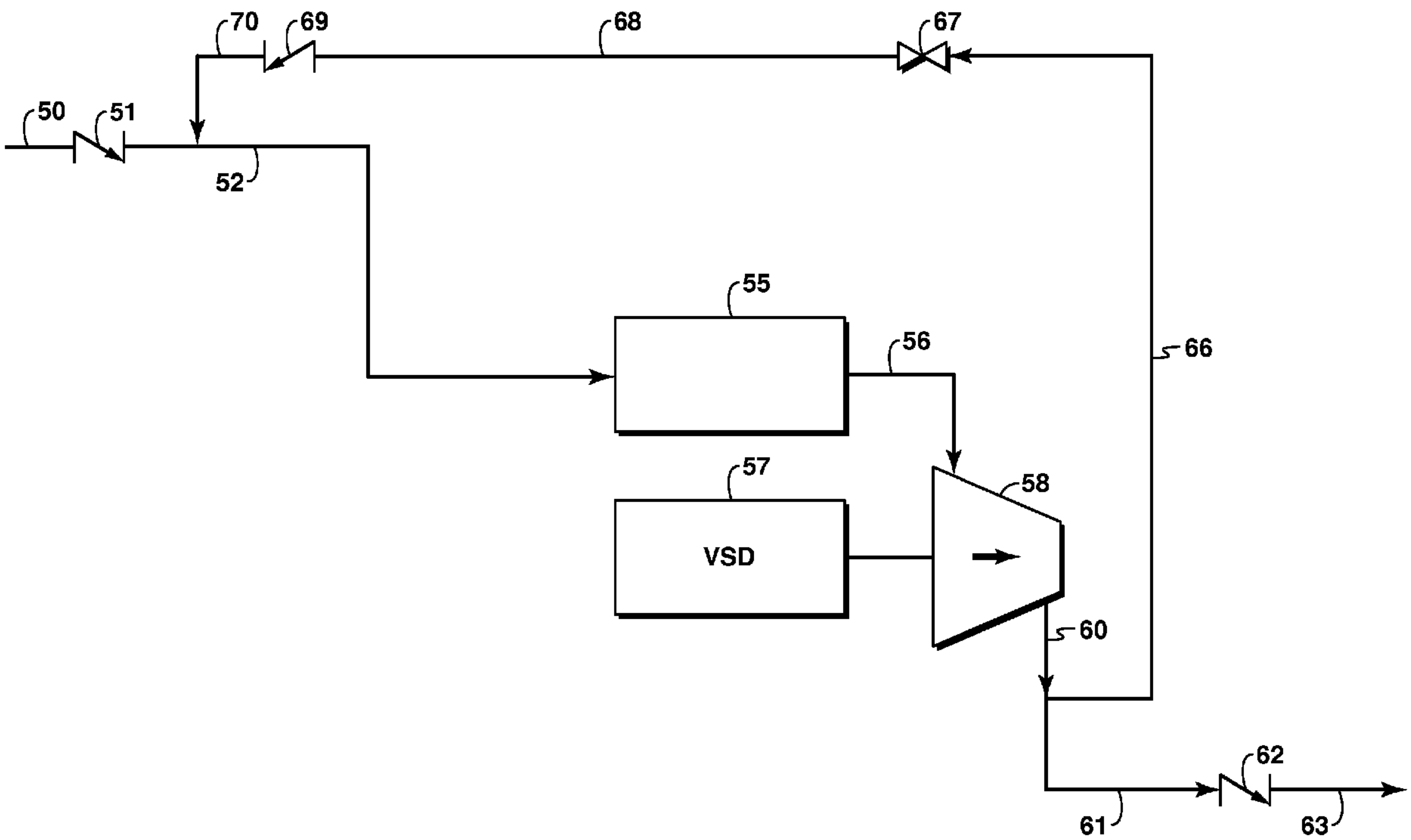
(74) **Agent:** BORDEN LADNER GERVAIS LLP

(54) **Titre : COMPRESSION OU DETENTE DE GAZ HUMIDE CENTRIFUGE AVEC UN SUPPRESSEUR ET/OU UN PULVERISATEUR DE GRUMEAUX**
(54) **Title: CENTRIFUGAL WET GAS COMPRESSION OR EXPANSION WITH A SLUG SUPPRESSOR AND/OR ATOMIZER**



(57) **Abrégé/Abstract:**
This disclosure is to an apparatus and method for increasing the ability of centrifugal compressors or expanders to handle multiphase fluids with increased liquid content by passing the fluid through a slug suppressor and/or an atomizing device prior to compression or expansion.

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— *with international search report (Art. 21(3))*

(54) Title: CENTRIFUGAL WET GAS COMPRESSION OR EXPANSION WITH A SLUG SUPPRESSOR AND/OR ATOMIZER

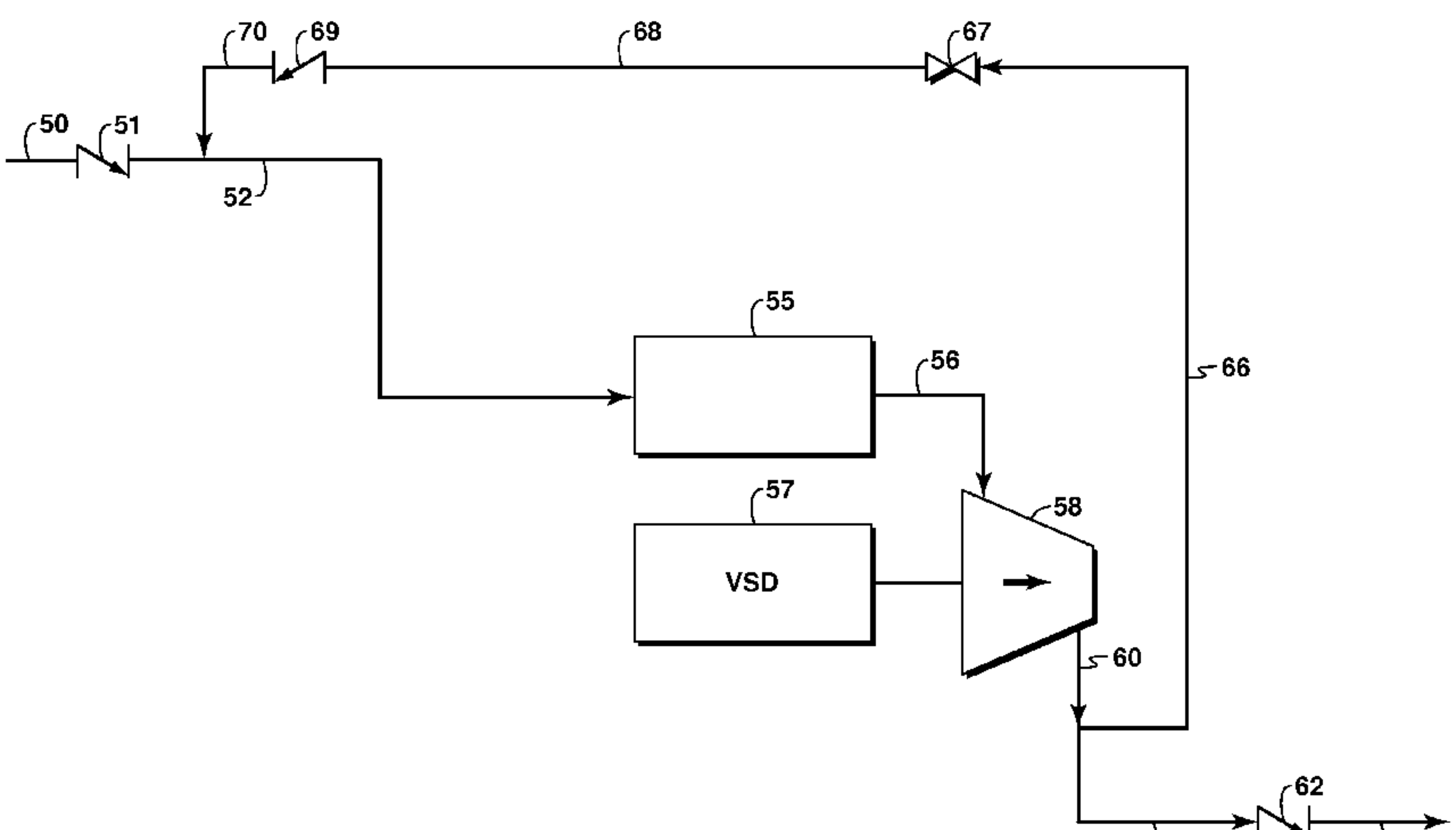

FIG. 2

(57) Abstract: This disclosure is to an apparatus and method for increasing the ability of centrifugal compressors or expanders to handle multiphase fluids with increased liquid content by passing the fluid through a slug suppressor and/or an atomizing device prior to compression or expansion.

WO 2011/066050 A1

CENTRIFUGAL WET GAS COMPRESSION OR EXPANSION WITH A SLUG SUPPRESSOR AND/OR ATOMIZER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application 61/264,414 filed 25 November 2009 entitled CENTRIFUGAL WET GAS COMPRESSION OR EXPANSION WITH A SLUG SUPPRESSOR AND/OR ATOMIZER.

BACKGROUND OF INVENTION

Field of the Invention

[0002] The subject matter disclosed in this application relates to technology utilized in the compression or expansion of a multiphase fluid in a fluid handling system.

Description of Related Art

[0003] This section is intended to introduce various aspects of the art, which may be associated with exemplary embodiments of the present invention. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present invention. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[0004] Traditionally it is understood that centrifugal compressors or gas expanders do not handle liquid slugs and thus it is assumed that they can only handle a fraction of one percent liquid by volume. Thus in many applications expensive liquid separators, dehydration processes and/or unit scrubbers are utilized to try and remove or separate the liquids prior to using centrifugal compressors or expanders. These devices are often designed for specific operating conditions and are then limited in the range of Gas Volume Fraction (GVF) that can be handled with a given process flow rate. Even with this expensive and complex processing equipment, if there is a sudden high level of liquids they can quickly saturate, fill and overflow the liquid separators once their capacity for liquid is exceeded resulting in slugging the compressor or expander equipment.

[0005] In general, multiphase pumps can be used if it is known that the fluid will generally be below 90% GVF. Centrifugal compressors are often restricted to applications with GVFs of 99.7 or higher and even this can cause problems within the machine for stability and affecting the reliability of the seals and bearings. Therefore, for processes outside this small range, the current practice is to separate the fluids prior to utilizing a centrifugal compressor even with the design limitation with the associated process and equipment. The same is true for gas expanders, which are functionally a centrifugal compressor running in reverse to extract energy in one form or another through a process pressure drop across the expander. The separators, scrubbers and dehydration units are not only expensive and limited in liquid capacity and volume flow range but they also tend to be very bulky, taking up expensive real estate in locations such as offshore platforms, subsea processing or onshore facilities. This coupled with complex control systems and additional auxiliary equipment like pumps, regulators, level controllers, transmitters and filters adds to the complexity and likelihood of failure of these systems. An example of a process where slugs may cause severe damage is shown in FIG. 1 which depicts a typical oil or gas well stream service where a separator 4 is used to separate liquids from the gas so that a centrifugal compressor 21 and pump 12 can then be used to boost the gas and liquid separately. The two are then combined again at 14 in order to transport both through a pipeline to a processing facility. If one machine could be used to transport the combined flow it has the potential to greatly reduce the overall cost and complexity of the total system.

[0006] Some additional issues with liquids are not only stability of the machine but also erosion of impellers and diffusers, fouling and resulting in imbalance if the liquids flash or vaporize while being compressed in the machine. However, testing has shown that erosion can be reduced or prevented by slowing down the liquid velocity at impact points and by reducing the droplet size. Fouling has also been reduced or even removed by increasing the liquid levels above the flash point in effect washing the internals of the machine.

[0007] The foregoing discussion of need in the art is intended to be representative rather than exhaustive. Technology that would improve the ability of compressors or expanders to handle the multiphase flow of fluid with a higher liquid content compared to the current state of the art would be of great value.

BRIEF SUMMARY OF THE DISCLOSURE

[0008] The above noted problems in handling multiphase fluid flow have been addressed by utilizing a liquid slug suppressor and/or an atomizing device to enhance the upstream mixing of the liquid with the gas, thus enabling the centrifugal compressor or expander to better handle higher levels of liquid. The atomizing device may be any one of known fluid atomizers including one or more atomizing nozzles or a flow mixer device. This can be used in existing designs to help protect the compressor or expander from process upsets with additional liquid volume or as a stand alone design to help eliminate some of the required equipment such as the separator or liquid pump.

[0009] The slug suppressor slows down a slug of liquid and mixes it with gas already in the device to reduce the sudden change in density. This allows time for the compressor driver to slow down as the torque or load increases with the increase in liquid volume or reduction of GVF. The atomizing device further helps turn liquid slugs into droplets or mist mixed in with the gas to better help the compressor in dealing with the change in density and load while reducing the impact, resulting in less erosion. Either product or both in series can be used in a compressor or expander application where there is a potential for some liquids or liquid upsets.

[0010] In context of this disclosure, the term "atomizing device" means any device or mechanism for breaking a liquid into a fog, mist, or spray of liquid. The term "atomized" as used herein is to be understood to mean small, discrete particles of liquid. Also the terms slug suppressor means any device that helps slow down the sudden change in fluid density of a high level of liquid within a gas stream by mixing the predominately liquid flow with gas that was flowing ahead of, with or behind the liquid.

[0011] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0012] The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present invention.

[0013] FIG. 1 is a schematic diagram of a known multiphase fluid handling system.

[0014] FIG. 2 is a schematic diagram of one embodiment of a multiphase fluid handling system according to the disclosure for compressing a multiphase fluid.

[0015] FIG. 3 is a schematic diagram of another embodiment of a multiphase fluid handling system according to the disclosure for expanding a multiphase fluid.

[0016] FIG. 4 is a schematic depiction of a slug suppressor and atomizing device combined.

[0017] FIG. 5 is a modified version of the multiphase fluid handling system shown in FIG. 2.

[0018] It should be noted that the figures are merely exemplary of several embodiments of the present invention and no limitations on the scope of the present invention are intended thereby. Further, the figures are generally not drawn to scale, but are drafted for purposes of convenience and clarity in illustrating various aspects of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Reference will now be made to exemplary embodiments and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Alterations of further modifications of the inventive features described herein, and additional applications of the principles of the invention as described herein, which would occur to one skilled in the relevant art and having possession of this disclosure, are to be considered within the scope of the invention. Further, before particular embodiments of the present invention are disclosed and described, it is to be understood that this invention is not limited to the particular process and materials disclosed herein as such may vary to some degree. It is also to be understood that the terminology used herein is used for the purpose of describing particular embodiments only and is not intended to be limiting, as the scope of the present invention will be defined only by the appended claims and equivalents thereof.

[0020] FIG. 1 illustrates a known system for handling a multiphase fluid in a well head environment. Fluid, which may include water, oil, and gas for example, is directed into a cooler 1 and then into a separator tank 4 via a check valve 2 and conduit 3. Water is separated out and a pump 6 pumps the water to a remote location via conduit 7. Oil and condensate are collected and pump 12 delivers the oil and condensate to conduit 15 via conduits 11 and 13. Gas flows from separator 4 to compressor 21 via conduit 20, then it passes through check valve 23 and is combined with the oil/condensate flow at 14. A recycle line 30 is provided which includes valve 31, cooler 32 and check valve 33.

[0021] The principles of the invention are shown in one embodiment as schematically shown in FIG. 2. Multiphase fluid, for example fluid from a well head, is directed to the apparatus by a conduit 50, check valve 51, and conduit 52. The mixture of liquid and gas enters a fluid treatment device 55. The fluid treatment device may be a slug suppressor or a known atomizing device, such as one or more atomizing nozzles or a flow mixer. It may also be a combination of these elements. An example of a combined slug suppressor and atomizing device is shown in FIG. 4. Liquid accumulates in inner chamber 107 and gas flows in outer chamber 108. Baffles 104 are provided in the walls of inner chamber 107 to allow for sudden increases in liquid to spill over into the gas stream and mix with the gas. Thus a sudden increase in liquid flow is slowed down by using some of the gas still in the slug suppressor to reduce the liquid volume. Atomizing nozzles 105 at the lower end of the liquid chamber atomize the liquid and spray it into the gas flow downstream of a tapered portion 109 of the gas flow path. The atomized liquid and gas streams continue to flow through conduit portion 106. A typical slug suppressor and atomizing device is available from Framo Engineering AS. A flow mixer may include counter swirling vanes or counter rotating vortices.

[0022] Referring again to FIG. 2, the mixture leaving the fluid treatment device 55 flows through conduit 56 to compressor 58. Compressed fluid leaves compressor 58 through conduit 60 and 61 to check valve 62 and to a distribution conduit 63 which delivers the compressed fluid to a desired location. A recycle line for the mixture from compressor 58 is provided at 66 that includes a valve 67, and check valve 69.

[0023] FIG. 3 illustrates the application of the principles of the invention in an expander system. A multiphase fluid passes through a multiphase flow meter 82, a control valve 84, and a conduit 85 into the fluid treatment device 55. From there the mixture flows through conduit 91, expander 93, conduit 94, check valve 95 and distribution conduit 96. The expander 93 may be connected to a generator or compressor 92 or any device that requires a source of power. A bypass line 99, 97 along with a valve 98 are provided for bypassing expander 93. A hydraulic torque converter 90 may be positioned between the expander 93 and generator or compressor 90.

[0024] Combining one or both of a slug suppressor and an atomizing device with torque control or speed reduction with increased load, liquid level or overall density of the fluid would further enable the wider operating range for a centrifugal compressor or expander. Speed control for the compressor for example can be achieved by utilizing a variable speed drive as shown in FIG. 2. A variable speed drive 57 (VSD), such as a motor or other mechanical or electrical drive, including but not limited to gas motor, steam or gas turbine, expander, hydraulic turbine, is connected to the compressor 58. The drive mechanism controlling the torque or speed between the driver and compressor may be electronic, hydraulic, or mechanical. Suitable means for controlling the variable speed drive may include sensors for sensing torque, load, fluid density, GVF or input power.

[0025] Speed or torque control helps make centrifugal compressors and expanders more robust, thus increasing reliability and reducing maintenance cost in wet services by designing the system to better manage a liquid slug and multiphase flow. This could be applied in all types of centrifugal compressor and expander applications where liquids are present or potentially present in the process, including well head services, subsea compressors or expanders, LNG expansion, wet gas compressors and other upstream and downstream processes.

[0026] An option for controlling the torque is through a hydraulic torque converter in place of using the VSD drive. Then conventional fixed speed motors, gas turbines and associated gears could be used for the compressor driver.

[0027] For an expander the flow control could use a two-or three-phase flow meter 82 to operate an inlet flow valve 84 or inlet guide vanes in order to reduce the flow as the GVF drops with increased liquid level, as shown in FIG 3. Other options are to use a hydraulic torque converter 90 between the gas expander 93 and what it is driving or any other method to measure the fluid density, multiphase flow mixture, mass flow, output power, or torque.

[0028] As shown in FIG. 5, the variable speed drive 57 of FIG. 2 may be replaced by a fixed speed driver 102. A hydraulic torque converter 101 may be positioned between the fixed speed driver and the compressor 58 to allow for varying the speed of compressor 58.

[0029] The present invention is further described in the following embodiments:

Embodiment A: Apparatus for compressing a multiphase fluid comprising:

a first conduit for conveying the multiphase fluid;

a slug suppressor connected to the first conduit;

a centrifugal compressor connected to an output of the slug suppressor; and

a distribution conduit connected to the compressor for conveying the compressed multiphase fluid to a desired location.

Embodiment B: The apparatus of embodiment A, further comprising an atomizing device positioned in the first conduit.

Embodiment C: The apparatus of embodiment B, wherein the atomizing device is a flow mixer that includes at least two counter swirling vanes or counter rotating vortices.

Embodiment D: The apparatus of any of embodiments A-C, wherein the driver for the compressor is an electric or gas motor, gas or steam turbine, expander, hydraulic turbine.

Embodiment E: The apparatus of any of embodiments A-D, further comprising a means for controlling the compressor speed based on produced torque, load, fluid density, multiphase flow measurement or output power.

Embodiment F: The apparatus of embodiment B or C, wherein the slug suppressor and atomizing device are combined in a housing having an inlet and outlet, wherein the housing comprises:

a first chamber for accumulating liquid;

a second chamber for accumulating gas;

a plurality of baffles between the first and second chambers for allowing accumulated liquid in the first chamber to spill over into the second chamber; and

a plurality of atomizing nozzles located at the end portion of the first chamber.

Embodiment G: Apparatus according to embodiment F, wherein the housing tapers from the inlet to the outlet.

Embodiment H: Apparatus according to any of embodiments A-G, further comprising a recycle conduit connected at one end to the output of the compressor and at its other end to the first conduit.

Embodiment I: Apparatus according to embodiment H, further comprising a recycle valve in the recycle conduit.

Embodiment J: Apparatus for expanding a multiphase fluid comprising:

a first conduit for conveying the multiphase fluid;

a slug suppressor connected to the first conduit;

an expander connected to an outlet of the slug suppressor; and a conduit connected to the expander for conveying the multiphase fluid to a desired location.

Embodiment K: The apparatus of embodiment J, further comprising an atomizing device connected to the first conduit.

Embodiment L: The apparatus of embodiment K, wherein the atomizing device is a flow mixer that includes at least two counter swirling vanes or counter rotating vortices.

Embodiment M: The apparatus of any of embodiments J-L, further comprising a generator or compressor connected to a power output shaft of the expander.

Embodiment N: The apparatus of embodiment K or L, wherein the slug suppressor and atomizing device are combined in a housing having an inlet and outlet, and the housing comprises

a first chamber for liquid;

a second chamber for accumulating gas;

a plurality of baffles between the first and second chamber for allowing accumulated liquid in the first chamber to spill over into the second chamber; and

a plurality of atomizing nozzles located at the end portion of the first chamber.

Embodiment O: Apparatus according to embodiment N, wherein the housing tapers from the inlet to the outlet.

Embodiment P: Apparatus according to any of embodiments J-O, further comprising a bypass conduit connected at one end to the output of the expander and at its other end to the first conduit.

Embodiment Q: Apparatus according to embodiment P, further comprising a bypass valve in the bypass conduit.

Embodiment R: Apparatus according to any of embodiments J-Q, further comprising means for controlling the expander or the driven equipment speed based on produced torque, load, fluid density, multiphase flow measurement or output power.

Embodiment S: A method of compressing a multiphase fluid comprising the steps of:

providing a slug suppressor or an atomizing device;

directing a flow of multiphase fluid into the slug suppressor or atomizing device;

directing the output flow from the slug suppressor or atomizing device into an intake portion of a compressor; and

compressing the multiphase fluid.

Embodiment T: A method of compressing a multiphase fluid including liquid and gas components comprising the steps of:

separating the liquid from the gas within a housing;

atomizing the liquid;

redirecting the atomized liquid back into the gas flow; and

compressing the resulting mixture of atomized liquid and gas.

Embodiment U: A method of expanding a pressurized multiphase fluid comprising the steps of:

providing a slug suppressor or atomizing device;

directing a flow of multiphase fluid into the slug suppressor or atomizing device;

directing the output flow from the slug suppressor or atomizing device into an intake portion of an expander; and

expanding the multiphase fluid.

Embodiment V: A method of expanding a pressurized multiphase fluid including liquid and gas components comprising the steps of:

separating the liquid from the gas within a chamber;

atomizing the liquid;

redirecting the atomized liquid back into the gas flow; and

expanding the resulting mixture of atomized liquid and gas.

Embodiment W: The method of embodiment S, further comprising the step of directing the multiphase fluid through a flow mixer prior to its being compressed.

Embodiment X: The method of embodiment S, wherein the compressor is a centrifugal compressor.

Embodiment Y: The method of embodiment S, further comprising the step of using an electric or gas motor, gas or steam turbine, expander, hydraulic turbine or other driving device to provide power to the compressor.

Embodiment Z: The apparatus of embodiment T, further comprising a means for controlling the compressor speed based on produced torque, load, fluid density, multiphase flow measurement or output power.

Embodiment AA: Apparatus for compressing a multiphase fluid comprising:

a first conduit for conveying the multiphase fluid;

an atomizing device connected to the first conduit;

a compressor connected to an output of the atomizing device; and

a distribution conduit connected to the compressor for conveying the compressed multiphase fluid to a desire location.

Embodiment BB: The apparatus of embodiment AA, wherein the atomizing device comprises one or more atomizing nozzles or a flow mixer connected to the first conduit.

Embodiment CC: The apparatus of embodiment AA or BB, further comprising an electric or gas motor, gas or steam turbine, expander, hydraulic turbine or other driving device to provide power to the compressor.

Embodiment DD: The apparatus of any of embodiments AA-CC, further comprising means for controlling the speed of the compressor based on torque, load, fluid density, GVF or input power.

Embodiment EE: Apparatus for expanding a multiphase fluid comprising:

a first conduit for conveying the multiphase fluid;

an atomizing device connected to the first conduit;

an expander connected to an output of the atomizing device; and

a distribution conduit connected to the expander for conveying the expanded multiphase fluid to a desired location.

Embodiment FF: The apparatus of embodiment EE, further comprising a slug suppressor connected to the first conduit.

Embodiment GG: The apparatus of embodiment EE or FF, further comprising means for controlling the speed of the expander or the driven equipment based on torque produced, load, fluid density, multiphase flow measurement, GVF or output power.

Embodiment HH: The apparatus of any of embodiments EE-GG, further comprising a generator or compressor connected to a power output shaft of the expander.

Embodiment II: The apparatus of embodiment HH, further comprising a bypass conduit connected at one end to the output of the expander and at its other end to the first conduit.

Embodiment JJ: The apparatus of embodiment II, further comprising a bypass valve in the bypass conduit.

Embodiment KK: The apparatus of any of embodiment EE-JJ, wherein the atomizing device is a flow mixer or one or more atomizing nozzles.

Embodiment LL: The apparatus of any of embodiments E, R, Y, or DD wherein the means for monitoring or controlling a stated parameter is comprised of a torque sensor, a load sensor, a fluid density sensor, a multiphase flow meter, an input power sensor, a torque converter, a computerized control system, an inlet or outlet control valve, recycle valve, a variable speed drive, a permanent magnet motor or other similar device.

[0030] It should be understood that the preceding is merely a detailed description of specific embodiments of this invention and that numerous changes, modifications, and alternatives to the disclosed embodiments can be made in accordance with the disclosure herein without departing from the scope of the invention. Rather, the scope of the invention is to be determined only by the appended claims and their equivalents.

CLAIMS:

1. Apparatus for compressing a multiphase fluid comprising:

a first conduit for conveying the multiphase fluid;

an atomizing device positioned in the first conduit;

a slug suppressor connected to the first conduit;

a centrifugal compressor connected to an output of the slug suppressor; and

a distribution conduit connected to the compressor for conveying the compressed multiphase fluid to a desired location;

wherein the slug suppressor and atomizing device are combined in a housing having an inlet and outlet, wherein the housing comprises

a first chamber for accumulating liquid;

a second chamber for accumulating gas, the second chamber surrounding the first chamber;

a plurality of baffles between the first and second chambers for allowing accumulated liquid in the first chamber to spill over into the second chamber; and

a plurality of atomizing nozzles located at a lower end of the first chamber and oriented to spray liquid from the first chamber into gas that has exited the second chamber.

2. The apparatus of claim 1 wherein the atomizing device is a flow mixer that includes at least two counter swirling vanes or counter rotating vortices.

3. The apparatus of claim 1 further comprising a variable speed drive connected to a power input shaft of the compressor.

4. Apparatus according to claim 1 wherein the housing tapers from the inlet to the outlet.

5. Apparatus according to claim 1 further comprising a recycle conduit connected at one end to the output of the compressor and at its other end to the first conduit.

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6. Apparatus according to claim 5 further comprising a recycle valve in the recycle conduit.

7. A method of compressing a multiphase fluid comprising:

providing a slug suppressor and an atomizing device;

directing a flow of multiphase fluid into the slug suppressor and the atomizing device;

directing the output flow from the slug suppressor and the atomizing device into an intake portion of a centrifugal compressor; and

compressing the multiphase fluid;

wherein the slug suppressor and the atomizing device are combined in a housing having an inlet and outlet, wherein the housing comprises

a first chamber for accumulating liquid;

a second chamber for accumulating gas, the second chamber surrounding the first chamber;

a plurality of baffles between the first and second chambers for allowing accumulated liquid in the first chamber to spill over into the second chamber; and

a plurality of atomizing nozzles located at a lower end of the first chamber and oriented to spray liquid from the first chamber into gas that has exited the second chamber.

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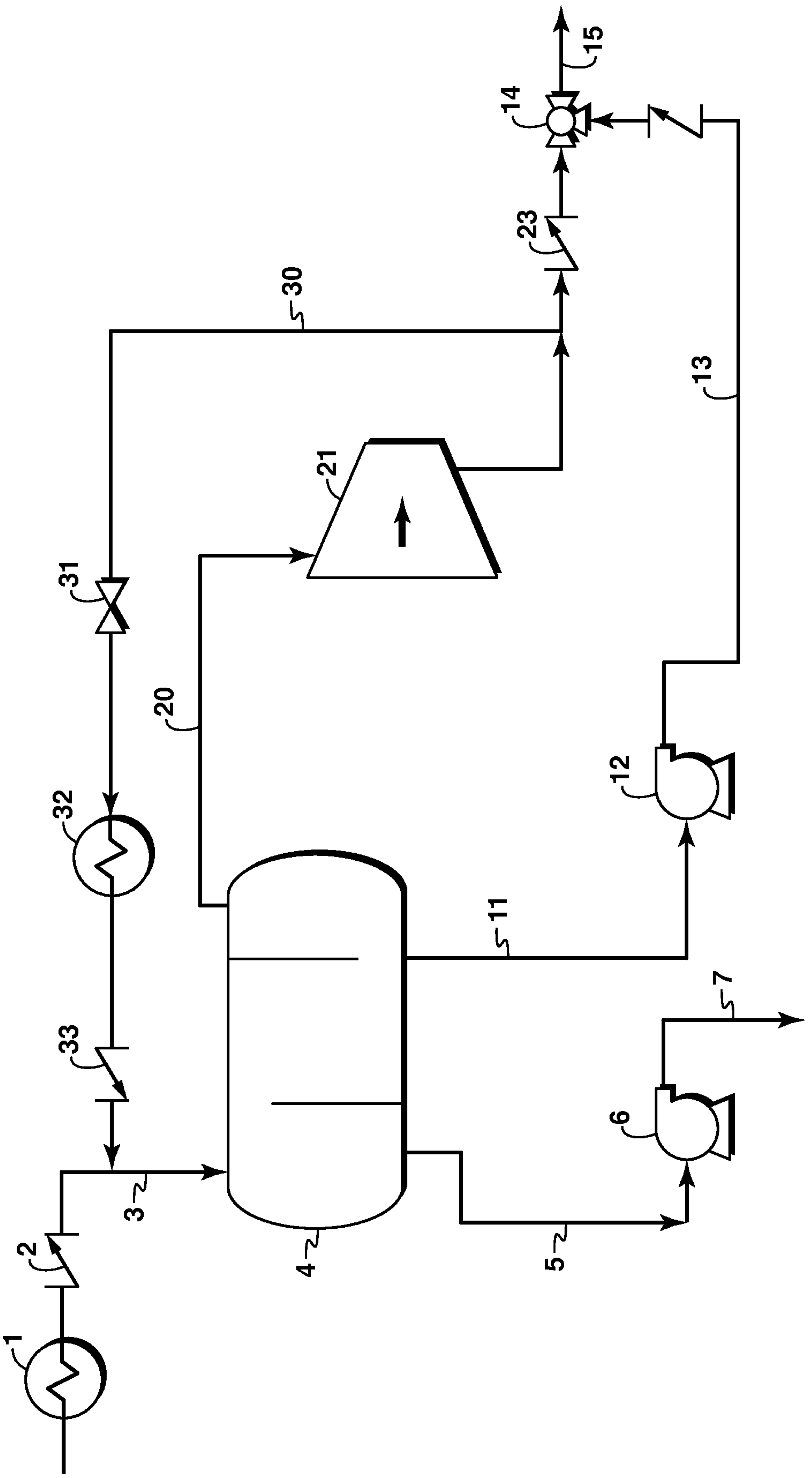


FIG. 1
Prior Art

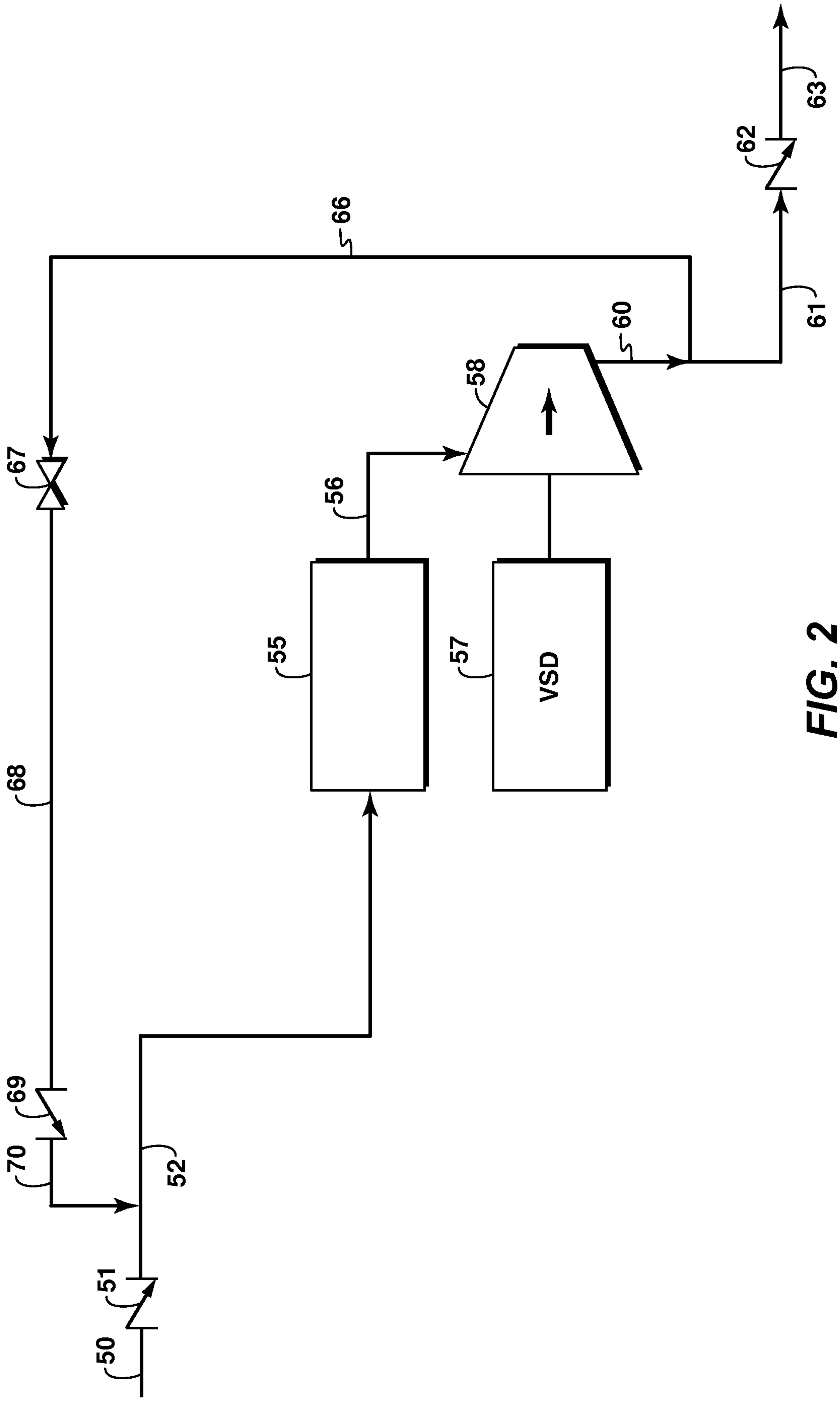
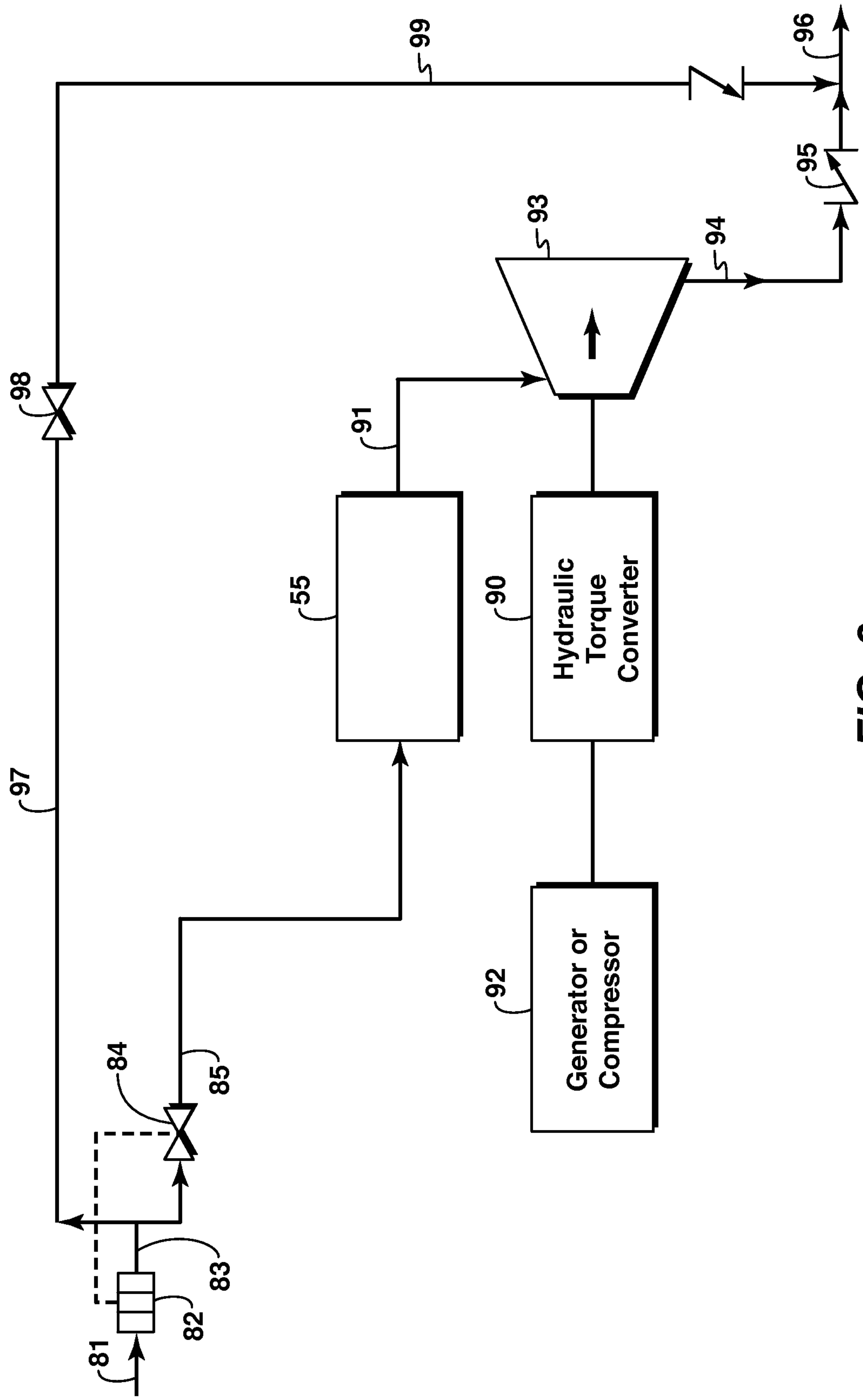


FIG. 2


99
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Hydraulic Torque Converter
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Generator or Compressor
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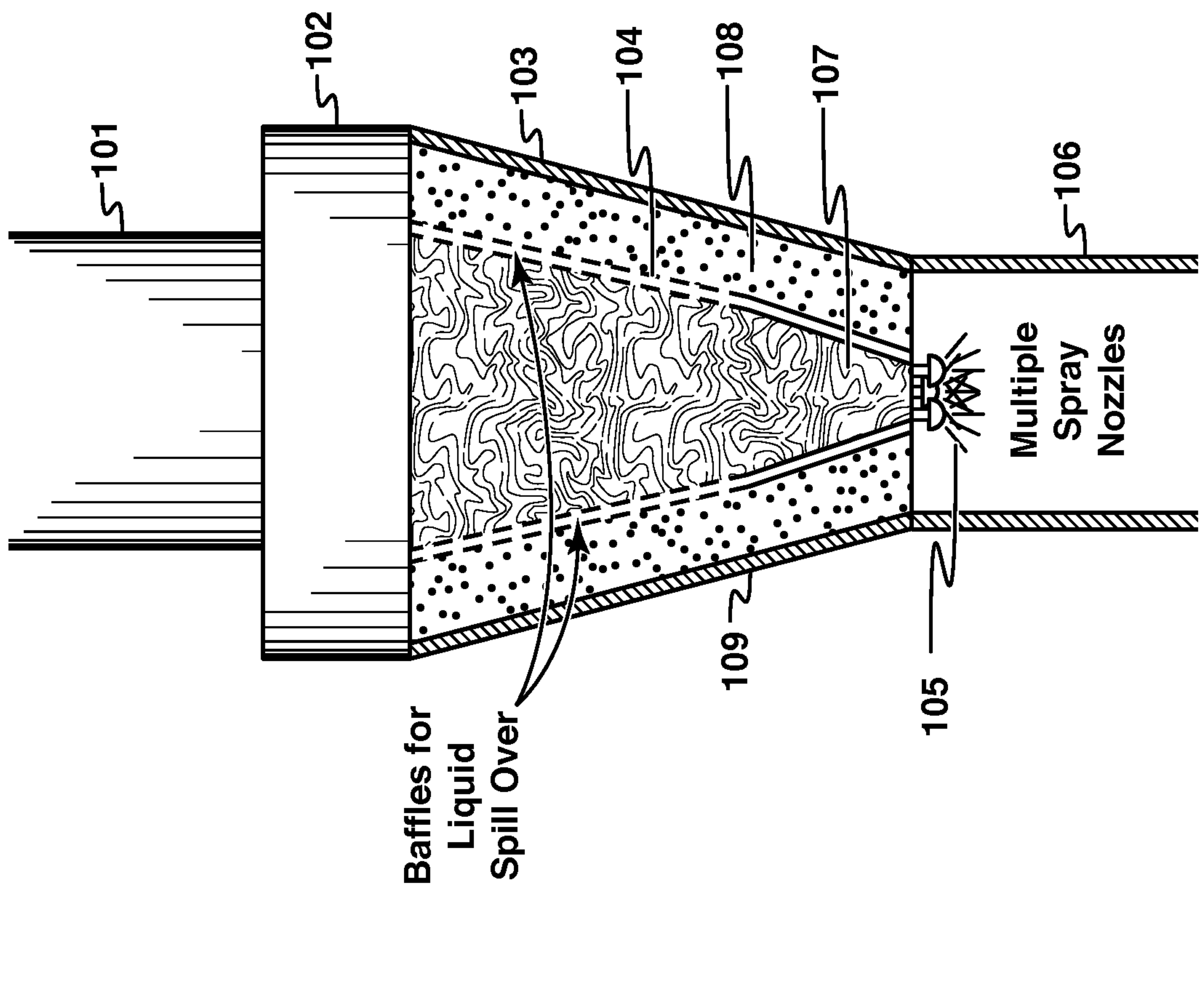
FIG. 3


101
102
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107
106
Multiple Spray Nozzles
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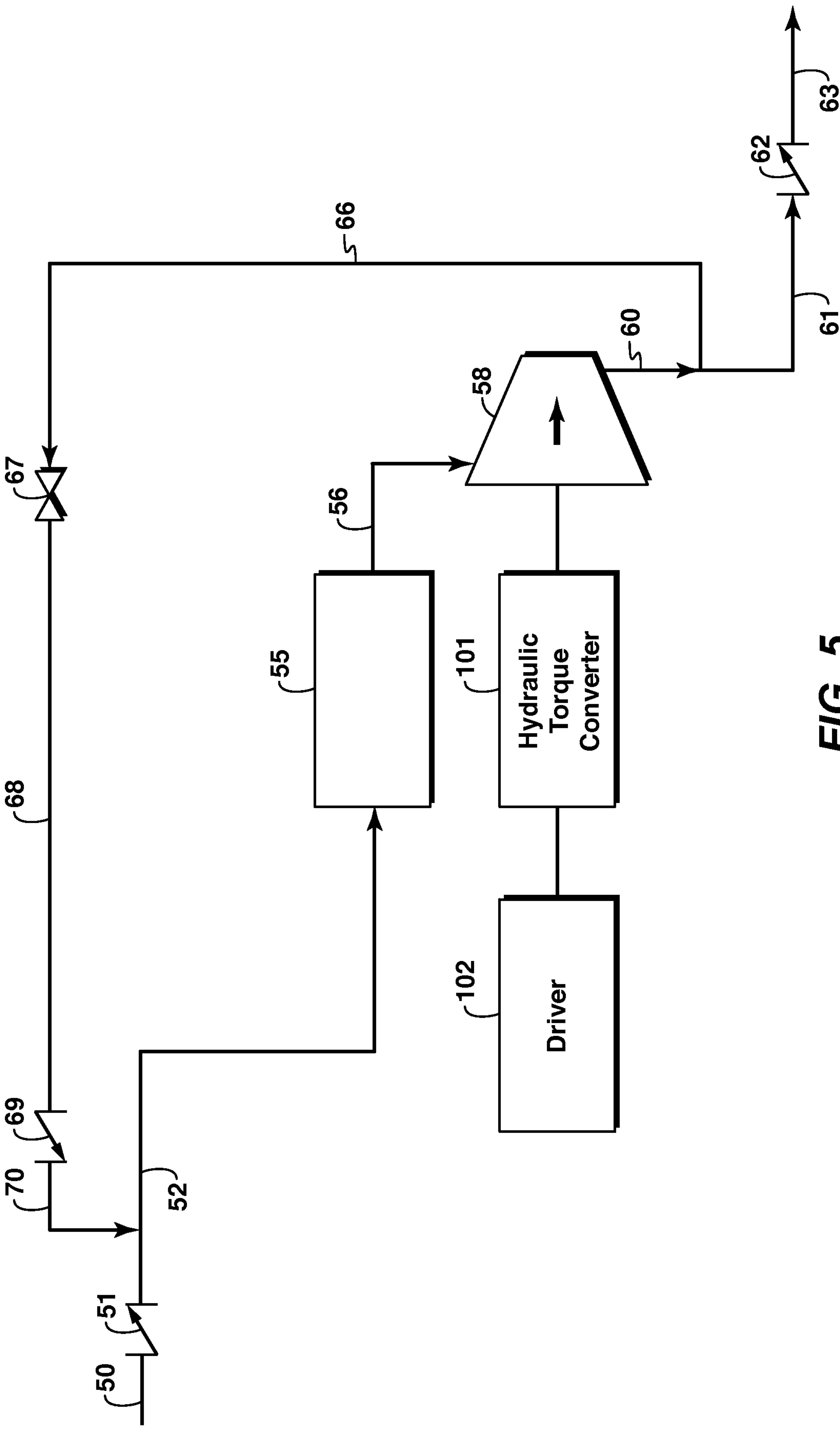
105
Baffles for Liquid Spill Over

FIG. 4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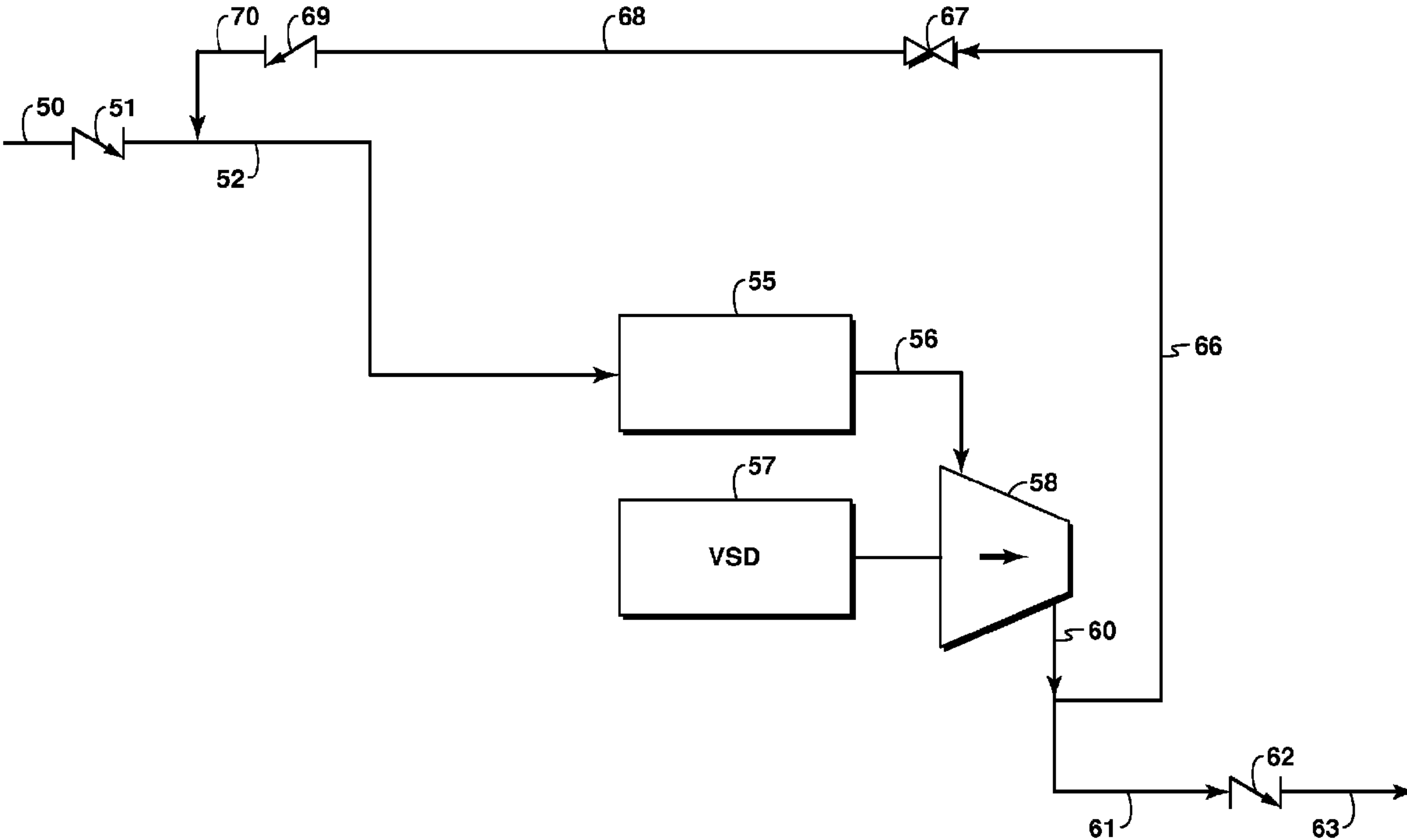
Hydraulic Torque Converter
102
Driver

FIG. 5



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VSD
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