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(54) **LOW-TEMPERATURE FULL CONTAINMENT TANK HAVING LOW-LIQUID-LEVEL MATERIAL EXTRACTION DEVICE**

(57) A cryogenic full containment storage tank having a low liquid level material extraction device, comprising an inner tank (1), an outer tank (2), an operation platform (3), and a material extraction device (6) capable of extracting a low liquid level material. The material extraction device (6) comprises a material circulation tank (61) and a cryopump (65) that are installed on the operation platform (3), a first Venturi mixer (62) installed at the bottom of the inner tank (1), and connecting pipelines. The low-temperature medium in the material circulation tank (61) enters the first Venturi mixer (62) through the cryopump (65) and an inlet pipeline (63), so that the low-temperature medium in the inner tank (1) enters the first Venturi mixer (62) through the suction hole (6202) of the first Venturi mixer (62), and then enters the material circulation tank (61) through a lead-outlet pipeline (64) after being mixed.

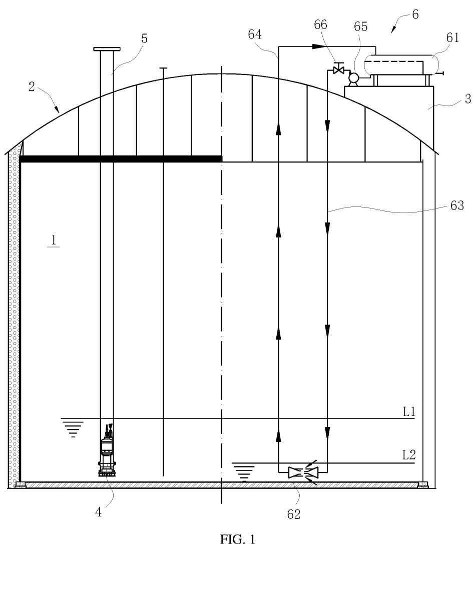

FIG. 1

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to the technical field of low-temperature liquefied gas storage, and more particularly, to a cryogenic full containment storage tank having a low liquid level material extraction device.

BACKGROUND

[0002] Substances that are gaseous at normal temperature and pressure but can be liquefied after proper freezing can be safely and efficiently stored in storage tanks with low temperature and normal pressure. Substances in the petrochemical industry that meet this characteristic include methane, ethylene, ethane, propylene, propane, butene, butane and other hydrocarbons , and substances in the chemical industry that meet this characteristic include ammonia . As methane is the main component of natural gas, and propane and butane are the main components of liquefied gas, they are mainly used as industrial and civil clean energy. As people pay more attention to environmental issues around the world, the consumption of clean energy such as liquefied hydrocarbons and liquefied natural gas (hereinafter referred to as LNG) is increasing. In addition, the number and scale of production of petrochemical enterprises that deeply process hydrocarbons as raw materials are also increasing, and the demand for large low-temperature storage tanks to store these clean energy and liquefied hydrocarbons also rises. Based on considerations for safety, the existing large cryogenic full containment storage tanks are not allowed to open holes on the wall and bottom. The pipelines connected to the storage tank are all in a top-in and top-out way, that is, the liquid is inputted and outputted from the roof of the storage tank. Due to the large diameter and the large height of the storage tank, the height of the tank dome plus the height of the tank wall is far greater than the suction vacuum height that the liquid can be pumped up to, so the discharging pump can only work under the liquid, that is, the discharging pump is a cryogenic submersible pump.

[0003] The cryogenic submersible pump requires sufficient low-temperature medium in the storage tank when starting, so the minimum liquid level must not be lower than the minimum operable liquid level required by the cryogenic submersible pump. At present, the minimum operable liquid level of the cryogenic submersible pump plus a certain safety margin is usually about 1.2 m, that is, the zone below 1.2 m from the bottom of the cryogenic full containment storage tank is usually a "dead zone" for operation, which results in a large ineffective working volume at the bottom of the tank. For example, an inner tank diameter of 50000 m^3 cryogenic full containment storage tank is about Φ 46 m, so a volume with a height of 1.2 m is about 1994 m^3. An inner tank diameter of 80000 m^3 cryogenic full containment storage tank is about Φ 59 m, so a volume with a height of 1.2 m height is about 3280 m^3. An inner tank diameter of 160000 m^3 cryogenic full containment storage tank is about Φ 87 m, and a volume with a height of 1.2 m height is about 7134 m^3.

[0004] The material at a bottom of the tank in range of the ineffective working volume cannot be discharged out of the tank through the cryogenic submersible pump. If the storage tank needs to perform outage maintenances, the material at the bottom can only be discharged by vaporization, which consumes a lot of energy and also needs a long period of time.

SUMMARY

[0005] An object of the present disclosure is to provide a cryogenic full containment storage tank having a low liquid level material extraction device, so as to solve the technical problem in the prior art that the ineffective working volume at the bottom of the storage tank is too large and there are too much residual medium that cannot be extracted.

[0006] In order to solve the above-mentioned technical problems, the present disclosure adopts the following technical solutions: a cryogenic full containment storage tank having a low liquid level material extraction device, comprising: an inner tank, an outer tank surrounding a periphery of the inner tank, an operation platform arranged on a top of the outer tank, and a material extraction device capable of extracting low liquid level material. The material extraction device capable of extracting low liquid level material comprises: a material circulation tank arranged on the operation platform, which is configured to contain low-temperature medium; a first Venturi mixer arranged at a bottom of the inner tank, wherein two ends of the first Venturi mixer are respectively an inlet and an outlet, and an outer periphery of the first Venturi mixer is provided with a suction hole; an inlet pipeline connected an outlet of the material circulation tank to the inlet of the first Venturi mixer; an outlet pipeline connected the outlet of the first Venturi mixer to an inlet of the material circulation tank; and a cryopump, arranged on the operation platform, and connected to the inlet pipeline; wherein while performing a medium extraction, the low-temperature medium in the material circulation tank enter the first Venturi mixer through the cryopump and the inlet pipeline, so that the low-temperature medium in the inner tank is capable of entering the first Venturi mixer through the suction hole under an action of a pressure difference, and entering the material circulation tank through the outlet pipeline after mixing.

[0007] The first Venturi mixer comprises a constriction section, a throat section and a diffusion section connected in sequence. A large-end opening of the constriction section is configured as the inlet of the first Venturi mixer, and is connected to the inlet pipeline. A large-end opening of the diffusion section is configured as the outlet of the first Venturi mixer, and is connected to the outlet pipeline. Two ends of the throat section are respectively connected to a small-end opening of the constriction section and a small-end opening of the diffusion section. The suction hole is opened corresponding to an outer periphery of the throat section, and is communicated with an interior of the throat section. The first Venturi mixer is placed horizontally in the inner tank.

[0008] The first Venturi mixer further comprises a suction cavity arranged around the outer periphery of the throat section and communicated with the interior of the throat section. Two ends of the suction cavity are respectively connected to an outer wall of the constriction section and an outer wall of the diffusion section. The suction hole is opened on an outer peripheral wall of the suction cavity.

[0009] The suction hole of the first Venturi mixer is opened on an outer peripheral wall of the throat section. The first Venturi mixer further comprises a suction pipe correspondingly arranged at the suction hole, and the suction pipe is communicated with an interior of the inner tank. The material circulation tank is further provided with a medium output port for outputting the low-temperature medium to the outside, and a liquid level control mechanism is provided to control an opening and closing of the medium output port when a preset liquid level is reached, and the preset liquid level is higher than a liquid level required for an operation of the cryopump during medium extraction.

[0010] The liquid level control mechanism is an overflow weir arranged in the material circulation tank. An outlet of the material circulation tank is communicated with an inner space of the overflow weir, and the medium output port is communicated with an outer space of the overflow weir.

[0011] The liquid level control mechanism is an overflow port arranged on a side wall of the material circulation tank, wherein a height of the overflow port is higher than the outlet of the material circulation tank, and the overflow port is communicated with the medium output port.

[0012] The liquid level control mechanism comprises an electrically connected liquid level gauge and a valve, wherein the liquid level gauge is configured to detect a liquid level in the material circulation tank, and the valve is correspondingly arranged at the medium output port.

[0013] The inlet pipeline is provided with a control valve to adjust a flow rate in the inlet pipeline, the control valve is located outside the outer tank, and the cryopump is located between the material circulation tank and the control valve.

[0014] The material extraction device further comprises a pressurizing unit, which is arranged on the outlet pipeline to increase a power for the low-temperature medium to flow to the material circulation tank.

[0015] The pressurizing unit comprises: a second Venturi mixer, a suction hole and an outlet of which are connected in series to the outlet pipeline; a pressurizing inlet pipeline connected an inlet of the second Venturi mixer to the outlet of the material circulation tank; and a pressurizing control valve arranged on the pressurizing inlet pipeline to adjust a flow rate in the pressurizing inlet pipeline.

[0016] It can be seen from the above technical solutions that the present disclosure has at least the following advantages and positive effects: the cryogenic full containment storage tank of the present disclosure is equipped with a material extraction device capable of extracting low liquid level material, The material extraction device comprises a material circulation tank, a cryopump arranged at an operation platform at a top of the tank, a Venturi mixer located at a bottom of the inner tank and corresponding connecting pipelines. The low-temperature medium in the material circulation tank enters the Venturi mixer through the cryopump. According to Bernoulli's principle and momentum transfer principle, the low-temperature medium will form a local low-pressure and high-speed flow entrainment effect in the Venturi mixer, making the low-temperature medium enter the Venturi mixer through the suction hole under the action of the pressure difference, and the mixed low-temperature medium returns to the material circulation tank together. During the cycle, the flow rate of the low-temperature medium returned to the material circulation tank is greater than the flow rate of the low-temperature medium pumped out from the material circulation tank, and the difference is the extracted low-temperature medium.

[0017] The material extraction device is mainly used as a supplementary discharge measure after the submersible pump in the cryogenic full containment storage tank is pumped to the minimum liquid level and shut down. This extraction device can extract the low liquid level low-temperature medium that is originally in the "dead zone" for operation, and the low-temperature medium above the liquid level where the suction hole of the Venturi mixer is located can be extracted by the material extraction device. As a result, the liquid level of the cryogenic full containment storage tank can be lowered to the position where the suction hole or the suction pipe of the first Venturi mixer is located, which is significantly lower than the minimum operable liquid level required by the submersible pump in the prior art, so that the ineffective volume of the cryogenic full containment storage tank can be significantly reduced, and the volume utilization rate of the tank can be improved. In the case of the same tank size, the effective working volume of the full containment storage tank can be increased. In the case of the same tank size, the effective working volume of the full containment storage tank can be increased. In the case of a certain effective working volume, the height of the inner and outer tanks can be reduced, thereby saving engineering investment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

FIG. 1 is a schematic structural diagram of a cryogenic full containment storage tank according to an embodiment of the present disclosure.

FIG. 2 is a schematic structural diagram of a material extraction device in FIG. 1.

FIG. 3 is a schematic diagram showing a mixing principle of the low-temperature medium in a first Venturi mixer in FIG. 2.

FIG. 4 is a schematic structural diagram of the cryogenic full containment storage tank according to another embodiment of the present disclosure.

FIG. 5 is a schematic structural diagram of the material extraction device in FIG. 4.

FIG. 6 is a schematic structural diagram of another Venturi mixer.

[0019] The descriptions of the reference numerals are as follows: 1- inner tank; 2- outer tank; 3-operation platform; 4- pump column; 5- submersible pump; 6/6a- material extraction device; 61/61a- material circulation tank; 6101/6101a- outlet; 6102/6102a- inlet; 6103/6103a- medium outlet; 6104a- overflow outlet; 611- overflow weir; 62- first Venturi mixer; 621- constriction section; 622/622b- throat section; 623- diffusion section; 624- suction cavity; 62b- Venturi mixer; 625b- suction pipe; 6201- inlet; 6202/6202b- suction hole; 6203- outlet; 63- inlet pipeline; 64/64a- outlet pipeline; 641a- first outlet section; 642a- second outlet section; 65-cryopump; 66- control valve; 67- pressurizing unit; 671- second Venturi mixer; 6711- inlet; 6712- suction hole ; 6713- outlet; 672- pressurizing inlet pipeline; 673- pressurizing control valve.

DETAILED DESCRIPTION

[0020] Exemplary embodiments embodying the features and advantages of the present disclosure will be described in detail in the following description. It should be understood that the present disclosure may have various changes in different embodiments without departing from the scope of the present disclosure, and the descriptions and drawings therein are essentially used for illustrating rather than limiting the present disclosure.

[0021] The present disclosure provides a cryogenic full containment storage tank for storing liquefied low-temperature medium. The low-temperature medium may be a hydrocarbon such as methane, ethylene, ethane, propylene, propane, butene and butane, and may also be ammonia commonly used in the chemical industry.

[0022] Referring to FIG. 1, the cryogenic full containment storage tank provided in this embodiment generally includes an inner tank 1 for storing the low-temperature medium, an outer tank 2 surrounding a periphery of the inner tank 1, an operation platform 3 arranged on a top of the outer tank 2, a pump column 4 extends through the top of the outer tank 2 to a bottom of the inner tank 1, a submersible pump 5 arranged in the pump column 4, and a material extraction device 6 for extracting the low liquid level material from the bottom of the inner tank 1.

[0023] Each of the inner tank 1 and the outer tank 2 generally includes a bottom plate arranged horizontally and a cylindrical body erected on the bottom plate. A heat insulating layer is provided between the bottom plate of the inner tank 1 and the bottom plate of the outer tank 2, and a heat insulating layer is provided between the cylindrical body of the inner tank 1 and the cylindrical body of the outer tank 2. A dome is provided on the top of the outer tank 2, a top plate is suspended below the dome, and a heat insulating layer is also arranged between the dome and the top plate. The top plate is connected to the inner tank 1 in a soft sealing manner. The pump column 4 extends through the top of the outer tank 2 to the bottom of the inner tank 1. The submersible pump 5 is arranged at a bottom of the pump column 4 and is immersed in the low-temperature medium of the inner tank 1, which is configured to transport the low-temperature medium in the inner tank 1 to the outside through the pump column 4. The operation platform 3 is fixed on the top of the outer tank 2, which may be configured to accommodate various pipeline valves and working accessories which the cryogenic full containment storage tank is equipped with, allowing operators to perform work and maintenance on it.

[0024] Compared to the cryogenic full containment storage tank in the prior art, the cryogenic full containment storage tank in this embodiment is equipped with a material extraction device 6, which is used as a supplementary discharge device after the submersible pump 5 is pumped to the minimum liquid level L1 and shuts down, so as to reduce the ineffective volume of the cryogenic full containment storage tank. It is worth mentioning that the material extraction device 6 involved in the present disclosure can not only extract the low liquid level material (that is, the low-temperature medium below the minimum operable liquid level L1 of the submersible pump 5), but also operate in the liquid level range where the submersible pump 5 in the pump column 4 can function. Therefore, in some cases, it may also be used as a backup facility with a small flow output other than the submersible pump 5. The material extraction device 6 will be described in detail below with reference to FIG. 2, and other specific structures including the inner tank 1, the outer tank 2, the operation platform 3, the pump column 4, and the submersible pump 5 can be referred to the structure of the related technology of the full-containment tank, which will not be described in detail herein.

[0025] Referring to FIGS. 1-2, the material extraction device 6 of this embodiment includes a material circulation tank 61, a first Venturi mixer 62, an inlet pipeline 63, an outlet pipeline 64 and a cryopump 65. Further, a control valve 66 is further provided on the inlet pipeline 63.

[0026] The material circulation tank 61 in this embodiment is a horizontal low-temperature tank, which is arranged on the operation platform 3. An inside of the material circulation tank 61 is configured to contain the low-temperature medium, and an outside of the material circulation tank 61 may be wrapped with cold insulating material.

[0027] Taking the view direction of FIG. 2 as a reference, an overflow weir 611 is arranged in the material circulation tank 61, and the overflow weir 611 divides the internal space of the material circulation tank 61 into two parts. When the low-temperature medium in the overflow weir 611 (i.e., a left side of the overflow weir 611 in the figure) exceeds a height of the overflow weir 611, the low-temperature medium overflow outside the overflow weir 611 (i.e., a right side of the overflow weir 611 in the figure). The space on the left side of the overflow weir 611 should meet the circulating volume requirements for medium extraction of the low-temperature medium, and the height of the overflow weir 611 should meet the requirements of the minimum operable liquid level of the cryopump 65. On this basis, the height of the overflow weir 611 is set according to the practice situation.

[0028] An outlet 6101 is provided at a bottom of a left end of the material circulation tank 61, and the outlet 6101 is communicated with the space enclosed by the overflow weir 611, which is configured to output the low-temperature medium during medium extraction.

[0029] A medium output port 6103 is further provided at a bottom of a right end of the material circulation tank 61, and the medium output port 6103 is communicated with the space outside the overflow weir 611 in the material circulation tank 61, which is configured to output the low-temperature medium to the outside.

[0030] An inlet 6102 is provided on a left side of a top of the material circulation tank 61, which is configured to receive the low-temperature medium.

[0031] The first Venturi mixer 62 is placed horizontally on a bottom plate of the inner tank 1 so as to have a low installation height. The first Venturi mixer 62 is a liquid-liquid mixer, which mainly includes a constriction section 621, a throat section 622 and a diffusion section 623 connected in sequence. In this embodiment, the first Venturi mixer 62 is further provided with a suction cavity 624.

[0032] Each one of the constriction section 621 and the diffusion section 623 is a hollow structure with gradient cross-section, a large-end opening of the constriction section 621 configured as an inlet 6201 of the first Venturi mixer 62, and a large-end opening of the diffusion section 623 configured as an outlet 6203 of the first Venturi mixer 62. One end of the throat section 622 is connected to a small-end opening of the constriction section 621, and the other end thereof is aligned with a small-end opening of the diffusion section 623.

[0033] The suction cavity 624 is circumferentially arranged on a periphery of the throat section 622, forming a dual cavity structure at the throat section 622. Two ends of the suction cavity 624 are respectively connected to an outer wall of the constriction section 621 and an outer wall of the diffusion section 623. An outer peripheral wall of the suction cavity 624 is provided with a plurality of suction holes 6202, and these suction holes 6202 are communicated with an interior of the inner tank 1, so that the low-temperature medium in the inner tank 1 can be sucked into the suction cavity 624. An annular cavity is formed between the suction cavity 624 and the throat section 622, and the suction cavity 624 is communicated with an interior of the throat section 622, so the low-temperature medium in the suction cavity 624 can further enter the throat section 622.

[0034] The inlet pipeline 63 extends through the top of the outer tank 2, and connects the inlet 6201 of the first Venturi mixer 62 to the outlet 6101 of the material circulation tank 61, so as to guide the low-temperature medium in the material circulation tank 61 into the first Venturi mixer 62 for extraction.

[0035] The outlet pipeline 64 also extends through the top of the outer tank 2, and connects the inlet 6102 of the material circulation tank 61 to the outlet 6203 of the first Venturi mixer 62, so as to guide the low-temperature medium in the first Venturi mixer 62 into the material circulation tank 61.

[0036] The cryopump 65 is arranged on the operation platform 3 and is connected to the inlet pipeline 63 to provide power for the flow of the low-temperature medium. The cryopump 65 is a non-submerged pump, that is, it is not required to be immersed in the low-temperature medium, and it may be a non-submerged pump with any structure.

[0037] The control valve 66 is arranged on the inlet pipeline 63, so that it can not only control the opening and closing of the inlet pipeline 63, but also adjust a flow rate of the low-temperature medium in the inlet pipeline 63. The control valve 66 is located downstream of the cryopump 65, but outside the outer tank 2.

[0038] The above-mentioned material circulation tank 61, the first Venturi mixer 62, the inlet pipeline 63, the extraction pipeline 64, the cryopump 65 and the control valve 66 are all required to be able to withstand the temperature of the extracted low-temperature medium, so they are made of low-temperature materials capable of withstanding the corresponding temperature.

[0039] Referring to FIGS. 2-3, the working principle of the material extraction device 6 is as follows. While extracting medium, the low-temperature medium in the material circulation tank 61 is driven by the power of the cryopump 65 and enters the first Venturi mixer 62 through the inlet pipeline 63. For ease of understanding, the low-temperature medium guided into the first Venturi mixer 62 from the material circulation tank 61 is referred to as initial low-temperature medium F0. According to the Bernoulli's (energy conservation) principle and the momentum transfer principle (momentum conservation), after the initial low-temperature medium F0 enters the first Venturi mixer 62, in the process of flowing from the constriction section 621 to the throat section 622, due to a decrease of the flow cross-sectional area, the flow speed increases, and the pressure decreases, resulting in an entrainment effect of local low pressure and high-speed flow at the throat section 622, so that the low-temperature medium Fi in the inner tank 1 enters the first Venturi mixer 62 through the suction holes 6202 under the action of the pressure difference. The sucked low-temperature medium Fi is mixed with the initial low-temperature medium F0. Due to an increase of the flow cross-section area, the flow speed reduces, and the pressure increases, the mixed low-temperature medium Fm in the diffusion section 623 enters the material circulation tank 61 through the lead-outlet pipeline 64. In this embodiment, the suction cavity 624 is further provided on a periphery of the throat section 622 of the first Venturi mixer 62, and the low-temperature medium in the inner tank 1 is first sucked into the suction cavity 624, and then enters the throat section 622 for mixing, so that the momentum of the initial low-temperature medium F0 can be more effectively utilized, and the mixed low-temperature medium can flow back to the material circulation tank 61 more smoothly.

[0040] The flow rate of the low-temperature medium reaching the material circulation tank 61 is greater than the flow rate of the initial low-temperature medium initially pumped into the first Venturi mixer 62 from the material circulation tank 61, and the excess part is the low-temperature medium extracted from the inner tank 1. After the above-mentioned continuous circulation process, the low-temperature medium in the inner tank 1 can be continuously extracted into the material circulation tank 61.

[0041] The low-temperature medium located in the overflow weir 611 in the material circulation tank 61 is used to maintain the medium extraction operation. When the low-temperature medium in the material circulation tank 61 exceeds the overflow weir 611, the low-temperature medium beyond the height of the overflow weir 611 can be transported outward through the medium output port 6103.

[0042] Referring to FIGS. 4-5, in another embodiment of the cryogenic full containment storage tank, the material extraction device 6a is further provided with a pressurizing unit 67 on the basis of the foregoing embodiment, and the pressurizing unit 67 is provided on the outlet pipeline 64, and the pressurizing unit 67 is configured to increase the power of the mixed low-temperature medium to flow to the material circulation tank 61a, so that the low-temperature medium can flow back to the material circulation tank 61a more smoothly. It is suitable for situations with a larger pumping height, such as a cryogenic full containment storage tank with a larger height. In this embodiment, the pressurizing unit 67 includes a second Venturi mixer 671, a pressurizing inlet pipeline 672 and a pressurizing control valve 673.

[0043] A composition structure of the second Venturi mixer 671 may be the same as that of the first Venturi mixer 62. A suction hole 6712 and an outlet 6713 of the second Venturi mixer 671 are connected in series to the outlet pipeline 64a. Specifically, the outlet pipeline 64a is divided into a first outlet section 641a and a second outlet section 642a, and the first outlet section 641a connects the outlet 6203 of the first Venturi mixer 62 to the suction hole 6712 of the second Venturi mixer 671, and the second outlet section 642a connects the outlet 6713 of the second Venturi mixer 671 to the inlet 6102a of the material circulation tank 61a.

[0044] The pressurizing inlet pipeline 672 communicates the inlet 6711 of the second Venturi mixer 671 with the outlet 6101a of the material circulation tank 61a, so as to guide a certain amount of initial low-temperature medium from the material circulation tank 61a into the second Venturi mixer 671. The initial low-temperature medium is further mixed with the mixed low-temperature medium from the first Venturi mixer 62 in the second Venturi mixer 671 to increase the pressure, so that the low-temperature medium has greater power to return to the material circulation tank 61a from the second outlet section 642a.

[0045] The pressurizing control valve 673 is arranged on the pressurizing inlet pipeline 672. On the one hand, it controls the opening and closing of the pressurizing inlet pipeline 672 , and on the other hand, it also regulates a flow rate in the pressurizing inlet pipeline 672.

[0046] Similar to the previous embodiment, the second Venturi mixer 671, the pressurizing inlet pipeline 672 and the pressurizing control valve 673 are also required to be able to withstand the temperature of the extracted low-temperature medium, so they are made of low-temperature materials capable of withstanding the corresponding temperature.

[0047] In this embodiment, the second Venturi mixer 671 is configured to increase the refluxing power of the low-temperature medium, and forms a two-stage series extraction process. In other embodiments, if the extraction height is higher and the return power is insufficient, more Venturi mixers may be connected in series to the outlet pipeline 64/64a to form a multi-stage series extraction process. The connection method of multi-stage series extraction may be deduced by analogy.

[0048] Compared to the previous embodiment, another difference of this embodiment is that the material circulation tank 61a is a vertical storage tank. The inlet 6102a of the material circulation tank 61a is located at the top, and the outlet 6101a of the material circulation tank 61a is located on the side wall close to the bottom. There is no overflow weir 611 in the material circulation tank 61a, but an overflow port 6104a is provided on the side wall of the material circulation tank 61a. The height of the overflow port 6104a is higher than the outlet 6101a of the material circulation tank 61a, and is higher than the liquid level required for medium extraction. The medium outlet port 6103a is extended out from and communicated with the overflow port 6104a.

[0049] The structure of the vertical material circulation tank 61a is also applicable to the material extraction device 6 in the previous embodiment.

[0050] In the above two embodiments, the material circulation tank 61/61a adopts the structure of the overflow weir 611 and the overflow port 6104a to form a liquid level control mechanism, so as to control the opening and closing of the medium output port 6103/6103a when the preset liquid level is reached. In other not-shown embodiments, the liquid level control mechanism may further include an electrically connected liquid level gauge and a valve, the liquid level gauge is configured to detect the liquid level in the material circulation tank, and the valve is correspondingly arranged at the medium output port.

[0051] Referring to FIG. 6, the Venturi mixers 62/671 in the above embodiments can also be replaced with a structure shown in FIG. 6. In the structure shown in FIG. 6, the Venturi mixer 62b is not equipped with the suction cavity 624, but a plurality of suction holes 6202b are opened on the outer peripheral wall of the throat section 622b, and each suction hole 6202b is further provided with a suction pipe 625b correspondingly. When the initial low-temperature medium F0 is guided into the constriction section 621 of the Venturi mixer 62b, under the action of the pressure difference, the low-temperature medium Fi in the inner tank 1 can be guided into the throat section 622b through the suction pipes 625b, and is mixed with the initial low-temperature medium Fi, and the mixed low-temperature medium Fm is guided to the next process.

[0052] In some other not shown embodiments, the suction pipes 625b may also be removed, and the low-temperature medium Fi in the inner tank 1 is directly sucked through the suction hole 6202b on the outer peripheral wall of the throat section 622b. In addition, for the structure of the first Venturi mixer 62 in the above-mentioned embodiment, a suction pipe may also be added at the suction hole 6202 of the suction cavity 624. Similarly, a suction pipe may also be added at the suction hole 6712 of the second Venturi mixer 671.

[0053] Based on the above description, when the cryogenic full containment storage tank in each embodiment of the present disclosure is in normal operation, the low-temperature medium is outputted through the pump column 4 under the power of the submersible pump 5. According to the minimum operable liquid level required to start and maintain the operation of the submersible pump 5, the submersible pump 5 can reduce the liquid level in the cryogenic full containment storage tank to the minimum position L1 shown in FIG. 1 and FIG. 3. According to the requirements of the general submersible pump 5 in the prior art, L1 is roughly about 1.2 m. When the liquid level in the cryogenic full containment storage tank drops to L1, the submersible pump 5 is stopped. If it is necessary to further extract the low-temperature medium from the inner tank 1, the material extraction device 6/6a is adopted to carry out the extraction, and the material extraction device 6/6a continuously extracts the low-temperature medium at the bottom of the inner tank 1 according to the working principle described above, until the liquid level drops to the first Venturi mixer 62, and the liquid level in this circumstance is located at L2. The L2 may be approximately 0.2 m to 0.3 m. Compared to the 1.2 m of L1, the liquid level in the inner tank 1 may be reduced by about 1m, which significantly reduces the ineffective volume of the cryogenic full containment storage tank, and improves the volume utilization rate of the cryogenic full containment storage tank.

[0054] In this cryogenic full containment storage tank, the power part and the control part of the material extraction device 6/6a are arranged outside the outer tank 2. Except that the Venturi mixer 62/671/62b and the pipeline part need to be immersed in the low-temperature medium, no other equipment or cables are immersed in the low-temperature medium, and the components in the tank can achieve maintenance-free operation throughout the life of the tank. It is worth mentioning that when the liquid level of the cryogenic full containment storage tank is higher than L1, the material circulation tank 61/61a of the material extraction device 6/6a may not store the low-temperature medium. When it is required to extract the low liquid level medium, the material circulation tank 61/61a may be filled with a certain amount of low-temperature medium as the initial power medium.

[0055] Although the present disclosure has been described with reference to several exemplary embodiments, it should be understood that the terminology used is used for description and illustration, and not for limitation. Since the present disclosure can be embodied in many forms without departing from the spirit or essence of the disclosure, it should be understood that the above-described embodiments are not limited to any of the foregoing details, but are to be construed broadly within the spirit and scope defined by the appended claims. Therefore, all changes and modifications that come within the scope of the claims or their equivalents should be covered by the appended claims.

Claims

1. A cryogenic full containment storage tank having a low liquid level material extraction device, comprising:

an inner tank;
an outer tank surrounding a periphery of the inner tank;
an operation platform arranged on a top of the outer tank; and
a material extraction device capable of extracting low liquid level material, comprising:

a material circulation tank arranged on the operation platform, which is configured to contain low-temperature medium;
a first Venturi mixer arranged at a bottom of the inner tank, wherein two ends of the first Venturi mixer are respectively an inlet and an outlet, and an outer periphery of the first Venturi mixer is provided with a suction hole;
an inlet pipeline connected an outlet of the material circulation tank to the inlet of the first Venturi mixer;

an outlet pipeline connected the outlet of the first Venturi mixer to an inlet of the material circulation tank; and

a cryopump, arranged on the operation platform, and connected to the inlet pipeline;

wherein while performing a medium extraction, the low-temperature medium in the material circulation tank enters the first Venturi mixer through the cryopump and the inlet pipeline, so that the low-temperature medium in the inner tank is capable of entering the first Venturi mixer through the suction hole under an action of a pressure difference, and entering the material circulation tank through the outlet pipeline after mixing.

2. The cryogenic full containment storage tank according to claim 1, wherein the first Venturi mixer comprises a constriction section, a throat section and a diffusion section connected in sequence, wherein a large-end opening of the constriction section is configured as the inlet of the first Venturi mixer, and is connected to the inlet pipeline, wherein a large-end opening of the diffusion section is configured as the outlet of the first Venturi mixer, and is connected to the outlet pipeline, wherein two ends of the throat section are respectively connected to a small-end opening of the constriction section and a small-end opening of the diffusion section, wherein the suction hole is opened corresponding to an outer periphery of the throat section, and is communicated with an interior of the throat section, and wherein the first Venturi mixer is placed horizontally in the inner tank.

3. The cryogenic full containment storage tank according to claim 2, wherein the first Venturi mixer further comprises a suction cavity arranged around the outer periphery of the throat section and communicated with the interior of the throat section, wherein two ends of the suction cavity are respectively connected to an outer wall of the constriction section and an outer wall of the diffusion section, wherein the suction hole is opened on an outer peripheral wall of the suction cavity.

4. The cryogenic full containment storage tank according to claim 2, wherein the suction hole of the first Venturi mixer is opened on an outer peripheral wall of the throat section,
wherein the first Venturi mixer further comprises a suction pipe correspondingly arranged at the suction hole, and the suction pipe is communicated with an interior of the inner tank.

5. The cryogenic full containment storage tank according to claim 1, wherein the material circulation tank is further provided with a medium output port for outputting the low-temperature medium to the outside, and a liquid level control mechanism is provided to control an opening and closing of the medium output port when a preset liquid level is reached, and the preset liquid level is higher than a liquid level required for an operation of the cryopump during medium extraction.

6. The cryogenic full containment storage tank according to claim 5, wherein the liquid level control mechanism is an overflow weir arranged in the material circulation tank, wherein an outlet of the material circulation tank is communicated with an inner space of the overflow weir, and the medium output port is communicated with an outer space of the overflow weir.

7. The cryogenic full containment storage tank according to claim 5, wherein the liquid level control mechanism is an overflow port arranged on a side wall of the material circulation tank, wherein a height of the overflow port is higher than the outlet of the material circulation tank, and the overflow port is communicated with the medium output port.

8. The cryogenic full containment storage tank according to claim 5, wherein the liquid level control mechanism comprises an electrically connected liquid level gauge and a valve, wherein the liquid level gauge is configured to detect a liquid level in the material circulation tank, and the valve is correspondingly arranged at the medium output port.

9. The cryogenic full containment storage tank according to claim 1, wherein the inlet pipeline is provided with a control valve to adjust a flow rate in the inlet pipeline, the control valve is located outside the outer tank, and the cryopump is located between the material circulation tank and the control valve.

10. The cryogenic full containment storage tank according to claim 1, wherein the material extraction device further comprises a pressurizing unit, which is arranged on the outlet pipeline to increase a power for the low-temperature medium to flow to the material circulation tank.

11. The cryogenic full containment storage tank according to claim 10, wherein the pressurizing unit comprises:

a second Venturi mixer, a suction hole and an outlet of which are connected in series to the outlet pipeline;

a pressurizing inlet pipeline, connected an inlet of the second Venturi mixer to the outlet of the material circulation tank; and

a pressurizing control valve, arranged on the pressurizing inlet pipeline to adjust a flow rate in the pressurizing inlet pipeline.

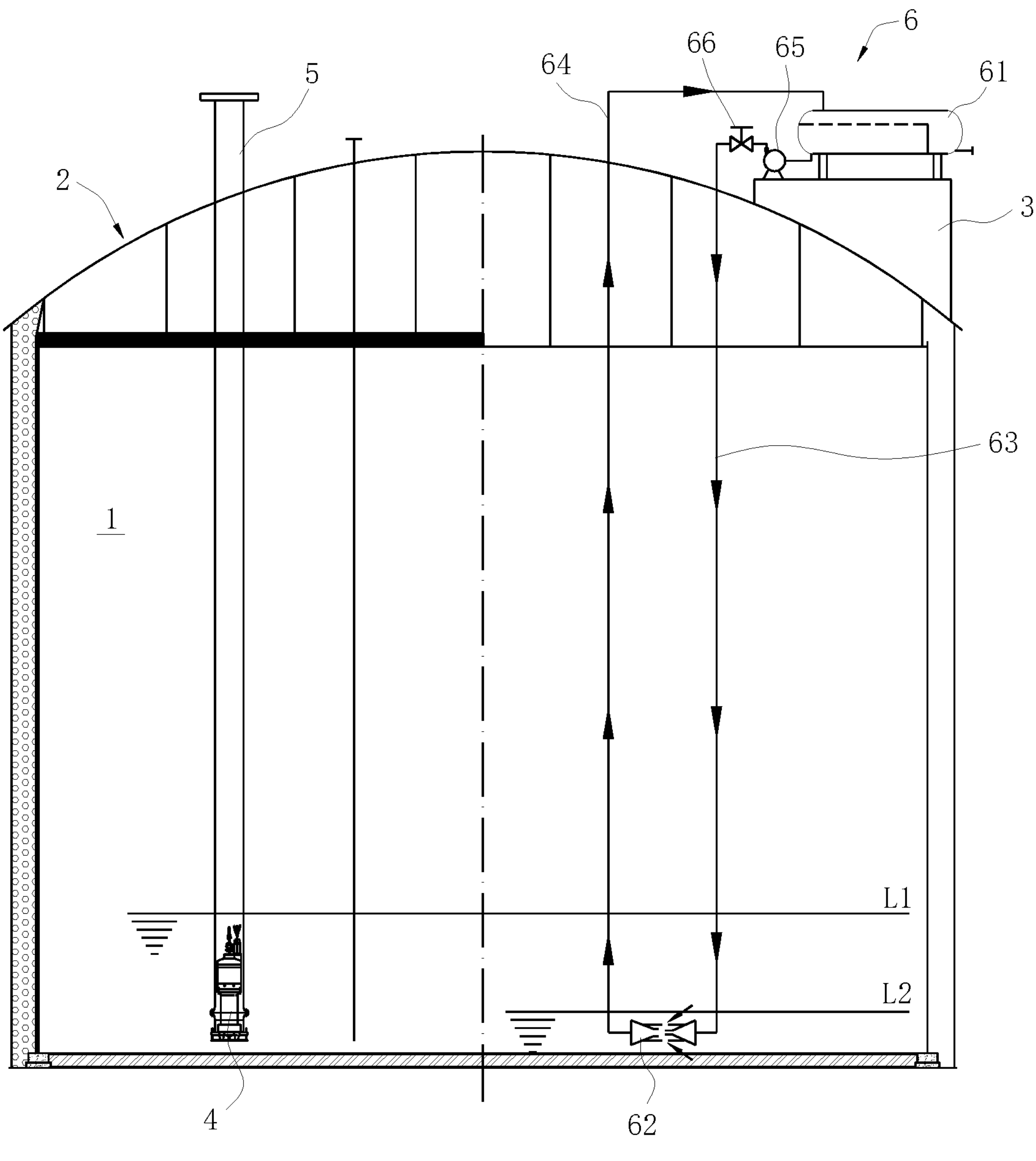


FIG. 1

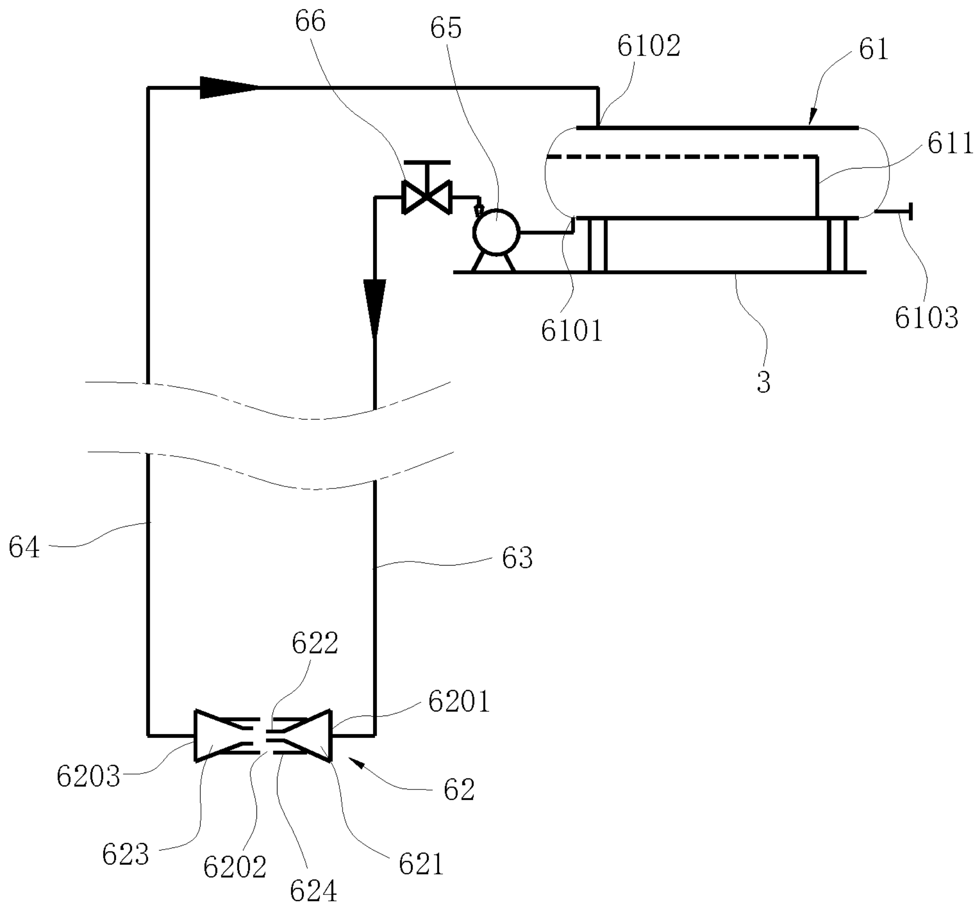

66
65
6102
61
611
6101
6103
3
64
63
622
6201
6203
62
623
6202
624
621

FIG. 2

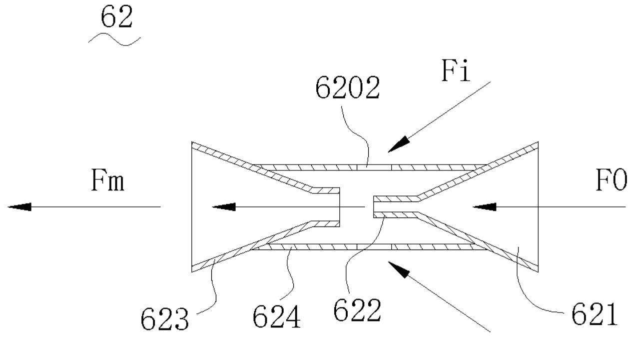

62
Fi
6202
Fm
F0
623
624
622
621

FIG. 3

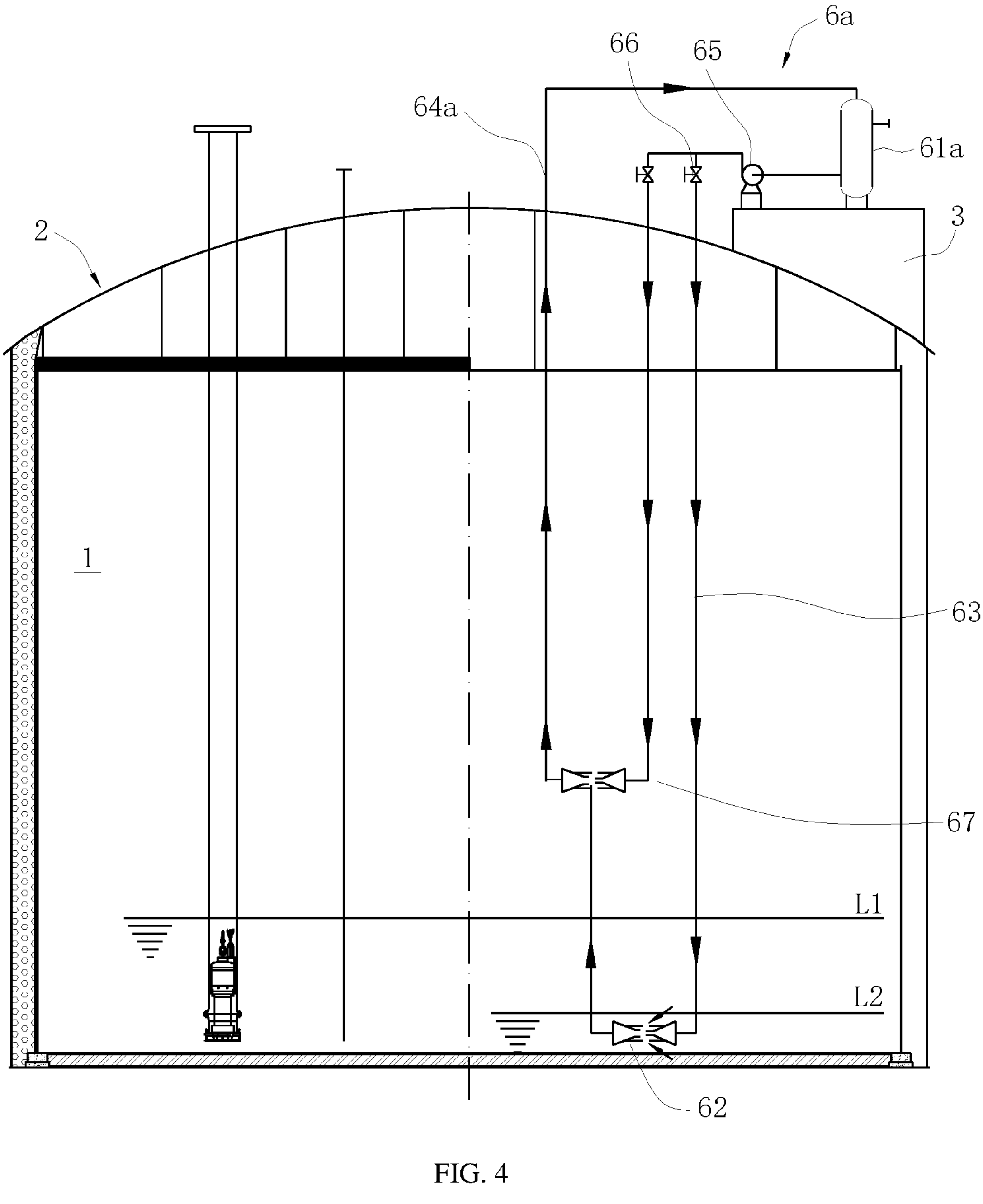
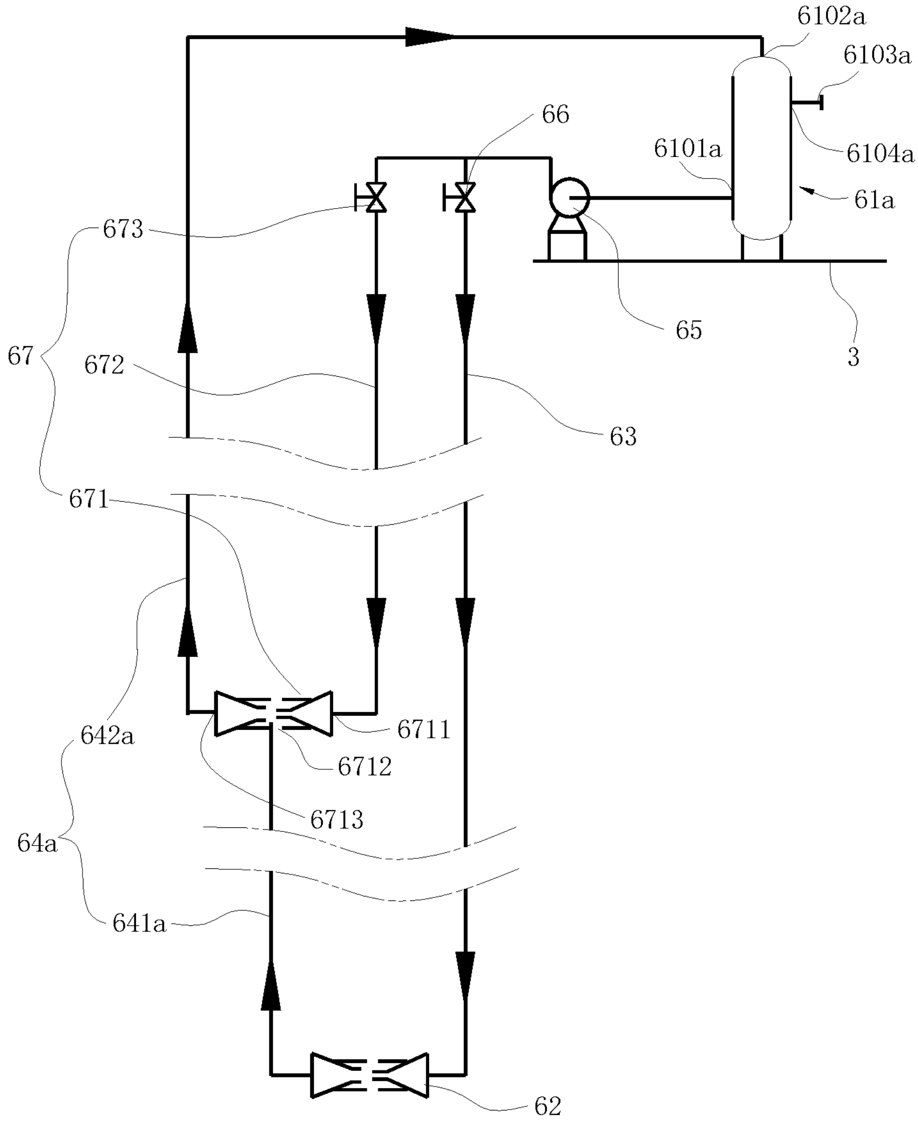


FIG. 4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6103a
66
6101a
6104a
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67
65
3
672
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671
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64a
641a
62

FIG. 5

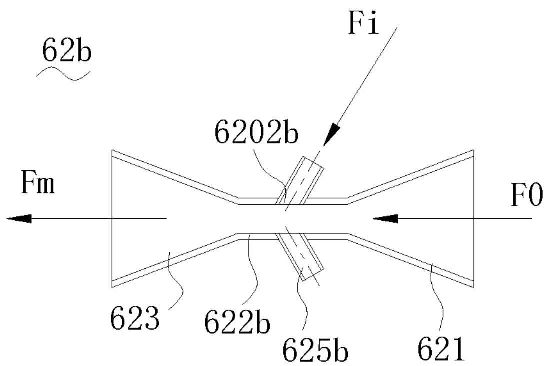
Fi
62b
6202b
Fm
F0
623
622b
625b
621

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No. **PCT/CN2020/132342**

A. CLASSIFICATION OF SUBJECT MATTER

F17C 9/00(2006.01)i; F17C 13/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F17C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT, WPI, EPODOC, CNKI: 低液位, 残液, 剩余, 低温, 卸, 抽, 文丘里, 泵, 循环, low, liquid, level, remain+, temperature, unload+, suc+, pump, venturi, circl+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 211083611 U (NANJING YANGZI PETROCHEMICAL DESIGN ENGINEERING COMPANY LTD. et al.) 24 July 2020 (2020-07-24) claims 1-11	1-11
A	CN 203248988 U (CHINA NATIONAL OFFSHORE OIL CORPORATION et al.) 23 October 2013 (2013-10-23) description, paragraphs [0011]-[0017], and figures 1-2	1-11
A	CN 207716090 U (XINXING ENERGY EQUIPMENT CO., LTD.) 10 August 2018 (2018-08-10) entire document	1-11
A	CN 208859947 U (RUSHAN CHUANGXIN NEW ENERGY TECHNOLOGY CO., LTD.) 14 May 2019 (2019-05-14) entire document	1-11
A	CN 109928497 A (HUNAN ZHONGTUO ENVIRONMENT ENGINEERING CO., LTD.) 25 June 2019 (2019-06-25) entire document	1-11
A	JP 2007024166 A (TAIYO NIPPON SANSO CORP.) 01 February 2007 (2007-02-01) entire document	1-11

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 February 2021	**08 March 2021**

Name and mailing address of the ISA/CN	Authorized officer
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Facsimile No. **(86-10)62019451**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/132342

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/132342

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN	211083611	U	24 July 2020	None	
CN	203248988	U	23 October 2013	None	
CN	207716090	U	10 August 2018	None	
CN	208859947	U	14 May 2019	None	
CN	109928497	A	25 June 2019	None	
JP	2007024166	A	01 February 2007	None	
JP	2007292180	A	08 November 2007	None	

Form PCT/ISA/210 (patent family annex) (January 2015)