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(54) **PROCESS AND SYSTEM FOR, RESPECTIVELY, THE UTILIZATION AND PROVISION OF FUEL GAS**

VERFAHREN UND SYSTEM FÜR, BEZIEHUNGSWEISE, DIE VERWENDUNG UND
BEREITSTELLUNG VON BRENNSTOFFGAS

PROCEDE ET SYSTEME SERVANT RESPECTIVEMENT A EXPLOITER ET A PRODUIRE DU GAZ
COMBUSTIBLE

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EP 0 681 671 B1

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Description

The invention relates to a process for the utilization of boil-off (decoction) from liquefied petroleum gas as fuel gas in combination with gas produced by evaporation of the liquefied petroleum gas, where the boil-off and evaporated gas are brought together and compressed.

The invention also relates to a system for carrying out the method, wherein boil-off and evaporated gas are brought together and compressed, comprising a storage tank for liquefied petroleum gas, an outlet line for decoction from the storage tank, an outlet line for liquefied gas from the storage tank, an evaporator in the outlet line for liquefied gas, a flowline (header) connected to the two outlet lines, a compressor connected to the flowline, and a pressure pipe from the compressor.

As the technical background for the invention, the point of departure is the situation currently found aboard LNG ships, i.e., ships designed to carry liquefied natural gas. Ships carrying liquefied natural gas (LNG ships) at atmospheric pressure normally are not equipped with recondensation systems. Therefore, the gas which boils off as a result of leakage of heat into the tanks, here defined as decoction (boil-off), is used as fuel gas in the ship's steam boiler. The temperature of the cargo at atmospheric pressure will be about minus 160°C for most LNG mixtures, while the gas temperature and pressure requirements at the inlet to the boiler burners are, respectively, plus 30°C and minimum 0.5 bar g. When under certain operating conditions the boil-off is not sufficient to meet the total requirement for the boiler, the gas amount may be increased by evaporating LNG, here defined as gas produced by the evaporation of the liquefied gas, which is taken directly from the tanks.

In a common arrangement today for the utilization of boil-off and gas produced by evaporation of the liquefied petroleum gas, a compressor maintains the desired tank pressure by evacuating boil-off. The boil-off will receive some heat in the tank dome and the pipe system, causing the temperature at the inlet to a separator placed in front of the compressor to be increased from minus 160°C to about minus 120°C.

The pressure increase in the compressor causes a temperature rise of about 30°C. To enable the supplying of the gas to the machine room with a temperature of about plus 30°C, a heat exchanger (heater) is installed after the compressor for further heating of the gas.

If it is necessary to increase the amount of gas supplied to the boilers, a pump suitable for this purpose is started in one of the tanks, and LNG at minus 160°C is sent on to an evaporator. Here the gas is evaporated and overheated to about minus 60°C, prior to entering said separator and mixing with the boil-off. The separator is considered necessary because LNG taken from the bottom of the tanks contains small amounts of heavier hydrocarbons which have a droplet form after the evaporation, or conceivably can condense in the inlet to

the compressor and damage it. When boil-off is used alone, the separator per se is not necessary, nor is it necessary if the temperature is sufficiently high in front of the compressor, eliminating the danger of precipitation of liquid drops.

It should be possible for the system to be run either with boil-off alone or with evaporation of LNG. The amounts will vary from 0 to 100% for both sources. If, for example, maximum gas consumption for the boilers is 5000 kg/hour and the boil-off amount is 4000 kg/hour, then 1000 kg/hour must be supplied via the evaporator. If the boil-off amount is 2000 kg/hour, then 3000 kg/hour must be supplied via the evaporator, etc. Thus, the suction temperature for the compressor could vary between the extremes of minus 60°C and minus 120°C.

An existing system of this type involves an arrangement requiring four main components, namely: an evaporator, separator, compressor and heater. The operating temperatures are such that these components must be classified as cryogenic equipment, with special requirements with regard to materials and construction. This also applies to the pipework and instrumentation.

The purpose of the present invention is to simplify the process and the system.

According to the invention, therefore, we propose a process as described in the introduction above, characterized in that the boil-off and liquefied gas prior to the compression are overheated and evaporated, respectively, in their separate sections in a combined heat exchanger and are brought together in a common mixing chamber.

With regard to the new system, it is proposed according to the invention that the aforementioned system be designed such that the evaporator is constructed as a combined heat exchanger having two separate throughflow tube bundles disposed in a common surrounding shell, one said bundle being connected to the outlet line for liquefied gas for the evaporation thereof, and the other tube bundle being connected to the outlet line for boil-off for the overheating thereof, which tubes flow into a common mixing chamber which is connected to the flowline.

By means of the invention, the process and the system are radically simplified. Because the suction temperature of the compressor is raised substantially, the separator may be omitted, and the compressor need not be cryogenic, with the special requirements for materials, construction and design associated therewith. Insulation of the pipelines may be omitted, and ice formation on the valves and expansion members is avoided. This simplification results in reduction of the amount of required space and a less complicated pipework system. The combined heat exchanger can be supplied at a price which is not substantially higher than that of each of the heat exchangers (evaporator and heater) in use today. The overall capital costs and operating expenses (including maintenance) over the lifetime of the ship will be reduced substantially.

Thermal engineering calculations indicate that it is possible to construct the combined heat exchanger with dimensions covering all conditions from 0-100% boil-off and from 0-100% evaporation. Furthermore, the apparatus may be regulated such that the gas exiting the heat exchanger maintains a temperature of plus 10°C, so that further heating of 20-30°C in the compressor will ensure that the gas supplied to the boilers has the correct temperature (and pressure).

The invention will now be explained in more detail, with reference to the drawings, where:

Fig. 1 is a purely schematic view of a known system, Fig. 2 shows a system according to the invention, and Fig. 3 shows the new combined heat exchanger with associated control system.

In Figure 1, numeral 1 designates a storage tank for liquefied petroleum gas, for example a tank for LNG aboard an LNG ship. As a result of heat penetration from the surroundings, so-called boil-off (decoction) will occur. This boil-off collects in the dome 2 of the storage tank and may be removed through an outlet line 3. This outlet line 3 runs to a separator 4, from which runs a line 5 to a compressor 6. In compressor 6 the boil-off is compressed, with an attendant increasing of the temperature. Further temperature increases take place in a heater 7, from which runs a line 8 carrying fuel gas.

Tank 1 contains liquefied natural gas having a temperature of around minus 160°. The boil-off, which is removed through line 3, will as a result of the supply of heat in dome 2 and in line 3 have a temperature of around minus 120°C at separator 4. In compressor 6 the temperature increases to about minus 90°C, and in heater 7 the temperature is increased to plus 40°C.

The system is designed in such a way that if the decoction is insufficient, i.e., if greater amounts of fuel gas are needed than the boil-off can supply, then liquefied natural gas is extracted by means of a pump 9. From this submerged pump runs outlet line 10 for liquefied gas, on to an evaporator 11. From evaporator 11 runs a line 12 to separator 4. When the evaporated gas arrives at the separator it will have a temperature of about minus 60°C.

The separator is considered necessary because the liquefied gas removed from the bottom of tank 1 after the evaporation contains small amounts of liquid drops. These can conceivably condense in the inlet of compressor 6 and damage it. For boil-off alone the separator is not necessary, nor is it necessary if the temperature is sufficiently high prior to the compressor to ensure that there is no danger of precipitation of liquid drops.

It is apparent from Figure 1 and the typical temperatures indicated therein that the operating conditions are such as to require that the components -- primarily the evaporator 11, separator 4, compressor 6 and heater 7 -- must be classified as cryogenic equipment, with

special requirements as regards materials and construction. This applies also to the pipework and instrumentation.

A schematic view of the system according to the invention is shown in Figure 2. The system is intended to be connected to a storage tank 1 with a dome 2 and submerged pump 9 and an outlet line 3 for boil-off, as well as an outlet line 10 for liquefied petroleum gas, as in the system in Figure 1.

The two outlet lines 3 and 10 are led to a combined heat exchanger 13. This has two separate tube bundles 14 and 15 in the same shell, namely a bundle 15 for the evaporation of the liquefied gas and a bundle 14 for the overheating of boil-off. Both tube bundles flow into a common mixing chamber 16. From there runs a line 17 to a compressor 18. From compressor 18 runs a fuel gas line 19.

The combined heat exchanger may be regulated such that the mixed gas in line 17 will have a temperature of plus 10°C. As a consequence hereof, the fuel gas supplied by compressor 18 will have a temperature of around 30°C. The compressor in Figure 2 may be of a normal type since the suction temperature, as mentioned above, will be high (plus 10°C instead of minus 120°C as in Figure 1).

Volume control is effected in the system in Figure 1 by means of a control valve at the inlet of evaporator 11 and by regulation of the suction volume of compressor 6.

In Figure 2 one can employ a volume control of the compressor as in Figure 1. Regulation of the combined heat exchanger 13 in Figure 2 can be carried out as exemplified in Figure 3.

In Figure 3 we again see the combined heat exchanger 13 with the two separate tube bundles 14 and 15, and the two outlet lines 3 and 10. In addition, we find flowline 17, which runs to the compressor, not shown in Figure 3.

A line 20 branches off from line 10 to the mixing chamber 16 of the combined heat exchanger.

Quadrangle 21 represents a temperature control. Quadrangle 22 represents a flow control. The flow control directs a control valve 23 in the boil-off line 3 as well as a control valve 24 in line 10. Both of these control loops will in practice be integrated in a common data processor which also handles the other control functions in the system.

Temperature control out from the combined heat exchanger is carried out here by means of injection of liquefied petroleum gas through line 20 in mixing chamber 16 when the heat exchanger is working with both overheating of boil-off and the evaporation of liquefied gas. In heating of boil-off only, the temperature is controlled by means of pressure adjustment of the supply of vapour through line 25. Condensate is eliminated through line 26.

The invention is not limited to LNG as gas. Other liquefied gases, the boil-off of which is suitable for fuel/power fuel gas, could of course derive benefit from the

invention.

Claims

1. A process for the utilization of decoction (boil-off) from liquefied petroleum gas as fuel gas in combination with gas produced by evaporation of the liquefied gas, where boil-off and evaporated gas are brought together and compressed,

characterized in that the boil-off and the liquefied gas prior to the compression are overheated and evaporated, respectively, in their separate sections of a combined heat exchanger and are brought together in a common mixing chamber.

2. A system for carrying out the process according to claim 1, where boil-off and evaporated gas are brought together and compressed, comprising

a storage tank (1) for liquefied petroleum gas, an outlet line (3) for boil-off from the storage tank, an outlet line (10) for liquefied petroleum gas from the storage tank (1), an evaporator (13) in the outlet line (10) for liquefied gas, a flowline (17) connected to the two outlet lines (3, 10), a compressor (18) connected to the flowline, and a pressure line (19) from the compressor,

characterized in that the evaporator (13) is designed as a combined heat exchanger (13) having two separate throughflow tube bundles (14, 15) in a common surrounding shell, one said bundle (15) being connected to the outlet line (10) for liquefied petroleum gas for the evaporation thereof, and the other bundle (14) being connected to the outlet line (3) for boil-off for the overheating thereof, which tube bundles (14, 15) flow into a common mixing chamber (16) connected to the flowline (17).

3. A system according to claim 2, **characterized in that** from the outlet line (10) for liquefied petroleum gas from the storage tank (1) there is provided a valve regulated line (20) to the common mixing chamber (16).

Patentansprüche

1. Verfahren zur Verwendung von Dekoktion (Abgekochtem) aus verflüssigtem Petroleumgas zusammen mit Gas, das durch Verdampfen des verflüssigten Gases hergestellt wurde als Brennstoffgas, wobei abgekochtes und verdampftes Gas zusammengebracht und verdichtet werden,

mengebracht und verdichtet werden,

dadurch gekennzeichnet, daß das abgekochte und das verflüssigte Gas in ihren getrennten Bereichen eines Kombinationswärmetauschers vor der Verdichtung überhitzt bzw. verdampft und in einer gemeinsamen Mischkammer zusammengebracht werden.

2. System zur Durchführung des Verfahrens nach Anspruch 1,

wobei abgekochtes und verdampftes Gas zusammengebracht und verdichtet werden, umfassend einen Lagertank (1) für verflüssigtes Petroleumgas, eine Auslaßleitung (3) für Abgekochtes aus dem Lagertank, eine Auslaßleitung (10) für verflüssigtes Petroleumgas aus dem Lagertank (1), einen Verdampfer (13) in der Auslaßleitung (10) für verflüssigtes Gas, eine mit den zwei Auslaßleitungen (3, 10) verbundene Strömungsleitung (17), einen mit der Strömungsleitung verbundenen Kompressor (18), und eine Druckleitung (19) aus dem Kompressor,

dadurch gekennzeichnet, daß der Verdampfer (13) als ein Kombinationswärmetauscher (13) ausgebildet ist, der zwei getrennte Durchflußröhrenbündel (14, 15) in einer gemeinsamen, umgebenden Hülle aufweist, wobei ein Bündel (15) mit der Auslaßleitung (10) für verflüssigtes Petroleumgas zu dessen Verdampfung verbunden ist und das andere Bündel (14) mit der Auslaßleitung (3) für Abgekochtes zu dessen Überhitzung verbunden ist, wobei die Röhrenbündel (14, 15) in eine gemeinsame Mischkammer (16) enden, die mit der Strömungsleitung (17) verbunden ist.

3. System nach Anspruch 2, **dadurch gekennzeichnet**, daß eine über ein Ventil gesteuerte Leitung (20) von der Auslaßleitung (10) für verflüssigtes Petroleumgas aus dem Lagertank (1) zu der gemeinsamen Mischkammer (16) vorgesehen ist.

Revendications

1. Procédé pour l'utilisation d'une décoction (gaz extrait par ébullition) de gaz de pétrole liquéfié en tant que gaz combustible en combinaison avec du gaz produit par évaporation du gaz liquéfié dans lequel les gaz chassés par ébullition et évaporés sont mélangés et comprimés, caractérisé en ce que le gaz chassé par ébul-

lition et le gaz liquéfié, avant la compression, sont surchauffés et évaporés, respectivement, dans leurs sections réparées d'un échangeur thermique combiné et ils sont introduits ensemble dans une chambre mélangeuse commune.

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2. Système pour la mise en oeuvre du procédé selon la revendication 1 dans lequel le gaz chassé par ébullition et le gaz évaporé sont mélangés et comprimés, comprenant :

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- un réservoir de stockage (1) pour du gaz de pétrole liquéfié,
- une conduite d'évacuation (3) pour le gaz chassé par ébullition du réservoir de stockage,
- une conduite d'évacuation (10) pour le gaz de pétrole liquéfié provenant du réservoir de stockage (1),
- un évaporateur (13) dans la conduite d'évacuation (10) pour le gaz liquéfié,
- une conduite d'écoulement (17) connectée aux deux conduites d'évacuation (3, 10),
- un compresseur (18) connecté à la conduite d'écoulement et,
- une conduite sous pression (19) provenant du compresseur,

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caractérisé en ce que l'évaporateur (13) est conçu sous la forme d'un échangeur thermique combiné (13) présentant deux faisceaux de tube de circulation de flux séparés (14, 15) dans une enveloppe commune les entourant, l'un desdits faisceaux (15) étant connecté à la conduite d'évacuation (10) du gaz de pétrole liquéfié en vue de l'évaporation de ce dernier et l'autre faisceau (14) étant connecté à la conduite d'évacuation (3) du gaz chassé par ébullition pour le surchauffage de ce dernier, lesquels faisceaux de tubes (14, 15) débouchent dans une chambre mélangeuse commune (16) connectée à la conduite de circulation (17).

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3. Système selon la revendication 2 caractérisé en ce que l'on prévoit une conduite (20) régulée par une vanne menant à la chambre mélangeuse commune (16), à partir de la conduite d'évacuation (10) pour le gaz de pétrole liquéfié provenant du réservoir de stockage (1).

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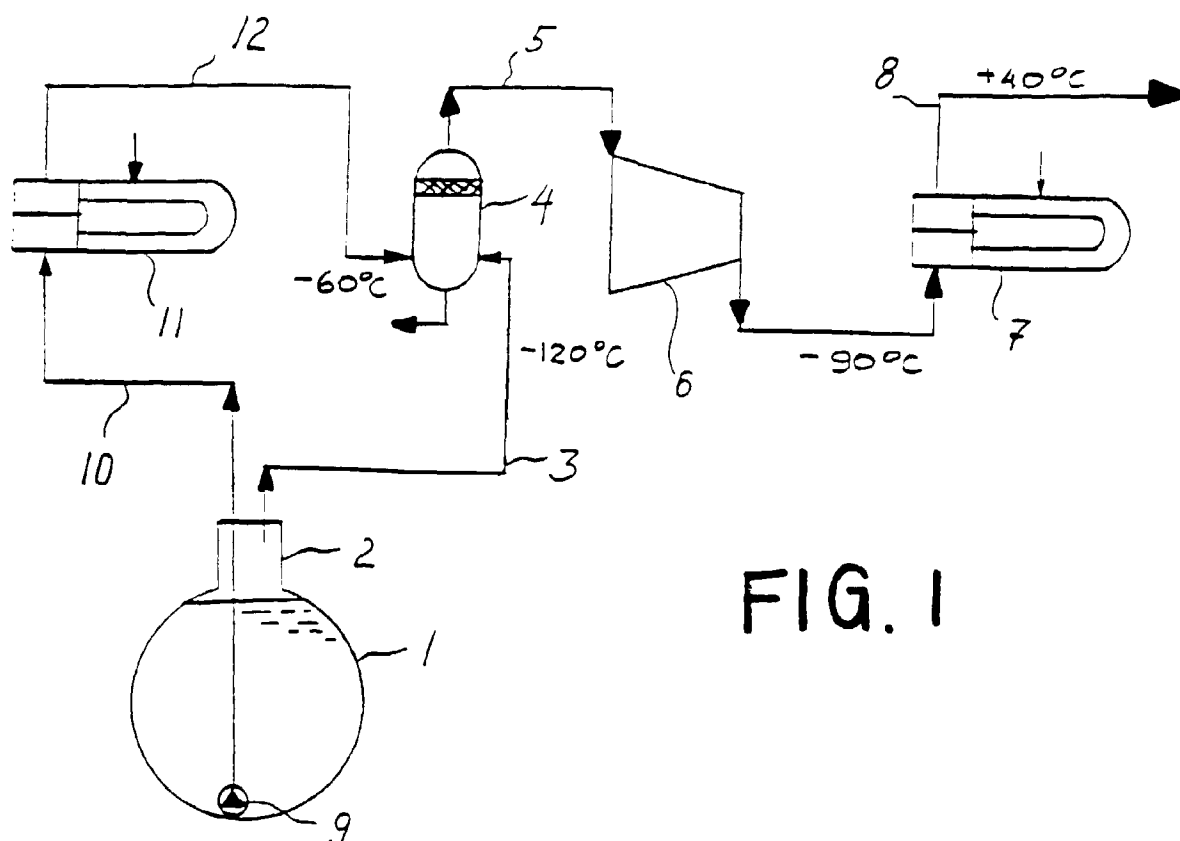


FIG. 1

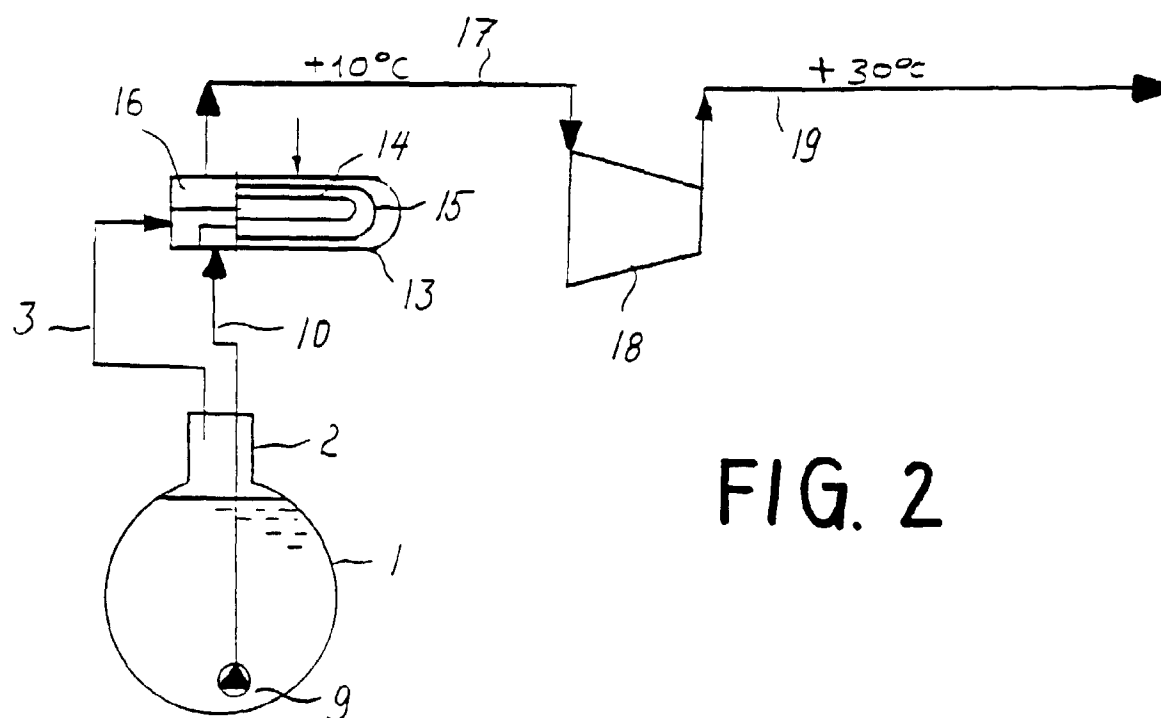


FIG. 2

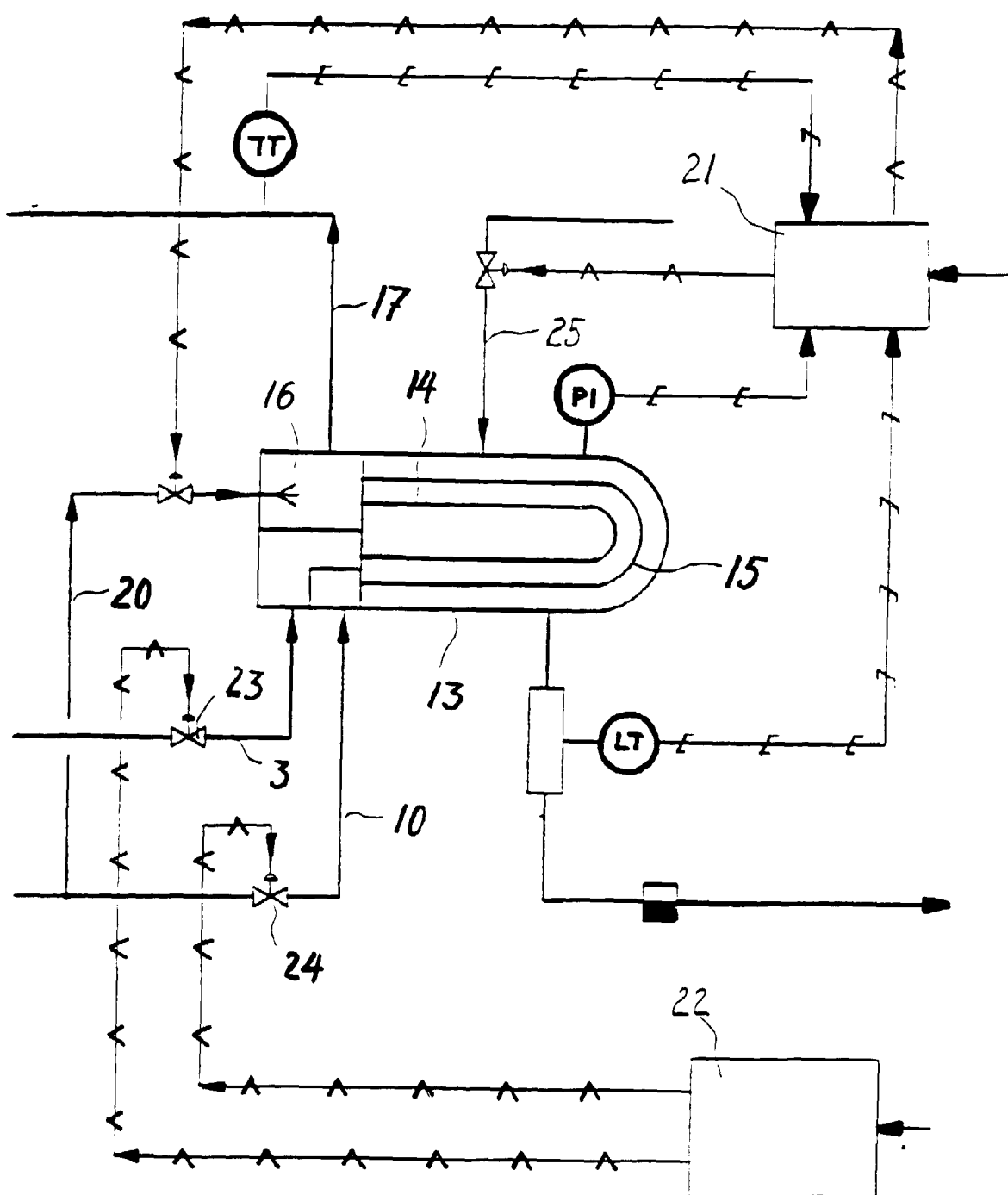


FIG. 3