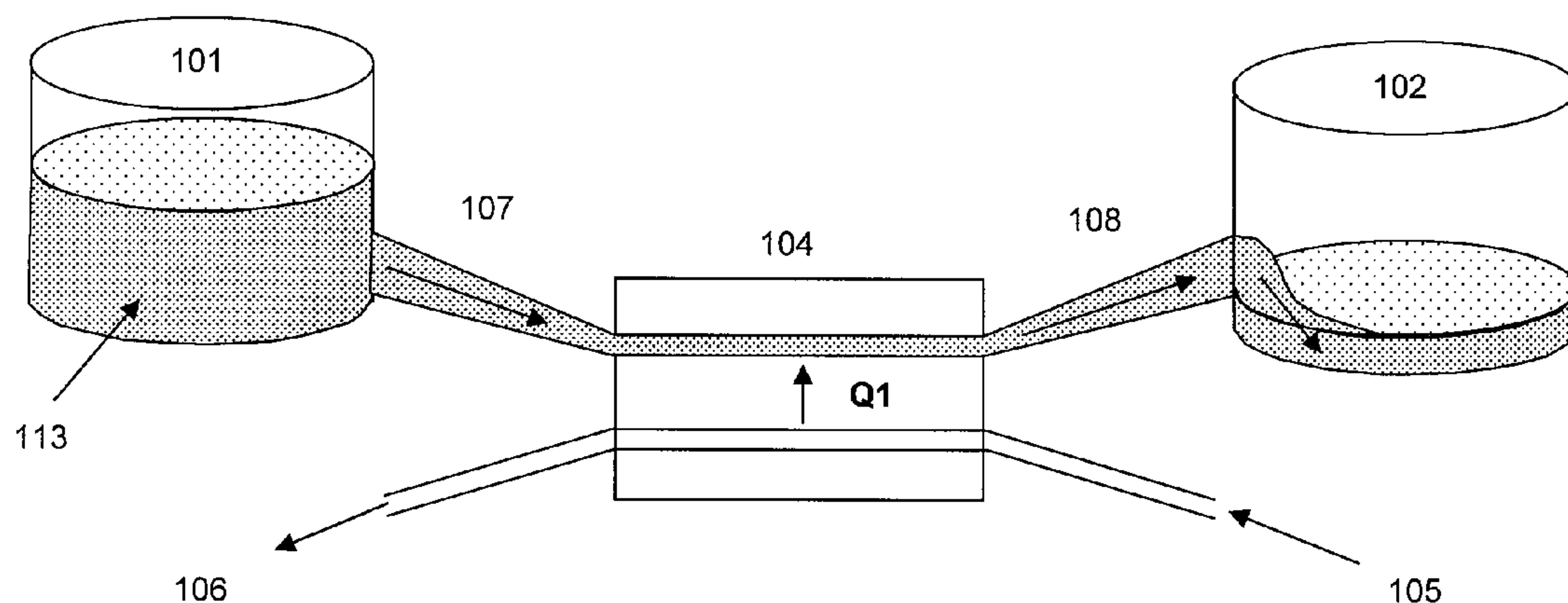




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(19) **United States**(12) **Patent Application Publication**
LaForce(10) **Pub. No.: US 2012/0180988 A1**(43) **Pub. Date: Jul. 19, 2012**(54) **MOVING THERMAL BED TO TIME SHIFT
LIQUIFACTION AND VAPORIZATION****Publication Classification**(51) **Int. Cl.**
F28D 15/00 (2006.01)(52) **U.S. Cl.** **165/104.13**(57) **ABSTRACT**

A method to store and utilize thermal energy is provided. During a first phase, transferring heat from the heat relocation media to the lower temperature reservoir, transferring heat from the higher temperature stream to the heat relocation media, and transferring heat from the heat relocation media to the high temperature reservoir, thereby at least partially liquefying the higher temperature stream. During a second phase, transferring heat from the higher temperature reserve to the heat relocation media, transferring heat from the heat relocation media to the lower temperature stream, and transferring heat from the heat relocation media to the lower temperature reservoir, thereby at least partially vaporizing the lower temperature stream.

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(US)(21) Appl. No.: **13/332,457**(22) Filed: **Dec. 21, 2011****Related U.S. Application Data**(60) Provisional application No. 61/434,088, filed on Jan.
19, 2011.**First Phase**

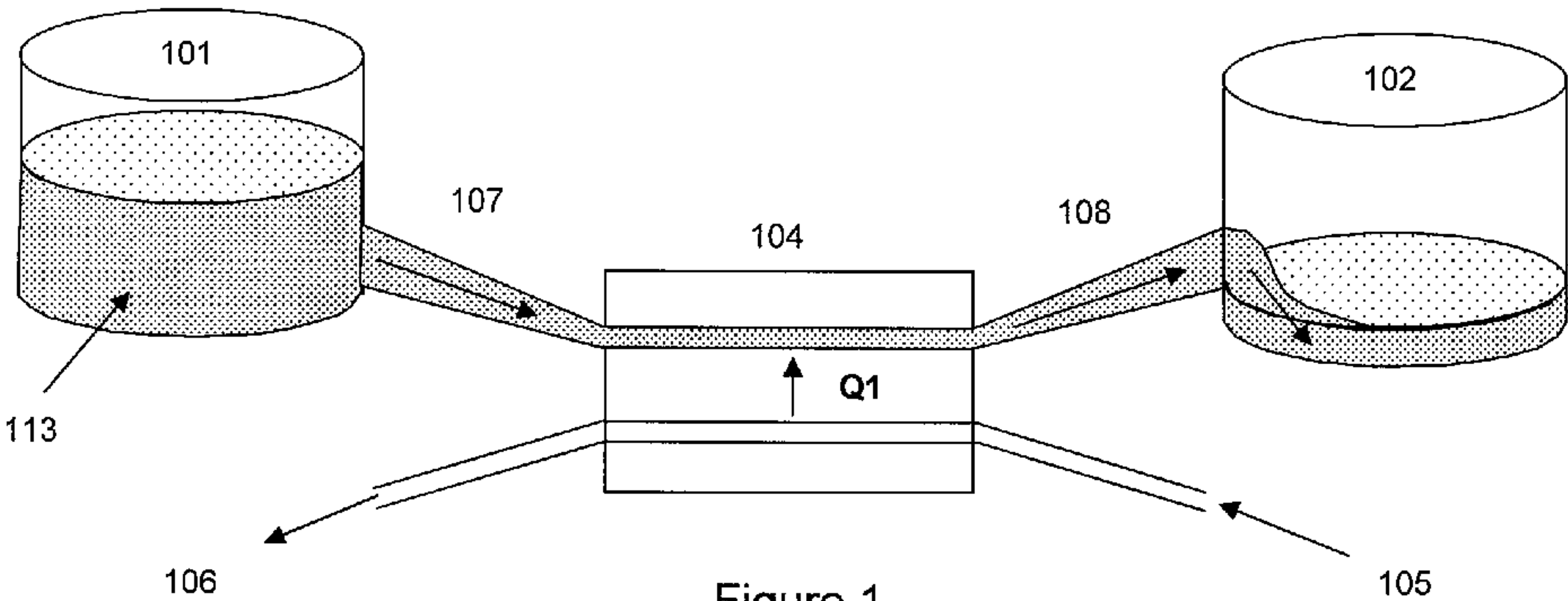


Figure 1

First Phase

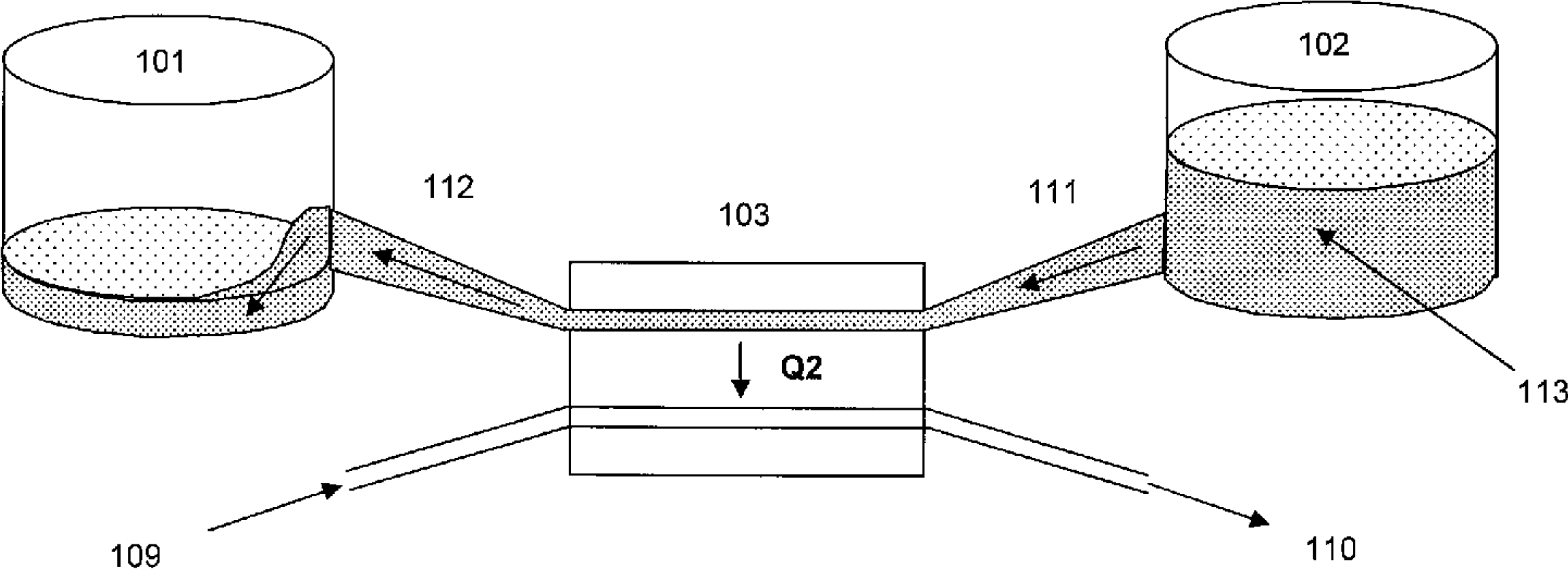


Figure 2

Second Phase

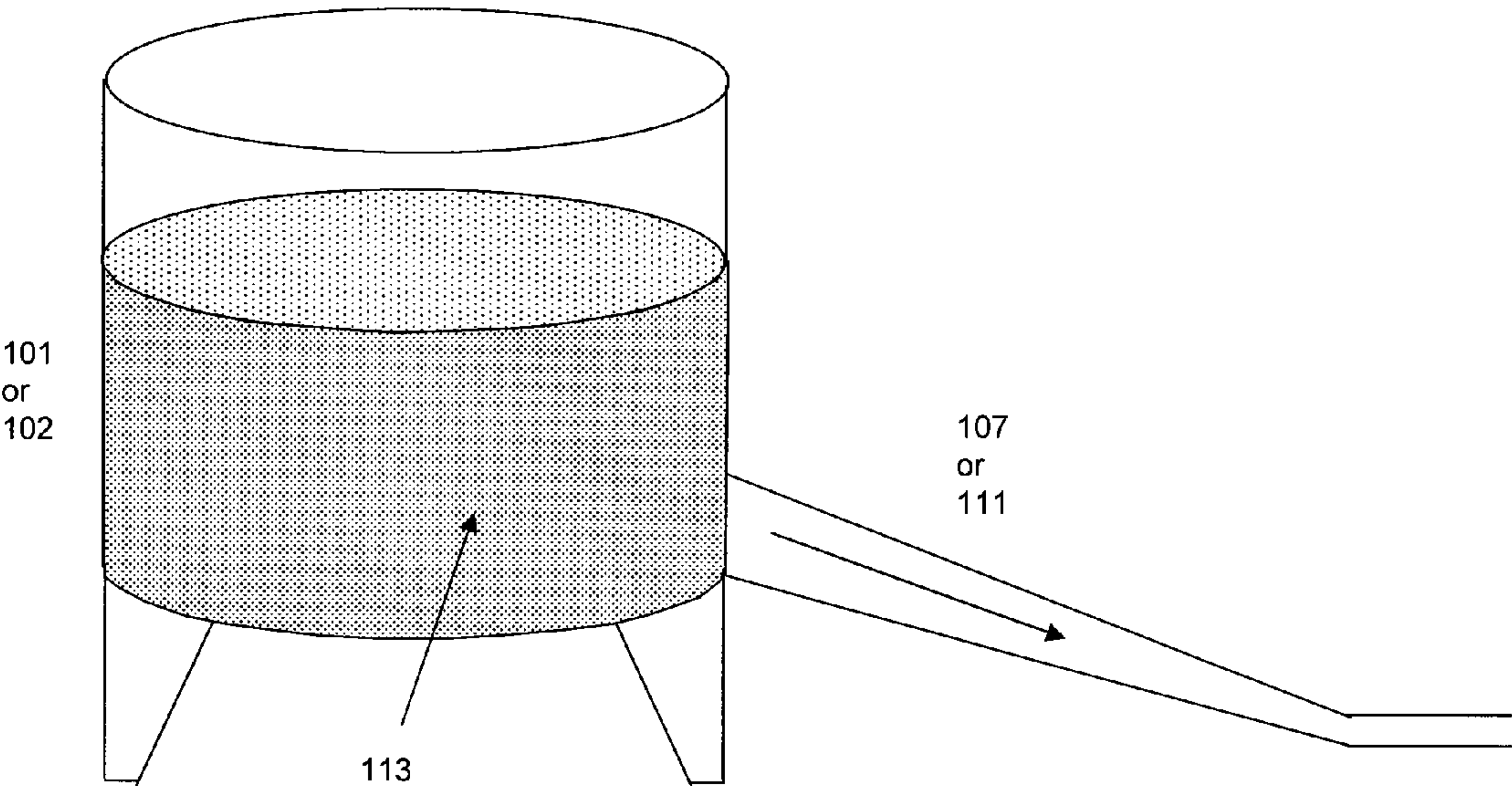


Figure 3

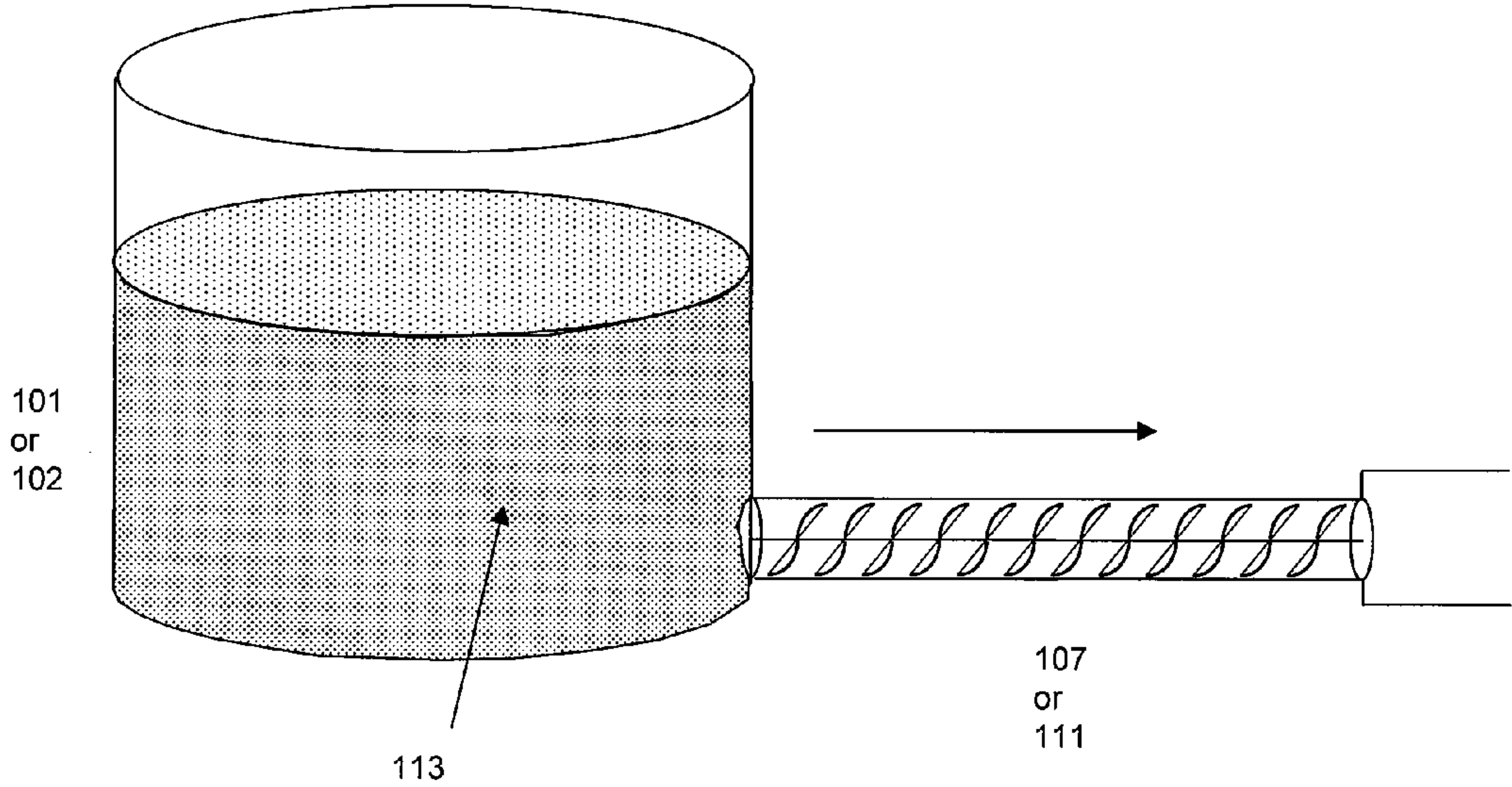
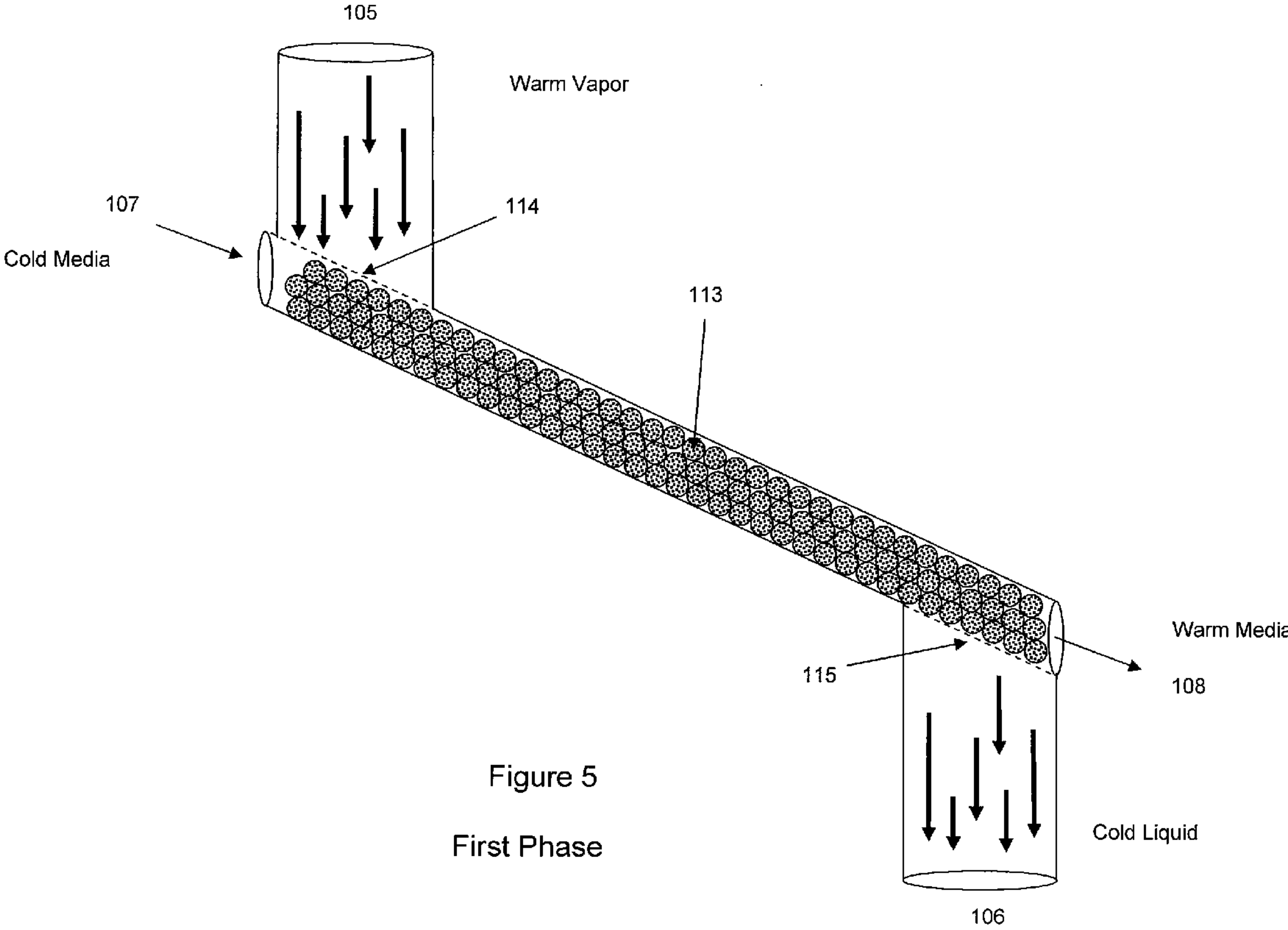


Figure 4



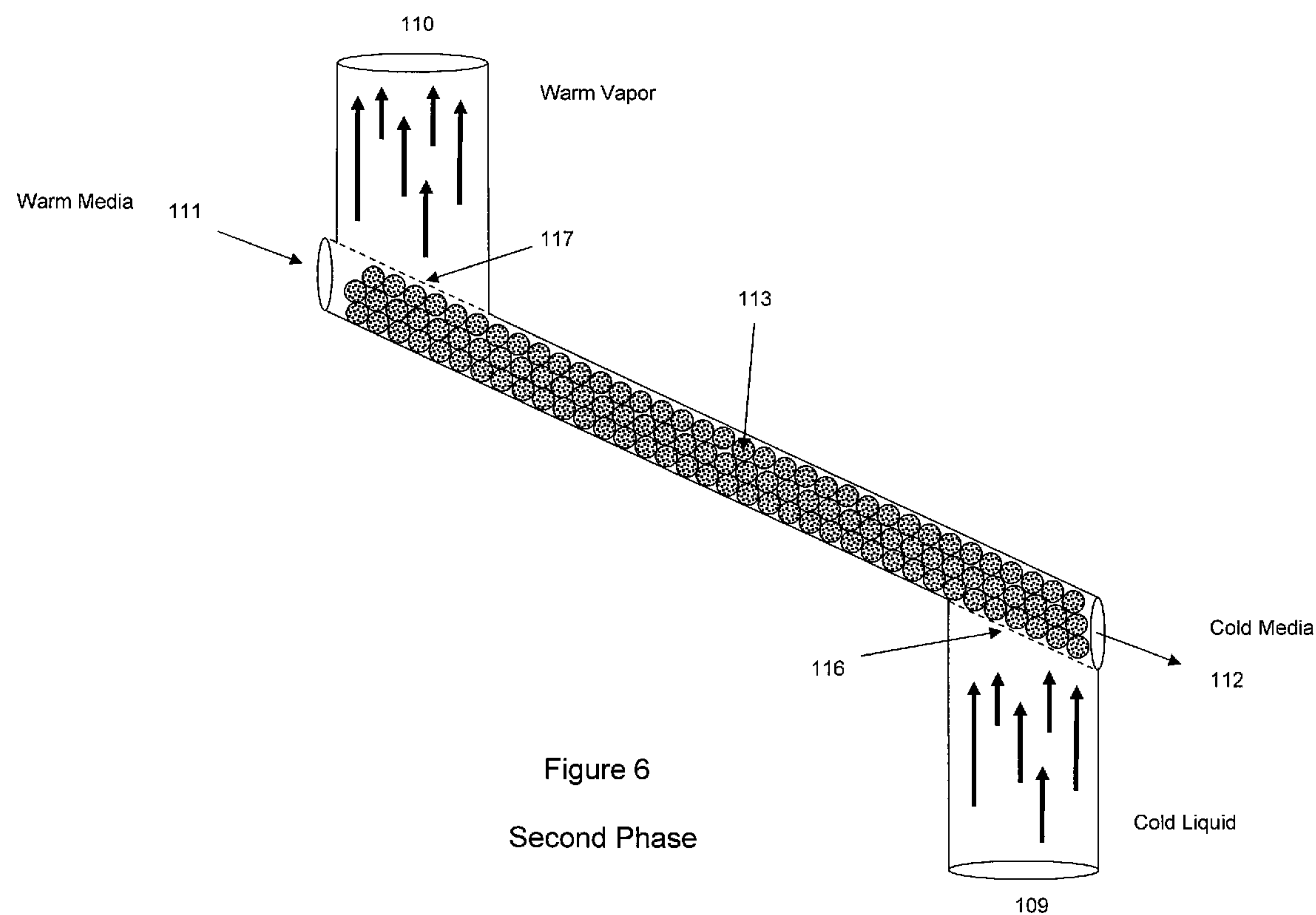


Figure 6
Second Phase

MOVING THERMAL BED TO TIME SHIFT LIQUIFACTION AND VAPORIZATION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit under 35 U.S.C. §119(e) to provisional application No. 61/434,088, filed Jan. 19, 2011, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] Currently, when a cycle contains vaporization and liquefaction, they are simultaneous and dependent upon one another. The present invention allows a liquefier to operate for a period of time, typically around 12 to 24 hours and store liquid product during times when power is plentiful and cheap-. This liquid would then be re-vaporized during times when power is expensive and possibly used to expand through a generator to return the stored power to the grid. The proposed invention provides a way to store thermal energy at the warm and cold end liquefier temperatures, and provides a means of providing an efficient thermal liquefaction and re-vaporization profile at these different times.

SUMMARY

[0003] A method to store and utilize thermal energy is provided. This method includes providing a heat relocation media. Also providing a higher temperature stream and a lower temperature stream, providing a heat transfer means between the higher temperature stream and the heat relocation media, and providing a heat transfer means between the lower temperature stream and the heat relocation media. Also providing a higher temperature reservoir and a lower temperature reservoir, providing a heat transfer means between the heat relocation media and the higher temperature reservoir, and providing a heat transfer means between the heat relocation media and the lower temperature reservoir. During a first phase, transferring heat from the heat relocation media to the lower temperature reservoir, transferring heat from the higher temperature stream to the heat relocation media, and transferring heat from the heat relocation media to the high temperature reservoir, thereby at least partially liquefying the higher temperature stream. During a second phase, transferring heat from the higher temperature reserve to the heat relocation media, transferring heat from the heat relocation media to the lower temperature stream, and transferring heat from the heat relocation media to the lower temperature reservoir, thereby at least partially vaporizing the lower temperature stream

BRIEF DESCRIPTION OF DRAWINGS

[0004] The invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, and in which:

[0005] FIG. 1 illustrates a first phase of operation, in accordance with one embodiment of the present invention.

[0006] FIG. 2 illustrates a second phase of operation, in accordance with another embodiment of the present invention.

[0007] FIG. 3 illustrates a gravity feed scheme, in accordance with another embodiment of the present invention.

[0008] FIG. 4 illustrates an auger fed scheme, in accordance with another embodiment of the present invention.

[0009] FIG. 5 illustrates a first phase of operation, in accordance with one embodiment of the present invention.

[0010] FIG. 6 illustrates a second phase of operation, in accordance with another embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0011] Illustrative embodiments of the invention are described below. While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

[0012] It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0013] Turning to FIGS. 1 and 2, which in the interest of clarity retains the same element numbers, which illustrates one embodiment of the present invention, a lower temperature reservoir 101, and a higher temperature reservoir 102 are provided. Lower temperature stream 109 is thermodynamically linked Q2 to lower temperature reservoir 101 by means of first heat exchanger 103. Higher temperature stream 105 is thermodynamically linked Q1 to higher temperature reservoir 102 by means of second heat exchanger 104.

[0014] FIG. 1 illustrates a first phase of operation. During this first phase, higher temperature stream 105 is introduced into second heat exchanger 104.

[0015] Lower temperature reservoir 101, which in this case acts as a cold source, providing cold stream 107. Cold stream 107 is introduced into second heat exchanger 104, wherein it exchanges heat indirectly Q1 with higher temperature stream 105, thereby producing a cooler stream 106, and a warmer stream 108. Warmer stream 108 is then introduced into high temperature reservoir 102. Cooler stream 106 may be at least partially liquefied. Higher temperature stream 105 may be essentially pure oxygen, essentially pure nitrogen or air.

[0016] FIG. 2 illustrates a second phase of operation. During this second phase, lower temperature stream 109 is introduced into first heat exchanger 103. Higher temperature reservoir 102, which in this case acts as a heat source, providing hot stream 111. Hot stream 111 is introduced into first heat exchanger 103, wherein it exchanges heat indirectly Q2 with lower temperature stream 109, thereby producing a warmer stream 110, and a cooler stream 112. Cooler stream 112 is then introduced into low temperature reservoir 101. Warmer stream 110 may be at least partially vaporized. Lower temperature stream 109 may be essentially pure oxygen, essentially pure nitrogen or air.

[0017] The first phase and the second phase may occur concurrently. In another embodiment, the first phase and the second phase do not occur concurrently, but are offset in time.

[0018] In one embodiment, a heat relocation media is used to store and utilize the thermal energy being transferred in this method. In one embodiment, cold stream 107 and/or hot stream 111 consists of a heat relocation media 113. The heat relocation media 113 may comprise a solid heat transfer media. The solid heat transfer media may be metal particles, carbon particles, pebbles, sand, shot, or ceramic particles. The solid heat transfer media may comprise solid or hollow spheres. The solid spheres may be made of ceramic, glass, or quartz. The hollow spheres may be comprised ceramic, glass, or quartz. The solid heat transfer media may comprise solid metal spheres. The metal may be steel, bronze, brass, iron, or copper. FIG. 3 illustrates an example of one possible embodiment, wherein the heat relocation media 113 is gravity fed. FIG. 4 illustrates an example of one possible embodiment, wherein the heat relocation media 113 is transported by means of an auger.

[0019] Referring to FIG. 5, during the first phase, cold stream 107 may consist of a heat relocation media 113. In this non-limiting example, the heat relocation media 113 is depicted as balls (either hollow or solid), but as discussed above, other alternatives are possible. The heat relocation media 113 may be moved along by means of gravity (as illustrated), an auger, or any other means known in the art. In this embodiment, higher temperature stream 105 (which may be a gas) enters into the top of second heat exchanger 104, wherein it passes through a first perforated region 114 which allows the high temperature stream 105 to pass through, but does not allow passage of the heat relocation media 113. Higher temperature stream 105 comes into direct contact with the heat relocation media 113. Cold heat relocation media 107 are heated up to form warmer stream 108, and the higher temperature stream 105 is cooled, and may be at least partially condensed, to form cooler stream 106. Cooler stream 106 then passes through a second perforated region 115 which allows the warm heat relocation media 108 to continue, but allows the cooler stream 106 to be separated. At this time, warm heat relocation media 108 are transported to higher temperature reservoir 102, which serves as a heat sink and stores the captured heat for later usage.

[0020] Referring to FIG. 6, lower temperature stream 109 (which may be a liquid) enters into the bottom of first heat exchanger 103. Lower temperature stream 109 comes into direct contact with the heat relocation media 113. Lower temperature stream 109 then passes through a third perforated region 116 which allows the lower temperature stream 109 to pass through, but does not allow passage of the heat relocation media 113. Hot stream 111 are cooled down to form colder stream 112, and the lower temperature stream 109 is heated, and may be at least partially vaporized, to form warmer stream 110. Warmer stream 110 then passes through a perforated region 117 which allows the warmer stream 110 to pass through, but does not allow passage of the heat relocation media 113. At this time, cold heat relocation media 112 are transported to lower temperature reservoir 101, which serves as a cold sink and stores the captured cold for later usage. This allows the vaporizing and liquefying stages to be decoupled, thereby allowing more flexibility in the system to accommodate varying demands.

What is claimed is:

1. A method to store and utilize thermal energy, comprising:
 - providing a higher temperature stream, and a lower temperature stream,
 - providing a higher temperature reservoir,
 - during a first phase,
 - transferring heat from said higher temperature stream to said high temperature reservoir, thereby at least partially liquefying said higher temperature stream; and
 - during a second phase,
 - transferring heat to said lower temperature stream from said higher temperature reservoir, thereby at least partially vaporizing said lower temperature stream
2. The method of claim 1, wherein said lower temperature stream is selected from the group consisting of essentially pure oxygen, essentially pure nitrogen, air.
3. The method of claim 1, wherein said higher temperature stream is selected from the group consisting of essentially pure oxygen, essentially pure nitrogen, air.
4. The method of claim 1, wherein said first phase and said second phase do not occur concurrently.
5. The method of claim 1, wherein said first phase and said second phase occur concurrently.
6. A method to store and utilize thermal energy, comprising:
 - providing a heat relocation media,
 - providing a higher temperature stream, and a lower temperature stream,
 - providing a heat transfer means between said higher temperature stream and said heat relocation media,
 - providing a heat transfer means between said lower temperature stream and said heat relocation media,
 - providing a higher temperature reservoir and a lower temperature reservoir,
 - providing a heat transfer means between said heat relocation media and said higher temperature reservoir,
 - providing a heat transfer means between said heat relocation media and said lower temperature reservoir,
 - during a first phase,
 - transferring heat from said heat relocation media to said lower temperature reservoir,
 - transferring heat from said higher temperature stream to said heat relocation media,
 - transferring heat from said heat relocation media to said high temperature reservoir, thereby at least partially liquefying said higher temperature stream; and
 - during a second phase,
 - transferring heat from said higher temperature reserve to said heat relocation media,
 - transferring heat from said heat relocation media to said lower temperature stream,
 - transferring heat from said heat relocation media to said lower temperature reservoir, thereby at least partially vaporizing said lower temperature stream.
7. The method of claim 6, wherein said heat relocation media comprises a solid heat transfer media.
8. The method of claim 7, wherein said solid heat transfer media is selected from the group consisting of metal particles, carbon particles, pebbles, sand, shot, and ceramic particles.
9. The method of claim 7, wherein said solid heat transfer media comprise solid spheres.
10. The method of claim 7, wherein said solid heat transfer media comprise hollow spheres.

11. The method of claim **9**, wherein said solid spheres are comprised of a material selected from the group consisting of ceramic, glass, or quartz.

12. The method of claim **10**, wherein said hollow spheres are comprised of a material selected from the group consisting of ceramic, glass, or quartz.

13. The method of claim **9**, wherein said solid heat transfer media comprises solid metal spheres.

14. The method of claim **9**, wherein said metal is selected from the group consisting of steel, bronze, brass, iron, and copper.

15. The method of claim **6**, wherein said lower temperature stream is selected from the group consisting of essentially pure oxygen, essentially pure nitrogen, air.

16. The method of claim **6**, wherein said higher temperature stream is selected from the group consisting of essentially pure oxygen, essentially pure nitrogen, air.

17. The method of claim **6**, wherein said first phase and said second phase do not occur concurrently.

18. The method of claim **6**, wherein said first phase and said second phase occur concurrently.

19. The method of claim **6**, wherein the amount of heat transferred from said higher temperature stream to said heat relocation media is greater than the amount of heat transferred from said heat relocation media to said lower temperature stream.

20. The method of claim **6**, wherein the amount of heat transferred from said higher temperature stream to said heat relocation media is less than the amount of heat transferred from said heat relocation media to said lower temperature stream.

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