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HEAT EXCHANGE APPARATUS AND METHOD

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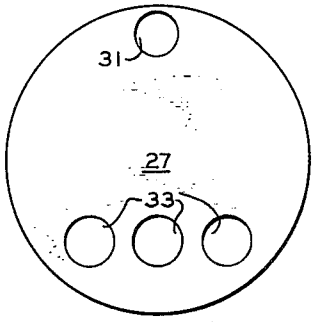

FIG. 5

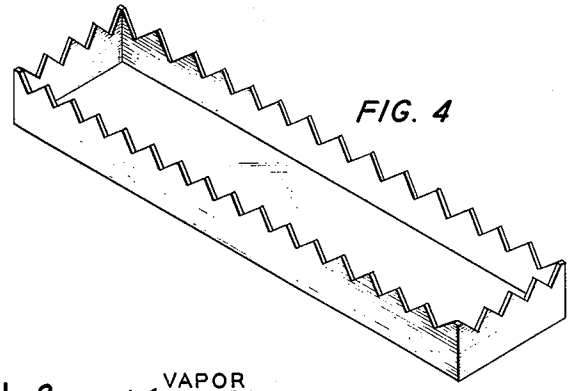

FIG. 4

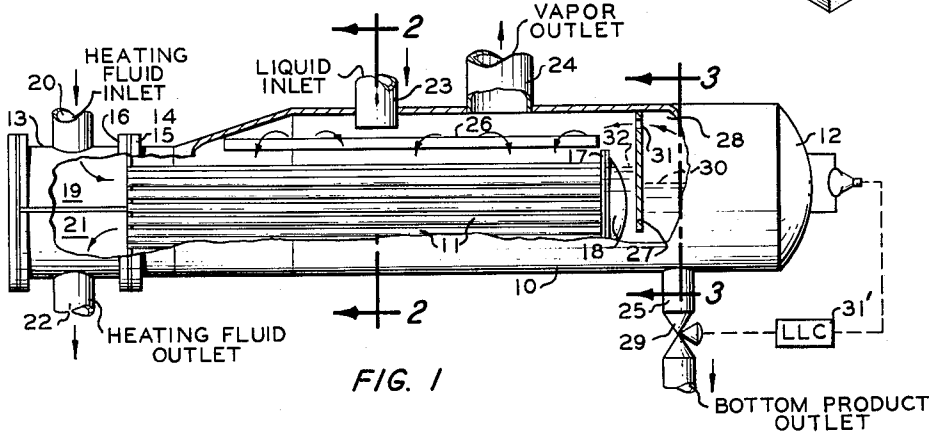

FIG. 1

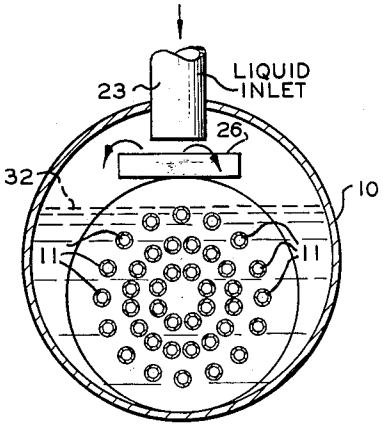

FIG. 2

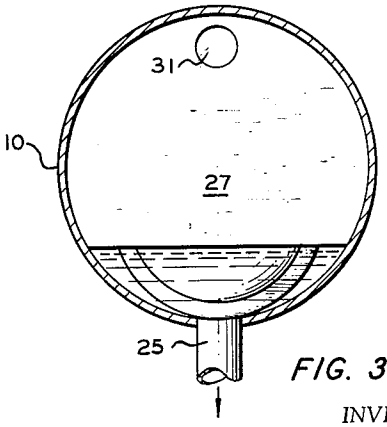

FIG. 3

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HEAT EXCHANGE APPARATUS AND METHOD

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This invention relates, in general, to apparatus and method for the heat exchange of liquids. More particularly, this invention relates to heat exchange apparatus of a tube-shell type wherein the liquid to be heated is partally vaporized in the shell of said heat exchange aparatus. In one aspect, this invention relates to an improved reboiler for use with a fractionation tower. In another aspect, this invention relates to an improved fractionation process.

In many heat transfer operations, it is desirable to subject a liquid to indirect heat exchange in order to vaporize a portion of the liquid for the purpose of either separating and recovering the vaporized portion or concentrating the liquid from which a portion has been vaporized. In either type operation, it is necessary, in order to provide an economical process, that the liquid feed not be subjected to any higher temperature than is necessary to effect vaporization of the desired portion of the feed; that is, the vapor evolved from the liquid feed should not be superheated because the heat carried away in such superheated vapor is lost from the heat exchange process. If the amount of heat lost in such superheated vapor is very large, the heat exchange process is very uneconomical.

In many conventional fractionating processes, a feed stream is fed into a vapor-liquid contacting device or tray located between the upper and lower ends of a vertical column. Although some heat may be supplied to the liquid feed before entering the column, it is necessary to supply heat in some manner to the lower section of the column if fractionating action is to occur on the trays below the point of introduction of the feed. It is standard practice to supply such heat by withdrawing a portion of the liquid from the bottom of the fractionation column and returning it to some elevated point in the column as the vapor, thereby supplying heat to the lower section of the column. It is desirable that the vapor not be returned to the column in a superheated condition because the vapor-liquid equilibrium existing on the trays to which the vapor is returned would be upset. The vaporization of the liquid withdrawn from the bottom of the column is often effected, as standard practice in the art, in a horizonally disposed heat exchanger of the tube and shell type wherein the liquid withdrawn is vaporized in the shell of the heat exchanger by the transfer of heat from a heat exchange liquid circulated in the tubes. In such aparratus, it is difficult to avoid superheating the vapor to be returned to the fractionation column.

An object of this invention is to provide shell-tube type heat exchange apparatus and method wherein liquid is vaporized in the shell of said apparatus without superheating. Another object of this invention is to provide a horizontally disposed heat exchange apparatus of the shell and tube type wherein vapor binding around the tubes is eliminated. Another object of this invention is the provision of a liquid outlet accumulator disposed in a horizontal heat exchange apparatus of the shell and tube type to effect control of the level of the liquid being vaporized within the shell of said apparatus. Another object of this invention is the provision of a feed distributor disposed above the tubes in a horizontal heat exchange apparatus of the shell and tube type to form a curtain of liquid feed for contacting the vapors evolved from the liquid being heated. Another object of this invention is to provide an improved fractionation process utilizing an external reboiler.

Other aspects, objects and advantages of the invention are apparent from a consideration of the accompanying disclosure, drawings and the appended claims.

In accordance with this invention, heat exchange apparatus of the shell and tube type is provided for vaporizing a portion of the liquid to be heated within the shell of said apparatus, said apparatus comprising, in combination, a horizontally disposed shell, a plurality of heat exchange tubes located in the lower portion of said shell and adapted for the circulation of the heat exchange fluid therethrough, a liquid feed inlet means located in the top of said shell, a liquid feed distributing means horizontally disposed above said heat exchange tubes in the vapor space between said tubes and said shell and adapted to receive said liquid feed and to provide a curtain of liquid feed for contacting the vapors evolved from the liquid being heated, and a vapor outlet means located in the top of said shell, and a liquid collecting zone disposed within the shell of said apparatus adjacent one end of said heat exchange tubes and having a liquid outlet means for withdrawing from said apparatus heated liquid and adapted for controlling the level of liquid maintained in contact with said heat exchange tubes.

In accordance with another concept of this invention, there is provided a vertically disposed baffle in a horizontally disposed heat exchange apparatus of the shell-tube type wherein a liquid which is fed into said apparatus through the top thereof is heated and a portion vaporized in the shell of said apparatus by the circulation of a heat exchange fluid through heat exchange tubes submerged in a body of said liquid maintained in said apparatus and the vapors evolved are withdrawn from the top thereof, said baffle dividing said heat exchange apparatus into a heat exchange zone and a liquid collecting zone, said baffle having a first opening in the lower portion thereof, permitting the flow of heated liquid from said heat exchange zone into said liquid collecting zone and a second opening in the upper portion thereof, permitting the flow of vapor from said liquid collecting zone into said heat exchange zone.

In accordance with another concept of this invention, there is provided a liquid collecting zone within a horizontally disposed heat exchange apparatus of the shell-tube type wherein a liquid which is fed into said apparatus through the top thereof is heated and a portion vaporized in the shell of said apparatus by the circulation of a heat exchange fluid through heat exchange tubes submerged in a body of said liquid maintained in said apparatus and the vapors evolved are withdrawn from the top thereof, said liquid collecting means having a liquid outlet means for the removal of liquid heated in said apparatus and collected in said liquid collecting zone and liquid level control outlets located in the top and bottom of said liquid collecting zone for controlling the level of liquid in the liquid collecting zone and thereby controlling the level of the liquid being heated to prevent superheating of the vapors evolved.

In accordance with another concept of this invention,

there is provided a liquid feed distributor tray means in a horizontally disposed heat exchange apparatus of the shell-tube type for contacting the vapors evolved from the liquid heated in the shell of said heat exchange apparatus with a shower of entering liquid feed in order to prevent superheating the vapors evolved from said liquid, said liquid feed distributor tray means being horizontally disposed above the heat exchange tubes adjacent the top of the shell of said heat exchange apparatus. In a preferred embodiment, the liquid feed distributor tray means has serrated vertical walls and extends the substantial length of the heat exchange zone.

In accordance with another concept of the invention, there is provided a method of preventing superheating of vapors evolved in a horizontally disposed heat exchange apparatus of the shell-tube type wherein a liquid is vaporized by circulation of a heat exchange liquid through heat exchange tubes submerged in said liquid, said method comprising controlling the level of liquid in said heat exchange zone by regulating the level of liquid in an adjacent liquid collecting means in open liquid communication with said heat exchange zone.

In accordance with another concept of this invention, there is provided a method of controlling the level of liquid being heated in a heat exchange zone in a horizontally disposed heat exchange apparatus of a shell-tube type, said method comprising regulating the level of liquid in an adjacent liquid collecting zone in open liquid communication with said heat exchange zone to thereby control the level of liquid in said heat exchange zone.

In accordance with another concept of this invention, there is provided a method for separating a stream in a fractionation tower, said method comprising withdrawing a liquid stream from the bottom of said tower, vaporizing a portion of said liquid stream in an external reboiler without superheating the vapor evolved, and returning said vapor onto a tray at an elevated location in said fractionation tower.

Referring to the drawings forming a part of this application, FIGURE 1 is a longitudinal sectional view of the heat exchange apparatus, FIGURE 2 is a sectional view taken along the line II—II of FIGURE 1, FIGURE 3 is a sectional view taken along the line III—III of FIGURE 1, FIGURE 4 is a perspective view of a preferred liquid feed distributor tray, and FIGURE 5 is a plan view of another form of baffle.

In FIGURE 1, there is shown a heat exchange apparatus, comprising a shell **10** containing a number of heat exchange tubes **11** arranged in a bundle in the lower portion of shell **10**. Shell **10** comprises a cylindrical body having one end closed by a unitary end wall **12** and a removable head **13** at the opposite end. Tubes **11** are secured at one end to a tube sheet **14** which is clamped between a flange **15** of shell **10** and a flange **16** of removable head **13**. At the opposite end, the tubes are secured to a floating tube sheet **17** to which a floating head **18** is secured.

Removable head **13** comprises an inlet header **19** having an inlet connection **20** and an outlet header **21** having an outlet connection **22**. Floating head **18** provides a reversing chamber at the opposite ends of tubes **11** for directing the heating fluid in its passage from inlet header **19** through a number of the tubes **11** in one direction and then through the remaining tubes **11** in the opposite direction to the outlet header **21**. The heating fluid may be any suitable fluid having an elevated temperature, such as steam or flue gases, and preferably steam is employed. It is to be understood that a number of tubes **11** and any desired arrangement of the tubes can be used. Although tubes **11** are shown in FIGURE 1 as straight horizontally disposed elongated tubes, tubes having other configurations, such as continuous helical tubes, can be used. It is to be noted in the embodiment of FIGURE 1 that the entire tube bundle can be removed as a unit from shell **10** by disengaging flanges **15** and **16**.

Shell **10** is provided with a liquid inlet **23** and a vapor outlet **24** in the top thereof. A bottoms product outlet **25** is provided in the bottom of shell **10** adjacent the enclosed end **12**. Liquid inlet **23** extends a short distance into shell **10** so that the open end of liquid inlet **23** terminates immediately above or within horizontally disposed liquid feed distributor tray **26** which is located above tubes **11** in the top of shell **10**. Liquid feed distributor tray **26** extends a substantial length of heat exchange tubes **11** and is mounted substantially horizontally so that the liquid feed entering through liquid inlet **23** overflows the vertical walls of liquid feed distributor tray **26** and thereby forms a continuous curtain of liquid feed. The upper edges of liquid feed distributor tray **26** can be constructed in a smooth continuous manner or can be constructed with discontinuous edges, such as serrated form shown in FIGURE 4.

Vertical baffle **27**, extending from the top of shell **10** to a point adjacent the bottom of shell **10** is located in the closed end thereof adjacent floating head **18** to thereby form a liquid collecting zone **28** in the closed end of shell **10**. Bottoms product outlet **25** in the bottom of shell **10** is located within liquid collecting zone **28**. The opening between the end of baffle **27** in the bottom of shell **10** permits the flow of heated fluid from the heating zone surrounding heat exchange tubes **11** into liquid collecting zone **28** and then out of the heat exchange apparatus through bottoms product outlet **25**. The flow of product through bottoms product outlet **25** is controlled by valve **29** in accordance with the liquid level **30** in liquid collecting zone **28** as determined by liquid level controller **31'** operatively connected to valve **29**. Vapors evolved in liquid collecting zone **28** are returned to the vapor space above exchange tubes **11** through opening **31** in baffle **27** adjacent the top of shell **10**.

In operation, the liquid to be heated and/or vaporized is supplied to the heat exchange apparatus through liquid inlet **23** and discharged into liquid feed distributor tray **26** which it overflows and forms a vertical curtain of falling liquid. Some level of liquid, such as level **32**, is maintained in the heat exchange zone and the liquid is heated by the circulation of heating fluid through heat exchange tubes **11**. The vapors evolved from the heated liquid collect in the vapor space in the top of shell **10** above heat exchange tubes **11** and are withdrawn through vapor outlet **24**. The heated liquid flows from around heat exchange tubes **11** underneath vertically disposed baffle **27** and into the liquid collecting zone **28** from which a portion is removed through bottoms product outlet **25**. The level of liquid **32** surrounding heat exchange tubes **11** is controlled by the level of liquid **30** in liquid collecting zone **28**. The level of liquid **30** in liquid collecting zone **28** is in turn determined by the position of valve **29** in bottoms product outlet **25** as determined by liquid level controller **31'**. Ordinarily, liquid level **32** will be maintained at an elevation sufficient to completely just sufficiently submerge all of heat exchange tubes **11**; however, as desired, liquid level **32** can be maintained at an elevation above or below the uppermost heat exchange tubes **11**. Preferably, all heat exchange tubes **11** are surrounded by liquid in order to avoid vapor binding around the tubes and also to avoid superheating the vapor evolved from the body of heated liquid. Depending upon the rate of flow of liquid into the heat exchange apparatus, liquid level **30** in liquid collecting zone **28** will ordinarily be maintained at a substantial lower elevation than the elevation of liquid level **32** and the lower edge of vertically disposed baffle **27** will at all times be submerged; however, liquid level **30** may, in some operations, be maintained at an elevation substantially equal to the elevation of liquid level **32**.

In any operation wherein the vapors evolve from the body of heated liquid may have become superheated, as for example, when the elevation of liquid level **32** is maintained at some point which exposes a few of heat

exchange tubes **11** to heat transfer contact with the vapor, the falling curtain of liquid overflowing liquid feed distributor tray **26** contacts such superheated vapor and prevents superheated vapor from being discharged from the heat exchange apparatus through vapor outlet **24**.

In FIGURE 5 is shown a modified baffle **27** which extends completely across the cross-section of shell **10** and is provided with three circular openings **33** in the lower section thereof adjacent the bottom of shell **10**. If desired, baffle **27** can be constructed with square openings, elongated slots, or an opening of any other configuration which will provide for the flow of fluid from the heat exchange zone into the liquid collecting zone. It is, therefore, understood that this invention is not limited to the use of an underflow baffle, as shown in FIGURE 3.

The heat exchange apparatus of this invention is useful, generally, for heating a liquid for the creation of vapor without superheating the vapor obtained. The heat exchange apparatus of this invention is very useful as an external reboiler for supplying heat to the lower section of a fractionation tower by heating a liquid fraction withdrawn from the bottom of said tower to generate the vapors fraction which is returned to the lower section of said tower at some point above the bottom of said tower. In such an operation in combination with a fractionating tower, the liquid fraction withdrawn from the bottom of the fractionating tower enters the heat exchange apparatus of this invention through liquid inlet **23** and is heated by the passage of steam through heat exchange tubes **11**. The vapor generated, at vapor-liquid equilibrium condition, is withdrawn from the heat exchange apparatus through vapor outlet **24** and returned to the lower section of the fractionation tower. Bottoms product is obtained from the heat exchange apparatus of this invention through outlet **25** from liquid collecting zone **28**. The apparatus of this invention can also be employed as an external reboiler in combination with separation columns of other types, such as a deethanizing absorber tower wherein the bottoms product is continuously contacted in the lower or stripping section of the tower with an absorption oil which is continuously recycled through the heat exchange apparatus of this invention in order to inject the absorption oil as a vapor into the bottom of said tower. The apparatus of this invention is not limited to use in combination with separation columns, as above described, but can be used in any unit operation wherein it is desired to generate a vapor stream by heating a liquid stream.

The heat exchange apparatus of this invention is particularly advantageous in the heating and vaporization of liquid streams in which a variation in composition is encountered, for example, a bottoms fraction obtained from a separation tower. Changes in composition of the liquid stream supplied to a horizontally disposed shell-tube type heat exchange apparatus results in the constant changing of the elevation of the liquid level in the heat exchange apparatus so that, in some operations, some of the heat exchange tubes are exposed to the vapor evolved from the liquid. The failure to keep the heat exchange at all times surrounded by the liquid to be heated results in a loss of heat transfer capacity because the heat transfer coefficients of a gas are much lower than those of a liquid. The exposure of the heat exchange tubes to the vapor also results in superheating of the vapor, and, therefore, a loss of heat. The apparatus of this invention overcomes these difficulties by permitting the level of liquid in contact with the heat exchange tubes to be maintained substantially constant, even with a liquid feed of varying composition.

Specific Example

In applying the invention to a debutanizing operation wherein butane and lighter are separated overhead, in a debutanizing tower, from a charge comprising butane and lighter plus heavier components including up to octanes, the following conditions exist in the reboiler unit along with the following stream compositions.

Reboiler Operation (10):
Pressure, p.s.i.a. 100
Temperature, ° F. 278

[Composition, Mol. Percent]

Component	Bottoms (25)	Vapor (24)
Butanes	1.0	3.2
Pentanes	38.2	61.1
Hexanes	27.0	23.2
Heptanes	20.3	9.1
Octanes	13.5	3.4
	100.0	100.0

By a simple bubble point, calculation, it can readily be shown that the vapor removed via **24** is substantially in equilibrium with liquid removed via **25**, at 100 p.s.i.a. and 278° F., which is desired and effected by the invention. That is, no superheating of the produced vapors occurs.

Reasonable variation and modification are possible within the scope of the foregoing disclosure, drawings and the appended claims to the invention, the essence of which is that there have been provided an apparatus and method for efficiently heating a liquid and vaporizing a portion thereof without superheating the vapor produced, the apparatus comprising, in combination, in a horizontally disposed heat exchange apparatus of the shell-tube type wherein a liquid which is fed into said apparatus through the top thereof is heated and a portion vaporized in the shell of said apparatus by the circulation of a heat exchange fluid through heat exchange tubes submerged in a body of said liquid maintained in said appartus and the vapors evolved are withdrawn from the top thereof, a vertically disposed baffle dividing the shell of said heat exchange apparatus into a heat exchange zone and a liquid collecting zone and adapted to provide for the flow of heated liquid from said heat exchange zone to said liquid collecting zone through an opening in the lower portion of said baffle, and a liquid feed distributor tray means horizontally disposed above said heat exchange tubes in said heat exchange zone for developing a shower of liquid which contacts the vapors evolved from the heated fluid and prevents the discharge of superheated vapors from said heat exchange apparatus; the method comprising (1) as a method of operating a separation column, passing a portion of the bottom fraction into a heat exchange zone, vaporizing a portion of said bottom fraction without superheating the vapor formed, and returning said vapor to the lower section of said separation column to thereby supply heat to said separation column, (2) as a method of controlling the level of liquid in the shell of a horizontally disposed heat exchange apparatus of the shell-tube type, regulating the level of a liquid in an adjacent liquid collecting zone in open liquid communication with said heat exchange zone.

We claim:

1. In a horizontally disposed heat exchange apparatus of the shell-tube type, vertically disposed baffle means dividing said apparatus into a heat exchange zone and an unobstructed liquid collection zone, said baffle means having a first opening in the lower portion thereof to provide for the flow of liquid from said heat exchange zone into said liquid collection zone, said baffle means having a second opening in the upper portion thereof to provide for the free and unobstructed flow of vapor from said liquid collection zone into said heat exchange zone, a bundle of heat exchange tubes disposed in the lower portion of said heat exchange zone, liquid feed inlet means and vapor outlet means both located directly above said bundle, liquid valved outlet means located in the bottom of said liquid collection zone, and a liquid feed distributor tray means located in said heat exchange

zone entirely above said bundle and directly below said liquid feed inlet means and said vapor outlet means, said tray distributor means adapted to provide a curtain of said liquid feed for contacting evolved vapor.

2. Apparatus according to claim 1, further comprising liquid level control means operatively connected to said liquid collection zone and said liquid valved outlet means and adapted to control the level of liquid in said zones.

3. Apparatus according to claim 2 wherein said tray distributor means is a horizontally disposed rectangular tray having vertical walls the top edge of which is serrated.

4. A heat exchange method comprising continuously introducing liquid feed into the top of a horiozntally disposed heat exchange zone the bottom portion of which is provided with a bundle of heat exchange tubes substantially immersed in said liquid, distributing said introduced liquid feed in the form of a downwardly descending curtain above said bundle, evaporating only a portion of said introduced liquid feed, allowing evolved vapor to contact said curtain, continuously withdrawing the resulting contacted vapor from said heat exchange zone, flowing liquid feed from the bottom of said heat exchange zone to a horizontally disposed adjacent liquid collecting zone, allowing vapor to pass in a free and unobstructed manner from the upper portion of said liquid collecting zone into the upper portion of said heat exchange zone, and continuously withdrawing liquid product from the bottom of said liquid collecting zone so as to control the level of liquid in said zones.

5. The method according to claim 4, wherein said level of liquid in said zones is controlled by balancing the withdrawal of liquid from said liquid collecting zone against the flow of liquid from said heat exchange zone into said liquid collecting zone.

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