Feb. 25, 1936. F. L. MAKER 2,031,610

APPARATUS FOR FRACTIONAL DISTILLATION

Filed April 25, 1932 4 Sheets-Sheet 1

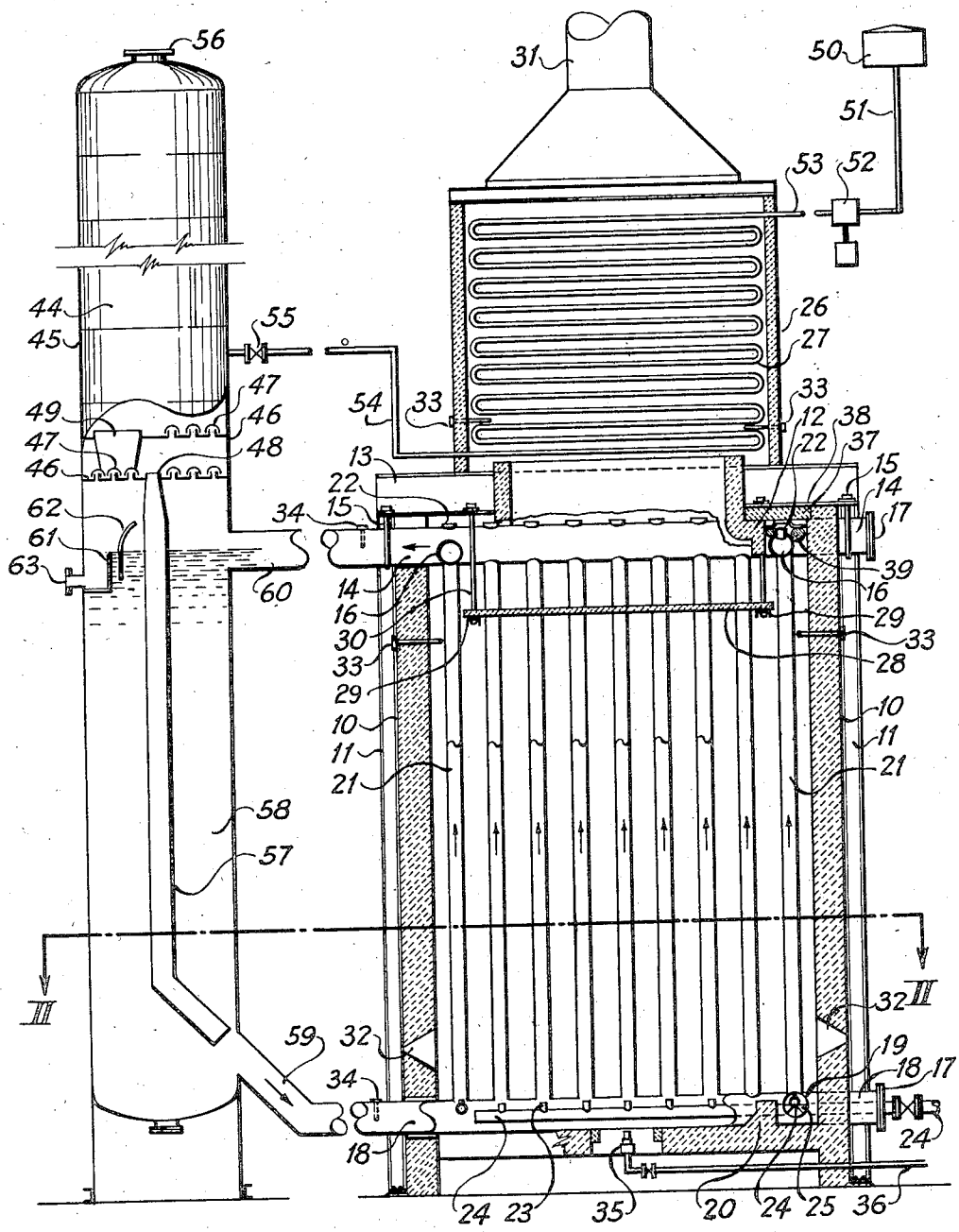


Fig. 1

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APPARATUS FOR FRACTIONAL DISTILLATION

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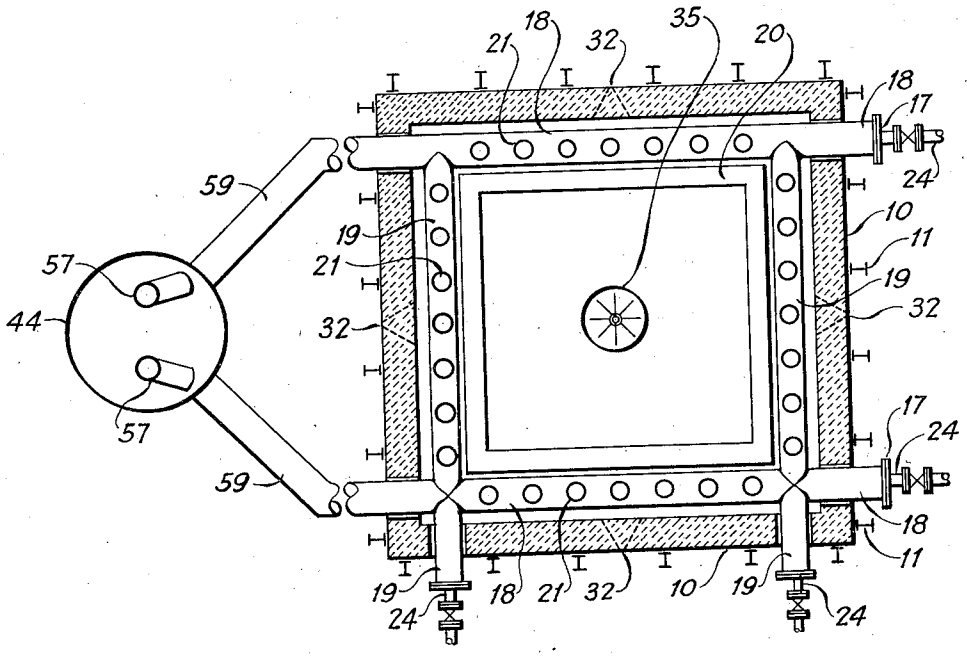


Fig. 2

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APPARATUS FOR FRACTIONAL DISTILLATION

Filed April 25, 1932 4 Sheets-Sheet 3

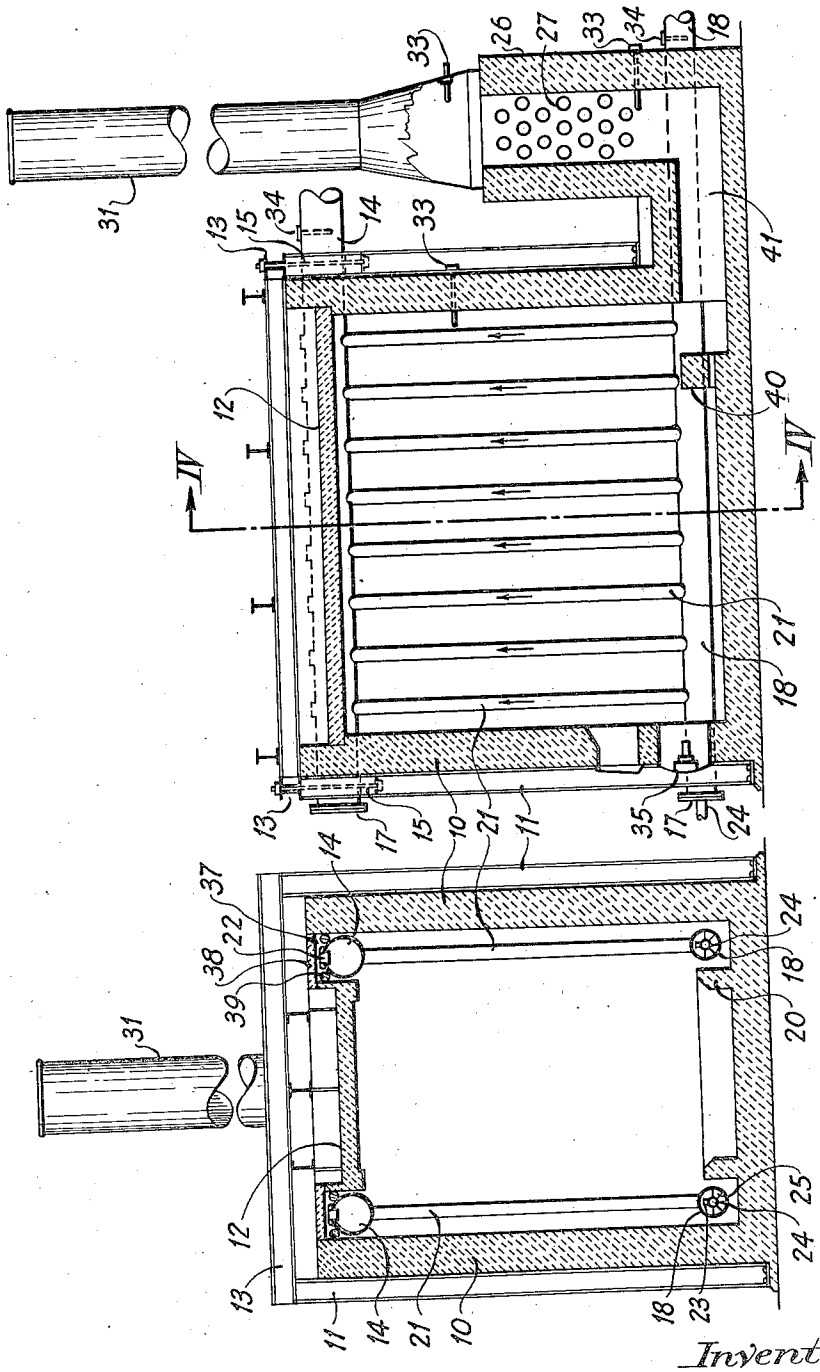


Fig. 3

Fig. 4

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APPARATUS FOR FRACTIONAL DISTILLATION

Filed April 25, 1932 4 Sheets-Sheet 4

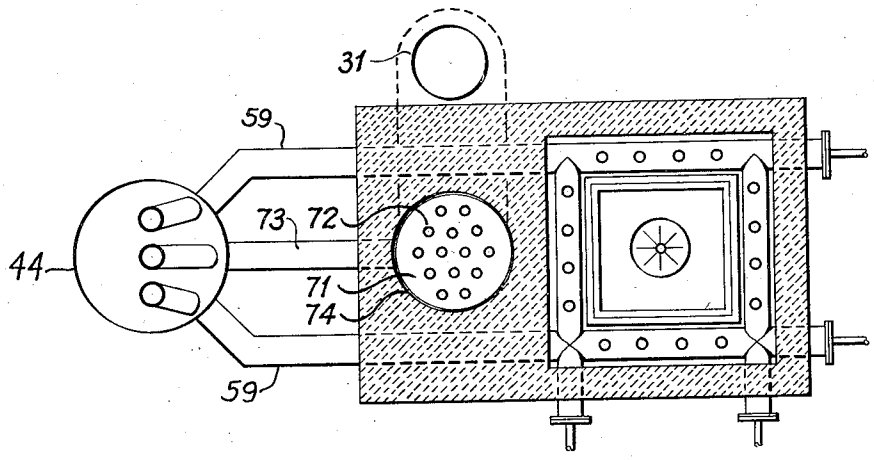


Fig. 6

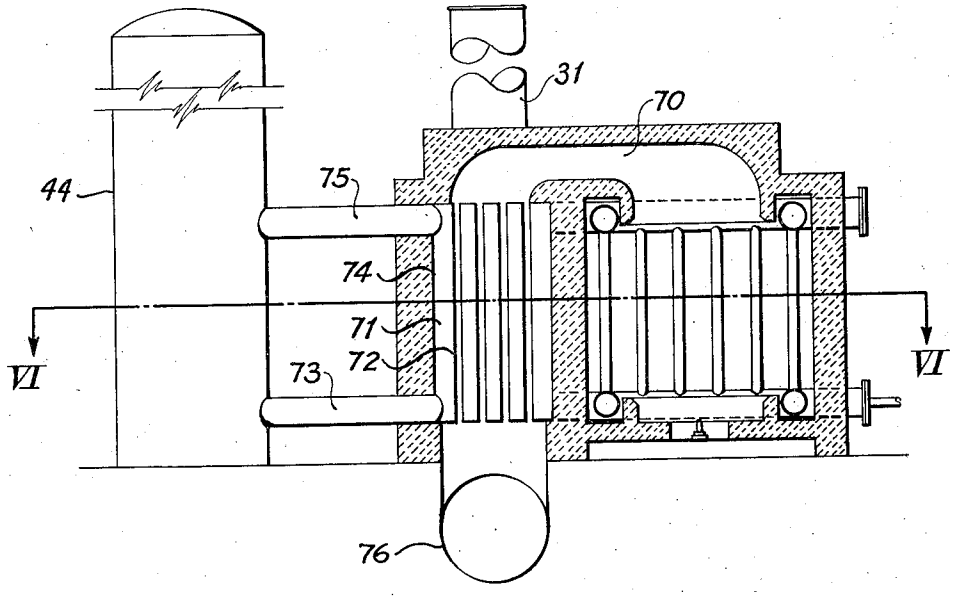


Fig. 5

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Patented Feb. 25, 1936 2,031,610

UNITED STATES PATENT OFFICE

2,031,610

APPARATUS FOR FRACTIONAL DISTILLATION

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Application April 25, 1932, Serial No. 607,383

4 Claims. (Cl. 196—108)

This invention relates to fractional distillation methods and apparatus and particularly to an improved form of tubular furnace or heater and to a fractionating column which is especially adapted to be used in conjunction with it.

In many industrial applications it is necessary to heat fluids for the purpose of vaporizing a portion of them under conditions where only a small temperature rise is desired. As an example, in the fractional distillation of petroleum, the most desirable location in the system to add the heat required for the fractionation process is to the liquid coming from the bottom plate in the fractionating column, so that a certain amount of vapor will be formed which will pass upward through the plates of the column and act as a vehicle for carrying the necessary heat into the liquid on the fractionating plates, and it is generally necessary to keep the maximum temperature low enough to avoid decomposition of the liquid.

The conventional shell still was long used for this purpose but its inherent disadvantages are such that it is being replaced by tubular stills or heaters.

It is well known that heating fluids in tubular heaters has the advantage that the heat transfer rate may be increased by suitably increasing the velocity of the liquid through the tubes. This increase in heat transfer rate will reduce the total area required for the given heating condition of the particular installation. Also the higher velocity tends to prevent the deposit of any sediment in the fluid on the heating surfaces, particularly as these surfaces may readily be disposed in a vertical or sloping direction. The higher velocity reduces the thickness of the fluid film next to the metal wall and also reduces the maximum temperature by increasing the heat transfer factor, thereby reducing a tendency toward decomposition of the fluid and preventing the formation of coke or scale on the heating surfaces. Another advantage of tubular heaters is that they may be constructed to operate at a higher efficiency than the conventional type of shell still, by arranging and proportioning the heating surfaces so that maximum use is made of radiant heat, and also by providing means by which the gases may be cooled by convection below the temperature at which they radiate strongly.

Tubular heaters also involve much less hazard of explosion and fire, as the most highly heated parts are of relatively small diameter and can easily be made very strong, and the destructive effect in case of failure is at the same time made small.

Heaters for fluids in which the heated surface is directly exposed to a source of intense radiation, or to a bed of very hot gases, or to heated refractory walls, will absorb heat by radiation from such source. With relatively small pieces of equipment where no great amount of heat is liberated per unit area of absorption surface, no difficulties are encountered, but commercial heating installations for easily decomposable fluids, such as, for example, petroleum hydrocarbons, immediately run into limitations of capacity due to the fact that the area of such equipment increases as the square of the dimensions, while the volume increases as the cube, so that combustion rates, which have been generally designed to be proportional to the volume, result in a greatly increased rate of heat liberation per unit area of absorbing surface. With such easily decomposable liquids, or with a liquid which readily deposits a sediment or scale on the heating surface, such high rates of heat transfer may cause a sediment or scale to be deposited on the heating surface, or by decomposition of the fluid cause formation of a coke, with resultant overheating of the surface, which may lead to structural failure.

It is essential in the design of such heaters to provide heating surface of sufficient extent, compared with the amount of heat liberated, so that with substantially uniform exposure of the heating surface to the source of radiant heat, the maximum desirable heat absorption rate will not be exceeded. This maximum desirable absorption rate will vary with different fluids, and with different temperatures of the fluid being heated, but in general must be limited to keep below the temperature at which scale or sediment will be deposited or at which decomposition of the fluid on the heating surface will be produced, with resulting deposit of coke or sediment on it.

Attempts have been made to utilize the advantages of tubular heaters by pumping the fluid to be heated through a furnace in which the tubes were arranged either substantially in series throughout, or in a relatively few parallel passes, generally not more than two, or a combination of these two arrangements, before passing the heated fluid to the fractionating column. Such operation is generally termed "flash distillation", and has the inherent disadvantage that, in order to secure substantially complete removal of the volatile components from the fluid, a large amount of the fluid must be vaporized, in some cases approaching a very large proportion of the total quantity heated. This results in an excessive heat demand for the system, and also in excessive size of the fractionating equipment in order to handle the large amounts of vapor generated.

Furthermore, such heaters generally have a relatively high pressure drop necessitated by the velocity required to secure the desired heat transfer, which pressure drop is further augmented by the large number of tubes usually connected

in series, and by the fact that as heating progresses vaporization of the liquid must occur, greatly increasing the volume of fluid flowing through the tubes. The cost of pumping the fluid may consequently be excessive.

For the complete removal of a volatile component from the mixture, with sharp separation of the overhead vapor and the bottom stream, the flash distillation method is theoretically incorrect. It is recognized that for efficient fractionation, the fresh feed entering the system, instead of being brought to its highest temperature in a furnace and then sent to a fractionating column, should enter the fractionating column at an intermediate point, and at a temperature intermediate between those existing at the bottom and the top of the fractionating column. Plates or bubble decks should be provided below the point of feed entrance as well as above. Furthermore, the heat required for the fractionation operation should be supplied below the bottom plates in the column, so that a temperature gradient will exist from the bottom to the top of the column.

In some cases, in order to achieve a satisfactory theoretical condition for the fractionation operation, the overflow liquid from the bottom plates of the fractionating column has been circulated through a tubular heater by a pump. Such liquid is frequently a mixture of numerous components of different boiling points and as vaporization proceeds in passing through the furnace the boiling temperature rises. If any considerable amount of vapor must be removed, the temperature required may rise to such a point that undesirable cracking or decomposition will take place. To avoid this, instead of heating all the liquid which comes from the bottom plates of the fractionating column, this liquid may be permitted to flow into a reservoir or tank which may be a part of the column structure, or separate from it and from which it is circulated through a heater by means of a pump at such a rate that only a relatively small amount of vaporization occurs in each pass of the liquid through the heater. By this means an excessive temperature rise may be prevented in the fluid passing through the heater.

However, the usual arrangement requires a circulating pump operating on a fluid which may be at a high temperature and very difficult to handle. Furthermore, if the temperature rise must be kept small to avoid decomposition, very large quantities of liquid must be circulated and the cost of power for such circulation may be excessive. If the fluid being pumped is oil at high temperature and pressure, there is always danger of spontaneous fire from leakage of hot oil from the pump at the stuffing boxes, or from joints of the piping flanges, and such leakage is very difficult to prevent at high temperatures, on account of the extreme fluidity of the oil and its lack of lubricating value. Also, such high temperature pumping equipment is very expensive and requires unusual and highly skilled attention for its safe and efficient operation and maintenance. Furthermore, any interruption of power supply to the circulating pump or any interruption of the oil feed will result in a great reduction or practically complete cessation of circulation and the small quantity of fluid remaining in the tubes of the heater will rapidly become overheated, with a danger of failure of the tubes and a hazard of fire. It is also very probable that an accumulation of coke or scale will take place in the tubes under these circumstances, requiring a shut-down for cleaning before operations can be resumed.

If no vaporization is permitted in the tubes, the amount of heat which can be absorbed with a given temperature rise is very limited, consequently some vaporization is normally required. With the usual design of tubular heater, which has a number of tubes in series or series-parallel, this progressive vaporization in the tubes increases the volume of liquid and gas so greatly that the pressure drop per tube increases very rapidly. Consequently, unless the area of the tube passages, or the number of tubes in parallel, is greatly increased toward the end of the fluid path through the furnace, the pressure drop per foot length of tube will also greatly increase as the fluid passes through the heater, so that the oil in the major portion of the tubular heating surface may be under such a high pressure that vaporization will be entirely stopped. The amount of heat which can be absorbed up to that point will either be limited by the maximum temperature allowable, or this maximum temperature will be exceeded in parts of the heater, even though the outlet temperature may not be higher than is desired. Many, if not all of the disadvantages enumerated have been overcome by the apparatus and method of operation which is described in the following paragraphs.

It is an object of this invention to provide a method and apparatus for fractional distillation which fulfills the theoretical requirements for maximum efficiency by adding the heat at the proper point in the system, the bottom of the fractionating column.

Another object is to provide a form of tubular heater in which decomposition of the liquid being heated will not readily occur.

Another object is to provide a form of tubular heater so arranged that a high rate of heat transfer can be secured, thereby reducing the total area of heat transfer surface required.

Another object is to provide an arrangement of a tubular heater and a fractionating column in which the fluid will be circulated by naturally existing convection differentials or thermal circulation without the use of a pump.

Another object is to provide a convection or thermo-syphon circulation system for a fractional distillation equipment in which such circulation may be augmented or assisted by gas lift secured by the injection of steam, vapor or gas, which may also augment vaporization of the liquid being treated.

Yet another object is to provide a tubular heater with thermo-syphon circulation, so that in the event of a stoppage of the feed supply, the circulation will continue even though the liquid may be evaporated in the reservoir to a point considerably below the outlet level of the top tubes of the furnace.

An object is to provide a design of tubular heater which is economical to construct and in which tube cleaning, inspection, and replacement is facilitated.

Another object is to provide a heater in which expansion of the element due to temperature rise is easily provided for without damage to the structure of the furnace tubes or the refractory walls surrounding them.

Another object is to provide a fractionating column which is especially adapted to the use with the heater herein disclosed and which ful-

fills the requirements for theoretically correct fractional separation of liquid mixtures.

Another object is to provide a tubular heater for substances for which the maximum temperature is desired to be limited, in which the heat absorption by direct radiation from the source of heat is limited to any desired maximum per unit area of absorbing surface, by providing a suitable amount of radiant heat absorbing surface which is substantially unformly exposed to radiation from said radiant heat source.

These and other objects and advantages of this invention will become apparent from the following detailed description of preferred embodiments of this invention and their manner of operation, it being understood that the invention is not limited to the arrangements specifically described.

In describing this invention reference will be made to the accompanying drawings which form a part of this specification. In these drawings:

Figure 1 represents a vertical sectional view through a heater provided with a superimposed convection bank in the outlet flue and constructed according to this invention. The accompanying fractionating column which is a part of this invention is also shown in this figure.

Figure 2 is a horizontal section on line II—II of the arrangement shown in Figure 1.

Figure 3 shows a vertical section of an alternative form of heater having two tube banks, one on each side wall, and provided with a convection of preheating bank in a separate chamber beside the main or radiant bank of tubes.

Figure 4 is a vertical sectional view on line IV—IV of the heater shown in Figure 3.

Figures 5 and 6 show an alternative diagrammatic arrangement of a radiant heater, fractionating column, and supplementary thermo-syphon convection heater.

In all of these figures the same reference numerals are used to designate elements which are common to all of the structures shown.

Referring to Figures 1, 2, and 3, the reference numeral **10** indicates a substantially square combustion chamber or furnace made of firebrick or other suitable refractory material. This is supported and tied together in the customary manner by means of outside steel buck stays **11**. The roof **12** of the furnace is preferably of the suspended arch type and is supported by steel beams **13** which, in turn, rest on the top of buck stays **11**. Two large tubular steel headers **14** are suspended by rods **15** from the beams **13** and pass completely through the furnace on opposite sides near the top. These headers are preferably shielded on both sides by the refractory wall of the chamber **10** and roof arch brick **12** as detailed in Figure 1.

Cross-headers **16**, which are preferably smaller in diameter than the main headers **14**, intersect the main headers in the corners of the chamber **10** as shown, and are disposed along the remaining two inner walls of the furnace with their bottom surfaces in the same horizontal plane as the bottom of headers **14**. These headers are similarly shielded. The headers **16** do not need to project through both the walls **10** of the chamber but only through one wall, as shown, for a purpose to be described below. The connections between the headers **14** and **16** are preferably made by welding. The outermost ends of the headers that extend through the brickwork are provided with flanged closure plates **17**, with the exception of the two nearest the fractionating column, for a purpose which will be explained below.

A similar set of main and cross-headers **18** and **19**, respectively, are similarly disposed near the bottom of the furnace with their upper surfaces in the same horizontal plane. Thus, all of the tubes between the upper and lower sets of headers may be of the same length, even though the main and cross-headers are of different diameter. These lower headers are preferably protected against direct radiation from the burner flame by refractory walls **20**.

A number of closely spaced vertical steel tubes **21** are disposed as shown between the upper and lower header assemblies, making a rectangular grid which completely surrounds the flame in the combustion chamber **10**. These tubes may either be expanded into suitable holes drilled in the upper and lower headers, or may be welded thereto, or attached to suitable ferrules welded or expanded into the upper and lower headers. This construction will be facilitated by suitably flattening the surface of the headers into which the tubes are to be expanded. Above the centers of the tubes in the upper headers **14** and **16**, access holes are provided in the headers in order that the tubes may be cleaned of coke or scale by means of the usual tube cleaning equipment. Similar access holes may be provided in the lower headers **18** and **19**, if desired. All of the holes are normally closed by screw plugs or taper plugs **22** similar to those used in steam boiler practice.

While but one row of tubes is illustrated, two or even more might be used, depending upon fluid circulation conditions, the heat to be transferred and the physical proportions of the furnace. For convenience in cleaning the interior of the tubes they should preferably be straight, but if the nature of the fluid handled is such that frequent cleaning will not be necessary, it may be preferable to have bent or S tubes which will permit individual differences of expansion of adjacent tubes.

These tubes **21** are preferably spaced a short distance from the refractory walls of the chamber **10**. By this means radiant heat passing between the tubes strikes the wall behind them, and by reflection and secondary radiation from the heated wall, heats the back of the tubes as well as the front which is exposed to direct radiation. In this way a greater heat transfer is also obtained per unit of tube length than if but one side of the tube were exposed to the radiant heat. Furthermore, the heat absorption of the tubes is made much more nearly uniform around their circumference, with a resultant uniform temperature of the tube and a decrease in the tendency of the tube to warp or bow on account of one side being hotter than the other.

The principal heat absorption in the combustion chamber **10** is by direct radiation from the flame, the heated gases and the heated refractory walls, but the rate of heat absorption by radiation naturally occurring is so much greater than will result by convection from the gases, which move relatively slowly through the furnace, that no special means are needed or provided to separate heat received by radiation and convection.

The lower header assembly **18** and **19** is preferably supported solely from the upper assembly **14** and **16** by the tubes **21**. As already stated, the upper header assembly is flexibly suspended from the steel structure of the furnace by the rods **15**. This construction results in freedom of movement on the part of the tubes and lower header assem-

bly under temperature variations and removes any possibility of damage to the refractory brickwork by such expansion or contraction. Suitable flanged collars and heat resisting packing (not shown) may be used between the headers and the openings through the refractory walls to prevent gas leakage either into or out of the combustion chamber.

In order to augment the convection current caused by the expansion and partial vaporization of the oil in the vertical tubes, steam or gas jet nozzles **23** may be placed in the lower headers **18** and **19** and directed upwardly into the tubes **21**. This results in a steam or gas lift effect which is very valuable when high rates of heat input and correspondingly high speeds of fluid circulation are desired. This lift effect may not be due in any large part to the kinetic energy of the steam or gas jet, but may be due to the decrease in density of the fluid and steam, or gas and vapor mixture in the tubes, or to a combination of this with the kinetic effect of the jet. The steam or gas also performs its usual desirable partial pressure function, whereby the vaporization of the oil mixture in the tubes **21** and the upper headers **14** and **16**, occurs at a lower temperature than would otherwise be required if the steam or gas were not present.

Nozzles **23** are mounted upon steam or gas headers **24** which are supplied from any suitable source (not shown). If steam is used, no great pressure in excess of the operating pressure of the heater is required, which will permit the use of exhaust or low pressure steam, which might otherwise be wasted. These pipes pass through and are welded or flanged to the corresponding closure members **17** of the lower header assembly. It will be noted that the pipes **24** which lie in headers **19** are at a higher level and are provided with shorter nozzles **23** than the pipes **24** which lie in headers **18**. This is to allow the pipes to cross without interference at the intersections of headers **18** and **19**. Pipes **24** are preferably supported by saddles **25** in order that the nozzles **23** will remain upright and aligned with their respective tubes. If desired, the steam may be passed through superheater tubes (not shown) in the radiant or convection portions of the heater before being injected into the fluid. As an alternative, water or other suitable liquid may be injected into the tubes through the nozzles **23** and will form steam or vapor by evaporation within the tubes.

In the example shown in Figure 1 the furnace or combustion chamber **10** is provided with a refractory chamber **26** on its roof through which chamber the heated products of combustion pass. A tubular preheating or convection coil **27**, which may be of continuously welded steel pipe as shown or which may be made of straight tubes and return bend headers is mounted in chamber **26** and may be used to preheat the liquid feed to the fractionating column, as will be explained below. A suitable radiation shield of refractory brick and/or high temperature resisting metal **28** may be provided in the main furnace chamber immediately below the flue opening leading to the chamber **26**, to prevent overheating the lower passes of the convection coil **27** by the direct radiation from the flame. Shield **28** may be supported by heat resistant metal bars **29** and bolts **30** as shown.

A steel stack **31** may be mounted on the outlet of chamber **26** to carry off products of combustion and to provide suitable draft for the furnace chamber **10**. Peep-holes **32** are provided around the walls of the chamber **10** so that the condition and temperature of the tubes **21**, the disposition of the flame from the burner, and the condition of the refractory brickwork in the chamber may be observed. Pyrometer points **33** may be located in the gas space of the chamber **10** and chamber **26** to indicate gas temperatures. Pyrometer wells **34** may be provided in the upper and lower header assemblies **14** and **18**, respectively, to indicate the vapor and fluid temperatures therein.

A burner **35**, preferably of the multiple outlet or extended surface type, is mounted in the center of the floor of the furnace chamber and is supplied with fuel through the line **36**. In case the flame distribution from a single burner is unsatisfactory, several suitably spaced smaller burners may be used, the object being to obtain substantially uniform radiation to the tubes **21**, and to avoid direct flame impingement thereon.

The roof or suspended arch **12** of the furnace is provided with openings **37** immediately above the row of plugs **22** in the upper header assembly **14** and **16**. These openings are normally closed by refractory blocks **38** and the spaces beside the header members are further sealed by means of flexible asbestos rolls **39**. The lifting out of blocks **38** gives access to the plugs or caps **22** which may then be removed from the headers to permit inspection, cleaning, or removal of tubes **21**.

In certain cases where heaters are desired of smaller heat-absorbing capacity than that shown in Figures 1 and 2, one or two sets of upper and lower horizontal headers connected by vertical tubes but not provided with cross-headers may be used. Such a construction is shown in Figures 3 and 4.

Referring to these figures, **10** again represents a square or rectangular furnace chamber made of refractory brick held together with steel buck stays **11** and provided with a suspended flat arch roof **12**, also of refractory brick. Along the side walls of this furnace, at the top and bottom thereof, are two main headers **14** and **18** respectively. These are shielded from the direct radiation of the fire by the tiles of the roof **12** and a refractory wall **20**, respectively. A single row of tubes **21** connect each of these pairs of headers, the lower headers being suspended from the upper by these tubes. The usual bolts **15** supported by beams **13** on top of the buck stays **11** support the upper headers.

In the example shown, a single burner **35** is mounted in the middle of the front wall of the furnace midway between the two banks of tubes and is arranged to give maximum heat radiation without flame impingement on the tubes. If gas fuel is used, it may be convenient to use multiple jet burners distributed over a portion of the front wall or a portion of the floor of the combustion chamber. A transverse baffle wall **40**, of refractory brick, is located on the floor of the furnace and near the rear wall. A flue **41** leads from the space behind the baffle wall **40** into a refractory convection chamber **26** located at the rear of the back wall of the furnace. A convection bank **27** similar to that described above is installed in chamber **26**. A steel stack **31** is mounted upon the top of the convection chamber **26** to remove the products of combustion therefrom and to provide a draft for the fire in the main combustion chamber **10**. The usual pyrometer points **33** may be provided in the furnace chamber and in the convection bank chamber **26** to indicate flue gas temperatures. Pyrom-

eter wells 34 may also be mounted in the upper and lower headers to indicate vapor and oil temperatures. Headers 14 and 18 extend out to the rear of the furnace to the accompanying fractionating column (not shown) as will be explained below.

The general construction of the headers as regards shielding, access means, steam jet nozzles and the like, may be the same as that described above.

The fractionating column shown in Figure 1 and generally designated as 44, is a part of this invention and is especially adapted for use with the tubular oil heaters of the convection or thermo-syphon circulation type just described. It is composed of the usual cylindrical shell 45 and is provided with a plurality of the conventional decks or plates 46 or equivalent vapor-liquid contacting means. These may be fitted with some form of bubble caps 47 and the usual arrangement of overflow weirs 48 and down-spouts 49. Any equivalent construction which would allow vapor to pass upward through the plates and would allow liquid to pass downward over them with intimate contact of the vapor and liquid, could be substituted for the arrangement described.

The oil or other liquid to be fractionally distilled is drawn from a tank 50 and passes through the line 51 to the feed pump 52 from which it is forced through the line 53 to the preheater or convection coil 27 of the tubular heater.

The preheated fluid passes from the coil 27 through line 54 and regulating valve 55 into the fractionating section of column 44 at a point intermediate in its height. Bubble decks 46 are provided both above this point, to fractionate the rising column of vapors, and below this point, to strip overflowing liquid passing downward of its lighter fractions. Part of the overhead vapor passing from the top plate through the outlet 56 may be condensed in a reflux condenser (not shown) and returned to the top plate or to intermediate plates, to assist in the fractionation, in the usual manner.

The usual overflow or down-spout from the lowest plate in the fractionating column is replaced in the example shown by two tubes or ducts 57 which pass downward to points near the bottom of the reservoir 58, which forms the lower part of the fractionating column structure. Directly opposite the outlets of these tubes are large outlet connections in the reservoir 58, from which circulating pipes 59 lead to the lower main headers 18 in the tubular heater. Similar connections and pipes 60 lead from the upper main headers 14 of the tubular furnace to the upper part of the reservoir.

A dam or weir, which may be in the form of an internal box 61 is arranged in reservoir 58 as shown and maintains a liquid height in this chamber at a point approximately on the level with the center of the upper circulating pipes 60 and tubular headers 14. A baffle or damping plate 62 is mounted in the reservoir 58 near the inner face of the weir plate 61 to provide a calm surface for the residuum liquid as it flows over the weir. The bottoms or residuum from the reservoir 58 passes out through outlet 63 and may be led through suitable heat exchange and/or cooling equipment (not shown) and thence to storage. It will be recognized that reservoir 58 may be an entirely separate vessel from the fractionating section above the bottom bubble plate or its equivalent, but for convenience these may be built, and are illustrated, in one unit.

In operation, fluid is fed into the fractionating column through the feed connection shown, until the system is filled to the top of weir 61, as indicated by its presence in the bottoms or draw-off line leading from outlet 63. The fire in the tubular heater is then started and the tubes and headers brought up to temperature. As the fluid in the tubes 21 is heated it will expand and vaporize, and the mixture of warm fluid and vapor in the tubes, being less dense than the fluid in reservoir 58, will be unable to balance the latter, and will be forced upward in the tubes while fresh fluid enters from below to take its place. This causes rapid circulation upward through the tubes and outward through cross-headers 16, main headers 14 and pipes 60 into the liquid reservoir 58. The vapor released in the tubes and headers passes upward through the bubble decks and is fractionated in the usual manner. A suitable mist or entrainment separator may be provided above the liquid surface and beneath the first bubble deck to mechanically remove entrained drops of fluid from the vapor, if such is found to be desirable.

The unvaporized liquid from the pipes 60 passes downwardly through the reservoir 58 and returns to the tubes in the heater through the circulating pipes 59, headers 18 and cross-headers 19. Circulation in the tubes has been found to be very rapid due to the rapid absorption of the radiant heat from the flame and to the ease with which vapor is released against the walls of the vertical tubes and in the headers. Circulation in the tubes, however, may be augmented by the steam or gas-lift from nozzles 23 when unusually high firing rates are desired, when the unit is to be started in a minimum time, or when the circulating liquid contains relatively little volatile component.

Tests have shown that the proportion of overflow liquid from the down-pipes 57, which lead from the lowest bubble deck in the fractionating column into the reservoir 58 and terminate opposite the inlets of circulating pipes 59, may be approximately 10% to 20% of the total circulation through the furnace. Therein lies one of the great advantages of this equipment, for, should the feed to the fractionating column cease, or should some disturbance stop the liquid flow from the lowest plate, the liquid in the reservoir 58 maintained by the weir 61 would continue to circulate through the heater for an appreciable time with no attention or mechanical assistance, until the fire could be extinguished and the unit cooled. This circulation would continue even after a considerable proportion of the fluid in the reservoir had evaporated and its liquid level had fallen materially below the connecting pipe 60 from the heater. This would prevent damage to the heater structure from total evaporation of its contents, which could result in overheating the tubes, causing them to fail and finally resulting in a disastrous fire.

It will be observed that this arrangement of a thermo-syphon heater with its accompanying fractionating column fulfills the theoretical conditions for the most efficient fractional distillation. The feed to the column may be preheated and admitted to the column at the most desirable point. The overflow or reflux liquid from the lowest plate in the column is immediately carried into the circulating heater along with liquid previously deposited in the reservoir at the bot-

tom of the fractionating column. The vapor is released in the vertical tubes with minimum pressure drop and with minimum possibility of coking or deposition of sediment. This vapor and steam or gas mixture passes through the upper circulating lines **60**, is delivered to the lowest plate of the fractionating column, and is substantially the sole supply of heat to the fractionation process.

Uniformity of circulation through the various tubes is automatically maintained. Should one or more tubes become temporarily overheated, or be subjected to an excessive share of the heat, the additional vaporization caused thereby will increase the rate of upward flow through these tubes, thereby cooling them and making the circulation proportional to the heat absorption rate.

It will be noted that no pumps or elaborate control devices are required to insure positive circulation in this apparatus. Also this construction permits of a low pressure drop through the heater, allowing the fluid to evaporate freely in the tubes so that large amounts of heat can be absorbed with small temperature rise. It is obvious also that the entire equipment can be readily constructed to operate under high pressure if desired.

The design of the apparatus is such that it lends itself particularly well to vacuum operation, as there are few joints to be made tight, no large surfaces to be reinforced or stayed and very slight pressure drop through the system, the only differential being that required to cause the desired circulation. No pumps are involved whose stuffing boxes may cause leakage, and as combustion rates can be readily and completely controlled, and as there is relatively small volumetric capacity and consequent low heat capacity, as well as little temperature lag in the heating element, the fluid temperature may be very accurately controlled with a minimum of attention. This is especially desirable in vacuum distillation processes.

A modification of the system outlined which includes the use of a thermo-siphon convection bank which heats liquid from the lower part of the reservoir of the fractionating column and delivers it again at the level of the upper vapor lines is shown diagrammatically in Figures 5 and 6.

This modification utilizes the tubular heater as described above with an overhead duct or flue **70** leading from the top of the heater to the top of a convection heater **71** of the internal or external tubular type. The flue gas may pass downward through, or around the tubes **72** in this heater, and thence through an underground duct **76** to the stack **31**. The liquid is drawn through circulating pipe **73** which connects a separate lower outlet of the reservoir **58** of the fractionating column **44** to the shell **74** surrounding the tubes in the convection heater in the example shown, or to a header supplying oil to the interior of the tubes. The liquid passes upward in the convection heater **71**, due to its expansion and partial evaporization, in a manner similar to the flow occasioned in the tubes of the radiant heating section. Steam or gas may be injected in the lower part of this convection section if desired.

The vapor and liquid from the top of the convection heater **71** is returned to the reservoir **58** of the fractionating column **44** through a separate vapor line **75**, which is at substantially the same level as the vapor lines **60** from the main tubular heater.

A similar arrangement in which the hot combustion gas from the radiant section passes upward through the convection section may also be used, as it is advantageous to pass these gases upward through the convection heater so that the hottest gases strike the surface which is cooled by the incoming oil from the reservoir, and not the surfaces at the top of the convection heater. This latter surface may be in contact with a mixture of fluid and vapor, will not so readily absorb heat at high rates, and might, therefore, become overheated. While the flow of gases and oil are not strictly counter-flow when the hot gas is passed upward, the slight temperature rise of the oil in the heater makes this inconsequential.

Although specific constructions embodying this invention have been described and illustrated, it is to be understood that the invention is not limited to those specific devices, and all such modifications and changes as come within the scope of the appended claims are embraced thereby.

I claim:

1. In a distillation apparatus the combination of a fractionating column, a liquid reservoir in the lower portion of said column, a liquid collecting plate in said column, a tubular heater, a duct in said column adapted to direct overflow liquid from said plate into the lower part of said heater, a plurality of substantially vertical parallel tubes within said heater for heating and partially vaporizing said liquid, means in said heater and aligned with the lower ends of said tubes for introducing a flow promoting fluid into said tubes, and means to return vapor and unvaporized liquid from the tops of said tubes to said reservoir.

2. A distillation apparatus comprising a fractionating column provided with a plurality of bubble plates, a fluid inlet intermediate adjacent bubble plates, a reservoir in said column below said bubble plates, a substantially horizontal upper header connected to the upper portion of said reservoir, a lower header connected to the lower portion of said reservoir, a plurality of parallel tubes connecting said headers, and a source of heat adjacent said tubes, the lowest of said bubble plates being provided with a duct leading downwardly into said reservoir and terminating adjacent the connection to said lower header.

3. In a distillation apparatus, the combination of a fractionating column, a liquid inlet for said column intermediate its length, a vertical liquid reservoir, an upper header connected to the upper portion of said reservoir, a lower header connected to the lower portion of said reservoir, a plurality of parallel tubes connecting said headers, a source of heat adjacent said tubes, a substantially unrestricted vapor connection between the upper portion of said reservoir and said fractionating column, a reflux connection from said column terminating in the lower portion of said reservoir adjacent the connection to said lower header, and means for withdrawing residuum from said reservoir substantially at the level of said upper header connection.

4. A distillation apparatus according to claim 3 with the further addition of means for introducing a flow producing fluid into said lower header.

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