June 2, 1942. W. SAMANS 2,284,623

VAPORIZER

Filed Oct. 13, 1939 3 Sheets-Sheet 1

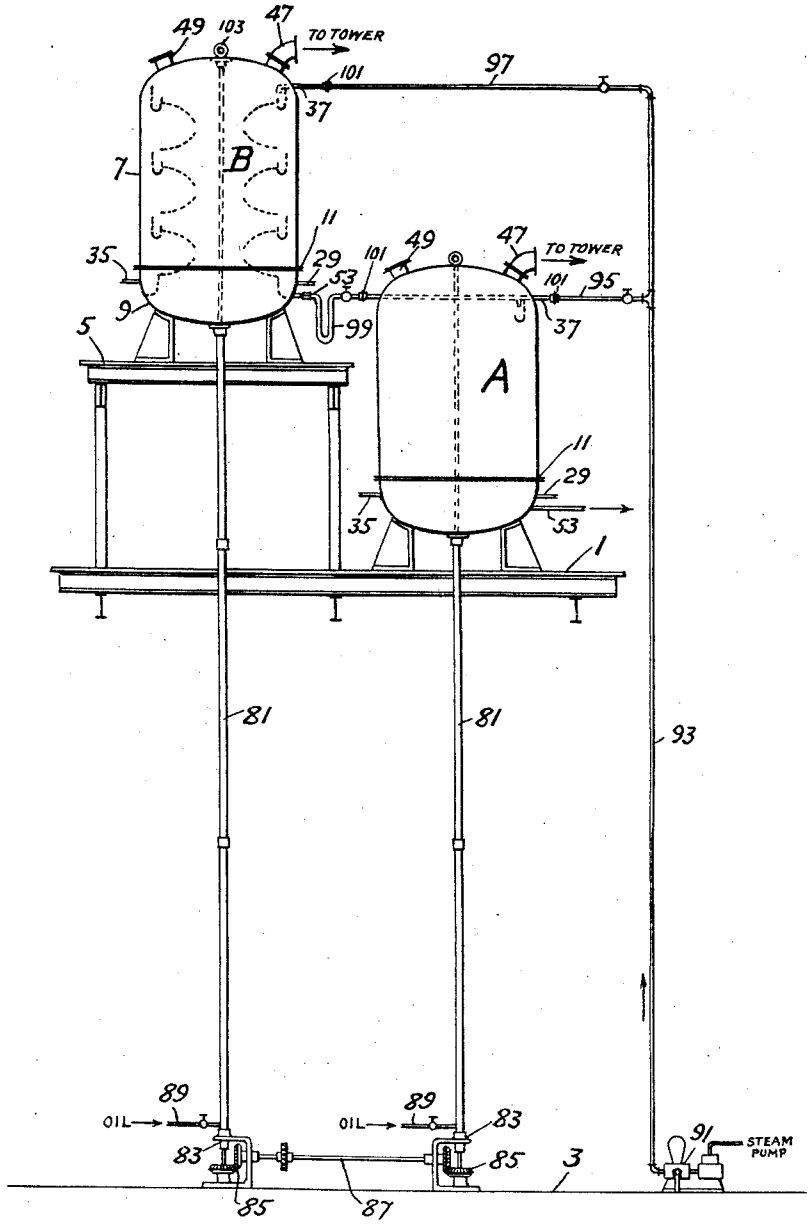


FIG. 1.

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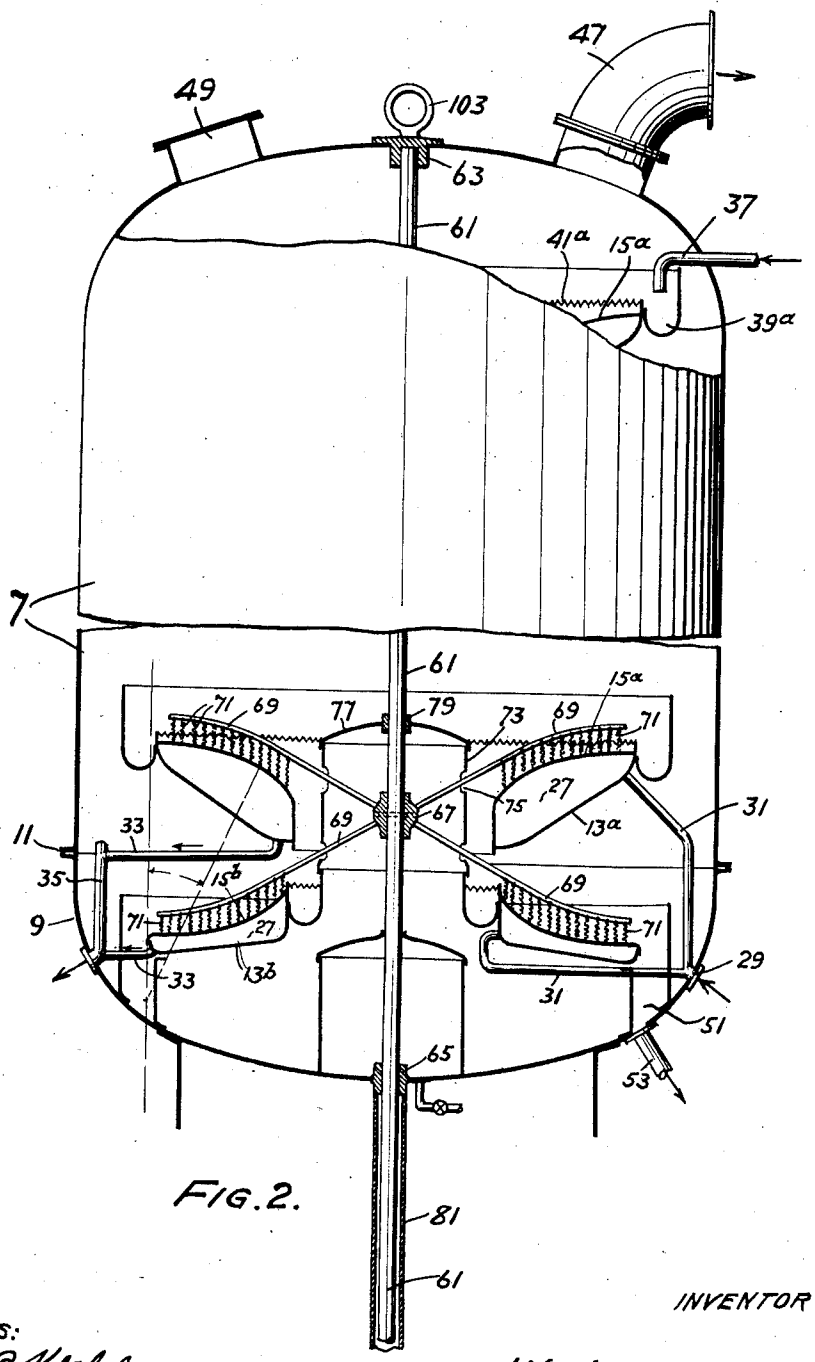


FIG. 2.

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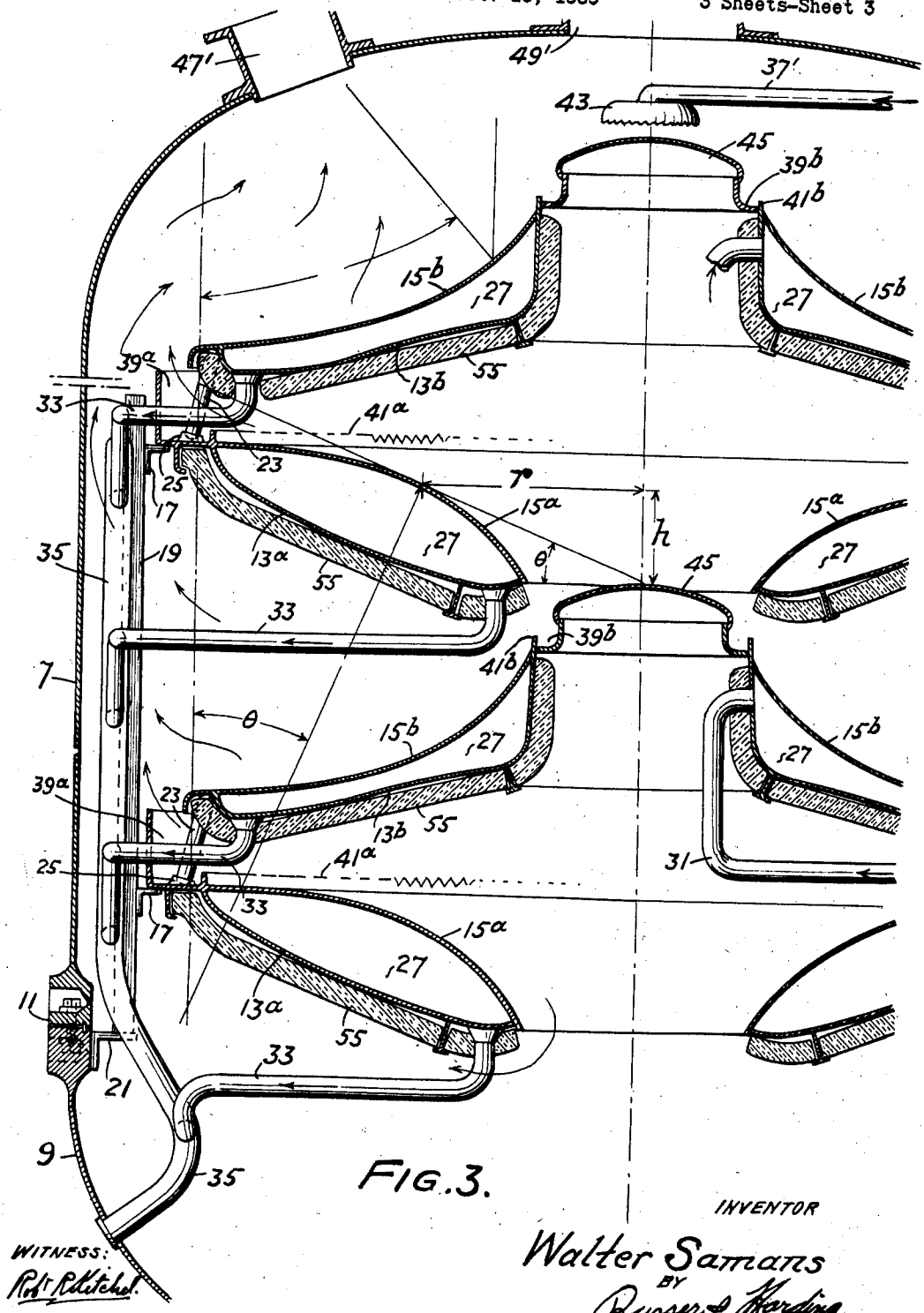


FIG. 3.

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Patented June 2, 1942 2,284,623

UNITED STATES PATENT OFFICE

2,284,623

VAPORIZER

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Application October 13, 1939, Serial No. 299,288

9 Claims. (Cl. 196—128)

This invention relates to vaporizers and more particularly to that type of vaporizer in which a liquid is vaporized by being conducted in a shallow stream over a heated surface.

In particular this invention is adapted for use in the distillation or fractionation of high boiling petroleum cuts to product lubricating oils, where the oil to be distilled is passed in a thin or shallow stream over surfaces heated indirectly, as by mercury or diphenyl vapor, to the desired temperature, under a vacuum sufficient to effect volatilization of the desired fraction.

In installations of this character, it is important in order to secure uniformity in the distillate that the heat transfer from the mercury vapor, for example, to the flowing oil be as nearly uniform as possible over all portions of the oil stream in any one section or unit of vaporizing surface. Because the critical rate of heat transfer between the mercury vapor on the hot surface of the partition and the liquid oil of which a fraction only is to be evaporated, flowing over the other side of the partition, is on the mercury side, the change in velocity in the radial flow of the oil over the trays does not materially affect the rate of heat transfer obtainable. However, since the depth of the liquid stream in vaporizers of this type is usually of the order of ⅛" to ¼", it is apparent that changes in the stream thickness would cause a material difference in the amount of evaporation that takes place.

Consequently, vaporizers of this general type heretofore designed cannot operate with a sufficiently uniform liquid thickness over the vaporizing surface, with resultant non-optimum uniformity in vaporization rate and in the distillate produced.

It is an object of the present invention to provide a vaporizer so designed that the thickness of the flowing liquid stream on any vaporizing surface will be substantially uniform over the entire surface.

It is a further object of this invention to provide means for cleaning or scraping the vaporizing surfaces during operation so that no deposits may tend to accumulate thereon.

An additional object of this invention is to provide a compact unit with maximum vaporizing surface and designed for easy accessibility.

Other and further objects of this invention will appear from the following description of a preferred embodiment of the invention as shown in the accompanying drawings, in which:

Figure 1 is an elevation, somewhat diagrammatic, of an associated pair of vaporizing units in accordance with this invention;

Figure 2 is an elevation, partly broken away, of a single vaporizing unit; and

Figure 3 is a detailed, sectional view showing the interior construction and arrangement of a (somewhat modified) vaporizing unit.

As shown in Figure 1, vaporizing unit A is supported on platform 1, which should be not less than 40 feet above the ground level, represented at 3, in order to permit the formation of a barometric column of liquid, here assumed to be lubricating oil stock. Vaporizing unit B is supported on platform 5 with its bottom adjacent the top of vaporizer A, as shown.

Each vaporizer comprises a lower shell 9 and an upper shell 7 secured together at 11 by a vacuum-tight joint. Within the shell are arranged, one above the other, a plurality of annular vaporizing pans or trays 13*a*, 13*b*, the upper or vaporizing surfaces 15*a*, 15*b*, of which slope alternately inwardly and outwardly, so that the oil to be distilled, entering at the top of the vaporizer passes downwardly in a zig-zag course over the surfaces 15*a*, 15*b*.

Each of the pans or trays 13*a* is supported on brackets 17 secured to uprights 19, which are in turn supported on and secured to brackets 21 affixed to the lower shell 7 adjacent its upper edge. Each of the pans or trays 13*b* is supported from the tray 13*a* immediately beneath it by means of rods 23 resting in sockets 25. Mercury vapor is conducted into the sealed interior 27 of pans 13*a*, 13*b*, where it delivers heat to the vaporizing surfaces 15*a*, 15*b*, through conduit 29 and branch conduits 31, and removed therefrom through branch conduits 33 and conduit 35.

In Figure 2 oil to be vaporized is admitted through conduit 37 and is fed into distributing trough 39*a* surrounding the uppermost pan 13*a*, whence it flows over the weir 41*a* and down the first vaporizing surface 15*a*.

In Figure 3 (which shows a somewhat modified form of construction) oil to be vaporized is admitted through conduit 37′ and is fed through distributor head 43 onto the surface of cap 45 and then into distributing trough 39*b* formed at the inner edge of pan 13*b*, whence it flows over the weir 41*b* and down the first vaporizing surface 15*b*.

In either case the oil stream flows downwardly through the vaporizer, flowing over the outer edge of each surface 15*b* into the distributing trough 39*a* of the next lower pan 13*a*, and over the inner edge of each surface 15*a* into the distributing

trough **39b** of the next lower pan **13b**. Caps **45** act to prevent any splashing of oil out of the troughs **39b**.

Vapors formed as the oil flows over the surfaces **15a**, **15b**, heated by the circulating mercury vapor in the spaces **27**, leave the vaporizer through outlet **47** and pass to a fractionating tower, not shown. An inspection manhole **49** is provided adjacent the outlet **47** (in Figure 3, **47'** and **49'**, respectively). Oil not vaporized in its passage over the vaporizing surfaces flows from the lowermost pan **13b** into an annular trough **51**, from which it leaves the vaporizer through conduit **53**. Insulation **55**, secured to the lower faces of pans **13a**, **13b**, protects the vapors formed from radiant heat emanating from the pans.

Of particular importance in accordance with this invention is the character of the flow surfaces **15a**, **15b**. These are so designed that, for film depths of the order of ¼'', the film depth or thickness of the fluid layer will be uniform over the entire flow surface.

This result is accomplished, in accordance with this invention, by having the slope s,

$$\left(s=\frac{h}{r}=\frac{r\tan\theta}{r}=\tan\theta\right)$$

of the flow surface, at any horizontal distance, r, from the axis, inversely proportional to the square of the distance r. Or, stated in the form of an equation:

$$s=\frac{K}{r^2}$$

where K is a constant for any particular apparatus, having a value depending, inter alia, on the desired flow, velocity of flow, and film thickness.

This relationship is true for both surfaces **15a** and **15b**. Indeed, surface **15b** is formed merely by rotating the plane 180°.

That, for a given flow, which is of course determined by the flow through conduit **37**, **37'**, the film depth on such a flow surface will be uniform can be seen from the following considerations:

The velocity of flow of hot oil over the flow surfaces in question may be considered as related to the slope of the surface and the depth or thickness of the flowing layer as set out in the Kutter modification of the Chezy formula for flow of water in open channels, since the viscosity of the hot oil, at operating temperatures, is of the same order as that of water.

This formula is as follows:

$$v=\left\{\frac{\frac{1.811}{n}+41.6+\frac{0.00281}{s}}{1+\left(41.6+\frac{0.00281}{s}\right)x\frac{n}{\sqrt{t}}}\right\}x\sqrt{ts} \qquad (1)$$

where s is the slope; t the mean hydraulic depth, in this case the film thickness; and n, a coefficient of surface roughness, experimentally determinable and constant for any given apparatus.

Since the term

$$\frac{0.00281}{s}$$

is negligible and may be disregarded for slopes of 1 in 1000 or greater, it is apparent from this formula that if t, the film depth, is to be kept constant, then the relationship

$$v=C\sqrt{s} \qquad (2)$$

must be maintained, where C is the constant of proportionality.

However, the total flow, q, is constant, by hypothesis, and may be represented, at any line on the flow surface, by the equation:

$$q=2\pi rtv \qquad (3)$$

where r is the radius, or horizontal distance from the axis, of such line; t is the film depth or thickness; and v the velocity of flow.

Substituting in (3) the value of v from Equation 2, we obtain

$$q=2\pi rtC\sqrt{s} \qquad (4)$$

from which it follows that if t is to be kept constant the relationship between r and s must be:

$$r\sqrt{s}=\frac{q}{2\pi tC} \qquad (5)$$

$$r^2s=\left(\frac{q}{2\pi tC}\right)^2=K \qquad (6)$$

$$s=\frac{K}{r^2}$$

which is the equation of the flow surfaces in question.

In the structure shown in Figures 1 and 2 means are provided for scraping the flow surfaces **15a**, **15b** to prevent the accumulation of any deposit on such surfaces. These means comprise a shaft **61** extending centrally through the vaporizer and journalled in bearings **63**, **65**. To the shaft **61** are secured a plurality of collars **67** in each of which are secured a plurality of scraper arms **69**, from the outer portions of which hang chains **71** of sufficient length to reach the heating surfaces **15a**, **15b**. As shaft **61** revolves slowly the chains **71** are dragged across and around the heating surfaces, clearing them of any accumulations. A casing **73** provided with openings **75** for the arms **69** is secured to the shaft **61** by cap **77** and collar **79**, and serves to aid in directing the liquid flow and to block off the central shaft-containing portion of the vaporizer.

Exteriorly of the vaporizer, shaft **61** extends through casing **81**, terminating in a stuffing box **83**, to bevel gearing **85**, through which it is driven from shaft **87**. Casing **81** is provided adjacent its lower end with an oil inlet **89**, through which oil stock similar to that being distilled in the vaporizer may be admitted to the interior of the casing. Since, as previously stated, the platform **1** is at least 40 feet above the ground level **3**, casing **81** forms a barometric column and enables the stuffing box **83** to have substantially atmospheric pressure on both sides when the vaporizer is, as is usual, under high vacuum; while bearing **65** need not be liquid tight.

Each vaporizing unit in accordance with this invention is designed to be used separately, or in series with other like vaporizers. Thus, in Figure 1, charging stock to be distilled may be pumped by pump **91** through conduits **93** and **95** to vaporizer A, the unvaporized portion issuing from outlet **53** being recirculated or otherwise used. Or the charging stock may be pumped through conduits **93** and **97** to vaporizer B, and the unvaporized portion leaving unit B fed into vaporizer A as charging stock, through conduit **99** which forms a liquid seal against the absolute pressure difference usually obtaining between two successive vaporizers in a series arrangement.

The vaporizing units are designed in accordance with this invention with the vaporizing pans, connecting piping, etc. substantially all secured to the lower shell **9** only, so that upon un-

ealing the joint 11, separating the unions 101 n the inlet conduit 37, and unbolting the flange f the vapor outlet 47, the entire upper shell 7 nay be lifted off, using eyebolt 103, and complete ccess to the interior structure obtained.

While the vaporizing pans 13a, 13b shown are ruly annular, it will be appreciated that pans of ny generally annular shape may be used, as various polygonal forms, etc.

What I claim and desire to protect by Letters Patent is:

1. In a vaporizer in which liquid to be vaporized is flowed in a thin stream over a heated vaporizing surface, the improvement which comprises a vaporizing surface positioned symmetrically about a vertical axis within said vaporizer, said surface having a slope, at any horizontal distance from said axis, substantially inversely proportional to the square of said distance.

2. In a vaporizer, a generally annular vaporizing pan positioned symmetrically about a vertical axis, the flow surface of said pan being characterized by a slope, at any horizontal distance from said axis, substantially inversely proportional to the square of said distance, and means for heating the flow surface of said pan.

3. A vaporizer comprising a shell, a vapor outlet therefrom, a plurality of generally annular vaporizing pans positioned vertically one above the other within said shell, the flow surfaces of said pans sloping radially alternately inwardly and outwardly, whereby liquid to be vaporized may flow downwardly over the flow surface of each pan to the flow surface of the next lower pan, following a zig-zag course, means for feeding liquid to be vaporized to the flow surface of the uppermost of said pans, means for withdrawing unvaporized liquid leaving the lowermost of said pans, and means for heating the flow surfaces of each pan; the said vaporizer being additionally characterized by the fact that the slope of the flow surface of each vaporizing pan at any horizontal distance from the vertical axis thereof is substantially inversely proportional to the square of said horizontal distance.

4. A vaporizer comprising a shell, a vapor outlet therefrom, a plurality of generally annular vaporizing pans positioned vertically one above the other within said shell, the flow surfaces of said pans sloping radially alternately inwardly and outwardly, whereby liquid to be vaporized may flow downwardly over the flow surface of each pan to the flow surface of the next lower pan, following a zig-zag course, a generally annular distributing trough surrounding the upper edge of the flow surface of each pan, a weir between said trough and said flow surface over which liquid flows onto the flow surface, means for feeding liquid to be vaporized into the distributing trough associated with the uppermost of said pans, means for withdrawing unvaporized liquid leaving the lowermost of said pans, and means for heating the flow surfaces of each pan; the said vaporizer being additionally characterized by the fact that the slope of the flow surface of each vaporizing pan at any horizontal distance from the vertical axis thereof is substantially inversely proportional to the square of said horizontal distance.

5. A vaporizer comprising a shell, a vapor outlet therefrom, a plurality of generally annular vaporizing pans positioned vertically one above the other within said shell, the flow surfaces of said pans sloping radially alternately inwardly and outwardly, whereby liquid to be vaporized may flow downwardly over the flow surface of each pan to the flow surface of the next lower pan, following a zig-zag course, a generally annular distributing trough surrounding the upper edge of the flow surface of each pan and positioned vertically below the lower edge of the flow surface of the pan immediately above, a weir between said trough and said flow surface over which liquid flows onto the flow surface, means for feeding liquid to be vaporized into the distributing trough associated with the uppermost of said pans, means for withdrawing unvaporized liquid leaving the lowermost of said pans, and means for heating the flow surfaces of each pan the said vaporizer being additionally characterized by the fact that the slope of the flow surface of each vaporizing pan at any horizontal distance from the vertical axis thereof is substantially inversely proportional to the square of said horizontal distance.

6. A vaporizer comprising a shell, a vapor outlet therefrom, a plurality of generally annular, double-walled vaporizing pans positioned vertically one above the other within said shell, the flow surfaces of said pans sloping radially alternately inwardly and outwardly, whereby liquid to be vaporized may flow downwardly over the flow surface of each pan to the flow surface of the next lower pan, following a zig-zag course, means for feeding liquid to be vaporized to the flow surface of the uppermost of said pans, means for withdrawing unvaporized liquid leaving the lowermost of said pans, and means for circulating a heating fluid through the interior space defined by the double walls of said pans; the said vaporizer being additionally characterized by the fact that the slope of the flow surface of each vaporizing pan at any horizontal distance from the vertical axis thereof is substantially inversely proportional to the square of said horizontal distance.

7. A vaporizer comprising a shell, a vapor outlet therefrom, a plurality of generally annular vaporizing pans positioned vertically one above the other within said shell, the flow surfaces of said pans sloping radially alternately inwardly and outwardly, whereby liquid to be vaporized may flow downwardly over the flow surface of each pan to the flow surface of the next lower pan, following a zig-zag course, means for feeding liquid to be vaporized to the flow surface of the uppermost of said pans, means for withdrawing unvaporized liquid leaving the lowermost of said pans, means for heating the flow surfaces of each pan, and insulation covering substantially all surfaces except the flow surface of said pans.

8. A vaporizer as claimed in claim 7 additionally characterized by the fact that the slope of the flow surface of each vaporizing pan at any horizontal distance from the axis is substantially inversely proportional to the square of said horizontal distance.

9. A vaporizer comprising a shell, a vapor outlet therefrom, a plurality of generally annular vaporizing pans positioned vertically one above the other within said shell, the flow surfaces of said pans sloping radially alternately inwardly and outwardly, whereby liquid to be vaporized may flow downwardly over the flow surface of each pan to the flow surface of the next lower pan, following a zig-zag course, means for feeding liquid to be vaporized to the flow surface of the uppermost of said pans, means for withdrawing unvaporized liquid leaving the lowermost of

said pans, and means for heating the flow surfaces of each pan; said vaporizer being additionally characterized by means for scraping the flow surfaces of the several pans during operation, said means comprising a central shaft extending through said shell, a plurality of radial arms secured to said shaft within the shell at different heights and rotatable therewith, the outer ends of said arms defining, when rotated, surfaces substantially parallel to and spaced above those of the several flow surfaces, a plurality of linked chains secured to the outer ends of said arms and of just sufficient length to extend to the flow surface immediately below the respective arm, a tube surrounding that portion of said shaft outside said shell, said tube being secured at its upper end to said shell and extending downwardly at least 40 feet, a stuffing box at the lower end of said tube sealing said shaft, means for introducing liquid substantially identical with that to be vaporized into said tube to fill the space between shaft and tube, whereby when said shell is under vacuum said stuffing box is exposed to substantially the same pressure on both sides, and means located beyond said stuffing box for rotating said shaft.

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