Nov. 10, 1931. E. METCALFE-SHAW 1,831,679

HEAT TRANSFERENCE

Filed Dec. 3, 1928 4 Sheets-Sheet 1

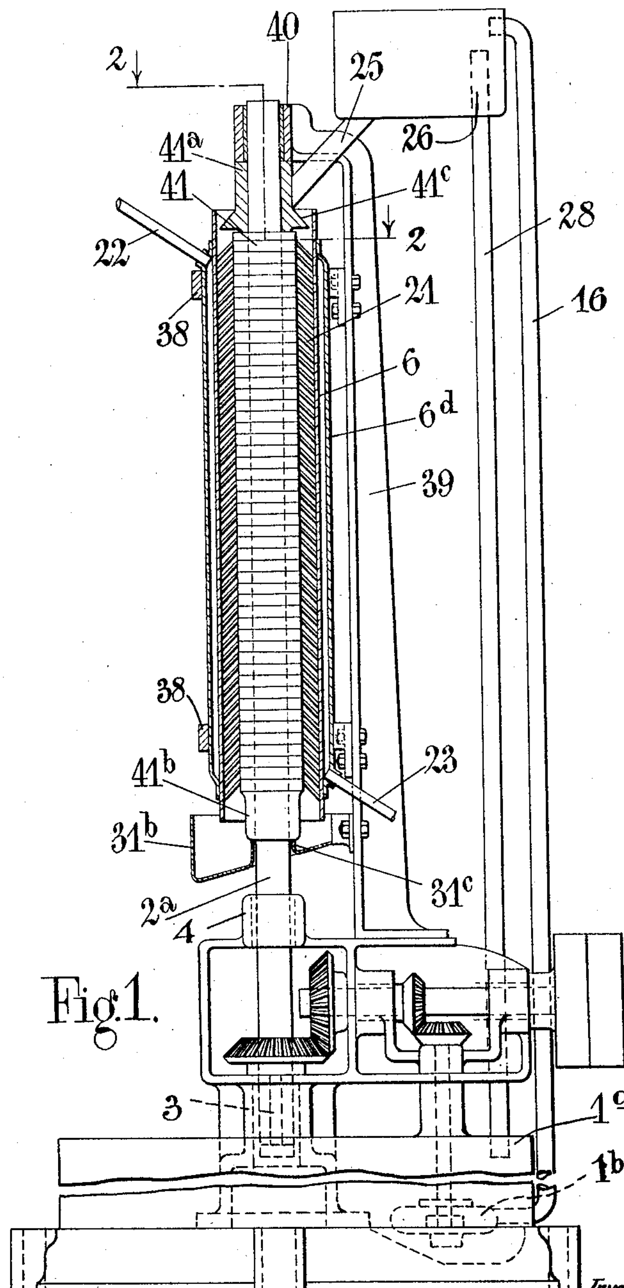

Fig.1.

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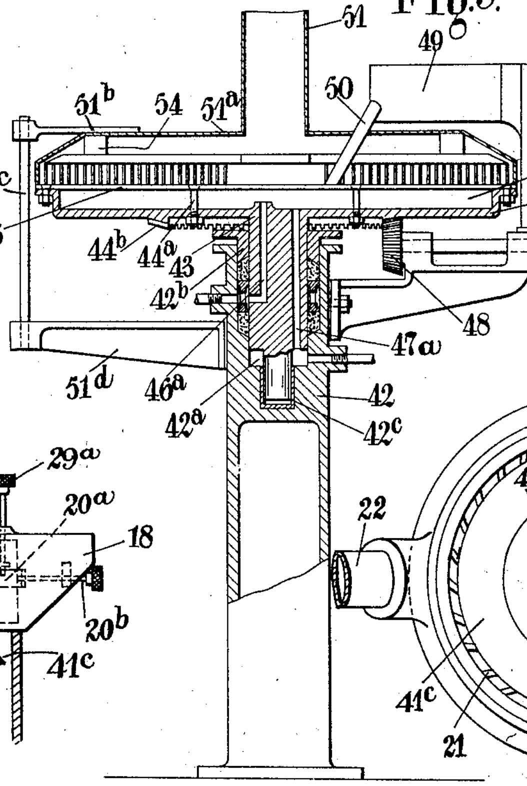
Fig.5.



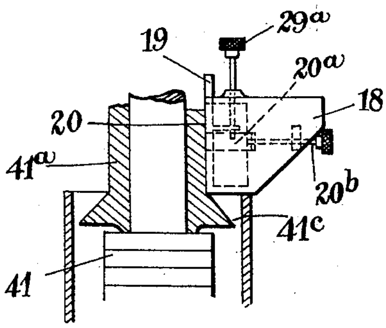


Fig.3.

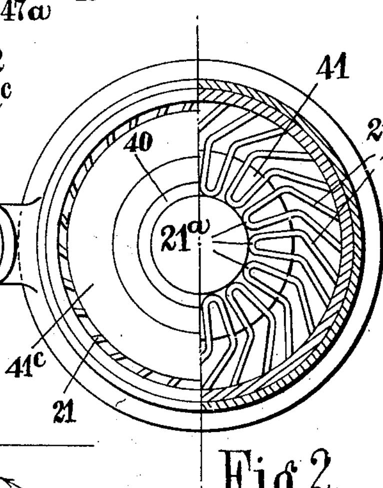


Fig.2.

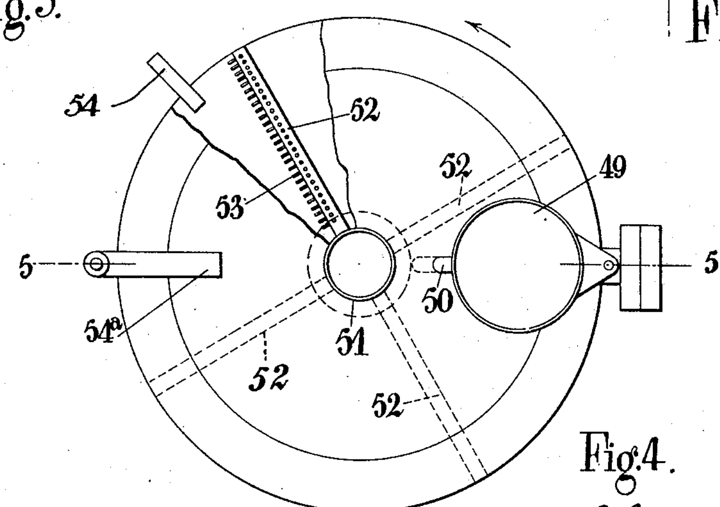


Fig.4.

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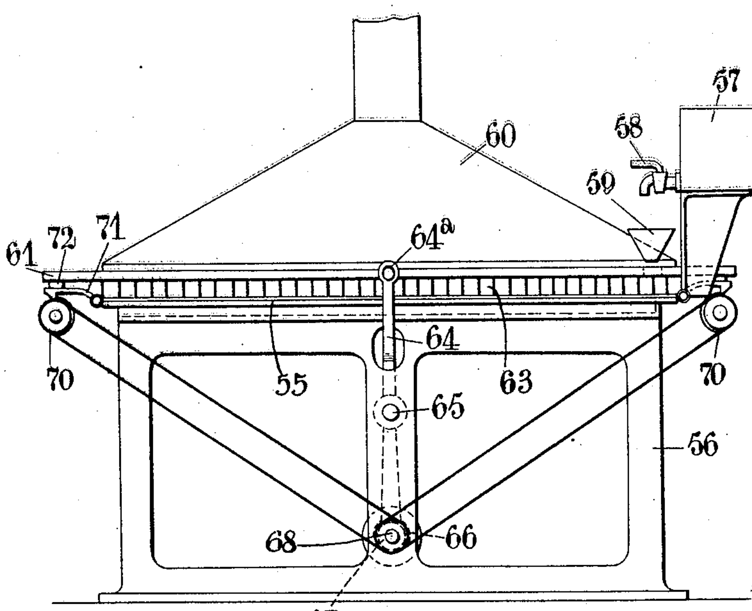

Fig. 6.

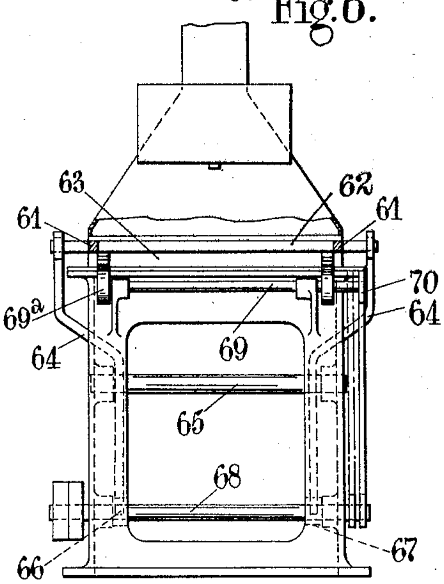

Fig. 7.

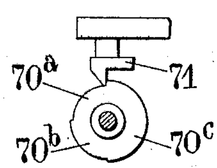

Fig. 8.

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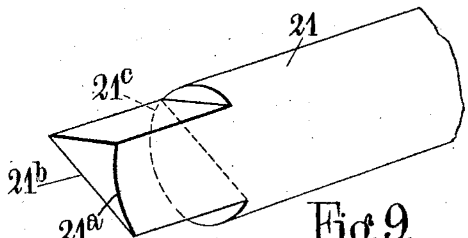

Fig. 9.

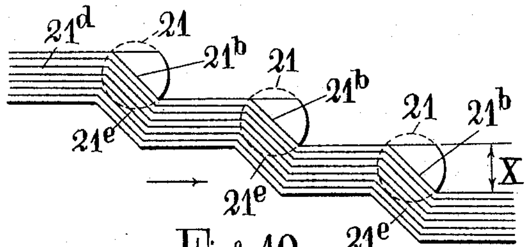

Fig. 10

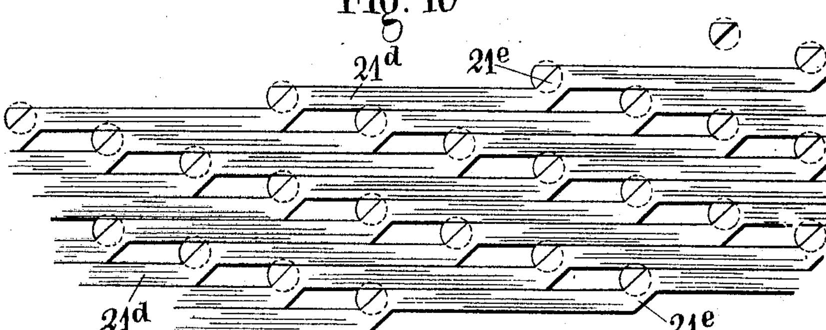

Fig. 11.

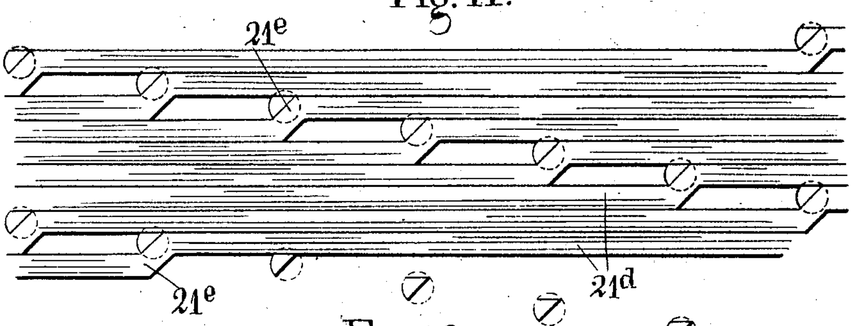

Fig. 12.

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Patented Nov. 10, 1931

1,831,679

UNITED STATES PATENT OFFICE

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HEAT TRANSFERENCE

Application filed December 3, 1928. Serial No. 323,431.

This invention relates to the transference of heat from solid surfaces to fluids, liquids or semi-liquids, including plastic or viscous compositions or mixtures, (hereinafter referred to as liquids), and the invention has reference to heat transference for a variety of purposes, including heat-treating liquids, semi-liquids and the like, concentration of solutions, liquid mixtures and the like, and evaporation or distillation of liquids.

Heat transference is not only effected with increased thermal efficiency as compared with present-day methods, but reduces the time factor of heat-treatment and enables relatively high temperatures to be employed without damage to the liquid under treatment.

A further important advantage achieved by the invention lies in this that in the concentration of solutions or mixtures, deposits, crystalline or otherwise, are reduced if not quite prevented from forming on or adhering to the surface, or if they occur are progressively removed.

Numerous subsidiary or additional advantages are derived from the invention and certain of these will be gathered from the description hereunder.

The invention comprises the constant mechanical removal and displacement of a film upon a surface receiving heat, to expose a clean or clear portion for the reception of a fresh film which in turn is displaced, the removal and formation of the film being recurrent.

The invention also consists in the heat treatment of a liquid by depositing a liquid progressively upon a heated surface in a thin layer and causing an organized movement of the layer over the surface to a discharge point. This is effected by mechanically removing portions of the layer at frequent intervals stage by stage in a manner adapted to expose a clear surface and laterally displace or relay it upon an exposed surface.

Another feature of the layer treatment according to the invention is that it lends itself to concentration or distillation (fractional or otherwise) by reason of the fact that a large surface is presented for the escape of vapour or gas and that, due to the thinness and movement of the layer, the passing or conversion of the liquid or a part thereof into vapour or gaseous form takes place mainly by simple evaporation as distinct from ebullition or the formation of bubbles within the liquid layer.

It will be appreciated that by reason of the constant motion and turning of the layer very much higher temperatures for the heating surface with greater rates of heat transfer can be employed than when the adhesion film of a layer remains more or less stagnant.

According to the invention the means adapted to effect the mechanical removal and diversion of the adhesion film or liquid layer comprise a plurality of scrapers or vanes adapted intimately to contact with the heated surface between which and the vanes relative movement is effected so that the vanes, so to speak, peel the film or layer from the surface, leaving in their track a clear or substantially clear area and displacing the portion of the film or layer acted upon transversely of the path.

A multitude of vanes is employed according to certain embodiments of the invention which are arranged with their faces inclined to the path of relative movement, laterally to displace or direct the liquid removed thereby, and further are arranged in spaced relationship or are pitched in two dimensions so that they lie in echelon, whereby there is a progressive feed from the path of one vane into the path of another.

Alternatively, the plurality of vanes are not adapted to give the removed or disturbed film a progressive displacement in one direction or a redirection from one predetermined path to another, but are formed or adapted to remove or displace the film (it may be equally on either side) and the cleared path is filled in by other portions of the layer flowing under gravity action down the surface.

According to another method of spreading and displacing a layer of liquid for heat treatment, the layer is acted upon in a plurality of zones alternately to scrape it from the surface so that it is more or less piled up and subsequently again spread out in a layer over a cleared part of the heating surface. For this purpose the vanes may be reciprocated and given a travel partly in contact with the heating surface to effect the clearing of the surface and partly in a slightly elevated plane to re-spread the layer.

The heating surface may have a diversity of forms and it will be appreciated that it may be in the form of a drum or cylinder (arranged vertically, horizontally or inclined), a cone, a rotary disc or a reciprocating table.

In the accompanying drawings:—

Figure 1 is a front elevation of a plant designed to carry out the invention according to one embodiment in which an internal surface is provided on which the liquid for treatment is heated by the aid of steam.

Figure 2 is a transverse section on the line 2—2 of Figure 1 (certain view lines being omitted) and illustrates a mode of mounting scrapers or vanes.

Figure 3 is a view of a detail.

Figure 4 is a plan view of plant in which the heating surface is of rotary disc form.

Figure 5 is a section on lines 5—5 of Figure 4.

Figures 6 and 7 are, respectively, side and end elevations of a plant having a heating surface in the form of a rectangular plane or table and in which the vanes have a relative reciprocatory or oscillatory motion.

Figure 8 is a detail view of a cam for operating in conjunction with the plant shown in Figures 6 and 7.

Figure 9 is an enlarged detail view illustrating one convenient form of vane or scraper element according to the invention.

Figure 10 is a diagram illustrating the action of the scrapers on a ribbon layer of liquid showing the diversion of the ribbon layer from one path to another.

Figures 11 and 12 are diagrams illustrating by way of example, two relative arrangements of the vanes with respect to one another giving a different movement of a liquid layer over the surface of the heating element.

In carrying the invention into effect according to one convenient mode (see Figures 1 and 2) as applied, by way of example, for sugar boiling or like processes by the aid of steam heat, a base 1, preferably supporting the storage tank 1*a*, has mounted upon it a column and driving gear for a rotary shaft 2*a* mounted in a footstep bearing 3 and further supported in a bearing 4 of the driving gear casting. A cylindrical element 6 concentric with the shaft 2*a* is supported in a stationary position by bracket members or annular supports 38 from a stanchion or other support 39 which also serves as a top bearing at 40 for the shaft 2*a*. The cylindrical element is provided with a jacket 6*d* through which steam is circulated by the pipes 22 and 23.

Vane elements or scrapers 21 are mounted upon the shaft 2*a* in any convenient manner; for example, the shaft is provided with a series of rings 41 abutting one against the other and clamped between an upper collar 41*a* and a lower collar 41*b*. The opposing surfaces of the rings 41 are grooved to accommodate the vanes 21 which according to one convenient mode are formed of U-shape integrally in pairs as shown at 21*a*, Figure 2. The rings 41 are formed on their opposing faces with corresponding U-shape slots to accommodate the ends of the vanes.

A chute 31*b* is mounted on the stanchion 39 below the end of the cylinder 6 and is provided with a flanged orifice 31*c* to accommodate the shaft 2*a*. This chute is adapted to receive the liquid as it drips from the lower margin of the cylinder 6 and deliver the same to the plant.

The liquid is fed to the inner surface of the cylinder 6 from a tank 26 through a pipe line 25 and mouthpiece (see Figure 3) which is contoured to conform to the circumference of the upper collar member 41*a*. The collar 41*a* is provided with a conical extension or skirt 41*c* which is of only slightly less diameter than the interior diameter of the cylinder 6 so that the liquid spread upon the collar 41*a* from the feed mouthpiece flows down upon and is spread from the periphery of the skirt 41*c* in a layer onto the interior surface of the cylinder where it is treated and given a progressively downward displacement by the vanes 21 in the manner more particularly described hereinafter. The tank 1*a* may act as a reservoir for the liquid to be treated and is provided with a centrifugal pump 1*b* (operated by the driving gear for the shaft 2*a*) adapted to deliver the liquid up the pipe 16 to the tank 26 at a rate predetermined to maintain a constant level or head of liquid in the feed tank 26. An overflow pipe 28 is fitted to the tank 26 to return any surplus discharged by the pump to the tank 1.

The mouth-piece 18 (see Fig. 3) is arcuate and adapted snugly to fit the contour of the collar 41*a*. In order to vary the width of the ribbon layer spread upon the collar by the mouthpiece, it may be provided with a sliding shutter 19 which may be adjusted by the rod 29*a* and for the purpose of varying the thickness of the layer the slot 20 in the side of the mouthpiece through which the liquid escapes may be adjusted by the slide 20*a* manipulated by the rod 20*b*.

It will be appreciated that the vanes or scrapers 21 are revolved by the driving gear while the cylinder 6 remains stationary. The revolution of the collar 41*a* under the mouthpiece 18 enables the latter to feed a ribbon layer of liquid to the face of the collar which flows down and is distributed by the skirt 41*c* onto the cylinder. The vanes, as they revolve act upon the continuously discharged ribbon layer and cause the liquid to be displaced progressively stage by stage down the heated surface 6, so that the liquid receives uniform heat treatment which is complete when the liquid reaches the lower end of the cylinder.

The invention has been described above with reference to the distribution of the liquid for treatment upon a surface of cylindrical form. The invention may, however, be carried into effect by the distribution thereof upon a rotating disc or flat table. One form of this arrangement is illustrated in Figures 4 and 5. A standard or column 42 is provided with a hollowed part 42*a* and has a stuffing box 42*b* and a footstep bearing 42*c* for the spindle 43 of a hollow table element 44. The table element is flanged and has a heating surface disc 45 mounted thereon and sealed at its periphery so as to make the space 46 under it steamtight. In order to avoid flexure or buckling of the disc supplementary supporting bolts or members 44*a* may be provided.

For supplying steam to the space 46, the spindle 43 is provided with inlet and outlet ducts 46*a* and 47*a* communicating with suitable inlet and outlet ducts. The table 44 on its lower surface is provided with an annular rack 44*b* with which a bevel pinion 48 of a driving gear is adapted to mesh for the purpose of giving the table and surface 45 rotational movement.

Liquid to be treated may be fed towards the centre of the table from a tank 49 which may be kept supplied with liquid from any suitable source. The liquid is fed on to the table by means of a pipe 50 terminating in a mouthpiece of the character already described in connection with the earlier figures. Coaxial with the table 44 is a vertical stationary pipe 51 and cover 51*a* to collect and carry away the evaporated steam. The cover 51*a* may be supported in any convenient manner as by spaced arms 51*b* (only one of which is shown) mounted on posts 51*c* carried by brackets 51*d* from the column 42. The cover 51*a* also carries a plurality (for example, twelve four only of which are shown) of radial arms 52 on which a series of vanes 53 is secured. The liquid is fed onto the disc near the centre and comes under the action of the vanes as the table revolves beneath such. The vanes cause the liquid progressively to move outward towards the circumference and the treatment is such that when the liquid arrives at the periphery it is ready for discharge and may be delivered by means of a scraper 54.

While for general purposes it is convenient to employ rotary motion for causing the progressive travel of the liquid over the heating surface, the same effect may be gained by providing relative reciprocation or oscillatory movement between the vanes and the heated surface bearing the liquid. For example, in Figures 6 and 7 a stationary rectangular hollow table 55 is carried by a suitable frame 56 and receives a heating medium through pipes or conduits (not shown) which are located in any suitable situation. The liquid is fed or supplied in a layer to one end of the table and is discharged from the other end. A supply tank 57 may be discharged through a control cock 58 into a funnel 59 which terminates in a mouth-piece element (not shown) which extends across the width of the table. Above the table a hood 60 may be provided for carrying away vapour and air.

A pair of longitudinal frame elements 61 have cross bars 62 each of which carries a series of vanes 63 adapted resiliently to bear upon the surface of the table. The frame for the vanes is given a reciprocating motion by means of the arms 64 pivoted on a shaft 65 and terminating in forks 66 which are engaged by cam elements 67 keyed upon shaft 68 which is driven by any suitable means. The rotation of the cams causes the cranked arms 64 to be oscillated and causes the table to be reciprocated. In addition to the rectilinear reciprocation, the vanes are provided with a motion transverse to the direction of reciprocation at each end of the reciprocating stroke so that they are alternately raised from and lowered onto the table. To accommodate this movement the arms 64 engage the frame element 61 by a pin-and-slot connection 64*a*. At each end of the table a cross shaft 69 is mounted and has secured to it a pair of stepped cam elements 69*a*. The shaft 69 may be rotated by chain and chain wheel gear 70 from the driving shaft 68 or by any other convenient driving connection. The vane-carrying frames 61 are floated upon the cams and rise and fall as they rotate and according to their contour. At the ends of the tables pivoted latch members 71 are provided the upper surface of which is flat and adapted to constitute a sliding track for bars or studs 72 secured to the under-side of the frame element 61. This arrangement permits the free reciprocation of the vanes while at the same time providing a means to cause their elevation at the end of their reciprocating stroke and their depression into contact with the table for the commencement of a stroke, or with an intermediate rise of the vanes during a portion of the reciprocatory travel according to the desired action of the vanes. For example, the cams 70 may be designed to have three steps 70*a*, 70*b* and 70*c*. The lowest step 70*a* and the next succeeding step 70*b* each occupy a quarter of a revolution while the highest step extends over the remaining half revolution. The latch members 71 in proceeding from the step 70*a* to step 70*b* are raised 1/16th″ and similarly in proceeding from step 70*b* to step 70*c* they are raised another 1/16th″. The timing of the cams is such that during the first half of the reciprocatory movement of the vanes, they move the liquid lying on the table forward so that the liquid is more or less piled in front of the vanes. The length of the stroke may have any suitable predetermined value and where the stroke is 1″ the vanes clear the liquid layer in front of them and push it forward for ½″. The cams then lift the vanes 1/16th″ in passing from the step 70*a* to the step 70*b* and during the remainder of the travel the vanes spread out the piled liquid again to a depth of 1/16th″, leaving the whole table surface covered. The spreading movement continues for the remainder of the reciprocatory stroke, that is to say, for a movement of ½″. At the end of the stroke the step 70*c* raises the latches 71 a further 1/16th″ lifting the vanes clear of the table and out of contact with the liquid layer. At this point the return reciprocatory stroke commences and the vanes are carried back out of contact with the liquid to their initial position.

The vanes between the longitudinal frames are arranged the full width of the table and may be formed as elongated rectangular plates.

The vanes are preferably formed on or constituted by the ends of pieces of wire adapted to afford a certain amount of resilience. They may be made from wire of circular cross section or they may be formed by members of other sections. The portion or body of the vanes in rear of their contact or active faces are preferably inclined in two directions, one towards their heating surface so as to prevent the liquid from creeping or running down the wires, and another to facilitate or accommodate the relative movement and to aid in resilient action. The vanes are adapted to contact with the surface or have a working clearance therewith. In order to avoid loss of heat, means may be provided for heating the vanes and their supports or the vanes may be heat insulated from their support.

Figure 9 is an enlarged view showing the active end of a vane wire which has been found suitable for use in conjunction with a cylindrical surface. The end of the wire is formed with a slightly convex surface 21*a* of a curvature corresponding with the curvature of the cylindrical surface. This face may be ground or run in on the cylindrical surface. Where the vane is intended to engage an external cylindrical surface the face 21 would be formed correspondingly concave. The wire is formed to provide a face or edge 21*b* and is set so that it lies at an angle of 45° or other appropriate angle to the path due to the relative motion between the vane and the heated surface. This face 21*b* is the active face adapted to scrape or peel the liquid from the cylindrical surface and divert it laterally, or in a direction transverse to the path above mentioned. At 21*c* the vane may be cut away in order that the adjacent edge of the surface 21*b* may be sharply defined.

A vane of the character illustrated in Figure 9 is adapted to promote a unidirectional displacement or diversion of a ribbon layer of liquid in an organized and predetermined progressive manner as hereinafter described.

Where however the invention is applied in connection with a vertically placed surface or where its position has a vertical component and it is intended that gravity shall take an active part in the movement of the layer of liquid, the vanes may be formed with a square, curved or double inclined active face or edges, such as may be presented by a round, oval, square or wedge-shaped section wire or rod. Similarly, vanes of the above character may be employed in connection with surface disposed such that gravity has no influence for movement on the layer but where movement is promoted or modified by centrifugal force.

In these cases the reforming of the layer or the filling in thereof behind or in the path of a vane may be aided by gravity or centrifugal action on the adjacent portions of the layer.

The action of the vanes upon a liquid film or ribbon is illustrated in Figure 10. The upper or leading edge of the face 21*b* lies upon the same horizontal line as the lower or trailing edge of the vane in front but it will be obvious that these faces 21*b* may overlap one another, if desired. The vanes 21 present the surface 21*b* towards the direction from which the surface carrying the film or ribbon 21*d* is moving, as shown by the arrow. It will be seen that each surface 21*b* in turn obstructs the path of the liquid so that the surface of the cylinder is cleared behind the vanes in the respective paths and at the same time diverts, by a wedge-like action upon the liquid, the ribbon or stream thereof, as at 21*e*, from its path in front of one surface 21*b* to a path a stage nearer the discharge and in front of the next surface 21*b*.

The vanes are arranged in a plurality of vertical series, each series comprising equally spaced vanes having active surfaces of predetermined dimension X, Figure 10. Every series is vertically displaced or pitched with reference to its adjacent vertical series on the following side (having reference to the relative movement) equal to the dimension X with the active face. The vertical spacing of the vanes in a vertical row is some predetermined multiple of the dimension X.

In the diagram, Figure 10, the pitch of the series of vanes is at a minimum, that is to say, the ribbon is deflected by the vanes of each vertical row or series of vanes.

Two examples of the pitching of the vertical rows of vanes are illustrated in Figures 11 and 12. In Figure 12 the vanes are pitched so that the paths of the liquid, as at 21*d*, are diverted, as at 21*e*, from the vanes of one vertical row to the vanes in a third vertical row (corresponding with the direction of rotational movement) from it, whereas in Figure 12 the paths 21*d* are diverted at 21*e* to vanes in the sixth vertical row from the vanes in the vertical row at which diversion takes place.

The pitch arrangements are given by way of example and it will be appreciated that any pitching relationship may be adopted. It will also be appreciated that the greater the pitch the longer the liquid remains in contact with the heating surface before it is turned over or disturbed.

The arrangement of the vanes in Figures 4 and 5 is such that active surfaces give the liquid layer a displacement radially outwards and the vanes of one arm 52 (see Figure 4) are pitched in the manner already described with respect to the vanes of adjacent arms. In the forms (see Figures 6 and 7) where there is a relative reciprocatory movement between the vanes and the heating surfaces, and where the liquid is alternately heaped up and spread out, a similar pitch arrangement may be employed in order that the whole surface of the table may be acted upon by the vanes.

The arrangement of vanes, the area and dimensions of the heating surface, the rate of feed of the liquid to the heating surface and the rate of relative movement will be predetermined and varied according to the particular treatment in view. The process of heat treatment will be devised and directed to the end in view, whether it be for the boiling of sugar or for other processes involving the extraction of the liquid or volatile content of a solution or body, or for evaporation or distillation. The invention is applicable for distillation processes in which it is desired to distil or extract a more volatile liquid from a body of less volatile liquid as it enables heat to be supplied in such a manner that the temperature of the mixed liquid is kept below that at which the less volatile constituent vaporizes and yet above the temperature at which the more volatile liquid can evaporate.

I claim:

1. A plant for heat transference between the surface of a solid body and a liquid comprising a surface, means for heating the surface, means for applying the liquid to the surface in a thin layer, a multiplicity of vanes acting adjacent the heated surface and means for effecting relative movement between the vanes and the surface, whereby the vanes remove portions of the layer, (to expose a substantially clear surface) simultaneously in a multiplicity of zones and displace the removed portions towards the zones of other vanes.

2. A plant for heat transference between the surface of a solid body and a liquid comprising a surface, means for heating the surface, means for applying the liquid to the surface in a thin layer, a multiplicity of vanes acting adjacent the heated surface and arranged in a plurality of rows, the vanes in each row being laterally displaced with reference to the corresponding vanes in adjacent rows not more than the width of the vanes and means for effecting relative movement between the vanes and the surface, whereby the vanes remove portions of the layer, (to expose a substantially clear surface) simultaneously in a multiplicity of zones and displace the removed portions towards the zones of other vanes.

3. A plant as claimed in claim 2 wherein the pitch of the vanes in each row is a multiple of a unit, said unit being not greater than the width of a vane.

4. A plant for heat transference between the surface of a solid body and a liquid comprising a surface, means for heating the surface, means for applying the liquid to the surface in a thin layer, a multiplicity of vanes acting adjacent the heated surface, said vanes being inclined to and resiliently engaging the surface, and means for effecting relative movement between the vanes and the surface, whereby the vanes remove portions of the layer, (to expose a substantially clear surface) simultaneously in a multiplicity of zones and displace the removed portions towards the zones of other vanes.

5. A plant for heat transmission between the surface of a solid body and a liquid comprising an externally heated cylinder, means for flowing the liquid onto the interior surface of the cylinder in a thin layer, a multiplicity of vanes positioned to engage and act upon the interior surface of the cylinder, and means for effecting relative rotation between the vanes and the cylinder, whereby the vanes remove portions of the layer, (to expose a substantially clear surface) simultaneously in a multiplicity of zones and displace the removed portions towards the zones of other vanes.

6. A plant for heat transmission between the surface of a solid body and a liquid comprising an externally heated cylinder arranged with its axis vertical, an inner rotatable shaft carrying a multiplicity of vanes positioned to engage and act upon the interior surface of the cylinder, said vanes being inclined to the surface downwardly and in the direction of rotation, and means for flowing liquid onto the interior surface of the cylinder in a thin layer, whereby the vanes remove portions of the layer, (to expose a substantially clear surface) simultaneously in a multiplicity of zones and displace the re-

moved portions towards the zones of other vanes.

7. A plant as claimed in claim 6, wherein the means for flowing the liquid onto the cylinder comprises a rotatable element adapted to deliver the liquid onto the inner surface of the cylinder in a thin layer and an arcuate mouthpiece for delivering the liquid to said rotatable element, means being provided for adjusting the flow of the liquid from the mouth-piece to said rotatable element.

8. A heat transference apparatus comprising an externally heated cylinder, means for applying liquid to the interior surface of the cylinder in a thin layer, and an inner rotatable shaft carrying a multiplicity of vanes positioned to engage and act upon said interior surface, said vanes being arranged in rows, the vanes in each row being laterally displaced with reference to the corresponding vanes in adjacent rows not more than the width of the vanes.

9. A heat transference apparatus as claimed in claim 8, wherein the pitch of the vanes in each row is a multiple of a unit, said unit being not greater than the width of a vane.

10. A plant for heat transference between the surface of a solid body and a liquid, comprising a surface, means for heating the surface, means for applying the liquid to the surface in a thin layer, a multiplicity of vanes acting adjacent the heated surface and means for effecting relative movement between the vanes and the surface, the arrangement being such that the vanes remove portions of the layer, (to expose a substantially clear surface) simultaneously in a multiplicity of paths and displace the removed portions of the layer transversely of said paths into paths cleared by the removal of other portions of the layer.

In testimony whereof I have signed my name to this specification.

EDWARD METCALFE-SHAW.