Jan. 16, 1940. W. T. HINCKLEY 2,187,030

MULTIPLE EFFECT EVAPORATOR AND THE LIKE

Filed June 28, 1937 3 Sheets-Sheet 1

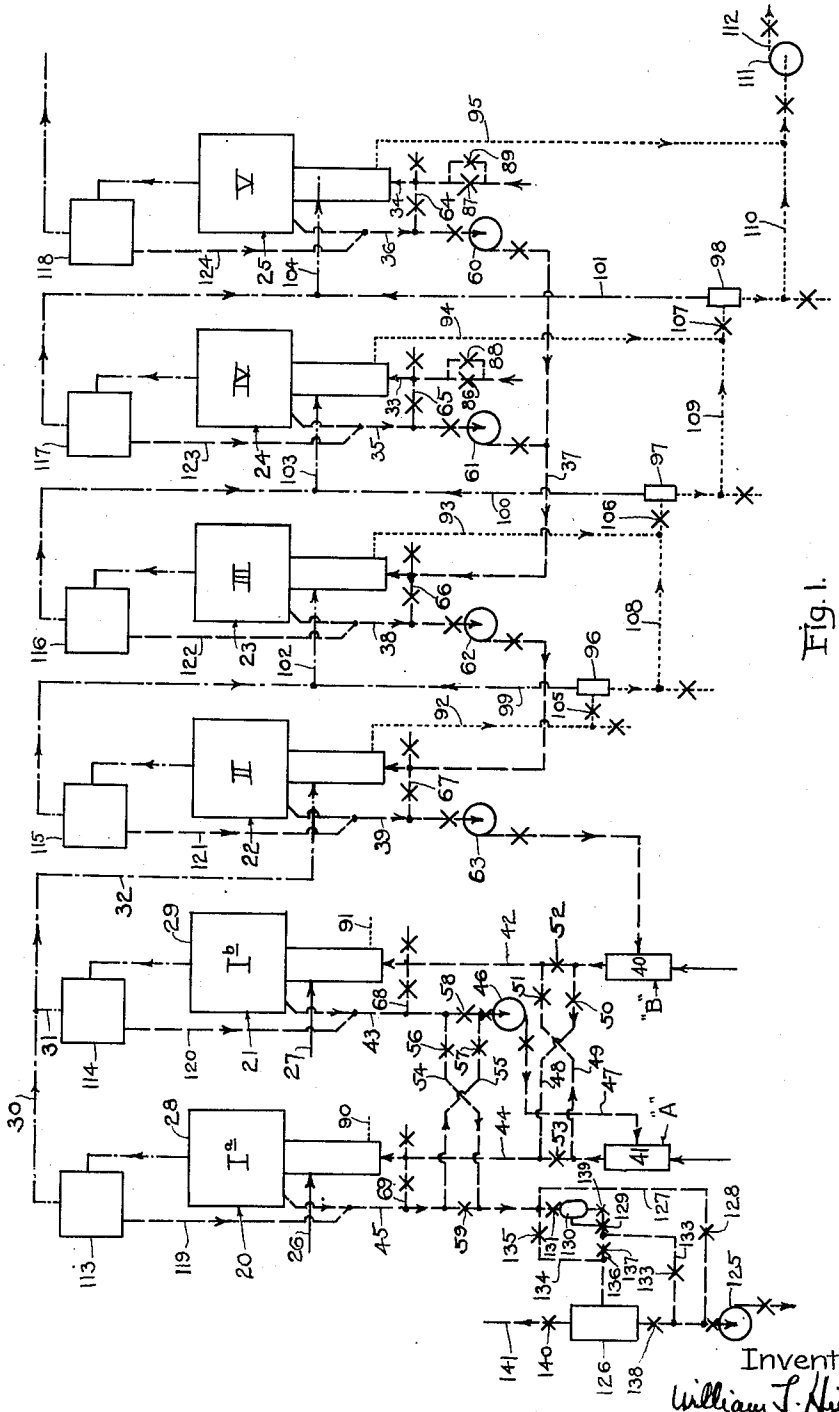


Fig. 1.

Inventor:
William T. Hinckley
by Thos. A. Banning Jr.
Atty.

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MULTIPLE EFFECT EVAPORATOR AND THE LIKE

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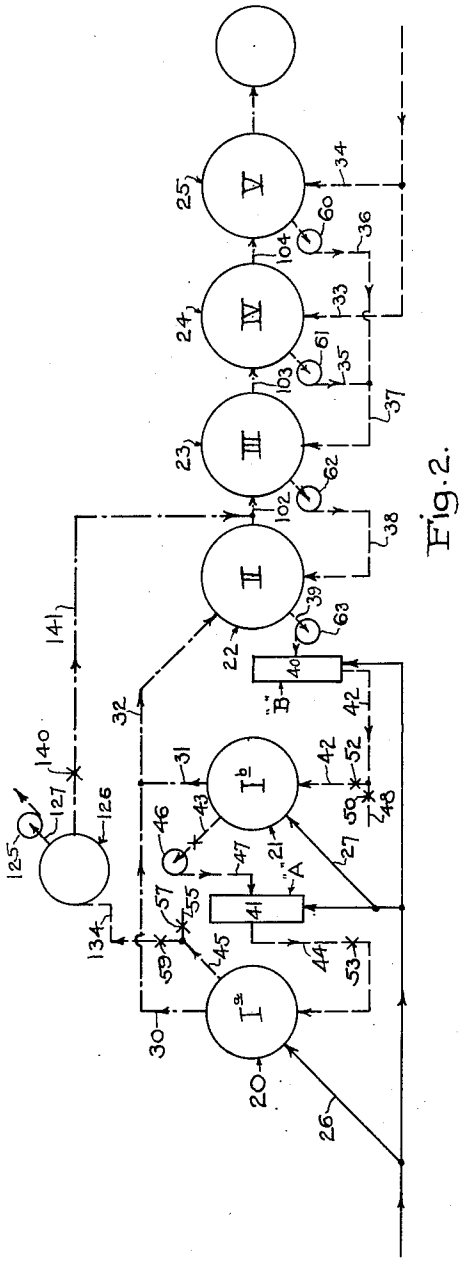


Fig. 2.

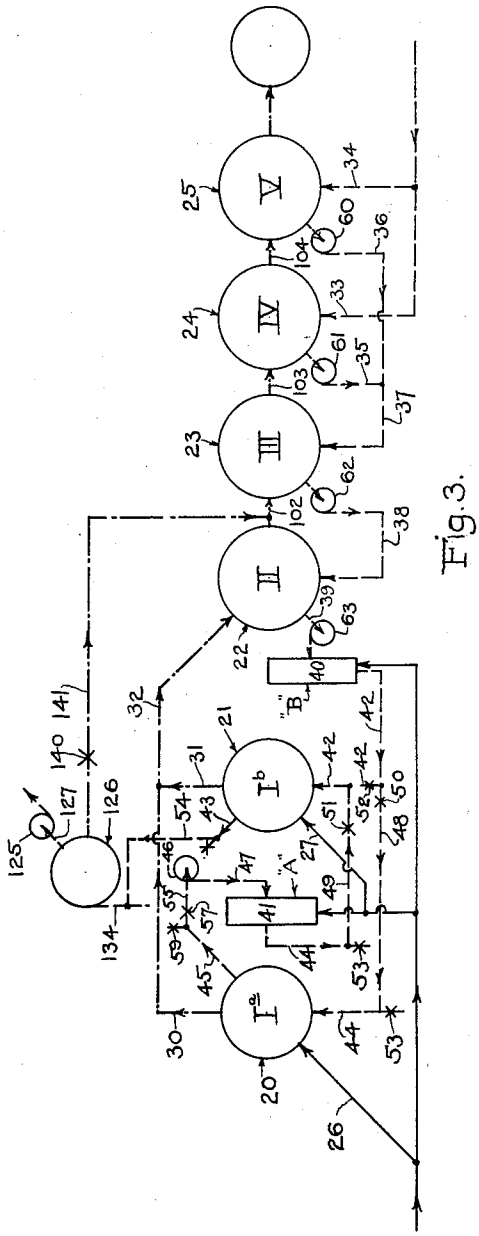


Fig. 3.

Inventor:
William T. Hinckley
by Thos. A. Lemmon
Atty.

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Filed June 28, 1937 3 Sheets-Sheet 3

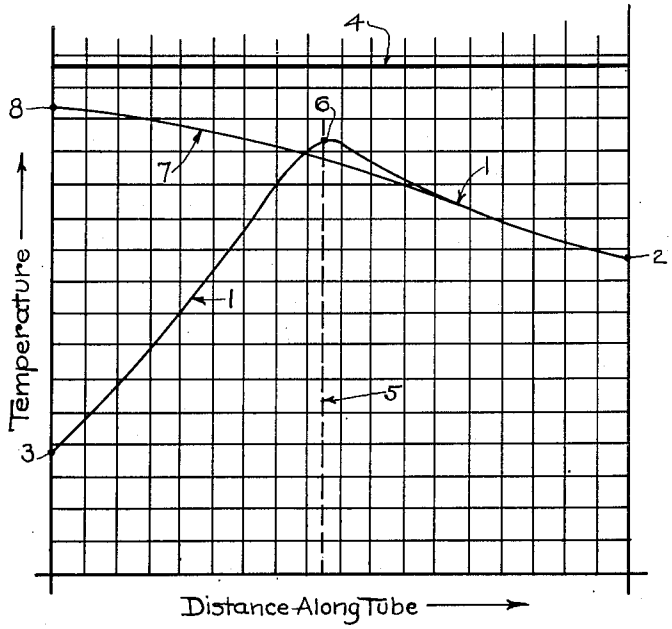


Fig. 4.

Inventor:
William T. Hinckley
by Thos. A. Ramey Jr.
Atty.

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UNITED STATES PATENT OFFICE

2,187,030

MULTIPLE EFFECT EVAPORATOR AND THE LIKE

William T. Hinckley, Chicago, Ill., assignor to Whiting Corporation, Harvey, Ill., a corporation of Illinois

Application June 28, 1937, Serial No. 150,747

8 Claims. (Cl. 159—17)

My invention relates to evaporators. Specifically, it relates to improvements in the design and operation of evaporators commonly known as the long tube vertical type.

One purpose of my invention is to secure large capacity from an evaporator. Another purpose of my invention is to secure higher rates of heat transfer in an evaporator. Another purpose of my invention is to improve the operation of multiple effect evaporators. Another purpose of my invention is to increase the concentration to which a given solution may be carried in a given evaporator.

It is a well known fact that in general there are two important methods of feeding concentrating evaporators; namely forward feed and backward feed. In forward feed the thin liquor is fed into the first, or highest pressure effect, and flows through the effects in series to finally issue from the last or lowest pressure effect. In backward feed the thin liquor is fed into the last or lowest pressure effect and passes through the evaporator so that the thick liquor is finally withdrawn from the first or highest pressure effect. Other methods of feeding concentrating multiple effect evaporators are merely modifications or combinations of these two.

When using forward feed, the liquor passes thru the effects in the order of decreasing pressure. When liquor at its boiling point is withdrawn from one effect and introduced into the next effect it is introduced into a space of lower pressure than the pressure with which it was previously in equilibrium and therefore it flashes. As will appear later in this discussion my invention is not in general concerned with forward feed operation, although it may have applications in very special cases of forward feed. In backward feed, liquor at its boiling point is withdrawn from any given effect and introduced into the next effect which is at a higher pressure. It is therefore introduced into such an effect at a temperature below its boiling point and a certain amount of heat is required to bring it to this boiling point before it can begin to boil. It may be stated here parenthetically that the choice between forward and backward feed is made on the basis of considerations entirely outside the scope of this application and consequently for the purposes of this discussion it may be assumed that backward feed having been decided upon, forward feed cannot be considered as an alternative.

In practically all types of evaporator construction with which I am acquainted other than long tube vertical evaporator, any one body contains a considerable volume of boiling liquor at the final concentration produced by that body. In such evaporators the rate of circulation or agitation within the body is such that colder feed is rapidly distributed thruout the whole mass of liquor and it is common experience that in such cases actual observations show that the temperature of the liquor thruout the body is practically uniform and at its boiling point.

Statements in the preceding paragraph are not true of the long tube vertical evaporator. In this case liquor is fed into the bottom of the tubes and any feed chamber there may be is filled with liquor at the inlet concentration and temperature. As the liquor passes up the tubes it is first heated, then boiled, is ejected from the top of the tubes at the final concentration, and the liquor is removed from the effect at this point to be taken either to the next effect or to be disposed of otherwise.

Referring at this point to Fig. 4, this figure is a diagrammatic plot of the conditions existing in a tube of such an evaporator. The horizontal distances or abscissae represent distances along the tube (the bottom of the tube being taken as the left hand edge of the diagram). Vertical distances are ordinates, representing temperatures. Curve 1 shows the course of the liquor temperatures up thru the tube. While the shape and position of this curve varies widely with feed temperature, feed rate, heat transfer coefficient, temperature drop and other factors, the general shape is typical. Point 2 on the right hand edge of the diagram is obviously the boiling point of the liquor at the pressure existing in the vapor head. Point 3 on the left hand edge of the diagram represents the feed temperature of the liquor and consequently is lower than point 2 in the case of backward feed. Curve 4 represents the temperature of the steam or other heating medium and is assumed to be constant thruout the space around the tubes. This is actually true in practice in the great majority of cases.

The liquor entering at the temperature indicated by point 3 is below its boiling point. Therefore, as the liquor passes up the tube it must first be heated as a liquid. Because of the effects of hydrostatic head and friction the pressure at the bottom of the tube is greater than in the vapor space. As the liquid passes toward the top of the tube its temperature rises regularly but the pressure on it is decreasing. At some point such as is indicated by the vertical line 5 the increase in the temperature of the liquor and the decrease in its pressure will have reached such a relationship that the liquor begins to boil, traveling up the

tube as a thin film along the wall, flashing as the pressure decreases, until finally the material reaches the top end of the tube and issues into the vapor head at the temperature shown by point 2.

It should be noted that the maximum temperature reached at point 6 is higher than the temperature indicated by point 2. The difference between these two temperatures may in actual practice be a matter of several degrees F.

In that part of the curve between points 3 and 6 the liquor is being heated as a liquid and the amounts of feed per tube of the long tube vertical evaporator are such that in practice the velocities in this part of the tube are extremely low and generally fall into the range of viscous flow. This means that thru this part of the tube the heat transfer coefficient will be low and by actual measurements on distilled water I have found these coefficients to be of the order of 50 to 100 B. t. u., per sq. ft. per degree F. per hour. Above point 6 the liquor is boiling and the volume of the steam generated is considerable, the velocities are high and heat transfer coefficients are very high. Those that I have measured range in the order of 800 to 5000 with the average well above a thousand. It follows therefore that any device or method of operation that serves to displace point 6 towards the bottom of the tube and thereby serves to decrease the proportion of the tube that is heating liquor in a non-boiling condition, will greatly improve the average heat transfer coefficient over the entire tube.

It is obvious that the higher the temperature of the feed with respect to the temperatures indicated by point 2 the less of the tube length will be employed for pure heating. I have found in practice that by suitably heating the incoming liquor point 6 can be depressed to the very bottom of the tube. Thus the entire tube will be employed for evaporating. Such a curve is shown as curve 7 in Fig. 4.

From the above preliminary discussion, I may state that a principal object of my invention is to provide, in a multiple effect long tube vertical evaporator, means to preheat the liquor before feeding the same to an effect; and specifically to provide means for effecting such preheating between effects of the multiple effect evaporator; and still more specifically to provide means for effecting such preheating prior to the feed of the liquor to the thick liquor effect in a backward flow multiple effect evaporator.

A further object of the invention will appear from the following statement:

"Black liquor" and certain other aqueous liquors present the characteristic that when an evaporator of the long tube vertical type is used for concentration of such liquor up to say 53% total solids, the tubes thereof become fouled after a time so that the operation and heat transfer coefficient become impaired and lowered. Now, if the operation be changed so that the concentration does not exceed say 48% total solids it is found that the continued operation at such lowered concentration will cause the fouling matter to be removed so that the operation will be again improved and the heat transfer coefficient will be again restored to its high point.

An important feature of the present invention consists in the subdivision of the thick liquor effect into two sub-effects, and in the provision of suitable connections and valves in the liquor lines so that the liquor can be passed through said sub-effects in series, but on reversing cycles, the liquor on one operation flowing through sub-effect A and then through sub-effect B, and on the next operation through sub-effect B and then through sub-effect A, etc. By this means, each sub-effect is used alternately for operation on liquor of maximum concentration and then on liquor of lower concentration, etc., the operation on each alternation being for substantially one half of the total cycle.

More specifically, this feature of my invention relates to the use of the above mentioned feature in multiple effect long tube vertical evaporators of the backward flow type, but is not limited thereto except as I may do so in the claims.

Still more specifically one feature of my invention relates to multiple effect long tube vertical evaporators of the backward flow type incorporating both of the above features of preheating and sub-division of the thick liquor effect, provided with the reversing feature above referred to.

Other objects and uses of the invention will appear from a detailed description of the same, which consists in the features of construction and combinations of parts hereinafter described and claimed.

In the drawings:

Figure 1 shows a typical flow sheet of a backward flow, six body, five effect, multiple effect, evaporator embodying the features of the present invention, the first being subdivided into two sub-effects through which the liquor flows in series, and both of which are heated by steam in parallel, the vapor heads of both of said sub-units or sub-effects being connected in parallel, said sub-units or sub-effects being provided with preheaters and with suitable connections and valves whereby the various features of the present invention may be practised;

Figure 2 shows a plan view of a typical layout embodying the features shown in the flow sheet of Figure 1, with the valves turned into such position that the liquor flows first through sub-effect 1B and then sub-effect 1A, with preheating of the liquor before entering each of said sub-effects;

Figure 3 shows a view similar to that of Figure 2 but with the valves reversed so that the liquor flows first through sub-effect 1A and then through sub-effect 1B, with preheating of the liquor before entering each of said sub-effects; and

Figure 4 shows a diagram of liquor temperatures, under ordinary operation without preheating, and also with preheating.

Referring first to Figures 1, 2, and 3, it will be noticed that there are provided the evaporators 20, 21, 22, 23, 24 and 25 respectively, the effects 22, 23, 24 and 25 being designated as the effects 2, 3, 4 and 5 respectively. The bodies 20 and 21 are the sub-effects 1A and 1B respectively. It will also be noted that the sub-effects 20 and 21 or 1A and 1B, are indicated as being of substantially smaller size than the effects 22, 23, 24 and 25 respectively.

It will also be noted that the heating units for the sub-effects 20 and 21 are both supplied with live steam in parallel as indicated by the arrows 26 and 27; and that the vapor heads 28 and 29 of said sub-effects are connected in parallel as shown by the lines 30 and 31, so that the vapor from both of them flows through the connection 32 to the heating unit of the second effect 22. From that point on the vapor from the vapor head of each effect flows to the heating

unit of the next succeeding effect in the manner which is well known and understood in this art.

It will also be noted that the inflowing liquor for both the 4th and 5th effects designated 24 and 25 is supplied to them in parallel through the connections 33 and 34 respectively; and the liquor concentrated in these two effects is delivered through the connections 35 and 36 in parallel to a common connection 37 by which the so concentrated liquor is delivered to the inflow connection of the 3rd effect designated 23. Thus it appears that the inflowing liquor of low concentration is treated in both of the effects 4 and 5 in parallel notwithstanding that the vapor heads of said effects are connected in series with each other. This is for the purpose of avoiding foaming when liquor of low concentration such as so-called "black liquor" is being treated, and notwithstanding the high degree of vacuum existing in the vapor head of the last or fifth effect.

The liquor inflowing into the 3rd effect through the connection 37 is concentrated therein and is delivered through the connection 38 to the heating unit of the 2nd effect designated 22; and from said 2nd effect 22 the more concentrated liquor is delivered through the connection 39 to a preheater 40 designated as "B". There is also another preheater 41 designated "A". Both preheaters 40 and 41 may be heated in any suitable manner as for example by the use of live steam.

From preheater 40 there is a connection 42 leading to the heating unit of sub-effect 1B designated 29; and the liquor treated in said sub-effect is delivered through a connection 43. Liquor from the preheater 41 may be delivered through a connection 44 directly to the heating unit of the sub-effect 1A designated 28; and the liquor treated in said sub-effect 1A is delivered therefrom through the connection 45. A pump 46 is provided and is adapted to draw liquor from the connection 43 and deliver the same through the connection 47 leading to the preheater 41.

With the arrangement thus far described liquor flows from the second effect designated 22, through the connection 39 to the preheater 40, through the connection 42 to the sub-effect 1B designated 29, and through the connection 43, to the pump 46 thence through the connection 47 to the preheater 41 thence through the connection 44 to the sub-effect 1A designated 28, and is finally delivered through the connection 45.

Extending between the connections 42 and 44 are the criss-cross connections 48 and 49 which are provided with valves 50 and 51 respectively; and the connection 42 is provided with the valve 52 between the criss-cross connections 48 and 49, and the connection 44 is also provided with a valve 53 between the criss-cross connections 49 and 48 respectively. Also extending between the connections 43 and 45 are the criss-cross connections 54 and 55 respectively which are provided with the respective valves 56 and 57; and the connection 43 is provided with the valve 58 between the connections 54 and 55, and the connection 45 is provided with the valve 59 between the connections 55 and 54 respectively.

In the system of operation previously referred to in which the liquor flows from the preheater 40 through the sub-effect 1B designated 29, through the connection 43 to the preheater 41 and then through the connection 44 to the sub-effect 1A designated 28 and finally through the discharge connection 45, the valves 52, 58, 53 and 59 are left open, and the valves 50, 51, 56 and 57 are closed. When it is desired to reverse the flow in the manner hereinbefore referred to, the valves 52, 58, 53 and 59 are closed and the valves 50, 51, 56 and 57 are opened. Under these circumstances the flow will be as follows:

From the connection 39 through the preheater 40 through the connection 48 through the connection 44 above the valve 53 to the sub-effect 1A designated 28, through the connection 45 connection 55 valve 57 pump 46 connection 47 preheater 41 connection 44 connection 49 valve 51 and connection 42 sub-effect 1B designated 29, connection 43 valve 56 and connection 54, to the point of discharge.

Thus it will be evident that by merely reversing the valves in the manner already explained the liquor is flowed through the sub-effects 1A and 1B in reversed order, but through the preheaters in the original order, and through the pump 46 at a position between the two sub-effects.

If desired pumps 60, 61, 62 and 63 may be provided in the connections 36, 35, 38 and 39 respectively for transferring the liquor; and also if desired cross connections 64, 65, 66 and 67, suitably valved, may be provided for the effects 5, 4, 3, and 2, designated 25, 24, 23 and 22, respectively, and cross connections, suitably valved, 68 and 69 may be provided for the sub-effects 1B and 1A, designated 29 and 28 respectively. By this means the liquor flow may be short-circuited across any particular effect or sub-effect in case it is desired to cut out the same for purposes of repair or otherwise.

Referring again to Figure 4 it will be noticed that during the upflow of liquor from the lower end of the tube up to the point where boiling commences as shown at 6, the tube is merely serving to deliver heat into the liquor for the purpose of heating it but without boiling of the liquor itself. This length of the tube may therefore be designated as the heating section, being that section in which the tube is ineffective for any useful purpose as far as actual boiling is concerned. On the other hand in the case of preheating, the liquor enters the lower end of the tube at a temperature 8 which is substantially the same as or above the maximum temperature 6 at which boiling commences. Due to this circumstance the liquor is practically ready to boil as soon as it enters the tube and actually it is theoretically possible to preheat the liquor up to a point such that boiling will commence as soon as the liquor enters and commences to rise through the tube. In fact a certain amount of boiling may actually take place in the chamber at the lower end of the tube and into which the liquor is originaly delivered.

With this arrangement it becomes unnecessary to use any portion of the tube for the purpose of merely heating the liquor, and the entire length of the tube may be used for boiling purposes. It is therefore evident that the curve 7 will commence to fall either at the point 8 where the liquor enters the tube or slightly above such point, and that a greatly increased overall heat transfer coefficient will be secured.

It will also be noticed that inasmuch as the liquor enters the tube at increased temperature it will begin boiling at a lower elevation in the tube so that the velocity of the liquor film will be increased. This will also result in an increased overall heat transfer coefficient and will make possible a greater amount of evaporation in a given tube.

It may be stated that the parallel thin liquor feed arrangement to the fourth and fifth effects, reduces the necessary size of the liquor pump for the fifth effect; and increases the concentration produced in the fifth effect, thereby reducing the foaming difficulties of that effect and increasing the capacity of the unit.

It is also to be noticed that by the ability to reverse the operating positions of the sub-effects, 1A and 1B, designated 28 and 29 respectively, I am enabled to secure the benefits of such periodic reversal, as set forth more in detail in the early portion of this specification; and either with or without the advantages of preheating, as desired. Also that the advantages of preheating may be secured either with or without the reversing feature. Therefore I wish it clearly understood that I do not limit myself to the simultaneous use of the reversing and the preheating arrangements, except as I may do so in the claims, but contemplate the use of these features either cojointly or severally as desired.

Referring particularly to the flow sheet of Figure 1, if desired, the liquor supply connections 33 and 34 may be provided with the main valves 86 and 87 respectively of large enough size to handle the full intended flow of liquor, and by-pass valves 88 and 89 respectively, of smaller size, and by means of which fine adjustments of flow may be secured, it being found in practice that such fine adjustments of flow cannot be readily made by the main valves alone, as by the smaller size by-pass valves.

I have also shown the condensation connections 92, 93, 94 and 95 from the heating units of the second, third, fourth and fifth effects, respectively, designated as 22, 23, 24 and 25. For the condensation connections 92, 93, and 94, there are the flash tanks 96, 97 and 98, to which said connections lead, and as shown, these flash tanks are placed, preferably, at progressively lower levels, as the vapor pressures become lower in the direction of flow. These flash tanks are connected by the vapor connections 99, 100 and 101 to the vapor connections 102, 103 and 104 of the next succeeding heating units of the effects 23, 24 and 25 respectively. The automatic control valves 105, 106 and 107 may be placed in the connections 92, 93 and 94 respectively.

From the flash tank 96 the connection 108 leads to the connection 93 of the next succeeding effect, and from the flash tank 97 the connection 109 leads to the connection 94 of the next succeeding effect; and a connection 110 leads from the flash tank 98 to join the connection 95 from the last effect so as to deliver all the condensation from the second, third, fourth and fifth effects, to a delivery pump 111, whence the total condensation is discharged through a connection 112.

Preferably the catchalls 113, 114, 115, 116, 117 and 118 are provided for the bodies 28, 29, 22, 23, 24 and 25 respectively, the vapor from the several evaporators being delivered to the respective catchalls, and there having any entrained liquor removed, such liquor being returned to the downcomers of the various evaporators by the connections 119, 120, 121, 122, 123 and 124, respectively, in the well understood manner.

If desired, the thick liquor may be delivered by the connection 45 to a delivery pump 125 either directly, or through a flash tank 126, and in either case, either with or without automatic regulation. For this purpose there is provided a connection 127 from the connection 45 directly to the pump 125, and provided with a valve 128; also an automatic regulating valve 129 having the control float chamber 130 is provided, the connection 45 being connected to said valve and float chamber under control of a valve 132; and from control valve 129 a connection 132 leads directly to the line 127 to the pump 125, being provided with a valve 133; also a connection 134 leads from the connection 45 to the flash tank 126, being provided with a valve 135; and a connection 136 leads from the automatic control valve 129 to the connection 134, being provided with a valve 137; and a valve 138 is provided between the flash tank 126 and the connection 132, and a valve 139 between the float chamber 130 and the automatic regulating valve 129. The valve 140 is provided in the vapor connection 141 from the flash tank.

I claim:

1. In a multiple effect long tube vertical evaporator of the backward flow type, including a second effect and two sub-effects of the first effect, means for supplying steam to such sub-effects in parallel, connections from the vapor heads of said sub-effects in parallel, a pair of preheaters corresponding to the sub-effects aforesaid, a transfer pump, a liquor connection from the second effect to one preheater, a liquor connection from the transfer pump to the other preheater, suitable valved connections for liquor flow from the first preheater to the second sub-effect and from the second preheater to the first sub-effect, suitable valved cross connections between the delivery sides of the two preheaters, and suitable valved cross connections between the delivery sides of the two sub-effects, the valves of all said connections permitting selective flow of liquor through the first preheater to either sub-effect and then through the other preheater to the other sub-effect as desired, substantially as described.

2. In a multiple effect long tube vertical evaporator including a thick last liquor effect comprising a pair of sub-effects and including an effect preceding said sub-effects, a pair of preheaters, a liquor connection from said preceding effect to the first preheater, a transfer pump, a liquor connection from the transfer pump to the second preheater and suitable cross connections and valves between the delivery sides of the preheaters and the inlets to the sub-effects and suitable cross connections and valves between the delivery sides of the sub-effects, permitting flow of liquor thru the first preheater then thru either sub-effect as selected, then through the transfer pump, then thru the other preheater and finally thru the other sub-effect, to a point of discharge, substantially as described.

3. In a multiple effect long tube vertical evaporator, a thick liquor effect comprising a pair of sub-effects, a pair of preheaters corresponding to said sub-effects, a transfer pump, and suitable connections and valves arranged to provide flow of liquor first thru one preheater, then thru either sub-effect as selected, then thru the transfer pump, then thru the other preheater, and then thru the other sub-effect to a point of discharge, substantially as described.

4. The method of removing fouling material from the tubes of the thick liquor effect of a multiple effect evaporator, and for improving the heat transfer coefficient thereof, which consists in passing the thick liquor through a pair of sub-effects of said thick liquor effect, first through one sub-effect and then through the other sub-effect, and then through the second sub-effect and then

through the first sub-effect alternately by periodically controlled intervals, to thereby subject each sub-effect to alternate action on liquor of highest concentration, and then on liquor of lower concentration, substantially as described.

5. The method of removing fouling material from the tubes of the thick liquor effect of a multiple effect evaporator, and for improving the heat transfer coefficient thereof, which consists in passing the liquor in series through two sub-effects of said thick liquor effect using said sub-effects alternately in primary and secondary cycles of change with substantially equal periods in each cycle, and in preheating the liquor prior to entrance into each sub-effect on each cycle of change, substantially as described.

6. In a multiple effect long tube vertical evaporator of the backward flow type, the combination of a first effect comprising a pair of sub-effects, a second effect, a transfer pump, and suitable cross-connections and valves arranged to provide flow of liquor from the second effect to either of the sub-effects of the first effect as selected, then through the transfer pump, and then through the other sub-effect of the first effect to a point of discharge, substantially as described.

7. In a multiple effect backward flow long tube vertical evaporator, a thick liquor first effect comprising a pair of sub-effects, a pair of pre-heaters, a second effect, and suitable connections and valves arranged to provide flow of liquor in series from the second effect first through one preheater, then through either sub-effect as selected, then through the other preheater, then through the other sub-effect to a point of discharge, substantially as described.

8. In a multiple effect long tube vertical evaporator, a final effect for the final concentration of liquor to a high degree occasioning fouling of tubes and impairment of heat transfer coefficient, wherein said fouling due to high liquor concentration may be removed by subjection of the tubes to treatment of lower concentration liquor, said final thick liquor effect comprising a pair of sub-effects, a common steam connection to both said sub-effects to submit said sub-effects to the same degree of heat, a common vacuum connection to the liquor in both said sub-effects to submit the liquor in both said sub-effects to the same degree of vacuum, cross connections and valves for flowing the liquor through said sub-effects in series, said connections and valves being so constructed and arranged as to provide for alternate periodic flow first through one of them and then through the other, and vice versa, whereby each said sub-effect is subjected to duty alternately for highest liquor concentration and for lower liquor concentration to remove fouling material accumulated during highest liquor concentration action, substantially as described.

WILLIAM T. HINCKLEY.