April 27, 1926. 1,582,067

H. K. MOORE

PROCESS OF AND APPARATUS FOR MULTIPLE EFFECT EVAPORATIVE SEPARATION

Filed Nov. 30, 1923 3 Sheets-Sheet 1

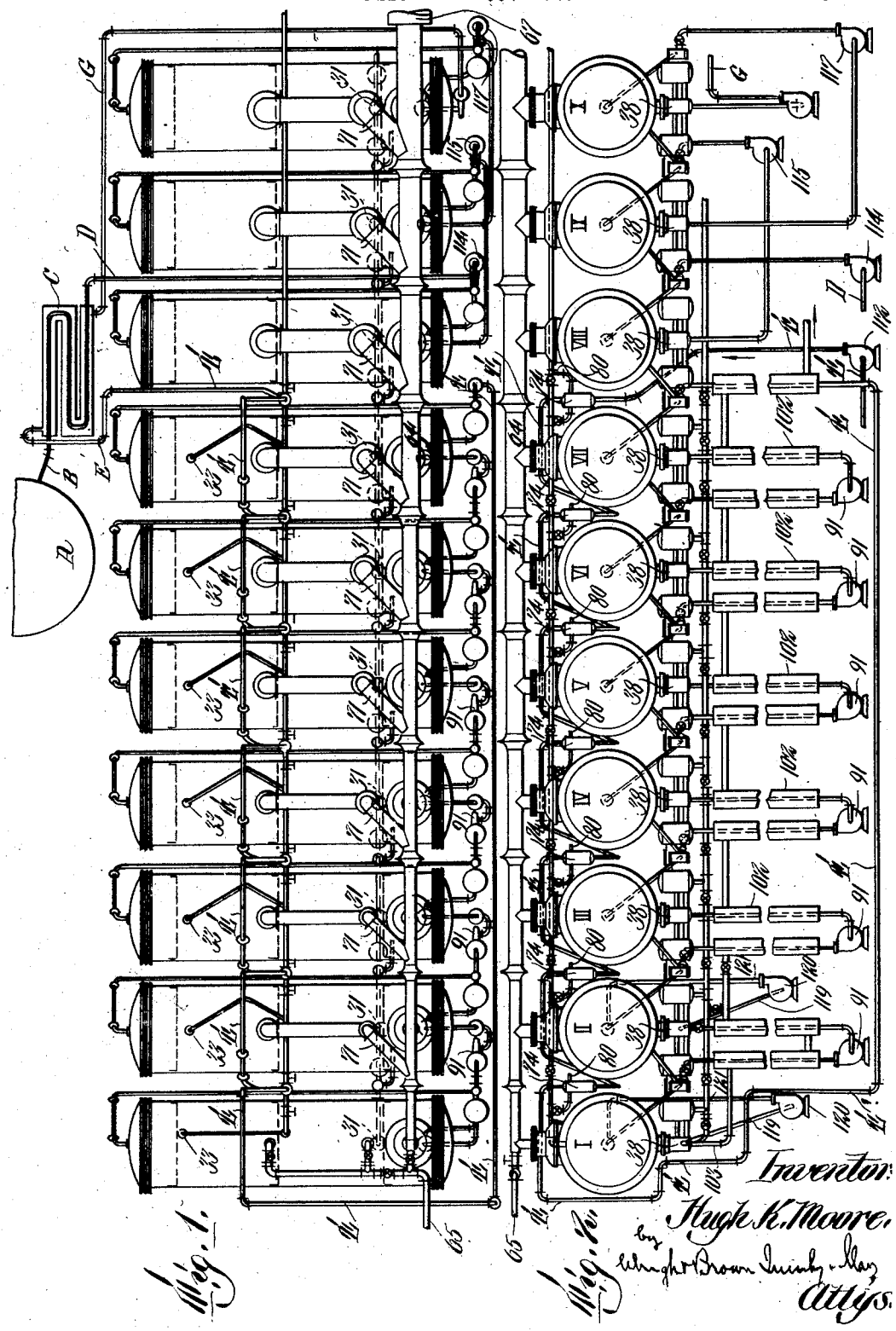


Fig. 1.

Fig. 2.

Inventor:
Hugh K. Moore.
by Eltinge & Brown, Cuming & Clay
Attys.

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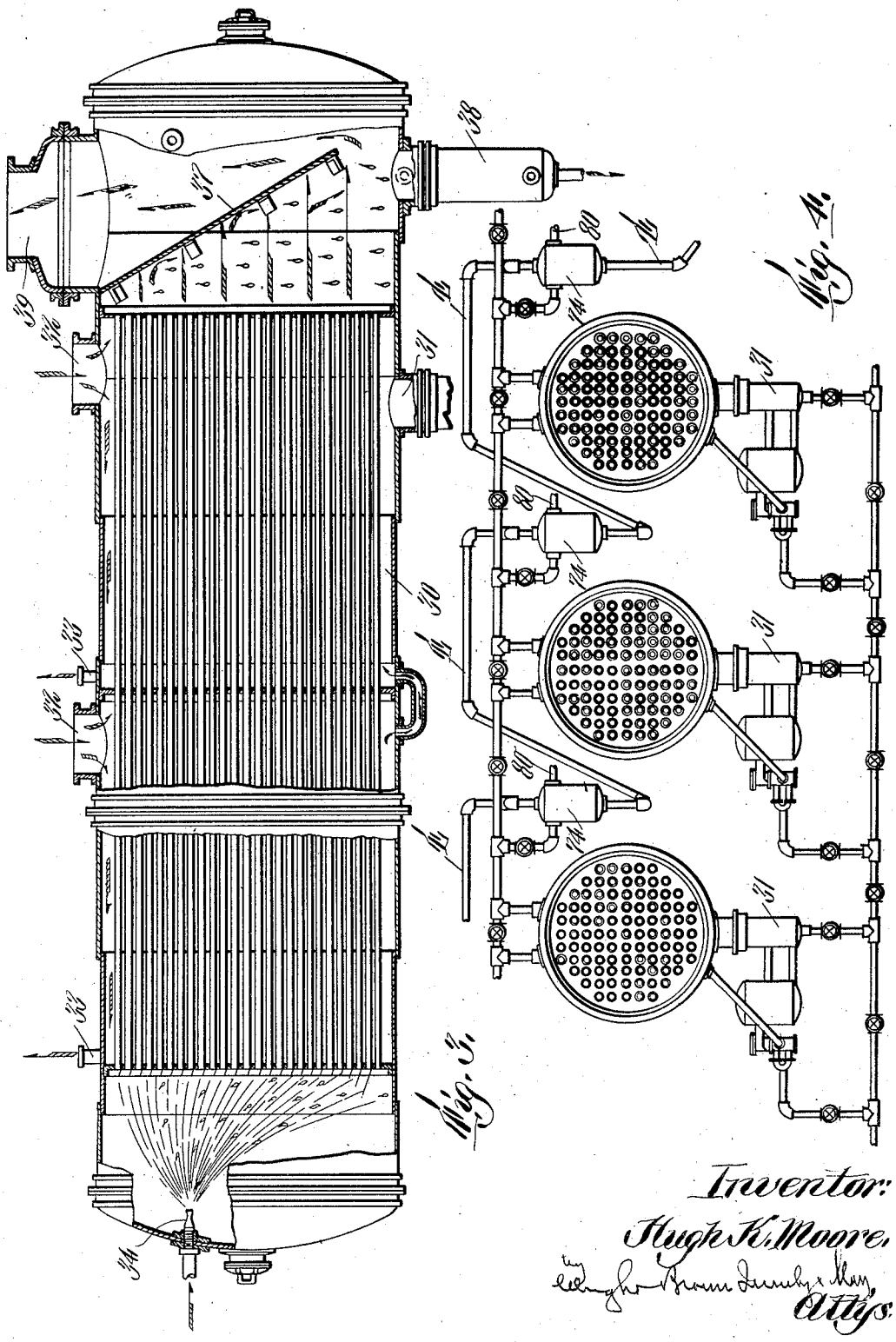


Fig. 4.

Fig. 3.

Inventor:
Hugh K. Moore,
by Cushman, Darby & Cushman
Attys.

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Filed Nov. 30, 1923 3 Sheets-Sheet 3

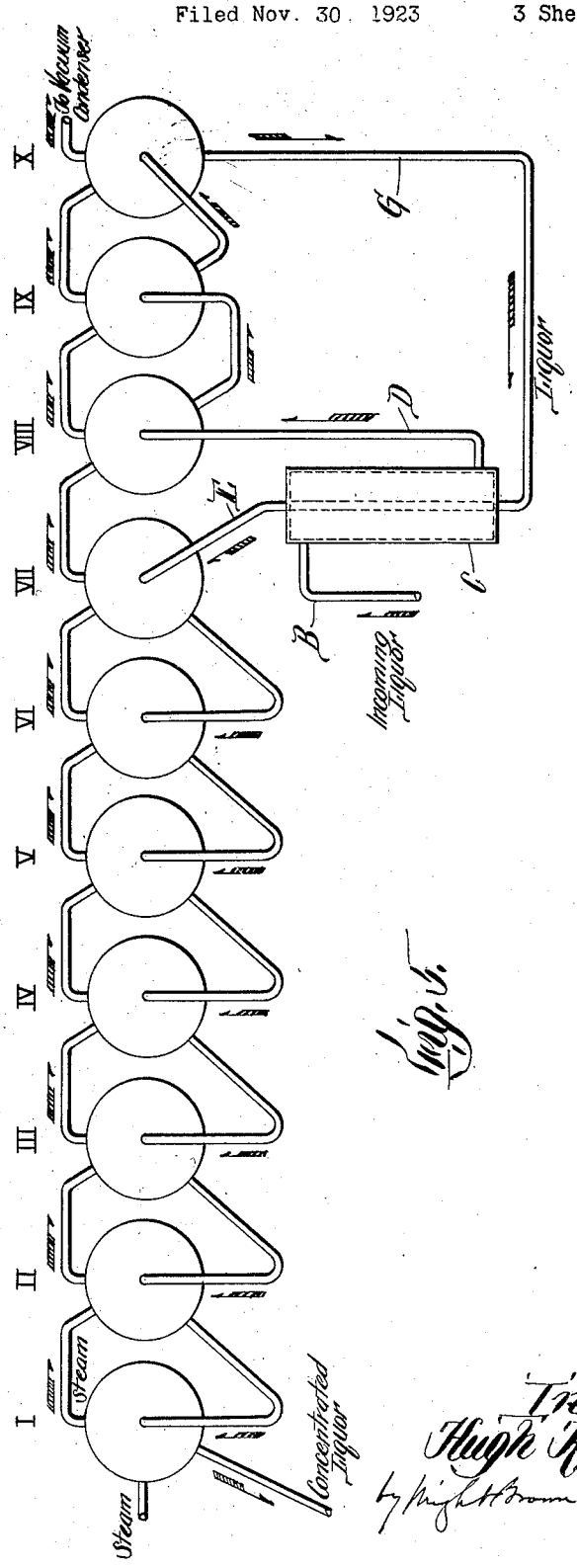


Fig. 3.

Inventor
Hugh K. Moore
by Wright Brown Quinby & May
Attys

Patented Apr. 27, 1926. 1,582,067

UNITED STATES PATENT OFFICE.

HUGH K. MOORE, OF BERLIN, NEW HAMPSHIRE, ASSIGNOR TO BROWN COMPANY, OF BERLIN, NEW HAMPSHIRE, A CORPORATION OF MAINE.

PROCESS OF AND APPARATUS FOR MULTIPLE-EFFECT EVAPORATIVE SEPARATION.

Application filed November 30, 1923. Serial No. 677,857.

To all whom it may concern:

Be it known that I, HUGH K. MOORE, a citizen of the United States, residing at Berlin, in the county of Coos and State of New Hampshire, have invented new and useful Improvements in Processes of and Apparatus for Multiple-Effect Evaporative Separation, of which the following is a specification.

In an application for Letters Patent Serial No. 595,017 filed October 26, 1922, I have illustrated and described an apparatus for and a process of evaporatively separating certain liquors so as to secure a maximum saving of heat, and I have therein explained in detail the principles upon which the process and the apparatus are founded. The process and apparatus are therein described as utilized specifically in the evaporation and the concentration of waste sulphite liquors, such as result in the manufacture or production of chemical wood pulp by the sulphite process so called. The present invention has for its object to provide a process of and apparatus for evaporating and concentrating certain liquors having characteristics which require a different mode of treatment. It sometimes happens that the conditions under which the evaporative separation is to occur, require the treatment of a liquor which greatly increases in viscosity with its concentration; and further that the liquor to be treated may be at a relatively high temperature at the time when it is to be subjected to evaporation and concentration. It is desirable of course, that the heat of the incoming liquor should be conserved unless other considerations make this undesirable. Again the greatly increased viscosity of the liquor due to its concentration with a consequent low heat conductivity, may require a mode of treatment different from that specifically described in my said application. For example, in the production of chemical wood pulp by the digestion of the wood chips with an acid cooking liquor containing sodium sulphite and sodium sulphate, together with free SO_2, or by digesting the wood chips in an alkaline solution rich in sodium sulphide, the waste liquor resulting from such digestion, when concentrated to a fifty per cent solution, may be so viscous and its heat conductivity so low at a temperature of say 100° F., that while the process specifically described in my application could be used in the evaporative separation of such liquors, nevertheless, it would not be with that degree of economy with which other liquors could be treated. Such liquors as those resulting from the digestion of wood pulp in an alkaline cooking liquor rich in sodium sulphide, or resulting from the digestion of wood pulp by an acid liquor comprising a soluble sulphate and a soluble sulphite, have such a high viscosity when reduced to a fifty per cent solution, that a mode of treatment is desirable differing specifically or in detail from that set forth in my said application. In explanation, it may be said that there is a direct relation between viscosity and heat conductivity, so that it is important that the viscosity or mobility of a solution should receive consideration in evaporatively separating such a solution. It is of course, desirable in subjecting such liquors to multiple-effect evaporation that the temperature difference between the liquor entering into an effect, and the steam entering the effect for the heating of such liquor, should be relatively small so that in considering the entire temperature spread, (that is, the difference in temperature between the initial steam entering the first effect of the series and the steam passing to the condenser to the last effect of the series,) should be as small as possible. Disregarding other factors, it may be stated as a general rule that the greater the mobility of a liquid (or the lesser the viscosity) at the same temperature level and the same temperature difference, the greater the heat conductivity of the liquor,—it being remembered that the temperature level of the liquor is the boiling point of that liquor at the pressure to which it may be subjected at the time. Consequently, one liquor containing fifty per cent solids at a given temperature level, say 100° F., when subjected to a 10° difference of exchange in temperature, may have a very low heat conductivity, whereas the same liquor at a temperature level of 200° F. with the same difference of exchange, may have a greatly increased heat conductivity. Consequently with such liquors, it may not be economically possible or desirable to pass the liquor through the several effects in such way that it is subjected first to increasing pressures and temperatures, and then to progressively de-

creasing temperatures and pressures, as in my said application,—for the reason that the lessened mobility or increasing viscosity of the liquor may too greatly decrease its heat conductivity for economical operation. Again, the conditions controlling the production of the waste liquor may be such that it is delivered for evaporation at a relatively high temperature. It is, of course, desirable that the heat of the entering liquor should be saved or conserved so as to reduce the total heat generated from an outside source for the evaporation process.

It is a principle of multiple-effect evaporation that the steam generated from the liquor in the first of a sequence of effects, passes to the next colder effect for the generation of steam from the liquor therein contained, and thus progressively throughout the remainder of the series of effects, the evaporator chamber of the last effect of the series being connected with a vacuum apparatus and a condenser, this irrespective of the order of the effects through which the liquor flows. Ordinarily in a multiple-effect evaporation, the liquor has been caused to flow through the sequence of effects in the same direction with the flow of the steam, in which case the liquor is introduced into the first effect, or else has been caused to flow through the sequence of effects in the opposite direction to the flow of the steam, in which case the liquor is introduced into the last and coldest effect. In accordance with the present invention, the entering liquor is introduced into an intermediate effect and is caused therefrom to flow through some of the effects in the same direction as the flow of steam therethrough, whereby it is subjected to decreasing pressures and decreasing temperatures, and is then caused to pass through the remainder of the effects in a direction opposite to the flow of the steam, whereby it is subjected to progressively increasing temperatures and increasing pressures. As a result of this mode of procedure the increasingly concentrated liquor, which becomes increasingly viscous at any given temperature with its concentration and thus decreases in heat conductivity, is subjected to such increasing temperatures that its mobility and heat conductivity are not lessened to such an extent as to prevent the liquor from being properly treated and brought to the desired concentration. The liquor to be treated is at a temperature much higher than that of the temperature level of the liquor in the intermediate effect into which it is to be introduced, and there is also a marked temperature difference between the liquor leaving the last and coldest effect, and the temperature level of the liquor in the effect to which that liquor leaving the last effect should be introduced. Consequently, in accordance with my invention, the heat of the initial entering liquor is utilized in heating the liquor leaving the last effect in the sequence of effects, as a result of which the initial entering liquor is reduced to a temperature approximating the temperature level of the intermediate effect into which it is introduced, and the liquor leaving the last effect of the series is raised to a point more nearly aproximating the temperature level of the effect into which it is introduced for further passage through the remaining effects of the series.

On the accompanying drawings, I have illustrated more or less diagrammatically and conventionally in Figure 1, a multiple-effect evaporator embodying the invention, and which may be utilized in the practice of a process in accordance with the invention.

Figure 2 represents an end view of the same apparatus.

Figure 3 represents a longitudinal section through one of the effects.

Figure 4 represents a section through three adjacent effects, and shows the drip pocket or well associated with each effect for the steam condensed in such effect, and the connections for transferring the drip from one effect to the steam chamber of the next colder effect.

Figure 5 is a diagrammatic showing of the course followed by the liquor through the various effects and the heat exchanges.

The multiple-effect evaporator as a whole, is illustrated as comprising a series of ten effects, each effect consisting of a combined evaporator and condenser. These effects are numbered I to X, inclusive, in the order in which they are arranged in respect to the passage of steam through the steam line. That is to say, steam which is externally generated, is delivered to effect No. I, herein termed the "first effect," for the evaporation of liquor contained therein. The steam generated from the liquor in effect No. I is passed to effect No. II for the generation of steam from the liquor contained in effect No. II,—and thus throughout the entire series, the "last effect" No. X having its evaporator chamber connected with a condenser and vacuum apparatus. Thus considering the sequence of effects from I to X, they are progressively colder and the pressures therein are progressively reduced,—this quite irrespective of the order of the effects in relation to the passage of the liquor therethrough. It is quite apparent that the liquor to be evaporated and concentrated, might be introduced into the first effect, No. I, and caused to pass through the effects progressively and in sequence until it was delivered from the last effect, No. X; or on the other hand, the liquor might be introduced initially into the last effect of the series, to wit, No. X, and caused to pass therefrom through the sequence of effects to

effect No. I, but this would not in either event change the order of the effects in respect of the passage of steam from effect No. I to effect No. X. In accordance with the present invention, however, the liquor is not introduced initially into either the first or the last of the series. On the contrary, it is delivered to an "intermediate effect," to wit, No. VIII for example, and is then caused to pass through progressively colder effects, to wit, effects IX and X, after which it is introduced into another intermediate effect, for example No. VII, and thence to pass through progressively hotter effects (Nos. VI, V, IV, III and II) until it reaches effect No. I, from which it is withdrawn at the desired degree of concentration, this course of the liquor through the various effects being diagrammatically shown in Figure 5. Thus the liquor is first subjected to decreasing temperatures and pressures, and then subjected to increasing temperatures and pressures during its passage through all of the effects. The number of the intermediate effect of the series, into which the initial or entering liquor is first introduced, depends upon the character of the liquor and its temperature, so that it will be understood that in describing the liquor as initially entering any certain intermediate effect of the series or sequence of effects, it is done merely by way of illustration, and that the liquor may be introduced initially into any other intermediate effect depending upon circumstances. In the present instance, I am assuming that a liquor is being evaporatively concentrated, such as that resulting from the digestion of wood pulp with an acid liquor containing both a soluble sulphate and a soluble sulphite, and that the liquor is at the temperature of approximately 172° F. when it is ready to be subjected to evaporation and concentration. In the present case for purposes of illustration, it may be assumed that the temperature level or boiling point of the liquor in No. I effect at the pressure in No. I effect, is approximately 232° F., and that the temperature level or boiling point of the last effect, No. X, is 100° F. under a pressure of two inches absolute (or a vacuum of twenty eight inches mercury). Under these conditions, the temperature level of the liquor contained in effect No. VIII is approximately 138° F. Inasmuch, however, as the entering liquor is at a temperature of 172° F., it would not be practicable to enter this liquor at that temperature into effect No. VIII without an economic loss. Again the liquor leaving effect No. X is at a temperature of approximately 100° F., whereas the temperature level or boiling point in effect No. VII is approximately 154° F. Therefore the liquor before it enters effect No. VIII and the liquor leaving effect No. X and before it enters effect No. VII, are caused to pass through a heat exchanger, whereby the liquor which enters effect No. VIII is reduced to a temperature approximating the temperature level of the liquor therein, and the liquor leaving effect No. X is heated to a temperature reasonably approximating the temperature level of the liquor in effect No. VII.

On the drawing, A indicates a tank for the liquor to be concentrated, which in the present case may be considered as having a temperature of approximately 172° F. A pipe B conducts the liquor from this tank to a heat exchanger indicated as a whole at C, and from the heat exchanger a pipe D conducts the liquor to a pump 114 by which the liquor is introduced into intermediate effect No. VIII. After passing through effects VIII, IX and X, which are progressively colder, the liquor delivered from the last effect, No. X, is pumped through pipe G back to the exchanger C, through which it is caused to pass in counter-current flow to the liquor delivered thereto through pipe B. The liquor delivered by the pipe D to the exchanger is thence delivered by a pump 112 through pipe E into the intermediate effect No. VII. The liquor from effect No. VII is caused to traverse the progressively hotter effects VI, V, IV, III, II and I, and from the first effect, No. I, it may, if desired, be treated as set forth in the Letters Patent No. 1,326,414 issued to John Quinn and myself on the 30th day of December 1919, for the recovery of the sodium compounds contained in the liquor.

Thus as herein briefly explained, the heat which is abstracted from the initial liquor prior to its introduction into an intermediate effect, No. VIII, is utilized in raising the temperature of the liquor delivered from the coldest or last effect, No. X, of the series, so as to bring it to a point where it approximates the boiling point or temperature level of an intermediate effect No. VII. As a result of this mode of treatment of the liquor, the entire temperature spread between the first and last effects, Nos. I and X, may be relatively small, and a large number of intermediate effects may be utilized with a relatively low temperature difference between each effect and the next succeeding or next preceding effect. As a further result, the increasingly concentrated liquor is subjected to increasingly higher temperatures and pressures as it traverses increasingly hotter effects VII to I, inclusive, so that I am able to compensate to a great extent for the increasing loss in heat conductivity of the liquor due to its increased concentration and viscosity.

For reasons set forth at large in my application Serial No. 595,017, it is desirable that the liquor undergoing evaporation in

the several effects, should not be under any hydrostatic head, and consequently, in carrying out the process of the present invention, I regard it as desirable to deliver the liquor to each effect, and into the conductor tubes thereof in the form of spray, and for this reason, there is associated with each effect a pump for delivering the liquor to the evaporator in an atomized form. Likewise for the same consideration, the conductor tubes of each effect are arranged substantially horizontally but slightly inclined towards their delivery ends so that when the operation has ceased, any residual liquor will flow therefrom. In the present case, the pumps for delivering the liquor to effects I to VII, inclusive, are indicated at 91, the pump for delivering the liquor to effect No. VIII is indicated at 114, and the pumps for delivering the liquor to effects IX and X, are indicated at 115 and 117. Each effect is provided with a well 38 depending from the forward end thereof, which receives the partially concentrated liquor after passing through the conductor tubes of that effect, and it is from this well that the liquor is forced by the pump to the spray nozzle of that effect to which it is desired to pass such liquor. The spray nozzle for each effect is indicated at 34 and by reference to Figure 3, it will be seen that I have conventionally illustrated the liquor as being sprayed into the ends of the conductor tubes, which pass through the steam chamber 30 of that effect. The steam and liquor issuing from the forward ends of the tubes are separated in passing around the baffle plate 37, the steam passing upwardly through the port 39 and the liquor being collected in the well 38. The steam entering the steam chamber of each effect from the preceding hotter effect enters the ports 32 and the condensate is emitted through the port 31. Uncondensed steam and entrained air pass from the steam chamber through the port 33 to a condenser 74, from which the condensate is delivered to a pipe common to all of the condensers, this pipe not being shown, but the branches leading thereto being indicated at 80, as indicated in Figure 3. Each of the ports 31 for the condensate from the steam chamber of the effect with which it is associated, constitutes a well in which the condensate accumulates, and from which the condensate is passed to the steam chamber of the next colder effect, as set forth in my said application Serial No. 595,017. Inasmuch as the means associated with each effect by which the level of the liquor in the well 38 controls the rate of flow of the liquor introduced into the effect, per se forms no feature of the present invention. I shall omit its description inasmuch as such means is described and illustrated in detail in my aforesaid application.

Considering the sequence of effects as illustrated in Figures 1 and 2, steam at the proper pressure and temperature is delivered to the first effect, No. I, through a pipe 65 for the generation of steam from the liquor which is sprayed into the conductor tubes therein. The steam thus generated is conducted by a section of the steam line indicated as a whole at 64, to the steam chamber of effect No. II, through the conduit 71. The steam line is provided with suitable valves or couplings, by which any effect may be by-passed in the event of an accident or for any other desired purpose. Finally, from effect No. X, the steam is conducted by the coldest end of the steam line to a condenser indicated conventionally at 67, with which is connected a vacuum apparatus, not shown.

Inasmuch as the liquor undergoing multiple-effect evaporation greatly decreases in volume, it may be desirable, to insure the proper wetting of the tubes in the effects numbered I and II, to provide means for circulating the liquor through those effects. To that end, I have illustrated conventionally upon the drawing each of the last mentioned effects as having associated therewith a circulating system comprising a pump 120 for pumping the liquor from the well 38 thereof to the spray nozzle. The pipe leading from the well to the pump is indicated at 119 and the pipe leading from the pump to the spray nozzle is indicated at 121.

Associated with effects Nos. II, III, IV, V, VI and VII, I have shown heat exchangers indicated at 102, through which the concentrated liquor delivered from the well 38 of effect No. I is passed in series, and from which it is delivered by pipe 103. These heat exchangers are utilized for heating the liquor passing from effect No. VII to effect No. VI, and thence through the increasingly hotter effects. In some cases, these heat exchangers need not be employed, especially where it is desired to conduct the concentrated liquor directly to a combined boiler and smelting furnace for the recovery of the inorganic content of such liquor.

Except for certain differences which have been hereinbefore pointed out, the apparatus as illustrated upon the drawings is substantially similar to the apparatus illustrated by the drawings of my said application Serial No. 595,017, to which reference may be made for further explanation of the various instrumentalities and the mode of operation.

Assuming that a certain waste liquor resulting from the manufacture of chemical wood pulp, contains 8 per cent solids and that it be desired to concentrate it to a point where it contains 50 per cent solids, that the liquor is initially at a temperature of about 172° F., that the steam entering the first effect, No. I, is at a temperature of about 252°

F., and that the temperature of the steam leaving the last effect, No. X, is 100° F., and that the process as herein-described is practiced, the approximate temperatures of the liquor and the steam entering and leaving the several effects may be tabulated somewhat roughly, as follows:

	Effects.									
	I	II	III	IV	V	VI	VII	VIII	IX	X
	°	°	°	°	°	°	°	°	°	°
Temperature of steam entering	252	232	220	210	196	182	168	154	138	125
Temperature of steam leaving	232	220	210	196	182	168	154	138	120	100
Temperature of liquor entering	225	212	197	182	168	154	152	142	138	120
Temperature of liquor leaving	240	225	212	197	182	168	154	138	120	100

In the foregoing table it is assumed that in passing through the heat exchanger, the initially hot liquor is reduced to a temperature of 142° F. before entering intermediate effect No. VIII, and the liquor leaving effect No. X is raised to a temperature of 152° F. before entering effect No. VII. The tabulation is given merely for explanatory purposes, since conditions are varied for liquors having different characteristics and for the temperatures of the liquors which are to be concentrated.

At the risk of repetition, I may advert once more to the fact that the initial liquor to be evaporated is introduced into an "intermediate" effect in the sequence of effects, and that this liquor is initially at a temperature much higher than the temperature level or boiling point of the liquor in the effect into which it is to be introduced. If the liquor at the high temperature, say 172° F. were delivered to an effect in which the temperature level or boiling point of the liquor were relatively low, say 138° F., it can be seen that there would be an enormous loss of heat due to self-evaporation, and that this heat would eventually be wasted in the final condenser located beyond the last effect of the series. This can be made clear if it should be assumed that liquor at a temperature of 172° F. were delivered to the last effect, No. X, in which the boiling point or temperature level of the liquor is 100° F. Under such circumstances, the heat in the liquor above 100° F. is immediately wasted in the condenser with which the vacuum apparatus is connected. In accordance with the present invention, however, I prevent the immediate loss of heat of the liquor entering into an intermediate effect above the temperature level of the liquor in that effect by utilizing the excess heat in raising the temperature of the liquor leaving the last or No. X effect, before it is introduced into the intermediate effect No. VII for passage through the next successively hotter effects. This enables me to heat a relatively cold liquor to a temperature approximating that of the temperature level of the liquor in that intermediate effect into which it is desirable to pass that cold liquor. It also enables me to employ a relatively small final condenser, which is operated with a relatively small quantity of water, and also to obtain great economies and conservation of heat.

What I claim is:

1. A process of multiple-effect evaporation, which comprises generating steam from the liquor contained in the first effect of a sequence of effects, generating steam from the liquor in each of the remaining effects of said sequence by the steam generated from the liquor in the immediately preceding hotter effect, introducing the liquor to be evaporated first to an intermediate effect of the sequence, conducting such liquor successively through progressively colder effect of said sequence, then passing such liquor to an intermediate effect which is hotter than the first mentioned intermediate effect, and thence progressively through increasingly hotter effects, whereby said liquor is first subjected to progressively decreasing temperatures, and then to progressively increasing temperatures.

2. A process of multiple-effect evaporation, which comprises causing the liquor to flow from an intermediate effect of a series of effects, through progressively colder effects of such series, and thence through progressively hotter effects of such series.

3. A process of multiple-effect evaporation for concentrating an initially hot liquor, which comprises introducing the liquor into an intermediate effect of a series of effects, then passing said liquor successively through the next progressively colder effects, passing such liquor therefrom successively through those effects of the series which are progressively hotter than said intermediate effect, and heating the liquor leaving said progressively colder effects by the initially hot liquor before it is introduced into said intermediate effect.

4. A process of multiple-effect evaporation for concentrating an initially hot liquor, which comprises cooling such liquor to a temperature approximating the temperature level of the liquor of an intermediate effect of a series of effects, and then introducing the cooled liquor into said intermediate effect, passing such liquor therefrom through one or more colder effects, then passing such liquor into an intermediate effect in the series which is hotter than the first mentioned intermediate effect, and thence through progressively hotter effects of the series, and heating the liquor before it enters the second said intermediate effect by the liquor being delivered to the first said intermediate effect.

5. A process of multiple-effect evaporation, which comprises entering the liquor into an intermediate effect of a series of effects, thence passing such liquor through one or more colder effects of said series, then heating such liquor and introducing it into an intermediate effect hotter than the first mentioned intermediate effect, and passing said liquor through those effects of said series which are progressively hotter than said second mentioned intermediate effect.

6. A process of multiple-effect evaporation, which comprises generating steam from the liquor at a given temperature and pressure, then subjecting such liquor to lower temperature and pressure for the generation of steam, finally subjecting such liquor to progressively higher temperatures and pressures for the generation of steam, and utilizing the steam generated from the liquor at its highest temperature and pressure for the generation of steam in that portion of the liquor subjected to the next lower temperature and pressure, and so on until the liquor subjected to the lowest temperature and pressure is heated by steam generated from that portion of the liquor which is subjected to the next lower temperature and pressure.

7. A process of multiple-effect evaporation, which comprises generating steam from the liquor at a given temperature and pressure, then subjecting such liquor to lower temperature and pressure for the generation of steam, finally subjecting such liquor to progressively higher temperatures and pressures for the generation of steam, utilizing the steam generated from the liquor at its highest temperature and pressure for the generation of steam in that portion of the liquor subject to the next lower temperature and pressure, and so on until the liquor subjected to the lowest temperature and pressure is heated by steam generated from that portion of the liquor which is subjected to the next lower temperature and pressure, and heating the liquor by an external source of heat after it has been subjected to the lowest temperatures and presures and before it is subjected to said progressively higher temperatures and pressures.

8. In multiple-effect evaporation of initially hot liquors which become relatively viscous when concentrated at the temperatures of the colder effects. the process of conserving heat which comprises cooling the supplied liquor to approximately the temperature of one of the intermediate effects of a series of effects, introducing said liquor into said intermediate effect, passing said liquor through the successive colder effects, warming the liquor from the coldest effect with heat from the supplied liquor, and passing the liquor thus warmed through the successively hotter remaining effects of said series.

9. In multiple-effect evaporation of initially hot liquors which become relatively viscous when concentrated at the temperatures of the colder effects, the process of conserving heat which comprises introducing the supplied liquor into an intermediate effect of a series of effects, such that upon passing to the successive colder effects of such series the liquor will have a relatively low viscosity in the coldest effect, preliminarily cooling said supplied liquor to the approximate temperature of said intermediate effect prior to its admission thereinto, passing the liquor from the coldest effect to that intermediate effect of the series which is next hotter than the first said intermediate effect, utilizing heat from the supplied liquor to warm the liquor from the coldest effect to approximately the temperature of the intermediate effect to which it is then passed, and further concentrating said liquor by passing it through successively hotter effects of said series of effects.

10. In multiple-effect evaporation of initially hot liquors which become relatively viscous when concentrated at the temperatures of the colder effects, the process of conserving heat which comprises introducing the supplied liquor into an intermediate effect of a series of effects, such that upon passing to the successive colder effects of such series, the liquor will have a relatively low viscosity in the coldest effect, preliminarily cooling said supplied liquor to the approximate temperature of said intermediate effect prior to its admission thereinto, passing the liquor from the coldest effect to that intermediate effect of the series which is next hotter than the first said intermediate effect, utilizing heat from the supplied liquor to raise the temperature of the liquor from the coldest effect to approximately the temperature of the intermediate effect to which it is then passed, further concentrating said liquor by passing it through successively hotter effects of said series of effects, and warming the liquor passing to each successive hotter effect with heat from the concentrated liquor from the hottest effect.

In testimony whereof I have affixed my signature.

HUGH K. MOORE.