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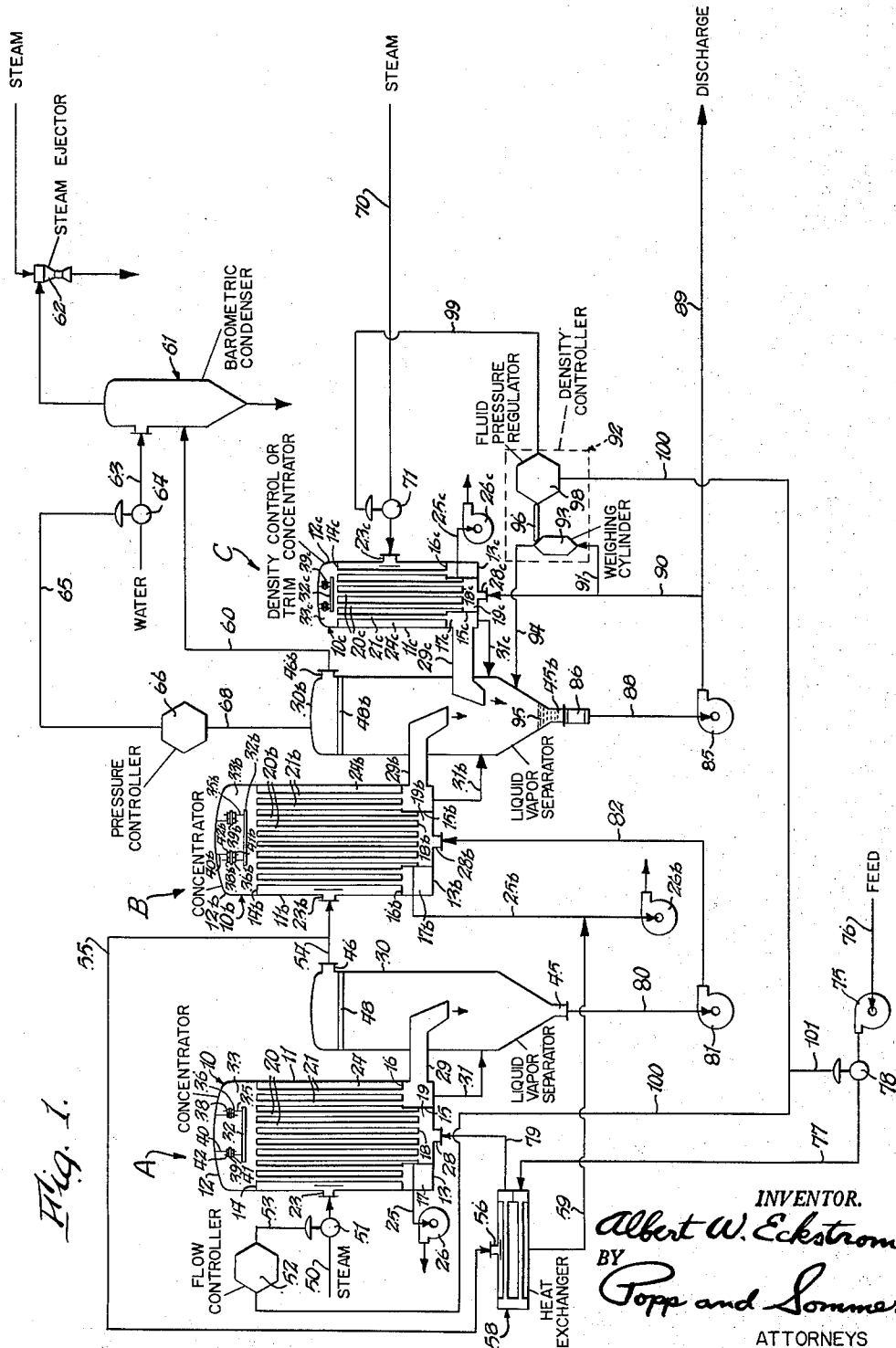
A. W. ECKSTROM

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APPARATUS FOR CONCENTRATING LIQUIDS

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APPARATUS FOR CONCENTRATING LIQUIDS
Albert W. Eckstrom, Snyder, N.Y., assignor to Blaw-Knox
Company, Pittsburgh, Pa., a corporation of Delaware
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This invention relates to apparatus for concentrating liquids and is particularly applicable where the density of the product must be held within very fine limits, such as $\pm 0.1^\circ$ Baumé (hereinafter Bé.) or with heat sensitive materials, such as corn syrup, fruit juices and urea, where holding under the temperatures required for concentration can result in degradation of color or other qualities of the product. The invention will be more particularly described in conjunction with the concentration of corn syrup.

It is accordingly a fundamental objective of the present invention to be able to concentrate a liquid within very fine limits of density, this being principally achieved by the use of a density control or trim concentrator at the output end of the apparatus through which a small proportion of the output is passed, concentrated, and returned to the system, the action of this density control or trim concentrator being responsive to small variations in weight or density of the output.

It is accordingly another fundamental objective of the present invention to concentrate heat sensitive materials with minimum time exposure to the temperatures required for concentration, this being achieved by single pass processing permitting the corn syrup to be concentrated in the order of five minutes in contrast with the conventional practice for holding the corn syrup in a batch concentration pan for from two to three hours.

Another object is to provide such a continuous process which is self adjusting and requires little supervision and in which, also, the labor requirements are greatly reduced as compared with conventional batch processing.

Another object is to provide such apparatus which has substantially constant steam and cooling water requirements in contrast with conventional batch processing where the steam and cooling water requirements are high at the start of the operation and progressively diminish toward the end of the operation.

Another object is to provide such apparatus which can be in the form of single, double, or higher multiple effect evaporators to suit any processing requirements.

Another object is to provide such a concentrator in which the density of the output is held within broader limits by means other than the density control or trim concentrator in order to adjust the apparatus to wide swings of steam supply pressure or concentration of the feed liquid beyond the capacity of the density control or trim concentrator which is essentially designed to hold the density of the output within very fine limits. This coarser control of the density of the output within such broader limits is achieved by controlling either or both the rate of input of dilute corn syrup or the input of the steam to the main concentrator in response to variations in weight of the output product.

Another object is to provide such apparatus in which a minimum of the material is held in process and in which the product leaving the last effect or main concentrator is adequately mixed so that the sampling done in achieving extract final density is truly representative of the output.

Another object is to provide such apparatus including rising and falling film evaporators in which the output of the uptake tubes is distributed uniformly to the downtake tubes.

Another object is to provide for such uniform distribu-

tion to the downtake tubes which is readily adjustable to suit the density of the liquid being distributed.

Another aim is to provide such apparatus which is simple and inexpensive considering the function which it performs and which will stand up under conditions of severe and constant use without getting out of order or requiring repairs.

Other objects and advantages of the invention will appear from the following description and drawings in which:

FIG. 1 is a diagrammatic representation of one form of the present invention for concentrating corn syrup.

FIG. 2 is an enlarged vertical section through the first effect shown in FIG. 1 and showing the construction of the concentrator in greater detail.

FIGS. 3 and 4 are horizontal sections taken generally on the correspondingly numbered lines on FIG. 2.

FIG. 5 is a fragmentary view similar to FIG. 2, on a still further enlarged scale, and showing in particular the adjustable mounting for a baffle plate which distributes liquid from uptake to downtake tubes in the concentrator.

FIG. 6 is an enlarged vertical section taken generally on line 6-6, FIG. 2 and showing the manner in which the inlet velocity of the vapor entering each downtake tube holds back the liquid entering these tubes and in effect forms a weir around the upper end of each downtake tube to maintain a liquid body of substantial depth flowing over the rim of each downtake tube at all times.

In FIG. 1 is diagrammatically illustrated a double effect evaporator particularly designed for concentrating corn syrup although the invention can be employed in a single effect evaporator as well as a triple or more effect evaporator. The two effects are designated at A and B and since the evaporators and vapor separators of the two effects are of similar construction the same reference numerals have been applied and the same description is deemed to apply, the corresponding parts of the effect B being distinguished by the suffix "b." In addition, the last effect B is provided with a density control or trim concentrator indicated generally at C and since the construction of this density control or trim concentrator C is of the same construction as the concentrators forming parts of the effects A and B, the same description is deemed to apply and the corresponding parts of the density control or trim concentrator C are distinguished by the suffix "c."

The concentrator for each of the effects A and B as well as the density control or trim concentrator C for the effect B, is designated generally at 10 and comprises a vertical cylindrical shell 11 having an upper end head 12 and a bottom end head 13. A tube sheet 14 extends across the upper end of this body and a smaller vertical cylinder 15 is welded to and rises from the bottom end head 13 and has an upper outwardly extending circular flange 16 which is welded to the shell 11 and forms an annular or ring-shaped tube sheet above an annular or ring-shaped chamber 17. A circular or disk-shaped tube sheet 18 extends across the inner cylinder 15 and forms a flash chamber 19 which is smaller than the surrounding ring-shaped chamber 17. A central series of uptake tubes 20 connect the tube sheets 14 and 18, and an outer series of downtake tubes 21 connects the tube sheets 14 and 16.

Steam from an inlet 23 is introduced into the steam chest or space 24 around all of the tubes, the condensate being withdrawn through an outlet 25 by a pump 26. The material in process is introduced through an inlet 28 into the flash chamber 19 and vapor and entrained liquid pass out through an outlet 29 from the chamber 17. The outlet 29 discharges both the vapor and entrained liquid material downwardly into a liquid-vapor separator 30 of any suitable construction. Liquid collect-

ing in the bottom of the chamber 17 flows through a drain 31 into the liquid vapor separator 30.

A feature of the invention resides in a circular baffle plate 32 in the chamber 33 above the tube sheet 14. This adjustable baffle plate is in the form of a horizontal circular disk arranged in spaced relation above the tube sheet 14 and directly above the central bundle of uptake tubes 20 and extending radially beyond the zone of discharge of these uptake tubes so as to direct the discharge from these uptake tubes horizontally and radially outwardly for even distribution of the liquid and vapor to the surrounding bundle of downtake tubes 21. It is important that the velocity of the vapor travelling radially from the rim of the circular baffle 32 be sufficient to carry the entrained liquid uniformly to the several downtake tubes 21 and the optimum vapor velocity for this purpose will depend upon the concentration of the liquid, a higher liquid concentration requiring a higher velocity of the vapor to carry the liquid uniformly to the downtake tubes 21. This velocity of the vapor travelling radially from the rim of the baffle plate 32 is readily controlled by adjusting the spacing of the baffle with reference to the tube sheet 14.

To this end an annular series of upstanding rods 35 are welded in spaced relation around the rim of the circular baffle plate 32 and each is threaded at its upper end to receive a pair of adjusting and locking nuts 36 and 38. A small horizontal plate or link 39 is held between each pair of adjusting nuts 36 and 38 and has an outwardly projecting end having a hole through which the depending end of a hanger rod 40 extends. The upper end of each depending hanger rod 40 is suitably welded to the upper end head or dome 12 of the concentrator and its lower end is threaded to receive a pair of adjusting and locking nuts 41, 42 which embrace the corresponding adjusting plate or link 39. It will be seen that by adjusting the upstanding rods 35 upwardly or downwardly with reference to the hanger rods 40 through adjustment of the several groups of adjusting and locking nuts 36, 38 or 41, 42, the circular baffle plate 32 can be adjusted to any elevation with reference to the tube sheet 14 to provide the desired velocity of the vapor leaving radially from below this circular baffle plate 32. The velocity of the vapor for this purpose can be from 30 to 150 feet per second.

The liquid from the liquid-vapor separator 30 passes out at 45 and the vapor at 46. This liquid-vapor separator is shown as having a liquid eliminator mat 48 across its upper part below the vapor outlet 46 to separate any entrained liquid from the vapor leaving the liquid-vapor separator.

The steam for the first effect A is supplied from a steam line 50 into the steam inlet 23 of the first effect A under control of a diaphragm valve 51 which in turn is under control of a flow controller 52, a pressure control line 53 connecting these parts. The outlet 46 from the liquid-vapor separator 30 of the first effect A is connected by a line 54 with the vapor inlet 23b of the second effect B. A branch line 55 from this vapor line 54 connects with the vapor inlet 56 of a heat exchanger 58 the vapor outlet line 59 from which discharges into the condensate outlet 25b of the second effect B via on the suction side of the condensate pump 26b. The vapor from the outlet 46b of the liquid-vapor separator 30b discharges via a line 60 into a barometric condenser indicated generally at 61, the vacuum in which is maintained by a steam jet ejector 62 and which is supplied with condensing water from a water line 63 under regulation of a diaphragm valve 64 which is under control, via a line 65 with a pressure controller 66. This pressure controller is actuated, via a line 68 in response to the vacuum which obtains in the liquid-vapor separator 30b.

Steam to the density control or trim concentrator C is supplied from a steam line 70 to the steam inlet 23c un-

der control of a diaphragm valve 71 which is under control as hereinafter described.

The dilute corn syrup to be processed is supplied by a pump 75 from a feed line 76 via line 77 containing a diaphragm valve 78 to the heat exchanger 58 and from this heat exchanger flows via a line 79 into the feed inlet 28 of the concentrator 10 of the first effect A. From the liquid outlet 45 of the liquid-vapor separator 30 of this first effect A the corn syrup passes via a line 80 to a transfer pump 81 which discharges into a line 82 leading to the feed inlet 28b of the concentrator 10b of the second effect B. From the outlet 45b of the liquid-vapor separator 30b of the second effect B, the concentrated corn syrup is pumped by a discharge pump 85 via a sight glass 86 and line 88 into the concentrated product discharge line 89.

A feature of the invention resides in the provision of a branch line 90 in the product discharge line 89 leading both into the feed inlet 28c of the density control or trim concentrator C and also, via a line 91, to a density controller indicated generally at 92. This density controller serves to control (1) the steam supplied, to the density control or trim concentrator 10c, (2) the steam supply to the first effect A, and (3) the feed of dilute corn syrup to the apparatus.

To this end the density controller 92 comprises a vertically movable weighing cylinder 93 supplied with the concentrated corn syrup from the branch 91 and discharging via a line 94 into the bottom of the liquid-vapor separator 30b in which a very small head 95 of liquid is maintained. This vertically movable weighing cylinder 93 is connected by a mechanical linkage 96 with a fluid pressure regulator 98 having one output line 99 connecting with the diaphragm valve 71 which controls the supply of steam to the density control or trim concentrator 10c. The fluid pressure regulator 98 of the density controller 92 has another output line 100 serving the flow controller 52 for the steam supplied to the first effect A. The fluid pressure regulator 98 of the density controller 92 also has a third output line 101, shown as being a branch of the line 100, actuating the diaphragm valve 78 controlling the feed of dilute corn syrup to the apparatus.

Operation

In the normal operation of the apparatus as above described, it will be assumed that the normal feed of corn syrup supplied at 76 will be at $26^{\circ} \pm 1^{\circ}$ Bé. at a temperature of from 130° to 140° F. and at a concentration of from 46.3 to 50% solids. It will be assumed, however, that the concentration of the feed corn syrup can depart from this normal range and be from 24° to 28° Bé. It will also be assumed that in normal operation steam is supplied at 50 at 0 lbs. p.s.i.g. pressure and that steam at 0 lbs. pressure is available at 70 for the density control or trim concentrator 10c. It will also be assumed that a vacuum of 26 inches of mercury is maintained in the liquid-vapor separator 30b, this vacuum being maintained by the pressure controller 66 regulating the diaphragm valve 64 which controls the amount of cooling water supplied to the barometric condenser 61. It will also be assumed that steam at 150 lbs. p.s.i.g. is supplied to the steam ejector 62 to maintain the required vacuum in the barometric condenser 61. The dilute corn syrup so supplied at 76 is pumped by the pump 75 past the diaphragm valve 78 and line 77 through the heat exchanger 58 and thence through the line 79 into the feed inlet 28 of the concentrator 10 of the first effect A. In the heat exchanger 58, the temperature of the feed liquid is raised to 173° F. and in the small inlet or flash chamber 19 of the concentrator 10 this feed liquid flashes. The vapor and dispersed liquid resulting from this flashing in the small chamber 19 is driven up the central bundle of uptake tubes 20 in the form of a rising film completely coating the inside of each of these tubes. The steam surrounding these tubes heats this film and since this film is liquid from the bottom to

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the top of these tubes, high heat transfer efficiency is obtained and the vapor with an entrained liquid is discharged at high velocity against the underside of the circular baffle plate 32 and is deflected by this plate to travel radially outwardly and to be discharged radially from the rim of this baffle plate.

A feature of the invention resides in maintaining a velocity of the vapor leaving radially from the rim of this circular baffle plate 32 in a range of from 30 to 150 feet per second. This velocity is necessary to insure even distribution of the entrained liquid to the upper ends or mouths of the downtake tubes 21. The velocity of the vapor, within this range, is determined by the degree of concentration of the liquid, liquids of higher concentration requiring a higher vapor velocity to carry the liquid uniformly to both the inner and outer circular rows of downtake tubes 21. This vapor velocity is determined by a spacing of the baffle 32 from the tube sheet 14, the closer the spacing the greater the velocity of the vapor leaving radially from under the rim of this baffle. To permit of adjusting the spacing to suit the degree of concentration of the entrained liquid discharged from the upper ends of the uptake tubes 20 the baffle is vertically adjustable, any adjusted position being obtained and maintained by adjustment of either or both of the two groups of adjusting and lock nuts 36, 38, or 41, 42.

The entrained liquid so discharged radially from under the rim of the circular baffle 32 builds up as a body 105 on top of the tube sheet 14 in the manner shown in FIG. 6. Thus, as illustrated in this figure, the inlet velocity of the vapor entering the upper end of each downtake tube 21 serves to hold back the liquid flowing over the rim of this tube and hence act as a weir in building up a body 105 of substantial depth on the tube sheet 14 and which serves to insure a uniform of flow, as a falling film 106, around the entire internal diameter of each downtake tube 21. This weir effect thereby insures the formation of a continuous falling film 106 covering the complete internal surface of each downtake tube 21. This film is both accelerated and agitated by the descending vapor, the agitation improving heat transfer efficiency. The surrounding steam heats this falling film 106 and since this falling film is liquid from the top to the bottom of these downtake tubes, rapid evaporation takes place.

The liquid entering the chamber 17 flows through the drain line 31 into the shell of the liquid-vapor separator 30 to the bottom thereof. The vapor and entrained liquid entering this chamber 17, flows out through the side outlet 29 thereof into the liquid-vapor separator 30 where the entrained liquid is separated both by the decreasing velocity and change in direction of the vapor and also by the mat 48 across the upper end of this liquid-vapor separator.

The vapor from this liquid-vapor separator 30, at a vacuum of, say 13.5 inches of mercury and at a temperature of 183° F., passes via the outlet 46 and line 54 to the vapor inlet 23b for the concentrator 10b for the second effect B, a part of the steam serving the heat exchanger 58 via the branch line 55 and the condensate from this heat exchanger 58 travelling through the line 59 to the condensate line 25b from the concentrator 10b of the second effect B. This vapor entering the concentrator 10b surrounds the tubes therein.

The corn syrup concentrated in the first effect A collects in the bottom of the liquid-vapor separator 30 and is withdrawn via the line 80 by the pump 81 and is discharged through the line 82 into the inlet 28b of the concentrator 10b for the second effect B. In the example assumed, this corn syrup so transferred from the first effect A to the second effect B is at a concentration of 57-63.5% solids and is at a temperature of 190° F. At this temperature, it flashes on entering the small inlet the chamber 19b of the concentrator 10b. The vapor and dispersed liquid resulting from this flashing is driven

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up the uptake tubes 20b in the form of a rising film. The surrounding vapor from this first effect A heats this film and since this film is liquid from the bottom to the top of each of these uptake tubes, high heat transfer efficiency obtains.

The vapor and liquid is discharged violently into the chamber 33b against the underside of the baffle 32b, this baffle forcing the vapor and entrained liquid to move horizontally and radially outwardly to escape radially from under the rim of this baffle for uniform distribution to the upper ends of the bundle of downflow tubes 21b. Since the corn syrup so deflected laterally by the baffle 32b of the second effect B is at a higher concentration than the corn syrup deflected laterally by the baffle 32 of the first effect A, other conditions being equal, the baffle 32b will be adjusted closer to the tube sheet 14b in order to provide the value of vapor velocity at the rim of the circular baffle 32b to carry the more concentrated corn syrup outwardly for uniform distribution to the various downflow tubes 21b. This spacing of the baffle 32b to achieve the required vapor velocity at its perimeter is achieved by adjustment of either group of adjusting and lock nuts 36b, 38b, or 41b, 42b.

The vapor from the chamber 33b enters the upper ends of the downtake tubes 21b and the inlet velocity of this vapor entering these tubes is such that it holds back the liquid from entering these tubes and in effect forms a weir around the upper end of each downtake tube 21b which insures a liquid body of substantial depth on top of the tube sheet 14b at all times. This weir effect insures the formation of a continuous falling film flowing down the inside of each of the downtake tubes 21b. This film is both accelerated and agitated by the descending vapor, the agitation insuring improved heat transfer efficiency from the surrounding vapor from the first effect A.

The vapor and liquid from the downtake tubes 21b is discharged into the chamber 17b, the liquid flowing through the drain line 31b into the shell of the liquid-vapor separator 30b and the vapor entering this shell at a higher elevation from the vapor outlet 29b. As previously indicated, a vacuum of 26 inches of mercury is maintained in this liquid-vapor separator 30b by the barometric condenser 61 and in the assumed example, the temperature of the vapor in this liquid-vapor separator is 125°. In this liquid-vapor separator, entrained liquid is separated from the vapor both by change and direction and velocity of the vapor and the passage through the mat 48b, the liquid collecting as a small body 95 in the bottom of this liquid-vapor separator at a temperature of 140° F. By maintaining the body 95 as a very small body, a minimum of corn syrup is held in process, it being a feature of the invention that the corn syrup passes through the apparatus substantially in a single pass and in a short period of time, namely in the order of five minutes, thereby to insure in a minimum degradation of color and quality due to prolonged exposure to temperature, particularly in the first effect A where the temperatures are higher. The concentrated corn syrup comprising the body 95 in the liquid-vapor separator 30b of the second effect B is withdrawn as the finished product by the pump 85 via the sight glass 86, and line 88 and discharged through the line 89. In the example assumed, the discharged product is at 44° Bé. $\pm 0.1^\circ$ Bé. at a 140° F. with 82.2% solid content.

It is a feature of the invention that the concentration of the finished product be held within very small limits, namely, $\pm 0.1^\circ$ Bé. even with wide variations in concentration of the feed liquid ($\pm 2^\circ$ Bé. from the 26° Bé. assumed) and notwithstanding variations in steam supply.

To this end, a small proportion of the corn syrup output is bypassed through the density control or trim concentrator 10c in which the required evaporation takes

place to maintain the concentration of the corn syrup product within such very fine limits, the action of this density control or trim concentrator 10c being controlled in response to the weight of the finished corn syrup product and variations in this weight of the finished product being also used to control the admission of steam to the first effect A and to control the rate of feed of dilute corn syrup to the apparatus.

Thus a small proportion of the finished product discharged by the pump 85 flows through the bypass line 90 into the chamber 19c of the density control or trim concentrator 10c which is maintained under vacuum by virtue of its outlets connecting with and discharging back into the liquid-vapor separator 30b of the second effect B and which is maintained under the assumed vacuum of 26 inches of mercury by the barometric condenser 61. The liquid so admitted to this chamber 19c is at the assumed outlet temperature of 140° F. and at this temperature flashes. The vapor and dispersed liquid resulting from this flashing is driven up the uptake tubes 20c in the form of a rising film. The surrounding steam, supplied from the steam line 70, heats this rising film and since this film is liquid from the bottom to the top of these uptake tubes 20c, high heat transfer efficiency obtains.

The vapor and liquid is discharged violently into the chamber 33c against the underside of the circular baffle plate 32c which diverts the vapor and entrained liquid to travel radially outwardly and escape radially from the perimeter of this baffle plate. As with the other concentrators 10 and 10b, it is important the vertical spacing of the circular baffle plate 32c above the tube sheet 14c be such as to provide that vapor velocity required to provide uniform distribution of the entrained liquid to the upper ends of the downtake tubes 21c. This vapor velocity is again within the range of from 30 to 150 feet per second and since the corn syrup is at its highest concentration, this velocity of the vapor escaping radially from the perimeter of the circular baffle plate 32c must be greater than the corresponding vapor velocity at the baffle plates 32 and 32b where the corn syrup in process is more dilute. The required spacing of the circular baffle plate 32c to obtain the required vapor velocity in distributing the concentrated corn syrup to the upper ends of the various downtake tubes 21c is obtained by adjusting either or both of the groups of adjusting and lock nuts 36c, 38c or 41c, 42c.

The inlet velocity of this vapor into the downtake tubes 21c is such that it holds back the liquid from entering these downtake tubes and in effect forms a weir around the upper end of each downtake tube which insures a liquid body of substantial depth on top of the tube sheet 14c at all times. This weir effect insures the formation of a continuous film flowing down the inside of each of the tubes 21c. This film is both accelerated and agitated by the descending vapor, the agitation insuring improved heat transfer efficiency.

The vapor and liquid discharged from these downtake tubes 21c into the chamber 17c, are returned to the liquid-vapor separator 30b, the liquid via the drain line 31c and the vapor via the outlet 29c.

The action of this density control or trim concentrator 10c is under exact control responsive to variations in weight of the finished product, these variations also serving to control the steam supply to the first effect A and the rate of supply of the dilute corn syrup.

To this end, in accordance with the present invention, a small stream of the output corn syrup is bypassed via the lines 90 and 91 through the weighing cylinder 93 and returned via the line 94 to the body of corn syrup 95 in the bottom of the liquid-vapor separator 30b of the second effect B. If the weight of this corn syrup flowing through the weighing cylinder 93 is above or below the Baumé limitations for the finished product, its vertical movement, through the mechanical linkage 96, actuates

the fluid pressure regulator 98 of the density controller 92 to adjust the output of this fluid pressure regulator to its outlet lines 99, 100 and 101. This controlling pressure in the line 99 serves to adjust the diaphragm valve 71 to either increase or decrease the supply of steam to the density control or trim concentrator 10c thereby to either increase or decrease its action in concentrating the small stream of output corn syrup bypassing there-through. This variation of control pressure in the line 100 adjusts the flow controller 52 and diaphragm valve 51 to vary the steam pressure supplied to the first effect A thereby to adjust the concentrating action of the multiple effect evaporator as a whole. This variation of control pressure in the line 101 serves to adjust the diaphragm valve 78 to control the rate of flow of the dilute corn syrup into the apparatus. The fine control of the concentration of the product, however, is achieved by adjusting the steam supply to the density control or trim concentrator 10c in response to changes in weight of the product resulting in vertical movement of the weighing cylinder 93.

As compared with the conventional concentration of corn syrup in a batch concentration pan for a period of from two to three hours, following which the batch is transferred to a standardizing tank where it is mixed with other corn syrup to bring its density exactly to that required, it will be seen that the present process possesses many advantages:

Thus the apparatus essentially involves a single pass operation in which the corn syrup is in process for only about five minutes and for the most part in the form of a thin rising or falling film subject to acceleration and agitation by the vapor generated so as to be subject to rapid heat transfer and minimum degradation. Even at the bottom of the liquid-vapor separator of the final effect, only a small body of liquid is maintained so as to reduce to a minimum the time the liquid is in process. It will also be noted that, being a single pass, continuous operation, the steam and cooling water requirements remain substantially constant whereas with the conventional batch processing these requirements are high at the start of the processing and low toward the end. It will also be seen that the processing is self-controlled to reduce to a minimum supervision and that as compared with batch processing the labor requirements are greatly reduced.

It will also be seen that by recirculating a small quantity of the output through the density control or trim concentrator and regulating the steam input to this trim concentrator in response to the density of the output, the density of the output can be held within very fine limits, with corn syrup within $\pm 0.1^\circ$ Bé.

At the same time, to accommodate wide swings in input, such as in steam or a feed liquid input of widely varying dilution, the apparatus will adjust either or both the input of steam or the rate of input of the dilute liquid to be processed, to adjust to such wide swings, with the density control or trim concentrator still adjusting the output density within very fine limits.

It will also be seen that the adjustable baffles 32, 32b and 32c provide simple and effective means for insuring uniform distribution of the discharge from the uptake tubes to the downtake tubes and which is easily adjustable to suit the density of the liquid in each concentrator at this point.

I claim:

1. In a concentrator having
 - (A) a shell,
 - (B) an upper tube sheet across the interior of said shell and forming a transfer chamber between it and the upper end of said shell,
 - (C) a bundle of vertical uptake tubes depending from said upper tube sheet and discharging into the center of said transfer chamber,
 - (D) an annular series of downtake tubes depending

from said upper tube sheet and surrounding said bundle of vertical uptake tubes and opening into said transfer chamber,

(E) means providing lower tube sheets at the lower ends of said tubes and an inlet flash chamber in communication with the lower ends of said uptake tubes and an outlet chamber in communication with the lower ends of said downtake tubes, and

(F) means introducing a heating medium into the space between said upper and lower tube sheets to heat said tubes;

the combustion therewith of means distributing the vapor and liquid discharged upwardly into said transfer chamber by said uptake tubes uniformly to the surrounding downtake tubes, comprising

(G) a substantially imperforate horizontal baffle plate in said transfer chamber in vertically spaced relation to said upper tube sheet directly above and with its margin extending beyond the horizontal limits of said bundle of uptake tubes and short of the side walls of said transfer chamber, said spaced relation being such as to provide a velocity of from 30 to 150 feet per second of the vapor leaving radially from under the margin of said baffle plate, and

(H) means adjusting the elevation of said baffle plate with reference to said upper tube sheet to adjust said velocity within said range.

2. In a concentrator having

(A) a shell,

(B) an upper tube sheet across the interior of said shell and forming a transfer chamber between it and the upper end of said shell,

(C) a bundle of vertical uptake tubes depending from said upper tube sheet and discharging into the center of said transfer chamber,

(D) an annular series of downtake tubes depending from said upper tube sheet and surrounding said bundle of vertical uptake tubes and opening into said transfer chamber,

(E) means providing lower tube sheets at the lower ends of said uptake and downtake tubes and providing an inlet flash chamber in communication with the lower ends of said uptake tubes and also providing an outlet chamber in communication with the lower ends of said downtake tubes, and

(F) means introducing a heating medium into the space between said upper and lower tube sheets to heat said tubes;

the combination therewith of means distributing the vapor and liquid discharged upwardly into said transfer chamber by said uptake tubes uniformly to the surrounding downtake tubes, comprising

(G) a substantially imperforate horizontal baffle plate in said transfer chamber in vertically spaced relation to said upper tube sheet directly above and with its margin generally in vertical alinement with the outermost row of said bundle of vertical uptake tubes and short of the side walls of said transfer chamber, said spaced relation being such as to provide a velocity of the vapor leaving radially from under the margin of said baffle plate sufficient to distribute entrained liquid therein uniformly to said downtake tubes.

3. In apparatus for concentrating a liquid to an exact density having

(A) a first effect concentrator including

- (a) its corresponding heating medium inlet and
- (b) its corresponding heating medium outlet,
- (c) its corresponding material-in-process inlet,
- (d) its corresponding material-in-process outlet, and

(e) its corresponding heat exchange means between said heating medium and material-in-process, and vaporizing a part of the material in process,

(B) a first effect liquid-vapor separator including

(a) its corresponding material-in-process inlet connected to said material-in-process outlet of said first effect concentrator;

(b) its corresponding material-in-process outlet and

(C) a corresponding means propelling the material in process from said material-in-process outlet of said first effect liquid-vapor separator, and

(D) a second effect concentrator including

(a) its corresponding heating medium inlet connected to said vapor outlet of said first effect liquid-vapor separator, and

(b) its corresponding heating medium outlet,

(c) its corresponding material-in-process inlet connected to receive material in process from said propelling means from said first effect liquid-vapor separator,

(d) its corresponding material-in-process outlet and

(e) its corresponding heat exchange means between said heating medium and material in process, and vaporizing a part of the material in process,

(E) a second effect liquid-vapor separator including

(a) its corresponding material-in-process inlet connected to said material-in-process outlet of said second effect concentrator,

(b) its corresponding material-in-process outlet and

(F) a corresponding means propelling the material in process from said material-in-process outlet of said second effect liquid-vapor separator to discharge from the apparatus;

the combination therewith of means maintaining the material in process so discharged from the apparatus at an exact density, comprising

(G) a trim density control concentrator including

(a) its corresponding heating medium inlet and

(b) its corresponding heating medium outlet,

(c) its corresponding material-in-process inlet connected to receive material in process from said propelling means from said second effect liquid-vapor separator,

(d) its corresponding material-in-process outlet arranged to discharge the material in process back into said second effect vapor-liquid separator,

(e) its corresponding heat exchange means between said heating medium and material in process, and vaporizing a part of the material in process, and

(H) control means including

(a) a vertically movable weighing receptacle through which a part of the stream of the material in process flows from said means propelling the material in process from said second effect liquid-vapor separator and which is supported to raise and lower in response to variations in the weight of the material in process in said weighing receptacle, and

(b) means responsive to such raising and lowering of said weighing receptacle and controlling the admission of heating medium to said heating medium inlet of said trim density control concentrator by reducing heating medium input in response to increasing weight of the liquid in said weighing receptacle and vice versa.

4. The combination set forth in claim 3 wherein said control means (H) additionally includes

(c) means responsive to such raising and lowering of said weighing receptacle (H) (a) and controlling the flow of the heating medium to said heating medium inlet (A) (a) of said first effect concentrator (A) by reducing the last mentioned flow of said heating medium in response to increasing weight of the material

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in process in said weighing receptacle (H)(a) and vice versa.

5. The combination set forth in claim 3 wherein said control means (H) additionally includes

(c) means responsive to such raising and lowering of said weighing receptacle (H)(a) and controlling the flow of material in process to said material-in-process inlet (A)(c) of said first effect concentrator (A) by increasing such last mentioned flow of material in process in response to increasing weight of the material in process in said weighing receptacle (H)(a) and vice versa.

6. In apparatus for concentrating a liquid to an exact density having

- (A) a first effect concentrator including
 - (a) its corresponding heating medium inlet and
 - (b) its corresponding heating medium outlet,
 - (c) its corresponding material-in-process inlet,
 - (d) its corresponding material-in-process outlet and
 - (e) its corresponding heat exchange means between said heating medium and material in process, and vaporizing a part of the material in process,
- (B) a first effect liquid-vapor separator including
 - (a) its corresponding material-in-process inlet connected to said material-in-process outlet of said first effect concentrator,
 - (b) its corresponding material-in-process outlet and
 - (c) its corresponding vapor outlet, and
- (C) a corresponding means propelling the material in process from said material-in-process outlet of said first effect liquid-vapor separator, and
- (D) a second effect concentrator including
 - (a) its corresponding heating medium inlet connected to said vapor outlet of said first effect liquid-vapor separator, and
 - (b) its corresponding heating medium outlet,
 - (c) its corresponding material-in-process inlet connected to receive material in process from said propelling means from said first effect liquid-vapor separator,
 - (d) its corresponding material-in-process outlet and
 - (e) its corresponding heat exchange means between said heating medium and material in process, and vaporizing a part of the material in process,
- (E) a second effect liquid-vapor separator including
 - (a) its corresponding material-in-process inlet connected to said material-in-process outlet of said second effect concentrator,
 - (b) its corresponding material-in-process outlet and
- (F) a corresponding means propelling the material in process from said material-in-process outlet of said second effect liquid-vapor separator to discharge from the apparatus;

the combination therewith of means maintaining the material in process so discharged from the apparatus at an exact density, comprising

- (G) a trim density control concentrator including
 - (a) its corresponding heating medium inlet and
 - (b) its corresponding heating medium outlet,
 - (c) its corresponding material-in-process inlet connected to receive material in process from said propelling means from said second effect liquid-vapor separator,
 - (d) its corresponding material-in-process outlet arranged to discharge the material in process back into said second effect vapor-liquid separator,
 - (e) its corresponding heat exchange means between said heating medium and material in

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process, and vaporizing a part of the material in process, and

(H) control means including

(a) a vertically movable weighing receptacle through which a part of the stream of the material in process flows from said means propelling the material in process from said second effect liquid-vapor separator and which is supported to raise and lower in response to variations in the weight of the material in process in said weighing receptacle, and

(b) means responsive to such raising and lowering of said weighing receptacle and controlling the admission of heating medium to said heating medium inlet of said first effect concentrator by reducing the last mentioned flow of said heating medium in response to increasing weight of the material in process in said weighing receptacle and vice versa.

7. In apparatus for concentrating a liquid to an exact density having

- (A) a first effect concentrator including
 - (a) its corresponding heating medium inlet and
 - (b) its corresponding heating medium outlet,
 - (c) its corresponding material-in-process inlet,
 - (d) its corresponding material-in-process outlet, and
 - (e) its corresponding heat exchange means between said heating medium and material in process, and vaporizing a part of the material in process,
 - (B) a first effect liquid-vapor separator including
 - (a) its corresponding material-in-process inlet connected to said material-in-process outlet of said first effect concentrator,
 - (b) its corresponding material-in-process outlet and
 - (c) its corresponding vapor outlet, and
 - (C) a corresponding means propelling the material in process from said material-in-process outlet of said first effect liquid-vapor separator, and
 - (D) a second effect concentrator including
 - (a) its corresponding heating medium inlet connected to said vapor outlet of said first effect liquid-vapor separator, and
 - (b) its corresponding heating medium outlet,
 - (c) its corresponding material-in-process inlet connected to receive material in process from said propelling means from said first effect liquid-vapor separator,
 - (d) its corresponding material-in-process outlet and
 - (e) its corresponding heat exchange means between said heating medium and material in process, and vaporizing a part of the material in process,
 - (E) a second effect liquid-vapor separator including
 - (a) its corresponding material-in-process inlet connected to said material-in-process outlet of said second effect concentrator,
 - (b) its corresponding material-in-process outlet and
 - (F) a corresponding means propelling the material in process from said material-in-process outlet of said second effect liquid-vapor separator to discharge from the apparatus;
- the combination therewith of means maintaining the material in process so discharged from the apparatus to an exact density, comprising
- (G) a trim density control concentrator including
 - (a) its corresponding heating medium inlet and
 - (b) its corresponding heating medium outlet,
 - (c) its corresponding material-in-process inlet connected to receive material in process from

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said propelling means from said second effect liquid-vapor separator,

(d) its corresponding material-in-process outlet arranged to discharge the material in process back into said second effect vapor-liquid separator, 5

(e) its corresponding heat exchange means between said heating medium and material in process, and vaporizing a part of the material in process, and 10

(H) control means including

(a) a vertically movable weighing receptacle through which a part of the stream of the material in process flows from said means propelling the material in process from said second effect liquid-vapor separator and which is supported to raise and lower in response to variations in the weight of the material in process in said weighing receptacle, and 15

(b) means responsive to such raising and lowering of said weighing receptacle and controlling the flow of material in process to said material-in-process inlet of said first effect concentrator by increasing such last mentioned flow of material in process in response to increasing weight of 20

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the material in process in said weighing receptacle and vice versa.

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