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METHOD AND APPARATUS FOR FIBER LIBERATION

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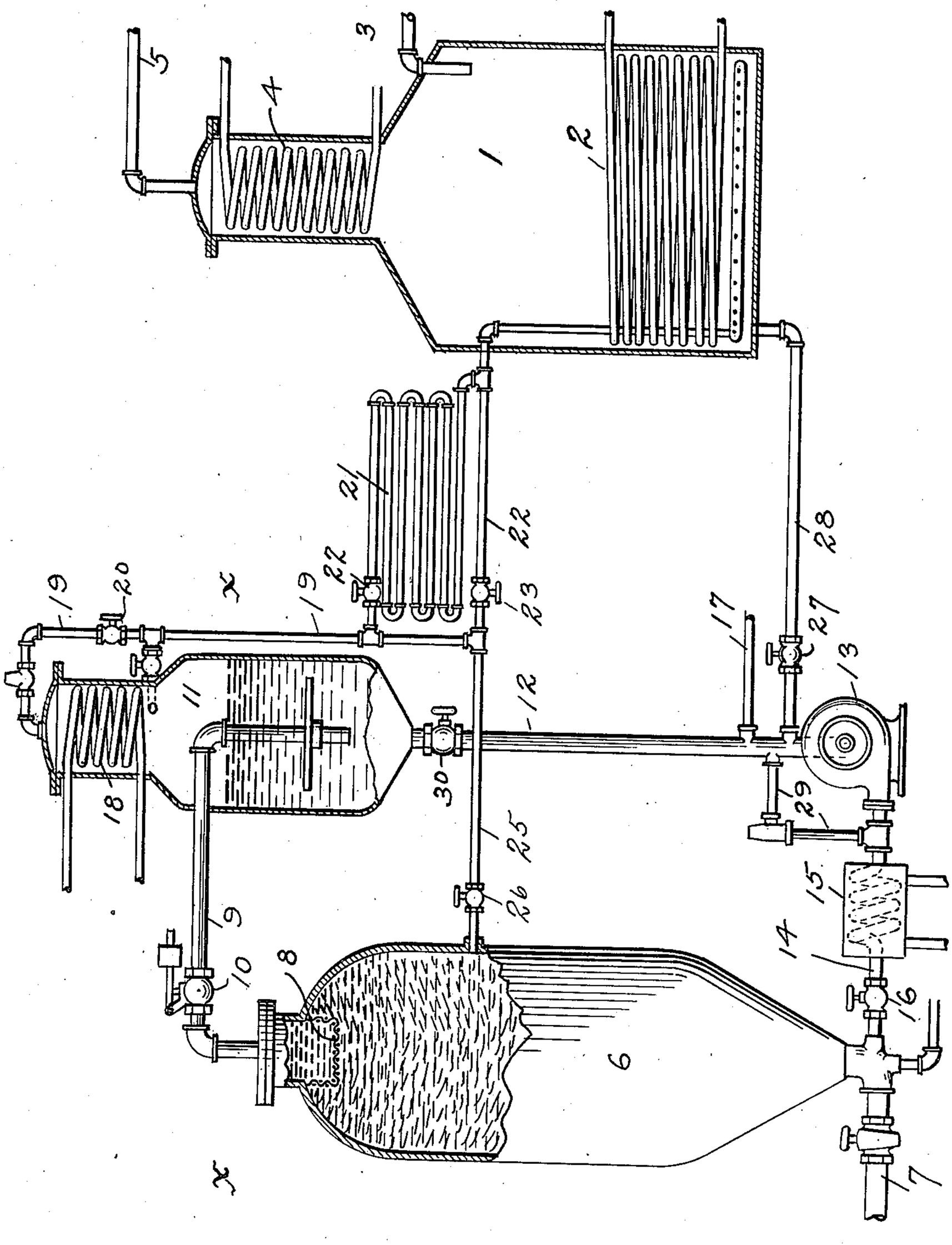

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METHOD AND APPARATUS FOR FIBER LIBERATION

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The present invention relates to a digester cooking apparatus and method for fiber liberation in the preparation of pulp especially applicable to the sulphite process, but also applicable to soda and sulphate treatment. While designed primarily for treatment of wood chips for production of paper pulp, it is to be understood that the method and apparatus are applicable to the treatment of other fibrous ligneous or cellulose materials for paper manufacture and other purposes.

In the digesting of pulp material the three controlling factors are temperature, digester pressure and concentration of acid in the cooking liquor. Since ordinarily the circulation and distribution of cooking liquor is dependent on convection currents and gas ebullition the mass of material is not ordinarily subject to uniform action of the cooking liquor nor to uniform temperature. Consequently some portions of the mass may be under-cooked while other portions are over-cooked. Losses of acid due to vaporization occur during the cooking operation which result in weakening of the cooking liquor.

In the present invention the digester contents are maintained under a constant hydrostatic head or pressure whereby the liquor is caused to penetrate the material. The digester is filled full of material and the level of the cooking liquor is raised above that of the digester dome so that there is no space or area of lower pressure into which gases may rise within the digester or into which material may be displaced to form channels or passage ways for the liquor through the mass. The cooking liquor is circulated under pressure through the cooking mass, being withdrawn from the top and reintroduced at the bottom of the digester. After withdrawal, the pressure upon the liquor is temporarily reduced and the entrained gases are collected and condensed and immediately returned to the liquor to maintain its required strength. The liquor is reheated prior to its reintroduction into the digester or is intermixed with live steam by which its temperature is raised to the desired degree and there uniformly maintained.

The object of the invention is to improve the apparatus as well as the method and mode of operation of digester cooking systems for pulp making operations whereby such apparatus will not only be cheapened in construction, but will be more efficient in use, uniform in action, economical in operation, automatic and unlikely to get out of repair.

A further primary object of the invention is to enable the production of pulp of uniform character and quality.

A further object of the invention is the more rapid reduction of the pulp material at a lower cooking temperature, and production of pulp of higher quality than now obtainable.

A further object of the invention is to provide for continuous and automatic recovery of acid gases resulting from the cooking operation and return of the recovered acid to the liquor to automatically and constantly maintain its prescribed degree of concentration within close limits of fluctuation.

A further object of the invention is to insure accurate control of temperature, pressure and liquor concentration and enrichment.

A further object of the invention is to provide a more effective and efficient apparatus and process of digesting fibrous material.

A further object of the invention is to materially increase the yield of pulp for a given digester capacity by utilizing the entire digester space.

A further object of the invention is to provide an apparatus and a method of treatment of fibrous material possessing the advantageous characteristics, features and steps as herein enumerated.

With the above primary and other incidental objects in view, as will more fully appear in the specification, the invention consists of the features of construction, the parts and combinations thereof, and the mode of operation, or their equivalents, as hereinafter described and set forth in the claims.

In the drawing, wherein is illustrated the preferred but obviously not necessarily the only form of embodiment of the invention, the single figure is an elevational view somewhat diagrammatic of an apparatus for carrying out the present process of treatment of pulp material.

While the present apparatus is especially designed for the reduction of wood chips in the production of paper pulp by the sulphite process, it is to be understood that fibrous material of other character may be likewise treated in the preparation of pulp for this and other purposes as the manufacture of nitrocellulose, cellulose acetate, pyroxylin, rayon and other analogous materials. Likewise the invention is not limited to the sulphite method of reduction but may be applied to soda and sulphate treatment.

In the drawing, 1 is a storage reservoir for a cooking liquor supply, in which the liquor is maintained at atmospheric pressure. The storage tank is provided with heater coils 2 for preheat-

ing the liquor supply. A raw acid supply conduit 3 discharges into the storage tank. Condenser coils 4 are provided in the top of the tank for condensation of any acid vapors arising from the heated liquor which condensation is returned to the liquor supply. Uncondensed vapors escape through the vent conduit 5 to the acid making plant where they are absorbed in the acid making towers.

The digester 6 may be of any convenient size and shape, that illustrated being a conventional form of digester having a domed top and conical bottom. At its bottom is communicates with the usual valved blow-off or discharge conduit 7 for the finished material, and at its top it is provided with a screen or baffle 8 for confining the material. A cooking liquor conduit 9 leads in elevated relation from the top of the digester and is provided with an expansion valve or pressure regulator 10 by which the contents of the digester are maintained under a predetermined hydrostatic pressure, which pressure falls somewhat in the conduit 9 beyond the valve or regulator 10.

The liquor conduit 9 discharges into a low pressure acid recovery compartment 11 extending well below the level of the top of the digester and so positioned as to contain a quantity of liquor, the fluid level of which is above the level of the digester. The liquid level is indicated at X—X. The digester being maintained entirely full of material and liquor under pressure there is little or no gas generation within the digester and consequent ebullition or bubbling. However, as the liquor passes the valve 10 into a lower pressure zone, the hot volatile portions of the liquor expand or vaporize into gas.

In the drawing the liquor conduit 9 is illustrated as being somewhat above the natural liquid level of the digester and acid recovery compartment, although the liquid level of the apparatus might be maintained above that of the conduit. The discharge end of the liquor conduit 9 is preferably fluid sealed within the compartment 11, the latter being provided with a baffle 11*a* to prevent violent agitation of the discharged liquor. From the bottom of the recovery compartment 11 there leads a suction or supply conduit 12 of a power pump 13 by which the liquor is returned to the digester under pressure through the conduit 14 extending through a heater 15 and provided with a check valve 16. There is thus established a circulatory system through which the cooking liquor is withdrawn from the top of the digester, the volatile gases condensed and the liquor restored to its original degree of concentration is returned under pressure to the bottom of the digester in a reheated condition. In lieu of reheating the liquor by passing it through the heater 15, live steam may be introduced through the steam line 17 into the suction conduit 12 or into the pressure conduit 14 or directly into the digester, which live steam in either event intermixes with the liquor to raise its temperature.

As the spent liquor is discharged into the low pressure compartment 11, the entrained gas rises therein into contact with condenser coils 18 in the upper portion thereof and the condensed liquor and acid falls back into the lower part of the compartment to again enrich the cooking liquor and maintain substantially its original concentration. Any uncondensed vapors escape from the recovery compartment 11 through a vent line 19, having therein a cutoff valve 20, through which they are conducted to a condenser or cooler 21 and thence returned to the liquor storage tank 1. The valve 20 of the vent conduit 19 is to be opened and closed as the occasion may require. A bypass conduit 22 communicates with the vent conduit 19 and serves to bypass the vapors and uncondensed gases around the second condenser or cooler 21. Valves 23 and 24 are provided in the vent conduit adjacent to the cooler and in the bypass respectively by the alternate opening and closing of which the vapors may be diverted through either course.

A relief conduit 25 leads from the side of the digester and connects with the vent line 19 and bypass 22, and includes a cutoff valve 26, which when opened relieves the pressure within the digester and allows a portion of the liquor to be drained off, preparatory to blowing off the digester when the cooking operation is fully completed.

In operation of the system, the digester 6 is filled to its top with chips or other fibrous material to be treated, where the screen 8 prevents their escape into the conduit 9. The valves 20 in the vent line 19, and 27 in the liquor supply conduit 28, are closed. A vacuum is induced by operation of a suction pump connected with the digester. The air is exhausted from the digester and associated liquor circuit, and as much as possible is drawn from the pores of the wood chips or other material to be treated, thus enabling greater penetration of the cooking liquor. The valve 30 in the suction conduit 12 of the pump 13 is closed and the valve 27 in the liquor supply conduit 28 is opened, admitting cooking liquor to the digester and circulatory system until the fluid level is a few inches at least above that of the top of the digester as is indicated at *x*—*x*. At the same time live steam may be admitted to supply heat, or the temperature of the liquor may be raised above that within the supply tank as it passes through the heater zone 15. The live steam is preferably admitted to the suction conduit 12 of the pump. By opening and closing the valves 20 and 27 alternately, the pump 13 is made to draw its supply of liquor either from the storage tank 1 or from the recovery compartment 11. A bypass 29, from the discharge to the suction side of the pump 13, having therein a pressure relief valve for bypassing any excess liquor serves to uniformly maintain the digester pressure.

When the digester has been charged to the required pressure and sufficient excess liquor has collected within the recovery compartment to raise the liquid level above the top of the digester, the valve 27 is closed and the valve 20 opened to establish a closed circuit for the liquor upwardly through the digester, then through the conduit 9 to the recovery compartment 11, from which it is pumped through the suction conduit 12 to the pump 13 and discharged back into the bottom of the digester through the conduit 14, being reheated en route. Being under pressure while in the digester and the digester being completely full there will be but little if any gasification and resulting ebullition within the digester. The release of pressure as the liquor leaves the digester permits the heated volatile portions to vaporize, but such vapors are not normally released or relieved as is usual in pulping operations, but the vapors and gases are recondensed within the recovery compartment 11 and returned to the cooking liquor with no loss of acid and with but minimum loss of heat. During normal operation the valve 20 in the vent conduit is kept closed and it is only under unusual conditions or

when preparing to blow off the digester that it is opened for the return of any uncondensed vapors to the storage tank. In preparing to blow off the digester, the valve 26 is opened to drain off the excess liquor and after being again closed steam is admitted to build up the required pressure to blow off the digester in the usual manner.

The circulation of the liquid under pressure insures that every portion of the mass being treated will be permeated and that uniform treatment will result. This pressure is uniformly maintained by pump 13 which delivers a slight excess of liquor, the excess pressure being bypassed through the bypass 29 and pressure regulator valve back to the suction side of the pump. The temperature of the cooking batch is uniformly maintained by the frequent reheating of the liquor during its circulation, which will require but slight rise in temperature and hence is quite economical. By utilizing the full capacity of the digester at each operation, the quantity of material treated is greatly increased. The acid content of the liquor is also maintained constant by preventing the escape or relief of gases and recondensing and returning the acid vapors to the liquor as a part of the continuous cycle of operation. In this way the essential factors of heat, pressure and acid concentration are uniformly maintained, resulting in the more rapid reduction of the material at a lower temperature and producing a much higher grade of pulp.

The described method and apparatus effect material economy of operation and affords a better quality of product. Less steam than is ordinarily required is used for cooking, and the temperature, being maintained uniformly at the prescribed cooking temperature, there is less condensation within the digester, and the inflowing liquor being preheated and under pressure, objectionable water hammering is obviated. The maintainance of uniform temperature is conducive to longer usefulness and less deterioration of the digester, which is highly susceptible to injury by rapid changes of temperature of relatively great degree to which such apparatus has been heretofore subjected.

The accurate and automatic control of the concentration and enrichment of the preheated liquor insures uniformity of successive cooks as well as uniformity of treatment of each particular batch operated upon, and more complete digestion of material due to forced penetration of liquor and uniform temperature control.

From the above description it will be apparent that there is thus provided a device of the character described possessing the particular features of advantage before enumerated as desirable, but which obviously is susceptible of modification in its form, proportions, detail construction and arrangement of parts without departing from the principle involved or sacrificing any of its advantages.

While in order to comply with the statute, the invention has been described in language more or less specific as to structural features, it is to be understood that the invention is not limited to the specific features shown, but that the means and construction herein disclosed comprise the preferred form of several modes of putting the invention into effect, and the invention is therefore claimed in any of its forms or modifications within the legitimate and valid scope of the appended claims.

Having thus described my invention, I claim:

1. In an apparatus for treating cellulose material, a digester to receive the material, a conduit connected thereto and forming with the digester a circulatory system for the cooking liquor, a supply reservoir for cooking liquor communicating with said circulatory system by which additional liquor may be introduced, a condenser associated with the circulatory system for condensing vapors arising from the circulating liquor and returning to the circulating liquor the resulting condensate prior to the re-introduction of the liquor into the digester, and a relief conduit from the digester to said supply reservoir.

2. In an apparatus for treating cellulose material, a digester to receive the material, a conduit connected thereto, and forming with the digester a circulatory system for the cooking liquor, a supply reservoir for cooking liquor communicating with said circulatory system by which additional liquor may be introduced, a condenser associated with the circulatory system for condensing vapors arising from the circulating liquor and returning to said circulatory system the resulting condensate, a relief conduit from the condenser to the supply reservoir for uncondensed vapors and a second condenser therefor.

3. In an apparatus for treating cellulose material, a digester to receive the material, a conduit connected thereto and forming with the digester a circulatory system for the cooking liquor, a supply reservoir for cooking liquor communicating with said circulatory system by which additional liquor may be introduced, and a relief conduit for returning unvaporized cooking liquor from the digester to the supply reservoir.

4. In an apparatus for treating cellulose material, a digester to receive the material, a conduit connected thereto and forming with the digester a circulatory system for the cooking liquor, a supply reservoir for cooking liquor communicating with said circulatory system by which additional liquor may be introduced, a relief conduit for returning unvaporized cooking liquor from the digester to said supply reservoir and a condenser associated with said reservoir for condensation of vapors arising from the liquor therein and adapted to return the condensate thereof to said reservoir.

5. In an apparatus for the reduction of cellulose material, a digester, a circulatory conduit for cooking liquor connected thereto and forming with the digester a closed cycle circulatory system, a pump interposed in said conduit for accelerating the flow of liquor to the digester under pressure, a pressure reducing valve in said conduit adjacent the outlet from the digester beyond which the pressure within the conduit is lowered below that within the digester, a supply reservoir for cooking liquor communicating with the conduit intermediate the pressure reducing valve and the pump, and a relief conduit leading from the digester back to the supply reservoir, and valves controlling the admission and relief of liquor to and from the circulatory system.

6. In an apparatus for the reduction of cellulose material, a digester, a circulatory conduit for cooking liquor connected thereto and forming with the digester a closed cycle circulatory system, a pump interposed in said conduit for accelerating the flow of liquor to the digester under pressure, a pressure reducing valve in said conduit adjacent the outlet from the digester beyond which the pressure within the conduit is lowered below that within the digester, a reservoir for a supplemental supply of liquor wherein the liquid

level is maintained above that of the top of the digester, said supplemental supply reservoir communicating with said conduit intermediate the pressure reducing valve and the pump.

7. In an apparatus for the reduction of cellulose material, a digester, a circulatory conduit for cooking liquor connected thereto and forming with the digester a closed cycle circulatory system, a pump interposed in said conduit for accelerating the flow of liquor to the digester under pressure, a pressure reducing valve in said conduit adjacent the outlet from the digester beyond which the pressure within the conduit is lowered below that within the digester, and a condenser for vapors arising from the circulating liquor communicating with the conduit intermediate the pressure reducing valve and the pump, the condensate from which is returned to the circulatory system.

8. In an apparatus for the reduction of cellulose material, a circulatory system for cooking liquor including a digester to receive the material, and a cooking liquor conduit connected thereto and forming a closed cycle wherein the liquor is circulated through the digester, and a vessel containing a supplemental supply of cooking liquor communicating with the circulatory system and inducing a hydrostatic pressure therein by which the digester is maintained completely filled with liquor additional to the material contained therein, a portion of the cooking liquor conduit being extended above the liquid level of the vessel whereby the pressure upon the liquor is temporarily relieved and a condenser associated with the vessel for condensing vapors arising from the circulating liquor and returning the condensate to the liquor prior to its re-introduction into the digester for maintaining the concentration thereof.

9. In an apparatus for the reduction of cellulose material, a circulatory system for cooking liquor including a digester to receive the material, and a cooking liquor conduit connected thereto and forming a closed cycle wherein the liquor is circulated through the digester, and pressure control means in said circulatory system by which the pressure of the cooking liquor within the digester is maintained above that of the liquor after passing therefrom.

10. In an apparatus for the reduction of cellulose material, a circulatory system for cooking liquor including a digester to receive the material, and a cooking liquor conduit connected thereto and forming a closed cycle wherein the liquor is circulated through the digester, and a condenser for vapors arising from the liquor outside the digester, the condensate of which is returned to the liquor prior to its re-introduction into the digester.

11. In an apparatus for the reduction of cellulose material, a digester, and a conduit for cooking liquor leading from the top of the digester and returning to the bottom thereof forming a closed cycle circulatory system through which the cooking liquor is circulated.

12. In an apparatus for the reduction of cellulose material, a digester, a conduit for cooking liquor leading from the top of the digester and returning to the bottom thereof forming a closed cycle circulatory system through which the cooking liquor is circulated, and means for creating alternate low and high pressure areas of the cooking liquor in different parts of such cycle.

13. In an apparatus for the reduction of cellulose material, a digester, a conduit for cooking liquor leading from the top of the digester and returning to the bottom thereof forming a closed cycle circulatory system through which the cooking liquor is circulated, a pressure regulator through which the liquor passes from the digester to a condition of lower pressure and a second pressure regulator for increasing the pressure of the cooking liquor returning to the digester.

14. The herein described method of treating cellulose material including digesting the material in a cooking liquor maintained under such condition as to retard vaporization of entrained volatile material, progressively withdrawing the cooking liquor from the material being digested and inducing the vaporization of the volatile portions thereof, condensing the vapors arising therefrom, returning the condensate to the withdrawn liquor prior to its return to the material and progressively returning the resulting liquor into digesting relation with the material operated upon.

15. In an apparatus for the treatment of cellulose material, a digester to receive the material, and means for supplying cooking liquor thereto in sufficient quantity to maintain the digester completely filled with material and liquor under pressure including a low pressure supply reservoir communicating with the digester in which a liquid level of surplus cooking liquor is maintained above the level of the top of the digester.

16. In an apparatus for production of cellulose, a digester, a circulatory conduit for the cooking liquor communicating with the digester and forming therewith a closed cycle in which the digester is included, an expansion chamber through which the circulating liquor is passed, a condenser associated therewith for condensing vapors arising from the liquor and returning the condensate thereto, and a reservoir for a surplus supply of cooking liquor in constant communication with the circulatory system by which the liquor therein is maintained under hydro-static pressure.

17. In an apparatus for reduction of cellulose material, a digester, a circulatory conduit for cooking liquor communicating with the digester and forming a closed cycle in which the digester is included, and means for circulating cooking liquor therethrough under such condition that the digester is maintained completely filled with material and cooking liquor throughout the period of operation, and means for maintaining the concentration of the cooking liquor substantially uniform including a condenser for condensing vapors arising therefrom and returning the condensate directly to the circulating liquor.

18. In an apparatus for the treatment of cellulose material, a digester receiving the material and cooking liquor, and means for maintaining the liquor and material in the digester under pressure, a circulatory system for the cooking liquor including a low pressure chamber through which liquor passes from the digester, and from which it is returned thereto wherein the lowering of pressure upon the liquor permits the vaporization of volatile portions thereof, a condenser for condensing the vapors arising from the low pressure liquor, the condensate of which is returned to the low pressure enriched liquor and such liquor returned to the digester by the continued circulation of such liquor.

19. The herein described method of treating cellulose material in the production of pulp, con-

sisting in digesting the material in a vessel completely filled with material and cooking liquor under pressure, circulating the cooking liquor through such vessel, withdrawing the cooking liquor under reduced pressure, collecting and condensing vapors arising from the liquor under reduced pressure, intermixing the condensation with the withdrawn liquor and returning the enriched liquor to the vessel under increased pressure.

20. In an apparatus for treatment of cellulose material, a digester, a conduit leading from the top of the digester and discharging into the bottom thereof, means for inducing a circulation of cooking liquor through the digester and through the conduit, and a vessel communicating with the conduit and containing a head of cooking liquor above the level of the digester by which the digester is maintained completely filled, and means for raising the temperature of the liquor introduced into the digester.

21. In a pulp making apparatus, a digester to receive the material, a conduit connected thereto and forming with the digester a circulatory system for cooking liquor, means for inducing a circulatory flow of liquor therethrough, and a condenser chamber included in the liquor circulatory system for condensing vapors arising from the circulating liquor and returning the condensate to the circulating liquor before re-introduction into the digester, whereby the concentration of the cooking liquor will be maintained substantially uniform.

22. In a pulp making apparatus, a digester to receive the material and cooking liquor, a circulatory conduit for the cooking liquor through which the liquor is discharged from the top of the digester and returned to the bottom thereof, means for circulating the liquor through said conduit, and a condenser associated with said circulatory conduit for condensing the vapors arising from the liquor during circulation and returning the condensate to the liquor prior to its return to the digester, whereby the liquor returning to the bottom of the digester is maintained substantially at the same concentration as that leaving the top thereof.

23. In a pulp making apparatus, a digester to receive the material and cooking liquor, means for maintaining the digester completely filled with an intermixture of material and cooking liquor under hydrostatic pressure, a conduit through which liquor is withdrawn from the top and returned to the bottom of the digester, a low pressure chamber through which the liquor flows before its return to the digester, a condenser associated therewith for reducing vapors arising from the cooking liquor and returning the condensate to the circulating liquor prior to its return to the digester, whereby the liquor leaving the top and returning to the bottom of the digester will be maintained at substantially uniform degree of concentration.

24. In an apparatus for the reduction of cellulose material, a digester, a circulatory conduit for cooking liquor connected thereto and forming with the digester a closed cycle circulatory system, a pump interposed in said conduit for accelerating the flow of liquor to the digester under pressure, a pressure reducing chamber through which the cooking liquor is passed wherein a pressure is maintained less than that within the digester, a condenser for condensing the vapors arising from the liquor, and returning the condensate to the circulating liquor.

25. In an apparatus for the reduction of cellulose material, a digester, a circulatory conduit for cooking liquor connected thereto and forming with the digester a closed cycle circulatory system, a pump interposed in said conduit for accelerating the flow of liquor to the digester under pressure, a pressure reducing chamber through which the liquor is passed intermediate its discharge from the digester and the pump wherein the pressure of the liquor is lowered to less than that within the digester, and a condenser associated therewith for condensing the vapors arising from the liquor and returning the condensate to the circulating liquor.

26. In an apparatus for the reduction of cellulose material, a digester, a circulatory conduit for cooking liquor connected thereto and forming with the digester a closed cycle circulatory system, a pump interposed in said conduit for accelerating the flow of liquor to the digester under pressure, and a reservoir for a supplemental supply of liquor wherein the liquid level is maintained above that of the digester and the pressure at less than that within the digester, and a supply connection thence to the intake side of said pump.

27. In a pulp making apparatus, a digester to receive a mixture of material and cooking liquor, a circulatory conduit connected therewith, including a pressure reducing chamber forming with the digester a closed cycle wherein the cooking liquor is circulated through the digester, and a condenser for returning to the circulating liquor prior to its return to the digester the condensate of vapors arising from the liquor within said pressure reducing chamber.

28. In a pulp making apparatus, a digester to receive a mixture of material and cooking liquor, a circulatory conduit connected therewith and forming with the digester a closed cycle wherein the cooking liquor circulates, and condenser means for reducing vapors arising from the circulating liquor and returning the condensate thereof to the circulating liquor prior to its re-introduction into the digester whereby the concentration thereof will be maintained substantially constant.

29. In a pulp making apparatus, a digester to receive a mixture of material and liquor, a circulatory system for the cooking liquor through which the liquor is progressively withdrawn from and returned to the digester, a storage reservoir for cooking liquor connected with the circulatory system for maintaining the supply of liquor to the digester, and a condenser associated with the storage reservoir for condensing the liquor vapors arising from the liquor within the reservoir and returning the condensate thereof to the stored liquor prior to its introduction into the digester.

30. In a pulp making apparatus, a digester to receive a mixture of material and liquor, a circulatory system for the cooking liquor through which the liquor is progressively withdrawn from and returned to the digester, a storage reservoir for cooking liquor connected with the circulatory system for maintaining the supply of liquor to the digester, and an auxiliary supply reservoir included in the circulating system wherein a surplus of liquor is maintained to maintain the liquor in the digester at a predetermined level.

31. In a pulp making apparatus, a digester to receive a mixture of material and liquor, a circulatory system for the cooking liquor through which the liquor is progressively withdrawn from and returned to the digester, a storage reservoir for cooking liquor connected with the circulatory system for maintaining the supply of liquor to

the digester, an auxiliary supply reservoir associated with the circulatory system for maintaining the liquor within the digester at a predetermined level, and condensers associated with each of the reservoirs for condensing the vapors arising from the liquor therein and returning the condensate to the liquor supply prior to its introduction into the digester.

32. In a pulp making apparatus, a digester to receive a mixture of material and liquor, a circulatory system for the cooking liquor through which the liquor is progressively withdrawn from and returned to the digester, a storage reservoir for cooking liquor connected with the circulatory system for maintaining the supply of liquor to the digester, an auxiliary supply reservoir associated with the circulatory system for maintaining the liquor within the digester at a predetermined level, a conduit interconnecting the auxiliary reservoir with the storage reservoir, and a condenser associated with said conduit wherein vapors arising from the liquor in the auxiliary reservoir are condensed and the condensate returned to the storage reservoir.

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