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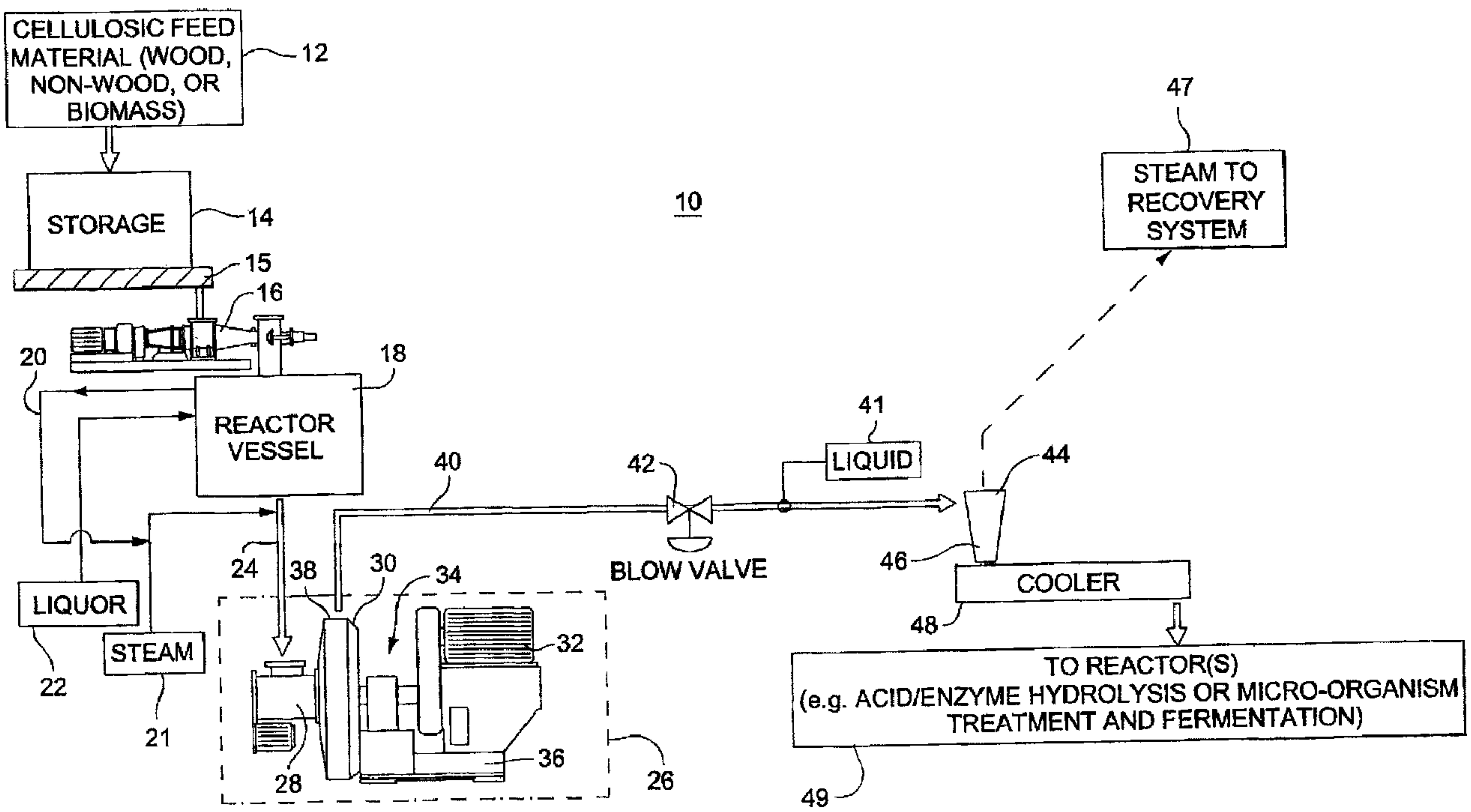
(54) Titre : COMPRESSEUR A HAUTE PRESSION ET PROCEDE DE DESINTEGRATION PAR VAPOCRAQUAGE

(54) Title: HIGH PRESSURE COMPRESSOR AND STEAM EXPLOSION PULPING METHOD



(57) Abrégé/Abstract:
A steam explosion pulping method including: impregnating a cellulosic biomass feed material in a pressurized reactor vessel; discharging the impregnated feed material from the vessel to a high pressure compressor; elevating a pressure of the feed material in the compressor; discharging the pressurized feed material from the compressor to a conduit coupled to a blow valve; rapidly reducing pressure of the pressurized feed material as the feed material passes through the blow valve, and pulping the feed material by expansion of fluid in the feed material during the rapid pressure reduction.

HIGH PRESSURE COMPRESSOR AND STEAM EXPLOSION PULPING METHOD

ABSTRACT OF THE DISCLOSURE

A steam explosion pulping method including: impregnating a cellulosic biomass feed material in a pressurized reactor vessel; discharging the impregnated feed material from the vessel to a high pressure compressor; elevating a pressure of the feed material in the compressor; discharging the pressurized feed material from the compressor to a conduit coupled to a blow valve; rapidly reducing pressure of the pressurized feed material as the feed material passes through the blow valve, and pulping the feed material by expansion of fluid in the feed material during the rapid pressure reduction.

HIGH PRESSURE COMPRESSOR AND STEAM EXPLOSION PULPING METHOD

RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/916,446 filed May 7, 2007, the entirety of which is incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to pre-treatment of cellulosic biomass feed materials, e.g., wood chips, for a steam explosion pulping. The invention relates particularly to discharging material from a digester and pressurizing a flow of steam and cellulosic material prior to steam explosion.

[0003] Steam explosion pulping typically involves steam used to break apart the cellulosic fibers (explosion pulping) and has been used, for example, for enzyme hydrolysis. Pulp is produced from cellulosic biomass feed material by pressurizing feed material with steam and subsequently rapidly reducing the pressure of the feed material impregnated with the steam. The rapid pressure reduction causes steam in the cells of the feed material to expand and thereby burst the cells. Pulp results from the bursting of cells in the feed material. The pulp with burst cells is further processed, for example, with enzymes to form sugars from the pulp.

[0004] The rapid reduction of the cooked feed material may be performed using a blow-valve. Prior to the blow-valve the cooked feed material and associated steam is pressured, such as to 15 bar. The stream of feed material and steam is preferably a high consistency stream having a solid consistency of 25% or more by weight. The feed material stream typically includes cellulosic biomass feed material, e.g., straws, fuel energy crops, paper pulp and agricultural waste products and other biomass; optionally cooking chemicals (which tend to be corrosive) and a large quantity of steam. In conventional systems, the amount of steam used in a pressurized reactor to cook and pressurize the feed material has been, for example, 500 lbs. (pounds) to 600 lbs. of steam for each ton of solid feed material. Further, the feed material stream is hot, such as at a temperature of 180°C (Celsius) to 210°C. The feed material stream is primarily steam, chemical vapors and solid cooked cellulosic material. This hot and high consistency stream is pressurized in the reactor vessel to, for example, 15 bar. The stream passes through a blow valve or other pressure release device (collectively referred to as a "blow valve") wherein steam explosion pulping occurs and the pressure of the feed material stream is reduced to, for example, 1 to 2 bars.

[0005] A conventional approach to pressurizing the feed stream is to add sufficient steam to the reactor vessel to achieve the desired pressure for steam explosion pulping, such as 15 bar. A difficulty with this approach is that it requires a large amount of steam, e.g., 500-800 lbs of steam per ton of solid feed material, to heat the material and to discharge (blow) out of the digester, which is well beyond the steam needed for pretreatment, e.g., cooking and steam impregnation, of the feed material. The required large volume of steam is expensive in terms of energy consumption to produce.

[0006] There is a long felt need for low-energy devices and techniques that pressurize a cellulosic biomass feed material stream to sufficiently high pressures for discharge for steam explosion pulping. The desired low-energy devices and techniques should pressurize the feed material stream to a pressure for steam explosion pulping and to propel the stream from the digester to a blow valve, such as above 15 bar, by using less energy than is conventionally consumed in generating the additional steam added to a reactor vessel to achieve the same pressurization and motive force for the feed material stream.

BRIEF DESCRIPTION OF THE INVENTION

[0007] A steam explosion pulping method has been developed comprising: impregnating a cellulosic biomass feed material in a pressurized reactor vessel; discharging the impregnated feed material from the vessel to a high pressure compressor; elevating a pressure of the feed material in the compressor; discharging the pressurized feed material from the compressor to a conduit coupled to a blow valve; rapidly reducing pressure of the pressurized feed material as the feed material passes through the blow valve, and pulping the feed material by expansion of fluid and steam in the feed material during the rapid pressure reduction.

[0008] A high pressure compressor has been developed comprising: a centrifugal impeller assembly including a disc and at least one removable vane plate attached to the disc, and a high pressure casing for the impeller assembly.

[0009] A method has been developed to convert e.g. a mechanical refiner to a high pressure compressor having an impeller, comprising: replacing a refining plate with a vane plate on a rotor disc, and converting a stator disc to a stator housing for the vane plate and rotor disc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIGURE 1 is a schematic diagram of a steam explosion pulping system for cellulosic biomass feed material, wherein the system has a centrifugal high-pressure compressor. The drawing shows a device with a horizontal shaft. An equivalent device may be configured with a vertical shaft.

[0011] FIGURE 2 is a side view, partially in cross-section, of the centrifugal high-pressure steam pump shown in Figure 1.

[0012] FIGURE 3 is a front view of an exemplary array of vane plate segments mounted on a rotor disc.

DETAILED DESCRIPTION OF THE INVENTION

[0013] A high pressure discharge compressor has been developed to pressurize a cooked cellulosic biomass feed material stream so that the stream may be subjected to steam explosion pulping. The high pressure discharge compressor applies centrifugal force to increase the pressure of a feed material stream from a pressurized reactor vessel. The centrifugal force applied to the stream increases the pressure to, for example, at least 0.5-1 bar above the pressure inside the cooking reactor. The pressurized stream is discharged from the compressor to a conduit that leads to a blow valve, where the steam explosion converts the feed material to pulp.

[0014] The high pressure discharge compressor may have a casing, rotating disc(s), drive motor, transmission and bearing, and maybe a front end screw that are similar to a conventional mechanical refiner, e.g., MDF refiner. The digester may have a scraper or a discharge conveyor (typically a screw) to feed the material to the compressor via a feed screw or by gravity. With a horizontal impeller (with a vertical shaft) the processed material from the reactor may just drop into the impeller. The compressor has compressor vane plate segments attached to the discs, in contrast to the refining plate segments attached to the discs in a conventional mechanical disc refiner. The compressor vane plate segments form an annular centrifugal impeller that accelerates the stream of feed material, without applying substantial refining action to the material (as is done in a conventional refiner).

[0015] In some steam explosion pulping applications, a mechanical refiner, such as a MDF refiner, is suitable as a high pressure compressor. However, the refining processed performed between the rotating and stationary discs is not needed for compression and increasing the pressure, and the additional energy requirements for refining may render the compression process less efficient for steam explosion pulping purposes. The increased pressure through the high pressure discharge compressor may allow to "re-circulate" some of the steam back to the reactor. Piping from the stator may be used to optionally feed some steam to the reactor.

[0016] FIGURE 1 is a schematic diagram of a steam explosion pulping system 10. Cellulosic biomass feed material 12 may be temporarily stored in a storage vessel 14, such as a buffer bin. Feed material 12 is moved by a feed conveyor 15, such as a screw conveyor, to a reactor feeding device 16. The storage vessel 14 may be omitted if the stream of feed material 12 is sufficient by itself to supply the needs of the reactor feeding device 16. The feed material may flow to the reactor feeding device as a continuous stream of dry material or in batches, depending on whether the reactor vessel 18 is a continuous reactor or a batch reactor.

[0017] An unpressurized stream, such as at 1 bar, of feed material enters the reactor feeding device 16, which seals against the pressure inside the reactor and the feed material is discharged from the device 16 to a high pressure reactor vessel 18. The reactor feeding device 16 preferably provides a pressure seal between the reactor vessel 18 and the unpressurized stream of feed material upstream of the reactor feeding device. Suitable reactor feeding devices include, by way of example, a plug feeder and/or rotary valve or a similar device.

[0018] The reactor vessel 18 may be a pressurized continuous digester vessel arranged vertically, inclined, or horizontally. For example, the feed material may enter the top of the vessel as shown in Figure 1. The reactor vessel 18 is pressurized, such as to a pressure of 3 to 15 bar (or higher). The feed material mixes in the reactor with steam 20, 21 and optionally cooking chemicals 22, e.g., liquor to dissolve and remove the lignin in woody feed material or to enhance the conversion of cellulose to simpler carbo-hydrates like sugars (such as C5 and C6 sugars). The steam and chemicals may be introduced to the reactor vessel 18 from external sources steam and liquor chemicals 21, 22.

[0019] The feed material is steam cooked, under pressure, in the reactor vessel to impregnate the cells of the feed material with water, steam and, possibly, cooking chemicals. The cooking process, e.g., steam impregnation of the feed material, may be a two (2) minute to fifteen (15) minute process in the vessel. During a continuous process, the retention period of the feed material in the vessel may be 2 to 15 minutes and this retention period serves as the cooking period. Cooking cellulosic materials at higher pressures is also referred to as autohydrolysis if no chemicals are added, e.g., by way of liquor, to the materials.

[0020] A rotating screw, auger or scraper in the reactor vessel 18, promotes mixing of the feed material, steam and chemicals and the migration of the feed material through the reactor vessel from inlet to a discharge. The stream 24 of feed material from the reactor is discharged to a conveyor (typically a screw conveyor) that feeds to a high pressure compressor 26.

[0021] The conveyor feeds the material discharged from the digester vessel to an inlet feed screw 28 of the compressor. The feed screw may be a full flight screw or ribbon feeder. The feed screw 28 may be separately driven or directly driven by a rotating shaft 56 that drives impeller disc 52 (see Fig. 2) of the compressor 26. The feed screw 28 serves as the inlet to impeller disc 52 of the high pressure compressor. The feed screw conveys the feed material towards the center of a rotating impeller disc 52 that propels the feed material towards the periphery of the disc.

[0022] The reactor vessel 18, reactor feeding device 16, conveyor 15 and storage bin 14 are conventional pulping devices being used in a novel manner in that they are used in connection with a high pressure compressor 26.

[0023] The stream 24 of cooked feed material, steam and cooking chemicals is discharged from the reactor vessel 18, such as through a bottom discharge conduit that may include a discharge screw. Preferably, the stream 24 has a high consistency, such as a solids consistency of at least 25% by weight. In particular, the stream is preferably at least 25% solid feed material and 75% or less steam and chemical vapors.

[0024] The pressure of the discharge stream 24 from the reactor vessel 18 may not be sufficient for steam explosion pulping, and particularly for providing a motive force to propel the steam through a blow valve. The pressure may be elevated to a sufficient pressure, e.g., 10 to 15 bar. Steam 20 from the reactor or digester vessel 18 may be utilized to transport the stream of feed material towards the blow valve 42, but the amount of steam added to the reactor or digester need not be sufficient to move the stream of feed material through the blow valve. An additional source of steam 21 may be added to the steam extracted from the reactor vessel 18 to transport the feed material stream 24 from the vessel to a high pressure compressor 26.

[0025] The energy requirements of the reactor vessel 18, especially with respect to the energy required to produce the steam supply 20, might be lower as compared to a conventional reactor vessel in which the steam supply elevates the pressure in the reactor to a pressure, e.g., 15 bar and provides enough motive steam for moving the feed material to the blow valve where steam explosion pulping occurs.

[0026] The stream of feed material 24 is fed to the high pressure discharge compressor 26 to elevate the steam pressure of the feed material to that necessary for steam explosion pulping. The compressor may increase the feed material pressure to 15 bar, for example. The high pressure discharge compressor may reduce the amount of motive external steam 21 needed to discharge the feed material through the conduit 40 and blow valve 42.

[0027] The compressor 26 may be a centrifugal compressor having an inlet feed mechanism 28, an impeller and impeller housing assembly 30, a motor or engine 32 to drive the rotating impeller, a transmission and bearing assembly 34, and a frame 36. The rotating impeller increases the pressure of the stream 24 by applying centrifugal force to the stream. The stream is discharged to a high pressure annular discharge housing 38 arranged around the periphery of the impeller. The high pressure compressor may have a horizontal shaft with a vertical disc, or may have a vertical shaft with a horizontal impeller.

[0028] From the discharge housing 38, the high pressure stream flows through conduit 40 and to a blow-valve 42. The stream enters the blow valve at a high pressure, e.g., above 10 to 15 bar, and expands as it passes through the valve. The expansion through the blow valve 42 rapidly reduces the pressure of the stream, such as to 1 to 2 bar. This rapid expansion causes the water vapor and/or fluid impregnated in the feed material, especially in the cells of the feed material, to expand and results in a steam explosion to burst the cells of the cellulosic biomass feed material. The expansion of the water and/or steam separates the feed material and explodes the cells of the feed material to create pulp from the feed material.

[0029] The conduit 40 may be coupled to a pressurized liquid source 41 that provides a liquid stream to the pressurized pulped feed material downstream of the blow valve. The liquid stream 41 may consist of water, high temperature catalyzing agents, acidic agents including but not limited to sulfuric acid, enzymes, or other agents formulated to enhance pre-digestion of cellulosic biomass feed material.

[0030] The cellulosic biomass material, after flowing through the blow valve 42, is pulped feed material that flows to a cyclone 44 (or a blow-tank or a centrifuge or similar device) to separate the pulp fibers and other solid materials from the steam and other vapors 47 in the steam. A cyclone separator or blow tank 44 has a lower discharge 46 for pulp and an upper vapor discharge for the steam, non-condensable gases (NCG), compressible gases and other chemical vapors 47. These gases 47 may be recovered, such as by passing through a heat exchanger to recover the heat energy in the vapor.

[0031] The pulp discharged from the lower discharge port 46 of the cyclone 44 might be cooled in a cooling device 48, which may be a belt or screw conveyor. The cooling prevents degradation of the enzymes in the pulp. From the cyclone or blow-tank, the cellulose pulp material is fed to a process stage 49, such as an acid hydrolysis, enzyme hydrolysis or micro-organism treatment and fermentation to, for example, produce the desired sugars and ultimately alcohols like for example ethanol. The process stage 49 may also form cellulose containing fibers for pulp or board products. The blow back valve, reactor or digester, cyclone, cooling device and other reactors may be similar to conventional pulping devices. These components are in novel arrangement that includes a high pressure compressor 26.

[0032] FIGURE 2 is side view, shown in partial cross section and cut-away view to show the impeller, of a high pressure centrifugal compressor 26 having a horizontal drive shaft. An impeller with a vertical drive shaft may be alternatively employed in the compressor. The compressor includes a rotating disc impeller 52 sealed in an annular casing 54 that is included in the impeller housing assembly. The disc impeller is mounted on a rotating shaft 56 that is supported by bearings 58 mounted on the frame 36 of the compressor. Gears in a transmission assembly 34 coupled the shaft 56 to a main drive motor 32. Alternatively, the shaft of the high pressure compressor may be directly coupled to a main drive motor. The axial position of the shaft 56 and its associated rotor disc 52 may be adjusted with a gap adjustment mechanism 60 that incrementally moves the rotor disc towards or away from an opposition stator disc or housing.

[0033] The housing 54 may be a solid cast metal annular housing that is sealed to provide a pressurized annular hollow space for the impeller and material feed stream flow path. The housing 54 defines a closed, pressurized chamber between the feed screw discharge 62 and diffuser discharge 38. The housing 54 is preferably rated for high pressures, such as 15 to 20 bar or greater. A seal 61, e.g., a mechanical seal or special stuffing box, is between the shaft and the high pressure compressor housing. The shaft bearings 58 are preferably installed outside the pressurized housing 54.

[0034] An inlet, such as a center inlet 62 to the front of the housing 54 provides inlet port for the stream of feed material that is feed to the rotor by a feed screw 28. The feed screw receives the stream of feed material from the conduit 24 and injects the feed material through the center inlet 62 and into the vanes of the rotor disc 52. The stream of feed material flows to the rotor disc 52 and passes through vanes on the rotor disc to the periphery 64 of the disc. Centrifugal force due to the rotation of the rotor disc propels the feed material from the center inlet 62 to the circumferential periphery of the rotor disc. If compressor has a vertical drive shaft, gravity may be the force that propels the material toward the rotating disc or impeller. If the compressor has a horizontal drive shaft, pressure is needed to propel the feed material to the rotating disc or impeller.

[0035] A diffuser 66 of the housing 54 forms an annular chamber around the periphery of the rotor disc 52. The kinetic energy of the fast moving stream of feed material exiting the rotor disc periphery is converted to a pressurized stream in the diffuser 66. An outlet 38 of the diffuser is coupled to the conduit 40 (Fig. 1) that feeds the high pressure stream of feed material to the blow valve 42.

[0036] FIGURE 3 is a front view of the rotor disc 52 that includes a circular disc 68, such as a full height or partial height disc, mounted on the shaft 56. On the face of the disc are mounted an annular array of vanes, preferably in plate segments 70. The pie-shaped plate segments may be mounted by bolts 72, e.g., two bolts per segment, to the disc. The vane plate segments are replaceable and can be removed by opening the housing 54 and unscrewing the bolts from the disc 52. The plate segments include impeller vanes 74 that may extend generally radially towards the periphery 54 of the rotor disc. Instead of plate segments, a solid disc may also be used.

[0037] The arrangement, number and geometry of the vanes on the plate segments 70 are dependent on the stream of feed material, the rotational velocity of the disc and the depth and shape of the housing. In addition, the vanes may have a variable height (along the z-axis in Fig. 3 which is in a direction out of the page). The vane height may be greatest at the inlet and gradually decrease in height along a radially outward direction. Further, the vane may be segmented such that some vane segments are arranged in a radially inward annular section and extend to the periphery of the disc, and other vanes may start at a radial mid-section of the disc and extend to the periphery. Further, the vanes may be straight and radial, or may have a spiral or other curved shape as they extend radially outward on the plate segment. The vanes may be cast or welded to the vane plate segments. Alternatively, the impeller vanes may be releasably attached directly to the rotating disc.

[0038] The rotor disc and associated vane plate segments may be generally planar, conical or a combination of planer and conical stages. A planar disc and vane plate segments is shown in Figures 2 and 3, wherein the face of the disc and plate segment is generally flat with the vanes having a height dimension extending parallel to the shaft axis and a length dimension vector extending perpendicular to the shaft axis, i.e., radially. A conical disc and plate segments may have a frustoconical shape wherein the vanes have a length dimension vector forming an acute angle, e.g., 87 degrees to 75 degrees, with respect to the shaft 56. A staged compressor may have a conical disc and plate segment that feeds to and possible merges into a planar disc and plate segment. Further, the feed screw 28 may effectively comprise an axial compression stage of the high pressure compressor.

[0039] The rotor disc with impeller vanes may be opposite to a stationary stator disc or the housing 54 of the disc. A stator disc 53 with a flat side facing the impeller vanes of the rotor disc may be preferable if the compressor is a modified mechanical refiner, which originally included a stator refining disc. The stator disc 53 may also have vanes (see Fig. 2) to guide the stream of feed material between the vanes of the rotor and prevent radially inward back flow of the stream.

[0040] An optional refining section, e.g., an annular series of bars or teeth 76 just radially inward of the periphery 64 of the plate segments, may be used to provide a final refining action and ensure that no large clumps of feed material pass into the conduit 40 and block the blow valve 42.

[0041] The high pressure compressor may be based on a mechanical refiner put to use as a compressor. Mechanical refiners, such as a MDF refiner, include rotating refining discs that refine the pulp and centrifugally accelerate the feed material to a higher pressure. A conventional refiner typically discharges and dissipates the pressure added to the refined feed material stream by the refining discs. The diffuser of a conventional mechanical refiner may be modified to maintain the high pressure at the discharge of the discs as the stream flows to a conduit 40. Accordingly, a conventional refiner may serve as a high pressure compressor 26 to boost the pressure of a stream of feed material into conduit 40.

[0042] Conventional mechanical refiners tend to have high energy demands applied to refining the feed material. The demand for high energy increases the cost of pulping and is not necessary for steam explosion pulping. In mechanical refining, the typical refining plates defiberize the material by forces applied to the feed material between a pair of opposing refiner discs and plates, where at least one disc rotates. The rotation of the disc applies centrifugal forces that move the feed material between the refiner discs/plates. In steam explosion pulping, the steam explosion converts the feed material to pulp and, thus, another refining process, such as mechanical refining between rotating plates is not needed.

[0043] While a conventional mechanical refiner may be adapted to discharge a feed stream at high pressure to a conduit having a blow-valve for steam explosion pulping, it is preferable that the rotor disc in the refiner also be converted to an impeller. The impeller has tall vanes and wide channels between the vanes. The feed material passes through the channels and the vanes guide the feed material radially outward under centrifugal force. The vanes preferably do not mechanically refine the feed material, as do the bars and grooves (or rows of teeth) in a conventional mechanical refiner. Accordingly, converting a mechanical refiner to include an impeller in place of the rotor refining disc should reduce the energy requirement of the refiner because the impeller avoids refining the feed material.

[0044] To convert a mechanical refiner to a high pressure compressor with an impeller, the housing is opened to expose the stator and rotor discs. The refining plates on the stator and rotor discs are removed. Impeller vane plate segments are mounted on the rotor disc, in place of the refining plate segments. The rotor disc may be advanced towards the stator disc using gap adjustment mechanism 60 such that the top edges of the impeller disc are adjacent the stator disc. Alternatively, stator plate segments may be mounted on the stator disc. The stator plate segments may be generally flat or otherwise shaped to conform to the top edges of the vanes on the vane plate segments and rotor disc. The stator disc or stator plate segments effectively form a stator housing for the impeller disc. In addition, the housing of the refiner is modified, if needed, to capture as high pressure the energy added to the biomass feed material by the rotor disc.

[0045] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

WHAT IS CLAIMED IS:

1. A steam explosion pulping method comprising:

impregnating a cellulosic biomass feed material in a pressurized reactor vessel;

discharging the impregnated feed material from the vessel to a high pressure compressor;

elevating a pressure of the feed material in the compressor;

discharging the pressurized feed material from the compressor to a conduit coupled to a blow valve;

rapidly reducing pressure of the pressurized feed material as the feed material passes through the blow valve, and

pulping the feed material by expansion of fluid in the feed material during the rapid pressure reduction.

2. A steam explosion pulping method as in claim 1 wherein the high pressure compressor includes a rotating disc and the elevation of pressure of the feed material includes applying centrifugal forces from the disc to the feed material.

3. A steam explosion pulping method as in claim 2 wherein the rotating disc is an impeller.

4. A steam explosion pulping method as in claim 2 wherein the rotating disc includes vanes directing the feed material radially outward.

5. A steam explosion pulping method as in claim 1 wherein the pressure of the feed material to a pressure at least 10 bars.

6. A steam explosion pulping method as in claim 1 further comprising a high pressure liquid stream added to the pulped feed material downstream of the blow valve.

7. A steam explosion pulping method as in claim 1 wherein the feed material is discharged at a pressure of at least 15 bar.

8. A steam explosion pulping method as in claim 7 wherein the pressure of the feed material passing through the blow vale is reduced to less than 2 bar.

9. A high pressure compressor comprising:

a centrifugal impeller assembly including a disc and at least one removable vane plate attached to the disc, and

a high pressure casing for the impeller assembly.

10. A high pressure compressor as in claim 9 further comprising an inlet device including a feed screw.

11. A high pressure compressor as in claim 9 wherein the feed screw is at least one of a ribbon feeder and a full flight screw.

12. A high pressure compressor as in claim 10 wherein the at least one removable vane plate comprises an annular array of removable vane plate segments.

13. A high pressure compressor as in claim 12 wherein each vane plate segment includes radial vanes extending radially to a periphery of the segment.

14. A high pressure compressor as in claim 10 wherein the high pressure compressor is a modified mechanical disc refiner.

15. A high pressure compressor as in claim 10 further comprising a high pressure discharge coupling to a conduit including a blow valve.

16. A high pressure compressor as in claim 10 further comprising a stator disc opposite to the centrifugal impeller assembly.

17. A method to convert a mechanical refiner to a high pressure compressor having an impeller, comprising:

replacing a refining plate with a vane plate on a rotor disc, and

converting a stator disc to a stator housing for the vane plate and rotor disc.

18. A method as in claim 17 wherein the modification to the stator disc is adding a flat faced stator plate to the stator disc.

19. A method as in claim 17 wherein a shaft for the rotor disc is axially adjusted to form a narrow a gap between the stator disc and rotor disc.

20. A method as in claim 17 wherein a diffuser housing is modified to include a high pressure discharge outlet.

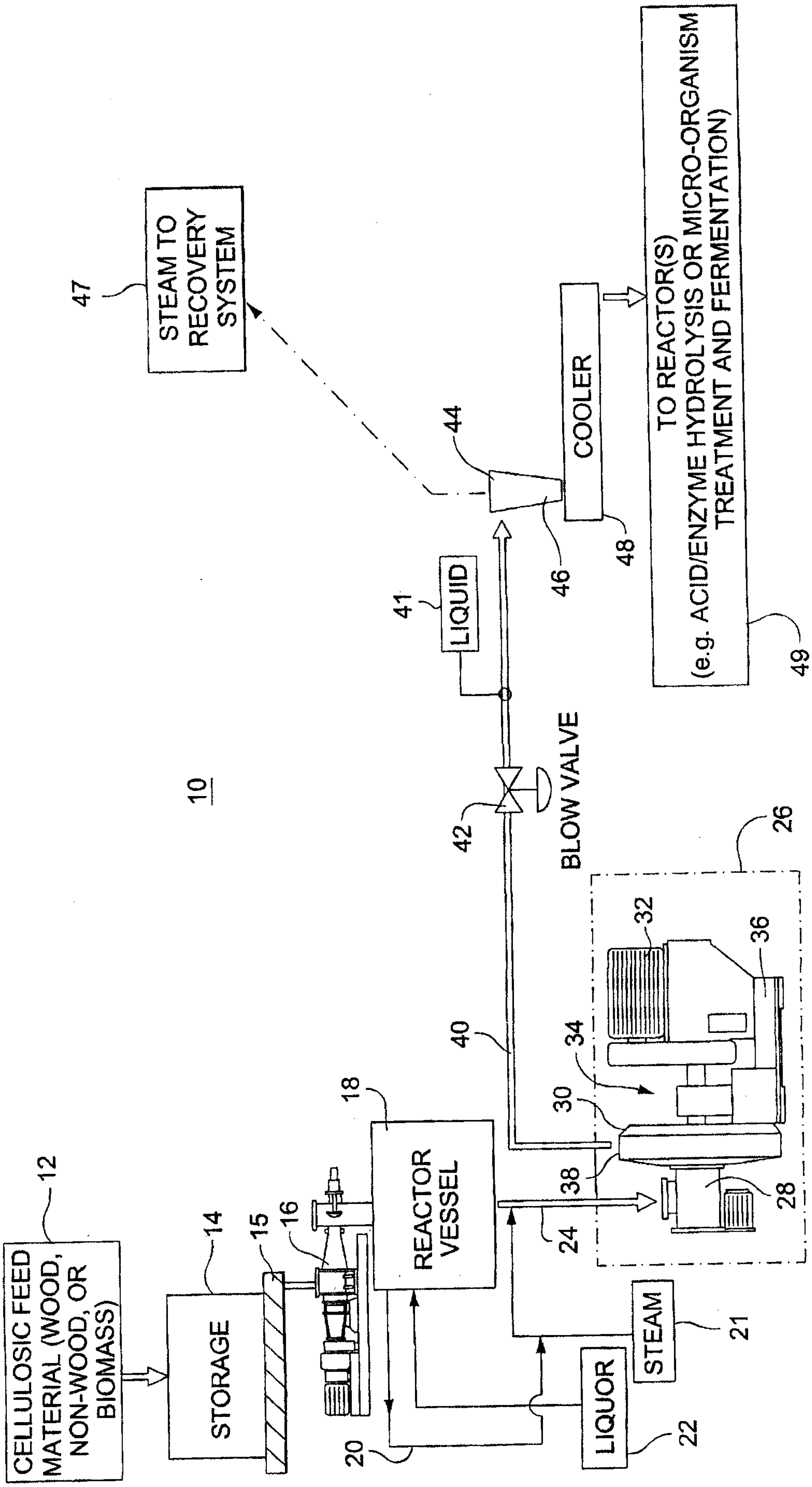

10
CELLULOSIC FEED MATERIAL (WOOD, NON-WOOD, OR BIOMASS)
12
STORAGE
14
15
16
REACTOR VESSEL
18
20
LIQUOR
22
STEAM
21
24
26
28
38
30
34
32
36
40
42
BLOW VALVE
LIQUID
41
44
46
COOLER
48
STEAM TO RECOVERY SYSTEM
47
TO REACTOR(S) (e.g. ACID/ENZYME HYDROLYSIS OR MICRO-ORGANISM TREATMENT AND FERMENTATION)
49

FIGURE 1

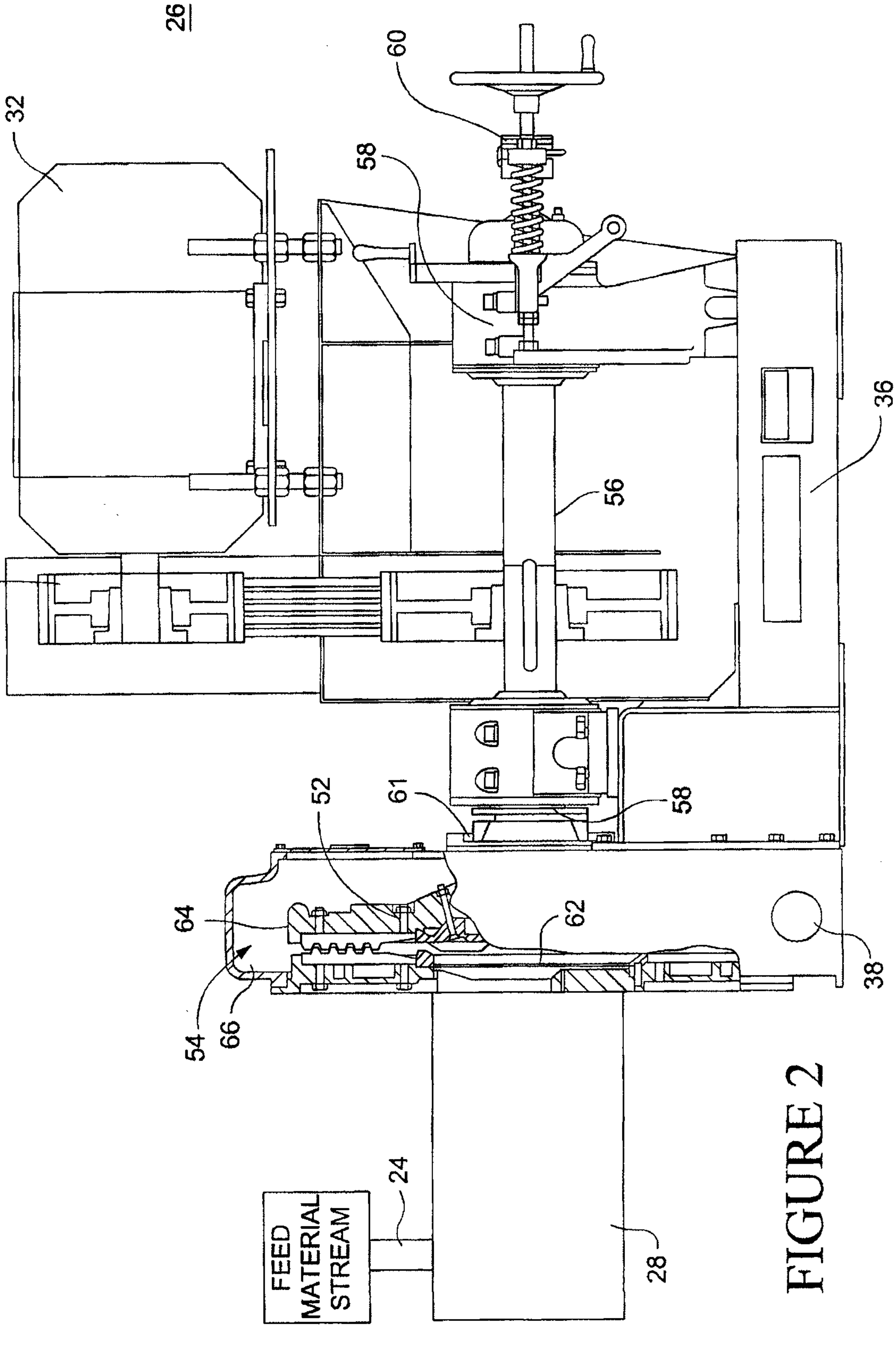

26
32
34
60
58
56
36
52
61
58
64
62
54
66
38
24
FEED MATERIAL STREAM
28

FIGURE 2

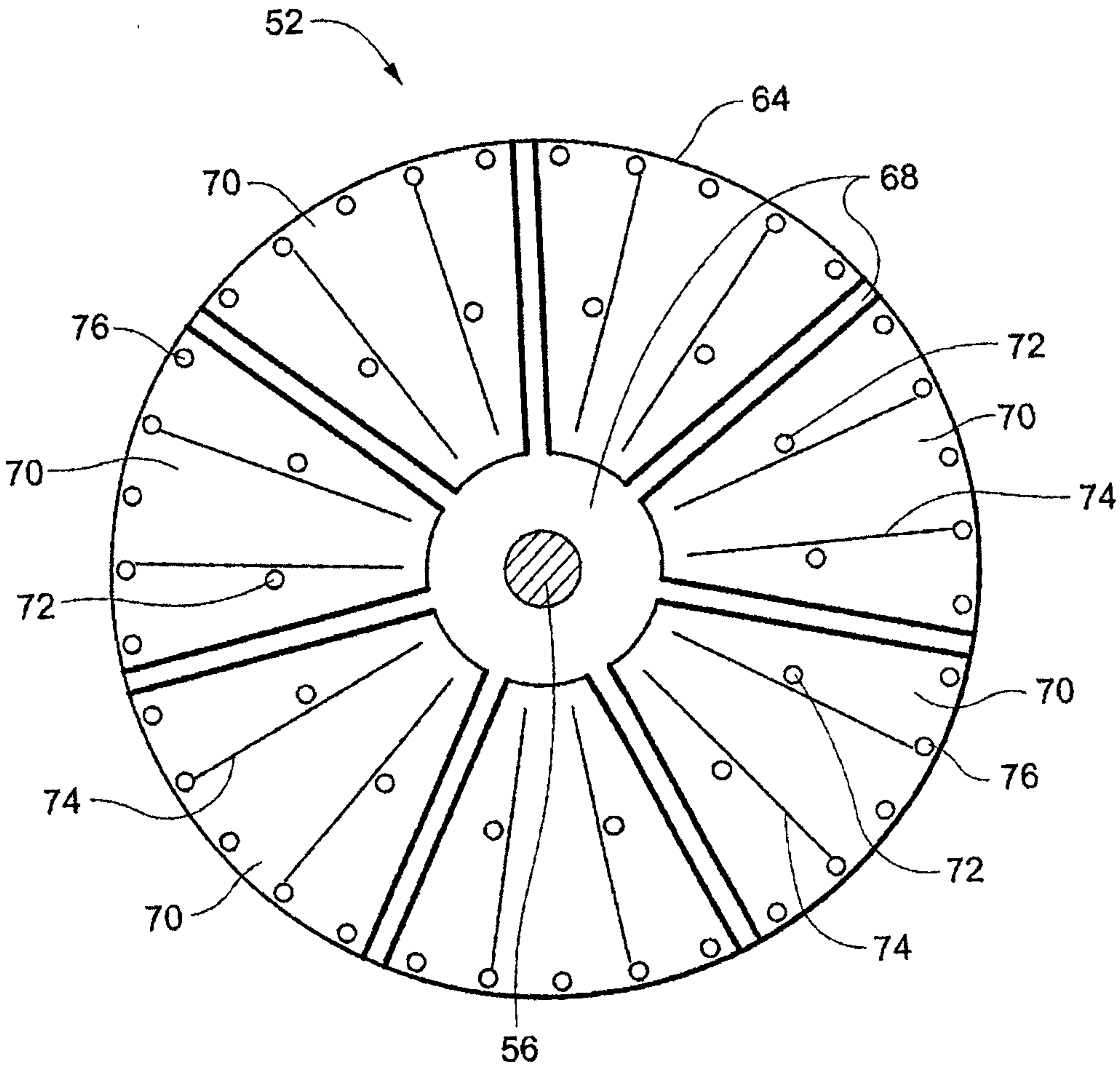


FIGURE 3

CELLULOSIC FEED MATERIAL (WOOD, NON-WOOD, OR BIOMASS)
12
STORAGE
14
15
16
10
47
STEAM TO RECOVERY SYSTEM
20
18
REACTOR VESSEL
41
LIQUID
40
42
44
24
38
30
34
BLOW VALVE
46
COOLER
LIQUOR
STEAM
32
48
22
21
TO REACTOR(S) (e.g. ACID/ENZYME HYDROLYSIS OR MICRO-ORGANISM TREATMENT AND FERMENTATION)
28
36
26
49