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(54) **CELLULOSE LIQUEFACTION MODULE**

23/10 (2013.01); **H02K 9/06** (2013.01); **H05B 6/64** (2013.01); **B01J 2219/00731** (2013.01)

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(58) **Field of Classification Search**

None

See application file for complete search history.

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 25 days.

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(52) **U.S. Cl.**

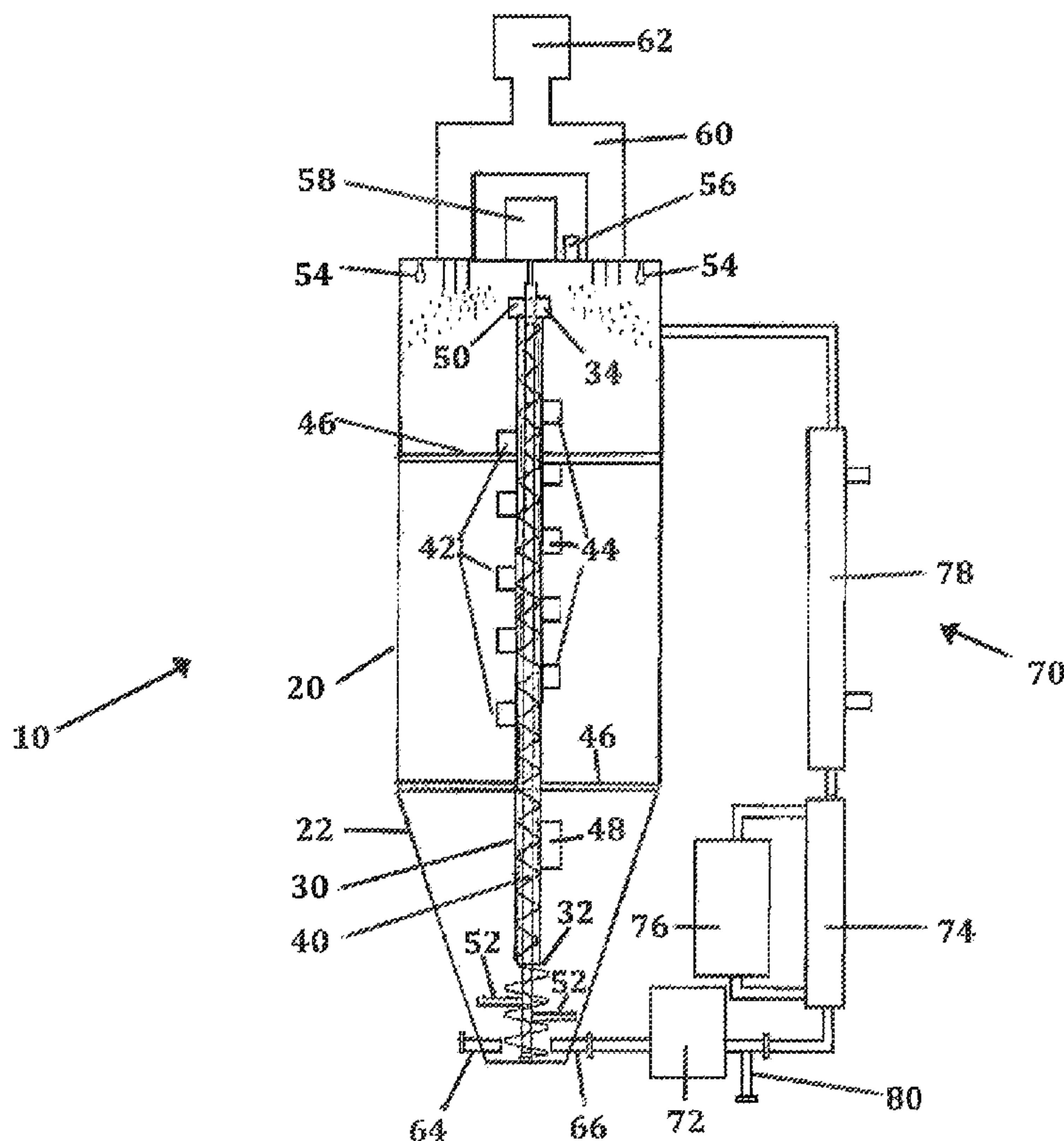
CPC **C12P 7/10** (2013.01); **B01J 8/008** (2013.01); **C12Y 302/01004** (2013.01); **F26B**

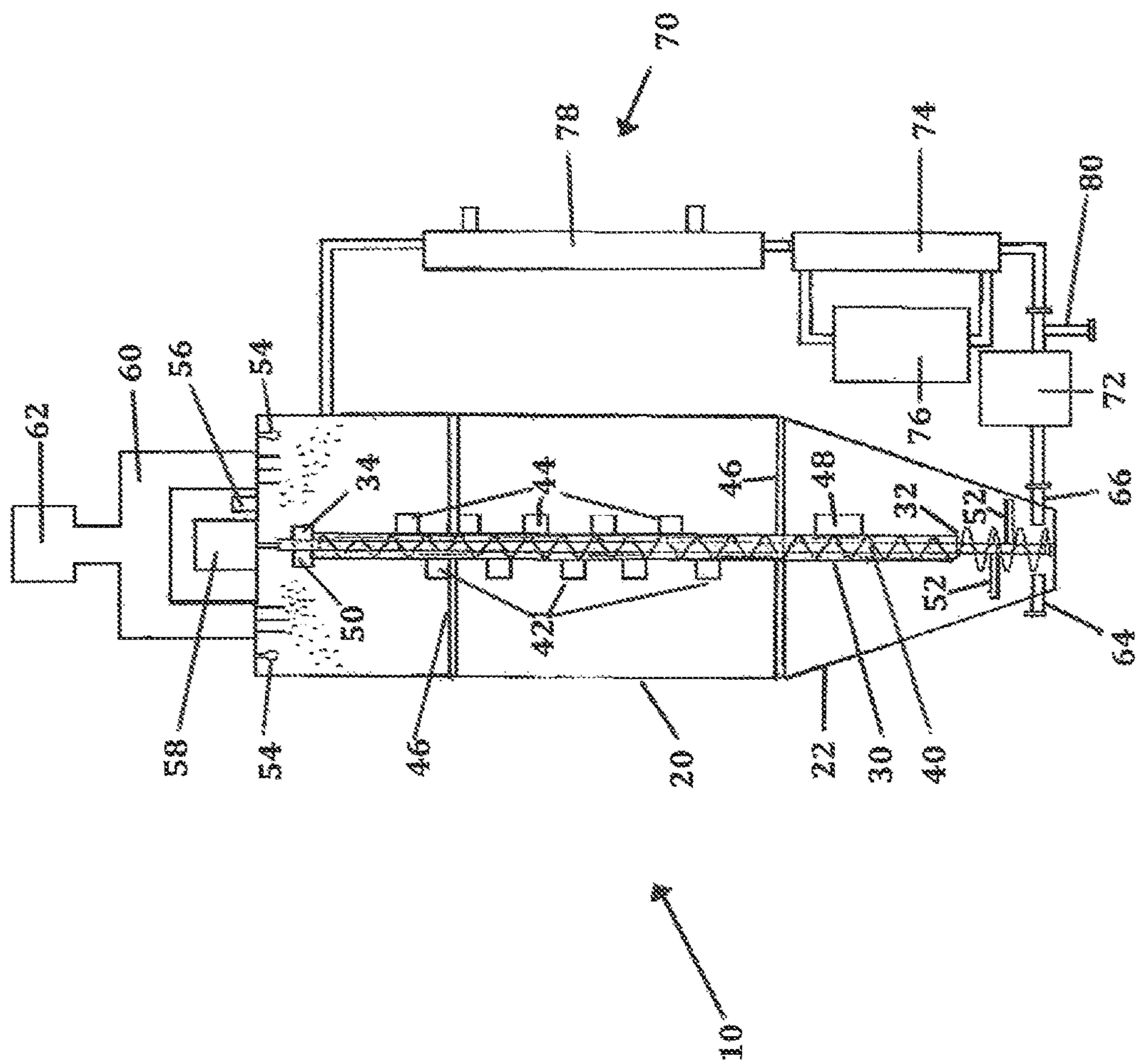
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ABSTRACT

A method of producing cellulose liquefaction and a cellulose liquefaction module that mixes and circulates cellulose material as a solid, and provides evaporative cooling in the module. The module includes a container having a vertically disposed tube that houses an auger conveyor that mixes and circulates solid cellulose material. Steam ports and activation agent injection ports are disposed within the tube to liquify the cellulose material. A forced air blower pushes air through the liquified cellulose material to provide evaporative cooling before discharge from the container.

8 Claims, 1 Drawing Sheet





1

CELLULOSE LIQUEFACTION MODULE

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application claims priority from U.S. Provisional Patent Application Ser. No. 62/357,498, filed Jul. 1, 2016, entitled Cellulosic Liquefaction Module, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates generally to material processing equipment, and more particularly to a cellulose liquefaction module.

Description of the Related Art

One of the key problems when converting cellulose material into bio fuels, such as ethanol or butanol, is that the cellulose material is initially in the material form of a solid, and solids cannot be pumped through pumps, tanks and piping designed for only liquid materials.

The traditional way of converting the cellulose material to a pumpable sugar water solution, and ultimately into a bio fuel that can be pumped, is to add water to the solid material. This material, in a slurry form, can then be pumped into liquid tanks. The slurry material is also mixed with an enzyme which causes further breakdown of the solid material into an even greater liquidized material.

The combination of the addition of excess water to the solids to make them pumpable, and liquefaction activity of the enzymes on the material, results in a solution that contains excess water, and the concentration of biofuels is too low to allow the economical separation of the biofuels from the water.

The method by which this water is removed is to then apply more energy later on in the process to boil off the excess water. The introduction of additional energy to remove the excess water often consumes so much energy that the process itself consumes more energy than is created from the biofuels produced.

A second problem involves the need for cooling a solid or heavy slurry quickly. Once the solids have been heated up sufficiently to open up the cells for better activation of enzymes, kill the undesirable bacteria, and break down the material to a liquid, the material then needs to be cooled down significantly. This has often been done by pumping the now liquid slurry through a cooling heat exchanger. This process takes considerable energy, and water used to aid in cooling is consumed and vaporized. Typically cooling of only 5000 gallons from about 200 degrees down to about 60 degrees, has taken several hours.

Those concerned with these and other problems recognize the need for an improved cellulose liquefaction module.

BRIEF SUMMARY OF THE INVENTION

The present invention discloses a method of producing cellulose liquefaction and a cellulose liquefaction module that mixes and circulates cellulose material as a solid, and provides evaporative cooling in the module. The module includes a container having a vertically disposed tube that houses an auger conveyor that mixes and circulates solid cellulose material. Steam ports and activation agent injection

2

ports are disposed within the tube to liquify the cellulose material. A forced air blower pushes air through the liquified cellulose material to provide evaporative cooling before discharge from the container.

Other objects, advantages, and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL
VIEWS OF THE DRAWINGS

These and other attributes of the invention will become more clear upon a thorough study of the following description of the best mode for carrying out the invention, particularly when reviewed in conjunction with the drawings, wherein:

FIG. 1 is a schematic view showing the cellulose liquefaction module of the present invention.

DETAILED DESCRIPTION OF THE
INVENTION

As can be seen by reference to FIG. 1, the cellulose liquefaction module that forms a basis of the present invention is designated generally by the reference number 10. The module 10 includes a container or a tank 20 with a cone bottom 22, and having a centrally located vertical tube 30 with a conveyor or auger 40 disposed within the tube 30. The tube 30 has a bottom intake 32 and a top outlet 34. The tube 30 also carries a series of steam ports 42, and activation agent or enzyme injection ports 44. Horizontal supports 46 stabilize the tube 30 and may include additional steam ports (not shown) and enzyme injection ports (not shown). It is to be understood that additional required heating and cooling needed in the tank 20 could be supplied by jacketing the tube 30 with an auxiliary heat exchanger. A microwave chamber 48 is disposed in the communication with the interior of the tube 30.

A spreader plate 50 is located in communication with the top outlet 34 of the tube 30, and a reverse pitch paddle agitator 52 is located adjacent the bottom intake 32 of the tube 30. The top of the tank 20 carries internal spray nozzles 54, a solids charging port 56, a gear box and motor auger drive 58, and a forced air blower 60 disposed in communication with the interior of the tank 20, and having an intake air purification chamber 62. The bottom of the tank 20 carries a solid discharge port 64 and a liquids discharge port 66. A liquid circulation loop 70 interconnects the liquids discharge port 66 and the top of the tank 20 and includes a pump 72, a microwave chamber 74 in communication with a microwave generator 76, and a heat exchanger 78. A finished liquid discharge port 80 discharges to a fermentation tank (not shown).

The cellulose liquefaction module 10 of the present invention allows the cellulose material to be mixed and circulated as a solid initially without any added water, and then later the cellulose material is mixed and circulated as a liquid.

Cellulose material is first reduced in size, generally to a consistency of thick and lumpy mashed potatoes, and then introduced into the tank 20 through the solids charging port 56.

The tank 20 has a cone bottom 22 and a vertical auger 40 with a surrounding tube 30 that allows the cellulose material to be handled initially as a solid with little to no addition of any water. The solids are carried up through the center tube

3

30 via the center vertical auger 40. The larger diameter bottom section of the auger 40 fully agitates the material in the bottom of the tank 20 and forces the material up through the tube 30.

Thus, even while the material is still in a solid state, steam can be applied to break open the cellulose material, and enzymes can be mixed thoroughly into the cellulose solid material as it passes up via the action of the center screw auger 40 carrying the material up the center mixing tube 30. This can allow for a significantly lower enzyme requirement due to complete mixing. Once the material reaches the top of the tube 30, a spreader plate 50 acts to spread the material out over the entire top area of the tank 20, and the material falls back down by gravity.

On one side of the mixing tube 30, steam can be applied from ports 42, and then on the other side enzymes or other activation related agents can be added from ports 44. The enzymes are thus thoroughly mixed into the material causing the material to begin to convert into the form of a slurry. Also, the enzymes can be added from other points in the container 20.

The vertical auger 40 carries the solid material up through the vertical tube 30 and past the steam injection nozzles 42. Once the materials, solid or liquid, have been heated up to the desired temperature to kill the bacteria and break open the material for maximum activation agent results, the heating portion is turned off and the enzymes can be thoroughly mixed into the material. Once the cellulose material has approached the desired degree of liquidity, the paddle agitator mixes the material which can be recirculated through the circulation loop 70.

To facilitate rapid cooling, the cellulose liquefaction module 10 utilizes a forced air blower 60 to provide evaporative cooling to complete this cooling affect. Evaporative cooling has been found to be about 9 times faster than the traditional heat exchanger method. To make this fast acting evaporative cooling action possible, incoming cool air is passed through an air purifier mechanism 62 to remove all bacteria from the cool air. This air is then passed through the fine cellulose material that has been spread across the top of the tank via the tank top mounted spreader 50 located at the top of the tank 20. The air passing through the finely spread particles cools the material quickly.

The end effect is a much faster cool down time, with considerable savings in energy, less consumption of water for cooling, and less capital cost since fewer tanks are needed to hold the material for the duration of the cooling process.

When the material is cooled to the desired temperature, the liquid cellulose material is discharged to the fermentation tanks through the finished liquid discharge port 80. Remaining solids are discharged through the solids discharge port 64 to a waste conveyer.

The system allows for an optional external heat exchanger 78. The external heat exchanger 78 can be used to heat or cool the liquefied material circulated through the loop 70. The center core tube 30 around the internal vertical auger 40 can also be used as a microwave chamber 48 to allow microwaves to be beamed through the material greatly improving the effectiveness of the enzymes, and oftentimes dramatically increasing the yield of bio fuel. Alternatively, the microwave chamber 74 can be placed externally and the material pumped through the chamber 74 with microwaves beamed through the material to allow improved enzyme activity.

This overall cellulose liquefaction module process is ideal for materials such as sugar beets and other materials that

4

already contain such a high water content. When these cellulose materials are broken down by the enzymes, the resulting end mixture of material has a high ratio of end product to water, since the present invention allows the conversion to occur with little to no additional water required.

Although only an exemplary embodiment of the invention has been described in detail above, those skilled in the art will readily appreciate that many modifications are possible without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the following claims.

I claim:

1. A cellulose liquefaction module, comprising:
 - a container having a top, and a cone-shaped bottom;
 - a vertically disposed tube with an interior, a bottom intake and a top outlet;
 - an auger disposed in the vertical tube interior;
 - the tube being disposed within the container;
 - horizontal stabilizer supports disposed to interconnect the container and the tube;
 - a series of steam ports disposed within the tube interior on a first side of the tube and on the horizontal supports;
 - activation agent injection ports disposed within the tube interior on a second side of the tube and on the horizontal supports;
 - a spreader plate disposed in the communication with the top outlet of the tube;
 - a paddle agitator disposed adjacent the bottom intake of the tube;
 - a downwardly directed forced air blower disposed at the top of the container and having an air intake purification chamber;
 - a liquid circulation loop interconnecting the container bottom and the container top;
 - a first microwave chamber disposed in communication with the tube interior;
 - a second microwave chamber disposed in communication with the liquid circulation loop; and
 - a heat exchanger located in the liquid circulation loop.

2. A method of liquifying cellulose material comprising the steps of:

- mixing and circulating solid cellulose material in the module of claim 1,
- applying heat and adding activation agents to reduce the cellulose material to a liquid in the module; and
- providing evaporative cooling of the liquefied cellulose material in the module.

3. The method of claim 2, wherein the solid cellulose material is mixed and circulated by the conveyor as it moves the cellulose material from the intake at the tube to the outlet of the tube.

4. The method of claim 3, wherein the solid cellulose material is mixed and circulated by being spread at the top of the module by the spreader plate, and by moving by gravity to the bottom of the container.

5. The method of claim 4, wherein evaporative cooling of the cellulose material occurs when air is blown downwardly through the cellulose material spread by the spreader plate at the top of the module.

6. The method of the claim 5, wherein the evaporative cooling is supplemented by passage of the cellulose material through the heat exchanger.

7. The method of claim 3, wherein heat is applied by steam from the steam ports, and activation agents are added from the activation agent injection ports.

5

6

8. The method of claim 7, wherein the cellulose material and added activation agents are exposed to microwave energy in the microwave chamber to improve the effect of the activation agents.

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