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(71) Applicant: VALMET AB [SE/SE]; ., 851 94 Sundsvall (SE).

(72) Inventor: DETLEFSEN, Jan; Lejdavägen 12, 865 32 Al-nö (SE).

(74) Agent: SVENSSON, Niklas; Valmet AB, 851 94 Sundsvall (SE).

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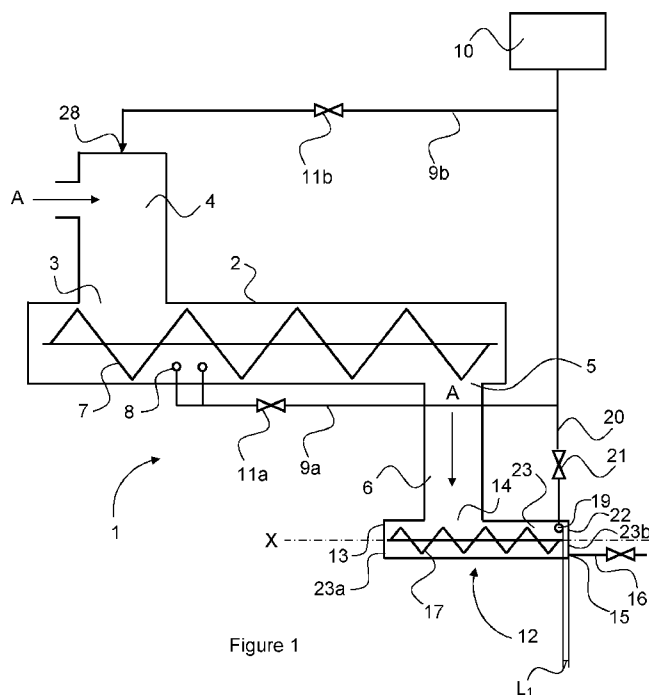


Figure 1

(57) Abstract: The invention relates to a discharge screw assembly (12) for discharging treated biomass material (A) received from a reactor vessel (2; 102), which discharge screw assembly comprises an inner space (23) that extends along a longitudinal axis (X) from a first end (23a) to a second end (23b) and an outlet (15) for discharging said biomass material out of said inner space, which outlet is located at the second end, wherein the inner space accommodates a discharge screw (17) for conveying said biomass material to the outlet. The discharge screw assembly further comprises at least one transport steam injection orifice (19) arranged at the second end. The invention also relates to a reactor assembly (1; 101) comprising a discharge screw assembly as described above and a method for treatment of biomass material in such a reactor assembly.

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DISCHARGE SCREW ASSEMBLY, REACTOR ASSEMBLY AND METHOD FOR TREATMENT OF BIOMASS MATERIAL

TECHNICAL FIELD

The invention relates to a discharge screw assembly for discharging treated biomass material received from a reactor vessel. The invention also relates to a reactor assembly for treatment of biomass material and a method for treatment of biomass material in such a reactor assembly.

BACKGROUND

Lignocellulosic biomass material (or biomass material) is abundant and can provide a sustainable resource for producing e.g. fuels, chemicals and biobased materials. Lignocellulosic biomass materials normally comprise primarily cellulose, hemicellulose, and lignin. Cellulose and hemicellulose are natural polymers of sugars, and lignin is an aromatic/aliphatic hydrocarbon polymer reinforcing the entire biomass network.

The usability of lignocellulosic biomass material is curtailed by its rigid structure. Therefore, a steam pre-hydrolysis stage is suitable to remove the hemicelluloses and render the cellulose accessible for a subsequent hydrolysis step. Pre-hydrolysis is typically performed at acid conditions, high temperature and a pressure up to 30 bar.

Reactor assemblies for pre-treatment or pre-hydrolysis of biomass material are known in the art. A reactor assembly may, for example, comprise a charger (T-pipe), one or more pressurized reactor vessels, in which the biomass material is pretreated with steam at elevated pressure and temperature, with or without the addition of chemicals, a discharger and a discharge screw assembly. The biomass material is fed into the charger, for example by means of a plug screw feeder, and falls through the charger into the reactor vessel. Steam is injected to raise the temperature and pressure within the reactor vessel and to propel the biomass material forward in a biomass material transport direction. The steam is preferably injected at one or more positions into the charger and/or into the reactor vessel near a reactor vessel inlet to quickly raise the

temperature of the biomass material. A conveyor screw may be accommodated within the reactor vessel to transport the biomass material through the reactor vessel, whereafter the biomass material is discharged through a reactor vessel outlet and into the discharger. The discharge screw assembly is connected to the lower portion of the discharger and comprises a discharge pipe with an inlet adapted to receive biomass material from the discharger. A discharge screw is accommodated within said discharge pipe to assist in conveying the biomass material towards an outlet. The biomass material is then discharged through the outlet for transport to subsequent processing equipment.

As mentioned above, steam is injected into the reactor vessel not only to raise the pressure and temperature within the reactor vessel but also to propel the biomass material in the biomass transport direction all the way through the outlet in the discharge pipe. A large amount of steam is needed to discharge the often wet and heavy biomass material through the outlet. This is especially the case when a steam explosion is desirable. Steam explosion occurs when the biomass material is treated at elevated pressure and then rapidly depressurized, resulting in an explosive disintegration of the biomass material into small particles. Steam explosion gives excellent access for the enzymes in a subsequent saccharification step.

A problem associated with the above described reactor assemblies is the formation of a hard coating on the conveyor and discharge screws in the reactor assembly. This coating makes it necessary to replace or clean said screws at certain intervals, resulting in production interruption and increased manufacturing costs.

OBJECT OF THE INVENTION

A first object of the invention is to provide an improved discharge screw assembly that solves the above problems.

A second object of the invention is to provide an improved reactor assembly that solves the above problems.

A third object of the invention is to provide a method for treatment of biomass material that solves the above problems.

SUMMARY

The term "treatment", in this context, refers to any suitable treatment of biomass material. The term "treatment" may, for example, refer to pre-hydrolysis of biomass material at elevated pressure and temperature.

An object arranged "at" another object does not have to be arranged directly in contact with said other object.

Biomass material "received from" a reactor vessel does not have to be received directly from said reactor vessel. The biomass material may, for example, be received from a charger connected to the reactor vessel.

The first object is achieved with a discharge screw assembly according to claim 1.

The discharge screw assembly is adapted for discharging treated biomass material received from a reactor vessel. The discharge screw assembly comprises a discharge pipe that defines an inner space that extends along a longitudinal axis from a first end to a second end. The discharge pipe comprises an inlet for receiving the biomass material into the inner space and an outlet for discharging the biomass material out of the inner space. The outlet is located at the second end. The inner space accommodates a discharge screw for conveying the biomass material from the inlet to the outlet. The discharge screw assembly further comprises at least one transport steam injection orifice arranged at the second end to inject transport steam into the inner space to propel the biomass material through the outlet.

It has been discovered that the hard coatings on the conveyor and discharge screws in prior art reactor assemblies are formed when biomass material particles are propelled forward by the injected steam and hits the screw flights at high speed. The solution to this problem is to inject steam for propelling the biomass material through the discharge pipe outlet near said outlet. This steam is hereinafter referred to as

transport steam. This arrangement makes it possible to considerably reduce the amount of steam injected into and/or before the reactor vessel (required to raise the pressure and temperature within the reactor vessel) and thus to reduce the force propelling the biomass material particles forward through the reactor assembly. This reduces the risk that biomass material particles will get stuck on the screw flights. The steam flow through the transport steam injection orifice may constitute as much as 90% of the total steam flow into the reactor assembly.

Observe that the injected transport steam also affects the temperature and pressure within the reactor vessel.

Advantageously, the transport steam injection orifice is located close to the second end, so that the portion of the discharge screw exposed to biomass material particles propelled forward by the transport steam is minimized. Advantageously, the distance along the longitudinal axis of the inner space between the transport steam injection orifice and the outlet is between 0-100 mm, preferably between 0-50 mm and even more preferably between 0-20 mm. Most preferably, the transport steam injection orifice is arranged directly above the outlet.

Advantageously, the outlet is located in an end wall at the second end of the discharge pipe. However, the outlet may also be located within a distance of 0-50 mm from the end wall, preferably as close to the end wall as possible.

Advantageously, the outlet is located within a lower half of the discharge pipe, where biomass material is gathered, and the transport steam injection orifice above the outlet, preferably within an upper half of the discharge pipe. However, it is possible to arrange the outlet within the upper half of the discharge pipe, and the transport steam injection orifice below the outlet, preferably within the lower half of the discharge pipe. The outlet may be located at the center of the end wall seen in a transverse direction of the discharge pipe or towards one side or the other of the discharge pipe.

The transport steam injection orifice may be arranged at an angle so that the transport steam is injected towards the outlet.

Advantageously, the transport steam injection orifice is arranged in an upper, preferably uppermost, portion of the discharge pipe for optimal discharge of the biomass material. Advantageously, the outlet is arranged at a bottom portion of the inner space.

The discharge screw assembly may comprise more than one transport steam injection orifice. It is, for example, possible to arrange a plurality of transport steam injection orifices distributed within a plane perpendicular to the longitudinal axis of the inner space.

The second object of the invention is achieved with a reactor assembly according to claim 5.

The reactor assembly comprises a reactor vessel for treatment of biomass material, at least one steam injection orifice arranged to inject steam into or before said reactor vessel, to raise the pressure and temperature within the reactor vessel, and a discharge screw assembly as described above. The discharge screw assembly comprises a discharge pipe that defines an inner space that extends along a longitudinal axis from a first end to a second end. The discharge pipe comprises an inlet for receiving the biomass material into the inner space and an outlet for discharging the biomass material out of the inner space, wherein the outlet is located at the second end. The inner space accommodates a discharge screw for conveying the biomass material from the inlet to the outlet. The discharge screw assembly further comprises at least at least one transport steam injection orifice arranged at the second end to inject transport steam into the inner space to propel the biomass material through the outlet.

In other words, a portion of the total steam flow is injected into the discharge pipe at the outlet. This reduces the amount of steam injected into and/or before the reactor vessel and thus reduces the speed at which biomass material particles are propelled forward through the reactor assembly. Consequently, less biomass material gets stuck on the conveyor and discharge screws.

The reactor assembly may comprise a steam conduit connecting said steam injection orifice to a steam source. The steam conduit may comprise a first valve for controlling the flow of steam through said steam injection orifice. The reactor assembly may further comprise a transport steam conduit connecting said transport steam injection orifice to a transport steam source. The transport steam conduit may comprise a second valve for controlling the flow of steam through said transport steam injection orifice. This arrangement makes it possible to independently control the amount of steam injected through the steam and transport steam injection orifices.

The steam and transport steam conduits may be connected to the same steam source. However, the steam and transport steam conduits may also be connected to different steam sources.

Each valve may be controlled by means of a control unit. Advantageously, the first and second valves are controlled by means of the same control unit.

Advantageously, at least one control unit is adapted to adjust the first and/or second valve(s) to ensure that the reactor vessel works at optimal pressure and temperature. For this purpose, the control unit may be adapted to receive information from one or more sensors arranged to measure (directly or indirectly) the temperature and pressure within the reactor vessel and to adjust the first and/or second valve(s) based on this information.

The reactor vessel may be arranged substantially vertically, substantially horizontally or inclined relative a horizontal plane so that a reactor vessel outlet is located higher than a reactor vessel inlet.

The reactor assembly may comprise more than one reactor vessel arranged one after the other, so that the biomass material is transferred from one reactor vessel to another reactor vessel for further treatment.

A blow line comprising a pressure release device, e.g. a blow valve or an orifice plate, configured to cause a steam explosion, may be connected to and arranged to receive biomass material from the outlet in the discharge pipe.

The third object of the invention is achieved with a method for treatment of biomass material in a reactor assembly according to claim 11. The method comprises the steps of receiving the biomass material in a reactor vessel for treatment of said biomass material, injecting steam into and/or before said reactor vessel to raise the temperature and pressure within the reactor vessel, transporting said biomass material from said reactor vessel to a discharge screw assembly, which discharge screw assembly comprises a discharge pipe that defines an inner space that extends along a longitudinal axis from a first end to a second end, receiving said biomass material in the inner space through an inlet, and conveying said biomass material from the inlet to an outlet located at the second end by means of a discharge screw accommodated within said inner space. The method further comprises the step of injecting transport steam into said inner space through at least one transport steam injection orifice arranged at the second end to propel said biomass material through said outlet.

The injection of transport steam into the discharge pipe at the outlet allows for a reduction of the steam flow into and/or before the reactor vessel. This reduces the force that propels the biomass material particles forwards and solves the problem of hard coatings forming on the screw flights.

Advantageously, the distance along the longitudinal axis of the inner space between the transport steam injection orifice and the outlet is between 0-100 mm, preferably 0-50 mm, and even more preferably between 0-20 mm. Most preferably, the injection orifice is arranged directly above the outlet. This further reduces the risk that a hard coating may form on the discharge screw.

Advantageously, the outlet is located in an end wall at the second end of the discharge pipe. However, the outlet may also be located within a distance of 0-50 mm from the end wall, preferably as close to the end wall as possible.

Advantageously, the outlet is located within a lower half of the discharge pipe, where biomass material is gathered, and the transport steam injection orifice above the outlet, preferably within an upper half of the discharge pipe. However, it is possible to arrange the outlet within the upper half of the discharge pipe, and the transport steam injection orifice below the outlet, preferably within the lower half of the discharge pipe.

The transport steam injection orifice may be arranged at an angle so that the transport steam is injected towards the outlet.

Advantageously, the transport steam injection orifice is arranged in an upper, preferably uppermost, portion of the discharge pipe, for optimal discharge of the biomass material. Advantageously, the outlet is arranged at a bottom portion of the inner space.

Advantageously, the flow of transport steam through the transport steam injection orifice is maintained at a certain level during use and it may be controlled by means of a valve. The transport steam may constitute as much as 90% of the combined steam flow into the reactor assembly.

The flow of transport steam through the transport steam injection orifice also affects the temperature and pressure within the reactor vessel.

The steam flow injected into and/or before the reactor vessel may be adjusted during use to achieve a certain pressure and temperature within the reactor vessel. The steam flow injected into and/or before the reactor vessel may be controlled by means of one or more valves. Thus, the steam flows through the steam and transport steam injection orifices may be independently controlled by means of separate valves.

Each valve may be controlled by means of a control unit. Advantageously, the valves are controlled by means of the same control unit.

Advantageously, the method comprises the step of controlling at least one control unit to adjust at least one valve to ensure that the reactor vessel works at optimal pressure and temperature. For this purpose, the control unit may be adapted to receive information from one or more sensors arranged to measure (directly or indirectly) the temperature and pressure within the reactor vessel and to adjust one or more valves based on this information.

In some embodiments, the steam may be conveyed from the outlet in the discharge pipe and through a blow line comprising a pressure release device, e.g. a blow valve or an orifice plate, configured to cause a steam explosion.

The above described invention is applicable to a variety of reactor assemblies suitable for different types of treatment of biomass material. The invention is particularly suitable for a reactor assembly adapted for pre-hydrolysis or pre-treatment of biomass material. Pre-hydrolysis of biomass material is usually performed at acid conditions, at a pressure of 5-30 bars (preferably 8-20 bars), at a temperature of 159-235°C (preferably 175-215°C) and for a duration of 2-45 minutes (preferably 5-30 minutes).

That is, the reactor may be a pre-hydrolysis reactor suitable for pre-hydrolysis of biomass material.

Another advantage with the above described invention is that it is not necessary to add additional steam for increasing the pressure and steam within the reactor vessel at the outlet end of the reactor vessel, as the transport steam injected at the second end of the discharge pipe affects the temperature and pressure within the reactor vessel. However, it is possible to have one or more additional inlets for injecting steam into the reactor vessel before the transport steam injection orifice.

The steam flow through the transport steam injection orifice may constitute as much as 90% of the total steam flow into the reactor assembly. Suitably, the steam flow through the transport steam injection orifice constitutes about 70% of the total steam flow into the reactor assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the present invention will now be described in more detail with reference to the appended drawings, wherein some parts have been removed for the sake of clarity, and wherein:

fig. 1 is a schematic illustration of a reactor assembly according to a first embodiment of the invention;

fig. 2 is a schematic illustration of a reactor assembly according to a

second embodiment of the invention;

fig. 3 is a block diagram illustrating an embodiment of a method according to the invention.

DETAILED DESCRIPTION

Fig. 1 is a schematic illustration of a first embodiment of a reactor assembly 1 for pre-hydrolysis treatment of biomass material A.

The reactor assembly 1 comprises a horizontally arranged and elongated reactor vessel 2. The reactor vessel 2 has a circular cross section, i.e. it has a cylindrical shape. The reactor vessel 2 comprises an inlet 3 for receiving the biomass material from a charger (T-pipe) 4, which receives the biomass material from a plug screw feeder (not shown). The inlet 3 is located at a first longitudinal end of the reactor vessel 2. The reactor vessel 2 also comprises an outlet 5 for delivering said biomass material A to a discharger 6 arranged below the outlet 5. The outlet 5 is arranged at an opposite longitudinal end of the reactor vessel 2 with respect to the inlet 3. A conveyor screw 7 adapted to be rotated by a motor (not shown) is accommodated within the reactor vessel 2 for conveying the biomass material A from the inlet 3 to the outlet 5.

Steam is injected to elevate the pressure and temperature within the reactor vessel 2. Steam is injected through steam injection orifices 28 into an upper portion of the charger 4. Further, a set of steam injection orifices 8 are arranged at a lower portion of the reactor vessel 2 near the inlet 3 for injection of steam directly into the reactor vessel 2. The steam injection orifices 8 are advantageously located near the inlet 3 to ensure that the desired temperature is reached as fast as possible and that the heating of the biomass material A is as homogeneous as possible, since a heterogeneous heating may lead to un-reacted, low-reacted or even over-reacted biomass material, which in turn may cause yield loss, formation of undesired by-products and/or problems in the downstream process. Steam is delivered to the reactor vessel 2 through steam conduits 9a, 9b connected to a steam source 10. The flow of steam into the reactor vessel 2 is controlled by means of first control valves 11a, 11b arranged in the steam conduits 9a, 9b, respectively. Chemicals may also be added to the biomass material A through means not shown in figure 1.

The discharger 6 is arranged to deliver said treated biomass material A to a discharge screw assembly 12. The discharge screw assembly 12 comprises a discharge pipe 13, which defines an inner space 23 that extends along a longitudinal axis X and has a first end 23a and a second end 23b located at opposite ends of the discharge pipe 13. The discharge pipe 13 further comprises an inlet 14 for receiving the biomass material A from the discharger 6 and an outlet 15 in an end wall 22 of the discharge pipe 13 for discharging the biomass material into a blow line 16. The blow line 16 conveys the biomass material to subsequent processing equipment (not shown).

A discharge screw 17 adapted to be rotated by a motor (not shown) is accommodated within the inner space 23 and arranged to convey the biomass material A from the inlet 14 to the outlet 15. The discharge pipe 13 further comprises at least one transport steam injection orifice 19 arranged at the second end 23b in an upper, preferably uppermost, portion of the discharge pipe 13. The transport steam injection orifice 19 is configured to inject transport steam into the inner space 23 to propel the often wet and heavy biomass material through the outlet 15. The transport steam injection orifice 19 is arranged within a distance L_1 along the longitudinal axis X from the outlet 15. Advantageously, the distance L_1 is within the interval 0-100 mm, preferably 0-50 mm, and even more preferably 0-20 mm. Most preferably, the transport steam injection orifice 19 is located directly above the outlet 15. This arrangement minimizes the risk that biomass material particles being propelled towards the outlet 15 by the steam form a coating on the discharge screw 17.

A transport steam conduit 20 is arranged to convey transport steam from the steam source 10 to the transport steam injection orifice 19. The transport steam conduit 20 comprises a second control valve 21 used to control the flow of transport steam through the transport steam conduit 20.

The method according to an embodiment of the invention will now be described in detail with reference to figure 1.

The biomass material A is fed into the charger 4 by means of the plug screw feeder (not shown). The plug screw feeder is designed so that the density of the biomass

material conveyed therethrough increases towards the charger 4, so that a dense plug of biomass material is generated within the plug screw feeder. This plug prevents steam from flowing back into the plug screw feeder. The biomass material A falls through the charger 4 and through the inlet 3 into the reactor vessel 2. Thereafter, the biomass material is conveyed by the conveyor screw 7 towards the outlet 5. The first control valves 11a, 11b are opened and steam is injected to elevate the pressure and temperature within the reactor vessel. The pre-hydrolyzed biomass material then falls into the discharger 6 and through the inlet 14 and into the inner space 23 within the discharge pipe 13. The discharge screw 17 conveys the biomass material A from the inlet 14 to the outlet 15, where transport steam injected through the transport steam injection orifice 19 propels the biomass material through the outlet 15 and into the blow line 16 and to subsequent processing equipment (not shown).

Figure 2 is a schematic illustration of a second embodiment of a reactor assembly 101 for pre-hydrolysis treatment of biomass material A. In figures 1 and 2, like features are represented by common reference numbers.

One difference between the reactor assemblies in figures 1 and 2 is that the reactor assembly 101 in figure 2 comprises a vertical reactor vessel 102. Biomass material A is fed by means of a plug screw feeder 130 through an inlet 103 into the vertical reactor vessel 102. The plug screw feeder 130 comprises a plug screw 131 adapted to be rotated by a motor (not shown) to convey the biomass material A to the reactor vessel 102. The plug screw feeder 130 comprises a section wherein the diameter of the plug screw feeder 130 decreases in a biomass transport direction, so that a dense plug of biomass material is formed within the plug screw feeder 130. This plug prevents steam from flowing from the reactor vessel 102 through the plug screw feeder 130 against the biomass material transport direction. A blow back damper 132 is arranged within the reactor vessel 102 opposite the inlet 103. The blow back damper 132 comprises a reciprocally movable rod 133, which at one end is provided with a conical damper head 134 and at the other end is connected to a hydraulic or pneumatic system (not shown) adapted to apply a pressure to the rod 133 to move the damper head 134 axially towards and away from the inlet 103. The damper head 134 can be moved from a retracted position, wherein the damper head 134 does not interact with the biomass material A discharged through the inlet 103, to an intermediate position, wherein the

damper head 134 exerts a counter-pressure on the biomass material discharged through the inlet 103 to assist in the formation of the plug of biomass material, and to a forward position wherein the damper head 134 seals the inlet 103.

The biomass material A falls through the reactor vessel 102 towards an outlet 105. Simultaneously, the biomass material is heated by steam. Steam is fed from a steam source 10 through a steam conduit 109 and steam injection orifices 108 into an upper portion of the reactor vessel 102. A first control valve 111 is arranged in the steam conduit 109, which first control valve 111 makes it possible to control the flow of steam into the reactor vessel 102.

A screw feeder 120 is arranged at the bottom of the reactor vessel 102 to receive the biomass material A that falls through the reactor vessel 102. The reactor vessel 102 may comprise means (not shown) arranged at the bottom of the reactor vessel 102 for conveying the biomass material to the screw feeder 120. The screw feeder 120 comprises a feed screw 121 arranged to rotate with a first rotational speed to feed the biomass material from the reactor vessel 102 to a discharge screw assembly 12 located at an opposite end of the screw feeder 120. The discharge screw assembly 12 is similar to the discharge screw assembly in figure 1 and comprises a discharge pipe 13 and a discharge screw 17 arranged within the discharge pipe 13. The discharge screw 17 is arranged to rotate with a second rotational speed higher than the first rotational speed. The discharge screw assembly 12 also comprises a plurality of transport steam injection orifices 19 arranged at a second end of the inner space 23 in an upper portion of the discharge pipe 13. The transport steam injection orifices 19 are arranged to inject transport steam into the discharge pipe 13. Transport steam is delivered to the transport steam injection orifices 19 by means of a transport steam conduit 20 comprising a second control valve 21, which is used to regulate the flow of transport steam through the transport steam conduit 20. Finally, A blow line 16 with a blow valve 18, wherein steam explosion occurs, 18 is connected to the outlet 15 to deliver the biomass material to subsequent processing equipment (not shown).

The biomass material A is transported to the plug screw feeder 130, wherein the biomass material is conveyed by means of the plug screw 131 towards the inlet 103 of the reactor vessel 102. The frustoconical part of the plug screw feeder 131 compacts

the biomass material into a dense plug, which prevents steam from flowing back through the plug screw feeder 131. The damper head 134 within the reactor vessel 102 may also assist in the formation of the plug. The plug of biomass material is then ejected into the reactor vessel 102, wherein the damper head 134 shreds the plug. The biomass material falls onto a pile (not shown) of biomass contained in the reactor vessel 102. Steam from the steam source 10 is injected into the reactor vessel 102 through steam injection orifices 108 to elevate the pressure and temperature within the reactor vessel 102. At the bottom of the reactor vessel 102, the pre-hydrolyzed biomass material A is delivered into the screw feeder 120 and the feed screw 121 conveys the biomass material A through the screw feeder to the discharge screw assembly 12. The discharge screw 17 conveys the biomass material A through the discharge pipe 13 to the outlet 15. Transport steam from the steam source 10 is injected through the transport steam injection orifices 19 to propel the wet and heavy biomass material through the outlet 15 and into the blow line 16 and through the blow valve 18, wherein steam-explosion occurs.

The injected transport steam in both Figure 1 and 2 also affects the temperature and pressure within the reactor.

The first and second controls valve may be controlled by means of one or more control units. Advantageously, the control valves are controlled by means of the same control unit. Advantageously, the control unit is adapted to adjust the first and/or second valve(s) to ensure that the reactor vessel works at optimal pressure and temperature. For this purpose, the control unit may be adapted to receive information from one or more sensors arranged to measure (directly or indirectly) the temperature and pressure within the reactor vessel and to adjust the first and/or second valve(s) based on this information.

Figure 3 is a block diagram illustrating an embodiment of a method according to the invention.

The method comprises the steps of receiving 301 the biomass material in a reactor vessel and injecting 302 steam into and/or before the reactor vessel to raise the temperature and pressure within the reactor vessel. The method further comprises the

step of conveying 303 the biomass material from the reactor vessel to a discharge screw assembly. The discharge screw assembly comprises a discharge pipe that defines an inner space arranged to receive 304 the biomass material via an inlet. The inner space extends along a longitudinal axis from a first end to a second end. Thereafter, the biomass material is conveyed 305 from the inlet to an outlet by means of a discharge screw accommodated within said inner space. The outlet is located at the second end. Transport steam is injected 306 into the inner space via at least one transport steam injection orifice to propel the biomass material through said outlet. The transport steam injection orifice is located at the second end, which minimizes the risk of biomass material forming a hard coating on the discharge screw.

Preferably, the transport steam injection orifice is arranged at a distance, measured along the longitudinal axis of the inner space, from the outlet, which distance is between 0-100 mm, preferably 0-50 mm, and even more preferably between 0-20 mm. Most preferably, the transport steam injection orifice is located directly above the outlet.

Advantageously, the transport steam injection orifice is arranged in an upper, preferably uppermost, portion of the discharge pipe.

The flow of transport steam into the discharge pipe may be constant over time at a certain pressure in the reactor vessel. Alternatively, the flow of transport steam may vary over time. The flow of transport steam may be regulated by means of a second control valve arranged in a transport steam conduit connected to the transport steam injection orifice(s).

Advantageously, the method comprises the step of independently controlling the flows of steam and transport steam. This embodiment is advantageous in that the flow of steam required to increase the pressure and temperature within the reactor vessel can be adjusted as needed without changing the flow of transport steam into the discharge pipe. The flow of transport steam may constitute as much as 90% of the combined flows of steam and transport steam.

The description above and the appended drawings are to be considered as non-limiting examples of the invention. The person skilled in the art realizes that several

combinations and modifications of embodiments may be made within the scope of the invention. For example, in the embodiments shown in figures 1 and 2, a plug screw feeder is used to maintain the pressure within the reactor vessel. The skilled person understands that other types of pressure isolation devices can be used, such as rotary valves or a lock-hopper system. Also, the steam and transport steam conduits in figures 1 and 2 are connected to the same steam source. It is, of course, possible to connect the steam and transport steam conduits to separate steam sources.

CLAIMS

1. A discharge screw assembly (12) for discharging treated biomass material (A) received from a reactor vessel (2; 102), which discharge screw assembly (12) comprises:

- a discharge pipe (13) that defines an inner space (23) that extends along a longitudinal axis (X) from a first end (23a) to a second end (23b), which discharge pipe (13) comprises an inlet (14) for receiving said biomass material (A) into said inner space (23) and an outlet (15) for discharging said biomass material (A) out of said inner space (23), which outlet (15) is located at the second end (23b), wherein the inner space (23) accommodates a discharge screw (17) for conveying said biomass material (A) from the inlet (14) to the outlet (15);

characterized in that said discharge screw assembly (12) comprises:

- at least one transport steam injection orifice (19) arranged at the second end (23b) to inject transport steam into said inner space (23) to propel said biomass material (A) through said outlet (15).

2. A discharge screw assembly (12) according to claim 1, wherein a distance (L_1) along the longitudinal axis (X) between the transport steam injection orifice (19) and the outlet (15) is between 0-100 mm, preferably between 0-50 mm, and even more preferably between 0-20 mm.

3. A discharge screw assembly (12) according to claim 1 or 2, wherein the transport steam injection orifice (19) is arranged in an upper, preferably in an uppermost, portion of the discharge pipe (13).

4. A discharge screw assembly (12) according to any of the preceding claims, which discharge screw assembly (12) comprises a plurality of transport steam injection orifices (19).

5. A reactor assembly (1; 101) for treatment of biomass material (A), which reactor assembly (1; 101) comprises:

- a reactor vessel (2; 102) for treatment of said biomass material (A); and

- at least one steam injection orifice (8, 28; 108) arranged to inject steam into or before said reactor vessel (2; 102);

characterized in that said reactor assembly (1; 101) comprises a discharge screw assembly (12) according to any of claims 1-4.

6. A reactor assembly (1; 101) according to claim 5, which reactor assembly (1; 101) comprises:

- a steam conduit (9a, 9b; 109) connecting said steam injection orifice (8, 28; 108) to a steam source (10) and comprising a first valve (11a, 11b; 111) for controlling the flow of steam through said steam injection orifice (8, 28; 108); and

- a transport steam conduit (20) connecting said transport steam injection orifice (19) to a transport steam source (10) and comprising a second valve (21) for controlling the flow of transport steam through said transport steam injection orifice (19).

7. A reactor assembly (1; 101) according to claim 6, wherein the steam conduit (9a, 9b; 109) and the transport steam conduit (20) are connected to the same steam source (10).

8. A reactor assembly (101) according to any of claims 5-7, wherein said reactor vessel (102) is arranged substantially vertically.

9. A reactor assembly (1) according to any of claims 5-7, wherein said reactor vessel (2) is arranged substantially horizontally or inclined relative a horizontal plane.

10. A reactor assembly (1; 101) according to any of claims 5-9, wherein the reactor vessel (2; 102) is adapted for pre-hydrolysis of said biomass material (A).

11. A method for treatment of biomass material (A) in a reactor assembly (1; 101), which method comprises the steps of:

- receiving (301) the biomass material (A) in a reactor vessel (2; 102) for treatment of said biomass material (A);

- injecting (302) steam into and/or before said reactor vessel (2; 102) to raise the temperature and pressure within the reactor vessel (2; 102);

- transporting (303) said biomass material (A) from said reactor vessel (2; 102) to a discharge screw assembly (12), which discharge screw assembly (12) comprises a discharge pipe (13) that defines an inner space (23) that extends along a longitudinal axis (X) from a first end (23a) to a second end (23b);

- receiving (304) said biomass material (A) in said inner space (23) through an inlet (14);

- conveying (305) said biomass material (A) from the inlet (14) to an outlet (15) located at the second end (23b) by means of a discharge screw (17) accommodated within said inner space (23);

characterized in that said method comprises the step of:

- injecting (306) transport steam into said inner space (23) through at least one transport steam injection orifice (19) arranged at the second end (23b) to propel said biomass material through said outlet (15).

12. A method according to claim 11, wherein a distance (L_1) along the longitudinal axis (X) between the transport steam injection orifice (19) and the outlet (15) is between 0-100 mm, preferably between 0-50 mm, and even more preferably between 0-20 mm.

13. A method according to claim 11 or 12, wherein the transport steam injection orifice (19) is arranged in an upper, preferably uppermost, portion of the discharge pipe (13).

14. A method according to any of claims 11-13, which method comprises the step of independently controlling the flows of steam and transport steam.

15. A method according to any of claims 11-14, which method comprises the step of pre-hydrolyzing said biomass material (A) in said reactor vessel (2; 102).

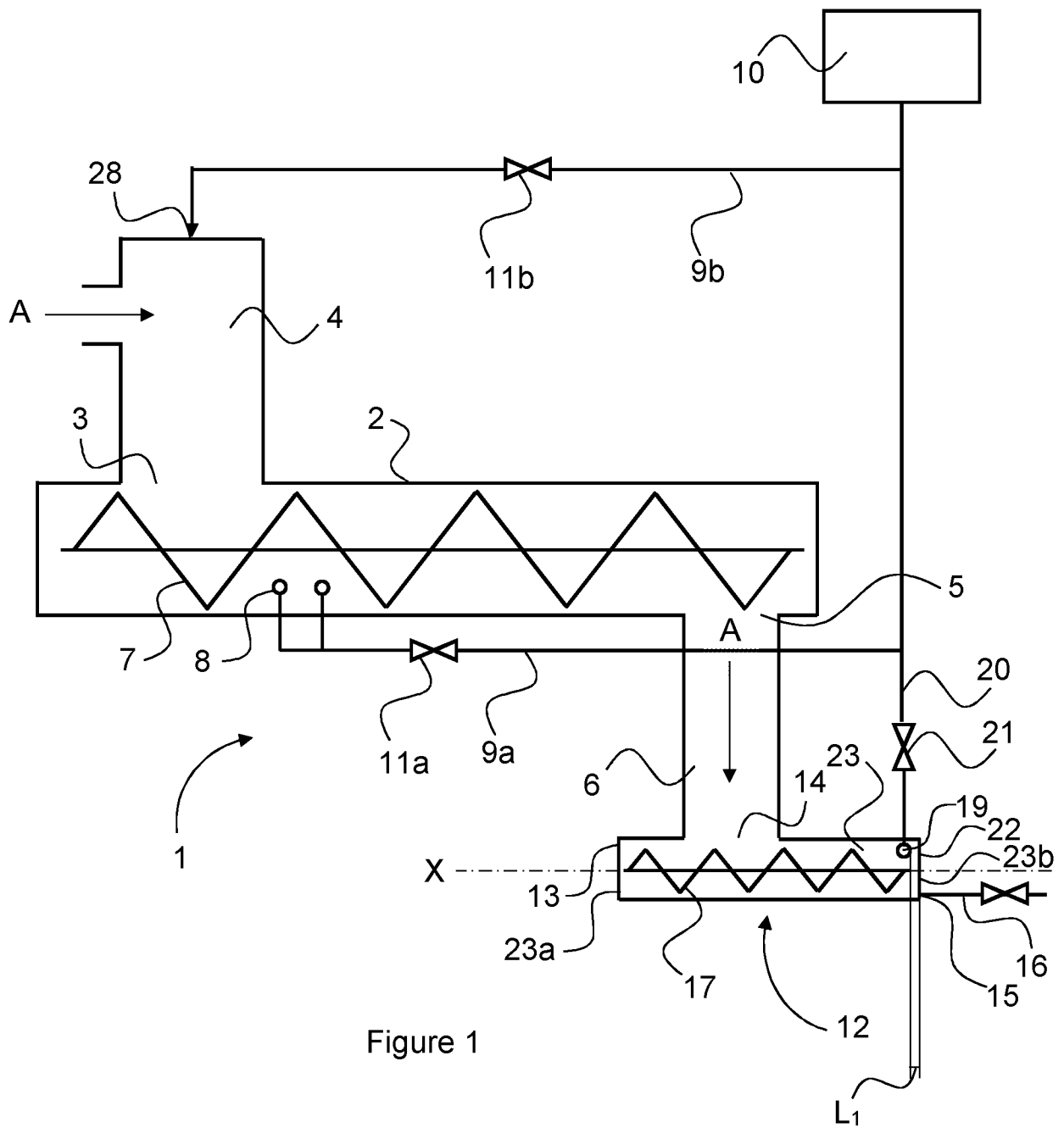


Figure 1

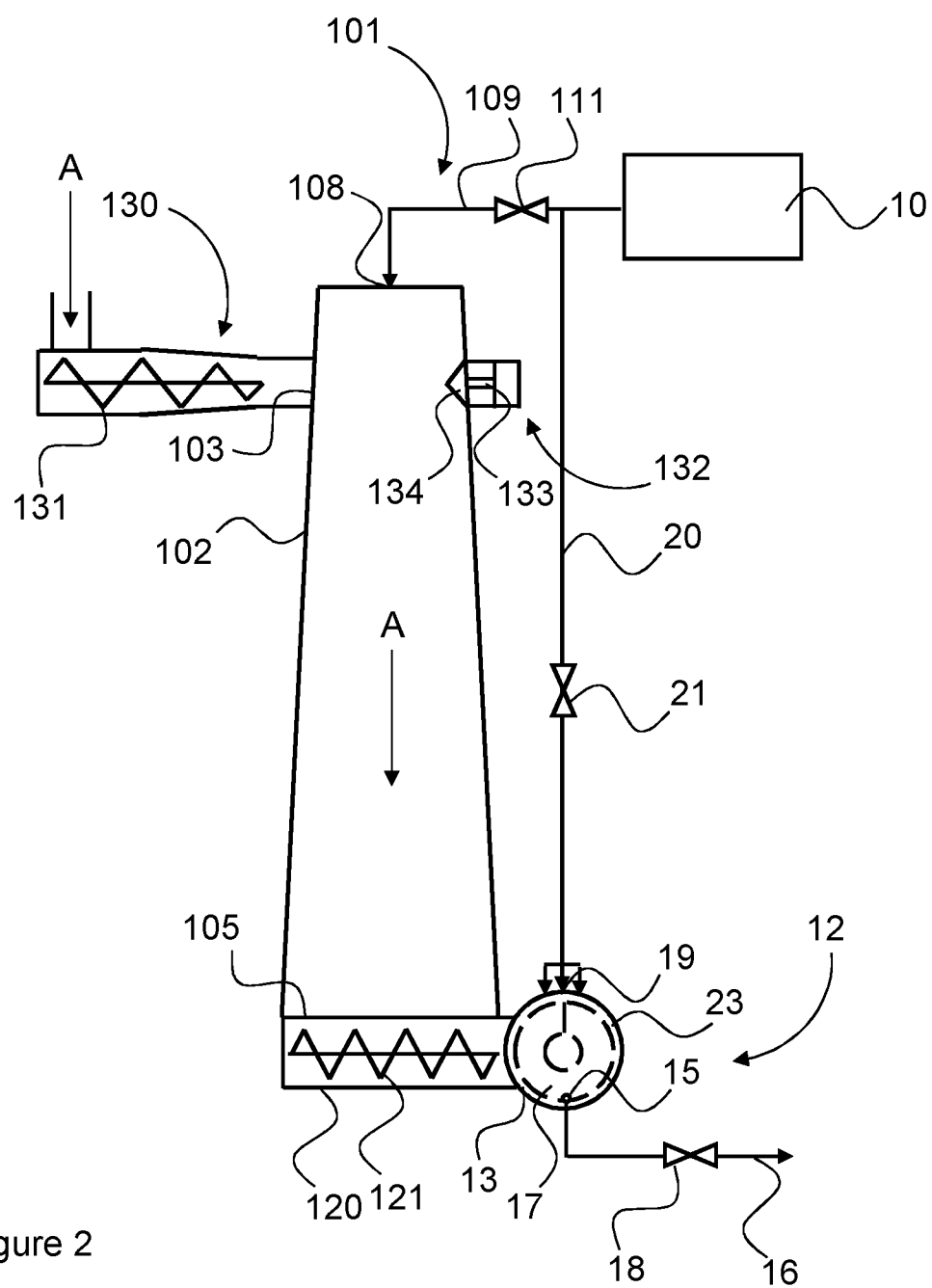


Figure 2

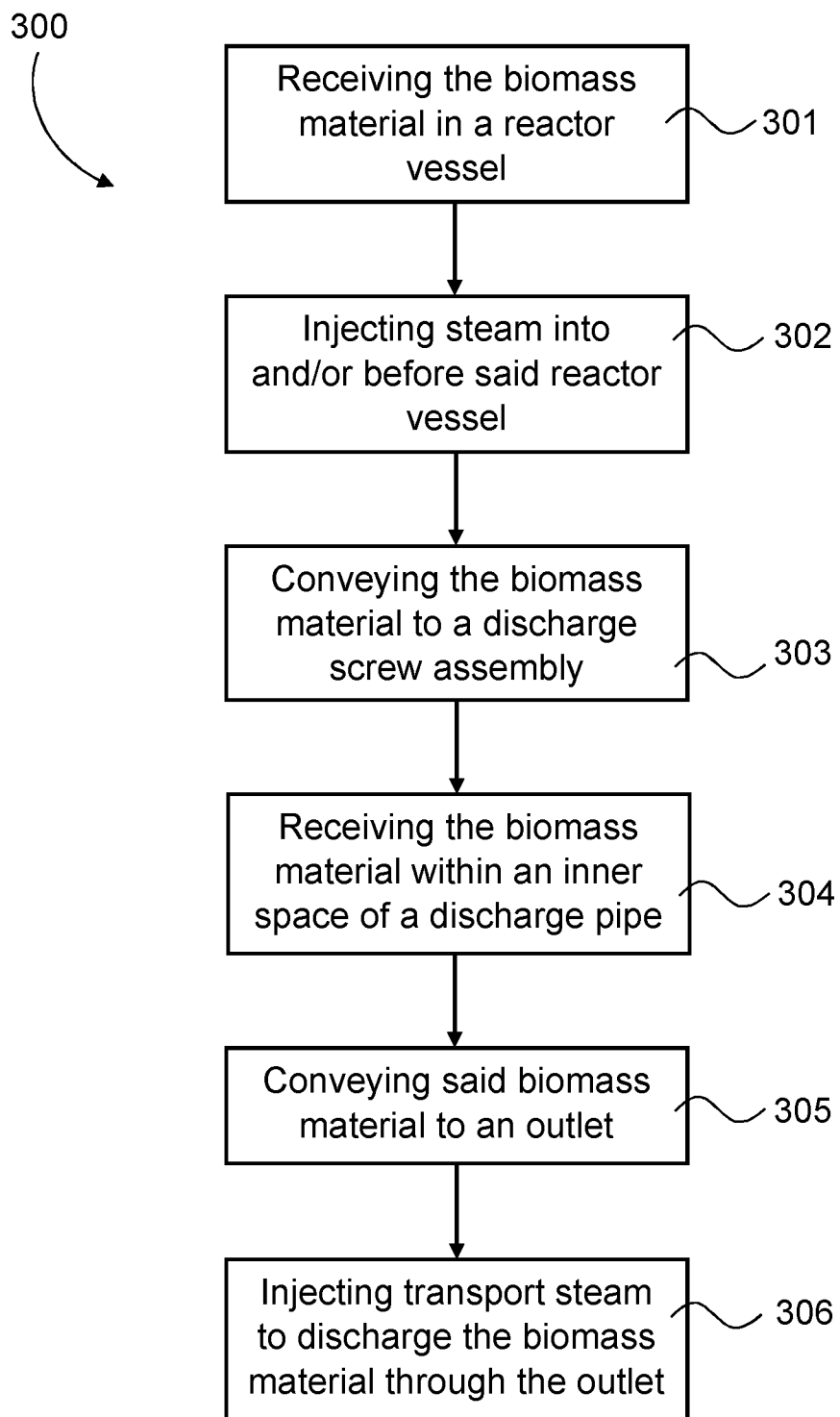


Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2020/050214

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B01J, B65G, D21C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 20010008177 A1 (LEBEL DAVID J ET AL), 19 July 2001 (2001-07-19); paragraph [0038]; figure 3	1, 3-4
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"D" document cited by the applicant in the international application	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
29-04-2020

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Name and mailing address of the ISA/SE
Patent- och registreringsverket
Box 5055
S-102 42 STOCKHOLM
Facsimile No. + 46 8 666 02 86

Authorized officer
Adrian Celsi
Telephone No. + 46 8 782 28 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2020/050214

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	WO 2015139141 A1 (IOGEN ENERGY CORP), 24 September 2015 (2015-09-24); paragraph [0094]; figure 1 -- -----	1-15

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International Patent Classification (IPC)

D21C 7/08 (2006.01)

B01J 3/02 (2006.01)

B01J 19/20 (2006.01)

D21C 1/02 (2006.01)

D21C 1/04 (2006.01)

B65G 33/24 (2006.01)

B65G 33/26 (2006.01)

D21C 7/06 (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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