

(19) **DANMARK**



Patent- og
Varemærkestyrelsen

(10) **DK/EP 3289627 T3**

(12) Oversættelse af
europæisk patentskrift

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- (51) Int.Cl.: **H 01 M 6/52 (2006.01)** **C 22 B 1/00 (2006.01)** **H 01 M 10/54 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2020-08-24**
- (80) Dato for Den Europæiske Patentmyndigheds
bekendtgørelse om meddelelse af patentet: **2020-05-20**
- (86) Europæisk ansøgning nr.: **16719400.0**
- (86) Europæisk indleveringsdag: **2016-04-28**
- (87) Den europæiske ansøgnings publiceringsdag: **2018-03-07**
- (86) International ansøgning nr.: **EP2016059526**
- (87) Internationalt publikationsnr.: **WO2016174156**
- (30) Prioritet: **2015-04-28 DE 102015207843**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV
MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
- (73) Patenthaver: **Duesenfeld GmbH, Rothbergstraße 8, 38176 Wendeburg, Tyskland**
- (72) Opfinder: **SCHOENITZ, Martin, Wabestraße 31, 38106 Braunschweig, Tyskland
HASELRIEDER, Wolfgang, Munstedter Straße 13, 38114 Braunschweig, Tyskland
WESTPHAL, Bastian, Karlstraße 92, 38106 Braunschweig, Tyskland
HANISCH, Christian, MADAMEWEG 112b, 38118 Braunschweig, Tyskland**
- (74) Fuldmægtig i Danmark: **Larsen & Birkeholm A/S Skandinavisk Patentbureau, Banegårdspladsen 1, 1570
København V, Danmark**
- (54) Benævnelse: **Fremgangsmåde til behandling af batterier, især genopladelige batterier, og
batteriforarbejdningsanlæg**
- (56) Fremdragne publikationer:
**WO-A1-2010/102377
DE-A1-102011 110 083**

Method for the treatment of used batteries, in particular rechargeable batteries, and battery processing installation

The invention relates to a method for the treatment of used lithium batteries,
5 such as lithium-ion batteries, according to the generic term in claim 1.

According to a second aspect, the invention relates to a battery processing installation according to the generic term in claim 5.

10 US 2005/0241943 A1 describes a method for processing used batteries in which the batteries are heated prior to a comminuting step, thereby destroying plastic components in the batteries. The disadvantage of this type of procedure is that the remaining components of the batteries may be contaminated with degradation products of the plastic.

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DE 10 2012 024 876 A1 describes a system for transferring transport-critical electrolyte cells, in which they are initially comminuted under inert gas and then dusted with a deactivation powder so as to prevent the electrochemically active material from spontaneously combusting. The disadvantage of this is that the
20 resulting material still poses a comparatively high hazard potential and that the dusting power itself poses a risk of explosion and that the formation of a flammable and explosive atmosphere in the transport container cannot be ruled out.

DE 10 2011 110 083 A1 describes a method for recovering active material from
25 a galvanic cell, in which the galvanic cells are initially mechanically comminuted, then pre-dried and subsequently sifted. Finally, the binder is broken down in an oven. This type of device is very well-suited to the efficient recycling of larger amounts of galvanic elements. However, for partial load operation, the construction of this installation is comparatively complex.

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WO 2010/102377 A1 describes a method in which the batteries to be recycled, such as lithium batteries, are heated in a rotary kiln and the resulting gases are sucked away. The disadvantage of this method is that it is difficult to reuse the

electrolyte and it produces large quantities of hydrogen fluoride and fluoro-organic compounds.

The invention aims to reduce disadvantages of the prior art.

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The invention solves the problem by means of a method with the features described in claim 1. According to a second aspect, the invention solves the problem by means of a battery processing installation with the features described in claim 5.

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The advantage of the invention is that the amount of electrolyte that can be obtained from the comminuted material through drying is such that an electrochemical reaction is no longer possible, or only to a negligibly small extent. In addition, no flammable or explosive gas phase forms above the battery fragments, as the organic carbonates of the electrolyte have been removed [from the fragments]. The comminuted material is therefore largely inert and can be transported safely, especially if it is packed under vacuum.

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A further advantage is that no additional material has to be added to deactivate the comminuted material. This decreases the complexity of the battery processing, reduces the weight of the deactivated comminuted material and increases the purity in the subsequent separation and recycling steps. In particular, in potential subsequent hydrometallurgical processing steps, a high degree of product purity that does not require the input of foreign ions is advantageous.

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In addition, it is advantageous that a comminuted material is obtained that can be transported safely. The organic carbonate content is preferably so small that the formation of a significant amount of fluorophosphates can be ruled out. Fluorophosphates are often strong neurotoxins, the formation of which must be reliably prevented. Furthermore, due to the low electrolyte content, it is guaranteed that a self-amplifying and intensifying build-up of heat triggered by an electrochemical reaction cannot occur.

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Within the scope of the present description, the term drying should be understood particularly to mean the removal of at least one solvent in the conducting salt. In particular, the drying is executed such that dimethyl carbonate and/or ethyl methyl carbonate is removed.

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The battery should be understood especially to mean a lithium battery. A lithium battery is a rechargeable battery whose electrochemical reaction involves lithium and/or lithium ions and/or a lithium compound.

10 A battery processing installation should also be understood particularly to mean a rechargeable battery processing installation for processing rechargeable batteries.

The transport container should also be understood particularly to mean transport
15 packaging. The transport packaging is preferably sealed by way of a vacuum seal. Aluminium composite foil is especially well-suited as transport packaging.

It is beneficial if the drying occurs after the comminuting of the batteries. It is indeed possible and represents a preferred embodiment that the batteries are
20 exposed to a vacuum when in an uncomminuted state such that at least parts of the electrolyte vaporise, wherein the resulting gas either escapes through a safety valve in the rechargeable battery or the battery is destroyed by the pressure difference between the external environment and the internal pressure, enabling the vaporising electrolyte to escape. However, since the electrolyte is
25 predominantly located between tightly wound or stacked and pressed layers of electrodes and separators and in their pores, and it is connected to other components of the batteries, this procedure can be very time-consuming. It is thus often more beneficial and represents a preferred embodiment of the invention for the batteries to be mechanically comminuted, for example through cutting,
30 cropping, impact, separating and/or compressing. This means that a larger interface is available for the transition of materials into the gas phase.

The drying may occur by way of vacuum drying, contact drying, convection dry-

ing and/or infra-red drying. It is favourable if the drying occurs while the comminuted material is being agitated and/or circulated.

Prior to being comminuted, the used batteries are preferably dismantled. This means that larger battery systems are dismantled into their smaller subcomponents, the modules or stacks, or even that the cells which contain the electrochemically active material are separated from the control electronics. The control electronics comprise, for example, semiconductor elements and/or sensors and are responsible for the charge control of the batteries.

The drying occurs under a vacuum. The size of the vacuum is preferably selected such that the vapour pressure of dimethyl carbonate at 80°C, especially at 70°C, is not reached. The drying therefore occurs at a maximum pressure of 300 hPa, in particular a maximum of 100 hPa. At such low pressures, considerable parts of most electrolytes vaporise, especially dimethyl carbonate and ethyl methyl carbonate, and do so at temperatures of less than 80°C. The advantage of low temperatures is that the formation of hydrogen fluoride is hindered. Hydrogen fluoride poses a potential risk for the battery processing installation and the surroundings. It is therefore beneficial to prevent the development of hydrogen fluoride.

The drying preferably occurs at a temperature that is lower than a decomposition temperature. The decomposition temperature should be understood particularly to mean the lowest temperature at which at least 80 percent by mass of the binder has decomposed into gaseous components after keeping the comminuted material at this temperature for an hour. The decomposition temperature can be measured by successively increasing the temperature of the comminuted material and recording when a loss of mass occurs, especially through the build-up of gas due to a decomposition of the binder, and the specified criteria is fulfilled. If necessary, the experiment must be conducted several times, each time using a new sample of comminuted material at an increased temperature.

It is favourable if the drying occurs under an atmosphere in which the partial pressure of the water is lower than 50 Pa, in particular lower than 10 Pa. A low

partial pressure of the water leads to a low reaction rate of lithium compounds to lithium hydroxide and thus only to a low build-up of hydrogen. This prevents the formation of flammable hydrogen-oxygen mixtures and contributes to the safety of the installation.

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In addition, it is favourable if the partial pressure of oxygen has a maximum value of 10 millibars, especially a maximum value of 5 millibars. This largely inhibits the reaction of oxygen with oxidisable components of the batteries. It is possible to achieve the low partial pressure of oxygen by means of drying at a low pressure. Alternatively or additionally, the drying may occur in an inert gas atmosphere.

A method is preferred in which the drying of the comminuted material is only completed if, after the completion of the drying process, no flammable or explosive gas mixture can form above the comminuted material that has been filled [in the container] and/or when the comminuted material is so dry that a flammable or explosive gas mixture can emerge in the transport container or during the subsequent processing. The property that the drying is completed if, after the completion of the drying process, no flammable or explosive gas mixture can form above the comminuted material that has been filled [in the container] should be understood particularly to mean that, within the space of one week at 50°C and 1013 hPa, no flammable gas mixture forms in a transport container in the form of a 50 litre container that has been half-filled (relative to its volume) with the comminuted material. Preliminary tests determine whether the criteria has been fulfilled. If a flammable gas mixture does form, the drying must be conducted for a longer time and/or at a lower pressure. The preliminary tests are repeated until a drying time and/or drying pressure has been identified at which, in a set of tests of three transport containers, the requirements for the property have been fulfilled for all three transport containers.

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The comminuted material is preferably dried until an electrolyte content in the comminuted material is so low that an electrochemical reaction is impossible. In other words, the electrolyte content is lower than a threshold value, the thresh-

old value being selected such that, if this threshold value is not achieved, the cell voltage is reduced to a maximum of one quarter. This threshold value is determined, for example, by defining the cell voltage of a battery in relation to the electrolyte content. Shortly before achieving the threshold value, the cell voltage
5 collapses, i.e. it decreases by at least 75%. If the threshold value is not achieved, the battery contains so little electrolyte that, to a good approximation, an electrochemical reaction is no longer possible.

The comminuted material is preferably dried for so long that a 50kg amount of
10 comminuted material, which is contained in a compacted form in a 50 litre drum, does not experience a build-up of heat, or the build-up of heat is so low that a thermal runaway, i.e. a thermally induced chain reaction, is ruled out for at least two months, and that any build-up of hydrogen is also so low that after two weeks, no excess pressure occurs if a negative pressure of 500 hPa is present
15 to begin with.

It is beneficial if the comminuted material is dried until the electrolyte content of organic components that are volatile at 80°C has a maximum value of 3% by weight, in particular a maximum of 2% by weight, especially preferably a maxi-
20 mum of 1.5% by weight.

The drying is preferably conducted for so long that the accumulated content of organic carbonates from the electrolyte that are volatile at 80°C falls short of 3% by volume in the atmosphere above the comminuted material.
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In particular, the drying is conducted until the dimethyl carbonate content is lower than 4% by volume, especially 3% by volume, and/or the cyclohexylbenzene content is lower than 1% by volume, in particular 0.5% by volume.

30 The drying preferably occurs immediately after comminution. This should be understood to mean that the time between the beginning of the comminution of the batteries and the point at which at least a part of the resulting comminuted material begins to dry is a maximum of five minutes, especially a maximum of one

minute. The rapid drying after comminution means that the mass of material that may potentially experience an electrochemical reaction remains small; the electrochemical reaction time of potential exothermic reactions also remains small. This reduces the risk for the installation and the surroundings.

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It is especially favourable if the vacuum is created by means of a jet pump. Jet pumps are largely resistant to aggressive gases that are due to be pumped, particularly if the appropriate blasting medium is selected. It is beneficial if the blasting medium, which is a fluid, has a pH value of at least 8, in particular of at least 9, for example at least 12. In this case, unwanted components of the gas that is being pumped can decompose or react to become less damaging substances. In this way, for example, dimethyl carbonates and/or ethyl methyl carbonates can be broken down by a saponification reaction. Any hydrogen fluoride contained in the blasting medium can be converted in the alkaline environment into a non-hazardous salt by way of an acid-base reaction.

The blasting medium preferably contains a substance that precipitates fluoride. For example, the blasting medium may contain sodium carbonate or calcium carbonate. The salts that result from the reaction with a fluorine compound, in particular hydrogen fluoride, are preferably separated, in particular filtered or removed by sedimentation. This at least largely prevents hydrogen fluoride or other poisonous fluorine compounds from being emitted into the surroundings.

The drying occurs at a maximum temperature of 80°C: this produces almost no hydrogen fluoride. This increases the service life of the battery processing installation and reduces the environmental risk.

According to a preferred embodiment, the method comprises the steps of condensing components of the electrolyte by cooling and/or increasing the pressure such that an electrolyte condensate occurs. For example, the condensation is conducted at a point that lies between the dryer and the vacuum pump relative to the flow of gas. In this case, gases coming from the dryer must initially pass through a condenser before reaching the vacuum pump. This causes the gase-

ous electrolyte in the gas, which is produced during the drying, to be at least largely separated in the condenser before the remaining gas reaches the pump. Electrolyte can be recovered in this way. In addition, the flow of gas through the vacuum pump decreases, which increases its [the vacuum pump's] service life and reduces its energy consumption.

According to a preferred embodiment, the method alternatively comprises the step of purifying the gas through the adsorption of the volatile organic components of an activated carbon filter in front of or behind the compressor unit.

Alternatively or additionally, the method according to the invention preferably comprises the step of purifying the gas produced during the drying before it reaches the vacuum pump. This may also occur, for example, by the gas through passing an activated charcoal filter and/or a filter that contains substances which react with hydrogen fluoride, such as a calcium salt like calcium carbonate or a potassium salt such as potassium carbonate.

The method according to the invention preferably comprises the step of drying at a drying temperature and for a drying time that have been selected such that the binder which binds the active material of the lithium battery to a carrier at least largely decomposes. It is favourable if this drying step, which can also be described as high temperature drying, occurs in a separate space from a first drying step, described above. The latter drying step can also be described as low temperature drying.

High temperature drying, during which the binder decomposes, is preferably conducted such that the resulting decomposition gases do not mix with the gases resulting from low temperature drying. It is possible that the high temperature drying and the low temperature drying occur at different pressures. For example, the high temperature drying can be executed at normal pressure.

The active material should be understood to mean the material that reacts electrochemically during operation of the batteries. The carrier for the active material

should be understood particularly to mean a carrier foil to which the active material is applied in the form of particles. For example, the carrier foil refers to a foil made of aluminium or an aluminium alloy. The binder is the material which binds the active material with the carrier; for example, the binder contains polyvinylidene fluoride.

It is beneficial if liquid nitrogen is added when comminuting the batteries. This cools the batteries, the comminuting machine and the comminuting material, and also drives oxygen and water vapour out of the atmosphere.

It is beneficial if the comminution occurs when the partial pressure of the water is a maximum of 20 Pa and/or the partial pressure of the oxygen is a maximum of 40 hPa, especially a maximum of 15 hPa.

According to a preferred embodiment, the method comprises the steps of removing the comminuted material from the transport container; detaching hard parts and/or separating active material from the carrier, particularly via a second comminuting stage and/or air jet sieving, thereby producing an active material fraction and a carrier fraction; and a separate packing of the active material fraction and carrier fraction in suitable transport containers. It is beneficial if these transport containers are designed to be airtight. By separating an active material fraction and a carrier fraction, transportation generally does not require any permits. An additional advantage is that fractions separated in this way only pose a small risk.

The removal of the comminuted material from the transport container is preferably conducted under vacuum and/or shielding gas.

It is possible, but not necessary, for the transport container to be filled with comminuted material under vacuum. It is beneficial if the transport container is a vacuum container, in particular an evacuated vacuum container, such that a negative pressure or vacuum occurs in the transport container once it has been sealed. Alternatively, the transport container may be filled with an inert gas.

In a preferred battery processing installation, the separation unit and the drying device are arranged in a joint standard container. The advantage of this is that it renders the battery processing installation especially easy to transport.

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The drying device is configured to dry the comminuted material until an electrolyte content is so low that an electrochemical reaction is impossible. If the drying device is operated in batch mode, which represents a preferred embodiment, the drying shall be performed, for example, for a pre-determined period of time. Alternatively or additionally, the content of organic substances, such as organic carbonates, in the atmosphere in the drying device is continually measured and the drying stopped once the concentration is lower than a pre-determined threshold concentration.

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According to a preferred embodiment, the battery processing installation, in particular the vacuum installation, comprises a condenser that is configured to condense organic components of the atmosphere in the dryer, especially organic carbonates such as dimethyl carbonate, ethyl methyl carbonate and/or ethylene carbonate. The capacitor is preferably arranged in the direction of material flow in front of a vacuum pump, by means of which the dryer is evacuated. It is beneficial if the condenser is cooled, preferably to a maximum temperature of 90°C, preferably a maximum of 80°C, especially preferably a maximum of 70°C. In order to keep the energy required for cooling low, the condenser, insofar as it is cooled, is cooled to a temperature of at least -10°C, in particular at least 10 °C.

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It is beneficial if the drying device comprises an agitator, for example an anchor agitator or a rod agitator, whose stirring rods can be arranged transversely to an agitator shaft. Alternatively or additionally, the agitator is an external agitator that moves the dryer as a whole.

The battery processing installation preferably has a vacuum installation that is connected to the drying device for the purpose of generating a vacuum in the

drying device. It is especially favourable if the vacuum installation is also arranged in the standard container. The standard container preferably refers to a container that conforms to ISO standard 668, preferably a 40 foot container or a 20 foot container.

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For example, the vacuum installation comprises a jet pump with a blasting medium that is used to generate the negative pressure.

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The battery processing installation preferably has a hard metal detachment device and/or a light fraction separation device; a separation device, especially a classification device, for separating active material from the carrier, in particular by means of a second comminution stage and/or air jet sieving, such that an active material fraction and a carrier fraction occur; and a second filling device for the separate filling of the active material fraction and the carrier fraction. It is beneficial if this filling device is designed for filling under negative pressure and/or inter gas.

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A hard metal detachment device should be understood particularly to mean a device for detaching fragments of peripheral components of the operating system, the battery cell casing and the electrical contacts. For example, the cemented carbide separation device has a magnet separation device and/or a separator, in particular a cross-flow separator and/or a zigzag separator. The separation device should be understood particularly to mean a device for detaching the separator foil.

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The light fraction separation device preferably has a zigzag separator and/or an air separator, wherein it is favourable if the air is conducted within a circuit. This reduces the exposure of the environment to harmful dust.

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The second filling device and the separation devices are preferably arranged in a joint standard container, for example in the first standard container described above or a second standard container. It is beneficial if the container is sealed so as to be dust-tight.

The battery processing installation preferably has an airlock between the comminution unit and the deactivation device, especially the drying device. For example, this refers to a rotary airlock. The airlock reduces the amount of oxygen introduced into the inactivation device, especially the drying device.

In the following, the invention will be explained in more detail by way of the attached figures. They show

- 10 Figure 1 a flow diagram of a method according to the invention,
- Figure 2 a cross-section through a battery processing installation according to the invention and
- 15 Figure 3 a cross-section through further optional components of a battery processing installation according to the invention.

Figure 1 shows a flow diagram of a method according to the invention. Batteries 10.1, 10.2, ..., in particular battery systems made up of several battery modules or battery stacks, which are in turn made up of several battery cells, are initially discharged in a discharge unit 12. This is followed by the dismantling of the batteries 10 at a dismantling station 14, if this is necessary because the battery systems cannot otherwise be delivered into the comminution unit for geometric or gravimetric reasons. In order to do this, the battery systems are opened and dismantled to the point at which the modules/stacks can be individually removed. If required, the cells can also be separated from the drive electronics. The resulting sub-units (modules/stacks) and/or cells 16.1, 16.2, ... are fed into a comminution unit 18, which comprises, for example, a rotary shear with a rotor and a stator or several rotors, or a cutting mill with a rotor and several rotors.

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The comminution unit 18 comminutes the batteries 10 under shielding gas 20, which is extracted, for example, from a shielding gas cylinder. Alternatively or additionally, liquid nitrogen from a liquid nitrogen source 19 may be may be in-

jected. The shielding gas may refer, for example, to nitrogen, a noble gas, carbon dioxide, nitrous oxide or another gas which is preferably not toxic.

Comminuted material 24 is produced during the comminuting; the material is fed
5 into an inactivation device in the form of a drying device 26. An airlock 28 is arranged between the comminution unit 18 and the drying device 26, the airlock being so gas-tight that the pressure device 26 is - to a good approximation - separated from the comminution unit 18 so as to be gas-tight.

10 The drying device 26 is connected to a vacuum installation 29 that comprises a vacuum pump 30 and creates a vacuum. A pressure p_{26} from $p_{26} \approx 100$ hPa, preferably 50 hPa, is present in the drying device 26. It should be noted that, within the scope of the present description, the vacuum pump should be understood particularly generally to mean a device that creates a vacuum. It is possible
15 and preferred, but not necessary, for the vacuum pump to simultaneously work as a compressor, such that gas is emitted from it under a pressure that is greater than the ambient pressure.

In the case depicted in figure 1, the vacuum pump is a compressor which sucks
20 in and compresses gas 31 that is present in the drying device 26. Alternatively or additionally, the vacuum installation 29 may have a jet pump which uses a blasting medium in the form of a liquid that is conducted at a high speed through Venturi nozzles. The blasting medium is alkaline and has a pH value of at least
25 pH 1 and is, for example, a 10% potassium hydroxide solution.

The vacuum installation 29 comprises a gas purification device 32 that is arranged between the drying device 26 and the vacuum pump 30, and which has a condenser 34 and/or an activated carbon filter 36 in the present case. The condenser is operated at a temperature of -10°C so that dimethyl carbonate and
30 ethyl methyl carbonate condense and can be dispensed into a condensate container 38. In addition, any water present is separated by freezing. A control valve 40 is designed to open if the pressure p_{26} becomes too great and to close if the pressure p_{26} becomes too small, i.e. when a pre-determined threshold value is

not reached.

The drying material is preferably moved during drying. This may be achieved via
agitating with an agitator 41, such as an anchor agitator or a rod agitator with
5 rods arranged perpendicular to the agitator shaft. Alternatively, it can be
achieved by way of a drying container that is moved.

The drying of the comminuted material results in deactivated comminuted mate-
rial 42, which is fed into a filling device 44. A transport container 46 is then filled
10 with the deactivated comminuted material 42 under vacuum and/or shielding
gas. The transport container 46 is preferably gas-tight. It is possible, but not
necessary, for the transport container 46 to be filled with inert gas prior to trans-
portation such that it is under normal pressure. Alternatively, it is also possible
for the transport container to be sealed under vacuum and transported. It is pos-
15 sible that, instead of the transport container, a vacuum-sealed foil is selected,
such as an aluminium compound foil.

The comminution unit 18 is fed with shielding gas 20 from the vacuum pump 30
via a flushing line 48. If the vacuum pump 30 also functions as a compressor -
20 as in the present case - which represents a preferred embodiment, the shielding
gas can be drawn over a pressurised gas cylinder 50. Alternatively or additional-
ly, the shielding gas 20 can be given off into the surroundings, following addi-
tional cleaning if necessary.

25 Figure 2 schematically depicts a cross-section through a battery processing in-
stallation 52 according to the invention, which comprises a standard container
54 in which the comminution unit 18, the drying device 26 and the filling device
44 are arranged. A first gas-tight conveyor 56 is arranged behind the comminu-
tion unit 18; the conveyor comprises, for example, a screw conveyor or a tube
30 chain conveyor. The first conveyor 56 delivers the comminuted material 24 to
the drying device 26, which is connected to the vacuum generation device, not
depicted in figure 2. A second conveyor 58 is arranged behind the drying device
26 in the direction of material flow; preferably, the conveyor is also designed to

be gas-tight and may include a screw conveyor or a tube chain conveyor. The second conveyor delivers the inactivated comminuted material 42 to the filling device 44.

- 5 Figure 3 depicts optional units - available in the present embodiment - of the battery processing installation 52 according to the invention which comprise a breakdown comminutor 60, as well as a separator 62. The breakdown comminutor 60 contains a transport container draining device 64, by means of which in-
- 10 46. The breakdown comminutor 60 produces breakdown material 66, which is fed into the separator 62. The separator may refer, for example, to a zigzag separator.

The battery processing installation 52 preferably comprises a comminutor, which

15 is preferably situated in the material flow in front of the classification device 74 and includes a rapid comminution tool, wherein a peripheral speed of the rotor is greater than 1 m/s, preferably greater than 10 m/s. This comminutor comminutes the comminuted material and subjects it to such mechanical stress that the electrochemically active coating at least partially detaches from the carrier. The

20 presence of such a comminutor is a generally preferred feature of a battery processing installation according to the invention.

A light fraction with a separator foil and fine coating material, and a heavy material fraction with carrier foils (aluminium and copper) with an easy-adhesive coating occur in the separator. Both fractions are each placed on a sieve for further

25 separation into coating and separator foil, or coating and metal foil. The further processing of the resulting fractions is conducted separately.

The breakdown material 66 is fed to the separator 62 by means of a third conveyor 68. A fourth conveyor 70 guides sifted material 72, in particular the material of the light fraction that leaves the separator 62, into a classification device

30 74. The classification device 74 preferably has an air jet sieve, which simultaneously functions as a separation device for separating the active material from

the carrier. The separation results in an active material fraction 76, with which a transport container 78 is filled.

In addition, a carrier fraction 80 is produced, which - in the present embodiment
5 - is fed into a filling unit 84 using a fifth conveyor 82; the filling unit fills a container 86 with the carrier fraction 80. The filling unit 84 comes together with a second filling unit 88 to form part of a second filling device.

Reference list

10	battery	50	pressurised gas cylinder
12	discharge unit	52	battery processing installation
14	dismantling station	54	standard container
16	cell	56	first conveyor
18	comminution unit	58	second conveyor
19	liquid nitrogen source		
20	shielding gas	60	breakdown comminutor
22	shielding gas cylinder	62	separator
24	comminuted material	64	transport container draining device
26	drying device	66	digestion material
28	airlock	68	third conveyor
29	vacuum installation		
30	vacuum pump	70	fourth conveyor
31	gas	72	sifted material
32	gas purification device	74	classification device
34	condenser	76	active material fraction
36	activated charcoal filter	78	transport container
38	condensate container		
40	control valve	80	carrier fraction
41	agitator	82	fifth conveyor
42	inactive comminuted material	84	filling unit
44	filling device	86	container
46	transport container	88	second filling unit
48	flushing line		
		p	force

Patentkrav

1. Fremgangsmåde til behandling af brugte lithiumbatterier (10) med trinnene:
 - (a) findeling af batterierne (10) således, at der opnås et findelt materiale (24),
 - (b) inaktivering af det findelte materiale (24) ved tørring således, at der opnås et inaktiveret findelt materiale (42),
kendetegnet ved, at
 - (c) tørringen udføres ved et maksimalt tryk på 300 hPa og en maksimal temperatur på 80°C, og
 - (d) det inaktiverede findelte materiale (42) fyldes i en transportbeholder (46).

2. Fremgangsmåde ifølge krav 1, **kendetegnet ved** at vakuummet skabes ved hjælp af en jetpumpe og et jetmedium for jetpumpen har en pH-værdi på mindst 8, fortrinsvis 9 og/eller indeholder et stof, der udfælder fluor.

3. Fremgangsmåde ifølge et af de ovenstående krav, **kendetegnet ved** trinnene:
 - (e) fjernelse af det findelte materiale (24) fra transportbeholderen (46)
 - (f) udskillelse af hårde dele og/eller separering af aktivt materiale fra bæreren, fortrinsvis gennem luftstrålesigter eller et andet findelingstrin, således at der opnås en aktiv materialefraktion (76) og en bærerfraktion (80), og
 - (g) separat pakning af den aktive materialefraktion (76) og bærerfraktionen (80) i transportbeholdere (78).

4. Fremgangsmåde ifølge et af de ovenstående krav, **kendetegnet ved**, at tørringen af det findelte materiale kun afsluttes, når der efter tørringsprocessen ikke kan dannes nogen brandfarlig eller eksplosiv gasblanding over det findelte materiale og/eller når det findelte materiale er så tørt, at ingen brandfarlig eller eksplosiv gasblanding kan opstå i transportbeholderen eller under den efterfølgende behandling.

5. Et batteriforarbejdningsanlæg til behandling af brugte batterier, fortrinsvis lithiumbatterier, med:
 - (a) en findelingsenhed (18) til findeling af batterierne (10), således at der opnås et findelt materiale (24),
 - (b) en inaktiveringsindretning i form af en tørreanordning (26) til inaktivering af det findelte materiale (24) og
 - (c) en vakuuminstallation, der er forbundet til tørreindretningen (26), **kendetegnet ved**
 - (d) en påfyldningsanordning (44) til påfyldning af det inaktiverede findelte materiale (24) i en transportbeholder (46),
 - (e) hvor vakuuminstallationens er forbundet til tørreindretningen (26) til frembringelse af et vakuum på mindst 300 hPa i tørreindretningen (26), og

(f) hvor tørreindretningen (26) er konfigureret til at tørre ved en maksimal temperatur på 80 ° C.

6. Batteriforarbejdningsanlæg ifølge krav 5, **kendetegnet ved**, at tørreanordningen (26) er konfigureret til at tørre det findelte materiale (24), indtil et elektrolytindhold er så lavt, at en elektrokemisk reaktion er umulig.

7. Batteriforarbejdningsanlæg ifølge krav 5 eller 6, **kendetegnet ved**, at findelingsenheden og tørreindretningen (26) er placeret i en standardbeholder (54).

8. Batteriforarbejdningsanlæg ifølge et af kravene 5 til 7, **kendetegnet ved** en vakuuminstallation, omfattende

- (a) en vakuumpumpe (30) og
- (b) en gasrensningssanordning (32), der er placeret mellem tørreanordningen (26) og vakuumpumpen (30), og
- (c) en kondensator (34) til kondensering af elektrolytter, fortrinsvis dimethylcarbonat og ethylmethylcarbonat.

9. Batteriforarbejdningsanlæg ifølge krav 8, **kendetegnet ved**, at

- vakuuminstallation (29) omfatter en jetpumpe med et jetmedium,
- jetmediet ledes i et kredsløb og
- jetmediet indeholder et stof, der reagerer med hydrogenfluorid.

10. Batteriforarbejdningsanlæg ifølge et af kravene 5 til 9, **kendetegnet ved**

- en anordning til udskilning af hårdt metal og/eller en anordning til udskilning af en let fraktion
- en separeringsindretning, fortrinsvis en klassificeringsindretning (74) til at separere aktivt materiale fra bæreren, fortrinsvis ved hjælp af luftstrålesigtning og/eller et andet findelingstrin, således at der forekommer en aktiv materialefraktion (76) og en bærefraktion (80), fortrinsvis aluminium - og kobberfolier, og
- en anden påfyldningsanordning (44) til den separate påfyldning af den aktive materialefraktion (76) og bærefractionen (80), fortrinsvis aluminium- og kobberfolier.

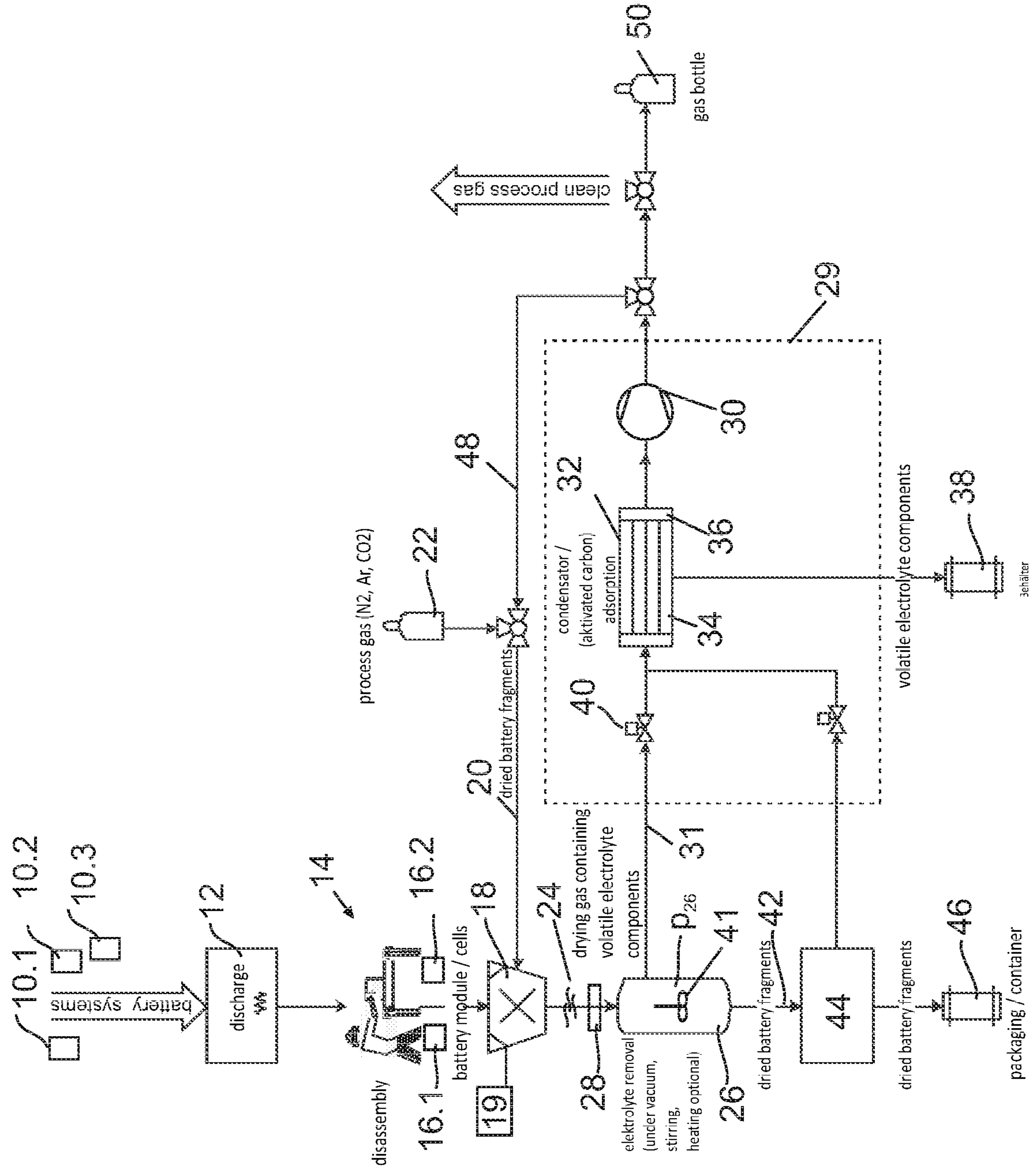


Fig. 1

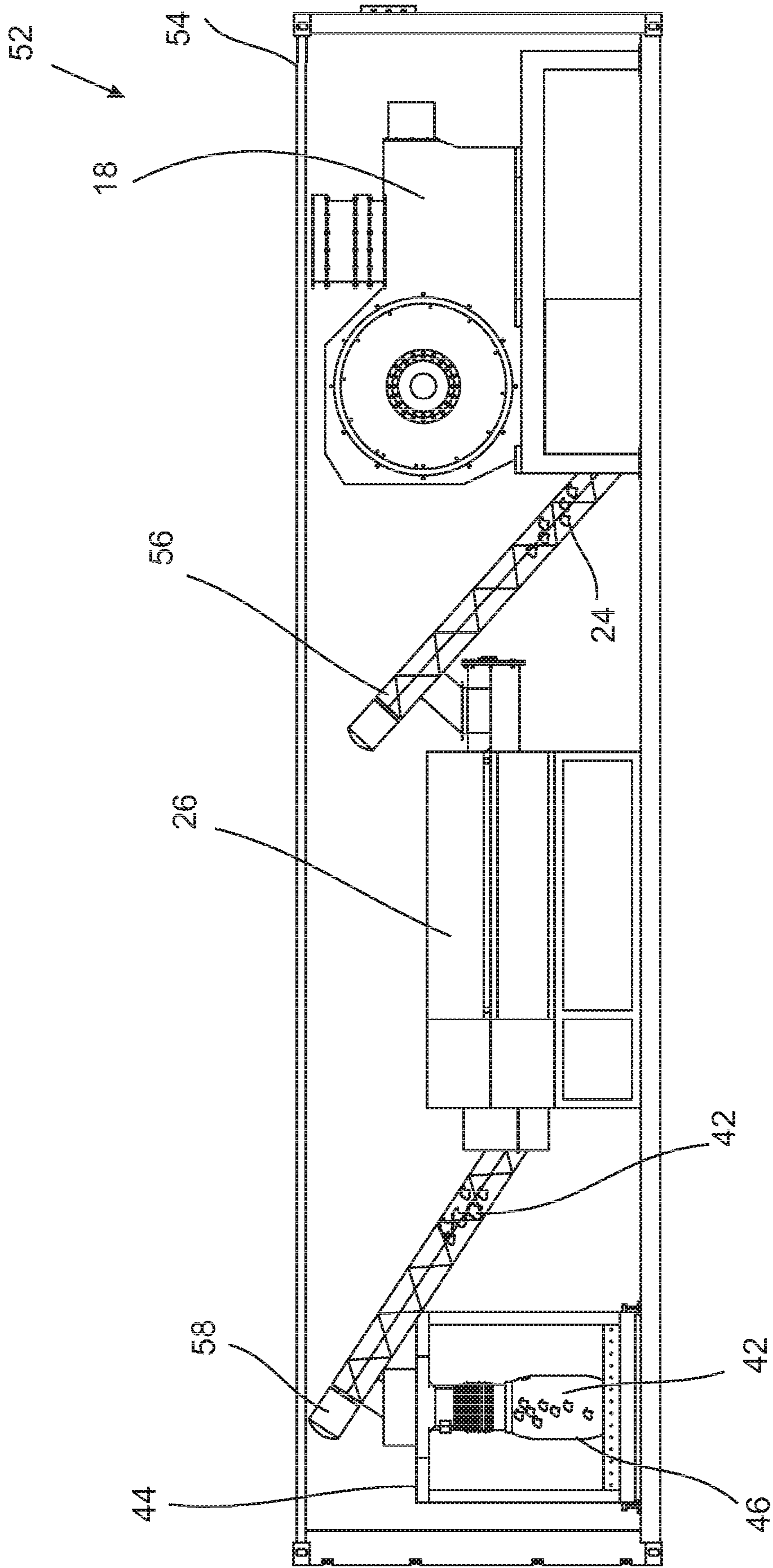


Fig. 2

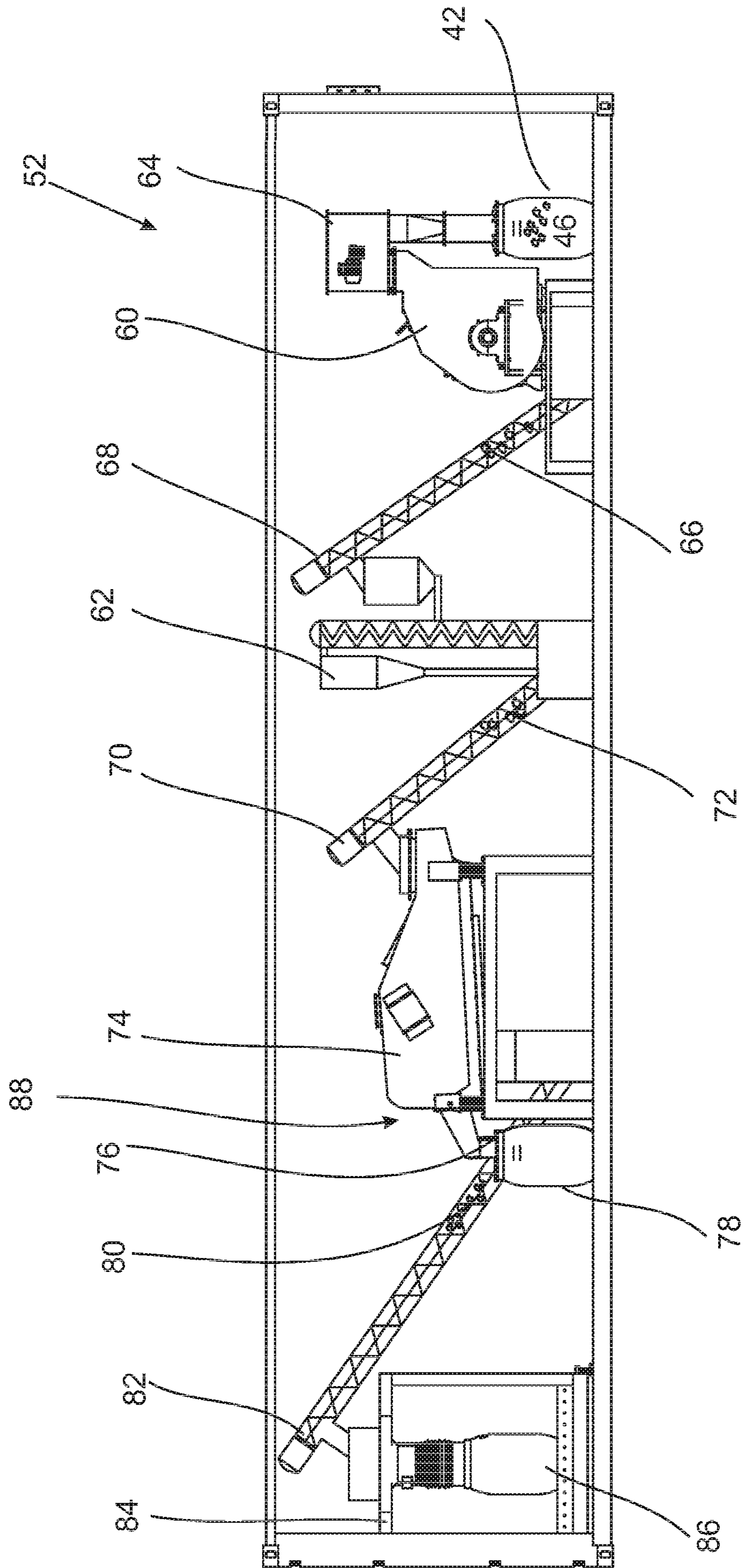


Fig. 3