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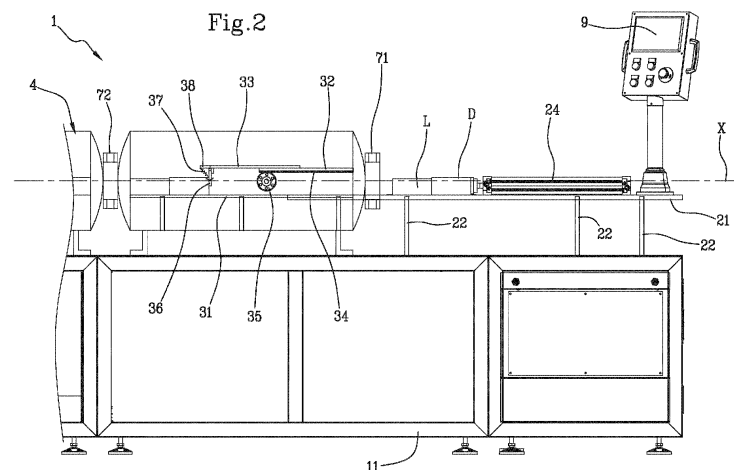
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(54) TUNNEL FURNACE FOR THE MELTING OF PLATINUM AND PALLADIUM

(57) Described is a tunnel furnace (1) for melting platinum and palladium, which comprises, on a load-bearing frame (11), along its direction of extension (X):
- a station (2) for loading at least one train of ingot moulds, located upstream of the tunnel furnace (1), comprising at least one ingot mould (L) having the metal to be melted and at least one spacer (D);
- a thrust chamber (3) and an outlet chamber (5) which have a variable pressure, designed to pass between a vacuum condition and an external pressure condition by depressurising and pressurising inert gas;
- a vacuum hood (4) interposed between the thrust cham-

ber (3) and the outlet chamber (5), connected to it, and which has a substantially constant vacuum pressure in such a way as to guarantee the degassing of said metal to be melted. The hood (4) comprises in succession at least one vacuumed melting zone (4a) and at least one vacuum solidification zone (4b);
- an unloading station (6) for the train of ingot moulds, positioned downstream of the tunnel furnace (1), in which the metal of the ingot mould (L) is in the solid ingot state;
- means (24, 12 32, 33, 34, 35, 36, 37, 52, 53, 54, 55, 56, 57, 61) for moving the train of ingot moulds between the loading station (2) and the unloading station (6).



Description

[0001] This invention relates to a tunnel furnace for melting precious and non-precious metals, in particular for platinum and palladium.

[0002] The production of platinum and palladium ingots is made difficult by the fact that these two metals tend not to release gas as oxygen and hydrogen present on the grain/powder/dross during the melting process but to retain them inside creating macro-voids in the ingot produced by the melting.

[0003] Moreover, the action of the oxygen together with high temperatures causes the oxidation of the ingot moulds housing the metallic material.

[0004] In the past, the melting of these metals comprised the heating with the oxyhydrogen blowpipe and the consequent hammering to obtain a single compact piece.

[0005] In order to overcome this trend, platinum and palladium are melted in a vacuum, so as to limit as much as possible the presence of gas in the metal, in special smelting furnaces and with personnel in charge of loading the ingot moulds in the furnace, closing it hermetically and unloading it so as to cool the ingot mould and metal, with all the problems connected with the safety of the operators and the labour costs.

[0006] Another problem of the manual process described above is that it does not allow the melted products to reach a high level of quality.

[0007] In addition, it is necessary to take into account the difficult repeatability of the results, since the outcome of this process is strictly linked to the sensitivity and experience of the operator.

[0008] According to the current state of the art, the automation of the production of precious metal ingots passes from the technology of the tunnel furnaces which comprises a train of ingot moulds being moved along the entire length of the tunnel furnace by means of suitable thrust devices, that is to say, means for pushing the train of ingots by the action of an actuator, passing through all the planned stations: loading of the material in the ingot moulds, melting of the metal, solidification, cooling and unloading of the finished ingot.

[0009] However, the production of platinum and palladium in vacuum does not match well with the configuration of these furnaces on account of the technical problem of making the train of ingots pass from zones in which a vacuum is not required (the loading and unloading stations), to zones in which, on the other hand, the vacuum is necessary (melting zone).

[0010] Moreover, the melting of platinum and palladium must occur in a station isolated atmospherically from the outside and in which a very strong vacuum must be guaranteed. Moreover, the graphite of the ingot moulds would have considerable problems to withstand extremely high temperatures in a controlled atmosphere.

[0011] Examples of furnaces for melting metals are described in JP H04 127958 (A) JP 2009/115413 (A). However,

these prior documents do not refer to the melting of platinum and palladium, but concern, respectively, multichamber and "gated system" type furnaces.

[0012] The aim of the invention is to overcome the above-mentioned drawbacks of prior art types of tunnel furnace for melting metals which allow the production of platinum and palladium ingots in an automated fashion.

[0013] In the context of the above-mentioned purpose, one aim of the invention is to provide a tunnel furnace for melting metals, particularly for platinum and palladium, which ensures melting of the metal in an area isolated atmospherically from the outside and in which there is a very strong vacuum.

[0014] Another aim of the invention is to allow the production with a minimum number of operators, who, amongst other things, can operate under the best safety conditions.

[0015] Yet another aim of the invention is to make a tunnel furnace for melting precious and non-precious metals, in particular for platinum and palladium, with means which are readily available on the market and using materials of common use, in such a way that the device is economically competitive. This purpose, as well as these and other aims which will become clearer below, are achieved by a tunnel furnace for melting metals, in particular for platinum and palladium, according to the invention, comprising, along its direction of extension:

- a station for loading at least one train of ingot moulds, located upstream of the tunnel furnace, comprising at least one ingot mould having the metal to be melted and at least one spacer;
- a thrust chamber and an outlet chamber both having a variable pressure, designed to pass between a vacuum condition and a condition of external pressure by means of the depressurisation and pressurisation of inert gas;
- a vacuum hood, interposed between said thrust chamber and said outlet chamber and connected to it, having a substantially constant vacuum pressure in such a way as to guarantee the degassing of said metal to be melted, and comprising in succession at least one vacuum melting zone and at least one vacuum solidification zone;
- a station for unloading said at least one train of ingot moulds, positioned downstream of the tunnel furnace, wherein said ingot mould has the metal in the solid ingot state;
- means for moving said at least one train of ingot moulds between said loading station and said unloading station.

[0016] Obviously, the external pressure condition is substantially atmospheric or higher (which is, to all intents and purposes, a technical equivalent).

[0017] Advantageously, the vacuum hood comprises, after the vacuum melting zone and the vacuum solidification zone, a vacuum cooling zone;

Advantageously, the loading station and the unloading station are integral with each other thanks to the fact that there is a first and a second supporting tray, respectively mounted on the two above-mentioned stations, which are in turn connected to the overall frame of the machine.

[0018] Preferably, the first supporting tray has a zero-setting contact for manual loading of the train of ingot moulds in a certain predetermined position.

[0019] The Applicant has provided that, in order to achieve a sort of pressurisation and decompression upstream and downstream of the vacuum hood, the thrust chamber and the outlet chamber are equipped with at least one pump or a dedicated pressure connection for the purpose and with guillotine valves at the inlet and outlet to prevent the passage of the air and hermetically close the chambers. For this purpose, the thrust chamber has a head valve for connection with the loading station and a second valve for connection with the vacuum hood; the outlet chamber, on the other hand, is interposed between a third valve which connects it to the vacuum hood and a tail valve for connection with the unloading station. Necessarily, for the correct operation of the vacuum hood, the second and the third valve can be opened only if the head and tail valves are closed and if the air is not present, respectively, in the thrust chamber or in the outlet chamber, in such a way that the oxygen, hydrogen and the other gases do not enter the melting and solidification zone.

[0020] Part of the means for moving the train of ingot moulds along the direction of extension of the furnace is a telescopic actuator which transmits a rectilinear motion towards the thrust chamber to the train of ingot moulds; this system has the advantage of reducing the overall dimensions on the loading surface, however, other linear movement systems are also acceptable.

[0021] Advantageously, the thrust chamber has transfer means for the train of ingot moulds from the loading station to the vacuum hood. These transfer means are also part of the above-mentioned movement means.

[0022] The transfer means comprise a thrust arm connected rigidly to a slide. The slide is designed to translate along the direction of extension of the furnace between the loading station and the vacuum hood, by means of the relative movement of a first rack, integral with the slide, and a first gearwheel driven by first motor means.

[0023] The Applicant has noted that a more effective result is achieved with this method, in particular allowing the movement of the train of ingot moulds without having to use pneumatic actuators which would also adversely affect the adjustment of the vacuum in the thrust and outlet chambers, as well as in the vacuum hood.

[0024] The thrust arm has a first movable contact hinged on a relative end, in such a way that the first movable contact can rotate, starting from an initial position, about a respective axis of rotation in the movement of the train of ingot moulds between the loading station and the vacuum hood.

[0025] When, on the other hand, the thrust arm must

move the train of ingot moulds from the thrust chamber to the vacuum hood, the movable contact is positioned in a direction substantially perpendicular to the feed plane of the thrust arm. In this case, its rotation is blocked on one side by the train of ingot moulds (which it must move) whilst, on the other side, by a shaped mechanical contact element on the thrust arm. When, on the other hand, the thrust arm returns, without train of ingot moulds to the initial position, the Applicant understood it is necessary to rotate the first contact in the opposite direction, in such a way as to allow the transfer of the slide between the vacuum hood and the loading station. This is with the mounting of a compression spring which, when the first contact is in the initial position, is in the rest configuration, whilst when the first contact slides on the successive ingot moulds it is compressed.

[0026] Preferably, the vacuum hood comprises firstly at least one inductor turn or alternative heating means such as heating elements, which defines the melting zone and is actuated by a generator. The turn is wound around a melting furnace made of material resistant to high temperatures. Following the inductor turn there is at least one solidification plate made of copper or other metals, cooled internally, which, on the other hand, defines said solidification zone and, therefore, the hood comprises at least a portion of a first water cooled cooling tunnel which defines a first vacuum cooling zone.

[0027] The first cooling zone contributes mainly to cooling the ingot mould, which therefore exits from the vacuum at a temperature that is not too high, so as to preserve the mechanical properties of the heat-resistant material from which it is made.

[0028] Advantageously, the vacuum hood comprises two covering walls defining a flow gap for a coolant fluid, such as, for example, cooling water, in such a way as to prevent overheating of the furnace.

[0029] The outlet chamber advantageously comprises a second cooling zone where there is a cooled pickup plate, preferably cooled by water, to complete the cooling of the ingot and of the ingot mould.

[0030] The Applicant has understood that, in order to better preserve the vacuum conditions of the hood and allow the correct closing of the guillotine valve, it is advantageous that the pickup plate is movable along the direction of extension of the furnace, in such a way as to allow the transfer of the train of ingot moulds from the vacuum hood to the unloading station.

[0031] The above-mentioned pickup plate is integral with a second rack moved by a second gearwheel driven by second motor means; by means of this linear movement the table transfers at least one train of ingot moulds from the vacuum hood to the outlet chamber.

[0032] Similarly to what is described for the transfer means, there is preferably a pickup arm connected to the unloading station and preferably driven by compressed air. The pickup arm has a second movable contact hinged on a relative end, in such a way that the second movable contact rotates, from the initial position, about a respec-

tive axis of rotation, to engage the train of ingot moulds in its movement between the outlet chamber and the unloading station. When, on the other hand, the train of ingots is unloaded, the pickup arm returns into position, that is to say, it moves in the opposite direction, between the unloading station and the outlet chamber, the action of second elastic means, such as a compression spring, return the second contact to the initial position.

[0033] The latter are also part of the above-mentioned movement means. Preferably, an electronic control unit is used for interacting with an operator and is programmable, in such a way as to control the automation of the furnace.

[0034] The invention also relates to a method for the production of ingots, made particularly of platinum and palladium or their alloys, which comprises the following sequence of steps:

- loading at least one train of ingot moulds comprising at least one ingot mould having the metal to be melted and at least one spacer in a loading station;
- transferring the train of ingot moulds from the loading station towards the inside of a thrust chamber, which is at an external pressure substantially equal to atmospheric pressure (or higher);
- isolating the thrust chamber relative to the outside, that is, relative to - on one side - the loading station and - on the other side - relative to the vacuum hood to which the thrust chamber is connected and which is at a predetermined vacuum pressure, by means of at least one vacuum pump and a head valve;
- bringing the inside of the thrust chamber substantially to the same predetermined pressure as the vacuum hood;
- communicating the thrust chamber with the vacuum hood opening a second valve;
- transferring the train of ingot moulds from the thrust chamber to a vacuum melting zone inside the vacuum hood;
- isolating the vacuum hood from the thrust chamber by closing the second valve;
- melting the metal contained inside the ingot mould;
- after melting, transferring the train of ingot moulds from the melting zone to a vacuum solidification zone, again in the vacuum hood;
- transferring the train of ingot moulds from the solidification zone to a first vacuum cooling zone, also inside the vacuum hood;
- communicating the vacuum hood with an outlet chamber, connected to the hood on the opposite side relative to the thrust chamber, by opening at least a third valve;
- transferring the train of ingot moulds from the vacuum hood to the outlet chamber, which has a pressure substantially equal to the predetermined vacuum pressure of the vacuum hood;
- isolating the thrust chamber from the vacuum hood, by closing the third valve;

- communicating the outlet chamber with an unloading station connected to it on the opposite side of the third valve, by opening a tail valve;
- after reaching the pressure equal to the external pressure also inside the outlet chamber, for example by introducing inert gas to speed up the process, the train of ingot moulds is transferred from the outlet chamber to the unloading station.

[0035] The above-mentioned steps, as well as all the other actions which contribute to defining the method for making ingots, made particularly of platinum and palladium or their alloys, according to the invention, are controlled by a programmable electronic control unit, designed to interact with an operator, which automates the furnace.

[0036] During the vacuum melting and the vacuum solidification, as well as preferably also during cooling in the first vacuum cooling zone, the vacuum hood is isolated from the outside with the simultaneous closing of the second and third valve (guillotine type).

[0037] After the transit of the train of ingot moulds, in order to favour the automation of the system, the thrust chamber is isolated from at least the vacuum hood and an inert gas is introduced, to speed up the reaching of the external pressure in the thrust chamber. In this way, a second train of ingot moulds, after the first, that is, the one already inside the vacuum hood, is pushed into the thrust chamber and is therefore ready to be transferred into the vacuum hood when, after the first train has come out, the vacuum will be formed inside the thrust chamber.

[0038] In the same way, after the first train of ingot moulds has been transferred to the unloading station, the vacuum is restored in the outlet chamber to receive the next train coming from the vacuum hood.

[0039] Advantageously, the cooling of the train of ingot moulds is further cooled at external pressure in the outlet chamber where there is a second cooling zone.

[0040] Further features and advantages of the invention are more apparent in the description below, with reference to a preferred, non-limiting embodiment of the tunnel furnace for the melting of precious and non-precious metals, in particular for platinum and palladium, illustrated by way of example and without limiting the scope of the invention, with the aid of the accompanying drawings, in which:

Figure 1 shows a side view of the tunnel furnace 1 as a whole;

Figure 2 shows a first detail of Figure 1, showing the loading station 2 and the thrust chamber 3;

Figure 3 shows a second detail of Figure 1, showing the vacuum hood 4;

Figure 4 shows a further detail of Figure 1, showing the outlet chamber 5 and the unloading station 6;

Figure 5A illustrates a side view of the vacuum hood 4 and the outlet chamber 5, with the pickup plate 52 ready to receive the train of ingot moulds coming

from the first cooling tunnel 43;

Figure 5B illustrates a side view of the vacuum hood 4 and the outlet chamber 5, with the train of ingot moulds which, pushed by the action of the movement means, is positioned on the pickup plate;

Figure 5C illustrates a side view of the vacuum hood 4 and the outlet chamber 5, with the train of ingot moulds completely inside the outlet chamber 5, following the withdrawal of the second cooling tunnel 43 along the direction X.

[0041] The above-mentioned drawings show a preferred embodiment of a tunnel furnace for melting metals, in particular for platinum and palladium, according to the invention, which is denoted in its entirety with the numeral 1 and which comprises, along its direction of extension X (Figure 1):

- a station 2 for loading a train of ingot moulds, located upstream of the tunnel furnace 1. This train of ingot moulds consists of an ingot mould L containing the metal to be melted, for example in the form of powder, grain and dross, and a spacer D;
- a thrust chamber 3 and an outlet chamber 5 both having a variable pressure, designed to pass between a predetermined vacuum pressure, for example 10^{-3} Pa, and the external atmospheric pressure by depressurising and pressurising the inert gas inside the chambers 3 and 5;
- a vacuum hood 4, interposed between the thrust chamber 3 and the outlet chamber 5 and connected to it. The hood 4 has a substantially constant vacuum pressure so as to guarantee the degassing of the metal to be melted during melting and also comprises, one after another, a melting zone 4a, a solidification zone 4b and a first cooling zone 4c;
- a station 6 for unloading the train of ingot moulds, positioned downstream of the tunnel furnace 1, wherein the metal of the ingot mould L is in the solid ingot state;
- means of moving the train of ingot moulds between the loading station 2 and the unloading station 6.

[0042] The loading station 2 comprises a first supporting tray 21, integral with a second supporting tray 61, by means of suitable supports 22 and 62 connected to the load-bearing frame 11 of the furnace 1. On the first tray 21 there is a zero-setting stop for loading the trains of ingot moulds manually or by means of conveyor belts. Each train consists of a ingot mould L and a spacer D, preferably made of graphite, and the possible use of other refractory materials such as boron nitride. The operator loads manually, or by using suitable means, the train on the tray 21 in a predetermined position. By means of the action of a telescopic actuator 24, of per se known type, the train is inserted inside the thrust chamber 3 to the desired position (Figure 2).

[0043] On the tray 21 there is also a control panel 9 by

means of which the operator interacts with the electronic control unit and can therefore control the status of the furnace 1 and act manually on the furnace 1.

[0044] By means of the telescopic actuator 24 it is possible to move the trains along the direction of extension X of the tunnel furnace 1 towards the thrust chamber 3. The chamber 3 is equipped with a front door which can be opened to allow operations for maintenance, installation and control of the system. Installed on the door there are inspection means, for example a window, for controlling the situation in the chamber 3 from the outside. At the ends of the chamber 3 there are two guillotine valves 71 and 72, respectively the head and second valve, with a circular cross section, which guarantee the seal of the chamber 3 when the vacuum condition is generated inside it.

[0045] The vacuum condition is generated by a vacuum pump system 78-79. This system also allows the chamber 3 to be pressurised with inert gas, such as nitrogen, up to the desired pressure level, normally atmospheric pressure, the level of which is monitored continuously by a pressure sensor. Depending on the measured pressure level, the vacuum pump system 78-79 activates to reach the desired pressure condition.

[0046] As illustrated in Figure 2, inside the thrust chamber 3 there is a sliding surface 31 for a slide 32 on which the train of ingot moulds is positioned. The train is moved from the chamber 5 to the vacuum hood 4 by a thrust arm 33 connected rigidly to the slide 32. The arm 33-slide 32 system can translate inside the chamber 3 along the direction X by means of the relative movement between a rack 34 defined on the lower face, with respect to the ground, of the slide 32, and a gearwheel 35 driven by a gear motor (not illustrated) located outside the chamber 3 (Figure 2). A movable contact 36 hinged on an end of the arm 33 is installed on the thrust arm 33. In this way, the contact 36 can rotate relative to the hinge when the train is moved from the inlet of the thrust chamber 3, from the loading station, due to the contact of the contact 36 with the train. Once the train of ingot moulds has passed beyond the movable contact 36 by the action of a return spring 37, the contact 36 is returned to the initial position. The rotation of the contact 36 in the opposite direction (in this case anticlockwise) which is generated during the operation for pushing the train from the thrust chamber 3 to the vacuum hood 4 is prevented by a first contact element 38 installed on the arm 33. The forward movement of the thrust arm 33 coincides with the movement of the train of ingot moulds from the thrust chamber 3 to the melting zone 4a of the vacuum hood 4, in this way the ingot mould containing the metal to be melted is positioned correctly in the centre of the inductor turn 41.

[0047] The vacuum hood 4, in a similar manner to the thrust chamber 3, has two doors: one rear and one front (not illustrated) which, if open, allow the maintenance, assembly and inspection of the system. It is also possible to visually check part of the inner chamber by means of an inspection window.

[0048] A second guillotine valve 72 (in common with the thrust chamber 3) and a third guillotine valve 73 (in common with the outlet chamber 5) are installed at the ends of the hood 4 which, with the action of the vacuum pump system 78-79, contributes to maintaining a pressure of approximately 10^{-3} Pa inside the hood 4. The vacuum hood 4 is also equipped with two walls, one outside and one inside (not illustrated), in the gap of which cold water flows for cooling the hood 4 due to the heat which is generated during melting of the metal (Figure 3).

[0049] The melting zone 4a has an inductor unit consisting of the turn 41 wound around a tunnel resistant to high temperatures, inside which the ingot moulds L and the spacers D slide.

[0050] With reference to Figure 3, the turn 41, connected to a generator 46, generates a magnetic field which by induction tends to heat the precious metal and the ingot mould until reaching the melting temperature of the metal. During the entire melting process inside the hood 4 a vacuum level is maintained substantially equal to 10^{-3} Pa, to guarantee the continuous degassing of residual gases present in the metal.

[0051] The degassing is also guaranteed by the presence of ingot moulds having a base and covers with shapes such as not to guarantee a hermetic seal. By means of the thrust system generated by the movement means, the trains of ingot moulds move from the melting zone 4a to the solidification zone 4b.

[0052] The solidification zone 4b consists of an internally cooled copper plate 42 which allows rapid cooling of the ingot moulds and the solidification of the metal inside the ingot mould, by the action of a hydraulic pump 77.

[0053] There is also a cupola 45 of heat-resistant material, of per se known type, designed to allow the reflection of heat on the cover of the ingot mould, and therefore slow down the cooling. The pressure is monitored through a pressure sensor (not illustrated), similarly to the thrust chamber 3, whilst the temperature of the ingot moulds on the solidification plate is monitored by an optical pyrometer (also not illustrated), which may also be applied in the melting chamber, directed on the ingot mould L. The cooling zone comprises a water-cooled tunnel 43, which allows the temperature of the ingot moulds coming out of the hood 4 to be lowered. The vacuum hood 4 is also advantageously equipped with specific passages for the hydraulic, pneumatic and electrical connections to be carried inside it.

[0054] In a similar manner to that described for the outlet chamber 3 and the vacuum hood 4, the outlet chamber 5 is also equipped with one or more doors which can be opened (not illustrated) for maintenance and control operations.

[0055] Advantageously, the chamber 5 is equipped with a gap cooling system like the chamber 3. The purpose of this station is to extract the train of ingot moulds from the cooling zone 4c of the hood 4 and continue the cooling as required, so that the graphite components can

be extracted from the furnace 1. In this way it is possible to prevent the graphite of the ingot moulds L, which are highly reactive at high temperatures, from reacting with the oxygen present in the atmosphere and being quickly consumed. Inside the chamber 5 there is a pickup plate 52 formed inside a second, water-cooled cooling tunnel 59, which is movable and retractable, moved with a gear-wheel 55-rack 54 system. The movement of the train from the vacuum hood 4 to the outlet chamber 5 occurs by the relative movement between the second rack 54, defined on the surface of the pickup plate 52 facing the ground, and the second gearwheel 55 driven by a second gear motor (not illustrated) which allow the feeding of the ingot mould L with the relative spacer D (Figure 4).

[0056] In order to remove the ingot moulds from the furnace 1, a pickup arm 53 is used. The latter is actuated by an extraction actuator 65 installed on the unloading station 6, which transfers the train of ingot moulds from the outlet chamber 5 to the unloading station 6. Similarly to what was described above for the thrust chamber 3, the pickup arm 53 is equipped with a second movable contact 56 hinged at one end, in such a way that the second contact 56 rotates about a respective axis of rotation 50 during the movement of the train of ingot moulds between the vacuum hood 4 and the unloading station 6.

[0057] After reaching the vacuum condition in the outlet chamber 5 thanks to the vacuum pump system (same pressure level of the hood 4, that is to say, 10^{-3} Pa) it is possible to open the second valve 73. Once the valve has been opened, the movable plate 52 moves from the chamber 5 to the hood 4 close to the cooling zone 5c (Figure 5A). The feed movement of the ingot moulds, generated by the movement means, means that a train moves from the cooling tunnel 43 up to above the movable plate 52 (Figure 5B). Once the ingot moulds have been loaded, the plate 52 retracts to its initial position, moving the ingot moulds from the vacuum hood 4 to the outlet chamber 5 (Figure 5C). The second guillotine valve 73 closes without obstructing any train of ingot moulds. The train remains on the cooled extraction plate 52 to be further cooled and be ready for extraction from the furnace 1. By using the vacuum pump system the outlet chamber 5 is pressurised, with inert gas, up to the external atmospheric pressure; once the temperature of the ingot moulds has been sufficiently reduced the tail guillotine valve 74 opens. By means of the extraction system with the extraction actuator 65, the ingot moulds are extracted from the outlet chamber 5 to the outside of the furnace. The tail valve 74 closes, the vacuum is created again inside the chamber 5 and the cycle is repeated.

[0058] Necessarily, the size of the opening of the valves 71-74 is such as to allow the passage of the train of ingot moulds between one chamber/hood and the other.

[0059] During the forward movement of the arm 53, the contact 56 rotates in contact with the train and slides above it during the forward movement. The contact 56 is made of an anti-wear material, so as not to consume

the ingot moulds L during the contact. Once the contact 56, thanks to the feed motion of the extraction actuator 65, has passed the train of ingot moulds, by means of the return action of the spring 57 interposed between the contact 56 and the arm 53 and thanks to a second contact element 58, it returns to the initial vertical position. In this way, when the actuator 65 retracts the contact 56 it allows the extraction of the train of ingot moulds from the chamber 5. Once the actuator 65 has completed its retraction stroke, the operator, or an automatic belt, may safely unload the train from the cooling plate 63.

[0060] Once the train has been extracted from the outlet chamber 5, the operator (or an automatic mechanism) can unload the train from the surface 61, extracting the ingot from the ingot mould, refilling the ingot mould L with the precious metal, positioning the train on the loading template and thereby starting the production cycle.

[0061] The furnace 1 obviously comprises a load-bearing frame 11 on which the stations 2 and 6, the chambers 3 and 5 and the vacuum hood 4 will rest. The pneumatic and hydraulic system of the furnace will also be located inside the frame 11.

[0062] From the above description it may be seen how the invention achieves the preset purpose and aims and in particular the fact that a tunnel furnace is made for the melting of metals, in particular for platinum and palladium, which allows the production of platinum and palladium ingots, or, in general, particularly reactive metals if melted in air in an automated manner.

[0063] In particular, the system comprising the movement means, controlled by a programmable electronic control unit, allows the transfer of the train of ingot moulds between the loading station and the unloading station, completing all the processing steps planned along the axis of extension of the tunnel furnace.

[0064] Another advantage of the invention is due to the fact that, by means of the strong vacuum formed in the vacuum hood, the metal is molten and solidified in an area isolated from the outside atmosphere; the thrust and outlet chambers, which have a variable pressure between the vacuum of the hood and the external atmospheric pressure or higher, act as compression and decompression chambers.

[0065] Moreover, another advantage of the invention is due to the fact that the complete automation, including the controlled opening and closing of the valves, allows the production of ingots using a minimum number of operators, who, thanks to the systems provided, operate in the best safety conditions.

[0066] Another advantage of the furnace and the method according to the invention is due to the fact that the automation of this process guarantees a high quality of the ingots produced and the perfect repeatability of the product, guaranteed by the industrial mechanisation.

[0067] Lastly, the use of means which are easily available on the market and the use of common materials makes the device economically competitive.

[0068] The invention can be modified and adapted in

several ways without thereby departing from the scope of the inventive concept.

[0069] Moreover, all the details of the invention may be substituted by other technically equivalent elements.

[0070] In practice, the materials used, as well as the dimensions, may be of any type, depending on requirements, provided that they are consistent with their production purposes.

Claims

1. A tunnel furnace (1) for melting platinum and palladium, comprising, on a load-bearing frame (11), along its direction of extension (X):

- a station (2) for loading at least one train of ingot moulds, located upstream of the tunnel furnace (1), comprising a succession of ingot moulds (L) with the metal to be melted, and a spacer (D) interposed between two successive ingot moulds;
- a thrust chamber (3) and an outlet chamber (5) both having a variable pressure, designed to pass between a vacuum condition and an external pressure condition by depressurising and pressurising inert gas;
- a vacuum hood (4), interposed between said thrust chamber (3) and said outlet chamber (5) and connected to it, having a substantially constant vacuum pressure in such a way as to guarantee the degassing of said metal to be melted, and comprising in succession at least one vacuum melting zone (4a) and at least one vacuum solidification zone (4b);
- a station (6) for unloading said at least one train of ingot moulds, positioned downstream of the tunnel furnace (1), wherein said ingot mould (L) has the metal in the solid ingot state;
- movement means (24, 12 32, 33, 34, 35, 36, 37, 52, 53, 54, 55, 56, 57, 61) for moving the at least one train of ingot moulds between said loading station (2) and the unloading station (6).

2. The furnace (1) according to claim 1, wherein said loading station (2) and said unloading station (6) comprise at least a respective first supporting tray (21) and a second supporting tray (61) connected to each other, said first supporting tray (21) having a zero-setting contact for loading said at least one train of ingot moulds.

3. The furnace (1) according to claim 1 or 2, wherein said thrust chamber (3) and said outlet chamber (5) respectively comprise, at the inlet, at least a head valve (71) and at least a third valve (73) and, at the outlet, at least a second valve (72) and at least a tail valve (74), to isolate the pressure inside the thrust

chamber (3) relative to the outside, preferably said at least a head valve (71) and/or said at least a second valve (72) and/or said at least a third valve (74) and/or said at least a tail valve (74) being of the guillotine type.

4. The furnace (1) according to claim 3, wherein the thrust chamber (3) comprises transfer means (32, 33, 34, 35, 36, 37) for said at least one train of ingot moulds from said loading station (2) to said vacuum hood (4).

5. The furnace (1) according to claim 4, wherein said transfer means (32, 33, 34, 35, 36, 37) comprise a thrust arm (33) connected to a slide (32) designed to translate along said direction of extension (X) between said loading station (2) and said vacuum hood (4) by the relative movement between a first rack (34) integral with said slide (32) and a first gearwheel (35) driven by first motor means, said first thrust arm (33) having a first movable contact (36) hinged on one end of it, in such a way that said first movable contact (36) can rotate about a respective axis of rotation (30) during the movement of said train of ingot moulds between said loading station (2) and said vacuum hood (4); whilst it can rotate, in the opposite direction, between said vacuum hood (4) and said loading station (2), by the action of first elastic means (37).

6. The furnace (1) according to any one of claims 1 to 5, wherein said vacuum hood (4) comprises in succession:

- at least one inductor turn (41), wound around a melting tunnel made of material resistant to high temperatures, defining said vacuum melting zone (4a);
- at least one solidification plate (42) defining said vacuum solidification zone (4b); and
- at least a portion of a first cooling tunnel (43) forming a first vacuum cooling zone (4c).

7. The furnace (1) according to any one of claims 1 to 6, wherein said outlet chamber (5) comprises a pickup plate (52), for cooling at least said ingot mould (L), extending along said direction of extension (X), forming a second cooling zone (5c) at a transition pressure between the vacuum pressure and the external pressure.

8. The furnace (1) according to claim 7, wherein the movement of said at least one train of ingot moulds on said pickup plate (52), from said vacuum hood (4) to said unloading station (6), is actuated by the use of a pickup arm (53), connected to said load-bearing frame (11), with said train of ingot moulds and the relative movement between a second rack

(54) integral with said pickup plate (52) and a second gearwheel (55) driven by second motor means (51), said pickup arm (53) having a second movable contact (56) hinged on one end, in such a way that said second movable contact (56) can rotate about a respective axis of rotation (50) during the movement of said train of ingot moulds between said vacuum hood (4) and said unloading station (6); whilst it can rotate in the opposite direction, between said unloading station (6) and said vacuum hood (4) by means of the action of second elastic means (57).

9. A method for the production of ingots, made of platinum and palladium or their alloys, comprising the succession of steps which consist of:

- loading at least one train of ingot moulds comprising at least one ingot mould (L) having the metal to be melted and a spacer (D) in a loading station (2);
- transferring said at least one train of ingot moulds from said loading station (2) towards the inside of a thrust chamber (3) at external pressure;
- isolating said thrust chamber (3) from the outside using at least one head valve (71);
- bringing the inside of said thrust chamber (3) to a predetermined vacuum pressure substantially equal to the pressure present in a vacuum hood (4) connected to it;
- communicating said thrust chamber (3) with said vacuum hood (4) by opening at least a second valve (72);
- transferring the at least one train of ingot moulds from the thrust chamber (3) to a vacuum melting zone (4a) inside said vacuum hood (4);
- isolating said vacuum hood (4) by closing said at least one second valve (72);
- melting the metal contained inside said at least one ingot mould (L);
- transferring the at least one train of ingot moulds from the vacuum melting zone (4a) to a vacuum solidification zone (4b) inside said vacuum hood (4);
- transferring the at least one train of ingot moulds from said vacuum solidification zone (4b) to a first vacuum cooling zone (4c) inside said vacuum hood (4);
- communicating said vacuum hood (4) with an outlet chamber (5) by opening at least a third valve (73);
- transferring said at least one train of ingot moulds from the vacuum hood (4) to an outlet chamber (5) connected to it and having a pressure substantially equal to the pressure of the vacuum hood (4);
- isolating the thrust chamber (5) by closing said at least one third valve (73);

- communicating said outlet chamber (5) with an unloading station (6) by opening at least one tail valve (74);
- transferring the at least one train of ingot moulds from said outlet chamber (5) to an unloading station (6).

10. The method according to claim 9, wherein, after the step of isolating said outlet chamber (5), the cooling of said at least one train of ingot moulds is completed in a second cooling zone (5c) inside said outlet chamber (5).

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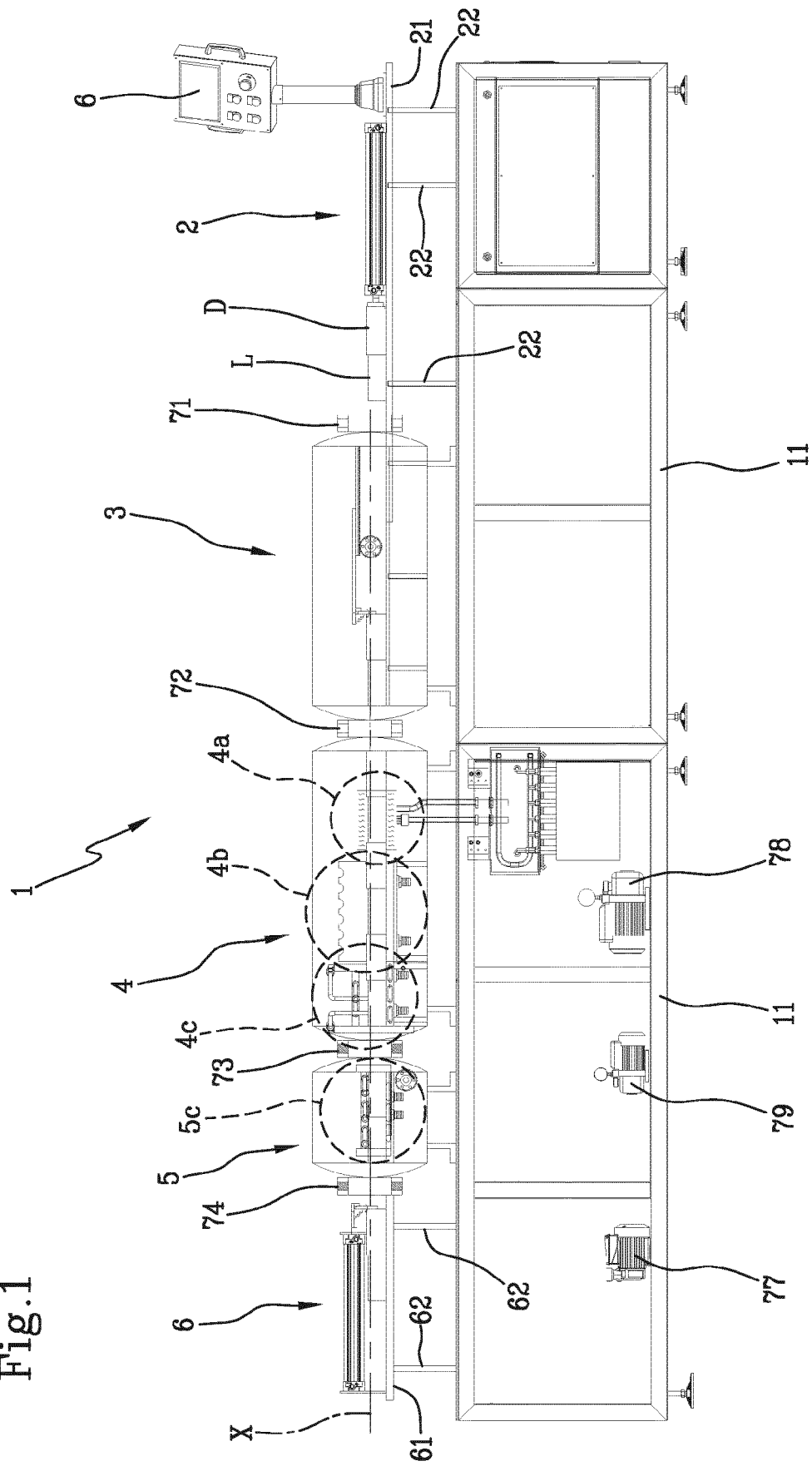
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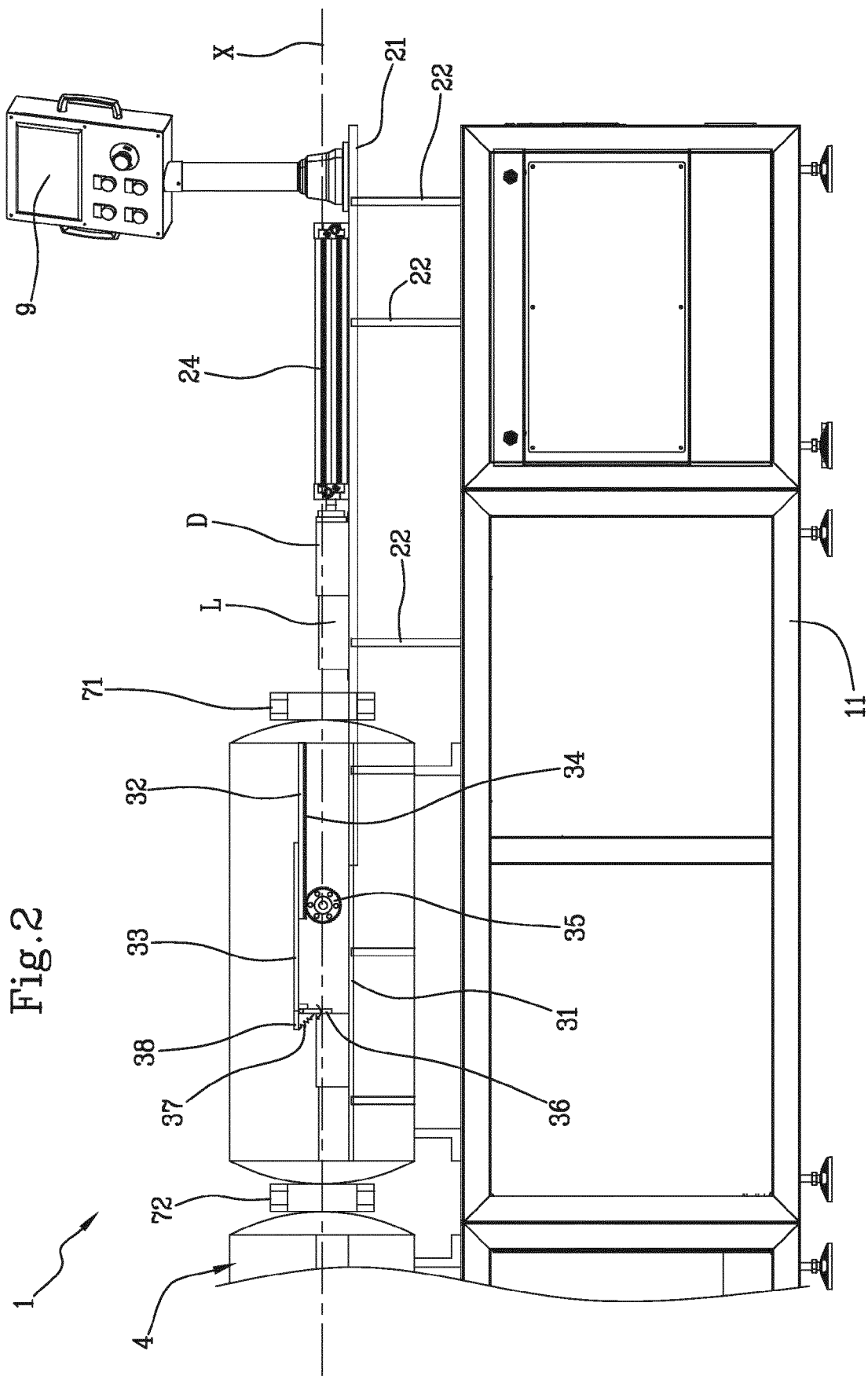
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Fig.1





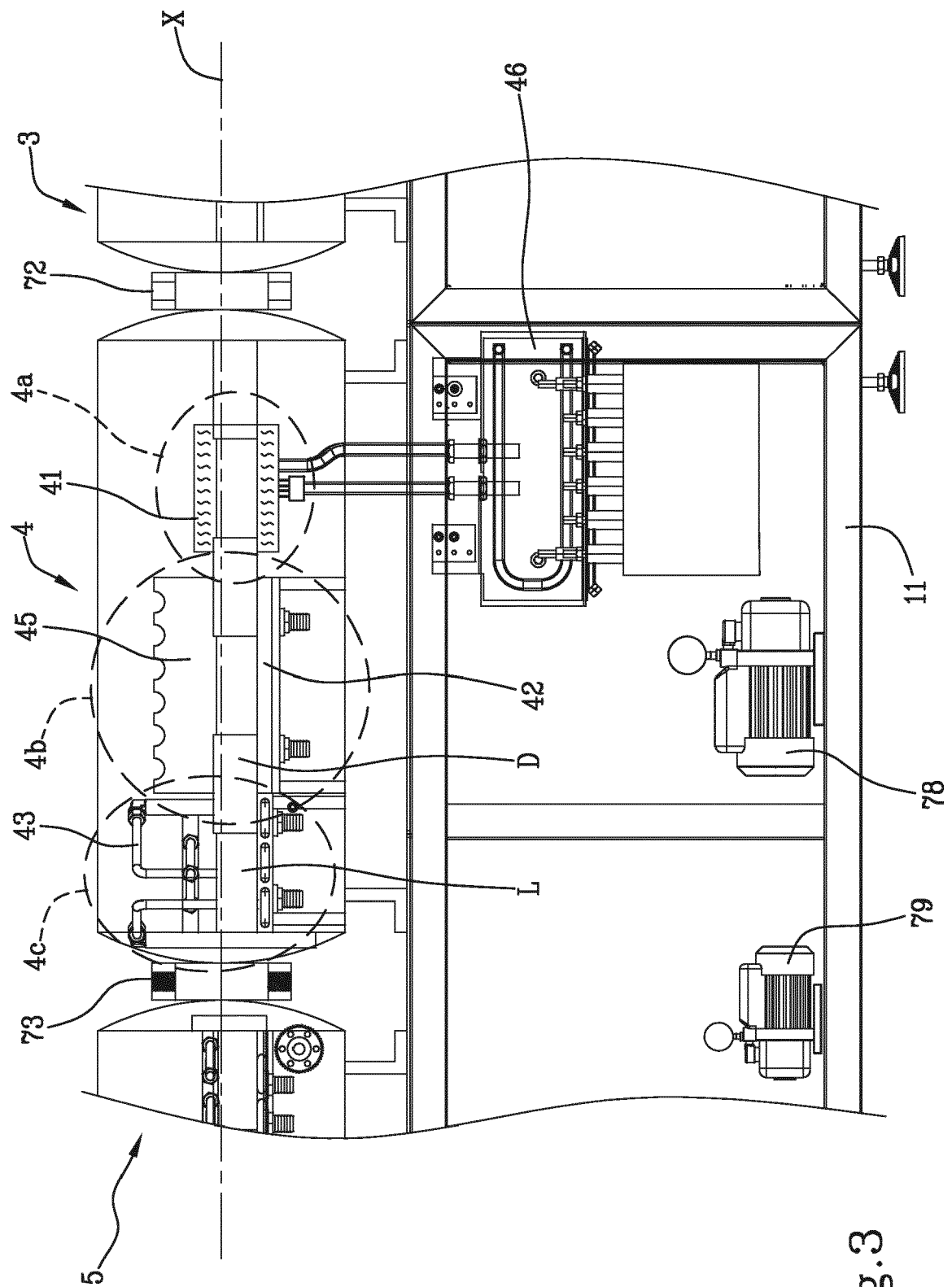


Fig. 3

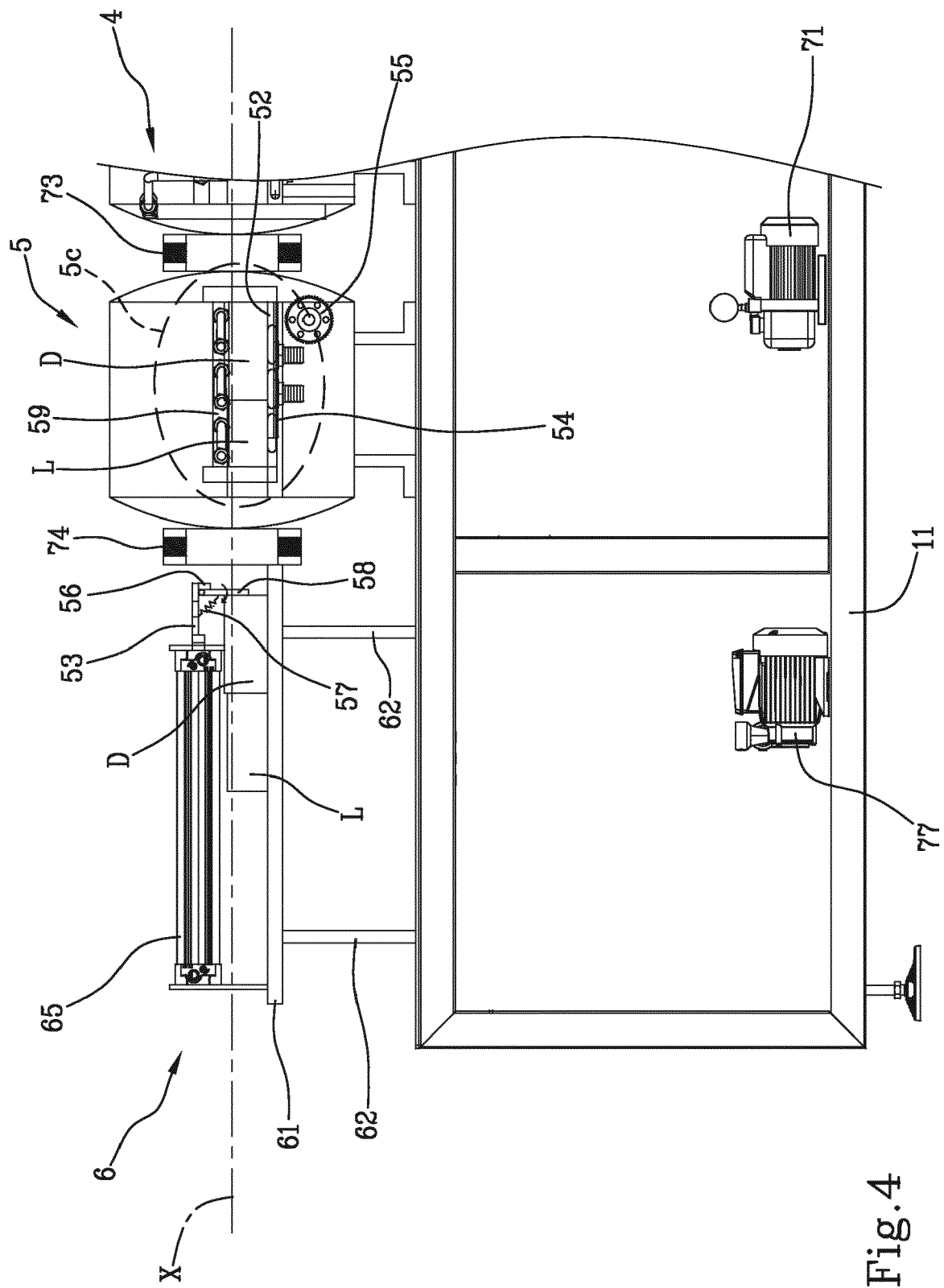


Fig. 4

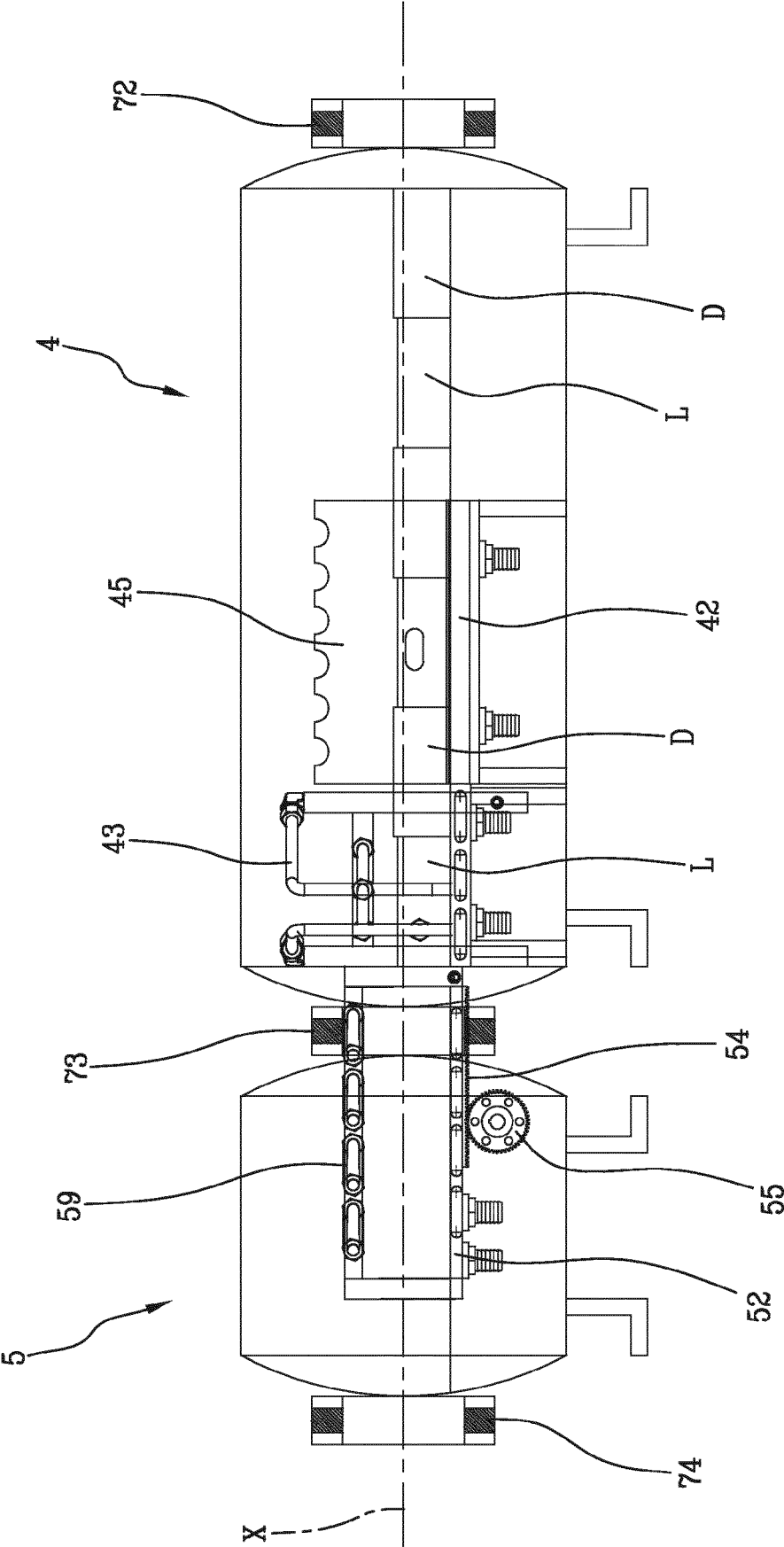


Fig.5A

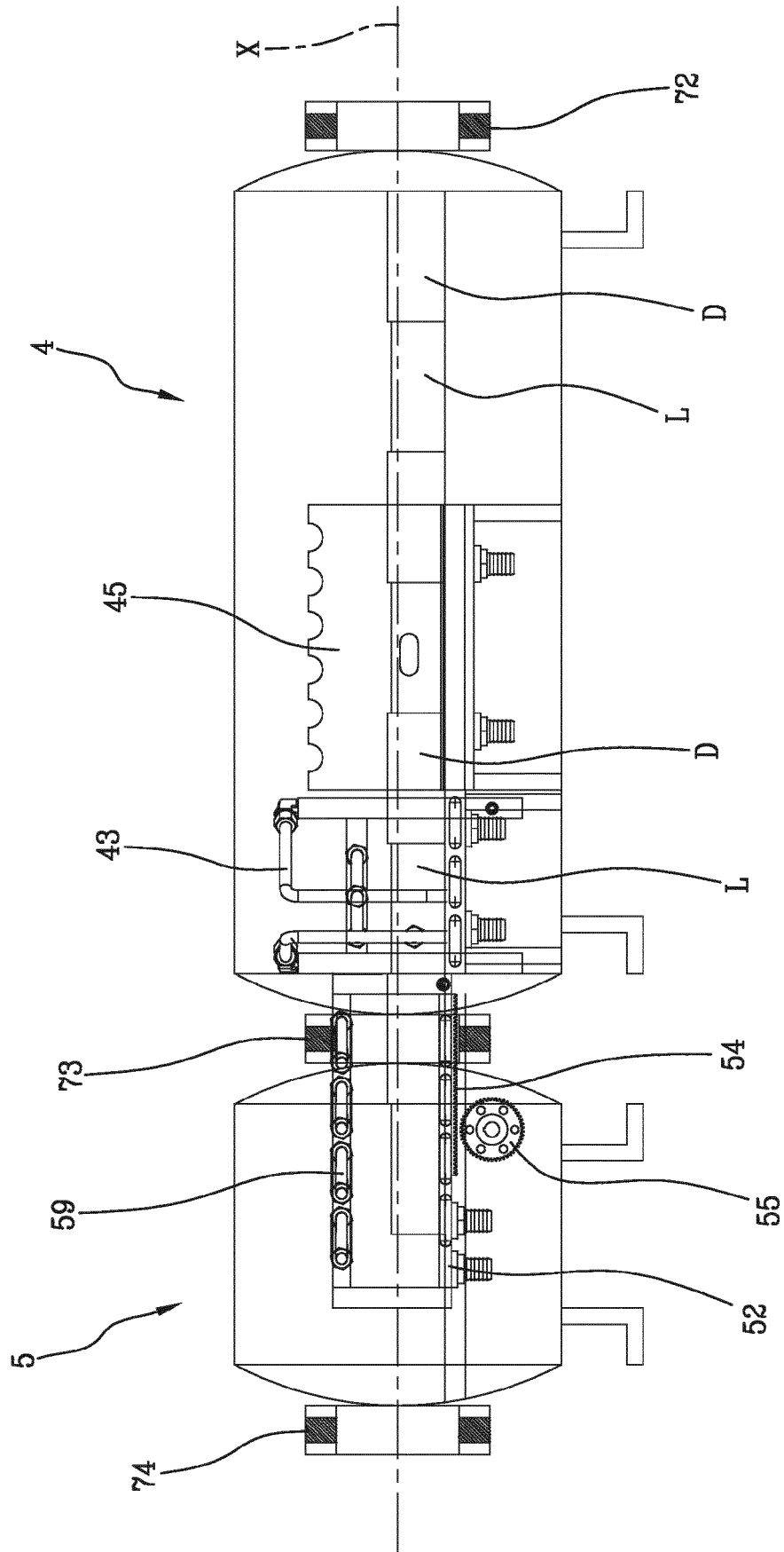


Fig. 5B

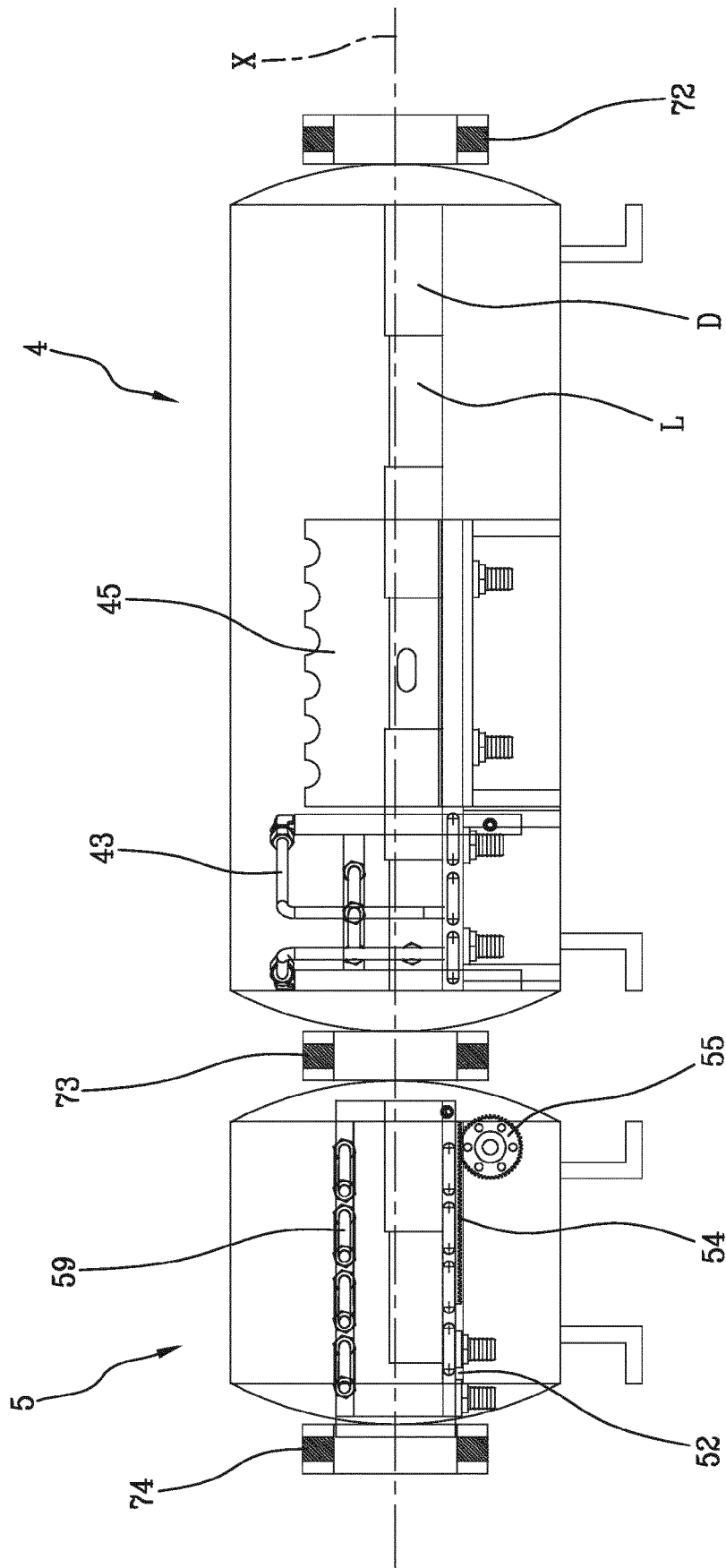


Fig. 5C



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Application Number
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			F27B F27D
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Place of search Munich		Date of completion of the search 30 November 2021	Examiner Gavriliu, Alexandru
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