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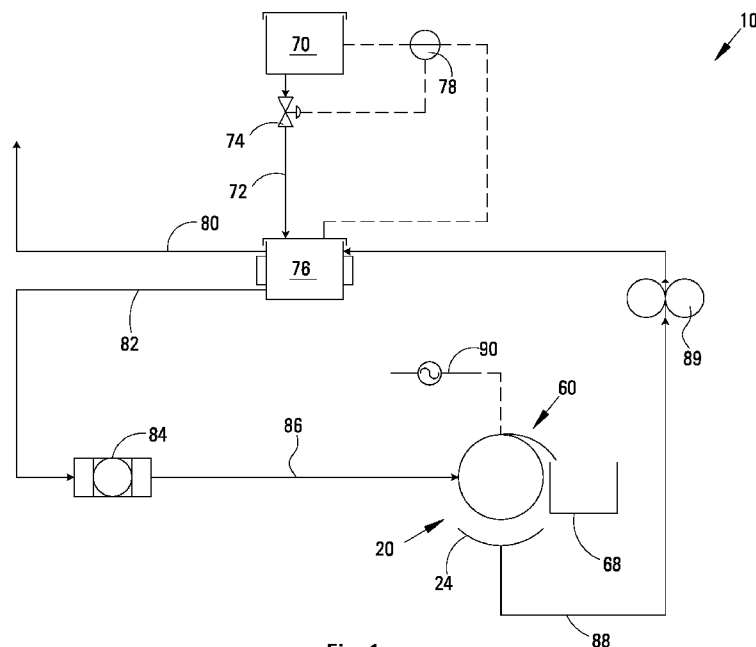


Fig. 1

(57) Abstract: A process for producing a metal includes continuously rotating a horizontal cylindrical cathode which is partially immersed in a bath of liquid metal ion- containing electrolyte. A potential difference is applied between the cathode and an anode located in the bath, which allows, by means of an electrolysis reaction effected on the electrolyte by the applied potential difference, metal from the electrolyte to be deposited in particulate form onto an outer surface of the cathode. The particulate metal is continuously removed from the outer surface of the cathode.

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PRODUCTION OF METALS

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THIS INVENTION relates to the production of metals. It relates in particular to a process for producing a metal, to a metal producing apparatus, and to a metal producing installation.

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Electrodeposition processes for producing metals, such as electrowinning and electrorefining, are well known operations used to recover metals in solution in an electrolyte by using electric current to induce a chemical reaction through electrolysis of the electrolyte. Electrodeposition processes are commercially important, for example in the production of metals such as copper, nickel, zinc and cobalt.

15

Conventional industrial electrodeposition processes are conducted in an electrolysis cell comprising a series of suspended electrodes which are vertically arranged inside the cell so that they are alternately anodic and cathodic. The electrolysis cell is filled with electrolyte, an ionically conducting solution containing positive metal ions. During normal operation the electrodes are immersed in the electrolyte and an electrical potential difference is applied across the electrodes so that current passes from the anodes to the cathodes, resulting in an electrochemical reaction whereby the metal cations in the electrolyte are reduced to neutral metal atoms which are deposited onto the cathode surfaces as a metal layers which strongly adhere to the cathode surface.

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Conventional electrodeposition processes are typically operated as batch or semi-batch processes. A plating cycle lasts for a predetermined period of time until an optimal thickness of the metal layer is formed on the cathode surface. At the end of a plating cycle, the electrolysis cell is taken off-line so that the cathodes can be harvested from the electrolysis cell in order to strip the formed

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metal layer from the cathode surface, and to process the remaining cathode. The stripping process can be carried out either manually or by equipment specifically designed for this task, but inevitably requires human intervention.

- 5 The Applicant has identified at least 2 major problems associated with conventional electrodeposition processes. Firstly, the processes operate as batch/semi-batch processes instead of as continuous processes resulting in loss of operation time. Secondly, due to manual handling by the operating staff, stripping of the metal layer from the cathode surfaces is time consuming,
10 laborious and often increases the risk of injury to operators.

Thus, a metal producing process which ameliorates the problems hereinbefore described would be beneficial.

- 15 According to a first aspect of the invention, there is provided a process for producing a metal, which process includes;
continuously rotating a horizontal cylindrical cathode which is partially immersed in a bath of liquid metal ion-containing electrolyte;
applying a potential difference between the cathode and an anode
20 located in the bath;
allowing, by means of an electrolysis reaction effected on the electrolyte by the applied potential difference, metal from the electrolyte to be deposited in particulate form onto an outer surface of the cathode; and
continuously removing the particulate metal from the outer surface of the
25 cathode.

The process thus includes the continuous electrodeposition of metal particles on a rotating cylindrical cathode outer surface *via* electrolysis, and the removal of the deposited metal particles.

30

The anode and cathode are thus spaced from each other. The electrolyte continuously flows through the space between the anode and the cathode.

The continuous removal of the particulate metal from the outer surface of the cathode may be effected by a leading edge of a stationary scraper blade being spaced with limited clearance from the outer surface of the cathode so that, as the cathode rotates, the deposited metal particles are dislodged by the leading edge of the scraper blade.

The dislodged metal particles may be guided by the scraper blade into a collecting zone for removal.

The method may include capturing residual metal particles which are not deposited on the cathode outer surface, or do not adhere thereto. The capturing may be effected by allowing the residual metal particles to deposit on a capture member located in the electrolyte bath, and from time-to-time withdrawing the capture member from the bath to remove the metal particles therefrom.

15

According to a second aspect of the invention, there is provided metal producing apparatus, which includes;

an electrolyte tank adapted to contain a bath of liquid metal ion-containing electrolytes;

20

a horizontal cylindrical cathode located at least partially within the tank;
drive means for driving the cathode to rotate continuously within the tank;
an anode in the tank and spaced from the cathode;

current supply means for applying a potential difference between the anode and the cathode, thereby, in use, to cause, through electrolysis of the electrolyte, particulate metal to deposit on an outer surface of the cathode; and

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metal removal means for continuously removing particulate metal deposited onto the outer surface of the cathode.

The apparatus may include a bath of liquid metal ion-containing electrolyte in the tank; in use, electrolyte continuously flows through the space between the anode and cathode. This flow behaviour serves to enhance mass transfer and ensures optimal metal-ion concentration in the electrolyte. Furthermore this continuous flow of electrolyte can be employed to continuously remove valuable "sludge" containing platinum group metals in the case where electrolyte feed is

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derived from an ore body containing such metals in the case where the source ore contains such metals.

5 The metal removal means may be arranged such that it removes particulate metal from an exposed portion of the outer surface of the cathode, i.e. a portion thereof which is not submerged in the electrolyte. The metal removal means may, in particular, be scraping means mounted adjacent the cathode surface.

10 The cathode is thus mounted in the tank so that, in use, its rotational axis extends horizontally.

More particularly, according to the second aspect of the invention, there is provided metal producing apparatus

15 an electrolyte tank configured to maintain a predetermined liquid metal ion-containing electrolyte depth therein;

a bath of liquid metal ion-containing electrolyte in the tank;

20 a cylindrical cathode mounted in the tank such that a longitudinal axis of the cathode extends in a horizontal direction and the cathode is partially immersed in the electrolyte, wherein the cathode is configured to rotate about its longitudinal axis;

a stationary anode mounted beneath the electrolyte surface level near an outer cylindrical surface of the cathode, with a flow passage for the electrolyte being defined between the anode and cathode;

25 a scraping means mounted adjacent the cathode surface, the scraping means configured to remove particulate metal that deposits on an outer surface of the cathode, from the cathode surface; and

means for applying a potential difference between the anode and the cathode to initiate an electrolysis reaction inside the electrolysis cell.

30 The process may be an electrowinning process or an electrorefining process.

The particulate metal may comprise any coarse metal particles, such as metal flakes or metal powder, which loosely adhere to the cathode surface, allowing the metal particles to be easily removed from the cathode surface by the

scraping means. Hence, the need for a metal layer to be stripped from the cathode surface is eliminated.

5 The electrolyte tank may comprise an inlet configured continuously to receive an electrolyte feed stream and a first outlet, configured continuously to discharge an effluent stream of spent electrolyte.

The cathode may, in particular, be a cylindrical drum.

10 In the case of an electrowinning process, the anode may be a permanent anode. In the case of an electrorefining process, the anode may be a sacrificial anode that releases metal ions into the electrolyte during operation.

15 The scraping means or scraper may be in the form of blade mounted adjacent the cathode outer surface and above the electrolyte surface level in position to scrape the cathode outer surface or to engage and remove, i.e. dislodge, deposited particulate metal from the cathode outer surface as the cathode rotates about its longitudinal axis. The scraper is thus a stationary scraper. The scraping means (or scraper) may be configured to remove a layer of
20 particulate metal deposited on the cathode outer surface, without the scraping means contacting the cathode surface. In particular, the scraping means may comprise a scraper blade having a free or leading edge, i.e. an edge thereof which is closest to the cathode outer surface, and which, in use, engages particulate metal deposited on the outer surface of the cathode as the cathode
25 rotates, thereby dislodging the particulate metal deposits from the cathode outer surface. In one embodiment, the leading blade edge may engage the cathode outer surface. However, in another embodiment, it may be spaced with clearance from the outer cathode surface. This clearance or gap may then be less than 100 μm e.g. between 10 and 80 μm e.g. about 20 μm . In other words,
30 even though the scraper blade does not contact the outer surface of the cathode, it still scrapes or dislodges particulate metal that has been deposited on the cathode outer surface. Thus, the scraper blade need not necessarily contact the cathode outer surface, and terms such as “scraper”, “scraping” and the like must be interpreted accordingly. Naturally, a layer of deposited

particulate metal, where thickness is the same as the clearance or gap, will then remain on the cathode outer surface. Preferably, the scraping means is associated with means for collecting any deposits removed from the cathode surface by the scraping means. The scraping means may be configured to

5 continuously remove deposits from the cathode surface without requiring that the electrolysis cell be taken off-line, thereby allowing the cell to operate continuously and eliminating the need to harvest the cathode from the electrolysis cell.

10 The apparatus may include capture means in the tank for capturing residual metal particles i.e. metal particles not deposited on the cathode outer surface. The capture means may be in the form of a removable liner located in the tank and arranged so that residual metal particles can be deposited on it. Thus, the liner may be of arcuate shape, mirroring the shape of the outer cathode surface

15 and located with clearance at least partly below the cathode so that residual metal particles can drop from the cathode outer surface onto the liner.

The metal powder may, in particular, be copper metal powder. The electrolysis process used for the production of copper metal powder may, in particular, be

20 an electrowinning process.

Proper control of the chemical composition of the electrolyte is an important aspect of this invention. In the event of copper metal powder production *via* electrowinning, the copper concentration in the electrolyte feed may typically be

25 maintained in the range of 30 g/L to 45 g/L (where 'g/L' means 'grams per litre'. The copper concentration in the spent electrolyte may typically be maintained in the range of 5 g/L to 15 g/L. The electrolyte typically contains sulphuric acid in a concentration range of 150 – 220 g/L. In order to produce copper powder according to the present invention, a current density in the range of 100 - 400

30 A/m², preferably 250 A/m², is typically maintained. The temperature of the electrolyte inside the electrolysis cell is typically 25 – 80°C, with a temperature of 60°C typically being maintained. A rotation speed of between 15 and 45 mm/h is recommended, with this speed being measured relative to the outer perimeter of the rotating horizontal cathode.

The electrodes may be of any suitable electrically conductive material. Preferably, in the case of copper metal powder production *via* electrowinning, the cathode may be a drum constructed of stainless steel, coated stainless steel, graphite, or a conductive polymer and the anode may be stainless steel,
5 coated stainless steel, graphite or rolled lead.

According to a third aspect of the invention, there is provided a metal producing installation, which includes;

metal producing apparatus according to the second aspect of the
10 invention; and

a bath of liquid metal containing electrolyte in the electrolyte tank of the apparatus.

The deposition of copper powder in accordance with this invention is
15 accomplished by maintaining the process conditions the apparatus and installation of the invention. Although the apparatus and installation of this invention are particularly useful for producing copper powder, they may be employed for the production of other metal powders by following procedures similar to those specifically described in connection with the production of
20 copper powder.

The invention will now be further described, by way of example, with reference to the accompanying diagrammatic drawings.

25 In the drawings,

FIGURE 1 shows a simplified flow diagram of a first embodiment of a process, on laboratory scale, for producing copper in accordance with the first aspect of the invention;

FIGURE 2 shows a three-dimensional view of the copper producing
30 apparatus shown in FIGURE 1;

FIGURE 3 shows a front view of the copper producing apparatus of Figure 1;

FIGURE 4 shows a top view of the copper producing apparatus of FIGURE 1;

FIGURE 5 shows a lateral cross sectional view of the copper producing apparatus of FIGURE 1;

FIGURE 6 shows a simplified flow diagram of a second embodiment of a process, on bench scale, for producing copper in accordance with the first aspect of the invention;

FIGURE 7 shows a three-dimensional view of the copper producing apparatus shown in FIGURE 6;

FIGURE 8 shows a top view of the copper producing apparatus of FIGURE 6;

FIGURE 9 shows a side view of the copper producing apparatus of FIGURE 6;

FIGURE 10 shows a cross sectional view through X - X of the copper producing apparatus of FIGURE 9;

FIGURE 11 shows an enlargement of one end portion of the copper producing apparatus of FIGURE 7, marked "A" in FIGURE 7; and

FIGURE 12 shows an enlargement of an opposing end portion of the copper producing apparatus of FIGURE 7, and seen from an opposite side.

In FIGURES 1 to 5, reference numeral 10 generally indicates a process in accordance with the first embodiment of the invention for producing copper.

The process 10 includes copper producing apparatus, generally indicated by reference numeral 20. The apparatus (or electrolyser) 20 includes an electrolyte tank, generally indicated by reference numeral 22. The tank 22 comprises a semi-cylindrical trough 24 closed off with end plates 26. A fresh electrolyte inlet 30 leads into the trough, while a spent electrolyte outlet 32 leads from the trough. An overflow (not shown) also leads from the trough. The trough 24 is mounted on a horizontal surface by means of foot pieces 34.

The apparatus 20 includes a cylindrical cathode, generally indicated by reference numeral 40, having a cylindrical outer surface 42. The cathode 40 is mounted to rotate (in the direction of arrow 43) in bearings 44 in the trough end plates 26, with an axle 46 protruding from one end of the cathode 40. The protruding end of the axle 46 is mounted, *via* a plastic rigid coupling 48, to an

electric motor (not shown). By means of the electric motor, the cathode 40 can thus be driven to rotate continuously about the horizontal axis.

5 The cathode 40 is located within a semi-cylindrical trough shaped anode, generally indicated by reference numeral 50. There is thus a peripheral gap 52 between the outer surface 42 of the cathode and the anode 50.

10 The apparatus 20 includes a stationary or static scraper, generally indicated by reference numeral 60. The scraper 60 includes a 2 mm thick scraper blade 62 of flexible polymeric material (such as PVC), fixed to a mounting component 64; a similar 2 mm thick PVC scraper blade 65 is also fixed to the mounting component 64 and is located below the blade 62, as shown in Figure 5. The free or leading edges 66, 67 of the scraper blades 62, 65 thus scrape against the cylindrical outer surface 42 of the cathode 40 thereby to remove any copper particles which have been deposited onto the outer surface 42. The scraper blade 65 is believed not to be essential and can be dispensed with, if desired.

20 Due to the flexibility of the scraper blade 62, its angle relative to the outer surface 42 of the cathode can be adjusted by moving the scraper blade 62 forwardly (towards the cathode 40) or rearwardly (away from the cathode 40) relative to the mounting component 64.

25 The apparatus 20 also includes a solids-capture tank 68 for catching copper particles removed by the scraper 60.

30 The process 10 includes a saturated electrolyte solution tank 70 with an electrolyte feed or flow line 72, fitted with a control valve 74, leading from the tank 70 to an electrolyte buffer tank 76 (fitted with a heating mantle (not shown) operated by means of a temperature controller (not shown)). The tanks 70, 76 are fitted with a conductivity meter 78. Typically, the tank 70 can be of PCV or the like.

A spent electrolyte overflow stream line 80 leads from the buffer tank 76, as does a fresh electrolyte feed stream 82. The line 82 leads into an activated

carbon filter 84, with a filtered electrolyte feedstream line 86 leading from the filter 84 to the trough inlet 30 of the apparatus 20.

5 A spent electrolyte return stream line 88 leads from the trough outlet 30 of the apparatus 20 back to the buffer tank 76, and is fitted with a pump 89.

The process 10 includes an electrical current (DC) supply 90 connected to the apparatus 20 for applying a potential difference between the anode 50 and the cathode 40.

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In use, filtered liquid electrolyte containing copper ions enters the tank 22 of the apparatus 20 through the trough inlet 30. The cathode 40 is continuously driven to rotate within the resultant electrolyte bath formed within the space 52 between the anode 40 and the cathode 50. The electrolyte then proceeds to overflow into trough 24 thereby driving continuous flow past the rotating electrode 40. By means of the electrical current supply 90, a potential difference is applied between the anode and cathode *via* the electrolyte, which consists of an aqueous solution of sulphuric acid and copper sulphate. Copper is deposited onto the outer surface 42 of the cathode in the form of powdery flakes, which are scraped off by the scraper blade 62 and collected in the capture tank 68. It will be appreciated that the scraping off of the powdery flakes of copper is also effected continuously.

25 It will be appreciated that by means of the process 10 and apparatus 20, continuous production and recovery of copper powdery flakes *via* an electrolysis process can be effected.

Spent electrolyte is monitored by means of the conductivity meter 78, and replenished from a saturated copper sulphate solution in the tank 70. Sulphate build-up in the process is controlled by the activated carbon filter 84.

Referring to Figures 6 to 12, reference numeral 100 generally indicates a process, in accordance with the second embodiment of the invention, for producing copper.

Process units and parts shown in Figures 6 to 12 which are the same or substantially similar to units and parts shown in Figures 1 to 5 are indicated with the same reference numerals.

- 5 The process 100 is similar to the process 10 but additionally includes:
a control valve 101, filter system 102 fitted with a waste stream line 103, filtered electrolyte holding tank 104, and control valve 105, in the spent electrolyte return stream line;
a distilled water tank 106 from which leads a feed line 107, fitted with a control
10 valve 108, to the electrolyte buffer tank 76;
its fresh electrolyte feed stream 82 leads into an insulated holding tank 108 and is fitted with a control valve 109, with the activated carbon filter 84 having been dispensed with;
the feed stream line 86 is fitted with a control valve 110;
15 it includes an acid supply 112 from which leads an acid feed line 114, fitted with a control valve 115, to the tank 76.

In the process 100, the spent electrolyte return stream line 88 is pumped *via* the pump 89 to the filter system 102. The filtered spent electrolyte proceeds to the
20 holding tank 104 from where it feeds into the buffer tank 76 at a controlled flow rate. A waste stream is removed from the process, along the line 103. The buffer tank 76 can also receive fresh acid and distilled water from the acid supply 112 and distilled water tank 106 respectively, to adjust the composition of the electrolyte. The distilled water tank 106 is provided to ensure a sufficient
25 supply of distilled water to the buffer tank 76.

The process 100 includes a copper producing apparatus, generally indicated by reference numeral 120. The apparatus 120 essentially comprises a series or combination of three of the copper producing apparatuses 20 as shown in
30 Figures 1 to 5, suitably modified. It will be appreciated that any number of modified copper producing apparatuses 20 could be connected in series in order to increase the plating capacity of the copper producing apparatus 120.

The apparatus 120, as for the apparatus 20 of Figures 1 to 5, includes the semi-cylindrical trough 24 closed off with the end plates 26. A plurality of the fresh electrolyte inlets 30 lead into the trough, while a spent electrolyte outlet (not shown) leads from the trough. An overflow (not shown) also leads from the trough. The trough 24 is, as for the apparatus 20, mounted on the base structure 34 which is configured to provide a horizontal support surface 122. The base structure is located inside a base tray 124.

The apparatus 120 includes three cylindrical cathodes arranged end-to-end in a cathode combination or bank, each cathode being generally indicated by the reference numeral 40 (as for the apparatus 20), each cathode having a cylindrical outer surface 42. The cathodes 40 are mounted to the axle or shaft 46 by means of radial spokes (not shown), the distal ends of which support circular roller flanges 126. The cathode combination or bank is mounted to rotate in bearings 44 in the trough end plates 26, with the axle 46 protruding from one end of the apparatus 120. The protruding end of the axle 46 is mounted, *via* a plastic rigid coupling 48, to an electric motor (not shown). By means of the electric motor, the bank of cathodes 40 can thus be driven to rotate continuously about the horizontal axis.

The cathodes 40 are, as in the apparatus 20, located within the semi-cylindrical trough shaped anode 50. A wedge plate 128 wedges the anode 50 firmly in position. There is thus a peripheral gap 52 between the outer surface 42 of each cathode and the anode 50.

The apparatus 120 includes three scrapers 60, one for each cathode. In the scrapers 60 of the apparatus 120 the stationary scraper blades 62 are rigid rather than flexible. Each scraper blade 62 is mounted onto the support surface 122 by means of a pair of spaced blade hinges, with a first portion 130 of each blade hinge being connected to the support surface 122 while a second portion 132 of each blade hinge is connected to the scraper blade 62.

A leading edge 134 of each scraper blade 62 is located adjacent the cathode outer surface 42. Each scraper blade 62 is arranged such that there is a gap

between the leading edge 134 of the scraper blade 124 and the cathode outer surface 42. The distance of the gap 135 between the leading edge 134 of the scraper blade 62 and the cathode outer surface 42 is about 20 μm . The Applicant has found that by having a gap between the blade's leading edge and the cathode outer surface, pitting and scoring of the cathode outer surface is minimized or even totally avoided. The distance of the gap is accurately controlled and adjusted by means of a pair of spaced slip blocks 136, each of which is attached to the scraper blade 62 by way of a mounting bracket 140. The accurate control and adjustment is more specifically achieved by an arrangement of 3 adjustment bolts 141 by means of which each slip block 136 is mounted to its bracket 140. The bolts 141 engage threads in passageways in the bracket and/or the slip block so that, by adjusting the bolts, the degree to which the slip block protrudes from its mounting bracket (and hence the size of the gap 135) is adjusted.

A trailing end portion 142 of each scraper blade 62 is connected to the base structure 34 by means of a pair of spaced poppet assemblies 143. Each assembly 143 comprises a poppet 144 housed in a poppet holder 146. A spring (not shown) is located (within the holder 146) around a lower end portion of the poppet 144 and urges the poppet 144 upwardly i.e. towards the blade 62. A pressure dimple 148 is provided between a rounded upper end of the poppet 144 and the end portion 142 of the scraper blade 62. The rounded upper end of the poppet 144 thus nestles in a rounded indentation in the pressure dimple, thereby permitting pivoting of the blade 62 relative to the poppet. The poppet 144 is mounted to the base structure 34 by means of a bracket 150.

It will be appreciated that the poppets 144 will, due to the upward force exerted by their springs, urge the leading edges 134 of the blades towards the cathode outer surface; however, the slip blocks 136 ensure that the leading blade edges 134 are kept clear of the cathode outer surface as the cathode rotates, thus creating the gap 135.

The apparatus 120 also includes a removable lining 154 onto which residual solid particulates, which have not been removed with the scraper blade 62,

accumulate over time. The removable lining 154 can be removed from the apparatus 120 from time-to-time to remove the accumulated solid particulates. The removable lining 154 can then be reinserted into the apparatus 120. The lining can be of any appropriate material, e.g. titanium, lead, platinum, or the like.

The apparatus 120 includes means for transferring a stationary electrical connection (which receives an electrical current from the DC current supply 90), into a rotary one. This means includes a brush holder mounting bracket 156, a brush holder 158, a composite material insulator 160 for a shaft contact point, and a brass ring 162 on the shaft that the brush actually makes contact with. A wire (not shown) connects the brass ring or bush 162 to each of the cathodes.

Components such as the slip block 136, flanges or rings 126, brush holder 158 and insulator 162 are of suitable non-electrically conductive material, e.g. that available under the trade name "Ertalyte" which is an unreinforced, semi-crystalline thermoplastic polyester based on polyethylene terephthalate (PET).

In the process 100, the spent electrolyte return stream line 88 is pumped *via* the pump 89 to the filter system 102. The filtered spent electrolyte proceeds to the holding tank 104 from where it feeds into the buffer tank 76 at a controlled flow rate. A waste stream is removed from the process, along the line 103. The buffer tank 76 can also receive fresh acid and distilled water from the acid supply 112 and distilled water tank 106 respectively, to adjust the composition of the electrolyte. The distilled water tank 106 is provided to ensure a sufficient supply of distilled water to the buffer tank 76.

In use, filtered liquid electrolyte containing copper ions enters the tank 22 of the apparatus 120 through the trough inlet 30. The cathodes 40 are continuously driven to rotate within the resultant electrolyte bath formed within the space 52 between the anode 50 and the cathodes 40. The electrolyte then proceeds to overflow into trough 24 thereby driving continuous flow past the rotating electrode 40. An electrical potential difference is applied between the anode and cathode *via* the electrolyte, which consists of an aqueous solution of

sulphuric acid and copper sulphate. Copper is deposited onto the outer surface 42 of the cathode in the form of powdery flakes, which are scraped off by the scraper blade 62 and collected in the capture tank 68. It will be appreciated that the scraping off of the powdery flakes of copper is also effected continuously.

- 5 The apparatus is not limited to the production of copper, but is particularly suited to the production of copper flakes/powder.

10 It will be appreciated that by means of the processes 10, 100 and the apparatus 20, 120, continuous production and recovery of copper powdery flakes *via* an electrolysis process can be effected.

The invention provides at least the following advantages:

15 The particle size and the deposition rate of the metal particulate can be controlled by altering the inter-electrode distance. A larger inter-electrode distance will tend to decrease particle size and deposition rate and *vice versa*.

The particle size and the deposition rate of the metal particulate can be controlled by altering the current density on the cathode. Higher current densities will result in larger particles and a faster deposition rate. The inverse is true of lower current densities.

20 The plate thickness and the metal deposition rate of the metal particulate can be controlled by means of the rotational speed of the horizontal drum cathode. Slower rotation rates will results in higher plating thicknesses/plating densities and *vice versa*.

25 The scraper angle and design enables complete removal of plated metal product.

The mass transfer rate for electrolytic plating and therefore the plating rate and the cell efficiency can be controlled by altering the inlet linear velocity of the electrolyte, its flow direction and its distribution. Higher flow rates will tend to increase mass transfer efficiency and lead to production cost reductions.

30 A combination of the above control parameters can contribute to a reduction in cost for the production of metals by electrolysis on a continuous basis.

It will be appreciated that by having a number of cathodes arranged in series, it is also possible to effect deposition of a different metal on each cathode outer surface, in the event that the electrolyte contains different metals, by selecting appropriate operating parameters, such as applied inter-electrode voltage.

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The invention thus provides an efficient and cost effective means of continuous producing particulate copper through continuous electrodeposition of copper particles on a rotating cylindrical cathode surface *via* electrolysis and continuously scraping the copper particles from the surface.

10

CLAIMS:

1. A process for producing a metal, including:
continuously rotating a horizontal cylindrical cathode which is partially
5 immersed in a bath of liquid metal ion-containing electrolyte;
applying a potential difference between the cathode and an anode
located in the bath;
allowing, by means of an electrolysis reaction effected on the electrolyte
by the applied potential difference, metal from the electrolyte to be deposited in
10 particulate form onto an outer surface of the cathode; and
continuously removing the particulate metal from the outer surface of the
cathode.
2. The process according to claim 1, wherein the continuous removal
15 of the particulate metal from the outer surface of the cathode is effected by a
leading edge of a stationary scraper blade spaced with limited clearance from
the outer surface of the cathode so that, as the cathode rotates, the deposited
metal particles are dislodged by the leading edge of the scraper blade.
- 20 3. The process according to claim 2, wherein the dislodged metal
particles are guided by the scraper blade into a collecting zone for removal.
4. The process according to any one of claims 1 to 3 inclusive, which
is an electrowinning process, and wherein the metal is copper.
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5. The process according to claim 4, which includes continuously
feeding electrolyte having a copper concentration in the range 30 g/L to 45 g/L
into the bath of electrolyte, continuously withdraw spent electrolyte having a
copper concentration in the range 5 g/L to 15 g/L from the bath, and maintaining
30 a current density to the anode and cathode in the range 100 A/m² to 200 A/m².
6. The process according to claim 4 or claim 5 wherein the cathode
is rotated at a speed of 15 to 45 mm/h, measured relative to the outer perimeter
of the cathode.

7. A metal producing apparatus, including:

an electrolyte tank adapted to contain a bath of liquid metal ion-containing electrolytes;

5 a horizontal cylindrical cathode located at least partially within the tank;
drive means for driving the cathode to rotate continuously within the tank;
an anode in the tank and spaced from the cathode;

current supply means for applying a potential difference between the
anode and the cathode, thereby, in use, to cause, through electrolysis of the
10 electrolyte, particulate metal to deposit on an outer surface of the cathode; and
metal removal means for continuously removing particulate metal
deposited onto the outer surface of the cathode.

8. The metal producing apparatus according to claim 7 which
15 includes the bath of liquid metal-containing electrolyte in the electrolyte tank,
with the metal removal means arranged such that it removes particulate metal
from an exposed portion of the outer surface of the cathode.

9. The metal producing apparatus according to claim 7 or claim 8,
20 wherein the metal removal means comprises scraping means having a scraper
blade mounted adjacent the cathode outer surface, the scraper blade having a
leading edge for engaging and removing particulate metal deposited on the
cathode surface.

25 10. The metal producing apparatus according to claim 9, wherein the
leading edge of the scraper does not contact the cathode outer surface so that
there is a blade mounted adjacent the cathode outer surface, such a gap
between the leading edge of the blade and the cathode outer surface.

30 11. The metal producing apparatus according to claim 6, wherein the
gap between the blades' leading edge and the cathode outer surface is
between 10 and 100 μm .

12. The metal producing apparatus according to claim 11, wherein the gap is about 20 μm .

13. A metal producing installation, which includes:

- 5 a metal producing apparatus according to claim 7; and
a bath of liquid metal-containing electrolyte in the electrolyte tank of the apparatus.

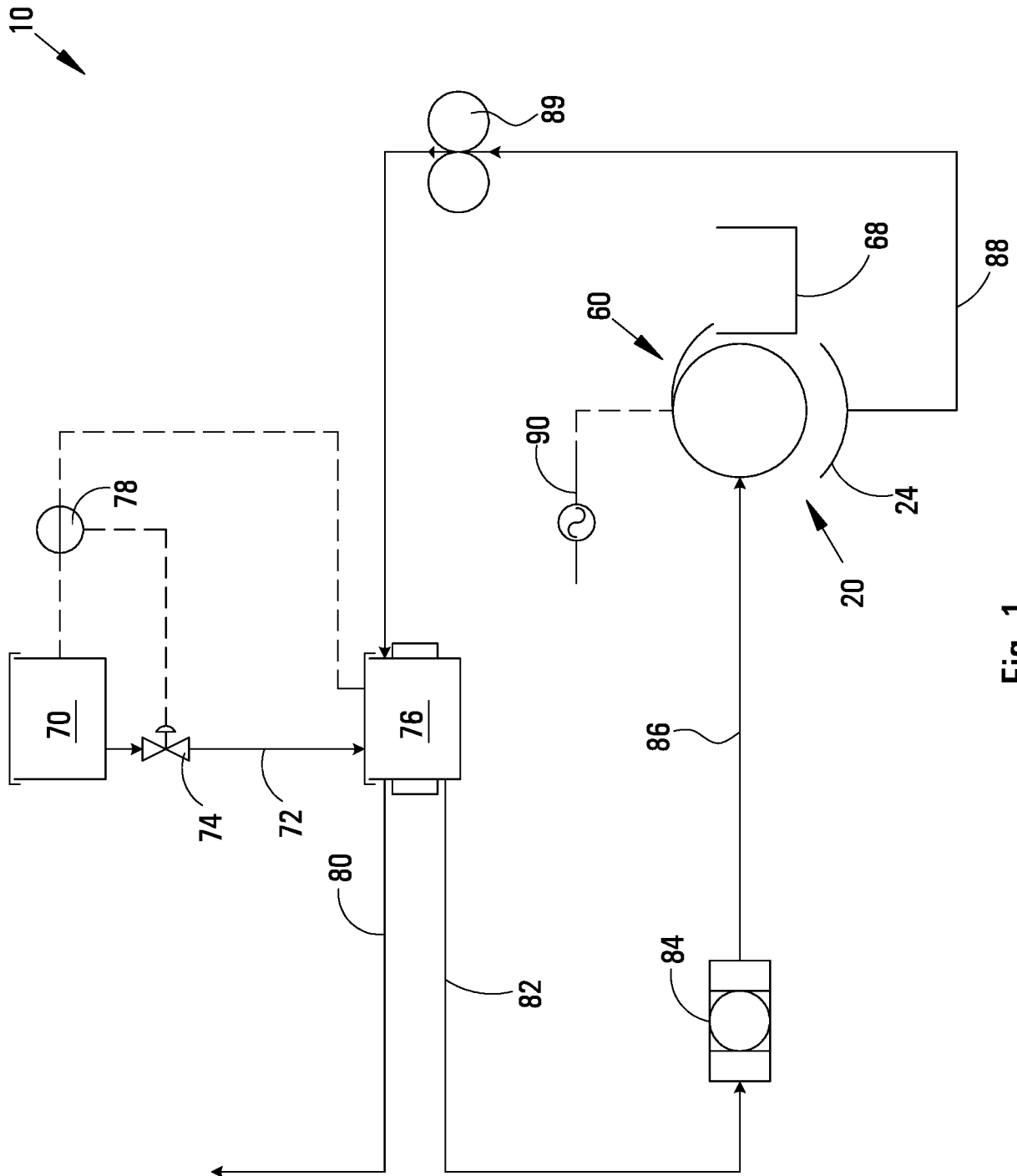


Fig. 1

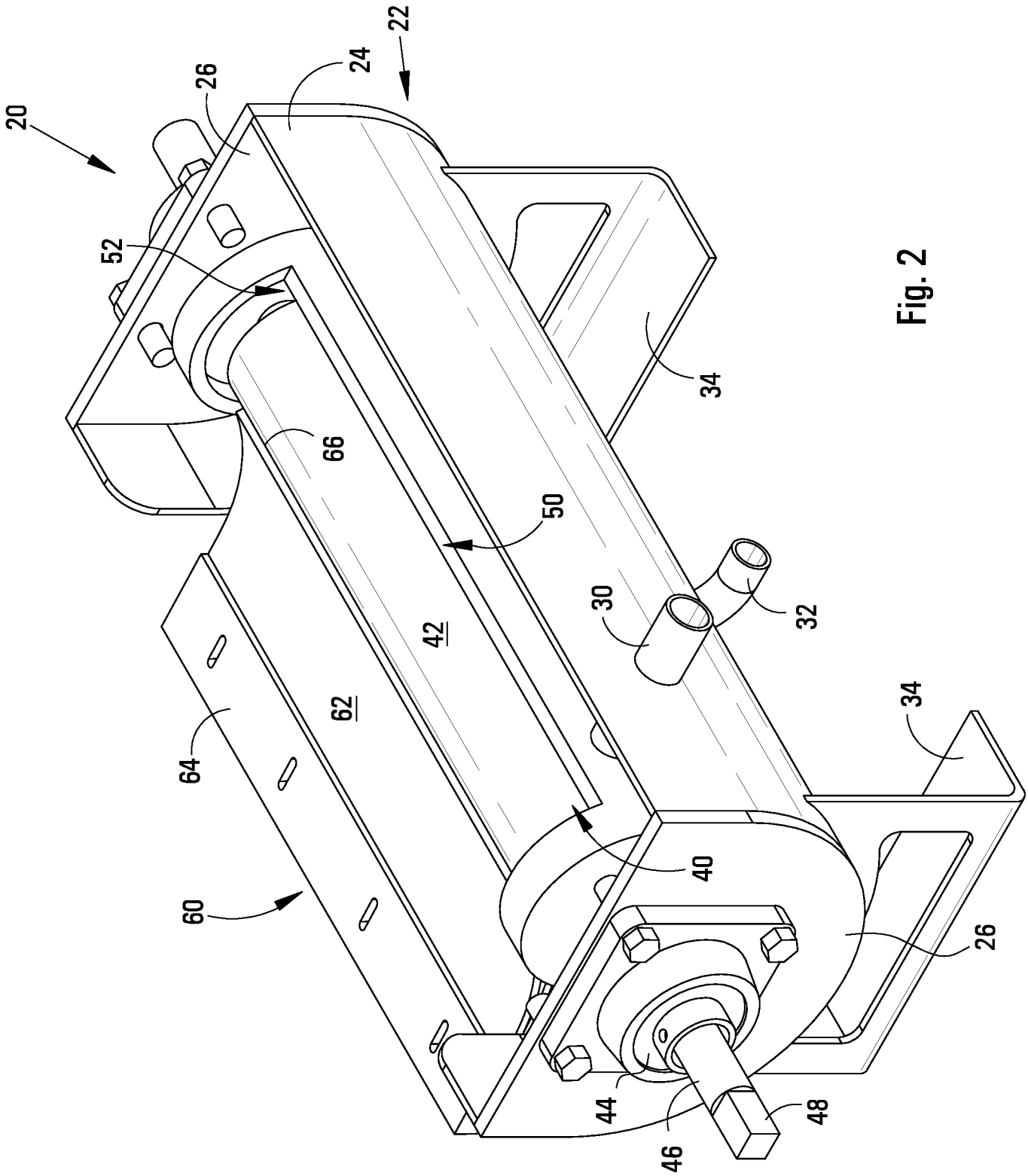


Fig. 2

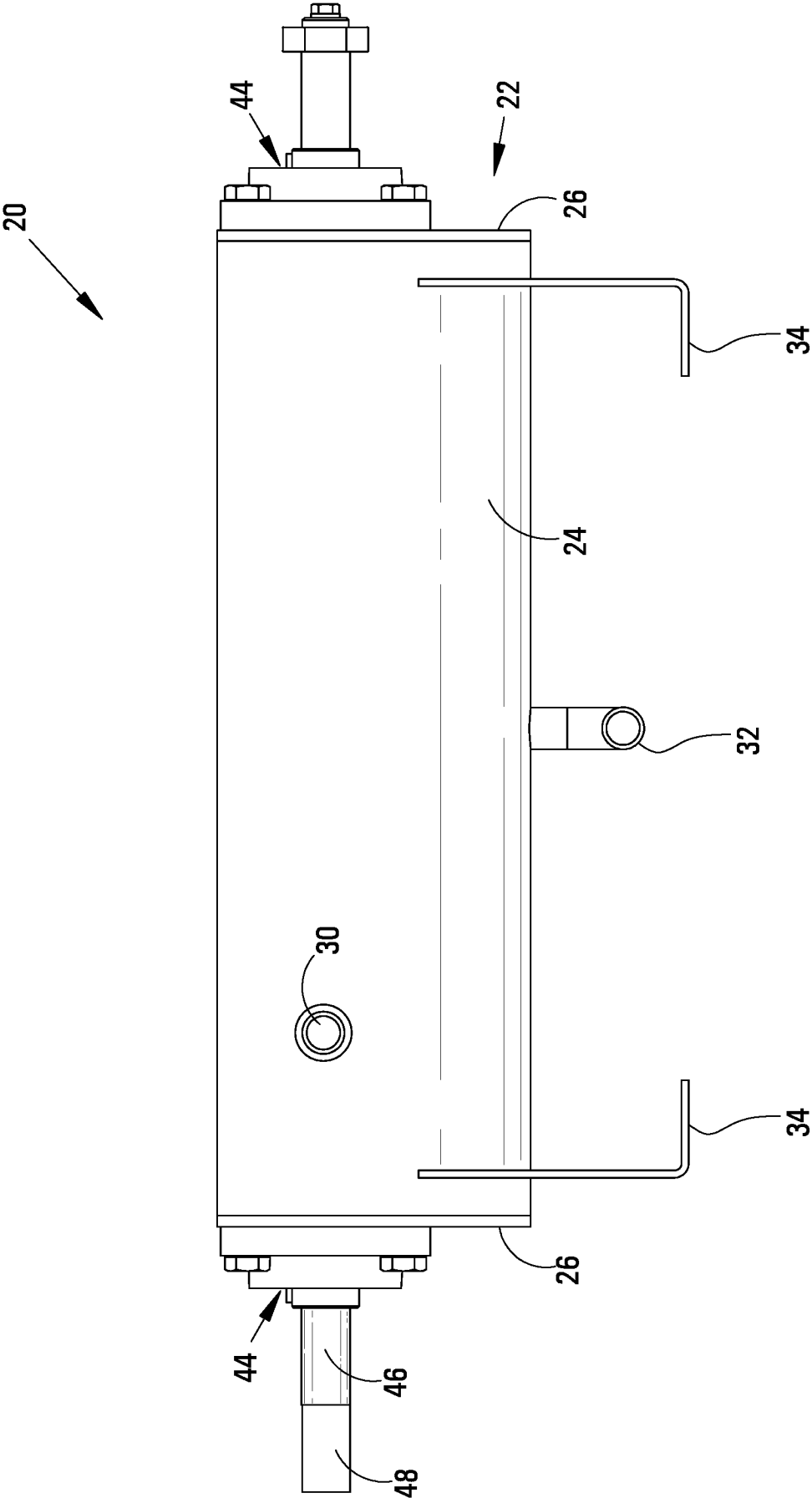


Fig. 3

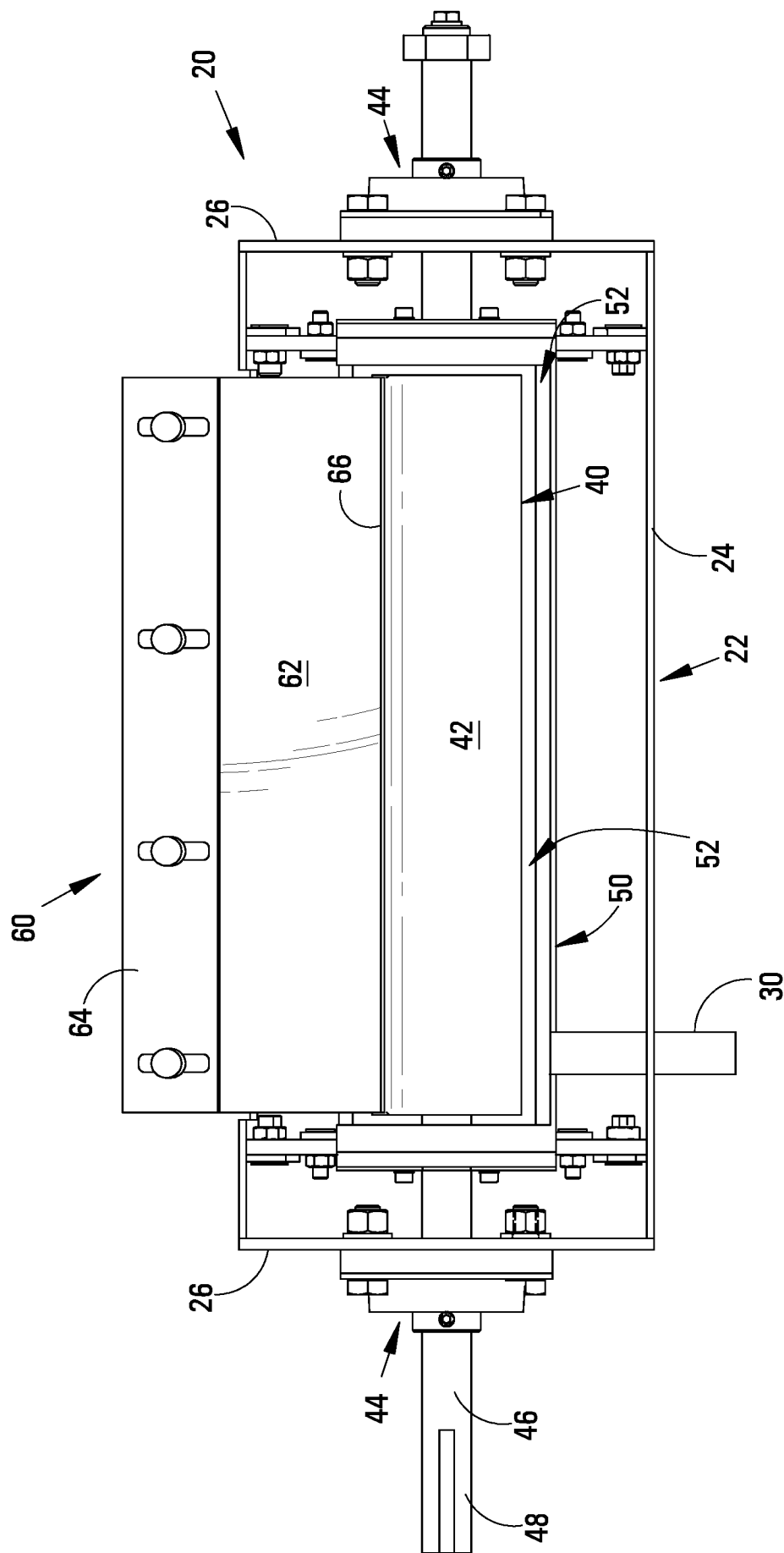


Fig. 4

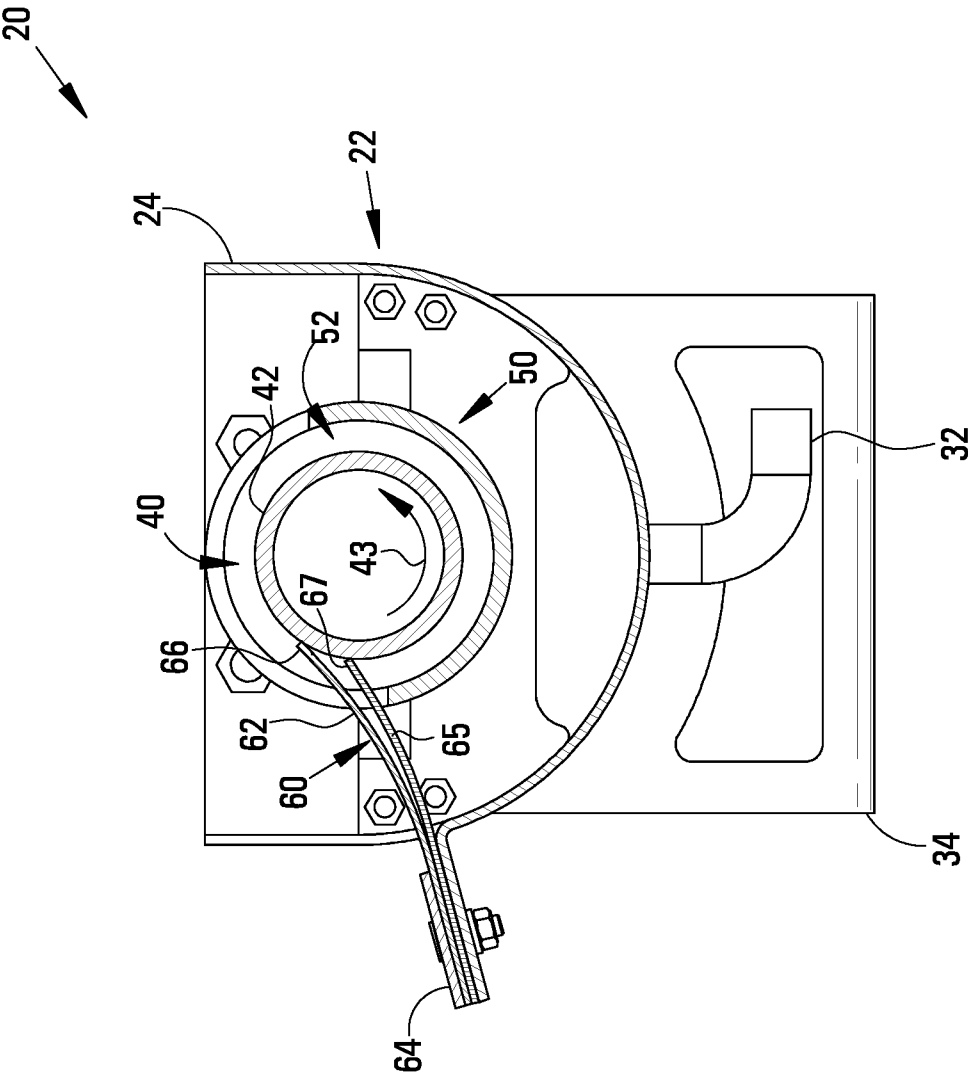


Fig. 5

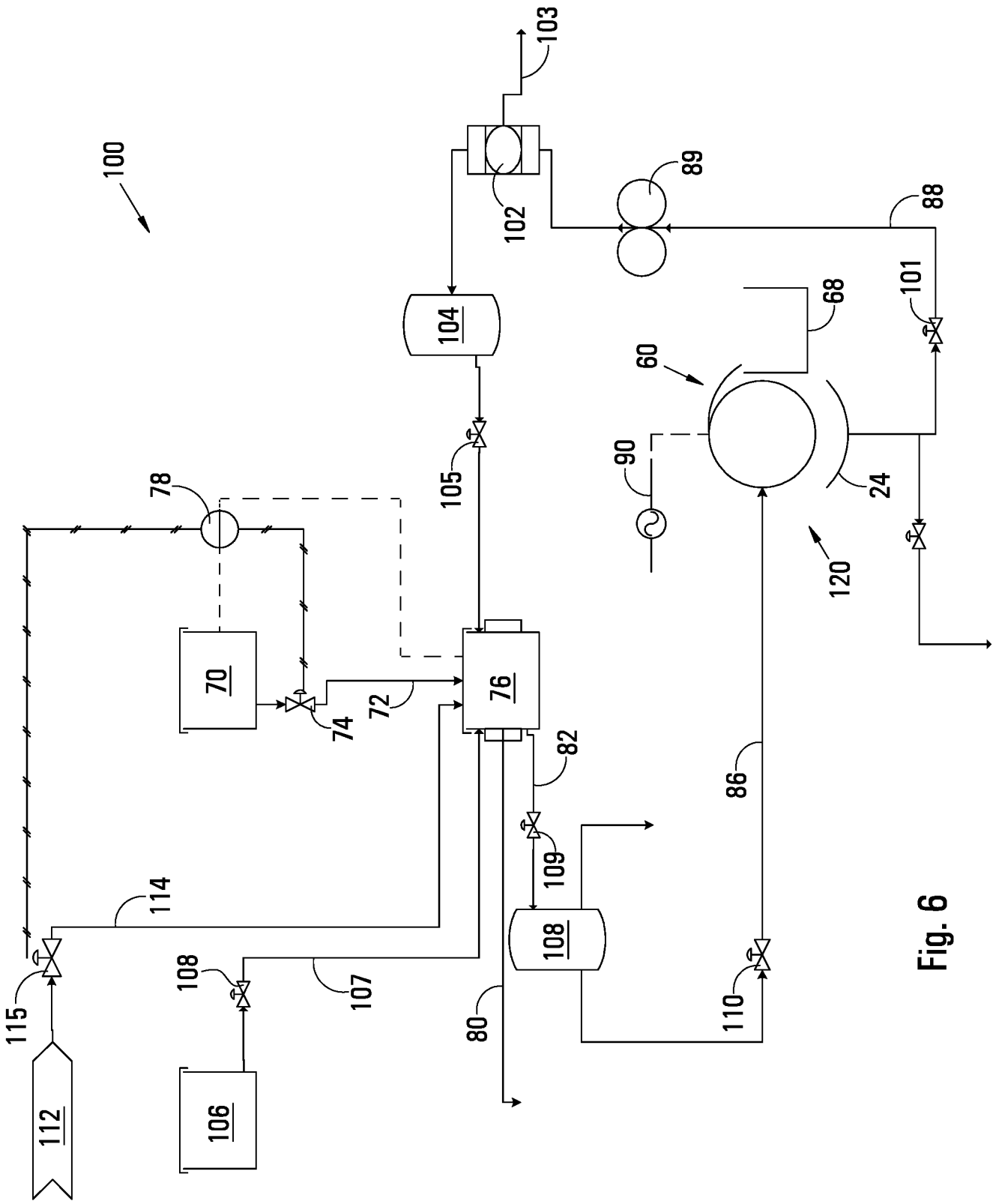


Fig. 6

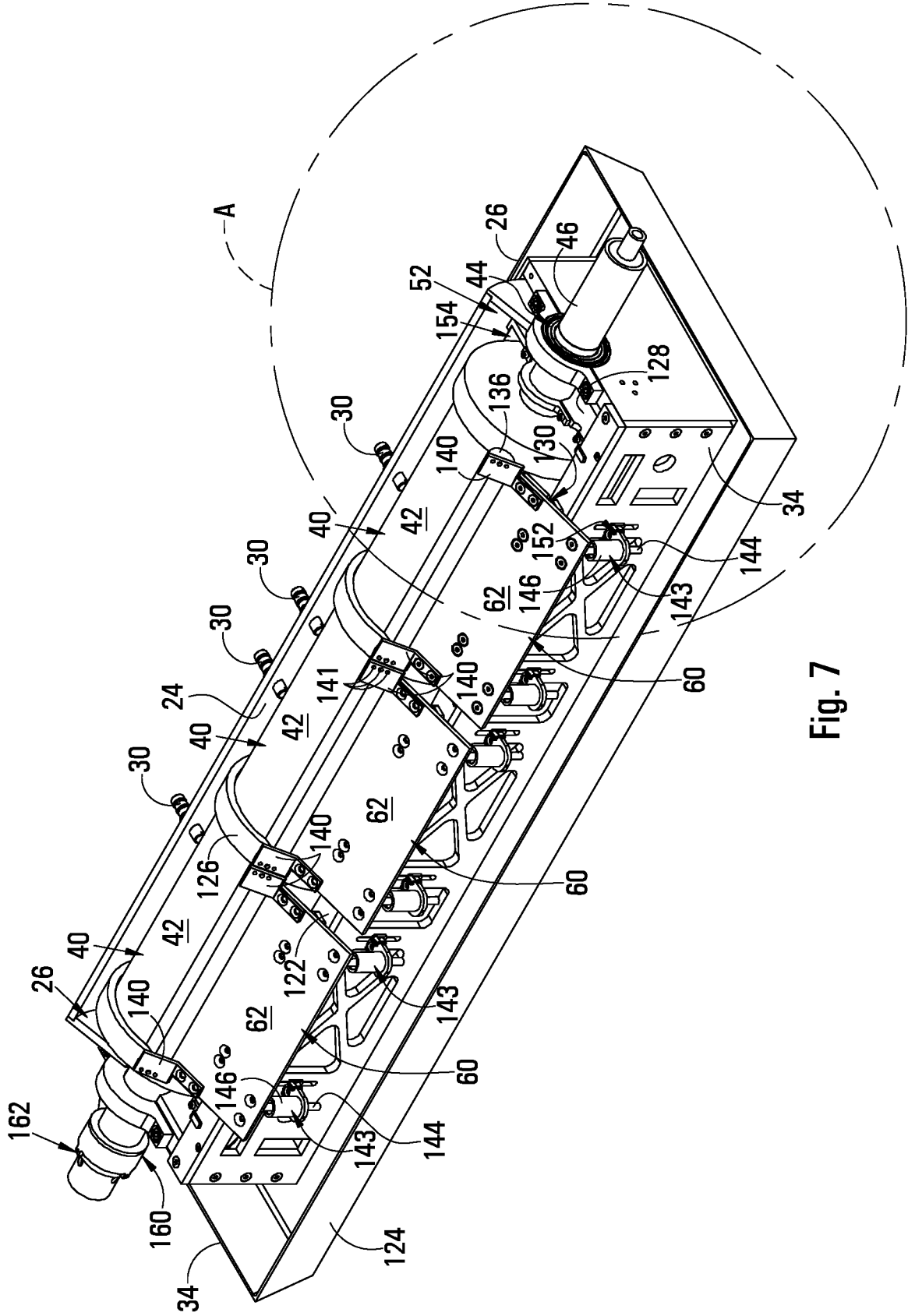


Fig. 7

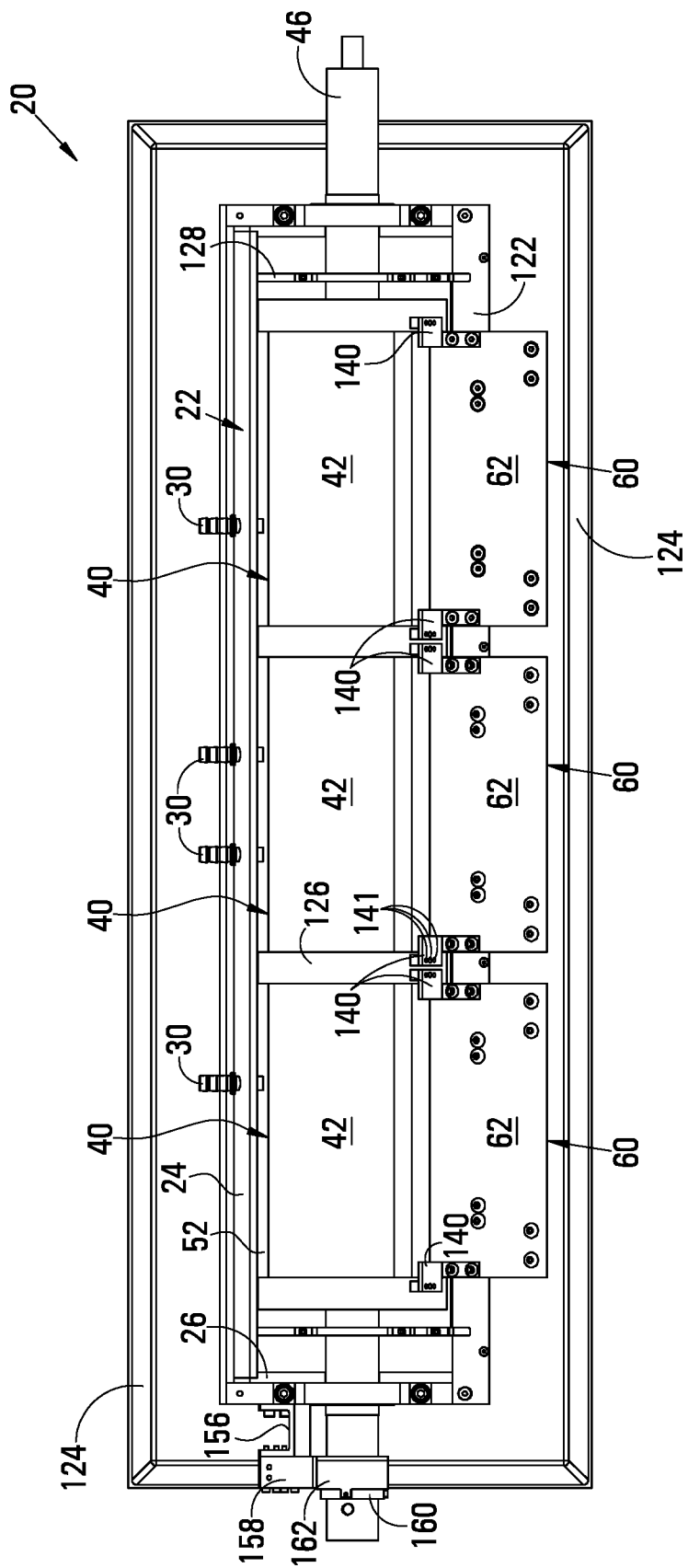


Fig. 8

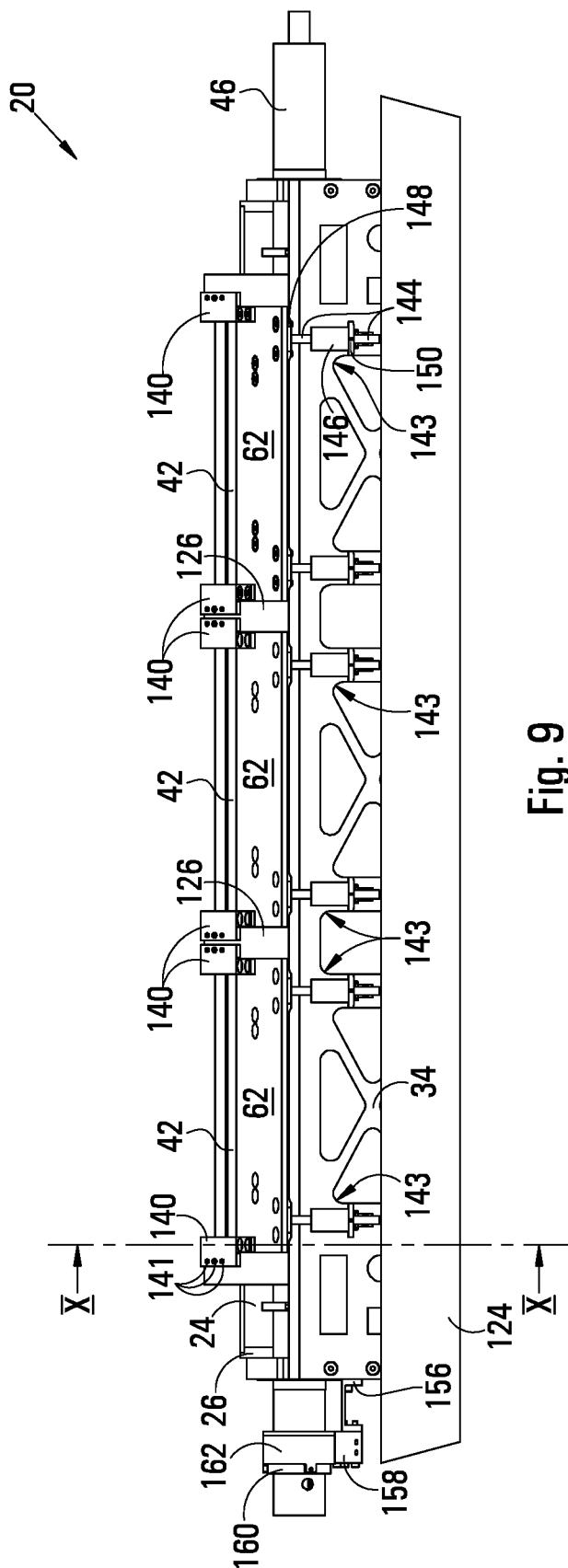


Fig. 9

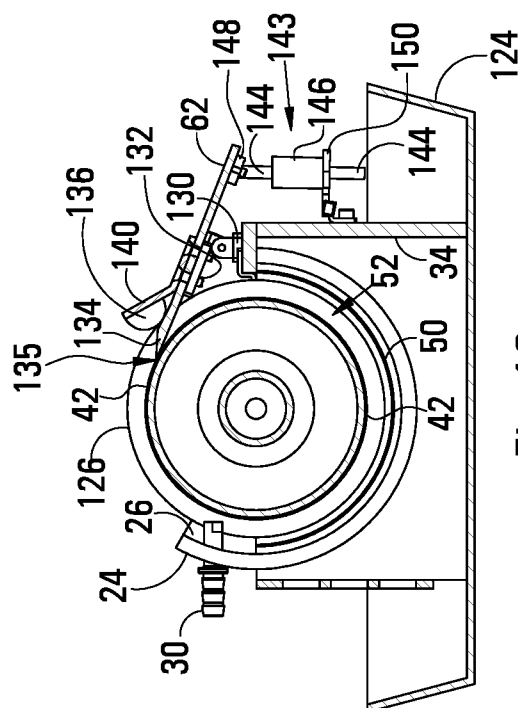


Fig. 10

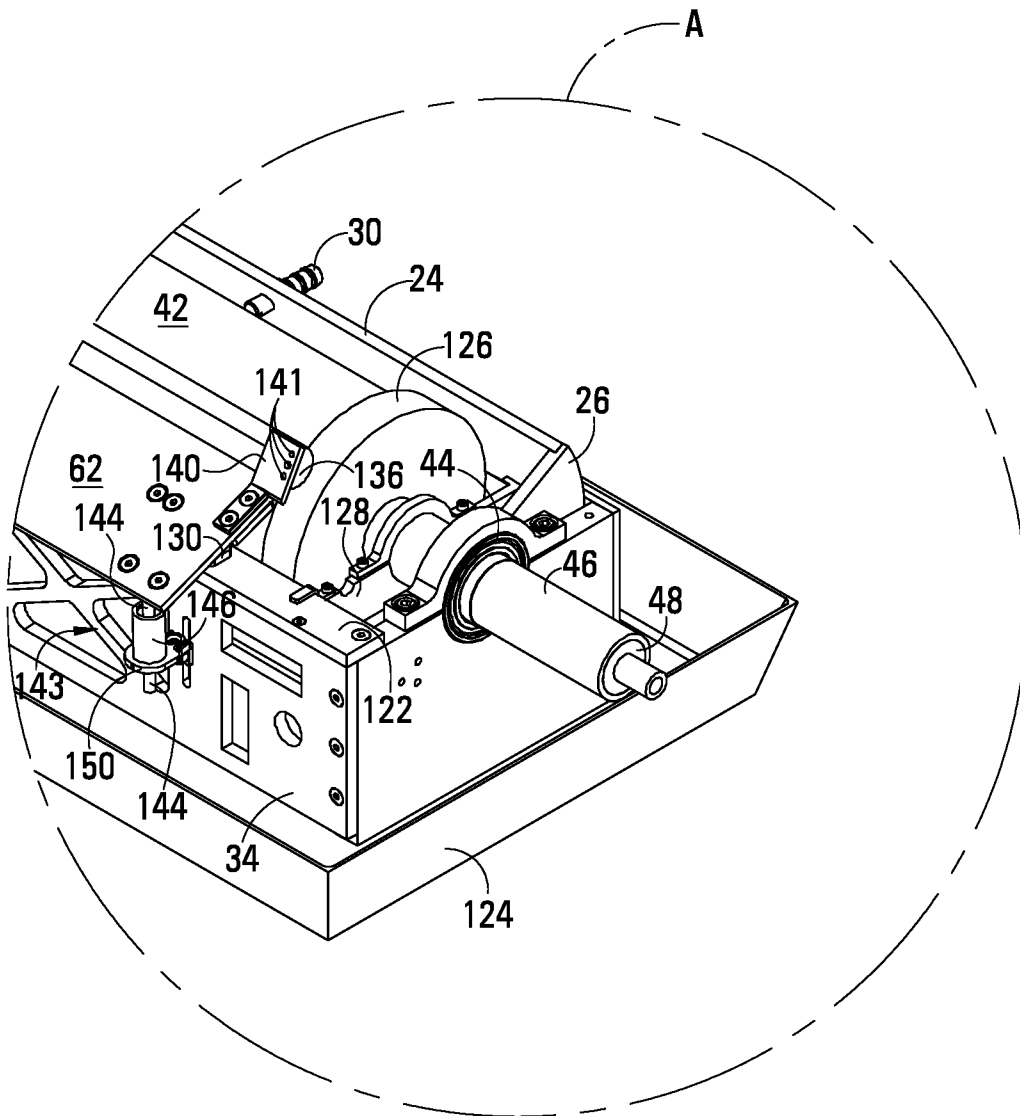


Fig. 11

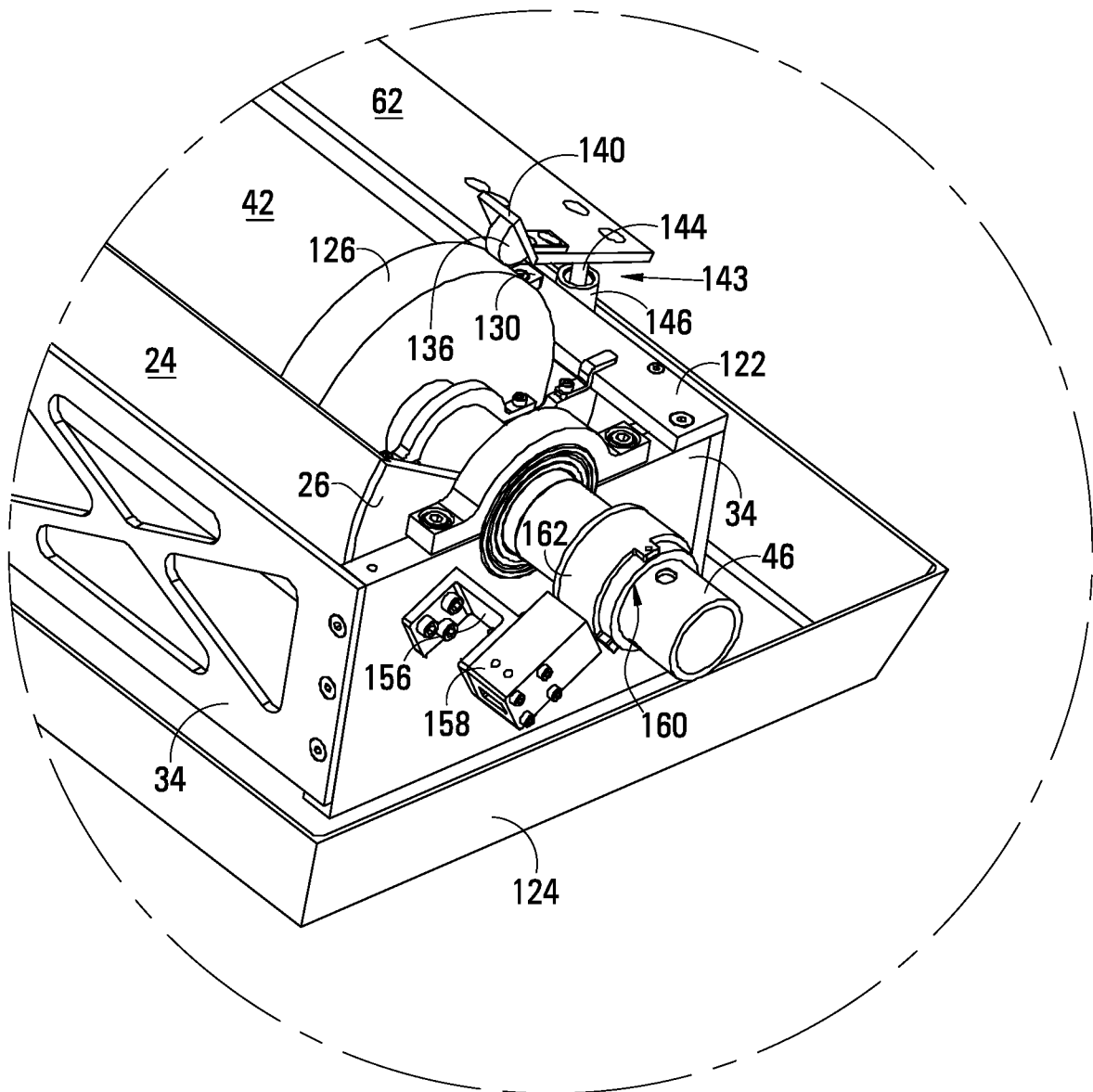


Fig. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/052622

A. CLASSIFICATION OF SUBJECT MATTER

INV. C25C7/00 C25C1/12 C25C5/02 C25C7/08
ADD.

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)
C25C

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CA 1 075 635 A (NAT RES DEV) 15 April 1980 (1980-04-15) page 22, line 17 - page 29, line 24; claims 1-5; figures 1,9 -----	1,2,4-13
X	US 3 772 003 A (GORDY J) 13 November 1973 (1973-11-13) column 7, lines 27-49; figure 1 -----	1-4,7-9, 13
X	FR 1 264 597 A (PRUNET, JEAN; GUILLEN, ANDRÉ) 23 June 1961 (1961-06-23) page 2, left-hand column; figure 1 -----	1-3,7-9, 13
A	US 2 313 338 A (HENRY HANNAY WILLIAM ET AL) 9 March 1943 (1943-03-09) page 2, left-hand column, lines 31-38 ----- -/--	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search

26 July 2017

Date of mailing of the international search report

08/08/2017

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Authorized officer

Hammerstein, G

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/052622

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP S60 2688 A (SUMITOMO METAL MINING CO) 8 January 1985 (1985-01-08) abstract; figures 1-3 -----	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2017/052622

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