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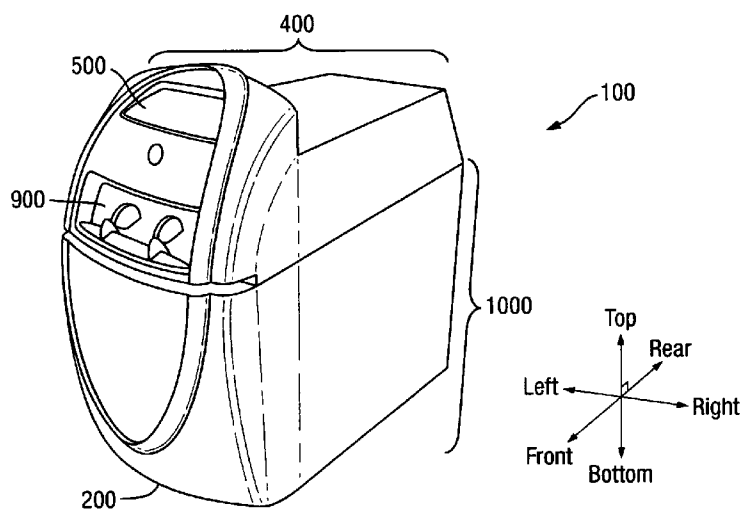
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(54) Title: DOCUMENT HANDLING APPARATUS



(57) Abstract: A document handling apparatus is disclosed. The apparatus comprises an input module for feeding documents one-by-one into the machine, a note handling assembly including a note transport system, secure document analysis assembly, diverter and stacker module. The secure document analysis assembly includes one or more detectors for detecting characteristics of the documents. The diverter directs documents along one of plural transport paths. Documents pass from the diverter into a safe via a through-safe transport and transport safe module to a series of roll storage modules, in which documents can be stored and later dispensed.

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DOCUMENT HANDLING APPARATUS

This invention relates to a document handling apparatus and associated methods. The document handling apparatus is particularly well adapted for receiving
5 and storing documents, and dispensing documents from storage to a user. The apparatus and methods are particularly suited to handling documents of value, such as banknotes.

Typical document handling apparatus are formed of a number of modules which are fitted to one another during assembly. In conventional structures it can be difficult
10 and cumbersome to hold one module accurately in position relative to another whilst fixing it in position, especially if the module is heavy. In other types of structure, previous attempts to improve this operation have involved cutting a tab out of a wall (such as a module wall) and folding it down so that the other module can rest on the folded surface. However, this is inherently weak since the weight of the module can
15 deflect the folded tab.

In accordance with a first aspect of the present invention, a method of providing a support in a sheet material comprises:

forming a first slot through the sheet material, the first slot having first and second opposing slot faces;
20 deforming a region of the sheet material adjacent to the first or second slot face such that the first or second slot face is displaced out of the plane of the sheet material, the first or second slot face providing a support surface for locating an object placed thereon relative to the sheet material.

This construction has been found to produce a stronger support surface and
25 better maintains the integrity of the sheet material.

In some embodiments, it is preferable that at least a portion of the first slot is substantially rectilinear such that the first and second slot faces have a planar portion on which an object can be slidably supported. To restrict the available lateral movement, it is further preferable that the first slot has curved or angled portions at
30 each extremity such that an object placed on the first or second slot face is retained between the slot extremities.

In embodiments where no lateral movement is desired, it may be advantageous if the first slot is U-shaped or at least a portion of the first slot is arcuate.

In some cases, only a single slot is required and the deformed region remains
35 integral with the wall around the remainder of its perimeter. However, it may be

preferable to further form a second slot through the sheet material, the second slot having third and fourth opposing slot faces. Preferably, the deformed region of the sheet material is defined between the first and second slots, and is preferably substantially U-shaped.

- 5 The slots can be formed using any suitable technique, such as cutting, machining or stamping. Preferably the deformed region is deformed out of the plane of the wall in the direction of the object to be supported. However, in other examples, the deformed region could be deformed in the opposite direction, the slot face not forming part of the deformed region being used as the support. In further examples, both sides
10 of the slot could be deformed in opposite directions.

 The invention also provides a structure comprising at least a first side wall formed of a sheet material having a support provided therein in accordance with the above-described technique, and a crosspiece adapted to adjoin the first side wall substantially perpendicularly to the plane of the first side wall, an end of the crosspiece
15 being supported on the first or second slot face to thereby locate the crosspiece relative to the first side wall.

 The structure preferably further comprises a second side wall, the second side wall being formed of a sheet material having a support provided therein in accordance with the above-described technique and supporting another end of the crosspiece.

- 20 Advantageously, the structure further includes fixing means for fixing the crosspiece to at least the first side wall when located relative to the first side wall. Preferably, the crosspiece is a shaft, still preferably a cylindrical shaft.

 In conventional document handling apparatus, documents are typically fed into the apparatus one-by-one either on a timed basis (starting and stopping the feeding
25 operation), or by similar start-stop techniques. Such techniques have been found to give an inaccurate inter-note gap: that is, the distance between each note fed into the machine varies as a result of slippage, wear of the feed components and note fitness, etc. This can lead to a decrease in the number of notes which can be stored on each RSM (since there may be too large a gap between each note), problems during
30 authentication/denomination (if there is not sufficient time between each note for the detectors to complete analysis) and, in the worst case, jams if the notes are too close together.

 In accordance with a second aspect of the present invention, a method of conveying an upstream document and a downstream document along a transport path
35 is provided, the method comprising:

a) conveying the upstream document from its source to a first predetermined position along the transport path;

b) halting the upstream document at the first predetermined position;

5 c) at a predetermined time based on the position of the downstream document, conveying the upstream document along the transport path at substantially the same velocity as the downstream document.

By halting the document at a well-defined location and continuing its movement only at a predefined time, it is possible to accurately control the distance between adjacent notes in the system.

10 Preferably, the arrival of the upstream document at the first predetermined position is detected by a first sensor located at the first predetermined position in the transport path, preferably an optical sensor. In other cases, this event could be determined by alternative means such as timing the document's progress.

In step c), the predetermined time could be determined in a number of ways.
15 For example, using a fixed delay after the last document was passed forward (e.g. every n seconds). However, it is advantageous if the predetermined time relates to the progress of the downstream document. Thus in one embodiment, the predetermined time corresponds to the arrival of the downstream document at a second predetermined position, detected by a second sensor located at the second predetermined position in
20 the transport path, preferably an optical sensor.

In a particularly preferred embodiment, in step c), the predetermined time occurs when a predetermined delay has elapsed since the departure of the downstream document from the first predetermined position is detected using the first sensor.

25 The method may also provide for monitoring of the inter-note gap: preferably, the method further comprises d) measuring the gap between the upstream and downstream documents. This can be achieved using any downstream sensor. Preferably, the duration of the predetermined delay is calculated based on the measured gap between adjacent downstream documents.

30 Advantageously, an average measured gap between adjacent downstream documents is calculated, and the duration of the predetermined delay is calculated based on the average measured gap. In addition or as an alternative, the measured gaps between pairs of adjacent downstream documents are recorded as a statistical distribution, and the duration of the predetermined delay is calculated based on the
35 recorded distribution. Preferably, the duration of the predetermined delay is calculated

to maintain the 95th percentile of the statistical distribution at or below a standard deviation of 2.

Advantageously, the upstream document is conveyed in step a) by a first drive assembly, which is stopped in step b) to halt the upstream document. Preferably, the upstream document is conveyed in step c) by a second drive assembly. Advantageously, the first predetermined position is located such that when the document is halted, the document is positioned to receive drive from the second drive assembly and its trailing edge is retained by the first drive assembly. Preferably, during step c), the first drive assembly is not driven such that a retardation force is applied to the document by the first drive assembly as it is conveyed by the second drive assembly.

Conventional note transport systems use a substantially linear transport path to maintain a straightforward construction and easy access to all parts of the transport path for jam clearance. However this arrangement can limit the number of detectors and sensors which can be provided in the document path due to size constraints, or result in an overly large apparatus. Some attempts have been made to reduce this problem by arranging the note path in a loop across the apparatus, however whilst all parts of the loop remain accessible, this leads to a complicated construction.

In accordance with a third aspect of the present invention a document transport assembly is provided for use in a document handling apparatus comprising first and second substantially parallel linear transport sections, each adapted to convey documents therethrough, joined by a U-turn transport section which is adapted to receive a document from the first linear transport section, turn the document through substantially 180 degrees and convey the document to the second linear transport section.

This construction results in a compact apparatus yet permits an extended transport path length, allowing for more detectors to be fitted alongside the path. The use of two linear sections allows for straightforward construction and their parallel arrangement means that one can be accessed through the other, e.g. by removing it.

Preferably, each of the first and second substantially parallel linear transport sections lie in substantially horizontal planes. However in other examples, the U-shaped transport could be re-orientated. For example, the linear paths could lie in vertical planes and be accessed from one or both sides.

Advantageously, each of the transport sections is adapted to convey documents whose dimension in the direction of travel is smaller than that perpendicular to the direction of travel. This makes best use of the length of available transport path.

Preferably, the document transport assembly is of modular construction, each of
5 the transport sections being adapted to detachably couple to one another. This not only aids construction but also assists during jam clearance.

Advantageously, at least one of the first and second substantially parallel linear transport sections comprises one or more detectors arranged to detect characteristics of documents conveyed therethrough.

10 In conventional systems utilising magnetic sensors, it has been necessary to isolate the magnetic heads as much as possible from sources of interference. Typically this is achieved by spacing the heads some distance from any moving parts (such as rollers), which had been found to cause variation in magnetic field due to currents being induced in the rotating material. It has therefore been found preferable in the past to
15 have only guide plates immediately opposite a magnetic head, rollers spaced to either side, or at most friction belts. However each of these approaches has problems, including the risk of a jam occurring between the two rollers, and the gap between the note and the magnetic head not being accurately set, due to a friction belt's inherent flexibility.

20 In accordance with a fourth aspect of the present invention a document handling apparatus is provided comprising a document path through the apparatus, a transport assembly for conveying a document along the document path, and a magnetic detector device adjacent at least a portion of the document path for detecting magnetic material in passing documents; wherein the transport assembly comprises at least one rotatable
25 member adjacent the magnetic detector device, the rotatable member arranged to support passing documents at a fixed distance from the magnetic detector device.

The use of a rotatable component near the magnetic head has previously been discouraged for all the reasons discussed above. However the present inventors have found that the use of a rotatable component in fact improves the sensor results since
30 the gap between the document and the magnetic head can be accurately set. Preferably, the rotatable member comprises a roller assembly.

Advantageously, the rotatable member comprises a non-magnetic material, preferably plastics or ceramic. This greatly reduces any interference due to the rotating element.

Conventional diverters are adapted to divert banknotes along one of two transport paths. The diverter is switched between two positions, one corresponding to each transport path, by an associated actuator. In some situations, it is necessary to provide more than two transport paths at a junction, which has required the use of more than one such diverter and associated actuators.

In accordance with a fifth aspect of the present invention a diverter assembly is provided for diverting documents between transport paths in a document handling apparatus, the diverter assembly comprising first and second blades pivotably engaged with one another, and coupling means provided between the first and second blades adapted to transfer rotation from the first blade to the second, such that when the first blade is rotated in a first direction, the second blade rotates in the opposite direction to switch the diverter assembly between transport paths.

By coupling the first and second blades in this way, a single actuation can control three transport paths.

Preferably, the diverter assembly further comprises an actuator coupled to the first blade for rotation thereof. Advantageously, the actuator comprises a solenoid.

Preferably, the coupling means comprises a first gear plate fixed to the first blade and rotatable therewith and a second gear plate rotatably mounted relative to the first blade, each gear plate comprising an arcuate rack gear, and a gear wheel provided between the first and second gear plates such that movement of the first gear plate causes movement of the second gear plate in the opposite direction, the second gear plate being adapted to engage the second blade so as to cause movement thereof during at least a portion of the movement of the second gear plate. Advantageously, the second gear plate is adapted to engage the second blade by abutting the second blade.

In some cases, it may be desirable to switch the diverter to allow an approaching note to take a different transport path from the last before the last note has exited the diverter. As such, the second blade is preferably sprung loaded. This allows the second blade to move with some independence from the first blade, resting on the exiting note without trapping it before returning to the "switched" position. Advantageously, the second blade is sprung towards the second gear plate.

Preferably, the first blade has two ends, allowing documents to pass between them, over the first blade to define a first transport path. Advantageously, a first end of the second blade is pivotably engaged with the first blade between the two ends of the first blade and a second end of the second blade extends away from the first blade to

define a second transport path between the first end of the first blade and the second end of the second blade, and a third transport path between the second end of the second blade and the second end of the first blade.

5 In a particularly preferred embodiment, the two ends of the first blade are bladed ends, adapted to allow documents to pass through the first transport path in either direction.

The present inventors have found that document transport is improved by corrugating the note. In conventional apparatus this was sometimes achieved by providing pairs of rollers offset from one another. However, this was found to be a
10 complex and expensive construction.

In accordance with a sixth aspect of the present invention a document transport assembly is provided for use in a document handling apparatus, the document transport assembly defining a document path therethrough and comprising at least one transport component on a first side of the document path for conveying documents
15 along the path and at least one protrusion provided on a second side of the document path adjacent the transport component and extending into the document path so as to cause deflection of passing documents.

Preferably, a plurality of transport components are provided, spaced laterally across the document path, the at least one protrusion extending into the document path
20 between the transport components. In a particularly preferred example, two protrusions are provided, laterally spaced across the transport path.

Advantageously, the at least one protrusion is a ramp having a linear or curved profile extending towards the document path.

Preferably the at least one transport component is a roller or friction belt.

25 In some examples, the transport component could be stationery, such as a guide plate, or free-wheeling, such as an idler roller, but preferably the at least one transport component is driven.

In a particularly preferred embodiment, the document transport assembly forms part of a stacker adapted to form documents into a stack.

30 In conventional roll storage modules, a scraper having a curved profile is provided to assist in removing documents from the storage roll during dispensing operations. The present inventors have found that this is not always effective.

In accordance with a seventh aspect of the present invention, a document storage device is provided for storing sheet documents, the device comprising a band,
35 which can be wound onto a document storage roller such that sheet documents can be

stored between adjacent windings of the band on the document storage roller and which can be unwound from the document storage roller thereby dispensing the stored documents, and a scraper assembly comprising a scraper for contacting the band on the document storage roller, the scraper defining a blade having a profile of which at least a portion is substantially rectilinear which, in use, contacts the band substantially perpendicularly to the length of the band.

Preferably, the substantially rectilinear portion of the blade profile is narrower than the width of the band.

Advantageously, the substantially rectilinear portion of the blade profile is formed by a region of the scraper which protrudes from the remainder of the blade profile.

Preferably, the scraper assembly is rotatable about a pivot and further comprises an end stop for contacting the band on the document storage roller, the scraper assembly being urged by a first biasing element such that the end stop maintains contact with the band on the document storage roller at a point distal from the pivot relative to the point of contact of the scraper with the band on the document storage roller.

An example of a document handling apparatus demonstrating the above mentioned inventions will now be described with reference to the accompanying drawings, in which:

Figures 1A and 1B are views of a document handling apparatus showing its constituent modules;

Figures 2A and 2B show two alternative cabinet configurations;

Figures 2C to 2F show three alternative door constructions;

Figures 2G and 2H show details of the housing;

Figures 3A to 3C depict alternative safe chassis constructions;

Figures 3D to 3G show the NHM chassis;

Figure 4 is a schematic overview of the modules contained within the NHM;

Figures 5A and 5B are two perspective views of a feeder module;

Figure 5C is an exploded view of the feeder module;

Figure 5D(i) is a cross section of the feeder module;

Figure 5D(ii) is a view of the feeder module from one side showing the drive components;

Figure 5E(i) to (iv) are exploded views of the shaft assemblies in the feeder module;

Figures 5F(i) to (iii) and 5G(i) to (iii) are views of the feeder module housed in its supports;

Figure 6A is a perspective view of the NHM transport system;

Figures 6B and 6C are perspective views of a secure document analysis (SDA) module;

Figures 6D and 6E show the lower NHM transport path;

Figure 6F is a cross section through the NHM transport system;

Figure 6G is an exploded view of the U-turn section;

Figure 6H is an assembled perspective view of the U-turn section;

Figure 6J is an exploded view of the lower NHM transport path;

Figure 6K shows an extended embodiment of the NHM transport system;

Figures 6L and 6M show an advanced SDA module;

Figure 6N is an exploded view of an extended lower NHM transport path;

Figure 6O is an exploded view of the extended NHM transport system;

Figure 6P is a cross section of the extended NHM transport system;

Figure 7A shows a reflective contact image sensor;

Figure 7B shows a magnetic sensor;

Figure 7C shows a UV paper property detector;

Figure 7D shows a light transmitter for a transmissive contact image sensor;

Figures 7E and 7F show an ultrasound detector;

Figure 7G shows the ultrasound detector transport module;

Figure 7H shows an exploded view of the upper section of ultrasound detector transport module;

Figure 7I shows an exploded view of the lower section of ultrasound detector transport module;

Figure 7J shows a transport extension section;

Figure 8A shows the front and rear sections of a diverter;

Figures 8B and 8C show details of the diverter construction;

Figures 8D and 8E show the diverter in a first position and in a second position respectively;

Figure 8F shows the diverter drive mechanism;

Figures 9A(i), (ii) and (iii) show a stacker module and its constituent parts;

Figure 9B is a cross section of the stacker module;

Figure 9C(i) and (ii) show details of the stacker module;

Figure 10 is an overview of the safe;

Figure 11A is a cross section of the through-safe transport;

Figure 11B is an exploded view of the through-safe transport;

Figure 11C is an exploded view of an extended variant of the through-safe transport;

5 Figure 12A is a cross section of the transport safe module;

Figure 12B is an exploded view of the transport safe module;

Figures 12C(i) to (v) are exploded view of the shaft assemblies in the transport safe module;

Figure 12D is a partially-assembled view of the transport safe module;

10 Figures 13A(i) to (iii) are views of a roll storage tower;

Figures 13B(i) and (ii) are perspective views of a roll storage module;

Figures 13C(i) to (v) are cross-sections of a roll storage module and details thereof;

Figures 13D(i) to (iv) show the band path through a roll storage module;

15 Figures 13E(i) to (viii) show the roller assemblies in a roll storage module;

Figures 13F(i) and (ii) are views of the note storage roller;

Figures 13G(i) and (ii) show the band rollers;

Figures 13H(i) and (ii) show the timing rollers;

Figures 13I(i), (ii) and (iii) show a band end sensor and marker tab;

20 Figures 13J(i) to (vii) and 13K(i) to (iii) show the pivot guide assembly and details thereof;

Figures 13L(i) and (ii) show an assembled roll storage module and its interaction with a neighbouring roll storage module;

Figures 13M to 13R show components of the roll storage diverters;

25 Figure 14A illustrates the organization of the control systems within the document handling apparatus;

Figure 14B schematically depicts the operation of a track sensor;

Figure 14C schematically depicts the operation of a skew sensor;

30 Figures 14D and 14E respectively show the location of the track and skew sensors and internal electrical systems along the complete note transport path of the NHM and safe; and

Figure 14F depicts the control systems and internal and external interfaces of the document handling apparatus.

1. Overview

This description relates to a multi-functional cash handling apparatus. Its primary modes of operation involve receiving a stack of banknotes and storing them in
5 appropriate storage modules, and dispensing banknotes from those storage modules to a user, typically a bank teller. A perspective view of the banknote handling apparatus 100 is shown in Figure 1a. A schematic cross-section is illustrated in Figure 1b.

The apparatus 100 comprises a cabinet or safe 200 within which is housed a frame to which a storage assembly 1000 is mounted. The storage assembly 1000
10 consists of a number of roll storage modules (RSMs) 1300 in which banknotes can be stored. On top of the cabinet 200, a note handling module (NHM) 400 is provided which consists of a number of components which input banknotes to the storage assembly 1000 and/or output banknotes from the storage assembly 1000 to the user. The note handling module (NHM) 400 comprises an input module 500, from which a
15 stack of banknotes are fed one by one into transport 600 for conveying each banknote past detectors 700 to a diverter 800. If the banknote is to be stored in the storage assembly 1000, the diverter 800 directs the banknote into the storage assembly 1000 via the through safe transport 1100 and the transport safe module 1200 to the appropriate RSM 1300. If the banknote is to be returned to the user, the diverter 800
20 directs the banknote to stacker 900 from which it can be collected by the user. When a banknote is to be dispensed from a roll storage module 1300, it is conveyed in the reverse direction out of the RSM 1300, along the transport safe module 1200, via the through safe transport 1100 to the diverter 800 which directs the banknote to the stacker 900 where it can be collected by the user.

25 There are a number of machine variants available, each of which is adapted for the specific end application. The description below will largely focus on a standard version, as shown in Figure 1b, and details of alternative configurations will be described in the appropriate sections below. The example shown incorporates six RSMs 1300, but other versions may include two, four, eight or more RSMs as desired.
30 The NHM 400 shown incorporates a standard set of detectors 700, but in an enhanced version, one or more additional detectors, such as an ultrasound detector could be included and the NHM transport 600 is extended towards the rear of the machine to accommodate this. The cabinet 300 itself is available in a number of different variants to suit different security requirements and provide one or more manual drop boxes on
35 the front if so desired.

The operation of the banknote handling apparatus 100 is controlled by a controller printed circuit board (PCB) which receives commands issued by the teller via an external terminal or personal computer and operates the apparatus accordingly.

Each sub-unit of the apparatus will be described in detail below.

5

2. Cabinet 200

The storage assembly 1000 is housed within a secure cabinet (or "safe") 200, mounted on a chassis 300 (see section 3.1 below). There are a number of cabinet variants available for different end applications, of which two examples are shown in
10 Figures 2a and 2b. Figure 2a shows a standard cabinet 200 in which the RSMs 1300 sit substantially at floor level. Figure 2b shows a variant in which the cabinet 201' is configured to support the storage assembly 1000 some distance off the floor. Both safe variants comprise substantially similar components, which are indicated throughout with
15 corresponding reference numerals, those in Figure 2b having the addition of a prime. As such, the description will centre on the standard cabinet 200 shown in Figure 2a, but it will be understood that substantially the same points apply to the variant shown in Figure 2b.

Two perspective views from different angles of the cabinet 200 are shown in
20 Figures 2a (ii) and (iii). Figure 2a(i) shows a rear view of the cabinet 200, and Figure 2a(iv) shows a partial perspective view of the cabinet interior.

The cabinet 200 comprises a cabinet body 201 consisting of walls 201a to f, and cabinet door 202 which provides access through cabinet wall 201f to the cabinet interior. The cabinet door 202 is mounted on cabinet body 201 by a secure hinge arrangement 208. The cabinet walls 201a to f are typically made of steel and may be
25 up to 40mm in thickness. The cabinet door 202 consists of an outer panel 202a, of similar construction to the wall panels 201a to 201f, and a locking assembly 202b mounted on the interior surface of panel 202a. The door is provided with at least one lock 203a which operates latches 203b and 203c to secure the door 202 into wall 201f
30 of the cabinet body 201. The latch 203b cooperates with a protrusion on the interior of wall 201f, and latches 203c cooperate with wall panel 201f (which constitutes the door frame) of the cabinet body 201. The cabinet door is further provided with a handle 204 for opening the door 202.

The cabinet body 201 is provided with an aperture 205 in its upper wall 201a for
35 transfer of notes between the storage assembly 1000 and the note handling module

400 which, in use, is mounted on top of the cabinet 200. When assembled, the aperture 205 contains the through safe transport module 1100.

5 The cabinet door 202 is provided with a number of sprung contacts 206 which, when the door is closed, make electrical connection with contact pads 207 provided on wall 201f of the cabinet. This addresses electromagnetic compatibility (EMC) requirements by establishing a Faraday's cage effect within the cabinet body 201 such that electromagnetic radiation is prevented from escaping from the cabinet 200 which might cause disturbance to other equipment in the vicinity. Similarly, radiation cannot infiltrate the cabinet, where it could potentially affect the components inside.

10 The interior of cabinet 200 is provided with a number of components for supporting the storage assembly 1000 and for connecting to and interacting with the storage assembly components. A side plate assembly 210 is mounted on the interior of cabinet wall 201b and comprises a number of PCBs which control the storage assembly components. More details as to the functions of the PCBs can be found in
15 section 14 below. On the interior of cabinet wall 201d, an alarm plate assembly 211 is mounted. This can consist of a number of different types of alarm, for example detecting unauthorised opening of the cabinet door 202, movement of the cabinet 201, or loss of power or communication. The alarm(s) may set off audible signals, alert remote parties and/or prevent the door 202 from being opened. In systems requiring
20 communication between the alarm panel 211 and some external system (such as the alarm system of the bank), a connection box 299 is provided on the rear of the cabinet.

The storage assembly 1000 is mounted into the cabinet 200 via a chassis 300 to be discussed in section 3.1 below. The chassis 300 is slidably mounted into the cabinet 200 by means of left and right slides 222a and 222b which are mounted on
25 brackets 221a and 221b to further brackets 220a and 220b, mounted on the interior walls of the cabinet 200. The provision of two brackets allows adjustment of the slides in order to ensure accurate alignment. In use, the chassis 300 is affixed to the slides 222 such that it is supported within the cabinet 200 and may be slid out a predetermined distance for maintenance and access to the RSMs 1300.

30 The PCBs of side plate assembly 210 connect to the storage assembly 1000 when it is inserted into the cabinet 200 via a connection point (not shown) which couples to the chassis 300. When the storage assembly 1000 is pulled out of the cabinet 200, the components are automatically disconnected. The PCBs 210 are connected through the back wall 201e of the cabinet body 201 to a distribution panel
35 298 for communication with a personal computer or other terminal. Power is provided

by a power supply box 298 which is input to side plate assembly 210. A cable guiding channel 295b is provided on the interior surface of top wall 201a to enable connection between the components on opposing walls of the cabinet body 201 without interfering with the movement of the storage assembly 1000 in and out of the cabinet 200.

5 A cable throughput 297 is also provided in the top wall 201a of the cabinet body 201 for communication between the storage assembly components and those in the NHM 400 mounted on top of the cabinet 200. Paint-free strips 296 are provided on top of the cabinet 200 for locating the NHM 400 thereupon in a manner permitting electrical conduction between the cabinet and the NHM casing. This extends the EMC cage effect to the NHM 400.

10 Figure 2b shows a second variant of the cabinet 200' which, as already described, is substantially similar to the first cabinet variant 200. Figures 2b(i) and 2b(ii) show two perspective views of the cabinet 200', with the cabinet door 202' open. Figure 2b(iii) shows a rear view of the cabinet 200', and Figure 2b(iv) shows a perspective view of the cabinet 200' with the cabinet door 202' closed.

15 The front of the cabinet 200 is provided with a door cover which conceals the locks and door handle. A first variant of the door cover 230 is shown in Figure 2c in rear (i) and front (ii) perspective views. The door cover 230 consists of a moulding arranged to fit over the front wall 201f of the cabinet 200. The door cover 230 is attached to the cabinet 200 by two hinge assemblies 234. Each hinge assembly consists of a plate hinge 234a attached to the interior of the door cover 230 via fixing pads 234b and shaft 234c. The hinge plate is fixed to the front panel 202a of the cabinet door 202 at points Y indicated at Figure 2a(i). The door cover 230 is provided with a doorstep 236 comprising a flexible strip which is affixed to the exterior of cabinet door 202 and, at its other end, to the interior of the door cover 230 via mounting plates 236a. The doorstep prevents the door cover 230 being opened by more than a predetermined angle. A clip 235 may be provided on the interior of the door cover 230 for safe storage of the users' manual or other documentation.

20 A magnet 232 is mounted via plate 231 to the interior of door cover 230 adjacent its edge furthest from the hinges 234. In use, the magnet 232 secures the door cover 230 against the cabinet door 202. Spacing feet 239a and b are provided to protect the door cover 230 from damage upon contacting the cabinet door 201.

25 A second variant of door cover 240 is depicted in Figures 2d in rear (i) and front (ii) perspective views. Figure 2d(iii) shows a partial view of the interior of door cover 240 showing the locking arrangement in detail.

The door cover 240 is provided with two manual drop boxes 250a and b which may be used by the operator to store rejected banknotes or to accept cheques or other documents of value. In this example, there are two drop boxes 250 but it will be appreciated that any number of drop boxes could be employed.

5 Banknotes or other documents are inserted into the drop box through an aperture 249 in the door cover 240. The present example shows two such apertures 249a and 249b corresponding to the two drop boxes 250a and 250b. The drop box consists of a metal shell 250 shaped to provide three walls of a chamber and a base. Figure 2e shows a drop box 250 removed from the door cover 240 for clarity. The
10 fourth wall of the chamber is provided by the interior of the door cover 240 itself, and it is preferable that this is ribbed so as to prevent too much contact between the input banknote and the door cover 240, which can lead to the build up of static. Similarly, the drop box shell 250 is provided with ribs 252 for strength and to avoid static.

The drop box 250 is affixed to door cover 240 via pivot points 255a at its lower
15 corner which are mounted into the side of door cover 240 and a centre plate 251. In use, the interior of the drop box can be accessed by the user pulling the top of drop box shell 250 away from the door cover 240 such that it pivots about pivot points 255a. A stopper 255b is provided to prevent the drop box being opened by more than a certain angle. A handle is provided at the top of the drop box shell 250 to assist the user in this
20 operation. A spring 258 is mounted on the interior side wall of door cover 240 which cooperates with an indentation in the side of the drop box shell 250 to retain the drop box shell in its upright position when the drop box is closed. A spacing foot 257 is provided to protect the door cover 240 from the edge of the drop box shell 250 as it is closed. A central wall 256 is moulded into the interior of door cover 240 to ensure that
25 the contents of the two drop boxes 250a and 250b are kept separate.

Since the door cover 240 may contain items of value, it is necessary to lock the door cover 240 when in its closed position against the cabinet 200. For this purpose, a locking mount plate 243b is provided on the wall of the door cover 240 and lock assemblies 243 are inserted therethrough which include latches 243a. The latches
30 243a cooperate with locking plate 242, mounted on the exterior of the cabinet door 202 via mounting plate 241 (the bolt holes used to mount plate 241 are identified as Z in Figure 2A(i)).

The door cover 240 is attached to the cabinet door 202 via hinge assemblies 244 which are substantially identical to hinge assemblies 234 described with respect to

door cover 230 shown in Figure 2c. Similarly, a doorstep 246 is also provided. Clips 259 can be provided to store the users' manual or other documentation in use.

Similar door cover units are available for the different cabinet variants such as the example 200' depicted in Figure 2b. A door cover 240' adapted for use with such a cabinet configuration is shown in Figure 2f and it will be seen that the drop boxes 250a' and 250b' extend approximately halfway down the door cover 240. Otherwise, the components are substantially identical to those already described with reference to Figure 2d, and corresponding reference numerals have been used with the addition of a prime from which it will be clear that the above description applies to this embodiment also.

As described in section 1 above, the note handling module 400 is mounted on top of the cabinet 200. In use, the note handling module 400 is protected by a set of covers which provide user access only to the input module 500 and stacker module 900. The main body of the NHM cover is shown in Figure 1a extending above the cabinet 200. Above the door cover 230/240 is provided a top cover in two parts. Figure 2g shows a perspective view of the top portion of the NHM cover which comprises a plastic moulding 260. A first aperture 261 is provided through the moulding 260 for access to the input module 500. The moulding 260 also includes a cut-out 262 which in use forms part of the aperture through which stacker module 900 is accessed. Clips 269 are provided to affix the moulding 260 to the feeder module 500 via bosses 596 (see Figure 5F(i)). A recess 263a is provided into which a handle unit 263b is fitted which is attached to latch plate 588 in the input module 500 (see section 5 below and Figure 5G(iii)). By depressing the handle unit 263b, the latch plate 588 decouples from the NHM chassis the input module 500 (including the cover moulding 260) can be pivoted away from the note transport 600, should the interior of the machine need to be accessed. Buttons 265a and 265b are mounted using retainer clips 266a and 266b through apertures 264a and 264b. The buttons are depressed by the user to operate components on a PCB 267 mounted behind them. The PCB 267 also includes a light source, and a lens 268 is mounted in front to transmit the light for display to the user.

Figure 2h shows a perspective view of the middle portion of the top cover, which fits to the top portion shown in Figure 2g. The mid-portion consists of a plastic moulding 270 adapted to cooperate with the plastic moulding 260 along its edge, and is provided with a cut-out 272 which corresponds to the cut-out 262, thereby completing the aperture providing access to the stacker region 900. Two teeth 271a and 271b are

affixed to the moulding 270 and assist in the formation of a stack in the stacker module 900.

3. Chassis

5

The note handling module (NHM) 400 and the storage assembly 1000 are each mounted to the cabinet 200 via a respective chassis. The safe chassis 300 carries the storage assembly 1000 and is slidably mounted within the cabinet 200. The safe chassis 300 is described in more detail in section 3.1 below.

10

The NHM chassis 350 is mounted on top of the cabinet 200 and slidably carries the NHM 400. The NHM chassis 350 is described in more detail in section 3.2 below.

3.1 Safe Chassis 300

15

A standard variant of the safe chassis 300 is depicted in Figure 3A. Figure 3a(i) shows the safe chassis 300 in perspective view, Figure 3a(ii) shows a portion of the front of safe chassis 300 in perspective view, Figure 3a(iii) shows a portion of the RSM locking arrangement 311 on the safe chassis 300 and Figure 3a(iv) shows a portion of the safe chassis 300 in perspective view from underneath.

20

The safe chassis 300 comprises a base frame 301 and a tower 302. The base frame 301 couples with slides 222a and 222b mounted on the interior of cabinet 200 at points 301a and 301b on each side of the base frame 301. The tower 302 is mounted on top of the base frame 301 at its front edge. The tower 302 encloses a cavity 303 which, when assembled, supports the transport safe module 1200. Underneath the

25

cavity 303, the tower 302 houses a power supply 304.

The chassis 300 is provided with a handle 305 which is rotatably mounted to the tower 302 at pivot points 305a and 305b. The handle 305 is used by the operator to pull the chassis 300, and the storage assembly 1000 mounted thereon, out of the cabinet 200. As shown best in Figure 3a(iv), the handle 305 also operates a lock bolt 306, mounted at the upper interior wall of the tower 302 via two mounting tabs 306b. The lock bolt 306 is urged into an upward position by spring 306a. When the handle 305 is opened by pivoting it toward the user, a plate attached to the handle 305 at pivot point 305b interacts with the lock bolt 306 to urge it into its downward position. In this state, the lock bolt 306 is clear of the cabinet 200, and the chassis 300 can therefore be

35 moved in or out of the cabinet without hindrance. When the chassis 300 is returned to

its proper position within the cabinet 200, and the handle 305 lowered to its rest position, the lock bolt 306 returns, by virtue of the spring 306a, to its upward position in which it engages a locking plate 209 in the interior of the cabinet 200 (see Figure 2A(iv)). If the chassis is not properly positioned within the cabinet, the lock bolt 306 will
5 not be able to return fully to its upward position, and as a result it is not possible to fully lower the handle 305. As such, the mechanism ensures that the chassis 300 is properly returned into the cabinet 200 before the cabinet door 202 can be closed.

The sidewalls of tower 302 also provide space for information labels 307 and 308 which may provide machine readable information such as a barcode.

10 Behind tower 302 is provided space for the RSMs 1300. In the example shown in Figure 3a, the safe chassis 300 is adapted to support three roll storage towers, each comprising two roll storage modules mounted on top of one another. Each roll storage tower (RST) is mounted onto the base frame 301 where it is locked into position by a respective latch assembly 311. The latch assembly 311 is shown in more detail in
15 Figure 3a(iii). Each latch assembly 311 consists of a lock bar 130 fixed to the base frame 301 and having at one end a tab extending upwards. Mounted on the tab via a pivot pin 314 is a latch clip 312, biased by a tension spring 313. In use, the latch clip 312 couples with a cut-out on the base of the roll storage tower to secure it into position on the chassis 300. To release the RST, the user depresses the latch clip 312 against
20 the action of spring 313, allowing the latch clip 312 to be disengaged from the RST.

The RSMs are controlled by roll storage controller PCBs supported in mountings 330 on the underside of the base frame 301. Each roll storage controller PCB can control up to two roll storage towers (i.e. up to four RSMs). In the example shown, two RSM PCB mountings 330 are provided, one driving two of the RSTs and the other used
25 to drive the one remaining RST.

An RSM PCB mounting 330 is shown in expanded perspective view in Figure 3B. The mounting comprises a tray 331 provided with support flanges 331a and 331b along each side which, in use, couple with runners 329 provided on the underside of the base frame 301 to hold the mounting 320 firmly against the chassis 300. The roll
30 storage controller PCB 332 is mounted on top of the tray 331 via a heat sink 335 and thermal gap fillers 336 and 334. The PCB 332 has connectors 333 for communication between the PCB 332 and the rest of the apparatus. When the mounting 330 is inserted into position, the connectors 333 couple with a further control circuit board 325 supported inside the base frame 310 adjacent to the RSTs in use. The coupling
35 between the mounting 330 and the circuit board 325 is shown most clearly in Figure

3a(iv). The circuit board 325 is provided with connectors for connecting to the RSTs when they are in position.

The mounting 330 is provided with a handle 338 for ease of access and a spring latch 337 which, when the mounting 330 is inserted into position, acts against the underside of the base frame 301 to secure the mounting 330 into position. To slide the mounting 330 away from the chassis 300, the spring latch 337 must be depressed by a user.

Power is provided to the PCBs 332 and 325 from the power supply 304 via cables running down cable guide 326. Communication cables also use this channel, which accesses the power supply 324 via aperture 323 in the tower 302, to link to the other control PCBs in the apparatus.

The power supply 304 and the communication cables connects to the main controller panel 210 on the interior wall of the cabinet 200 via connector 324 attached to the exterior wall of the tower 302. Thus, when the chassis 300 is removed from the cabinet 200, power to the storage assembly is disconnected.

It will be appreciated that the banknote handling apparatus may be adapted to comprise any number of roll storage modules 1300, and in order to do so the chassis must be adapted accordingly. Figure 3c shows a second variant of the safe chassis 300' which is adapted to carry four RSTs (i.e. eight RSMs). The construction of the safe chassis 300' is identical to that of the first variant 300 shown in Figure 3a and as such its components are labelled using corresponding reference numbers with the addition of a prime. It will be understood that the above description applies to the variant shown in Figure 3c also. The main alteration is that four latch assemblies 311' are provided, one for each RST, and each of the two RSM controller PCBs are used to capacity in order to control all four RSTs.

3.2 Note Handling Module Chassis

The note handling module (NHM) of the banknote sorting device resides above cabinet 200. It is fixed within a metal chassis that provides structural support for the NHM apparatus. The metal chassis comprises two main parts: an elongate static frame that extends along the length of the safe and a metal carriage that rests within the static frame in use and slides forwards to over-hang the front of the safe for access.

The static frame (not shown) is bolted to paint free strips 296 on the upper surface of the cabinet 200 and includes two laterally spaced elongate slides that extend

along the length of the cabinet 200. Thus an electrical connection is made between the safe and the NHM chassis to extend the EMF radiation shield. The moveable carriage 350 thus slides within the elongate slides in a similar manner to a standard office drawer. The slides thus also restrain the lateral motion of the movable carriage.

5 The movable carriage is shown in Figures 3D and 3E. The carriage 350 comprises left 350a and right 350b sheet metal sides that are laterally spaced with respect to the centre of the cabinet 200 and extend along the length of the cabinet. The two sides 350a, b are fixed a set distance apart by front support member 350c and rear metal plate 350d. The left side of the carriage 350a is raised to a height greater than
10 the right 350b in order to accommodate a control board mounting platform 359, upon which is mounted a series of control circuit boards for control of the NHM systems. This control includes that of the drive transport system and high level sensor processing (see section 14). Both sides 350a and 350b are raised in height at the front of the carriage 350 to accommodate the input module 500 and stacker system 900 mounted,
15 in use, therein. The main drive motor 356 of the transport system is also fixed to the raised portion of the left carriage side 350a, together with an output transport auxiliary drive motor 363.

Both sides of the carriage 350a, b further contain a series of circle apertures 362, which are positioned within indented flanges along the bottom of each sheet metal
20 side. These are used to mount a variety of transport modules within the moveable carriage 350, the indentation being used as a guide to locate each module before it is secured with screws. Circle apertures have been found to be particularly effective in this embodiment, since they are to accommodate cylindrical shafts or pins provided on the relevant modules. However, in other cases it may be preferable to provide
25 indentations having different shapes. For example, if it is desired to support a crosspiece (such as a shaft) at a particular height but allow lateral sliding, it is useful to provide an indentation having a planar surface on which the crosspiece rests.

In this example the indentations are made by:

forming a first slot through the wall, the first slot having first and second
30 opposing slot faces;

deforming a region of the wall adjacent to the first or second slot face such that the first or second slot face is displaced out of the plane of the wall, the first or second slot face providing a support surface for locating an object placed thereon relative to the wall.

In embodiments where no lateral movement is desired, it is advantageous if the first slot is U-shaped or at least a portion of the first slot is arcuate, as in the case of the circle apertures 362 shown in Figures 3D and 3E: here the "circle" cut into the carriage wall is the first slot.

- 5 In some cases, only a single slot is required and the deformed region remains integral with the wall around the remainder of its perimeter. However, it may be preferable to further form a second slot through the sheet material, the second slot having third and fourth opposing slot faces. The embodiment shown in Figures 3D and 3E is such a case: the vertical cuts either side of the circle aperture take the place of
10 the second slot to separate the deformed region from the wall underneath. Preferably, the deformed region of the sheet material is defined between the first and second slots, and is preferably substantially U-shaped.

- The slots can be formed using any suitable technique, such as cutting, machining or stamping. Preferably the deformed region is deformed out of the plane of
15 the wall in the direction of the object to be supported. However, in other examples, the deformed region could be deformed in the opposite direction, the slot face not forming part of the deformed region being used as the support. In further examples, both sides of the slot could be deformed in opposite directions.

- In use, a series of wheels (not shown) are also mounted along the base of each
20 side of the moveable carriage 350 and these wheels run upon the elongate rails of the static frame, allowing the movable carriage 350 to slide forwards and backwards in the x-direction.

- In the default operating position the carriage 350 will be at rest above the cabinet 200. Typically, the main body of the banknote handling apparatus 100 is
25 located under a desk or built into the office environment to save space and to reduce the footprint of the apparatus 100. However, for prior art devices located in this way problems arose when access to the NHM was required, for example in the case of a note jam or when repair was required. By using a movable carriage 350, the main components of the NHM can be accessed by pulling the carriage 350 forwards and out
30 from its normal residence. The carriage 350 then slides out above the front of the cabinet 200, in a similar manner to a drawer within an office cabinet system.

- To prevent the movable carriage 350 from accidentally moving when in use a locking mechanism is also provided to lock the carriage into one of two places: an extended position overhanging the front of the cabinet 200 or a default, in-use position
35 above the cabinet 200. This locking mechanism comprises a catch 355 at the rear of

the right carriage side 350b. The catch 355 has two apertures 364 on the respective bends of two lateral flanges 365. When locked, these apertures 364 mate with the front and rear corners of an indentation within the right side of the static frame. The catch 355 is further connected to a three member linkage that comprises tab member 352, elongate member 353 and catch member 354. Tab member 352 comprises tab 351 and is pivotally connected to the right side 350b of the moveable carriage 350 about a pivot point near its centre. Elongate member 353 is fixed to both tab member 352 and catch member 354 and moves forwards and backwards (with a pivoting motion of tab member 352) whilst remaining substantially horizontal. Catch member 354 is also pivotally connected to the right side 350b of the movable carriage 350.

Typically, when an operator needs to access the NHM the moveable carriage 350 is located in an in-use position above the cabinet 200. In this position the catch 355 is locked within a rear indentation on the right side of the static figure. When the operator pushes tab 351 towards the front of the moveable carriage 350, tab member 352 rotates in a clockwise direction (from the perspective viewpoint of Figure 3D) about its pivoted connection to the right side 350b of the carriage, horizontally displacing the elongate member 353. The same horizontal displacement of the elongate member 353 can also be performed using a lever linkage instead of the pivoted tab member. A lever would then allow a vertical displacement of tab 351 to be translated into the horizontal motion of the elongate member 353. This displacement in turn rotates catch member 354 in a clockwise direction about its own pivoted connection which raises the catch 355. When the catch 355 is raised it is no longer locked within the indentation upon the static frame, allowing the movable carriage 350 to slide along the elongate rails of the static frame. The three member linkage is also sprung to bias the catch 355 towards a lowered position. The biasing force of the spring requires constant pressure to be applied to the tab 351 in order to raise the catch 355, which prevents accidental unlocking of the moveable carriage from the static frame. Within the scope of the current note handling device, the mechanism described above could be substituted for any mechanism that achieves a similar release of catch 355.

After catch 355 is uncoupled from the indentation on the static frame and the carriage 350 is moved forwards, the underside of the horizontal section of the catch 355 will slide upon the top edge of the right side of the static frame. When the catch 355 is aligned with a second indentation at the front of the right side of the static frame, the catch 355 will once again "click" into the indentation and thus lock the moveable

carriage 350 into place. Once the catch 355 is locked into place it can only be released again applying pressure to tab 351.

At the rear of the static frame is a bracket with a spring release (not shown). applying a repellent bias between the moveable carriage 350 and the inner frame.

- 5 When moving the moveable carriage to its at-rest position over the safe, a rearward force must be applied to the carriage to overcome the force of the spring bias and lock the carriage into place using catch 355. If not enough force is applied the spring will displace the moveable carriage forward from the at-rest position. The position of the moveable carriage 350 can thus be used as a visual confirmation that the moveable
- 10 carriage is locked into place. When the moveable carriage 350 is fully closed, the static frame makes contact with microswitch 357h, which in turn signals to the control systems.

- To accommodate a secure document analysis (SDA) module for housing detectors 700, an inner frame is also provided which is pivotably connected to a pivot
- 15 shaft 366 at the rear of the movable carriage 350. This inner frame is illustrated in Figures 3F and 3G. The inner frame 375 comprises two sheet metal sides 375a and 375b and a rear panel 375c mounted perpendicularly between these sides. At the rear of each side 375a, b, there are two mounting slots 380 wherein the pivot shaft 366 of the movable carriage 350 sits. The inner frame 375 can thus pivot about the rear of the
- 20 moveable carriage 350 as the rear of the inner frame rotates around the pivot shaft 366.

- By pivoting the inner frame 375 an operator can gain access to additional areas of the note transport 600. To prevent the inner frame 375 being lifted off the pivot shaft 366 two locking sections 381 are provided to close the entrance of each mounting slot 380. Each locking section 381 is screwed to an associated side of the inner frame 375 with
- 25 screws 381c, d. These screws can be loosened to allow each locking section 381 to rotate to a position wherein it no longer constrains the pivot shaft 366. This in turn allows the rear of the inner frame 375 to be lifted off the pivot shaft 366. The whole secure document analysis module can then be removed for repair or replacement.

- To prevent the inner frame 375 from pivoting freely when in use a further locking
- 30 mechanism is provided, which locks the inner frame to the horizontal. This locking mechanism comprises a pivoted bar 376 with an indentation 382. The indentation 382 mates with the protrusion 361 on the right side 350b of the movable carriage 350. The pivoted bar 376 can pivot freely around shaft stub 378, however, the range of rotation of the end of the pivoted bar 376 is constrained by a second shaft stub 379 resident within
- 35 arc aperture 384. The pivoted bar is biased to the vertical by a tension spring 383. In

use, when the inner frame 375 rests in a horizontal position within the movable carriage 350, the indentation 382 is coupled with the protrusion 361 preventing the inner frame 375 from rotating upwards. When a force is applied to lift handle 377 from the horizontal, the pivoted bar 376 pivots against the retaining force of the bias spring 383
5 to uncouple the indentation 382 from the protrusion 361 and thus allow the inner frame 375 to rotate upwards.

Typically, a gas cylinder (not shown) is connected to the movable carriage 350 and the inner frame 375 to control the pivoting motion of the inner frame. The base of the cylinder of the gas cylinder is mounted to movable carriage 350 and the piston of
10 the gas cylinder is mounted to the inner frame 375. When the inner frame 375 is held horizontal this retracts the piston and compresses a gas such as air within the cylinder. When the locking mechanism is released by unlocking the pivoted bar 376, a light pressure applied upwards to the inner frame 375 will release the piston, causing it to extend against the pressure of the compressed gas. The extension of the piston will
15 rotate the inner frame 375 a set distance and provide safe access to the note transport path. A similar arrangement is used within the SDA module and is illustrated in Figure 6A.

When a gas cylinder is employed as above it is important that the inner frame 375 is not accidentally released while the moveable carriage 350 is sliding forwards to
20 an extended position as this could injure an operator or damage an external cover. Thus, a third locking mechanism is provided to lock the inner frame 375 to the horizontal when the movable carriage 350 is sliding. This third mechanism comprises a protruding tab 367 located on the elongate member 353 of the moveable carriage 350 which mates with the right inner frame side 375b through cut-out section 385. When
25 sliding, the protruding tab 367 is locked within an indentation at the front of the cut out section 385. The lip of the indentation 386 prevents the inner frame from rotating upwards even if pivoted bar 376 is released. However, when catch 355 clicks into place in one of the two indentations on the static frame, the protruding tab 367 on elongate member 353 moves backwards and is no longer limited by the lip 386 on the
30 right inner frame 375b. The front of the inner frame 375 is then free to rotate upwards.

Latch 357a is used to lock the feeder module into place and prevent it from pivoting open during use. An indentation on the rear of the latch 357a mates with a protrusion on the feeder module frame, and the protrusion is only free to move, and the feeder module free to pivot outwards, once the latch 357a has been pivoted by an
35 operator against the bias of spring 357b.

The front of sliding member 357e is pivotably attached to the feeder module chassis and prevents the feeder module from pivoting too far. The motion of the sliding member 357e is constrained by pin 357d which is constrained to move within aperture 357c. When the sliding member 357e is fully displaced to the front of the device, indicating the feeder module is fully pivoted, then latch 357a pivots back down under the spring bias to lock the feeder module in the fully extended position. Thus to pivot the feeder module back to its operating position latch 357a has to be pivoted upwards by an operator. In some embodiments the sliding member 357e has a dog leg so the operator has to lift the sliding member 357e after releasing the latch 357a to pivot the feeder module back to the operating position. The control systems sense that the feeder module is closed when microswitch 357g is activated by tab 599b on the feeder module chassis (see Fig 5G(i)).

4. Note Handling Module 400

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A schematic illustration of the note handling module is shown in Figure 4. The operating apparatus of the note handling module are mounted within the metal chassis, illustrated in Figures 3D to 3G on top of the cabinet 200. The apparatus principally comprises four components: an input module 500, a secure document analysis (SDA) assembly 601, a horizontal transport section and an output or stacker module 900. The input module 500 contains input hopper 501 and receives and separates notes provided by an operator. The stacker assembly 900 contains an output hopper where notes are delivered to an operator. Between the input 500 and output 900 modules the SDA assembly 601 and the horizontal transport section provide the NHM transport 600 along which a note travels. As the note moves along the NHM transport 600 properties of the note can be detected by detectors 700 within the SDA assembly 601. A variety of different detector systems can be installed to record different properties of the note.

The NHM transport 600 is separated into two parallel note paths aligned with the horizontal. An upper path 410 is defined within the SDA assembly 601 and a lower path 411 is defined by the lower surface of the SDA assembly 601 and the horizontal transport section. A U-turn section 405 allows a note to move from the upper path 410 to the lower path 411 by rotating the note 180°. Within both paths there is a maximum distance of 42mm between drive points to minimise note tracking and presentation problems. Notes are typically transported along the transport path at speeds of

between 600mm/sec and 1.3m/sec depending on the specifications of the detector systems 700 mounted therein.

The destination of a note is controlled by the diverter 800 which allows three different note paths: from the input module 500 to the output module 900; from the input module 500 to the roll storage modules 1300; or from the roll storage modules 1300 to the output module 900. The NHM 400 interfaces with the storage assembly 1000 below the diverter. This interface is provided by the through safe transport 1100.

Within the SDA assembly 601 a plurality of detectors 700 can be installed. In a first basic embodiment a single detector system is used to detect basic properties of a note. In a second, more advanced embodiment multiple detectors are installed with the SDA assembly 601 and the NHM further comprises an advanced ultrasonic detector (not shown) for detecting the ultrasonic properties of a note.

5. Input Module 500

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The input module 500 is the subunit of the NHM 400 responsible for inputting banknotes one by one into the apparatus 100. As shown in Figure 1b above, the input module 500 is situated at the front of the NHM 400 above the stacker module 900. The input module 500 comprises an input hopper 501, into which a stack of banknotes is placed by the user, and a series of roller mechanisms which feed the banknotes, one by one, into the NHM transport 600. Figures 5a to 5g show the input module 500 in various aspects as will be described below. Throughout the Figures, the path followed by the banknotes is indicated by the arrow P.

Figures 5a and 5b show the input module 500 in perspective view from two different angles. The main body of the input module 500 comprises an input hopper 501 defined by a base 501c and four walls on its top, bottom, left and right sides, extending toward the user. In use, a stack of banknotes is placed within the input hopper 501 arranged such that the long edges of the banknotes abut the base 501c of the hopper. The stack of banknotes rests against a plastic cover plate 502 which is provided with ribs 502a to assist in guiding the stack into position. To ensure proper feeding, the notes should be centred laterally in the feed hopper. Guides may be provided for this purpose (not shown).

Adjacent to the base 501c, the cover plate 502 has two apertures 502b (only one of which is visible in Figure 5a), through which pickerwheels 530 extend. The input module 500 is mounted in the NHM 400 such that the cover 502 makes an angle of

approximately 45 to 60 degrees with the vertical. As such, when the stack of banknotes is in position, the lowermost banknote rests on the pickerwheels 530 protruding through cover plate 502.

Upon receipt of a transaction request from the user, the feed process is initiated.

5 Pressure is applied to the banknote stack by a pusher plate 504, which is best viewed in Figure 5c. When not in use, the pusher plate 504 is positioned within a recess on the top wall of input hopper 501. The pusher plate 504 is mounted upon guide bars 504a and 504b at each end which couple with slots 501a and 501b in the side walls of the hopper 501. In its rest position (as shown in Figures 5a and 5b), the pusher plate is
10 held in its recess by support arms 506a and b which couple to pivot points 505a and b on the guide bars 504a and b. At its other end, the support bar 506a and b pivotably connect to a pivot arm 507a and b which is rotatably mounted on a support shaft 511 running underneath the hopper 501. The pivot arms 507a and 507b are connected to plates 508a and 508b. Plate 508a on the left hand side of the apparatus is arranged
15 with an extension to which is mounted a ball bearing 510. In use, this ball bearing 510 engages a spiral cam 521 mounted outside the hopper 501 and driven by pusher plate motor 522 (see Figure 5f(iii)).

On initiation of a feed operation, the pusher plate motor 522 rotates the spiral cam 521, the ball bearing 510 following the spiral groove, such that the ball bearing 510
20 moves towards the centre of the spiral cam 521. This rotates the plate 508a, and therefore the lever arm 507a, in the direction X marked on Figure 5b. As such, the support arm 506a and the pusher plate 504 are moved toward the cover plate 502 in a controlled manner. In this way, pressure is applied to the intervening banknote stack.

The pressure applied by the pusher plate 504 is increased until a predefined
25 pressure is obtained. In order to monitor the pressure on the banknote stack, the pickerwheels on which the stack rests are spring mounted. The configuration of this mounting is described below. A sensor arm 513 is rotatably mounted on support shaft 511 and extends under the input hopper 501 towards its base 501c. At its end, the sensor arm 513 follows an upward curve which ends with a short flange positioned
30 directly underneath the pickerwheel shaft 531. This arrangement is most clearly viewed in the cross-section of Figure 5d(i). When the pressure on the banknote stack is such that the movement of the sprung loaded pickerwheel shaft 531 exerts a downward force on the sensor arm 513, the sensor arm 513 rotates downwardly about support shaft 511. In doing so, a tab 512, provided on the upper surface of the sensor arm 513,
35 loses contact with a microswitch 514 provided on a PCB which is mounted directly

underneath the input hopper 501. This loss of contact is detected by the microswitch 514 and, based on the output signal from the microswitch 514, the pusher plate motor 522 prevents any additional pressure being applied to the stack by the pressure plate 504. As the stack height decreases as notes are fed into the machine, the pressure on the pickerwheels 530 decreases, and the sensor arm 513 returns to its upper position by virtue of tension spring 516 which extends between the sensor arm 513 and the underside of the hopper 501. Thus contact with the microswitch is resumed and the pressure plate motor 522 moves the pusher plate 504 further towards the stack in order to maintain the pressure thereupon.

Once the entire stack of banknotes has been fed into the apparatus, the pusher plate motor 522 is reversed to return the pusher plate 504 to its rest position. Tension springs 509A and 509B are provided between the pivot arms 507A, 507B and the wall of hopper 501 to assist in returning the pusher plate to its rest position. In order to detect when the pusher plate 504 has reached its rest position within the recess in the top surface of hopper 501, a second microswitch 519 is provided on the PCB 517. A spring arm 520 is provided on the inside of pivot arm 507b which, when the pivot arm is extended and the pusher plate is thus held in its rest position, contacts the microswitch 519. When the pusher plate is lowered, the spring arm 520 loses contact with the microswitch 519. The signal from the microswitch 519 is used by the pusher plate motor 522 to stop turning the spiral cam as soon as the pressure plate reaches its home position and thereby avoid damage to any of the components.

The presence of banknotes in the input hopper 501 is detected by two transmissive optical sensors which comprise LEDs 525a and b, mounted in housings 527a and b on the exterior upper surface of the hopper 501, and corresponding receivers 526a and b mounted on the PCB 517. Apertures are provided through the hopper 501 and pusher plate 504 (see items 528a and b in Figure 5c) to provide a light path between the sensor components.

The feeder module 500 is supported within the NHM 400 on a frame consisting of left and right frame arms 598a and 598b, shown in Figures 5f and 5g. The frame is connected to the NHM at pivot points 595a and 595b which allow the input module 500 to be rotated away from the NHM transport 600 and stacker module 900 for access to these components. The frame walls 598a and b also provide mountings for the roller shafts which make up the feed mechanism and the motors which drive them.

The roller assemblies which feed notes into the apparatus are best viewed in the cross-section of Figure 5d(i). The arrangement for transferring drive between the

various shafts are shown Fig 5d(ii), which is a side view in which various components including the motors themselves have been removed for clarity. The main roller shafts are shown in Figure 5e, and are identified as shafts A to D using the same notation in Figures 5d(i) and (ii).

- 5 As previously described, the pickerwheels 530 extend into the hopper 501 through apertures in the cover plate 502. The pickerwheels 530 are fixedly supported on shaft assembly A which is shown in Figure 5e(ii). The two pickerwheels 530a and 530b are spaced laterally on pickerwheel shaft 531. Each pickerwheel comprises a high friction surface material to ensure good transfer of drive between the roller and the adjacent banknote. The pickerwheel shaft 531 is mounted in support arms 535a and 535b via bearing assemblies 533a and 533b respectively. Each support arm 532 is mounted at a pivot point 536a and 536b to the interior of the adjacent frame wall 598a or 598b. This is most clearly shown in Figure 5g(ii) which shows the components mounted on left hand frame wall 598a, viewed from the interior of the input module 500.
- 10 The pickerwheel shaft is urged into its upward position, protruding through the cover plate 502, by tension springs 535 connected between the support arms 532 and the frame walls 598. As already described, this arrangement is used to maintain a predetermined pressure on the banknote stack.

- In order to drive the pickerwheel shaft assembly A whilst still permitting movement of the shaft, rotation is transferred to shaft 531 via a timing belt 590B which couples with pulley wheel 534 affixed to the right hand end of the shaft (see Fig 5d(ii)). The timing belt 590B is driven by motor 593A via drive cog 593A and intermeshing pulley cog 591B, both mounted on the outside of arm 598B.
- 20 The first feed motor 593 also provides drive to separator rollers 540 mounted on shaft assembly B. Drive is transferred to the shaft 541 from drive cog 593A and intermeshing pulley cog 591A which turns timing belt 590A, coupled to a pulley wheel 543 provided on the right hand end of the shaft 541. As shown in Figure 5d(i), the separator rollers 540 act against free-wheeling preliminary rollers 555 to provide the first pinch point in the banknote path. Three separator rollers 540a, b and c are

- 25 mounted on separator shaft 541 as shown in Figure 5e(i). The large diameter of the separator rollers prevents significant bending of the note and thus reduces the possibility of damage to the note during feeding. The separator rollers 540 each comprise a high friction surface material to transfer drive to the banknotes. The separator shaft 541 is supported between the frame walls 598a and b in bearings 542a
- 30

and b. A pulley wheel 543 is connected to the left hand end of separator shaft 541 and is driven synchronously with the pickerwheel shaft assembly A.

The separator shaft 541 may also pass through an optional friction brake assembly 544. The friction brake assembly 544 comprises two annular halves 544a and 544b. Annulus 544a is not attached to the shaft 541 but rather is fixed relative to the hopper 501 via tab 544c provided on the annulus and bracket 544d mounted on the hopper 501 (shown in Figure 5g(i)) which couples with tab 544c in use. As such, annulus 544a does not rotate with the shaft 541. Annulus 544b, on the other hand, is fixedly mounted on shaft 541 and therefore rotates with it when the shaft assembly is driven.

The stationary annulus 544a is urged against the rotatable annulus 544b by a spring assembly comprising a washer 547 and clip 545 mounted on the shaft 541 either side of the brake 544, and a compression spring 546 acting to urge the stationary annulus 544a towards the rotatable annulus 544b. In this way, friction between the two annular halves 544a and 544b resists rotation of the shaft. Drive from the motor 593 is sufficient to overcome the friction, and thereby rotate the separator wheels 540, but when there is no drive, the friction brake 544 acts to slow, or preferably stop, the shaft 541 from turning any further. If the brake assembly is not provided, the separator shaft is stopped by the inertia of the stepper motor.

A set of four idler rollers 550 is additionally mounted on the separator shaft 541. Each idler roller 550a, b, c and d is mounted in a support bracket 551a, b, c and d which clips to recesses in the separator shaft 541 at either end and between the set of three separator wheels 540a, b and c. Each idler roller 550 is urged toward the banknote path P via a compression spring 552a, b, c and d acting between the support bracket 551a, b, c and d and a rear crossbar 580 shown in Figure 5d(i). These idler rollers shall be returned to below.

At the right hand end of the separator shaft assembly B, two eccentric cams 549a and 549b are mounted, separated by washers 548. The eccentric cams 549a and 549b are used to transfer drive to a contra-roller shaft assembly C shown in Figure 5e(iii). Six contra-rollers 560a, 560b, 560c, 560d, 560e and 560f are mounted on a contra-roller shaft 561 just behind the preliminary rollers 555 in the note path P. The contra-roller shaft C is supported between the frame arms 598a and 598b in supports 562a and 562b. Bolt assemblies 563a and 563b secure the supports 562a and 562b through an arcuate aperture in each frame arm 598a and 598b which allows the position of the contra-roller shaft 561 relative to the separator rollers 540 to be adjusted.

In use, the contrarollers 560a to f slightly interleave with the separator rollers 540a to c such that a degree of corrugation is achieved in the passing banknote. This assists in separating overlapping banknotes.

5 The contra-rollers 560 are provided to prevent double note feeds. In order to achieve this, the contra-roller shaft 561 is driven slowly in the reverse direction (i.e. urging notes back towards the hopper 501) by twin one way clutches 564a and 564b mounted on its right end. Each clutch 564 comprises a forked extension which, in use, couples with a respective eccentric cam 549 on the separator shaft 541. As the separator shaft 541 rotates, the eccentric cams 549 oscillate the clutches 564 back and
10 forth. The one way clutches transfer drive to the contra-roller shaft 561 only when rotated in the desired direction, and the eccentric cams are arranged such that as one oscillates its respective clutch in the correct direction, the other moves its respective clutch back in the opposite direction (which drive is not transferred to the contra-roller shaft). In this way, the contra-roller shaft is sinusoidally rotated continuously in the
15 same direction at a rate much slower than that at which the separator shaft 541 (and the pickerwheel shaft 531) is driven.

The contra-rollers 560a to f comprise low friction material in order to act only on double fed notes and not impede the passage of properly fed single notes.

20 The preliminary rollers 555, which are mounted on the exterior of the hopper base 501c, as shown in Figure 5b, act to hold the leading edge of the banknote down as it enters the nip between the contra-rollers and the separator wheels in order to prevent edge damage. The preliminary rollers 555 are mounted to the base of the hopper 501 in housings 556 which are lightly sprung towards the separator rollers by compression springs 557.

25 The pickerwheels 530 and separator wheels 540 are intermittently operated by the motor 593 to feed a single note at a time. As each note is fed in, the neighbouring intermediate shaft assembly D (opposed by the idler rollers 550 mounted on separator shaft 541) is also driven to receive the note and convey it forward. Intermediate shaft assembly D comprises intermediate feed rollers 570a, b, c and d, mounted on a shaft
30 571 which is independently driven by a second feed motor 592 via drive cog 572 on the left end of the shaft, via timing belt 592b and motor cog 592a (see Figure 5d(ii)). A one-way clutch is provided on shaft 571 to prevent any reverse rotation.

A transmissive optical sensor 583 is provided adjacent to the exit from the input module 500 as indicated by arrows 583 and 584 in Figure 5d(i). When the sensors 583
35 detect the presence of a note, drive to the pickerwheels 530, separator wheels 540 and

intermediate shaft assembly D is stopped and the brake 544 (if provided) assists in halting rotation. The note is thus stopped in the grip of intermediate shaft assembly D and its position is accurately known.

At a predetermined time, intermediate shaft assembly D is actuated to drive the
5 note forward into the transport system. The note is received by transport belts 630a, b and c and opposing rollers 613 (see Figure 6A), which represent the entry point to the SDA Assembly (see section 6 below). The belts are continuously driven at the same speed as the downstream transport. By stopping the note at a well-defined position and having control over the time at which it is injected into the transport system, the gap
10 between notes can be accurately set. Ultimately, this optimises the number of notes which can be stored on each RSM whilst also helping to avoid note jams and ensuring that the notes are sufficiently spaced to enable accurate authentication and denomination.

In this example, the predetermined time is calculated based on the previous
15 note to have exited the feeder into the transport system. Specifically, the system waits for a predetermined delay to elapse from the time at which the previous note passed into the transport system (based on the detection of the trailing edge of the previous note by the sensor 584) before moving the current note forward.

The note is picked out of the nip between the separator rollers and contra-rollers
20 by intermediate shaft assembly D whilst the pickerwheels 530 and separator wheels 540 are stationary. The action of the rotating rollers 570 picking the note from the stationary separator rollers 540 assists in ensuring that a single note is fed into the NHM 600. The banknote is then conveyed out of the input module 500 through a guide plate 585 mounted on rear crossbars 581 and 580 which also support the sensor
25 components 583 and 584.

When the sensor detects that the note has exited the module, after a predetermined delay (which may, in some cases, have zero time duration), the pickerwheels 530, separator wheels 540 and intermediate shaft assembly D are driven once again to feed the next note into the system as far as the sensor 584.

30 The input module is described as a controlled synchronous feeder type.

In certain embodiments, the gap between each pair of upstream and downstream notes is measured by a track sensor in the transport system. This can be used in a feedback system to adjust the predetermined time at which the next note is injected into the system and thereby adjust the inter-note gap.

In the present example, two optional control algorithms are implemented in order to keep the gap between the two banknotes within a certain tolerance. Over time, the various feed rollers suffer wear which diminishes the friction between the roller and the banknote. This tends to increase the gap between notes due to the additional time
5 it takes for the worn component to move each banknote.

A first algorithm maintains the average inter-note gap by varying the duration of the predetermined delay to either increase or decrease the note injection rate. The average inter-note gap is measured over a large number of input events, around 5000 to 10000 notes, in order to account for long-term wear. When the algorithm is no longer
10 able to compensate for the degree of wear (i.e. the inter-note gap cannot be brought within acceptable limits by varying the note injection rate), a signal is output to the user to indicate that the unit requires servicing.

A second algorithm compensates for variations in friction on a note-by-note basis to ensure that the 95th percentile of the inter-note gap distribution is kept below a standard deviation of 2. Again, this is implemented by varying the delay between
15 detecting the trailing edge of the note leaving the feeder module and beginning the next feed operation.

In order to ensure there the gap between notes is sufficient to allow the apparatus to make appropriate decisions for each note and switch diverting
20 components accordingly, the gap between notes must be maintained above a certain minimum. It can be increased from this by the algorithms but cannot be shortened. An appropriate minimum inter-note gap has been found to be 80mm for a transport speed of 1 m/s. In cases where the transport speed is slower, the inter-note gap may be reduced (e.g. for a transport speed of 0.6 m/s, a gap of 60mm may suffice).

A maximum inter-note gap value is set by the roll storage modules (RSMs). Firstly, the greater the inter-note gap, the fewer notes can be wound onto the storage
25 roller. Secondly, due to the present algorithm used to control the start stop sequence within the RSMs it is not possible to have a note gap greater than 110mm without affecting the jam resistance or accountancy accuracy of the device. Therefore the
30 maximum inter-note gap for the exemplary embodiment is 110mm, but this may differ in other RSM implementations.

The minimum banknote width (short-edge dimension) which can be fed by the input module depends on the distance between the pickerwheel shaft assembly A and the continuous transport roller assembly D. In order to feed notes of a certain width,
35 this distance must be shorter than the width of the note, since whilst it is being

conveyed, the note will warp and appear to become shorter. Thus, in order to feed a 55mm wide note (for example), it has been found that the distance between shaft assemblies A and D should not be greater than 46.9mm.

The input module assembly is enclosed by the provision of rear cross bars 580 and 581 as shown in Figure 5f(ii) which are mounted behind the roller assembly already described. A latch plate 588 is fitted over the hopper 501 to complete the enclosure as shown most clearly in Figures 5g(i) and (iii). The latch plate 588 is pivotably mounted to the frame walls 598a and b at pivot points 588a, and is urged into position by spring 588b at its left hand side. The latch plate can be lifted into an upper position by actuation of handle unit 263b in the NHM cover (see section 2 above). In its lower position, as shown in Figure 5g(i), hooks 588c on the latch plate 588 engage bosses 358a and 358b provided on the NHM chassis (see Fig. 3D), thereby preventing pivoting of the input module away from the note transport 600. The latch can be decoupled from the NHM chassis by operation of the handle unit 263b to allow opening of the input module to access the note transport 600 or the stacker module 900. A microswitch 357g is provided on the NHM chassis for detection of the position of the input module 500. When the input module is closed, a tab 599b on the left hand side of the input module (see Figure 5g(i)) engages the microswitch 357g indicating that the input module is positioned ready for use.

In order to ensure accurate alignment between the feeder module 500 and the note transport 600, two guide plates 587 (Figures 5G(ii) and (iii)) are provided on the left and right arms 598a and 598b.

The underside of the assembly is completed by guard plate 597 which, in use, forms the top of the stacker module 900. The guard plate 597 is provide with anti-static ribs 597A to reduce contact between the stacked notes and the guard plate 597 as they pass.

An optical transmitter 594 is mounted to the guard plate 597, aligned with a corresponding receiver 970 disposed in the stacker guide plate 901 (see section 9). The resulting transmissive sensor pair is used to detect notes entering the stacker module 900.

6. Note Transport 600

6.1 Secure Document Analysis (SDA) Assembly

5 As discussed with respect to Figure 4 the note handling module comprises parallel upper 410 and lower 411 paths. The upper path 410 is provided by the secure document analysis (SDA) assembly. The SDA assembly has both an upper and lower section. The upper path is defined by the lower surface of the SDA's upper section and the upper surface of the SDA's lower section. The lower path 411 is defined by the
10 lower surface of the SDA's lower section and the upper surface of the horizontal transport section. Typically the distance between the upper and lower surfaces of each path is no greater than 40mm. The paths must also handle notes of a width up to 185mm (including skewed widths). A U-turn section 405 is provided at the end of the upper 410 and lower 411 paths in order to rotate the note by 180°.

15 Figure 6A provides a perspective view of the front and right side of the SDA assembly 601. The SDA assembly 601 comprises two halves: SDA lower section 602 and SDA upper section 603. The SDA upper section 603 rotates about shaft 611 to the rear of the SDA upper section. Shaft 611 is mounted within apertures in two joining plates 604 which are fixed to either side of the SDA lower section 602. The SDA upper
20 section can thus pivot and open in a clam-shell-like manner to gain access to the upper transport path 410.

 Similar to the NHM chassis, a gas cylinder assembly is provided to hold the two sections open at a large enough angle for an operator to safely gain access to the upper transport path 410. The gas cylinder comprises a cylinder 605 and a piston 606.
25 The cylinder 605 is pivotably connected to the SDA lower section 602 at pivot point 607b. The piston 606 is then pivotably connected to the SDA upper section 603 at pivot point 607a. When the piston 606 is retracted, the SDA upper section 603 is substantially horizontal and the SDA assembly 601 is closed. This also pressurises the gas inside the cylinder 605. When pressure in the cylinder 605 extends the piston 606,
30 the SDA upper section 603 rotates around pivot shaft 611 and the SDA assembly 601 opens. To retain piston 606 in a retracted state, left 614a and right 614b latches are provided at the front of the SDA upper section 603. These latches are biased to the vertical by a tension spring (not shown). When SDA upper section 603 is horizontal and the gas in the cylinder 605 is under pressure, these latches 614a,b clip securely
35 into slots 614c,d, thus holding the SDA assembly 601 together. The latches 614a,b are

in turn pivotally connected to movable handle 608. When a rearward force is applied to handle 608 the latches 614a,b pivot forwards and unlock from the slots 614c,d. The pressurised gas within the cylinder can then extend the piston. Static handle 609 is provided next to the moveable handle 608 to lift open the SDA upper section 605 if a
5 force additional to that provided by the gas cylinder is required.

The SDA upper section is illustrated in Figures 6B and 6C. Figure 6B shows the SDA upper section from the same perspective as Figure 6A. On top of the SDA upper section 603 is mounted the detector circuitry housing 616. The sensor electronics and circuitry for detector module 700 are located within this metal compartment. At the front
10 of the SDA upper section 603 are three large plastic rollers 613abc which are mounted on bearings on fixed shaft 613d. The large plastic rollers 613abc project from a plastic guide casing 613g and rotate as a note is driven into the upper transport path 410. During operation the lower surface 615u of the SDA upper section 603 provides a guide for the movement of notes within the upper transport path 410. This lower surface 615u
15 can be constructed from either sheet metal or from plastic. Typically, antistatic plastic is used to prevent the build up of static caused by the frictional contact between passing notes and the transport surfaces. The lower surface 615u is provided with ridges 615r. These reduce the friction between a passing note and the lower surface 615u by reducing the contact area between the two. This prevents the note from
20 sticking or tearing.

To facilitate the initial movement of the note within the upper transport path 410 five sets of small rubber rollers 620 are fixed on five freely-rotating roller shafts 617. The roller shafts 617 are located in bearings in the sideplate. The bearings are mounted in slots in the sideplates and are biased towards the note path by spring 619.

In the first embodiment illustrated in Figures 6A to 6F, one detector module 700 is mounted at the rear of the SDA assembly 601. The detector module 700 is typically a transmissive and/or reflective optical and/or infrared sensor system comprising a light source and line scan sensor. The line scan or contact image sensor (CIS) is mounted between two idle roller shafts 617f and 617g. These roller shafts 617f and 617g
25 contain five pairs of small rubber rollers 626a and 627u and provide a more controlled passage of the note past the detector assembly 700.

The underside of the SDA upper section 603 is shown in Figure 6C. This Figure shows the section from a rear perspective view incorporating the rear and left sides of the section. The five pairs of rubber rollers 626u are mounted within plastic guide
35 portions 625u. These guide portions comprise a plurality of guide fingers which again

reduce the contact surface area between a note and the guide and help stabilise the note as it passes across the detector window 701u. The two guide sections 625u clip together with a jigsaw-like dovetail section 628.

The lower section 602 of the SDA assembly 601 is illustrated in Figures 6D and 6E. Figure 6D shows the section from a perspective view incorporating exploded views of the front and left sides of the section. At the front of the lower SDA assembly 602, there are located three transport belts 630 to move the note towards the detector module 700 at the rear of the SDA assembly 601. Each belt is entrained around a system of three pulleys: a first pulley is rigidly attached to shaft 631; a second pulley is rigidly attached to shaft 636a; and a third pulley is rigidly attached to shaft 643, below shaft 631. Shaft 631 is connected to a first drive gear 632 which in turn is connected to a first idle gear 638. This freely rotating idle gear 638 is then connected to the output transport drive system comprising output transport motor 363 on the movable carriage 350 (see section 8.2). At the rear of the belt, shaft 636a is rigidly connected to a second drive gear 636b which in turn is connected to a gear train system used to drive the two rear roller shafts 635a, 635b.

Figure 6E shows the lower section 602 from a perspective view incorporating exploded views of the rear and left sides of the section. Within each belt there are four sets of small rubber rollers 644 which are mounted on four shafts 645. These shafts 645 are allowed to rotate freely and the rollers 644 provide support for belt above and below. The rollers are aligned to complement upper rubber rollers 620. At the rear of the lower SDA assembly 602 is the light source 700L for the optical and/or IR sensor system 700L.

Referring back to Figure 6D, in a similar manner to the upper SDA assembly 603, the light source window 701l is mounted between two guide plates 625l. These guide plates 625l also contain a series of fingers to help guide the note across the sensor face 701l. Mounted within these fingers are another series of rubber rollers. These rollers comprise two pairs of rubber rollers 626l, 627l respectively mounted on forward shaft 635b and rear shaft 635a. Both these shafts are driven. Forward shaft 635b is attached to a third drive gear 635d which is connected to a second idle gear 633. The second idle gear 633 is connected to the second drive gear 636b, driven by the drive system comprising belts 630. Rear shaft 635a is fixed to a fourth drive gear 635c which is connected to the third drive gear 635d via third idle gear 634. The gearing ratios in this gearing system are weighed so that both sets of rollers 626l and 627l are driven at the same speed.

The underside of the lower SDA section 602, which comprises the top surface of the lower transport path, is shown from a perspective view incorporating the rear and left sides in Figure 6E. At the front of the lower surface of the lower SDA section 602 is a guide plate 629. Within this guide plate there are mounted two note tracking
5 optosensors 650. These sensors detect the departure of a note from the lower transport path 411 in a direction towards the stacker assembly. Behind these optosensors is another set of three belts 637. Each belt 637 within the set is entrained around two pulleys: one rigidly mounted to a front shaft 639 and another rigidly mounted to a rear shaft 642. Motor drive gear 871 mounted to motor 363 drives idler
10 gear 874 which in turn drives idler shaft 638 which drives shaft 639 which drives belts 637. Belts 637 drive gear 642 which drives idler gears 641 and 640 which in turn drives diverter exit roller 836. Within each belt 637 there are two sets of freely rotating rollers 655, which help to support the belt as a note is carried towards the front of the lower transport path 411.

15 The set of rear pulleys for the third belt system 637 is mounted within plastic guide plating 651. This guide plating again comprises a series of fingers that help prevent the note sticking within the lower transport path 411. Beyond the end of the third belt system 637 are another four pairs of rubber rollers 654. These are freely rotating idle rollers and are spring mounted within the housing of the lower SDA
20 assembly 602. They complement a set of rubber rollers present within the diverter assembly.

At the rear of the lower SDA assembly 602 is a further rear guide plate 615tu. This guide plate may either be constructed from sheet metal or formed anti-static plastic. This plate further contains two sets of optosensors 652, 653. The front set of
25 optosensors 652 comprises one transmissive optosensor 652a and one receptive optosensor 652b. This pair is complemented on the other side of the lower transport path by a prism system for reflecting the light from transmissive optosensor 652a to receptive optosensor 652b (see Figure 14B). The rear set of optosensors 653
30 comprise two transmissive optosensors. These transmissive optosensors have a complementary pair of receptive optosensors mounted on the opposite surface of the lower transport path 411 (see Figure 14C).

There are also five sets of idle rubber rollers 648 mounted within the rear guide plate 615tu. Referring back to Figure 6D, each roller set comprises three small rubber rollers mounted to a freely rotating shaft. Each shaft is mounted between two flanges
35 which rise perpendicularly from the upper surface of the rear guide plate 615tu. Each

roller shaft 648s is mounted within an enlarged aperture of a size greater than the diameter of the shaft 648s. The shaft 648s is then connected to a bent wire spring 648sp which biases the rubber rollers and allows them to be moved against the tension of the spring in an upward direction as a note passes.

5 Figure 6F illustrates a cross-section through the SDA assembly 601 along line A to A' shown in Figure 6A. In use, a note will be received from the input module 500 within the opening between the large idle rollers 613abc and the first belt system 630. The note is then carried in the direction of the belt rotation towards the rear of the SDA assembly 601 by the frictional forces present between the belt and the note. The note
10 also makes contact with the first set of freely rotating rollers 620 on the upper SDA section 603. The note then reaches the sensor assemblies 700u and 700l. The leading edge of the note is pinched between upper idle rollers 626u and lower driven rollers 626l. The note is then driven past the faces of the upper and lower sensor assemblies in order to obtain measurements of certain properties of the note. After
15 these have been obtained, the leading edge of the note is pinched by the upper idle rollers 627u and the driven rollers 627l and the latter roller set will drive the notes forward to the rear of the module with idle sprung rollers 627u providing a downwards pressure on the note. On exiting the upper transport path the note will then enter the u-turn assembly 405.

20

6.2 U-Turn Assembly

The u-turn assembly 405 is illustrated in Figures 6G and 6H. Figure 6G shows an exploded perspective view of the assembly from the front and right sides and Figure
25 6h shows an assembled perspective view from the rear and right sides. The u-turn section 405 comprises three main components: a note feed and exit section, a note transport system comprising three belts 663, and a set of plastic guide sections 660,661.

The note enters the u-turn section between upper casing section 670u and
30 middle casing section 672. Three entry guide blocks 671u direct the note into the u-turn assembly. The note is then received between the belts 663 of the note transport system and a set of three large plastic rollers 668. Each belt 669 is entrained around a system of four pulleys 669. The pulley system comprises four shafts: an upper driven shaft 664u, an upper idle shaft 665u, a lower idle shaft 665l and a lower drive shaft
35 664l. The left end of the lower drive shaft 664l is connected to the transport drive

system. The set of three large plastic rollers 668 freely rotate around a middle-mounted shaft 667 and provide tension in each belt 663. Each of the five shafts is mounted between two side plates 662a,662b.

After entering the u-turn section, a note will be guided by inner plastic guide 661
5 and outer plastic guide 660. The two plastic guides are separated into a number of individual sections that run from left to right. Each section is of a width equivalent to that of the two middle sections 660b and 660c. The sections that make up the inner plastic guide 661 clip onto the middle-mounted shaft 667. The sections that make up the outer plastic guide clip onto the upper and lower idle shafts 665. As these guide
10 sections simply clip into place each individual section can be removed by an operator if access to the note transport system is required, for example to clear any trapped notes. To remove a section from the outer plastic guide 660 an operator needs to squeeze the top and bottom of the section to be removed, which will unclip the section from the upper and lower idle shafts 665.

15 After a note enters the u-turn assembly 405 it is guided between the inner and outer plastic guides 660,661 and is rotated 180 degrees around the set of three middle-mounted rollers 668 by the clockwise rotation of the belt system (from the perspective of Figure 6G and 6H). The note then exits the u-turn assembly 405 between the middle casing section 672 and a lower casing section 670l. A set of exit guide blocks 671l
20 guide the note into the lower transport path 411.

6.3 Horizontal Transport Section

Figures 6I and 6J show upper and lower perspective views of the horizontal
25 transport section 680. Figure 6I shows an exploded view from the rear and right sides. Figure 6J shows an exploded view from the rear and left sides.

At the rear of the horizontal transport section 680 is another three belt transport system 677 which receives notes from the lower exit of the u-turn assembly 405 and propels them forward towards the diverter 800. Each belt 677a, b, c is entrained around
30 a driven pulley and an idler pulley. The rear pulley is connected to a rear drive shaft 692 which is driven by a rear drive gear 681. The front pulley is connected to first shaft 693 which is connected to gear 695. The rear drive gear 681 is connected to a first idle gear 682, which in turn is connected to the transport drive system. Within the belt there are three sets of freely rotating rollers 679. Each of the three freely rotating rollers 679
35 is positioned opposite a complementary freely rotating roller 648 in the lower surface of

the lower SDA section 602 (see Figure 6E). The front and rear pulleys of the belt system 677 are also positioned opposite complementary freely rotating rollers located at the front and rear of guide plate 615tu in the lower surface of the SDA lower section 602.

5 The three belt transport system 677 is positioned within a lower guide plate 615tl. This lower guide plate 615tl also contains small apertures for mounting the complementary parts of the optical sensor sets 652,653 within the lower transport path. As the rear optosensors 653 are transmissive optosensors, they have a complementary set of optoreceivers 685a and 685b. Optosensors 652 are mounted
10 opposite a prism located under the lower guide plate 615tl which will receive light transmitted by the transmissive optosensor 652a at its entrance 652c and reflect the light signal to the optoreceiver 652b via its exit 652d. The transmissive optosensor set 653 is used for detecting the skew of the note and prism optosensor set 652 is used to detect the arrival of a note at the diverter section 800 (see Section 14.2).

15 The state of the diverter assembly 800 determines the destination of a note: either the stacker assembly 900 at the front of the machine or the roll storage modules 1300 within the storage assembly. The diverter mechanism is described in more detail in Section 8 and here we will only consider its operation with respect to the lower transport path 411. When the diverter is in the default position, a set of moveable guide
20 fingers 811 are kept horizontal. Four pairs of rubber rollers 807 to the rear of the diverter receive the note and drive the note forward over the moveable guide fingers 811 to a second set of rollers 808. The rear set of rubber rollers 807 are driven from the front shaft 693 via a first gear train comprising front drive gear 695, second idle gear 684 and large rear diverter gear 831. Front shaft 693 is driven by transport belts 681.
25 The front set of rubber rollers 808 are driven by front diverter gear 836, which is connected to idler gear 640 upon the SDA assembly 601. Diverter exit roller 835 is driven through idler gear 683 which in turn is connected to the through safe transport 1100.

 Within the diverter assembly 800, there are two further sets of transmissive
30 optosensors 678. Light transmitted by a set of transmissive optical sensors 678a is received by a complementary set of optoreceivers 678b. These signals received by the optoreceivers are used to detect the skew of the note as it is driven towards the through safe transport 1100.

 At the front of the horizontal transport 680, two sets of freely rotating rollers 679
35 are mounted within a front guide casing 676. These freely rotating rollers 679 are

sprung and are positioned opposite the front pulleys of the third belt transport system 649 and the first set of idle rollers 655 on the lower section 602 of the SDA assembly.

After the note exits the horizontal transport section and the lower transport path 411, it is driven towards the accelerating rubber rollers of the stacker assembly 900.

5

6.4 Advanced Secure Document Analysis (SDA) Assembly

Figures 6K to 6P illustrate a second embodiment of the secure document analysis (SDA) assembly originally illustrated in Figures 6A to 6F. The modified SDA assembly illustrated in Figure 6K allows additional detector units to be installed. This increases the number of different note properties that can be measured. To accommodate additional detector units modules the design of the SDA assembly is modified and the differing features will be explained below. Elements of the modified SDA assembly that are identical to the first embodiment are given the same reference numerals as those used in Figures 6A to 6F. Elements that have been modified are denoted by the postfix X.

Figure 6K illustrates the modified SDA design. Modified belt transport system 630 is shorter than the original belt system 630X and modified belts 630X a,b,c extend just under half the length of the lower advanced SDA section 602X. Guide surface 615I is also shorter than its equivalent in the first embodiment in correspondence with the shortening of the belt transport system. At the rear of the upper surface of the lower SDA section 602X three additional sets of rollers 699X, 626X and 627X, are added to guide the note past additional detector unit detectors mounted within the modified SDA assembly 601X.

Three additional detector units are illustrated in Figure 6L. In addition to the single detector unit 700u of Figure 6B there are now three more detector bays which occupy the interior of the upper SDA section 603X. A series of rubber rollers remain on the upper surface of the upper SDA section 603X, however the spacing between the roller shafts 617X is increased to accommodate one freely rotating roller on either side of each additional detector unit.

Each detector unit or bay contains a sensor module. Typically, in a standard advanced SDA assembly, the first sensor module 707 comprises a ultraviolet paper property detector (UVPPD); the second sensor module comprises a reflective optical or contact image sensor (CIS) 705u; the third sensor module comprises infrared and/or visible light transmitters 708 for use in reflective and transmissive optical sensors; and

the rear sensor module comprises a magnetic sensor 706. However, the note handling device 100 is designed so that these modules can be rearranged, removed or replaced depending on particular operating circumstances. Details of these sensor modules are given in Section 7.

5 The note transport surfaces of these sensor modules are illustrated in Figure 6N. The initial three large freely rotating rollers 613abc remain at the front of the upper SDA section 601X. The first set of front rollers 620X(i) are also substantially identical to the front rollers of roller set 620 in Figure 6C. However, in the re-designed lower section of the upper advanced SDA assembly 603X, rollers 620X(ii) are moved closer
10 to the first set of rollers 620X(i) in order to accommodate the sensor interface of the UVPPD sensor module 707. There are also a series of additional guide panels 625X and roller sets 626X and 627X to guide each note past the note transport surfaces of the additional detector units. The first guide panel 625X(i) has additional fingers in order to apply more contact pressure to the note and keep the skew of the note to a
15 minimum. After the note transport surface of the UVPPD sensor module 707 is a smaller second guide unit 625X(ii), in which are mounted five pairs of small rubber rollers 626X(i). Each of the guide sections 625X has a jigsaw like tab identical to the tab 628 displayed in Figure 6C. This allows guide panels to be slotted together. The note transport surfaces for the reflective CIS sensor module 705u and the light
20 transmitter 708 are substantially identical to that of the initial UVPPD sensor module 707. After the reflective CIS sensor module 705u there is another small guide panel 625X(iii), with another set of guide rollers 626X(ii) which are identical to rollers 626X(i). By using five pairs of rollers a note can be kept substantially aligned as it passed under the note transport surfaces of the relevant sensor modules.
25 After the note transport surface of light transmitter module 708 there is another substantially larger guide panel 625X(iv) in which two pairs of rollers 626X(iii) and 627X(i) are mounted. Guide panel 625X(iv) is also of greater length than the previous guide panels as the magnetic sensor 706 needs to be distanced from sources of electromagnetic interference, such as other sensor modules. Exit guide panel 625X(v)
30 is similar to exit guide panel 625u shown in Figure 6C.

Figure 6N illustrates the lower section 602X of the modified SDA assembly. As was visible in Figure 6K, belts 630X are now of a reduced length to accommodate the additional sensor modules. In this second embodiment the original lower sensor module 700l illustrated in Figure 6D is removed and replaced with a guide panel
35 625X(viii) and a set of plastics guide rollers 699X(ii) on a non-ferrous shaft to transport

a banknote past the note transport surface of the magnetic sensor module 706 resident in the upper SDA section 603X. Within the lower section 602X a CIS sensor 705l is mounted between two modified guide plates 625X(vi) and 625X(vii) opposite the corresponding light transmitter module 708 within the upper section 603X. Rubber rollers 699X(i) are mounted within the lower surface of the lower section 602X within guide panel 625X(vi) opposite the reflective CIS sensor 705u within the upper section 603X in order to drive the note past the note transport surface of the upper sensor. Rubber rollers 626X(iv) are then mounted opposite roller set 626X(ii) to drive the note through past the note transport surface of the lower CIS sensor 705l. Rubber rollers 627X(iii) and 626X(v) are mounted after the lower CIS sensor 705l in middle guide panel 625X(vii) opposite upper rollers 626X(iii) and 627X(i). At the rear of the lower section 602X opposite the magnetic sensor module 706 within the upper section 603X is a modified sensor module surface 625X(viii) in which there are mounted another set of multiple rubber rollers 699X(ii). These rubber rollers 699X(ii) transport the note past the magnetic heads above the upper note transport surface of the magnetic sensor 706. The rear guide plate 625X(ix) is similar in form to the rear guide member in guide set 625l in Figure 6D.

Rubber rollers 699X(i), 626X(iv), 627X(iii), 626X(v), 699X(ii), and 627X(iv) are all driven by a gearing system comprising gears 633X, 634X and 635X. In a similar manner to the first embodiment, gear 636Xa is driven through the rotation of shortened belts 630X. Gear 636Xa then in turn rotates gear 633Xa which drives the subsequent drive train. Idle gears 633X transfer torque from adjacent roller shafts and large gear 634X compensates for the transport gap needed for the installation of the CIS sensor 705l. The underside of the lower SDA section 602X as illustrated in Figure 6O is unaltered from that shown in Figure 6E.

Figure 6P shows the new arrangement of the second embodiment, wherein the view illustrates a section through the SDA assembly 601X as marked by line A to A' on Figure 6K. Figure 6P also illustrates the arrangement of the sensor modules when the modified SDA assembly 601X is closed and in use.

In addition to the SDA assembly of the first or second embodiments, there is also the option of including a ultrasonic detector 730 within the upper note transport path 410. This is located after the SDA assembly and comprises ultrasonic transmitter 710 and receiver 709 units. These units are housed within an ultrasonic detector assembly which extends the upper note transport path 410. A corresponding unit of horizontal transport 785 is also included to extend the lower transport path 411. When

an ultrasonic detector is included after the SDA assembly, then the u-turn assembly is mounted after the ultrasonic detector module 730.

7. Sensor systems 700

5

There are four different detector modules that can be mounted within the SDA assembly. These include optical, magnetic, UV, and IR systems. An additional ultrasound detector unit can also be added and is contained within an individually removable unit. Each sensor will now be described in turn.

10

7.1 Reflective Contact Image Sensor (CIS)

The contact image sensor (CIS) is an optical line scan sensor, which produces a digital image of a note by measuring the intensity of light reflected from the surface of the note as it passes under the line scan apparatus. The sensor module 705 is illustrated in Figure 7A. The line scan apparatus 711 is housed within casing 715a which allows it to be mounted within the SDA assembly. In certain embodiments the line scan apparatus comprises a CIS sensor from Mitsubishi Electric. Attached to the line scan apparatus 711 is a control circuit board 712a which performs preliminary analysis of the line scan signal. The control circuit board 712a is then connected to more advanced signal processing circuitry mounted within housing 616 above the SDA assembly 601. In some embodiments, an aperture 714 is provided in casing 715a which allows connecting wires to leave the casing 715a. Such wires are held in place with clips 713.

25

As a note passes under the line scan apparatus 711, a single pixel line, one pixel wide will be captured. This line will extend across the long edge of the note in a direction perpendicular to note transport. Typically, the signal making up the line data is digitised before further processing and the resolution of the captured image in the transport direction is between 30 and 200dpi depending on the speed of the note transport drive mechanism. Across the transport direction, the resolution is generally higher, varying from around 100dpi to 200dpi depending on the configurations used. As the note passes and subsequent lines are scanned, a complete image of the note is generated. This image can be passed to image processing algorithms for pattern recognition or validation tasks.

30

It is also possible to extend the line scan apparatus 711 to operate in two different illumination modes: visible and infrared. In visible illumination mode, a light source within the line scan apparatus will illuminate the note using light of visible wavelengths. Typically, best results are obtained with a limited colour combination.

5 Through experiment, it has been found that a combination of green and blue in the approximate ratio 25:75 provides a resultant note image with the most clearly defined visual features. In particular, any soiling of the note is enhanced for accurate detection. The use of a limited colour combination also simplifies the line scan apparatus 711 and reduces the number of illumination sources needed.

10 An infrared light source can also be provided together with an infrared line scan detector. The line scan apparatus 711 can include a separate line scan detector for each illumination mode, or, more commonly, a single line scan detector for all illumination wavelengths. When using an IR light source, one line scan will capture one line of an infrared image of a note. By recording a plurality of lines the complete
15 infrared image of a note can be generated. This can be used in advanced pattern recognition and validation, for example on banknotes with IR features such as the Euro. The IR image can also be analysed to detect IR patterns within ink printed onto the note or to detect IR properties of the note paper. When both visible and IR sources are used with a single line scan detector, the illuminated colour is altered with every line, i.e. the
20 source alters between visible and IR on alternate lines. Even though, as a consequence, this reduces the sampling frequency for each single colour to half of the maximum scanning frequency of the line scan apparatus 711, in turn halving the maximum possible pixel resolution in the transport direction, the reduction in data is compensated for by subsequent detection and analysis algorithms allowing a high
25 operating speed. In order to further increase the speed of operation of the note transport the data can also be down sampled after capture.

7.2 Transmissive CIS Sensor

30 A CIS sensor can also be used to detect visible and infrared light transmitted through a passing note. The amount of light transmitted through a note can then provide additional input for pattern recognition or validation algorithms. A transmissive image can also be used on its own to detect the presence of threads and foils or watermarks or in combination with the reflective image. When using a CIS sensor in a
35 transmissive capability, a separate light source is provided in a detector unit within the

SDA assembly opposite the CIS sensor. In the second embodiment of Figure 6P, this light source 708 illuminates a note from the lower surface of the upper SDA section 603X and a CIS sensor 705I is mounted directly below this light source within the lower SDA section 602X. Any light sources within the transmissive CIS sensor itself are then disabled so that when a line scan is performed by line scan apparatus 711, the apparatus only detects light that has been transmitted through the note from separate light source or transmitter 708. The light source is typically a combined visible/IR source with similar spectral characteristics to the source within the reflective CIS apparatus.

A light transmitter 708 is illustrated in Figure 7D. This transmitter comprises illumination source 719, transparent screen 721, mounting 720, and control board 712d. The control board also prevents unwanted stray light escaping above the illumination source 719. All the apparatus are mounted within casing 715d.

If a transmissive CIS sensor is installed together with a reflective CIS sensor then the two resultant images can be used to detect note thickness or the presence of double notes. A double feed detection is performed by evaluating the transmission and the reflection intensities for a predefined set of test spots with a two-dimensional evaluation. Such a processing method is described in International Patent Application WO2004/080865A1.

To calibrate the CIS sensors there are defined static and dynamic calibration tests. The static tests involve examining white paper in situ under the sensors, wherein the properties of the paper are well documented. To further test intensity levels and other properties a section of foam is also pressed against the note transport surface of the sensor to provide a set reference. In the dynamic tests a series of paper and polymer notes are passed through the note handling apparatus and the properties of the notes are recorded. These properties are then compared with well defined reference values for the paper and polymer notes and any discrepancies are used to alter the sensor configurations.

7.3 Magnetic Sensor

The magnetic sensor allows the presence of magnetic ink or a magnetic thread on a banknote to be detected. The magnetic sensor consists of 16 channels. Each channel has a width of 10mm. The channels are aligned in two rows, wherein each row contains eight channels. The data offset between the rows is compensated for by the

control circuitry and therefore all the channels are seen to be in one virtual row. A series of line scans will be made using the row of channels so that an image of the magnetic properties of the notes can be constructed. The data within this image can then be used in validation routines or possibly for note denomination.

5 An example of such a detector is illustrated in Figure 7B, the magnetic heads are located within casing 716, with a non-magnetic screen 717 between the magnetic detector heads and a passing note. Control circuitry 712b is then mounted on top of the arrangement of heads and is responsible for preliminary processing. The assembled detector assembly is mounted within casing 715b.

10 The two rows of magnetic heads that make up the 16 channels can also be seen within Figure 7B. The three pronged feet of the magnetic heads are mounted within circuit board 712b in rows 726a and 726b. The magnetic heads themselves are located vertically below these mountings. To calibrate the magnetic sensor a number of encoded documents are fed into the note handling apparatus and the measured
15 properties are compared with expected, well defined reference values for each encoded document.

7.4 Ultra Violet Paper Property Detector (UV PPD)

20 The UV PPD detector tests the UV properties of a passing banknote. The UV detector is a single stripe detector mounted perpendicularly to the transport direction. It covers an area of three millimetres. The detector contains two channels, 0 and 1, with two states: UV LED on and UV LED off. For each line of a passing banknote, the following scans are done: channel 0-UV LED off, channel 1-UV LED off, channel 0-UV
25 LED on, channel 1-UV LED on. This gives four virtual pixels for each line.

Each channel within the UV PPD detector will comprise a photodiode adapted to measure the intensity of UV radiation reflected from the note. A resultant image of the UV light reflected from the banknote will be stored in an image file four pixels wide. This image of UV reflectance can then be used as part of validation routines.

30 The UV detector can also be used to detector fluorescence under UV illumination. In this case, a UV illumination source within the sensor is used to illuminate a passing banknote. The illumination can then cause certain features in the note to fluoresce and emit light in various spectral bands, including light in the visible spectrum. This emitted light is then detected by a photodetector such as a photodiode
35 or photodiode array and used to generate an image of the banknote fluorescence. This

can then be used for pattern recognition or validation. A system that uses such a combined UVPPD sensor is described in European patent EP1254435B1.

The UV PPD detector is illustrated in Figure 7C. The detector is mounted in mounting 718 under control circuitry 712c. Casing 715c then sits on top of mounting
5 718.

Again, to calibrate the sensor a note or document with known UV properties is fed into the note handling apparatus and the known properties are compared to those measured from the sensor.

10 7.5 Ultrasound Detector

The ultrasound detector comprises ultrasonic transmitting and receiving transducers arranged on opposite sides of the upper transport path 410, and a processing system for monitoring ultrasound signals received by the receiving
15 transducer. This apparatus allows the monitoring of banknotes in order to provide the following features: an indication of thickness (as in double edge detection); an indication of the presence of tape (i.e. to detect adhesive tape used to repair a tear in a note); watermark detection and inspection (i.e. detection of the presence or absence of a watermark and its pattern); tear detection (both closed, where the tear does not
20 extend to the edge, and open, where the tear does extend to the edge); corner fold detection; and the detection of security threads. The principle of operation of these systems is to detect the intensity of ultrasound signals either transmitted through or reflected back from a banknote from which certain information about the banknote can be deduced.

The transmitting and receiving transducers are illustrated in Figures 7E and 7F respectively. Beginning with the transmitting transducers, each detector comprises 16 channels, each channel being provided by a high frequency ultrasonic transducer 722, for example type MA200D made by Murata Manufacturing Co. Ltd. Each transducer is mounted at a set angle within plastic mounting 723 to help route unwanted reflections
30 away from the sensors. The transducers are connected to processing circuit board 712e which is in turn connected to more advanced processing within sensor box 616 on the SDA assembly 601X or attached to the control board mounting platform 359. The complete assembly is then mounted within housing 715e.

On the other side of the transport path to the transmissive transducers
35 illustrated in Figure 7E are mounted the receiving transducers illustrated in Figure 7F.

The receiving transducers 724 are mounted at an angle to face the transmissive transducers on the other side of the transport path. Each transducer 724 is held within plastic mounting 725 and is connected to preliminary control processing board 712f. In order to accommodate the extra processing circuitry needed to monitor received ultrasonic transmissions, additional circuit board 712g is attached to the top of preliminary control processing board 712f. These elements are then housed within casing 710f. This casing also has holes 727 to prevent reflections from the casing interfering with the receiving transducers 724.

A single ultrasound channel will comprise a transmitter 722 and receiver 724 transducer pair. The signal received by each receiving transducer in each channel will be sampled and digitised in order to produce an ultrasound "pixel". As the note passes the 16 channels that make up each row produce a line scan of the ultrasonic properties of a note. By combining multiple lines an ultrasonic "image" of the note can be generated which can be analysed to check for the presence or absence of the features described earlier. Examples of similar ultrasonic detector systems which use angled sensors are given in GB patent application number 0526381.9 and US patent application number 60/706,753.

To calibrate the ultrasound detector two test documents are passed through the note handling apparatus. Each document will have well known but different acoustic properties which can be used to interpret the measured sensor output. Typically, one document is a foil document and the other is a plastic/foil document.

7.6 Ultrasound Detector Transport Module 730

The ultrasonic transmitter and detector sensor modules described previously are mounted within a standalone transport assembly. This assembly is illustrated in Figure 7G. The assembly 730 comprises upper section 735 and lower section 760. The upper section 730 contains the receiving transducer module 710 and the lower section 760 contains the transmitting transducer module 709. The two sections are hinged in a similar manner to the SDA assembly, with the lower section 760 attached to pivot plates 761a and 761b. Pivot shaft 732, attached to upper section 735, is then allowed to rotate within the two pivot plates 761 thus hinging the assembly 735 at the rear.

Top section 735 is locked to the lower section 760 to prevent the assembly 730 opening during transport or removal. This is achieved using a locking mechanism

comprising handle 743, locking bar 746a, short protrusion 746 and leaf springs 731. When locked, an indentation within each locking bar 746a clips onto each protrusion 746b on the lower section 760. The locking bar 746a is biased towards the rear of the transport section by leaf spring 731b. Only when a rearward force is applied to handle
5 743 will the locking bar 746a pivot around pivot shaft 743s against the biasing force of spring 731. When the locking bar 746a is released then the upper section 735 can then be opened by pivoting the section around pivot shaft 732.

The upper section 735 of ultrasound assembly 730 is illustrated in more detail in an exploded perspective view of the first and right sides shown in Figure 7H. The
10 upper section 735 comprises two sensor module bays: the frontward bay being occupied by the ultrasound receivers 710 in casing 710f and the rearward bay 795 remaining empty. Additional sensor modules can be placed in a modular fashion within the empty sensor bay if required. Each sensor bay is mounted between two sets of guide rollers. The ultrasound receiver detector 710 is installed between rollers 738a
15 and rollers 738b. In a similar manner to the guide rollers present in the upper SDA section 603, the guide rollers are attached to sprung shafts 739. These shafts 739 are allowed to move in extended apertures 796 and are biased towards the lower surface of the upper section 735 by leaf springs 740. The rearward sensor bay 795 is located between rollers 738b and rollers 738c. These rollers are also mounted on sprung
20 shafts. The three sets of rollers 738 are mounted within three guide sections 736. These sections are similar to those that make up the guide sections 625, 625X in the SDA assembly 601. They also contain ridges to reduce the friction between a note and the section surface and are typically made from anti static plastic.

The lower section 760 of the ultrasound assembly 730 is shown in an exploded
25 perspective view of the front and left sides in Figure 7I. To complement the design of the upper section 735 there are again two sensor module bays. The front bay contains the ultrasound transmitting transducers 709 and the rear bay 767 is empty. Above the casing 715e for the ultrasound transmitting transducers 709 is a plastic guide 778 with spacing to allow the ultrasound wave to propagate upwards from the transmitting
30 transducers towards the receiving transducers 709. Guide plate 778 is mounted within guide section 780 which comprises a plurality of fingers to feed the note into the ultrasound assembly and contains a number of apertures before and after the ultrasound sensor module 709 to accommodate guide rollers 776a and 776b. On the far side of the empty sensor bay 767 is another guide plate 779 which clips onto guide
35 plate 780 and also comprises apertures for a rear set guide rollers 776c. The guide

plate 780 also comprises a plurality of exit guide fingers that guide the note towards the entrance of the u-turn assembly installed in use behind the ultrasound assembly 730. Guide rollers 776 are mounted on shafts 777 that are driven by a gearing system including gears 773. Gears 773 are connected to large gears 771 and 772. These
5 gears are in turn driven by gears 790 and 791 of the transport extension section 785 illustrated in Figure 7J.

On the underside of the lower section 760, is a sheet metal guide plate 768 within which two sets of freely rotating guide rollers 765 are located. These rollers 765 are attached to shafts 766 and are spring mounted through wire spring 764. The lower
10 surface of the lower section 760 forms the upper surface of the extended lower transport path. Guide fingers 769 are additionally added to the front of the upper section of the extended lower transport path to smooth the progress of the notes along the path.

The lower surface forms the extended lower transport path in a complementary
15 manner with the transport extension section 785. Transport extension section 785 is illustrated in a perspective view of the front and left sides shown in Figure 7J. It comprises a three belt system 786 that conveys a note from the exit of the u-turn section 671 to the horizontal transport section. These belts are entrained around two pulleys connected to shafts 789b and 792b. Gears 789a and 792a are respectively
20 mounted to these shafts and are in turn respectively driven by large gears 790 and 791. These large gears then connect with large gears 771 and 772 on the lower section 760 of the ultrasound assembly 730. Idle gear 793 transfers torque to the belt system of the u-turn section and gear 789a is connected to gear 682 at the rear of the horizontal transport section (illustrated in Figure 6J).

25 Ultrasound assembly 730 and lower transport extension 785 can be added as a modular unit to an existing note handling device configuration if additional detector systems are required. To add the ultrasound assembly the u-turn assembly is first uncoupled from the moveable carriage 350. The transport section 785 is then attached to the moveable carriage 350 in its place and the lower section 760 of the ultrasound
30 assembly 730 is then connected above the transport section 785 within the inner frame 375. The u-turn assembly is then re-installed behind the transport section 785.

8. Diverter and Transport Mechanisms

8.1 Diverter 800

5 The diverter assembly is shown in Figures 8A to 8E and comprises two main sections: a rear section 802 containing the diverter itself and a front section 801.

 The rear section 802 houses two sets of rubber rollers. An upper set of rollers comprises four medium rubber roller pairs 807 mounted on a first driven shaft 803. Large rear diverter gear 831 is fixed to the end of this first driven shaft 803 and, as
10 described previously, is connected to the rear belt system 677 shown in Figure 6J. A lower set of ten rear rubber rollers 843 are mounted on a second shaft 806. These rollers are allowed to rotate freely.

 The front section 801 also contains a set of medium sized front rubber rollers 808,809 and a set of ten front rubber rollers 810. The ten front rubber rollers 810 are
15 mounted to complement the ten rear rubber rollers 843 below the diverter guide fingers.

 These front rubber rollers 810 are connected to lower shaft 805 which is driven by the through safe transport via small front gear 855 and third idle gear 683 of the horizontal transport section (see Figure 6J).

 The operation of the diverter 800 is described below in relation to the three main
20 transport directions.

8.1.1 Input Module to Stacker (Reject)

\$ When the moveable guide fingers 811 are at rest they reside in a substantially horizontal position as illustrated in Figure 8A and 8D;

25 \$ in the default horizontal position, a note approaching from the lower transport path in the direction 840 will be driven over the moveable guide fingers 811 (the first blade) by the rear medium rollers 807;

 \$ as the note passes over these rollers 807 the leading edge of the note will also be taken up by the front medium rollers 808 and 809 which expel the note from the
30 diverter section towards the stacking module.

8.1.2 Input Module to RSM (Deposit)

\$ When the diverter is activated the rear ends of the fingers 811 will raise as illustrated in Figure 8E and a set of vertical guide fingers 812 (the second blade) will
35 rotate towards the front of the diverter assembly;

\$ a note arriving from the lower transport path assembly 411 in the x-direction 840 will then be driven underneath the moveable guide fingers 811 by the rear rubber rollers 807 and the note will follow the guide surface of the rear section 802;

\$ the leading edge of the note will then be received between the small rubber
5 rollers 810 and 843 and the rotation of the rollers 810,843 will drive the note downwards 841 towards the through safe transport.

8.1.3 RSM to Stacker (Dispense)

\$ when a note is retrieved from the roll storage modules, it approaches the
10 diverter assembly 800 in the z-direction 842;

\$ moveable guide fingers 811 then must be switched to a default horizontal position, with the vertical guide fingers 812 at rest against the surface of rear section 802;

\$ the note will then approach lower rollers 810,843 which will rotate to further
15 transport the note in the z-direction 842;

\$ as the vertical guide fingers 812 are flush against the surface of rear section 802, the note will pass by the front surface of these guide fingers 812 and proceed to follow the front underside curve of moveable guide fingers 811;

\$ the leading edge of the note will then reach the front driven rollers 808, 809
20 which will guide the note, together with the third belt transport system of the lower SDA section 602, towards the stacker module.

Figure 8B and 8C show the diverter 830 mechanism in more detail. The moveable guide fingers 811 are rigidly fixed to a diverter shaft 824. The diverter shaft
25 824 is held rigidly in place within a set of rotatable members 817a,b by pins 824p. Thus when the rotatable members 817 rotate so do the moveable guide fingers 811. Concentrating on the left side of the mechanism, the rotatable member 817a also features a pin protrusion 827a. To this pin protrusion 827a is attached an actuating bar member 813. The end of actuating bar member 813 is connected to the piston of a
30 solenoid 694. This solenoid can be seen in Figure 6I. The solenoid 694 is mounted within a casing 690 below the horizontal transport guide plate 615gl. The default position of the solenoid piston 691 is an extended position. When the solenoid 694 is actuated, the piston 691 retracts.

When the piston retracts, the connecting rod 813 is displaced towards the rear
35 of the diverter assembly 800. This in turn applies a force to pin 827a and member

817a. This force causes member 817a to rotate around an axis defined by diverter shaft 824. If viewing the diverter mechanism from direction Y' in Figure 8B, the clockwise rotation of member 817a thus causes the diverter shaft 824 to also rotate in a clockwise direction. This lifts the rear end of the moveable guide fingers 811. The
5 moveable guide fingers are thus aligned in a plane at an angle to the horizontal (see Figure 8E).

Concurrently, the rotation of member 817a also causes a complementary rotation of gear 819a. Gear 819a is mounted between gearing track 818a on member 817a and gearing track 826a on complementary member 821a. The clockwise rotation
10 of member 817a causes the gearing track 818 to rotate clockwise on a circumferential path. This then rotates gear 819a in a clockwise direction around an axis defined by pin 820a. This rotation of gear 819a then causes gearing train 826a to move in a forward direction rotating complementary member 821a in an anticlockwise direction. The vertical guide fingers 812 are free to rotate around diverter shaft 824. They are
15 biased towards a vertical position by tension spring 825 connected to modified finger 823 and tension spring post 802p. At rest the vertical guide fingers thus rest against the guide surface of the rear section. On each end of the vertical guide fingers 812 are two modified fingers 823a. Modified finger 823a rests upon tab 822a on complementary member 821a. Thus when complementary member 821a rotates
20 counterclockwise tab 822a also rotates counterclockwise about the axis formed by the diverter shaft 824 causing the vertical guide fingers 812 to also rotate about the aforementioned axis. The vertical guide fingers 812 are thus now aligned at an angle to the vertical. When the piston 691 is fully retracted the diverter mechanism 830 is held in the activated arrangement shown in Figure 8E. Any note coming from direction 840 will
25 now be directed down towards the roll storage modules in direction 841.

When power is removed from the solenoid 694 then the piston 691 will again extend under the force of a compressive bias spring wrapped around the piston 691. The extension of the piston 691 displaces connecting rod 813 in the forward x-direction and causes member 817a to rotate counterclockwise. This counterclockwise rotation
30 returns the moveable guide fingers 811 to a horizontal position through the rotation of the connected diverter shaft 824. Concurrently, the gearing train 818a causes gear 819a to also rotate counterclockwise, which in turn causes complementary member 821a to rotate clockwise. This then rotates tab 822a clockwise and allows the vertical guide fingers 812 to rotate back to a substantially vertical position due to the biasing
35 effect of spring 825.

The spring tension is selected such that, if the solenoid is deactivated whilst a note is passing through the diverter between the lower transport path assembly 411 and the RSMs, should the guide fingers come into contact with the note when they switch position, they will rest lightly on the note allowing it to complete its passage through the diverter. Once the note has passed, the spring 825 will return the guide fingers fully to their default position, such that the subsequent notes will be diverted as intended by the deactivation of the solenoid. This has significant advantages since the solenoid can be switched more rapidly upon receipt of a command, without having to wait for the present note to exit the diverter.

The use of a compression spring to bias the solenoid piston 691 is particularly useful in the case of an error or system failure. If an error or system failure occurs it is advantageous to direct as many notes as possible to the output stacker module in order to prevent the loss of these notes with the safe. To direct notes to the stacker module the moveable guide fingers 811 must be substantially horizontal. As the tensioned spring wrapped around the solenoid piston 691 actively biases this piston 691 to the extended position, when power is cut from the solenoid, the piston 691 will automatically extend. This causes the connecting rod 813 to extend and consequentially the moveable guide fingers 811 will return to a horizontal position. As it takes more time to actuate the solenoid than it does switch it off, this allows a very quick return to the default position to direct the notes to the stacker module.

In some circumstances, during power loss a note may be halfway through the diverter assembly on its passage to the roll storage modules. In this case, it is advantageous that the note continues along its route to the roll storage modules to prevent note jams. To prevent the note becoming trapped underneath the vertical guide fingers 812 when the piston of the solenoid extends, the vertical guide fingers 812 can rotate slightly around the diverter shaft 824 against the force of tension spring 825. This allows the note to pass underneath the vertical guide fingers 812 and travel onwards in direction 841 to the storage modules. A preceding note travelling along in direction 840 will then pass directly over the fingers 811 and out to the stacker module.

In the case of a diverter and/or through safe note jam there is an additional emergency path a note may take. If during a "purge" operation to remove notes from these areas the diverter mechanism 830 is actuated by switching on the solenoid 694 and the direction of NHM and/or safe transport is reversed, then a note can exit the diverter in direction 842 onto the rear of the lower transport path 411 via rear surfaces of vertical guide fingers 812 and the angled underside surfaces of moveable guide

fingers 811. This "reversed" note transport is only initiated for a short time, typically until a note is clear of the diverter. The transport can then be driven in a forward direction after de-activating the solenoid to "purge" the note to the stacker hopper. Alternatively, the transport can stop and an operator can remove the note manually. As removing a
5 note from the note transport is easier than removing it from the diverter assembly, then the "purge" operation can save time and possibly save the intervention of a skilled service engineer.

8.2 Transport Drives

10

The belts and rollers of the upper transport path 410 and rear section of lower transport path 411 are driven from a single motor 356 via a drive transport system illustrated in Figure 8F. Torque from the motor is transferred to the rear of the horizontal transport section via a timing belt 853 affixed to the left side 350a of
15 moveable carriage 350. The teeth of the timing belt 853 mesh with those on gear 873 at the front of the moveable carriage 350 and gear 851 at the rear of the carriage. These gears are mounted on axle stubs 857 and 856 respectively. Tension in the belt is kept through rotating cylinder 854 on the outside of the timing belt 853 and rotating cylinder 858 on the inside of the timing belt 853. Teeth 873a and 851a mesh with the
20 teeth on the timing belt 853 in order to provide traction and to prevent slippage. Gear 873b meshes with idler gear 879 which meshes with gear 878 connected to motor shaft 870, which drives the rotation of timing belt 853. Gear 878 is also operably connected to gear 632 to drive the front three belts 630 of the SDA assembly 601. The belts 630 then drive gear 636b of the SDA assembly 601 which drives the gear train system comprising gears 633, 635d, 634 and 635c. The timing belt transfers rotational motion
25 to gear 851b at the rear of the moveable carriage 350. Gear 851b meshes with idle gear 682 at the rear of the horizontal transport section which in turn drives gear 681 and rotates the rear drive shaft 692 and belts 677. The rotation of the rear belts 677 then also drives gear 695 and idle gear 684 to provide torque to gear 831 of the diverter mechanism 800.
30

As mentioned previously, the rollers 810 and 843 within the lower section of the diverter assembly 800 are driven from through safe transport 1100 via idle gear 683.

Belt system 637 on the lower section of the SDA assembly 601 is driven by output transport auxiliary drive motor 363, which is affixed to the left side of the
35 moveable carriage. Motor drive gear 871 is mounted to motor 363 which drives idler

gear 874 which in turn drives idler shaft 638 which drives shaft 639 which drives belts 637. Belts 637 drive gear 642 which drives idler gears 641 and 640 which in turn drives diverter exit roller 836. Motor 363 thus drives the output transport at the front of the lower note transport path after the diverter and the stacker wheels. This allows each
5 part of the transport to be controlled independently, making jam clearance and automatic note purge operations easier.

9. Stacker 900

10 Notes that are to be output to the user are directed to the stacker module 900 by the diverter 800. Figures 9A(i) and (ii) show the assembled stacker 900 in front and rear perspective views, and details of the components making up each shaft assembly J, K and L are shown in Figures 9A(iii),(iv) and (v) respectively. Figure 9B shows a cross-section of the stacker 900 in situ.

15 The stacker 900 is located at the front of the NHM 400 underneath the input module 500 at the end of the NHM transport 600. On reaching the end of NHM transport 600, the note is picked from the transport belt by a pinch point between roller shaft assemblies K and L and passed to a pair of stacker wheels 910.

As best viewed in Figure 9B, an optical prism sensor comprising emitter 960A, receiver 960B and a prism 966 disposed on the opposite side of the transport path, is provided before the first nip created by roller assemblies K and L. The emitter and receiver are aligned with the prism 966 such that the light path from the emitter 960A crosses the transport path, is transmitted laterally by the prism 966 and returns across the transport path to the detector 960B. The use of a prism sensor provides various
20 advantages over conventional transmissive sensors, not least in that all the electrical components, and the associated wiring, are constrained to one side of the transfer path, thus simplifying the construction. Moreover, since the light beam traverses the passing banknote twice, the signal to noise ratio is improved.

The roller assemblies K and L are supported between side plates 902A and 902B as shown best in Figure 9A. Roller assembly K comprises four rollers 920A to D mounted on shaft 921 which is mounted within bearing assemblies 923A and B and clips 924A and B supported in the side walls 902A and B. At its left end, the shaft 921 is fixedly connected to a cog 925 which meshes with cog 935 immediately above it which is affixed to the right hand end of the shaft assembly L. Shaft assembly L
30 comprises seven rollers 930A to G mounted on a shaft 931 which is supported between

side walls 902A and B in bearing and clip assemblies as before. The cog 935 is driven by the NHM transport 600 via a further cog 874 (see section 6 above). Thus, drive is transferred from the NHM transport 600 to shaft assemblies K and L, rotating each of them so as to move the incoming banknotes towards the stacker wheels 910.

5 It will be noted that the rollers 920 and 930 have a larger diameter than those rollers making up the NHM transport 600. As a result, banknotes are accelerated into the stacker wheels 910. This assists in ensuring that each banknote is properly received by the stacker wheel veins and thereby helps to prevent the ejection of banknotes due to centrifugal force. The acceleration also achieves a larger gap
10 between adjacent banknotes which assists in the formation of the stack.

Figures 9C (i) and (ii) show two ramps 940A and 940B provided on stacker plate 901 either side of central drive roller 930D. Each ramp extends into the document path causing deflection of oncoming banknotes as best shown in the cross section of Figure 9C (i) (here, the deflection is exaggerated for clarity). The resulting corregation of the
15 note has been found to assist in ensuring each note is properly received by the stacker wheels and a tidy stack is formed. In this example, each ramp has a curved profile but the ramps could be in the form of any other suitable protrusion.

Before entering the stacker wheels 910A and 910B, notes pass over brush assemblies 962 which protrude through apertures provided in the guide surface (see
20 Figure 9B). Each brush assembly consists of a body 962B which supports brush elements 962A, the free extremities of which extend into the banknote path. Contact with the brushes helps to remove any static charge built up on the notes to improve formation of the stack. The brush assemblies 962 are supported on cross beam 961 underneath the guide surface. The cross beam 961 is also provided with cable clips
25 963 for holding cables running to the various sensors in the stacker module 900.

The stacker wheels form part of shaft assembly J and protrude through elongate apertures 901A and B in guide plate 901. Each stacker wheel 910A and B comprises a solid plastic core and a plurality of arcuate protrusions defining veins therebetween. In use, a banknote enters the veins at the top of the wheel which is then rotated to turn the
30 banknote through an angle and deposit it on the guide plate such that a stack of banknotes is built up. Teeth 903 are provided on the guide plates to support the growing banknote stack.

The stacker wheel shaft assembly J is shown in Figure 9A(iii) and comprises the two stacker wheels 910A and 910B mounted on shaft 911. The shaft 911 is mounted in
35 bearing clip assemblies supported in the side plates 902A and 902B as before. At its

left hand end, the shaft is provided with a cog 915. Drive is transferred to the cog 915 from the NHM transport 600 via cogs 935 and 925 which mesh with transfer cog 950 mounted on the exterior of side plate 902A. The cog 950 is provided with a stacked cog 951 which drives a second transfer cog 953 via a timing belt 952. The transfer cog 953 is also a stacked cog which meshes with stacker wheel cog 915 to provide drive thereto. The gearing is such that the stacker wheels 910 are rotated at a speed much slower than that of the roller assemblies K and L.

Between the stacker wheels 910, a receiving part 970 of a transmissive optical sensor is mounted and aligned with a corresponding transmitter 594 which is mounted on the underside of the input module 500. The resulting transmissive optical pair is used to detect the passage of notes into the stacker wheels 910.

A pair of optical transmitter sensors comprising emitters 964 and receivers 965 is disposed at the floor of the base plate 901 in order to detect the presence of a note in the banknote stack.

15

10. Storage assembly 1000

The storage assembly 1000 is mounted within the cabinet 200 on safe chassis 300. An overview of the storage assembly 1000 is shown in Figure 10. The storage assembly includes a number of roll storage modules (RSMs) 1300, in which banknotes are stored.

The transfer between the RSMs 1300 and the note handling module 400 is effected through safe transport 1100 and transport safe module 1200. The through safe transport 1100 is located in the top wall of the cabinet 200 to draw notes therethrough between the diverter 800 and the transport safe module 1200. The transport safe module 1200 guides notes from the through safe transport 1100 to the RSMs, re-orientating them from a vertical direction of motion to horizontal. Note transport throughout the storage assembly 1000 is driven by safe transport motor 1299 which is provided in the transport safe module 1200. All of the RSMs 1300 as well as the through safe transport 1100 and the lowermost roller pair of the diverter 800 are driven synchronously by this one motor.

The storage assembly components are controller by PCBs mounted on the safe chassis and on the interior of the cabinet 200.

35

11. Through Safe Transport 1100

Bank notes enter and exit the storage assembly 1000 via through safe transport 1100, situated between the diverter 800 and the transport safe module 1200 as shown in Figure 11a. The through safe transport 1100 is located at the interface between the storage assembly 1000 and the NHM, within an aperture 205 provided in the upper cabinet wall 201 (see Figure 2a(iii)). As described in section 2 above, the thickness of the cabinet walls 201 may be varied to suit particular security requirements. As such, the through safe transport 1100 is available in two variants. The first, depicted in cross-section in Figure 11a and in expanded perspective view in Figure 11b, is employed in configurations having relatively thin safe walls, of up to approximately 3mm in thickness. The second variant, depicted in expanded perspective view in Figure 11c, is twice as long and is adapted for use in safe configurations having a cabinet wall thickness of between 12 and 40mm thick. This extended variant could, in theory, be used for any cabinet thickness, but the use of the shorter variant does enable the overall machine to be made smaller.

Figure 11a shows the first variant of the through safe transport 1100 in situ. Essentially, the through safe transport 1100 comprises a pair of roller shaft assemblies 1111 and 1121 located within the cabinet wall 201 and aligned with the diverter 800 to provide a nip which picks banknotes out of the last pinch point in the diverter created by roller shafts 805 and 806. Guide plates 1150 and 1160 are arranged between the roller assemblies 1111 and 1121 to guide the notes from the diverter 800 into the storage assembly. The guide plate 1150 and 1160 are provided with guide fingers 1151 and 1161 respectively which interleave with the guide structures of the diverter 800 to ensure smooth passage between the two components. Similarly, the lower edges of the guide plates 1150 and 1160 are provided with guide fingers 1152 and 1162 respectively which direct the banknotes into the transport safe module 1200.

The rear roller assembly consists of rollers 1110a, b and c (only one of which is visible in Figure 11a) fixedly mounted on shaft 1111 which is supported by bearings 1113 and 1114 in left and right brackets 1170a and 1170b which secure the through safe transport assembly into the top wall of the cabinet 200. The shaft 1111 extends at its left hand end through a bearing plate 1171 which is biased upward via a tension spring 1172 connected to the left bracket 1170a. The bearing plate 1171 is provided with a spigot 1171a on which a cog 1173 is mounted. In use, the cog 1173 extends through an aperture in the upper surface of left bracket 1170a and meshes with cog

835 on the diverter to transfer drive from the through safe transport 1100 to the lower portion of the diverter.

The cog 1173 is driven by meshing cog 1174 fixedly mounted on rear shaft 1111. Drive is transferred to the cog 1174 from the transport safe module 1200, as will
5 be discussed in section 12 below. Bearing 1175 provides a fixed distance between cog 1213 on the transport safe module 1200 and cog 1174.

The front shaft assembly comprises rollers 1120a, b and c mounted on shaft 1121 in bearings 1123 and 1124 supported by left and right brackets 1170a and 1170b. The ends of the front shaft 1121 do not extend past these bearings. The front rollers
10 1120a, b and c are therefore free to idle against the driven rear roller assembly.

The through safe transport 1100 is completed by front and rear cross supports 1129 and 1119 respectively which attach to the left and right brackets 1170a and 1170b at either end.

The second through safe transport variant 1100' is extended in the direction of
15 note transport by a second roller shaft pair, as shown in Figure 11c. Many of the components making up the second variant 1100' are identical to those of the first variant and these are indicated in Figure 11c by the use of the same reference numerals with the addition of a prime. The guide plates 1150' and 1160', the front and rear cross supports 1129' and 1119', and the left and right support brackets 1170a' and
20 1170b' are extended to accommodate the additional roller shafts.

The lower rear shaft assembly comprises rollers 1130a, b and c (not shown), mounted on shaft 1131 which is supported in a bearing (not visible) through the left support bracket 1170a' where it is fixedly mounted to drive cog 1176. Drive cog 1176 receives drive from the transport safe module 1200. An additional cog 1177 is provided
25 to link drive cog 1176 to cog 1174' which drives the upper rear shaft 1111' as in the first variant 1100. Thus, both the upper and lower rear rollers 1110 and 1130 are driven synchronously. Both the upper and lower front rollers 1120 and 1140 idle against the respective driven shaft assembly.

30 **12. Transport Safe Module 1200**

Bank notes are transferred between the through safe transport 1100 and the RSMs 1300 by the transport safe module 1200. The primary function of the transport safe module 1200 is to guide the note from the through safe transport to the RSMs,
35 changing the orientation of each note from vertical to horizontal during the transfer.

This is achieved using a set of three transport belts 1121 and opposing rollers 1267, 1270 and 1272 which together define a curved banknote path P between the through safe transport 1100 and the RSMs 1300. The transport safe module 1200 also houses the safe transport motor 1299 which provides drive not only to the transport
5 safe module 1200 but also to the through safe transport 1100 (as described in section 11 above) and each of the RSMs 1300, described in section 13 below.

The transport safe module 1200 is shown in cross-section in Figure 12a. The module is constructed in two main parts: the transport inner assembly, shown in expanded perspective view in Figure 12b, and the fixed guide structure shown in
10 expanded perspective view in Figure 12d. The fixed guide structure is fixedly mounted into the tower 302 which forms part of the safe chassis 300, described above in section 3.1. The transport inner assembly is pivotably mounted to the fixed guide assembly such that the banknote path within the transport safe module 1200 can be accessed for maintenance by pivoting the transport inner assembly away from the fixed guide
15 structure.

As shown in Figure 12b, the transport inner assembly comprises three transport belts 1221a, b and c supported on five roller assemblies E, F, G, H and I. The roller assemblies are shown in more detail in Figures 12c (i) to (v) respectively. The roller assemblies E to I are supported between side plates 1201a and 1201b which are
20 rotatably mounted to the fixed guide structure at pivot points 1202a and 1202b. Shaft assemblies E, F, H and I are supported in bearings positioned within apertures 1205, 1204, 1203 and 1202 in the side plates 1202.

The lowermost shaft assembly I, shown in Figure 12c(iii), comprises belt rollers 1250a, b and c mounted on a shaft 1251. The shaft 1251 is mounted in bearings 1252a and b between the side plates 1201a and 1201b. At its left end, the shaft 1251
25 attaches to a pulley wheel 1254 which is driven by the transport safe motor 1299 via a timing belt 1298. Thus, shaft assembly I provides drive to all of the shaft assemblies E, F, G and H via transport belts 1221a, b and c. At its right end, the shaft 1251 attaches to a cog 1255 which in turn operates cog 1295 (shown in Figure 12d) to transfer drive to
30 the roll storage modules 1300.

The shafts E, F, G and H are all of similar construction having three belt rollers mounted on respective shafts supported in bearings between side plates 1201a and 1201b. Shaft assembly h is provided at its right hand end with a timing wheel 1248 which, when the transport safe 1200 is fully assembled, interacts with optical sensor

1284 (see Figure 12d) to form a slotted optosensor which is used to monitor the speed of the transport belts.

5 Shaft assembly G is not supported within bearings but rather extends through elongated slots 1206a and b in the side plates 1201a and b. When the assembly is in its closed position, the shaft assembly G is located at the top of the elongate aperture 1206 and exerts little or no pressure on the transport belt 1221. When the inner transport assembly is pivoted away from the fixed guide structure, the shaft assembly G is urged downward by light tension springs 1209a and b such that the shaft 1241 slides relative to the elongate apertures 1206. In this way, pressure is applied to the transport belts 1221 ensuring that they stay in position while the transport assembly is open. Otherwise, the loss of tension arising from the belts assuming a straight path between the upper and lower shaft assemblies E and I when the guide assembly is not in position to enforce a curved path, would lead to the belts 1221 disengaging themselves from the belt rollers.

15 The uppermost shaft assembly E, shown in Figure 12c(iv), extends at its left end through the side plate 1201a into a swing arm defined by brackets 1211 and 1215 between which are supported cogs 1213. The shaft 1231 is provided with a gear 1234 which meshes with the gears 1213 which, in use, transfer drive to the through safe transport 1100 located above. The swing arm is maintained in position by virtue of a tension spring 1211a between the right hand bracket 1211 and the side plate 1201a.

20 Adjacent the roller assemblies are provided four guide members 1220a, 1220b, 1220c and 1220d which, together with the fixed guide structure, define the curved transport path P. The guide members 1220 are held in assembled relation by support shafts 1222, 1223 and 1224 which pass through apertures in each guide member. A latch support shaft 1256 is supported between apertures 1207a and 1207b in the side plates 1206b, through which it extends to carry latch plates 1258a and b via spacers 1257a and b through apertures 1258a'. The latch plate 1258 is provided with a cut-out which couples with a protrusion on the fixed guide structure to secure the inner transport assembly into its closed position. The latch plates 1258a and b are urged into position via tension springs 1259a and b. In order to open the transport safe module, the user depresses the tabs 1258a and/or b to release them from the protrusions on the guide structure. The inner transport assembly is completed by a cross support 1210 affixed between the side plates 1201a and b.

35 The completed inner transport assembly is shown on the left hand side of Figure 12D, which also shows the fixed guide structure in expanded perspective view. The

fixed guide structure is supported between side plates 1260a and b which are mounted on the safe chassis 300. The inner transport assembly is pivotably mounted to the side plates 1260a and b via apertures 1262a and b through which shaft 1251 of the drive shaft assembly I extends. A screw on the end of the guide support shaft 1222 forms a
5 stopper which extends through arcuate apertures 1261a and b in the side plates 1260a and b, limiting the angle through which the inner transport assembly may be opened.

The side plates 1260a and b support between them three curved outer guides 1266. Each guide 1266 comprises a curved plastic moulding having six apertures therein, each of which supports in use a roller 1267 mounted on a shaft 1268. At their
10 lower ends, the guides 1266 are mounted on a shaft 1269 which sits just above the drive shaft I when assembled. Three rollers 1270 are mounted on the shaft 1269 at the base of each guide 1266 to form the last nip in the transport safe with the drive shaft rollers 1250. At the top of each guide 1266, a roller 1272 is supported between forked extensions mounting a roller shaft 1273 between them. Leaf springs 1271 are provided
15 to urge the rollers 1272 toward the transport path.

The top of the transport safe is completed by guide plates 1274 and 1275 which cover the inner transport assembly and the guides 1266, and assist the smooth passage of the banknote from the through safe transport 1100 into the transport safe 1200 where the notes follow the curved path defined between the inner transport
20 assembly and the guides 1266.

Two optical sensor pairs 1276 and 1277 are provided in the guide plates 1274 and 1273 to detect passage of a banknote between the transport safe module 1200 and the through safe transport 1100. The sensors 1276 and 1277 are controlled by a PCB mounted on support bracket 1279.

25 At the lower end of the transport safe module 1200, two guide plates 1279 and 1280 are provided to guide the banknotes between the transport safe module 1200 and the RSMs 1300. Here, a prism sensor consisting of emitter 1281a, receiver 1281b and a prism (not shown), is provided to detect the passage of notes therethrough. Each electrical component is mounted in a housing 1283 on the lower guide plate 1280. The
30 prism is mounted on the upper guide plate 1279 and consists of an elongate polymer plate having opposing 45 degree angled surfaces corresponding to the position of the emitter 1281a and receiver 1281b. In this example, the emitter 1281a and receiver 1281b are positioned approximately 60mm apart, spaced laterally across the transfer path. The use of a prism sensor is preferred since all of the electrical components are
35 positioned on the same side of the banknote path, and thus no wiring is required to

have access to the other side. In addition, the signal to noise ratio is improved compared with a standard sensor arrangement in which the components are on opposing sides of the transfer path, since the light beam passes through the note twice. The prism sensor is able to detect the passing of the leading edge of the banknote.

5 The fixed guide structure is secured into the safe chassis 300 via a mounting shaft 1265 which extends between the side plates 1263a and b and into the tower of the safe chassis 300. Guide plates 1263 and 1264 are mounted on the side plates 1260 to provide alignment of the transport safe with the surrounding modules. Plates 1263a and 1263b centralise the transport safe 1200 relative to the through safe transport 1100
10 by urging against the sides of the through safe transport 1100. Plates 1264a and 1264b provide guidance when fitting the roll storage towers (RSTs) to the safe chassis so that they are horizontally restrained.

 The transport motor is mounted on the inside of the left hand side plate 1260a. As previously described, drive is transferred to the shaft 1251 via timing belt 1298
15 cooperating with pulley 1254. The shaft 1251 is additionally provided with a manual turning wheel arrangement comprising a connector 1297 and hand wheel 1296 providing for manual turning of the transport belt in both directions.

 The transport safe 1200 is completed by back plate 1286 mounted between side plates 1260a and b. The back plate 1286 supports a control PCB 1289 via a heat sink
20 1288 and a thermal filler 1287.

13. Roll Storage Module 1300

 Banknotes are stored by the apparatus in a set of roll storage modules (RSMs)
25 1300. A typical apparatus may have six RSMs 300, stacked into three roll storage towers (RSTs) 1399, each comprising an upper RSM 1300' and a lower RSM 1300. In other cases, eight RSMs may be deployed.

 An overview is shown in Figure 13A, which depicts (i) a RST in perspective view from the right hand side; (ii) a RST in perspective view from the left hand side; and (iii)
30 a RST viewed from the rear of the apparatus, which has been opened so as to reveal the transport path between the upper RSM 1300' and the lower RSM 1300. As will be described in more detail below, the two RSMs are joined by a hinge assembly 1304. Throughout the figures, the note path is depicted by the arrow P_{IN} , denoting the direction of travel of notes passing into the RSM 1300.

The upper and lower RSMs are substantially identical to one another, save for some minor alterations enabling the lower RSM to latch to the safe chassis 300, and for the upper RSM to latch securely to the lower RSM. In view of this, the description below will focus primarily on the lower RSM 1300. However, it will be appreciated that
5 substantially the same description applies to the upper storage module 1300'. The minor differences between the upper and lower modules will be detailed as appropriate below.

The type of note to be stored by each RSM can be selected as appropriate for the end application. In most cases, each RSM will be used to store a different
10 denomination of the same currency. For example, in the case of Euros, the six RSMs may be configured to store five Euro, ten Euro, twenty Euro, fifty Euro, one hundred Euro and two hundred Euro notes respectively. In some cases, it may be necessary to dedicate more than one RSM to a particular denomination, for example two RSMs may be used to store five Euro banknotes. It may also be desirable to dedicate one or more
15 of the RSMs as an "object" RSM, in which case the RSM is used to store any document fed into the apparatus which does not meet the criteria for storage in any of the other RSMs. For example, the object RSM may store banknotes which have been rejected either due to failed authenticity tests or non-recognition of the denomination. Alternatively, an object RSM may be used to store other currencies or denominations
20 for which there is no dedicated RSM. Given that the contents of an object RSM are varied, typically, the object RSM is not used for dispensing any banknotes, but more as a reject bin.

Each RSM is supported in a frame structure mounted on the base frame 301 of the safe chassis 300. The structure is described in detail in Section 3.1 below.

25 Essentially, the RSM 1300 stores banknotes between adjacent windings of a band wound onto a storage roller. Each RSM comprises a band roller and a note storage roller, to each of which are attached the opposite ends of the band. The band roller stores the band that is not currently in use, and the band is transferred, by rotating the two rollers, from the band roller onto the note storage roller when it is desired to
30 store a banknote. Banknotes to be stored are supplied to the band near to where it is wound onto the note storage roller such that the banknote is entrapped between adjacent windings of the band on the document storage roller. By rotating the two rollers in the opposite direction, the band is transferred from the document storage roller to the band roller. Notes stored between the windings on the note storage roller
35 are thus released. The number of notes that can be stored depends on the diameter of

the storage roller and the length of tape available. In this example, each RSM can store up to 350 notes. The banknote storage components will be described in Section 13.2 below.

5 In order to release documents from the document storage roller consistently when a banknote is to be dispensed, a scraper is provided which helps to lift the banknote away from the underlying band. The scraper is a blade-like element supported in a pivot guide assembly which is urged into contact with the band on the banknote storage roller to engage the leading edge of the banknotes as they are dispensed to ensure that they peel off the band and into the document transport system
10 for onward conveyance. The pivot guide assembly is arranged to adjust its position within the RSM as the number of stored notes increases or decreases in order to maintain its position relative to the next banknote to be dispensed. The pivot guide assembly is described in more detail in Section 13.3 below.

Transport to and from each RSM is provided by an integral transport module
15 defined in the top surface of the lower RSM 1300, and in the base surface of the top RSM 1300'. Thus, notes are transported between the upper and lower RSMs and each RSM is provided with a diverter which can be activated to guide the banknote into the respective RSM. Conversely, when a banknote is to be dispensed, the transport is reversed and the diverter of the appropriate RSM opens such that a banknote is
20 transported away from the RSM and out of the storage assembly through the transport safe module 1200. The note transport will be described in more detail in Section 13.4 below.

Each RSM is provided with a number of sensors for detecting the passage of notes therethrough. As well as detecting note jams, the output from the sensors can be
25 used to maintain a record of the notes stored in and dispensed from each RSM 1300. The sensor system will be described in Section 13.5 below.

13.1 RSM Structure

30 Figures 13B(i) and (ii) show a roll storage module 1300 in perspective view from the right and left sides respectively. The RSM is supported between left and right side plates 1301a and 1301b which in use, couple with the latch plate assembly 311 on the safe chassis 300 via cutouts 1301c to secure the RSM in position. Structural rigidity is provided by cross beams 1302a, 1302b and 1302c as well as shaft 1302d. At the rear

of each side plate 1301, vertical guides 1303a and 1303b are provided which, in use, couple with the adjacent RSM to ensure accurate alignment.

On the left hand side plate 1301a, two lower brackets 1304a are provided which form the lower half of hinge assembly 1304 which couples the lower RSM 1300 to the upper RSM 1300'. Each bracket is provided with a bolt latch 1304b which, when assembled, engages a latch plate 1304c (see Figure 13L(i)) on the upper RSM 1300'. Once the latch plate 1304c is disengaged from bolt latches 1304b, the hinge is free to open.

On the right hand side wall, a second latch plate 1305a is mounted about a pivot point 1305c. The latch plate 1305a is urged by a tension spring 1305b into position where it engages a protrusion on the upper RSM 1300'. To release the RSMs and thereby access the note path, the latch 1305a is depressed by a user against the spring 1305b. When the upper RSM 1300' is returned to its closed position, the spring 1305b re-engages the latch plate 1305a with the protrusion and the roll storage tower is secured.

13.2 Note Storage

In use, banknotes are stored on storage roller 1320 between successive band windings supplied from band rollers 1310a and b. The band 1309 itself consists of a length of tape made from a tough and resilient material such as Mylar™. In this example, two bands 1309 are employed to retain the notes on the note storage roller 1320. However, it will be appreciated that any number of such bands could be used. Further, in this example, each banknote is held onto the storage roller 1320 by a single turn of band, such that the layering on the note roller is band/note/band/note etc. However, "dual band" examples are also envisaged in which each note is secured between bands on either side, i.e. the layering is band/note/band/band/note/band/band etc.

Figure 13c(i) shows the positions of the storage roller 1320 and the band rollers 1310 relative to one another, and it will be seen that they are separated by pivot guide assembly 1340. The band rollers 1310 form part of shaft assembly M, the construction of which is shown in Figure 13E(vii). The storage roller 1320 forms part of shaft assembly N, shown in Figure 13E(viii). From the band rollers 1310, the band passes over a third roller assembly R which performs a number of functions including sensing the band position and the speed of band transport. The band then takes a convoluted

path through rollers arranged on the pivot guide assembly 1340 to reach the note storage roller 1320. A schematic diagram showing the path of the bank 1309 is shown in Figure 13D(ii).

The band roller assembly M, shown in Figure 13E(vii) and Figure 13G, comprises two band rollers 1310a and 1310b, on which are wound the two bands 1309. The band rollers have geared extensions 1312a and b which mesh with a bevel gear 1313. The band rollers 1310 freewheel relative to the mounting shaft 1311 whereas the bevel gear is fixably mounted to a peg provided on the shaft 1311, as shown most clearly in Figure 13G(i). As the shaft rotates, the bevel gear causes the two band rollers to rotate synchronously. However, if the tension on one band is varied, the bevel gear acts so as to place the same tension on the other band. Thus, tension in the bands is maintained equal.

The shaft 1311 is supported in bearings 1314a and b between the side plates 1301a and b of the RSM 1300. At its left hand end, the shaft 1311 is provided with a pulley wheel 1316 which is driven by the band roller motor 1319, mounted on the inside of the left hand side wall 1301a. As shown best in Figure 13B(ii), drive is transferred from the motor to the band rollers via a drive cog 1318 and a timing belt 1317 which couples with the pulley wheel 1316.

The construction of the note storage roller assembly N is shown in Figure 13E(viii) and Figure 13F. The storage roller 1320 is formed in two semi-cylindrical halves 1320b and 1320c. The completed storage roller has channels 1320a defined in its surface which, in use, receive the first windings of the bands 1309.

The shaft 1321 extends through bearings 1322a and b supported in the side plates 1301a and b of the RSM and is provided at its left hand end with a pulley wheel 1323. The pulley wheel 1323 is driven by note storage motor 1329, mounted on the inside of the right hand side plate 1301b as shown most clearly in Figure 13B(ii). As depicted in Figure 13(iii), drive is transferred to the storage roller via a drive cog 1328 and timing belt 1327.

Both the band roller assembly M and the note storage assembly N are provided with manual hand wheels 1315 and 1324 respectively, which are accessible from the right hand side of the RSM as shown in Figure 13B(i). Each hand wheel 1315 and 1324 has a ratchet action which ensure that tension is maintained in the bands. The band can only be wound onto the band rollers 1310 when the band roller shaft is rotated and band can only be wound onto the note storage roller when the storage

roller shaft is rotated. This prevents the possibility of a loop of slack band being created between the band rollers and the storage roller.

The two motors driving the band 1309 between the band rollers 1310 and the storage roller 1320 are controlled in unison so as to maintain a predetermined tension in the band. As the diameter of the band roller and the storage roller change, the speed of the motors has to be adjusted to maintain the tension constant. This is described further in our British patent application No. 0525676.3. When a note is to be stored, the motors 1319 and 1329 are operated so as to transfer the tape from the band rollers 1310 to the storage roller 1320. When a banknote is to be dispensed from the storage roller, the drive is reversed such that band is transferred from the storage roller to band rollers, the most recently stored banknote being picked off the band and transported out of the RSM by the pivot guide assembly 1340.

As mentioned above, between the band rollers 1310 and storage roller 1320, the bands pass over roller assembly R, shown in Figure 13E(vi) and Figure 13H. Two rollers 1330a and b are fixably mounted to shaft 1331 which is supported in bearings 1332a and b between side walls 1301a and b of the RSM. At its left hand end, the shaft 1331 carries a slotted timing wheel 1333. When assembled, this cooperates with an optical sensor 1334 mounted on the outside of the left side plate 1301a (only the mounting plate for the sensor is visible in Figure 13B(ii)) to form a slotted optosensor. The band 1309 passes over the rollers 1330, driving them as the band is transferred between the band rollers 1310 and the storage roller 1320. Thus the timing roll 1334 can be used to monitor the speed of the band transfer.

As an alternative, the speed of the band can be detected by monitoring the speed of the motors 1319 and 1329 as well as the diameter of either the band rollers 1310 or the storage roller 1320. This is described in our British patent application number 0525676.3. The diameter of either roller is constantly changing as the tape is wound from one roller to the other. However at any given time, the diameter can be calculated by counting the number of turns of the band onto or off the roller. Using this technique, it is possible to do away with the need for a timing wheel assembly and simply use outputs from one or more of the motors to determine the band speed.

The shaft assembly R also brings the band 1309 into close proximity to a band end detector 1335. A pair of such detectors are mounted on bracket 1302a adjacent to each roller 1330a and b. Figure 13(i) shows the band end sensor assembly 1335 in more detail. Preferably, the band end sensor comprises a magnetic sensor which can detect a magnetic feature in the passing band 1309. In conventional apparatus,

inductive sensors have been used to detect metal strips applied to the end of each band. However, such inductive sensors are expensive and it is desirable to avoid their use. It has also been proposed to use an optical sensor for the detection of the band end, but in practice it has been found that dust in the RSM results in inaccurate readings. However, the magnetic sensor has been found to provide good results at reasonable costs.

The magnetic feature on the band can be provided in a number of ways, but in this example a magnetic label is applied to the band. It is preferable that the label is made out of a flexible magnetic material, and suitable substances are available which typically contain cobalt as the magnetic element. It is preferred that the label is as thin as possible in order to avoid having a lump in the band which could damage the scraper. A particularly preferred label shape is shown in Figure 13I(iii) which depicts an "H" shaped label 1309a adhered to the band 1309. The scraper point touches the band along its centre line at which the magnetic label is narrowest. This results in lateral flexing of the band 1309 which prevents damage to the scraper. Other shapes such as chevron shaped labels have been proposed but it has been found that these tend to unstick themselves from the band 1309 at their point.

In a particularly preferred configuration, a single magnetic feature is provided on each of the two bands 109, a relatively short distance from one end of the band. On the first band, the magnetic feature is provided adjacent the note storage roller end of the band, whereas on the other band, the feature is provided near the band roller end. In this way, one of the magnetic sensors 1335 is dedicated to detecting the end of the band as the band is entirely wound onto the note storage roller 1320, and the other magnetic sensor 1335 is dedicated to detecting the end of the band as the tape returns to the band rollers 1310. Alternatively, a magnetic feature could be provided near to each end of one (or each) band. However, this has a disadvantage that it is necessary to provide some distinguishing feature in the magnetic label in order that the signal from the magnetic sensors can be interpreted so as to determine which of the band ends has been detected. This could be achieved, for example, by providing one end of the band with a single magnetic feature, and the other end of the band with two magnetic features. However, this would increase the expense and complexity of the arrangement.

13.3 Pivot Guide Assembly

Note transport within the RSM 1300 is achieved by the pivot guide assembly 1340. When a banknote is to be stored, the pivot guide assembly 1340 receives the
5 banknote from the diverter and guides it to the note storage roller 1320. When a note is to be dispensed, a scraper mounted in the pivot guide assembly assists in detaching the banknote from the storage roller 1320 and the banknote is then guided back to the diverter and away from the RSM 1300.

The mounting of the pivot guide assembly 1340 in the RSM is best viewed in
10 Figure 13C(i). The pivot guide assembly comprises a shovel shaped arm which extends from the note transport (at the top of the lower RSM) to the opposing side of the RSM, where it is arranged to clear the wall by a small distance. The pivot guide assembly is pivotably mounted to the RSM frame by shaft 1341 which supports side
15 arms 1343a and b of the pivot guide assembly. The pivot guide assembly 1340 is shown fully assembled in Figures 13J(i) and 13K(i) which show two perspective views. Figures 13J(ii) and (iii) show the pivot guide assembly in various stages of construction, in perspective view from the front. Figures 13J (iv), (v), (vi) and (vii) show the scraper
itself in more detail. Figures 13K(ii) and (iii) show the final stages of construction in perspective view from the rear.

20 Springs 1374 attached to hooks 1374a in the pivot guide assembly 1340 urge the assembly towards the storage roller 1320. The main body is shaped so as to form a gentle curve along which the notes are guided in use. At its end nearest the note transport, the guide assembly body is provided with guide fingers which assist in achieving smooth passage between the note transport components and the pivot guide
25 assembly.

Two apertures 1340a and 1340b are provided in the body of the pivot guide assembly 1340, their positions corresponding to those of the bands 1309. In the upper half of each aperture, a roller belt assembly comprising rollers 1349 and 1351 and transport belt 1350, is disposed, and a roller cog 1347 is provided at the base of the
30 belt 1350. As shown in Figure 13K(ii), four further rollers are arranged in each aperture so as to form a series of cooperating rollers as shown best in Figure 13K(i). Adjacent the roller cog 1347, a narrow drive transfer roller cog 1366 is disposed which meshes with the cog on roller cog 1347. Band rollers 1363 and 1365 are provided next in the series, around which the band 1309 passes in use. Finally, an idler roller 1361 is

disposed between the band roller 1365 and the body of the pivot guide assembly 1340 which rests on the storage roller 1320 when assembled.

In use, the bands 1309 transfer drive to the rollers 1365 and 1363 which in turn drive roller cogs 1366 and 1347 to turn the transport belt 1350. In this way, when notes are to be stored, and the band 1309 is driven toward the storage roller 1320, the rollers
5 are to be stored, and the band 1309 is driven toward the storage roller 1320, the rollers in the pivot guide assembly and the transfer belt 1350 are driven so as to transport notes along the guide assembly toward the note storage roller 1320. When a banknote is to be dispensed, the band is transferred in the opposite direction and the rollers and transport belt reverse their direction of motion such that the banknote is transported
10 away from the storage roller 1320.

As shown in Figure 13J(iii), at the top end of the guide assembly, the note path is defined between the main body of the guide assembly 1340 and a guide plate 1344 which attaches thereto via shaft 1345. At the top end of the guide 1344 are provided two rollers 1357a and 1357b which oppose the transport belts 1350a and b when
15 assembled. Springs 1371 urge the guide plate 1344 so as to ensure contact between the rollers 1357 and the transport belt 1350 and maintain a small gap between the guide fingers on the guide 1344 and those on the main body of the guide assembly 1340. The tension springs 1371 are mounted between hooks 1371a on the guide 1344 and shaft 1341 mounted in the RSM.

20 The guide 1344 also supports two roller brackets 1356a and b on which are mounted two rollers 1354 and 1355 which also oppose the transport belt 1350a. To maintain contact between the rollers and the belt, each roller bracket 1356 is biased by tension spring 1372 which is connected between hooks 1372a on each roller bracket 1356 and shaft 1341 within the RSM.

25 The guide 1344 also provides support for two scrapers 1352a and 1352b. Each scraper comprises a plastic moulding having a blade which contacts the surface of the storage roller 1320 in use. The scraper 1352 is arranged to contact the outermost winding of the band on the storage roller 1320 at an angle which is optimised to peel the approaching banknote off the underlying band. Depending on how many notes are
30 currently stored on the storage roller 1320, this angle varies between approximately 17° and 32°. The scraper 1352 is urged against the storage roller 1320 by tension spring 1370 which acts between hook 1370a on the scraper 1352 and shaft 1341 mounted between the side plates of the RSM.

Figures 13J(iv) and (v) show a scraper having a curved profile for contacting the
35 band. However, the present inventors have found the scraper to be more effective if a

flat profile is presented to the band. Such a scraper 1352' is shown in Figures 13J(vi) and (vii).

In the present example, the flat portion 1352'a is approximately half the width of the band and protrudes from the rest of the scraper body.

5 Finally, the guide 1344 supports in its centre a prism assembly 1353 which will be discussed with reference to the sensors in Section 13.5 below.

As will be appreciated from Figure 13C(i), the completed pivot guide assembly contacts the storage roll 1320 at two positions. Firstly, the edge of the scraper 1352 intersects the circumference of the storage roller 1320 at a predetermined angle.
10 Secondly, the lowermost roller 1361, mounted in the main body of the pivot guide assembly 1340 contacts the storage roller 1320 at a point distal from the pivot (shaft 1341) relative to the point of contact of the scraper with the storage roller 1320. Both the scraper 1352 and the main body of the pivot guide assembly 1340 are biased towards the storage roller 1320 by springs 1370 and 1374. In this way, constant
15 contact between the scraper and the storage roller is maintained. Moreover, as the diameter of the storage roll changes according to the number of notes thereupon, the angle between the scraper and the storage roll is adjusted to optimise the performance of the scraper. This concept is described in more detail in our British patent application number 0525870.2.

20 Thus the pivot guide assembly has a number of functions including note guidance into and out of the RSM and maintaining tension on the band 1309. However, its key function is to maintain the scraper in contact with the storage roller 1320 and at the optimum angle for scraping, which varies with the diameter of the storage roller.

25 **13.4 Note Transport**

Note transport between the RSM and the transport safe module 1200 is achieved by transport modules integrated into the base of the upper RSM 1300' and the top of the lower RSM 1300. Figure 13L(i) shows the upper RSM 1300' (upside down),
30 and Figure 13L(ii) shows an upper RSM 1300' adjacent to a lower RSM 1300. For clarity, the two RSMs are shown with a small gap between them. However, in practice, the upper RSM will sit on top of the lower RSM such that the two sets of transport components interact to define a transport path therebetween.

The transport path comprises four sets of opposing rollers shafts separated by
35 guide members which are ribbed so as to minimise the amount of contact between the

guide and the passing banknote. As best shown in Figure 3C(i), the lower RSM is provided (from front to back) with a first roller assembly 1375 having rollers which protrude through a first guide component 1376. A second drive roller assembly 1377 opposes a first set of guide rollers 1379 defining therebetween a nip which brings the
5 banknote into the pivot guide assembly 1340 when the diverter 1378 is open. If the diverter 1378 is closed, the banknotes pass over the top to a third set of drive rollers 1380 which interleave with a second guide component 1381. The fourth set of drive rollers 1382 draws the banknote over the third guide component 1383 from which it passes into the next RSM 1300. Opposing each set of drive rollers 1375, 1377, 1380
10 and 1382 are corresponding sets of rollers in the upper RSM 1300'.

The construction of each roller assembly is shown in Figure E(i) to (v). The first drive roller assembly 1375 is shown in Figure 13E(iii) and comprises a series of rubber rollers 1375a mounted on shaft 1375b. The shaft is supported between side plates 1301a and b of the RSM in bearings 1375c. Stacked cogs 1375d and 1375e are
15 provided on its right end.

The second drive roller assembly 1377 is shown in Figure 13E(iv). The assembly comprises large diameter rubber rollers 1377a mounted on shaft 1377b supported in bearings 1377c between the side plates of the RSM. At its right hand end, the shaft engages pulley wheel 1377d. Shaft 1379 does not form part of the note
20 transport across the top of the RSM, but rather is inset such that a note will only meet the roller assembly 1379 if it has been diverted into that RSM. The rollers 1379a oppose and form a nip with large diameter rollers 1377a on the second drive shaft 1377. The rollers 1379a are supported on shaft 1379b between bushings 1379c supported in the side plates 1301a and b of the RSM. The shaft 1379 is not driven but
25 the rollers 1379a idle against the second drive rollers 1377a. Torsion springs 1379d are provided to urge the idler rollers 1379a against the driven rollers 1377a.

The third roller assembly 1380 is shown in Figure 13E(v). The construction of the shaft assembly is identical to that of shaft 1379 in that the rollers are not driven. However, the rollers 1380a are urged against rollers 1379a by torsion springs 1380d.
30 As such, the rollers are caused to idle in the direction of transport across the top of the RSM 1300.

The fourth drive roller assembly 1382 is shown in Figure 13E(ii) and comprises rubber rollers 1382a mounted on shaft 1382b in bearings 1382c in the side plates of the RSM. At its right hand end, the shaft 1382b engages stacked cogs 1382d and 1382e.
35 As shown best in Figure 13B(i), a drive cog 1385 is mounted on a spigot on the external

surface of the right hand side plate 1301b. This drive cog 1385 meshes in use with cog 1375d on the neighbouring RSM. Thus drive is transferred from one RSM to the next in a "daisy chain" fashion.

5 The drive cog 1385 meshes with cog 1382d on drive shaft 1382. On the stacked cog 1382e, a timing belt 1390 is provided which transfers drive to the second drive shaft 1377 and the first drive shaft 1375. The timing belt 1390 also drives a stacked cog 1391 which is mounted on a spigot at the top of side plate 1301. In use, the stacked cog 1391 meshes with cog 1377' on the upper RSM 1300' (see Figure 13L(ii)), transferring drive to at least the pair of rollers defining the nip which draws
10 notes into the pivot guide assembly 1340 of the upper RSM. The remaining roller assemblies on the upper RSM 1300' are not driven and instead are arranged to idle against the driven roller assemblies on the lower RSM.

The timing belt 1390 is tensioned by rollers 1389 and 1388 mounted on brackets 1387 on the side plate 1301b.

15 The note guide components 1376, 1381 and 1383 are shown in Figures 13M, 13N and 13P. Each comprises a shaft mounting a set of guide ribs into position between the side plates 1301a and b. The first guide component 1376, shown in Figure 13M(i) and (ii), comprises a shaft 1376a and a set of guide ribs 1376b which are extended parallel to the direction of transport in order to accommodate rollers 1375s
20 therebetween.

The second guide assembly 1381 is shown in Figure 13N and comprises a shaft 1381a and guide rollers 1381b. The guide rollers 1381b are substantially symmetrical about the shaft so as to accommodate 1380a at the first side 1382a at the second side.

The third guide assembly 1383 is shown in Figure 13P and comprises a shaft
25 1383a and guide fingers 1383b. The guide fingers 1383b are extended in the direction of note transport in order to ensure there are no gaps between one RSM and the next. The guide component is provided with one half of a sensor assembly which detects passage of a banknote across the guide component. As such, the upper and lower guide assemblies 1383 and 1383' differ in minor details of their construction. The lower
30 guide component 1383, shown in Figure 13P, is provided with a prism 1383c and mounting plate 1383d which aligns with apertures 1383c in the guide rib plate 1383b. The upper guide component 1383' is shown in Figure 13Q and is provided with a optical emitter 1383c' and detector 1383d' arranged so as to transmit and receive light through apertures (not shown) in the rib plate component. In use, the optical components

1383c' and 1383d' align with the apertures 1383c in the lower guide plate to form a prism sensor.

The diverter 1378 is positioned adjacent the entrance to the pivot guide assembly 1340. The diverter comprises a set of guide fingers essentially similar to those of the guide assembly 1381, but in this case the ribs are pivotable between a first position (as shown in Figure 13C) in which the leading edge ribs are raised so as to direct an incoming banknote into the pivot guide assembly 1340, and a second position in which the ribs lie flush with the guide assemblies 1376 and 1381 such that incoming banknotes pass over the top of the diverter 1378 and onto the next RSM 1300.

The diverter is controlled by a rotary solenoid 1384 mounted on the outside of the left side plate 1301a as best shown in Figure 13B(ii). The rotary solenoid 1384 is shown in more detail in Figure 13R and it will be seen that it comprises a main body 1384 containing the electronic and magnetic components, and a connecting bracket 1384b which fixedly connects to a pin extending from the main body 1384 and to the end of the diverter shaft. Screws 1384c and 1384d ensure that there is no rotation of the diverter shaft relative to the solenoid pin. Cable 1384e provides power and control to the solenoid 1384. The solenoid 1384 is operated by RSM control circuit boards mounted in the safe chassis 1300.

In a preferred embodiment, the current to the solenoid is monitored in order to determine whether the diverter has been successfully moved from one position to the other. By monitoring the current, back EMF generated in the solenoid when movement of the diverter takes place can be detected thus confirming successful movement between the open and closed positions. This does away with the need for any additional sensors for confirming that movement of the diverter has successfully taken place. This concept is discussed in more detail in our British patent application number 0525678.9.

The forwardmost RSM 1300 receives drive from the safe transport motor 1299 which is housed in the transport safe module 1200. Drive is transferred to the RSM by cog 1295 at the base of the transport safe module 1200.

30

13.5 Sensors

Each RSM 1300 includes a number of sensors for tracking the passage of a note into and out of the RSM. A first sensor is required to detect the passage of the note in the note transport between the upper and lower RSM 1300 and 1300'. To this

35

end, a prism sensor is provided in guide plate 1383. As described with reference to Figures 13P and 13Q, the lower guide member 1383 is provided with a prism 1386c, whereas the upper guide member 1383' is provided with optical emitter and receiver elements 1383c' and 1383d'. The optical path from the emitter crosses the banknote path P and is guided by the prism 1383d laterally across the note guide where it re-crosses the note path at a point aligned with the detector element 1383d'. The use of a prism sensor as opposed to a conventional transmissive sensor is preferred since all of the electrical components are constrained to a single side of the note path thus simplifying the wiring. Further, the signal to noise ratio is improved since the light path crosses the banknote twice.

The prism sensor in guide plate 1383 is used to sense the passage of a note from one RSM to the next. In the case of the forwardmost RSM, the function of the sensor is performed by prism sensor 1281 at the exit from the transport safe module 1200.

Two further prisms sensors are disposed in the pivot guide assembly 1340. As shown in Figure 13J(ii), the main body of the pivot guide assembly 1340 is provided with four apertures 1340c behind which the optical components are mounted. As shown in Figure 13K(i), two optical pairs are mounted. The first, comprising emitter 1368a and receiver 1368b is mounted toward the scrapers 1352a and b. The second, comprising emitter 1369a and receiver 1369b is mounted closer to the guide ribs forming the top of the pivot guide assembly.

The sensor assemblies are completed by the provision of prism component 1353, mounted on guide 1344 (see Figure 13J(iii)). The prism component 1353 consists of a transparent plastic moulding incorporating two sets of angled walls, the first aligning with sensor elements 1368, and the second with sensor elements 1369. Thus the prism component 1353 completes two separate light paths within the single component.

The resulting optical sensors 1368 and 1369 are longitudinally displaced in the direction of note transport along the pivot guide assembly 1340. The use of two sensors displaced in this manner makes it possible to improve the accuracy of the sensed information and ultimately reduce counting errors.

Signals from the two sensors are used to identify the times at which the leading and trailing edges of the note pass the sensors. In conjunction with the known speed of the bands, calculated using a timing wheel or based on the roll diameter (see Section 13.2 above), it is possible to calculate the perceived length of each note. As well as

using this for counting notes into and out of the RSM, potential jams can be identified if the perceived length of the note is unduly long. Importantly, the two sensors also make it possible to detect the direction of transport of the passing banknote, as well as its length. This helps to reduce counting errors, especially in jam scenarios where notes
5 may have to be reversed in and out of the RSM a number of times in order to clear the jam. A single sensor would not be able to identify the direction of motion of each note and errors in counting how many notes remain on the storage roller are likely. By being able to detect the direction of motion, it is possible to keep an accurate record of which notes are on the roller and which ones have been dispensed.

10 As notes are stored onto the roller, the sensors are used to keep a log of each note's position on the roll and, optionally, its length. As notes are dispensed, the sensors are used to measure the length of each note and this can be compared with the logged length for that particular note. If there is any discrepancy between the lengths, and in particular if the detected length appears greater than that expected, the
15 RSM can be automatically stopped to prevent damage caused by a note jam. Further, if no note is detected by the sensors, it may be that the note to be dispensed has passed the wrong side of the scraper 1352. In this case, if the RSM were to continue dispensing, the missed note would likely be dropped into the base of the RSM. However, by using the sensors to monitor the notes as they are dispensed, this can be
20 avoided.

It is further preferred that the RSM is provided with a non-volatile random access memory (RAM) in which the log of notes is stored. Thus, the information pertaining to the notes on the roller is maintained when the apparatus is switched off, which makes it possible to monitor the notes as they are dispensed even if the machine
25 has been powered down since the notes were originally stored.

The use of prism sensors is preferred since the wiring is simplified compared to a conventional transmissive sensor. However, the same operations could be carried out using conventional transmissive sensor, a reflective sensor or any other type of sensor which can monitor the progress of a note past a particular point. In the case of
30 optical sensors, it is preferred that an optical emitter is provided with a lens to focus the light beam onto the prism.

In a particularly preferred embodiment, the signal processing uses a "debounce" program at software level in which false signals are avoided by resampling a signal once a change in the signal is observed. In effect, the signal profile from the sensor is
35 monitored, and a change in status from "covered" (by a banknote) to "uncovered" is

only recorded when the signal has settled such that transient spikes can be eliminated. However, in alternate embodiments, a digital sensor detecting just "high" or "low" signals may be sufficient.

In the case of prism sensors, it is preferred that the lateral spacing of the optical components is kept to a minimum. In the present example, the separation between the emitter and receiver in each optical pair is of the order of 8mm. This should be contrasted with the prism sensors in the transport safe module 1200 and in the guide assembly of the RSMs, in which the spacing is of the order of 60mm. By selecting a smaller prism, any skew experienced by the note does not significantly slow the response of the sensor. The wider the optical components are apart, the longer it will take to receive a signal from the sensor if the note has even a small degree of skew. Where the prism is small, the skewed note crosses the prism arrangement faster and it is therefore possible to obtain results more quickly.

14. Control Systems

14.1 System Organisation

Figures 14A and 14F illustrate the organisation of the control systems within the handling device. Reference is also made to Figures 14D and 14E which show the elements that are controlled by these control systems.

The control of the note handling device is overseen by the Main Control Unit (MCU) 1435. This is connected via a Controller Area Network (CAN) 1482 to four sets of differentiated sub-controllers: Note Controller (NC) 1420 which oversees the NHM systems; SDA Controller 1441 which oversees the operation of the sensor systems within the SDA 1451; Transport Controller (TC) 1440 which controls the Transport Safe 1200 systems; and one or more Roll-Storage Controllers (RC) 1427 which control the operation of the RSMs. The MCU 1435 has a variety of interfaces 1432 that allow it to be connected to external hardware 1433. A software application 1434 loaded upon the external hardware 1433 can then send commands to the MCU 1435 to activate a deposit, dispense or through-verify operation, and, in turn, receive data from the sub-controllers via the MCU 1435. concerning these operations

The sensor, motor, and solenoid systems of the NHM are all controlled by the Note Controller (NC) 1420. The circuitry that makes up the NC 1420 is typically located amongst control circuitry mounted to the side of the movable carriage 350, although it

can also be accommodated within the detector circuitry housing 616 on top of the SDA assembly, and is powered by the power supply unit mounted within the storage assembly 1000. The NC 1420 receives a variety signals from sensor systems installed within the NHM 400 including digital optical sensors located in the feed hopper 1422
5 and the stacker area 1421 and a variety of note monitoring sensors positioned along the note transport path. The note monitoring sensors include track sensors 1424 which detect the arrival and exit of a note at a certain position along the note transport path, and skew sensors 1423 which, as well as detecting the arrival and exit of a note as for standard track sensors, also detect the angle of skew of a passing banknote.

10 The NC 1420 is also responsible for the control of the NHM note transport systems, through control of the main NHM transport motor 356 and the output transport motor 363. The control circuitry for the control of the NHM note transport system is typically mounted on the left hand side of the movable carriage 350. For basic embodiments such as that shown in Figures 6A to 6F, one motor 356 is used to drive
15 the NHM transport and another motor 363 is used to drive the stacker and related output systems. A set of three feeder motors 1439 for use in the feeder module feed systems are also controlled by the NC 1420. Typically all motors are pulse-width-modulated, stepper motors. An element of feedback control from the motors is provided by measuring the back electromagnetic force (EMF) produced by each motor.

20 The solenoid 694 which activates the diverter assembly 800 is controlled in a similar manner to the transport motors. It is activated by supplying a current from the NC 1420 and information about the state of the solenoid is obtained by measuring the back EMF across the solenoid and passing this information back to the NC 1420. A similar method of feedback control is described in GB Patent Application No. 525678.9.

25 Sensor modules 700 within the SDA assembly are provided with their own preliminary control circuitry 712 (see Figures 7A to 7F) to perform initial processing and digitization of sensor signals. This preliminary control circuitry is then connected to more advanced control circuitry 1425 mounted within the detector circuitry housing 616 on top of the SDA assembly. Within this advanced processing circuitry 1425 digitized
30 signals from the sensors are processed to generate high level information about a passing banknote. The SDA Controller 1441 oversees communication between these two areas as well as receiving commands from, and sending processed data to, the MCU 1435. The processing operations performed by the SDA advanced processing circuitry 1425 include generating identification and/or denomination information from the
35 digitalised data and providing a high level measure of fitness or authentication. For

example, the information from a reflective CIS sensor will be used to generate a note image. This note image can then be enhanced using well known image processing algorithms to provide an enhanced note image for input into pattern classification and recognition algorithms. These algorithms will then compare the enhanced note image with reference images of known notes that are held in memory within the advanced processing circuitry 1425. If a match is found a note type identifier will be generated, if no match is found an exception or "no match" identifier will be generated. Likewise, a signal from the UVPPD sensor can be processed to generate a UV "image" of the note. This can then be checked against a general reference image pattern stored in memory and representative of validity, or alternatively can be checked against a particular UV reference "image" pattern linked to the note identified using the CIS sensor image. The output of the SDA advanced processing circuitry 1425 will be a note property message consisting of a number of data fields, which is then forwarded to the SDA Controller 1441 and in turn the MCU 1435. The messages and communications that can pass from the MCU 1435 to the SDA Controller 1441 includes control information used to configure or disable the senses within the SDA assembly. In certain embodiments the functions performed by the SDA advanced processing circuitry 1425 can also be performed by the SDA controller 1441, depending on a variety of factors including the number and type of sensor systems involved and the available processing hardware.

The Transport Controller (TC) 1440 receives commands from the MCU 1435 and controls the Transport Safe 1200 systems including safe transport motor 1299, and the safe transport skew 1439 and track 1438 sensors. It is thus responsible for controlling the transport of a note until the note roll systems within each RSM. The circuitry comprising the TC is typically mounted to the inside of the safe cabinet.

Each RSM mounted within the storage assembly is controlled by a Roll-Storage Controller (RC) 1427. The circuitry that comprises the set of RCs is split between the series of roll storage controller PCBs supported in mountings 330 on the underside of the safe chassis 300. As each roll storage controller PCB can accommodate up to two roll storage towers, each roll storage controller PCB can hold the circuitry required for four RSMs.

Within each RSM the RC 1427 controls the RSM roll tape motors 1428, the RSM diverter solenoids 1429 and the RSM sensor systems 1431. Within each RSM there are two roll tape motors 1428; one controlling the speed of rotation of the roll on which banknotes are stored, and a second motor controlling the speed of rotation of the two rolls of Mylar tape. The speed of rotation of these motors can be monitored either

by using a slotted optosensor and a timing wheel or by again measuring the back EMF generated by the motor. If a slotted optosensor and timing wheel are used, the slotted optosensor will be added to the list of RSM sensor systems 1431 that provide signals to the safe controller 1427. These signals will be relayed to the RST control boards which
5 are mounted underneath their respective RST stack. The RC 1427 also controls the two RSM diverter solenoids 1429 which are used to divert banknotes into the upper or lower roll storage module (RSM) in a RSM stack. The position of these solenoids is measured using the back EMF as described above.

The RSM sensor systems 1431 comprise a magnetic detector 1469 for
10 detecting a magnetic element located at the start of one of the rolls of Mylar tape and the end of the other roll of Mylar tape. They also comprise two track sensors 1457, 1458, mounted on the articulated scraper that makes contact with the note roll, and a track sensor mounted at the rear exit pathway of each RST. As with the signals from the slotted optosensor, the signals from all the RSM sensor systems will be routed to
15 the RC circuitry resident on the RST control boards below each RST stack. Signals from each RC 1427 can then be sent to the MCU 1435. The RCs 1427 also receive control commands from the MCU 1435.

Referring to Figure 14F, in normal use the MCU 1435 will be connected to external hardware 1433 via external control interfaces 1432. The external control
20 interfaces 1432 comprise interface control circuitry and appropriate hardware interfaces for connecting the MCU 1435 to external systems. Typically these include USB 1432 - c, -f , Ethernet 1432b, parallel 1432h and/or RS232 1432 -d, -e, -f, -i, connections located on the rear of the safe. These interfaces are then used for networking the note handling device when located in an office environment. In these situations the MCU
25 1435 will receive instructions from a software application 1434 running on the external hardware 1433 and also send back data on the operation of the device.

The SDA Controller 1441 is also provided with an internal USB 1432j and/or Ethernet link. This allows direct connectivity to the SDA controller 1441. A service engineer can use these interfaces to connect a laptop 1472 or other appropriate device
30 to the SDA controller 1441. The engineer can then initiate a number of servicing or update operations including but not limited to: SDA sensor testing and configuration, the download of note processing data during device testing, updating currency tables and processing algorithms, and note transport diagnostics.

In typical operation the control of the complete note handling apparatus 100
35 would be overseen by software application 1434. This application is typically a cash

handling system that is designed for use by a cashier in charge of the operation of the note handling device. For example a user interface provided by the software application 1434 may feature icons for verification and denomination, deposit, or dispensing of banknotes. By selecting one of these icons the appropriate mode of operation will be initiated in the node handling device. Details of the contents of the RSMs and a history of note processing errors can also be fed back from the controllers of the note handling device and displayed on screen.

Figure 14F illustrates some of the possible internal and external interfaces of the note handling device. As described previously the MCU 1435 connects directly to a number of external systems 1433 through a variety of external interfaces 1432. These include a PC terminal 1433b and/or a safe master server 1433d connected via a standard RS-232 interface 1432f, 1432i. It is also possible to use a RS-232 to USB converter to allow connectivity to modern terminal systems. The software application 1434 used to control the note handling device is then installed upon the terminal 1433b or server 1433d. The MCU 1435 can also be connected to an external printer 1433c via a parallel interface 1432h. This then allows operation logs and diagnostic information to be supplied to the printer 1433c from the MCU 1435.

The MCU 1435 also supervises the alarm and lock systems installed within the note handling device. These systems may be proprietary or integrated within the design of the safe and NHM. In any case the MCU will send and receive signals over standard input/output (I/O) lines 1483 to operate control of the safe door lock 1478 and monitor the integrity of the safe cabinet. The MCU also communicates with the power supply systems 1478 over the same channels 1483. The MCU 1435 then relays the state of the alarm system to outside monitoring systems 1474 via external interface 1432g. These monitoring systems can also involve the external control of the safe locking systems. Finally, a PC-card 1477 is also connected to the MCU 1435 for extra communicative functionality.

As well as control from external hardware systems, some embodiments of the note handling device include an internal embedded personal computing (EPC) system 1481. This can either be mounted within the safe cabinet or integrated with the NHM electronics, depending on the characteristics of the hardware required. The EPC 1481 is directly connected to the MCU 1435 via one or more RS 232 connections 1480 or other more complex communication buses. These connections or buses also include an interface for the connection of a service laptop 1472. Terminal Services 1479 software or other equivalents are then installed on the EPC 1481 to allow it to be

controlled via remote systems. These remote systems can be located anywhere upon the Internet or an Intranet network. Typically the EPC 1481 is networked using an Ethernet connection 1432b, although this can also be achieved using a wireless communications system.

5 The EPC 1481 can also be connected to external I/O devices via a variety of common interfaces. These include a monitor, keyboard, mouse, printer or speaker system, connected through interfaces such as USB, RS 232, or parallel connections 1432a. In a similar manner USB 1432c or RS 232 1432d interfaces can be provided to connect a range of external memory devices 1471, such as card readers, coin handlers
10 or memory sticks, that can be used to update, backup, or record server systems operating on the EPC 1481.

14.2 Banknote Transport Control

15 The tracking and control of a banknote as it moves within the note handling device is provided by a number of sensor components which are controlled by the aforementioned Note Controller (NC) 1420. SDA controller 1441, Transport Controller (TC) 1440 and Roll-Storage Controllers (RCs) 1427. Two main sensor systems are used to monitor note tracking and note presentation along all sections of the note
20 transport path throughout the device. These two sensor systems are illustrated in more detail in Figures 14B and 14C.

14.2.1 Track Sensor 1400

25 The arrival of the leading edge of a banknote along the note transport path is detected using a track sensor 1400. This is illustrated in Figure 14B. The track sensor comprises optical transmitter 1401, reflecting prism 1403 and optical receiver 1402. Typically the optical transmitter 1401 is provided by an LED that emits light in either the infrared or visible spectrums. The optical transmitter 1401 is located on one side of the
30 transport path, in the illustrated example in an upper surface 1416 of the transport path. The reflecting prism 1403 is mounted in the opposite surface 1417, in this example below the optical transmitter 1401 and receiver 1402. Light transmitted from the optical transmitter 1401 thus crosses the note transport path 1404 and enters reflecting prism 1403. Light is then reflected through the prism 1405 before being reflected back across

the note transport path 1406 toward the optical receiver 1402. Typically the optical receiver 1402 comprises a photodiode.

As a note 1407 is travelling along the note transport path (into the paper in this example) it will pass through transmitted 1404 and reflected 1406 light beams. This will then prevent a light signal from reaching optical receiver 1402. This then generates a signal at the optical receiver 1402, which is relayed to the NHM controller. A reflecting prism 1403 is used as it effectively provides two points of note detection whilst only using a single transmitter 1401 and receiver 1402. This is because the note 1407 can block either transmitted light beam 1404 or reflected light beam 1406 and still register a note arrival signal.

After the trailing edge of a note passes by the sensor system the optical circuit consisting of paths 1404, 1405 and 1406 is again completed and the exit of the note from the sensors area is signalled. By measuring the time between the breaking and reforming of the optical circuit, the time it takes for a note to pass the sensor apparatus can be measured. If the speed of the note transport system is also known then a value for the width of a note can be calculated, presuming a note is fed into the note transport paths with its long-edge perpendicular to the direction of travel.. However, this system does not allow for any calculation of the skew of the note. Thus an angled note travelling along the note transport may take longer to pass by the track sensor 1400 and generate an erroneous note length value.

14.2.2 Skew Sensor 1410

A sensor system that can measure the skew of a passing note is illustrated in Figure 14C. The skew of a note is defined as the angle the leading edge of a note makes with the perpendicular to the direction of note transport. Skew sensor 1410 comprises two sets of transmissive optosensors 1411 and 1413 and two sets of receptive optosensors 1412 and 1414. The transmissive optosensor in each pair will transmit a single beam of light 1418, 1415 across the note transport path to the optoreceptor on the opposite side of the note transport path. Optical receivers 1412 and 1414 can each generate a signal to signify that it no longer receives a transmitted light beam 1418 and 1415.

The two sets of optosensor pairs can then detect when each side of the leading edge of a note passes therebetween. If the leading edge of a note is perpendicular to the note transport path then beams 1418 and 1415 will be cut at the same time and

produce concurrent signals in optical receivers 1412 and 1414. However, if the note is skewed then one of the optical receivers sets will detect the note's arrival before the other. For example, if a note 1407 is travelling into the paper and has become skewed so that the leading edge of a note 1407 makes a positive angle with the perpendicular to the note transport path in the plane of note transport then optical receiver 1412 will detect the lack of a light signal 1418 at a time t_1 . As the note travels along the transport path optical receiver 1414 will then detect the absence of a light signal 1415 at a different time t_2 . The difference between these two times, $t_2 - t_1$, can then be used together with the note transport speed obtained through the monitoring note transport motor 356 and the horizontal spacing between the two optical receivers 1412, 1414, to calculate the angle of skew of the passing banknote. If the leading edge of the banknote has a negative angle of skew with respect to the perpendicular of the note transport path then this sequence of detection will be reversed with optical receiver 1414 detecting a lack of light signal 1415 before optical receiver 1412 detects a lack of light signal 1418.

It should also be noted that each skew sensor also performs as a track sensor, sensing the arrival and departure of each note along the transport path. In this manner, when one or both light beams 1418 and 1415 are broken by a passing note, a signal is sent signifying the arrival of a note at the sensor. Similarly, when either or both optical detectors 1412 and 1414 detect light beams 1418 and 1415 respectively, a signal is sent signifying that a note has left the sensor area.

14.3 Note-Monitoring Sensor Arrangement and Control

The operation of a note deposit routine will now be described with reference to the systems of Figure 14A. The deposit routine begins when the MCU 1435 receives a "deposit" command from the software application 1434 via the external interfaces 1432 (or from the EPC 1481). The MCU 1435 then informs the RCs 1427, TC 1440 and SDA Controller 1441 that a deposit command has been received to allow these sub-controllers to prepare their systems and change their state if required. The MCU 1435 then informs the NC 1420 that a deposit operation is required. The NC 1420 then has control of the NHM and activates a deposit sequence stored in memory, which will feed the note into the NHM. The MCU 1435 then waits until the NC 1420 communicates an "idle" signal, signifying that the notes have passed through the NHM. After it has received the NC signal, the MCU 1435 then waits for a predetermined period of time,

typically a few seconds, before setting the RCs 1427, TC 1440 and SDA Controller 1441 to "idle" and informing the software application 1434 that the operation is complete.

5 A similar sequence of events also occurs for a dispense operation. This begins when the software application 1434 transmits a "dispense" command to the MCU 1435. The MCU 1435 then prepares the sub-controllers by setting them to "dispense" mode; this involves first setting the NC 1420, then the TC 1440 to prepare them to receive a note from a RSM. The MCU 1435 then activates the desired RC 1427, which will vary according to the command received from the software application 1434, and the
10 selected RSM 1465 dispenses the required note which proceeds to pass through the Transport Safe 1200 to the stacker 900 via the NHM. After activating the required RC 1427, the MCU 1435 waits for the RC 1427 to transmit an "idle" signal signifying the note has passed out of its control. The MCU 1435 then sets the TC 1440 and NC 1420 to idle and informs the software application 1434 that the dispense operation is
15 complete.

The electronic devices controlled during the operations above are illustrated in Figures 14D and 14E. These Figures respectively show the location of the track and skew sensors and internal electrical systems along the complete note transport path of the NHM and safe.

20 The first set of sensors 1450 are located in the feed hopper of the note handling device. These sensors comprise an optical transmitter mounted in the top of the hopper and an optical receiver mounted in the bottom of the hopper. This sensor 1450 then detects the presence of notes within the feed hopper. When a deposit or through-verify command is received from the software application 1434 via the MCU 1435 and
25 NC 1420 then note feed will not commence until sensor 1450 detects the presence of notes within the feed hopper. After this signal has been received then the feed of notes will begin after a set time delay. The feed procedure utilizes one motor 522 from feed motor set 1450 to compact the notes within the feed hopper, and the remaining motors to operate the feed roller systems. The feed motor set 1439 is controlled by the NC
30 1420. The note will then proceed through the feedhopper assembly. At the exit to the feed hopper assembly is a set of skew sensors 1453. These sensors record the skew of a note as it enters the main note transport path, as occasionally a note may become skewed by the feed hopper mechanisms. Typically no immediate action is taken using the data from skew sensor 1453. However data is recorded which can be used as a

reference for further measurements made within the SDA assembly. Alternatively, the control system can also be designed to stop the note transport if the skew is too great.

The feeding and first detection of a note will generate a NC note software object which will comprise an 8 byte message with a newly generated note ID and a
5 timestamp recording the time of entrance. This NC note object is then sent to the SDA controller 1441, where additional note properties detected by the SDA sensors are added to the note object.

During or before the feeding process the NC 1420 will initiate the rotation of main drive motor 356 which will provide power to various drive mechanisms that form
10 the upper note transport path within the SDA assembly 601,601X. The note will thus then travel through the SDA assembly wherein one or more note properties will be detected by SDA sensor systems 1451. Lower level data from the SDA systems 1451 is also used to derive information about note tracking and note presentation; problems that can be detected by SDA sensor systems 1451 include double or overlapping notes,
15 miscentered notes, skewed notes, a lack of a gap between neighbouring notes, irregular gaps between neighbouring notes, irregular speed and note passage or unexpected detected notes. These tracking and presentation problems will be recorded by setting the second byte of the note object received from the NC 1420. The note object unique ID is used to reference the note whose note characteristic data are
20 created within the SDA Controller 1441.

If the width of a note is too wide or a note is moving too slowly then the note transport path is stopped and a message is relayed to the SDA Controller 1441. The SDA Controller 1441 can then relay an error message to the MCU 1435, which in turn can communicate with the software application 1434 which can inform the user. The
25 user can then choose to initiate a note purging operation or manually access the note path to check for any errors and clear any jams. For any other detected tracking and/or presentation problems a message is sent to the NC 1420 to forward the note directly to the output stacker 900. The NC 1420 then ensures that diverter solenoid 694 is off, rendering the diverted guide fingers 811 substantially horizontal, and in turn allowing a
30 note to proceed towards the stacker 900. If an ultrasound detector module is added to the note handling device then the sensor systems 1452 from this module will interface with the SDA advance processing circuitry 1425 and SDA Controller 1441. Information from the ultrasound sensor systems 1452 can then be added to the information used to make decisions about note tracking and note presentation.

The information from the SDA sensor systems is also used to generate information about the fitness of a note. This fitness information typically conforms to the specifications suggested by the European Central Bank. Through image processing on the variety of note "images" produced by the sensor systems the following note features

5 can be detected: soil or dirt upon the note, "dog ears" or corner folds, missing corners, open tears, holes, mutilations, composed notes consisting of two or more parts of different notes, localised concentrations of soil or stains, graffiti upon the note, crumples, washed notes, inner folds or missing parts. Washed notes can also be detected by monitoring the UV properties of a note. A note can have a fitness level

10 depending on the severity of these features. Typically, four levels are used: automated teller machine (ATM) fit, fit for circulation, fit for storage and unfit for storage. The decision making criteria for these or additional user-defined levels, for example threshold calculations, may be modified by the operator or administrator. The fitness levels are calculated by the SDA Controller 1441 from the sensor data and are added to

15 a note property message or record reference with a notes unique ID. This information is then used to determine the note's destination.

After the note has exited the SDA assembly and the optional ultrasound assembly it is rotated through 180° by the U-turn assembly and continues the lower transport path 411. Within the lower transport path 411 a set of skew sensors 653

20 detect the skew of a note for a second time to allow for any increase or decrease in skew due to the transport components of the upper transport path 410. If the skew detector 653 detects that the skew of the note is greater than a given threshold or that the length of the note is too small then the NC 1420 is informed and the note is forwarded to the output stacker module as for rejection within the SDA. Additionally if

25 the gap between a first note and a second note recorded by the skew sensor 653 is too small then both notes will be directed to the stacker output. Track sensor 652 is also used to calculate the gap between a note arriving at this sensor and a note arriving at previous skew sensors 653. Typically, a safe gap range is 60-80mm between consecutive notes. If the gap is outside this range the error will be generated. If an

30 unexpected note is detected by track sensor 652 then this note is directed to the output stacker.

The NC 1420, under control of the MCU 1435, oversees the activation of the diverter 800 based on the current operation mode of the note handling device 100. For a deposit operation, solenoid 694 will be actuated by the NC 1420 to direct a note into

35 the safe. The destination of a note within the safe is determined by a note assignment

table. The note assignment table resides persistently in the memory within the MCU 1435. The MCU 1435 transfers this note assignment table to the volatile note assignment table of the NC 1420. The note assignment table is used by the NC 1420 for one or more destination mapping calculations which take as their input a note property message from the SDA Controller 1441. The note property message will contain details of the note presentation, note denomination or identification and fitness or authentication and will be referenced by a unique note ID for each note. These message fields are used as basis for note sorting depending upon the chosen sub-mode message of operation. Notes can possibly be sorted depending on currency, denomination, facing or orientation of the note, fitness of the note, value of the note or user specified sensor signals as described previously. The fitness of the note is typically classified according to a given combination of SDA sensor signals. The currency, denomination, or value of a note is typically obtained by the aforementioned pattern recognition based on a note image. Authentication can be based on the IR, UV or magnetic properties of a note and, depending on the stringency of user defined standards one, two or all of these properties can be used to determine whether a note is authentic and hence decide the destination of a note.

In a standard note handling device there are seven possible destinations for a note, the stacker 900, or one of six roll storage modules 1300 within the safe 1000. Typically, there is a many-to-one mapping between recorded note properties contained in the note property message and the appropriate destination. The many-to-one mapping is defined in the note assignment table. The NC 1420 typically performs the mapping operation and outputs control signals to separate destinations accordingly. If the note is destined for the stacker hopper then the NC 1420 de-activates the diverter solenoid (as for rejected notes) Thereby the output transport motor 363 is continuously running. The note will then pass to the stacker 900 over the diverter 800 via exit track sensor 1462. The exit track sensor 1462 provides a signal to the NC 1420 which allows it to stop the note transport if a note is detected to be too wide or travelling too slowly. This then prevents any problems that may occur if an irregular note is stacked. Within the stacker module is a digital sensor of similar form to sensor 1450 in which an extended track sensor measures the presence of a note within the stacker hopper.

If the note has valid fitness and/or authentication properties and has been allotted an RSM for storage through the mapping operation then the NC 1420 will activate diverter solenoid 694 in order to activate the diverter 800. This is achieved when the note's leading edge is detected at track sensor 652. After the note has been

diverted towards the safe by the diverter mechanism as described in section 8, it is again checked for skew by skew sensor 678. This then allows a measure of note tracking and note presentation properties before the note enters the through safe transport 1100 and the transport safe module 1200. If adverse note presentation or tracking properties are detected by skew sensors 678 then the system can be configured to operate a "purge" mechanism which will rapidly reverse the direction of the transport safe system 1200 and reverse the path of the irregular note towards the stacker 900. The measurement from the skew sensor 678 can also be used to adjust the speed of the safe transport system in certain embodiments in order to reduce the effect of skewed notes.

After the note has passed through the through safe transport 1100 it passes another set of skew sensors 1439 at the entrance to the transport safe module 1200. Skew sensors 1439 communicate with TC 1440. Information from the NC 1420 concerning the skew measurements from the skew sensor 678 can be communicated to the MCU 1435 and compared the TC's measurement of skew sensors 1439 to check for any change in skew during the note's passage through the through safe transport 1100. Skew sensor 1439 also provides the only indication of skew before the note is stored in a roll storage module 1300.

The arrival of a note at the roll storage modules 1300 is detected by track sensors 1438 at the exit of the transport safe system 1200. Diverter solenoid 1456 determines whether a note passes to a lower roll storage module and diverter solenoid 1460 determines whether a note passes to an upper roll storage module. Diverter solenoid 1456 takes precedence over diverter solenoid 1460 and, to allow a note to reach roll storage towers B or C, the diverter solenoids in each preceding roll storage tower must be deactivated. The exit of a note from each roll storage module stack is determined by track sensor 1459.

For example, if a note has been identified as a particular denomination which needs to be stored in the upper roll storage module of roll storage tower C, then this destination will be decided by NC 1420 and the relevant information passed to the RCs 1427. The RCs 1427 will then deactivate the diverter solenoids in roll storage towers A and B and also deactivate diverter solenoid 1456 in roll storage tower C. The note will then proceed through roll storage towers A and B and be detected at track sensors 1459a and 1459b. Track sensor 1459b sets a deadline by which RSM roll tape motors 1461 must be activated in the upper RSM in roll storage tower C in order to transport the note from the horizontal RSM transport path into the note bundle of the chosen

RSM. The RCs 1427 will activate diverter solenoid 1460 which will cause the note to move upwards along RSM path 1464 to the roll storage note bundle or roll 1465. While moving towards the note bundle, the note will be detected by two closely mounted track sensors 1458 and 1457 which detect the presence of a note before it is wrapped
5 around the note bundle or roll 1465. The use of two sensor allows both the speed and direction of the note to be calculated. These variables can then be used by safe controller 1427 to adjust the speed of RSM roll tape motors 1461 to compensate for any undesirable characteristics.

A similar procedure is undertaken for a dispense operation. A dispense
10 operation will typically be activated via the software application 1434, as described above. The software application 1434 can either provide a value of note that needs to be dispensed or quantity values for a particular denomination of note. These are received by the MCU 1435 and converted into a sequence of separate dispense operations that will provide the required total or quantity of notes. This list will identify
15 the number of notes which are required from each RSM. Operation will then proceed through the list, dispensing notes from one RSM at a time until the appropriate number of notes have been outputted to the stacker hopper.

Beginning with the first set of notes to dispense, the RSM in which the notes are stored is identified from the aforementioned list, together with the number of notes
20 needed to be dispensed. This information is passed to RC 1427. For example, ten notes may be required from the lower RSM of roll storage tower B. The RCs 1427 will then configure the RSM diverter solenoids 1429 so that a note can pass from the note bundle or roll 1465 in the lower tower of roll storage stack B to transport safe 1200 and eventually the stacker 900. The RCs 1427 will then initiate the rotation of RSM roll tape
25 motors 1428 in a dispense direction which will cause a note to unroll from the note bundle 1465 and begin to travel down RSM transport path 1464. The note will then be first detected by track sensor 1457 and then by track sensor 1458. Using the data from these sensors, the RCs 1427 can check that the note is moving in the right direction and that a single note has been dispensed from the roll. The note will then pass along
30 the horizontal RSM transport path past track sensor 1459a. The data from sensors 1457 to 1459 can be used to measure the gap between notes and to signal errors to the RCs 1427 if they occur. As each note is detected leaving the note roll 1465 it is subtracted from the stated number of notes required from the particular roll storage module. The RCs also monitor the signals from magnetic tape end detectors 1469.

The first dispensed note will then continue moving through the safe transport past skew sensors 1439. The sensors then provide the first indication of skew after a note has left the roll storage module. Further clarification is provided by diverter skew sensors 678. The information from skew sensors 1439 and 678 is announced but there
5 is no reaction on it, because skewed notes are transported to the stacker 900 anyway as a matter of course. A note will then pass through the diverter 800 and out towards the stacker 900 module as described previously. Data from all track and skew sensors can be used to count the number of notes dispensed. The RSM roll tape motors 1428 are typically deactivated when the last note is detected at track sensors 1438 or 1459,
10 depending on the roll storage tower being dispensed from. This then confirms that the last note has left the roll storage module transport path 1464 and thus the rotation of roll storage module roll tape motors 1428 is no longer needed to carry it along the transport path.

After the last note has then left the storage assembly 1000 and diverter 800
15 sections and has been detected at track sensor 1462, then the transport safe systems 1200 can be deactivated by the TC 1440.

Typically, each track and skew sensor is used individually but this information can be combined in either the MCU 1435 or a software application 1434. Conflicts between various sets of information can then be monitored and errors relied to the user
20 if they are found.

CLAIMS

1. A method of providing a support in a sheet material, the method comprising:
forming a first slot through the sheet material, the first slot having first and
5 second opposing slot faces;
deforming a region of the sheet material adjacent to the first or second slot face
such that the first or second slot face is displaced out of the plane of the sheet material,
the first or second slot face providing a support surface for locating an object placed
thereon relative to the sheet material.
10
2. A method according to claim 1 wherein at least a portion of the first slot is
substantially rectilinear such that the first and second slot faces have a planar portion
on which an object can be slidably supported.
- 15 3. A method according to claim 1 or claim 2 wherein the first slot has curved or
angled portions at each extremity such that an object placed on the first or second slot
face is retained between the slot extremities.
4. A method according to any of the preceding claims wherein the first slot is U-
20 shaped.
5. A method according to any of the preceding claims wherein at least a portion of
the first slot is arcuate.
- 25 6. A method according to any of the preceding claims further comprising forming a
second slot through the sheet material, the second slot having third and fourth opposing
slot faces.
7. A method according to claim 6 wherein the deformed region of the sheet
30 material is defined between the first and second slots, and is preferably substantially U-
shaped.
8. A structure comprising at least a first side wall formed of a sheet material having
a support provided therein in accordance with any of the preceding claims, and a
35 crosspiece adapted to adjoin the first side wall substantially perpendicularly to the plane

of the first side wall, an end of the crosspiece being supported on the first or second slot face to thereby locate the crosspiece relative to the first side wall.

5 9. A structure according to claim 8 further comprising a second side wall, the second side wall being formed of a sheet material having a support provided therein in accordance with any of claims 1 to 7 and supporting another end of the crosspiece.

10 10. A structure according to claim 8 or claim 9 further including fixing means for fixing the crosspiece to at least the first side wall when located relative to the first side wall.

11. A structure according to any of claims 9 to 10 wherein the crosspiece is a shaft, preferably a cylindrical shaft.

15 12. A method of conveying an upstream document and a downstream document along a transport path, the method comprising:

a) conveying the upstream document from its source to a first predetermined position along the transport path;

b) halting the upstream document at the first predetermined position;

20 c) at a predetermined time based on the position of the downstream document, conveying the upstream document along the transport path at substantially the same velocity as the downstream document.

25 13. A method according to claim 12 wherein the arrival of the upstream document at the first predetermined position is detected by a first sensor located at the first predetermined position in the transport path, preferably an optical sensor.

30 14. A method according to claim 12 or claim 13 wherein the predetermined time corresponds to the arrival of the downstream document at a second predetermined position, detected by a second sensor located at the second predetermined position in the transport path, preferably an optical sensor.

15. A method according to claim 12 or claim 13 wherein in step c), the predetermined time occurs when a predetermined delay has elapsed since the departure of the

downstream document from the first predetermined position is detected using the first sensor.

16. A method according to any of claims 12 to 15 further comprising
5 d) measuring the gap between the upstream and downstream documents.
17. A method according to claim 16 when dependent on claim 15, wherein the duration of the predetermined delay is calculated based on the measured gap between adjacent downstream documents.
10
18. A method according to claim 17 wherein an average measured gap between adjacent downstream documents is calculated, and the duration of the predetermined delay is calculated based on the average measured gap.
- 15 19. A method according to claim 17 wherein the measured gaps between pairs of adjacent downstream documents are recorded as a statistical distribution, and the duration of the predetermined delay is calculated based on the recorded distribution.
- 20 20. A method according to claim 19 wherein the duration of the predetermined delay is calculated to maintain the 95th percentile of the statistical distribution at or below a standard deviation of 2.
- 25 21. A method according to any of claims 12 to 20 wherein the upstream document is conveyed in step a) by a first drive assembly, which is stopped in step b) to halt the upstream document.
22. A method according to any of claims 12 to 21 wherein the upstream document is conveyed in step c) by a second drive assembly.
- 30 23. A method according to claims 21 and 22 wherein the first predetermined position is located such that when the document is halted, the document is positioned to receive drive from the second drive assembly and its trailing edge is retained by the first drive assembly.

24. A method according to claim 23 wherein, during step c), the first drive assembly is not driven such that a retardation force is applied to the document by the first drive assembly as it is conveyed by the second drive assembly.

5 25. A document transport assembly for use in a document handling apparatus comprising first and second substantially parallel linear transport sections, each adapted to convey documents therethrough, joined by a U-turn transport section which is adapted to receive a document from the first linear transport section, turn the document through substantially 180 degrees and convey the document to the second
10 linear transport section.

26. A document transport assembly according to claim 25 wherein each of the first and second substantially parallel linear transport sections lie in substantially horizontal planes.

15

27. A document transport assembly according to claim 25 or claim 26 wherein each of the transport sections is adapted to convey documents whose dimension in the direction of travel is smaller than that perpendicular to the direction of travel.

20 28. A document transport assembly according to any of claims 25 to 27 wherein the document transport assembly is of modular construction, each of the transport sections being adapted to detachably couple to one another.

29. A document transport assembly according to any of claims 25 to 28 wherein at
25 least one of the first and second substantially parallel linear transport sections comprises one or more detectors arranged to detect characteristics of documents conveyed therethrough.

30. A document handling apparatus comprising a document path through the
30 apparatus, a transport assembly for conveying a document along the document path, and a magnetic detector device adjacent at least a portion of the document path for detecting magnetic material in passing documents; wherein the transport assembly comprises at least one rotatable member adjacent the magnetic detector device, the rotatable member arranged to support passing documents at a fixed distance from the
35 magnetic detector device.

31. A document handling apparatus according to claim 30 wherein the rotatable member comprises a roller assembly.

5 32. A document handling apparatus according to claim 30 or claim 31 wherein the rotatable member comprises a non-magnetic material, preferably plastics or ceramic.

33. A diverter assembly for diverting documents between transport paths in a document handling apparatus, the diverter assembly comprising first and second
10 blades pivotably engaged with one another, and coupling means provided between the first and second blades adapted to transfer rotation from the first blade to the second, such that when the first blade is rotated in a first direction, the second blade rotates in the opposite direction to switch the diverter assembly between transport paths.

15 34. A diverter assembly according to claim 33 further comprising an actuator coupled to the first blade for rotation thereof.

35. A diverter assembly according to claim 34 wherein the actuator comprises a solenoid.

20

36. A diverter assembly according to any of claims 33 to 35 wherein the coupling means comprises a first gear plate fixed to the first blade and rotatable therewith and a second gear plate rotatably mounted relative to the first blade, each gear plate comprising an arcuate rack gear, and a gear wheel provided between the first and
25 second gear plates such that movement of the first gear plate causes movement of the second gear plate in the opposite direction, the second gear plate being adapted to engage the second blade so as to cause movement thereof during at least a portion of the movement of the second gear plate.

30 37. A diverter assembly according to claim 36 wherein the second gear plate is adapted to engage the second blade by abutting the second blade.

38. A diverter assembly according to any of claims 33 to 37 wherein the second blade is sprung loaded.

35

39. A diverter assembly according to claim 38 when dependent on at least claim 36 wherein the second blade is sprung towards the second gear plate.
40. A diverter assembly according to any of claims 33 to 39 wherein the first blade
5 has two ends, allowing documents to pass between them, over the first blade to define a first transport path.
41. A diverter assembly according to claim 40 wherein a first end of the second blade is pivotably engaged with the first blade between the two ends of the first blade
10 and a second end of the second blade extends away from the first blade to define a second transport path between the first end of the first blade and the second end of the second blade, and a third transport path between the second end of the second blade and the second end of the first blade.
42. A diverter assembly according to claims 40 and 41 wherein the two ends of the first blade are bladed ends, adapted to allow documents to pass through the first transport path in either direction.
15
43. A document transport assembly for use in a document handling apparatus, the document transport assembly defining a document path therethrough and comprising at least one transport component on a first side of the document path for conveying documents along the path and at least one protrusion provided on a second side of the document path adjacent the transport component and extending into the document path so as to cause deflection of passing documents.
20
44. A document transport assembly according to claim 43 wherein a plurality of transport components are provided, spaced laterally across the document path, the at least one protrusion extending into the document path between the transport components.
25
45. A document transport assembly according to claim 44 wherein two protrusions are provided, laterally spaced across the transport path.
30

46. A document transport assembly according to any of claims 43 to 45 wherein the at least one protrusion is a ramp having a linear or curved profile extending towards the document path.
- 5 47. A document transport assembly according to any of claims 43 to 46 wherein the at least one transport component is a roller or friction belt.
49. A document transport assembly according to any of claims 43 to 48 wherein the document transport assembly forms part of a stacker adapted to form documents into a
10 stack.
50. A document storage device for storing sheet documents, the device comprising a band, which can be wound onto a document storage roller such that sheet documents can be stored between adjacent windings of the band on the document storage roller
15 and which can be unwound from the document storage roller thereby dispensing the stored documents, and a scraper assembly comprising a scraper for contacting the band on the document storage roller, the scraper defining a blade having a profile of which at least a portion is substantially rectilinear which, in use, contacts the band substantially perpendicularly to the length of the band.
- 20 51. A document storage device according to claim 50 wherein the substantially rectilinear portion of the blade profile is narrower than the width of the band.
52. A document storage device according to claim 50 or 51 wherein the
25 substantially rectilinear portion of the blade profile is formed by a region of the scraper which protrudes from the remainder of the blade profile.
53. A document storage device according to any of claims 50 to 52 wherein the scraper assembly is rotatable about a pivot and further comprises an end stop for
30 contacting the band on the document storage roller, the scraper assembly being urged by a first biasing element such that the end stop maintains contact with the band on the document storage roller at a point distal from the pivot relative to the point of contact of the scraper with the band on the document storage roller.

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Fig.1A.

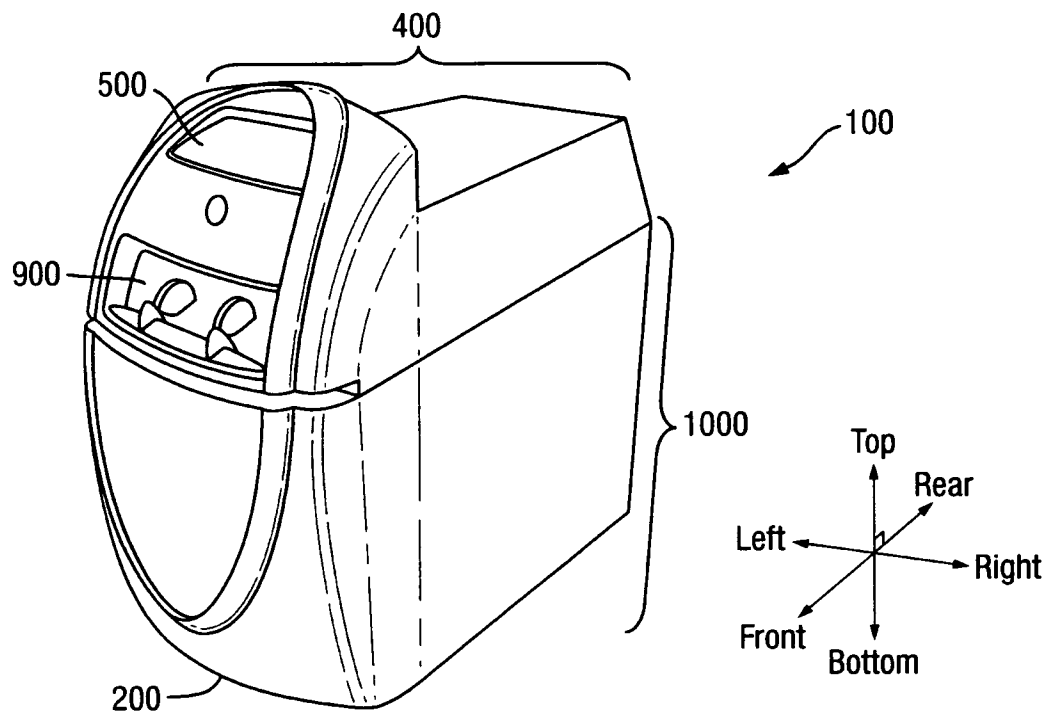
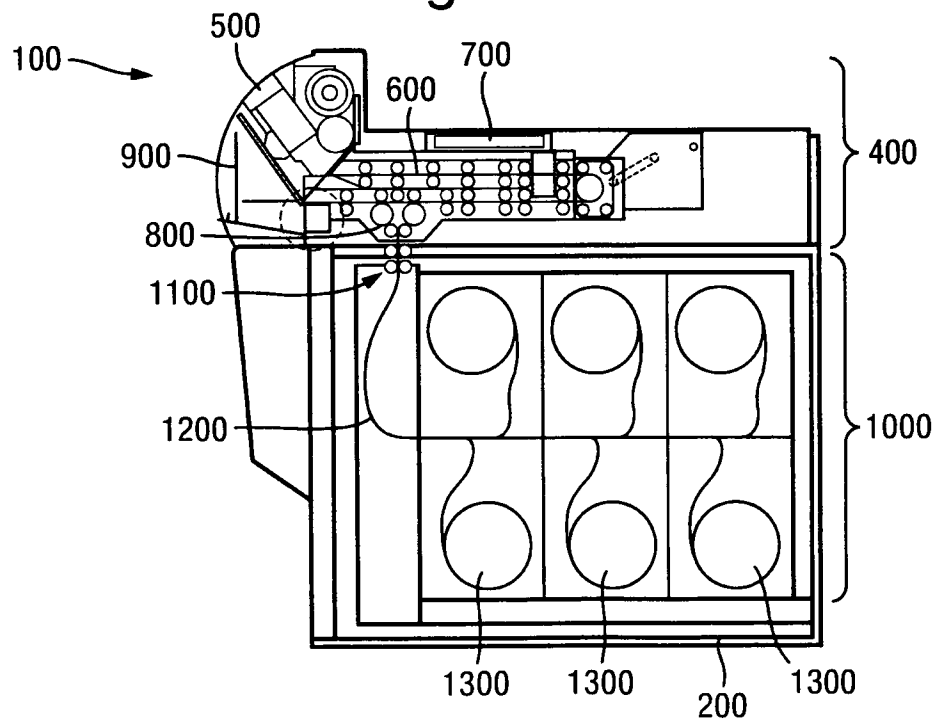
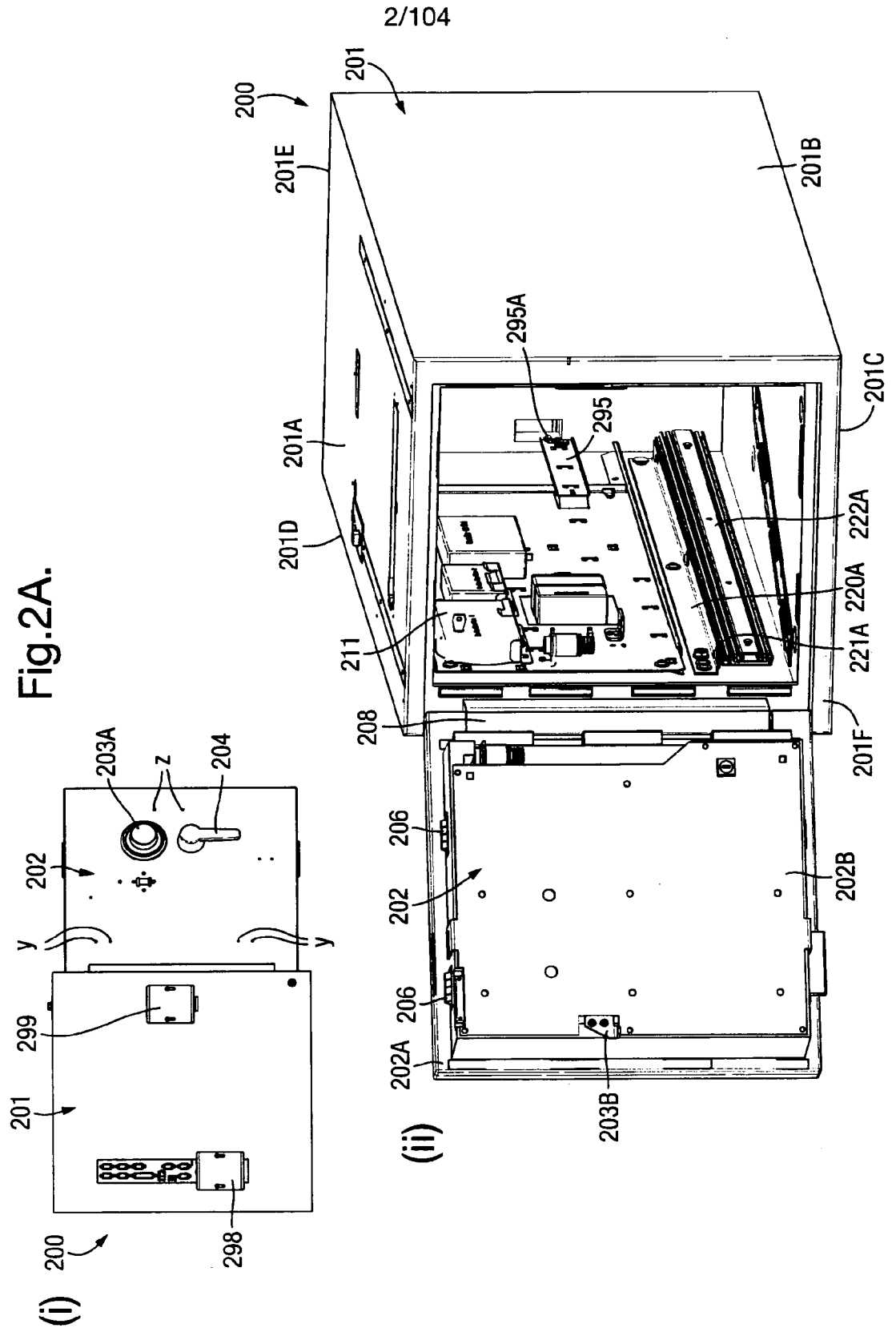
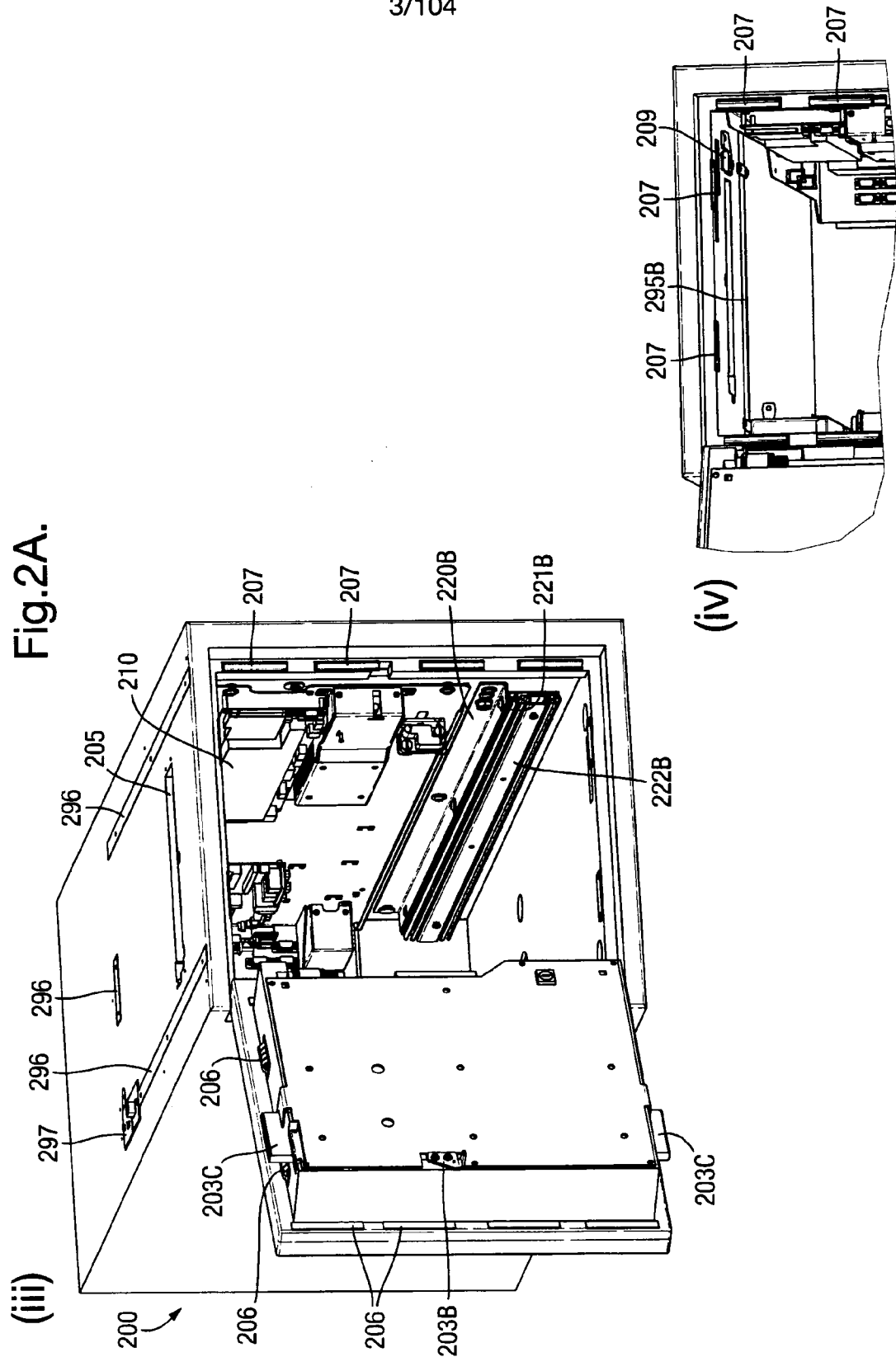


Fig.1B.

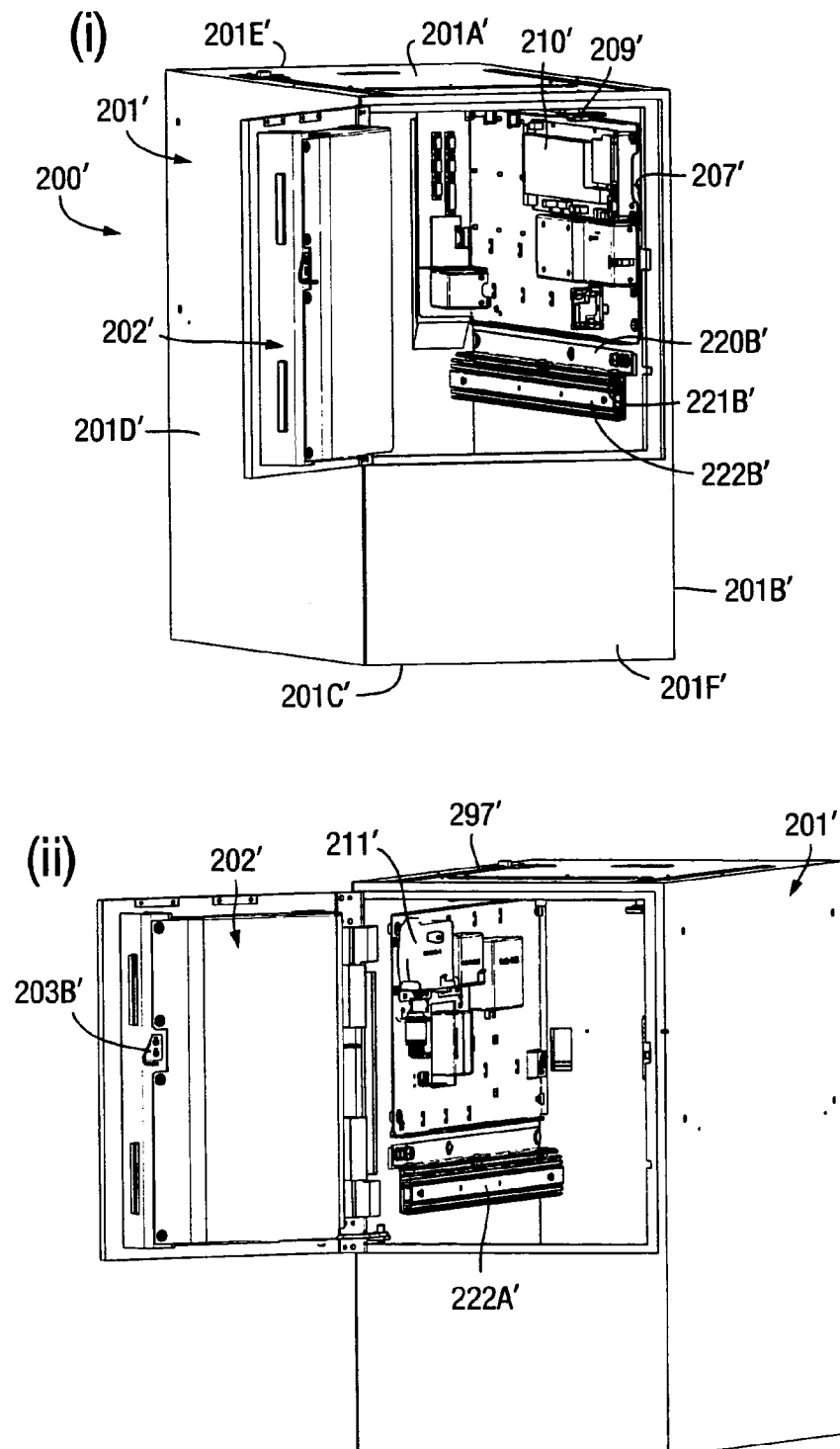






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Fig.2B.



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Fig.2B.

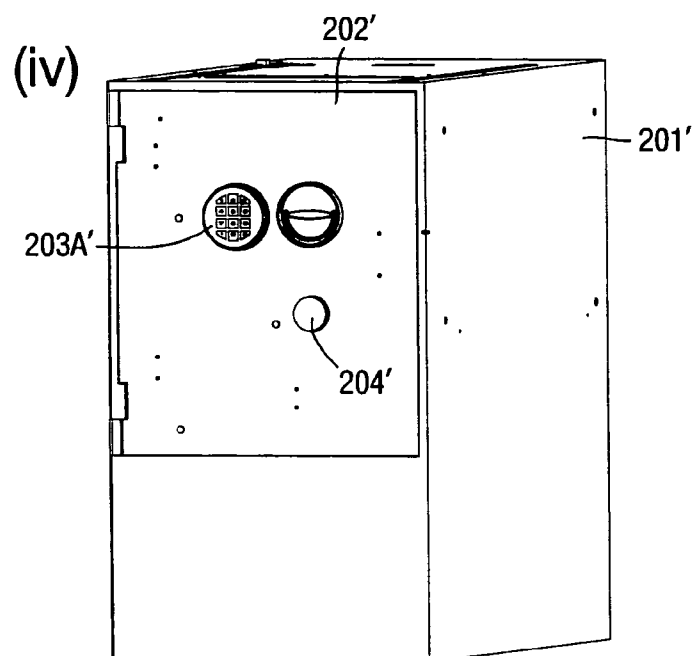
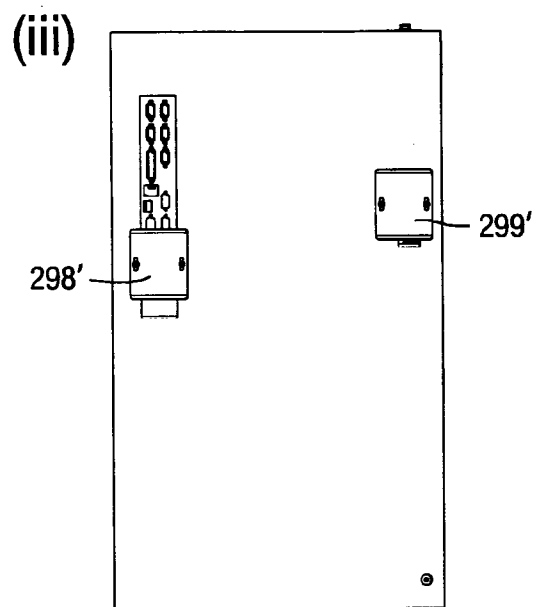
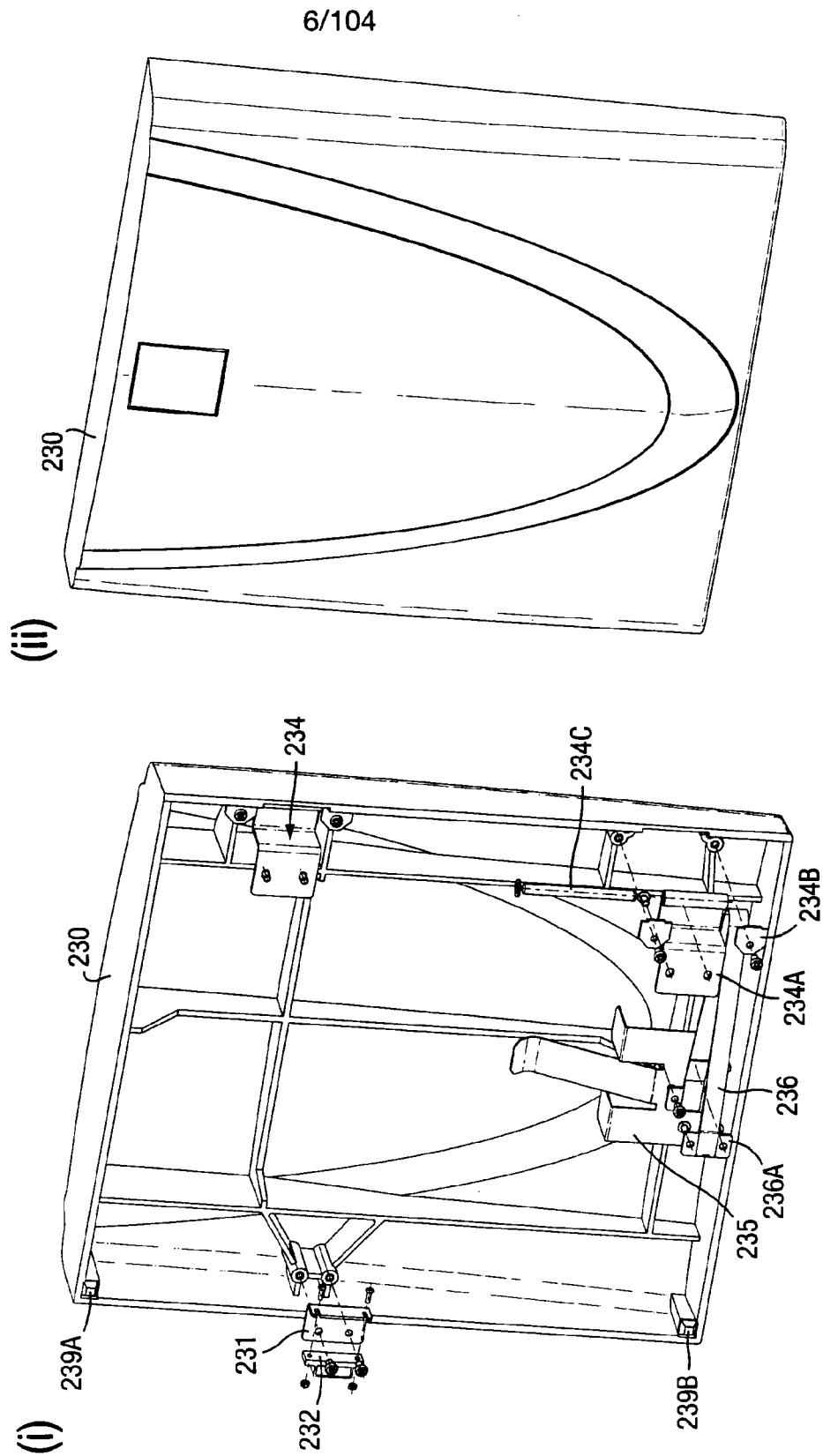
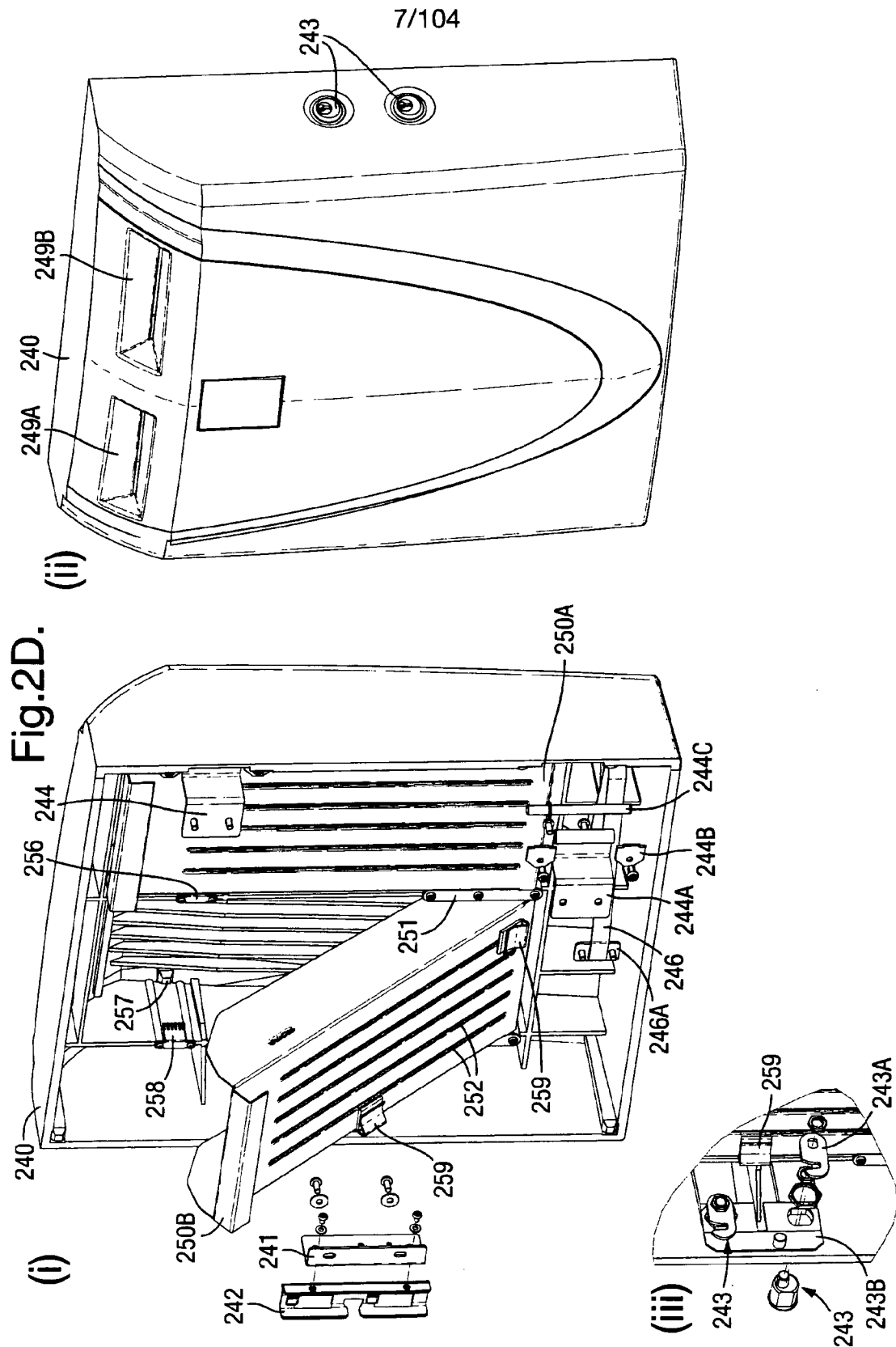


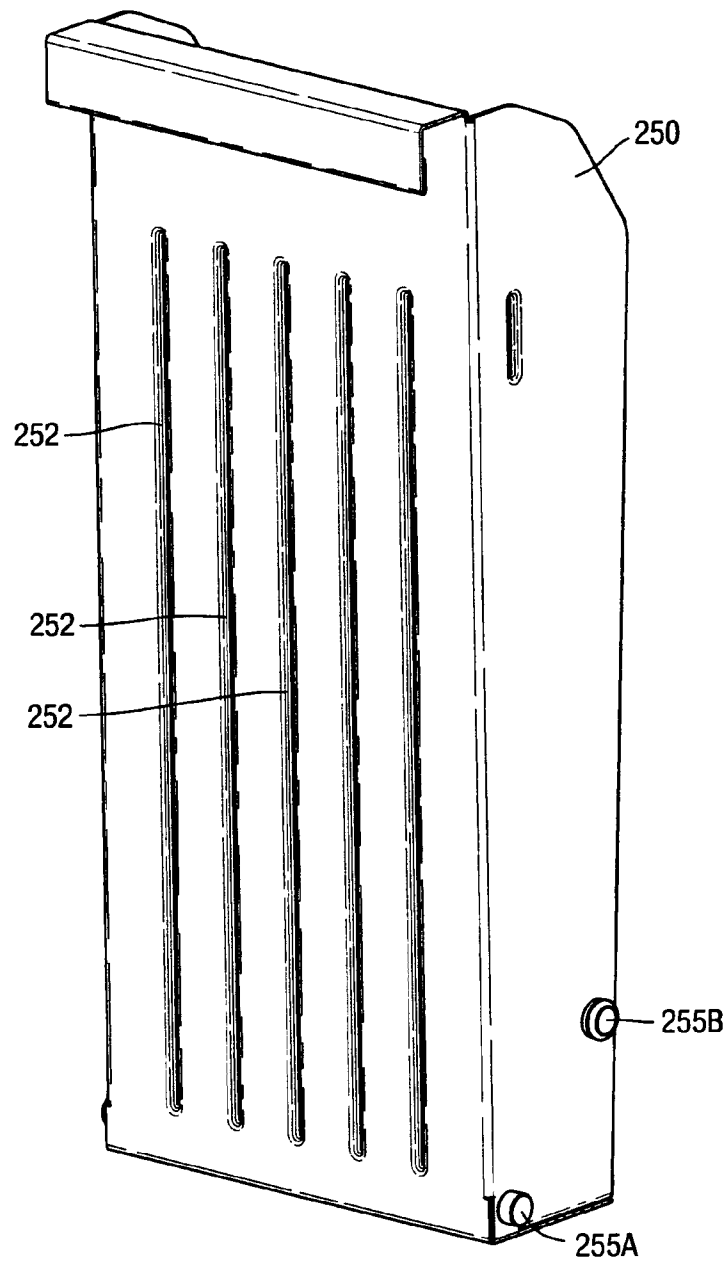
Fig.2C.

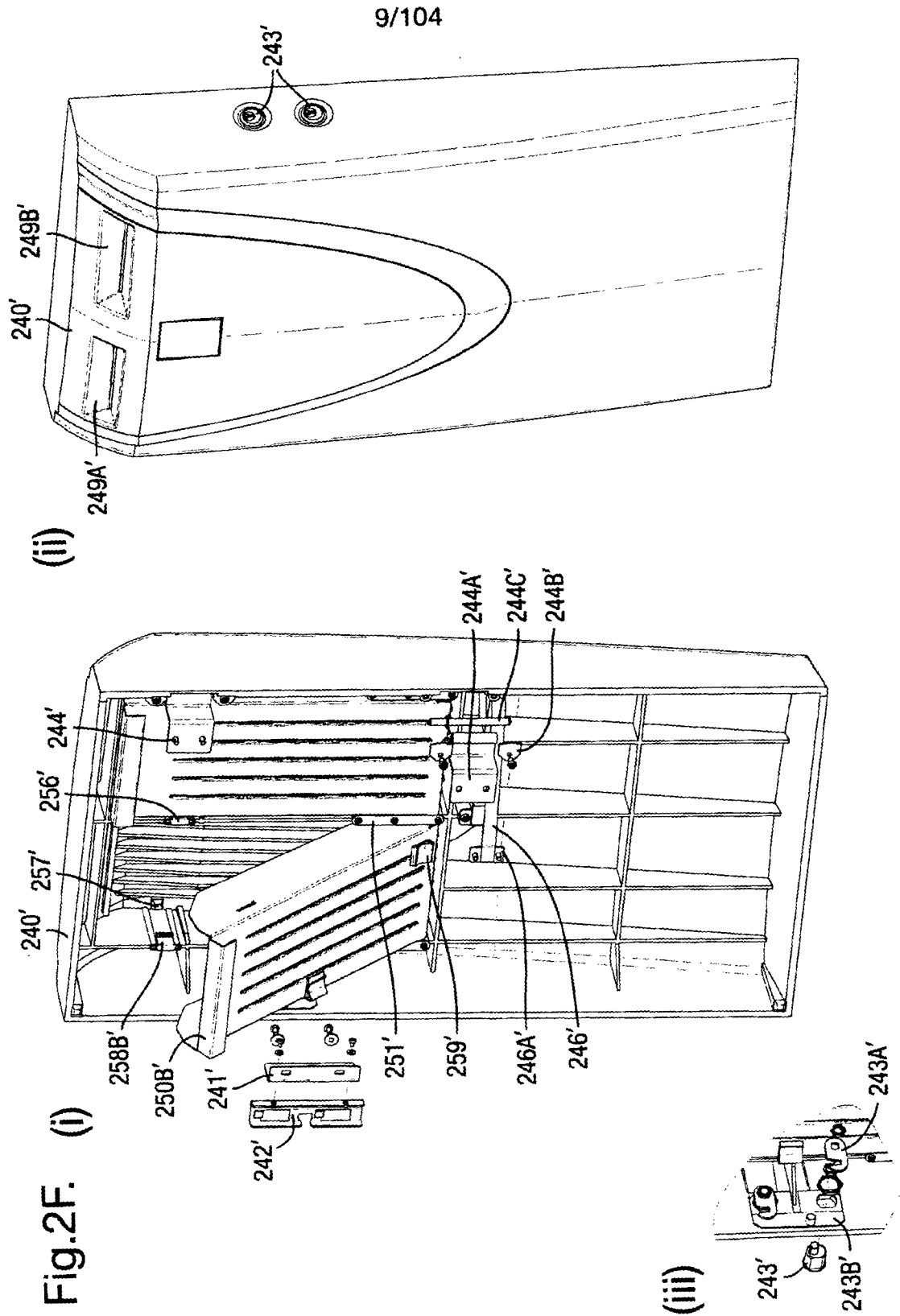




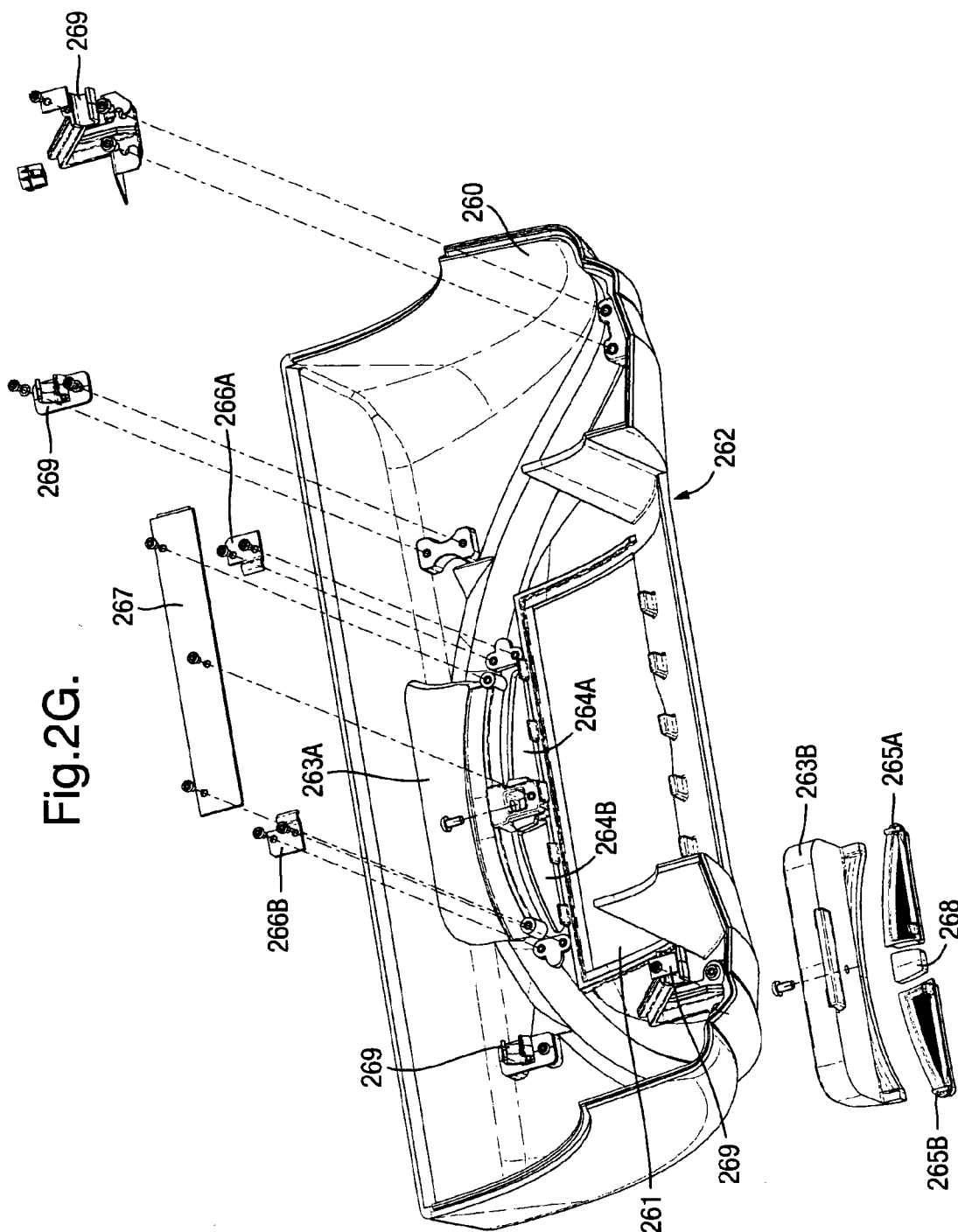
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Fig.2E.



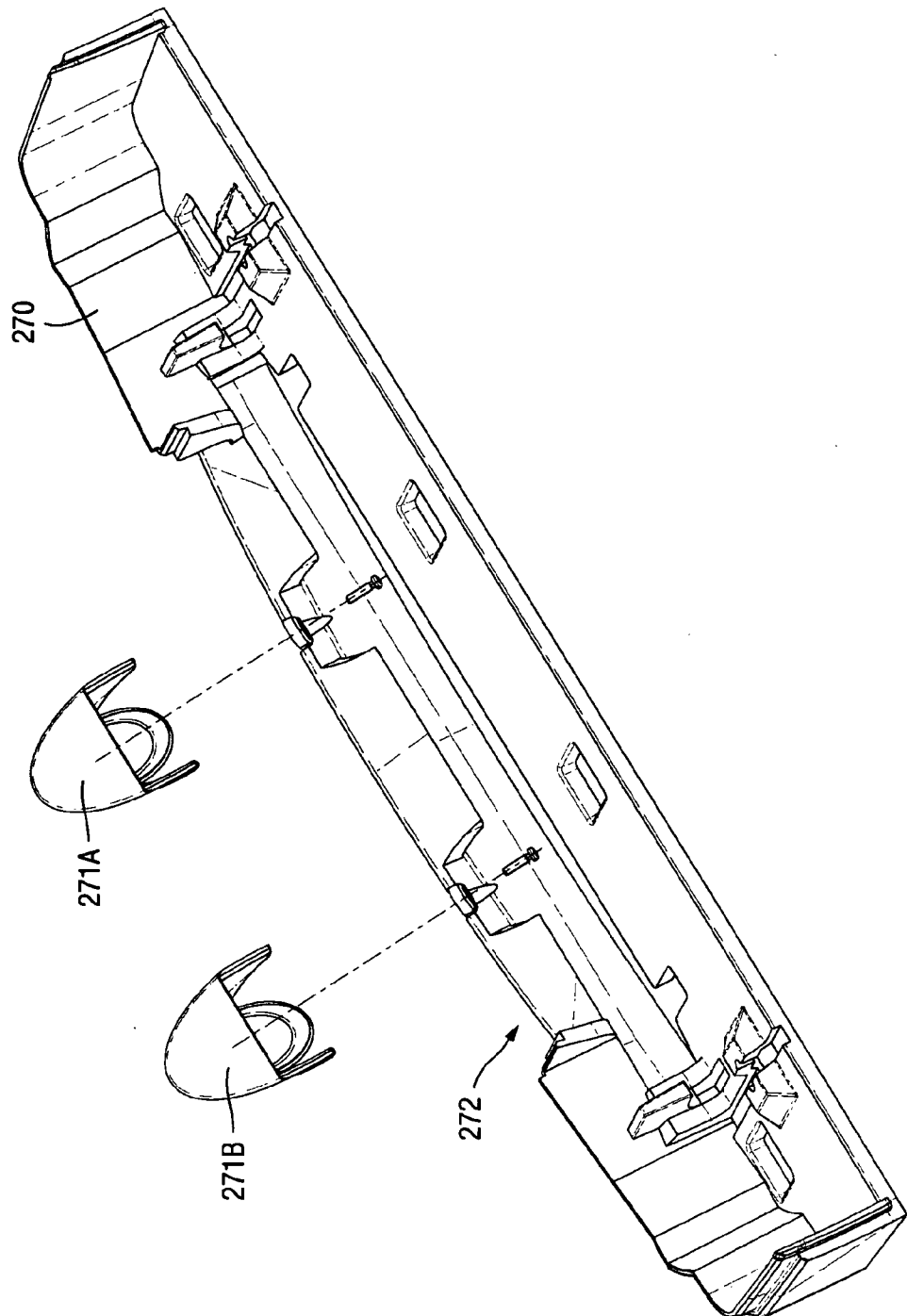


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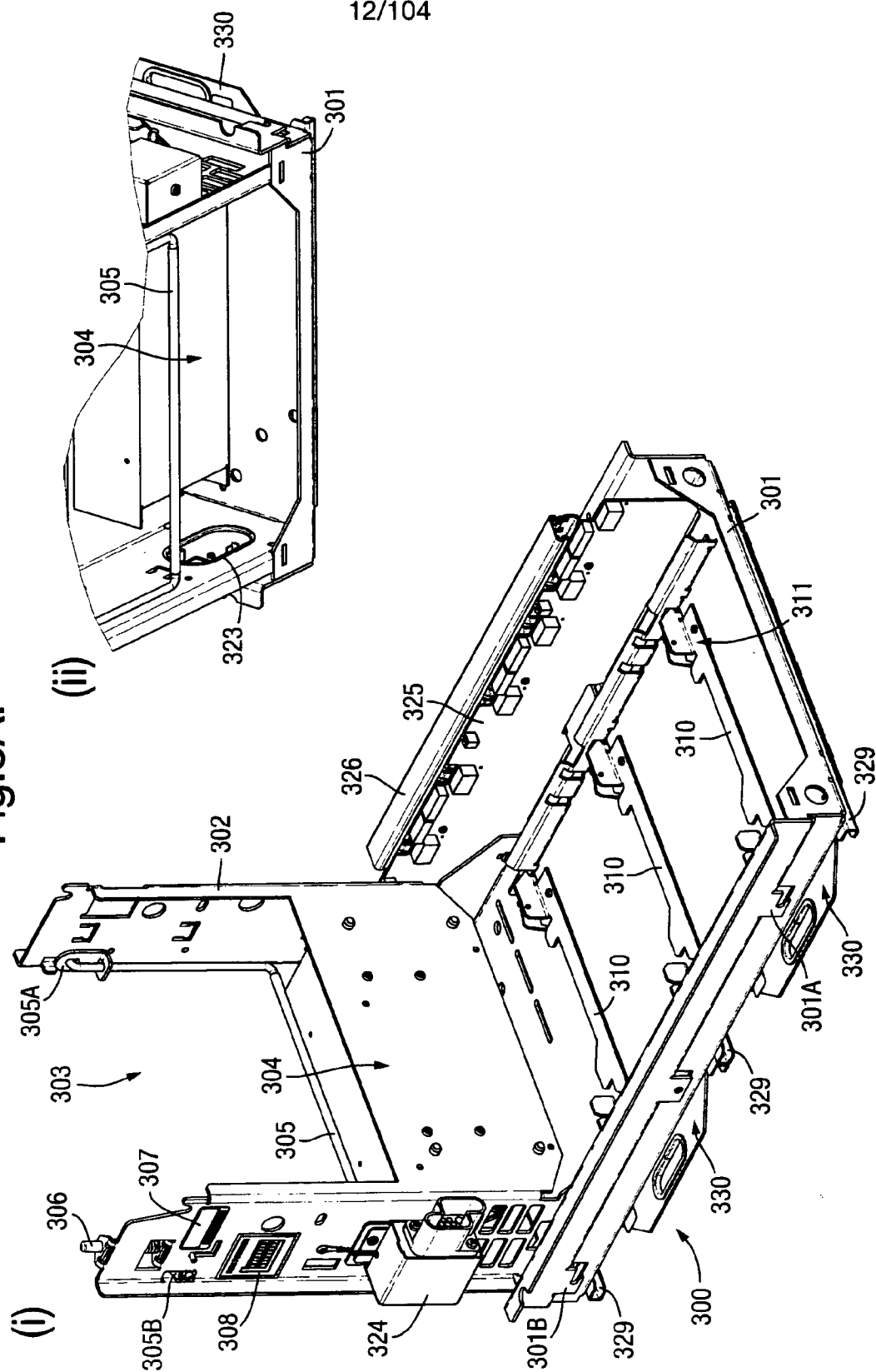
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Fig.2H.



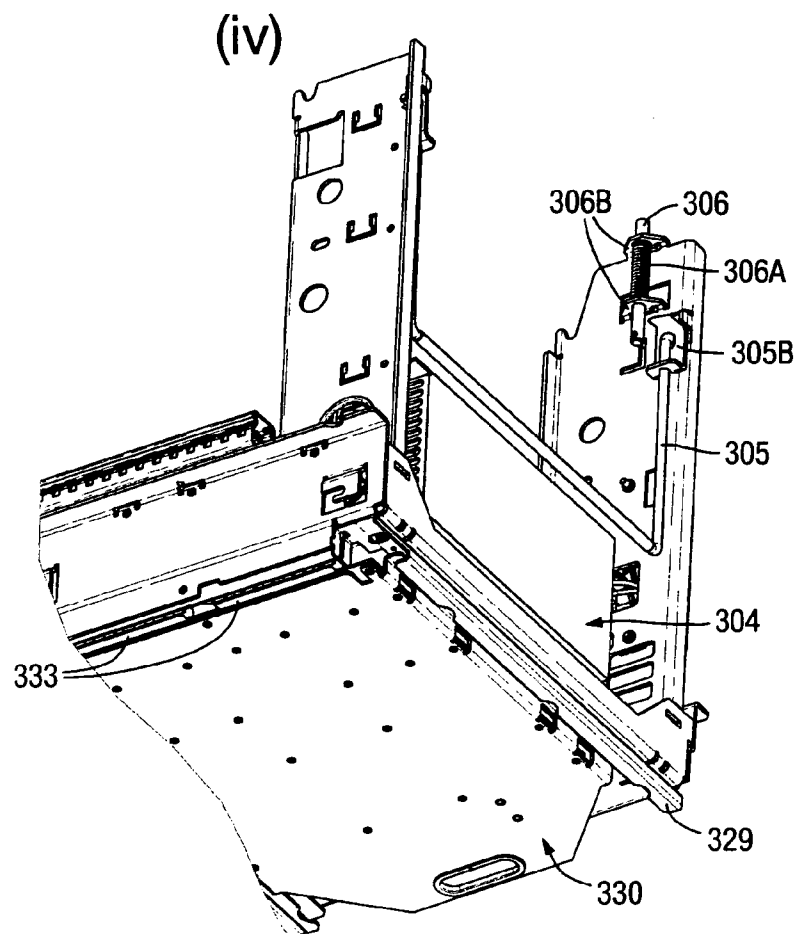
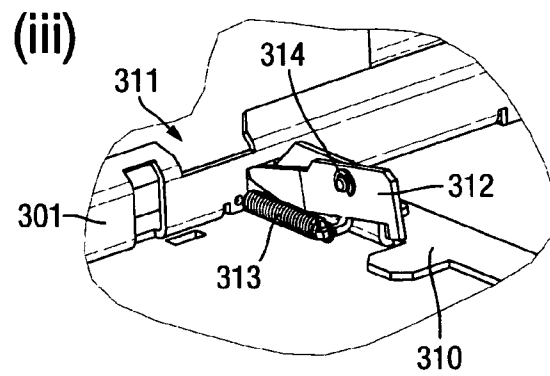
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Fig.3A.



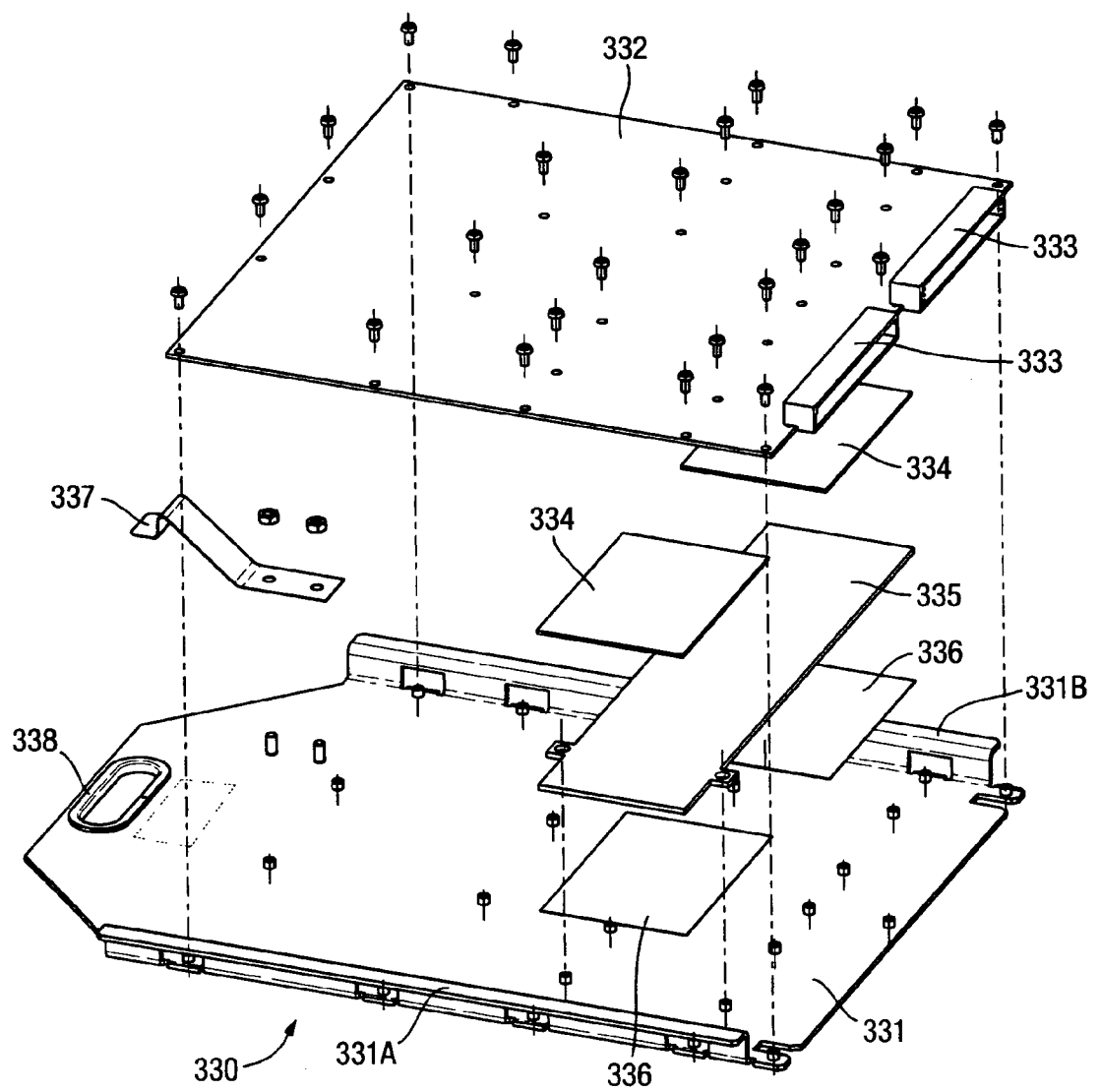
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Fig.3A.

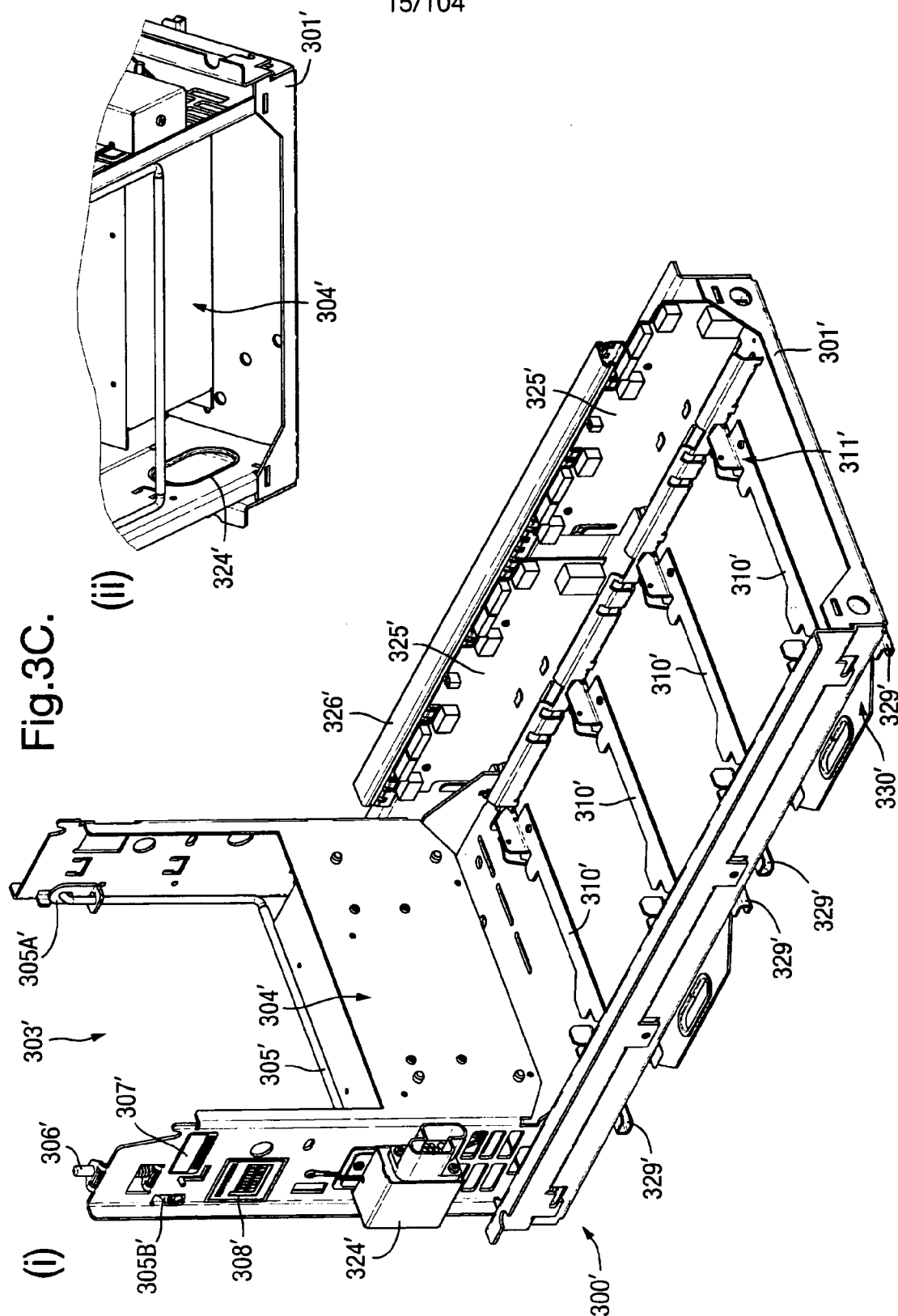


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Fig.3B.

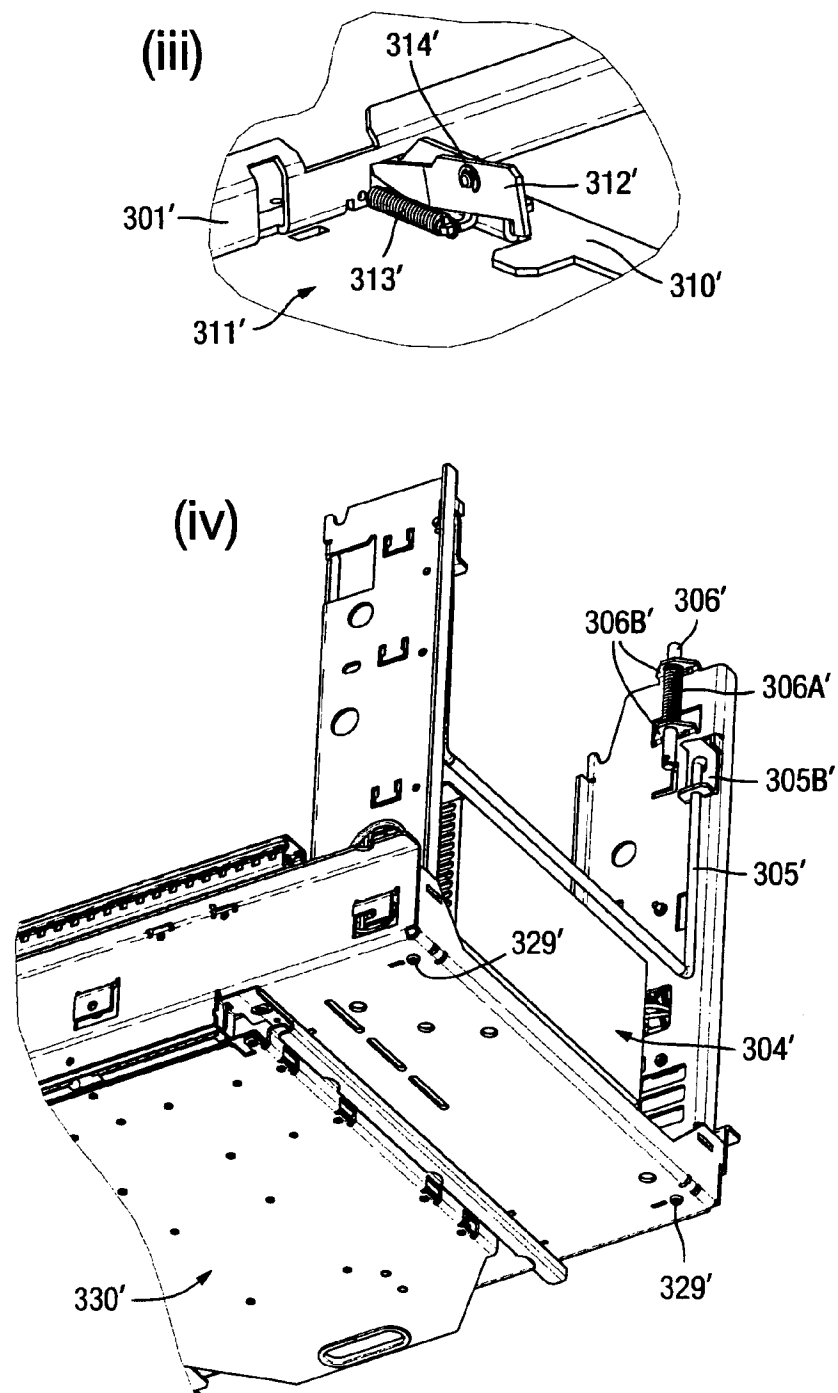


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Fig.3C.



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Fig.3D.

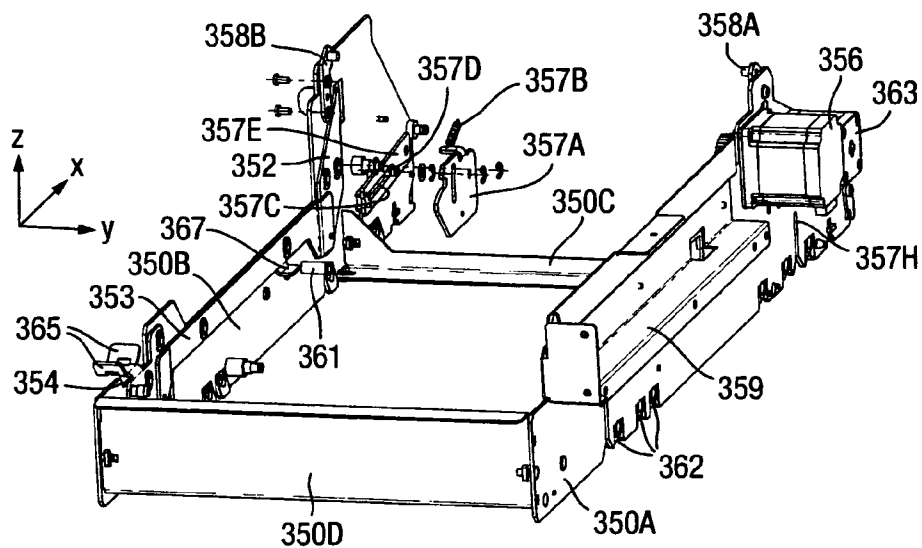
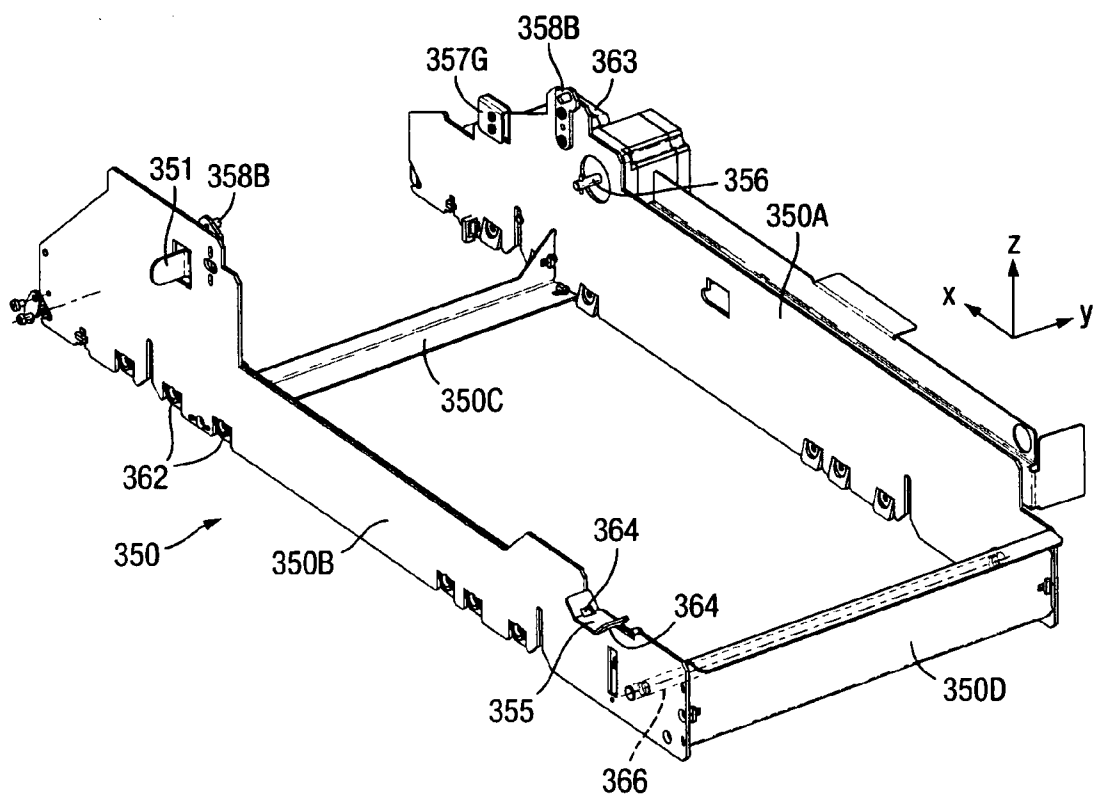
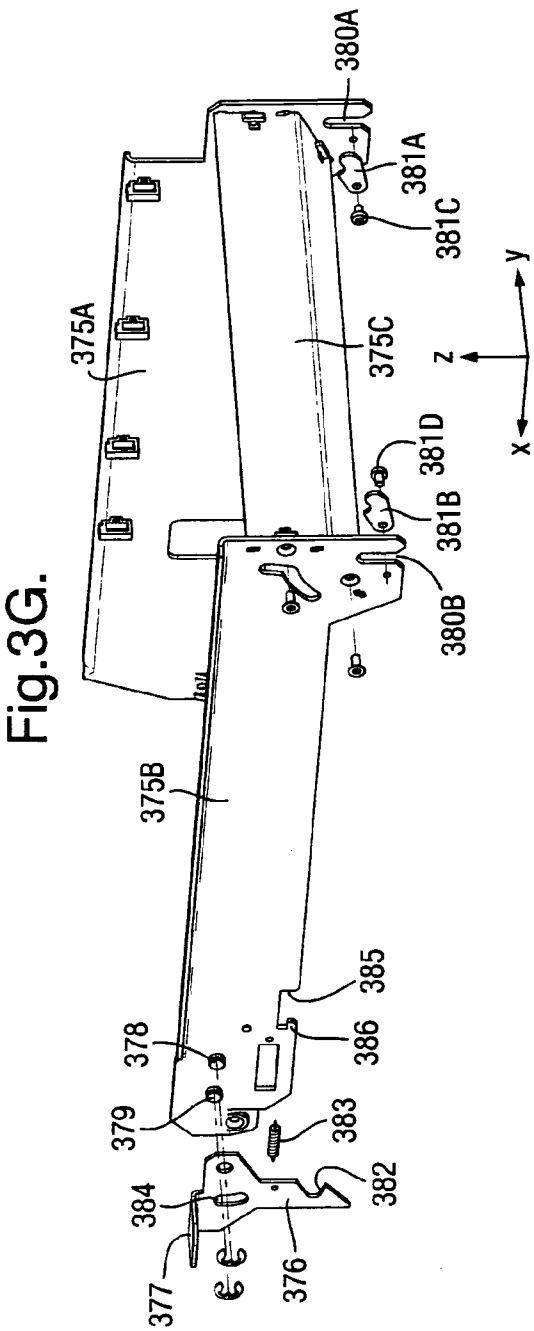
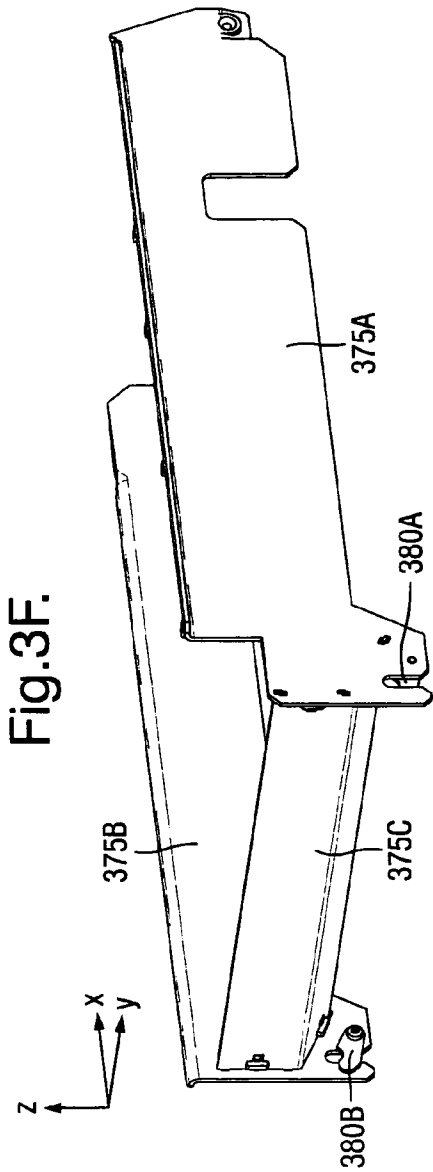


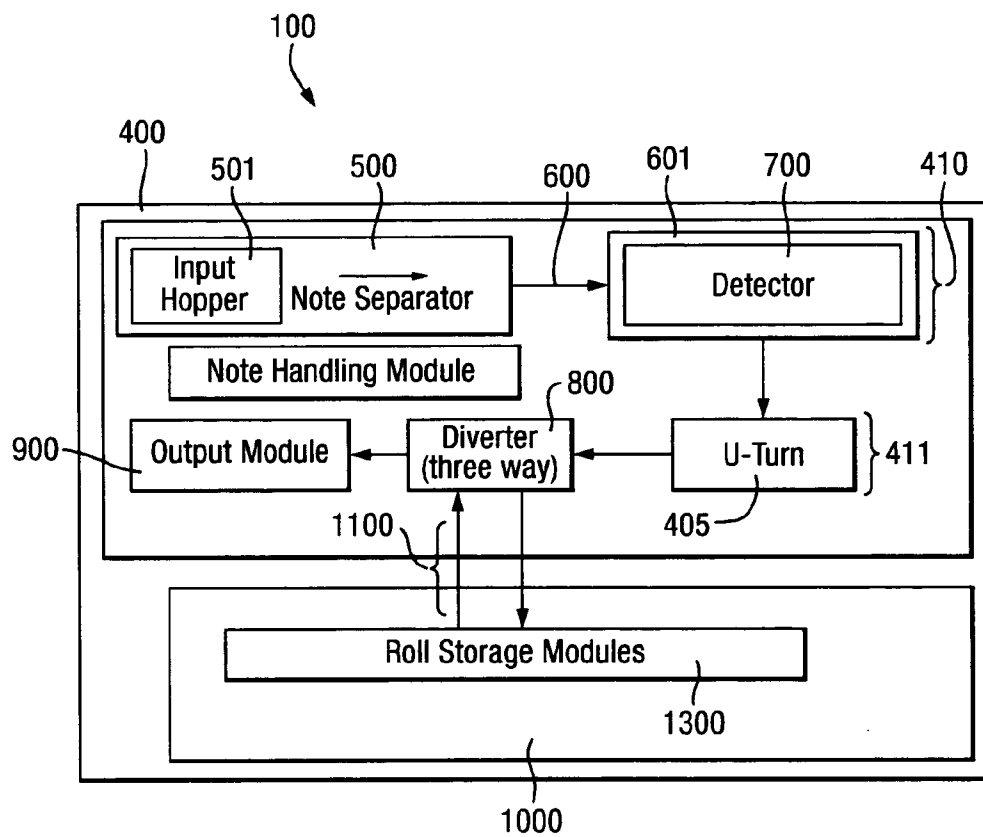
Fig.3E.

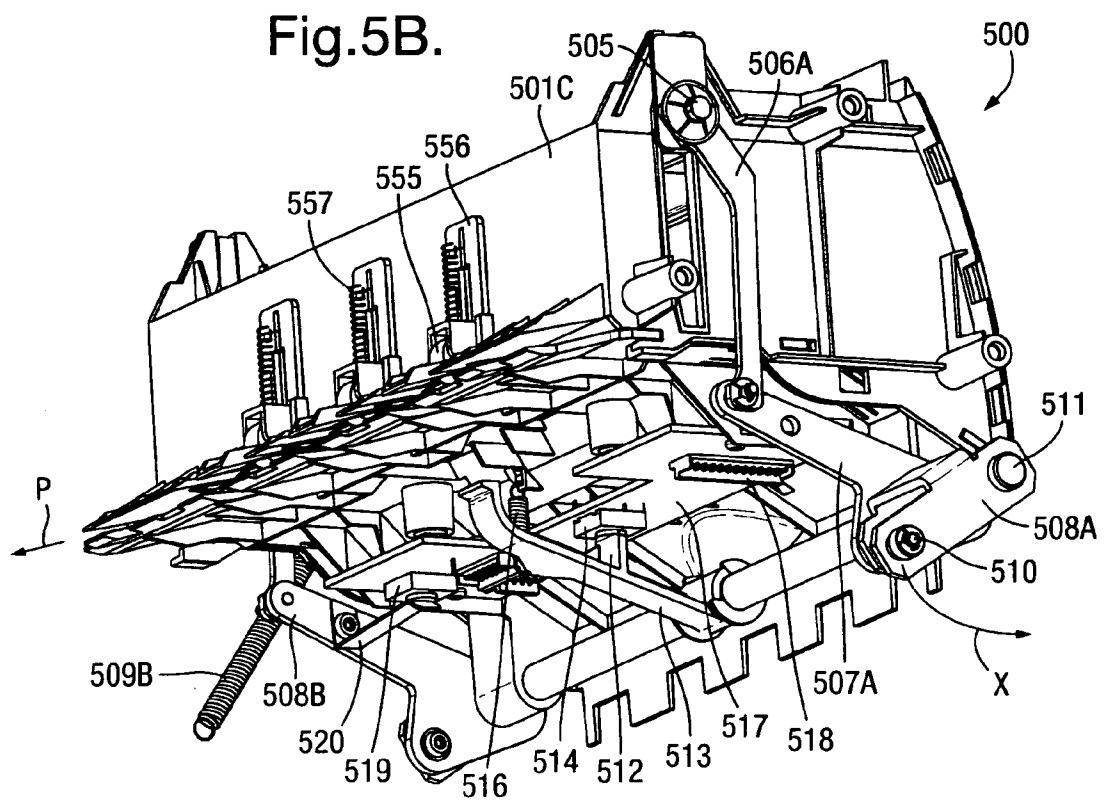
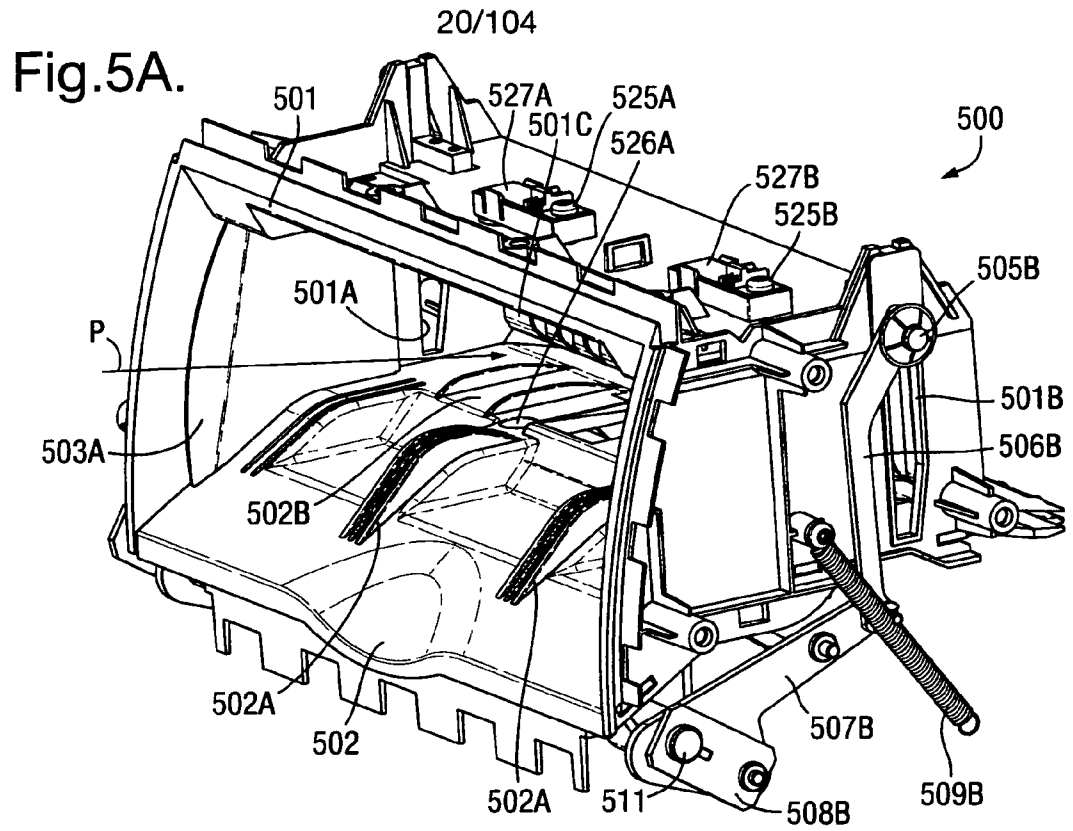




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Fig.4.





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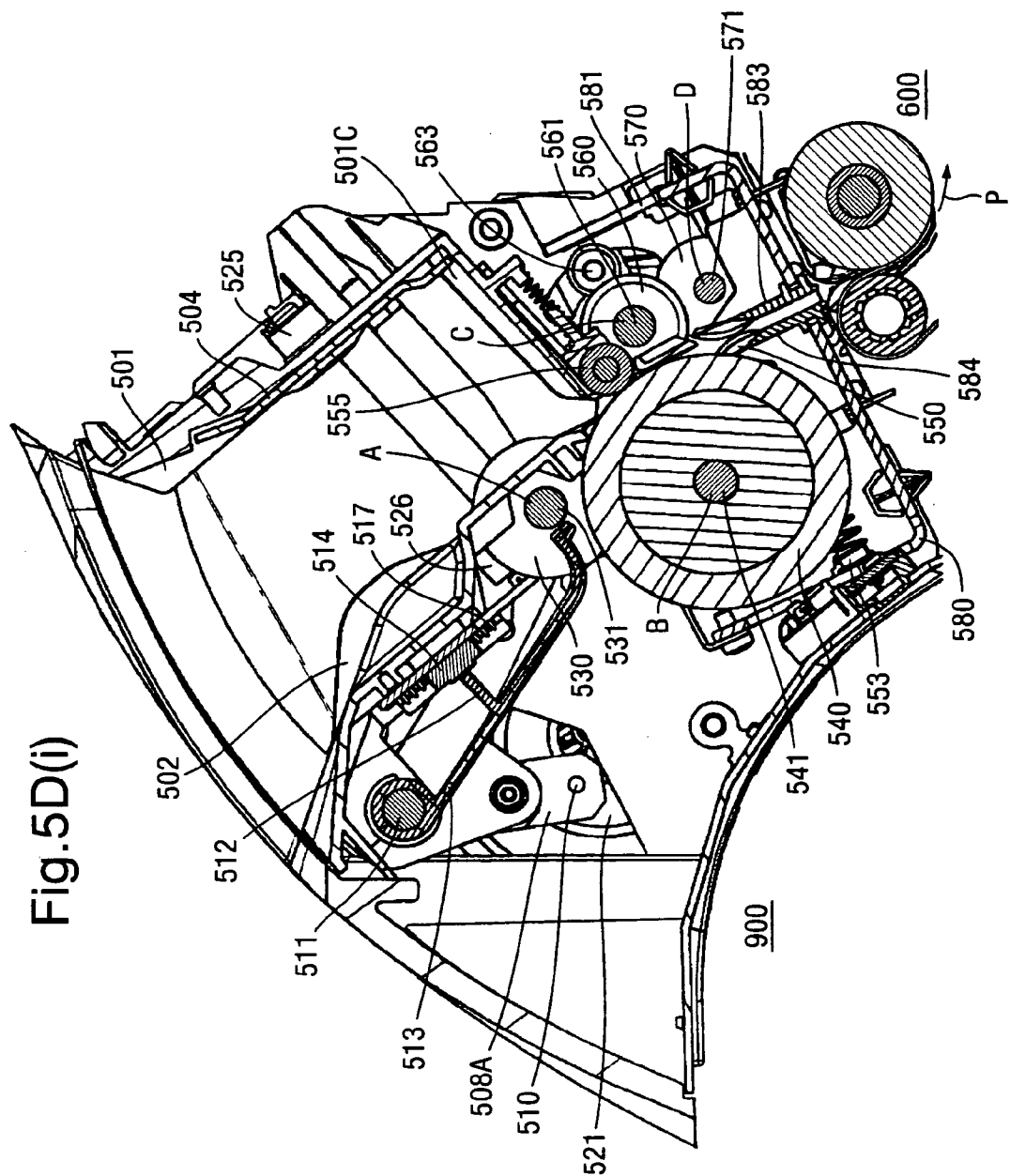
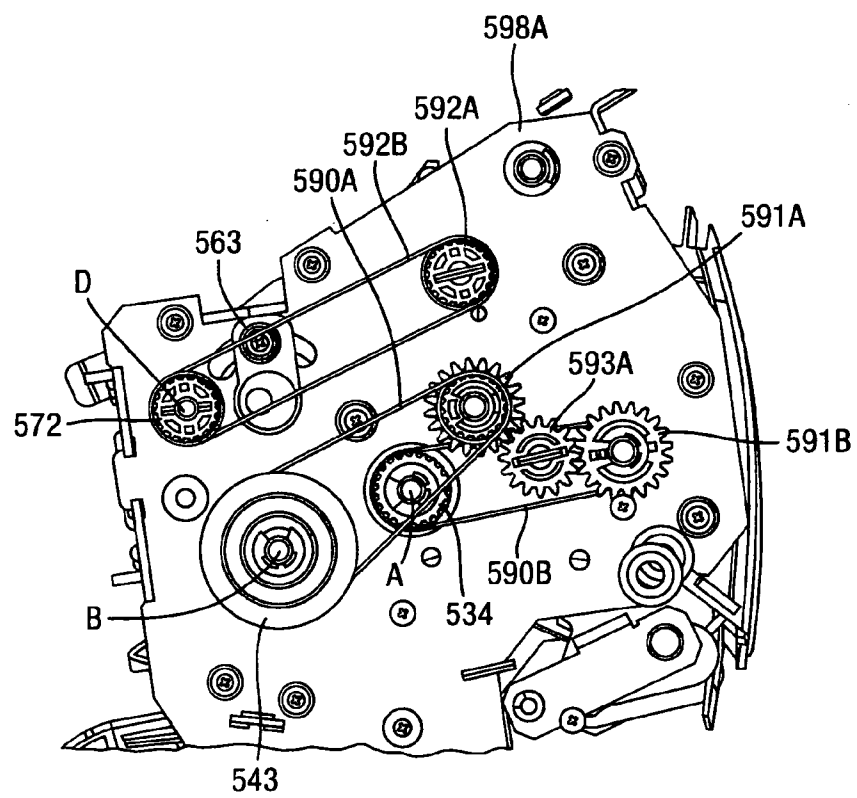


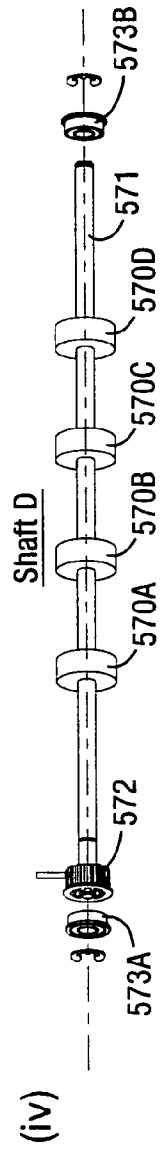
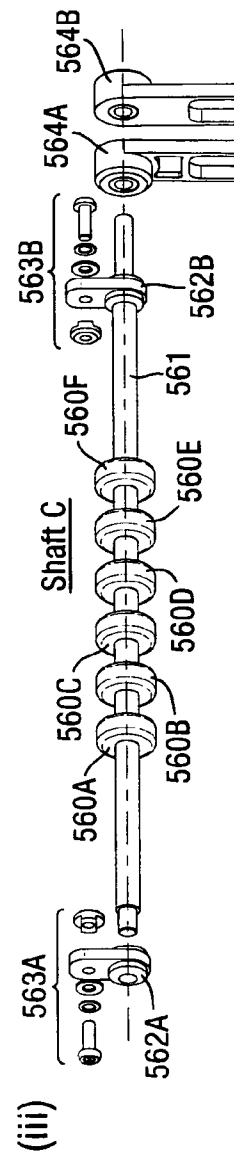
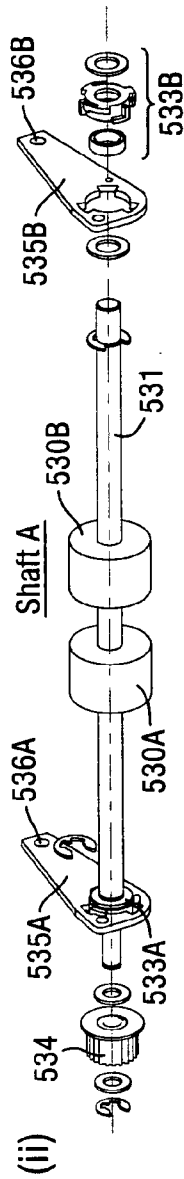
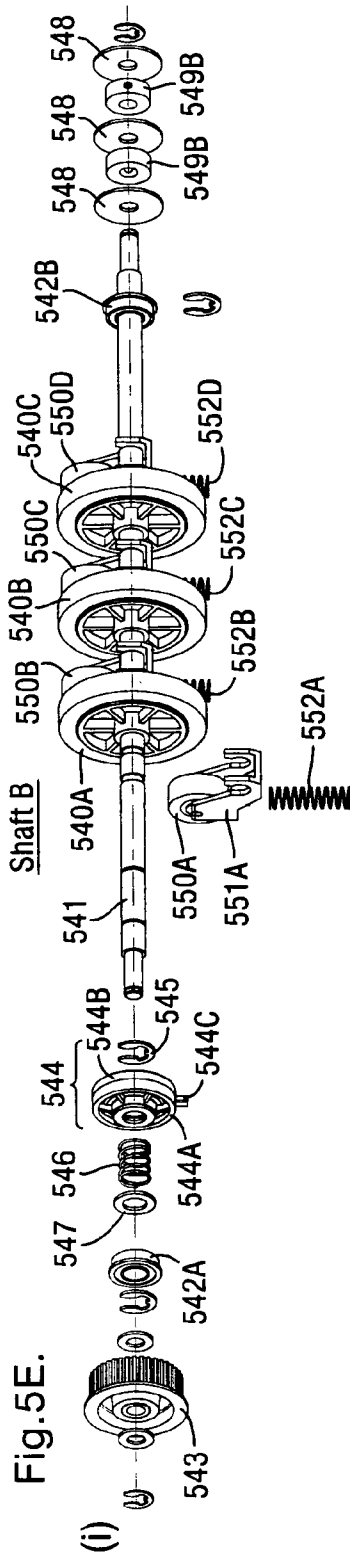
Fig. 5D(i)

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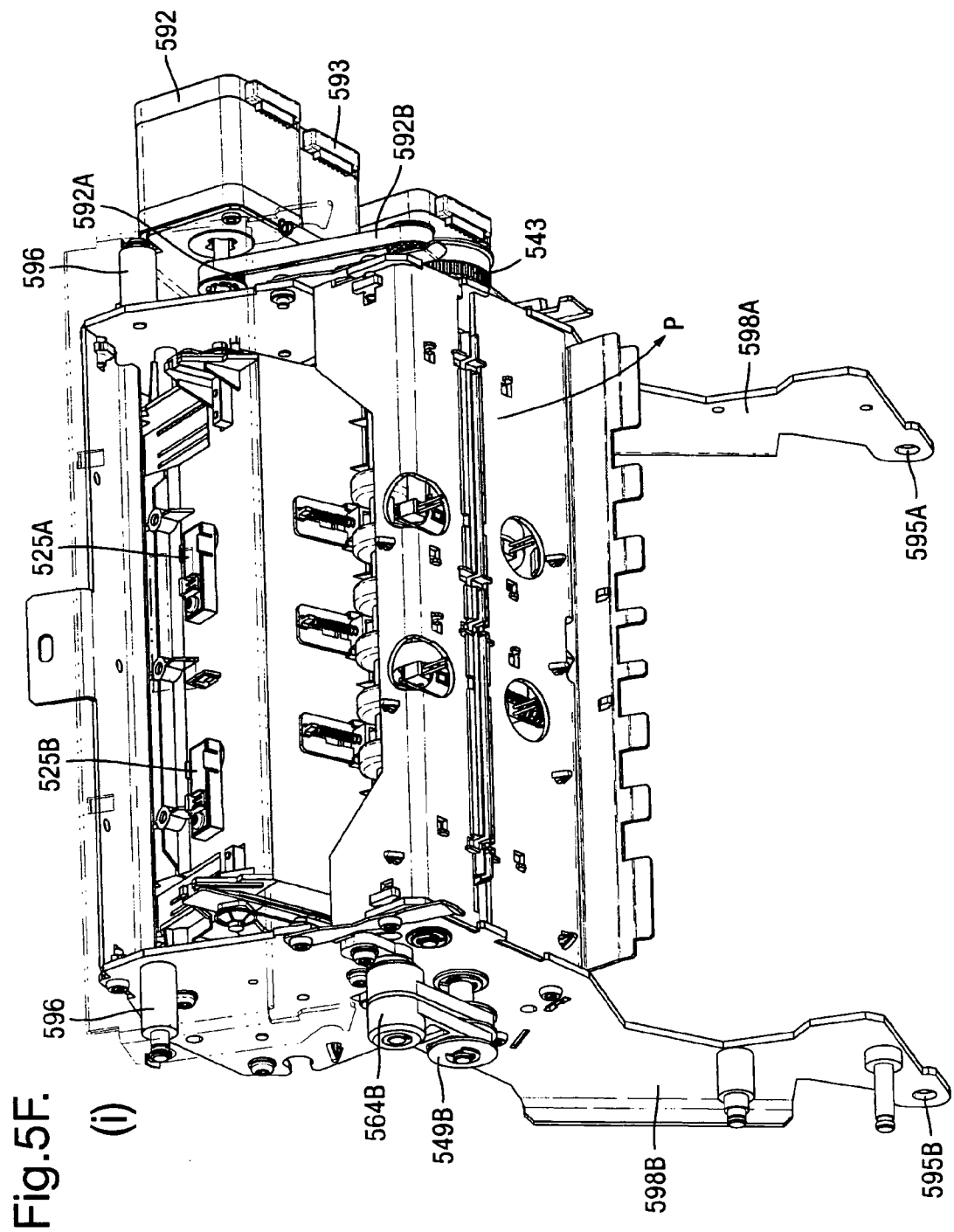
Fig.5D(ii)



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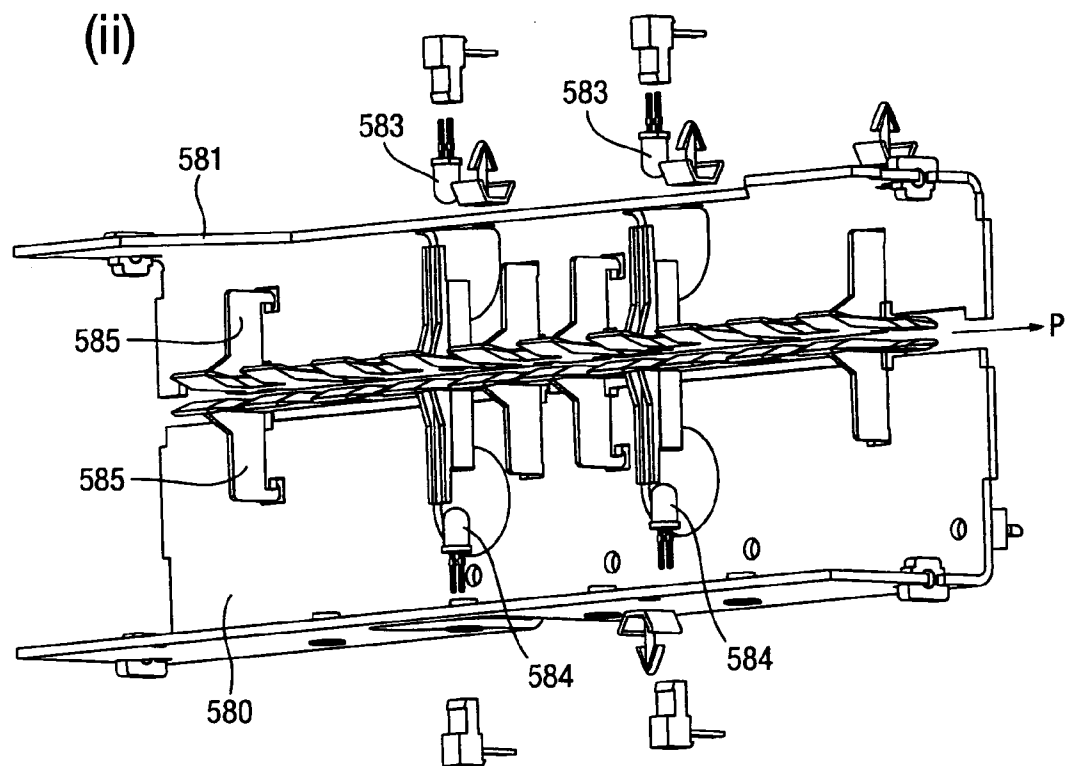


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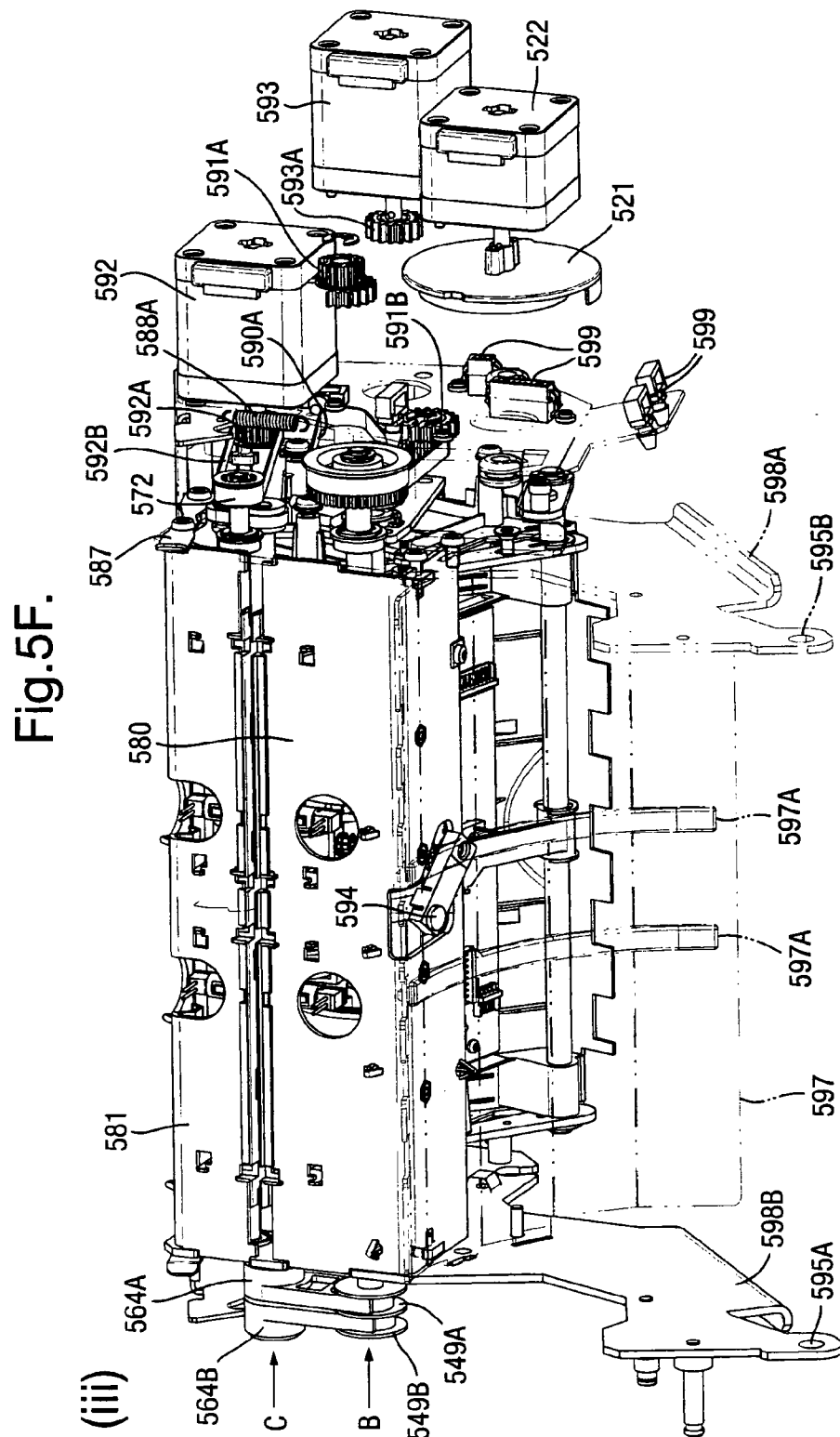


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Fig.5F.

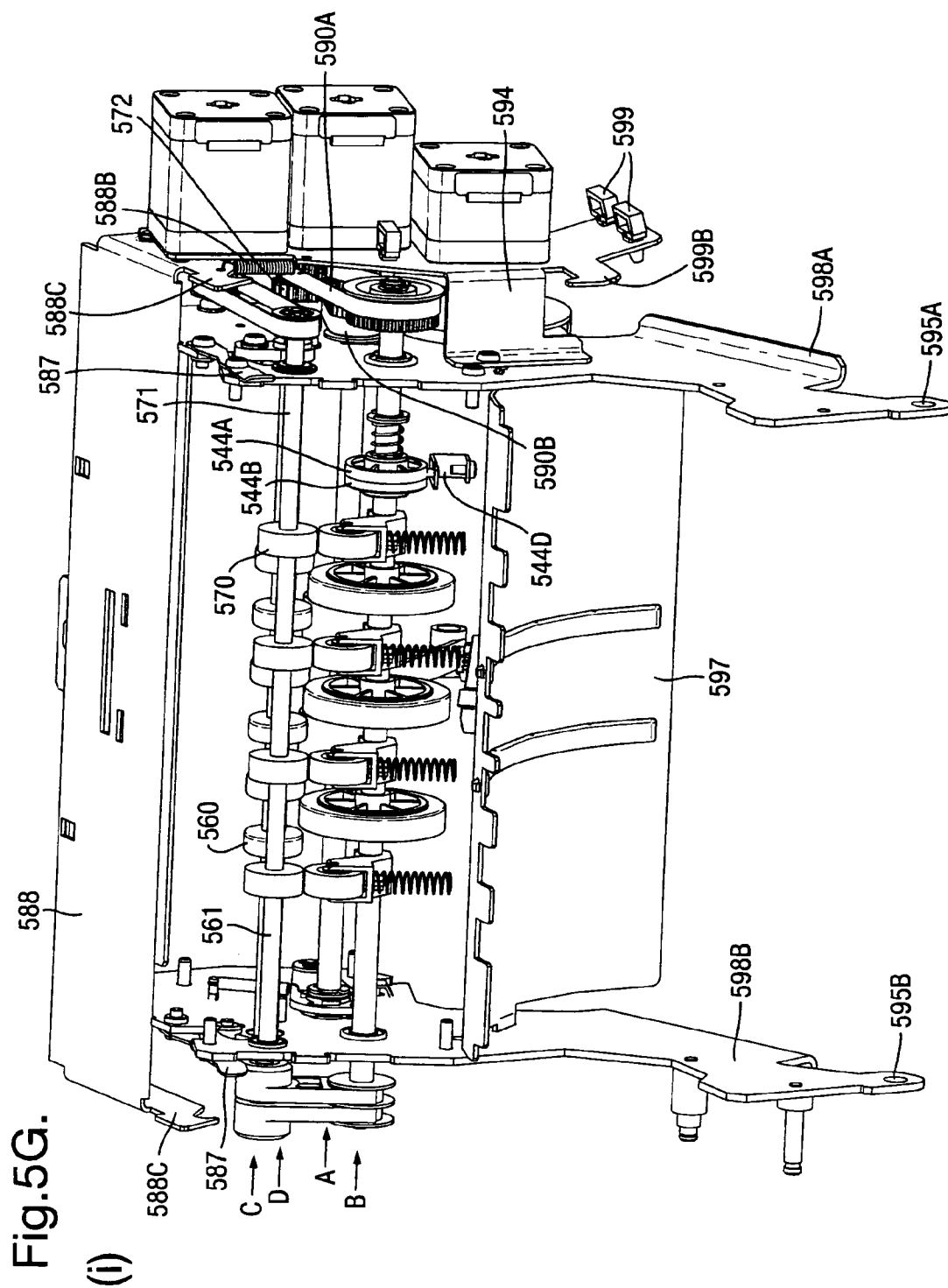


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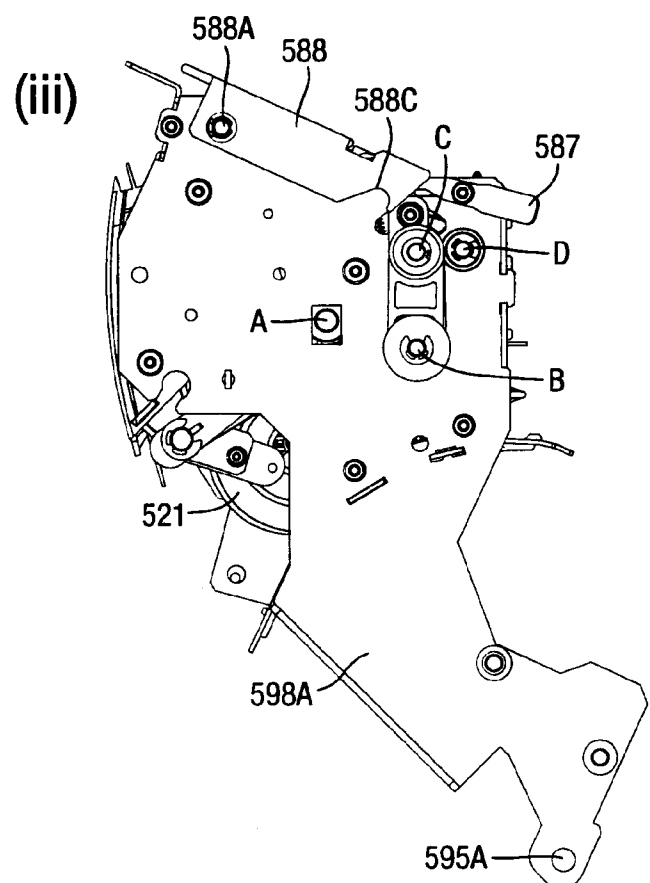
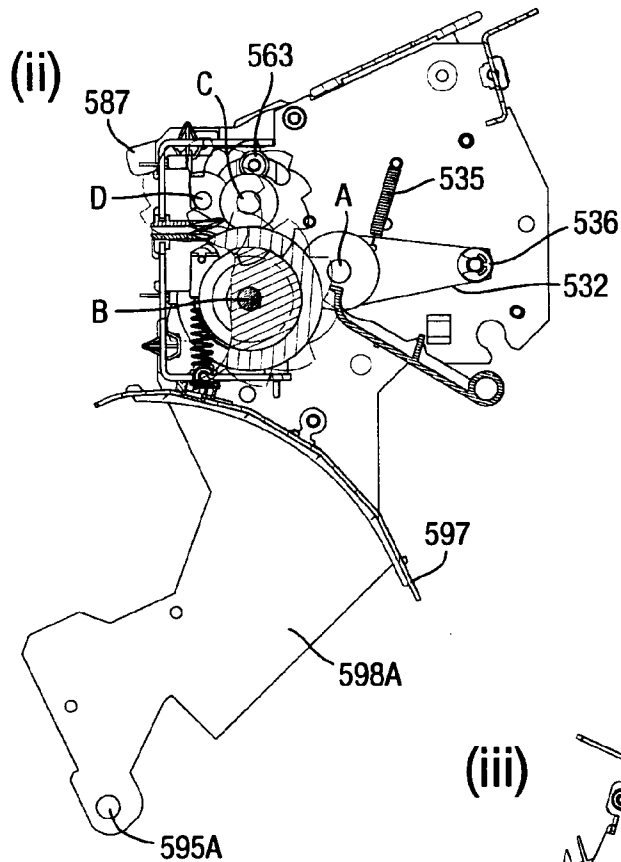
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Fig.5G.



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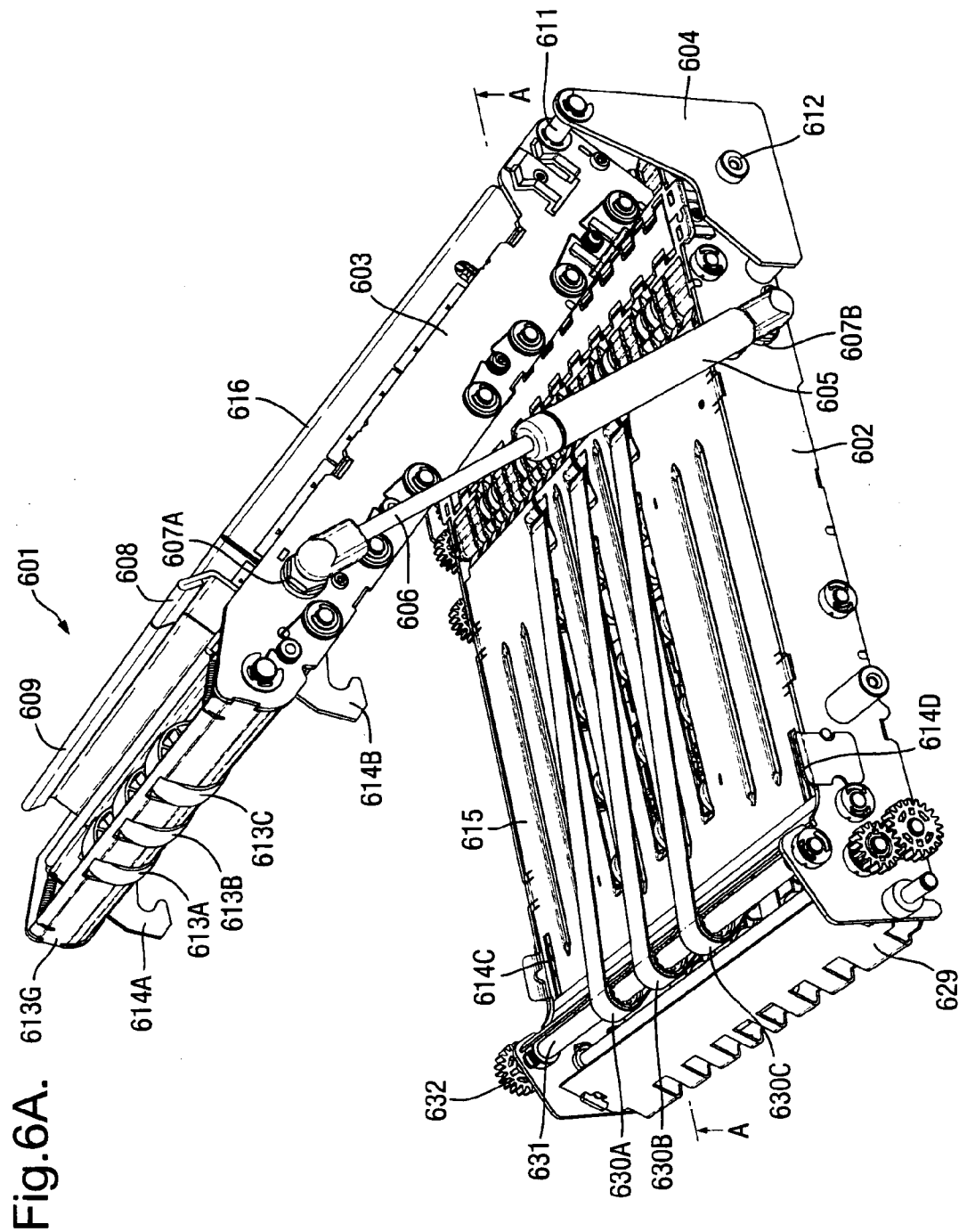


Fig. 6A.

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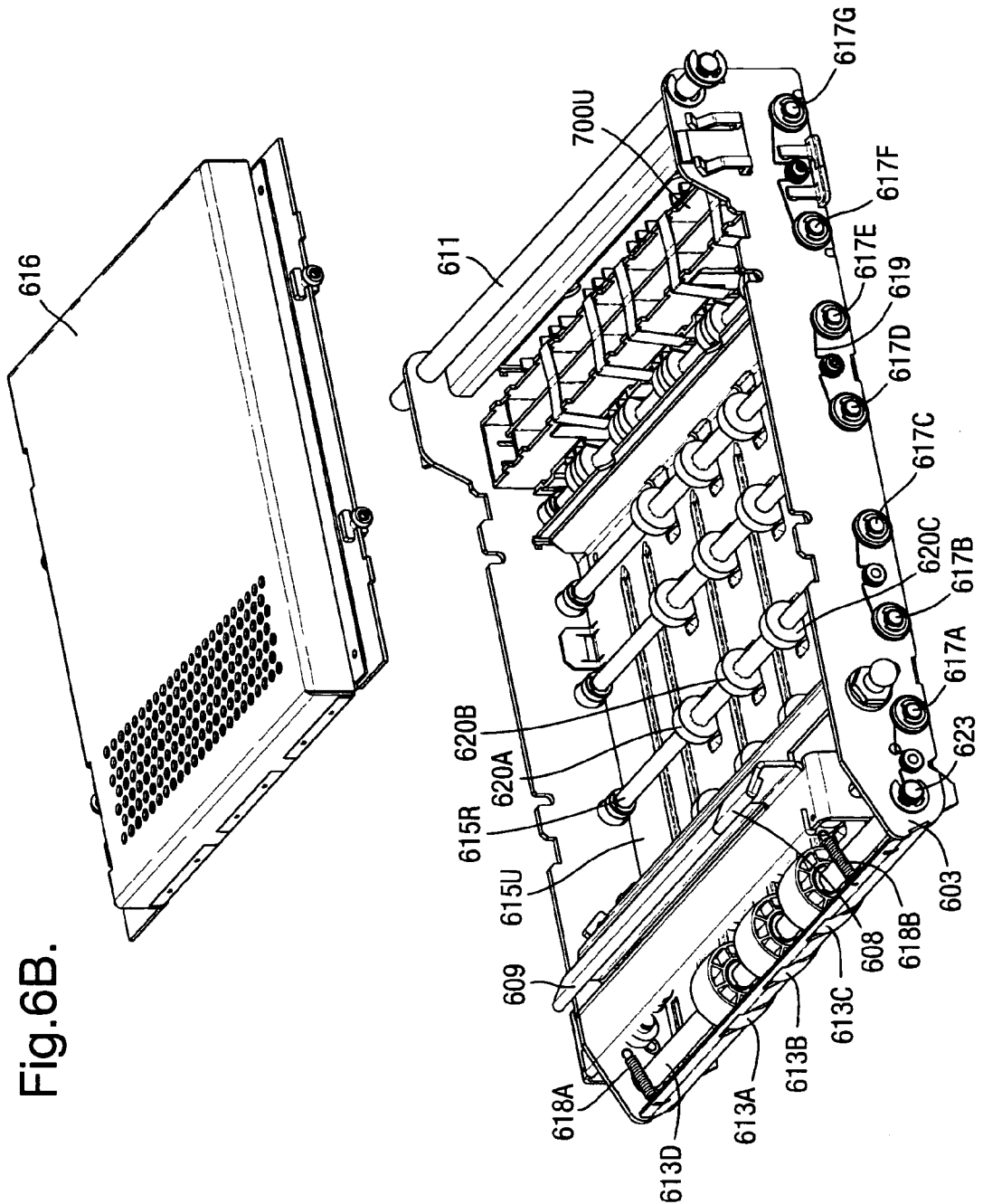
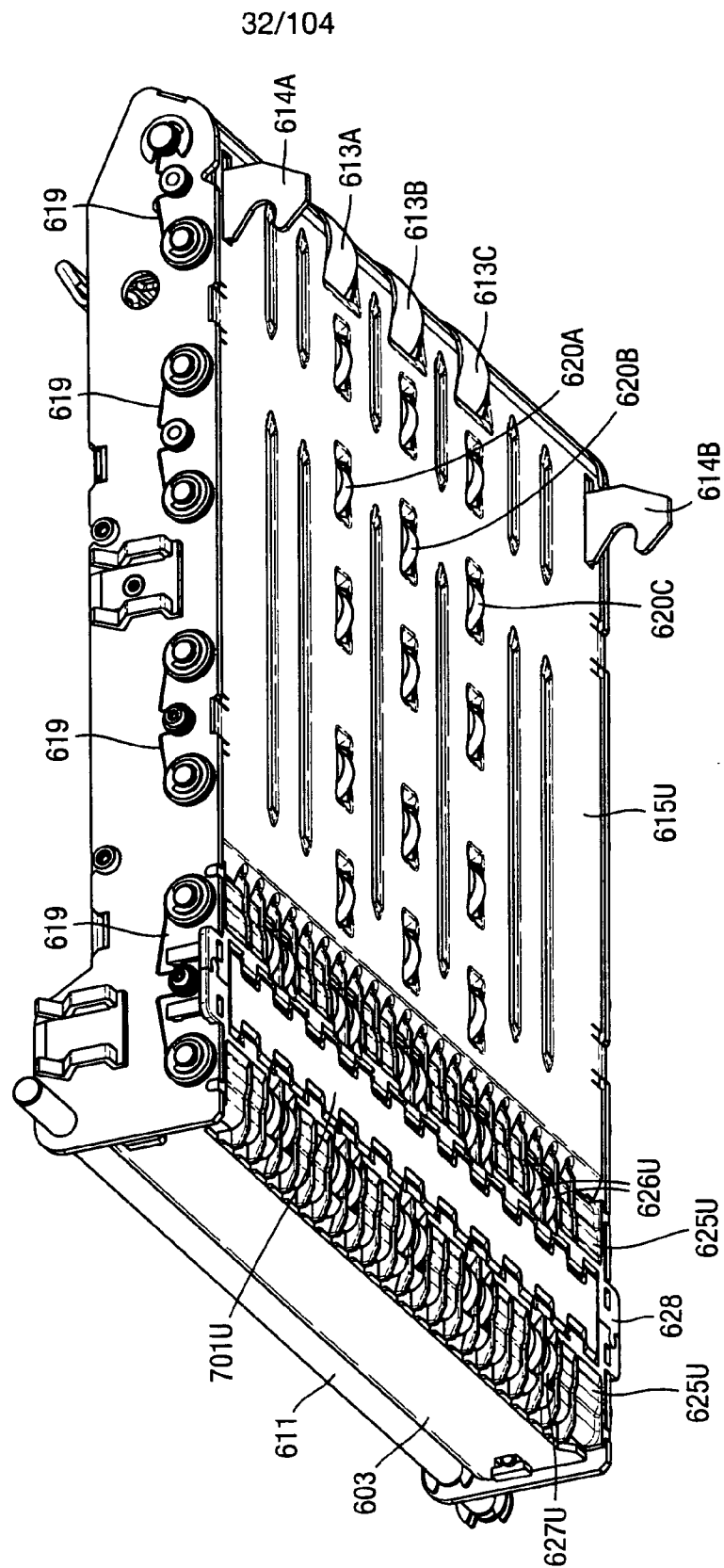


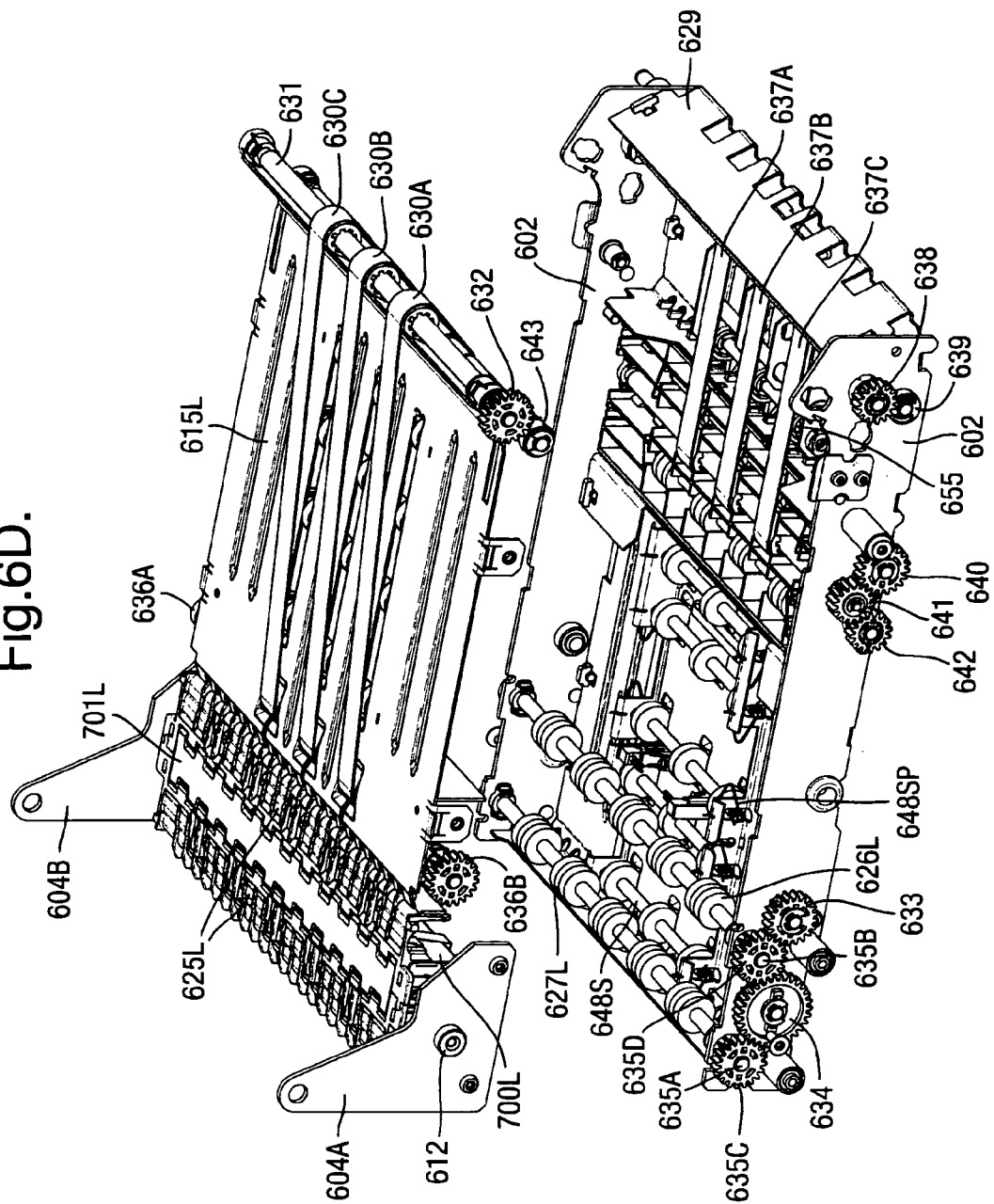
Fig. 6B.

Fig.6C.

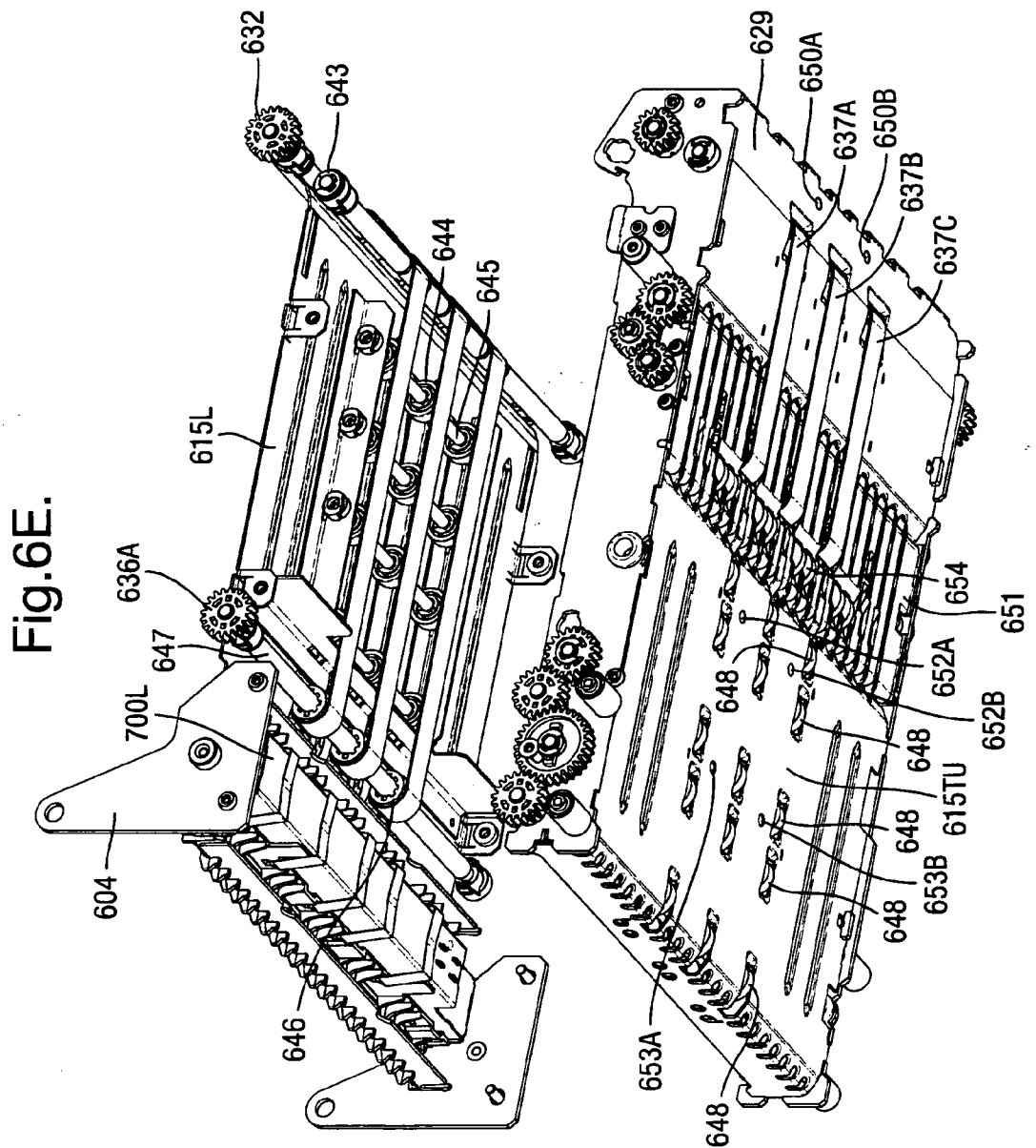


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Fig.6D.

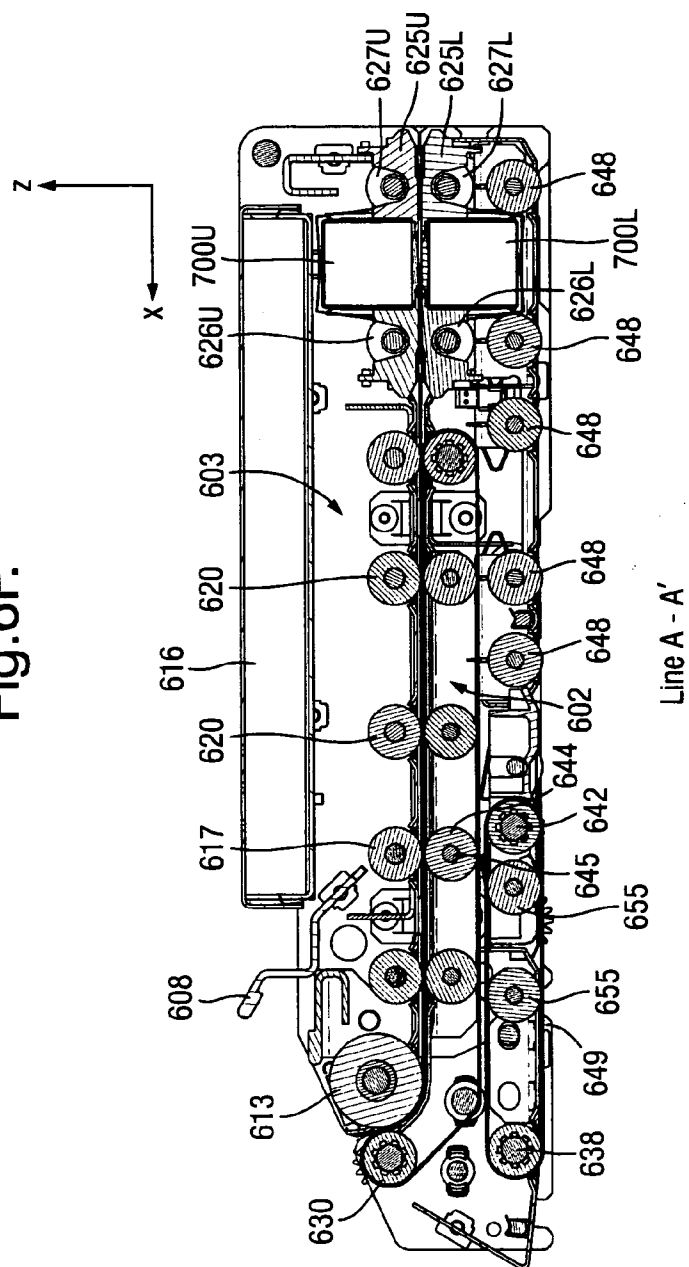


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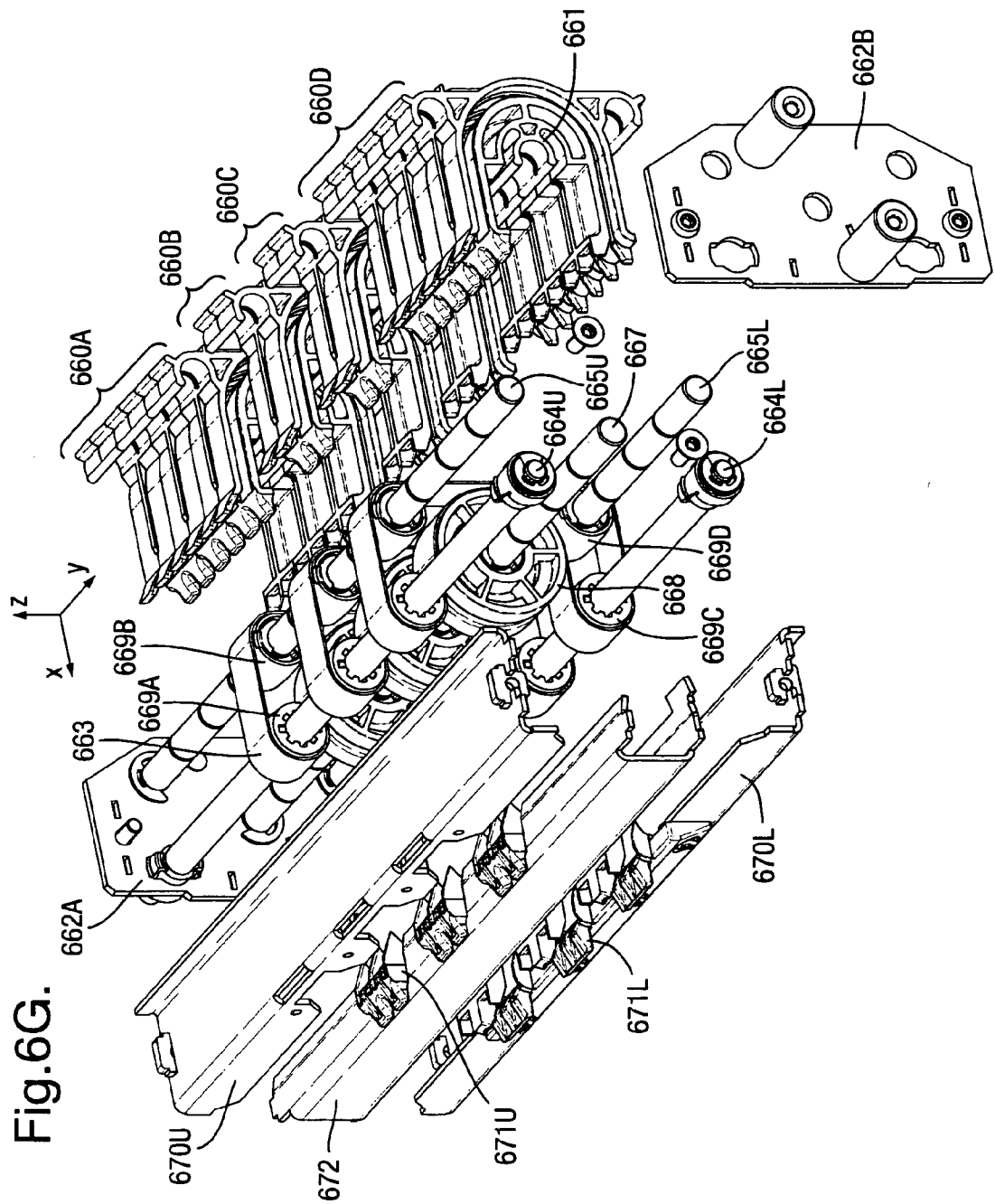


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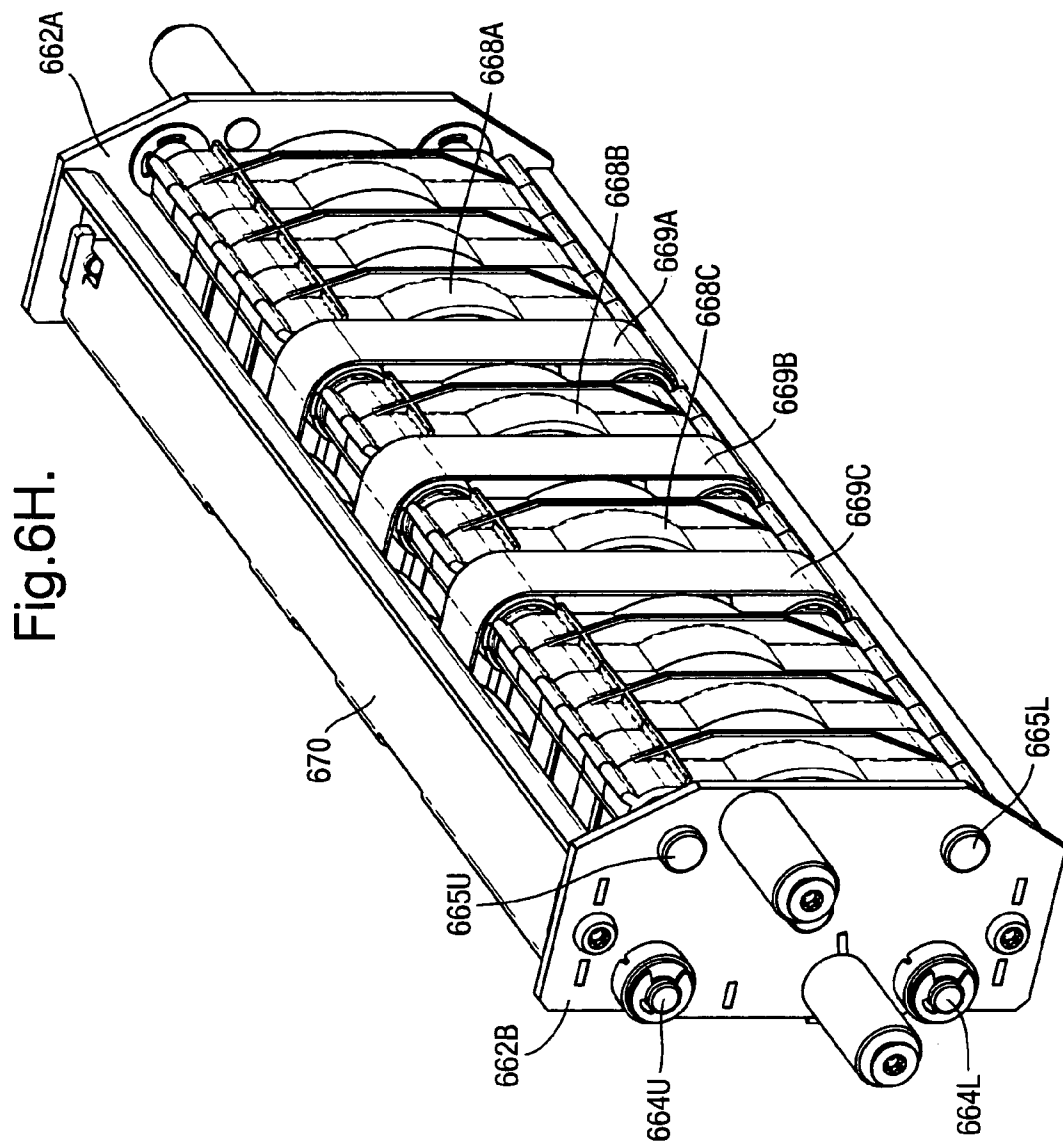
Fig. 6F.



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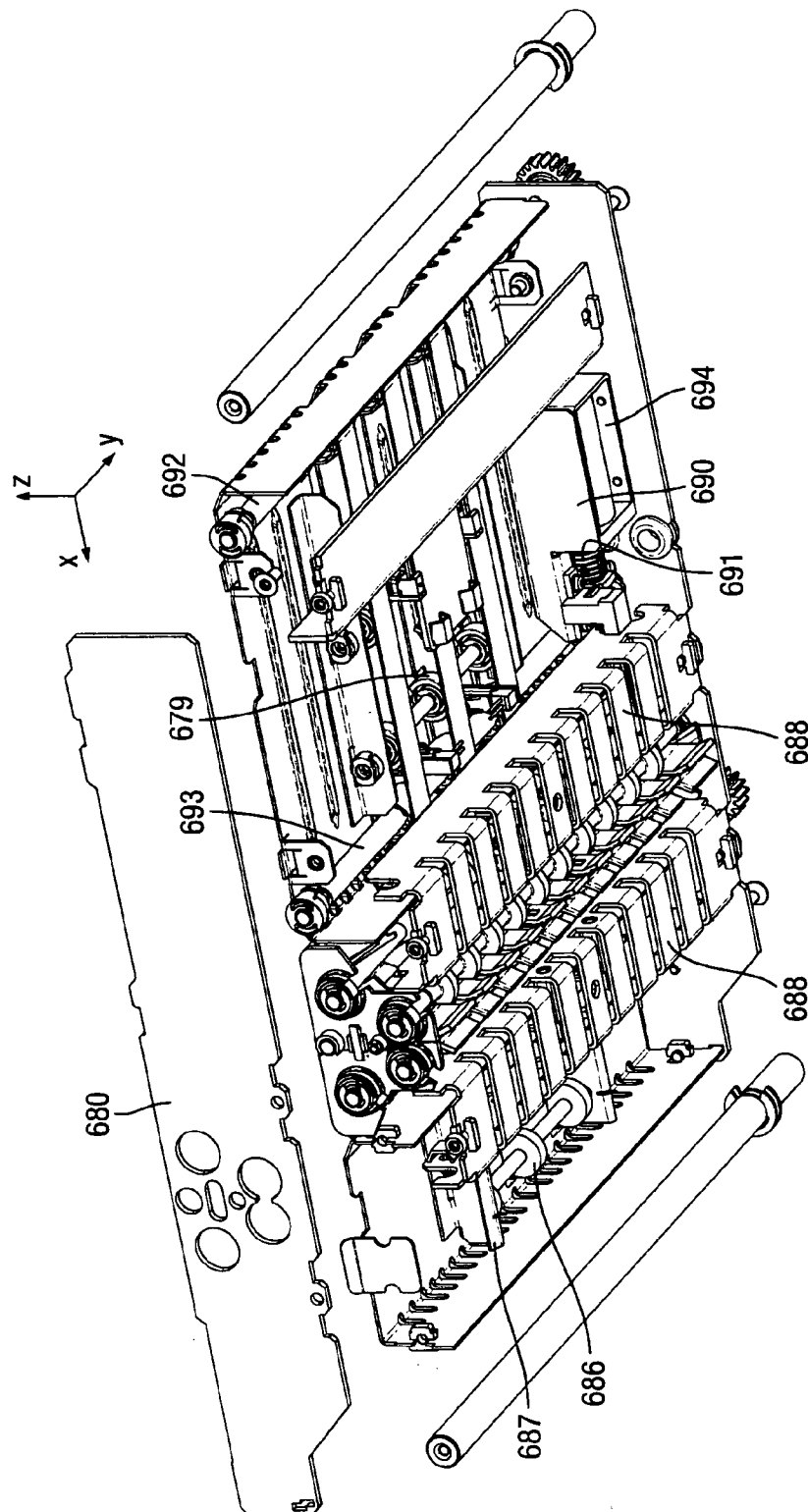


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Fig.6I.



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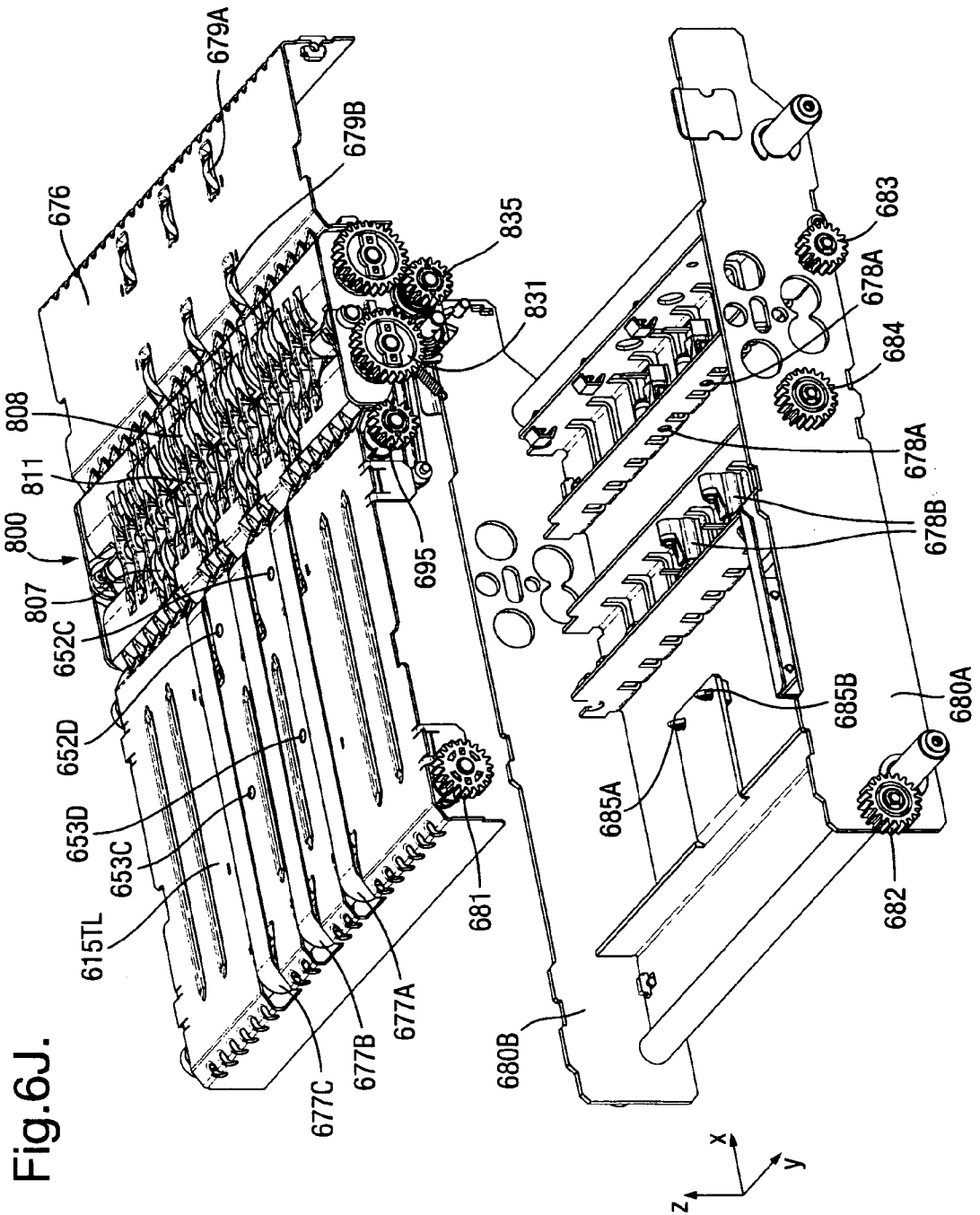
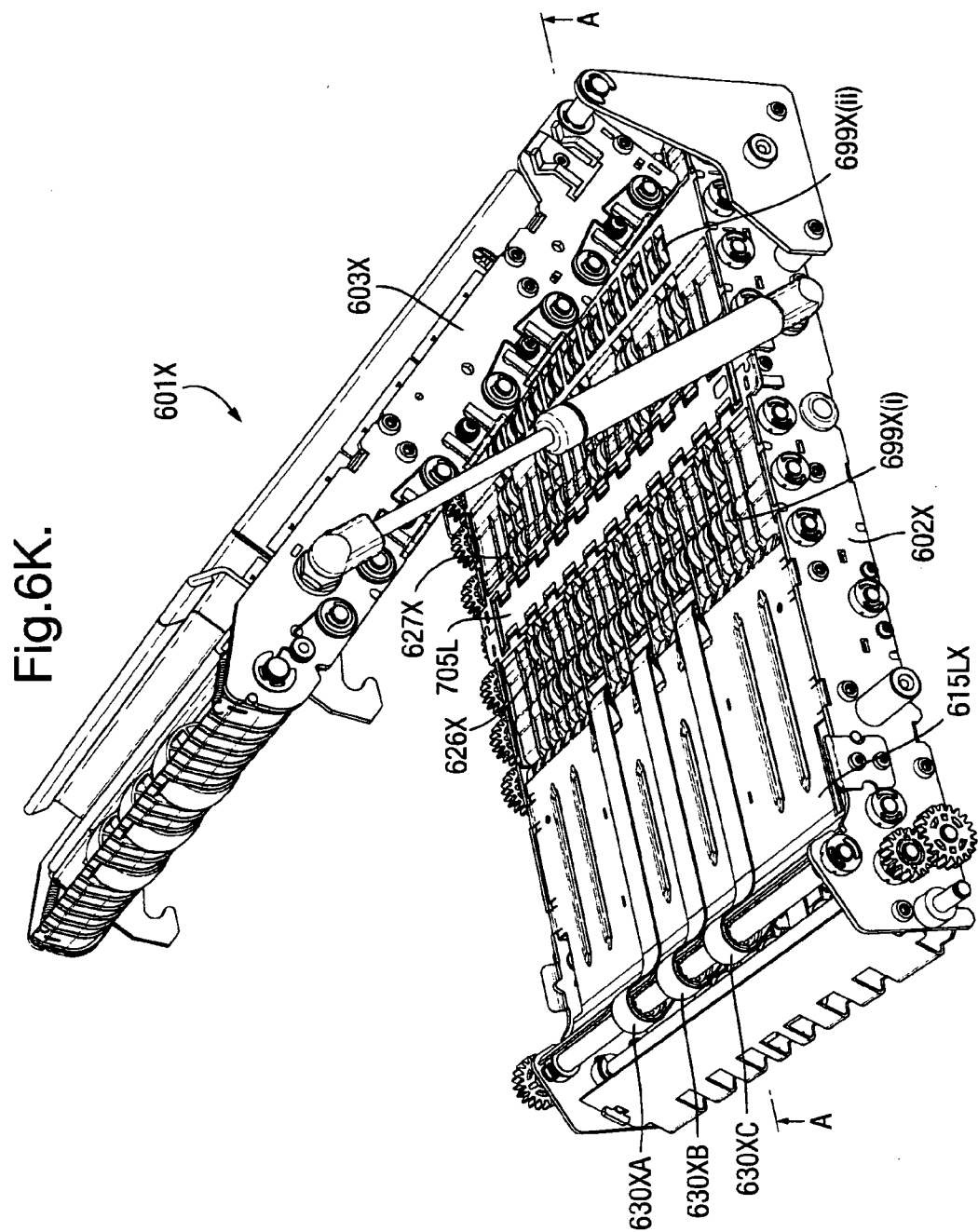
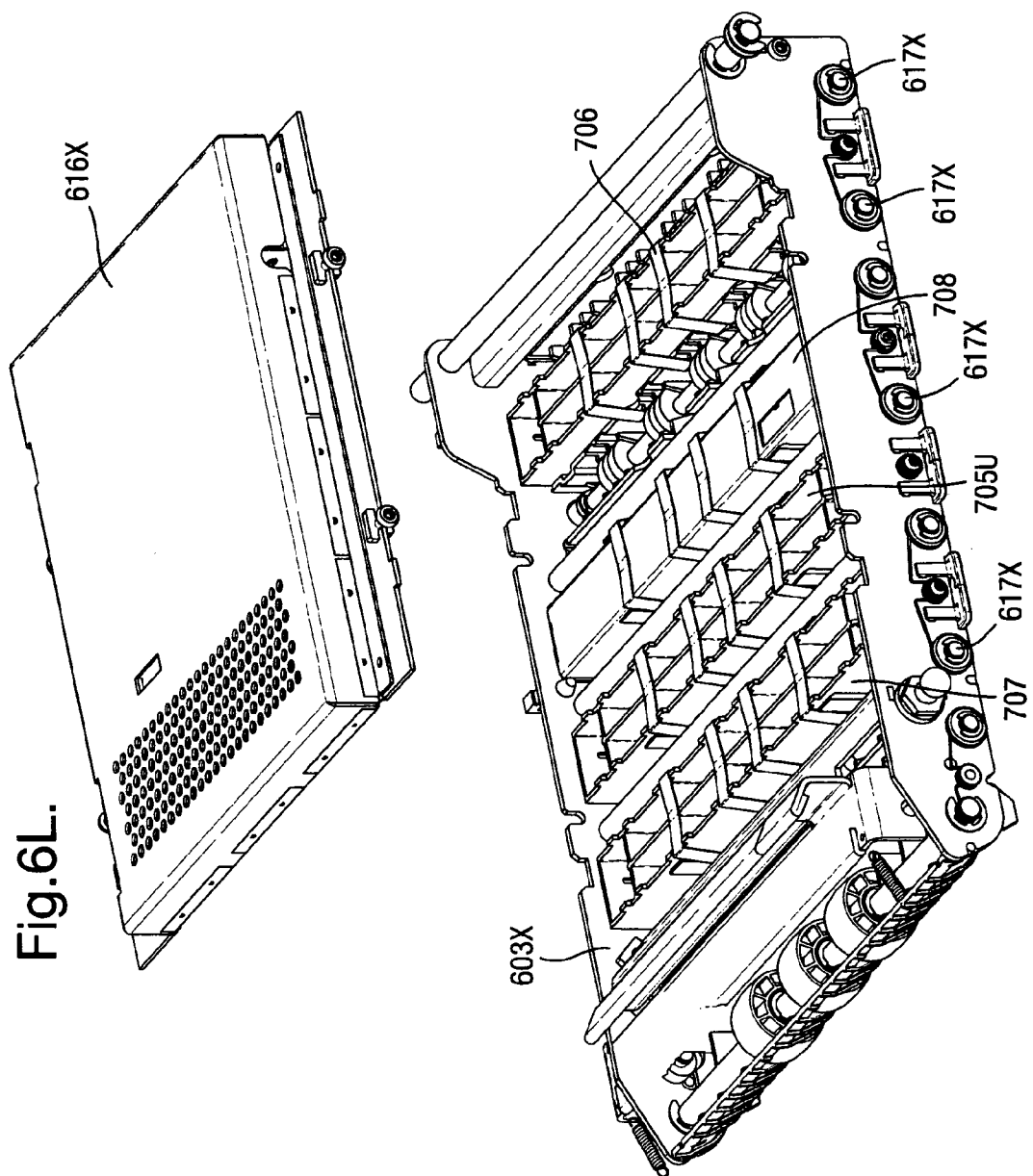


Fig. 6J.

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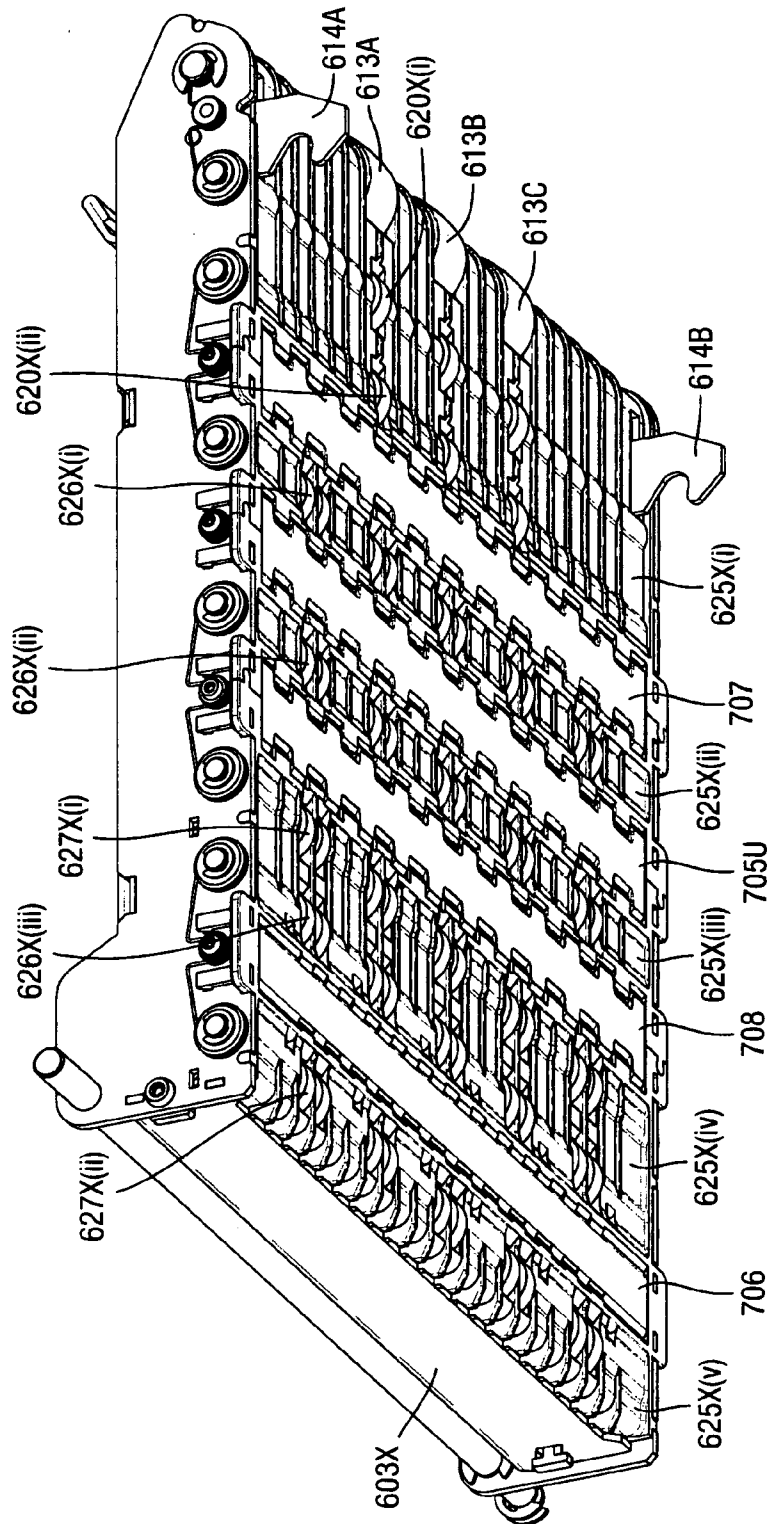


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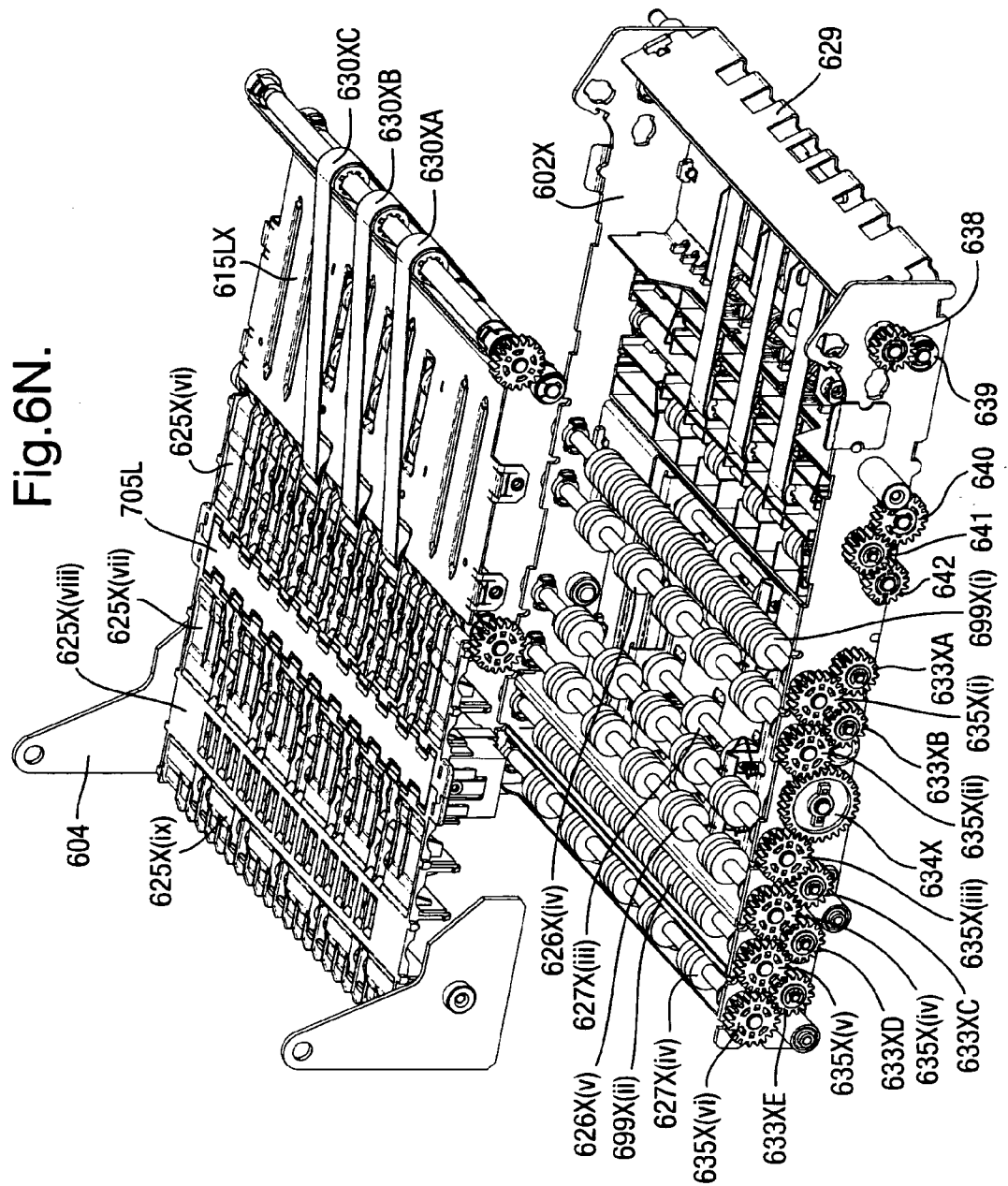


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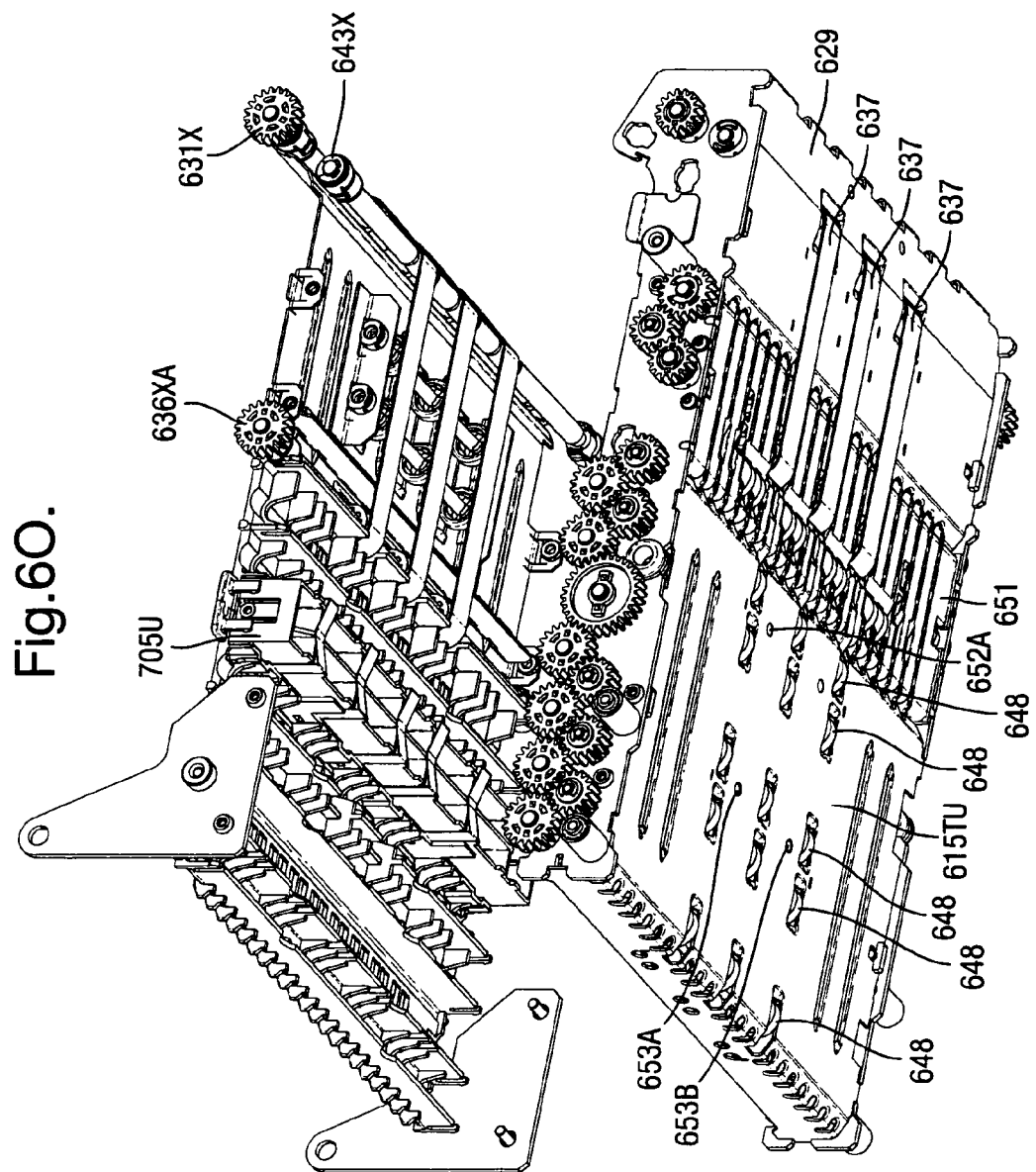
Fig.6M.

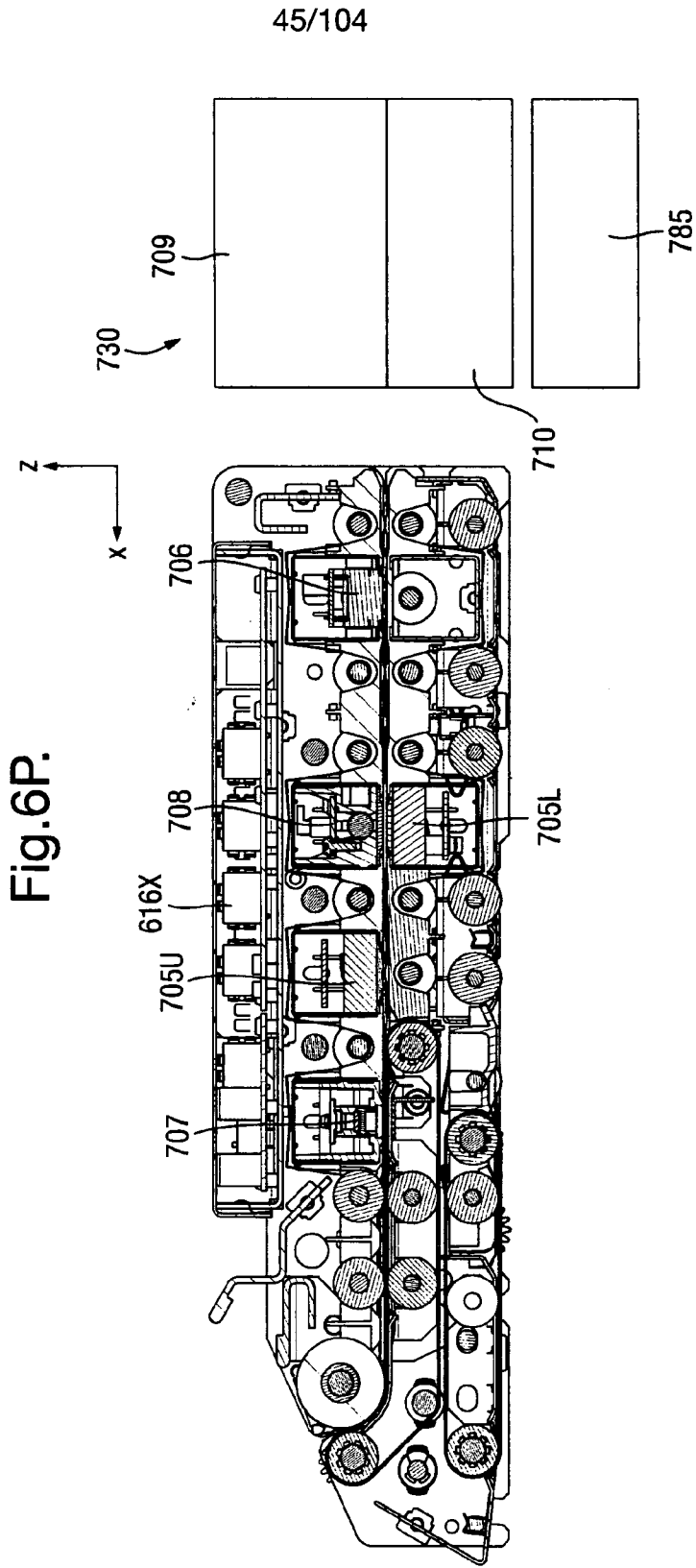


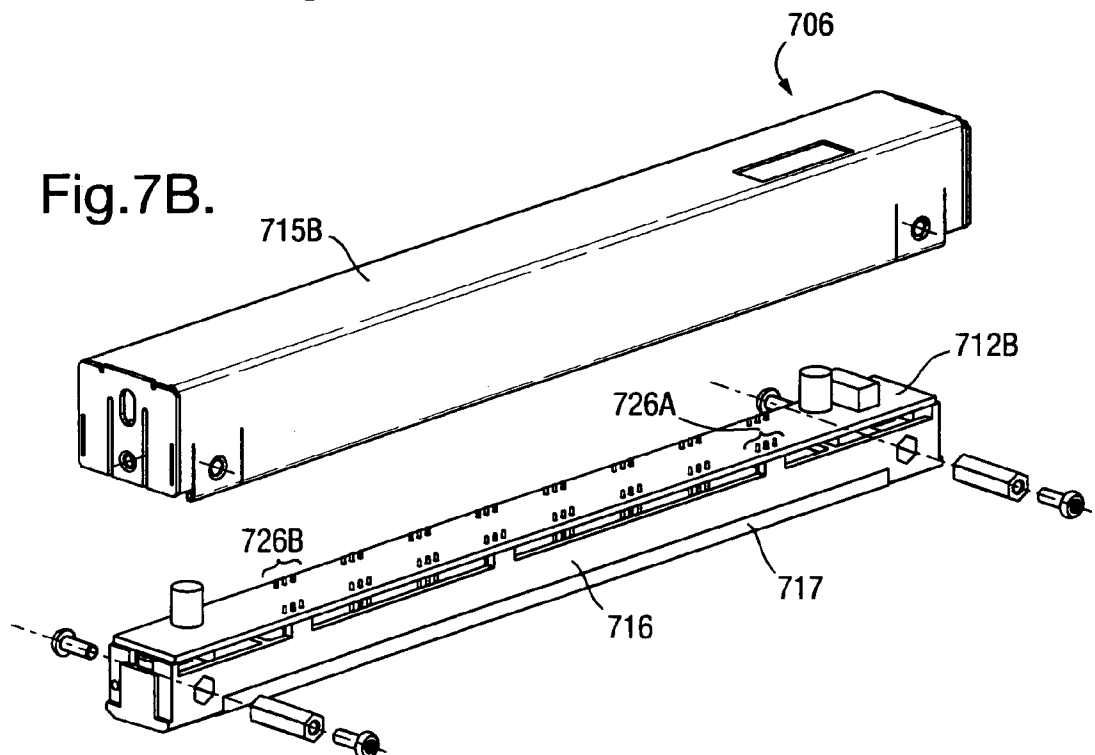
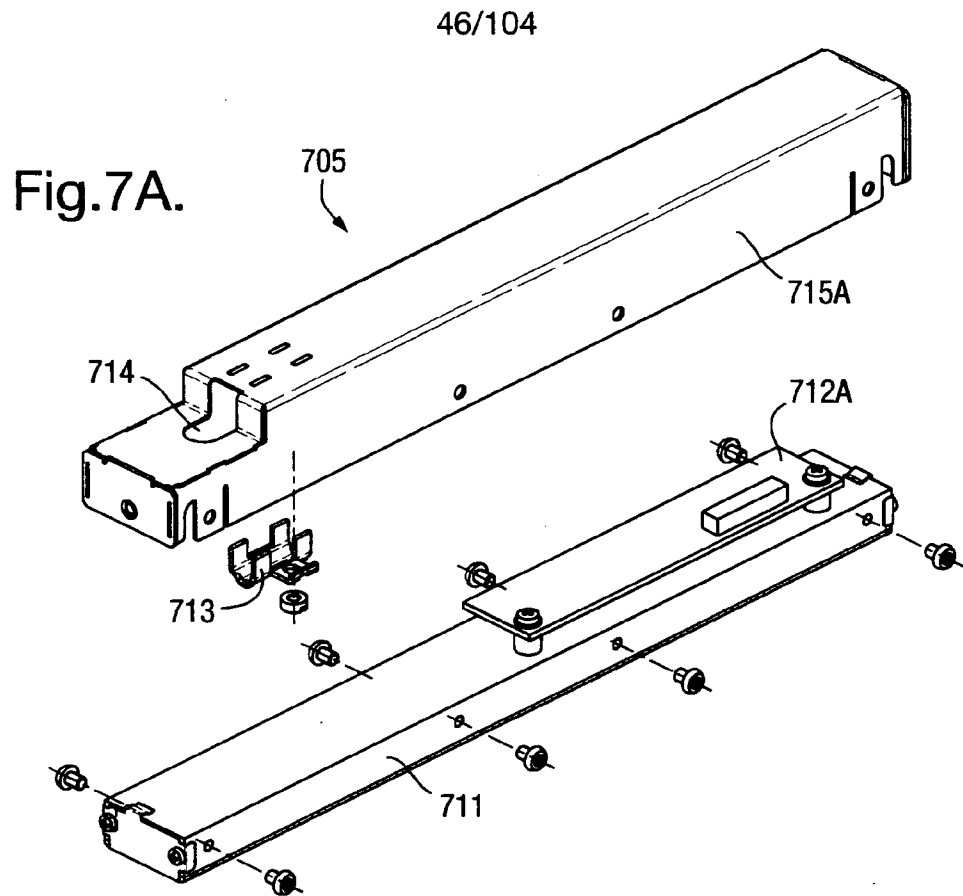
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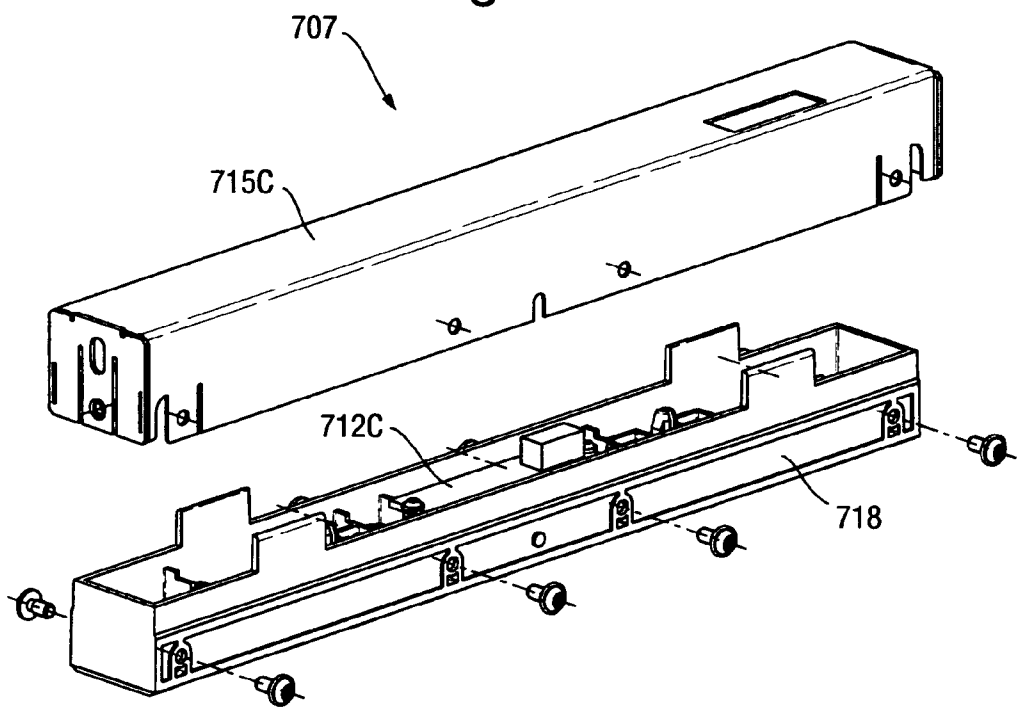






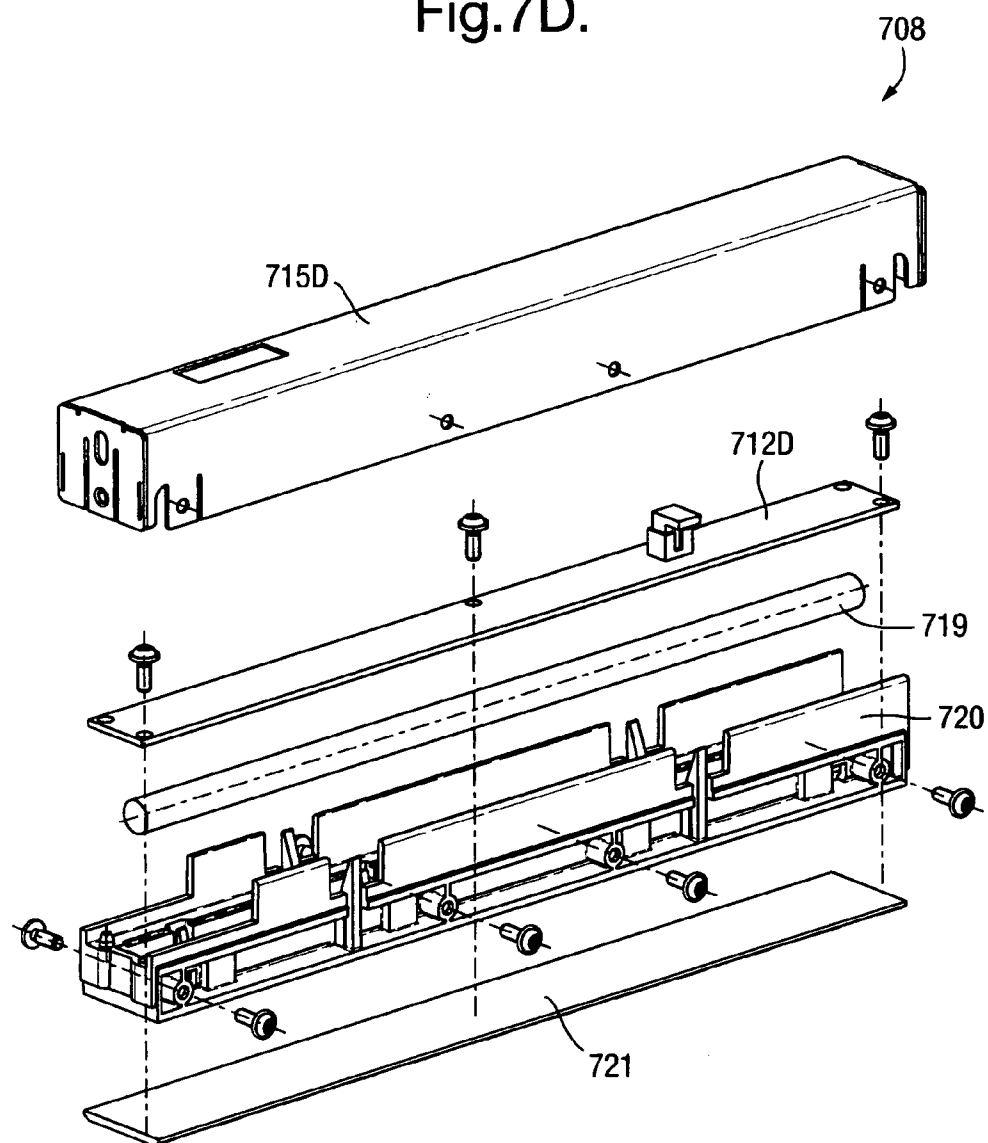
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Fig.7C.



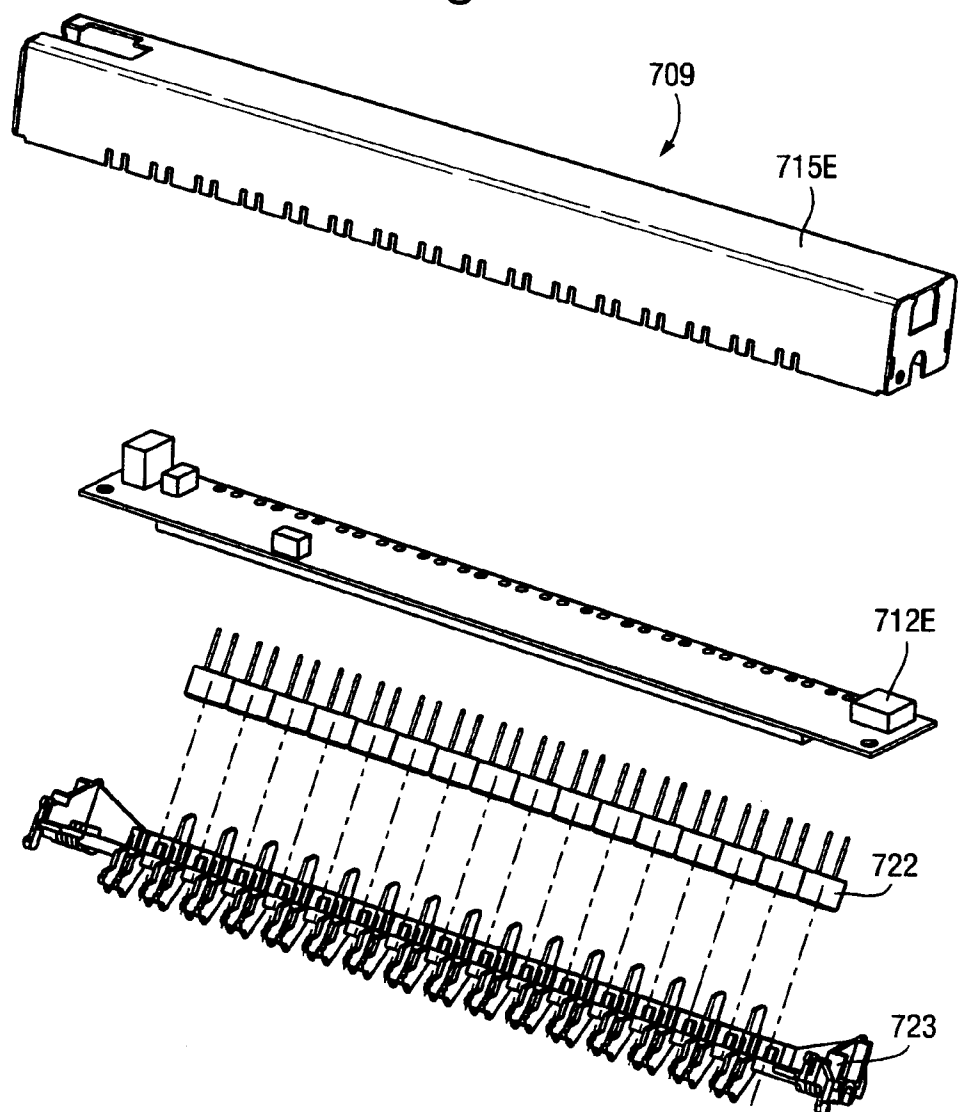
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Fig.7D.



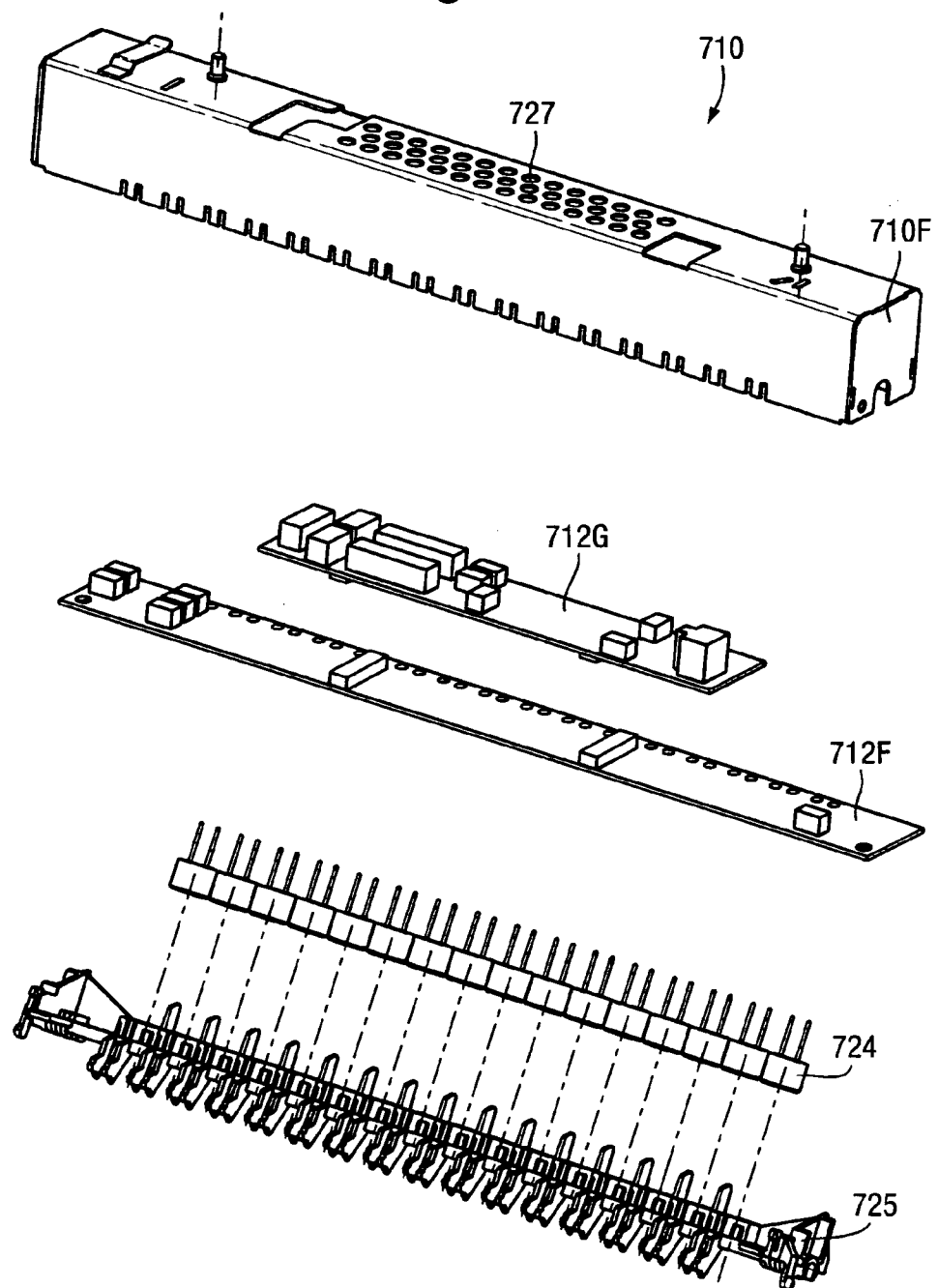
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Fig.7E.



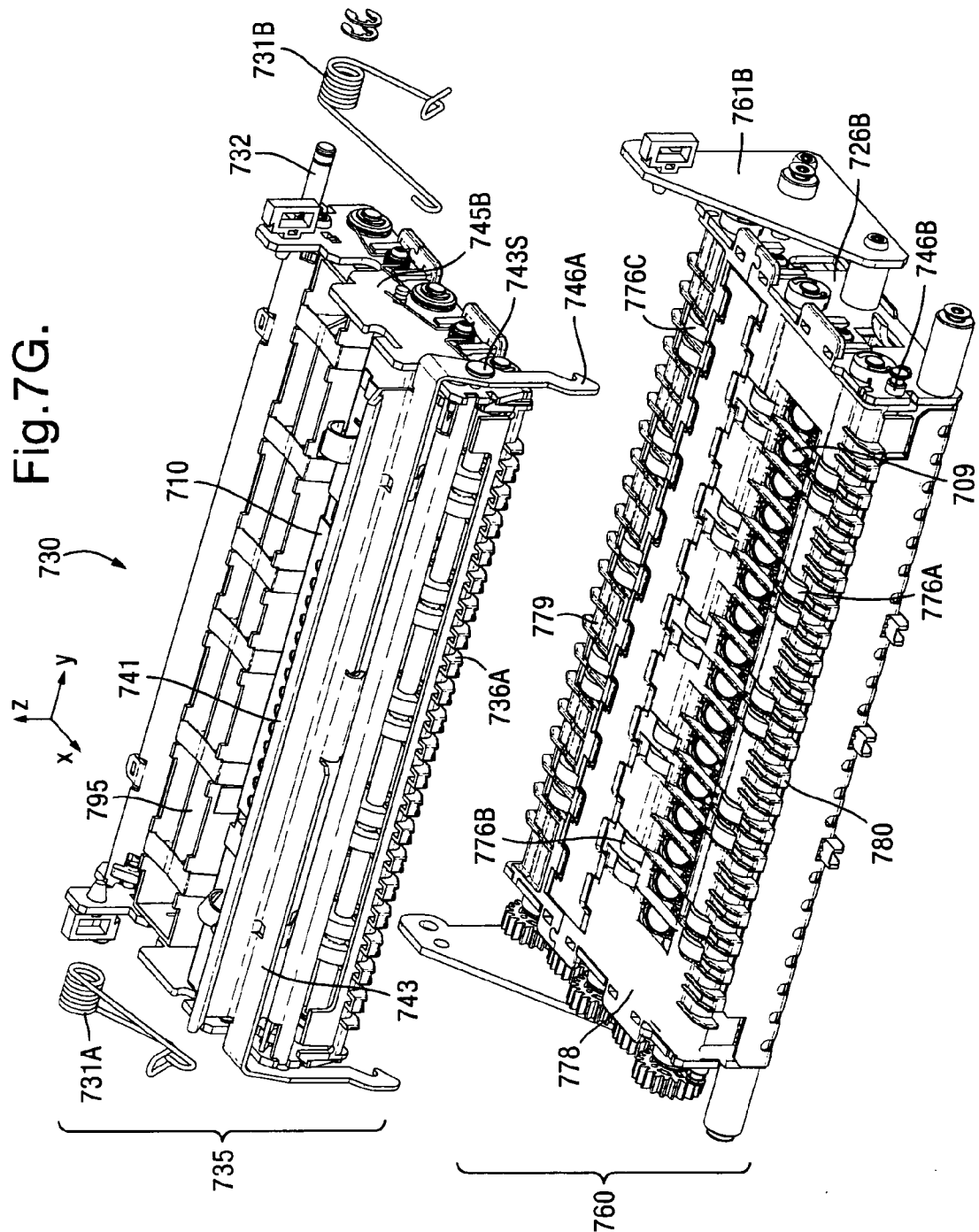
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Fig.7F.

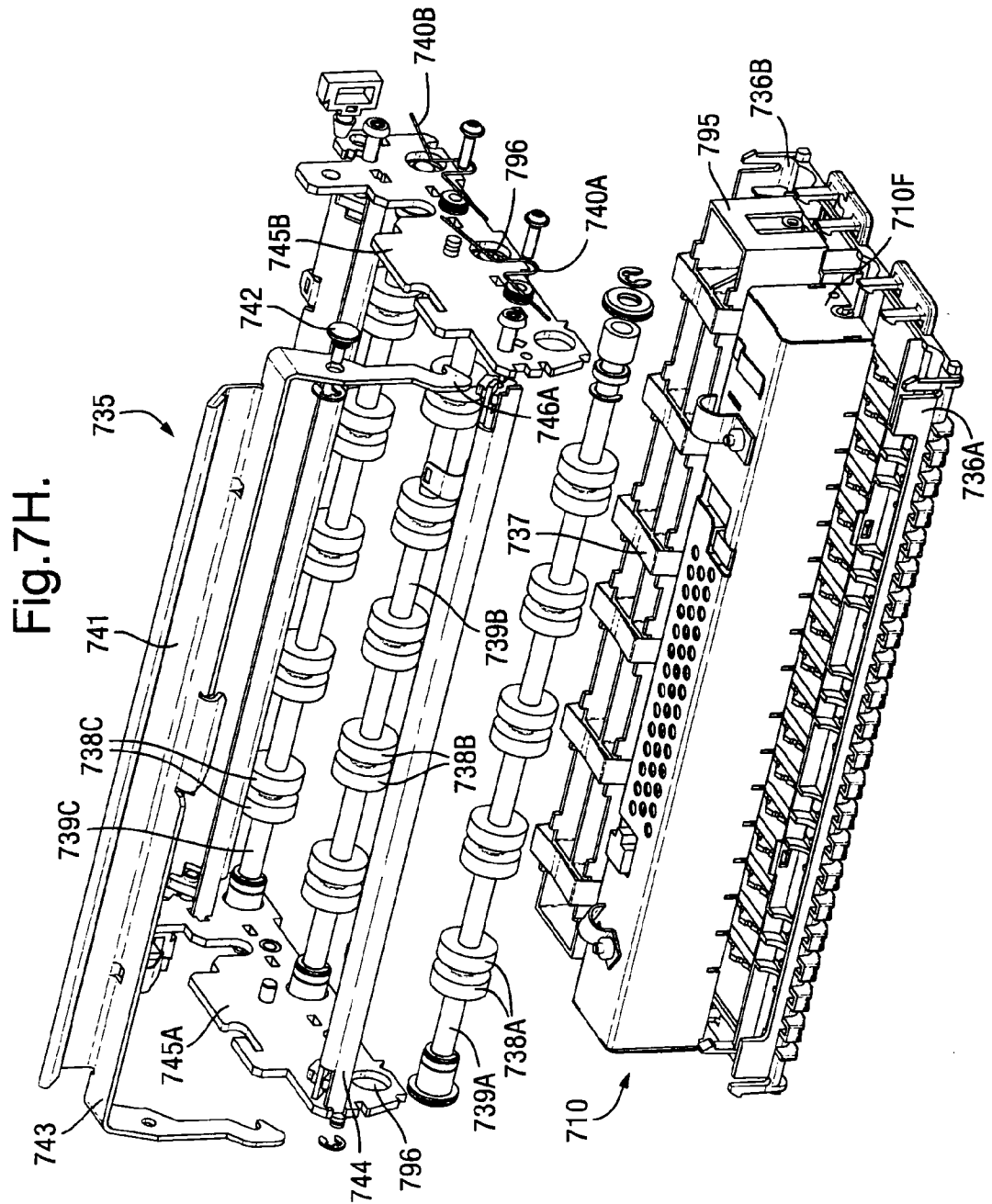


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Fig. 7G.



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Fig.7I.

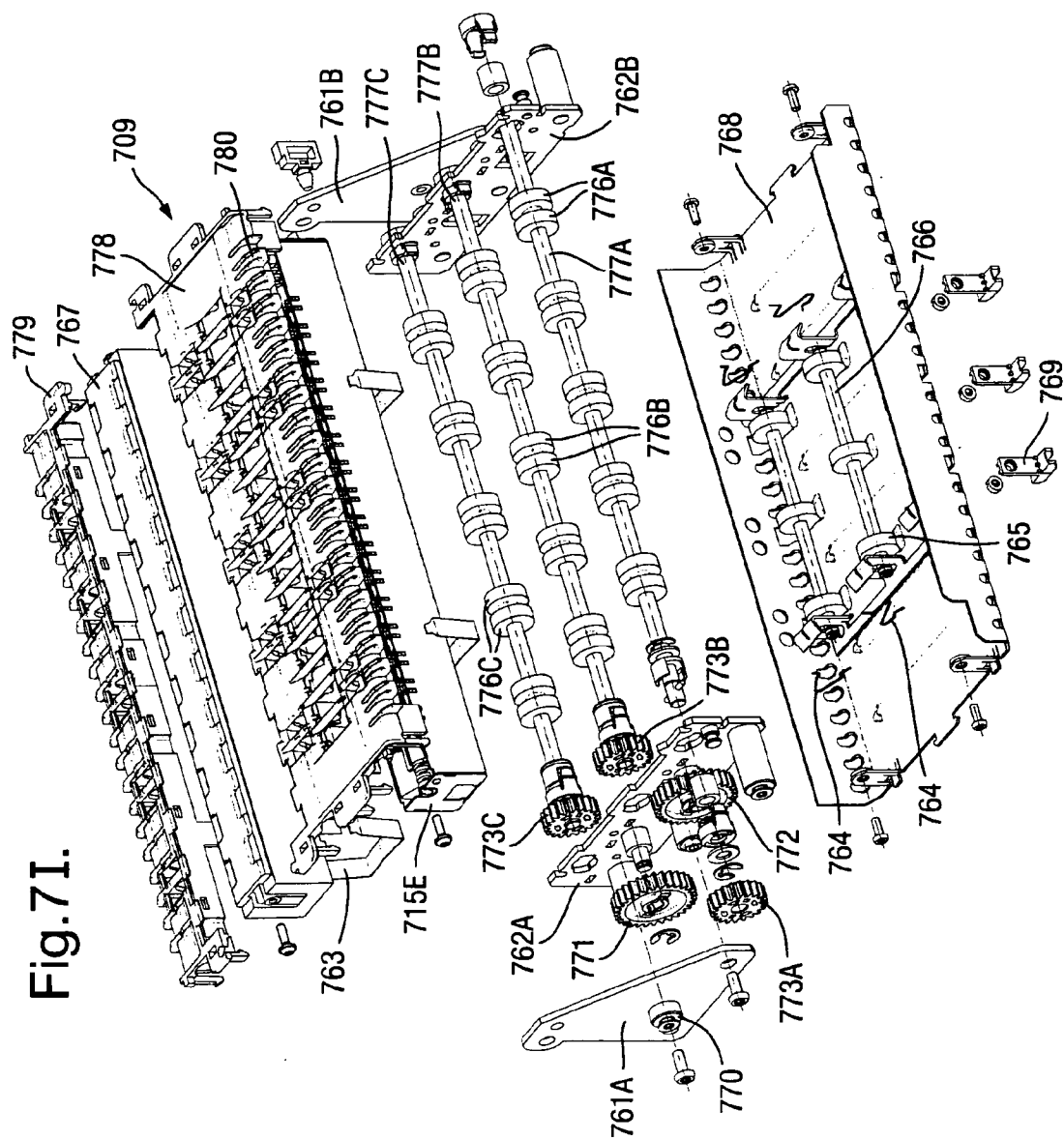
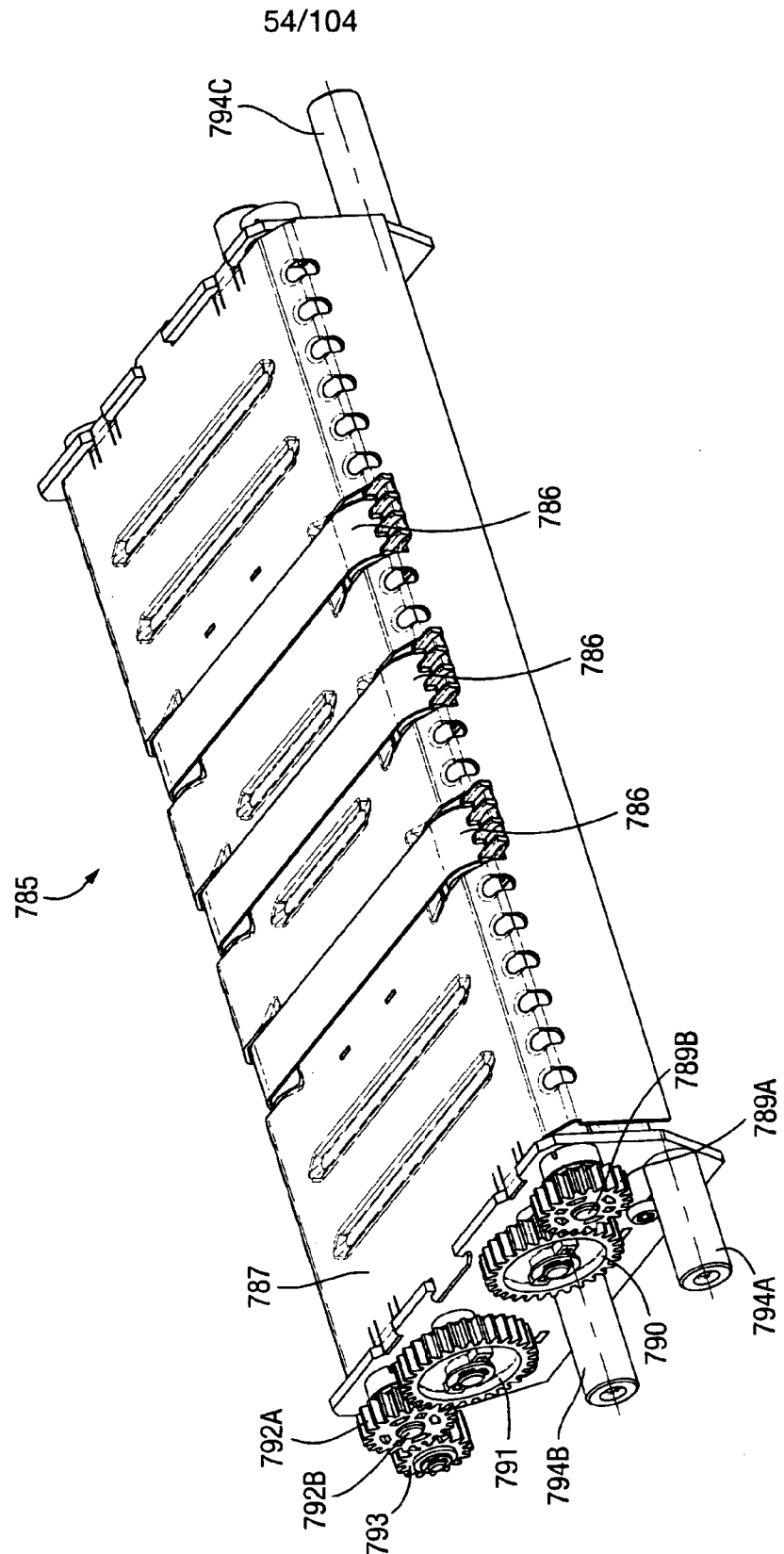
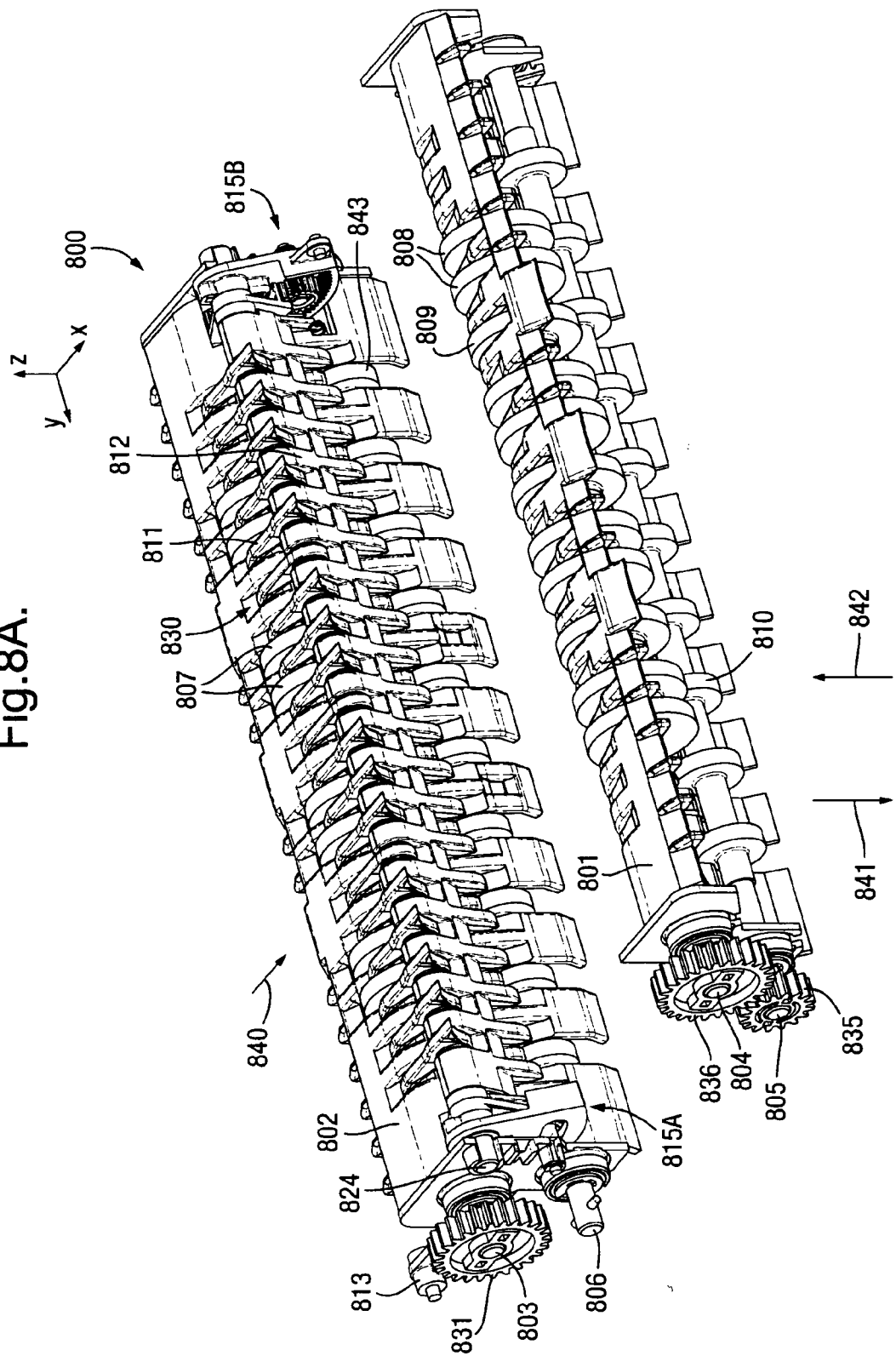


Fig.7J.

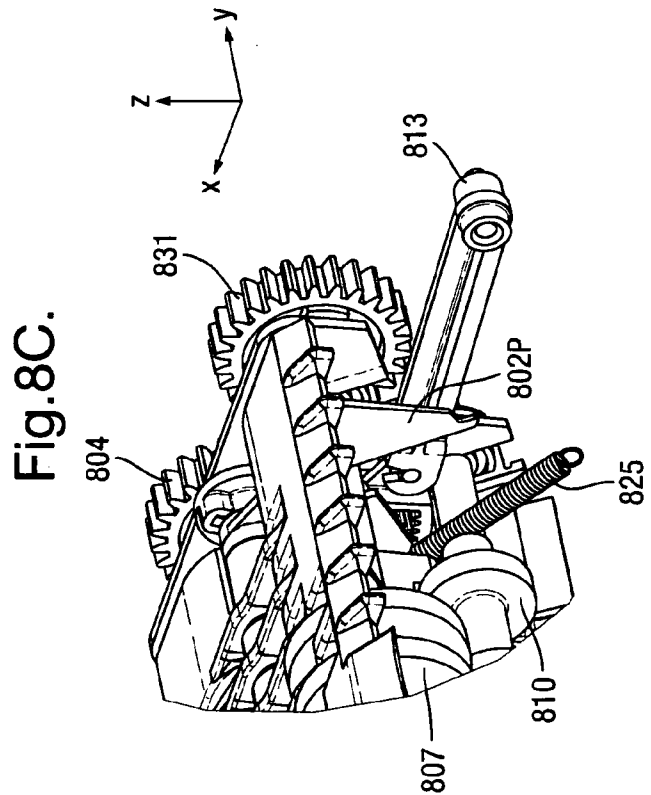
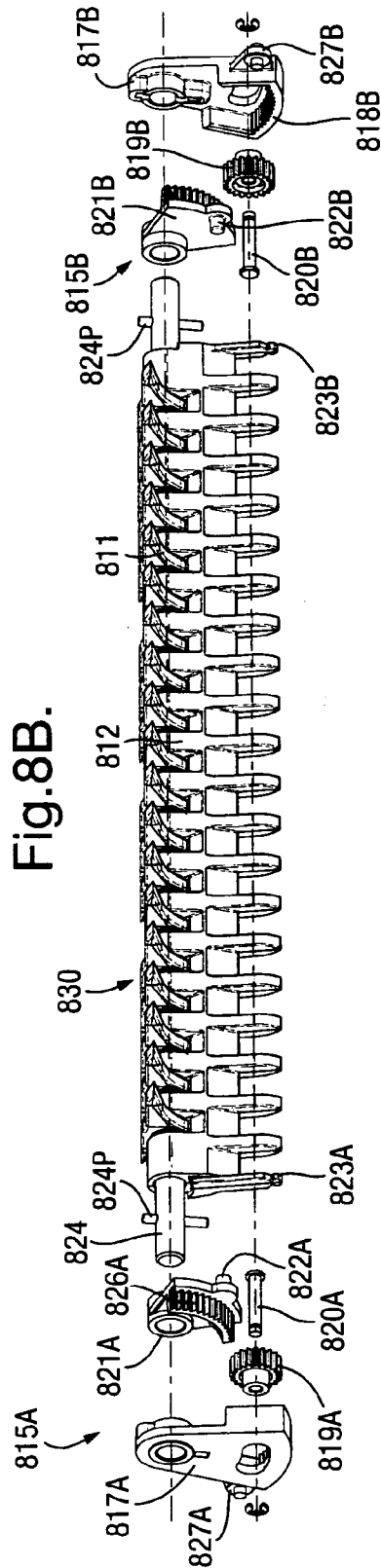


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Fig.8A.



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Fig.8D.

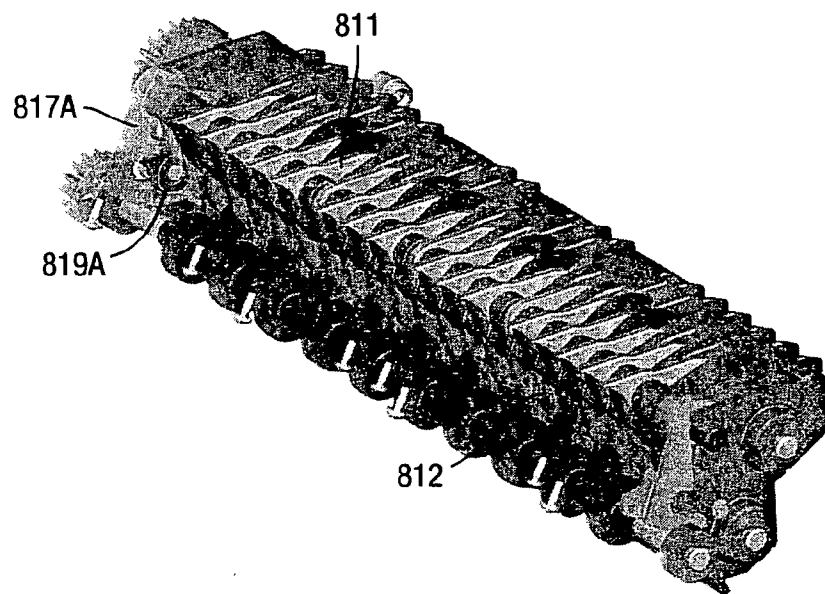
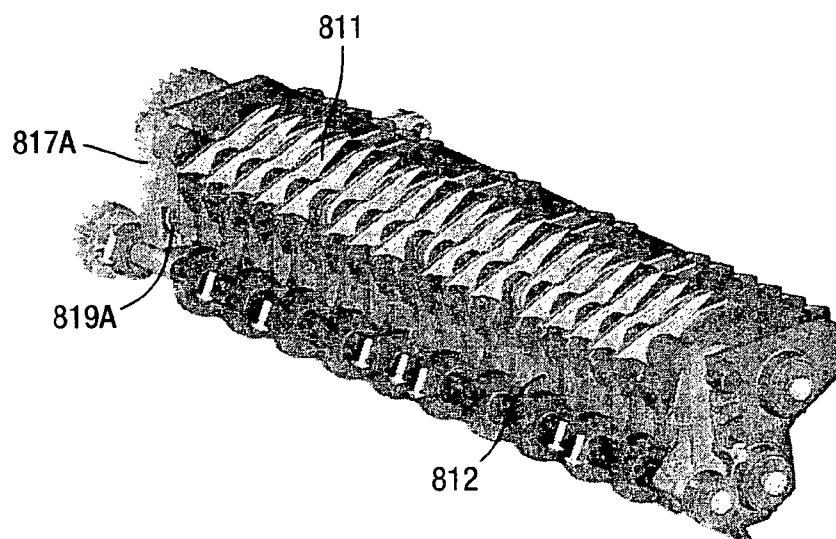
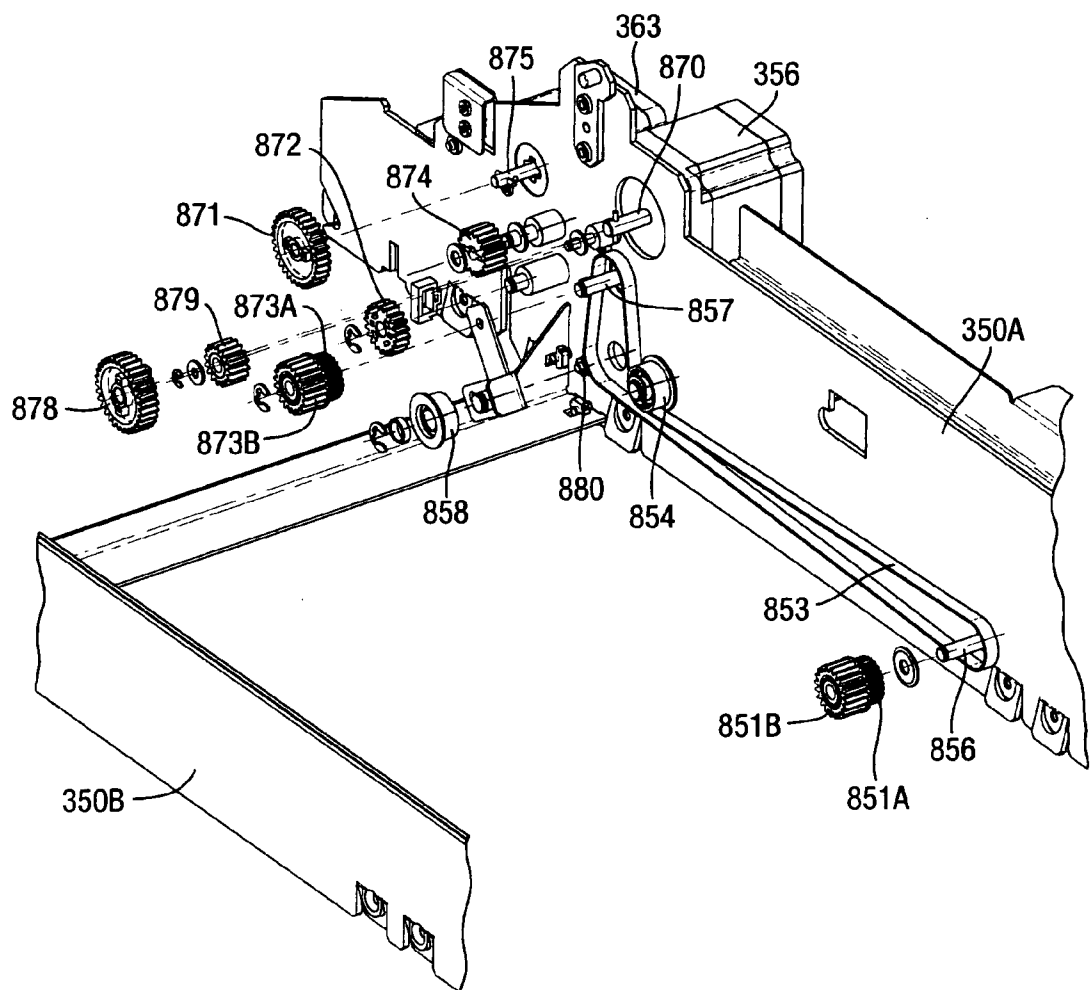


Fig.8E.



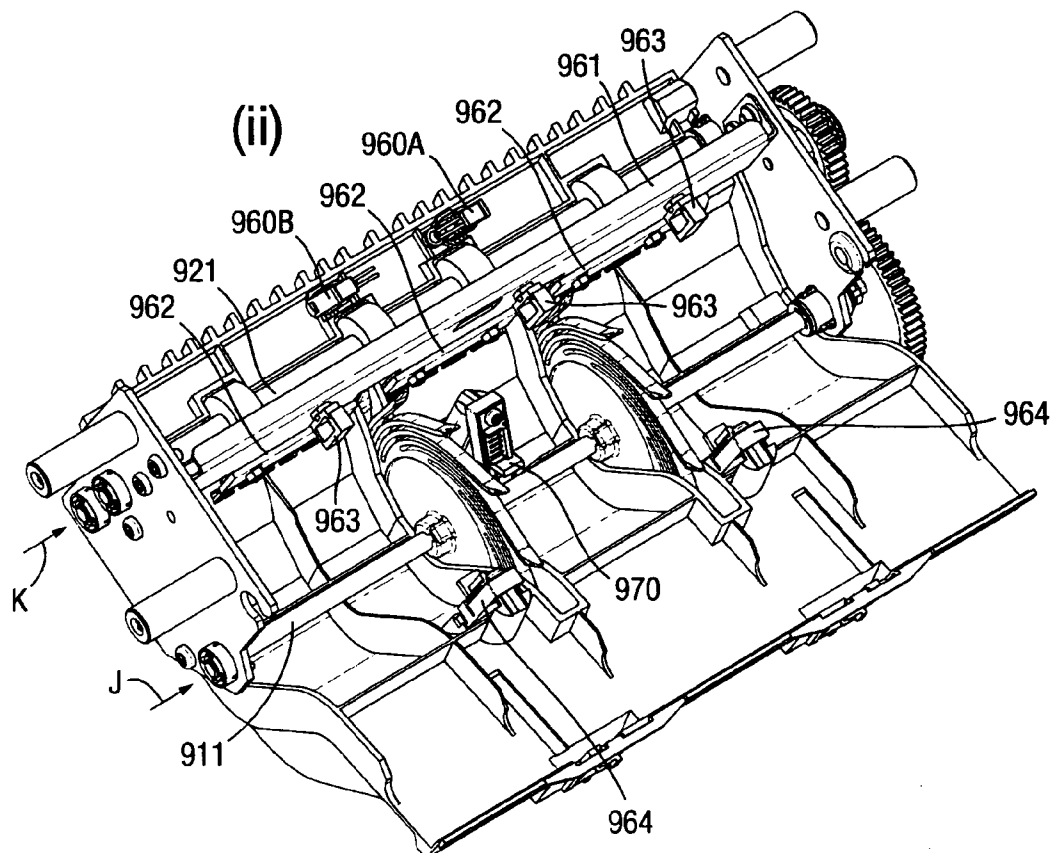
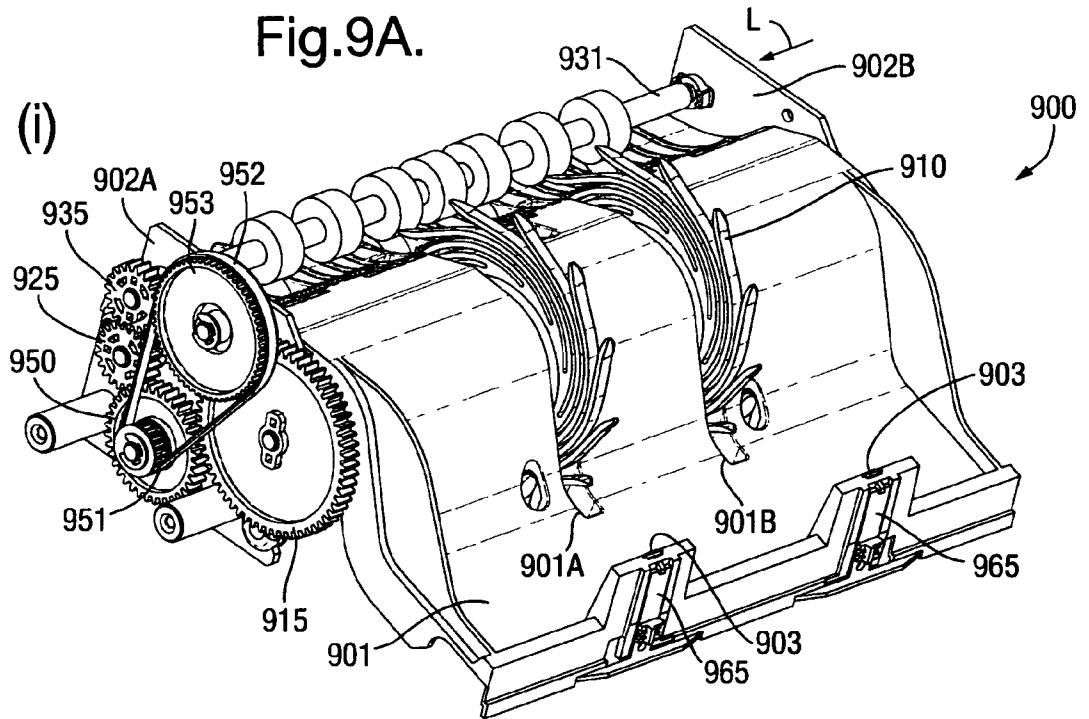
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Fig.8F.



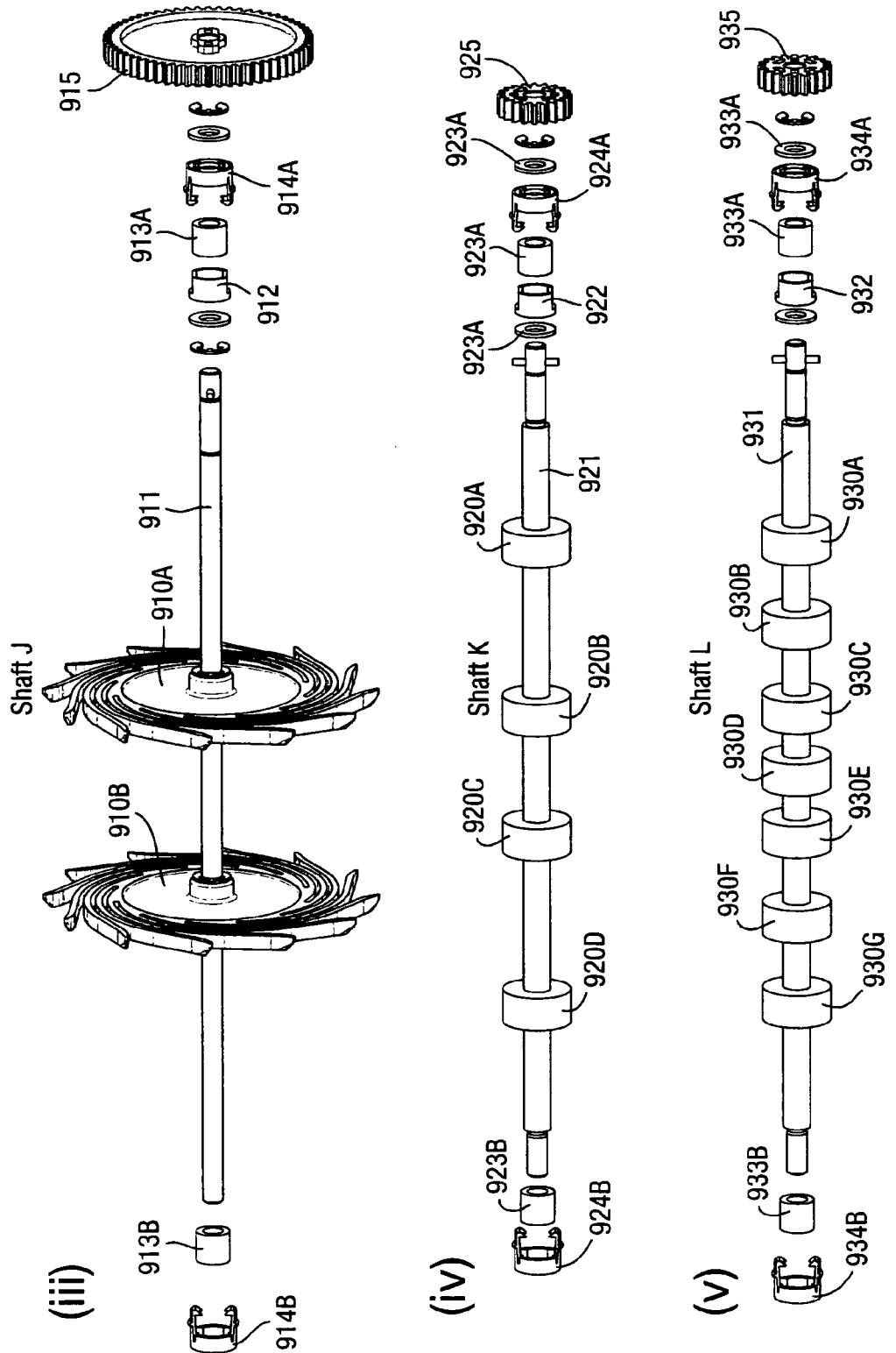
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Fig.9A.



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Fig.9A.



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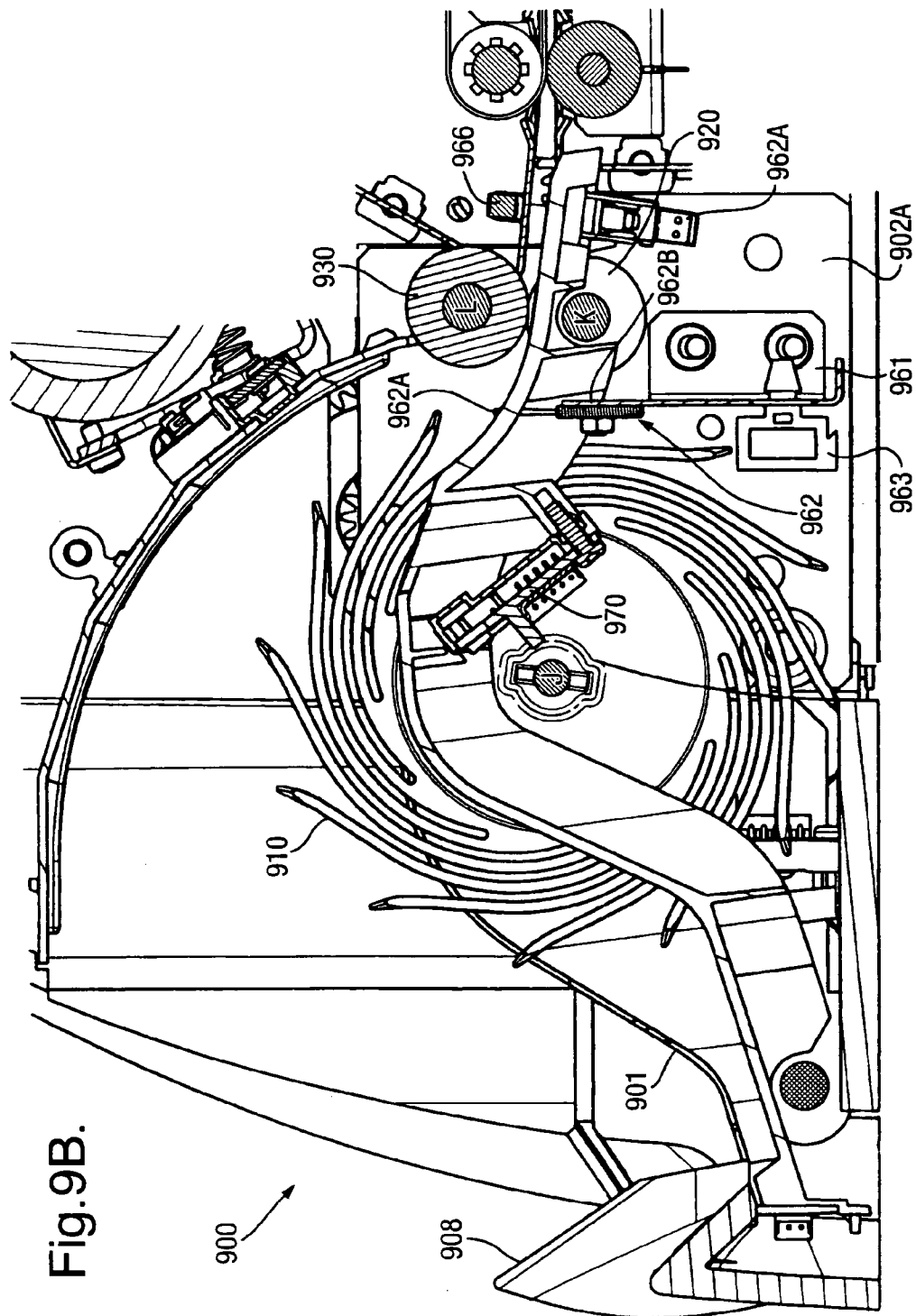


Fig. 9B.

Fig.9C(i).

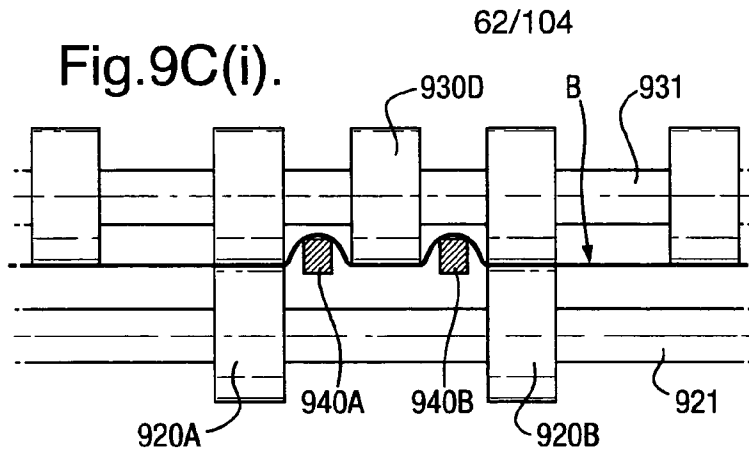
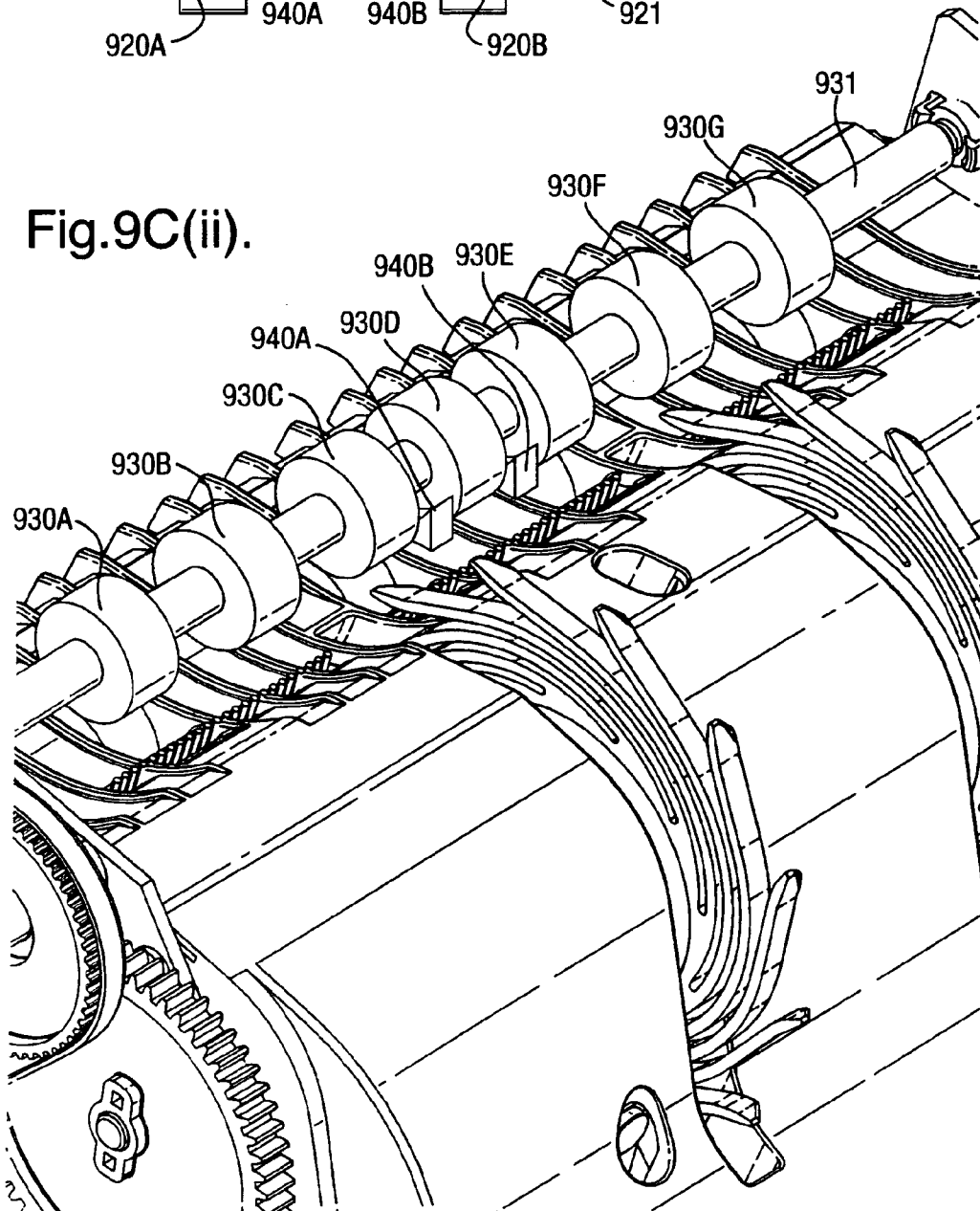


Fig.9C(ii).



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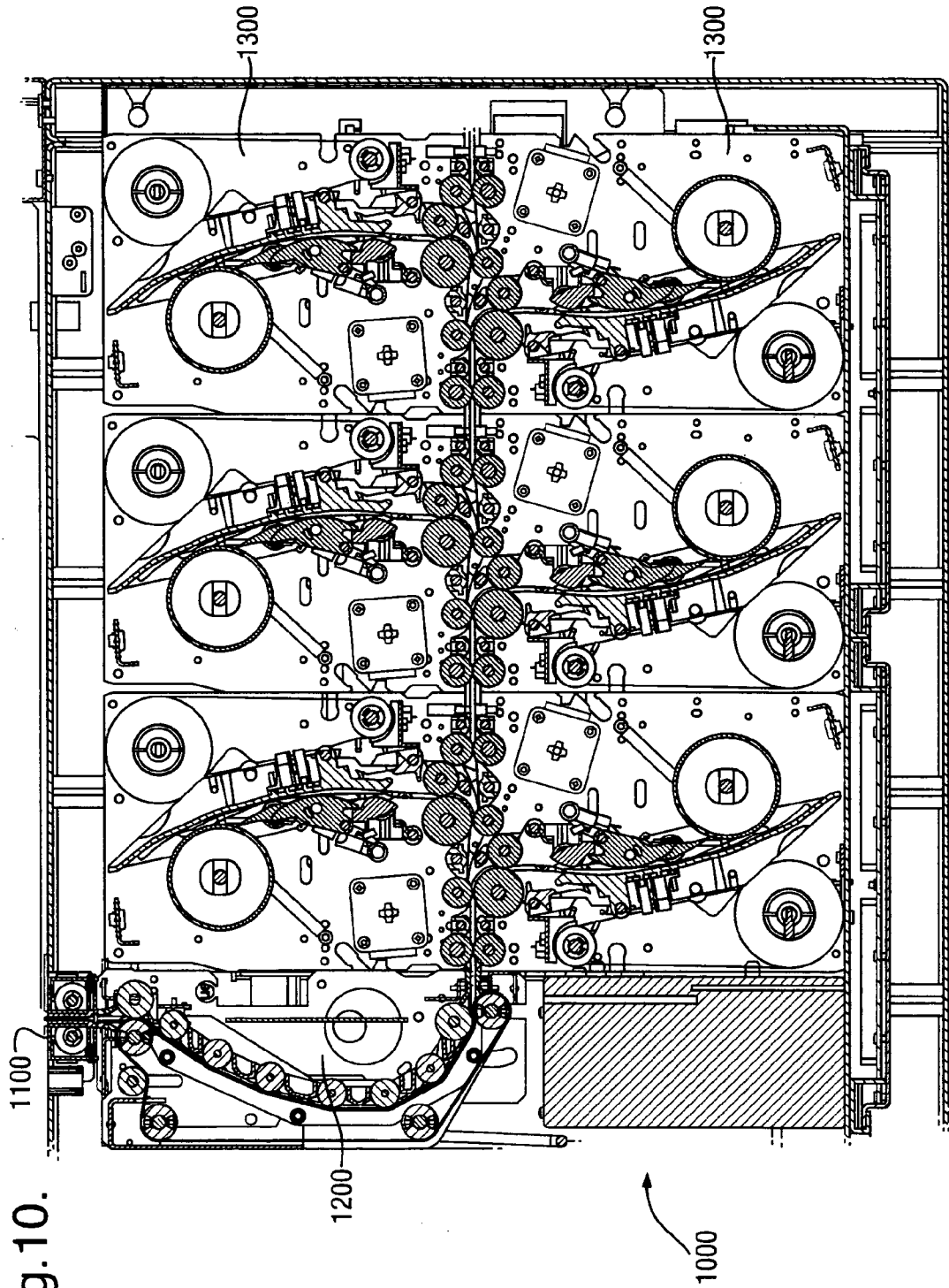
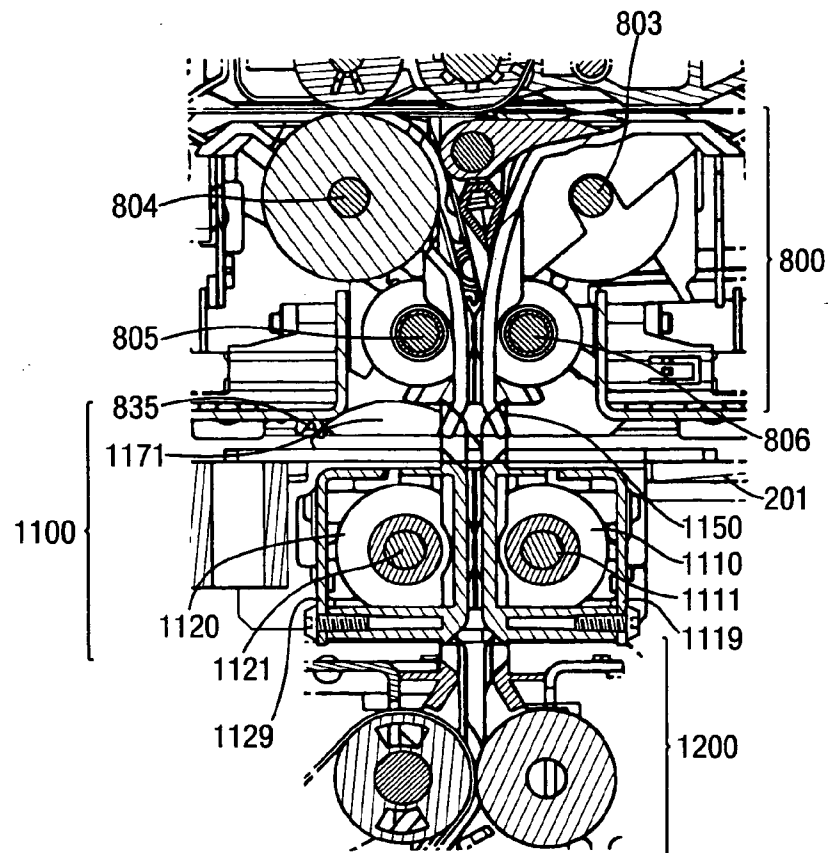


Fig. 10.

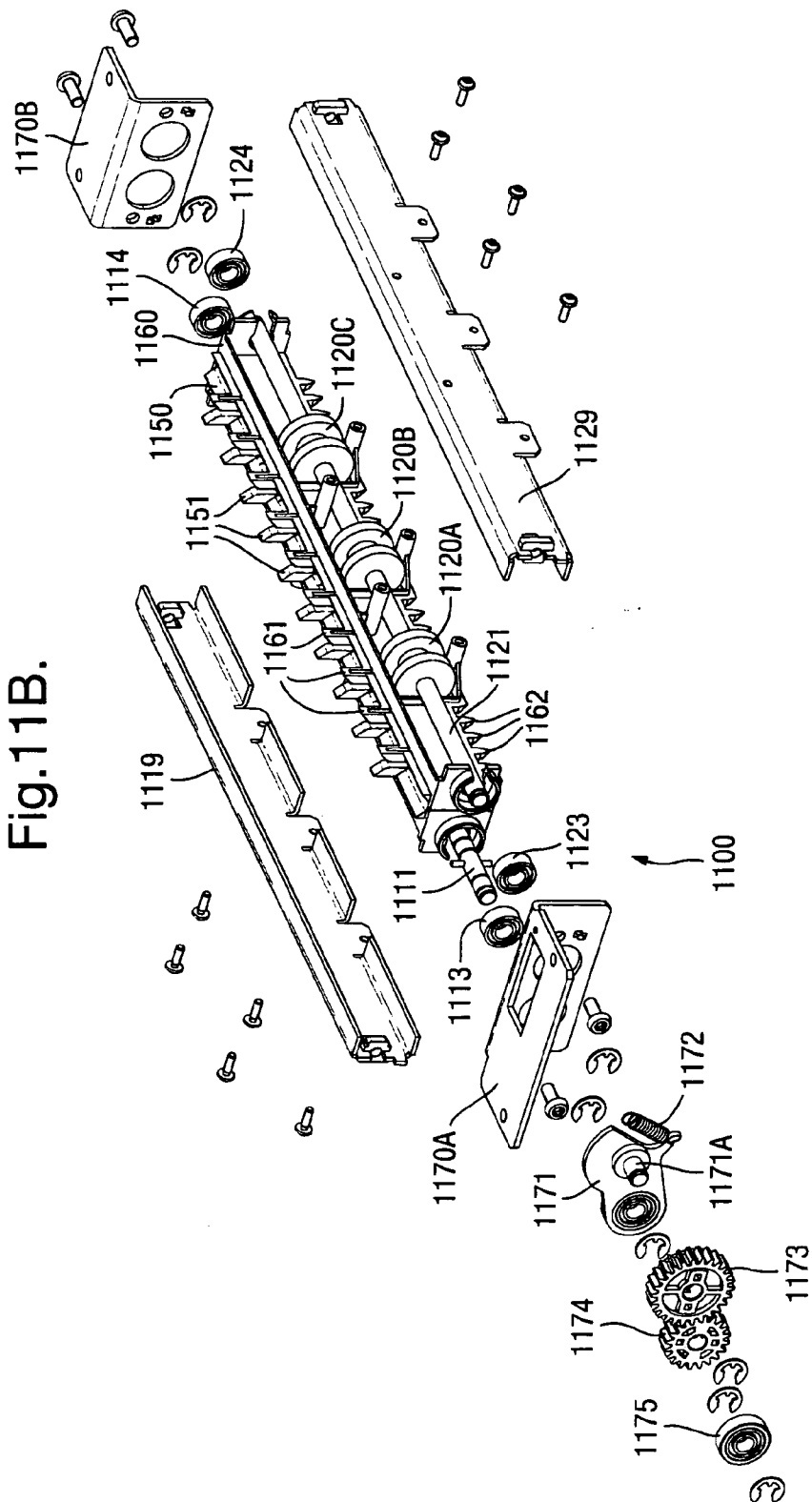
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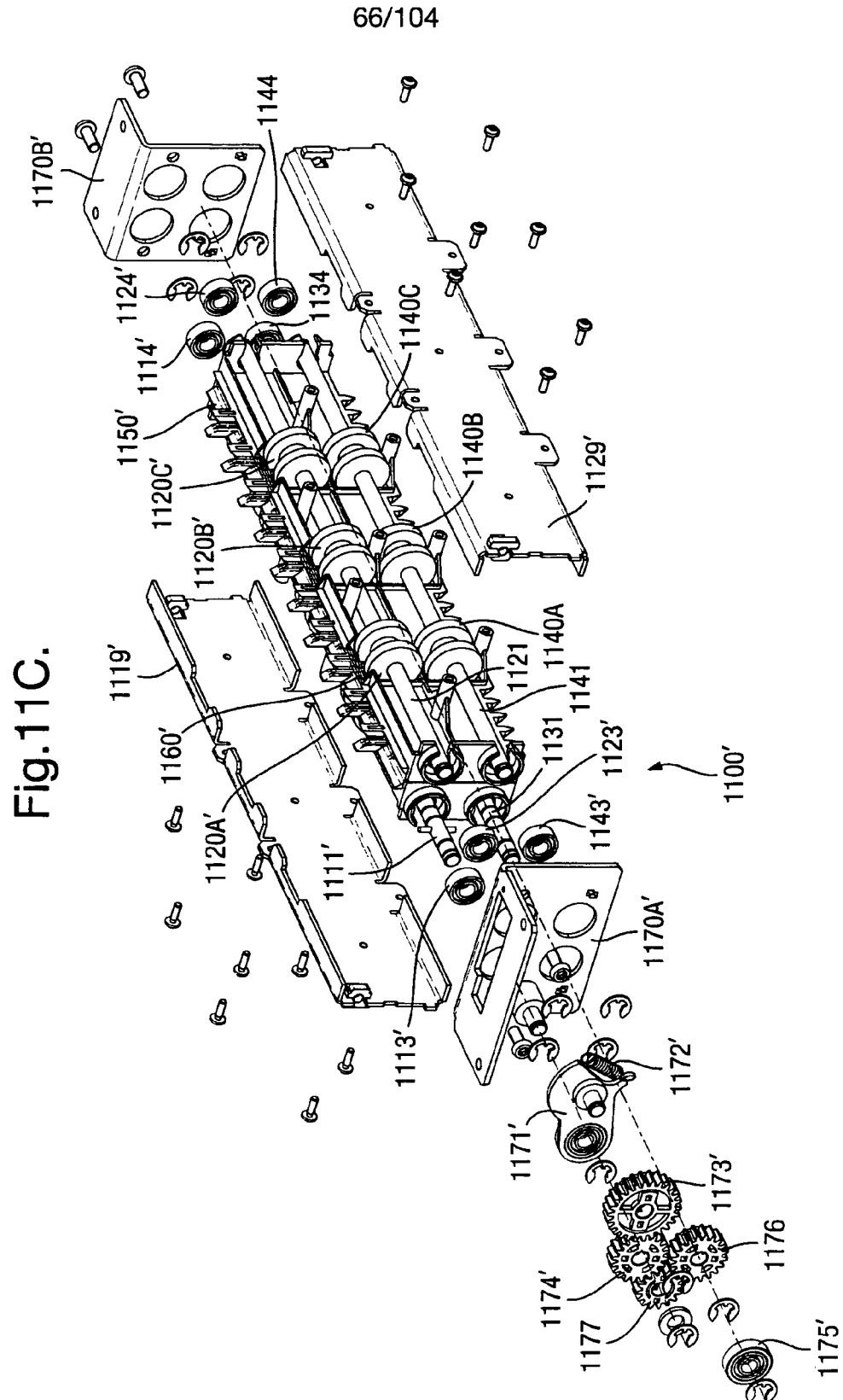
Fig.11A.



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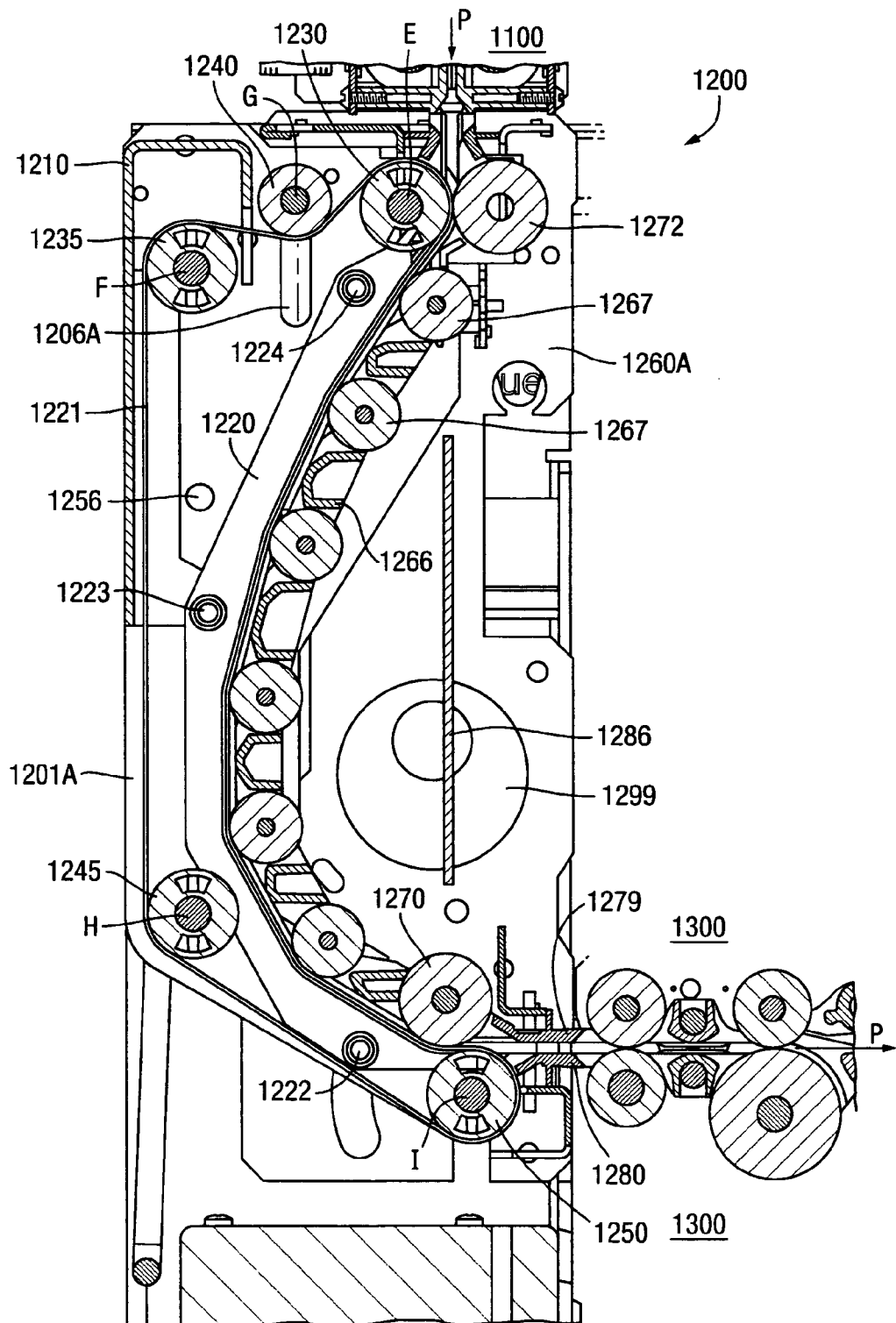
Fig. 11B.





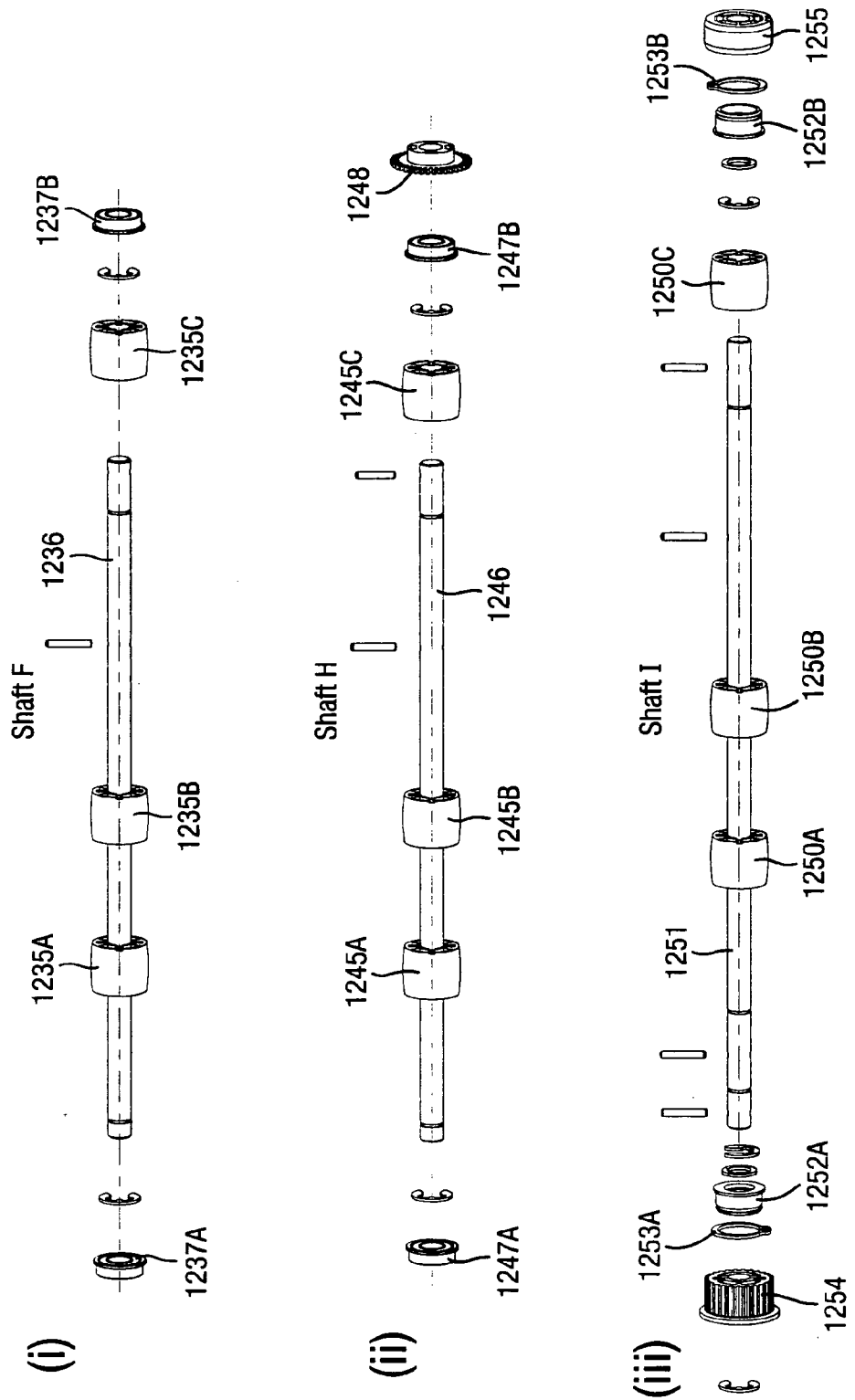
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Fig.12A.



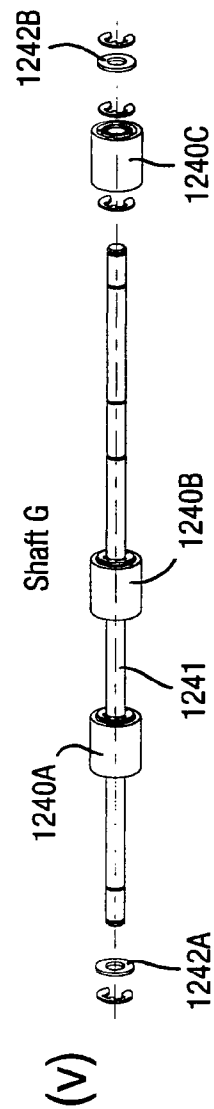
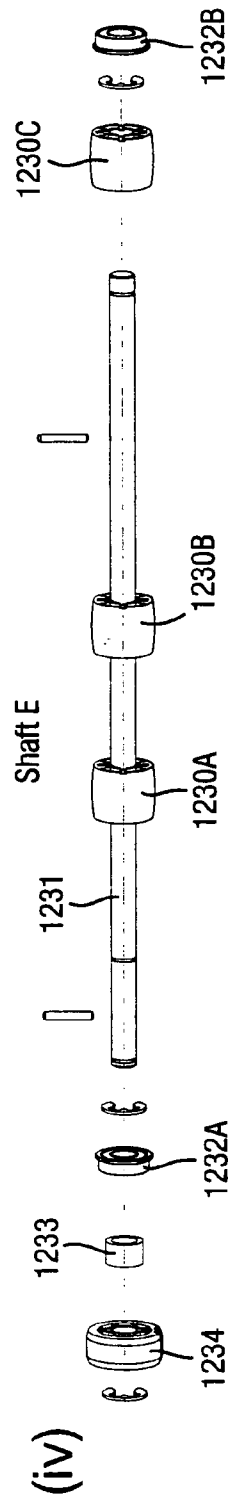
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Fig.12C.



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Fig.12C.



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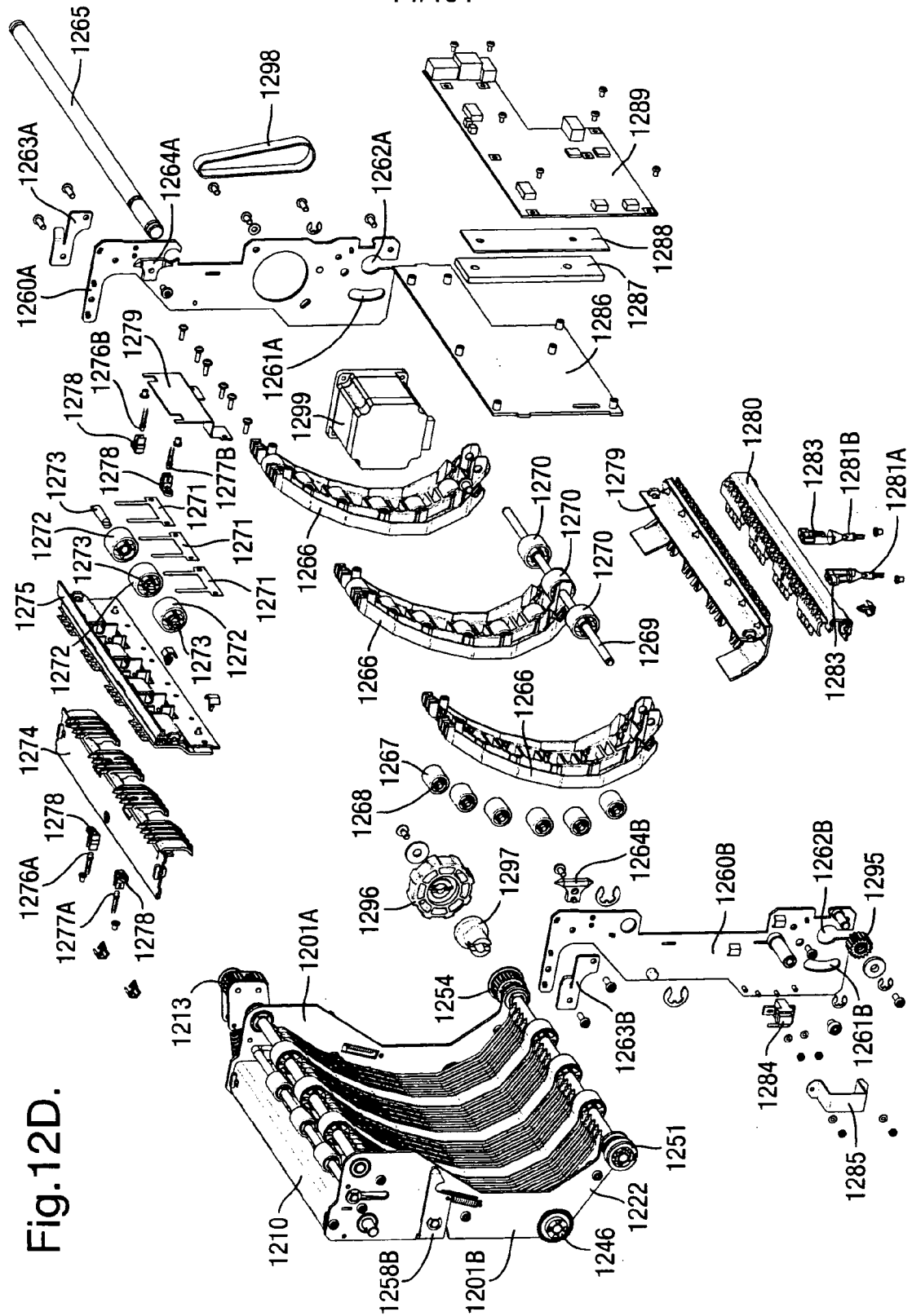


Fig.12D.

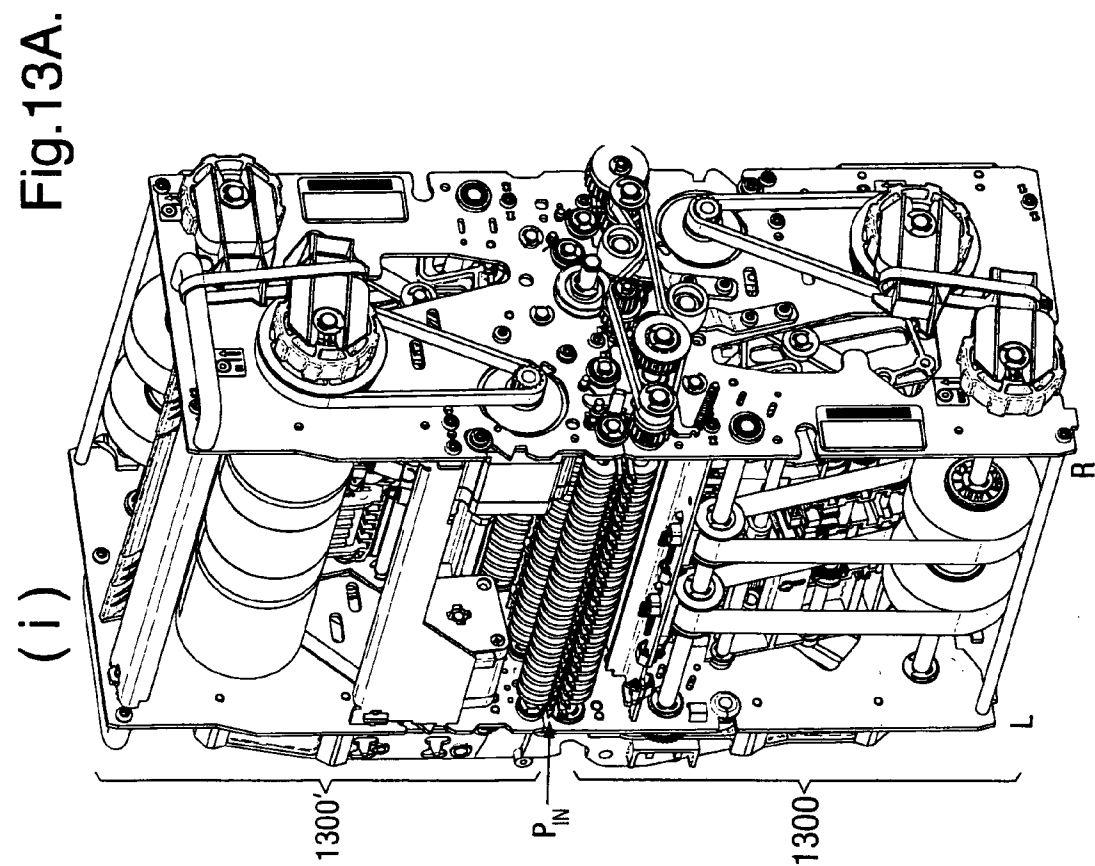
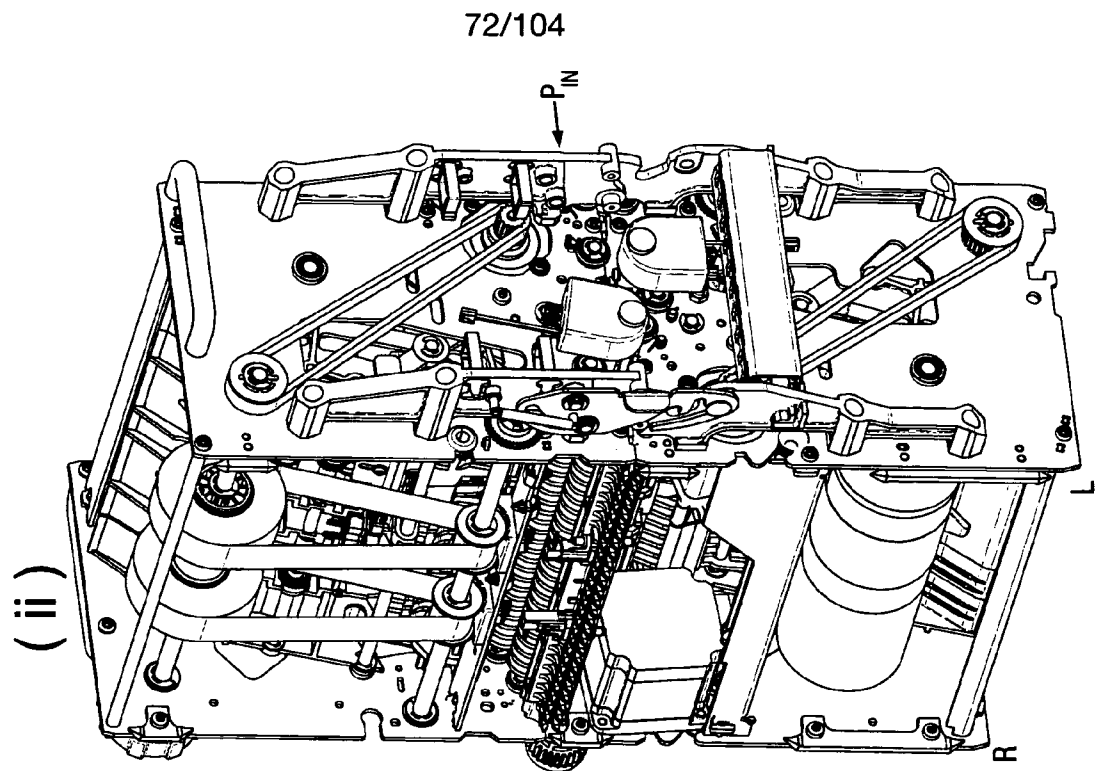
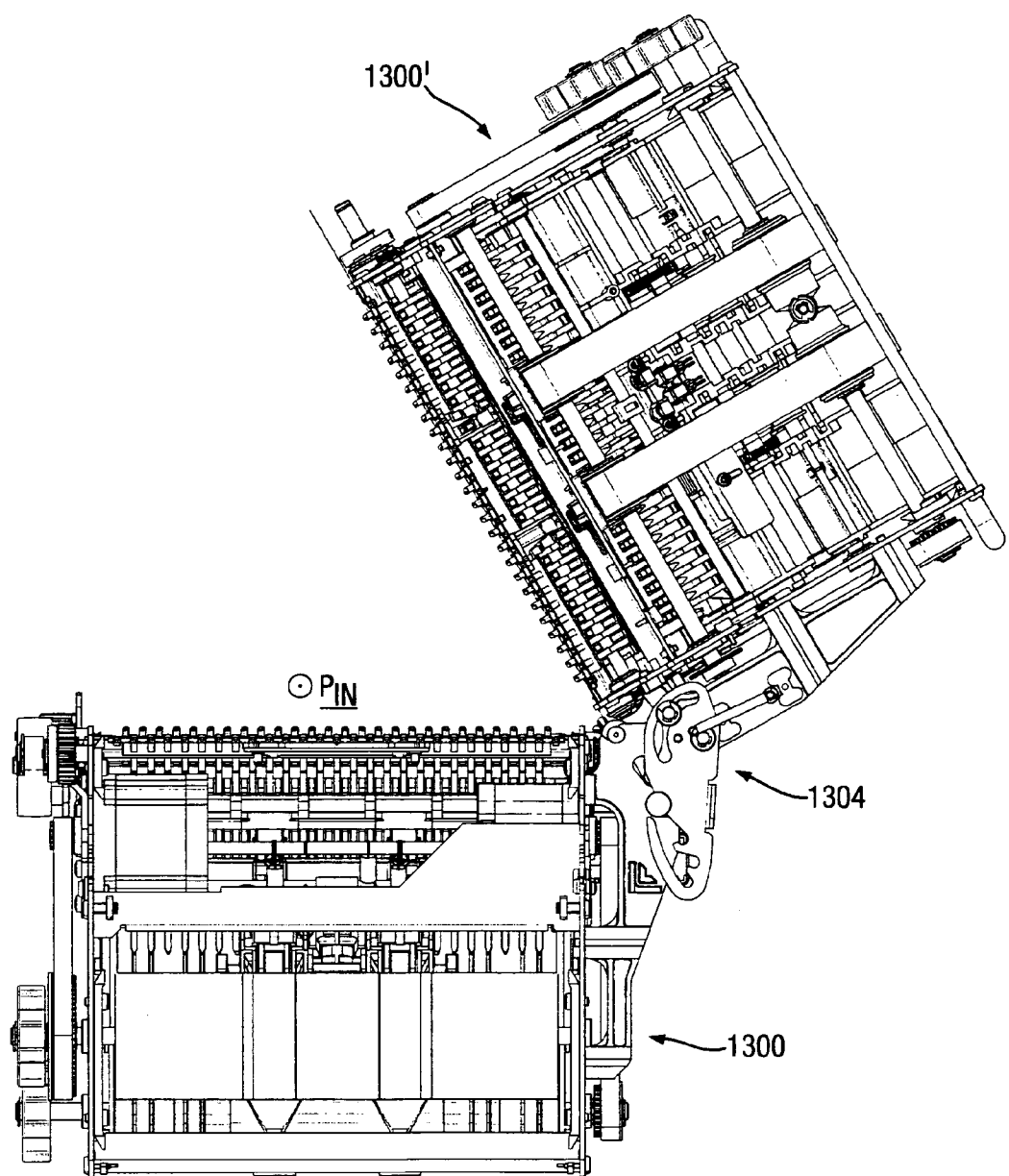


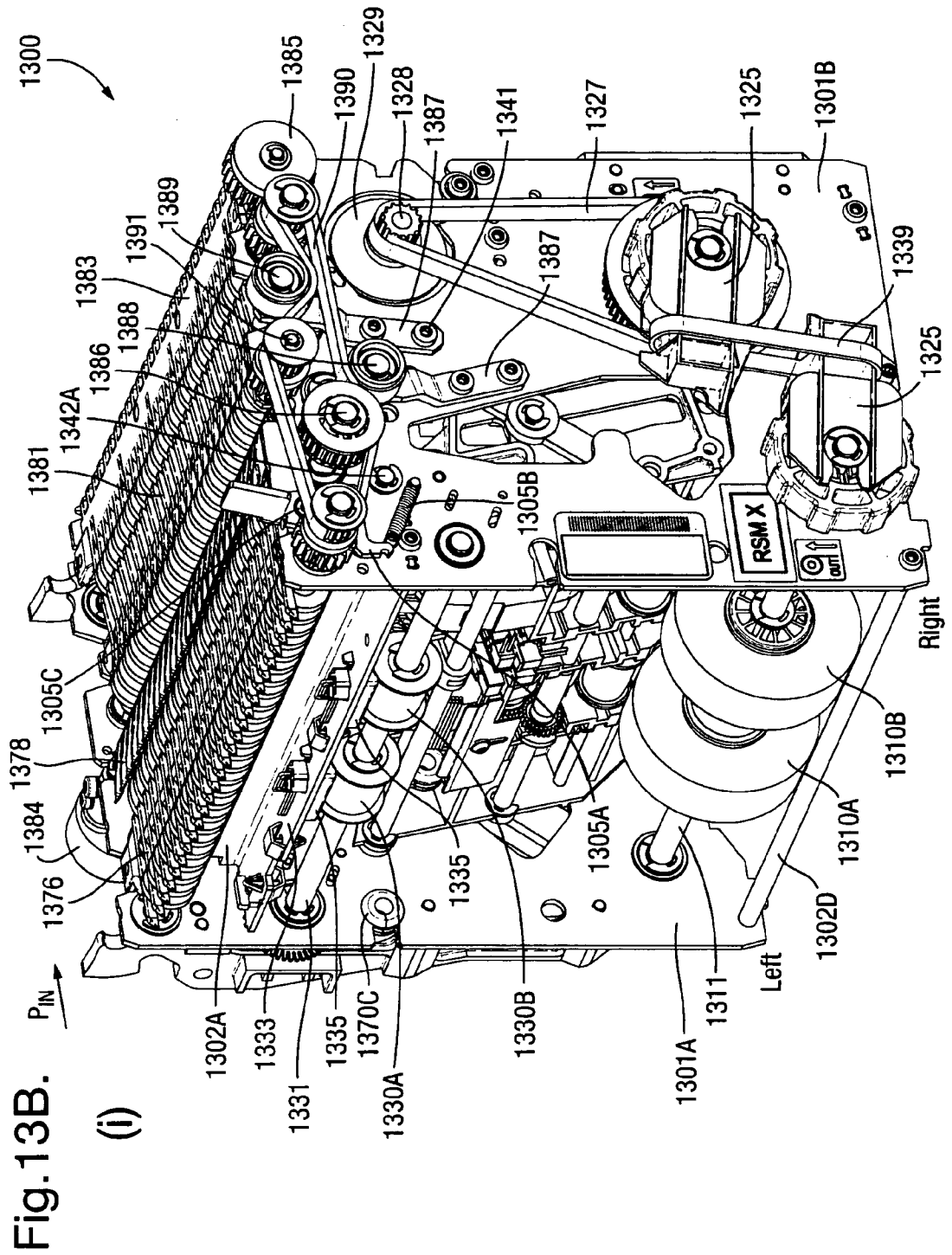
Fig.13A.

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Fig.13A (iii).



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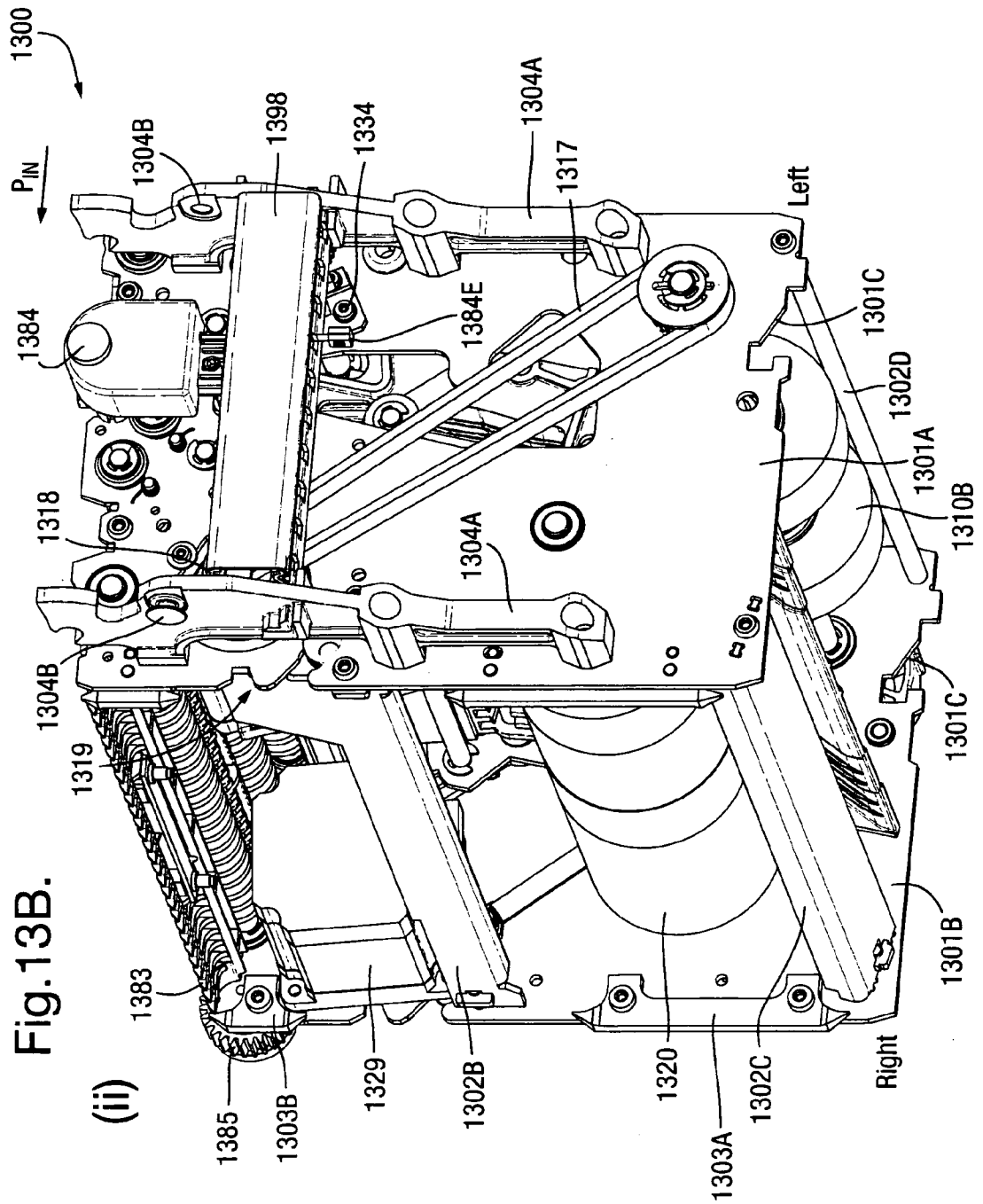
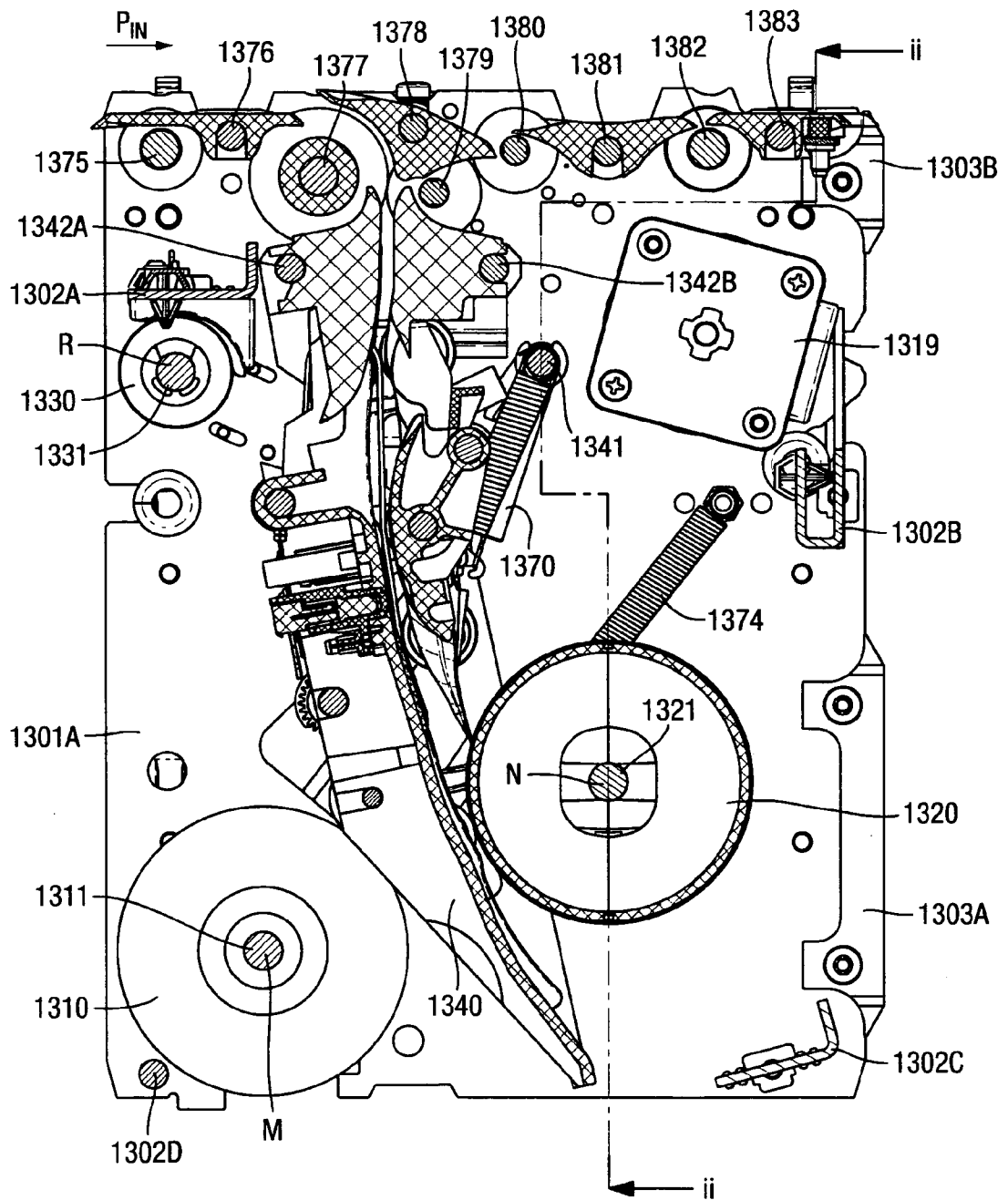


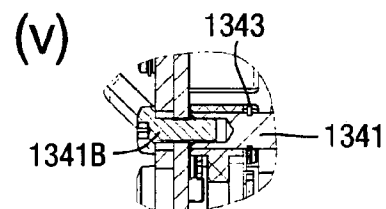
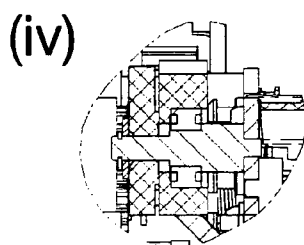
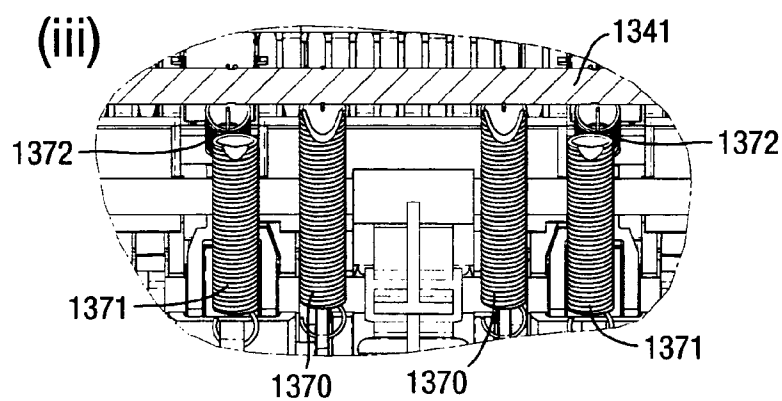
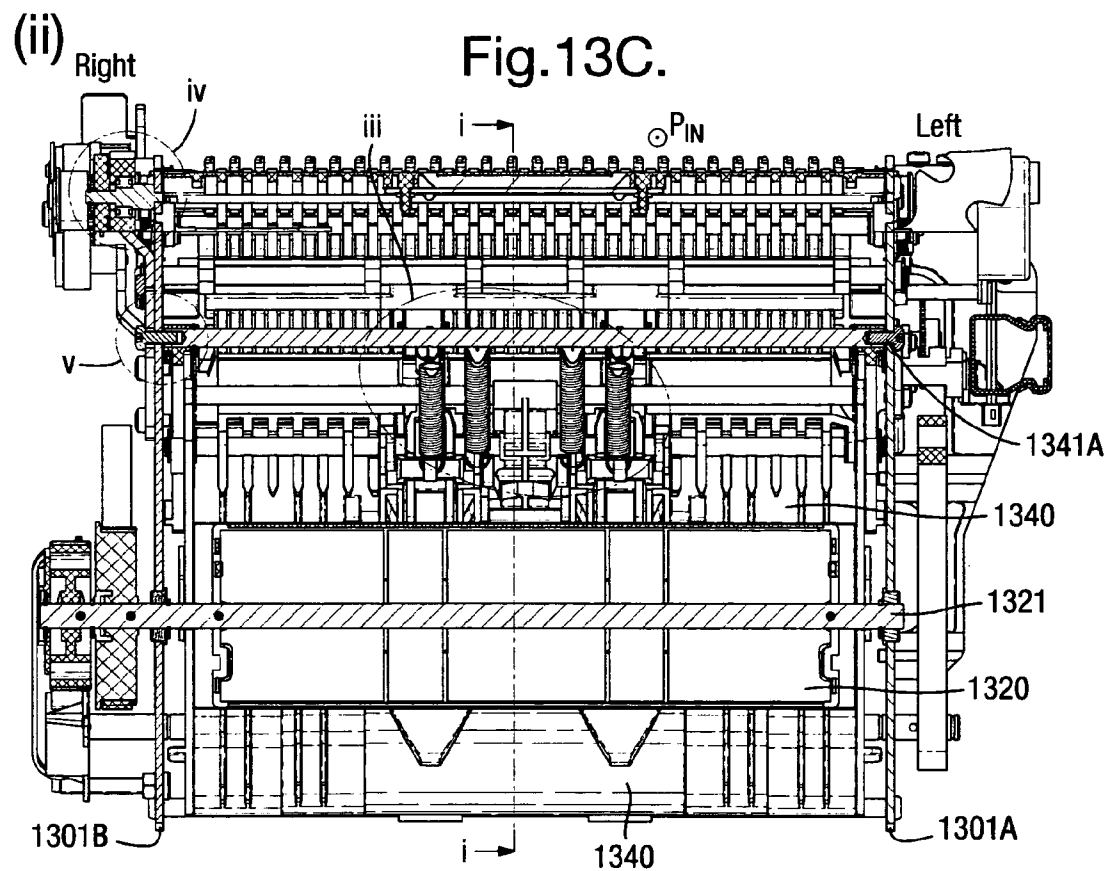
Fig. 13B.

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Fig.13C.

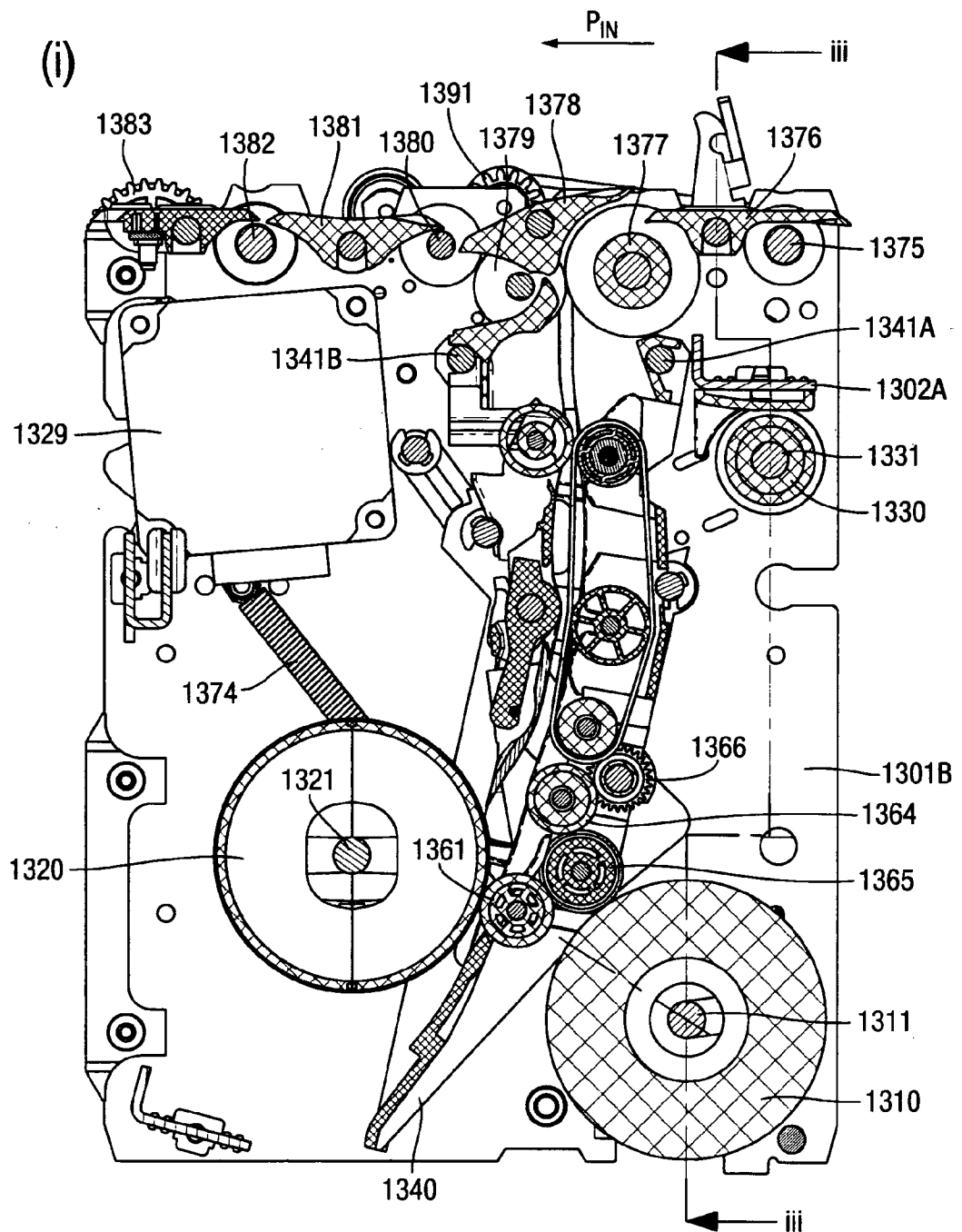


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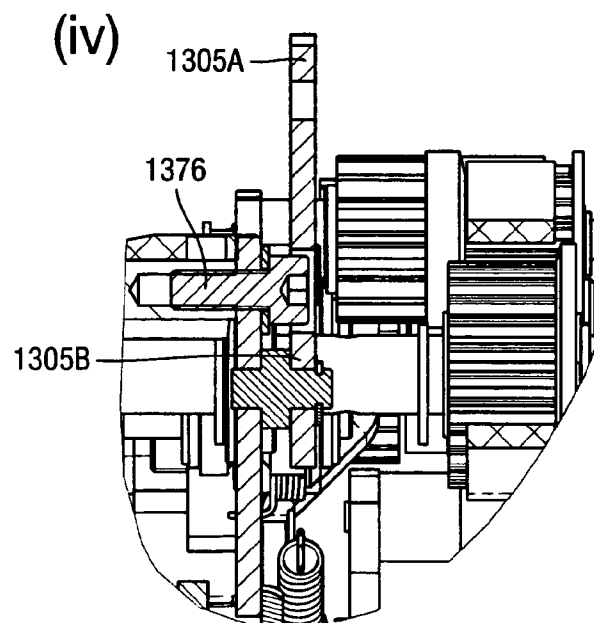
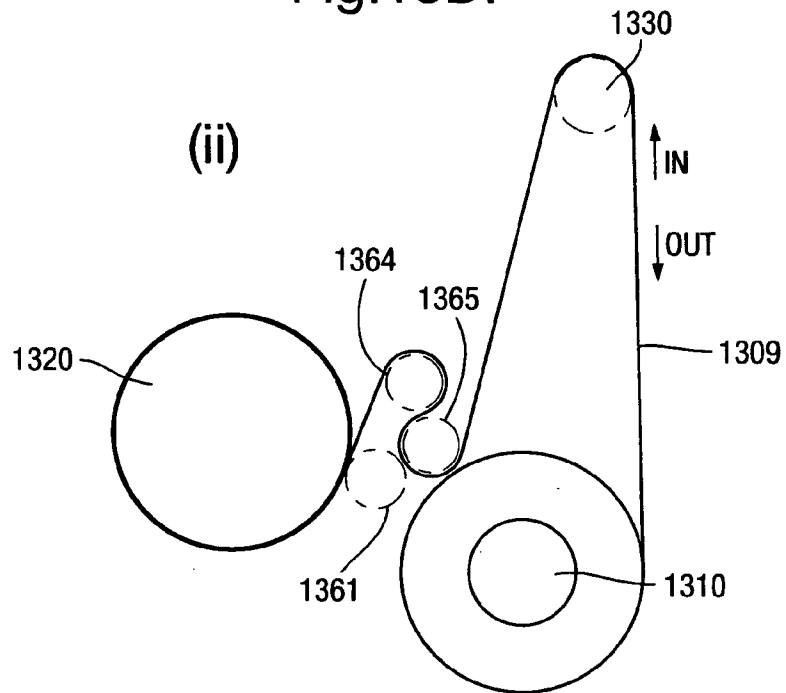
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Fig.13D.

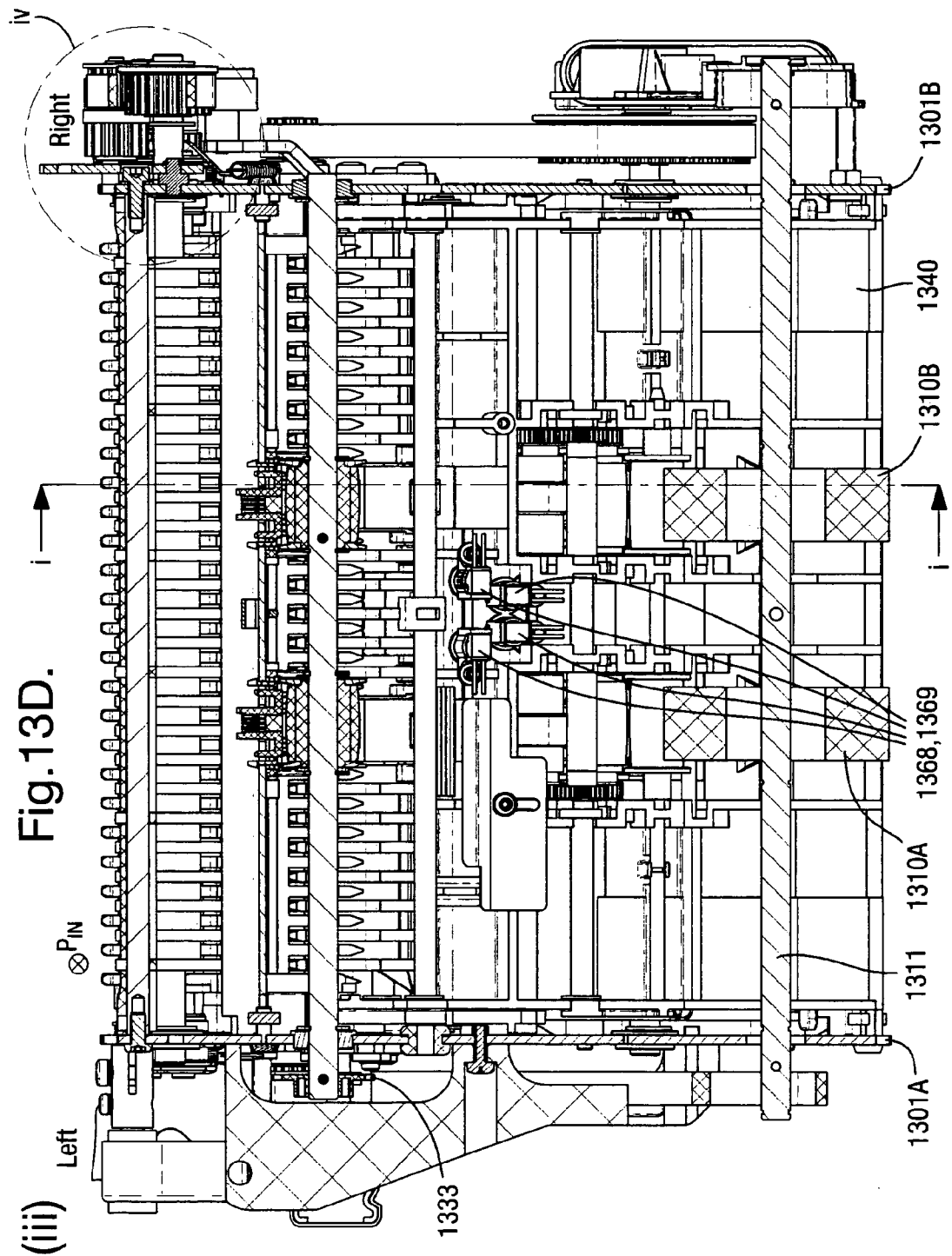


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Fig.13D.

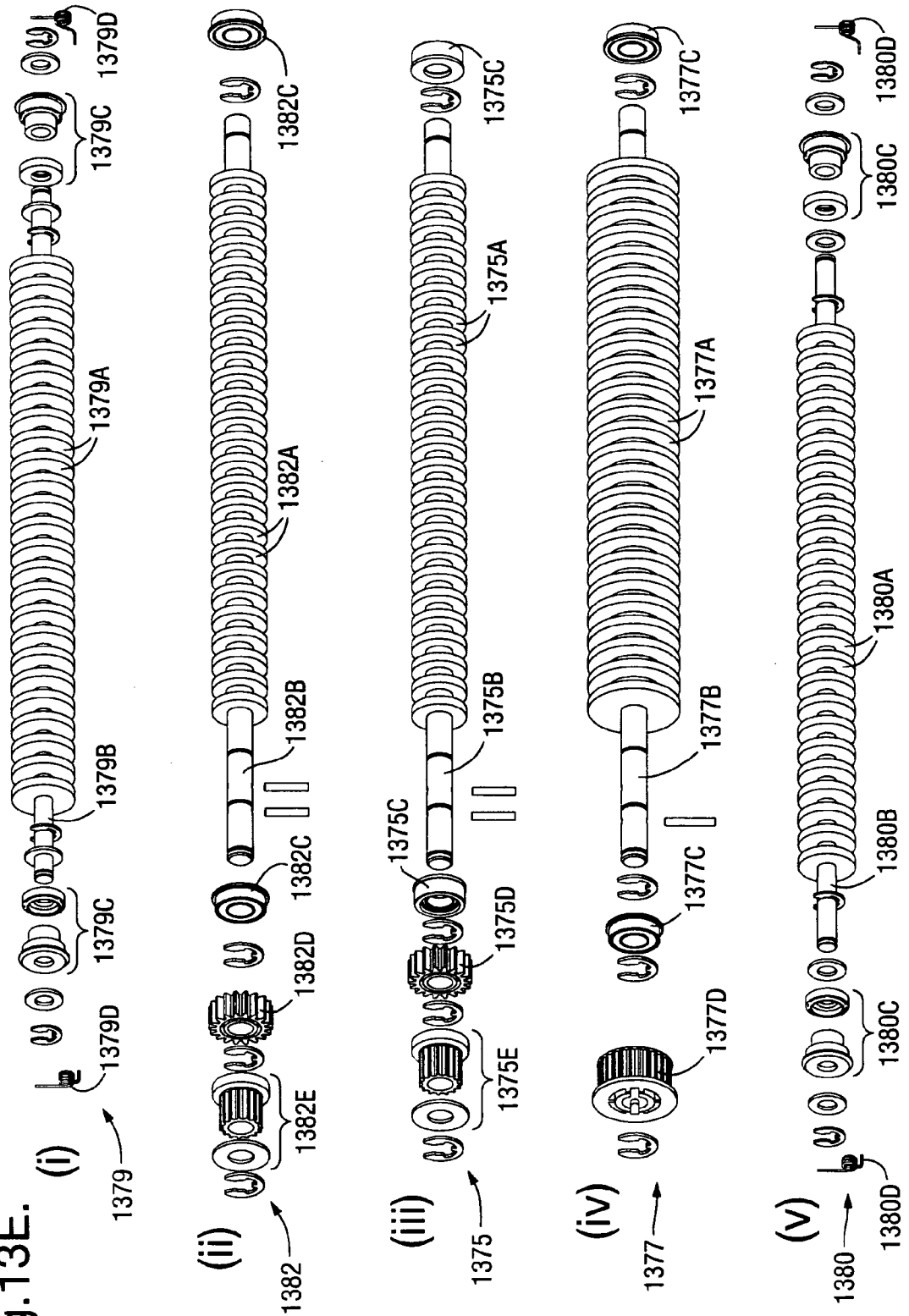


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Fig.13E.



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Fig.13E.

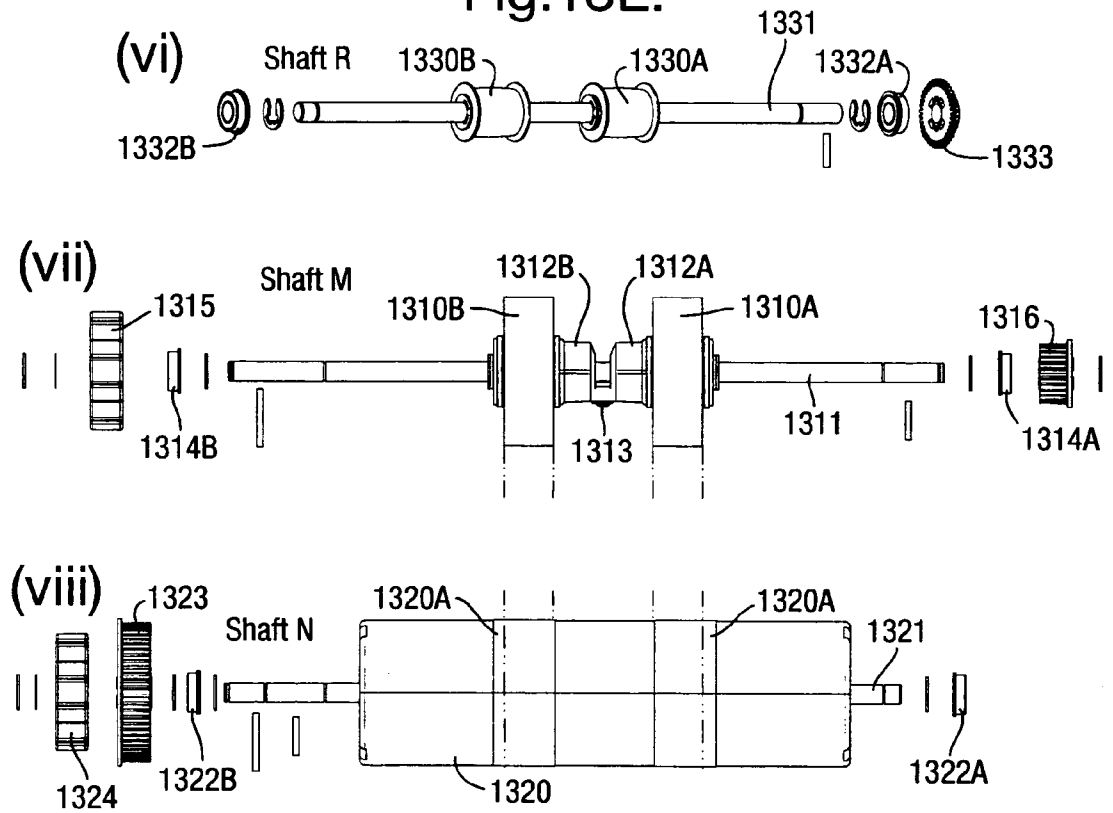


Fig.13F.

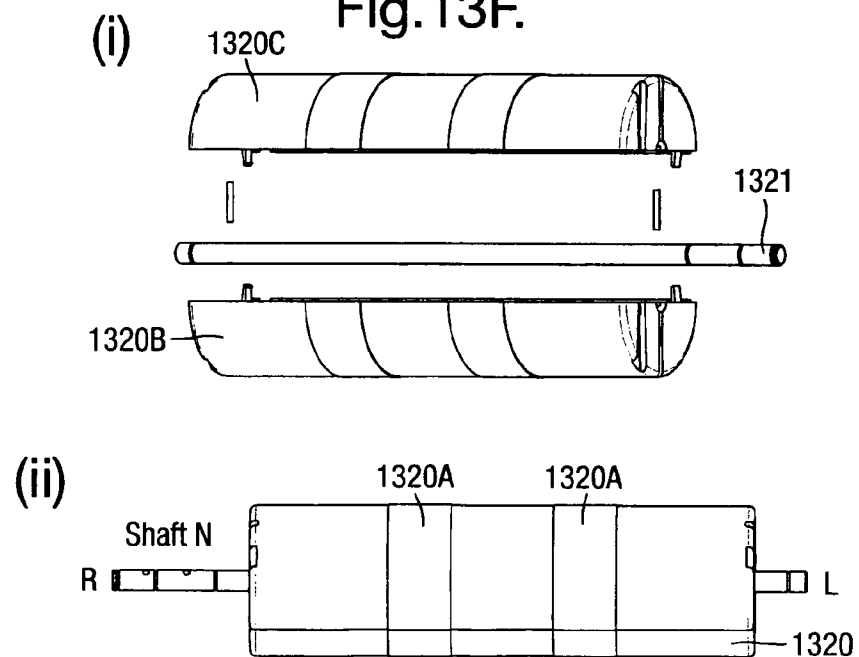
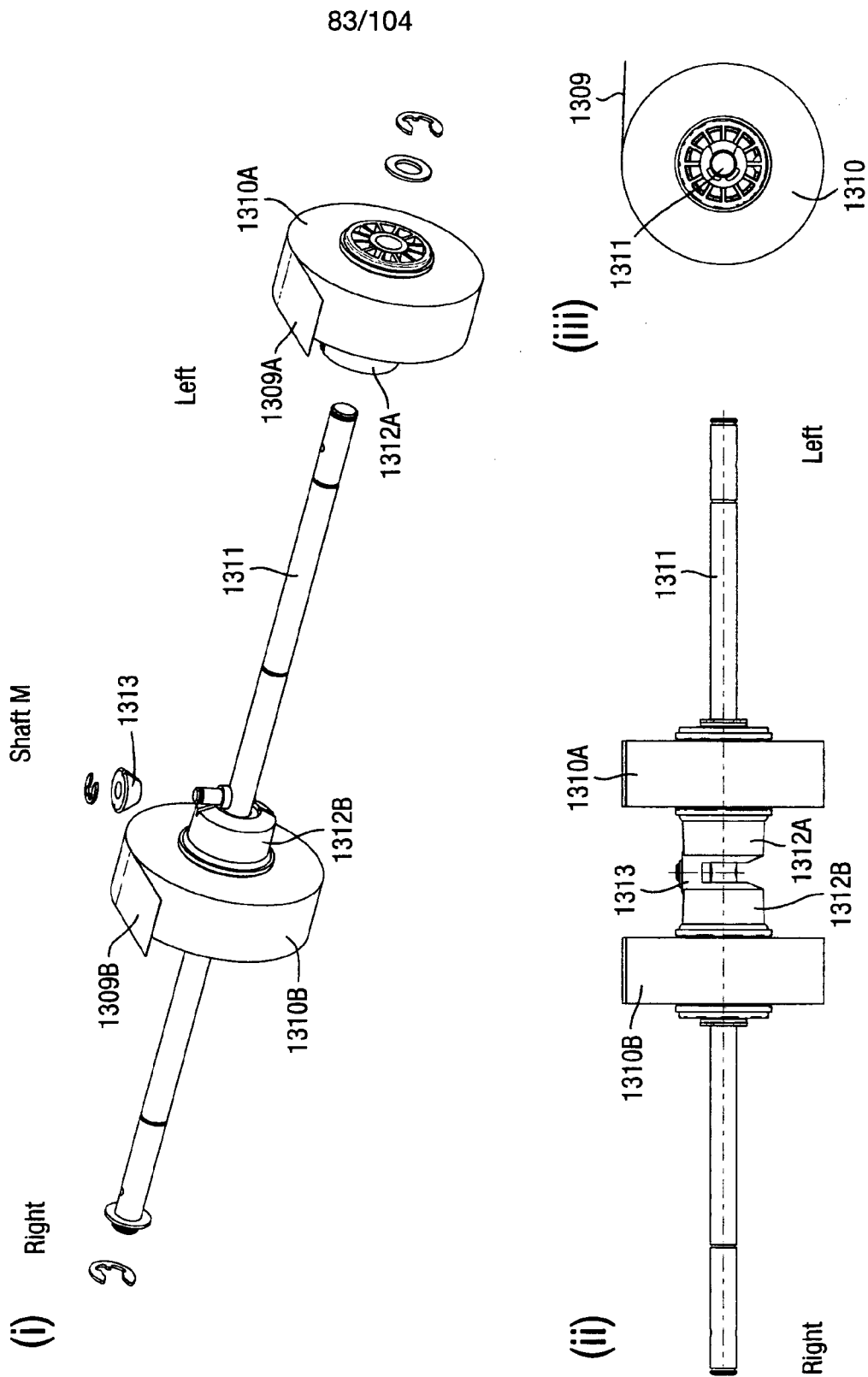
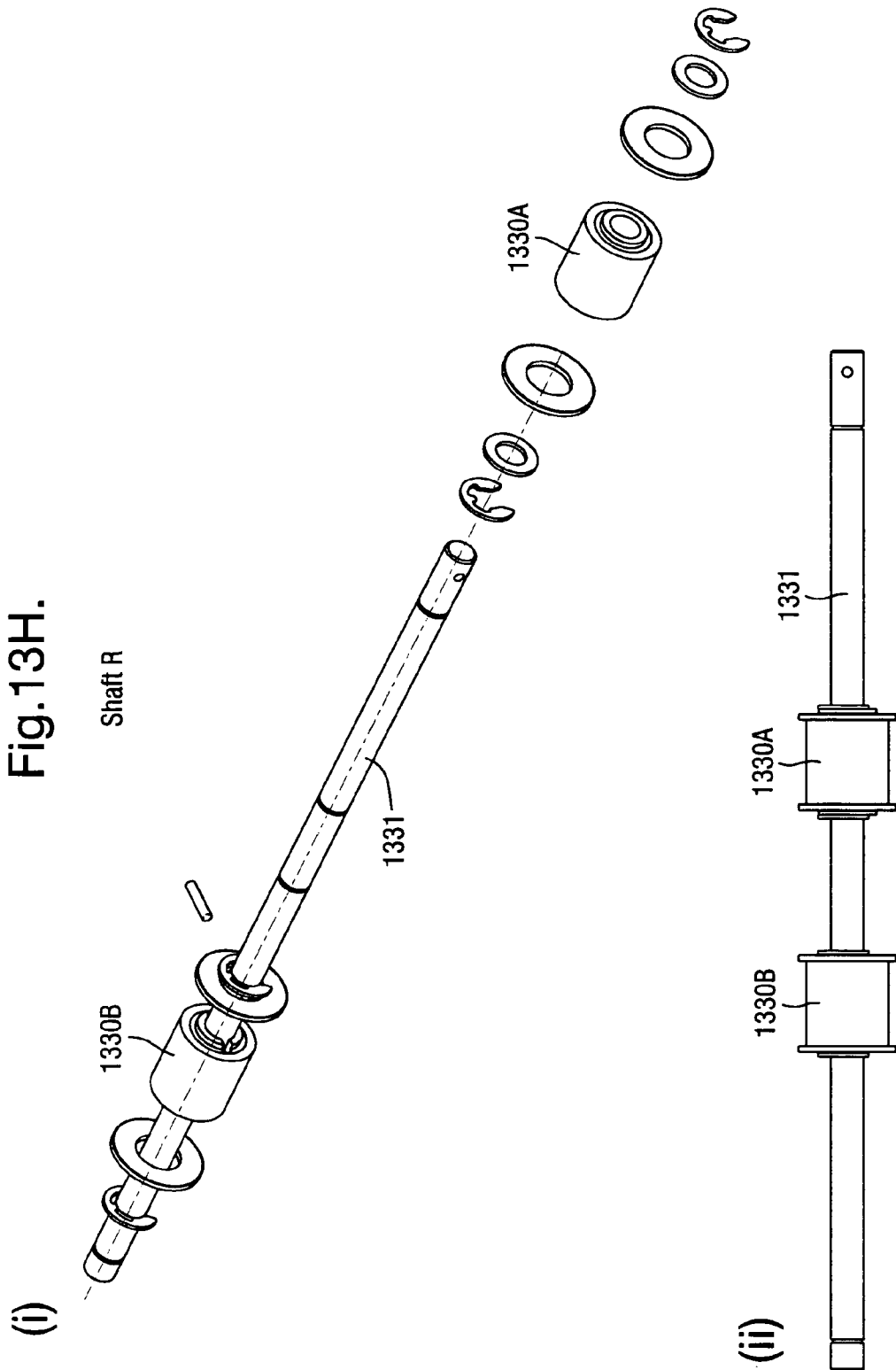


Fig.13G.



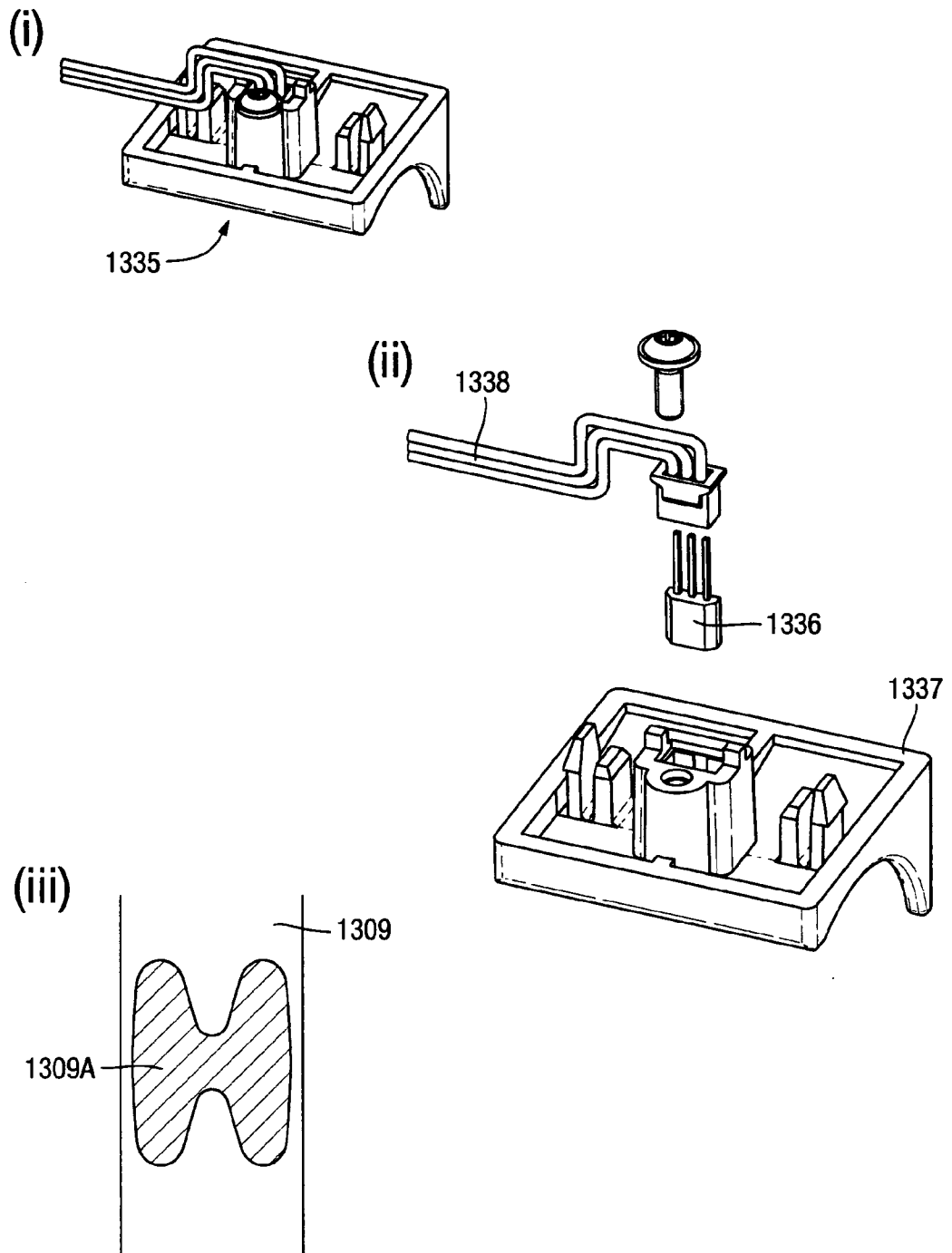
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Fig.13H.



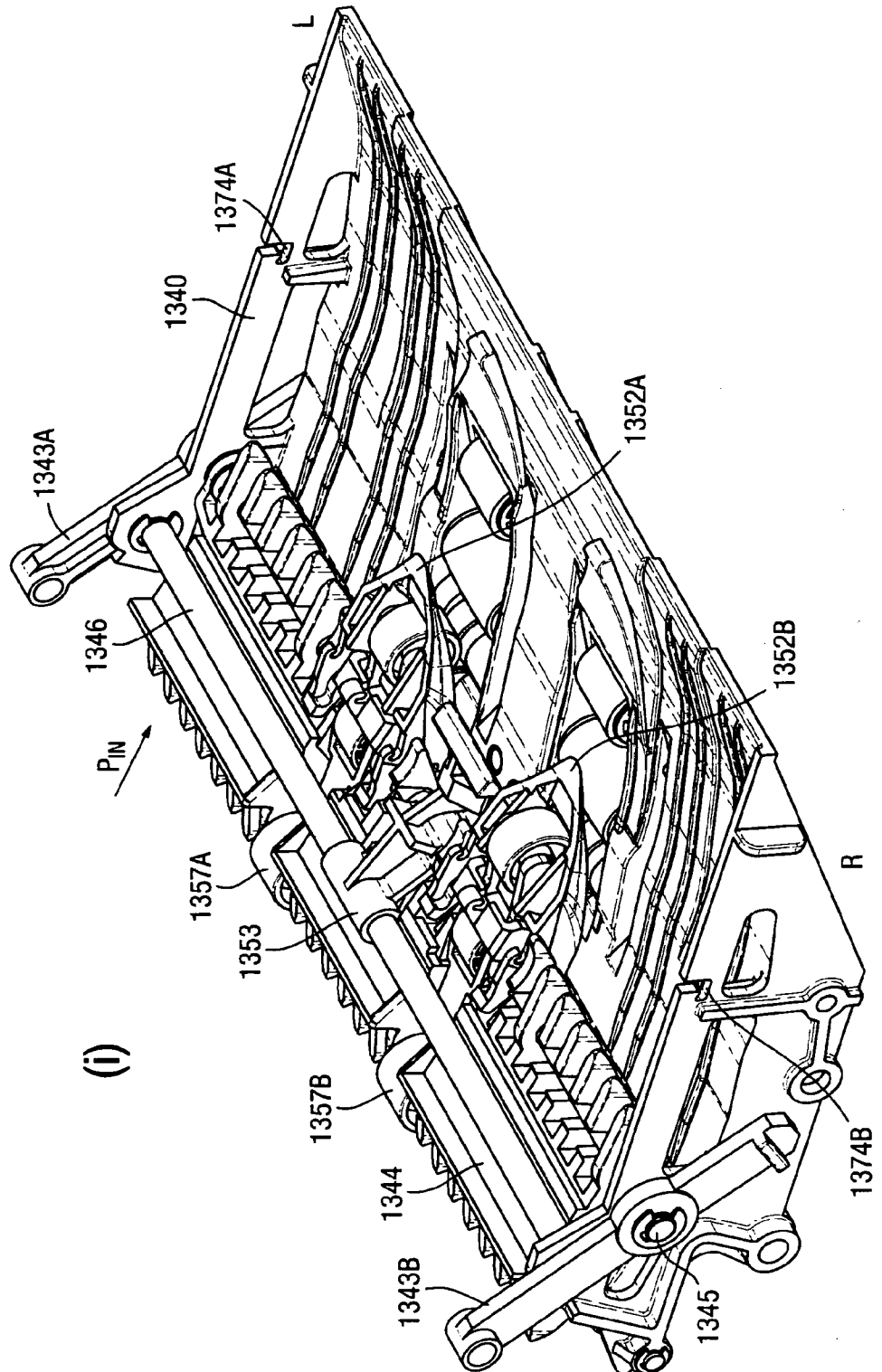
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Fig.13I.

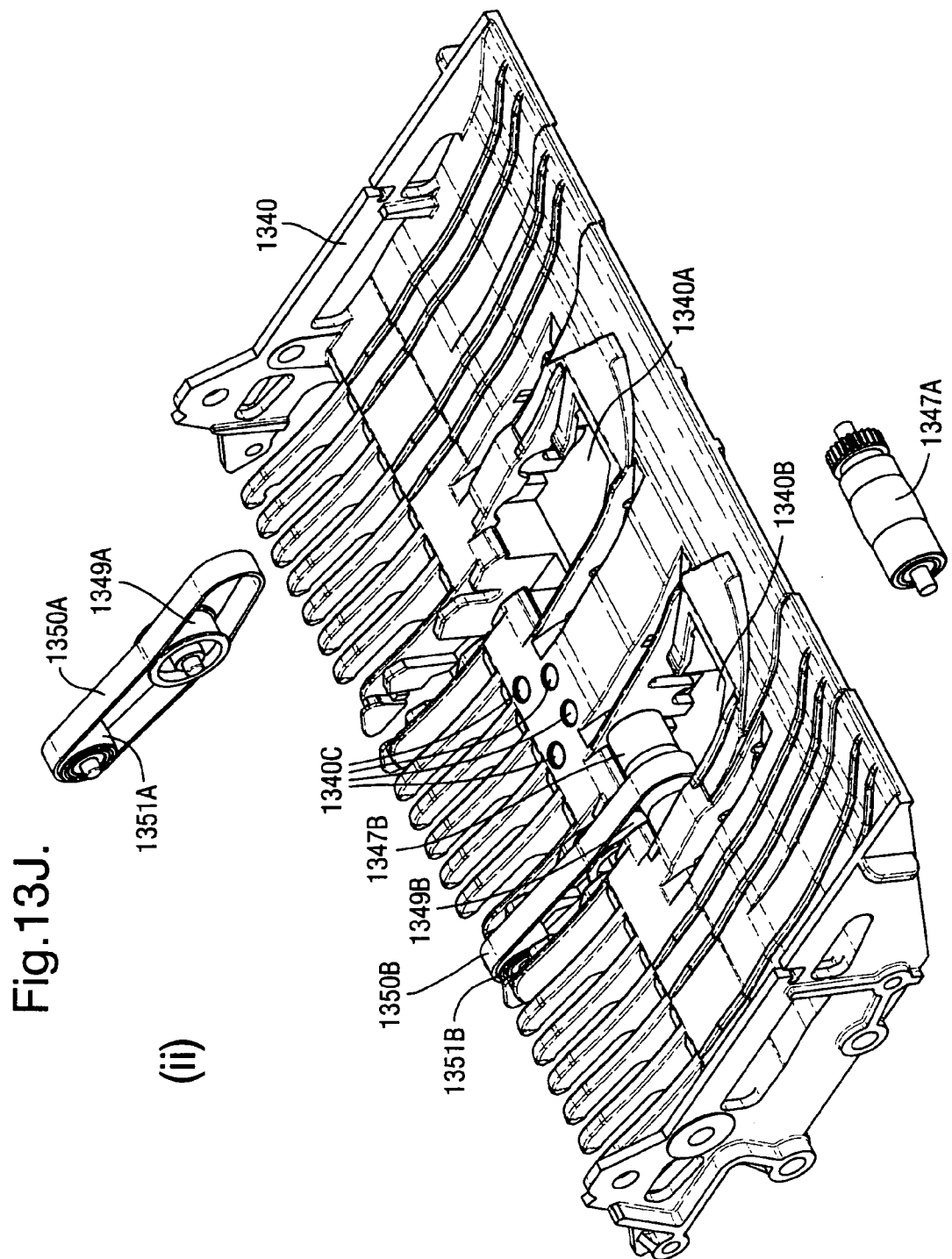


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Fig.13J.

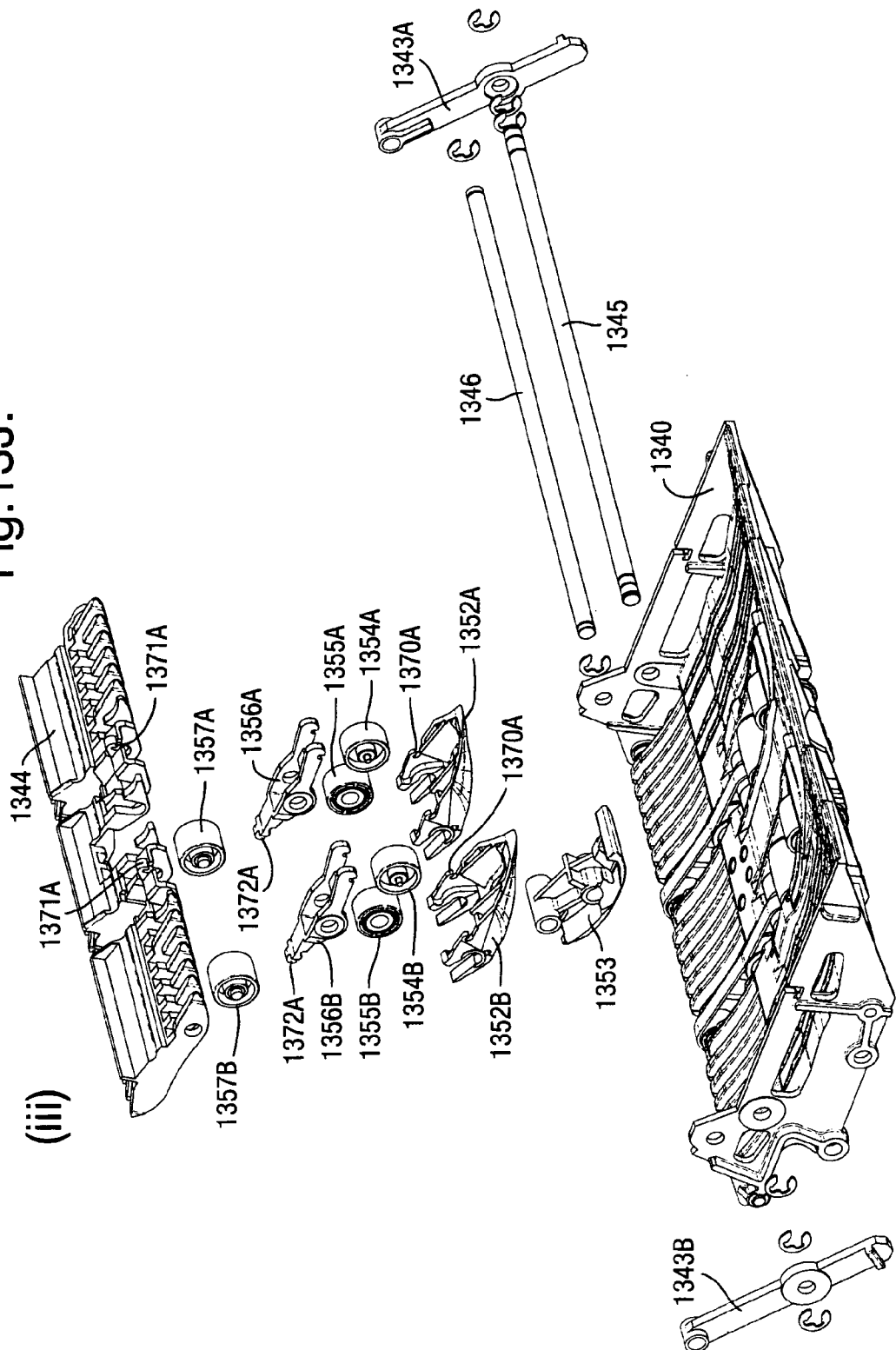


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Fig. 13J.



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Fig.13J.

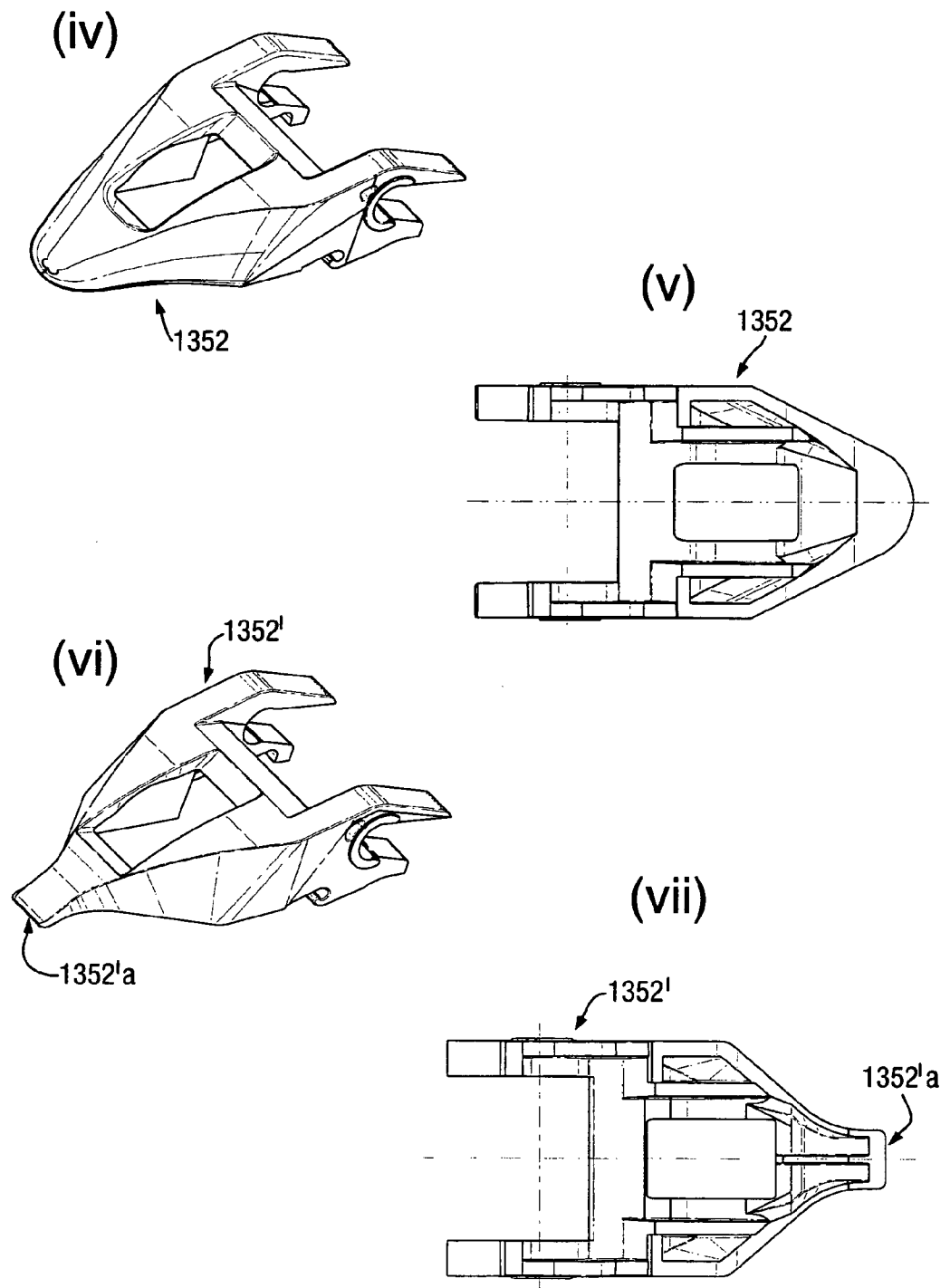
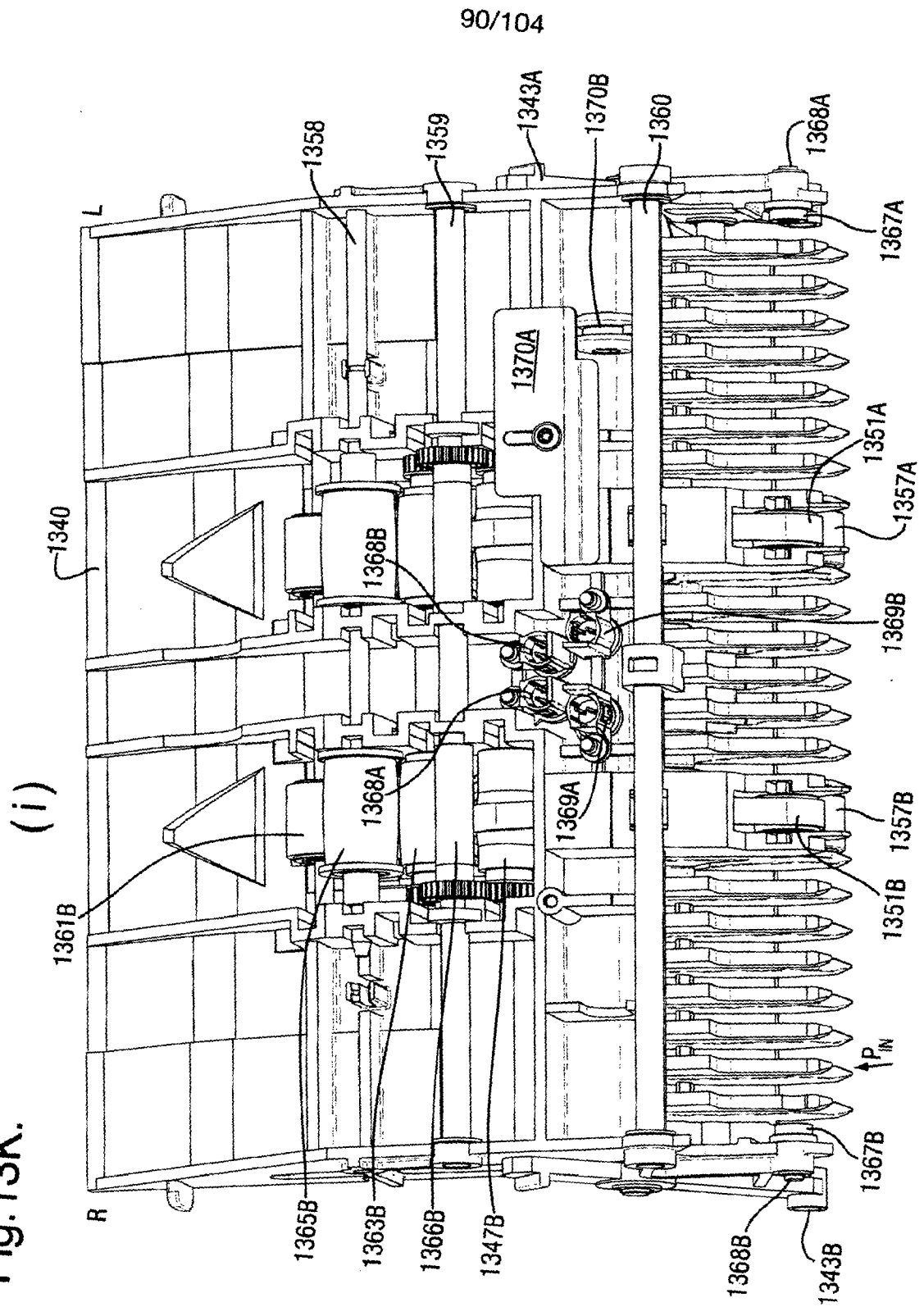


Fig.13K.



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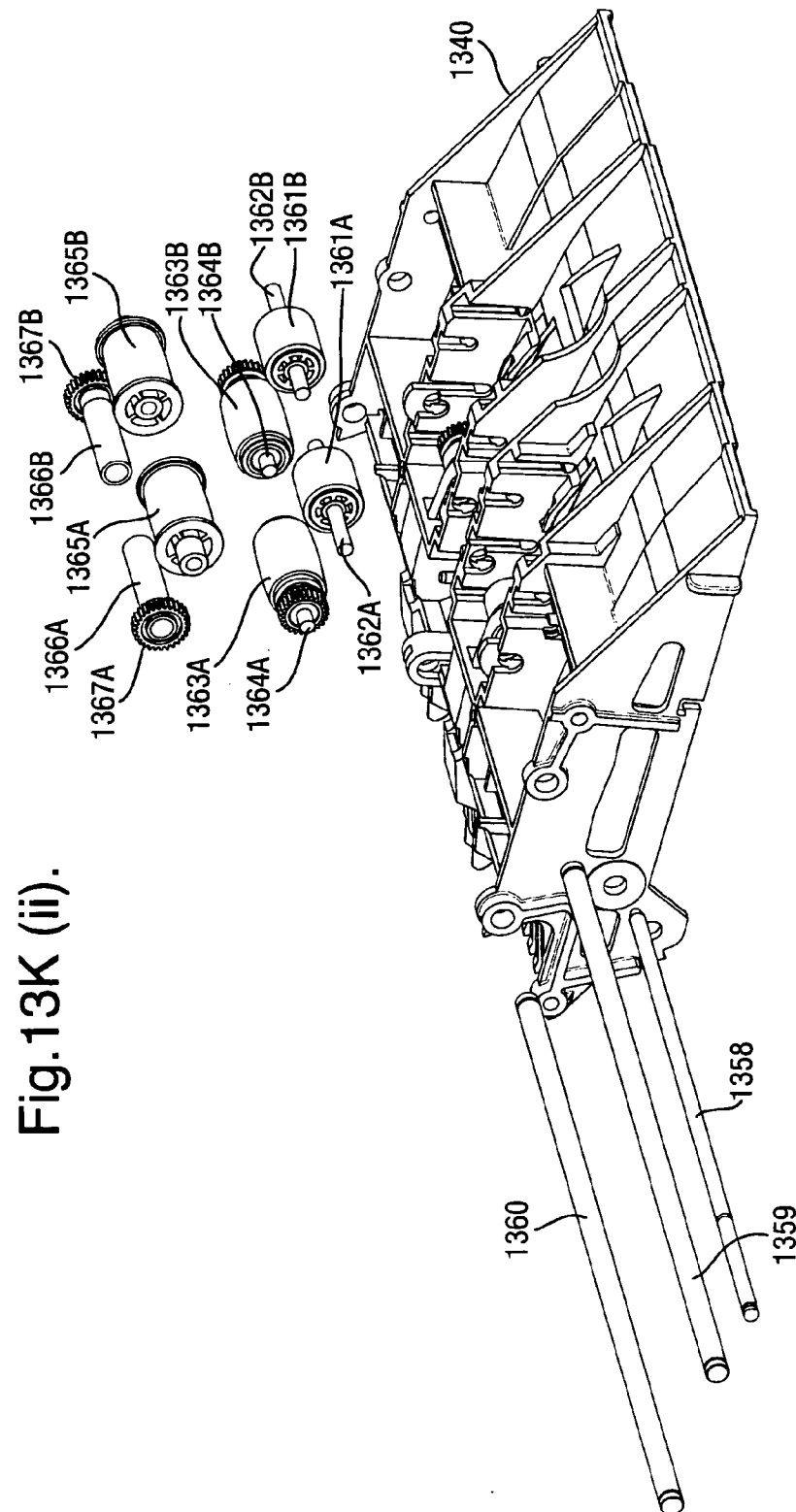


Fig. 13K (ii).

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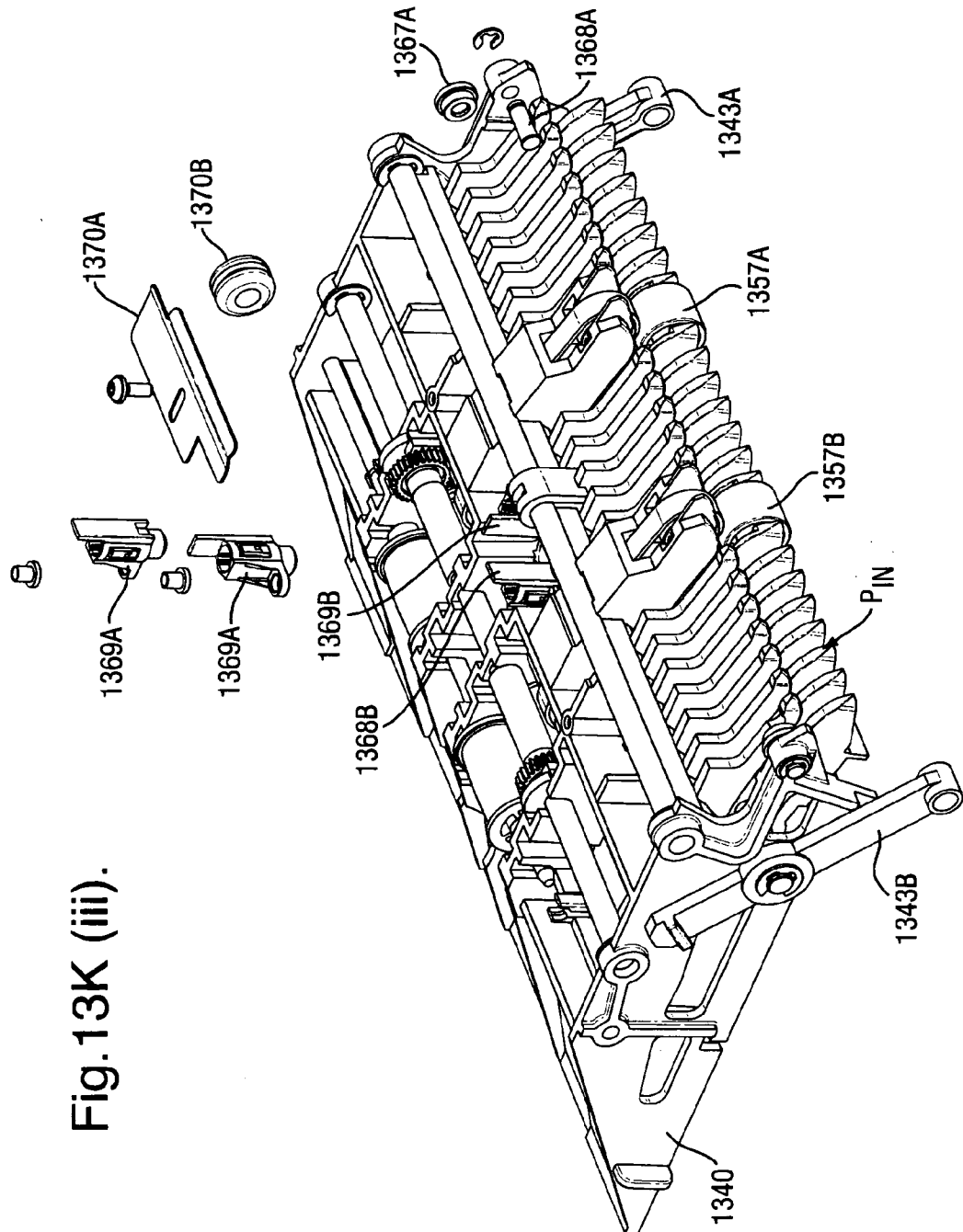
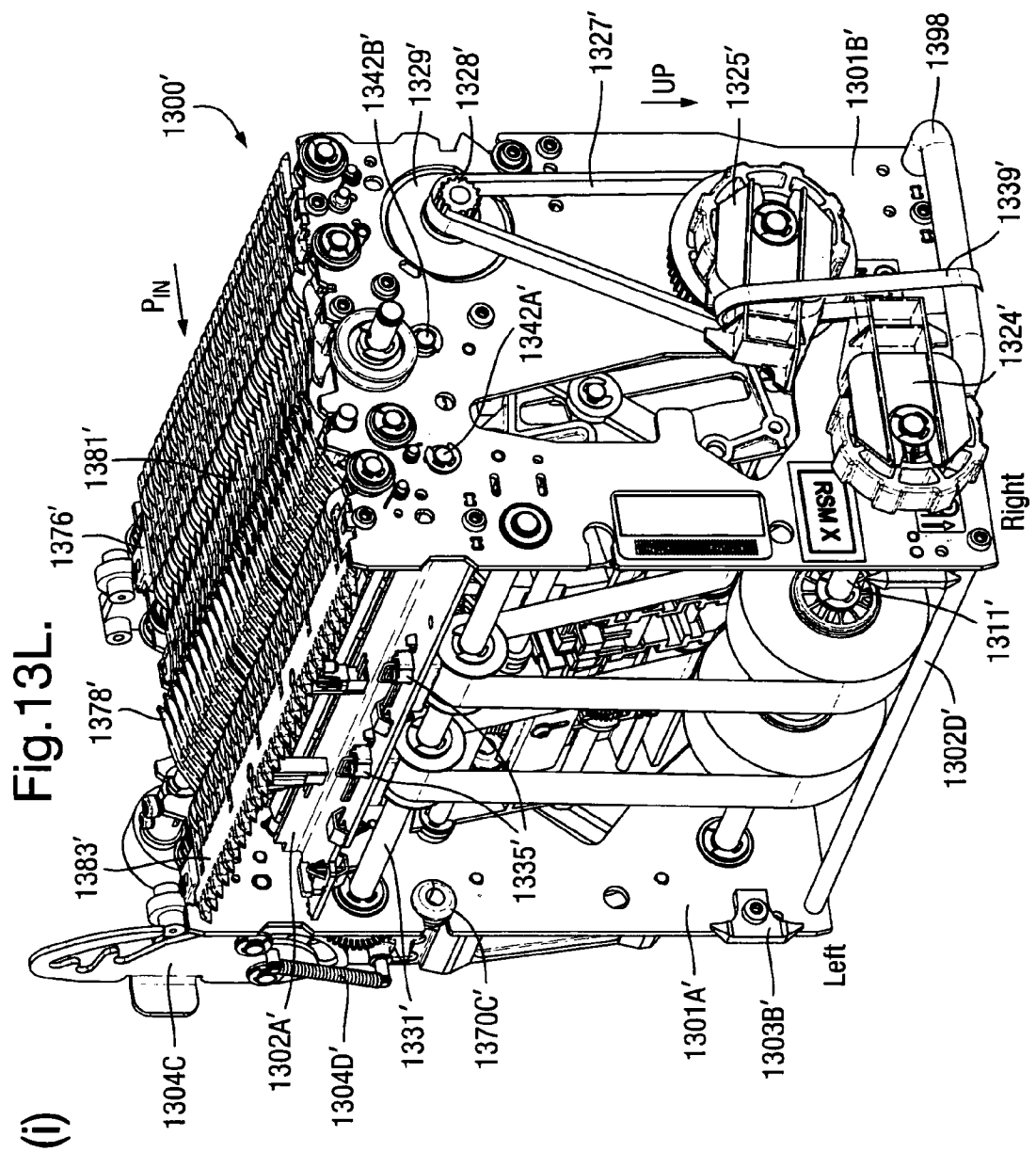


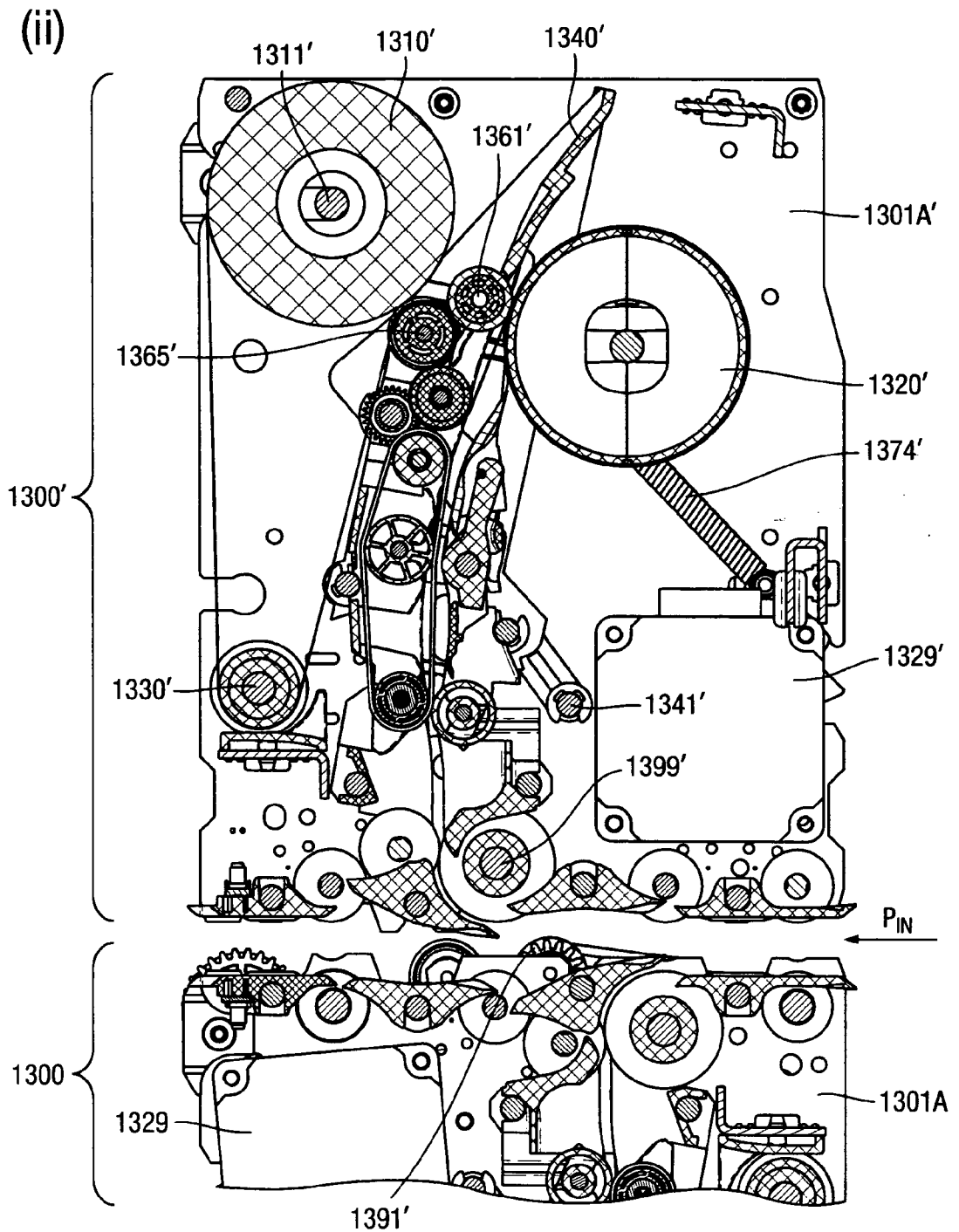
Fig. 13K (iii).

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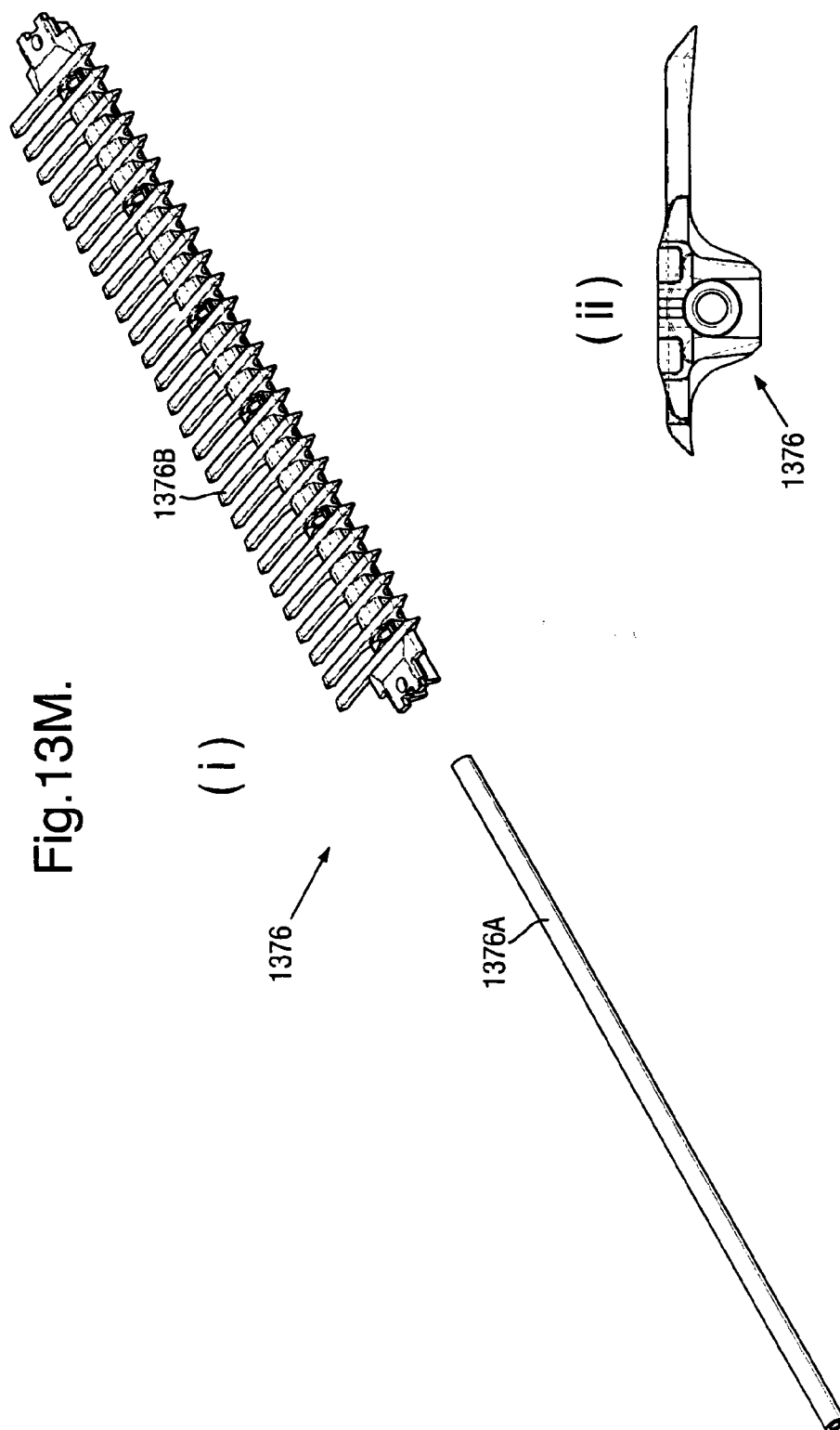


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Fig.13L.



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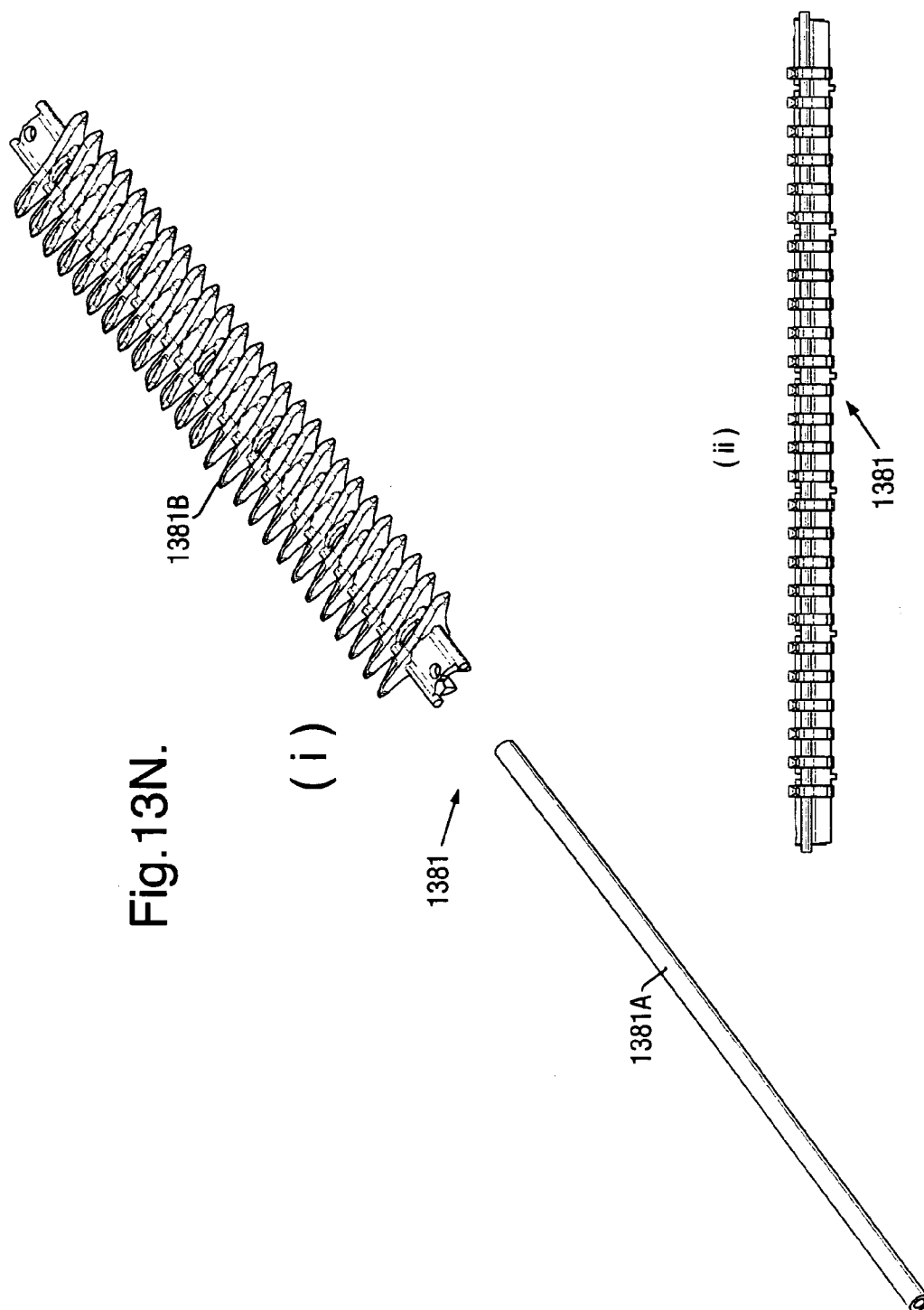
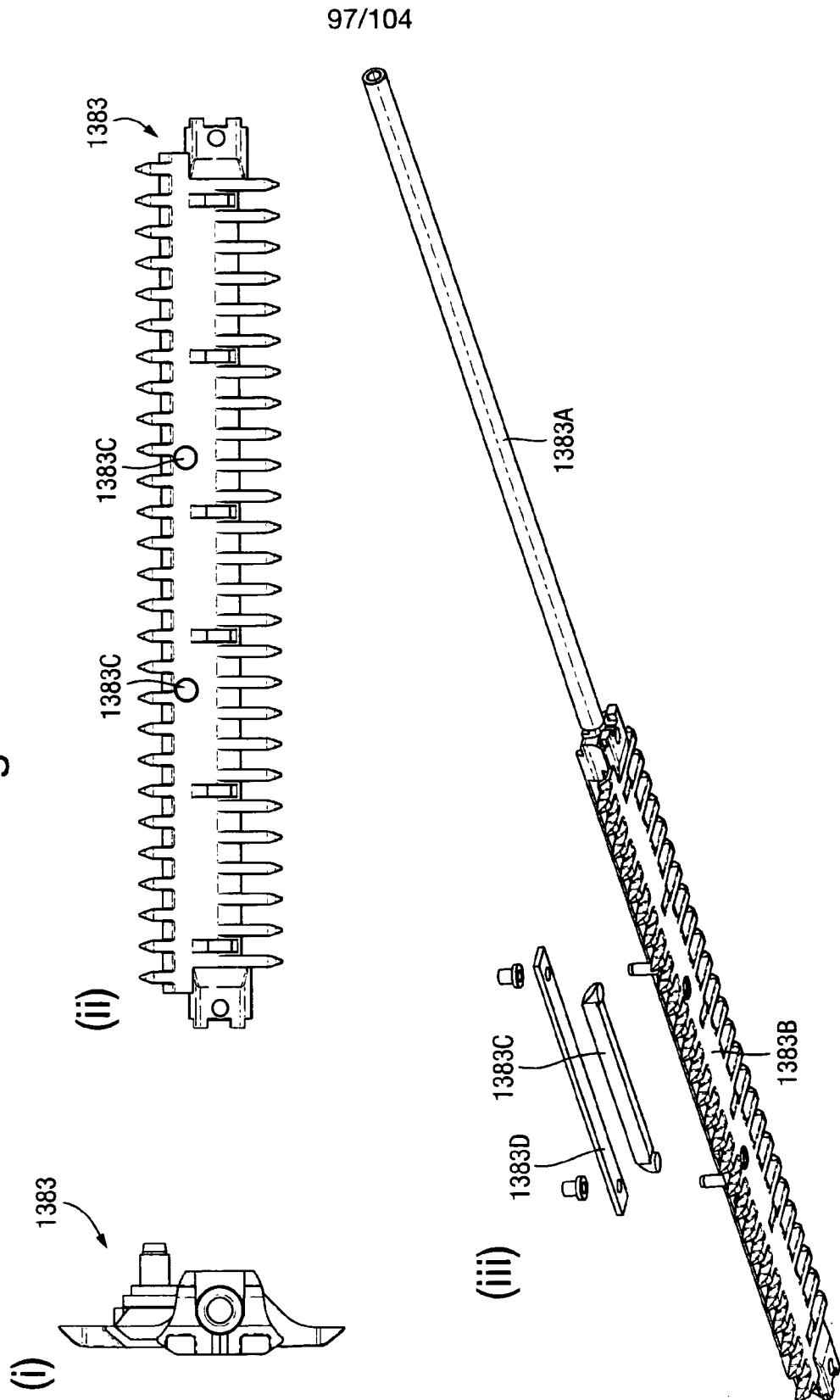
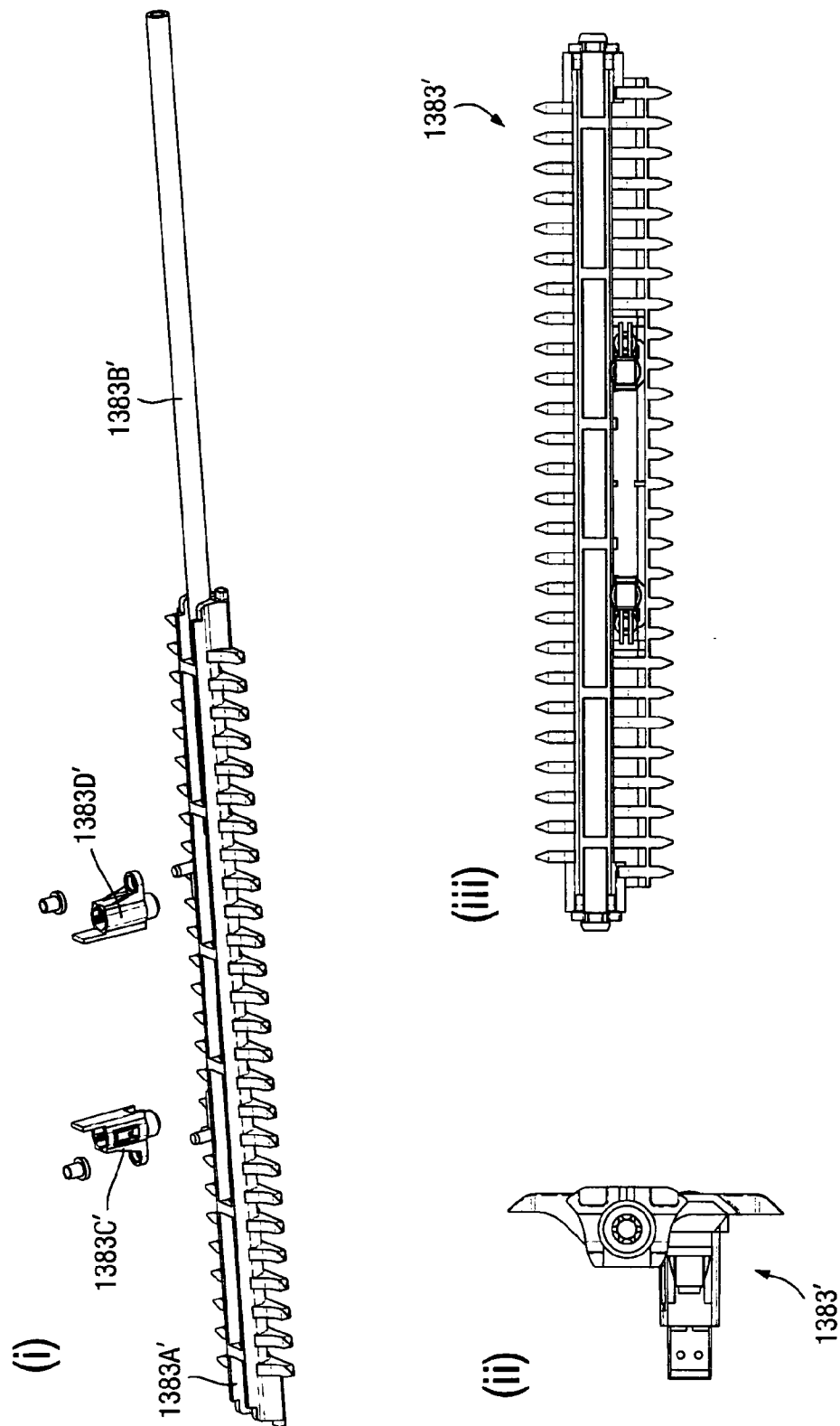


Fig.13P.



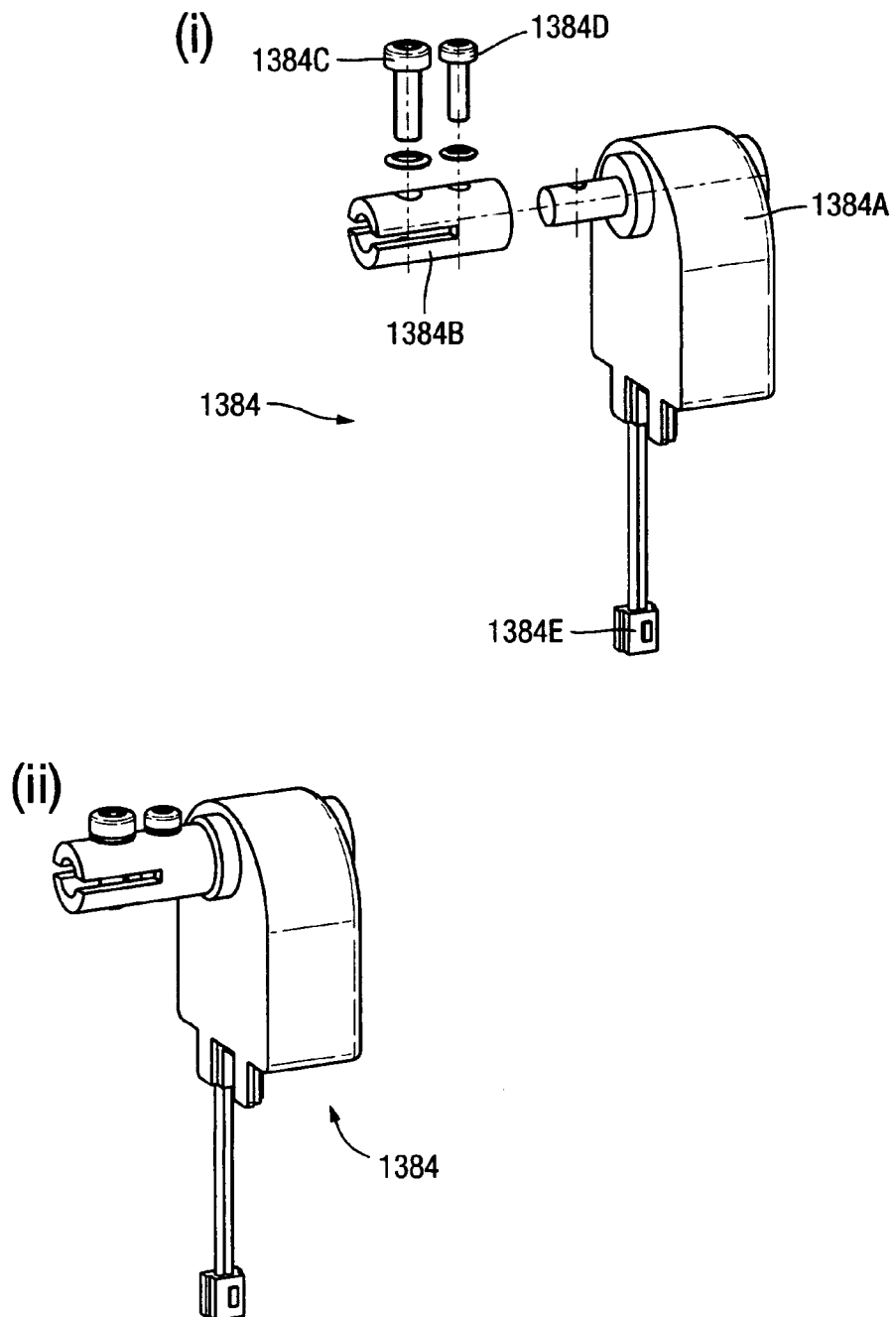
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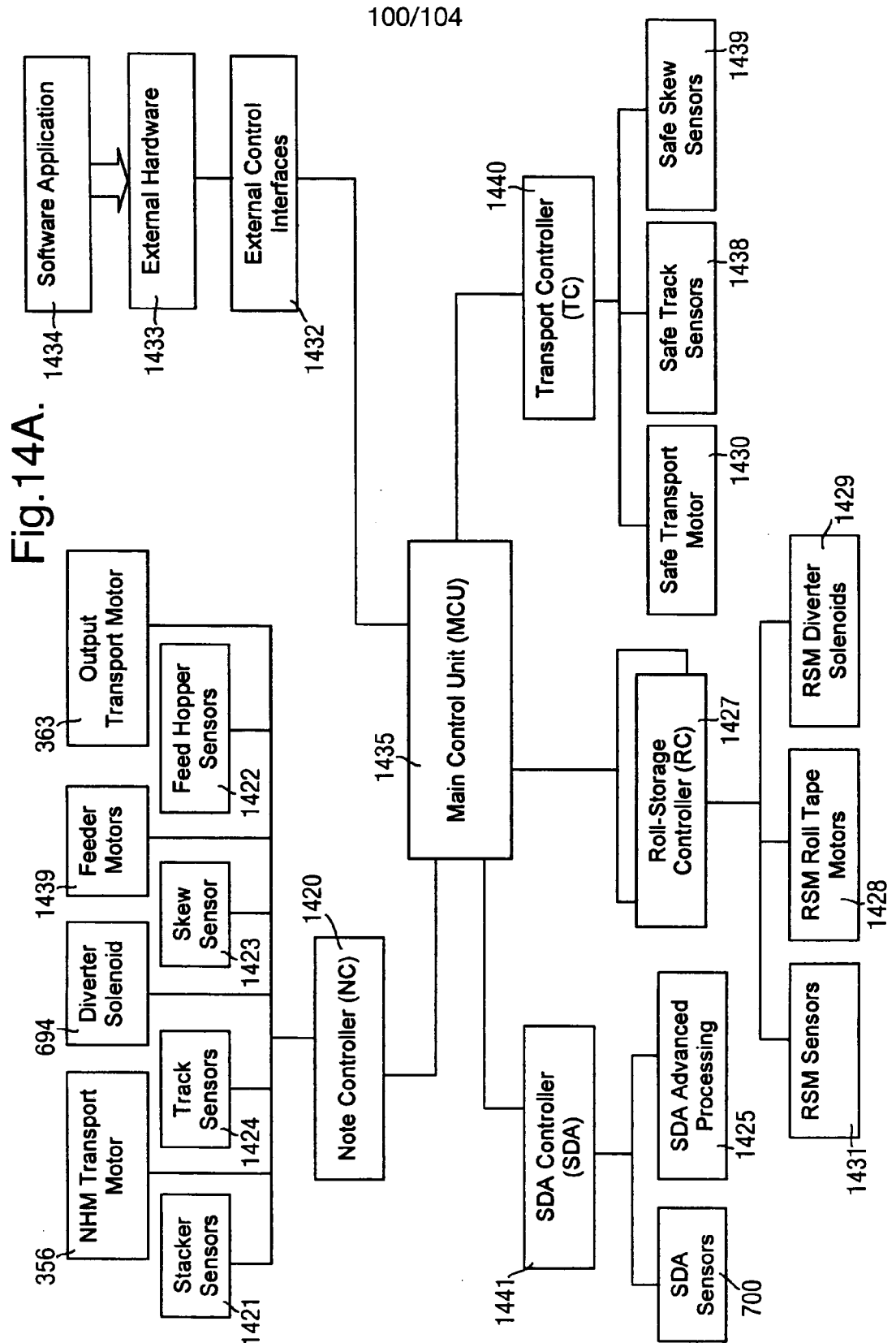
Fig.13Q.



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Fig.13R.





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Fig.14B.

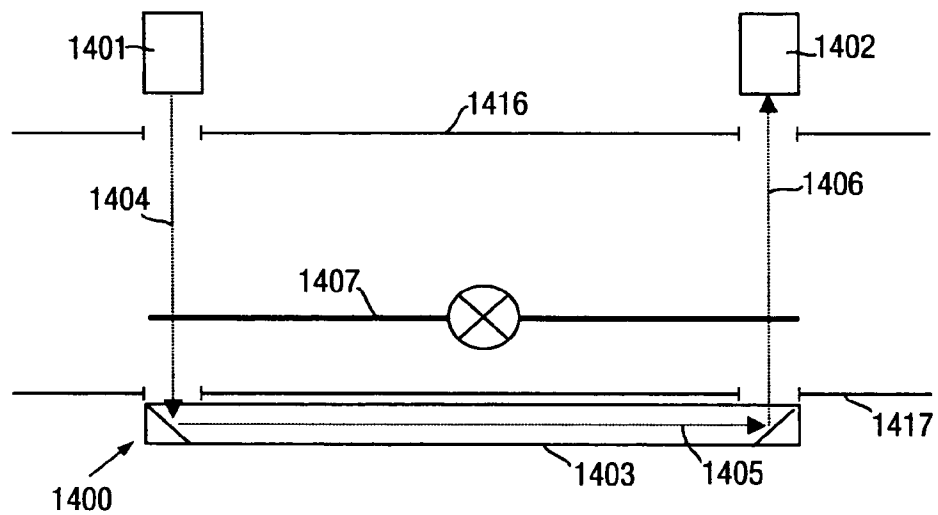


Fig.14C.

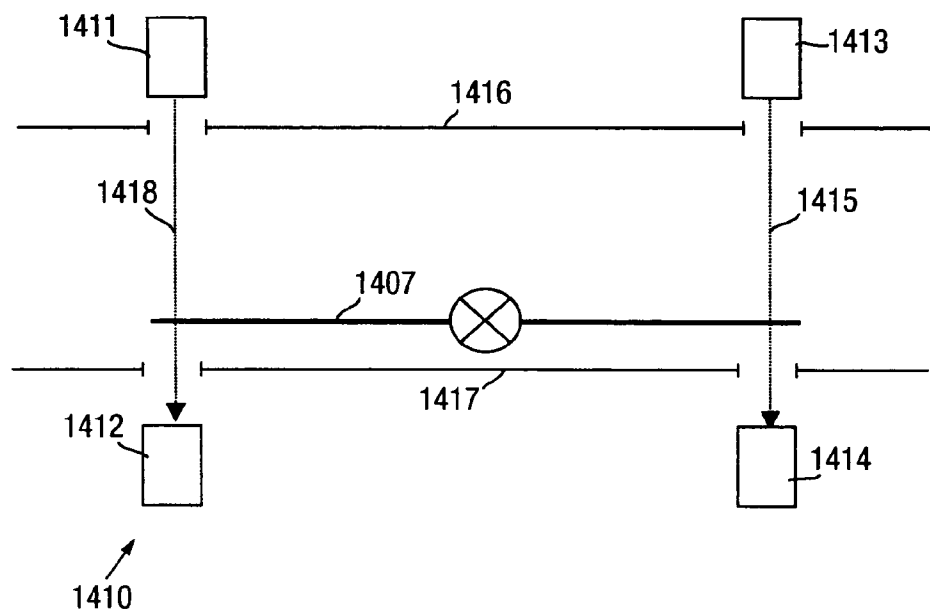
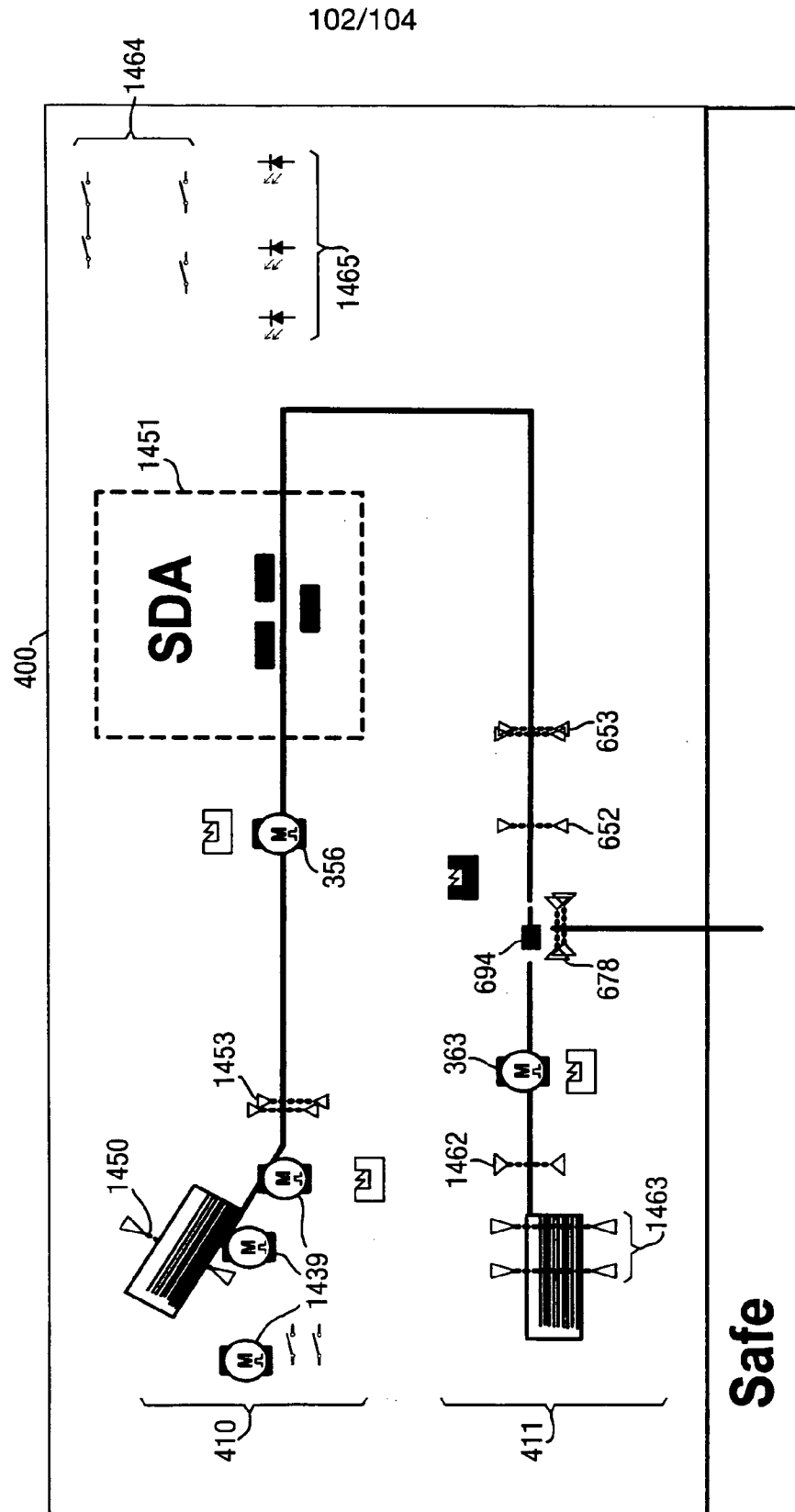
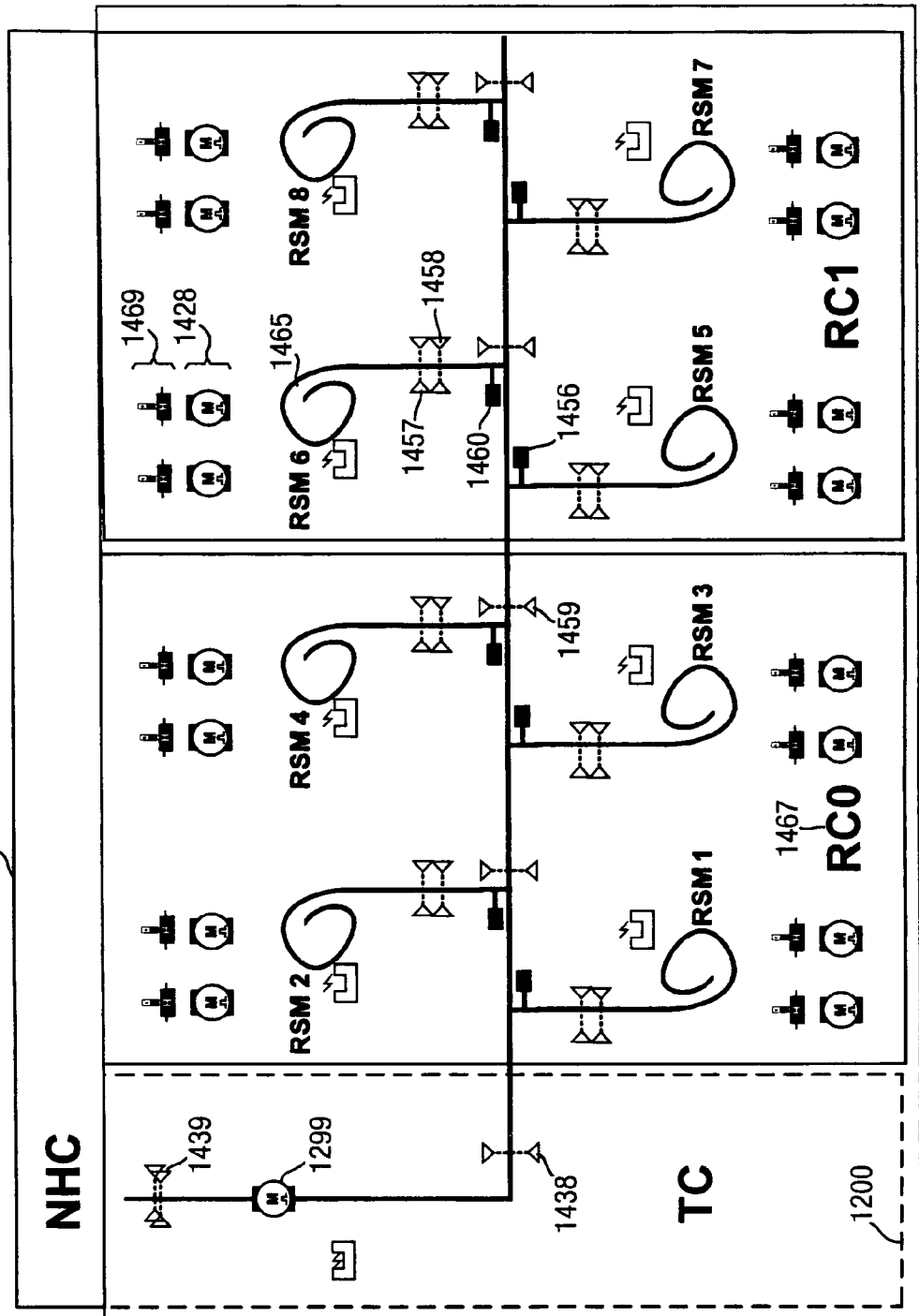


Fig.14D.



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Fig.14E.



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