Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2754182 A1 1999/11/11

(21) 2 754 182

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 1999/04/30

(41) Mise à la disp. pub./Open to Public Insp.: 1999/11/11

(62) Demande originale/Original Application: 2 737 959

(30) Priorité/Priority: 1998/05/01 (US60/083927)

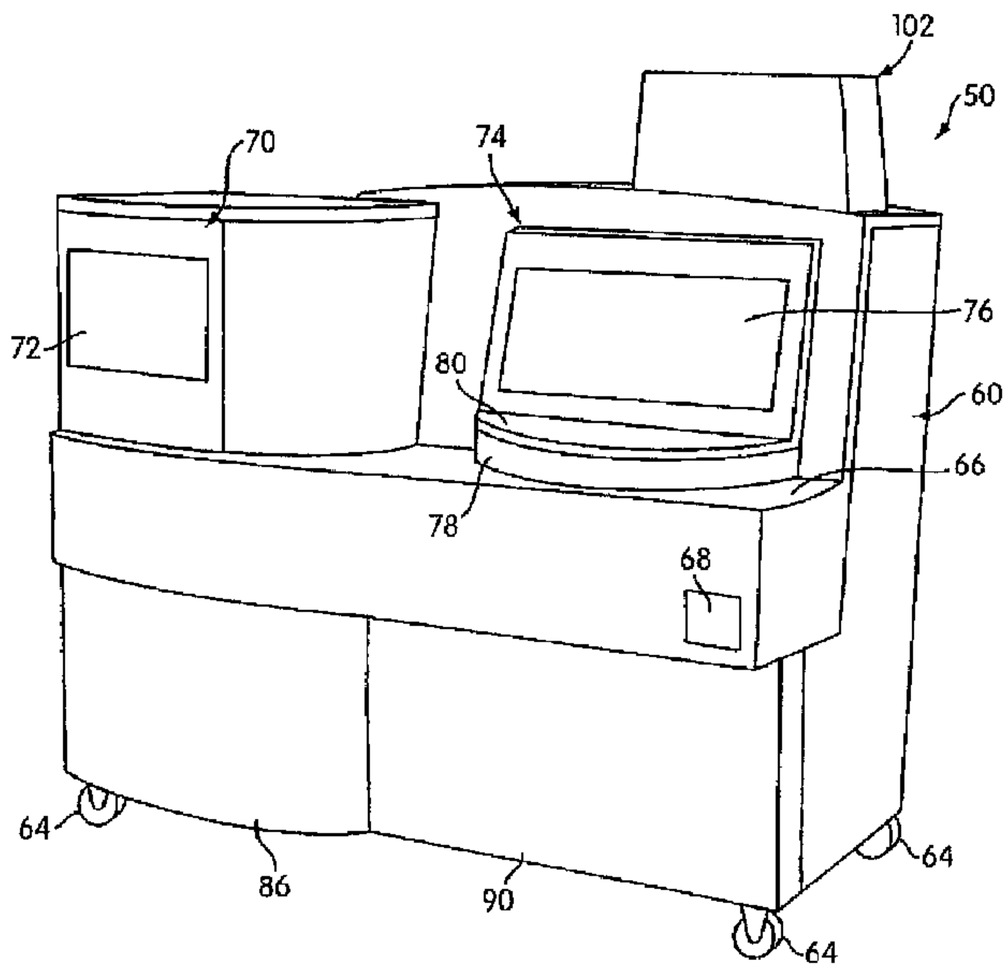
(51) Cl.Int./Int.Cl. *C12Q 1/68* (2006.01), *C12M 1/38* (2006.01), *C12N 15/10* (2006.01), *C12P 19/34* (2006.01), *G01N 1/28* (2006.01), *G01N 35/00* (2006.01), *C12M 1/42* (2006.01)

(71) Demandeur/Applicant:
GEN-PROBE INCORPORATED, US

(72) Inventeurs/Inventors:
AMMANN, KELLY G., US;
BURNS, RALPH E., US;
HANSBERRY, ERNEST V., US;
HORNER, GLEN A., US;
JAKUB, CHERYL A., US;
...

(74) Agent: DIMOCK STRATTON LLP

(54) Titre : ANALYSEUR AUTOMATISE POUR DIAGNOSTICS ET PROCEDE CORRESPONDANT
(54) Title: AUTOMATED DIAGNOSTIC ANALYZER AND METHOD



(57) Abrégé/Abstract:
An automated analyzer for performing multiple diagnostic assays simultaneously includes multiple stations, or modules, in which discrete aspects of the assay are performed on fluid samples contained in reaction receptacles. The analyzer includes stations for automatically preparing a specimen sample, incubating the sample at prescribed temperatures for prescribed periods, performing an analyte isolation procedure, and ascertaining the presence of a target analyte. An automated receptacle transporting system moves the reaction receptacles from one station to the next. The analyzer further includes devices for carrying a plurality of specimen tubes and disposable pipette tips in a machine-accessible manner, a device for agitating containers of target capture reagents comprising suspensions of solid support material and for presenting the containers for machine access thereto, and a device for holding containers of reagents in a temperature controlled environment and presenting the containers for machine access thereto. A method for performing an automated diagnostic assay includes an automated process for isolating and amplifying a target analyte. The process is performed by automatically moving each of a plurality of reaction receptacles containing a solid support material and a fluid sample between stations for incubating the contents of the reaction receptacle and for separating the target analyte bound to the solid support from the fluid sample. An amplification reagent is added to the separated analyte after the analyte separation step and before a final incubation step.

CA 2754182 A1 1999/11/11

(21) 2 754 182

(13) A1

(72) **Inventeurs(suite)/Inventors(continued)**: KLING, JOHN E., US; NIEGLOS, DONALD J., US; SCHNEIDER, ROBERT E., US; SMITH, ROBERT J., US

Abstract:

An automated analyzer for performing multiple diagnostic assays simultaneously includes multiple stations, or modules, in which discrete aspects of the assay are performed on fluid samples contained in reaction receptacles. The analyzer includes stations for automatically preparing a specimen sample, incubating the sample at prescribed temperatures for prescribed periods, performing an analyte isolation procedure, and ascertaining the presence of a target analyte. An automated receptacle transporting system moves the reaction receptacles from one station to the next. The analyzer further includes devices for carrying a plurality of specimen tubes and disposable pipette tips in a machine-accessible manner, a device for agitating containers of target capture reagents comprising suspensions of solid support material and for presenting the containers for machine access thereto, and a device for holding containers of reagents in a temperature controlled environment and presenting the containers for machine access thereto. A method for performing an automated diagnostic assay includes an automated process for isolating and amplifying a target analyte. The process is performed by automatically moving each of a plurality of reaction receptacles containing a solid support material and a fluid sample between stations for incubating the contents of the reaction receptacle and for separating the target analyte bound to the solid support from the fluid sample. An amplification reagent is added to the separated analyte after the analyte separation step and before a final incubation step.

AUTOMATED DIAGNOSTIC ANALYZER AND METHOD

1. FIELD OF THE INVENTION

The present invention relates to an automated analyzer for performing multiple diagnostic assays simultaneously.

2. BACKGROUND OF THE INVENTION

None of the references described or referred to herein are admitted to be prior art to the claimed invention.

Diagnostic assays are widely used in clinical diagnosis and health science research to detect or quantify the presence or amount of biological antigens, cell abnormalities, disease states, and disease-associated pathogens, including parasites, fungi, bacteria and viruses present in a host organism or sample. Where a diagnostic assay permits quantification, practitioners may be better able to calculate the extent of infection or disease and to determine the state of a disease over time. In general, diagnostic assays are based either on the detection of antigens (immunoassays) or nucleic acids (nucleic acid-based assays) belonging to an organism or virus of interest.

Nucleic acid-based assays generally include several steps leading to the detection or quantification of one or more target nucleic acid sequences in a sample which are specific to the organism or virus of interest. The targeted nucleic acid sequences can also be specific to an identifiable group of organisms or viruses, where the group is defined by at least one shared sequence of nucleic acid that is common to all members of the group and is specific to that group in the sample being assayed. The detection of individual and groups of organisms and viruses using nucleic acid-based methods is fully described by Kohne, U.S. Patent No. 4,851,330,and Hogan, U.S. Patent No. 5,541,551.

The first step in a nucleic acid-based assay is designing a probe which exhibits specificity, under stringent hybridization conditions, for a

nucleic acid sequence belonging to the organism or virus of interest. While nucleic acid-based assays can be designed to detect either deoxyribonucleic acid (DNA) or ribonucleic acid (RNA), ribosomal RNA (rRNA), or the gene encoding rRNA (rDNA), is typically the preferred nucleic acid for detection of a prokaryotic or eukaryotic organism in a sample. Ribosomal RNA target sequences are preferred because of their relative abundance in cells, and because rRNA contains regions of sequence variability that can be exploited to design probes capable of distinguishing between even closely related organisms. (Ribosomal RNA is the major structural component of the ribosome, which is the situs of protein synthesis in a cell.) Viruses, which do not contain rRNA, and cellular changes are often best detected by targeting DNA, RNA, or a messenger RNA (mRNA) sequence, which is a nucleic acid intermediate used to synthesize a protein. When the focus of a nucleic acid-based assay is the detection of a genetic abnormality, then the probes are usually designed to detect identifiable changes in the genetic code, such as the abnormal Philadelphia chromosome associated with chronic myelocytic leukemia. *See, e.g.*,Stephenson *et al.*, U.S. Patent No. 4,681,840.

When performing a nucleic acid-based assay, preparation of the sample is necessary to release and stabilize target nucleic acids which may be present in the sample. Sample preparation can also serve to eliminate nuclease activity and remove or inactivate potential inhibitors of nucleic acid amplification (discussed below) or detection of the target nucleic acids. *See, e.g.*,Ryder *et al.*, U.S. Patent No. 5,639,599,which discloses methods for preparing nucleic acid for amplification, including the use of complexing agents able to complex with ferric ions contributed by lysed red blood cells. The method of sample preparation can vary and will depend in part on the nature of the sample being processed (*e.g*, blood, urine, stool, pus or sputum). When target nucleic acids are being extracted from a white blood cell population present in a diluted or undiluted whole blood sample, a differential lysis procedure is generally

followed. *See, e.g.*,Ryder *et al.*, European Patent Application No. 93304542.9 and European Patent Publication No. 0547267. Differential lysis procedures are well known in the art and are designed to specifically isolate nucleic acids from white blood cells, while limiting or eliminating the presence or activity of red blood cell products, such as heme, which can interfere with nucleic acid amplification or detection.

Before or after exposing the extracted nucleic acid to a probe, the target nucleic acid can be immobilized by target-capture means, either directly or indirectly, using a "capture probe" bound to a substrate, such as a magnetic bead. Examples of target-capture methodologies are described by Ranki *et al.*, U.S. Patent No. 4,486,539,and Stabinsky, U.S. Patent No. 4,751,177. Target capture probes are generally short sequences of nucleic acid (*i.e.*,oligonucleotide) capable of hybridizing, under stringent hybridization conditions, with a sequence of nucleic acid which also contains the target sequence. Magnets in close proximity to the reaction vessel are used to draw and hold the magnetic beads to the side of the vessel. Once the target nucleic acid is thus immobilized, the hybridized nucleic acid can be separated from non-hybridized nucleic acid by aspirating fluid from the reaction vessel and optionally performing one or more wash steps.

In most instances, it is desirable to amplify the target sequence using any of several nucleic acid amplification procedures which are well known in the art. Specifically, nucleic acid amplification is the enzymatic synthesis of nucleic acid amplicons (copies) which contain a sequence that is complementary to a nucleic acid sequence being amplified. Examples of nucleic acid amplification procedures practiced in the art include the polymerase chain reaction (PCR), strand displacement amplification (SDA), ligase chain reaction (LCR), and transcription-associated amplification (TAA). Nucleic acid amplification is especially beneficial when the amount of target sequence present in a sample is very low. By amplifying the target sequences and detecting the amplicon synthesized,

the sensitivity of an assay can be vastly improved, since fewer target sequences are needed at the beginning of the assay to better ensure detection of nucleic acid in the sample belonging to the organism or virus of interest.

Methods of nucleic acid amplification are thoroughly described in the literature. PCR amplification, for instance, is described by Mullis *et al.* in U.S. Patent Nos. 4,683,195,4,683,202 and 4,800,159, and in *Methods in Enzymology*, 155:335-350 (1987). Examples of SDA can be found in Walker, *PCR Methods and Applications*, 3:25-30 (1993), Walker *et al.* in *Nucleic Acids Res.*, 20:1691-1996 (1992) and *Proc. Natl. Acad. Sci.*, 89:392-396 (1991). LCR is described in U.S. Patent Nos. 5,427,930 and 5,686,272. And different TAA formats are provided in publications such as Burg *et al.* in U.S. Patent No. 5,437,990; Kacian *et al.* in U.S. Patent Nos. 5,399,491 and 5,554,516; and Gingeras *et al.* in International Publication No. WO 88/01302, and International Publication No. WO 88/10315.

Detection of a targeted nucleic acid sequence requires the use of a probe having a nucleotide base sequence which is substantially complementary to the targeted sequence or, alternatively, its amplicon. Under selective assay conditions, the probe will hybridize to the targeted sequence or its amplicon in a manner permitting a practitioner to detect the presence of the targeted sequence in a sample. Effective probes are designed to prevent non-specific hybridization with any nucleic acid sequence which will interfere with detecting the presence of the targeted sequence. Probes may include a label capable of detection, where the label is, for example, a radiolabel, fluorescent dye, biotin, enzyme or chemiluminescent compound. Chemiluminescent compounds include acridinium esters which can be used in a hybridization protection assay (HPA) and then detected with a luminometer. Examples of chemiluminescent compounds and methods of labeling probes with

chemiluminescent compounds can be found in Arnold *et al.*, U.S. Patent Nos. 4,950,613,5,185,439 and 5,585,481; and Campbell *et al.*, U.S. Patent No. 4,946,958.

HPA is a detection method based on differential hydrolysis which permits specific detection of the acridinium ester-labeled probe hybridized to the target sequence or amplicon thereof. HPA is described in detail by Arnold *et al.* in U.S. Patent Nos. 5,283,174 and 5,639,599. This detection format permits hybridized probe to be distinguished from non-hybridized probe in solution and includes both a hybridization step and a selection step. In the hybridization step, an excess of acridinium ester-labeled probe is added to the reaction vessel and permitted to anneal to the target sequence or its amplicon. Following the hybridization step, label associated with unhybridized probe is rendered non-chemiluminescent in the selection step by the addition of an alkaline reagent. The alkaline reagent specifically hydrolyzes only that acridinium ester label associated with unhybridized probe, leaving the acridinium ester of the probe:target hybrid intact and detectable. Chemiluminescence from the acridinium ester of the hybridized probe can then be measured using a luminometer and signal is expressed in relative light units (RLU).

After the nucleic acid-based assay is run, and to avoid possible contamination of subsequent amplification reactions, the reaction mixture can be treated with a deactivating reagent which destroys nucleic acids and related amplification products in the reaction vessel. Such reagents can include oxidants, reductants and reactive chemicals which modify the primary chemical structure of a nucleic acid. These reagents operate by rendering nucleic acids inert towards an amplification reaction, whether the nucleic acid is RNA or DNA. Examples of such chemical agents include solutions of sodium hypochlorite (bleach), solutions of potassium permanganate, formic acid, hydrazine, dimethyl sulfate and similar compounds. More details of a deactivation protocol can be found in Dattagupta *et al.*, U.S. Patent No. 5,612,200.

When performed manually, the complexity and shear number of processing steps associated with a nucleic acid-based assay introduce opportunities for practitioner-error, exposure to pathogens, and cross-contamination between assays. Following a manual format, the practitioner must safely and conveniently juxtapose the test samples, reagents, waste containers, assay receptacles, pipette tips, aspirator device, dispenser device, and magnetic rack for performing target-capture, while being especially careful not to confuse racks, test samples, assay receptacles, and associated tips, or to knock over any tubes, tips, containers, or instruments. In addition, the practitioner must carefully perform aspirating and dispensing steps with hand-held, non-fixed instruments in a manner requiring precise execution to avoid undesirable contact between assay receptacles, aerosol formation, or aspiration of magnetic particles or other substrates used in a target-capture assay. As a further precaution, the magnetic field in a manually performed target-capture assay is often applied to only one side of the assay receptacle so that fluids can be aspirated through a pipette tip inserted along the opposite side of the assay receptacle. Although applying a magnetic field to only one side of the assay receptacle is a less efficient means for performing a target capture assay, it is designed to prevent magnetic particles from being unnecessarily aspirated as a result of practitioner inaccuracies.

A need exists for an automated diagnostic analyzer which addresses many of the concerns associated with manual approaches to performing nucleic acid-based assays. In particular, significant advantages can be realized by automating the various process steps of a nucleic acid-based assay, including greatly reducing the risk of user-error, pathogen exposure, contamination, and spillage, while significantly increasing through-put volume. Automating the steps of a nucleic acid-based assay will also reduce the amount training required for practitioners and virtually eliminate sources of physical injury attributable to high-volume manual

applications.

SUMMARY OF THE INVENTION

The above-described needs are addressed by an automated clinical analyzer constructed and operated in accordance with aspects of the present invention. In general, the automated clinical analyzer integrates and coordinates the operation of various automated stations, or modules, involved in performing one or more assays on a plurality of reaction mixtures contained in reaction receptacles. The analyzer is preferably a self-contained, stand alone unit. Assay specimen materials and reaction receptacles, as well as the various solutions, reagents, and other materials used in performing the assays are preferably stored within the analyzer, as are the waste products generated when assays are performed.

The analyzer includes a computer controller which runs analyzer-controlling and assay-scheduling software to coordinate operation of the stations of the analyzer and movement of each reaction receptacle through the analyzer.

Reaction receptacles can be loaded in an input queue which sequentially presents each receptacle at a pick-up position to be retrieved by a transport mechanism, which automatically transports the reaction receptacles between the stations of the analyzer.

Specimen containers are carried on a first ring assembly, and disposable pipette tips are carried on a second ring assembly. Containers of target capture reagent, including a suspension of solid support material, are carried on an inner rotatable assembly constructed and arranged to selectively agitate the containers or present the containers for access by the probe of an automatic robotic pipette system. Reaction mixtures, including fluid specimen material and target capture reagent, are prepared by the pipette system within each reaction receptacle.

The analyzer further includes receptacle mixers for mixing the contents of a receptacle placed therein. The mixer may be in fluid

communication with fluid containers and may include dispensers for dispensing one or more fluids into the receptacle. One or more incubators carry multiple receptacles in a temperature-controlled chamber and permit individual receptacles to be automatically placed into and removed from the chamber. Magnetic separation wash stations automatically perform a magnetic separation wash procedure on the contents of a receptacle placed in the station.

In the preferred method of operation, assay results may be ascertained by the amount of light, emitted from a receptacle at the conclusion of the appropriate preparation steps. Accordingly, the analyzer includes a luminometer for detecting and/or quantifying the amount of light emitted by the contents of the reaction receptacle. A deactivation queue may be provided to deactivate the contents of a reaction receptacle placed therein at the conclusion of the assay.

Reaction receptacles can be independently transported between stations by the transport mechanism, and the stations can be operated in parallel to perform different assay procedures simultaneously on different reaction receptacles, thereby facilitating efficient, high through-put operation of the analyzer. Moreover, the present invention facilitates arranging the various stations associated with a nucleic acid-based assay onto a single, contained platform, thereby achieving efficient space utilization.

Various embodiments of this invention provide an automated instrument for separating and amplifying a target nucleic acid sequence that may be present in a sample, the instrument comprising:

a separation station constructed and arranged to separate a target nucleic acid containing the target nucleic acid sequence from non-target nucleic acid that may be present in the sample;

an amplification station comprising a first incubator defining a temperature-controlled chamber, the first incubator being adapted to receive a reaction receptacle containing the separated target nucleic acid and to incubate the contents of the reaction receptacle, to which amplification reagents have been provided, for a period of time and under conditions sufficient to permit the target sequence to be amplified; and

one or more receptacle transport mechanisms, each receptacle transport mechanism being constructed and arranged to transport reaction receptacles between stations of the instrument.

Various embodiments of this invention provide a process for separating and amplifying a target nucleic acid sequence that may be present in a sample, the process comprising the automated steps of:

at a separation station, separating a target nucleic acid containing the target nucleic acid sequence from non-target nucleic acid that may be present in the sample;

in a reaction receptacle, transporting the separated target nucleic acid to an amplification station; and

at the amplification station, incubating the contents of the reaction receptacle, to which amplification reagents have been provided, in a first temperature-controlled incubator for a period of time and under conditions sufficient to permit the formation of an amplification product indicative of the presence of the target nucleic acid in the sample,

wherein the separation and amplification stations are contained within a housing.

Other objects, features, and characteristics of the present invention, including the methods of operation and the function and interrelation of the elements of structure, will become more apparent upon consideration of the following description and the appended claims, with reference to the accompanying drawings, all of which form a part of this disclosure, wherein like reference numerals designate corresponding parts in the various figures.

DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a perspective view of an automated nucleic acid-based diagnostic analyzer according to the present invention;

FIGURE 2 is a perspective view of the structural frame of the analyzer of the present invention;

FIGURE 3 is a plan view of a portion of the assay processing deck of the analyzer of the present invention;

FIGURE 4 is an exploded perspective view of the assay processing deck;

FIGURE 5 is a plan view of a specimen ring and a pipette tip wheel of the assay processing deck of the analyzer of the present invention;

FIGURE 6 is a perspective view showing the specimen ring and the pipette tip wheel;

FIGURE 6A is a partial cross-sectional view along the line 6A-6A in FIGURE 5;

FIGURE 7 is a perspective view of a multi-axis mixer of the processing deck of the analyzer of the present invention;

FIGURE 8 is a plan view of the multi-axis mixer;

FIGURE 9 is a side elevation of the multi-axis mixer;

FIGURE 10 is a plan view of the multi-axis mixer with container holders and a turntable cover removed therefrom;

FIGURE 11 is a cross-sectional view of the multi-axis mixer taken in the direction 11-11 in FIGURE 10;

FIGURE 12 is a perspective view of a drive assembly of the multi-axis mixer;

FIGURE 13 is a perspective view of a transport mechanism of the processing deck of the analyzer of the present invention;

FIGURE 14 is a perspective view of a manipulating hook mounting plate and a manipulating hook actuating mechanism of the transport mechanism, with the manipulating hook member engaged with a reaction receptacle and in a retracted position;

FIGURE 15 is the same as FIGURE 14, except with the manipulating hook member in the extended position;

FIGURE 16 is an exploded perspective view of the transport mechanism;

FIGURE 17 is a side-elevation of a temperature ramping station of the processing deck of the analyzer of the present invention;

FIGURE 18 is a front-elevation of the temperature ramping station;

FIGURE 19 is a perspective view of a rotary incubator of the processing deck of the analyzer of the present invention;

FIGURE 20 is an exploded view of a portion of a housing and access opening closure mechanisms according to a first embodiment of the rotary incubator;

FIGURE 21 is a partial view of a skewed disk linear mixer of the rotary incubator, shown engaged with a reaction receptacle employed in a preferred mode of operation of the analyzer of the present invention;

FIGURE 22 is an exploded perspective view of the first embodiment of the rotary incubator;

FIGURE 23 is a perspective view of the rotary incubator according to a second embodiment thereof;

FIGURE 23A is an exploded perspective view of the second embodiment of the rotary incubator;

FIGURE 23B is a partial exploded perspective view of an access opening closure mechanism of the second embodiment of the rotary incubator;

FIGURE 23C is an exploded view of a receptacle carrier carousel of the second embodiment of the rotary incubator;

FIGURE 24 is a perspective view of a magnetic separation wash station of the processing deck of the present invention with a side plate thereof removed;

FIGURE 25 is a partial transvers cross-section of the magnetic

separation wash station;

FIGURE 25A is a partial transverse cross-section of a tip of an aspirating tube of the magnetic separation wash station with a contamination-limiting tiplet carried on the end thereof;

FIGURE 26 is an exploded perspective view of a receptacle carrier unit, an orbital mixer assembly, and a divider plate of the magnetic separation wash station;

FIGURE 27 is a partial cross-sectional view of a wash buffer dispenser nozzle, an aspirator tube with a contamination-limiting tiplet engaged with an end thereof, and a receptacle carrier unit of the magnetic separation wash station, showing a multi-tube unit reaction receptacle employed in a preferred mode of operation of the analyzer carried in the receptacle carrier unit and the aspirator tube and contamination-limiting tiplet inserted into a receptacle vessel of the multi-tube unit;

FIGURE 28 is a partial cross-sectional view of the wash buffer dispenser nozzle, the aspirator tube, and the receptacle carrier unit of the magnetic separation wash station, showing the multi-tube unit carried in the receptacle carrier unit and the aspirator tube engaging the contamination-limiting tiplet held in a contamination-limiting element holding structure of the multi-tube unit;

FIGURES 29A-29D show a cross-section of a first embodiment of a tiplet stripping hole of a tiplet stripping plate of the magnetic separation wash station and a tiplet stripping operation using the tiplet stripping hole;

FIGURES 30A-30D show a cross-section of a second embodiment of a tiplet stripping hole and a tiplet stripping operation using the tiplet stripping hole;

FIGURE 31A is a plan view of a third embodiment of a tiplet stripping hole of a tiplet stripping plate of the magnetic separation wash station;

FIGURES 31B-31C show a cross-section of the third embodiment of the tiplet stripping hole and a tiplet stripping operation using the tiplet

stripping hole;

FIGURE 32 is a perspective view of an orbital mixer with a front plate thereof removed;

FIGURE 33 is an exploded view of the orbital mixer of the processing deck of the analyzer of the present invention;

FIGURE 34 is a top-plan view of the orbital mixer;

FIGURE 35 is a top perspective view of a reagent cooling bay of the processing deck of the analyzer of the present invention;

FIGURE 36 is a top perspective view of a reagent cooling bay with the container tray removed therefrom;

FIGURE 37 is a bottom plan view of the reagent cooling bay;

FIGURE 38 is an exploded view of the reagent cooling bay;

FIGURE 39 is a top perspective view of a modular container tray of the reagent cooling bay;

FIGURE 40 is a perspective view of a first embodiment of a luminometer of the processing deck of the analyzer of the present invention;

FIGURE 41 is a partial exploded perspective view of the luminometer of the first embodiment;

FIGURE 42A is a partial perspective view of a receptacle transport mechanism of the first embodiment of the luminometer;

FIGURE 42B is an end view of the receptacle transport mechanism of the first embodiment of the luminometer;

FIGURE 42C is a top view of the receptacle transport mechanism of the first embodiment of the luminometer;

FIGURE 43 is a break away perspective view of a second embodiment of the luminometer of the present invention;

FIGURE 44 is an exploded perspective view of a multi-tube unit door assembly for the luminometer of the second embodiment;

FIGURE 45 is an exploded perspective view of a shutter assembly for a photosensor aperture for the luminometer of the second

embodiment;

FIGURE 45A is a perspective view of an aperture plate of the shutter assembly of the luminometer of the second embodiment;

FIGURE 46 is a perspective view of a receptacle vessel positioner assembly of the luminometer of the second embodiment, including a receptacle vessel positioner disposed within a receptacle vessel positioner frame;

FIGURE 47 is a perspective view of the receptacle vessel positioner;

FIGURE 48 is a side elevation of the receptacle vessel positioner assembly;

FIGURE 49 is a perspective view showing the receptacle vessel positioner of the receptacle vessel positioner assembly operatively engaging a multi-tube unit employed in a preferred mode of operation of the analyzer;

FIGURE 50 is a perspective view of a multi-tube unit transport mechanism of the luminometer of the second embodiment;

FIGURE 51 is a partial perspective view showing a multi-tube unit transport and drive screw of the multi-tube unit transport mechanism of the luminometer;

FIGURE 52 is a perspective view of a lower chassis of the analyzer of the present invention;

FIGURE 53 is a perspective view of a right-side drawer of the lower chassis;

FIGURE 54 is a perspective view of a left-side drawer of the lower chassis;

FIGURE 55 is a perspective view of a specimen tube tray employed in a preferred mode of operation of the analyzer of the present invention;

FIGURE 56 is a top plan view of the specimen tube tray;

FIGURE 57 is a partial cross-section of the specimen tube tray through line "57-57" in FIGURE 55;

FIGURE 58 is a perspective view of a multi-tube unit employed in a preferred mode of operation of the analyzer of the present invention;

FIGURE 59 is a side elevation of a contact-limiting pipette tiplet employed in a preferred mode of operation of the analyzer of the present invention and carried on the multi-tube unit shown in FIGURE 58; and

FIGURE 60 is an enlarged bottom view of a portion of the multi-tube unit, viewed in the direction of arrow "60" in FIGURE 58.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

ANALYZER OVERVIEW

An automated diagnostic analyzer according to the present invention is designated generally by reference number 50 in FIGURES 1 and 2. Analyzer 50 includes a housing 60 built over an internal frame structure 62, preferably made of steel. The analyzer 50 is preferably supported on caster wheels 64 structurally mounted to the frame structure 62 so as to make the analyzer movable.

The various stations involved in performing an automated assay and the assay specimens are housed within housing 60. In addition, the various solutions, reagents, and other materials used in performing the assays are preferably stored within the housing 60, as are the waste products generated when assays are performed with the analyzer 50.

Housing 60 includes a test receptacle loading opening 68, which is shown in FIGURE 1 to be disposed in a forwardly facing panel of the housing 60, but could as well be located in other panels of the housing 60. A pipette door 70 having a view window 72 and a carousel door 74 having a view window 76 are disposed above a generally horizontal work surface 66. A forwardly protruding arcuate panel 78 accommodates a specimen carousel, which will be described below. A flip-up arcuate specimen door 80 is pivotally attached to the housing so as to be vertically pivotal with respect to arcuate panel 78 so as to provide access to a forward portion of the specimen carousel behind the panel 78. Sensors indicate when the

doors are closed, and the specimen door 80, the carousel door 74, and the pipette door 70 are locked during analyzer operation. The locking mechanism for each door preferably consists of a hook attached to a DC rotary solenoid (rated for continuous duty) with a spring return. Preferred rotary solenoids are available from Lucas Control Systems, of Vandalia, Ohio, model numbers L-2670-034 and L-1094-034.

An extension portion 102, preferably made of a transparent or translucent material, extends above the top portion of housing 60 so as to provide vertical clearance for moving components within the housing 60.

The assays are performed primarily on a processing deck 200, which is the general location of the various assay stations of the analyzer 50 described below. For simplicity of the illustration, the processing deck 200 is shown in FIGURE 2 without any of the assay stations mounted thereon. The processing deck 200 comprises a datum plate 82 to which the various stations are directly or indirectly mounted. Datum plate 82 preferably comprises a machined aluminum plate. The processing deck 200, also known as the chemistry deck, separates the interior of the housing into the chemistry area, or upper chassis, above the datum plate 82 and the storage areas, or lower chassis 1100, located below the datum plate 82.

A number of fans and louvers are preferably provided in the upper chassis portion of the housing 60 to create air circulation throughout the upper chassis to avoid excessive temperatures in the upper chassis.

As the analyzer 50 of the present invention is computer controlled, the analyzer 50 includes a computer controller, schematically represented as box 1000 in FIGURE 2, which runs high-level analyzer-controlling software known as the "assay manager program". The assay manager program includes a scheduler routine which monitors and controls test specimen movement through the chemistry deck 200.

The computer system 1000 which controls the analyzer 50 may include a stand-alone computer system including a CPU, keyboard, monitor, and may optionally include a printer device. A portable cart may

also be provided for storing and supporting the various computer components. Alternately, the computer hardware for running the analyzer-controlling software may be integrally housed within the housing 60 of the analyzer 50.

Low level analyzer control, such as control of electric motors and heaters used throughout the analyzer 50 and monitoring of fluid levels within bulk fluid and waste fluid containers, is performed by an embedded controller, preferably comprising a Motorola 68332 microprocessor. Stepper motors used throughout the analyzer are also preferably controlled by preprogrammed, off-the-shelf, microprocessor chips available from E-M Technologies, Bala Cynwyd, Pennsylvania.

The processing deck 200 is shown schematically in FIGURES 3 and 4. FIGURE 3 represents a schematic plan view of a poriton of the processing deck 200, and FIGURE 4 represents a schematic perspective view of the processing deck. The datum plate 82 forms the foundation of the processing deck 200 on which all stations are directly or indirectly attached.

Processing deck 200 includes a reaction receptacle input queue 150 which extends from opening 68 in front of housing 60. A plurality of reaction receptacles are loaded in a stacked fashion in the input queue 150. The purpose of the input queue is to hold a prescribed number of reaction receptacles and to sequentially present them at a pick-up position to be retrieved by a transport mechanism (described below). A reflective sensor at the pick-up position verifies the presence of a receptacle at that position. The input queue also includes a device for counting the number of receptacles resident therein at any given time.

A reaction receptacle shuttle assembly (not shown) within the queue moves the receptacles along a receptacle advance path toward the pick-up position. Optical sensors indicate when the shuttle assembly is in its home and fully extended positions. The queue includes a drawer which may be pulled out for loading the receptacles therein. Before the drawer

is opened, however, it must be unlocked and the shuttle must disengage from the receptacle advance path. When the drawer is again closed, it is locked and the shuttle engages the receptacles and moves them toward the pick-up position. Optical sensors indicate when the drawer is closed and when the shuttle has engaged a receptacle. As each receptacle is removed from the pick-up position by the transport mechanism, the receptacle shuttle advances the receptacles one receptacle-width, so that the next receptacle is in the pick-up position.

The reaction receptacles are preferably integrally formed linear arrays of test tubes and known as multi-tube units, or MTUs. The preferred reaction receptacles (MTUs) will be described in more detail below.

A first ring assembly, which in the preferred embodiment comprises a specimen ring 250, is mounted on a pivoting jig plate 130 at a distance above the datum plate 82. Specimen ring 250 is generally circular and preferably holds up to nine specimen trays 300 in an annular fluid container carrier portion thereof, and each of the specimen trays preferably holds 20 specimen-containing containers, or test tubes 320. The specimen ring 250 is constructed and arranged to be rotatable about a first generally vertical axis of rotation and delivers the specimen tubes 320 to a specimen pipette assembly 450, preferably an automated robotic pipette system. The forward portion of specimen ring 250 is accessible through the flip-up carousel door 80 provided in housing 60 so that trays 300 of test tubes 320 can be easily loaded onto the specimen ring 250 and unloaded from the specimen ring. Specimen ring 250 is driven by a motor, as will be described in more detail below.

A second ring assembly, which in the preferred embodiment comprises a pipette tip wheel 350, is located in an interior portion of the specimen ring 250, so that at least a portion of the outer perimeter of the pipette tip wheel 350 is disposed radially inwardly of the inner periphery of the ring 250. Pipette tip wheel 350 carries thereon a plurality of

commercially available packages of pipette tips. Pipette tip wheel 350 is motor driven to rotate independently of specimen ring 250 about a second axis of rotation that is generally parallel to the first axis of rotation of the specimen ring 250.

An inner rotatable assembly constructed and arranged to carry a plurality of fluid containers is provided at an interior portion of the pipette tip wheel 350. In the preferred embodiment, the inner rotatable assembly comprises a multi-axis mixer 400 located radially inside the pipette tip wheel 350 (i.e., the second ring assembly) and specimen ring 250 (i.e., the first ring assembly). The multi-axis mixer 400 includes a rotating turntable 414 that is rotatable about a third axis of rotation that is generally parallel to the first and second axes of rotation and on which are mounted four independently and eccentrically rotating container holders 406. Each of the container holders 406 receives a container, preferably in the form of a plastic bottle, containing a fluid suspension of magnetic particles with immobilized polynucleotides and polynucleotide capture probes. Each container holder 406 is generally cylindrical in shape and includes an axis of symmetry, or axis of rotation. The multi-axis mixer 400 rotates each of the containers eccentrically with respect to the center of the holder 406, while simultaneously rotating the turntable 414 about its center so as to provide substantially constant agitation of the containers to maintain the magnetic particles in suspension within the fluid.

The specimen pipette assembly, or robot, 450 is mounted to the frame structure 62 (see FIGURE 2) in a position above the specimen ring 250 and pipette tip wheel 350. The specimen pipette assembly 450 includes a pipette unit 456 having a tubular probe 457 mounted on a gantry assembly to provide X, Y, Z motion. Specifically, the pipette unit 456 is linearly movable in the Y-direction along a track 458 formed in a lateral rail 454, and the lateral rail 454 is longitudinally movable in the X-direction along a longitudinal track 452. The pipette unit 456 provides vertical, or Z-axis motion of the probe 457. Drive mechanisms within the

specimen pipette assembly 450 position the pipette unit 456 to the correct X, Y, Z coordinates within the analyzer 50 to pipette fluids, to wash the probe 457 of the pipette unit 456, to discard a protective tip from an end of the probe 457 of the pipette unit 456, or to stow the pipette unit 456 during periods of nonuse, e.g., in a "home" position. Each axis of the specimen pipette assembly 450 is driven by a stepper motor in a known and conventional manner.

The pipette assembly is preferably an off-the-shelf product. Presently preferred is the Robotic Sample Processor, model number RSP9000, available from Cavro Inc. of Sunnyvale, California. This model includes a single gantry arm.

The specimen pipette assembly 450 is preferably coupled to a syringe pump (not shown) (the Cavro XP 3000 has been used) and a DC driven diaphragm system fluid wash pump (not shown). The syringe pump of the specimen pipette assembly 450 is preferably mounted to the internal frame structure 62 within the housing 60 of the analyzer 50 at a position above the left-hand side of the chemistry deck 200 and is connected to pipette unit 456 by suitable tubing (not shown) or other conduit structures.

A specimen preparation opening 252 is provided in the jig plate 130, so that the specimen pipette assembly 450 can access a reaction receptacle 160 in the input queue 150 located below the jig plate 130.

The specimen pipette assembly 450 of the analyzer 50 engages specimen mbes 320 carried on the specimen ring 250 through openings 140, 142 of an elevated cover plate 138 and engages pipette tips carried on the pipette tip wheel 350 near the back portions of the specimen ring 250 and pipette tip wheel 350, respectively. Accordingly, an operator can have access to the forward portions of specimen ring 250 and pipette tip wheel 350 through the carousel door opening 80 during operation of the analyzer without interfering with pipetting procedures.

A tip wash/disposal station 340 is disposed adjacent to the specimen ring 250 on the jig plate 130. Station 340 includes a tip disposal

tube 342 and a wash station basin 346. During specimen preparation, the pipette unit 456 of the specimen pipette assembly 450 can move into position above the wash station basin 346 where the tubular probe 457 can be washed by pumping distilled water through the probe 457, the basin of the wash station 346 being connected, preferably by a flexible hose (not shown), to a liquid waste container in the lower chassis 1100.

The tip disposal tube 342 comprises an upstanding tubular member. During specimen transfer from a specimen tube 320 to a reaction receptacle 160, an elongated pipette tip is frictionally secured onto the end of the tubular probe 457 of the pipette unit 456, so that specimen material does not come into contact with the tubular probe 457 of the pipette unit 456 when material is drawn from a specimen tube 320 and into the elongated pipette tip. After a specimen has been transferred from a specimen tube 320, it is critical that the pipette tip used in transferring that specimen not be used again for another unrelated specimen. Therefore, after specimen transfer, the pipette unit 456 moves to a position above the tip disposal tube 342 and ejects the used, disposable pipette tip into the tip disposal tube 342 which is connected to one of the solid waste containers carried in the lower chassis 1100.

An elongated pipette tip is preferably also frictionally secured to the probe 457 for transferring target capture reagent from containers carried on the multi-axis mixer 400 to a reaction receptacle 160. Following reagent transfer, the pipette tip is discarded.

As noted, the specimen ring 250, the pipette tip wheel 350, and the multi-axis mixer 400 are preferably mounted on a hinged jig plate 130 (see FIGURES 5 and 6) supported above the datum plate 82. The jig plate 130 is hinged at a back end 132 thereof (see FIGURE 6) so that the plate, and the ring 250, the wheel 350, and the mixer 400 mounted thereon, can be pivoted upwardly to permit access to the area of the chemistry deck below the jig plate.

A first, or right-side, transport mechanism 500 is mounted on the

datum plate 82 below the jig plate 130 and specimen ring 250 on generally the same plane as the input queue 150. Transport mechanism 500 includes a rotating main body portion 504 defining a receptacle carrier assembly and an extendible manipulating hook 506 mounted within the main body 504 and extendible and retractable with respect thereto by means of a powered hook member drive assembly. Each of the reaction receptacles 160 preferably includes manipulating structure that can be engaged by the extendible manipulating hook 506, so that the transport mechanism 500 can engage and manipulate a reaction receptacle 160 and move it from one location on the processing deck 200 to another as the reaction receptacle is sequentially moved from one station to another during the performance of an assay within the reaction receptacle 160.

A second, or left-side, transport mechanism 502, of substantially identical construction as first distribution arm 500, is also included on the processing deck 200.

A plurality of receptacle parking stations 210 are also located below the jig plate 130. The parking stations 210, as their name implies, are structures for holding specimen-containing reaction receptacles until the assay performing stations of the processing deck 200 of the analyzer 50 are ready to accept the reaction receptacles. The reaction receptacles are retrieved from and inserted into the parking stations 210 as necessary by the transport mechanism 500.

A right-side orbital mixer 550 is attached to the datum plate 82 and receives reaction receptacles 160 inserted therein by the right-side transport mechanism 500. The orbital mixer is provided to mix the contents of the reaction receptacle 160. After mixing is complete, the right-side transport mechanism 500 removes the reaction receptacle from the right-side orbital mixer 550 and moves it to another location in the processing deck.

A number of incubators 600, 602, 604, 606, of substantially identical construction are provided. Incubators 600, 602, 604, and 606 are preferably

rotary incubators. Although the particular assay to be performed and the desired throughput will determine the desired number of necessary incubators, four incubators are preferably provided in the analyzer 50.

As will be described in more detail below, each incubator (600, 602, 604, 606) has a first, and may also have a second, receptacle access opening through which a transport mechanism 500 or 502 can insert a reaction receptacle 160 into the incubator or retrieve a reaction receptacle 160 from the incubator. Within each incubator (600, 602, 604, 606) is a rotating receptacle carrier carousel which holds a plurality of reaction receptacles 160 within individual receptacle stations while the receptacles are being incubated. For the nucleic acid-based diagnostic assay preferably performed on the analyzer 50 of the present invention, first rotary incubator 600 is a target capture and annealing incubator, second rotary incubator 602 is an active temperature and pre-read cool-down incubator (also known as an "AT incubator"), third rotary incubator 604 is an amplification incubator, and fourth rotary incubator 606 is a hybridization protection assay incubator. The construction, function, and role of the incubators in the overall performance of the assay will be described in more detail below.

The processing deck 200 preferably also includes a plurality of temperature ramping stations 700. Two such stations 700 are shown attached to the datum plate 82 between incubators 602 and 604 in FIGURE 3. Additional ramping stations may be disposed at other locations on the processing deck 200 where they will be accessible by one of the transport mechanisms 500, 502.

A reaction receptacle 160 may be placed into or removed from a temperature ramping station 700 by either transport mechanism 500 or 502. Each ramping station 700 either raises or lowers the temperature of the reaction receptacle and its contents to a desired temperature before the receptacle is placed into an incubator or another temperature sensitive station. By bringing the reaction receptacle and its contents to a desired

temperature before inserting it into one of the incubators (600, 602, 604, 606), temperature fluctuations within the incubator are minimized.

The processing deck 200 also includes magnetic separation wash stations 800 for performing a magnetic separation wash procedure. Each magnetic separation wash station 800 can accommodate and perform a wash procedure on one reaction receptacle 160 at a time. Therefore, to achieve the desired throughput, five magnetic separation wash stations 800 working in parallel are preferred. Receptacles 160 are inserted into and removed from the magnetic separation wash stations 800 by the left-side transport mechanism 502.

A reagent cooling bay 900 is attached to the datum plate 82 roughly between the incubators 604 and 606. Reagent cooling bay 900 comprises a carousel structure having a plurality of container receptacles for holding bottles of temperature sensitive reagents. The carousel resides within a cooled housing structure having a lid with pipette-access holes formed therein.

A second, or left-side, orbital mixer 552, substantially identical to right-side orbital mixer 550, is disposed between incubators 606 and 604. The left-side orbital mixer 552 includes dispenser nozzles and lines for dispensing fluids into the reaction receptacle resident within the left-side orbital mixer 552.

A reagent pipette assembly, or robot, 470 includes a double gantry structure attached to the frame structure 62 (see FIGURE 2) and is disposed generally above the incubators 604 and 606 on the left-hand side of the processing deck 200. Specifically, reagent pipette assembly 470 includes pipette units 480 and 482. Pipette unit 480 includes a tubular probe 481 and is mounted for linear movement, generally in the X-direction, along track 474 of lateral rail 476, and pipette unit 482, including a tubular probe 483, is also mounted for linear motion, generally in the X-direction, along track 484 of lateral rail 478. Lateral rails 476 and 478 can translate, generally in a Y-direction, along the longitudinal track 472.

Each pipette unit 480, 482 provides independent vertical, or Z-axis, motion of the respective probe 481, 483. Drive mechanisms within the assembly 470 position the pipette units 480, 482 to the correct X, Y, Z coordinates within the analyzer 50 to pipette fluids, to wash the tubular probes 481, 483 of the respective pipette units 480, 482, or to stow the pipette units 480, 482 during periods of nonuse, e.g., in "home" positions. Each axis of the pipette assembly 470 is driven by a stepper motor.

The reagent pipette assembly 470 is preferably an off-the-shelf product. The presently preferred unit is the Cavro Robotic Sample Processor, model RSP9000, with two gantry arms.

The pipette units 480, 482 of the reagent pipette assembly 470 are each preferably coupled to a respective syringe pump (not shown) (the Cavro XP 3000 has been used) and a DC driven diaphragm system fluid wash pump. The syringe pumps of the reagent pipette assembly 470 are preferably mounted to the internal frame structure 62 within the housing 60 of the analyzer 50 at a position above the left-hand side of the chemistry deck 200 and are connected to the respective pipette units 480, 482 by suitable tubing (not shown) or other conduit structures.

Each pipette unit 480, 482 preferably includes capacitive level sensing capability. Capacitive level sensing, which is generally known in the medical instrumentation arts, employs capacitance changes when the dielectric of a capacitor, formed by the pipette unit as one plate of the capacitor and the structure and hardware surrounding a container engaged by the pipette unit as the opposite plate, changes from air to fluid to sense when the probe of the pipette unit has penetrated fluid within a container. By ascertaining the vertical position of the probe of the pipette unit, which may be known by monitoring the stepper motor which drives vertical movement of the pipette unit, the level of the fluid within the container engaged by the pipette unit may be determined.

Pipette unit 480 transfers reagents from the reagent cooling bay 900 into reaction receptacles disposed within the incubator 606 or the orbital

mixer 552, and pipette unit 482 transfers reagent materials from the reagent cooling bay 900 into reaction receptacles disposed within the amplification incubator 604 or the orbital mixer 552.

The pipette units 480, 482 use capacitive level sensing to ascertain fluid level within a container and submerge only a small portion of the end of the probe of the pipette unit to pipette fluid from the container. Pipette units 480, 482 preferably descend as fluid is pipetted into the respective tubular probes 481, 483 to keep the end of the probes submerged to a constant depth. After drawing reagent into the tubular probe of the pipette unit 480 or 482, the pipette units create a minimum travel air gap of 10 µl in the end of the respective probe 481 or 483 to ensure no drips from the end of the probe as the pipette unit is moved to another location above the chemistry deck 200.

The results of the assay preferably performed in the analyzer 50 of the present invention are ascertained by the amount of chemiluminescence, or light, emitted from a receptacle vessel 162 at the conclusion of the appropriate preparation steps. Specifically, the results of the assay are determined from the amount of light emitted by label associated with hybridized polynucleotide probe at the conclusion of the assay. Accordingly, the processing deck 200 includes a luminometer 950 for detecting and/or quantifying the amount of light emitted by the contents of the reaction receptacle. Briefly, the luminometer 950 comprises a housing through which a reaction receptacle travels under the influence of a transport mechanism, a photomultiplier tube, and associated electronics. Various luminometer embodiments will be described in detail below.

The processing deck 200 also preferably includes a deactivation queue 750. The assay performed in the analyzer 50 involves the isolation and amplification of nucleic acids belonging to at least one organism or cell of interest. Therefore, it is desirable to deactivate the contents of the reaction receptacle 160, typically by dispensing a bleach-based reagent into

the reaction receptacle 160 at the conclusion of the assay. This deactivation occurs within the deactivation queue 750.

Following deactivation, the deactivated contents of the reaction receptacle 160 are stored in one of the liquid waste containers of the lower chassis 1100 and the used reaction receptacle is discarded into a dedicated solid waste container within the lower chassis 1100. The reaction receptacle is preferably not reused.

ANALYZER OPERATION

The operation of the analyzer 50, and the construction, cooperation, and interaction of the stations, components, and modules described above will be explained by describing the operation of the analyzer 50 on a single test specimen in the performance of one type of assay which may be performed with analyzer 50. Other diagnostic assays, which require the use of one or more of the stations, components, and modules described herein, may also be performed with the analyzer 50. The description herein of a particular assay procedure is merely for the purpose of illustrating the operation and interaction of the various stations, components, and modules of the analyzer 50 and is not intended to be limiting. Those skilled in the art of diagnostic testing will appreciate that a variety of chemical and biological assays can be performed in an automated fashion with the analyzer 50 of the present invention.

The analyzer 50 is initially configured for an assay run by loading bulk fluids into the bulk fluid storage bay of the lower chassis 1100 and connecting the bulk fluid containers to the appropriate hoses (not shown).

The analyzer is preferably powered up in a sequential process, initially powering the stations, or modules, that will be needed early in the process, and subsequently powering the stations that will not be needed until later in the process. This serves to conserve energy and also avoids large power surges that would accompany full analyzer power-up and

which could trip circuit breakers. The analyzer also employs a "sleep" mode during periods of nonuse. During sleep mode, a minimal amount of power is supplied to the analyzer, again to avoid large surges necessary to power-up an analyzer from complete shut-down.

A number of reaction receptacles 160, preferably in the form of plastic, integrally formed multiple-tube units (MTUs), which are described in more detail below, are loaded through opening 68 into the input queue 150. Henceforth, the reaction receptacles 160 will be referred to as MTUs, consistent with the preferred manner of using the analyzer 50.

The reaction receptacle shuttle assembly (not shown) within the input queue 150 moves the MTUs 160 from the loading opening 68 to the pick-up position at the end of the queue 150. The right-side transport mechanism 500 takes an MTU 160 from the end of the queue 150 and moves it to a bar code reader 253 to read the unique bar code label on that MTU which identifies that MTU. From the bar code reader 253, the MTU is moved to an available specimen transfer station 255 below opening 252.

MULTIPLE TUBE UNITS

As shown in FIGURE 58, an MTU 160 comprises a plurality of individual receptacle vessels 162, preferably five. The receptacle vessels 162, preferably in the form of cylindrical tubes with open top ends and closed bottom ends, are connected to one another by a connecting rib structure 164 which defines a downwardly facing shoulder extending longitudinally along either side of the MTU 160.

The MTU 160 is preferably formed from injection molded polypropylene. The most preferred polypropylene is sold by Montell Polyolefins, of Wilmington, Delaware, product number PD701NW. The Montell material is used because it is readily moldable, chemically compatible with the preferred mode of operation of the analyzer 50, and has a limited number of static discharge events which can interfere with

accurate detection or quantification of chemiluminescence.

An arcuate shield structure 169 is provided at one end of the MTU 160. An MTU manipulating structure 166 to be engaged by one of the transport mechanisms 500, 502 extends from the shield structure 169. MTU manipulating structure 166 comprises a laterally extending plate 168 extending from shield structure 169 with a vertically extending piece 167 on the opposite end of the plate 168. A gusset wall 165 extends downwardly from lateral plate 168 between shield structure 169 and vertical piece 167.

As shown in FIGURE 60 the shield structure 169 and vertical piece 167 have mutually facing convex surfaces. The MTU 160 is engaged by the transport mechanisms 500, 502 and other components, as will be described below, by moving an engaging member laterally (in the direction "A") into the space between the shield structure 169 and the vertical piece 167. The convex surfaces of the shield structure 169 and vertical piece 167 provide for wider points of entry for an engaging member undergoing a lateral relative motion into the space. The convex surfaces of the vertical piece 167 and shield structure 169 include raised portions 171, 172, respectively, formed at central portions thereof. The purpose of portions 171, 172 will be described below.

A label-receiving structure 174 having a flat label-receiving surface 175 is provided on an end of the MTU 160 opposite the shield structure 169 and MTU manipulating structure 166. Labels, such as scannable bar codes, can be placed on the surface 175 to provide identifying and instructional information on the MTU 160.

The MTU 160 preferably includes tiplet holding structures 176 adjacent the open mouth of each respective receptacle vessel 162. Each tiplet holding structure 176 provides a cylindrical orifice within which is received a contact-limiting tiplet 170. The construction and function of the tiplet 170 will be described below. Each holding structure 176 is constructed and arranged to frictionally receive a tiplet 170 in a manner

that prevents the tiplet 170 from falling out of the holding structure 176 when the MTU 160 is inverted, but permits the tiplet 170 to be removed from the holding structure 176 when engaged by a pipette.

As shown in Figure 59, the tiplet 170 comprises a generally cylindrical structure having a peripheral rim flange 177 and an upper collar 178 of generally larger diameter than a lower portion 179 of the tiplet 170. The tiplet 170 is preferably formed from conductive polypropylene. When the tiplet 170 is inserted into an orifice of a holding structure 176, the flange 177 contacts the top of structure 176 and the collar 178 provides a snug but releasable interference fit between the tiplet 170 and the holding structure 176.

An axially extending through-hole 180 passes through the tiplet. Hole 180 includes an outwardly flared end 181 at the top of the tiplet 170 which facilitates insertion of a pipette tubular probe (not shown) into the tiplet 170. Two annular ridges 183 line the inner wall of hole 180. Ridges 183 provide an interference friction fit between the tiplet 170 and a tubular probe inserted into the tiplet 170.

The bottom end of the tiplet 170 preferably includes a beveled portion 182. When tiplet 170 is used on the end of an aspirator that is inserted to the bottom of a reaction receptacle, such as a receptacle vessel 162 of an MTU 160, the beveled portion 182 prevents a vacuum from forming between the end of the tiplet 170 and the bottom of the reaction receptacle vessel.

LOWER CHASSIS

An embodiment of the lower chassis of the present invention is shown in FIGURES 52-54. The lower chassis 1100 includes a steel frame 1101 with a black polyurethane powder coat, a pull-out drip tray 1102 disposed below the chassis, a right-side drawer 1104, and a left-side drawer 1106. The left-side drawer 1106 is actually centrally disposed within the lower chassis 1100. The far left-side of the lower chassis 1100 houses

various power supply system components and other analyzer mechanisms such as, for example, seven syringe pumps 1152 mounted on a mounting platform 1154, a vacuum pump 1162 preferably mounted on the floor of the lower chassis 1100 on vibration isolators (not shown), a power supply unit 1156, a power filter 1158, and fans 1160.

A different syringe pump 1152 is designated for each of the five magnetic separation wash stations 800, one is designated for the left-side orbital mixer 552, and one is designated for the deactivation queue 750. Although syringe pumps are preferred, peristaltic pumps may be used as an alternative.

The vacuum pump 1162 services each of the magnetic separation wash stations 800 and the deactivation queue 750. The preferred rating of the vacuum pump is 5.3-6.5cfm at 0" Hg and 4.2-5.2cfm at 5" Hg. A preferred vacuum pump is available from Thomas Industries, Inc. of Sheboygan, Wisconsin, as model number 2750CGHI60. A capacitor 1172 is sold in conjunction with the pump 1162.

The power supply unit 1156 is preferably an ASTEC, model number VS1-B5-B7-03, available from ASTEC America, Inc., of Carlsbad, California. Power supply unit 1156 accepts 220 volts ranging from 50-60 Hz, i.e., power from a typical 220 volt wall outlet. Power filter 1158 is preferably a Corcom model 20MV1 filter, available from Corcom, Inc. of Libertyville, Illinois. Fans 1160 are preferably Whisper XLDC fans available from Comair Rotron, of San Ysidro, California. Each fan is powered by a 24VDC motor and has a 75 cfm output. As shown in FIGURE 52, the fans 1160 are preferably disposed proximate a left-side outer wall of the lower chassis 1100. The fans 1160 are preferably directed outwardly to draw air through the lower chassis from the right-side thereof to the left-side thereof, and thus, to draw excess heat out of the lower chassis.

Other power supply system components are housed in the back left-hand side of the lower chassis 1100, including a power switch 1174,

preferably an Eaton circuit breaker switch 2-pole, series JA/S, available from the Cutler-Hammer Division of Eaton Corporation of Cleveland, Ohio, and a power inlet module 1176 at which a power cord (not shown) for connecting the analyzer 50 to an external power source is connected. The power supply system of the analyzer 50 also includes a terminal block (not shown), for attaching thereto a plurality of electrical terminals, a solid state switch (not shown), which is preferably a Crydom Series 1, model number D2425, available from Cal Switch, Carson City, California, for switching between different circuits, and an RS232 9-pin connector port for connecting the analyzer 50 to the external computer controller 1000.

The right-side drawer and left-side drawer bays are preferably closed behind one or two doors (not shown) in front of the analyzer, which is/are preferably locked by the assay manager program during operation of the analyzer. Microswitches are preferably provided to verify door-closed status. The far left bay is covered by a front panel. End panels are provided on opposite ends of the lower chassis to enclose the chassis.

Four leveler feet 1180 extend down from the four corners of the chassis 1100. The leveler feet 1180 include threaded shafts with pads at the lower ends thereof. When the analyzer is in a desired location, the feet 1180 can be lowered until the pads engage the floor to level and stabilize the analyzer. The feet can also be raised to permit the analyzer to be moved on its casters.

Bulk fluids typically contained in the containers of the lower chassis 1100 may include wash buffer (for washing immobilized target), distilled water (for washing fixed pipette tips), diagnostic testing reagents, silicon oil (used as a floating fluid for layering over test reagents and specimen), and a bleach-based reagent (used for sample deactivation).

The right-side drawer 1104 is shown in detail in FIGURE 53. The right-side drawer 1104 includes a box-like drawer structure with a front drawer handle 1105. Although drawer handle 1105 is shown as a conventional pull-type drawer handle, in the preferred embodiment of the

analyzer 50, handle 1105 is a T-handle latch, such as those available from Southco, Inc. of Concordville, Pennsylvania. The drawer 1104 is mounted in the lower chassis on slide brackets (not shown) so that the drawer 1104 can be pulled into and out of the lower chassis. A sensor (not shown) is preferably provided for verifying that the drawer 1104 is closed. The front portion of the drawer includes bottle receptacles 1122 for holding bottle 1128 (shown in FIGURE 52), which is a dedicated pipette wash waste-containing bottle, and bottle 1130 (also shown in FIGURE 52), which is a dedicated waste bottle for containing waste from a magnetic wash, target-capture procedure. Bottle 1130 is preferably evacuated.

The analyzer 50 will not begin processing assays if any of the bottles required in the lower chassis 1100 are missing. Bottle receptacles 1122 preferably include bottle-present sensors (not shown) to verify the presence of a bottle in each receptacle 1122. The bottle-present sensors are preferably diffuse reflective type optical sensors available from SUNX/Ramco Electric, Inc., of West Des Moines, Iowa, model EX-14A.

Right-side drawer 1104 further includes a waste bin 1108 for holding therein spent MTUs and specimen tips. Waste bin 1108 is an open box structure with a sensor mount 1112 at a top portion thereof for mounting thereon a sensor, preferably a 24VDC Opto-diffuse reflector switch (not shown), for detecting whether the waste bin 1108 is full. Another diffuse reflector type optical sensor (not shown) is positioned within right-side drawer 1104 to verify that the waste bin 1108 is in place. Again, diffuse reflective type optical sensors available from SUNX/Ramco Electric, Inc., of West Des Moines, Iowa, model EX-14A, are preferred.

A deflector 1110 extends obliquely from a side of the waste bin 1108. Deflector 1110 is disposed directly below a chute through which spent MTUs are dropped into the waste bin 1108 and deflects the dropped MTUs toward the middle of the waste bin 1108 to avoid MTU pile-ups in a corner of the waste bin 1108. Deflector 1110 is preferably pivotally mounted so that it can pivot upwardly to a substantially vertical position so

that when a waste bag, which lines the waste bin 1108 and covers the deflector 1110, is removed from the waste bin 1108, the deflector 1110 will pivot upwardly with the bag as it is pulled out and therefore will not rip the bag.

A printed circuit board (not shown) and cover 1114 can be mounted to the front of the waste bin 1108. Sensor mounts 1116 and 1117 are also mounted to the front of waste bin 1108. Sensors 1118 and 1119 are mounted on sensor mount 1116, and sensors 1120 and 1121 mounted on sensor mount 1117. Sensors 1118, 1119, 1120, and 1121 are preferably DC capacitive proximity sensors. The upper sensors 1118, 1119 indicate when the bottles 1128 and 1130 are full, and the bottom sensors 1120, 1121 indicate when the bottles are empty. Sensors 1118-1121 are preferably those available from Stedham Electronics Corporation of Reno, Nevada, model number C2D45AN1-P, which were chosen because their relatively flat physical profile requires less space within the tight confines of the lower chassis 1100 and because the Stedham sensors provide the desired sensing distance range of 3-20 mm.

The analyzer 50 will preferably not begin performing any assays if the assay manager program detects that any of the waste fluid containers in the right-side drawer 1104 are not initially empty.

The capacitive proximity sensors 1118-1121 and the bottle-present, waste-bin-present, and waste-bin-full optical sensors of the right-side drawer 1104 are connected to the printed circuit board (not shown) behind cover 1114, and the printed circuit board is connected to the embedded controller of the analyzer 50.

Because the right-side drawer 1104 cannot be pulled completely out of the lower chassis 1100, it is necessary to be able to pull the waste bin 1108 forward so as to permit access to the waste bin for installing and removing a waste bag liner. For this purpose, a handle 1126 is mounted to the front of the waste bin 1108 and teflon strips 1124 are disposed on the bottom floor of the right-side drawer 1104 to facilitate forward and

backward sliding of the waste bin 1108 in the drawer 1104 when bottles 1128 and 1130 are removed.

Details of the left-side drawer 1106 are shown in FIGURE 54. Left-side drawer 1106 includes a box-like structure with a front mounted handle 1107 and is mounted within the lower chassis 1100 on slide brackets (not shown). Although handle 1107 is shown as a conventional pull-type drawer handle, in the preferred embodiment of the analyzer 50, handle 1107 is a T-handle latch, such as those available from Southco, Inc. of Concordville, Pennsylvania. A sensor is provided for verifying that the left-side drawer 1106 is closed.

Left-side drawer 1106 includes a tiplet waste bin 1134 with a mounting structure 1135 for mounting thereon a tiplet-waste-bin-full sensor (not shown). A tiplet-waste-bin-present sensor is preferably provided in the left-side drawer 1106 to verify that the tiplet waste bin 1134 is properly installed. Diffuse reflective type optical sensors available from SUNX/Ramco Electric, Inc., of West Des Moines, Iowa, model EX-14A, are preferred for both the tiplet-waste-bin-full sensor and the tiplet-waste-bin-present sensor.

Bundling structures 1132 are provided for securing and bundling various tubing and/or wires (not shown) within the lower chassis 1100. The bundling structures preferably used are Energy Chain Systems manufactured and sold by Igus, Inc. of East Providence, Rhode Island.

A printed circuit board 1182 is mounted behind a panel 1184 which is located behind the tiplet waste bin 1134. A solenoid valve mounting panel 1186 is located below the tiplet waste bin 1134.

Left-side drawer 1106 includes a forward container-holding structure for holding therein six similarly sized bottles. The container structure includes divider walls 1153, 1155, 1157, and 1159 and container blocks 1151 having a curved bottle-conforming front edge, which together define six container-holding areas. Lower sensors 1148 and upper sensors 1150 (six of each) are mounted on the divider walls 1155, 1157, and 1159.

The upper and lower sensors 1148, 1150 are preferably DC capacitive proximity sensors (preferably sensors available from Stedham Electronics Corporation of Reno, Nevada, model number C2D45AN1-P, chosen for their flat profile and sensing range). The upper sensors 1150 indicate when the bottles held in the container structure are full, and the lower sensors 1148 indicate when the bottles are empty. In the preferred arrangement, the left two bottles 1146 contain a detecting agent ("Detect I"), the middle two bottles 1168 contain silicon oil, and the right two bottles 1170 contain another detecting agent ("Detect II").

Bottle-present sensors (not shown) are preferably provided in each of the container-holding areas defined by the container blocks 1151 and the dividing walls 1153, 1155, 1157, and 1159 to verify the presence of bottles in each container-holding area. The bottle-present sensors are preferably diffuse reflective type optical sensors available from SUNX/Ramco Electric, Inc., of West Des Moines, Iowa, model EX-14A.

A large centrally located container receptacle 1164 holds a bottle 1140 (shown in FIGURE 52), preferably containing deionized water. Container receptacles 1166 (only one is visible in FIGURE 54) hold bottles 1142 and 1144 (also shown in FIGURE 52) preferably containing a wash buffer solution. A dividing wall 1143 between the receptacle 1164 and 1166 has mounted thereon sensors, such as sensor 1141, for monitoring the fluid level in the bottles 1140, 1142, and 1144. The sensors, such as sensor 1141, are preferably DC capacitive proximity sensors (preferably sensors available from Stedham Electronics Corporation of Reno, Nevada, model number C2D45AN1-P).

Container receptacles 1164 and 1166 preferably include bottle-present sensors (not shown) for verifying that bottles are properly positioned in their respective receptacles. The bottle-present sensors are preferably diffuse reflective type optical sensors available from SUNX/Ramco Electric, Inc., of West Des Moines, Iowa, model EX-14A.

The analyzer 50 will not begin performing any assays if the assay

manager program determines that any of the bulk-fluid containers in the left-side drawer 1106 are initially empty.

The capacitive proximity fluid level sensors, the various bottle-present sensors, the tiplet-waste-bin-full sensor, and the tiplet-waste-bin-present sensors are all connected to the printed circuit board 1182, and the printed circuit board 1182 is connected to the embedded controller of the analyzer 50.

Four solenoid valves (not shown) are mounted below the solenoid valve mounting panel 1186. The solenoid valves connect bulk fluid bottles where fluids are stored in pairs of bottles, i.e., the bottles 1140, 1142 containing wash buffer solution, the two bottles 1146 containing the "Detect I" agent, the two bottles 1168 containing oil, and the two bottles 1170 containing the "Detect II" agent. The solenoid valves, in response to signals from the respective capacitive proximity sensors, switch bottles from which fluid is being drawing when one of the two bottles containing the same fluid is empty. In addition, the solenoid valves may switch bottles after a prescribed number of tests are performed. The preferred solenoid valves are teflon solenoid valves available from Beco Manufacturing Co., Inc. of Laguna Hills, California, model numbers S313W2DFRT and M223W2DFRLT. The two different model numbers correspond to solenoid valves adapted for use with two different tube sizes. Teflon solenoid valves are preferred because they are less likely to contaminate fluids flowing through the valves and the valves are not damaged by corrosive fluids flowing through them.

Bottle 1136 (see FIGURE 52) is a vacuum trap held in a vacuum trap bracket 1137, and bottle 1138 contains a deactivating agent, such as bleach-containing reagent. Again, bottle-present sensors are preferably provided to verify the presence of bottles 1136 and 1138.

A hand-held bar code scanner 1190 may be provided in the lower chassis 1100 for scanning information provided on scannable container labels into the assay manager program. Scanner 1190 is connected by a

cord to printed circuit board 1182 of the left-side drawer 1106 and is preferably stowed on a bracket (not show) mounted on dividing wall 1143. Scanners available from Symbol Technologies, Inc., of Holtsville, New York, series LS2100, are preferred.

SPECIMEN RING AND SPECIMEN TUBE TRAYS

Specimens are contained in the specimen tubes 320, and the tubes 320 are loaded into the tube trays 300 outside the analyzer 50. The trays 300 carrying the specimen tubes 320 are placed onto the specimen ring 250 through the access opening provided by opening the flip-up carousel door 80.

Referring to FIGURES 5 and 6, the first ring assembly, or specimen ring, 250 is formed of milled, unhardened aluminum and includes a raised ring structure defining an annular trough 251 about the outer periphery of ring 250 with a plurality of raised, radially extending dividers 254 extending through trough 251. Preferably, nine dividers 254 divide the trough 251 into nine arcuate specimen tube tray-receiving wells 256. The trough 251 and wells 256 define an annular fluid container carrier portion constructed and arranged to carry a plurality of containers as will be described below.

Specimen ring 250 is preferably rotationally supported by three 120°-spaced V-groove rollers 257, 258, 260 which engage a continuous V-ridge 262 formed on the inner periphery of ring 250, as shown in FIGURES 5 and 6, so that the ring 250 is rotatable about a first central axis of rotation. The rollers are preferably made by Bishop-Wisecarver Corp. of Pittsburg, California, model number W1SSX. Rollers 257 and 260 are rotationally mounted on fixed shafts, and roller 258 is mounted on a bracket which pivots about a vertical axis and is spring biased so as to urge roller 258 radially outward against the inner periphery of ring 250. Having two fixed rollers and one radially movable roller allows the three rollers to accommodate an out-of-round inner periphery of the ring 250.

In addition, the ring 250 can be easily installed and removed by merely pushing pivoting roller 258 radially inwardly to allow the specimen ring 250 to move laterally to disengage continuous V-ridge 262 from the fixed V-groove rollers 257, 260.

Specimen ring 250 is driven by stepper motor 264 (VEXTA stepper motors available from Oriental Motor Co., Ltd. of Tokyo, Japan as model number PK266-01A are preferred) via continuous belt 270 (preferably available from SDP/SI of New Hyde Park, New York, as model number A6R3M444080) which extends over guide rollers 266, 268 and around the outer periphery of ring 250. A home sensor and a sector sensor (not shown), preferably slotted optical sensors, are provided adjacent the ring 250 at a rotational home position and at a position corresponding to one of the specimen tube tray receiving wells 256. The ring 250 includes a home flag (not shown) located at a home position on the wheel and nine equally-spaced sector flags (not shown) corresponding to the positions of each of the nine specimen tube tray receiving wells 256. The home flag and sector flags cooperate with the home sensor and sector sensors to provide ring position information to the assay manager program and to control the ring 250 to stop at nine discrete positions corresponding to established coordinates for user re-load and access by pipette unit 450. Preferred sensors for the home sensor and sector sensor are Optek slotted optical sensors, model number OPB857, available from Optek of Carrollton, Texas.

A specimen cover is disposed over a portion of the annular fluid container carrier portion, or trough 251, and comprises an arcuate cover plate 138 fixed in an elevated position with respect to the wheel 250 on three mounting posts 136. Plate 138 has an arcuate shape generally conforming to the curve of the trough 251. A first opening 142 is formed in the plate 138, and a second opening 140 is formed in the plate 138 at a greater radial distance from the axis of rotation of ring 250 than opening 142 and at a circumferentially-spaced position from opening 142.

Referring to FIGURES 55-57, each specimen tube tray 300 comprises a test tube rack structure that is curved to conform to the curvature of the ring 250. Each tray 300 comprises a central wall structure 304 with lateral end walls 303 and 305 disposed on either end of wall 304. A floor 312 extends across the bottom of the tray 300. The principle purposes of specimen tube tray 300 are to hold specimen tubes on the specimen ring 250 for access by the specimen pipette assembly 450 and to facilitate loading and unloading of multiple specimen tubes into and from the analyzer.

A plurality of Y-shaped dividers 302 are equidistantly spaced along opposite edges of the tray 300. Each two adjacent dividers 302 define a test-tube receiving area 330. End wall 303 includes inwardly bent flanges 316 and 318, and end wall 305 includes inwardly bent flanges 326 and 328. The respective inwardly bent flanges of end walls 303 and 305 along with the end-most of the dividers 302 define the end-most tube receiving areas 332. The receiving areas 330, 332 are arcuately aligned along two arcuate rows on opposite sides of central wall structure 304

Referring to FIGURE 57, within each tube receiving area 330, 332, a leaf spring element 310 is attached to central wall 304. Leaf spring element 310, preferably formed of stainless spring steel, elastically deflects when a test tube 320 is inserted into the tube-receiving area 330 or 332 and urges the tube 320 outwardly against the dividers 302. Thus, the tube 320 is secured in an upright orientation. The shape of the dividers 302 and the elasticity of the leaf spring elements 310 allow the tray 300 to accommodate specimen tubes of various shapes and sizes, such as tubes 320 and 324. Each tray 300 preferably includes nine dividers 302 along each edge to form, along with end walls 303 and 305, ten tube-receiving areas 330, 332 on each side of central wall structure 304 for a total of twenty tube-receiving areas per tray. Indicia for designating tube-receiving areas 330 and 332, such as raised numerals 306, may be provided on the tray, such as on central wall 304.

Each tray 300 may also include boss structures 308, shown in the illustrated embodiment to be integrally formed with the end-most dividers 302. An upright inverted U-shaped handle (not shown) may be attached to the tray at boss structures 308 or some other suitable location. Upright handles can facilitate handling of the tray 300 when loading and unloading the tray 300 through the arcuate carousel door 80, but are not necessarily preferred.

A gap is provided between adjacent dividers 302 so that bar-code labels 334, or other readable or scannable information, on the tubes 320 is accessible when the tube is placed in the tray 320. When a tray 300 carried on wheel 250 passes beneath the plate 138 of the specimen cover, one tube 320 in a curved row at a radially-inward position with respect to wall structure 304 will be aligned with first opening 142 and another tube 320 in a curved row at a radially-outward position with respect to wall 304 will be aligned with second opening 140. The ring 250 is indexed to sequentially move each tube 320 beneath the openings 140, 142 to permit access to the tubes.

Referring again to FIGURE 5, bar code scanners 272 and 274 are disposed adjacent the ring 250. Opticon, Inc. scanners, model number LHA2126RR1S-032, available from Opticon, Inc. of Orangeburg, New York, are preferred. Scanner 272 is located outside ring 250, and scanner 274 is disposed inside ring 250. Scanners 272 and 274 are positioned to scan bar code data labels on each specimen tube 320 carried in the specimen tube tray 300 as the ring 250 rotates a tray 300 of specimen tubes 320 past the scanners 272, 274. In addition, the scanners 272, 274 scan the bar code label 337 (see FIGURE 55) on the outer portion of bent flanges 316 and 318 of end wall 303 of each tray 300 as the tray 300 is brought into the specimen preparation area. Various information, such as specimen and assay identification, can be placed on the tubes and/or each tray 300, and this information can be scanned by the scanners 272, 274 and stored in the central processing computer. If no specimen tube is present,

the tray 300 presents a special code 335 (see FIGURE 55) to be read by the scanners 272, 274.

PIPETTE TIP WHEEL

As shown primarily in FIGURES 5 and 6, a second ring assembly of the preferred embodiment is a pipette tip wheel 350 and comprises a circular ring 352 at a bottom portion thereof, a top panel 374 defining a circular inner periphery and five circumferentially-spaced, radially-protruding sections 370, and a plurality of generally rectangular risers 354 separating the top panel 374 from the ring 352 and preferably held in place by mechanical fasteners 356 extending through the top panel 374 and ring 352 into the risers 354. Five rectangular openings 358 are formed in the top panel 374 proximate each of the sections 370, and a rectangular box 376 is disposed beneath panel 374, one at each opening 358. Top panel 374, ring 352, and risers 354 are preferably made from machined aluminum, and boxes 376 are preferably formed from stainless steel sheet stock.

The openings 358 and associated boxes 376 are constructed and arranged to receive trays 372 holding a plurality of disposable pipette tips. The pipette tip trays 372 are preferably those manufactured and sold by TECAN (TECAN U.S. Inc., Research Triangle Park, North Carolina) under the trade name "Disposable Tips for GENESIS Series". Each tip has a 1000 µl capacity and is conductive. Each tray holds ninety-six elongated disposable tips.

Lateral slots 378 and longitudinal slots 380 are formed in the top panel 374 along the lateral and longitudinal edges, respectively, of each opening 358. The slots 378, 380 receive downwardly-extending flanges (not shown) disposed along the lateral and longitudinal edges of the trays 372. The slots 378, 380 and associated flanges of the trays 372 serve to properly register the trays 372 with respect to openings 358 and to hold the trays 372 in place on the panel 374.

Pipette tip wheel 350 is preferably rotationally supported by three 120°-spaced V-groove rollers 357, 360, 361 which engage a continuous V-ridge 362 formed on the inner periphery of ring 352, as shown in FIGURES 5, 6, and 6A, so that the pipette tip wheel 350 is rotatable about a second central axis of rotation that is generally parallel to the first axis of rotation of the specimen ring 250. The rollers are preferably made by Bishop-Wisecarver Corp. of Pittsburg, California, model number W1SSX. Rollers 357 and 360 are rotationally mounted on fixed shafts, and roller 361 is mounted on a bracket which pivots about a vertical axis and is spring biased so as to urge roller 361 radially outwardly against the inner periphery of ring 352. Having two fixed rollers and one radially movable roller allows the three rollers to accommodate an out-of-round inner periphery of ring 352. In addition, the wheel 350 can be easily installed and removed by merely pushing pivoting roller 361 radially inwardly to allow the ring 352 to move laterally to disengage continuous V-ridge 362 from the fixed V-groove rollers 357, 360.

Pipette tip wheel 350 is driven by a motor 364 having a shaft-mounted spur gear which meshes with mating gear teeth formed on an outer perimeter of ring 352. Motor 364 is preferably a VEXTA gear head stepper motor, model number PK243-A1-SG7.2, having a 7.2:1 gear reduction and available from Oriental Motor Co., Ltd. of Tokyo, Japan. A gear head stepper motor with a 7.2:1 gear reduction is preferred because it provides smooth motion of the pipette tip wheel 350, where the spur gear of the motor 364 is directly engaged with the ring 352.

A home sensor and a sector sensor (not shown), preferably slotted optical sensors, are provided adjacent the pipette tip wheel 350 at a rotational home position and at a position of one of the boxes 376. The pipette tip wheel 350 includes a home flag (not shown) located at a home position on the wheel and five equally-spaced sector flags (not shown) corresponding to the positions of each of the five boxes 376. The home flag and sector flags cooperate with the home sensor and sector sensors to

provide wheel position information to the assay manager program and to control the pipette tip wheel 350 to stop at five discrete positions corresponding to established coordinates for user re-load and access by pipette unit 450. Preferred sensors for the home sensor and sector sensor are Optek Technology, Inc. slotted optical sensors, model number OPB980, available from Optek Technology, Inc. of Carrollton, Texas.

MULTI-AXIS MIXER

Referring to FIGURES 7-12, the multi-axis mixer 400 includes a rotating turntable structure 414 (see FIGURE 10) rotatably mounted on a center shaft 428 supported in center bearings 430 to a fixed base 402 mounted to the jig plate 130 by means of mechanical fasteners (not shown) extending through apertures 419 formed about the outer periphery of the fixed base 402. A cover member 404 is attached to and rotates with turntable 414.

Turntable 414 is preferably in the form of a right angle cross comprising three 90°-spaced rectangular arms 444 of equal length extending radially outwardly from the center of the turntable 414 and a fourth arm 445 having an extension 417 making arm 445 slightly longer than arms 444. As shown in FIGURES 10-12, the center portion of turntable 414 is connected to center shaft 428 by a screw 429.

Four container holders 406 are disposed on the ends of the arms 444 and 445 of turntable frame 414. Each container holder 406 is attached to one of four vertical shafts 423, which are rotatably supported in container holder bearings 415. Container holder bearings 415 are pressed into the arms 444, 445 of the turntable 414 and are disposed at equal radial distances from shaft 428.

The cover member 404 includes four circular openings with upwardly-turned peripheral flanges 401 through which shafts 423 extend. Upward flanges 401 can advantageously prevent spilled liquids from flowing into the openings.

The container holders 406 comprise generally cylindrical members having an open bottom and an open top for receiving and holding a container 440, preferably a plastic bottle, of target capture reagent.

The target capture reagent used with the preferred assay includes magnetically responsive particles with immobilized polynucleotides, polynucleotide capture probes, and reagents sufficient to lyse cells containing the targeted nucleic acids. After cell lysis, targeted nucleic acids are available for hybridization under a first set of predetermined hybridization conditions with one or more capture probes, with each capture probe having a nucleotide base sequence region which is capable of hybridizing to a nucleotide base sequence region contained on at least one of the targeted nucleic acids. Under a second set of predetermined hybridization conditions, a homopolymer tail (e.g., oligo(dT)) of the immobilized polynucleotides is capable of hybridizing with a complementary homopolymer tail (e.g., oligo(dA)) contained on the capture probe, thereby immobilizing targeted nucleic acids. Target-capture methods and lysing procedures are well known in the art and are described more fully in the background section *supra*.

A container retainer spring 408 spans a lateral slot formed in the wall of each container holder 406 and helps to hold the container 440 within the container holder 406 by urging the container 440 toward a portion of the inner peripheral wall of the holder 406 opposite the spring 408.

Each container holder 406 is secured to an associated vertical shaft 423 by a shaft block structure 432. Shaft block structure 432 includes curved end portions which conform to the inside of the cylindrical container holder 406, and the container holder 406 is secured to the block 432 by fasteners 434. A generally circular aperture 449 receives the shaft 423. A slot 438 extends from aperture 449 to an end of the block 432 which does not extend all the way to the inside of the container holder 406, and a second slot 436 extends from an edge of the block 432 generally

perpendicularly to slot 438 so as to define a cantilevered arm 435. A machine screw 437 extends through a through-hole 441 formed laterally through block 432 and into a threaded hole 447 formed laterally through arm 435. As screw 437 is tightened, arm 435 deflects, thus tightening aperture 449 around shaft 423.

The shaft block structure 432, the shaft 423, and the container holder bearings 415 associated with each container holder 406 define a preferred container holder mounting structure associated with each container holder 406 that is constructed and arranged to mount the container holder 406 to the turntable 414 and permit the container holder 406 to rotate about an axis of rotation 412 of the shaft 423.

Container holder planetary gears 422 are attached to the opposite ends of shafts 423. The planetary gears 422 operatively engage a stationary sun gear 416. A drive pulley 418 is attached to center shaft 428 and is coupled to a drive motor 420 by a drive belt (not shown). Drive motor 420 is preferably mounted so as to extend through an opening (not shown) in the jig plate 130 below the base 402. Drive motor 420 is preferably a stepper motor, and most preferably a VEXTA stepper motor, model number PK264-01A, available from Oriental Motor Co., Ltd. of Tokyo, Japan. The drive motor 420, via the drive belt and drive pulley 418, rotates the center shaft 428 and the turntable 414 attached thereto. As the turntable frame 414 rotates about the center line of center shaft 428, the planetary gears 422 engaged with sun gear 416 cause the shafts 423 and container holders 406 attached thereto to rotate at the ends of the arms 444 of the turntable frame 414. Each container holder 406 is preferably mounted such that the axis of rotation 410 thereof is offset from the axis of rotation 412 of the associated shaft 423. Thus, each container holder 406 rotates eccentrically about axis 412 of the associated shaft 423. Accordingly, the planetary gears 422 and the sun gear 416 constitute rotational motion coupling elements constructed and arranged to cause the container holders 406 to rotate about the respective axes of rotation of the

shafts 423 as the turntable 414 rotates about the axis of rotation of the shaft 428.

A bar code scanner device 405 is preferably mounted on a bracket 403 and reads bar code information of the containers 440 through a scanner slot 407 formed in each container holder 406. The preferred scanner is a model number NFT1125/002RL scanner, available from Opticon, Inc. of Orangeburg, New York.

The multi-axis mixer 400 usually rotates during operation of the analyzer 50 to agitate the fluid contents of the containers 440 to thereby keep the target capture reagent in suspension, stopping only briefly to permit pipette unit 456 to withdraw an amount of mixture from one of the containers. Pipette unit 456 draws mixture from a bottle at the same location each time. Therefore, it is desirable to monitor the positions of the bottles so that the bottle from which mixture is withdrawn each time can be specified.

Four optical slotted sensors 426, each comprising an optical emitter and detector, are stationed around the periphery of fixed base 402, spaced at 90° intervals. Optical sensors available from Optek Technology, Inc. of Carrollton, Texas, model number OPB490P11, are preferred. A sensor tab 424 extends down from extension 417 at the end of arm 445 of the turntable 414. When sensor tab 424 passes through a sensor 426, the communication between the emitter and detector is broken thus giving a "container present" signal. The tab 424 is only provided at one location, e.g., the first container location. By knowing the position of the first container, the positions of the remaining containers, which are fixed relative to the first container, are also known.

Power and control signals are provided to the multi-axis mixer 400 via a power and data connector. While the multi-axis mixer 400 provides mixing by rotation and eccentric revolution, other mixing techniques, such as vibration, inversion, etc. may be used.

SPECIMEN PREPARATION PROCEDURE

To begin specimen preparation, the pipette unit 456 moves to transfer target capture reagent, preferably mag-oligo reagent, from a container 440 carried on the multi-axis mixer 400 into each of the receptacle vessels 162 of the MTU 160. The target capture reagent includes a support material able to bind to and immobilize a target analyte. The support material preferably comprises magnetically responsive particles. At the beginning of the specimen preparation procedure, the pipette unit 456 of the right-side pipette assembly 450 moves laterally and longitudinally to a position in which the probe 457 is operatively positioned over a pipette tip in one of the trays 372.

The tip trays 372 are carried on the pipette tip wheel 350 so as to be precisely positioned to achieve proper registration between the pipette tips and the tubular probe 457 of the pipette unit 456. The pipette unit 456 moves down to insert the free end of the tubular probe 457 into the open end of a pipette tip and frictionally engage the pipette tip. The Cavro processors preferably used for pipette unit 456 includes a collar (not shown), which is unique to Cavro processors. This collar is moved slightly upwardly when a pipette tip is frictionally engaged onto the end of the tubular probe 457, and the displaced collar trips an electrical switch on the pipette unit 456 to verify that a pipette tip is present. If tip pick-up is not successful (e.g., due to missing tips in the trays 372 or a misalignment), a missing tip signal is generated and the pipette unit 456 can move to re-try tip engagement at a different tip location.

The assay manager program causes the multi-axis mixer 400 to briefly stop rotating so that the pipette unit 456 can be moved to a position with the tubular probe 457 and attached pipette tip of the pipette unit 456 aligned over one of the stationary containers 440. The pipette unit 456 lowers the pipette tip attached to the tubular probe 457 into the container 440 and draws a desired amount of target capture reagent into the pipette tip. The pipette unit 456 then moves the probe 457 out of the

container 440, the multi-axis mixer 400 resumes rotating, and the pipette unit 456 moves to a position above opening 252 and the specimen transfer station 255. Next, the pipette unit 456 descends, moving the pipette tip and the tubular probe 457 through the opening 252, and dispenses a required amount of target capture (typically 100-500 µl) into one or more of the receptacle vessels 162 of the MTU 160. It is preferred that the target capture reagent is drawn only into the pipette tip and not into the probe 457 itself. Furthermore, it is preferred that the pipette tip be of sufficient volumetric capacity to hold enough reagent for all five vessels 162 of the MTU 160.

After target capture reagent transfer, the pipette unit 456 then moves to a "tip discard" position above tip disposal tube 342, where the disposable pipette tip is pushed or ejected off of the end of the tubular probe 457 of the pipette unit 456, and falls through tube 342 toward a solid waste container. An optical sensor (not shown) is disposed adjacent to tube 342, and before tip discard, the specimen pipette assembly 450 moves the pipette unit 456 into a sensing position of the sensor. The sensor detects whether a tip is engaged with the end of the tubular probe 457 to verify that the tip is still held on the tubular probe 457 of the pipette unit 456, thereby confirming that the tip was on the tubular probe 457 throughout specimen preparation. A preferred sensor is a wide-gap slotted optic sensor, model OPB900W, available from Optek Technology, Inc. of Carrollton, Texas.

Preferably, the pipette tip is ejected by the collar (not shown) on the tubular probe 457 of pipette unit 456. The collar engages a hard stop when the tubular probe 457 is raised, so that as the probe 457 continues to ascend, the collar remains fixed and engages an upper end of the pipette tip, thereby forcing it off the tubular probe 457.

After pipetting the target capture and discarding the pipette tip, the probe 457 of the pipette unit 456 can be washed by running distilled water through the tubular probe 457 at the tip wash station basin 346. The tip

wash water is collected and drains down into a liquid waste container.

Following the reagent dispensing procedure, the pipette unit 456 on the right pipette assembly 450 moves laterally and longitudinally to a position in which the tubular probe 457 of the pipette unit 456 is centered over a new pipette tip on one of the tip trays 372. After successful tip engagement, the pipette unit 456 moves back over the specimen ring 250, adjacent to the specimen preparation opening 252 and withdraws a test specimen (about 25-900 µl) from a specimen tube 320 that is aligned with one of the openings 140, 142 of the cover plate 138. Note that both openings 140, 142 include upwardly extending peripheral flanges to prevent any fluids spilled onto the plate 138 from running into the openings 140, 142. The pipette unit 456 then moves over the MTU 160 in the specimen transfer station 255, moves down through opening 252, and dispenses test specimen into one of the receptacle vessels 162 of the MTU 160 containing target capture reagent. Pipette unit 456 then moves to the "tip discard" position above the tip disposal tube 342, and the disposable pipette tip is ejected into the tube 342. Pipette unit 456 then picks up a new disposable pipette tip from the pipette tip wheel 350, the specimen ring 250 indexes so that a new specimen tube is accessible by the pipette unit 456, unit 456 moves to and draws specimen fluid from the specimen tube into the disposable pipette tip, the pipette unit 456 then moves to a position above the specimen transfer station 255, and dispenses specimen fluid into a different receptacle vessel 162 containing target capture reagent. This process is preferably repeated until all five receptacle vessels 162 contain a combination of fluid specimen sample and target capture reagent.

Alternatively, depending on the assay protocol or protocols to be run by the analyzer 50, the pipette unit 456 may dispense the same test specimen material into two or more of the receptacle vessels 162 and the analyzer can perform the same or different assays on each of those aliquots.

As described above with respect to pipette units 480, 482, pipette unit 456 also includes capacitive level sensing capability. The pipette tips used on the end of the tubular probe 457 are preferably made from a conductive material, so that capacitive level sensing can be performed with the pipette unit 456, even when a tip is carried on the end of the tubular probe 457. After the pipette unit has completed a test specimen dispensing procedure, the pipette unit 456 moves the tubular probe 457 back down into the receptacle vessel 162 until the top of the fluid level is detected by the change in capacitance. The vertical position of the tubular probe 457 is noted to determine whether the proper amount of fluid material is contained in the receptacle vessel 162. Lack of sufficient material in a receptacle vessel 162 can be caused by clotting in the test specimen, which can clot the tip at the end of the tubular probe 457 and prevent proper aspiration of test specimen material into the tip and/or can prevent proper dispensing of test specimen from the tip.

After specimen transfer, the pipette tip is discarded into the tip disposal tube 342 as described above. Again, the tubular probe 457 of the pipette of unit can be washed with distilled water if desired, but washing of the probe is typically not necessary because, in the preferred method of operation, specimen material only comes into contact with the disposable pipette tip.

The assay manager program includes pipette unit control logic which controls movements of the pipette units 456, 480, 482, and preferably causes pipette unit 456 to move in such a manner that it never passes over a specimen tube 320 on the specimen ring 250, except when the pipette unit 456 positions the tubular probe 457 over a specimen tube 320 to withdraw a test specimen or when the specimen tube 320 is below the plate 138 of the specimen cover. In this way, inadvertent fluid drips from the tubular probe 457 of the pipette unit 450 into another specimen tube, which might result in cross-contamination, are avoided.

Following specimen preparation, the MTU 160 is moved by the

right-side transport mechanism 500 from the specimen transfer station to the right orbital mixer 550 in which the specimen/reagent mixtures are mixed. The structure and operation of the orbital mixers 550, 552 will be described in further detail below.

After the MTU 160 is withdrawn from the specimen transfer station by the right-side transport mechanism 500, the reaction receptacle shuttle assembly within the input queue 150 advances the next MTU into a position to be retrieved by the right-side transport mechanism 500 which moves the next MTU to the specimen transfer station. Specimen preparation procedures are then repeated for this next MTU.

TRANSPORT MECHANISMS

The right-side and left-side transport mechanisms 500, 502 will now be described in detail. Referring to FIGURES 13-16, the right-side transport mechanism 500 (as well as the left-side transport mechanism 502) has a manipulating hook member that, in the illustrated embodiment, includes an extendible distributor hook 506 extending from a hook mounting structure 508 that is radially and slidably displaceable in a slot 510 on a plate 512. A housing 504 on top of the plate 512 has an opening 505 configured to receive the upper portion of an MTU 160. A stepper motor 514 mounted on the plate 512 turns a threaded shaft 516, which, in cooperation with a lead screw mechanism, moves the distributor hook 506 from the extended position shown in FIGURES 13 and 15, to the retracted position shown in FIGURE 14, the motor 514 and threaded shaft 516 constituting elements of a preferred hook member drive assembly. Stepper motor 514 is preferably a modified HSI, series 46000. HSI stepper motors are available from Haydon Switch and Instrument, Inc. of Waterbury, Connecticut. The HSI motor is modified by machining the threads off one end of the threaded shaft 516, so that the shaft 516 can receive the hook mounting structure 508.

The housing 504, motor 514, and the plate 512 are preferably

covered by a conforming shroud 507.

As shown in FIGURE 16, a stepper motor 518 turns a pulley 520 via a belt 519. (VEXTA stepper motors, model number PK264-01A, available from Oriental Motor Co., Ltd. of Tokyo, Japan, and SDP timing belts, model number A6R51M200060, available from SDP/SI of New Hyde Park, New York, are preferred). Pulley 520 is preferably a custom-made pulley with one hundred sixty-two (162) axial grooves disposed around its perimeter. A main shaft 522 fixedly attached to the plate 512, by means of a uniquely-shaped mounting block 523, extends down through a base 524 and is fixed to the pulley 520. Base 524 is mounted to the datum plate 82 by means of mechanical fasteners extending through apertures 525 formed about the outer periphery of the base 524. A flex circuit 526 provides power and control signals to the hook mounting structure 508 and motor 514, while allowing the plate 512 (and the components carried on the plate) to pivot sufficiently so as to rotate as much as 340° with respect to the base 524. The transport mechanism 500, 502, assembly preferably includes hard stops (not shown) at either end of the unit's rotational path of travel.

An arm position encoder 531 is preferably mounted on an end of the main shaft 522. The arm position encoder is preferably an absolute encoder. A2 series encoders from U.S. Digital in Seattle, Washington, model number A2-S-K-315-H, are preferred.

The assay manager program provides control signals to the motors 518 and 514, and to the hook mounting structure 508, to command the distributor hook 506 to engage the MTU manipulating structure 166 on MTU 160. With the hook 506 engaged, the motor 514 can be energized to rotate the shaft 516 and thereby withdraw the hook 506, and the MTU 160, back into the housing 504. The MTU 160 is securely held by the transport mechanism 500, 502 via the sliding engagement of the connecting rib structure 164 of the MTU 160 with opposed edges 511 of plate 512 adjacent slot 510. The plate 512 thereby constitutes an element of a

preferred receptacle carrier assembly that is constructed and arranged to be rotatable about an axis of rotation (e.g., the axis of shaft 522) and to receive and carry a reaction receptacle (e.g., MTU 160). The motor 518 can rotate the pulley 520 and shaft 522 via the belt 519 to thereby rotate the plate 512 and housing 504 with respect to the base 524. Rotation of the housing 504 thus changes the orientation of the engaged MTU, thereby bringing that MTU into alignment with a different station on the processing deck.

Sensors 528, 532 are provided in opposite sides of the housing 504 to indicate the position of the distributor hook 506 within the housing 504. Sensor 528 is an end-of-travel sensor, and sensor 532 is a home sensor. Sensors 528, 532 are preferably optical slotted sensors available from Optek Technology, Inc. of Carrollton, Texas, model number OPB980T11. For the home sensor 532, the sensor beam is broken by a home flag 536 extending from the hook mounting structure 508 when the hook 506 is in its fully retracted position. The beam of the end-of-travel sensor 528 is broken by an end-of-travel flag 534 extending from the opposite side of the hook mounting structure 508 when the hook 506 is fully extended.

An MTU-present sensor 530 mounted in the side of the housing 504 senses the presence of an MTU 160 in the housing 504. Sensor 530 is preferably a SUNX, infra-red sensor, available from SUNX/Ramco Electric, Inc., of West Des Moines, Iowa.

TEMPERATURE RAMPING STATIONS

One or more temperature ramping stations 700 are preferably disposed below the jig plate 130 and specimen ring 250 (no temperature ramping stations located below the specimen ring 250 are shown in the figures). After mixing the contents of the MTU 160 within the orbital mixer 550, the right-side transport mechanism 500 may move the MTU 160 from the right orbital mixer 550 to a temperature ramping station 700, depending on the assay protocol.

The purpose of each ramping station 700 is to adjust the temperature of an MTU 160 and its contents up or down as desired. The temperature of the MTU and its contents may be adjusted to approximate an incubator temperature before inserting the MTU into the incubator to avoid large temperature fluctuations within the incubator.

As shown in FIGURES 17-18, a temperature ramping station 700 includes a housing 702 in which an MTU 160 can be inserted. The housing 702 includes mounting flanges 712, 714 for mounting the ramping station 700 to the datum plate 82. A thermoelectric module 704 (also known as a Peltier device) in thermal contact with a heat sink structure 706 is attached to the housing 702, preferably at the bottom 710. Preferred thermoelectric modules are those available from Melcor, Inc. of Trenton, New Jersey, model number CP1.4-127-06L. Although one thermoelectric module 704 is shown in FIGURE 17, the ramping station 700 preferably includes two such thermoelectric modules. Alternatively, the outer surface of the housing 702 could be covered with a mylar film resistive heating foil material (not shown) for heating the ramping station. Suitable mylar film heating foils are etched foils available from Minco Products, Inc. of Minneapolis, Minnesota and from Heatron, Inc. of Leavenworth, Kansas. For ramp-up stations (i.e., heaters), resistive heating elements are preferably used, and for ramp-down stations (i.e., chillers), thermoelectric modules 704 are preferably used. The housing 702 is preferably covered with a thermal insulating jacket structure (not shown).

The heat sink structure used in conjunction with the thermoelectric module 704 preferably comprises an aluminum block with heat dissipating fins 708 extending therefrom.

Two thermal sensors (not shown) (preferably thermistors rated 10 KOhm at 25°C) are preferably provided at a location on or within the housing 702 to monitor the temperature. YSI 44036 series thermistors available from YSI, Inc. of Yellow Springs, Ohio are preferred. YSI

thermistors are preferred because of their high accuracy and the ±0.1℃ interchangeability provided by YSI thermistors from one thermistor to another. One of the thermal sensors is for primary temperature control, that is, it sends signals to the embedded controller for controlling temperature within the ramping station, and the other thermal sensor is for monitoring ramping station temperature as a back-up check of the primary temperature control thermal sensor. The embedded controller monitors the thermal sensors and controls the heating foils or the thermoelectric module of the ramping station to maintain a generally uniform, desired temperature within the ramping station 700.

An MTU 160 can be inserted into the housing, supported on the MTU support flanges 718 which engage the connecting rib structure 164 of the MTU 160. A cut-out 720 is formed in a front edge of a side panel of the housing 702. The cut-out 720 permits a distributor hook 506 of a transport mechanism 500 or 502 to engage or disengage the MTU manipulating structure 166 of an MTU 160 inserted all the way into a temperature ramping station 700 by lateral movement with respect thereto.

ROTARY INCUBATORS

Continuing with the general description of the assay procedure, following sufficient temperature ramp-up in a ramping station 700, the right-side transport mechanism 500 retrieves the MTU from the ramping station 700 and places the MTU 160 into the target capture and annealing incubator 600. In a preferred mode of operation of the analyzer 50, the target capture and annealing incubator 600 incubates the contents of the MTU 160 at about 60℃. For certain tests, it is important that the annealing incubation temperature not vary more than ±0.5℃ and that amplification incubation (described below) temperature not vary more than ±0.1℃. Consequently, the incubators are designed to provide a consistent uniform temperature.

The details of the structure and operation of the two embodiments

of the rotary incubators 600, 602, 604 and 606 will now be described. Referring to FIGURES 19-23, each of the incubators has housing with a generally cylindrical portion 610, suitably mounted to the datum plate 82, within an insulating jacket 612 and an insulated cover 611.

The cylindrical portion 610 is preferably constructed of nickel-plated cast aluminum and the metal portion of the cover 611 is preferably machined aluminum. The cylindrical portion 610 is preferably mounted to the datum plate 82 atop three or more resin "feet" 609. The feet 609 are preferably formed of UltemÛ-1000 supplied by General Electric Plastics. The material is a poor thermal conductor, and therefore the feet 609 function to thermally isolate the incubator from the datum plate. The insulation 612 and the insulation for the cover 611 are preferably comprised of 1/2 inch thick polyethylene supplied by the Boyd Corporation of Pleasantown, California.

Receptacle access openings 614, 616 are formed in the cylindrical portion 610, and cooperating receptacle access openings 618, 620 are formed in the jacket 612. For incubators 600 and 602, one of set of access openings is positioned to be accessible by the right-side transport mechanism 500 and the other set of access opening is positioned to be accessible by the left-side transport mechanism 502. Incubators 604 and 606 need to be accessible only by the left-side transport mechanism 502 and therefore only have a single receptacle access opening.

Closure mechanisms comprising revolving doors 622, 624 are rotatably positioned within the openings 614 and 616. Each revolving door 622, 624 has a MTU slot 626 extending through a solid cylindrical body. The MTU slot 626 is configured to closely match the profile of the MTU 160, having a wider upper portion compared to the lower portion. A door roller 628, 630 is attached on top of each of the doors 622, 624, respectively. The revolving doors 622, 624 are actuated by solenoids (not shown) which are controlled by commands from the assay manager program to open and close the doors 622, 624 at the proper times. A door

622 or 624 is opened by turning the door 622, 624 so that the 626 thereof is aligned with the respective receptacle access opening 614, 616 and is closed by turning the door 622, 624 so that the MTU slot 626 thereof extends transversely to the respective access opening 614, 616. The cylindrical portion 610, cover 611, doors 622, 624, and a floor panel (not shown) constitute an enclosure which defines the incubation chamber.

The doors 622, 624 are opened to permit insertion or retrieval of an MTU into or from an incubator and are closed at all other times to minimize heat loss from the incubator through the access openings 614, 616.

A centrally positioned radial fan 632 is driven by an internal fan motor (not shown). A Papst, model number RER 100-25/14 centrifugal fan, available from ebm/Papst of Farmington, Connecticut, having a 24VDC motor and rated at 32 cfm is preferred because its shape is well-suited to application within the incubator.

Referring now to FIGURE 22, an MTU carousel assembly 671 is a preferred receptacle carrier which carries a plurality of radially oriented, circumferentially-arranged MTUs 160 within the incubator. The MTU carousel assembly 671 is carried by a top plate 642, which is supported by the cylindrical portion 610 of the housing, and is preferably actuated by a rotation motor 640, preferably a stepper motor, supported at a peripheral edge of on the top plate 642. Rotation motor 640 is preferably a VEXTA stepper motor, model number PK246-01A, available from Oriental Motor Co., Ltd. of Tokyo, Japan.

The MTU carousel 671 includes a hub 646 disposed below the top plate 642 and coupled, via a shaft 649 extending through the top plate 642, to a pulley 644. Pulley 644 is preferably a custom-made pulley with one hundred sixty-two (162) axial grooves disposed around its perimeter and is coupled to motor 640 through a belt 643, so that motor 640 can rotate the hub 646. Belt 643 is preferably a GT® series timing belt available from SDP/SI of New Hyde Park, New York. A 9:1 ratio is preferably provided

between the pulley 644 and the motor 640. The hub 646 has a plurality of equally spaced-apart internal air flow slots 645 optionally separated by radially-oriented, circumferentially arranged divider walls 647. In the illustration, only three divider walls 647 are shown, although it will be understood that divider walls may be provided about the entire circumference of the hub 646. In the preferred embodiment, divider walls 647 are omitted. A support disk 670 is attached to hub 646 and disposed below top plate 642 in generally parallel relation therewith. A plurality of radially extending, circumferentially-arranged MTU holding members 672 are attached to the bottom of the support disk 670 (only three MTU holding members 672 are shown for clarity). The MTU holding members 672 have support ridges 674 extending along opposite sides thereof. Radially oriented MTUs are carried on the MTU carousel assembly 671 within stations 676 defined by circumferentially adjacent MTU holding members 672, with the support ridges 674 supporting the connecting rib structures 164 of each MTU 160 carried by the MTU carousel assembly 671.

The MTU carousel assembly rotates on a carousel drive shaft to which the drive pulley (644 in the illustrated embodiment) is attached. A carousel position encoder is preferably mounted on an exterior end of the carousel drive shaft. The carousel position encoder preferably comprises a slotted wheel and an optical slot switch combination (not shown). The slotted wheel can be coupled to the carousel assembly 671 to rotate therewith, and the optical slot switch can be fixed to the cylindrical portion 610 of the housing or top plate 642 so as to be stationary. The slotted wheel/slot switch combination can be employed to indicate a rotational position of the carousel assembly 671 and can indicate a "home" position (e.g., a position in which an MTU station 676 designated the #1 station is in front of the access opening 614). A2 series encoders from U.S. Digital in Seattle, WA, model number A2-S-K-315-H, are preferred.

A heat source is provided in thermal communication with the

incubator chamber defined within the incubator housing comprising the cylindrical portion 610 and cover 611. In the preferred embodiment, Mylar film-encased electrically-resistive heating foils 660 surround the housing 610 and may be attached to the cover 611 as well. Preferred mylar film heating foils are etched foils available from Minco Products, Inc. of Minneapolis, Minnesota and Heatron, Inc. of Leavenworth, Kansas. Alternative heat sources may include internally mounted resistive heating elements, thermal-electric heating chips (Peltiers), or a remote heat-generating mechanism thermally connected to the housing by a conduit or the like.

As shown in FIGURES 19 and 22, a pipette slot 662 extends through the incubator cover 611, radially-aligned pipette holes 663 extend through the top plate 642, and pipettes slots 664 are formed in the support disk 670 over each MTU station 676, to allow pipetting of reagents into MTUs disposed within the incubators. In the preferred embodiment of the analyzer 50 for the preferred mode of operation, only two of the incubators, the amplification incubator 604 and the hybridization protection assay incubator 606, include the pipette holes 663 and pipette slots 662 and 664, because, in the preferred mode of operation, it is only in these two incubators where fluids are dispensed into MTUs 160 while they are in the incubator.

Two temperature sensors 666, preferably thermistors (10 KOhm at 25° C), are positioned in the top plate 642. YSI 44036 series thermistors available from YSI, Inc. of Yellow Springs, Ohio are preferred. YSI thermistors are preferred because of their high accuracy and the ±0.1°C interchangeability provided by YSI thermistors from one thermistor to another. One of the sensors 666 is for primary temperature control, that is, it sends singles to the embedded controller for controlling temperature within the incubator, and the other sensor is for monitoring temperature of the incubator as a back-up check of the primary temperature control sensor. The embedded controller monitors the sensors 666 and controls

the heating foils 660 and fan 632 to maintain a uniform, desired temperature within the incubator housing 610.

As a transport mechanism 500, 502 prepares to load an MTU 160 into an incubator 600, 602, 604, or 606, the motor 640 turns the hub 646 to bring an empty MTU station 676 into alignment with the receptacle access opening 614 (or 616). As this occurs, the door-actuating solenoid correspondingly turns the revolving door 622 (or 624) one-quarter turn to align the MTU slot 626 of the door with the MTU station 676. The access opening 614 is thus exposed to allow placement or removal of an MTU 160. The transport mechanism 500 or 502 then advances the distributor hook 506 from the retracted position to the extended position, pushing the MTU 160 out of the housing 504, through the access opening 614, and into an MTU station 676 in the incubator. After the distributor hook 506 is withdrawn, the motor 640 turns the hub 646, shifting the previously inserted MTU 160 away from the access opening 614, and the revolving door 622 closes once again. This sequence is repeated for subsequent MTUs inserted into the rotary incubator. Incubation of each loaded MTU continues as that MTU advances around the incubator (counter-clockwise) towards the exit slot 618.

An MTU sensor (preferably an infrared optical reflective sensor) in each of the MTU stations 676 detects the presence of an MTU 160 within the station. Optek Technology, Inc. sensors, model number OPB770T, available from Optek Technology, Inc. of Carrollton, Texas are preferred because of the ability of these sensors to withstand the high temperature environment of the incubators and because of the ability of these sensors to read bar code data fixed to the label-receiving surfaces 175 of the label-receiving structures 174 of the MTUs 160. In addition, each door assembly (revolving doors 622, 624 or door assembly 650) preferably includes slotted optical sensors (not shown) to indicate door open and door closed positions. Sensors available from Optek Technology, Inc. of Carrollton, Texas, model number OPB980T11, are preferred because of

the relatively fine resolution provided thereby to permit accurate monitoring of door position. A skewed disk linear mixer (also known as a wobbler plate) 634 is provided within housing 610 adjacent MTU carousel assembly 671 and operates as a receptacle mixing mechanism. The mixer 634 comprises a disk mounted in a skewed manner to the shaft of a motor 636 which extends through opening 635 into the housing 610. The motor is preferably a VEXTA stepper motor, model number PK264-01A, available from Oriental Motors Ltd. of Tokyo, Japan, which is the same motor preferably used for the MTU carousel assembly 671. A viscous harmonic damper 638 is preferably attached to motor 636 to damp out harmonic frequencies of the motor which can cause the motor to stall. Preferred harmonic dampers are VEXTA harmonic dampers, available from Oriental Motors Ltd. The operation of the skewed disk linear mixer 634 will be described below.

Only two of the incubators, the amplification incubator 604 and the hybridization protection assay incubator 606, include a skewed disk linear mixer 634, because, in the preferred mode of operation, it is only in these two incubators where fluids are dispensed into the MTUs 160 while they are in the incubator. Thus, it is only necessary to provide linear mixing of the MTU 160 by the skewed disk linear mixer 634 in the amplification incubator 604 and the hybridization protection assay incubator 606.

To effect linear mixing of an MTU 160 in the incubator by linear mixer 634, the MTU carousel assembly 671 moves the MTU 160 into alignment with the skewed disk linear mixer 634, and the skewed disk of the skewed disk linear mixer 634 engages the MTU manipulating structure 166 of the MTU 160. As the motor 636 spins the skewed disk of the skewed disk linear mixer 634, the portion of the skewed disk structure engaged with the MTU 160 moves radially in and out with respect to the wall of the housing 610, thus alternately engaging the vertical piece 167 of the MTU manipulating structure 166 and the shield structure 169. Accordingly, the MTU 160 engaged with the skewed disk linear mixer 634

is moved radially in and out, preferably at high frequency, providing linear mixing of the contents of the MTU 160. For the amplification incubation step of the preferred mode of operation, which occurs within the amplification incubator 604, a mixing frequency of 10 Hz is preferred. For the probe incubation step of the preferred mode of operation, which occurs within the hybridization protection assay incubator 606, a mixing frequency of 14 Hz is preferred. Finally, for the select incubation step of the preferred mode of operation, which also occurs within the hybridization protection assay incubator 606, a mixing frequency of 13 Hz is preferred.

The raised arcuate portions 171, 172 may be provided in the middle of the convex surfaces of the vertical piece 167 and the shield structure 169 of the MTU 160, respectively, (see FIGURE 47) to minimize the surface contact between the skewed disk linear mixer 634 and the MTU 160 so as to minimize friction between the MTU 160 and the skewed disk linear mixer 634.

In the preferred embodiment, a sensor is provided at the skewed disk linear mixer 634 to ensure that the skewed disk linear mixer 634 stops rotating in the "home" position shown in FIGURE 21, so that MTU manipulating structure 166 can engage and disengage from the skewed disk linear mixer 634 as the MTU carousel assembly 671 rotates. The preferred "home" sensor is a pin extending laterally from the skewed disk linear mixer structure and a slotted optical switch which verifies orientation of the skewed disk linear mixer assembly when the pin interrupts the optical switch beam. Hall effect sensors based on magnetism may also be used.

An alternate MTU carousel assembly and carousel drive mechanism are shown in FIGURES 23A and 23C. As shown in FIGURE 23A, the alternate incubator includes a housing assembly 1650 generally comprising a cylindrical portion 1610 constructed of nickel-plated cast aluminum, a cover 1676 preferably formed of machined aluminum, insulation 1678 for

the cover 1676, and an insulation jacket 1651 surrounding the cylindrical portion 1610. As with the previously described incubator embodiment, the incubator may include a linear mixer mechanism including a linear mixer motor 636 with a harmonic damper 638. A closure mechanism 1600 (described below) operates to close off or permit access through a receptacle access opening 1614. As with the previously described embodiment, the incubator may include one or two access openings 1614 depending on the location of the incubator and its function within the analyzer 50.

A centrifugal fan 632 is mounted at a bottom portion of the housing 1650 and is driven by a motor (not shown). A fan cover 652 is disposed over the fan and includes sufficient openings to permit air flow generated by the fan 632. A carousel support shaft 1654 includes a lower shaft 1692 and an upper shaft 1690 divided by a support disk 1694. The support shaft 1654 is supported by means of the lower shaft 1692 extending down into the fan cover 1652 where it is rotatably supported and secured by bearings (not shown).

An MTU carousel 1656 includes an upper disk 1658 having a central portion 1696. A top surface of the support disk 1694 engages and is attached to a bottom surface of the central portion 1696 of the upper disk 1658 so that the weight of the carousel 1656 is supported from below. As shown in FIGURE 23C, a plurality of radially extending, circumferentially spaced station dividers 1660 are attached beneath the upper disk 1658. A lower disk 1662 includes a plurality of radial flanges 1682 emanating from an annular inner portion 1688. The radial flanges 1682 correspond in number and spacing to the carousel station dividers 1660, and the lower disk 1662 is secured to the bottom surfaces of the carousel station dividers 1660, with each flange 1682 being secured to an associated one of the dividers 1660.

The radial flanges 1682 define a plurality of radial slots 1680 between adjacent pairs of flanges 1682. As can be appreciated from

FIGURE 23C, the width in the circumferential direction of each flange 1682 at an inner end 1686 thereof is less than the width in the circumferential direction of the flange 1682 at the outer end 1684 thereof. The tapered shape of the flanges 1682 ensures that the opposite sides of the slots 1680 are generally parallel to one another.

When the lower disk 1662 is attached beneath the carousel station dividers 1660, the widths of the flanges along at least a portion of their respective lengths are greater than the widths of the respective dividers 1660, which may also be tapered from an outer end thereof toward an inner end thereof. The flanges 1684 define lateral shelves along the sides of adjacent pairs of dividers 1660 for supporting the connecting rib structure 164 of an MTU 160 inserted into each MTU station 1663 defined between adjacent pairs of dividers 1660.

A pulley 1664 is secured to the top of the central portion 1696 of the top disk 1658 and a motor 1672 is carried by a mounting bracket 1670 which spans the diameter of the housing 1650 and is secured to the cylindrical portion 1610 of the housing at opposite ends thereof. The motor is preferably a Vexta PK264-01A stepper motor, and it is coupled to the pulley (having a 9:1 ratio with respect to the motor) by a belt 1666, preferably one supplied by the Gates Rubber Company. A position encoder 1674 is secured to a top central portion of the mounting bracket 1672 and is coupled with the upper shaft 1690 of the carousel support shaft 1654. The encoder 1674 (preferably an absolute encoder of the A2 series by U.S. Digital Corporation of Vancouver, Washington) indicates the rotational position of the carousel 1656.

An incubator cover is defined by an incubator plate 1676, preferably formed of machined aluminum, and a conforming cover insulation element 1678. Cover plate 1676 and insulation element 1678 include appropriate openings to accommodate the encoder 1674 and the motor 1672 and may also include radial slots formed therein for dispensing fluids into MTUs carried within the incubator as described with regard to the above

embodiment.

An alternate, and preferred, closure mechanism 1600 is shown in FIGURE 23B. The cylindrical portion 1610 of the incubator housing includes at least one receptacle access opening 1614 with outwardly projecting wall portions 1616, 1618 extending integrally from the cylindrical portion 1610 along opposite sides of the access opening 1614.

A rotating door 1620 is operatively mounted with respect to the access opening 1614 by means of a door mounting bracket 1636 attached to the cylindrical portion 1610 of the housing above the access opening 1614. Door 1620 includes an arcuate closure panel 1622 and a transversely extending hinge plate portion 1628 having a hole 1634 for receiving a mounting post (not shown) of the door mounting bracket 1636. The door 1622 is rotatable about the opening 1634 with respect to the access opening 1614 between a first position in which the arcuate closure panel 1622 cooperates with the projecting wall portions 1616, 1618 to close off the access opening 1614 and a second position rotated outwardly with respect to the access opening 1614 to permit movement of a receptacle through the access opening 1614. An inner arcuate surface of the arcuate panel 1622 conforms with an arcuate surface 1638 of the door mounting bracket 1636 and an arcuate surface 1619 disposed below the receptacle access opening 1614 to permit movement of the arcuate panel 1622 with respect to the surfaces 1638 and 1619 while providing a minimum gap between the respective surfaces so as to minimize heat loss therethrough.

The door 1620 is actuated by a motor 1642 mounted to the incubator housing by means of a motor mounting bracket 1640 secured to the cylindrical portion 1610 of the housing beneath the receptacle access opening 1614. The motor shaft 1644 is coupled to a lower actuating plate 1626 of the rotating door 1620 so that rotation of the shaft 1644 is transmitted into rotation of the rotating door 1620. Motor 1642 is most preferably an HSI 7.5° per step motor available from Haydon Switch and Instrument, Inc. of Waterbury, Connecticut. The HSI motor is chosen

because of its relatively low cost and because the closure assembly 1600 does not require a high torque, robust motor.

Door position sensors 1646 and 1648 (preferably slotted optical sensors) are operatively mounted on opposite sides of the door mounting bracket 1636. The sensor 1646 and 1648 cooperate with sensor tabs 1632 and 1630 on the hinge plate 1628 of the door 1620 for indicating the relative position of the rotating door 1620 and can be configured so as to indicate, for example, a door open and a door closed status.

A door cover element 1612 is secured to the outside of the cylindrical portion 1610 of the housing so as to cover the door mounting bracket 1636 and a portion of the rotating door 1620. The cover element 1612 includes an access opening 1613 aligned with the access opening 1614 of the incubator housing and further includes a receptacle bridge 1615 extending laterally from a bottom edge of the access opening 1613. The receptacle bridge 1615 facilitates the insertion of a receptacle (e.g., an MTU 160) into and withdrawal of the receptacle from the incubator.

While in the target capture and annealing incubator 600, the MTU 160 and test specimens are preferably kept at a temperature of about 60℃ ±0.5℃ for a period of time sufficient to permit hybridization between capture probes and target nucleic acids. Under these conditions, the capture probes will preferably not hybridize with those polynucleotides directly immobilized by the magnetic particles.

Following target capture incubation in the target capture and annealing incubator 600, the MTU 160 is rotated by the incubator carousel to the entrance door 622, also known as the right-side or number one distributor door. The MTU 160 is retrieved from its MTU station 676 within incubator 600 and is then transferred by the right-side transport mechanism 500 to a temperature ramp-down station (not shown) below the specimen ring 250. In the ramp-down station, the MTU temperature is brought down to the level of the next incubator. This ramp-down station that precedes the active temperature and pre-read cool-down incubator

602 is technically a heater, as opposed to a chiller, because the temperature to which the MTU is decreased, about 40℃, is still greater than the ambient analyzer temperature, about 30℃. Accordingly, this ramp-down station preferably uses resistive heating elements, as opposed to a thermoelectric module.

From the ramp-down station, the MTU 160 is transferred by the right-side transfer mechanism 500 into the active temperature and pre-read cool-down incubator 602. The design and operation of the active temperature and pre-read cool-down 602 is similar to that of the target capture and annealing incubator 600, as described above, except that the active temperature and pre-read cool-down incubator 602 incubates at 40 ± 1.0℃.

In the AT incubator 602, the hybridization conditions are such that the polythymidine tail of the immobilized polynucleotide can hybridize to the polyamine tail of the capture probe. Provided target nucleic acid has hybridized with the capture probe in the annealing incubator 600, a hybridization complex can be formed between the immobilized polynucleotide, the capture probe and the target nucleic acid in the AT incubator 602, thus immobilizing the target nucleic acid.

During active temperature binding incubation, the carousel assembly 1656 (or 671) of the active temperature and pre-read cool-down incubator 602 rotates the MTU to the exit door 624, also known as the number two, or left-side, distributor door, from which the MTU 160 can be removed by the left-side transport mechanism 502. The left-side transport mechanism 502 removes the MTU 160 from the active temperature and pre-read cool-down incubator 602 and places it into an available magnetic separation wash station 800.

Temperature ramping stations 700 can be a bottle neck in the processing of a number of MTUs through the chemistry deck 200. It may be possible to use underutilized MTU stations 676 in one or more of the incubators in which temperature sensitivity is of less concern. For

example, the active temperature binding process which occurs within the active temperature and pre-read cool-down incubator 602 at about 60℃ is not as temperature sensitive as the other incubators, and up to fifteen (15) of the incubator's thirty (30) MTU stations 676 may be unused at any given time. As presently contemplated, the chemistry deck has only about eight ramp-up stations, or heaters. Accordingly, significantly more MTUs can be preheated within the unused slots of the active temperature and pre-read cool-down incubator 602 than within the ramp-up stations 700. Moreover, using unused incubator slots instead of heaters allows the omission of some or all of the heaters, thus freeing up space on the chemistry deck.

MAGNETIC SEPARATION WASH STATIONS

Turning to FIGURES 24-25, each magnetic separation wash station 800 includes a module housing 802 having an upper section 801 and a lower section 803. Mounting flanges 805, 806 extend from the lower section 803 for mounting the magnetic separation wash station 800 to the datum plate 82 by means of suitable mechanical fasteners. Locator pins 807 and 811 extend from the bottom of lower section 803 of housing 802. Pins 807 and 811 register with apertures (not shown) formed in the datum plate 82 to help to locate the magnetic separation wash station 800 on the datum plate 82 before the housing 802 is secured by fasteners.

A loading slot 804 extends through the front wall of the lower section 803 to allow a transport mechanism (e.g. 502) to place an MTU 160 into and remove an MTU 160 from the magnetic separation station 800. A tapered slot extension 821 surrounds a portion of the loading slot 804 to facilitate MTU insertion through the slot 804. A divider 808 separates the upper section 801 from the lower section 803.

A pivoting magnet moving structure 810 is attached inside the lower section 803 at a pivot 812 so as to be pivotable about point 812. The magnet moving structure 810 carries permanent magnets 814, which are

positioned on either side of an MTU slot 815 formed in the magnet moving structure 810. Preferably five magnets, one corresponding to each individual receptacle vessel 162 of the MTU 160, are held in an aligned arrangement on each side of the magnet moving structure 810. The magnets are preferably made of neodymium-iron-boron (NdFeB), minimum grade n-35 and have preferred dimensions of 0.5 inch width, 0.3 inch height, and 0.3 inch depth. An electric actuator, generally represented at 816, pivots the magnet moving structure 810 up and down, thereby moving the magnets 814. As shown in FIGURE 25, actuator 816 preferably comprises a rotary stepper motor 819 which rotates a drive screw mechanism coupled to the magnet moving structure 810 to selectively raise and lower the magnet moving structure 810. Motor 819 is preferably an HSI linear stepper actuator, model number 26841-05, available from Haydon Switch and Instrument, Inc. of Waterbury, Connecticut.

A sensor 818, preferably an optical slotted sensor, is positioned inside the lower section 803 of the housing for indicating the down, or "home", position of the magnet moving structure 810. Sensor 818 is preferably an Optek Technology, Inc., model number OPB980T11, available from Optek Technology, Inc. of Carrollton, Texas. Another sensor (not shown), also preferably an Optek Technology, Inc., model number OPB980T11, optical slotted sensor, is preferably provided to indicate the up, or engaged, position of the magnet moving structure 810.

An MTU carrier unit 820 is disposed adjacent the loading slot 804, below the divider 808, for operatively supporting an MTU 160 disposed within the magnetic separation wash station 800. Turning to FIGURE 26, the MTU carrier unit 820 has a slot 822 for receiving the upper end of an MTU 160. A lower fork plate 824 attaches to the bottom of the carrier unit 820 and supports the underside of the connecting rib structure 164 of the MTU 160 when slid into the carrier unit 820 (see FIGURES 28 and 29). A spring clip 826 is attached to the carrier unit 820 with its opposed

prongs 831, 833 extending into the slot 822 to releasably hold the MTU within the carrier unit 820.

An orbital mixer assembly 828 is coupled to the carrier unit 820 for orbitally mixing the contents of an MTU held by the MTU carrier unit 820. The orbital mixer assembly 828 includes a stepper motor 830 mounted on a motor mounting plate 832, a drive pulley 834 having an eccentric pin 836, an idler pulley 838 having an eccentric pin 840, and a belt 835 connecting drive pulley 834 with idler pulley 838. Stepper motor 830 is preferably a VEXTA, model number PK245-02A, available from Oriental Motors Ltd. of Tokyo, Japan, and belt 835 is preferably a timing belt, model number A 6G16-170012, available from SDP/SI of New Hyde Park, New York. As shown in FIGURES 25 and 26, eccentric pin 836 fits within a slot 842 formed longitudinally in the MTU carrier unit 820. Eccentric pin 840 fits within a circular aperture 844 formed in the opposite end of MTU carrier unit 820. As the motor 830 turns the drive pulley 834, idler pulley 838 also rotates via belt 835 and the MTU carrier unit 820 is moved in a horizontal orbital path by the eccentric pins 836, 840 engaged with the apertures 842, 844, respectively, formed in the carrier unit 820. The rotation shaft 839 of the idler pulley 838 preferably extends upwardly and has a transverse slot 841 formed therethrough. An optical slotted sensor 843 is disposed at the same level as the slot 841 and measures the frequency of the idler pulley 838 via the sensor beam intermittently directed through slot 841 as the shaft 839 rotates. Sensor 839 is preferably an Optek Technology, Inc., model number OPB980T11, sensor, available from Optek Technology, Inc. of Carrollton, Texas.

Drive pulley 834 also includes a locator plate 846. Locator plate 846 passes through slotted optical sensors 847, 848 mounted to a sensor mounting bracket 845 extending from motor mounting plate 832. Sensors 847, 848 are preferably Optek Technology, Inc., model number OPB980T11, sensors, available from Optek Technology, Inc. of Carrollton, Texas. Locator plate 846 has a plurality of circumferentially spaced axial

openings formed therein which register with one or both sensors 847, 848 to indicate a position of the orbital mixer assembly 828, and thus a position of the MTU carrier unit 820.

Returning to FIGURES 24 and 25, wash buffer solution delivery tubes 854 connect to fittings 856 and extend through a top surface of the module housing 802. Wash buffer delivery tubes 854 extend through the divider 808 via fittings 856, to form a wash buffer delivery network.

As shown in FIGURES 28 and 29, wash buffer dispenser nozzles 858 extending from the fittings 856 are disposed within the divider 808. Each nozzle is located above a respective receptacle vessel 162 of the MTU 160 at a laterally off-center position with respect to the receptacle vessel 162. Each nozzle includes a laterally-directed lower portion 859 for directing the wash buffer into the respective receptacle vessel from the off-center position. Dispensing fluids into the receptacle vessels 162 in a direction having a lateral component can limit splashing as the fluid runs down the sides of the respective receptacle vessels 162. In addition, the laterally directed fluid can rinse away materials clinging to the sides of the respective receptacle vessels 162.

As shown in FIGURES 24 and 25, aspirator tubes 860 extend through a tube holder 862, to which the tubes 860 are fixedly secured, and extend through openings 861 in the divider 808. A tube guide yoke 809 (see FIGURE 26) is attached by mechanical fasteners to the side of divider 808, below openings 861. Aspirator hoses 864 connected to the aspirator tubes 860 extend to the vacuum pump 1162 (see FIGURE 52) within the analyzer 50, with aspirated fluid drawn off into a fluid waste container carried in the lower chassis 1100. Each of the aspirator tubes 860 has a preferred length of 12 inches with an inside diameter of 0.041 inches.

The tube holder 862 is attached to a drive screw 866 actuated by a lift motor 868. Lift motor 868 is preferably a VEXTA, model number PK245-02A, available from Oriental Motors Ltd. of Tokyo, Japan, and the

drive screw 866 is preferably a ZBX series threaded anti-backlash lead screw, available from Kerk Motion Products, Inc. of Hollis, New Hampshire. The tube holder 862 is attached to a threaded sleeve 863 of the drive screw 866. Rod 865 and slide rail 867 function as a guide for the tube holder 862. Z-axis sensors 829, 827 (slotted optical sensors) cooperate with a tab extending from threaded sleeve 863 to indicate top and bottom of stroke positions of the aspirator tubes 860. The Z-axis sensors are preferably Optek Technology, Inc., model number OPB980T11, sensors, available from Optek Technology, Inc. of Carrollton, Texas.

Cables bring power and control signals to the magnetic separation wash station 800, via a connector 870.

The magnet moving structure 810 is initially in a down position (shown in phantom in FIGURE 25), as verified by the sensor 818, when the MTU 160 is inserted into the magnetic separation wash station 800 through the insert opening 804 and into the MTU carrier unit 820. When the magnet moving structure 810 is in the down position, the magnetic fields of the magnets 814 will have no substantial effect on the magnetically responsive particles contained in the MTU 160. In the present context, "no substantial effect" means that the magnetically responsive particles are not drawn out of suspension by the attraction of the magnetic fields of the magnets 814. The orbital mixer assembly 828 moves the MTU carrier unit 820 a portion of a complete orbit so as to move the carrier unit 820 and MTU 160 laterally, so that each of the tiplets 170 carried by the tiplet holding structures 176 of the MTU 160 is aligned with each of the aspiration tubes 860, as shown in FIGURE 28. The position of the MTU carrier unit 820 can be verified by the locator plate 846 and one of the sensors 847, 848. Alternatively, the stepper motor 830 can be moved a known number of steps to place the MTU carrier unit 820 in the desired position, and one of the sensors 847, 848 can be omitted.

The tube holder 862 and aspirator tubes 860 are lowered by the lift

motor 868 and drive screw 866 until each of the aspirator tubes 860 frictionally engages a tiplet 170 held in an associated carrying structure 176 on the MTU 160.

As shown in FIGURE 25A, the lower end of each aspirator tube 860 is characterized by a tapering, step construction, whereby the tube 860 has a first portion 851 along most of the extent of the tube, a second portion 853 having a diameter smaller than that of the first portion 851, and a third portion 855 having a diameter smaller than that of the second portion 853. The diameter of the third portion 855 is such as to permit the end of the tube 860 to be inserted into the flared portion 181 of the through hole 180 of the tiplet 170 and to create an interference friction fit between the outer surface of third portion 855 and the two annular ridges 183 (see FIGURE 46) that line the inner wall of hole 180 of tiplet 170. An annular shoulder 857 is defined at the transition between second portion 853 and third portion 855. The shoulder 857 limits the extent to which the tube 860 can be inserted into the tiplet 170, so that the tiplet can be stripped off after use, as will be described below.

The tiplets 170 are at least partially electrically conductive, so that the presence of a tiplet 170 on an aspirator tube 860 can be verified by the capacitance of a capacitor comprising the aspirator tubes 860 as one half of the capacitor and the surrounding hardware of the magnetic separation wash station 800 as the other half of the capacitor. The capacitance will change when the tiplets 170 are engaged with the ends of the aspirator tubes 860.

In addition, five optical slotted sensors (not shown) can be strategically positioned above the divider 808 to verify the presence of a tiplet 170 on the end of each aspirator tube 860. Preferred "tiplet-present" sensors are Optek Technology, Inc., model number OPB930W51, sensors, available from Optek Technology, Inc. of Carrollton, Texas. A tiplet 170 on the end of an aspirator tube 860 will break the beam of an associated sensor to verify presence of the tiplet 170. If, following a tiplet pick-up

move, tiplet engagement is not verified by the tiplet present sensors for all five aspirator tubes 860, the MTU 160 must be aborted. The aborted MTU is retrieved from the magnetic separation wash station 800 and sent to the deactivation queue 750 and ultimately discarded.

After successful tiplet engagement, the orbital mixer assembly 828 moves the MTU carrier unit 820 back to a fluid transfer position shown in FIGURE 27 as verified by the locator plate 846 and one or both of the sensors 847, 848.

The magnet moving structure 810 is then raised to the up position shown in FIGURE 24 so that the magnets 814 are disposed adjacent opposite sides of the MTU 160. With the contents of the MTU subjected to the magnetic fields of the magnets 814, the magnetically responsive particles bound indirectly to the target nucleic acids will be drawn to the sides of the individual receptacle vessels 162 adjacent the magnets 814. The remaining material within the receptacle vessels 162 should be substantially unaffected, thereby isolating the target nucleic acids. The magnet moving structure 810 will remain in the raised position for an appropriate dwell time, as defined by the assay protocol and controlled by the assay manager program, to cause the magnetic particles to adhere to the sides of the respective receptacle vessels 162.

The aspirator tubes are then lowered into the receptacle vessels 162 of the MTU 160 to aspirate the fluid contents of the individual receptacle vessels 162, while the magnetic particles remain in the receptacle vessels 162, adhering to the sides thereof, adjacent the magnets 814. The tiplets 170 at the ends of the aspirator tubes 860 ensure that the contents of each receptacle vessel 162 do not come into contact with the sides of the aspirator tubes 860 during the aspirating procedure. Because the tiplets 170 will be discarded before a subsequent MTU is processed in the magnetic separation wash station 800, the chance of cross-contamination by the aspirator tubes 860 is minimized.

The electrically conductive tiplets 170 can be used in a known

manner for capacitive fluid level sensing within the receptacle vessels 162 of the MTUs. The aspirator tubes 860 and the conductive tiplets 170 comprise one half of a capacitor, the surrounding conductive structure within the magnetic separation wash station comprises the second half of the capacitor, and the fluid medium between the two halves of the capacitor constitutes the dielectric. Capacitance changes due to a change in the nature of the dielectric can be detected.

The capacitive circuitry of the aspirator tubes 860 can be arranged so that all five aspirator tubes 860 operate as a single gang level-sensing mechanism. As a gang level-sensing mechanism, the circuitry will only determine if the fluid level in any of the receptacle vessels 162 is high, but cannot determine if the fluid level in one of the receptacle vessels is low. In other words, when any of the aspirator tubes 860 and its associated tiplet 170 contacts fluid material within a receptacle vessel, capacitance of the system changes due to the change in the dielectric. If the Z-position of the aspirator tubes 860 at which the capacitance change occurs is too high, then a high fluid level in at least one receptacle vessel is indicated, thus implying an aspiration failure. On the other hand, if the Z-position of the aspirator tubes at which the capacitance change occurs is correct, the circuitry cannot differentiate between aspirator tubes, and, therefore, if one or more of the other tubes has not yet contacted the top of the fluid, due to a low fluid level, the low fluid level will go undetected.

Alternatively, the aspirator tube capacitive circuitry can be arranged so that each of the five aspirator tubes 860 operates as an individual level sensing mechanism.

With five individual level sensing mechanisms, the capacitive level sensing circuitry can detect failed fluid aspiration in one or more of the receptacle vessels 162 if the fluid level in one or more of the receptacle vessels is high. Individual capacitive level sensing circuitry can detect failed fluid dispensing into one or more of the receptacle vessels 162 if the fluid level in one or more of the receptacle vessels is low. Furthermore,

the capacitive level sensing circuitry can be used for volume verification to determine if the volume in each receptacle vessel 162 is within a prescribed range. Volume verification can be performed by stopping the descent of the aspirator tubes 860 at a position above expected fluid levels, e.g. 110% of expected fluid levels, to make sure none of the receptacle vessels has a level that high, and then stopping the descent of the aspirator tubes 860 at a position below the expected fluid levels, e.g. 90% of expected fluid levels, to make sure that each of the receptacle vessels has a fluid level at least that high.

Following aspiration, the aspirator tubes 860 are raised, the magnet moving structure 810 is lowered, and a prescribed volume of wash buffer is dispensed into each receptacle vessel 162 of the MTU 160 through the wash buffer dispenser nozzles 858. To prevent hanging drops of wash buffer on the wash buffer dispenser nozzles 858, a brief, post-dispensing air aspiration is preferred.

The orbital mixer assembly 828 then moves the MTU carriers 820 in a horizontal orbital path at high frequency to mix the contents of the MTU 160. Mixing by moving, or agitating, the MTU in a horizontal plane is preferred so as to avoid splashing the fluid contents of the MTU and to avoid the creation of aerosols. Following mixing, the orbital mixer assembly 828 stops the MTU carrier unit 820 at the fluid transfer position.

To further purify the targeted nucleic acids, the magnet moving structure 810 is again raised and maintained in the raised position for a prescribed dwell period. After magnetic dwell, the aspirator tubes 860 with the engaged tiplets 170 are lowered to the bottoms of the receptacle vessels 162 of the MTU 160 to aspirate the test specimen fluid and wash buffer in an aspiration procedure essentially the same as that described above.

One or more additional wash cycles, each comprising a dispense, mix, magnetic dwell, and aspirate sequence, may be performed as defined by the assay protocol. Those skilled in the art of nucleic acid-based

diagnostic testing will be able to determine the appropriate magnetic dwell times, number of wash cycles, wash buffers, etc. for a desired target capture procedure.

While the number of magnetic separation wash stations 800 can vary, depending on the desired throughput, analyzer 50 preferably includes five magnetic separation wash stations 800, so that a magnetic separation wash procedure can be performed on five different MTUs in parallel.

After the final wash step, the magnet moving structure 810 is moved to the down position and the MTU 160 is removed from the magnetic separation wash station 800 by the left-side transport mechanism 502 and is then placed into the left orbital mixer 552.

After the MTU 160 is removed from the wash station, the tiplets 170 are stripped from the aspiration tubes 860 by a stripper plate 872 located at the bottom of the lower section 803 of the housing 802.

The stripper plate 872 has a number of aligned stripping holes 871 corresponding in number to the number of aspiration tubes 860, which is five in the preferred embodiment. As shown in FIGURES 29A to 29D, each stripping hole 871 includes a first portion 873, a second portion 875 smaller than first portion 873, and a bevel 877 surrounding portions 873 and 875. The stripper plate 872 is oriented in the bottom of the housing 802 so that the small portion 875 of each stripping hole 871 is generally aligned with each associated aspiration tube 860, as shown in FIGURE 29A. The aspiration tubes 860 are lowered so that the tiplet 170 at the end of each aspirator tube 860 engages the stripping hole 871. Small portion 875 is too small to accommodate the diameter of a tiplet 170, so the bevel 877 directs the tiplet 170 and the aspirator tube 860 toward the larger portion 873; as shown in FIGURE 29B. The aspirator tubes 860 are made of an elastically flexible material, preferably stainless steel, so that, as the aspirator tubes 860 continue to descend, the bevelled portion 877 causes each of aspirator tubes 860 to deflect laterally. The small portion 875 of the stripping hole 871 can accommodate the diameter of

the aspirator tube 860, so that after the rim 177 of the tiplet 170 clears the bottom of stripping hole 871, each of the aspirator tubes 860 snaps, due to its own resilience, into the small portion 875 of the stripping hole 871 as shown in FIGURE 29C. The aspirator tubes 860 are then raised, and the rim 177 of each tiplet 170 engages the bottom peripheral edge of the small portion 875 of stripping hole 871. As the aspirator tubes 860 ascend further, the tiplets 170 are pulled off the aspirator tubes 860 by the stripping holes 871 (see FIGURE 29D). The stripped tiplets 170 are directed by a chute into a solid waste container, such as the tiplet waste bin 1134.

The capacitance of the aspiration tubes 860 is sampled to verify that all tiplets 170 have been stripped and discarded. The stripping step can be repeated if necessary.

An alternate stripper plate 882 is shown in FIGURES 31A to 31C. Stripper plate 882 includes a number of stripping holes 881 corresponding to the number of aspirator tubes 860, which is five in the preferred embodiment. Each stripping hole 881 includes a through-hole 883 surrounded by a bevelled countersink 887. A pair of tangs 885 extend laterally from diametrically opposed positions below the through-hole 883. Tangs 885 are preferably made from a spring steel and include a v-notch 886 at their ends.

As an aspirator tube 860 with a tiplet 170 disposed on its end is lowered toward stripping hole 881, bevelled portion 887 ensures that any misaligned tubes are directed into the through-hole 883. The spacing between the ends of the opposed tangs 885 is less than the diameter of the tiplet 170, so as the aspirator tube 860 and tiplet 170 are lowered, the tiplet engages the tangs 885, causing them to deflect downwardly as the tiplet 170 is forced between tangs 885. When the aspirator tubes 860 are raised, the notches 886 of the tangs 885 grip the relatively soft material of the tiplet 170, thus preventing upward relative movement of the tiplet 170 with respect to the tangs 885. As the tubes continue to ascend, the tangs

885 pull the tiplet 170 off the tube 860. When the aspirator tubes 860 are subsequently lowered to strip a subsequent set of tiplets, the tiplet held between the tangs from the previous stripping is pushed through the tangs by the next tiplet and is directed toward waste bin 1134 (see FIGURE 52) located in the lower chassis 1100 generally below the five magnetic separation wash stations 800.

Still another alternate, and the presently preferred, stripper plate 1400 is shown in FIGURES 30A-30D. Stripper plate 1400 includes five stripper cavities 1402, each including an initial frusto-conical portion 1404. The frusto-conical portion 1404 tapers down to a neck portion 1406 which connects to an enlarged straight section 1408. Straight section 1408 is offset with respect to the center of neck portion 1406, so that one side of the straight section 1408 is flush with a side of the neck portion 1406, and an opposite side of the straight section 1408 is offset from and undercuts the side of the neck portion 1406, thereby forming a ledge 1414. Following the straight section 1408, a sloped portion 1410 is provided on a side of the stripper cavity 1402 opposite the ledge 1414. Sloped portion 1410 tapers inwardly toward a bottom opening 1412.

As an aspirator tube 860 with a tiplet 170 on its end is moved toward the stripper cavity 1402, the frusto-conical portion 1404 directs the tiplet 170 and tube 860 toward the neck portion 1406. The aspirator tube 860 continues to descend, and the tiplet 170 enters the straight section 1408 as the rim 177 of the tiplet 170 clears the bottom of the frusto-conical portion 1404 and passes through the neck portion 1406.

If the aspirator tube 860 and the stripper cavity 1402 are in proper, preferred alignment, a portion of the rim 177 of the tiplet 170 will be disposed below the ledge 1414 of the stripper cavity 1402 when the tiplet 170 has moved through the neck portion 1406 and into the straight section 1408. To ensure that a portion of the rim 177 will be disposed beneath the ledge 1414, the tiplet 170 engages the lower slopped portion 1410 as the aspirator tube 860 descends further to urge the aspirator tube laterally

to direct the tiplet 170 below the ledge 1414.

The annular shoulder 857 (see FIGURE 25A) formed at the bottom of the aspirator tube 860 ensures that the tube 860 is not forced further into the through hole 180 of the tiplet 170 as the tube 860 is lowered into the stripper cavity 1402. The aspirator tube 860 then ascends, and the ledge 1414 catches the rim 177 and strips the tiplet 170 off the tube 860. The stripped tiplet 170 falls through bottom opening 1412 and into the waist bin 1134 in the lower chassis 1100 (see FIGURE 52).

With each of the stripper plates described above, the position of the tiplet-stripping elements are not all the same. For example, the ledges 1414 of the stripper cavities 1402 of the stripper plate 1400 are not at the same height throughout all the cavities. Preferably, three tiplet-stripping elements are at one height, and two tiplet-stripping elements are at a slightly different height above or below the other three elements. The result of the offset tiplet-stripping elements is that the static friction of the tiplet 170 on the end of the aspirator tube 860 need not be overcome, or broken, for all five tubes 860 at once. As the aspirator tubes 860 begin to ascend, static friction of the tiplets 170 is broken for one set (two or three) of aspirator tubes 860 first, and then, as the tubes 860 continue to ascend, static friction of the tiplets 170 is broken for the remaining tubes 860. By not breaking static friction of the tiplets 170 for all five aspirator tubes 860 at once, the loads to which the tube holder 862, drive screw 866, threaded sleeve 863, and lift motor 868 are subjected are kept to a lower level.

ORBITAL MIXERS

The left orbital mixer 552 (and the right orbital mixer 550), as shown in FIGURES 32-34, are constructed and operate in the same manner as the lower housing section 803 and the orbital mixer assembly 828 of the magnetic separation wash stations 800 described above. Specifically, the orbital mixer 550 (552) includes a housing 554, including a

front plate 551, a back plate, and mounting flanges 555, 556, for mounting the orbital mixer 550 (552) to the datum plate 82. An insert opening 557 is formed in a front edge of the housing 554. An MTU carrier 558 has a fork plate 560 attached to the bottom thereof and an MTU-retaining clip 562 attached to a back portion of the carrier 558 with opposed prongs of the clip 562 extending into an inner cavity of the carrier 558 that accommodates the MTU. An orbital mixer assembly 564 includes a drive motor 566 mounted to a motor mounting plate 567, a drive wheel 568 having an eccentric pin 570, an idler wheel 572 having an eccentric pin 573, and a belt 574. Drive motor 566 is preferably a stepper motor, and most preferably a VEXTA, model number PK245-02A, available from Oriental Motors Ltd. of Tokyo, Japan. Belt 574 is preferably a timing belt, model number A 6G16-170012, available from SDP/SI of New Hyde Park, New York. The orbital mixer assembly 564 is coupled to the MTU carrier 558 through the eccentric pins 570, 573 to move the MTU carrier 558 in an orbital path to agitate the contents of the MTU. The drive wheel 568 includes a locator plate 576, which, in conjunction with sensor 578 attached to sensor mounting bracket 579, verifies the proper positioning of the MTU carrier 558 for inserting an MTU 160 into the orbital mixer 552 (550) and retrieving an MTU 160 from the orbital mixer. Sensor 578 is preferably an Optek Technology, Inc., model number OPB980T11, sensor, available from Optek Technology, Inc. of Carrollton, Texas.

A top plate 580 is attached atop housing 554. Top plate 580 of the left orbital mixer 552 includes a number of tube fittings 582, preferably five, to which are coupled a like number of flexible delivery tubes (not shown) for delivering a fluid from a bulk fluid container to an MTU 160 located within the mixer via dispenser nozzles 583. Top plate 580 also includes a plurality of pipette openings 581, corresponding in number to the number of individual receptacle vessels 162 comprising a single MTU 160, which is preferably five.

With the MTU 160 held stationary in the left orbital mixer 552, pipette unit 480 of the left pipette assembly 470 transfers a prescribed volume of amplification reagent from a container within the reagent cooling bay 900 into each receptacle vessel 162 of the MTU 160 through the pipette openings 581. The amplification reagent used will depend upon the amplification procedure being followed. Various amplification procedures are well known to those skilled in the art of nucleic acid-based diagnostic testing, a number of which are discussed in the background section above.

Next, the contents of the MTU are mixed by the orbital mixer assembly 564 of the orbital mixer 552 to ensure proper exposure of the target nucleic acid to amplification reagent. For a desired amplification procedure, those skilled in the art of nucleic acid-based diagnostic testing will be able to determine the appropriate components and amounts of an amplification reagent, as well as mix frequencies and durations.

After pipetting amplification reagent into the MTU 160, the pipette unit 480 is moved to a rinse basin (described below) on the processing deck 200, and pipette unit 480 is washed by running distilled water through probe 481. The distilled water is pumped from bottle 1140 in the lower chassis 1100, and the purge water is collected in a liquid waste container 1128 in the lower chassis 1100.

After mixing the contents of the MTU 160, a layer of silicon oil is dispensed into each receptacle vessel through the dispenser nozzles 583. The layer of oil, pumped from bottles 1148 in the lower chassis 1100, helps prevent evaporation and splashing of the fluid contents of the MTU 160 during subsequent manipulation and incubation of the MTU 160 and its contents.

REAGENT COOLING BAY

The reagent cooling bay 900 will now be described.

Referring to FIGURES 35-39, the reagent cooling bay 900 includes

an insulating jacket 902 fitted around a cylindrical housing 904, preferably made from aluminum. A cover 906, preferably made of Delrin, sits atop housing 904 with a registration tab 905 of cover 906 fitting within slot 907 in housing 904 to ensure proper orientation of the cover 906 An optical sensor may be provided proximate to or within slot 907 for verifying that tab 905 is seated within slot 907. Alternatively, an optical sensor assembly 909 can be secured to an edge of an upper rim of the housing 904 for verifying cover placement. The optical sensor assembly 909 cooperates with a sensor-tripping structure (not shown) on the cover 906 to verify that the cover is in place. Optical sensor assembly 909 preferably includes an Optek Technology, Inc. slotted optical sensor, model number OPB980T11, available from Optek Technology, Inc. of Carrollton, Texas. The cover 906 also includes pipette openings 908 through which pipette units 480, 482 can access reagent containers within the cooling bay 900.

The housing 904 is attached to a floor plate 910, and the floor plate 910 is attached to the datum plate 82 by means of suitable mechanical fasteners extending through openings formed in mounting flanges 911 spaced about the periphery of the floor plate 910. Cooling units 912, preferably two, are attached to floor plate 910. Each cooling unit 912 comprises a thermoelectric module 914 attached cool-side-up to the bottom surface of floor plate 910. Thermoelectric modules available from Melcor, Inc. of Trenton, New Jersey, model number CP1.4-127-06L, provide the desired cooling capacity. A heat sink 916, including a plurality of heat-dissipating fins 915, is attached to, or may be integral with, the bottom surface of floor plate 910, directly below the thermoelectric module 914. A fan unit 918 is attached in a position to drain heat away from heat sink 916. Fan units 918 are preferably Orix fans, model number MD825B-24, available from Oriental Motors Ltd. of Tokyo, Japan. Together, the cooling units 912 cool the interior of the housing 904 to a prescribed temperature for the benefit of temperature-sensitive reagents (e.g., enzymes) stored within the bay 900.

Two temperature sensors (not shown) are disposed within the cooling bay 900 housing 904 for monitoring and controlling the interior temperature thereof. The temperature sensors are preferably thermistors (10 KOhm at 25℃), and YSI 44036 series thermistors available from YSI, Inc. of Yellow Springs, Ohio are most preferred. YSI thermistors are preferred because of their high accuracy and the ±0.1℃ interchangeability provided by YSI thermistors from one thermistor to another. One of the sensors is a primary temperature control sensor, and the other is a temperature monitoring sensor. On the basis of the temperature indications from the primary control sensor, the embedded controller adjusts power to the thermoelectric modules 914 and/or power to the fan units 918 to control cooling bay temperature. The temperature monitoring sensor provides a verification check of the primary temperature control sensor.

As shown in FIGURE 37, container tray 922 is a one-piece turntable structure with bottle-holding cavities 924 sized and shaped to receive and hold specific reagent bottles 925. A drive system for container tray 922 includes a motor 926, a small pulley 931 on the shaft of motor 926, a belt 928, a pulley 930, and a shaft 932.

(a VEXTA stepper motor, model number PK265-02A, available from Oriental Motor Co., Ltd. of Tokyo, Japan, and an SDP timing belt, GT® Series, available from SDP/SI of New Hyde Park, New York, are preferred). Motor 926 and cooling units 912 extend through openings (not shown) formed in the datum plate 82 and extend below the floor plate 910.

Container tray 922 may include a central, upstanding handle 923 to facilitate installation of the tray 922 into and removal of the tray 922 from the housing 904. A top portion 933 of shaft 932 extends through floor plate 910 and is received by a mating aperture (not shown) formed in the bottom of the tray 922. A sensor 940 extending up through the floor plate 910 and into the housing 904 verifies that tray 922 is in place within the

housing 904. Sensor 940 is preferably a capacitive proximity sensor available from Advanced Controls, Inc., of Bradenton, Florida, model number FCP2.

A position encoder 934 (preferably a slotted disk) in conjunction with an optical sensor 935 may be used to detect the position of the container tray 922, so that a specific reagent bottle 925 may be aligned under the pipette openings 908 in the cover 906.

As shown in FIGURE 36, a preferred alternative to the position encoder 934 and optical sensor 935 includes four slotted optical sensors 937 (only two sensors are visible in FIGURE 36) provided inside the housing 904 along with a flag pin (not shown) extending from the bottom of container tray 922. One sensor is provided for each quadrant of the container tray 922, and the flag trips one of the four sensors to indicate which quadrant of the container tray 922 is aligned with the pipette openings 908. Sensors 937 are preferably Optek Technology, Inc. sensors, model number OPB980T11, available from Optek Technology, Inc. of Carrollton, Texas.

A preferred alternative to the one-piece container tray 922 shown in FIGURE 37 is a modular tray 1922 shown in FIGURES 35 and 39. Tray 1922 includes a circular base plate 1926 and an upstanding handle post 1923 attached to a central portion thereof. Modular pieces 1930 having bottle-holding cavities 1924 are preferably connected to one another and to the base plate 1926 by pins 1928 and screws (not shown) to form the circular tray 1922. Other means of securing the modular pieces 1930 may be employed in the alternative to pins 1928 and screws. The modular pieces 1930 shown in the figures are quadrants of a circle, and thus, of course, four such pieces 1930 would be required to complete the tray 1922. Although quadrants are preferred, the modular pieces may however be sectors of various sizes, such as, for example, 1/2 of a circle or 1/8 of a circle.

Alphanumeric bottle location labels 1940 are preferably provided

on the base plate 1926 to identify positions within the tray 1922 for reagent containers. The preferred label scheme includes an encircled letter-number pair comprising a leading letter A, E, P, or S with a trailing number 1, 2, 3, or 4. The letters A, E, P, and S, designate amplification reagent, enzyme reagent, probe reagent, and select reagent, respectively, corresponding to the preferred mode of use of the analyzer 50, and the numbers 1-4 designate a quadrant of the tray 1922. Each modular piece 1930 includes a circular hole 1934 at the bottom of each bottle-holding cavity 1924. The holes 1934 align with the bottle location labels 1940, so that the labels 1940 can be seen when the modular pieces 1930 are in place on the base plate 1926.

The modular pieces 1930 of the container tray 1922 are configured to accommodate reagent containers of different sizes corresponding to reagent quantities sufficient for performing two hundred fifty (250) assays or reagent quantities sufficient for performing five hundred (500) assays. Four 250-assay modular quadrants permit the reagent cooling bay to be stocked for 1000 assays, and four 500-assay modular quadrants permit the reagent cooling bay to be stocked for 2000 assays. Modular quadrants for 250 or 500 assay reagent kits can be mixed and matched to configure the container tray for accommodating various numbers of a single assay type or various numbers of multiple different assay types.

An insulation pad 938 is disposed between the container tray 922 and the floor plate 910. Power, control, temperature, and position signals are provided to and from the reagent cooling bay 900 by a connector 936 and a cable (not shown) linked to the embedded controller of the analyzer 50.

A bar code scanner 941 is mounted to an upstanding scanner mounting plate 939 attached to floor plate 910 in front of an opening 942 formed in a side-wall of the cooling bay 900. The bar code scanner 941 is able to scan bar code information from each of the reagent containers carried on the container tray 922. As shown in FIGURE 39, longitudinal

slots 1932 are formed along the bottle-holding cavities 1924, and bar code information disposed on the sides of the reagent container held in the bottle-holding cavities 1924 can be align with the slots 1932 to permit the bar code scanner 941 to scan the bar code information. A preferred bar code scanner is available from Microscan of Newbury Park, California under model number FTS-0710-0001.

Pipette rinse basins 1942, 1944 are attached to the side of the housing 904. Each rinse basin 1942, 1944 provides an enclosure structure with a probe-receiving opening 1941, 1945, respectively, formed in a top panel thereof and a waste drain tube 1946, 1948, respectively, connected to a bottom portion thereof. A probe of a pipette unit can be inserted into the rinse basin 1942, 1944 through the probe-receiving opening 1941, 1945, and a wash and/or rinse fluid can be passed through the probe and into the basin. Fluid in the rinse basin 1942, 1944 is conducted by the respective waste drain tube 1946, 1948 to the appropriate waste fluid container in the lower chassis 1100. In the preferred arrangement and mode of operation of the analyzer 50, probe 481 of pipette unit 480 is rinsed in rinse basin 1942, and probe 483 of pipette unit 482 is rinsed in rinse basin 1944.

After the amplification reagent and oil are added to the receptacle vessels 162 of MTU 160 in the left orbital mixer 552, the left-side transport mechanism 502 retrieves the MTU 160 from the left orbital mixer 552 and moves the MTU 160 to an available temperature ramp-up station 700 that is accessible to the left-side transport mechanism 502, i.e. on the left side of the chemistry deck 200, to increase the temperature of the MTU 160 and its contents to about 60℃.

After sufficient ramp-up time in the ramp-up station 700, the left-side transport mechanism 502 then moves the MTU 160 to the target capture and annealing incubator 600. The left-side distributor door of the

target capture and annealing incubator 600 opens, and the MTU carousel assembly 671 within the incubator 600 presents an empty MTU station 676 to permit the left-side transport mechanism to insert the MTU into the incubator 600. The MTU 160 and its contents are then incubated at about 60°C for a prescribed incubation period. During incubation, the MTU carousel assembly 671 may continually rotate within the incubator 600 as other MTUs 600 are removed from and inserted into the incubator 600.

Incubating at 60°C in the annealing incubator 600 permits dissociation of the capture probe/target nucleic acid hybridization complex from the immobilized polynucleotide present in the assay solution. At this temperature, oligonucleotide primers introduced from the reagent cooling bay 900 can hybridize to the target nucleic acid and subsequently facilitate amplification of the target nucleotide base sequence.

Following incubation, the MTU carousel assembly 671 within incubator 600 rotates the MTU 160 to the left-side distributor door 624, the left side distributor door 624 opens, and the left-side transport mechanism 502 retrieves the MTU 160 from the MTU carousel assembly 671 of the target capture and annealing incubator 600. The left-side transport mechanism 502 then moves the MTU 160 to, and inserts the MTU 160 into, an available temperature ramp-down station 700 that is accessible to the left-side transport mechanism 502. The temperature of the MTU 160 and its contents is decreased to about 40°C in the ramp-down station. The MTU 160 is then retrieved from the ramp-down station by the left-side transport mechanism 502 and is moved to the active temperature and pre-read cool-down incubator 602. The left-side distributor door of the AT incubator 602 opens, and the MTU carousel assembly 671 within incubator 602 presents an empty MTU station 676, so that the left-side transport mechanism 502 can insert the MTU into the incubator 602. Within the active temperature and pre-read cool-down incubator 602, the MTU is incubated at about 41°C for a period of time necessary to stabilize the temperature of the MTU.

From the active temperature and pre-read cool-down incubator 602, the MTU is moved by transport mechanism 502 to the amplification incubator 604 in which the temperature of the MTU is stabilized at 41.5℃. The MTU carousel assembly 671 within the amplification incubator 604 rotates to place the MTU at the pipetting station below the pipette openings 662 formed in the cover 611 (see, e.g., FIGURE 19). The container tray 922 within the reagent cooling bay 900 rotates to place the enzyme reagent container below a pipette opening 908, and pipette unit 482 of pipette assembly 470 transfers enzyme reagent from the reagent cooling bay 900 to each of the receptacle vessels 162 of the MTU 160.

As explained above, pipette units 480, 482 use capacitive level sensing to ascertain fluid level within a container and submerge only a small portion of the end of the probe 481, 483 of the pipette unit 480, 482 to pipette fluid from the container. Pipette units 480, 482 preferably descend as fluid is drawn into the respective probe 481, 483 to keep the end of the probe submerged to a constant depth. After pipetting reagent into the pipette unit 480 or 482, the pipette unit create a minimum travel air gap of 10 μl in the end of the respective probe 481 or 483 to ensure no drips fall from the end of the probe.

After enzyme reagent is added to each receptacle vessel 162, the MTU carousel assembly 671 of amplification incubator 604 rotates MTU 160 to the skewed disk linear mixer 634 within amplification incubator 604 and the MTU 160 and its contents are mixed as described above at about 10 Hz to facilitate exposure of the target nucleic acid to the added enzyme reagent. The pipette unit 482 is moved to rinse basin 1942, and the probe 483 is rinsed by passing distilled water through it.

The MTU 160 is then incubated within amplification incubator 604 at about 41.5℃ for a prescribed incubation period The incubation period should be sufficiently long to permit adequate amplification of at least one target nucleotide base sequence contained on one or more target nucleic

acids which may be present in the receptacle tubes 162. Although the preferred embodiment is designed to facilitate amplification using a transcription-mediated amplification (TMA) procedure, which is discussed in the background section *supra*, practitioners will easily appreciate those modifications necessary to perform other amplification procedures using the analyzer 50. In addition, an internal control sequence is preferably added at the beginning of the assay to provide confirmation that the amplification conditions and reagents were appropriate for amplification. Internal controls are well known in the art and require no further discussion here.

Following amplification incubation, the MTU 160 is moved by the left-side transport mechanism 502 from the amplification incubator 604 to an available ramp-up station 700 that is accessible to the left-side transport mechanism 502 to bring the temperature of the MTU 160 and its contents to about 60℃. The MTU 160 is then moved by the left-side transport mechanism 502 into the hybridization incubator 606. The MTU 160 is rotated to a pipetting station in the hybridization incubator 606, and a probe reagent from the reagent cooling bay 900 is pipetted into each receptacle vessel, through openings 662 in the cover 611 of the hybridization incubator 606, by the pipette unit 480. The probe reagent includes chemiluminescent detection probes, and preferably acridinium ester (AE)-labeled probes which can be detected using a hybridization protection assay (HPA). Acridinium ester-labeled probes and the HPA assay are well known in the art and are described more fully in the background section *supra*. While AE-labeled probes and the HPA assay are preferred, the analyzer 50 can be conveniently adapted to accommodate a variety of detection methods and associated probes, both labeled and unlabeled. Confirmation that detection probe has been added to the receptacle vessels 162 can be accomplished using an internal control that is able (or its amplicon is able) to hybridize to a probe in the probe reagent, other than the detection probe, under the HPA assay conditions

extant in the receptacle vessels 162 in the hybridization incubator 606. The label of this probe must be distinguishable from the label of the detection probe.

After dispensing probe reagent into each of the receptacle vessels 162 of the MTU 160, the pipette unit 480 moves to the pipette rinse basin 1944, and the probe 481 of the pipette unit is rinsed with distilled water.

The MTU carousel assembly 671 rotates the MTU 160 to the skewed disk linear mixer 634 where the MTU 160 and its contents are mixed, as described above, at about 14 Hz to facilitate exposure of the target amplicon to the added detection probes. The MTU 160 is then incubated for a period of time sufficient to permit hybridization of the detection probes to the target amplicon.

After hybridization incubation, the MTU 160 is again rotated within incubator 606 by the MTU carousel assembly 671 to the pipetting position below the pipette openings 662. A selection reagent stored in a container in the reagent cooling bay 900 is pipetted into each receptacle vessel 162 by the pipette unit 480. A selection reagent is used with the HPA assay and includes an alkaline reagent that specifically hydrolyzes acridinium ester label which is associated with unhybridized probe, destroying or inhibiting its ability to chemiluminesce, while acridinium ester label associated with probe hybridized to target amplicon (or amplicon of the internal standard) is not hydrolyzed and can chemiluminesce in a detectable manner under appropriate detection conditions.

Following addition of the selection probe to each of the receptacle vessels 162 of the MTU 160, the pipette probe 481 of the pipette unit 480 is rinsed with distilled water at the pipette rinse basin 1944. The MTU 160 is rotated by the MTU carousel assembly 671 within the incubator 606 to the skewed disk linear mixer 634 and mixed, as described above, at about 13 Hz to facilitate exposure of the target amplicon to the added selection reagent. The MTU is then incubated in the incubator 606 for a period of time sufficient to complete the selection process.

After selection incubation is complete, the left-side transport mechanism 502 transfers the MTU 160 into an available ramp-down station 700 that is accessible to the left-side transport mechanism 502 to cool the MTU 160. After the MTU 160 is cooled, it is retrieved from the ramp-down station by the left-side transport mechanism 502 and is moved by the transport mechanism 502 into the active temperature and pre-read cool-down incubator 602 to stabilize the temperature of the MTU 160 at about 40℃.

When a period sufficient to stabilize the temperature of the MTU 160 has passed, the MTU carousel assembly 671 within active temperature and pre-read cool-down incubator 602 rotates to present the MTU 160 at the right-side distributor door of the incubator 602. The right-side distributor door is opened and the MTU 160 is removed from active temperature and pre-read cool-down incubator 602 by right-side transport mechanism 500.

The right-side transport mechanism 500 moves the MTU to a bar code scanner (not shown) which scans MTU bar code information posted on the label-receiving surface 175 of the label-receiving structure 174 of the MTU 160. The bar code scanner is preferably attached to an outer wall of the housing of the luminometer 950. A preferred bar code scanner is available from Opticon, Inc., of Orangeburg, New York, as part number LHA1127RR1S-032. The scanner verifies the total time of assay prior to entering the luminometer 950 by confirming the correct MTU at the correct assay time. From the bar code reader, the right-side transport mechanism 500 moves the MTU 160 to the luminometer 950.

In a preferred mode of operation, before the right-side transport mechanism 500 moves the MTU 160 into the luminometer 950, the MTU 160 is placed by the right-side transport mechanism 500 into an available MTU ramp-down station, or chiller, to decrease the temperature of the MTU 160 to 24±3℃. It has been determined that the MTU contents exhibit a more consistent chemiluminescent "light-off" at this cooler

temperature.

LUMINOMETER

Referring to FIGURES 40-42C, a first embodiment of the luminometer 950 includes an electronics unit 952 within a housing 954. A photomultiplier tube (PMT) 956 linked to the electronics unit 952 extends from within the housing 954 through a PMT plate 955, with the front end of the PMT 956 aligned with an aperture 953. A preferred PMT is available from Hamamatsu Corp. of Bridgewater, New Jersey as model number HC 135. Signal measurements using the preferred PMT are based on the well known photon counter system.

The aperture 953 is centered in an aperture box 958 in front of the PMT plate 955. The aperture 953 and aperture box 958 are entirely enclosed by a housing, defined by a floor plate 964, a top plate 966, the PMT plate 955, and a back frame 965 and back plate 967, which prevents stray light from entering the aperture 953 and which is attached to the datum plate 82. An MTU transport path extends through the housing in front of the aperture 953, generally transversely to an optical axis of the aperture. MTUs 160 pass through the luminometer 950 via the MTU transport path. A back rail 991 and a front rail 995 are disposed on opposite sides of the MTU transport path and provide parallel horizontal flanges which support the connecting rib structure 164 of an MTU 160 disposed within the luminometer 950. Revolving doors 960 are supported for rotation within associated door housings 961 disposed on opposite ends of the MTU transport path and are turned by door motors 962, which may comprise stepper motors or DC gear motors.

The door housings 961 provide openings through which MTUs 160 can enter and exit the luminometer 950. An MTU 160 enters the luminometer 950 by means of the right-side transport mechanism 500 inserting the MTU 160 through one of the door housings 961. The MTU 160 exits the luminometer under the influence of an MTU transport

assembly, various embodiments of which are described below, which moves MTUs through the MTU transport path and eventually out of the luminometer through the other door housing 961.

Revolving doors 960 are generally cylindrical and include a cut-out portion 963. Each revolving door 960 can be rotated between an open position, in which the cut-out portion 963 is generally aligned with the opening of the associated door housing 961, so that an MTU 160 can pass through the opening, and a closed position, in which a side of the revolving door opposite the cut-out portion 963 extends across the opening of the associated door housing 961 so that neither an MTU 160 nor light can pass through the opening. Except when an MTU 160 is entering or exiting the luminometer 950, the revolving doors 960 are preferably in their respective closed positions to prevent stray light from entering the luminometer. Because test results are ascertained by the amount of light detected by the PMT 956, stray light from sources other than the receptacle 160 being sampled can cause erroneous results.

As shown in FIGURES 39-41, the MTU transport assembly may include an MTU advance motor 972 which drives a lead screw 974 through a timing belt (not shown) or bevel gears 975. A screw follower 976 engaged to the lead screw 974 is coupled to an MTU bracket 977 extending away from lead screw 974 to engage the MTU 160. The MTU bracket 977 has a guide flange 978 with an elongated, slightly arcuate guide hole 979 formed therein. A guide rod 980 extends through the luminometer 950 adjacent and parallel to the lead screw 974. Guide rod 980 extends through guide hole 979.

To advance the MTU bracket 977 (from bottom to top in FIGURE 40C), the lead screw 974 turns counter-clockwise, as viewed in FIGURE 42B. Due to system friction, the screw follower 976 and the MTU bracket 977 will also turn counter-clockwise with the lead screw 974 until the guide rod 980 contacts the left-side of the guide hole 979. When guide rod 980 contacts the side of guide hole 979, MTU bracket 974 and screw follower

976 can no longer rotate with lead screw 974, and further rotation of the lead screw 974 will cause the MTU bracket 974 and screw follower 976 to advance along the lead screw 974. Arms 981 extending from the MTU bracket 977 will also rotate counter-clockwise over a limited arc to engage the MTU 160 and advance it through the luminometer 950, as the lead screw 974 rotates.

After the MTU 160 has passed the PMT 956, that MTU is ejected from the luminometer 950 and the next MTU can be pulled through the luminometer 950. The MTU bracket 977 moves toward the MTU entrance end of the MTU transport path by clockwise rotation of the lead screw 974. System friction will cause the screw follower 976 and MTU bracket 977 to rotate clockwise until the guide rod 980 contacts the right-side of guide opening 979, after which, continued rotation of the lead screw 974 will cause the screw follower 976 and the MTU bracket 977 to retreat along the lead screw 974. This clockwise movement of the MTU bracket 977 will cause the arms 981 to rotate clockwise over a limited arc to disengage from the MTU, so the MTU bracket 977 can retreat without contacting the MTU. That is, the arms 981 will pass over the top of the MTU as the MTU bracket 977 retreats

As shown in FIGURE 39, a blinder 982, driven by a blinder actuator 993, moves vertically up and down, in alignment with the aperture 953. Blinder 982 includes a front panel 983 which is mounted for sliding movement with respect to the aperture block 958 and which includes a generally rectangular opening (not shown) formed therein which can be aligned with the aperture 953. A top portion of the front panel 983 blocks the aperture 953 when the opening formed in panel 983 is not aligned with the aperture 953 and thus operates as a shutter for the aperture 953. The blinder 982 includes two side-walls 987, arranged in parallel on opposite sides of the opening and generally perpendicular to the front panel 983, and a back wall 988 spanning the back edges of the sidewalls 987 opposite the front wall 983 and generally parallel to the front wall 983. The side-

walls 987 and the back wall 988 define a partial rectangular enclosure sized to accommodate one receptacle vessel 162 of the MTU 160 when the blinder 982 is moved up beneath one of the receptacle vessels 162 of an MTU 160 by the blinder actuator 993. Blinder actuator 993 may be a linear stepper actuator including a stepper motor 992 and a lead screw 994. HSI linear stepper actuators, available from Haydon Switch and Instrument, Inc. of Waterbury, Connecticut have been used.

After the MTU 160 is placed into the luminometer 950 by the right-side transport mechanism 500, the motor 972 is energized to pull the first receptacle vessel of the MTU into alignment with the aperture 953. The blinder 982, which is normally stowed out of the MTU transport path, is raised by the blinder actuator 993 until the side walls 987 and back wall 988 of the blinder 982 surround the receptacle vessel 162 and the opening formed in the front panel 983 of the blinder 982 is aligned with the aperture 953. The blinder 982 substantially prevents light from sources other than the receptacle vessel 162 in front of the aperture 953 from reaching the aperture 953, so that the PMT 556 detects only light emissions from the receptacle vessel directly in front of the aperture 953.

With the PMT shutter open, different detecting reagents (Detect I and Detect II), drawn from containers 1148, 1170 of the lower chassis 1100, are sequentially delivered into the aligned receptacle vessel 162 through dedicated delivery lines (not shown) extending to a reagent port 984 at the top of the luminometer 950. The Detect I and Detect II reagents are hydrogen peroxide-containing and sodium hydroxide-containing reagents, respectively, and combine to form a basic hydrogen peroxide solution which enhances the chemiluminescence of acridinium ester label which has not been hydrolyzed. Because basic hydrogen peroxide is unstable, the Detect I and Detect II reagents are preferably combined in the receptacle tube 162 just prior to detection in the luminometer 950.

After the addition of Detect II, the light emitted from the contents

of the receptacle vessel 162 is detected using the PMT 956 and the PMT shutter is then closed. The PMT 956 converts light emitted by chemiluminescent labels into electrical signals processed by the electronics unit 952 and thereafter sent to the controller 1000 or other peripheral unit via cables (not shown) linked to a connector 986.

In cases where less sensitivity is required, it may be possible to use an optical sensor in place of a photomultiplier tube. A diode is an example of an acceptable optical sensor which can be used with the luminometer 950. An optical sensor may also be appropriate when the material of the MTU 160 is relatively transparent, rather than the translucent appearance of the preferred polypropylene material. When selecting a material for the MTU 160, care should be taken to avoid materials that naturally luminesce or are predisposed to electrostatic build-up, either of which can increase the chances of a false positive or interfering with quantification measurements.

The above-described process is repeated for each receptacle vessel 162 of the MTU 160. After the chemiluminescent signal from each receptacle vessel 162 of the MTU 160 has been measured, the motor 972 advances to move the MTU 160 through the exit door 961 and out of the luminometer 950 and into the amplicon deactivation station 750.

An alternate, and presently preferred, luminometer is generally designated by reference number 1360 in FIGURE 43. Luminometer 1360 includes a housing 1372 having a bottom wall 1370, door assemblies 1200 on opposite sides of the bottom wall 1370 which define end portions of the housing 1372, an optical sensor shutter assembly 1250 which defines a front wall of the housing 1370, a top wall (not shown), and a back wall (not shown), which complete the housing 1370 and define an enclosure therein. The right-side door assembly 1200 defines a receptacle entrance opening 1374, and the left-side door assembly 1200 defines a receptacle exit opening 1376 through which a MTU 160 can be passed into and out of the housing 1370. Each door assembly 1200 controls access through the

respective opening 1374 or 1376 and comprises an end wall 1202. a cover plate 1232. and a rotating door 1220 rotatably disposed between the end wall 1202 and the cover plate 1232. The optical sensor aperture shutter assembly 1250 controls light entering an optical sensor (not shown in FIGURE 43). for example a photomultiplier tube. Assembly 1250 includes a light receiver mounting wall 1250 and a cover plate 1290 having an aperture 1292 formed therein.

A bar code scanner 1368 is attached to a front portion of the housing 1372 for scanning MTUs prior to their entry to the luminometer 1360.

A receptacle transport assembly 1332 moves a receptacle (e.g., a MTU 160) through the luminometer 1360 from the entrance opening 1374 to the exit opening 1376. The assembly 1332 includes a transport 1342 movably carried on a threaded lead screw 1340 that is rotated by a motor 1336 coupled to the lead screw 1340 by a belt (not shown).

A dispensing nozzle 1362 is attached in the top wall (not shown) and is connected by conduit tubes 1362 and 1364 to a pump and ultimately to bottles 1146 and 1170 in the lower chassis 1100. Nozzle 1362 dispenses the "Detect I" and the "Detect II" regents into the receptacles 162 of the MTU 160 within the housing 1372.

A receptacle vessel positioner assembly 1300 is disposed within the housing 1372 and is constructed and arranged to position each tube 162 of the MTU 160 in front of the aperture 1292 and to optically isolate each tube being positioned from adjacent tubes, so that only light from one tube at a time enters the aperture 1292. The positioner assembly 1300 comprises a receptacle positioner 1304 rotatably mounted within a positioner frame 1302 that is secured to the floor 1370 of the housing 1372.

The door assembly 1200 for the MTU entrance opening 1374 and exit opening 1376 of the luminometer 1360 is shown in FIGURE 44. Door assembly 1200 includes a luminometer end-wall 1202 which forms an end

wall of the luminometer housing 1372. End-wall 1202 includes a first recessed area 1206 with a second, circular recessed area 1208 superimposed on the first recessed area 1206. A circular groove 1207 extends about the periphery of the circular recessed area 1208. A slot 1204, having a shape generally conforming to a longitudinal profile of an MTU 160, is formed in the circular recessed area 1208 to one side of the center thereof. A short center post 1209 extends from the center of the circular recessed area 1208.

The rotating door 1220 is circular in shape and includes an axial wall 1222 extending about the periphery of the rotating door 1220. The axial wall 1222 is disposed a short radial distance from the outer peripheral edge of the rotating door 1220, thus defining an annular shoulder 1230 about the outermost peripheral edge outside the axial wall 1222. A slot 1226, having a shape generally conforming to the longitudinal profile of an MTU is formed in the rotating door 1220 at an off-center position.

The rotating door 1220 is installed into the circular recessed area 1208 of the end-wall 1202. A central aperture 1224 receives the center post 1209 of the end-wall 1202, and circular groove 1207 receives axial wall 1222. The annular shoulder 1230 rests on the flat surface of the recessed area 1206 surrounding the circular recessed area 1208.

End-wall 1202 includes a drive gear recess 1210 which receives therein a drive gear 1212 attached to the drive shaft of a motor 1213 (See FIGURE 43 in which only the motor 1213 for the right side door assembly 1200 is shown). Motor 1213 is preferably a DC gear motor. A preferred DC gear motor is available from Micro Mo Electronics, Inc. of Clearwater, Florida, under model number 1524TO24SR 16/7 66:1. The outer circumference of the axial wall 1222 of the rotating door 1220 has gear teeth formed thereon which mesh with the drive gear 1212 when the shutter is installed into the circular recess 1208.

The cover plate 1232 is generally rectangular in shape and includes

a raised area 1234 having a size and shape generally conforming to the recessed area 1206 of the end-wall 1202. Cover plate 1232 has formed therein an opening 1236 having a shape generally conforming to the longitudinal profile of an MTU, and, when the cover plate 1232 is installed onto the end-wall 1202, the raised rectangular area 1234 is received within the rectangular recessed area 1206 and opening 1236 is in general alignment with opening 1204. Thus, the rotating door 1220 is sandwiched between the cover plate 1232 and the end-wall 1202, and the openings 1236 and 1204 together define the entrance opening 1374 and exit opening 1376.

When the drive gear 1212 is rotated by the motor 1213, the rotating door 1220, enmeshed with the drive gear 1212, is caused to rotate about the center post 1209. When the opening 1226 is aligned with openings 1204 and 1236, MTUs 160 can be passed through the opening 1374 (1376) of the door assembly 1200. With the rotating door 1220 disposed within the circular recessed area 1208 and the raised area 1234 of the cover plate 1232 disposed within the recessed area 1206 of the end-wall 1202, a substantially light-tight structure is achieved, whereby little or no light enters through the door, when the opening 1226 is not aligned with openings 1204 and 1236.

Optical slotted sensors are disposed within slots 1214 and 1216 disposed on the outer edge of the circular recessed area 1208 at diametrically opposed positions. Preferred sensors are available from Optek Technology, Inc. of Carrollton, Texas, model number OPB857. The slotted sensors disposed within slots 1214 and 1216 detect the presence of a notch 1228 formed in the axial wall 1222 to signal door open and door closed status.

The optical sensor aperture shutter assembly 1250 is shown in FIGURE 45. A light receiver, such as a photomultiplier tube 956, is coupled with a light receiver opening 1254 formed in a light receiver mounting wall 1252. The light receiver mounting wall 1252 includes a

generally rectangular, two-tiered raised area 1256, which defines a generally rectangular shoulder 1257 and a circular recessed area 1258 superimposed on the rectangular raised area 1256. A circular groove 1261 extends about the periphery of circular recessed area 1258. A center post 1259 is positioned at the center of the circular recessed area 1258. Light receiver opening 1254 is formed in the circular recessed area 1258. In the illustrated embodiment, the light receiver opening 1254 is disposed below the center post 1259, but the light receiver opening 1254 could be placed at any position within the circular recessed area 1258.

The aperture shutter assembly 1250 includes a rotating shutter 1270 having an axial wall 1274 with gear teeth formed on the outer periphery thereof. Axial wall 1274 is formed near, but not at, the outer periphery of the shutter 1270, thereby defining annular shoulder 1276. Rotating shutter 1270 is installed in the circular recessed area 1258 with center post 1259 received within a central aperture 1272 formed in the rotating shutter 1270 and with axial wall 1274 received within circular groove 1261. A drive gear 1262 disposed within a gear recess 1260 and coupled to a drive motor 1263 meshes with the outer gear teeth formed on the axial wall 1274 of the rotating shutter 1270 to rotate the rotating shutter 1270 about the center post 1259. A preferred drive motor 1263 is a DC gear motor available from Micro Mo Electronics, Inc. of Clearwater, Florida, as model number 1524TO24SR 16/7 66:1. Micro Mo gear motors are preferred because they provide a high quality, low backlash motor. An opening 1280 is formed in the rotating shutter 1270 which can be moved into and out of alignment with light receiver opening 1254 as the rotating shutter 1270 is rotated.

With the shutter 1270 installed in the circular recessed area 1258, a cover plate, or sensor aperture wall, 1290 is installed onto the sensor mount 1252. As shown in FIGURE 45A, sensor aperture wall 1290 includes a generally rectangular, two-tiered recessed area 1296 which defines a generally rectangular shoulder 1297 and which is sized and

shaped to receive therein the rectangular raised area 1256 of the sensor mount 1252. A sensor aperture 1292 is formed through the aperture wall 1290 and is generally aligned with the light receiver opening 1254 formed in the sensor mount 1252. The sensor aperture 1292 is generally in the shape of an elongated oval having a width generally corresponding to the width of an individual receptacle vessel 162 of an MTU 160 and a height corresponding to the height of the intended viewing area. Although opening 1280 of shutter 1270 is shown in the illustrated embodiment to be circular, opening 1280 can have other shapes, such as rectangular, with a width corresponding to the width of a receptacle vessel 162 or an elongated oval similar to sensor aperture 1292. Rotation of the rotating shutter 1270 to a position in which the opening 1280 is aligned with the light receiver opening 1254 and the sensor aperture 1292 permits light to reach the sensor 956, and rotation of the rotating shutter 1270 to a position in which the opening 1280 is not aligned with light receiver opening 1254 and sensor aperture 1292 prevents light from reaching the sensor 956.

Slotted optical sensors are disposed in slots 1264 and 1266 and detect a notch 1278 formed in the axial wall 1274 of the shutter 1270 to detect opened and closed positions of the shutter 1270. Preferred slotted optical sensors are available from Optek Technology, Inc., of Carrollton, Texas, as model number OPB857.

The aperture wall 1290 includes an upwardly facing shoulder 1294 extending across the width thereof. A downwardly facing shoulder of the MTU 160, defined by the connecting rib structure 164 of the MTU 160 (see FIGURE 45), is supported by the shoulder 1294 as the MTU 160 slides through the luminometer.

The receptacle vessel positioner assembly 1300 is shown in FIGURES 46 and 48-49. The receptacle vessel positioner 1304 is operatively disposed within the receptacle vessel positioner frame 1302. The receptacle vessel positioner 1304 is mounted in the receptacle vessel

positioner frame 1302 for rotation about a shaft 1308. Shaft 1308 is operatively coupled to a rotary solenoid, or, more preferably, a gear motor 1306, to selectively rotate the receptacle vessel positioner 1304 between the retracted position shown in FIGURE 46 and the fully extended position shown in FIGURE 48. A preferred gear motor drive is available from Micro Mo Electronics, Inc. of Clearwater, Florida, as model number 1724T024S+16/7 134:1+X0520.

As shown in FIGURE 47, the receptacle vessel positioner 1304 includes a V-block structure 1310 defining two parallel walls 1312. Receptacle vessel positioner 1304 further includes an area at the lower end thereof where a portion of the thickness of the receptacle vessel positioner 1304 is removed, thus defining a relatively thin arcuate flange 1314.

When an MTU 160 is inserted into the luminometer 1360, the receptacle vessel positioner 1304 is in the retracted position shown in FIGURE 46. When an individual receptacle vessel 162 is disposed in front of the sensor aperture 1292 (see FIGURE 45A), so that a sensor reading of the chemiluminescence of the contents of the receptacle vessel 162 can be taken, the receptacle vessel positioner 1304 rotates forwardly to the engaged position shown in FIGURE 49. In the engaged position shown in FIGURE 49, the V-block 1310 engages the receptacle vessel 162, thus holding the receptacle vessel in the proper position in alignment with the light receiver aperture 1292 of the luminometer. As shown in FIGURE 45, aperture wall 1290 includes a protrusion 1298 extending from the back of wall 1290 into the MTU passage of the luminometer. The protrusion 1298 is aligned with the aperture 1292 so that when the receptacle vessel positioner 1304 engages a receptacle vessel 162, the receptacle vessel is pushed laterally and encounters protrusion 1298 as a hard stop, thus preventing the receptacle vessel positioner 1304 from significantly tilting the receptacle vessel 162 within the MTU passage. The parallel sidewalls 1312 of the V-block 1310 prevent stray light from adjacent receptacle vessels 162 of the MTU 160 from reaching the light

receiver while a reading is being taken of the receptacle vessel 162 disposed directly in front of the aperture 1292.

A slotted optical sensor 1318 is mounted to a lower portion of the frame 1302, with the arcuate flange 1314 operatively positioned with respect to the sensor 1318. A preferred slotted optical sensor is available from Optek Technology, Inc., of Carrollton, Texas, as model number OPB930W51. An opening 1316 is formed in the flange 1314. Opening 1316 is properly aligned with the sensor 1318 when the receptacle vessel positioner 1304 engages a receptacle vessel 162 and the receptacle vessel 162 and protrusion 1298 prevent further rotation of the receptacle vessel positioner 1304. If a receptacle vessel 162 is not properly positioned in front of the receptacle vessel positioner 1304, the receptacle vessel positioner 1304 will rotate forwardly to the position shown at FIGURE 48, in which case opening 1316 will not be aligned with the sensor 1318 and an error signal will be generated.

If a gear motor 1306 is employed for rotating the receptacle vessel positioner 1304, it is necessary to provide a second sensor (not shown) to generate a positioner-retracted, i.e., "home", signal to shut off the gear motor when the receptacle vessel positioner 1304 is fully retracted, as shown in FIGURE 46. A preferred sensor is available from Optek Technology, Inc. of Carrollton, Texas as model number OPB900W.

The MTU transport assembly 1332 is shown in FIGURE 50. The MTU transport assembly 1332 is operatively positioned adjacent a top edge of an intermediate wall 1330 (not shown in FIGURE 43) of the luminometer 1360. Intermediate wall 1330, which defines one side of the MTU transport path through the luminometer housing 1372, includes a rectangular opening 1334. The receptacle vessel positioner frame 1302 (see, e.g., FIGURE 57) is mounted to the intermediate wall 1330 proximate the opening 1334, and the receptacle vessel positioner 1304 rotates into engagement with an MTU 160 through the opening 1334.

The MTU transport 1342 is carried on the threaded lead screw

1340 and includes a screw follower 1344 having threads which mesh with the threads of the lead screw 1340 and an MTU yoke 1346 formed integrally with the screw follower 1344. As shown in FIGURE 51, the MTU yoke 1346 includes a longitudinally-extending portion 1356 and two laterally-extending arms 1348 and 1350, with a longitudinal extension 1352 extending from the arm 1350. The lead screw 1340 is driven, via a drive belt 1338, by a stepper motor 1336. A preferred stepper motor is a VEXTA motor, available from Oriental Motors Ltd. of Tokyo, Japan, model PK266-01A, and a preferred drive belt is available from SDP/SI of New Hyde Park, New York.

When an MTU 160 is inserted into the MTU transport path of the luminometer 950 by the right-side transport mechanism 500, the first receptacle vessel 162 of the MTU 160 is preferably disposed directly in front of the sensor aperture 1292 and is thus properly positioned for the first reading. The width of the yoke 1346 between the lateral arms 1348 and 1350 corresponds to the length of a single MTU 160. The transport 1342 is moved between a first position shown in phantom in FIGURE 50 and a second position by rotation of the lead screw 1340. Slotted optical sensors 1341 and 1343 respectively indicate that the transport 1342 is in the either the first or second position. Due to friction between the lead screw 1340 and the screw follower 1344, the MTU transport 1342 will have a tendency to rotate with the lead screw 1340. Rotation of the MTU transport 1342 with the lead screw 1340 is preferably limited, however, to 12 degrees by engagement of a lower portion of the yoke 1346 with the top of the intermediate wall 1330 and engagement of an upper stop 1354 with the top cover (not shown) of the luminometer housing 1372.

To engage the MTU that has been inserted into the luminometer 1360, the lead screw 1340 rotates in a first direction, and friction within the threads of the screw follower 1344 and the lead screw 1340 causes the transport 1342 to rotate with lead screw 1340 upwardly until the upper stop 1354 encounters the top cover (not shown) of the luminometer 1360.

At that point, continued rotation of the lead screw 1340 causes the transport 1342 to move backward to the position shown in phantom in FIGURE 50. The lateral arms 1348, 1350 pass over the top of the MTU as the transport 1342 moves backward. Reverse rotation of the lead screw 1340 first causes the transport 1342 to rotate downwardly with the lead screw 1340 until a bottom portion of the yoke 1346 encounters the top edge of the wall 1330, at which point the lateral arms 1348 and 1350 of the yoke 1346 straddle the MTU 160 disposed within the luminometer 1360.

The MTU transport mechanism 1332 is then used to incrementally move the MTU 160 forward to position each of the individual receptacle vessels 162 of the MTU 160 in front of the optical sensor aperture 1292. After the last receptacle vessel 162 has been measured by the light receiver within the luminometer, the transport 1342 moves the MTU 160 to a position adjacent the exit door, at which point the lead screw 1340 reverses direction, thus retracting the transport 1342 back, as described above, to an initial position, now behind the MTU 160. Rotation of the lead screw 1340 is again reversed and the transport 1342 is then advanced, as described above. The exit door assembly 1200 is opened and the longitudinal extension 1352 of the yoke 1346 engages the MTU manipulating structure 166 of the MTU 160 to push the MTU 160 out of the luminometer exit door and into the deactivation queue 750.

DEACTIVATION STATION

In the amplicon deactivation station 750, dedicated delivery lines (not shown) add a deactivating solution, such as buffered bleach, into the receptacle vessels 162 of the MTU 160 to deactivate the remaining fluid in the MTU 160. The fluid contents of the receptacle vessels are aspirated by tubular elements (not shown) connected to dedicated aspiration lines and collected in a dedicated liquid waste container in the lower chassis 1100. The tubular elements preferably have a length of 4.7 inches and an inside diameter of 0.041 inches.

An MTU shuttle (not shown) moves the MTUs 160 incrementally (to the right in FIGURE 3) with the delivery of each subsequent MTU 160 into the deactivation station 750 from the luminometer 950. Before an MTU can be delivered to the deactivation queue 750 by the luminometer 950, the MTU shuttle must be retracted to a home position, as sensed by a strategically positioned optical slot switch. After receiving an MTU 160 from the luminometer, the shuttle moves the MTU 160 to a deactivation station where the dedicated delivery lines connected to dedicated injectors dispense the deactivating solution into each receptacle vessel 162 of the MTU 160. Previous MTUs in the deactivation queue, if any, will be pushed forward by the distance moved by the MTU shuttle. Sensors at the deactivation station verify the presence of both the MTU and the MTU shuttle, thus preventing the occurrence of a deactivating fluid injection into a non-existent MTU or double injection into the same MTU.

An aspiration station (not shown) includes five, mechanically coupled aspirator tubes mounted for vertical movement on an aspirator tube rack and coupled to an actuator for raising and lowering the aspirator tubes. The aspiration station is at the last position along the deactivation queue before the MTUs are dropped through a hole in the datum plate 82 and into the waste bin 1108. Each time an MTU moves into the deactivation station, the aspirator tubes cycle up and down one time, whether an MTU is present in the aspiration station or not. If an MTU is present, the aspirator tubes aspirate the fluid contents from the MTU. When the next MTU is moved into the deactivation station by the MTU shuttle, the last-aspirated MTU is pushed off the end of the deactivation queue and falls into the waste bin 1108.

The steps and sequence of the above-described assay procedure performed on the analyzer 50 in the preferred mode of operation are graphically and succinctly described in the document Gen-Probe TIGRIS Storyboard v.1.0,June 23, 1997, a copy of which was filed with the provisional disclosure upon which priority is claimed for the present

specification and the contents of which are hereby incorporated by reference.

Ideally, the analyzer 50 can run about 500 preferred assays in an 8 hour period, or about 1,000 preferred assays in a 12 hour period. Once the analyzer 50 is set-up and initialized, it ordinarily requires little or no operator assistance or intervention. Each sample is handled identically for a given assay, although the analyzer is capable of simultaneously performing multiple assay types in which different MTUs may or may not be handled identically. Consequently, manual pipetting, incubation timing, temperature control, and other limitations associated with manually performing multiple assays are avoided, thereby increasing reliability, efficiency, and throughput. And because an operator's exposure to samples is generally limited to the loading of samples, risks of possible infection are greatly reduced.

While the invention has been described in connection with what are presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

Furthermore, those of the appended claims which do not include language in the "means for performing a specified function" format permitted under 35 U.S.C. §112(¶6), are not intended to be interpreted under 35 U.S.C. §112(¶6) as being limited to the structure, material, or acts described in the present specification and their equivalents.

What is claimed is:

1. An automated method for simultaneously performing a plurality of amplification reactions in an analyzer, the method comprising performing in the analyzer the automated steps of:

(a) immobilizing a target nucleic acid from each of a plurality of samples on a solid support comprising a magnetically-responsive particle, thereby forming, in each of the samples, a complex comprising the target nucleic acid and the solid support, wherein the complex is suspended in a fluid component of each of the samples;

(b) exposing the complex formed in each of the samples to a magnetic field;

(c) during step (b), purifying the target nucleic acid in each of the samples by aspirating at least a portion of the fluid component of each of the samples;

(d) mixing the target nucleic acid purified in each of the samples in step (c) and reagents for performing an amplification reaction in one of multiple receptacles of an integrally formed set of receptacles, wherein the target nucleic acid purified in each of the samples in step (c) is mixed with the reagents for performing an amplification reaction in a different one of the multiple receptacles;

(e) moving the set of receptacles to a temperature-controlled environment; and

(f) within the temperature-controlled environment, performing an amplification reaction with the target nucleic acid in each of the multiple receptacles, thereby forming amplification products, each of the amplification products in each of the multiple receptacles having a nucleic acid sequence that is the same as or complementary to a sequence contained in the target nucleic acid from each of the samples.

2. The method of claim 1, wherein the target nucleic acid in each of the samples is the same or different.

3. The method of claim 1, wherein the target nucleic acid in each of the samples is the same target nucleic acid.

4. The method of any of claims 1 to 3, wherein each of the multiple receptacles has an open top end during the steps of the method.

5. The method of any one of claims 1 to 4, wherein each of the multiple receptacles has a tubular shape.

5. The method of any one of claims 1 to 5, wherein the aspirating of step (c) is performed with a robotic pipettor.

7. The method of any one of claims 1 to 6, wherein step (d) comprises agitating the contents of the multiple receptacles to facilitate the mixing of the target nucleic acid and the reagents for performing an amplification reaction in each of the multiple receptacles.

8. The method of any one of claims 1 to 7 further comprising, after step (c), the automated step of washing the complex of each the samples one or more times with a wash buffer.

9. The method of any one of claims 1 to 8, wherein the temperature-controlled environment is provided by an incubator adapted to receive the set of receptacles therein.

10. The method of any one of claims 1 to 9, wherein the set of receptacles is moved in step (e) with a transport mechanism.

11. The method of claim 10, wherein the transport mechanism has a rotational path of travel.

12. The method of any one of claims 1 to 11 further comprising performing in the analyzer the automated step of dispensing a layer of oil into each of the multiple receptacles prior to step (f).

13. The method of any one of claims 1 to 12 further comprising performing in the analyzer the automated step of detecting one or more of the amplification products formed in step (f) in each of the multiple receptacles.

14. The method of claim 13, wherein the detecting step comprises hybridizing one or more probes to at least a portion of the amplification products in each of the multiple receptacles.

15. The method of claim 14, wherein each of the probes includes a detectable label.

16. The method of any one of claims 1 to 15, wherein the target nucleic acid present in each of the samples is from an organism or virus.

17. The method of any one of claims 1 to 16, wherein the analyzer is a stand-alone unit.

18. The method of any one of claims 1 to 17, wherein the steps of the method are performed within a housing of the analyzer.

19. The method of claim 18, wherein the steps of the method are performed on a processing deck contained within the housing.

20. The method of claim 18 or 19, wherein the housing remains closed during the steps of the method.

21. An automated method for preparing and amplifying a target nucleic acid present in a sample, the method comprising performing in an analyzer the automated steps of:

(a) combining, in a receptacle, a sample containing a target nucleic acid and a magnetically-responsive solid support, the solid support forming a complex with the target nucleic acid, wherein the complex is suspended in a fluid component of the sample, the receptacle being part of a unit comprising a plurality of integrally formed receptacles, and the unit holding a removable contact-limiting element configured to permit passage of the fluid component of the sample therethrough;

(b) subjecting the contents of the receptacle to a magnetic field, thereby isolating the target nucleic acid within the receptacle;

(c) mounting the contact-limiting element on an end of an aspirator probe;

(d) purifying the target nucleic acid isolated in step (b) by contacting the fluid component of the sample with the contact-limiting element and aspirating at least a portion of the fluid component with the aspirator probe while the complex remains subjected to the magnetic field; and

(e) subjecting the target nucleic acid purified in step (d) to an amplification procedure that results in the formation of amplification products, each of the amplification products formed from the target nucleic acid having a nucleic acid sequence that is the same as or complementary to a target sequence contained within the target nucleic acid.

22. The method of claim 21, wherein each of the receptacles has an open top end.

23. The method of claim 21 or 22, wherein each of the receptacles has a tubular shape.

24. The method of any one of claims 21 to 23, wherein the contact-limiting element is electrically conductive.

25. The method of claim 24 further comprising an automated step of sensing the level of the fluid component in step (d), where the aspirator probe and the contact-limiting element constitute a portion of a capacitor for performing capacitive fluid level sensing.

26. The method of any one of claims 21 to 25, wherein the contact-limiting element is a tiplet comprising a generally cylindrical structure having an axially extending through-hole.

27. The method of any one of claims 21 to 26, wherein the contact-limiting element is one of a plurality of contact-limiting elements held by the unit, each of the contact-limiting elements being configured to permit passage of a fluid component of a sample therethrough, and each of the contact-limiting elements being operationally associated with one of the receptacles of the unit.

28. The method of any one of claims 21 to 27, wherein the contact-limiting element is held in a frictional fit by the unit prior to aspirating the fluid component of the sample in step (d).

29. The method of any one of claims 21 to 28 further comprising, after step (d), washing the solid support one or more times with a wash buffer.

30. The method of any one of claims 21 to 29, wherein the target nucleic acid is immobilized on the solid support with a capture probe.

31. The method of any one of claims 21 to 30, wherein the fluid component of the sample comprises non-target nucleic acid.

32. The method of any one of claims 21 to 31, wherein the unit is moved to a temperature-controlled environment for performing step (e).

33. The method of claim 32, wherein the temperature-controlled environment is provided by an incubator adapted to receive the unit therein.

34. The method of any one of claims 21 to 33 further comprising an automated step of dispensing a layer of silicone oil into the receptacle prior to step (e).

35. The method of any one of claims 21 to 34, wherein the target nucleic acid is obtained from an organism or virus, and wherein the target nucleic acid is specific for the organism or virus.

36. The method of any one of claims 21 to 35 further comprising hybridizing one or more probes to at least a portion of the amplification products.

37. The method of claim 36, wherein each of the probes comprises a detectable label.

38. The method of claim 37 further comprising an automated step of detecting the label of each of one or more of the probes hybridized to the amplification products, thereby providing an indication of the presence of the target nucleic acid in the sample.

39. The method of any one of claims 21 to 38, wherein the analyzer is a stand-alone unit.

40. The method of any one of claims 21 to 39, wherein the steps of the method are performed within a housing of the analyzer.

41. The method of claim 40, wherein the steps of the method are performed on a processing deck contained within the housing.

42. The method of claim 40 or 41, wherein the housing remains closed during the method.

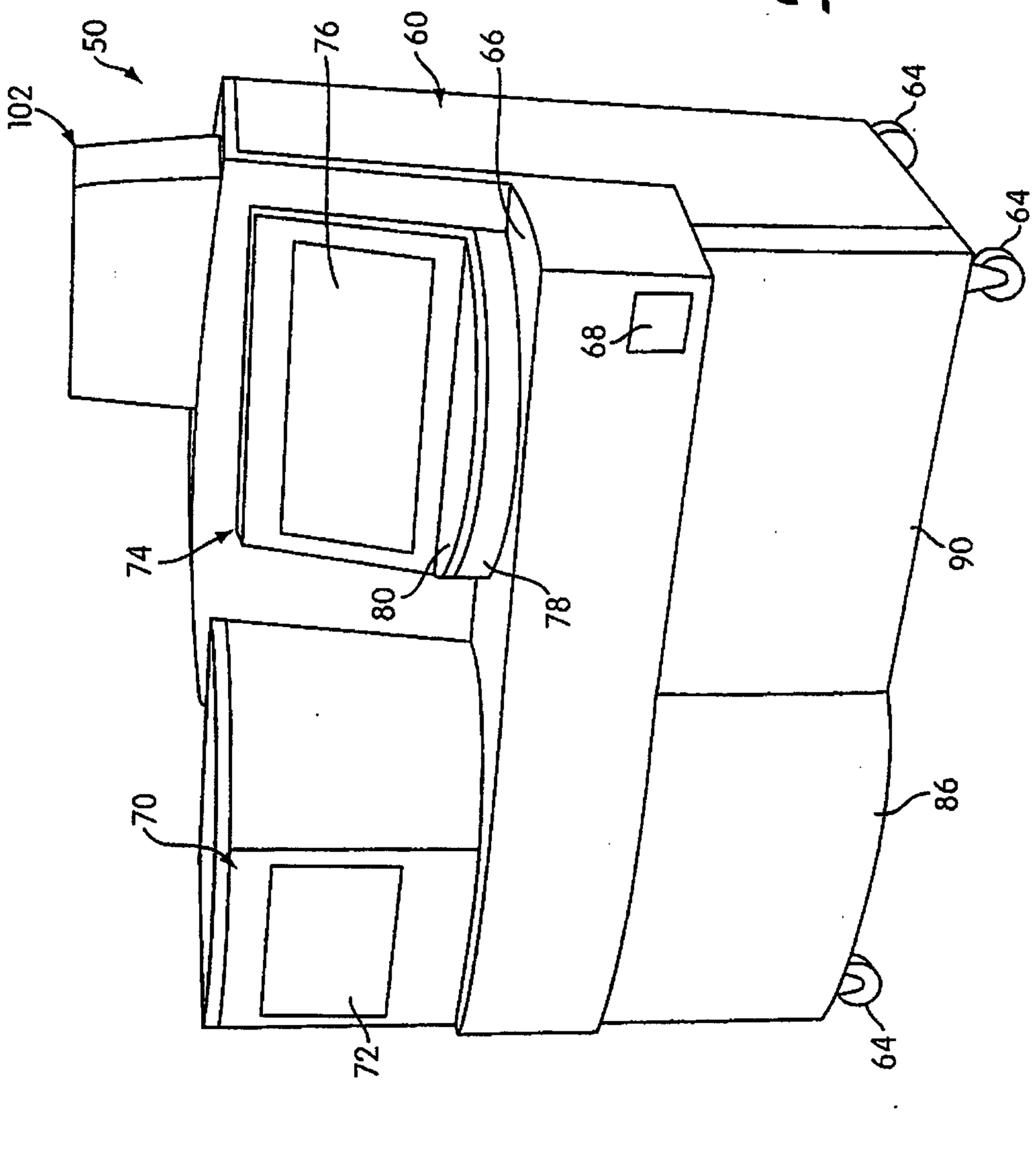


Fig. 1

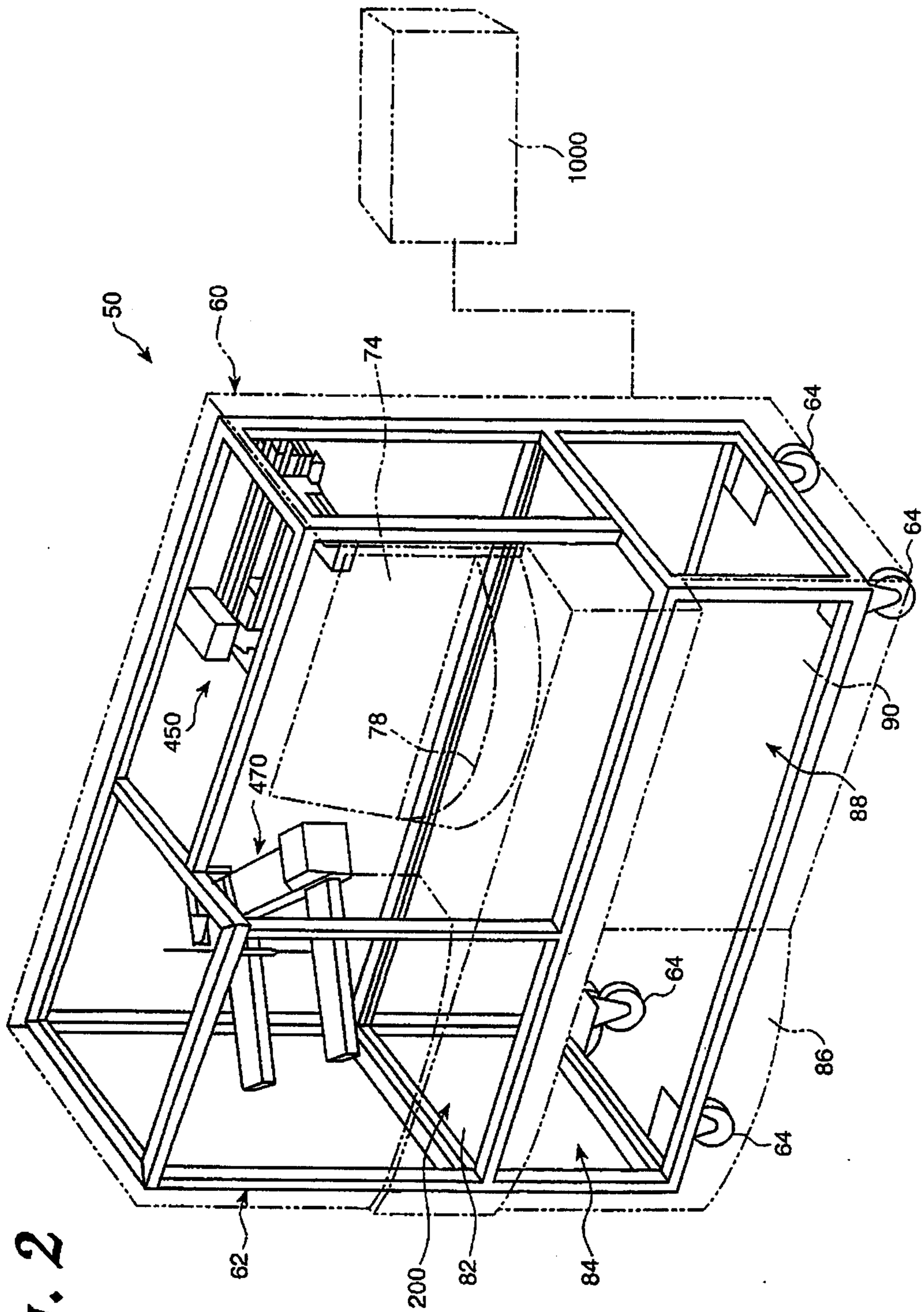


Fig. 2

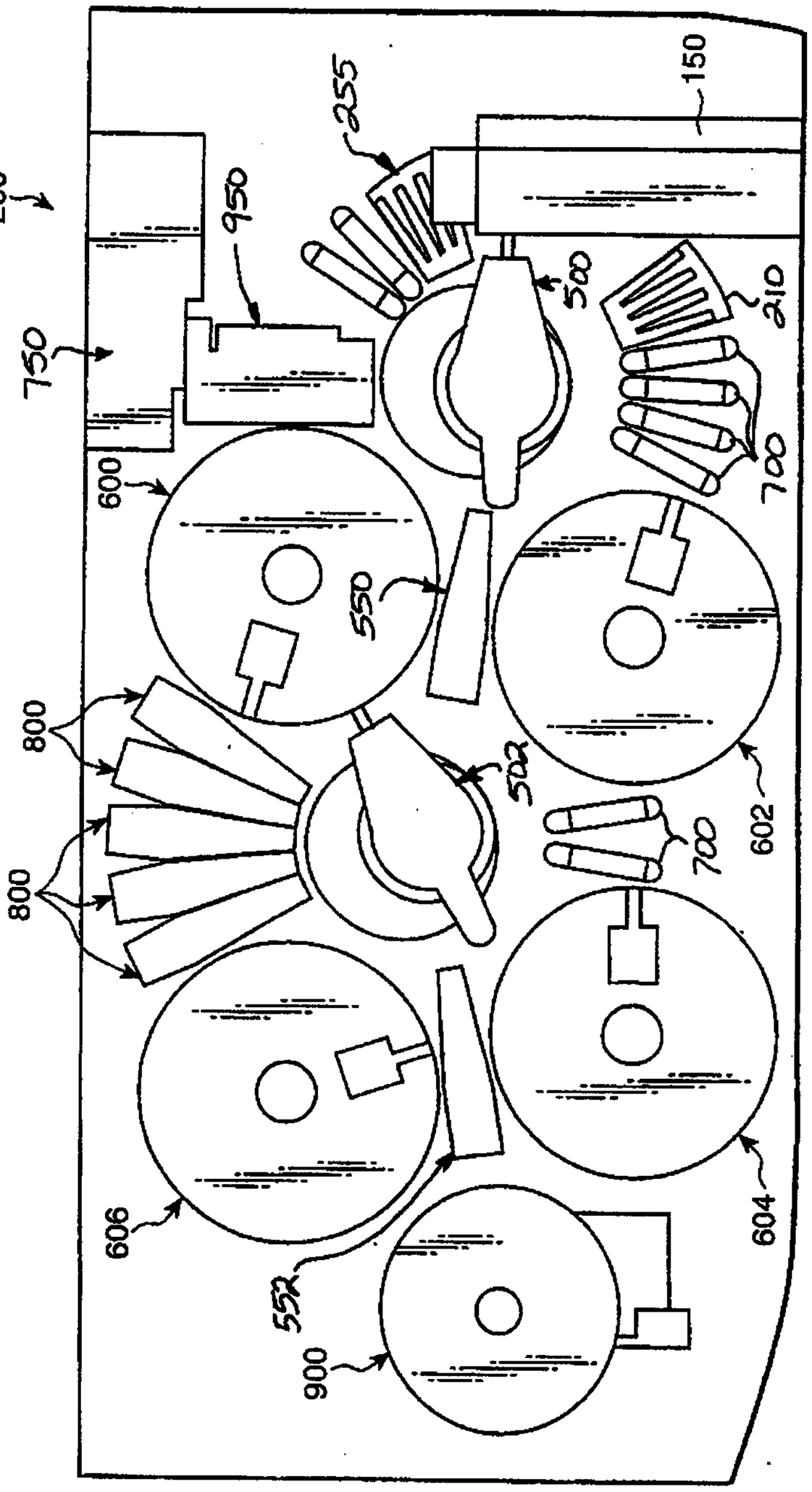
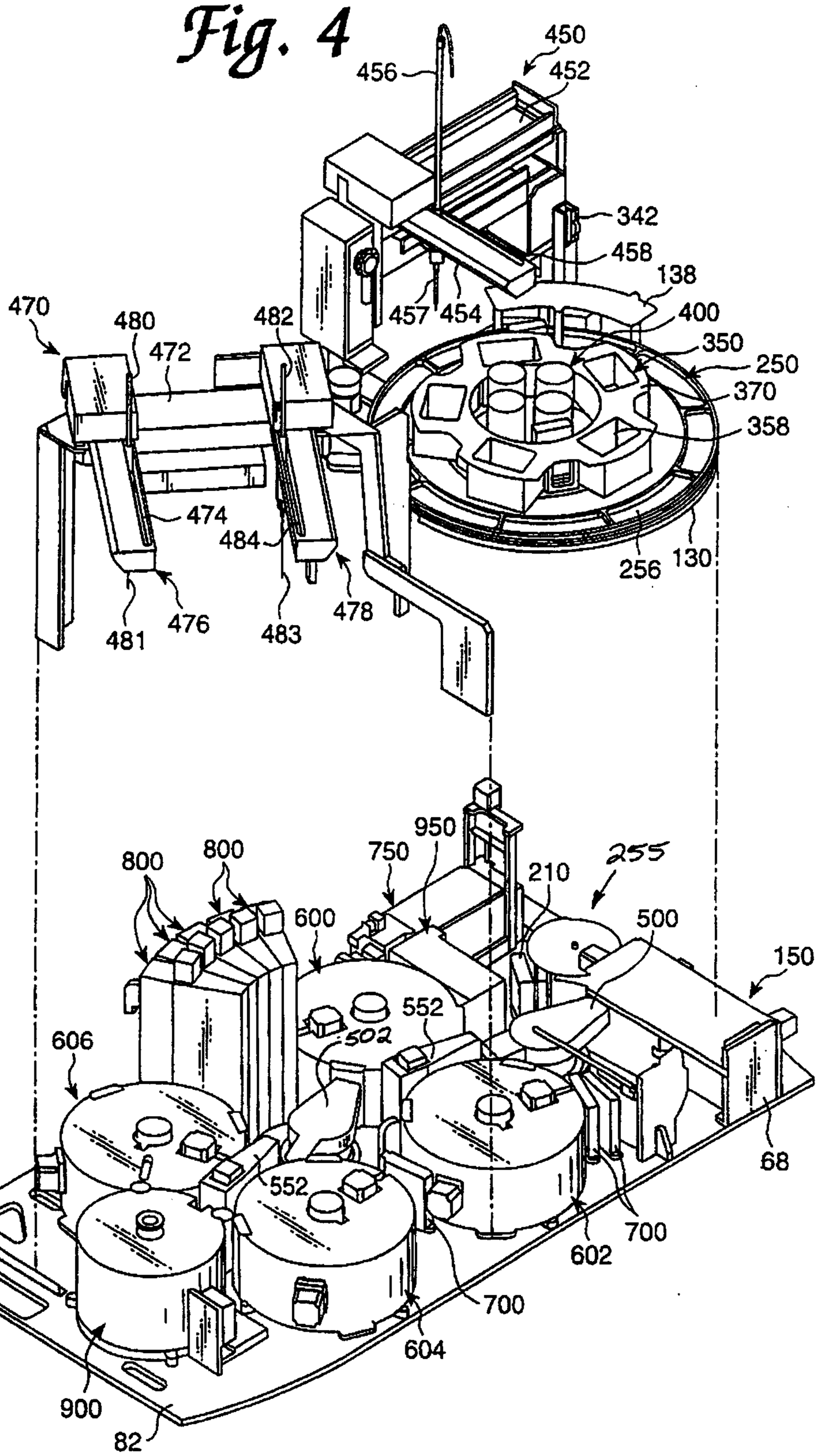

200
750
600
800
800
950
255
150
500
210
700
550
502
700
602
606
552
900
604

Fig. 3

Fig. 4


450
452
456
342
458
138
400
350
250
370
358
457
454
470
480
482
472
474
484
481
476
483
478
256
130
800
800
750
950
210
255
500
600
150
552
502
606
552
68
700
602
700
604
900
82

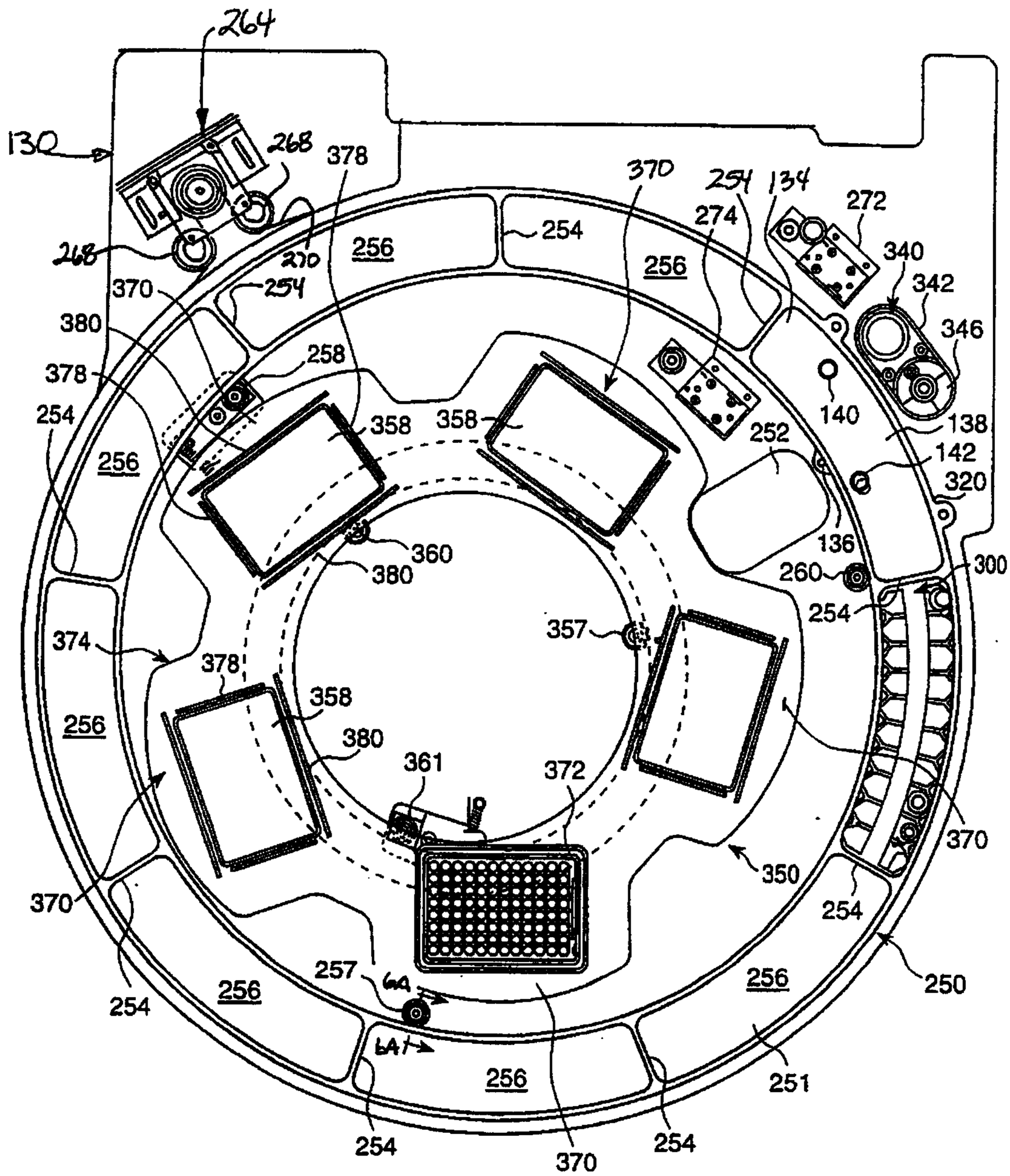

264
130
268
378
370
254
134
272
274
340
342
346
256
254
268
270
370
380
378
254
258
358
358
252
140
138
142
320
136
260
300
254
256
360
380
357
374
378
358
380
361
372
370
350
254
370
257
64
64'
254
256
256
256
251
254
254
370
250

Fig. 5

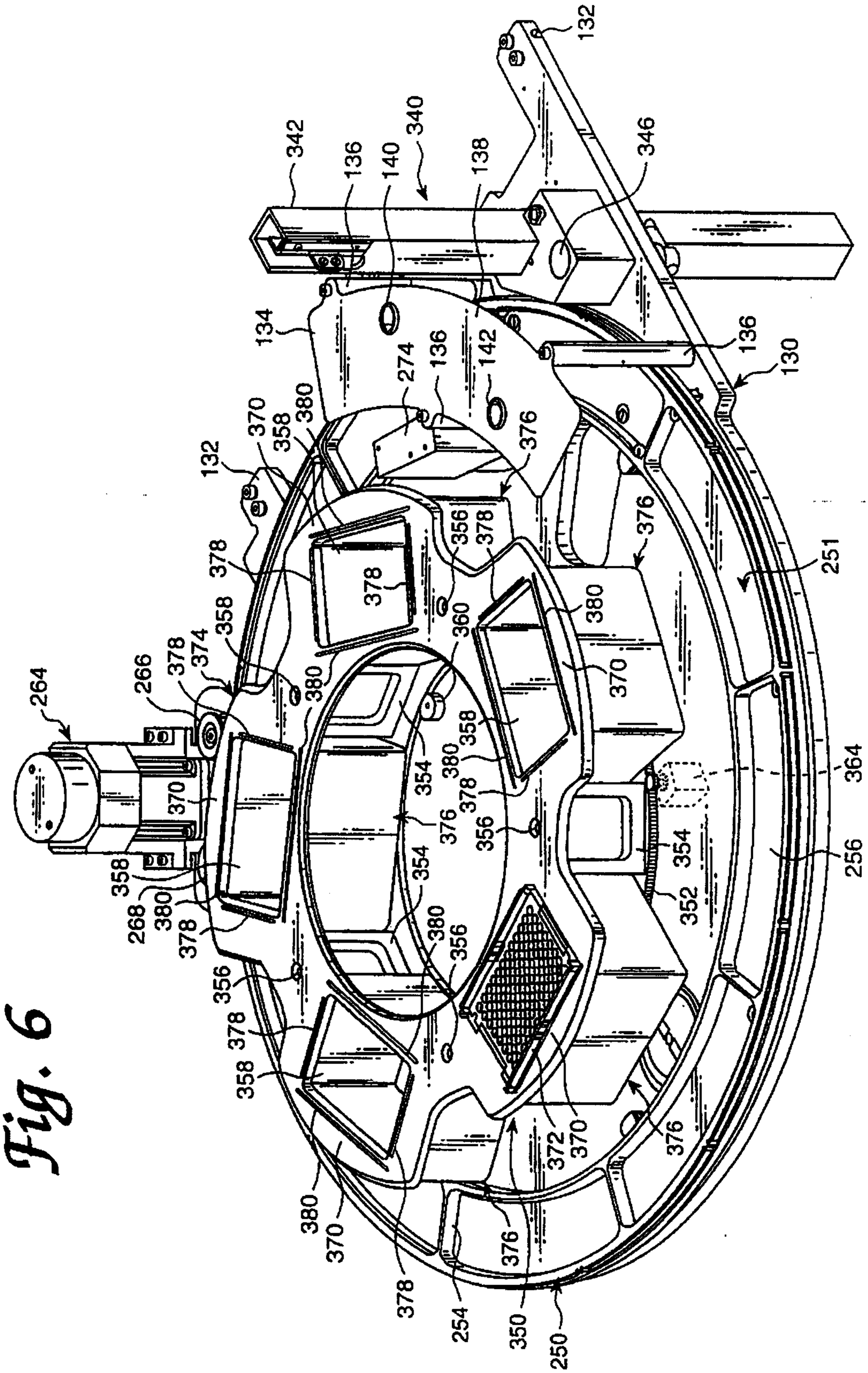

342
136
140
340
138
132
346
134
274
136
142
136
130
370
358
380
132
376
376
356
378
378
378
251
358
374
360
380
380
358
266
264
370
354
380
358
268
380
378
356
354
376
356
352
354
256
378
358
372
370
376
380
370
378
254
350
250

Fig. 6

Fig. 6A

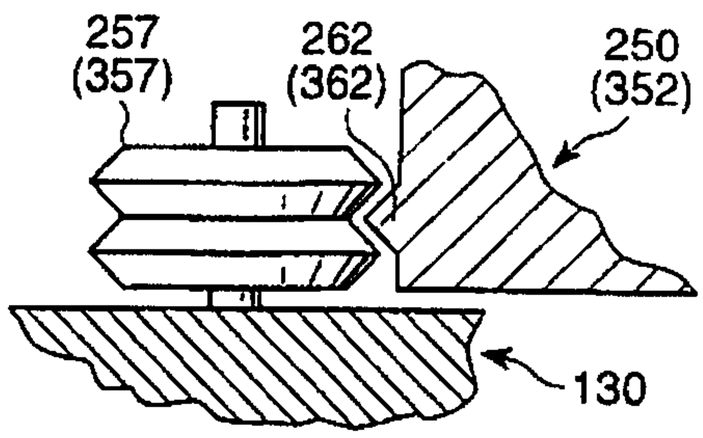


Fig. 7

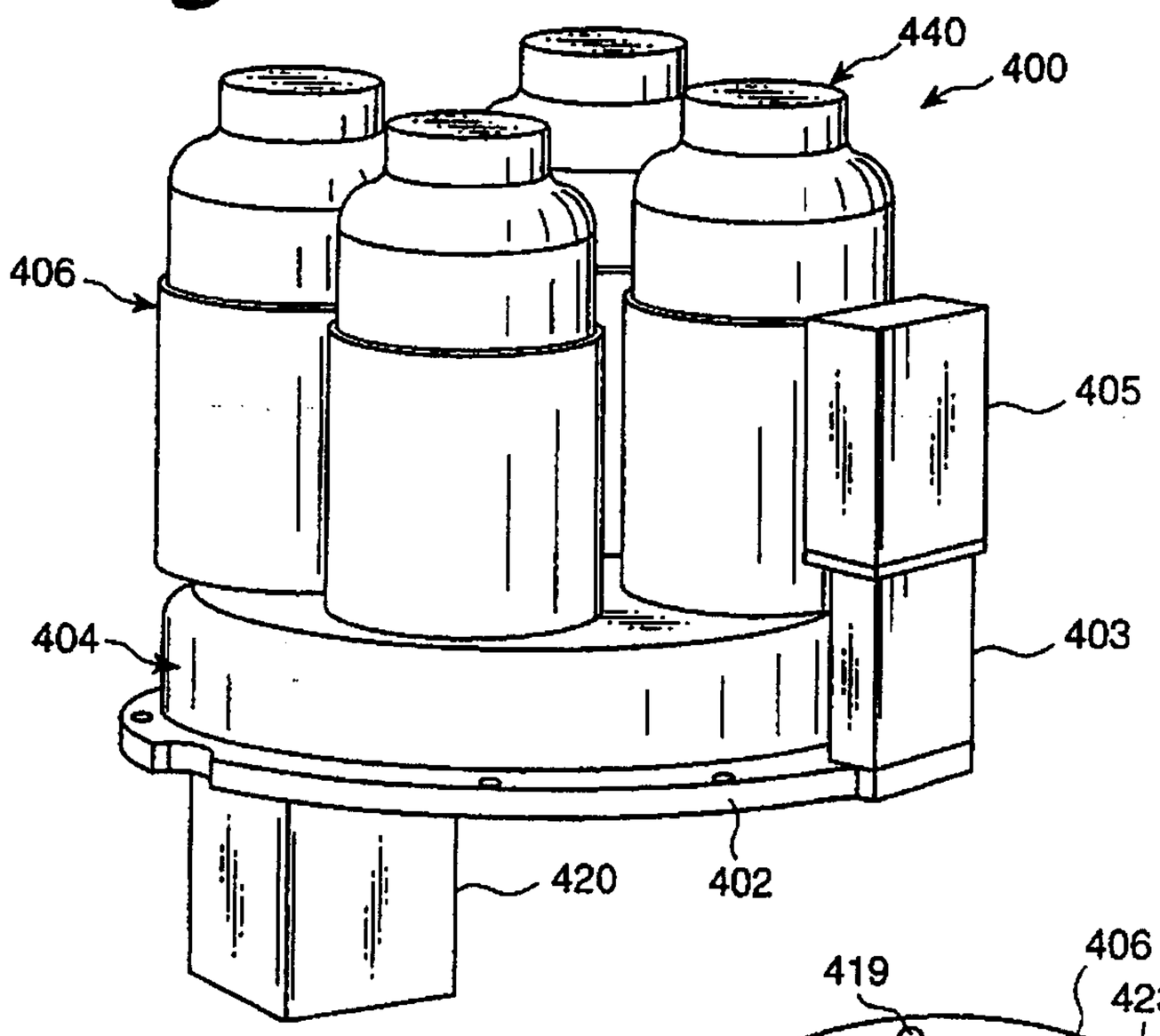
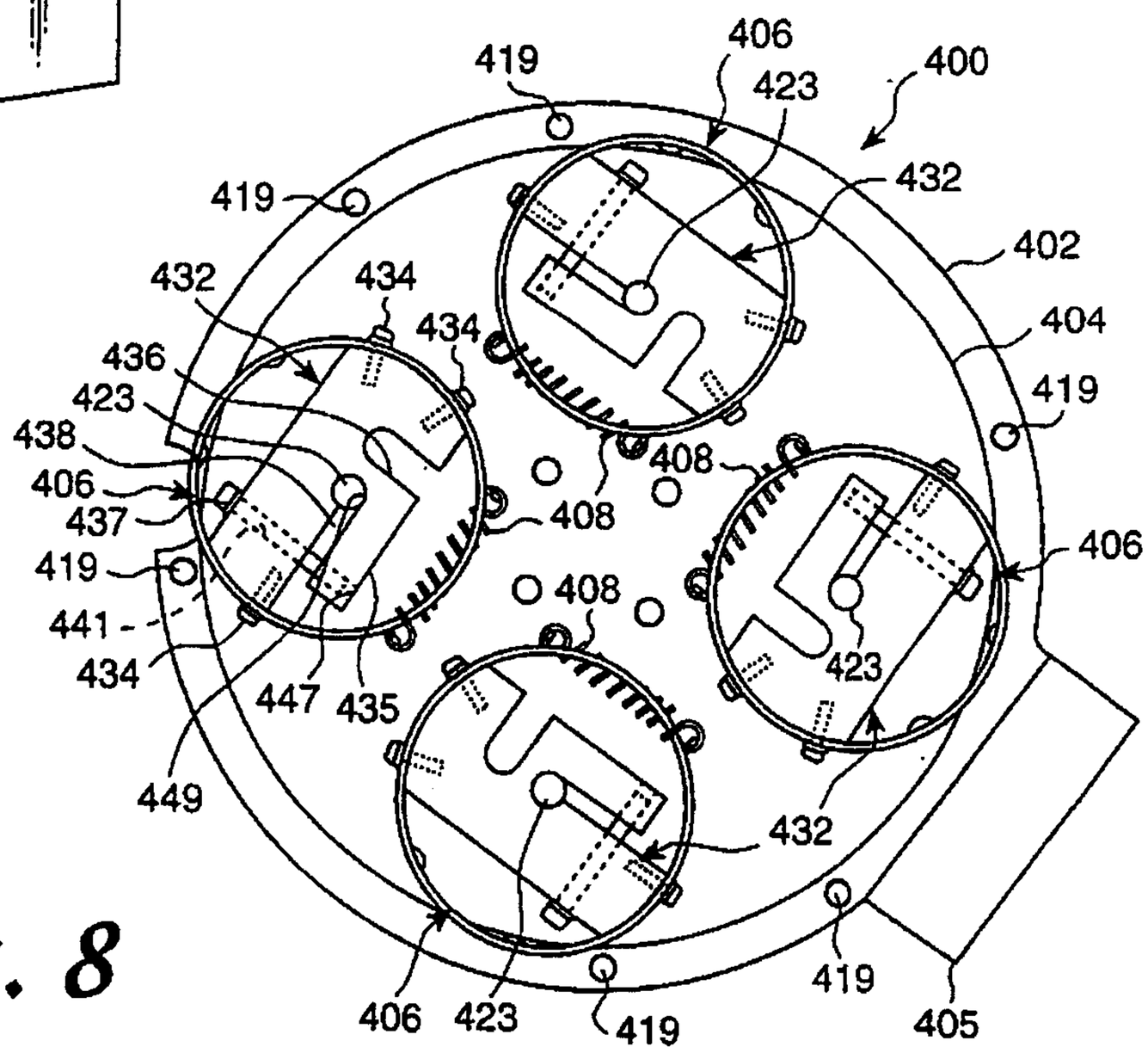


Fig. 8



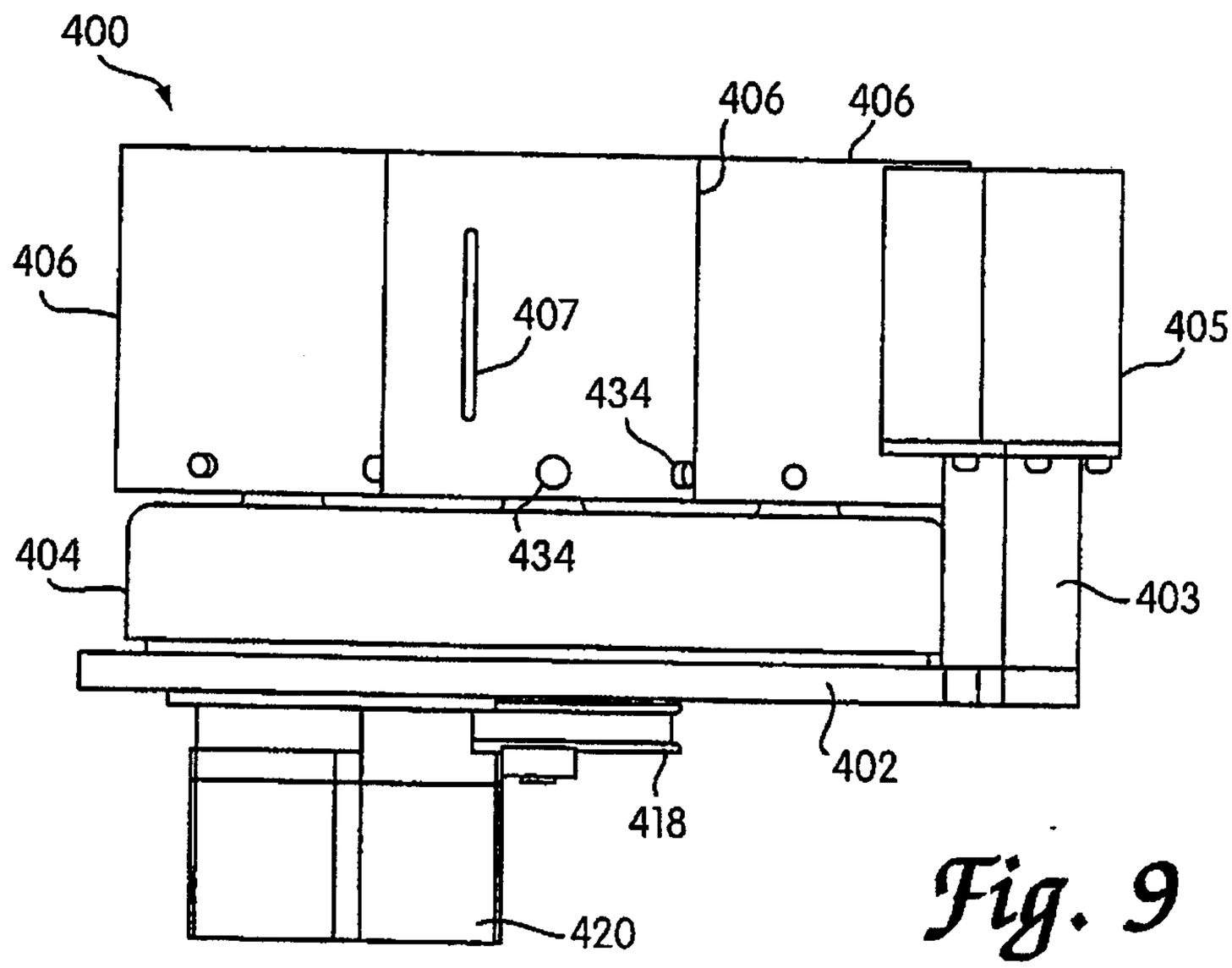


Fig. 9

Fig. 10

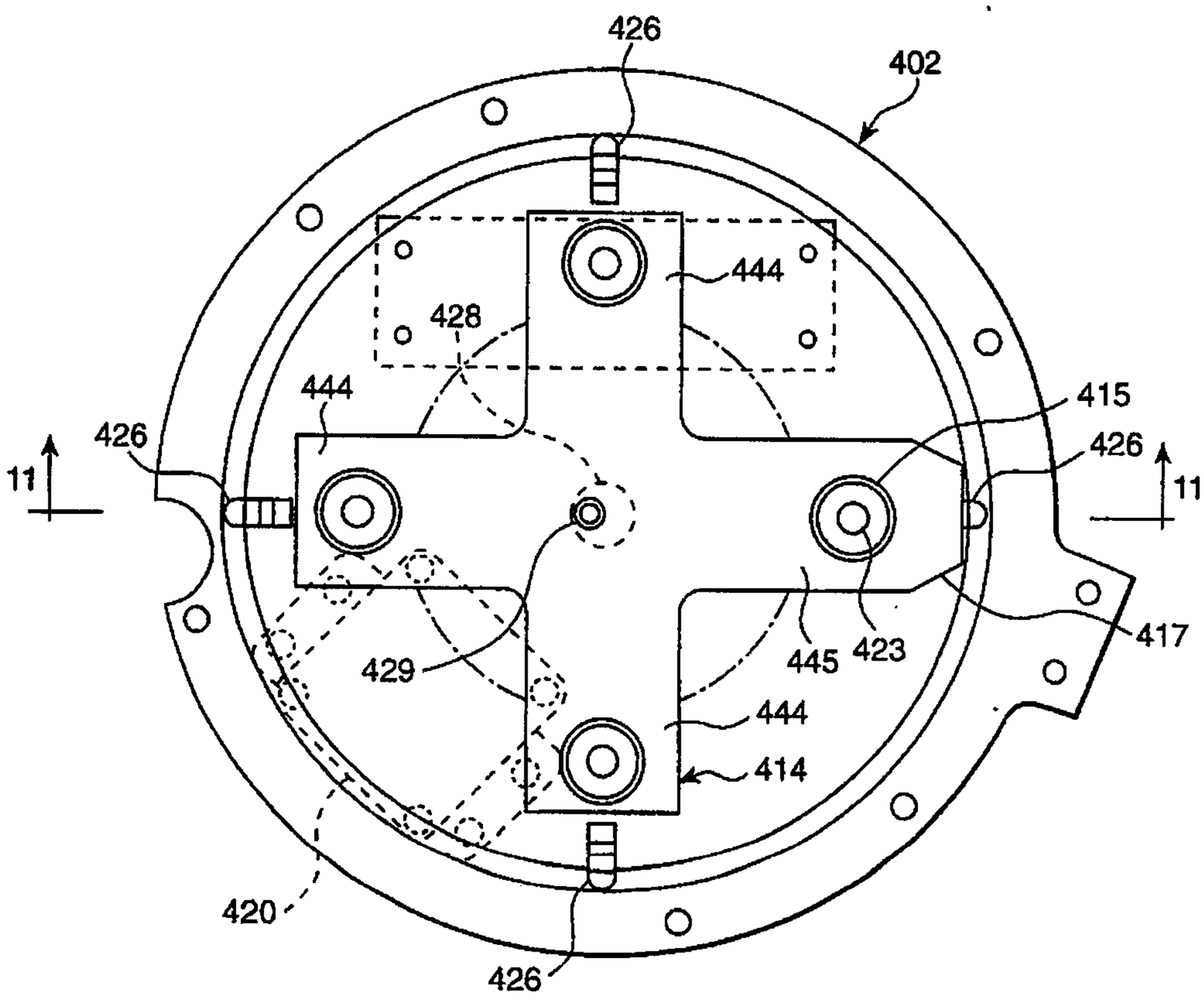

426
402
444
428
444
415
426
426
11
11
417
429
445
423
444
414
420
426

Fig. 11

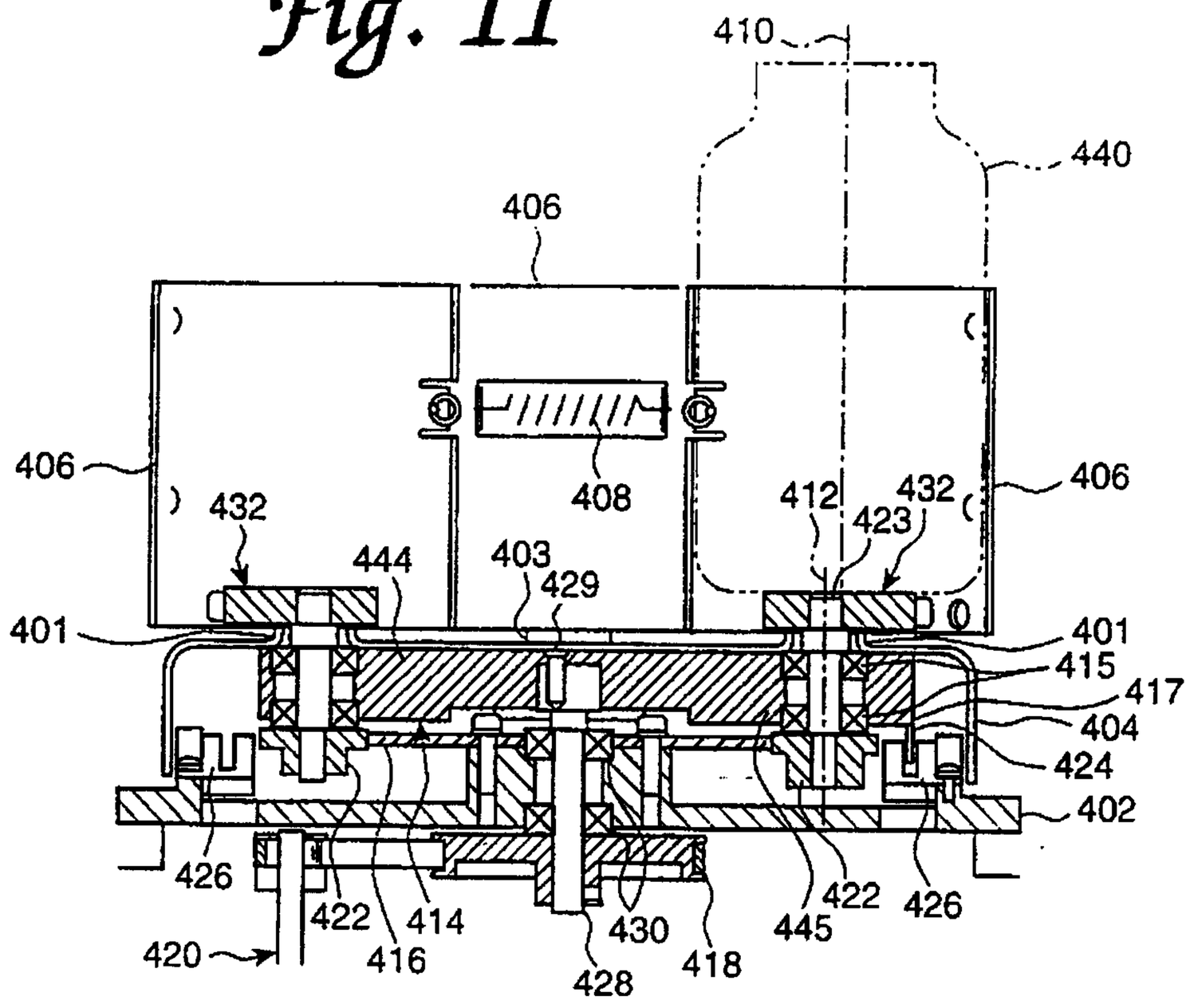
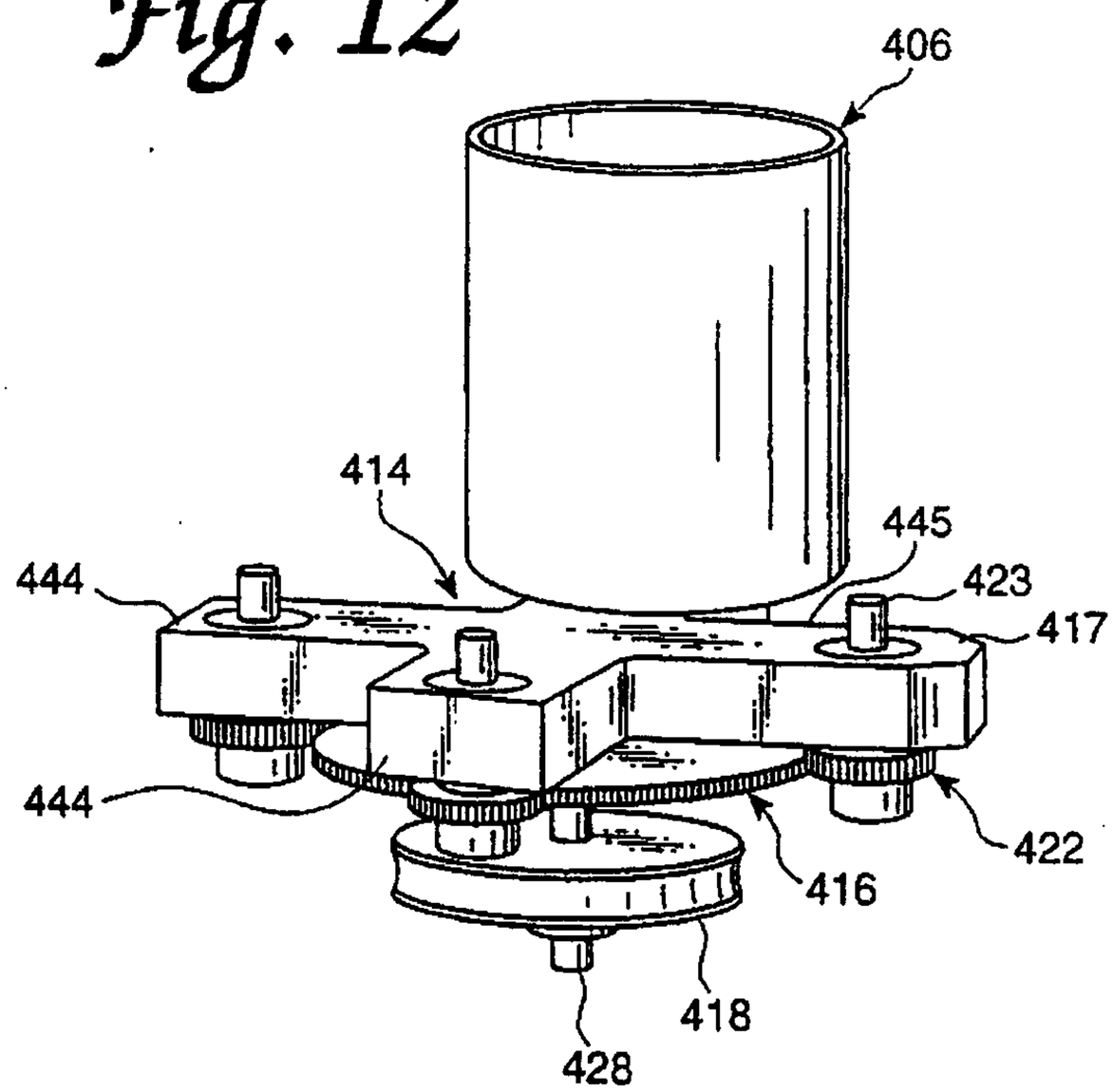

410
440
406
406
408
406
432
412
423
432
444
403
429
401
401
415
417
404
424
402
426
422
414
416
420
428
430
418
445
422
426

Fig. 12


406
414
445
444
423
417
444
422
416
418
428

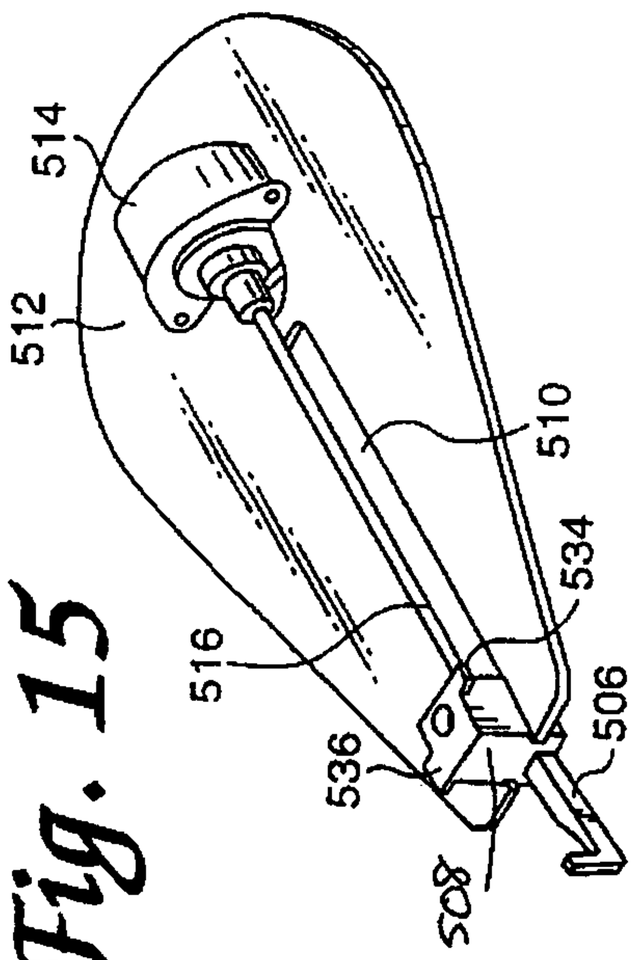


Fig. 15

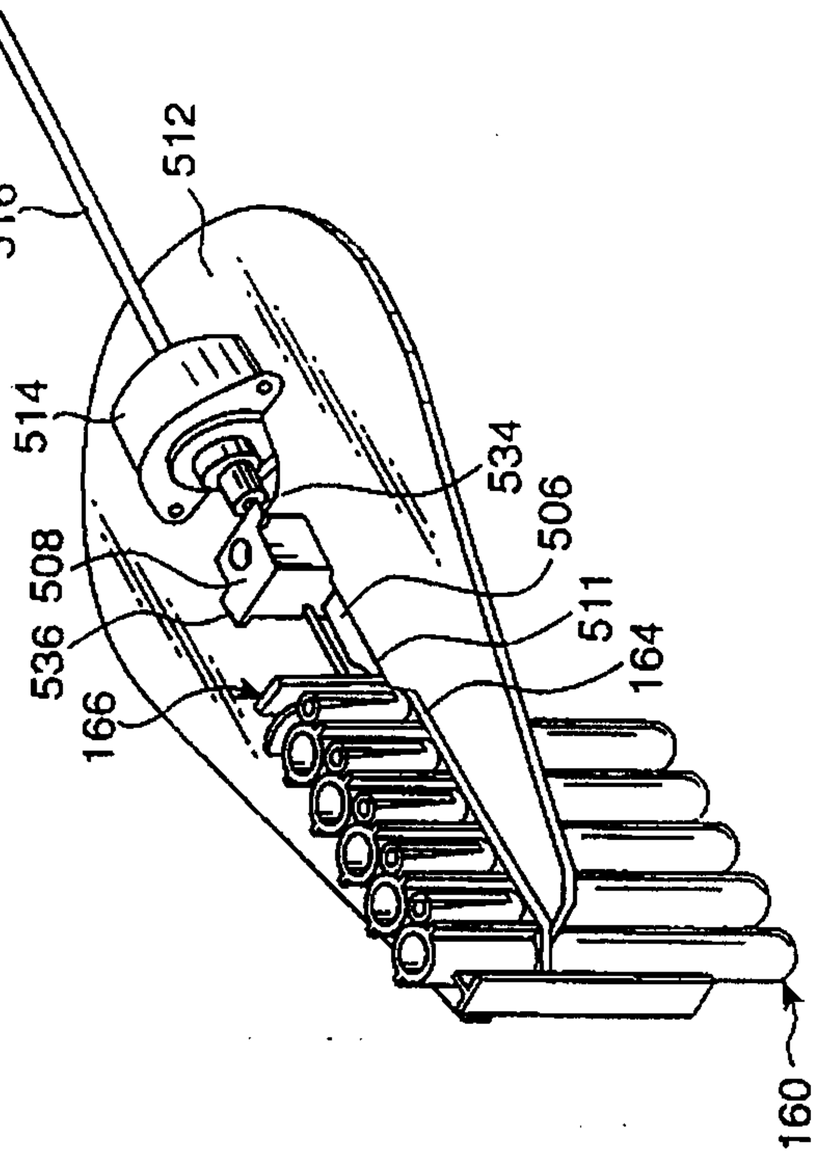


Fig. 14

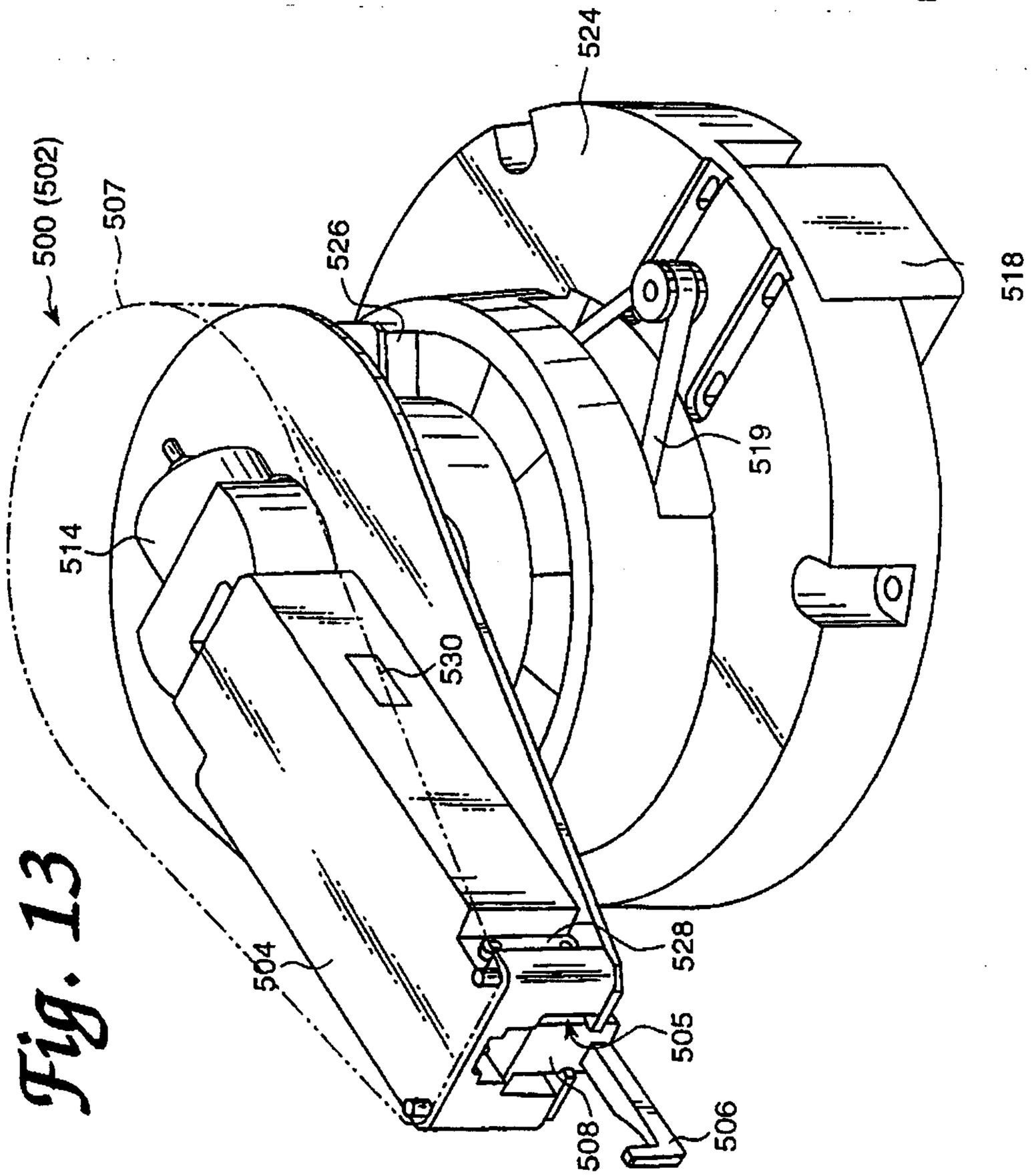


Fig. 13

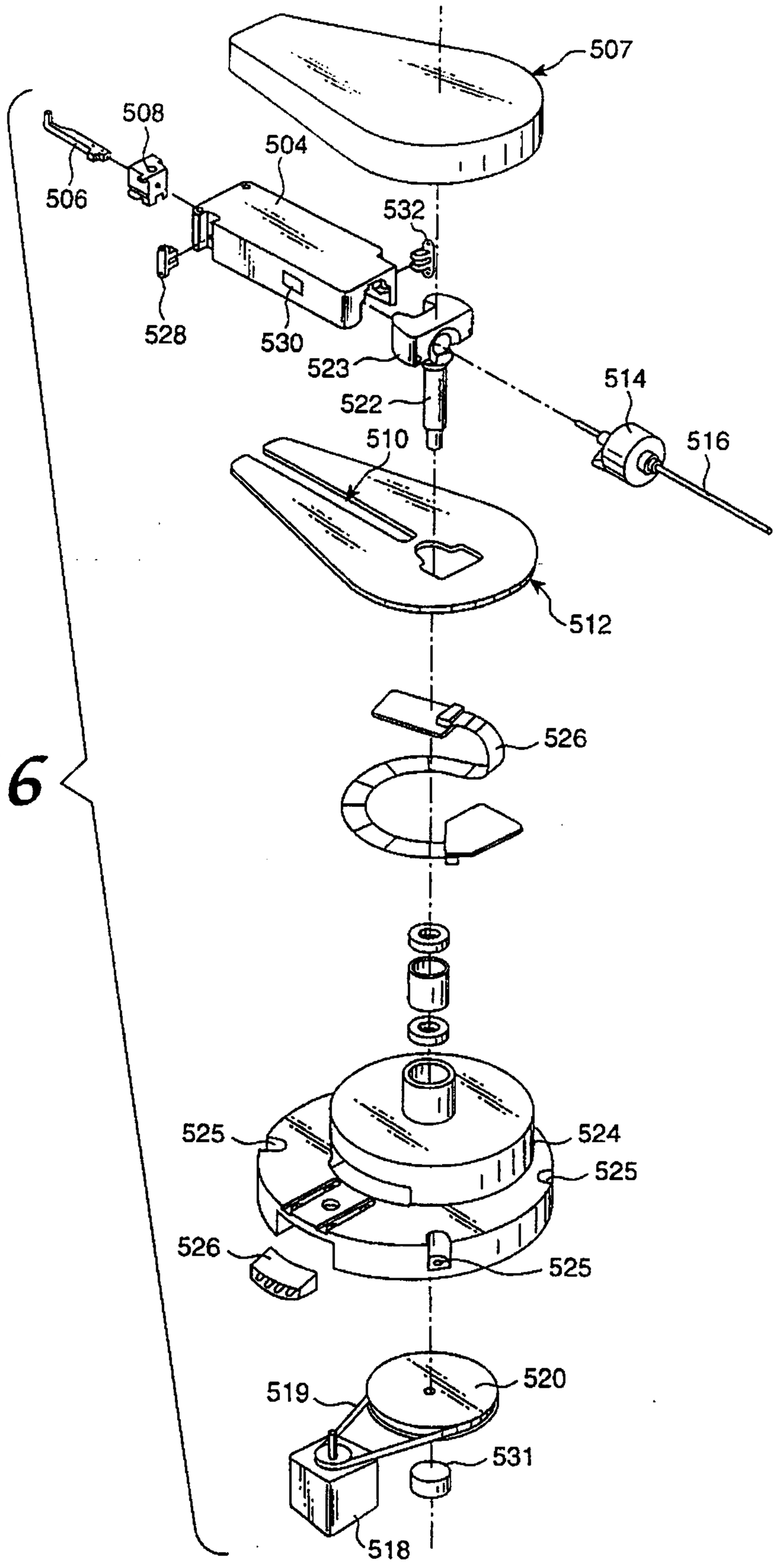

507
508
504
506
532
528
530
523
514
522
516
510
512
526
525
524
525
526
525
519
520
531
518

Fig. 16

Fig. 17

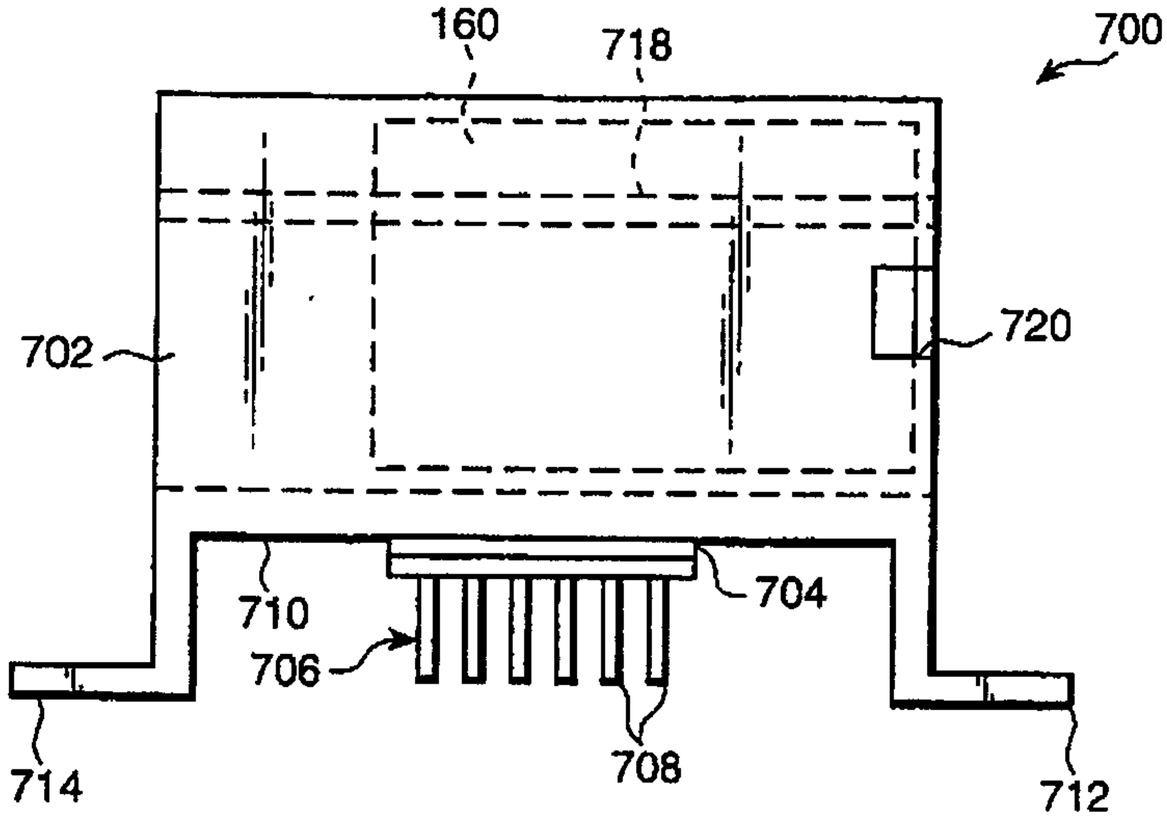
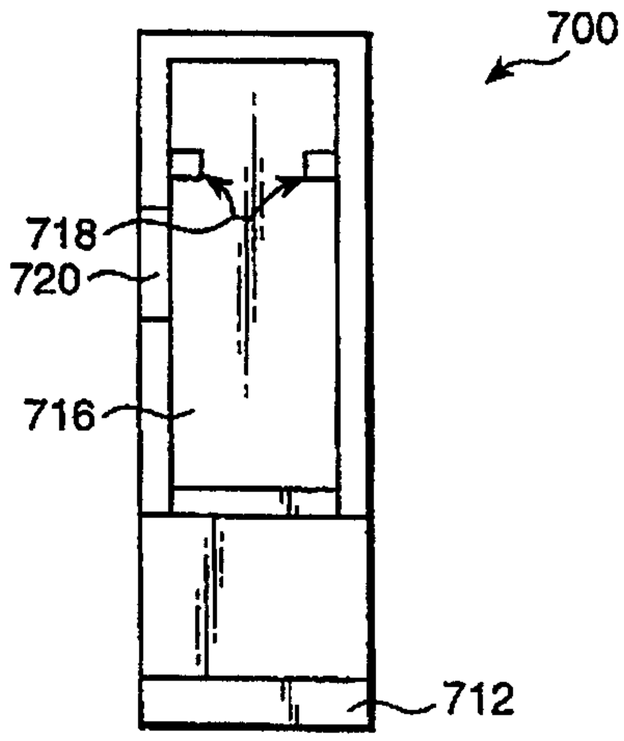


Fig. 18



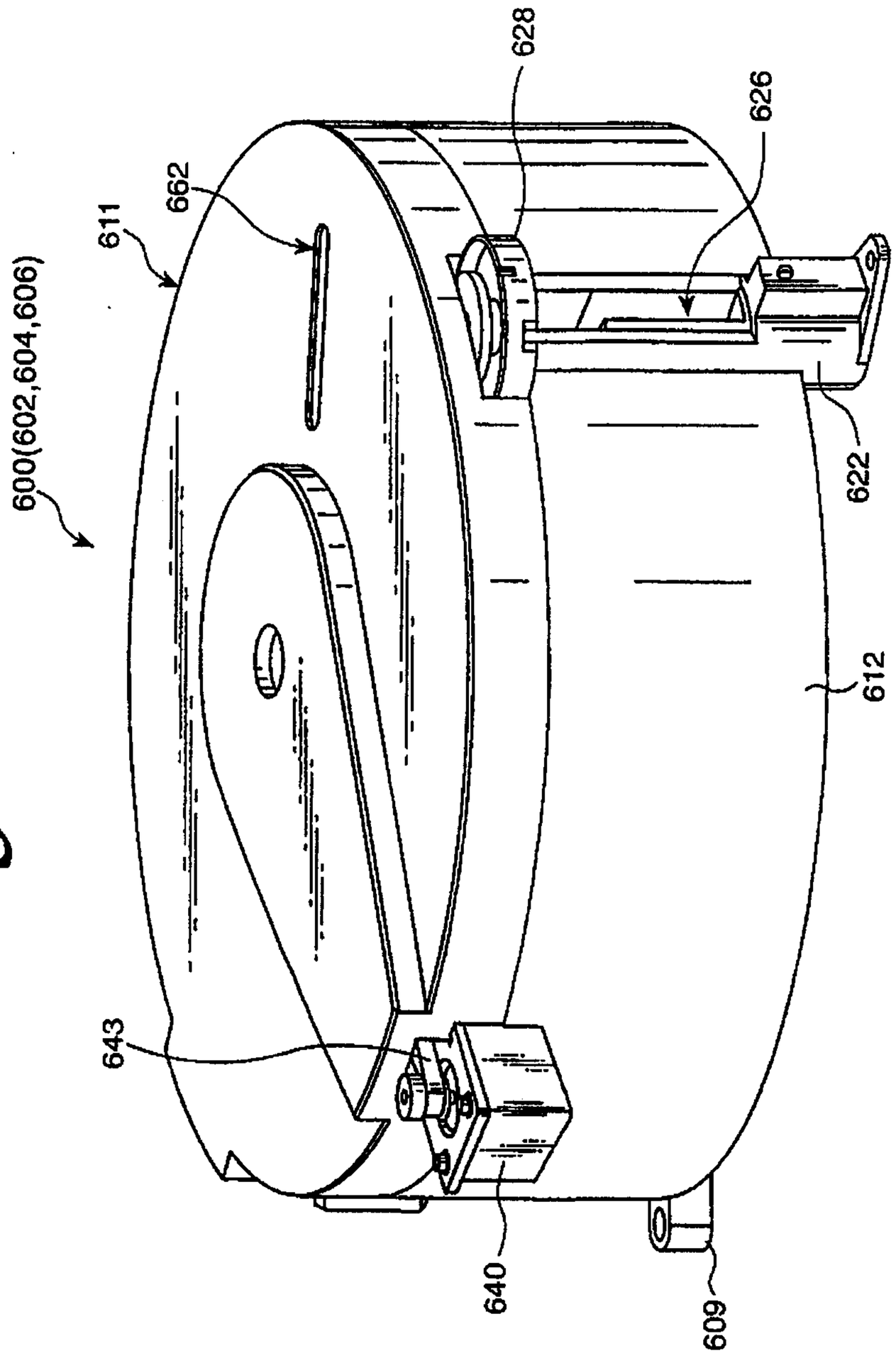


Fig. 19

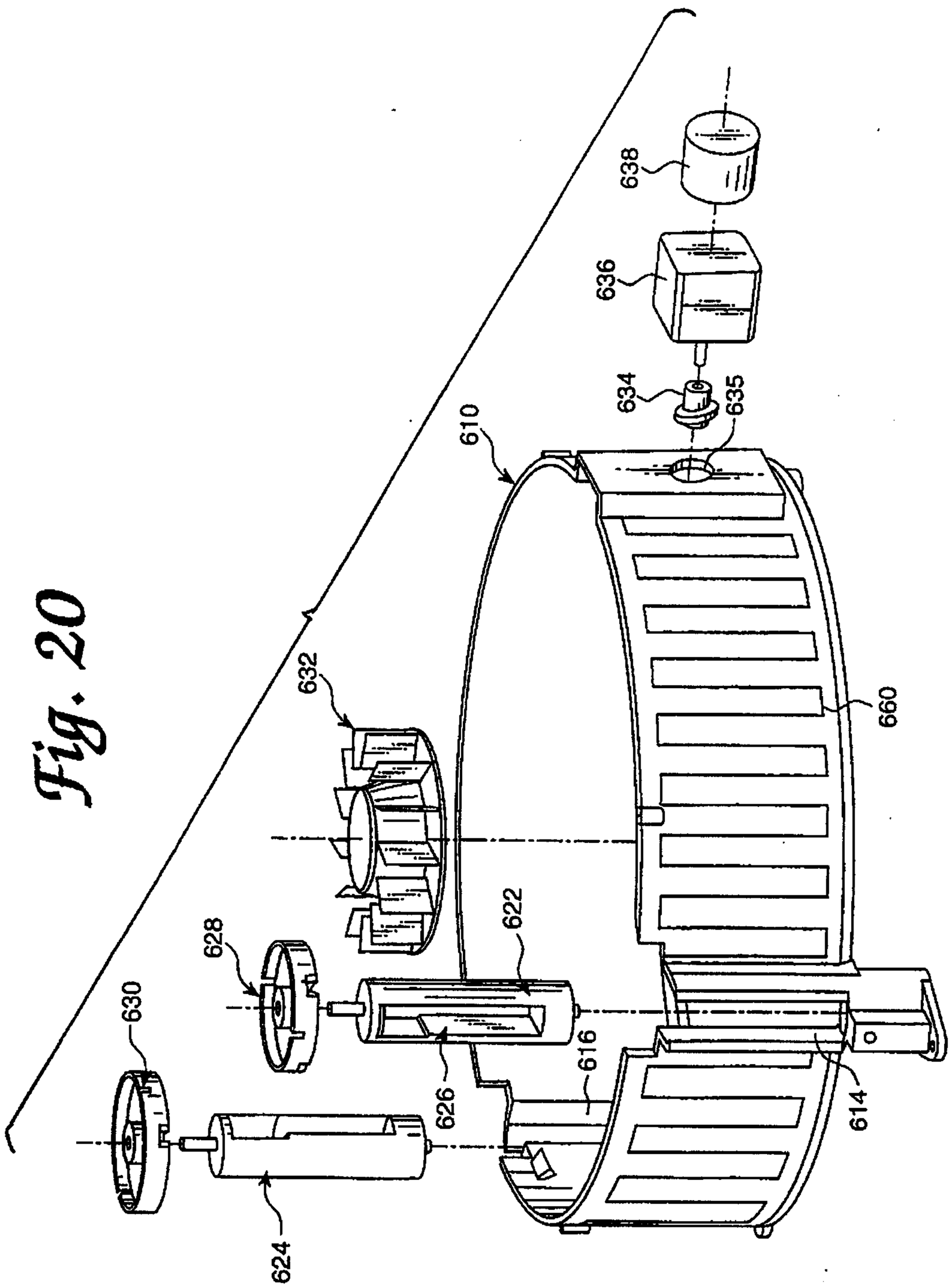


Fig. 20

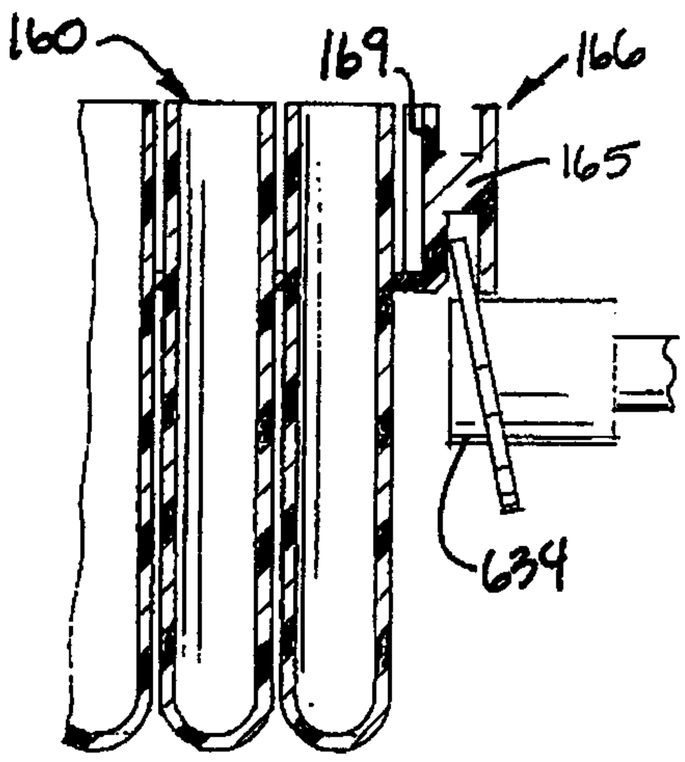
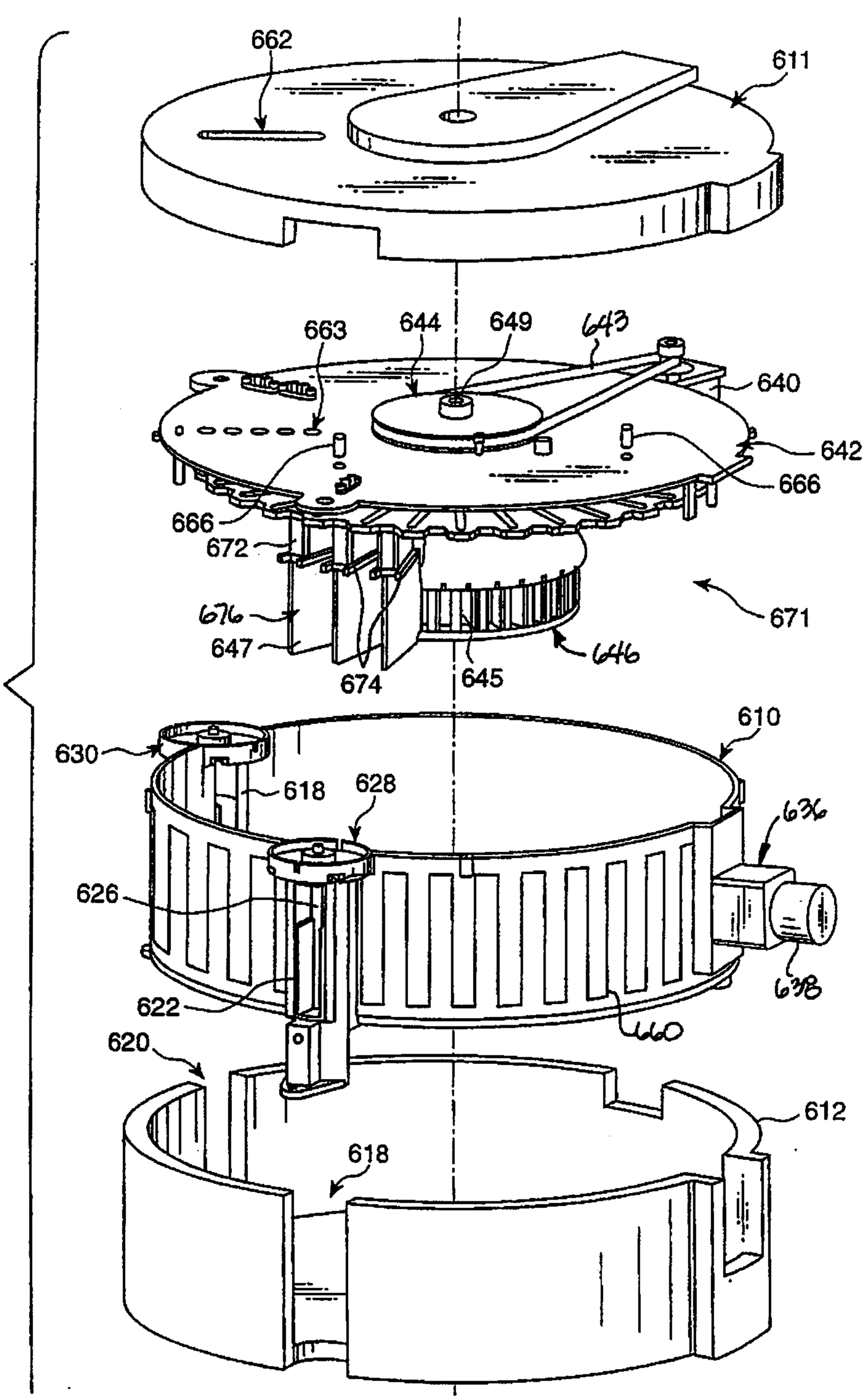


Fig. 21

Fig. 22


662
611
663
644
649
643
640
642
666
666
672
676
647
674
645
646
671
610
630
618
628
636
626
622
638
660
620
612
618

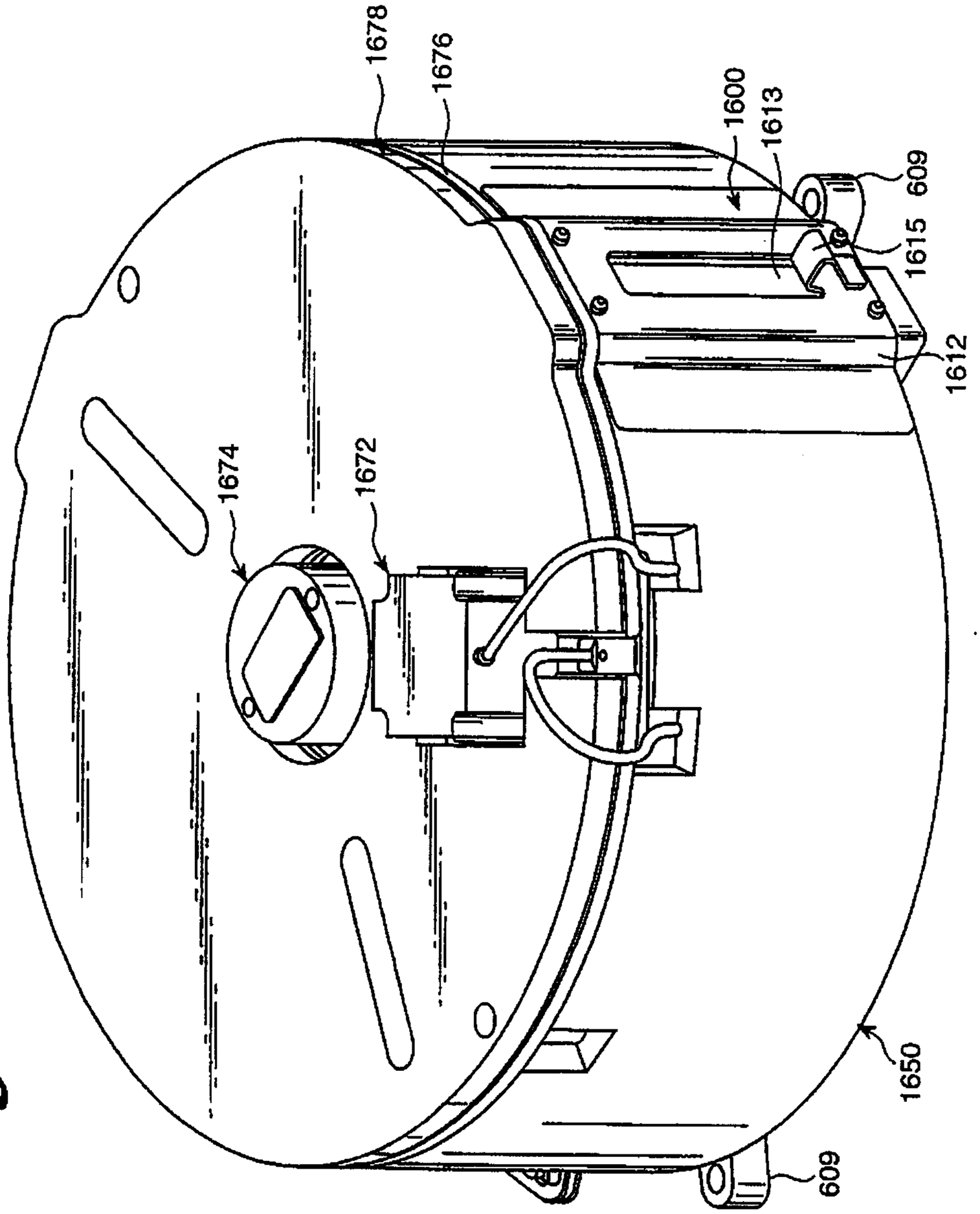


Fig. 23

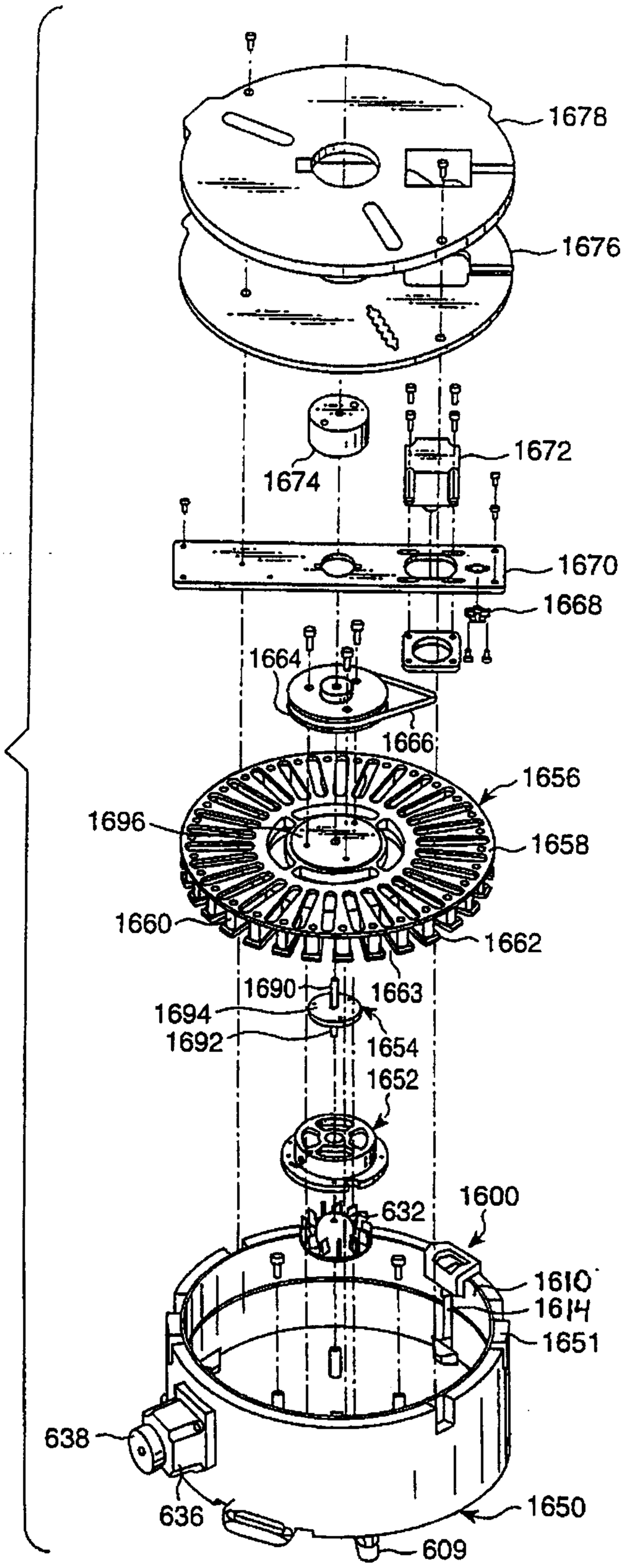

1678
1676
1674
1672
1670
1668
1664
1666
1656
1696
1658
1660
1662
1690
1663
1694
1692
1654
1652
632
1600
1610
1614
1651
638
636
1650
609

Fig. 23A

Fig. 23B

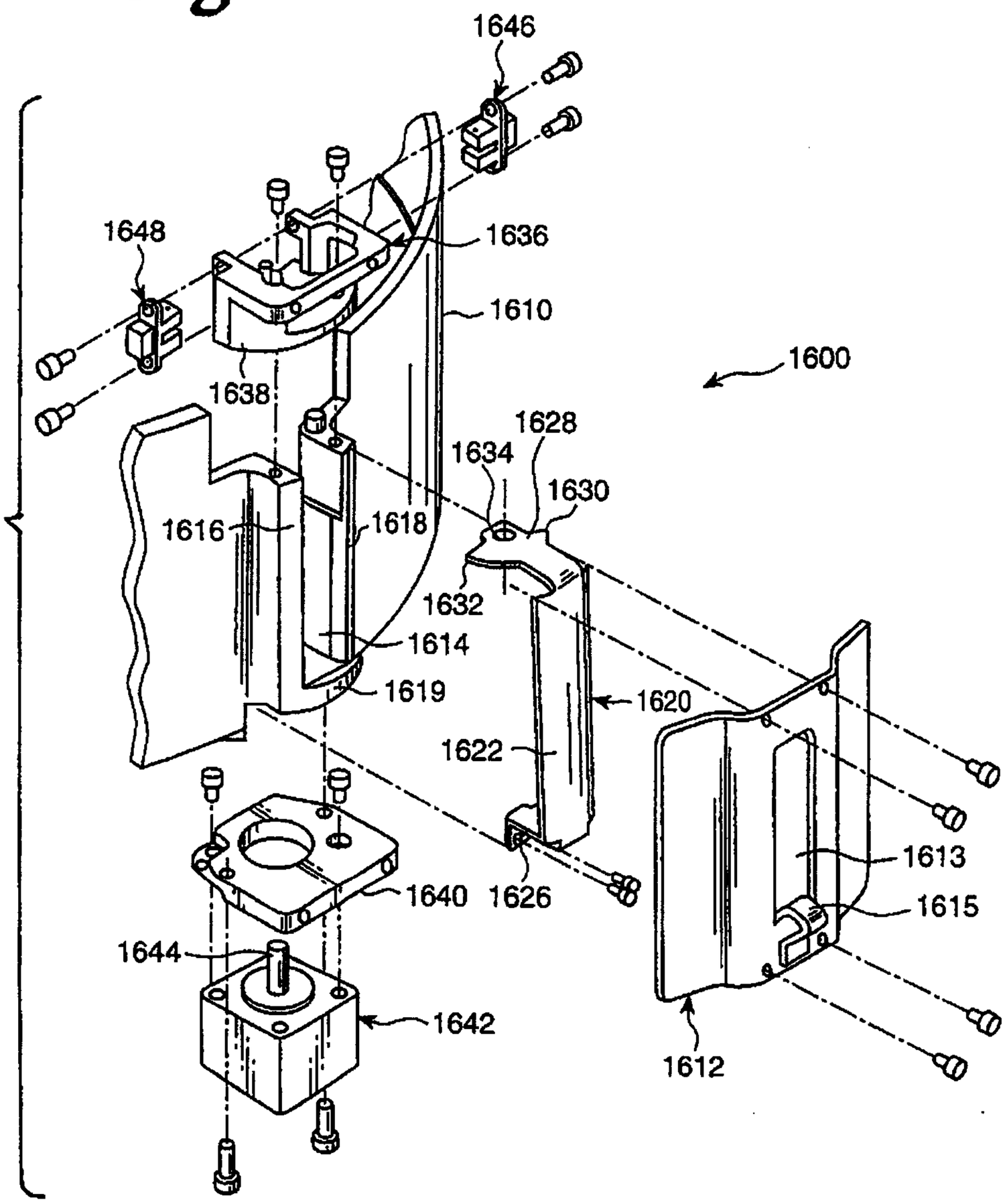

1646
1648
1636
1610
1600
1638
1628
1634
1630
1616
1618
1632
1614
1619
1620
1622
1613
1640
1626
1615
1644
1642
1612

Fig. 23C

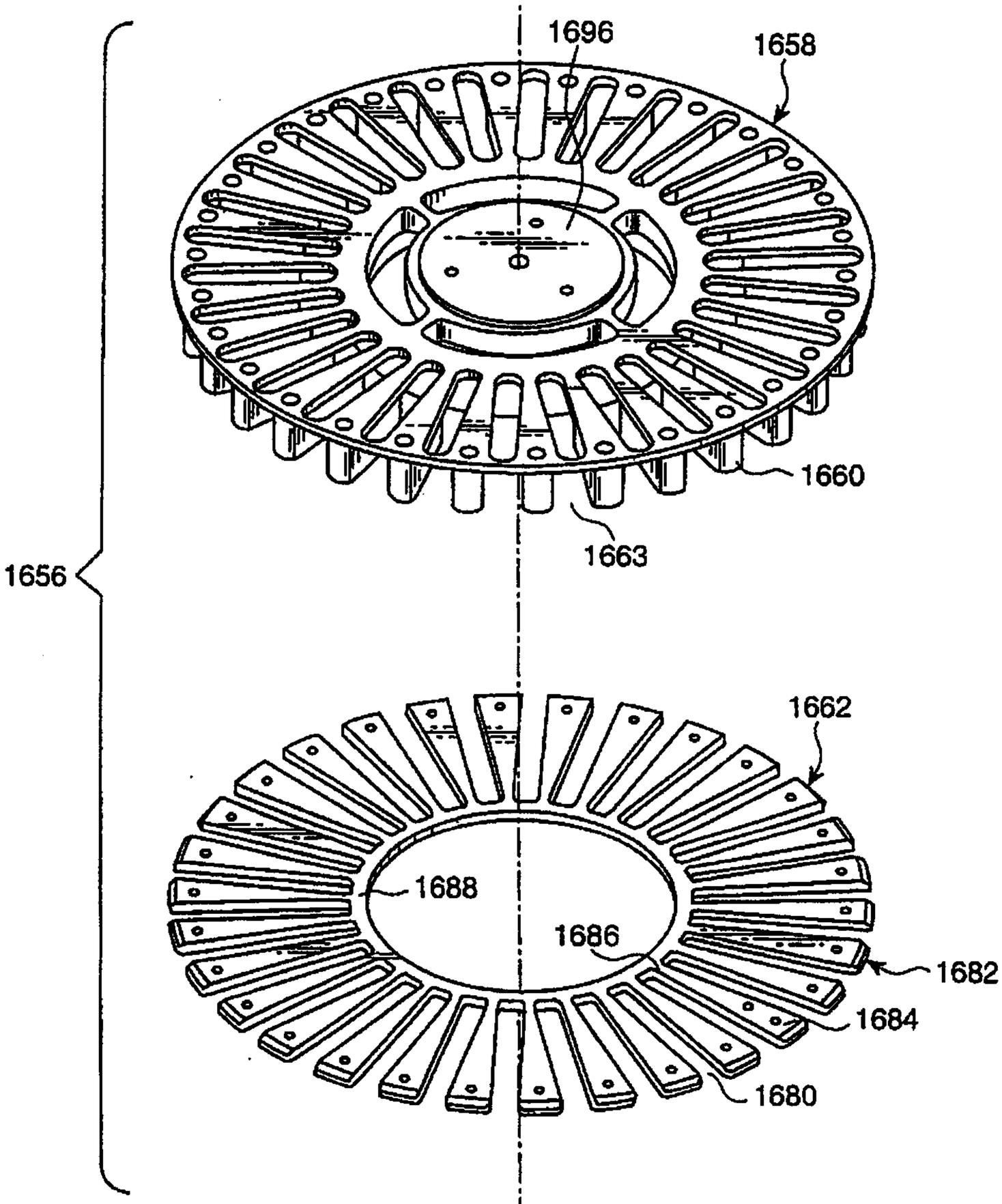


Fig. 24

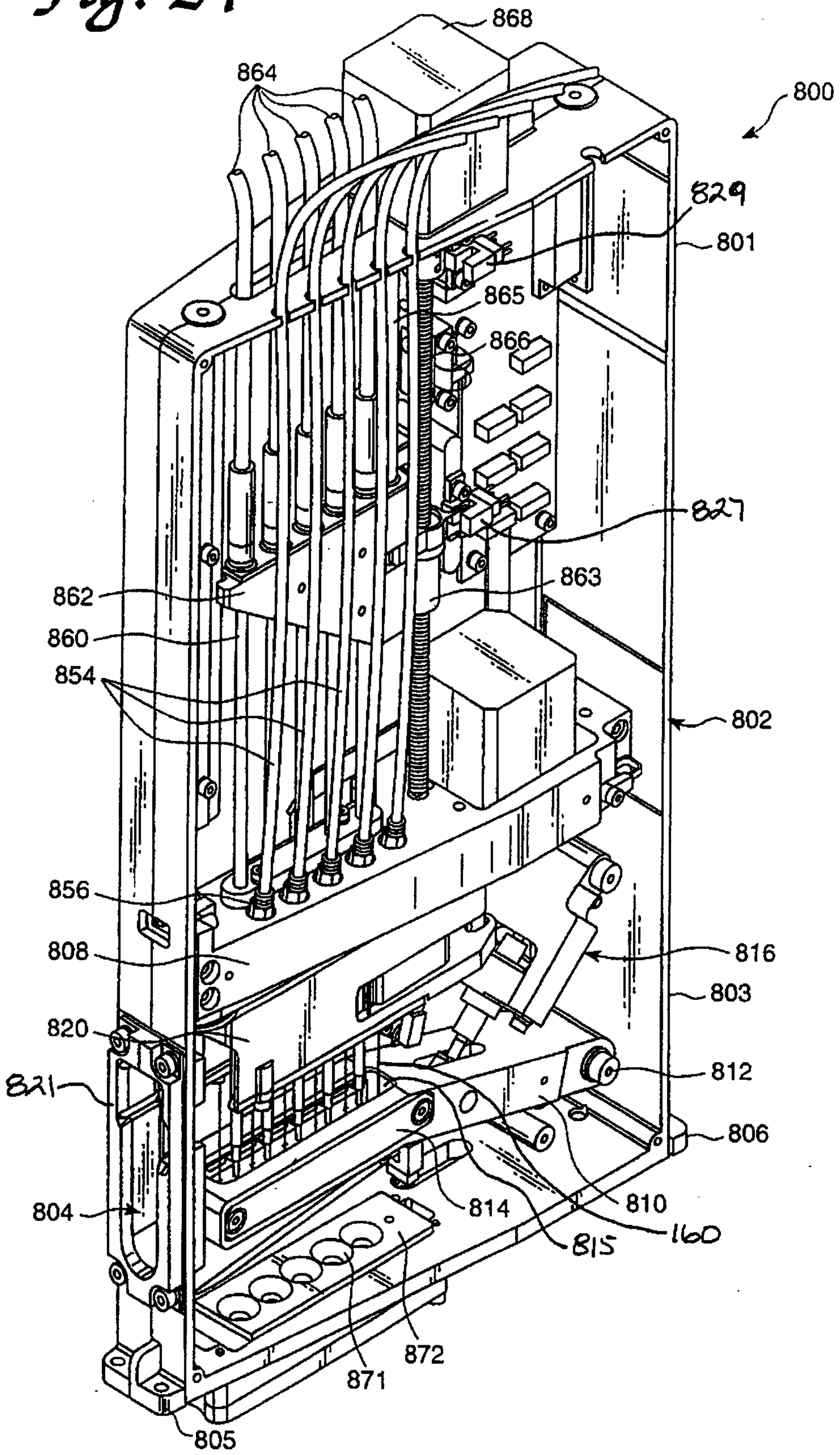

868
864
800
829
801
865
866
827
863
862
860
854
802
856
808
816
803
820
821
812
806
804
814
810
815
160
872
871
805

Fig. 25

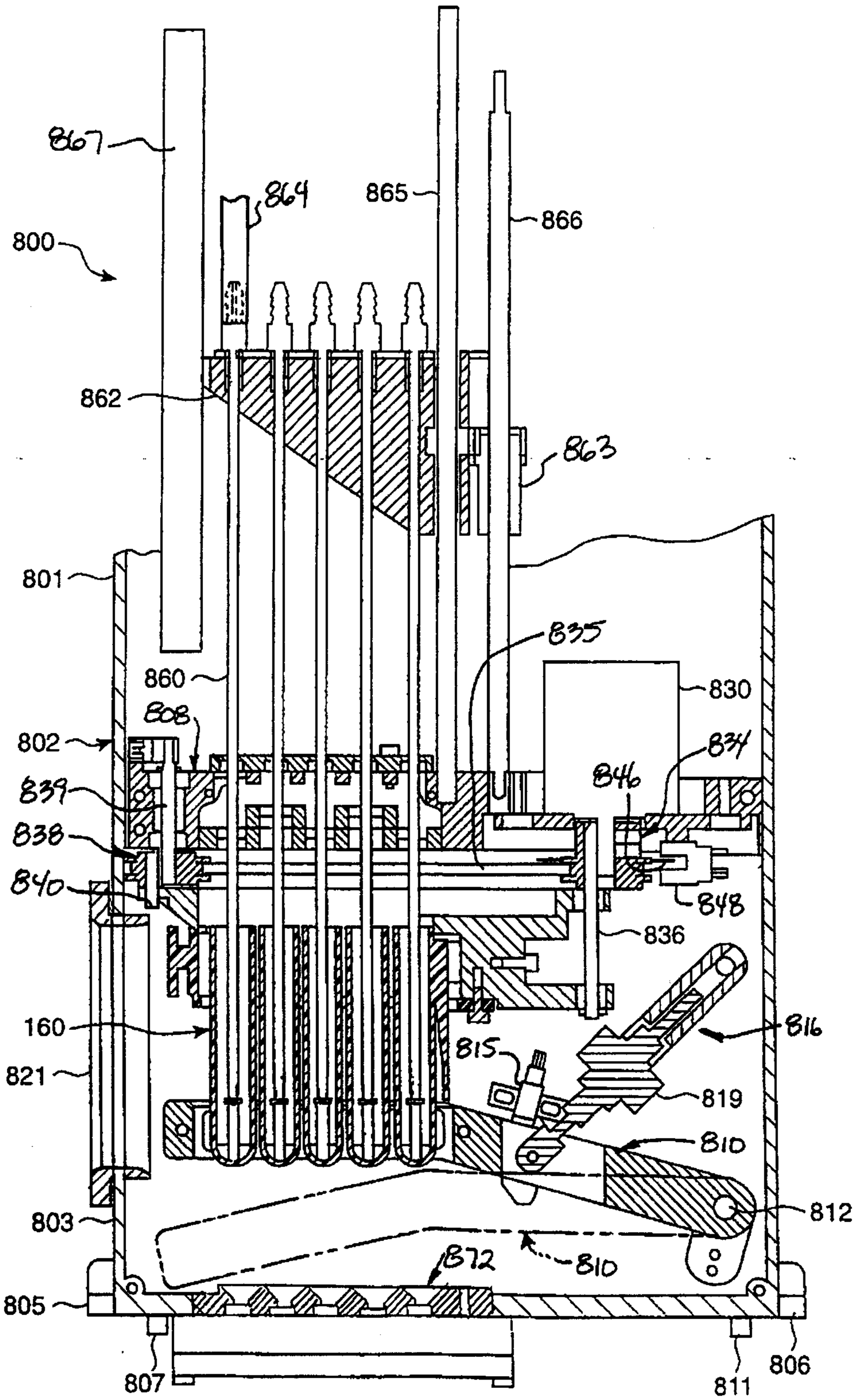
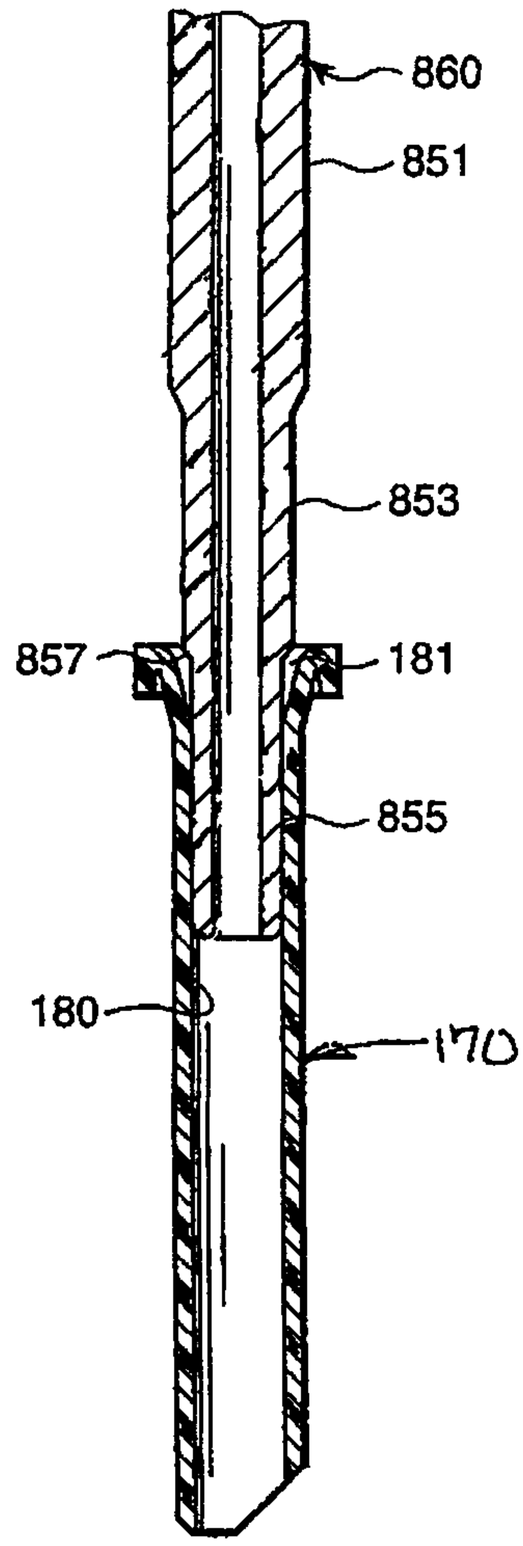

867
864
865
866
800
862
863
801
860
835
830
808
802
834
839
846
838
840
848
836
160
816
815
821
819
810
812
803
872
810
805
807
811
806

Fig. 25A



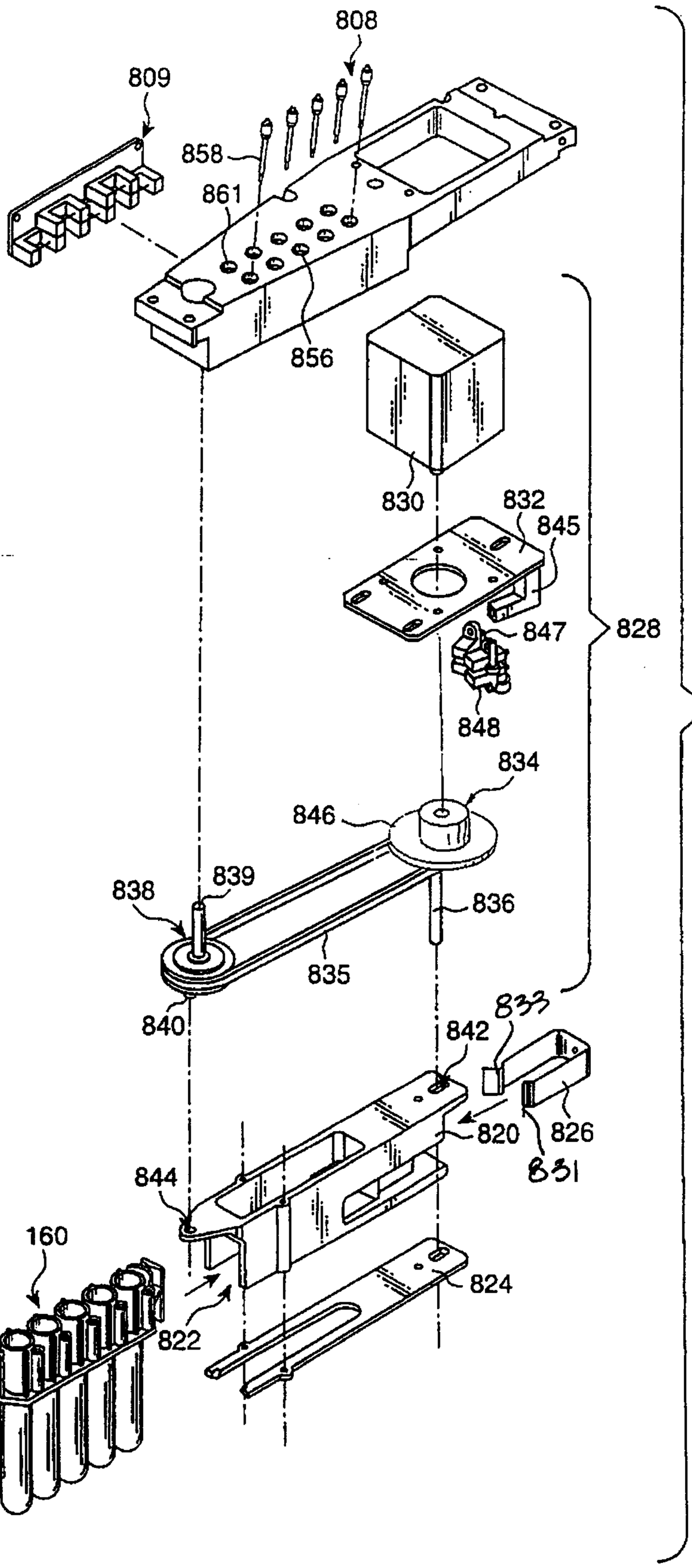

808
809
858
861
856
830
832
845
847
828
848
834
846
838
839
836
835
840
842
833
820
826
831
844
160
822
824

Fig. 26

Fig. 27

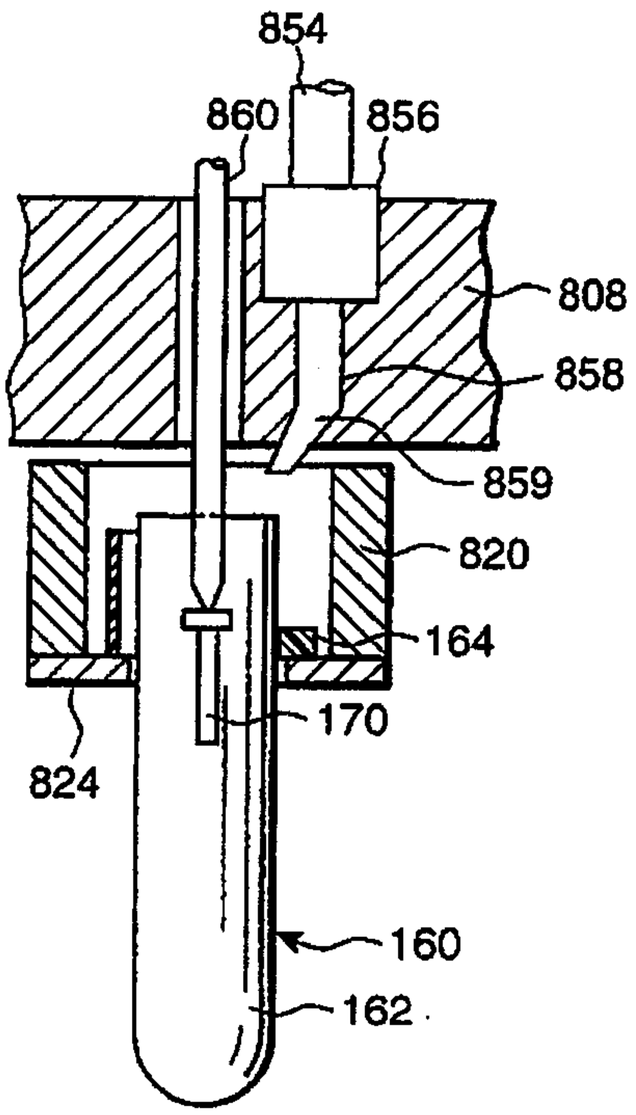
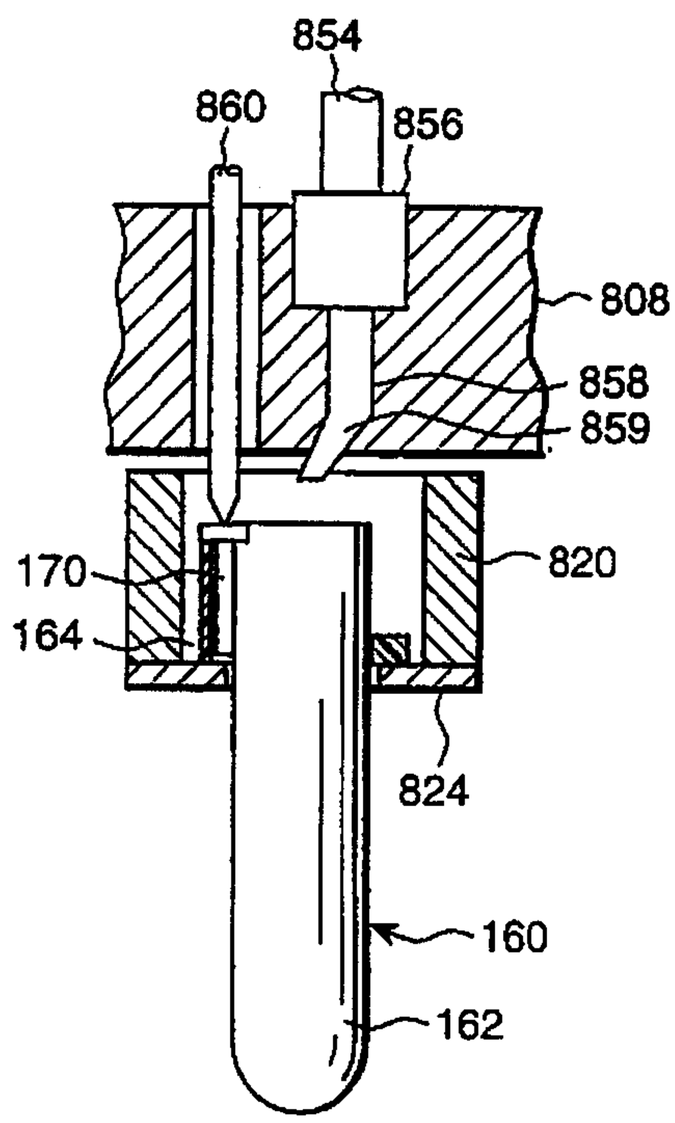

854
860
856
808
858
859
820
164
170
824
160
162

Fig. 28


854
860
856
808
858
859
820
170
164
824
160
162

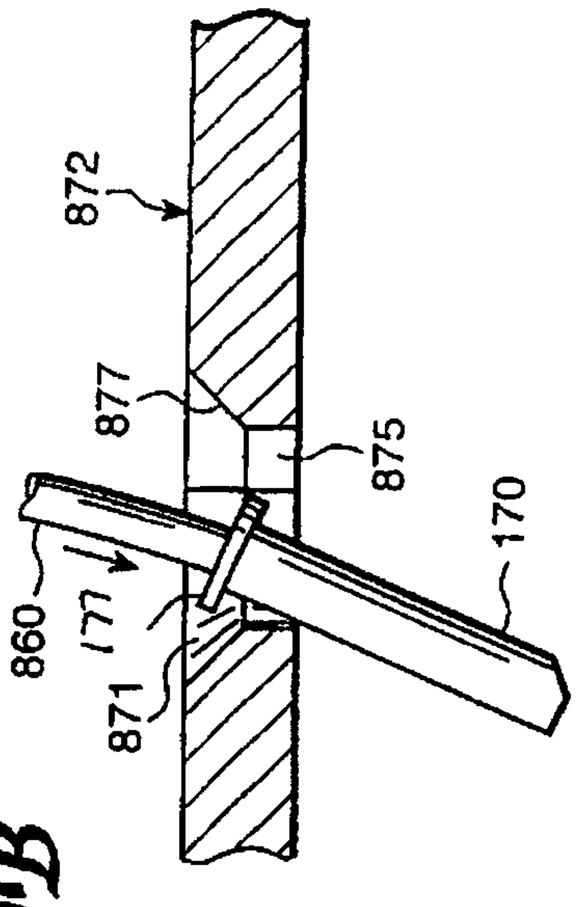


Fig. 29B

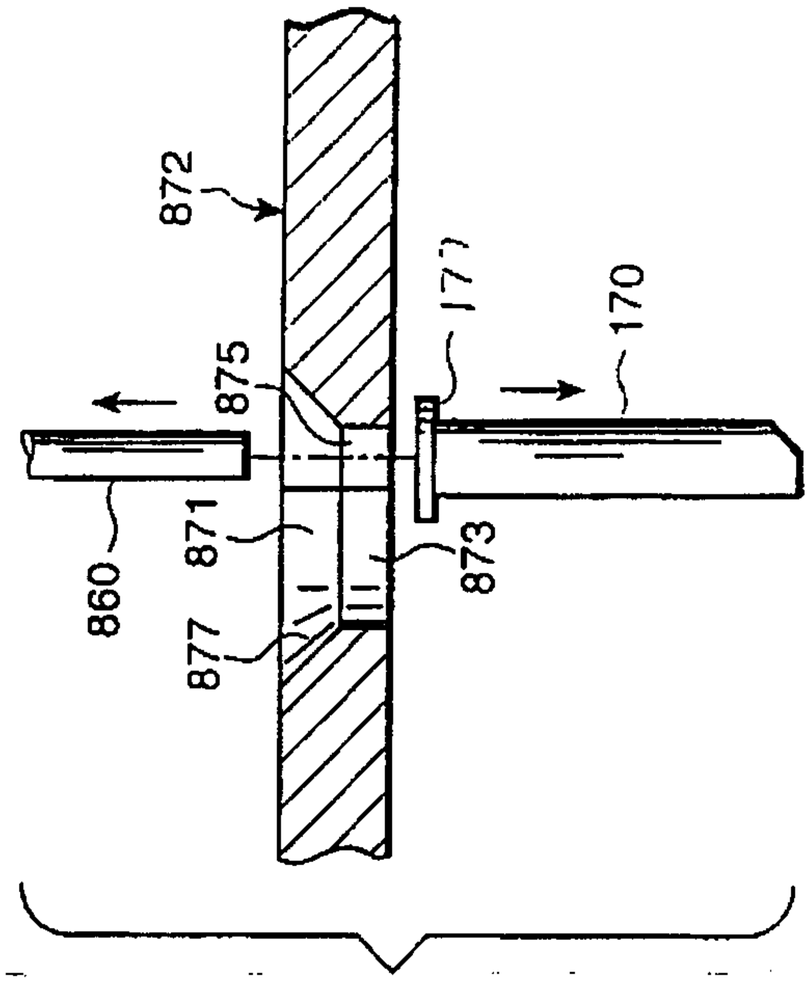


Fig. 29D

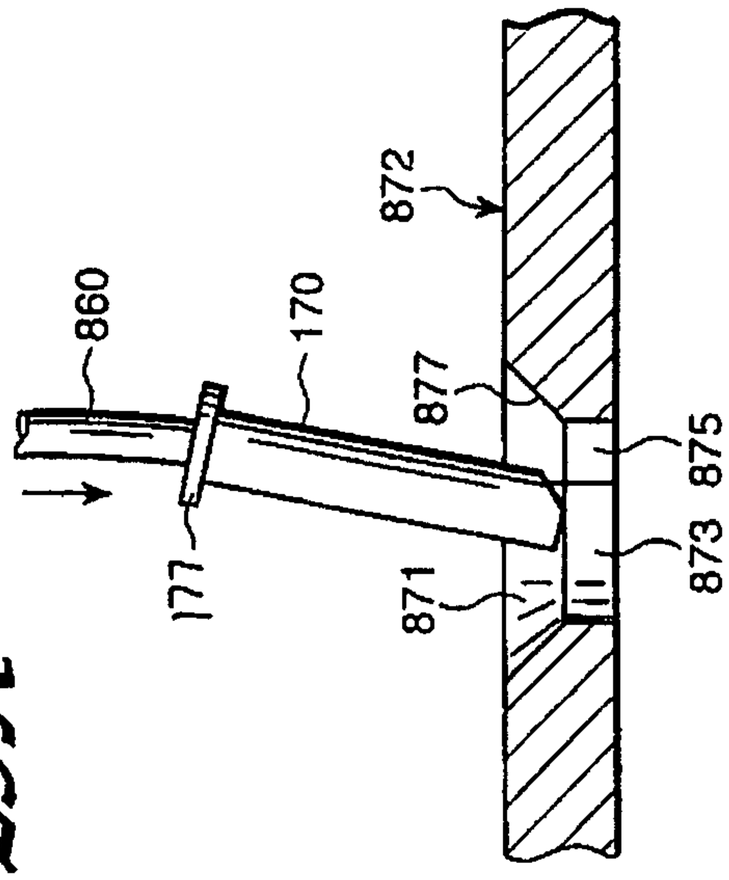


Fig. 29A

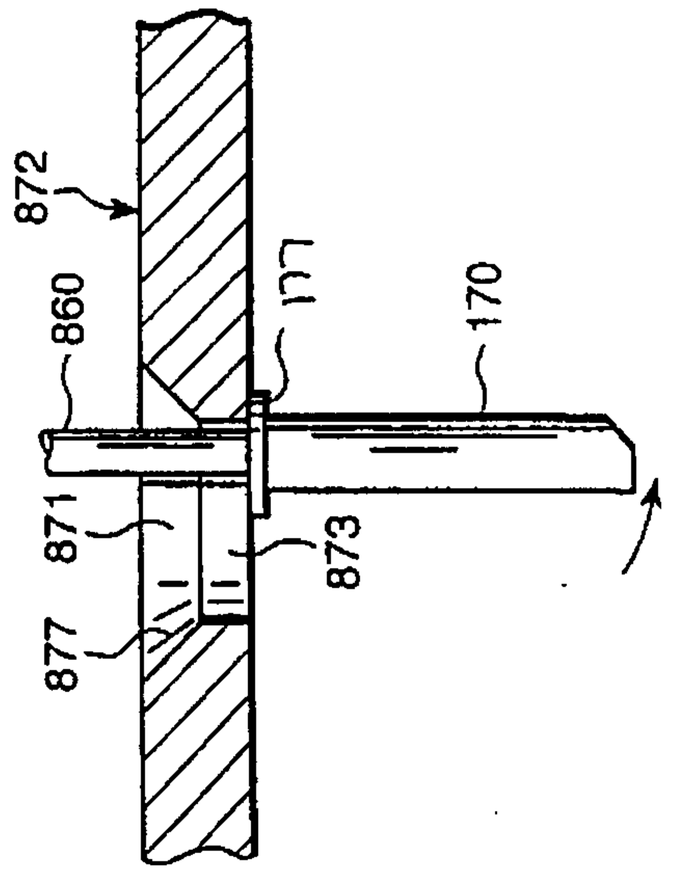


Fig. 29C

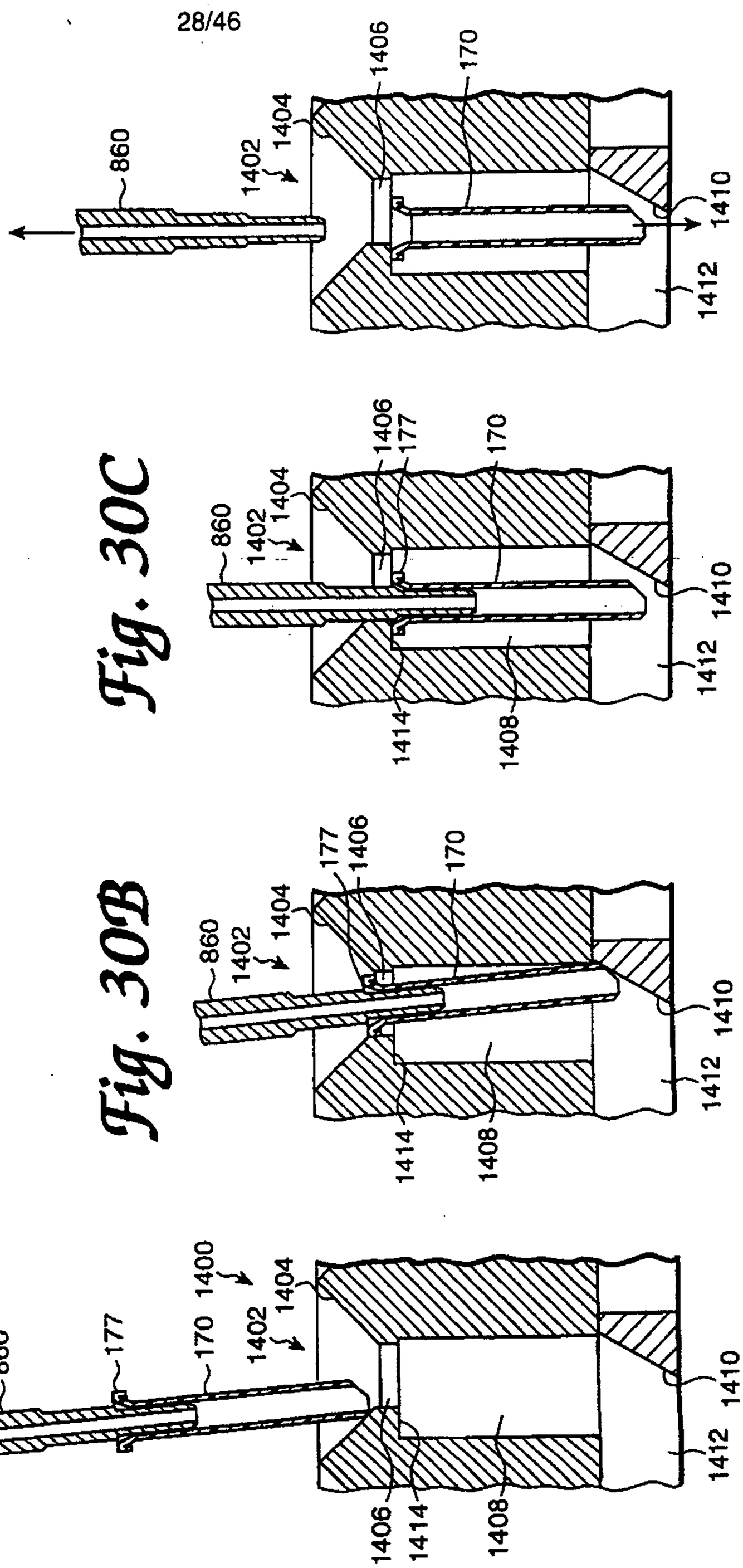


Fig. 30D

Fig. 30C

Fig. 30B

Fig. 30A

Fig. 31A

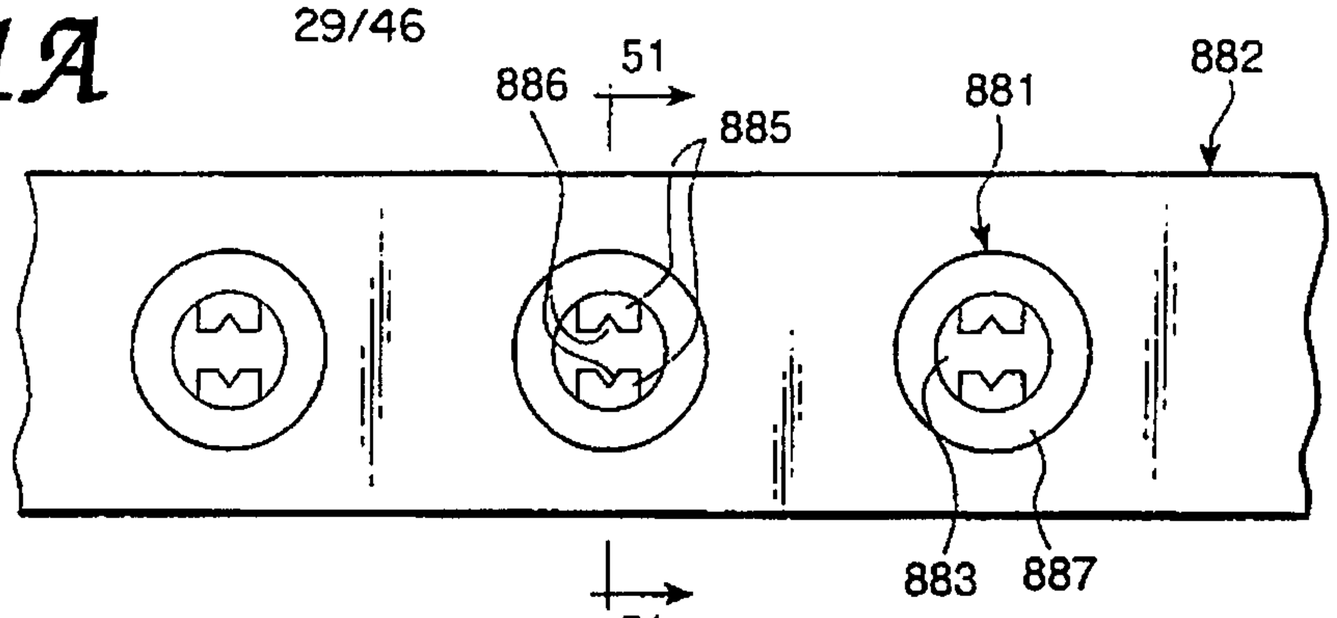


Fig. 31B

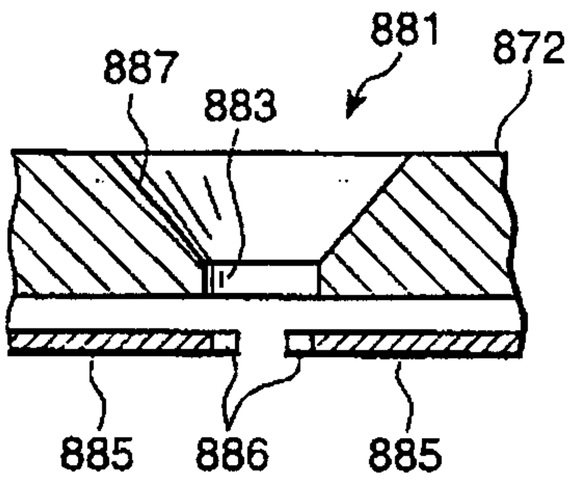
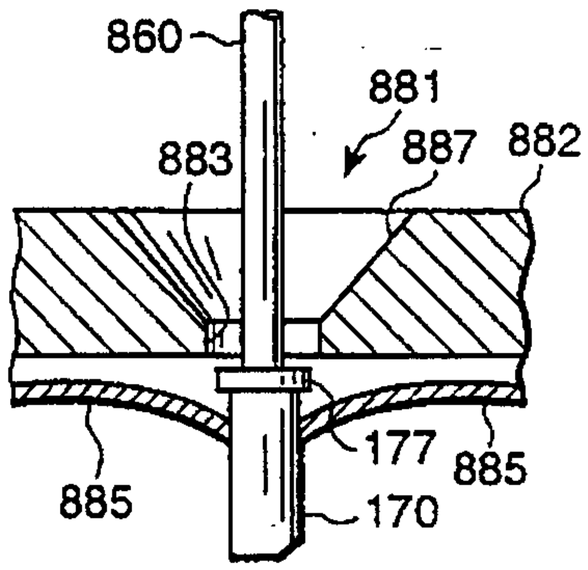


Fig. 31C



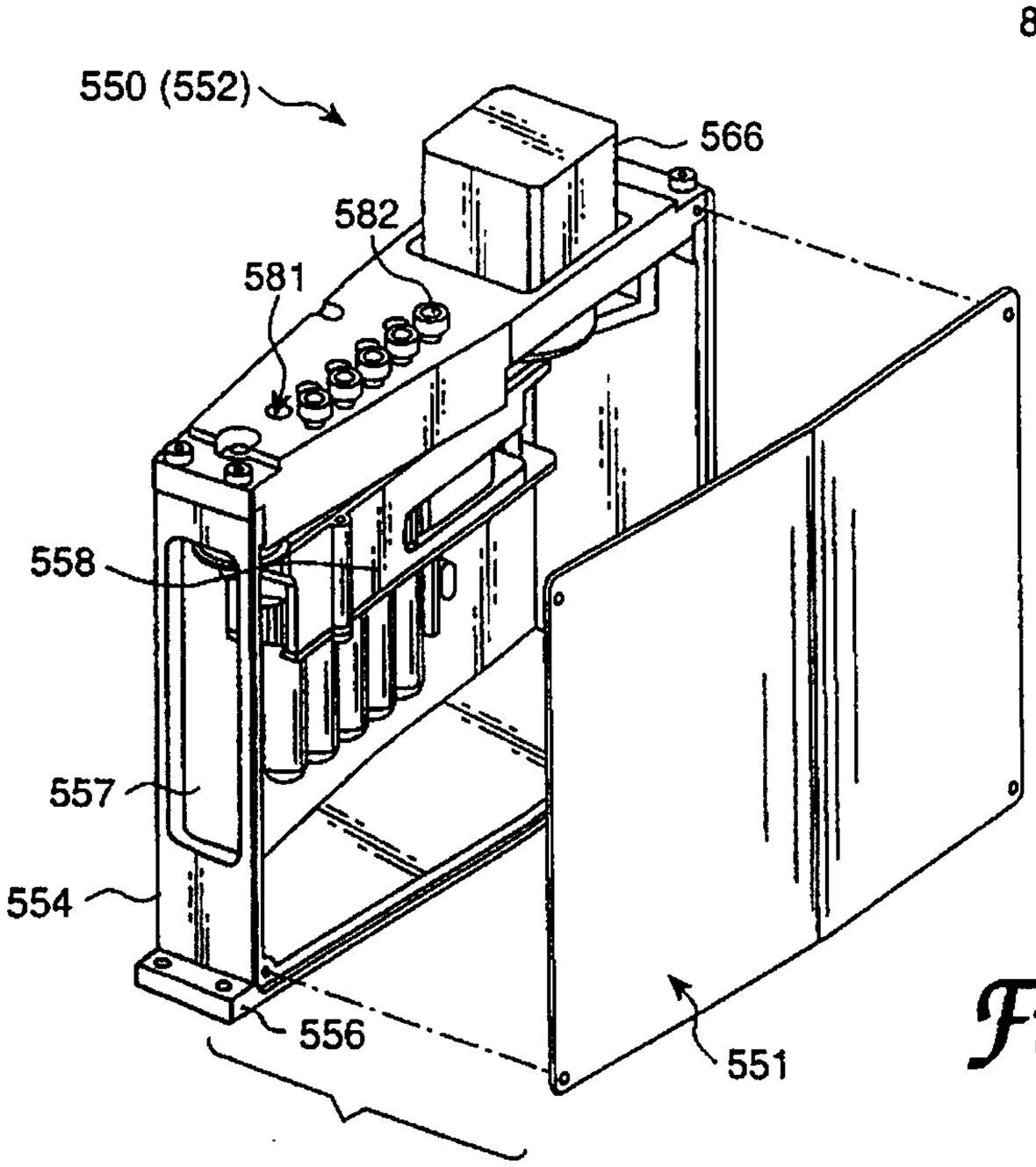


Fig. 32

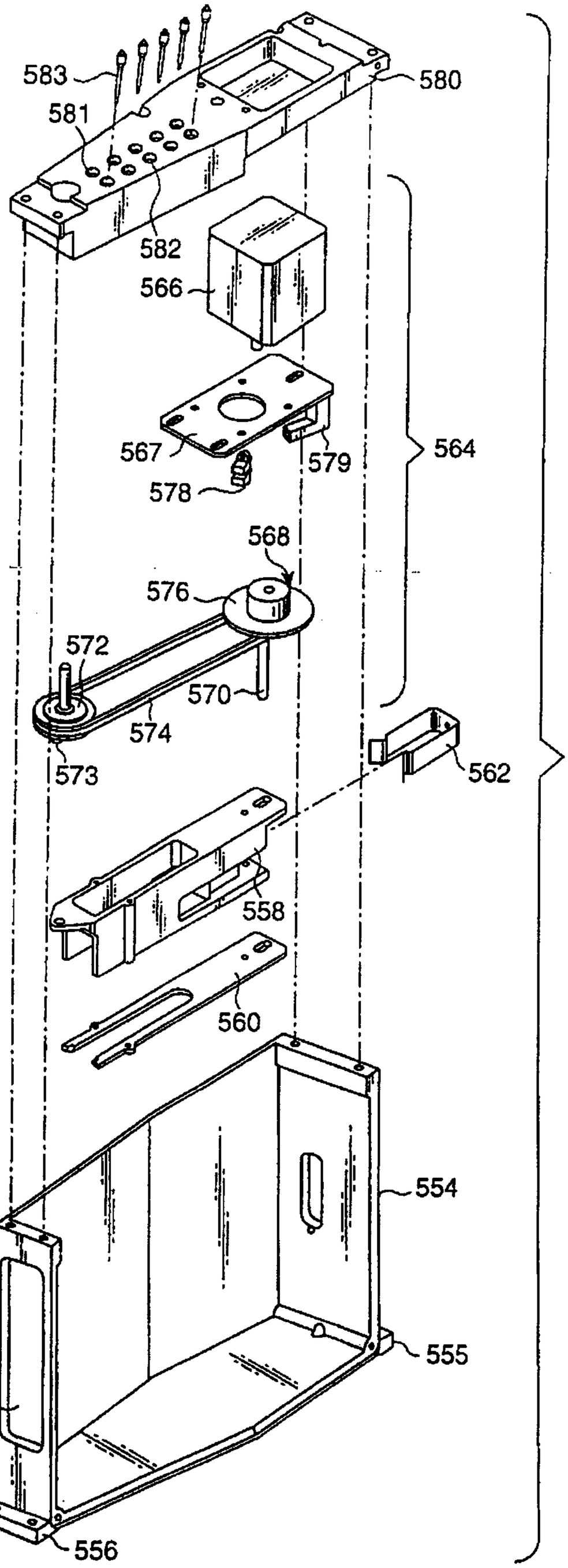

583
581
580
582
566
567
579
564
578
568
576
572
570
574
573
562
558
560
554
555
557
556

Fig. 33

Fig. 34

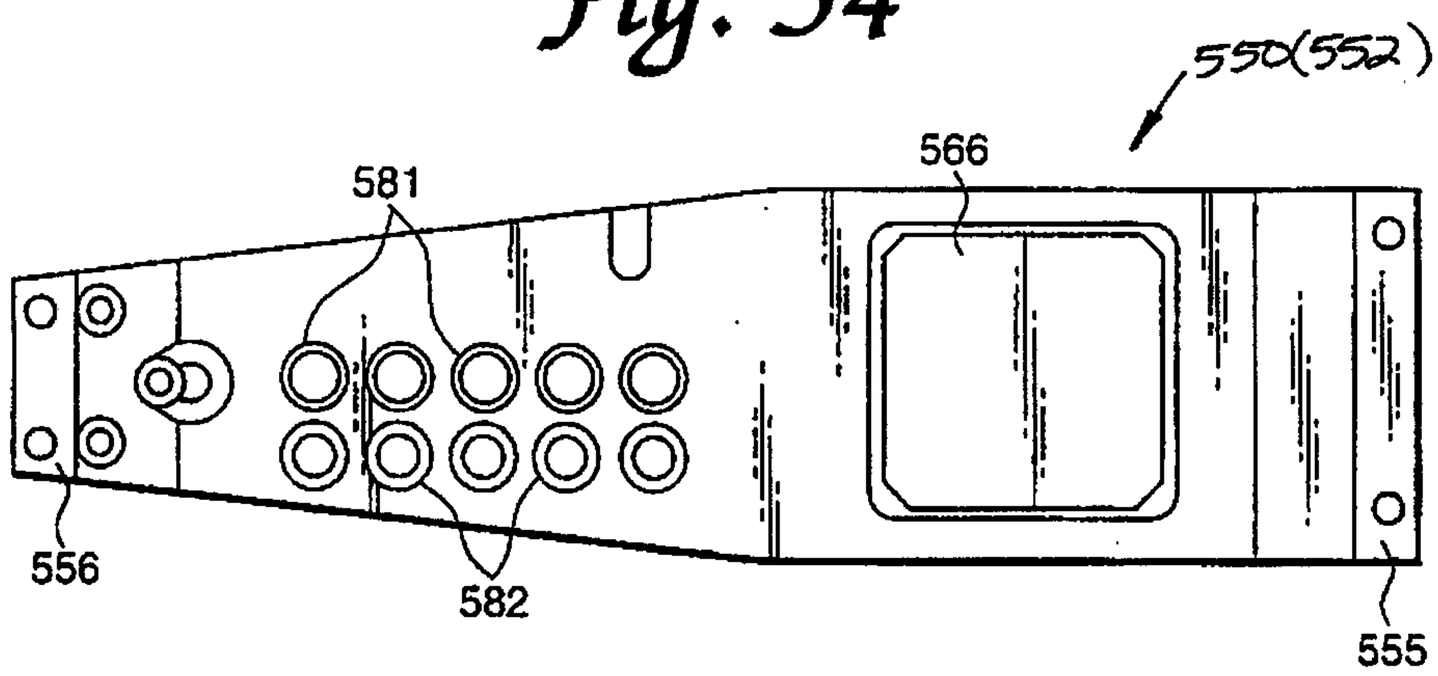

550(552)
566
581
556
582
555

Fig. 35

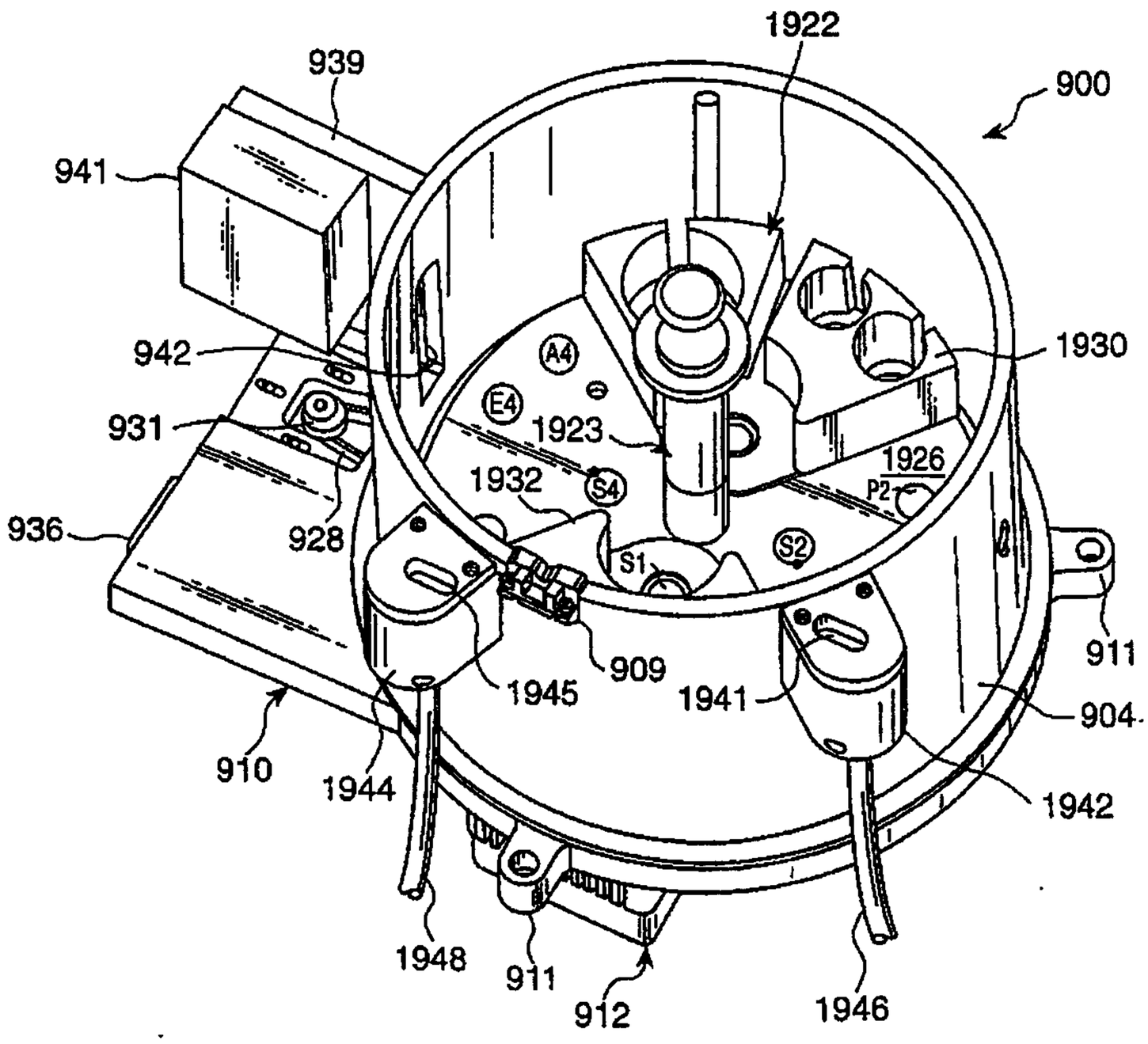

1922
939
900
941
942
1930
931
A4
E4
1923
1926
P2
1932
S4
936
928
S1
S2
911
909
1945
1941
904
910
1944
1942
1948
911
912
1946

Fig. 36

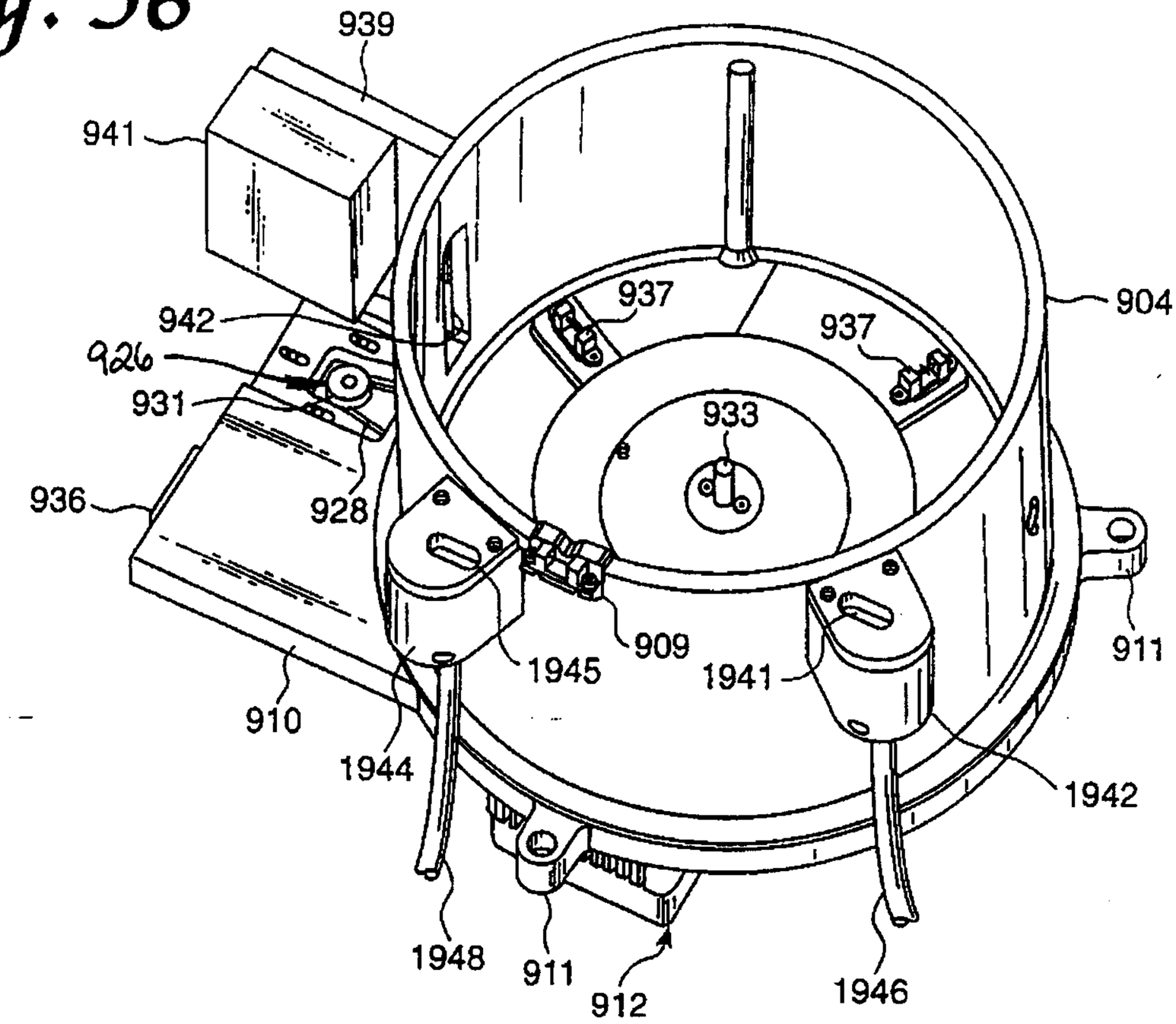
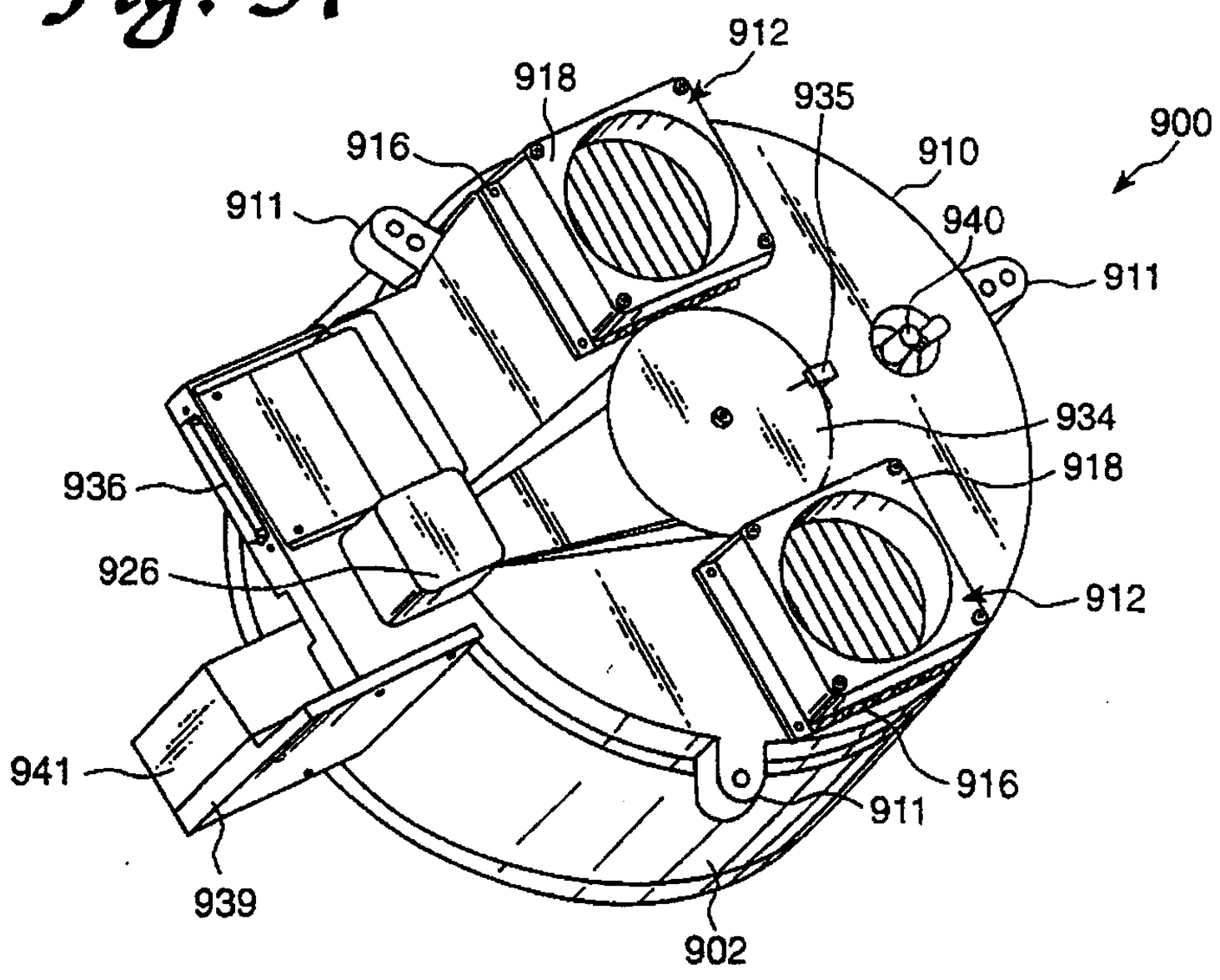

939
941
942
926
931
928
936
910
1944
1948
911
912
1946
1945
909
1941
911
1942
904
937
937
933

Fig. 37


912
918
916
911
935
910
900
940
911
934
918
936
926
912
941
939
911
916
902

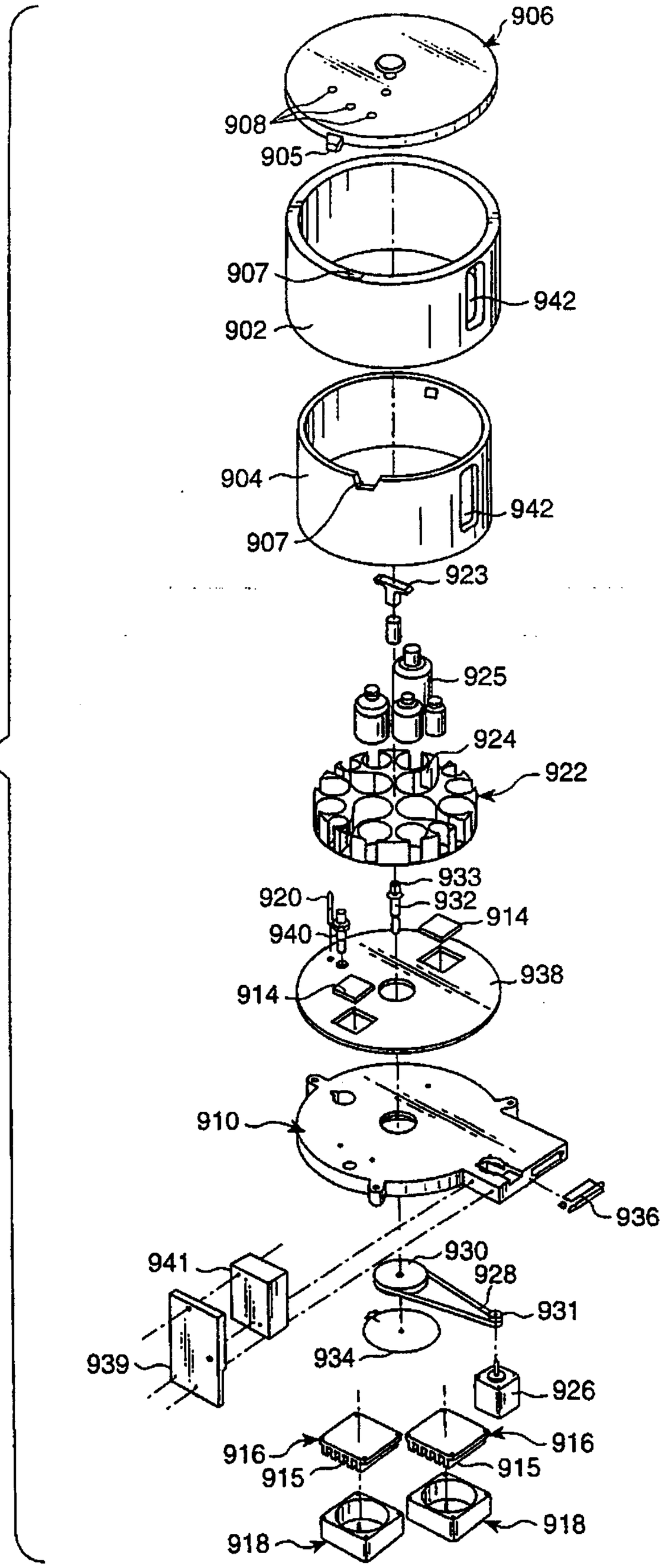

906
908
905
907
942
902
904
907
942
923
925
924
922
933
920
932
914
940
938
914
910
936
941
930
928
931
939
934
926
916
915
916
915
918
918

Fig. 38

Fig. 39

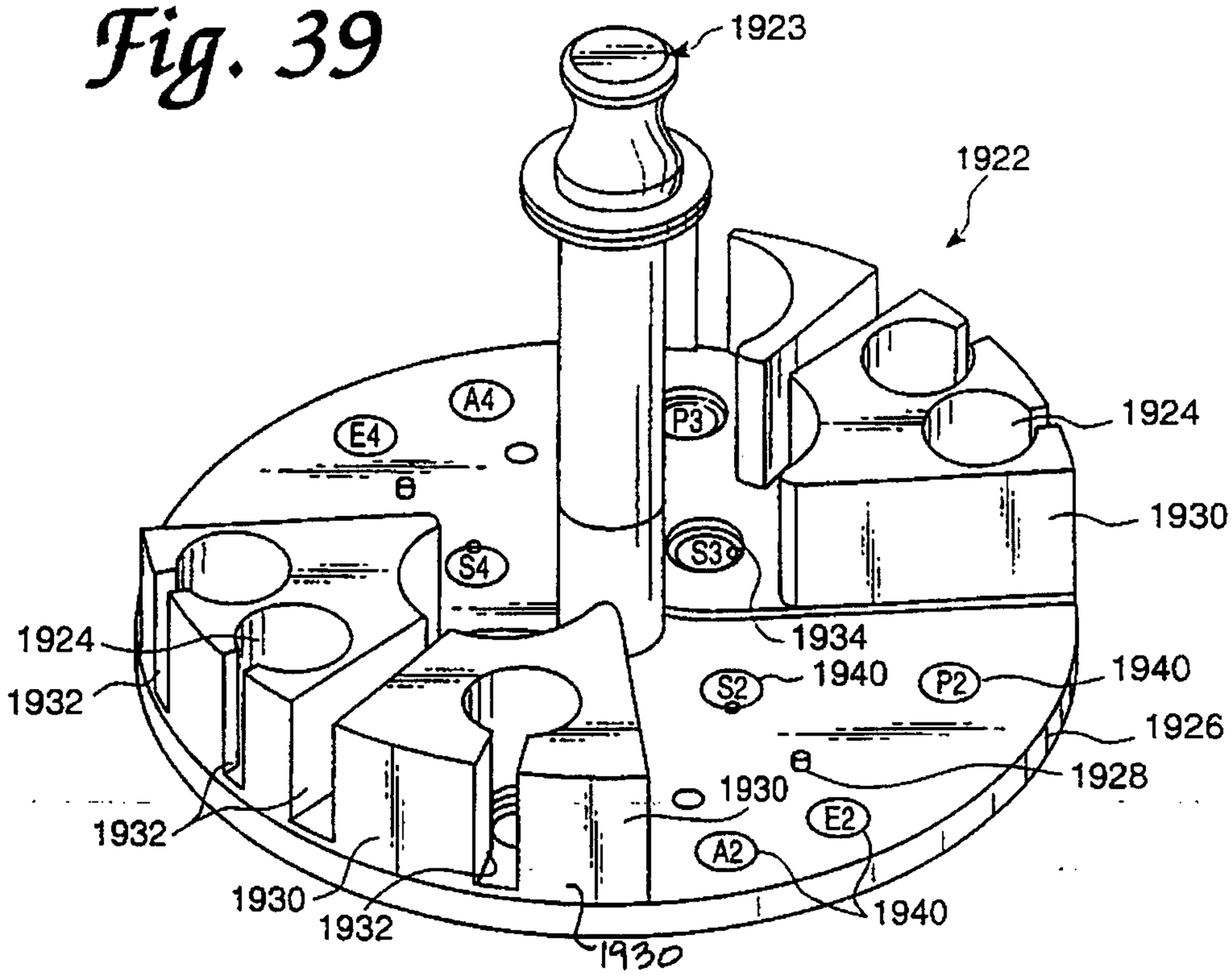

1923
1922
A4
E4
P3
1924
1930
S4
S3
1934
1924
1940
1932
S2
1940
P2
1926
1928
1930
1932
E2
A2
1930
1932
1940
1930

Fig. 40

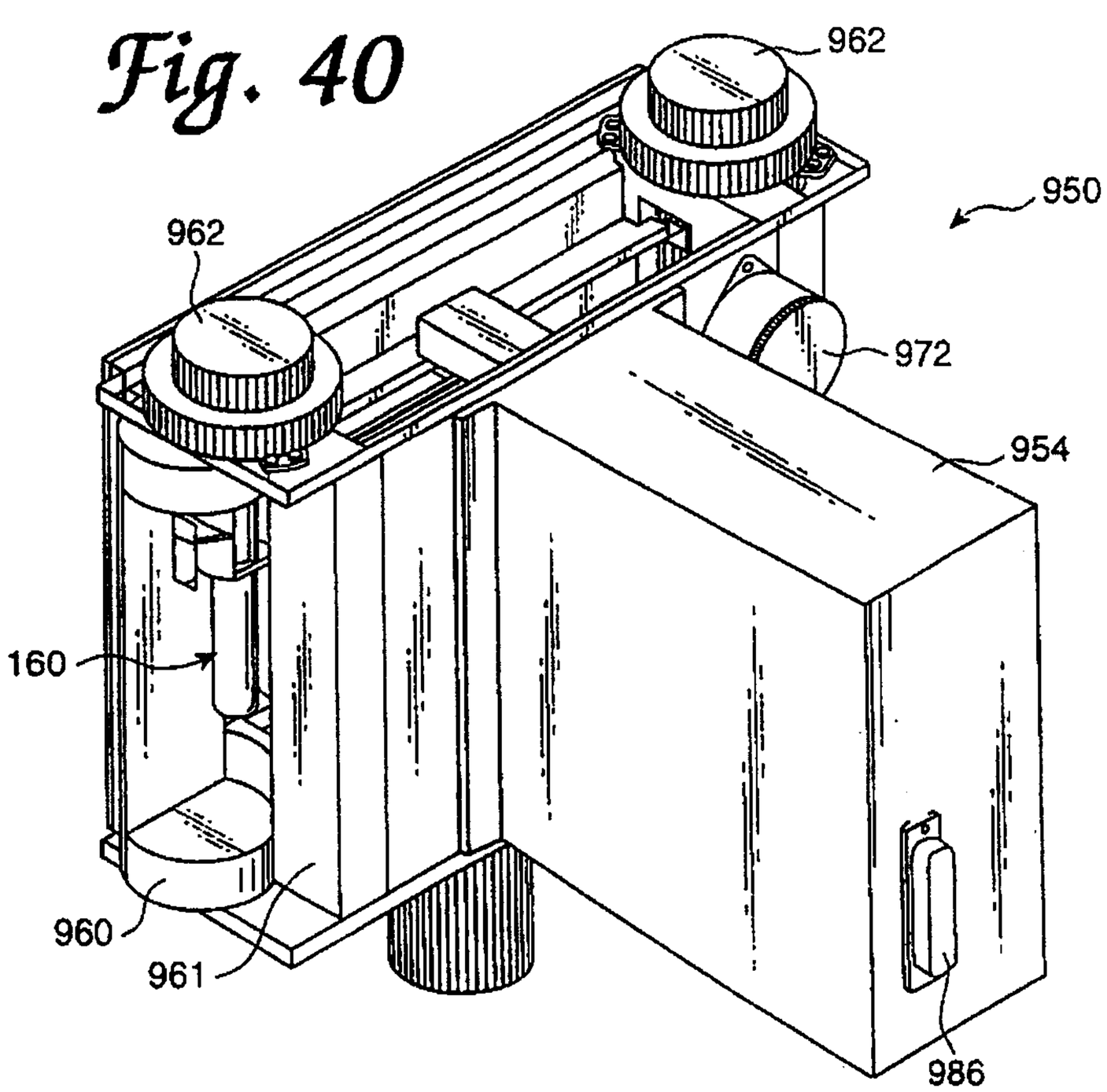

962
950
962
972
954
160
960
961
986

Fig. 41

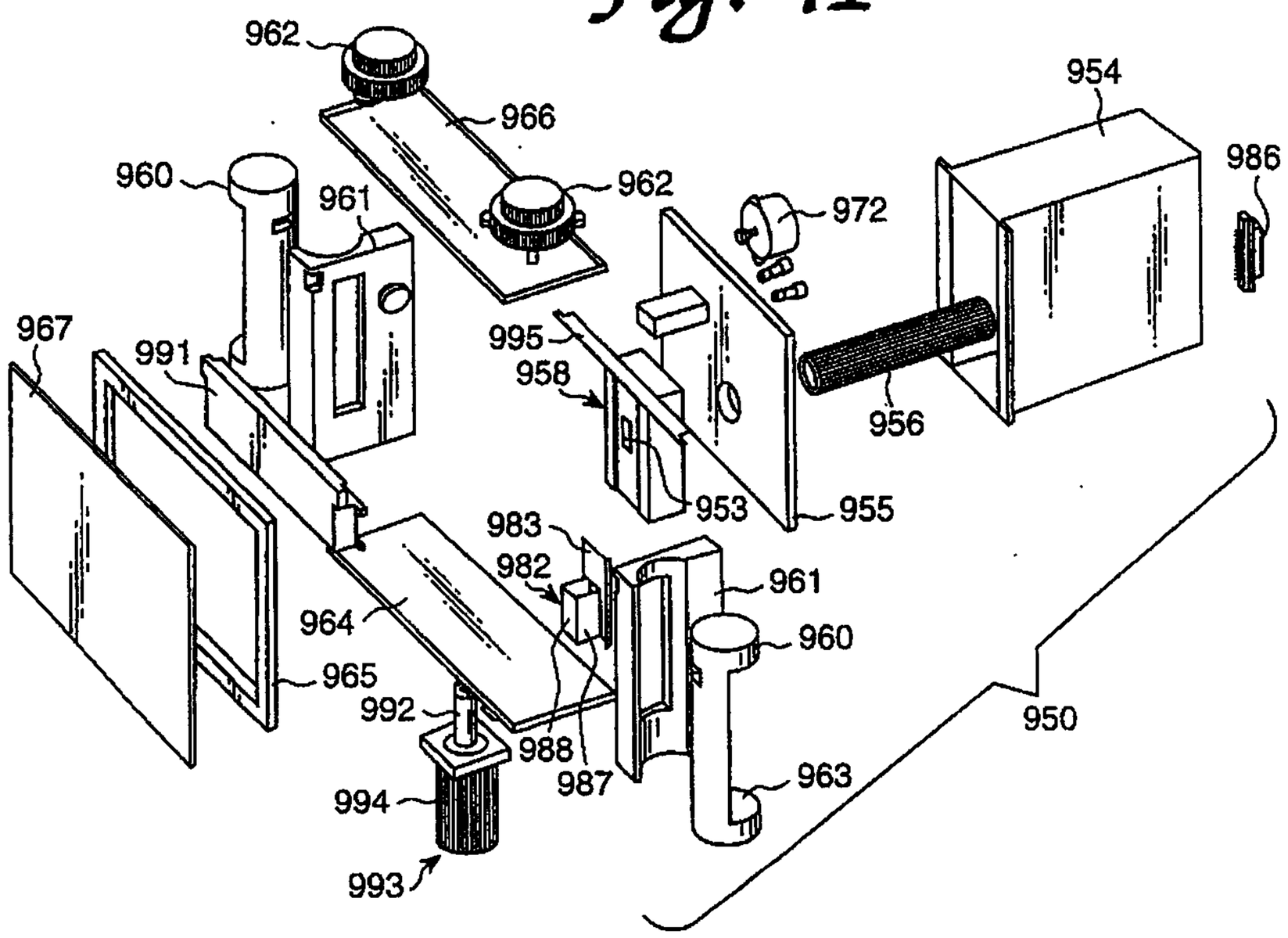

962
966
960
961
962
954
986
972
967
991
995
958
956
953
955
983
982
961
960
964
965
992
988
987
963
994
993
950

Fig. 42A

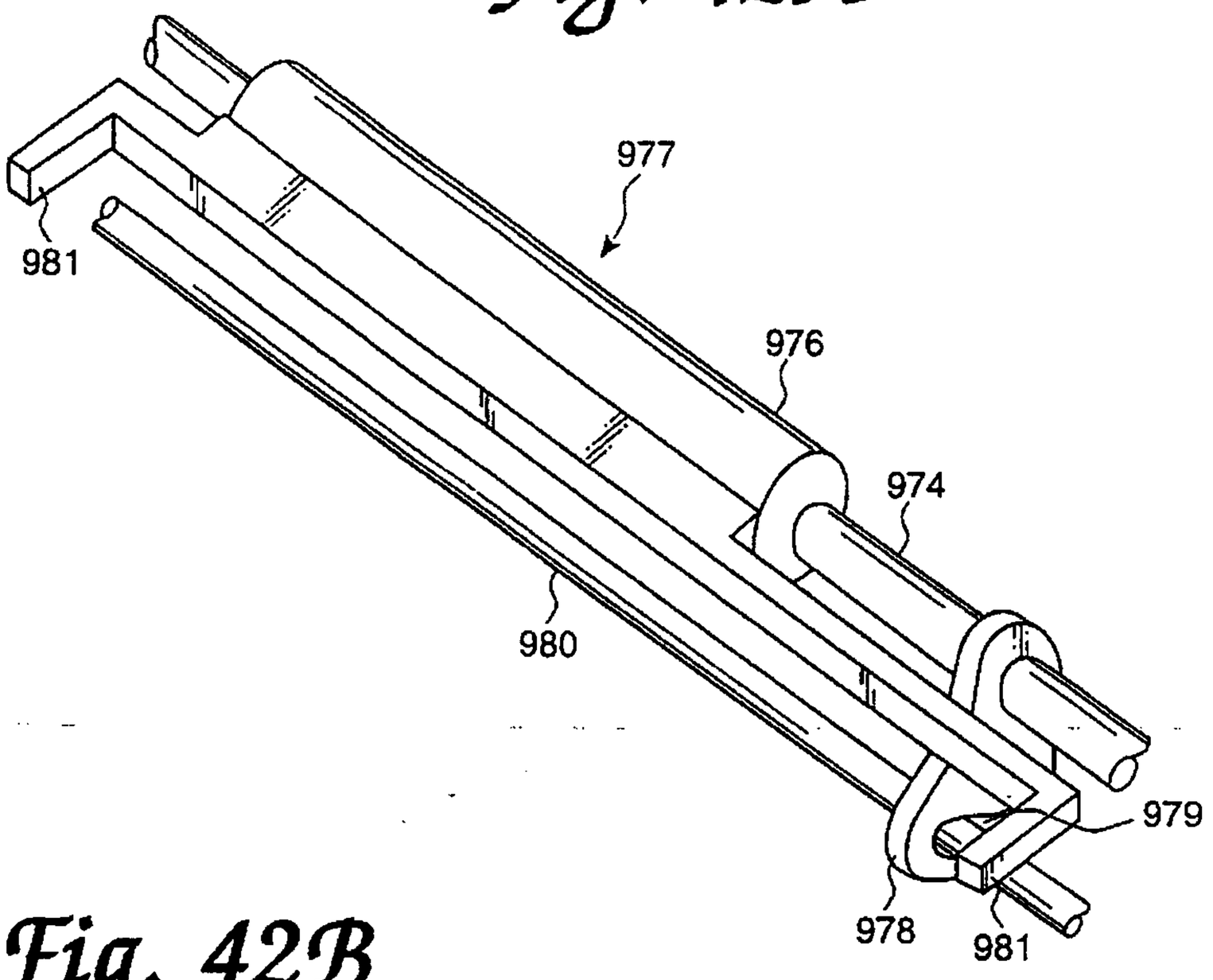


Fig. 42B

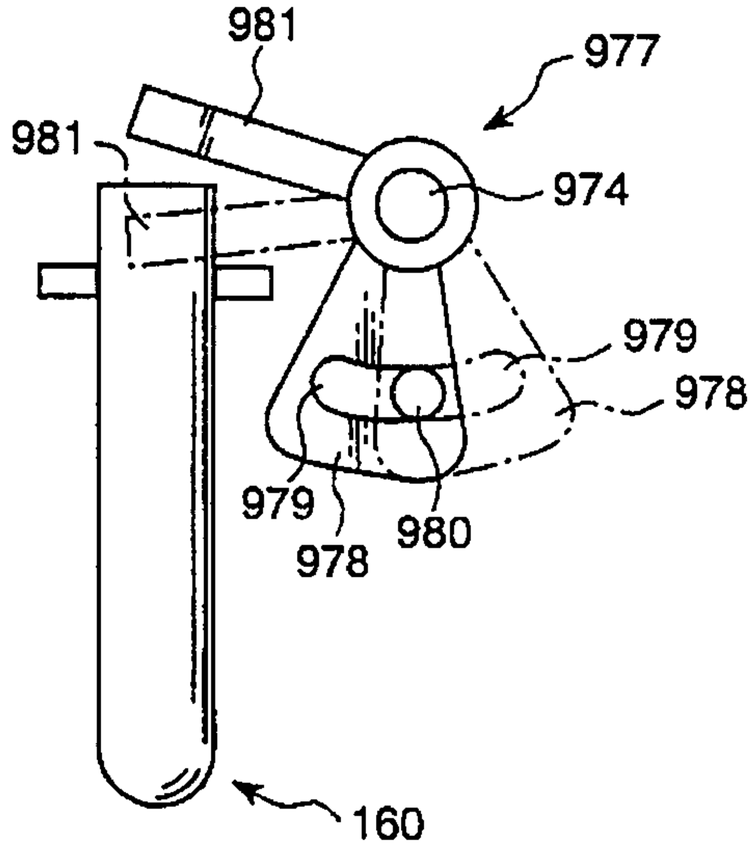


Fig. 42C

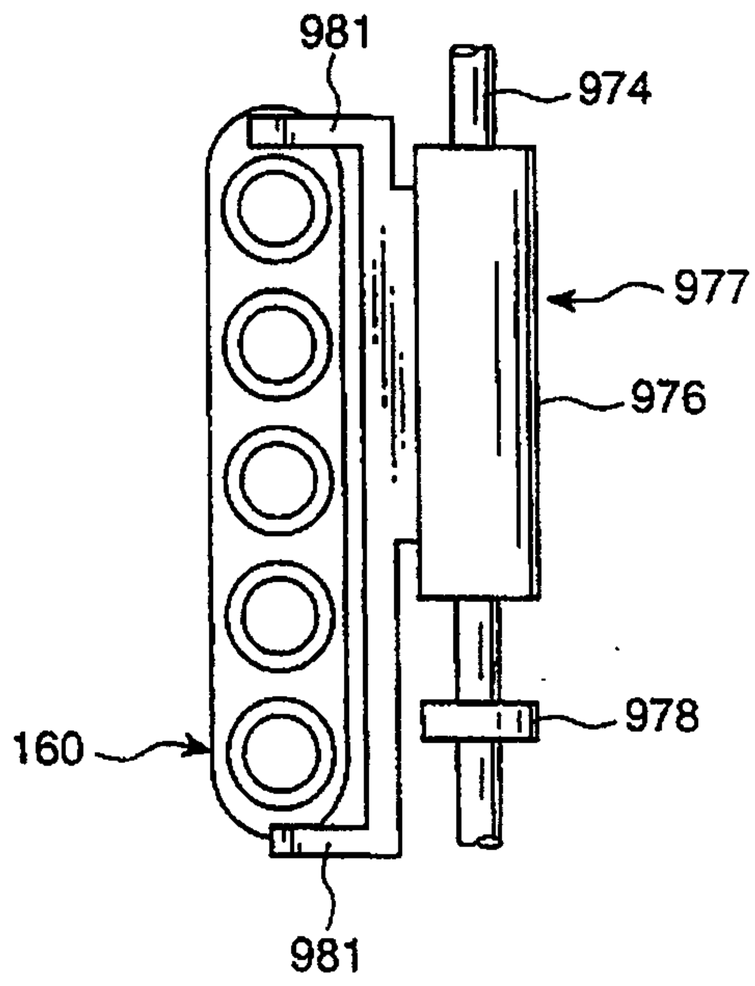
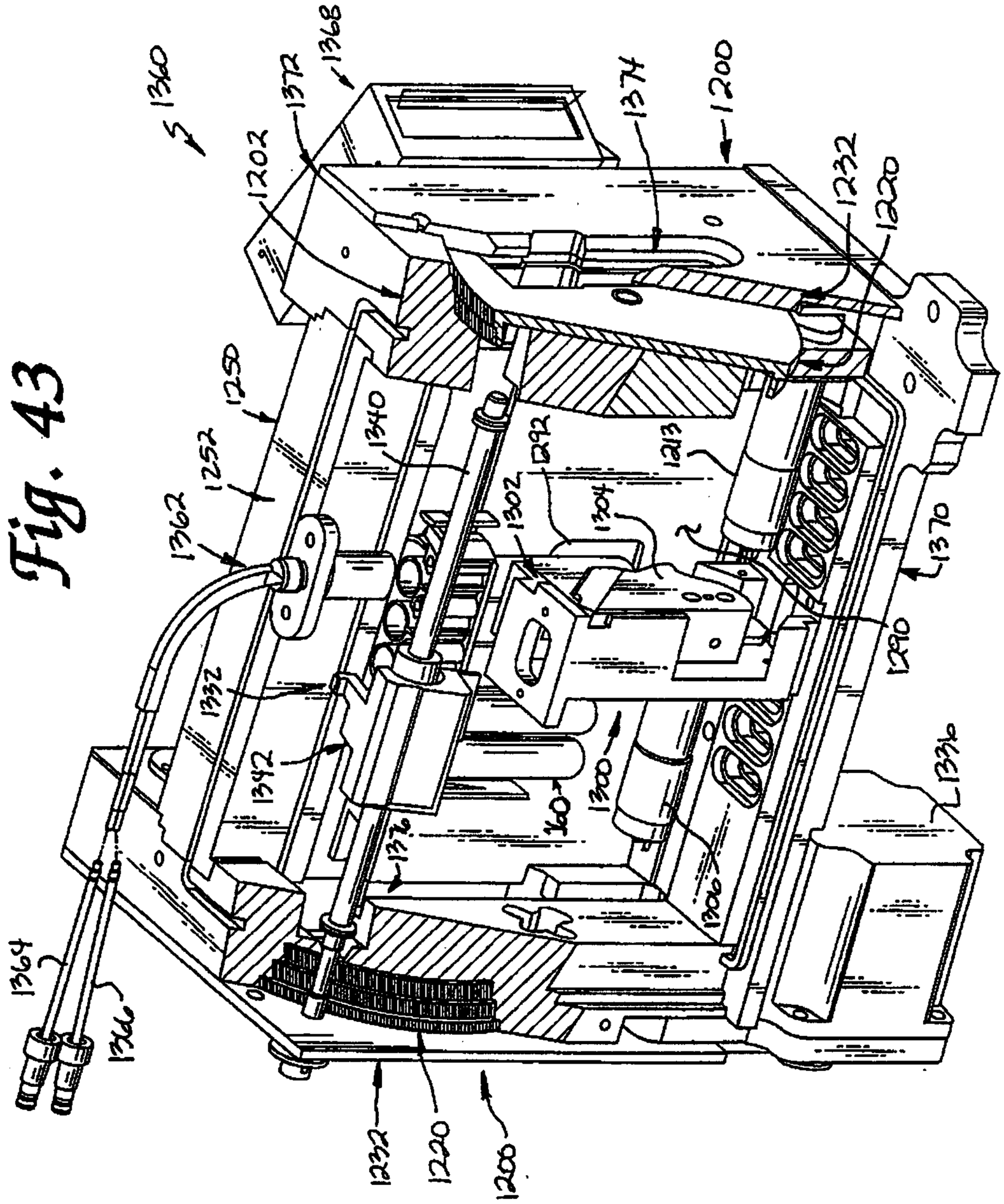


Fig. 43


1340
1372
1368
1202
1374
1200
1232
1220
1250
1252
1340
1342
1362
1304
1302
1370
1290
1332
1342
1372
1300
1306
1334
1344
1346
1222
1220
200

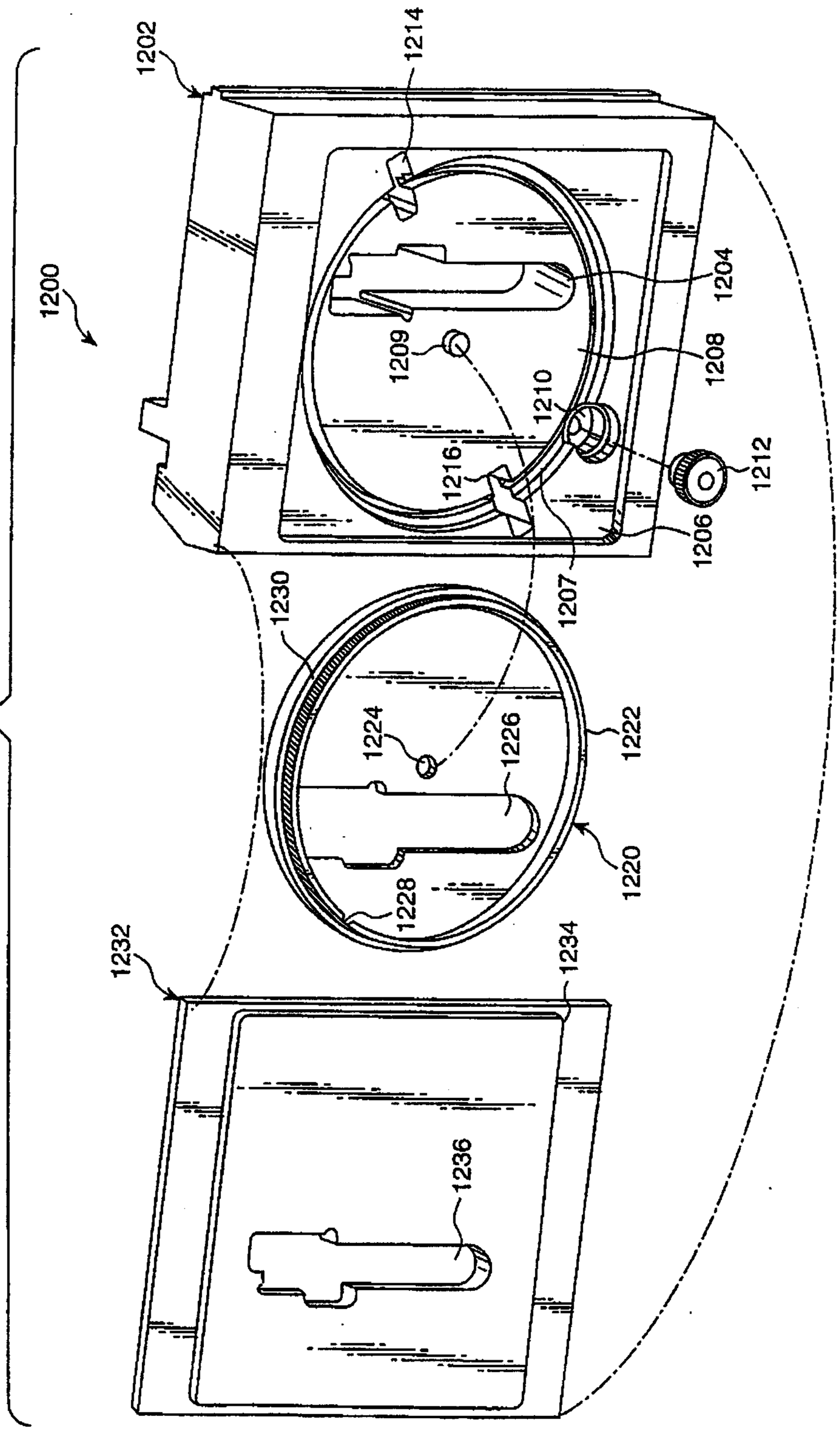

1202
1214
1200
1204
1209
1208
1210
1216
1212
1206
1207
1230
1224
1226
1222
1220
1228
1232
1234
1236

Fig. 44

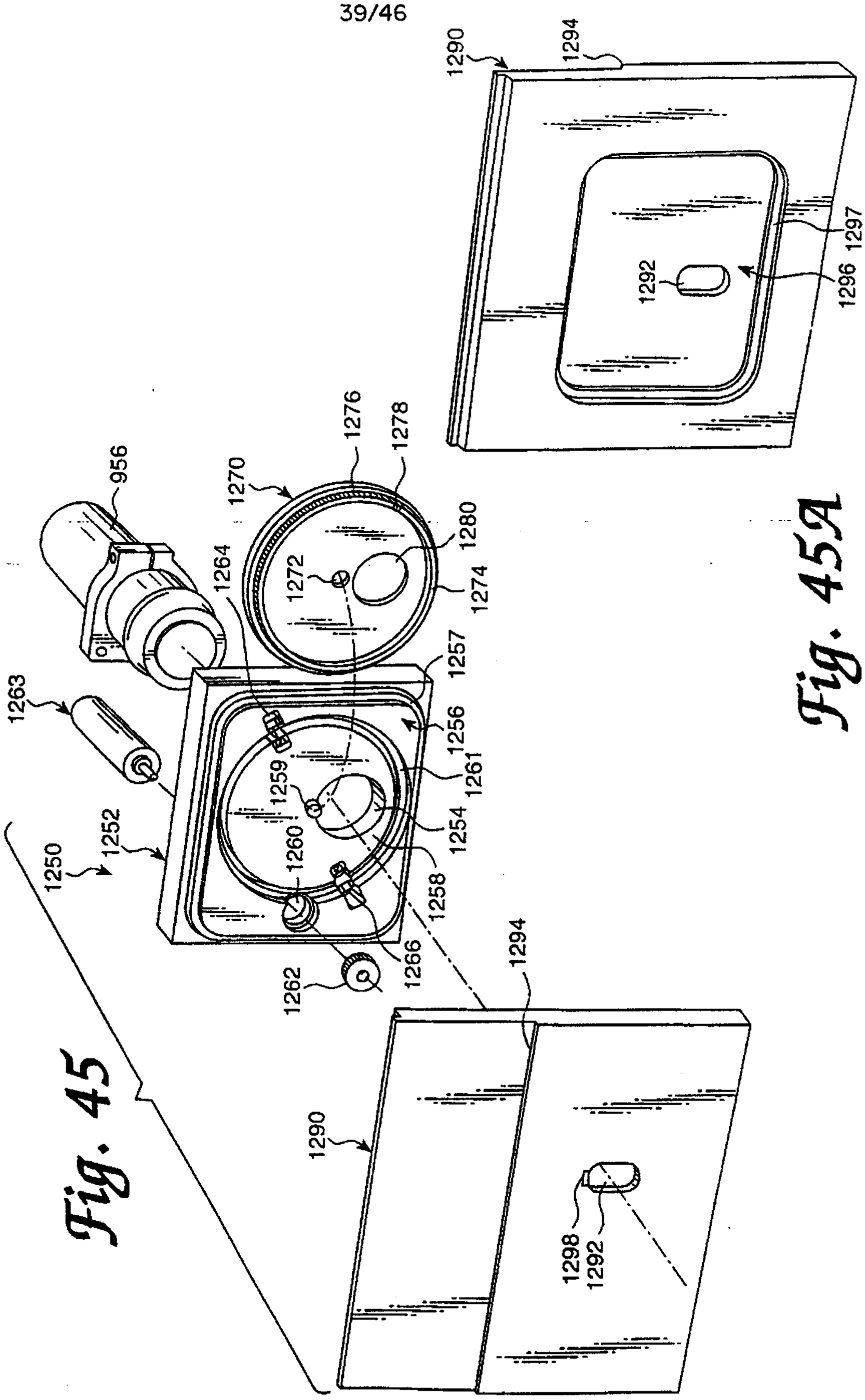

1290
1294
1297
1296
1292
956
1270
1276
1278
1280
1264
1272
1274
1257
1263
1256
1261
1259
1254
1260
1258
1252
1250
1262
1266
1294
1290
1298
1292

Fig. 45A

Fig. 46

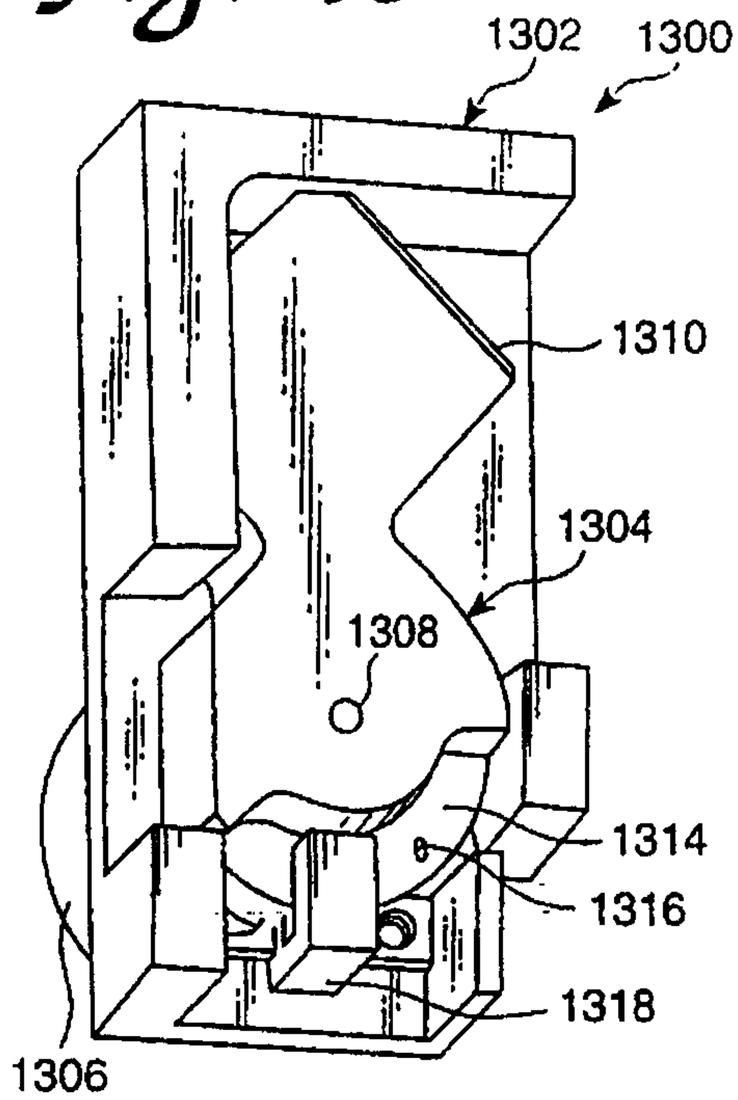


Fig. 47

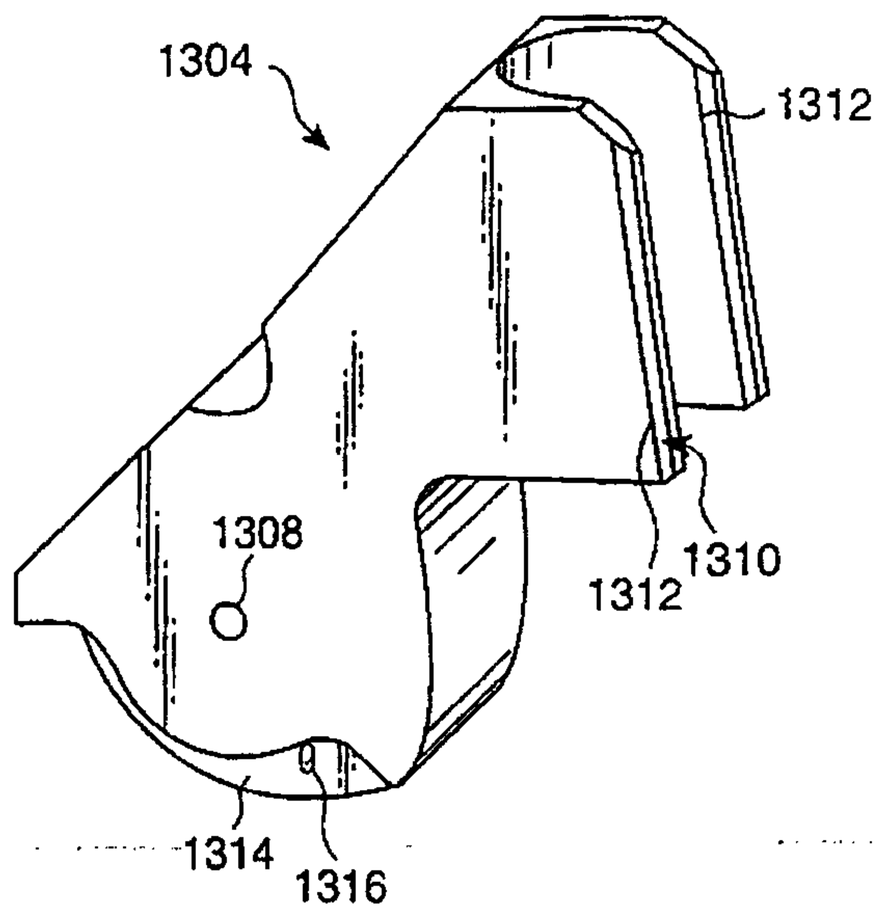


Fig. 48

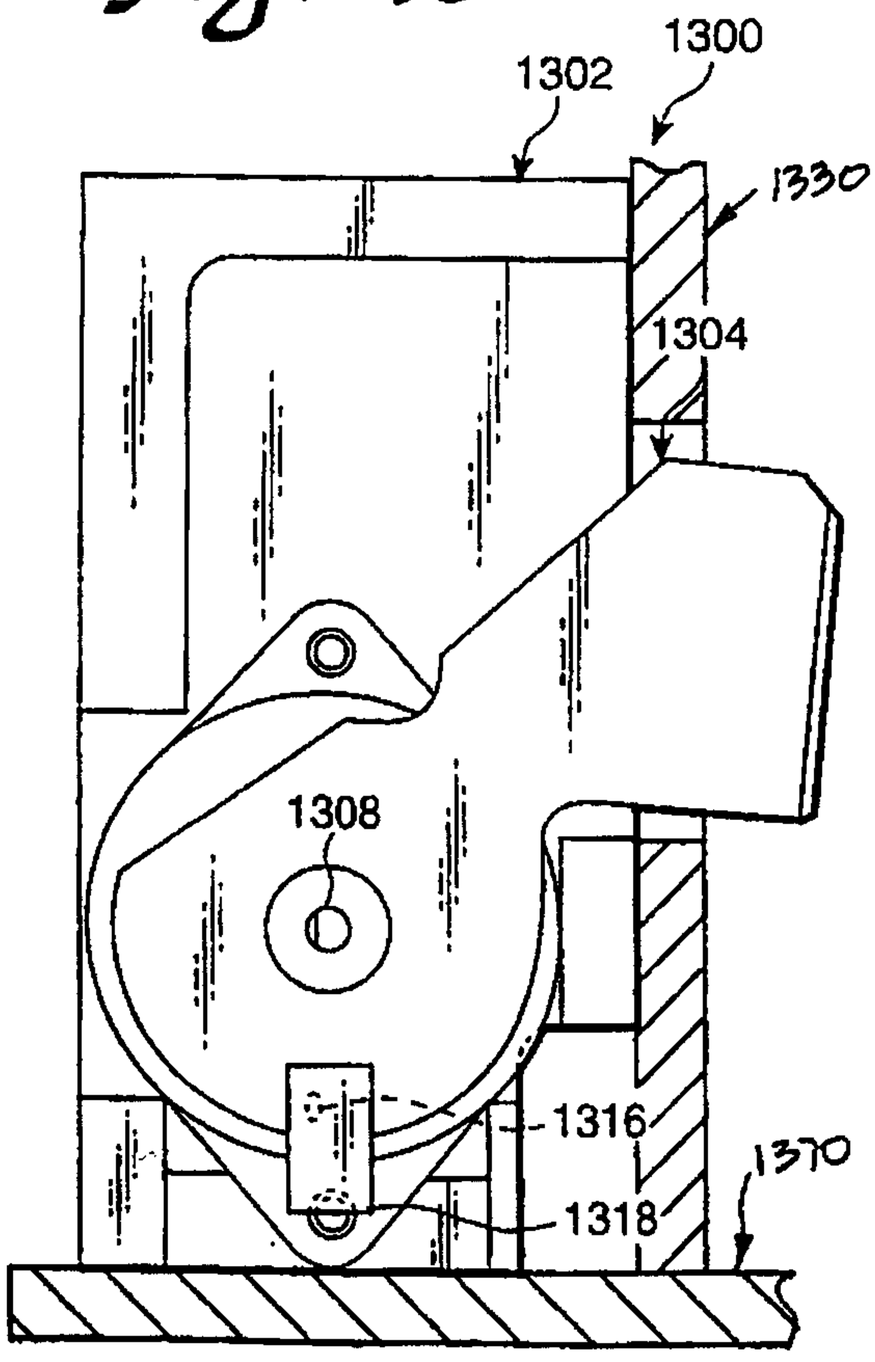


Fig. 49

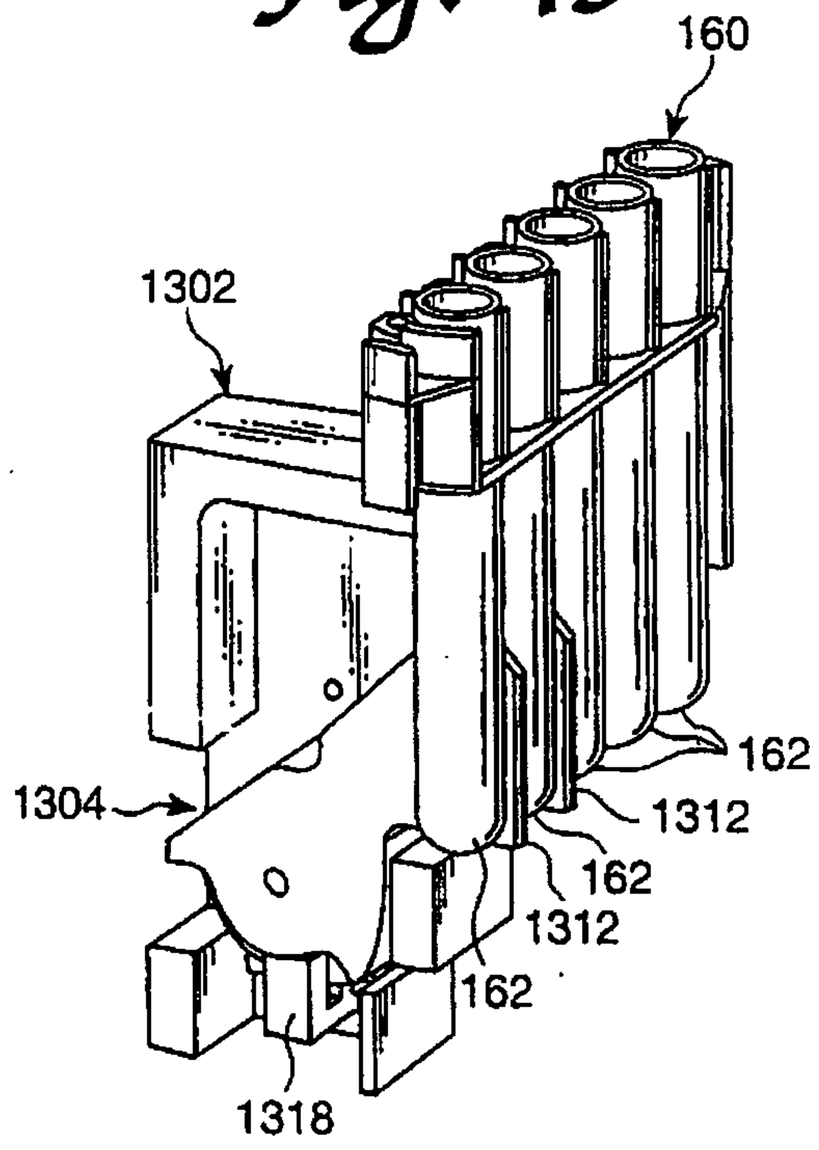


Fig. 50

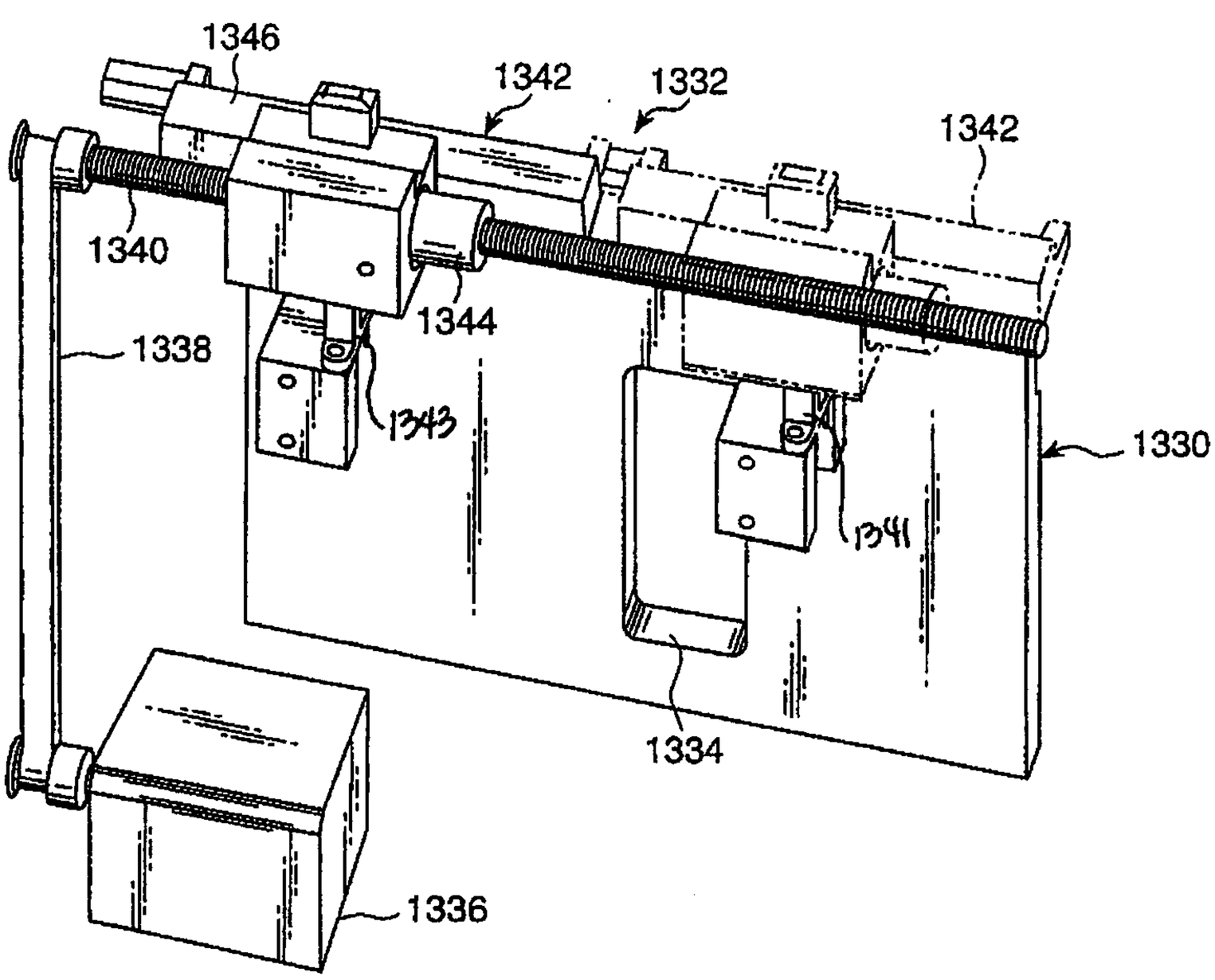
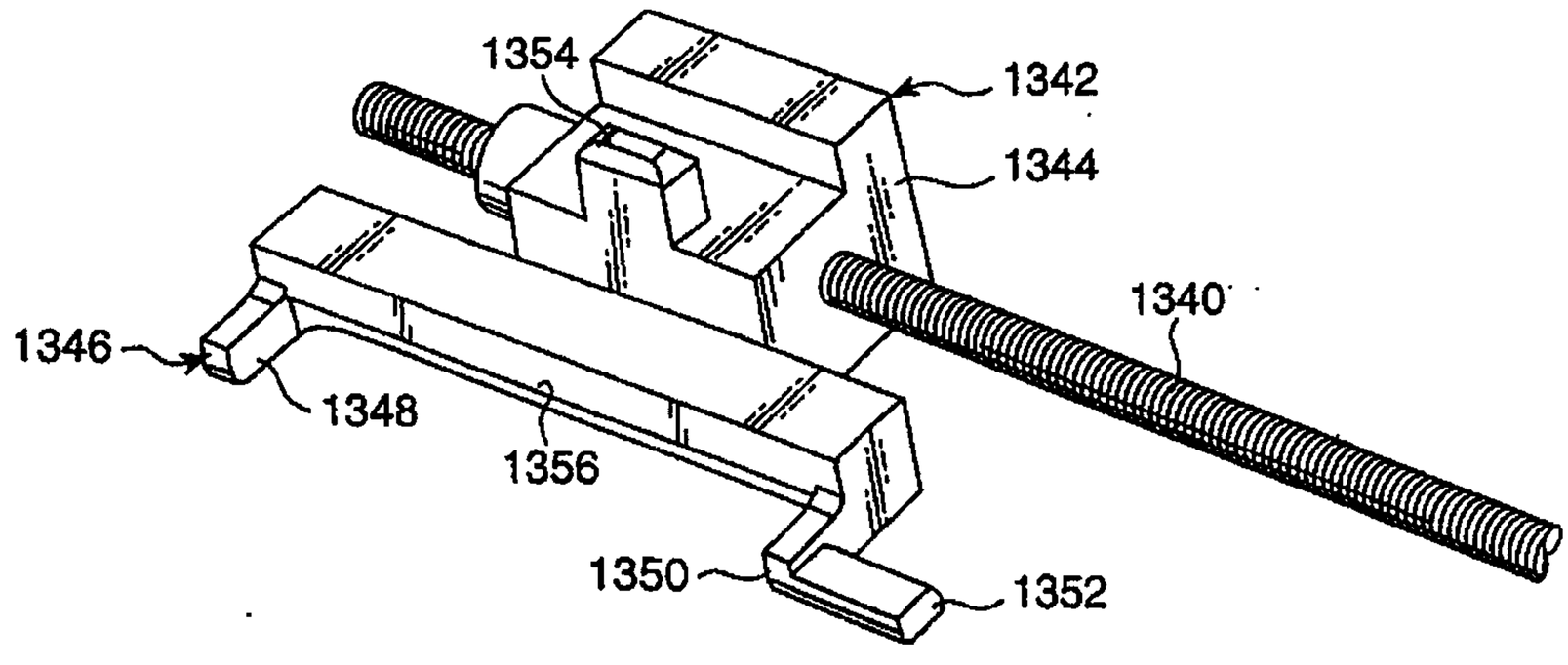

1346
1342
1332
1342
1340
1344
1338
1343
1330
1341
1334
1336

Fig. 51


1354
1342
1344
1340
1346
1348
1356
1350
1352

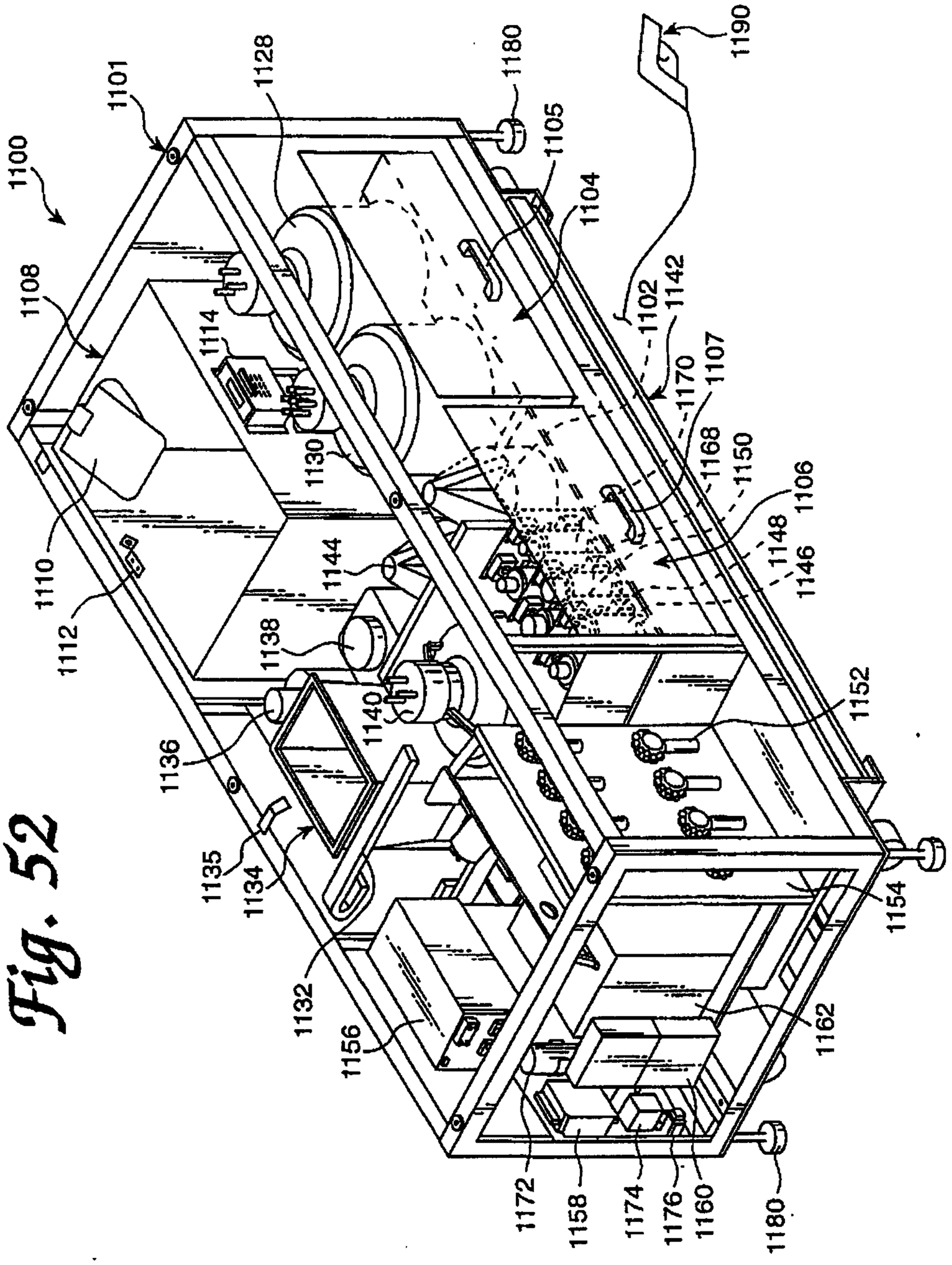
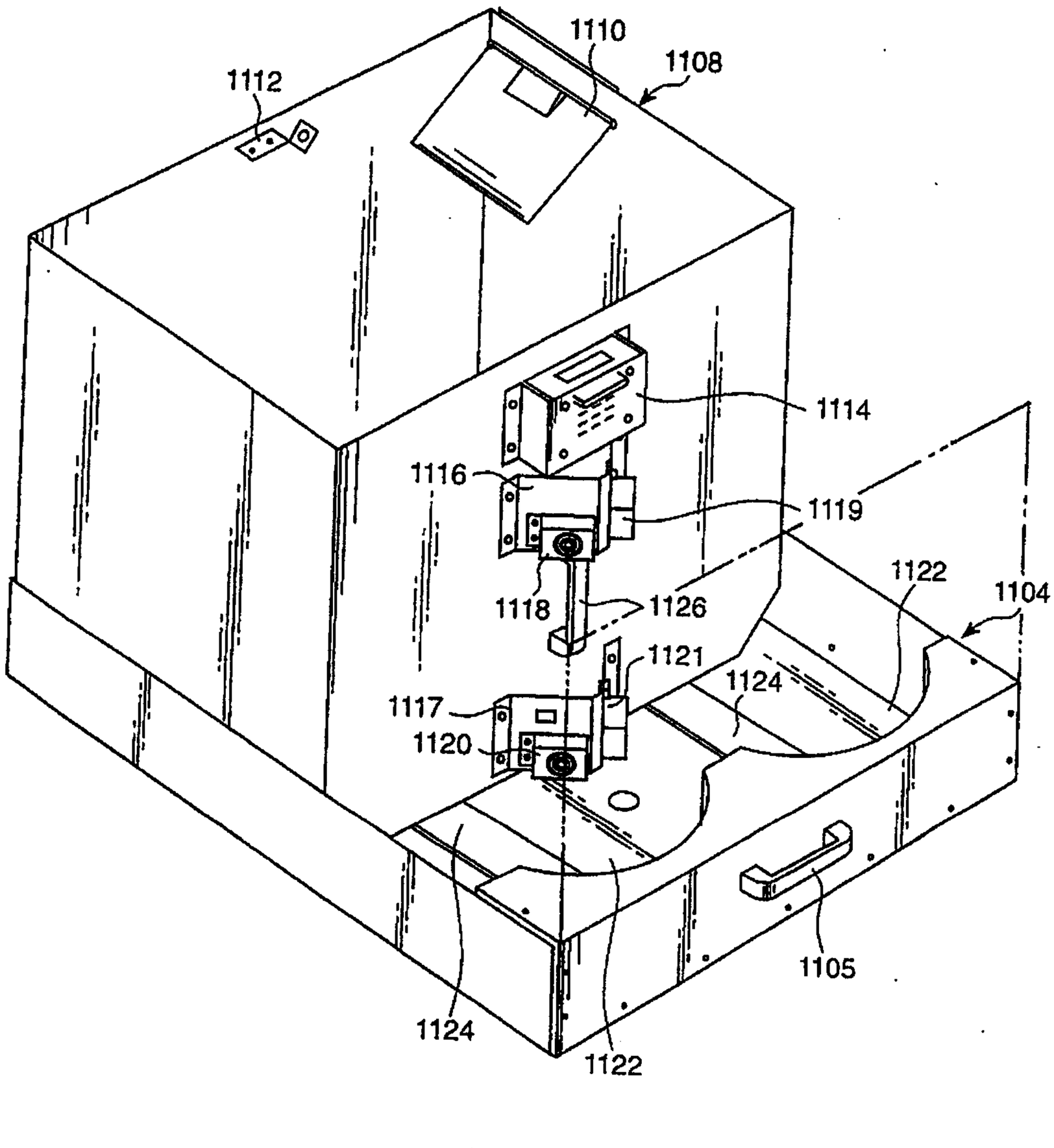

1100
1101
1128
1180
1105
1104
1190
1102
1142
1107
1170
1168
1150
1106
1148
1146
1108
1114
1130
1110
1144
1112
1138
1140
1152
1136
1135
1134
1154
1132
1156
1162
1172
1158
1174
1176
1160
1180

Fig. 52

Fig. 53


1110
1108
1112
1114
1116
1119
1122
1104
1118
1126
1121
1124
1117
1120
1124
1122
1105

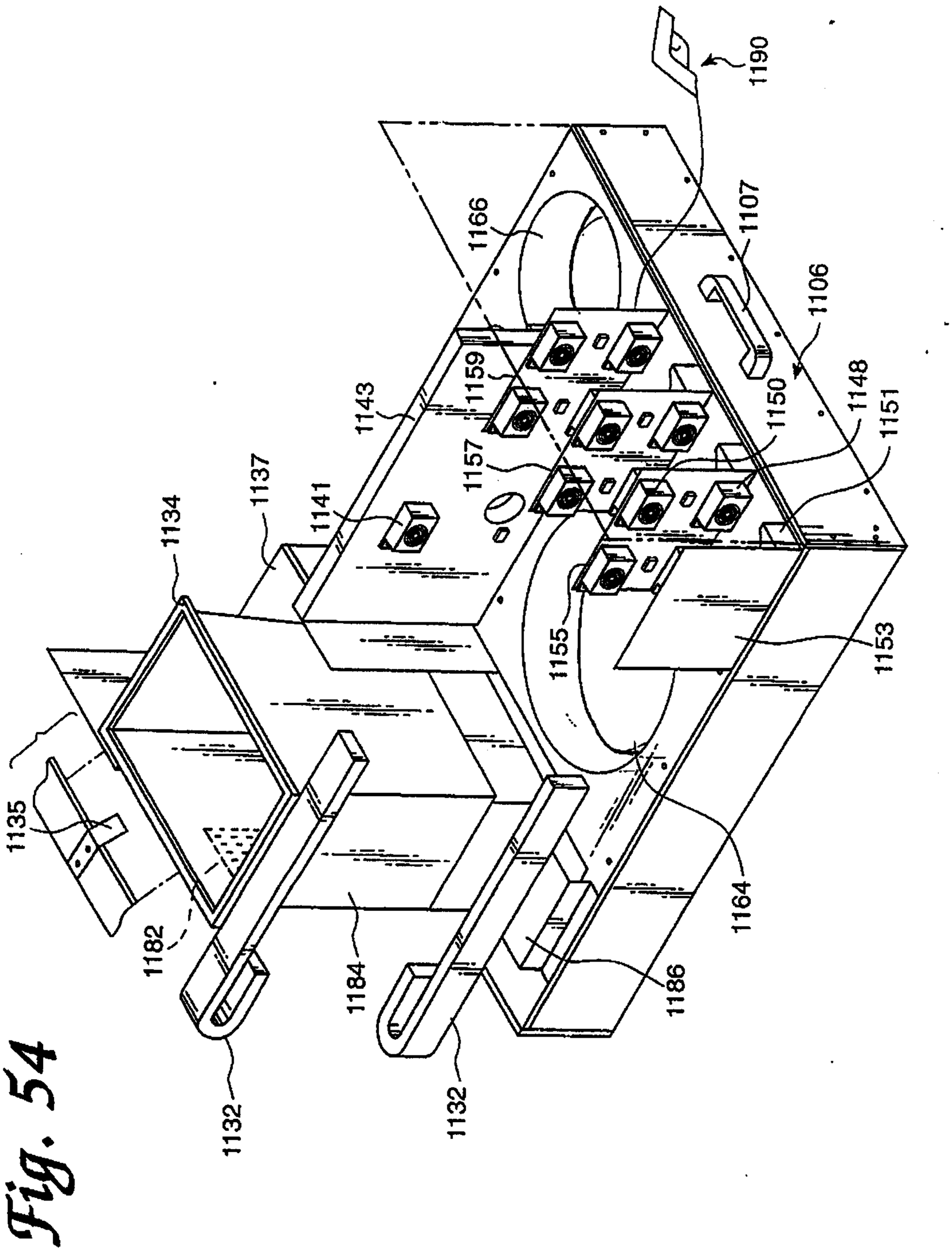

1190
1166
1107
1106
1159
1143
1148
1150
1151
1157
1137
1141
1134
1155
1153
1135
1164
1182
1184
1186
1132
1162

Fig. 54

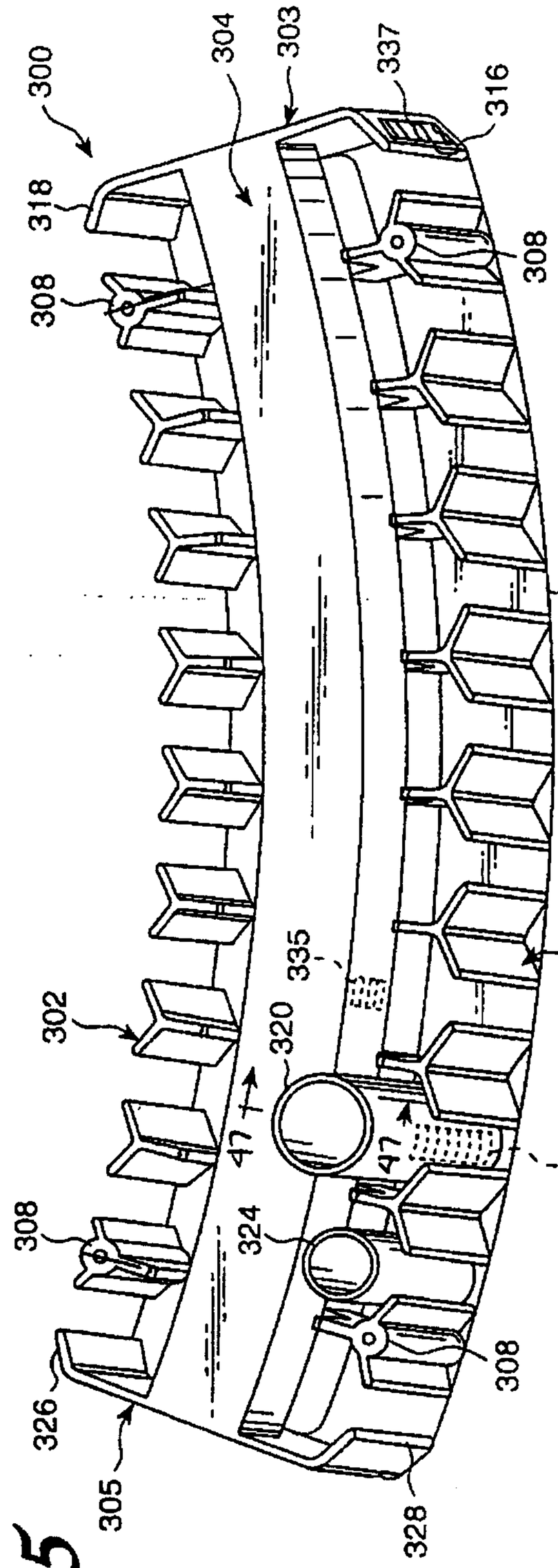


Fig. 55

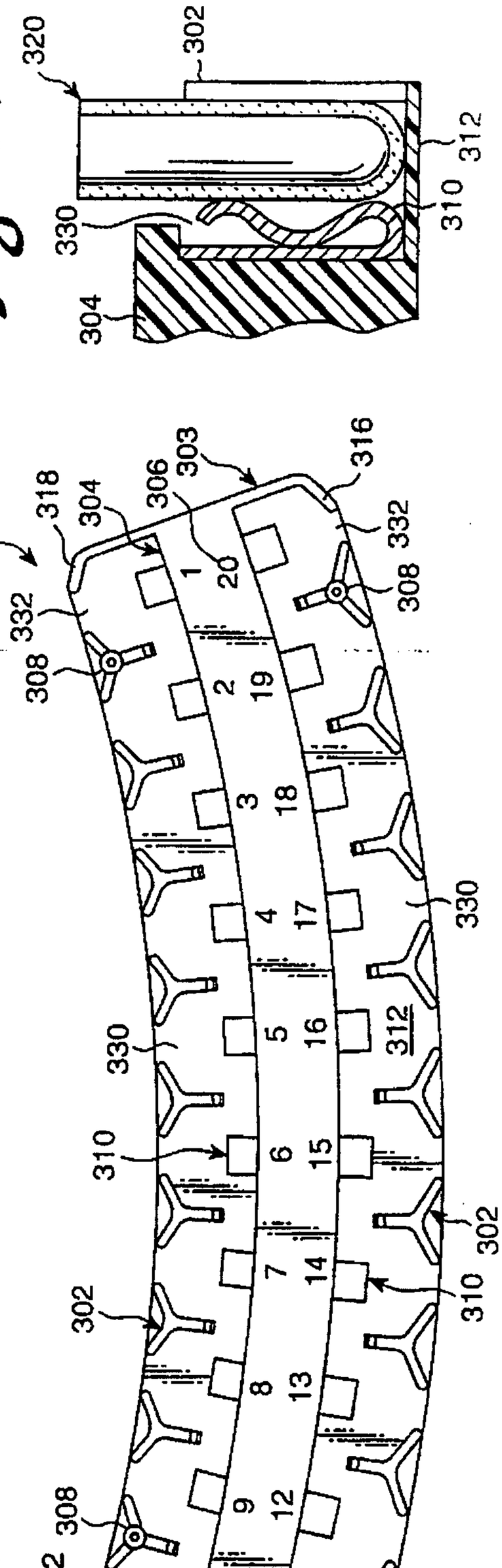


Fig. 56

Fig. 57

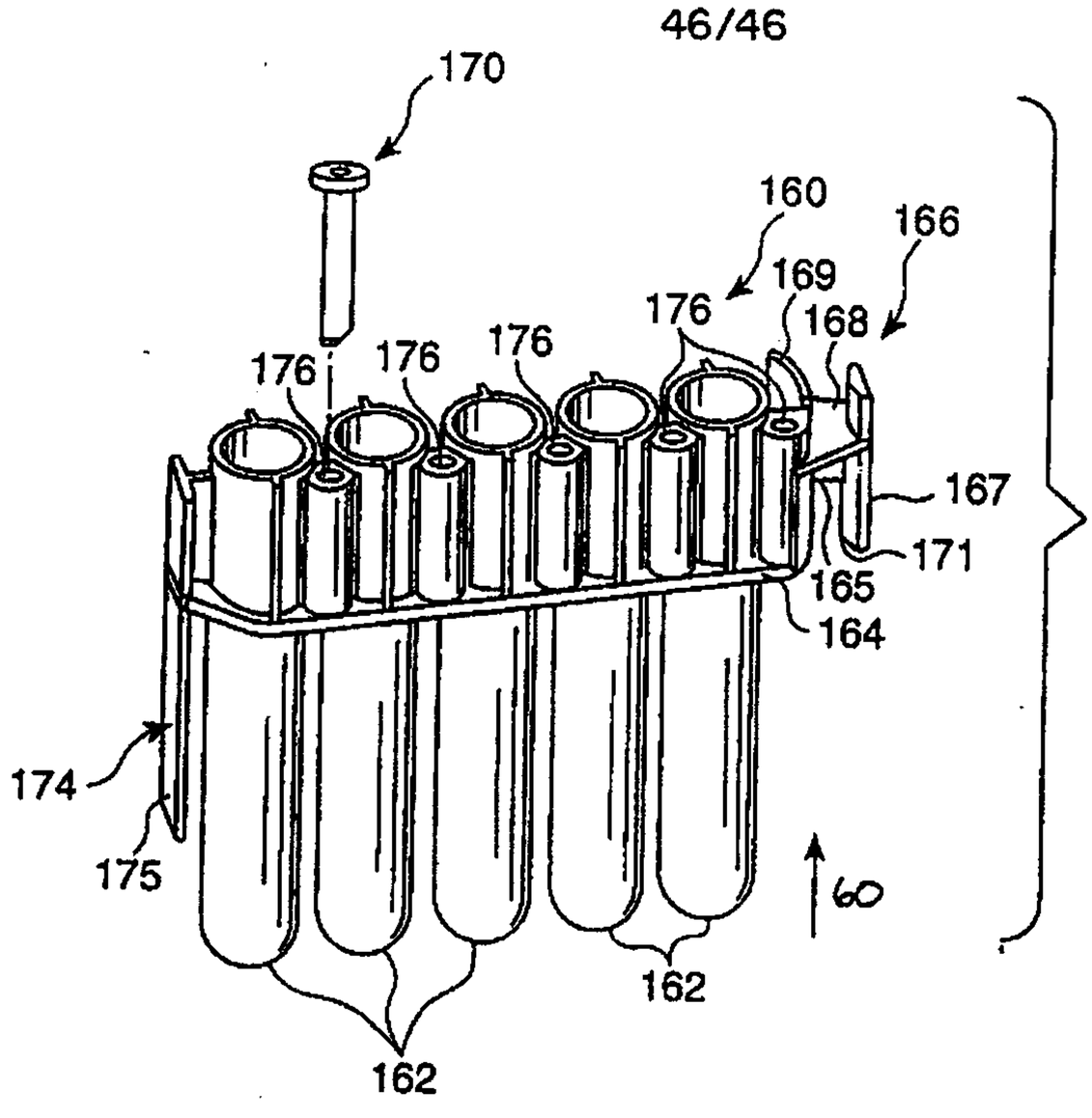


Fig. 58

Fig. 59

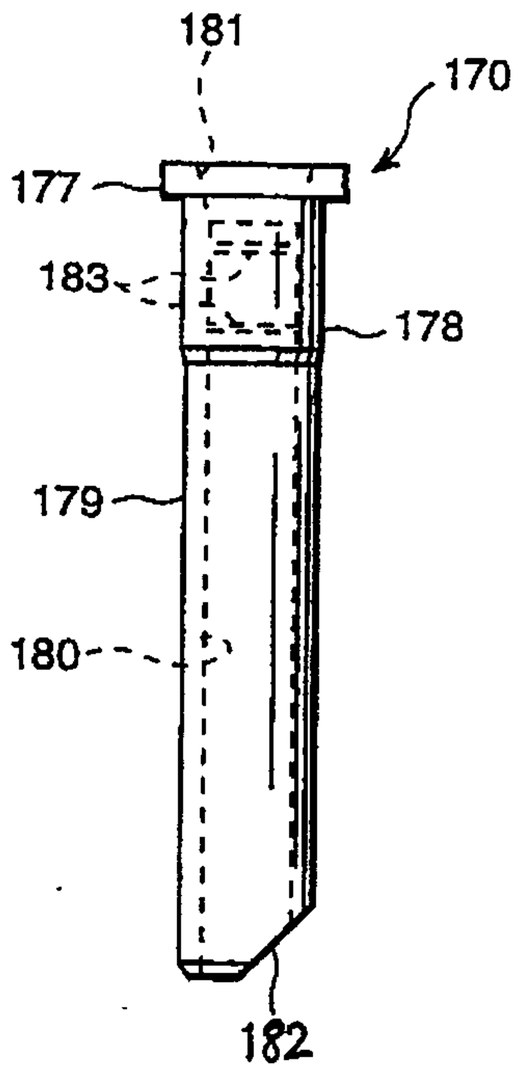
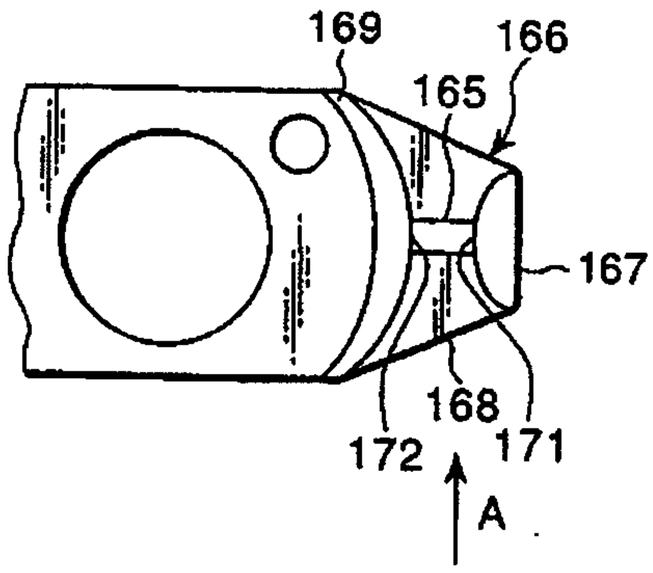
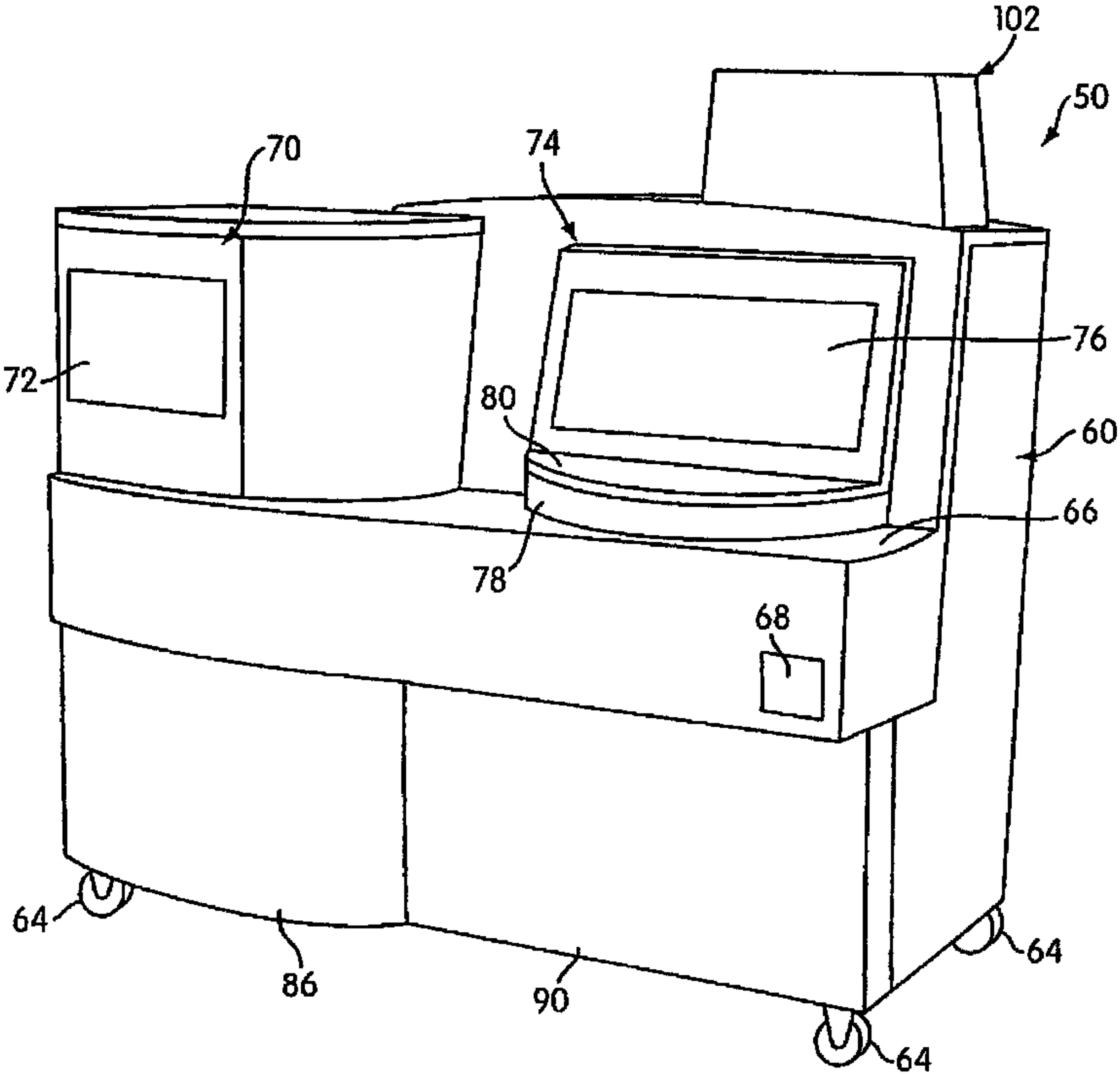


Fig. 60




102
50
70
74
72
76
80
60
66
78
68
64
86
90
64
64