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**Bianchi**

(10) **Patent No.:** **US 7,352,938 B2**  
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(54) **DRIVE FOR SYSTEM FOR PROCESSING FIBER OPTIC CONNECTORS**

4,819,386 A 4/1989 Struyf  
4,831,784 A 5/1989 Takahashi  
4,832,435 A 5/1989 Suzuki et al.  
4,850,152 A 7/1989 Heynacher et al.  
4,891,916 A 1/1990 Rhoades et al.

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 294 days.

(Continued)

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **10/890,527**

DE 40 04 665 A1 8/1991

(22) Filed: **Jul. 12, 2004**

(65) **Prior Publication Data**

(Continued)

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OTHER PUBLICATIONS

**Related U.S. Application Data**

“ADC FasTerm® Singlemode UPC and Multimode LX.5® Connector Installation Instructions,” *ADC Telecommunications, Inc.*, Issue 2, pp. 1-26 (May 2002).

(60) Provisional application No. 60/579,755, filed on Jun. 14, 2004.

(Continued)

(51) **Int. Cl.**

**G02B 6/00** (2006.01)  
**G02B 6/04** (2006.01)  
**G02B 6/06** (2006.01)

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(52) **U.S. Cl.** ..... **385/115**; 385/116; 385/147

(58) **Field of Classification Search** ..... 385/115  
See application file for complete search history.

(57) **ABSTRACT**

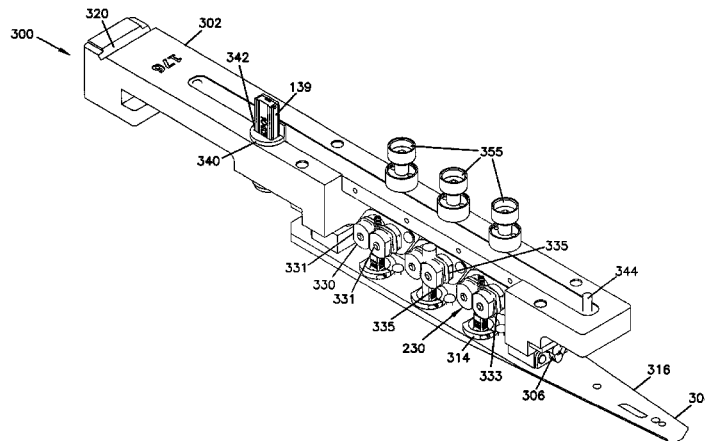
An apparatus for moving a fiber including a plurality of fiber optic connectors through a system for processing the plurality of fiber optic connectors. The apparatus can include a first drive mechanism for moving the fiber through the system, such as a cart and a conveyor. The apparatus can include a second drive mechanism for moving the plurality of fiber optic connectors through the system, such as a screw drive. The apparatus can also include a controller for coordinating movement of the first drive mechanism with the second drive mechanism.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,577,312 A 12/1951 Donahue  
3,868,794 A 3/1975 Zitkus  
4,291,502 A 9/1981 Grimsby et al.  
4,498,260 A 2/1985 Doty  
4,587,768 A 5/1986 Doyle  
4,649,670 A 3/1987 Snyder  
4,693,035 A 9/1987 Doyle  
4,709,512 A 12/1987 Okubo et al.  
4,802,680 A 2/1989 Fuchs

**8 Claims, 34 Drawing Sheets**



## U.S. PATENT DOCUMENTS

4,905,415 A 3/1990 Moulin  
 4,944,079 A 7/1990 Nakamura et al.  
 4,979,334 A 12/1990 Takahashi  
 5,107,627 A 4/1992 Mock, Jr. et al.  
 5,136,820 A 8/1992 Luther  
 5,184,433 A 2/1993 Maack  
 5,201,148 A 4/1993 Rupert et al.  
 5,216,846 A 6/1993 Takahashi  
 5,218,786 A 6/1993 Takahashi  
 5,265,381 A 11/1993 Takahashi  
 5,281,884 A 1/1994 Basavanhally et al.  
 5,317,663 A 5/1994 Beard et al.  
 5,321,917 A 6/1994 Franklin et al.  
 5,345,323 A 9/1994 Basavanhally et al.  
 5,349,784 A 9/1994 Grois et al.  
 5,351,445 A 10/1994 Takahashi  
 5,403,227 A 4/1995 Franklin et al.  
 5,447,464 A 9/1995 Franklin et al.  
 5,458,528 A 10/1995 Lurie et al.  
 5,458,531 A 10/1995 Matsuoka et al.  
 5,461,689 A 10/1995 Matsuoka et al.  
 5,516,328 A 5/1996 Kawada  
 5,547,418 A 8/1996 Takahashi  
 5,556,323 A 9/1996 Luther et al.  
 5,559,916 A 9/1996 Terao et al.  
 5,577,149 A 11/1996 Averbeck et al.  
 5,601,474 A 2/1997 Takahashi  
 5,643,064 A 7/1997 Grinderslev et al.  
 5,667,426 A 9/1997 Minami et al.  
 5,674,114 A 10/1997 Miller et al.  
 5,711,701 A 1/1998 Grinderslev et al.  
 5,720,653 A 2/1998 Miller et al.  
 5,741,171 A 4/1998 Sarfaty et al.  
 5,743,787 A 4/1998 Ishiyama et al.  
 5,770,001 A 6/1998 Nagayama et al.  
 5,778,125 A 7/1998 Busse et al.  
 5,813,902 A 9/1998 Wiegand  
 5,947,797 A 9/1999 Buzzetti  
 6,077,154 A 6/2000 Takashi et al.  
 6,106,368 A 8/2000 Childers et al.  
 6,110,013 A 8/2000 Minami et al.  
 6,113,469 A 9/2000 Yoshikawa et al.  
 6,126,519 A 10/2000 Minami et al.  
 6,157,863 A 12/2000 Chandler et al.  
 6,165,055 A 12/2000 Takahashi et al.  
 6,183,343 B1 2/2001 Buzzetti  
 6,190,239 B1 2/2001 Buzzetti  
 6,257,971 B1 7/2001 Takahashi et al.  
 6,276,842 B1 8/2001 Xu et al.  
 6,280,293 B1 8/2001 Minami et al.  
 6,302,763 B1 10/2001 Buzzetti  
 6,302,773 B1 10/2001 Kato et al.  
 6,347,974 B1 2/2002 Chandler et al.  
 6,396,996 B1\* 5/2002 Carpenter et al. .... 385/137  
 6,428,215 B1 8/2002 Nault  
 6,466,310 B2 10/2002 Nguyen et al.

6,599,030 B1 7/2003 Millmann  
 6,641,472 B2 11/2003 Boyer et al.  
 6,698,937 B2 3/2004 Grimes et al.  
 6,718,111 B1 4/2004 Suek et al.  
 6,733,184 B2 5/2004 Nguyen et al.  
 6,752,536 B2 6/2004 Boyer et al.  
 6,817,931 B2 11/2004 Minami  
 6,827,632 B2 12/2004 Zimmer et al.  
 6,831,738 B2 12/2004 Rogers et al.  
 6,860,646 B1 3/2005 Suek et al.  
 6,918,816 B2 7/2005 Bianchi  
 2001/0023164 A1 9/2001 Minami et al.  
 2002/0160700 A1 10/2002 Boyer et al.  
 2003/0007774 A1\* 1/2003 Christopher et al. .... 385/147  
 2003/0031447 A1 2/2003 Nault

## FOREIGN PATENT DOCUMENTS

DE 197 52 228 A1 5/1998  
 EP 0 579 056 A1 1/1994  
 EP 0 621 107 A1 10/1994  
 JP 59-161256 9/1984  
 JP 60-217055 10/1985  
 JP 61-113005 5/1986  
 JP 63-283854 11/1988  
 JP 63-316811 12/1988  
 JP 5-19140 1/1993  
 JP 5-157941 6/1993  
 JP 5-164942 6/1993  
 JP 6-138343 5/1994  
 SU 738825 6/1980  
 WO WO 98/14810 4/1998  
 WO WO 03/023537 A1 3/2003

## OTHER PUBLICATIONS

"SFP-550," *Seikoh Giken USA*, 2 pages (2004).  
 "MCP 24 Fixture Plates," *Nanometer Technologies*, 1 page (visited May 24, 2004).  
 "Fiber Optic," *Nanometer Technologies*, 1 page (visited May 24, 2004).  
 "MCP 24 Figure 8 Polishing," *Nanometer Technologies*, 1 page (visited May 24, 2004).  
 "MCP 24 Universal Polishing Fixture," *Nanometer Technologies*, 1 page (visited May 24, 2004).  
 "MCP 24 Advantages and Specs," *Nanometer Technologies*, 1 page (visited May 24, 2004).  
 "MCP 24 Mass Connector Polisher," *Nanometer Technologies*, 1 page (2004).  
 "MCP 24 Mass Connector Polisher—Technical Information," *Nanometer Technologies*, 1 page (2004).  
 "MCP 24 Fixture Plates," *Nanometer Technologies*, 1 page (2004).  
 U.S. Appl. No. 10/356,358, Apparatus and Method for Polishing a Fiber Optic Connector, filed Jan. 31, 2003.  
 "ADC FasTerm™ Multimode LX.5™ Connector Installation Instructions," *ADC Telecommunications, Inc.*, Issue 2, pp. 1-25 (Apr. 2001).

\* cited by examiner

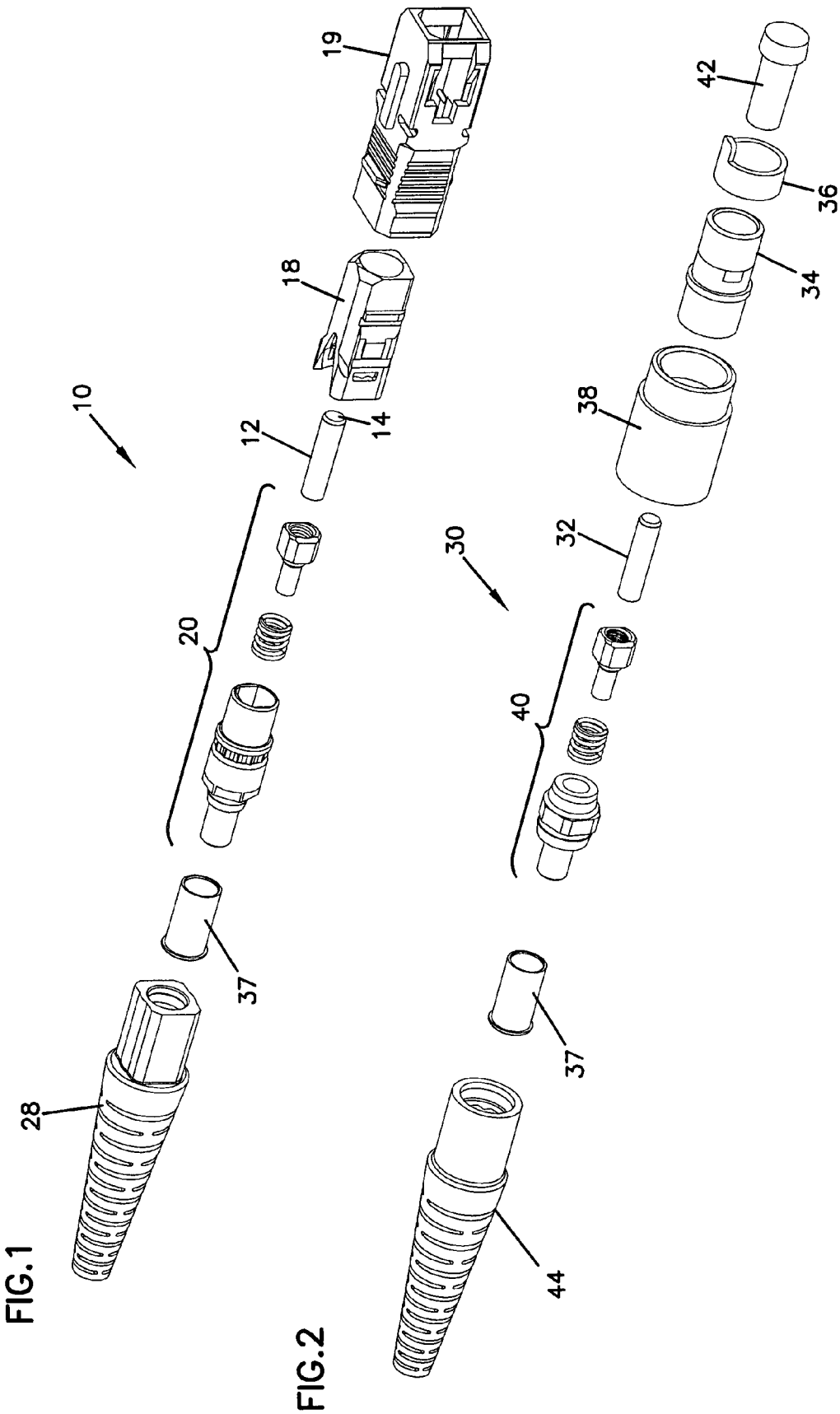
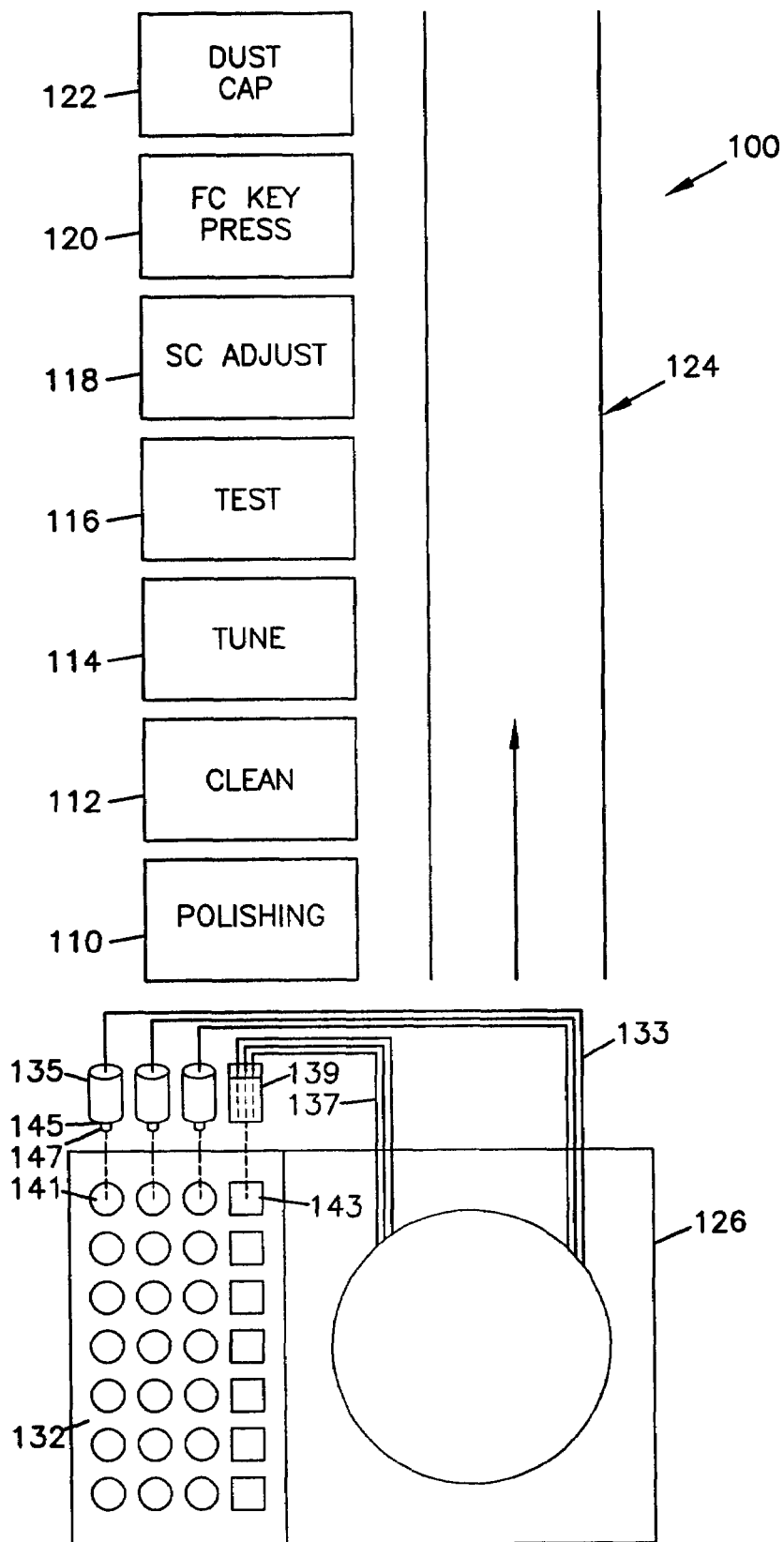


FIG. 1

FIG. 2

FIG.3



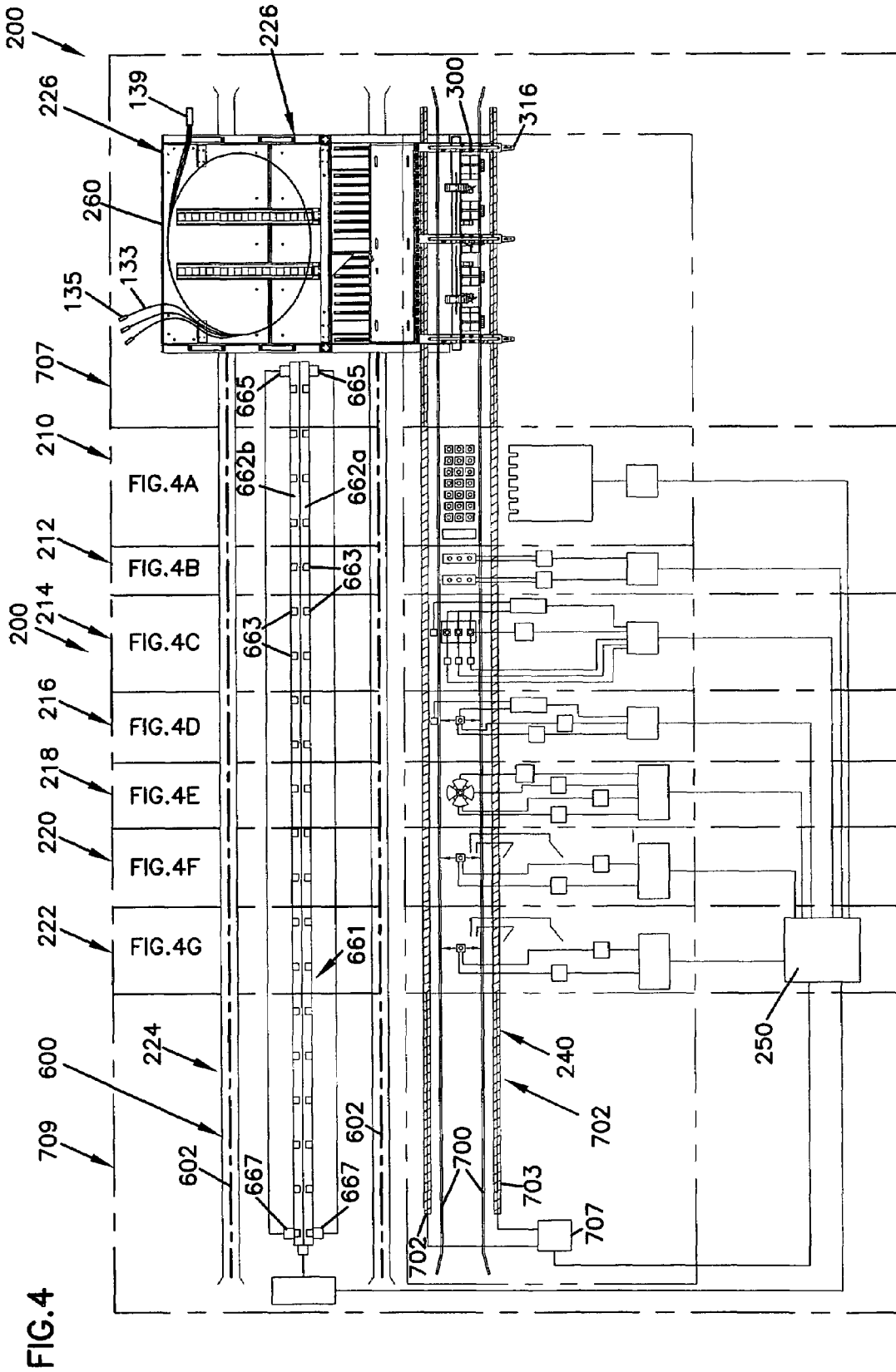




FIG. 4C

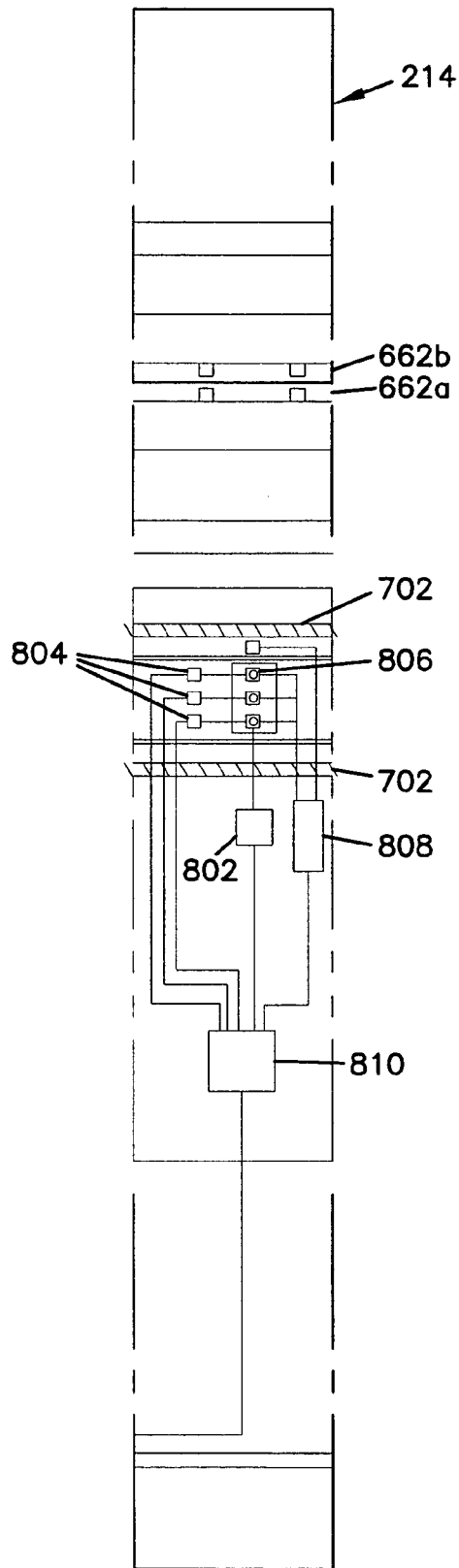


FIG. 4D

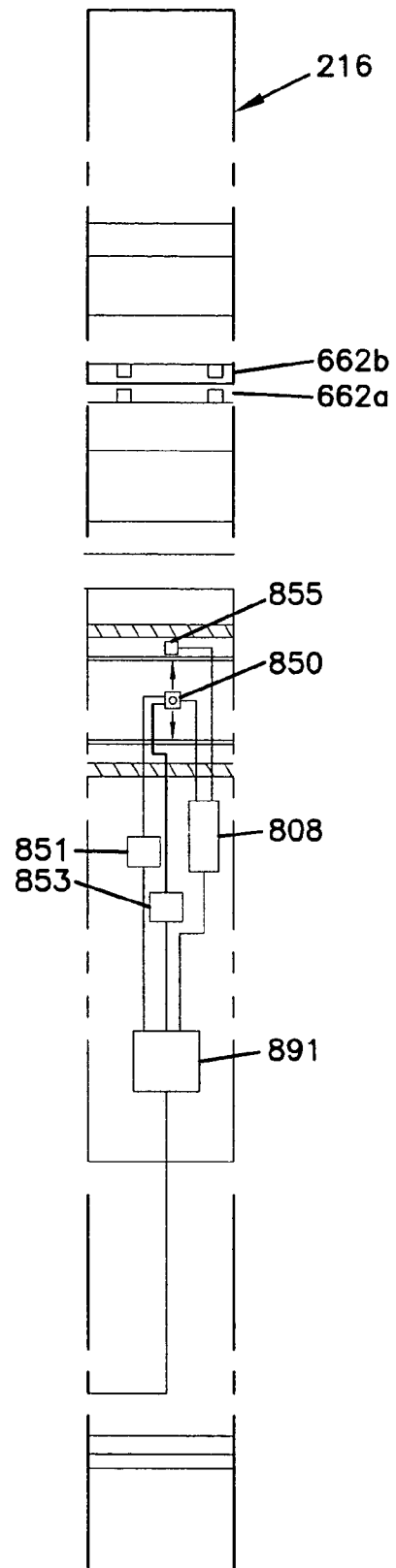


FIG. 4E

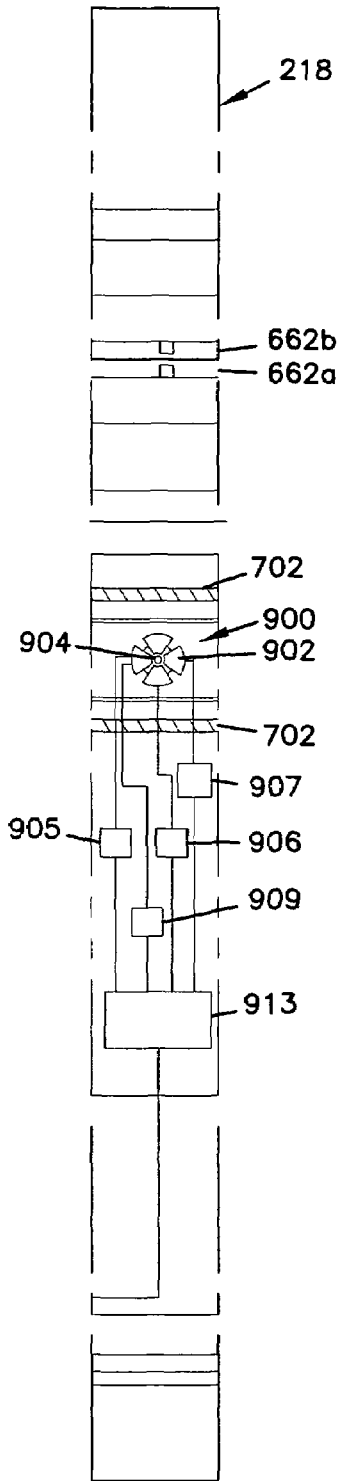


FIG. 4F

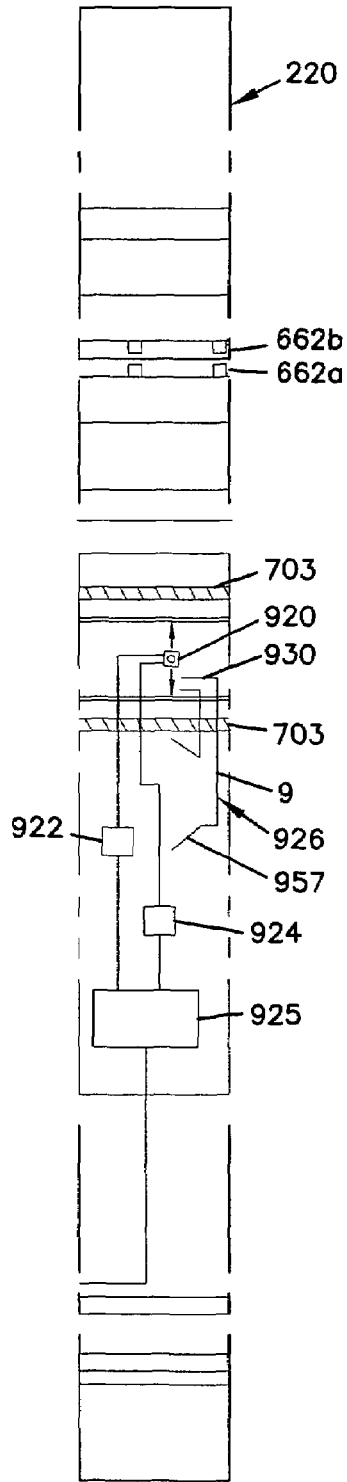


FIG. 4G

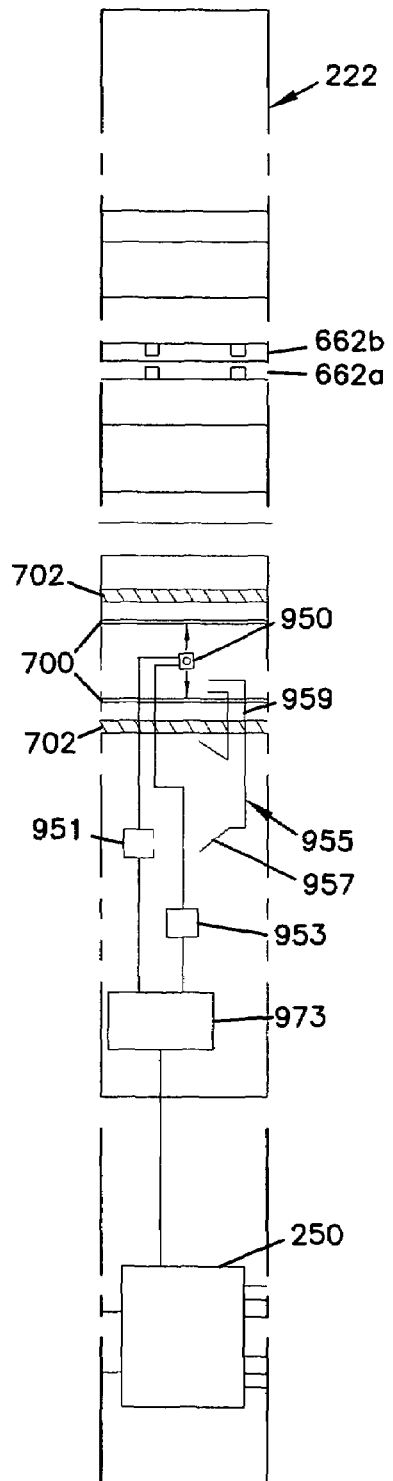
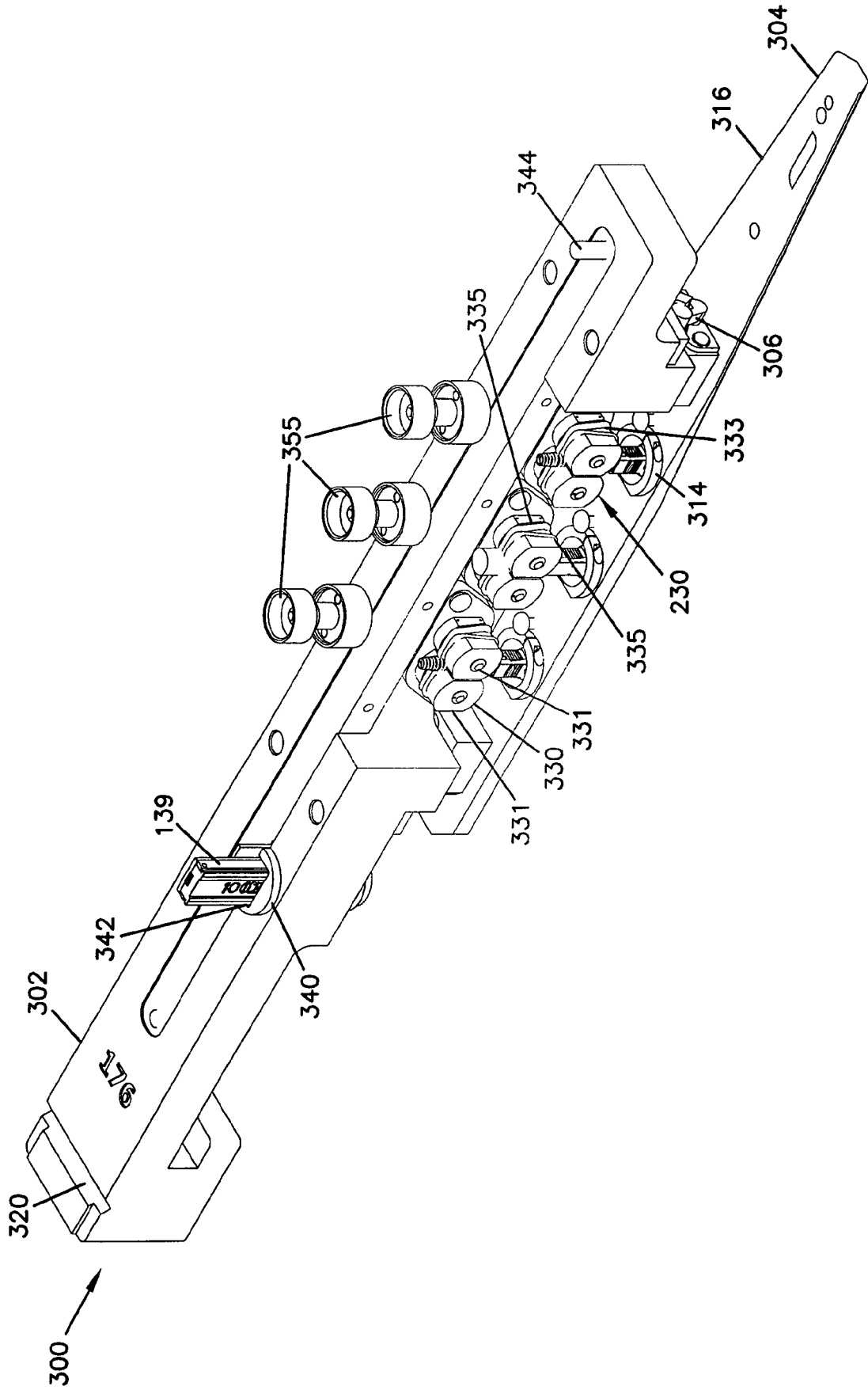
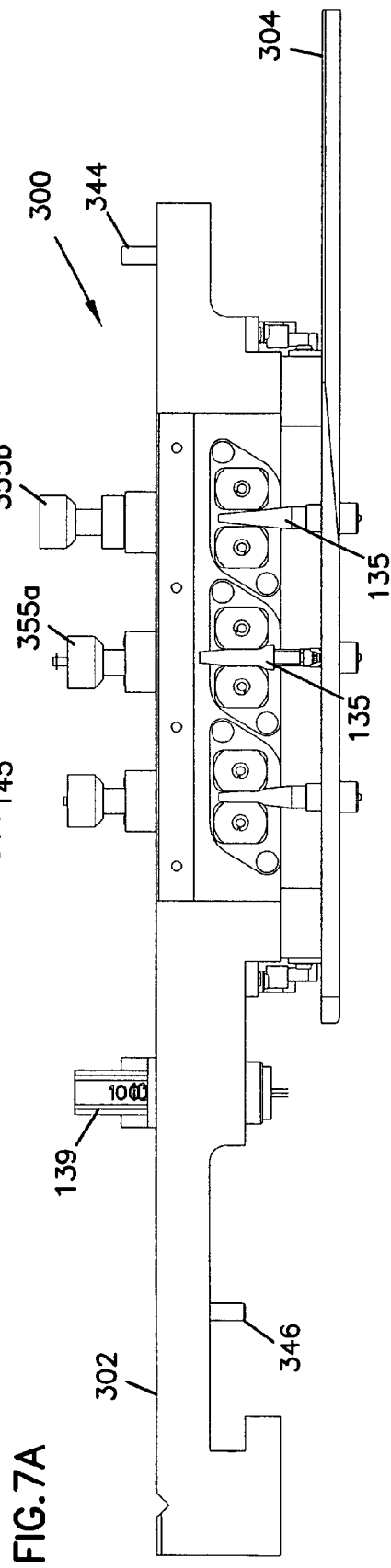
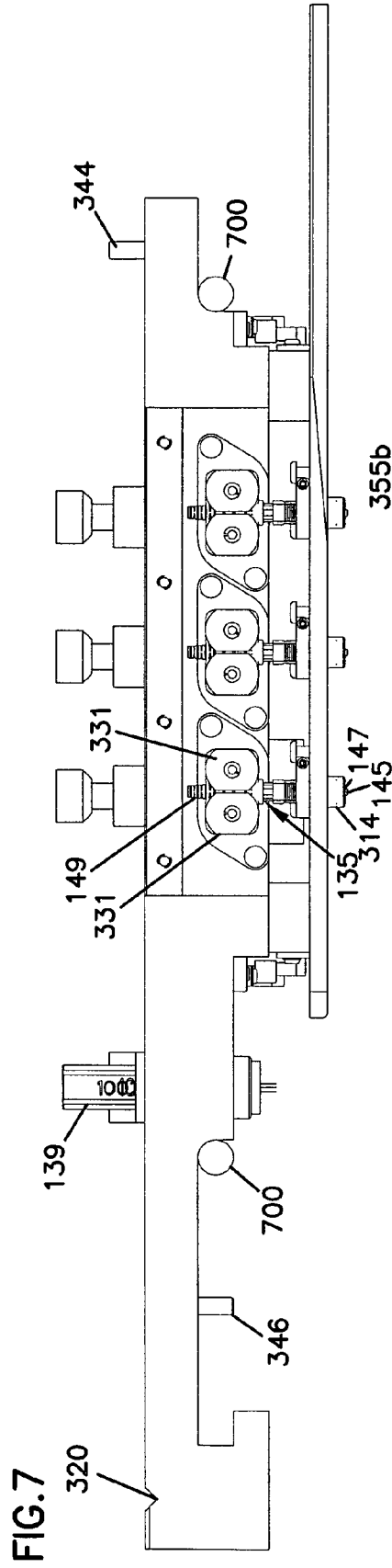
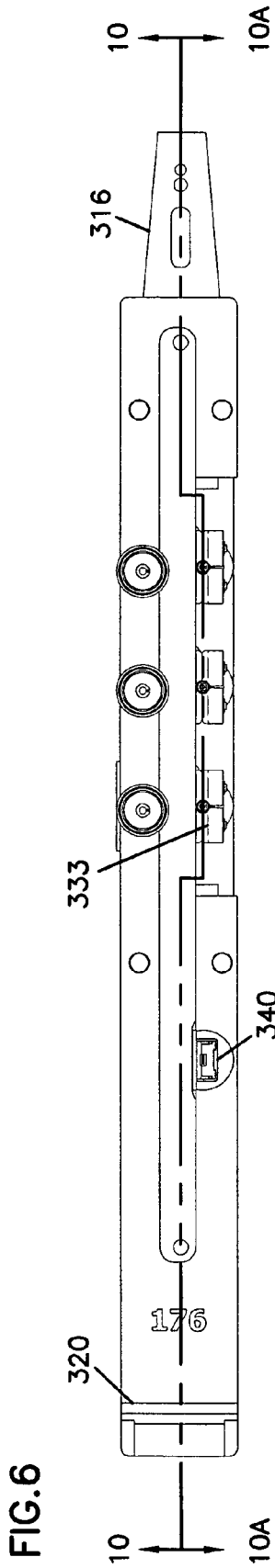




FIG. 5





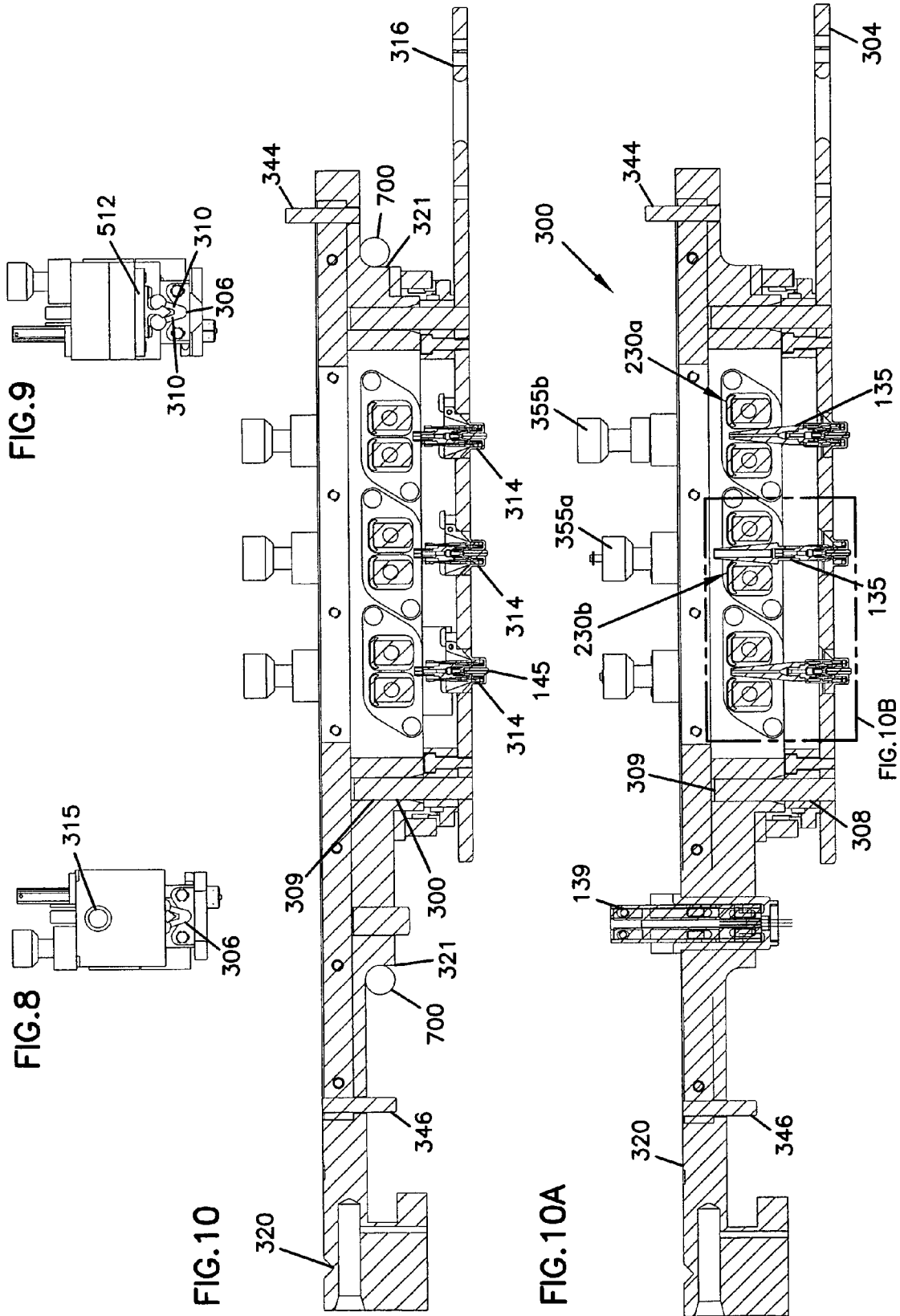
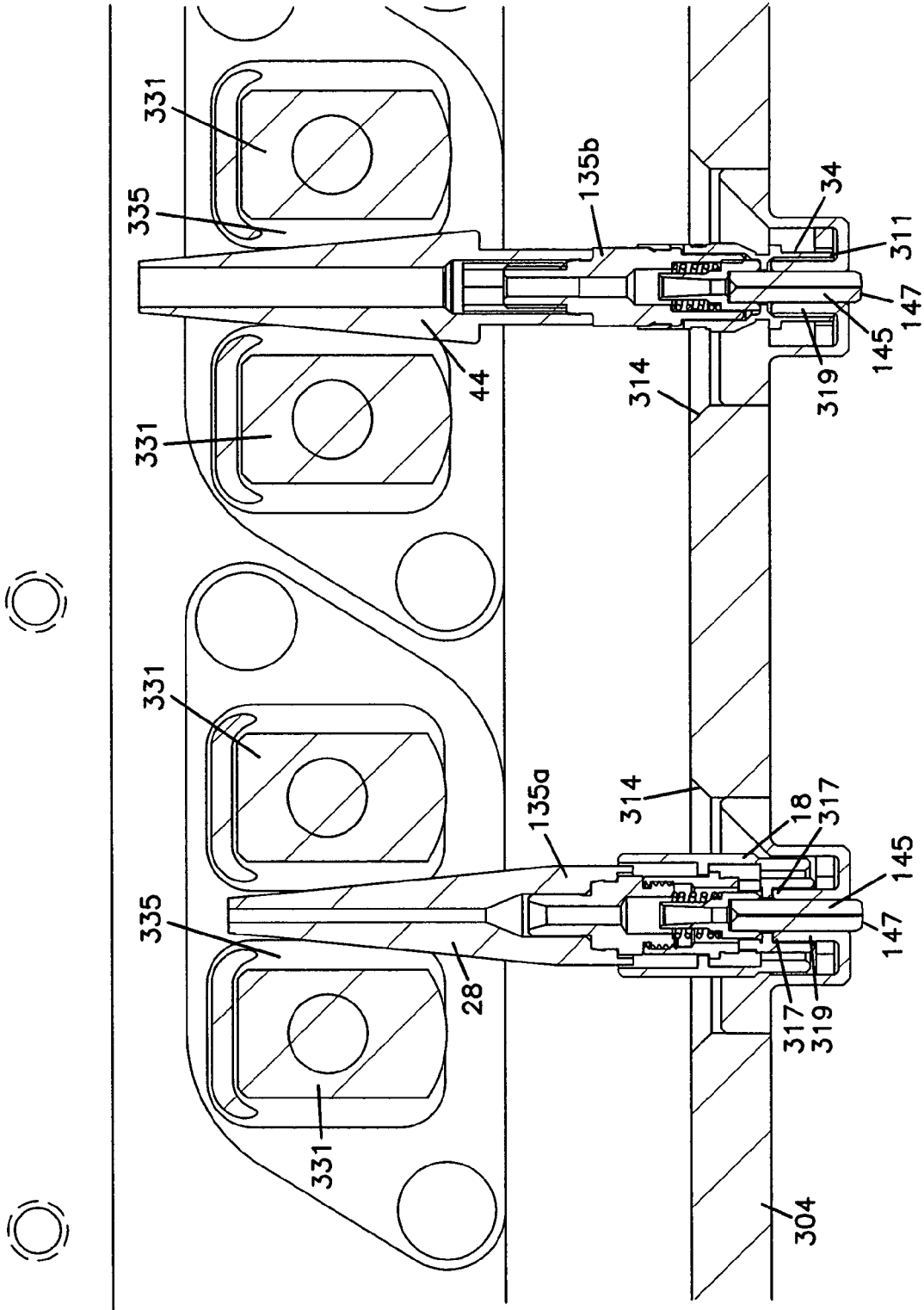
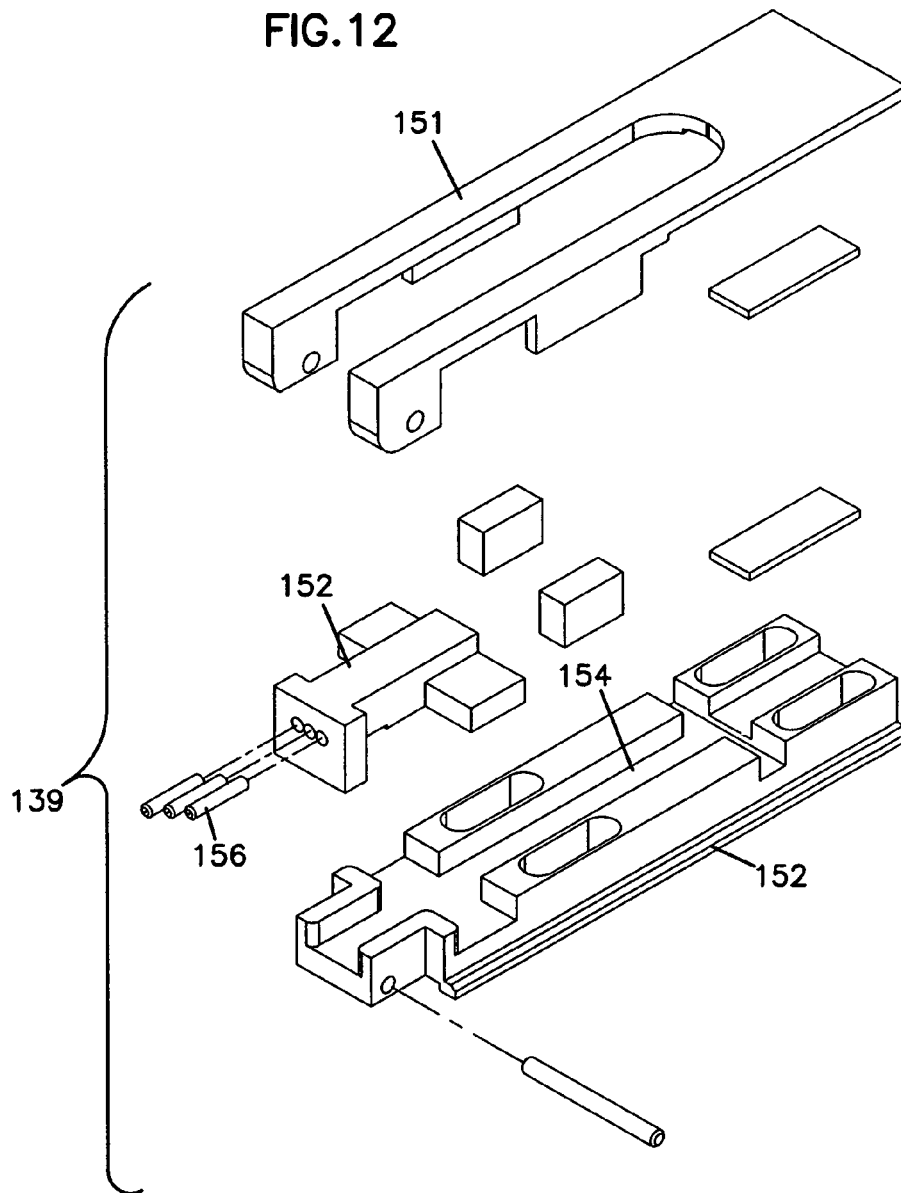
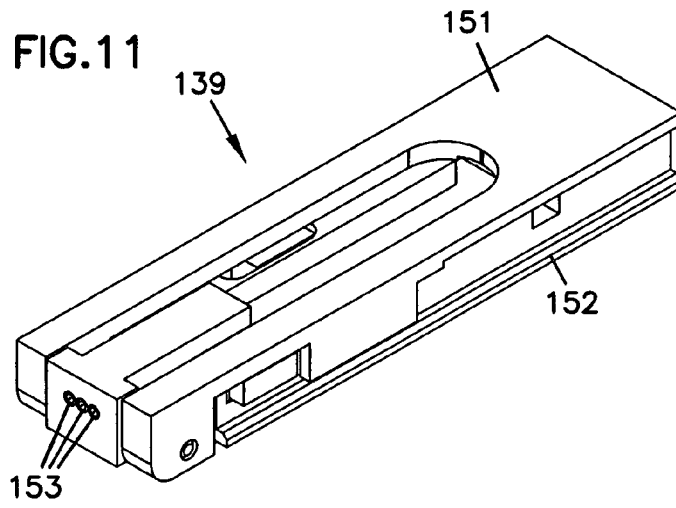


FIG. 10B





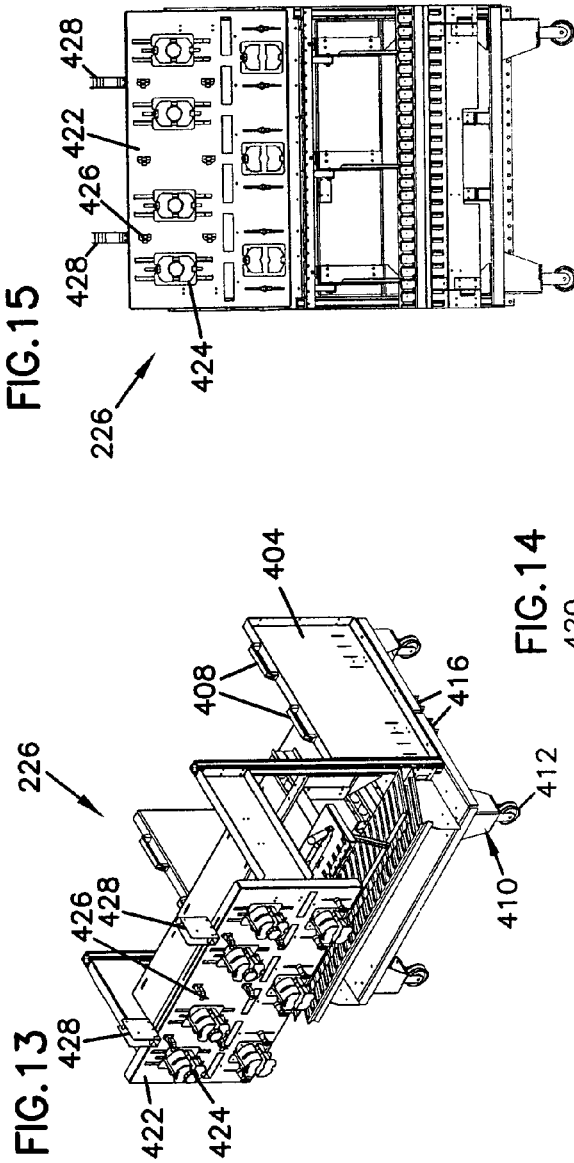


FIG. 13

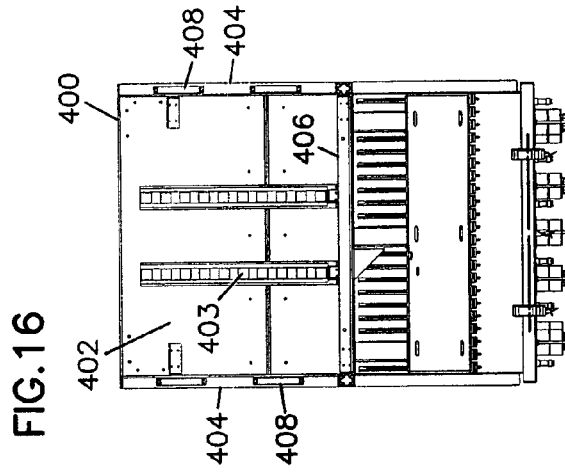


FIG. 14

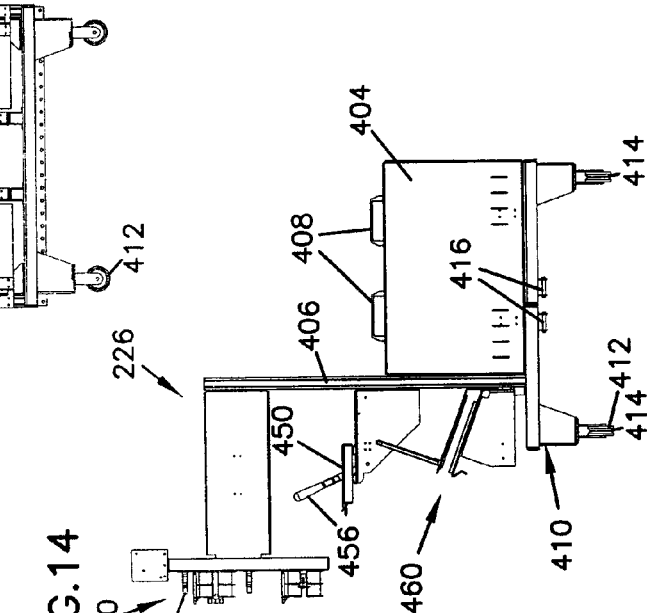


FIG. 15

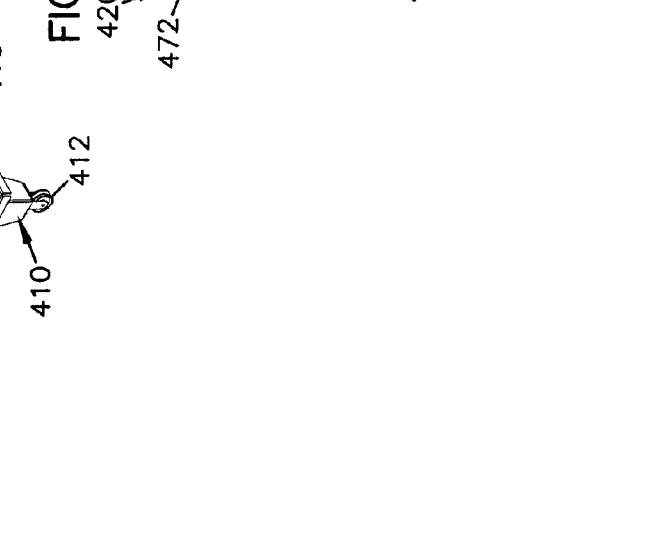


FIG. 16

FIG. 17

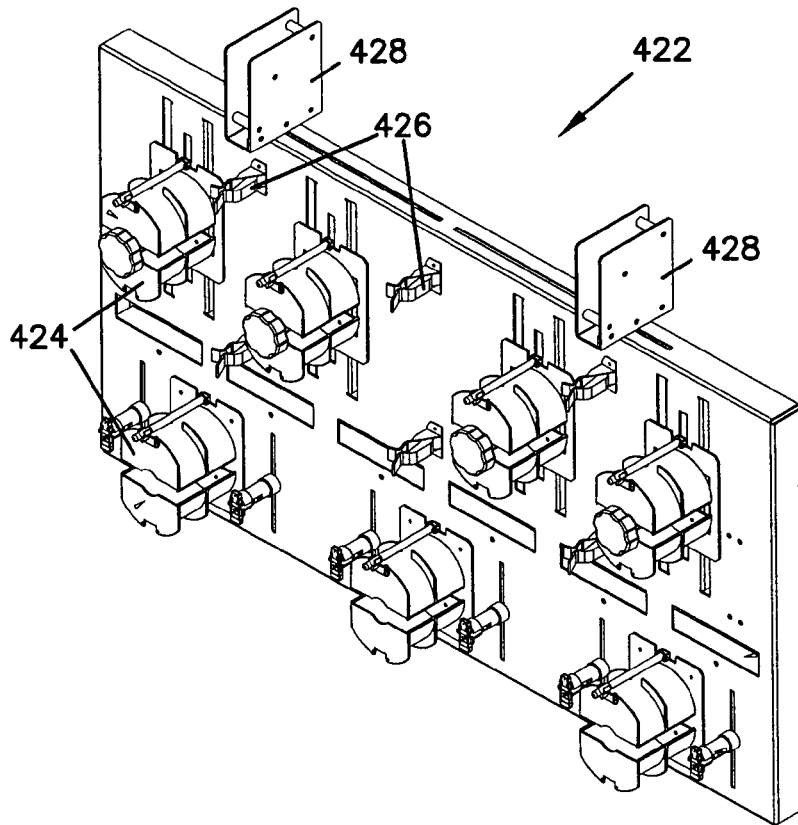
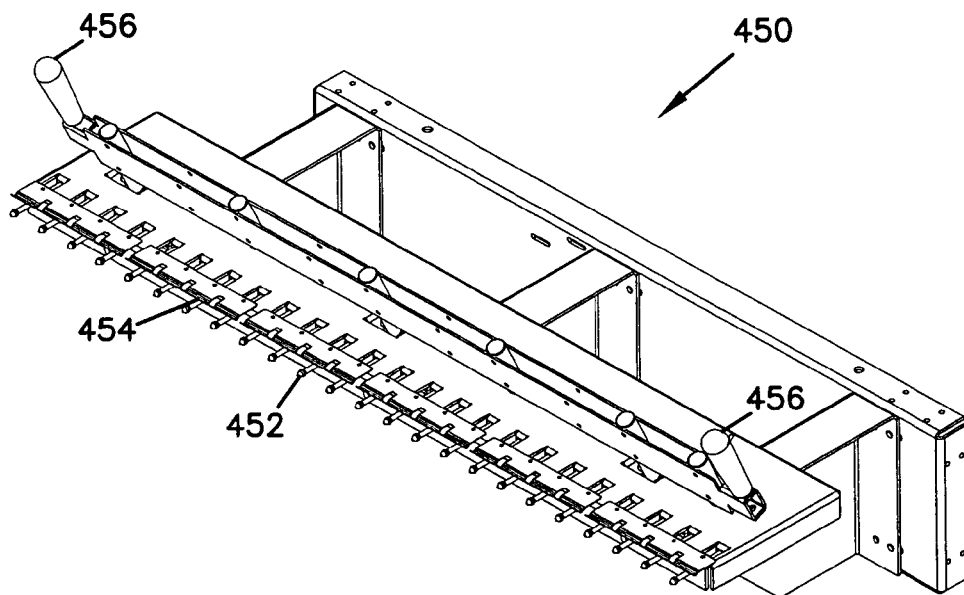
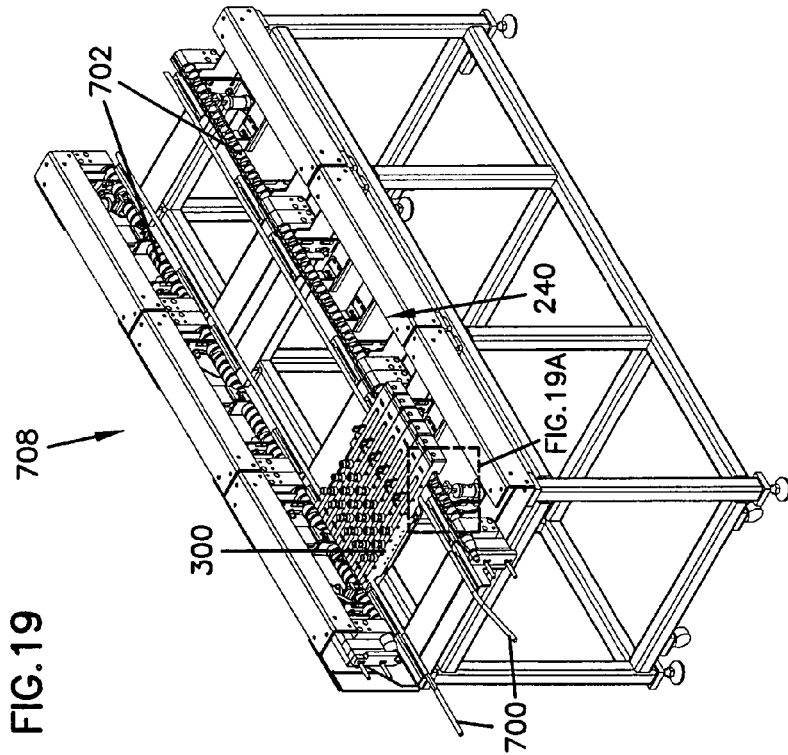
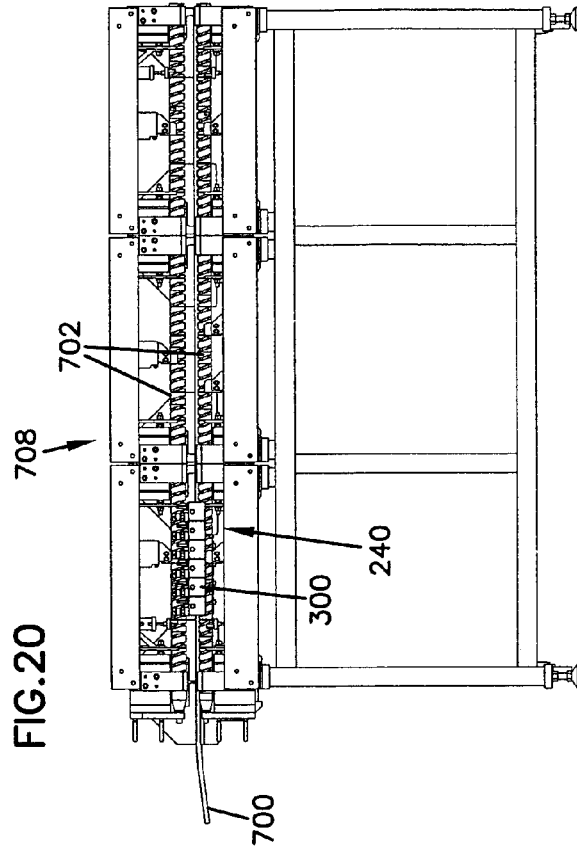
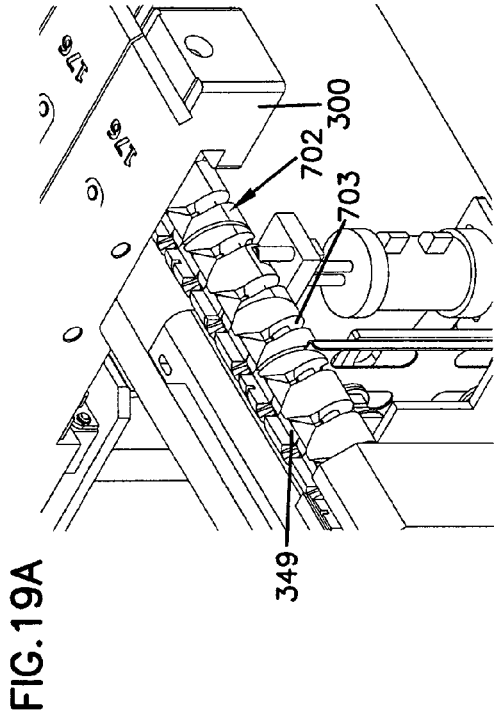


FIG. 18







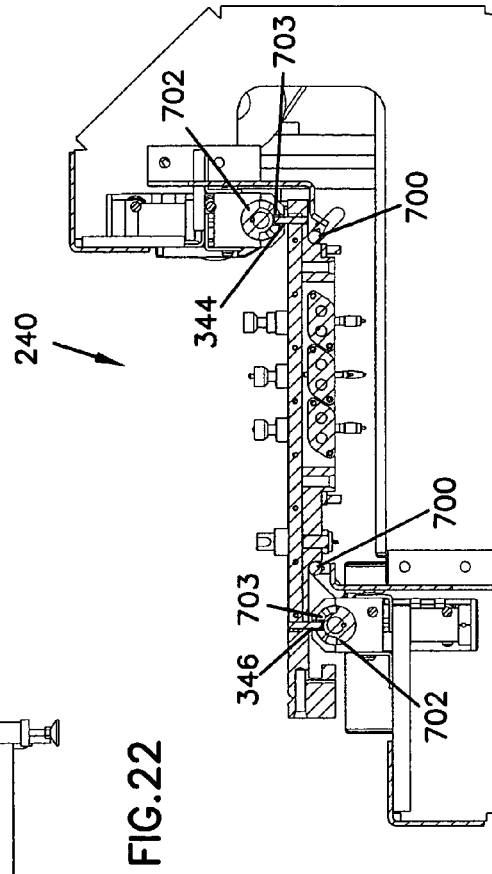
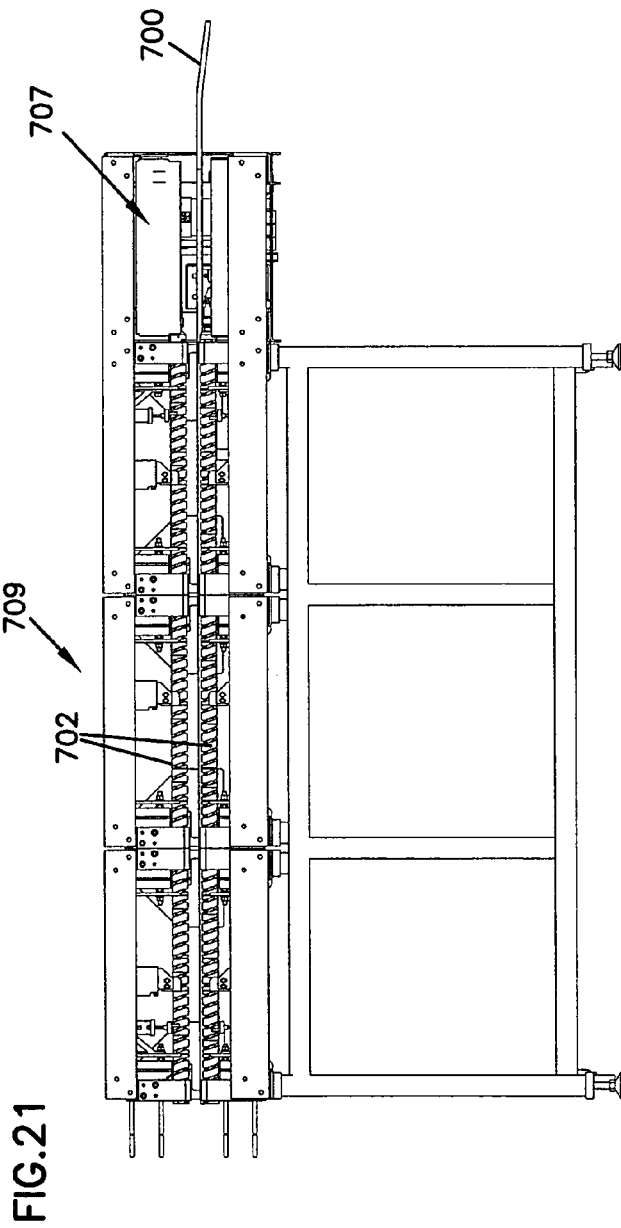


FIG. 22

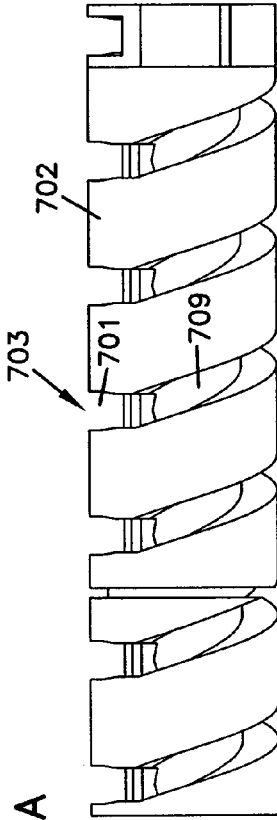


FIG. 23A

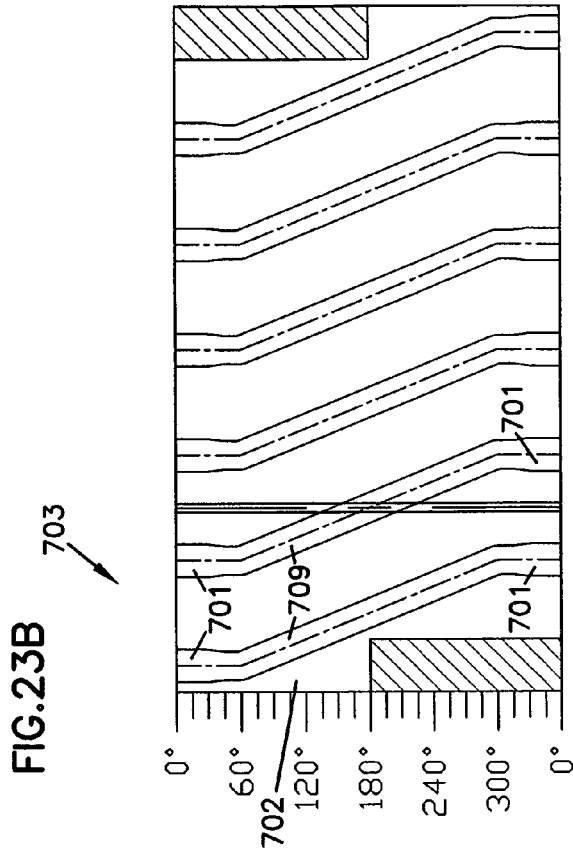


FIG. 23B

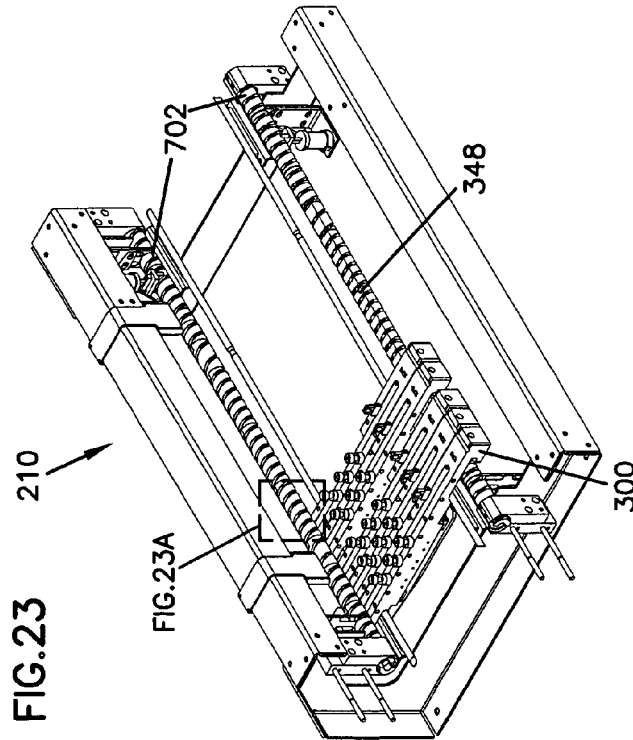


FIG. 23

FIG.24

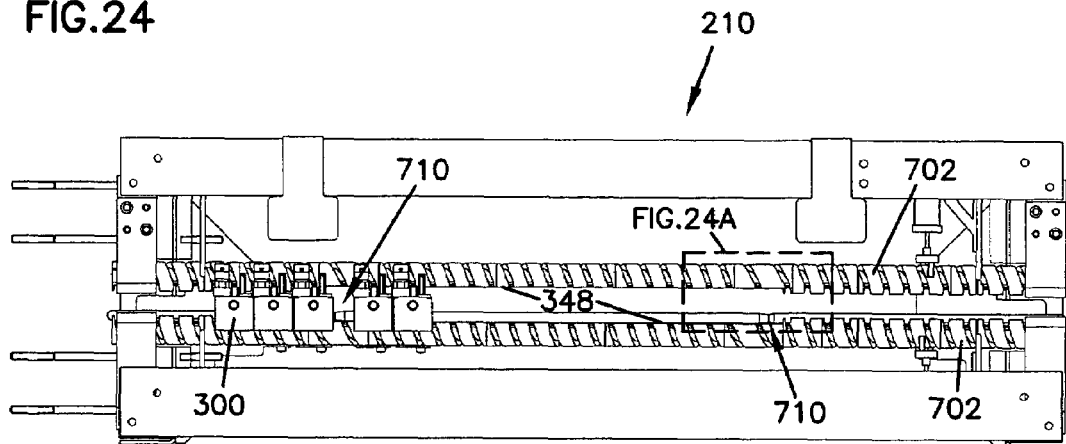


FIG.24A

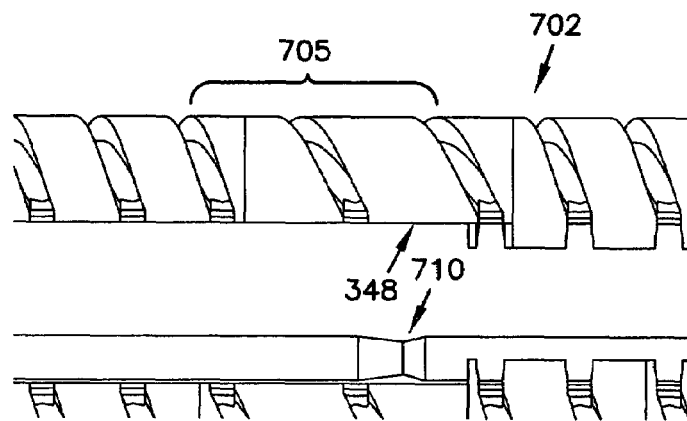


FIG.25

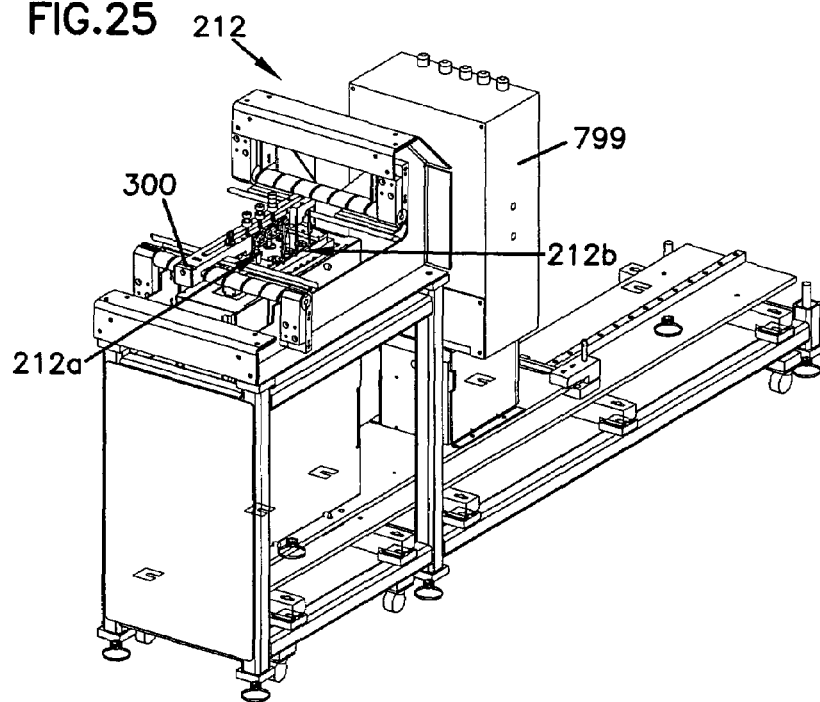


FIG.26

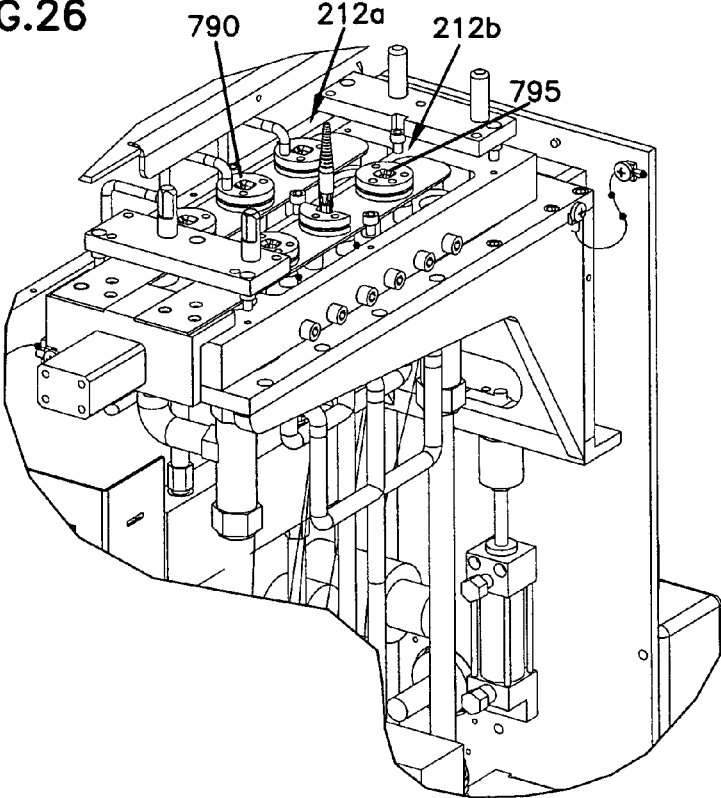
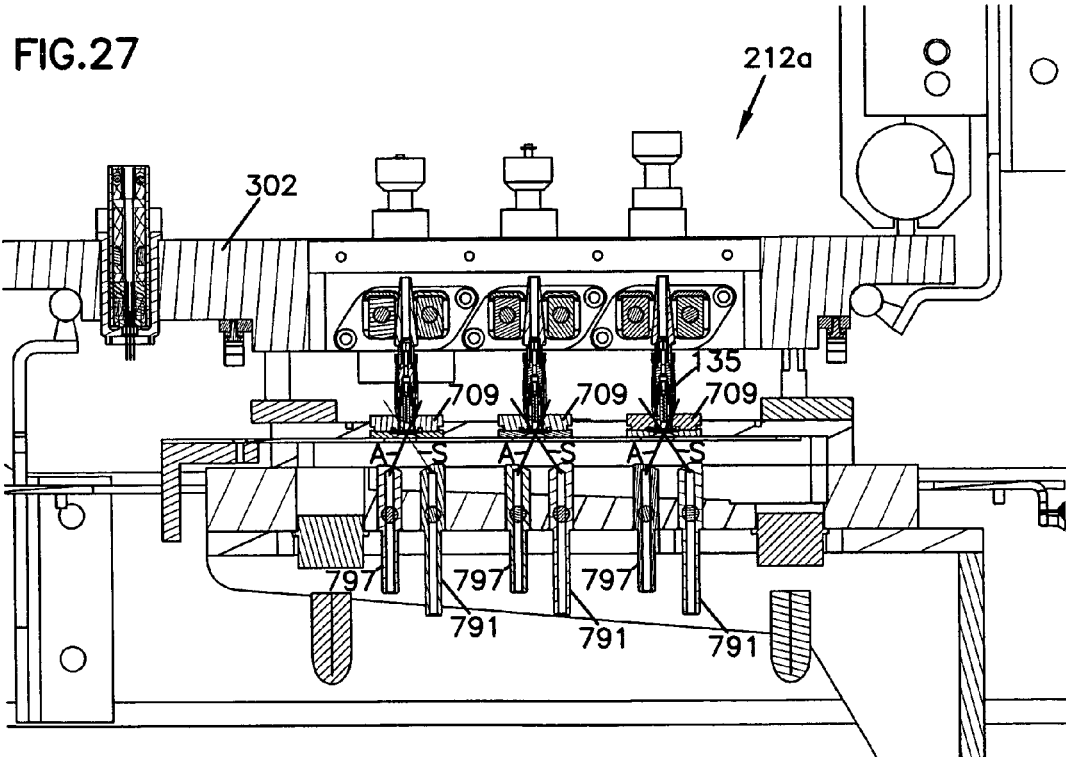
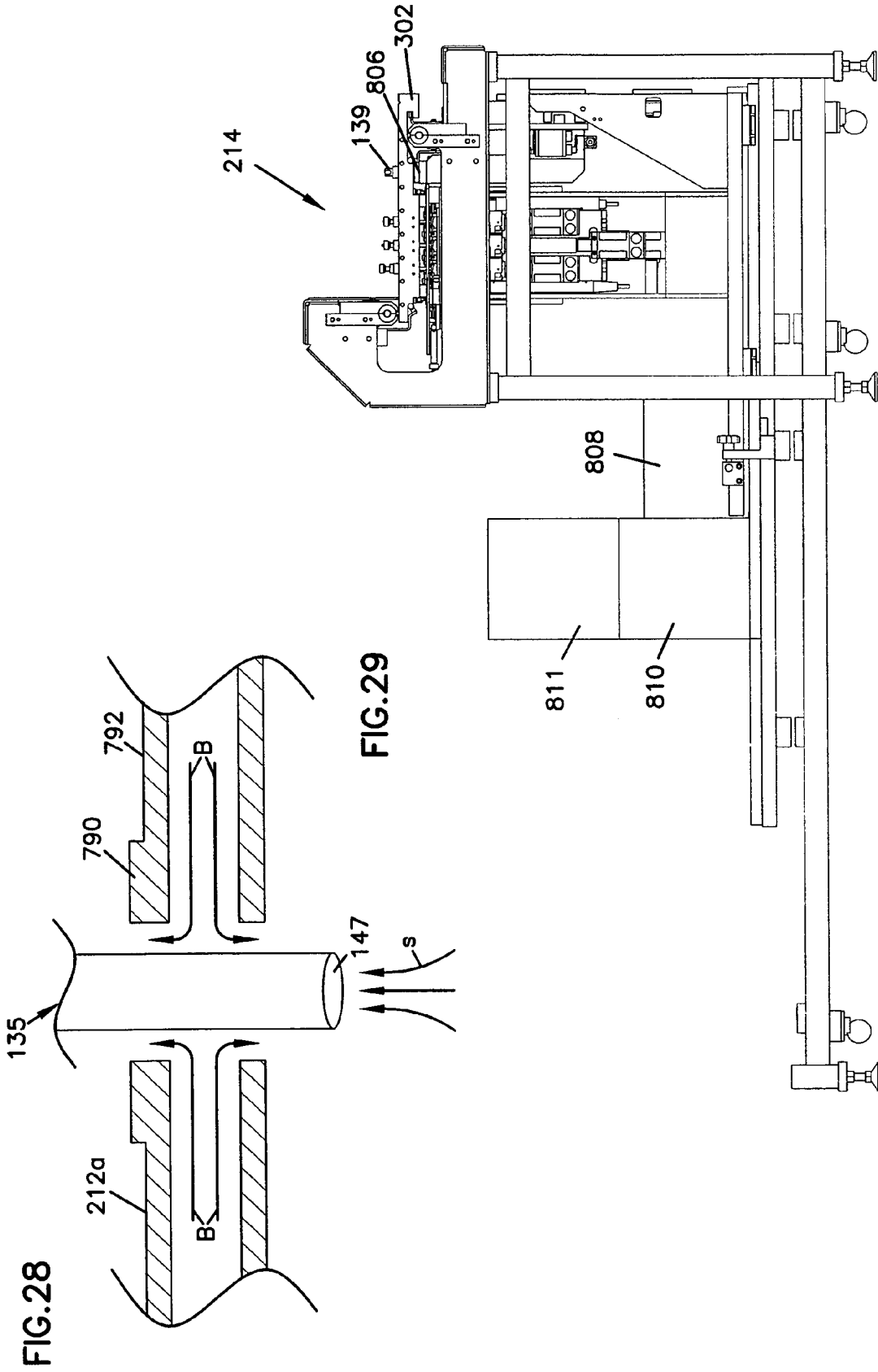


FIG.27





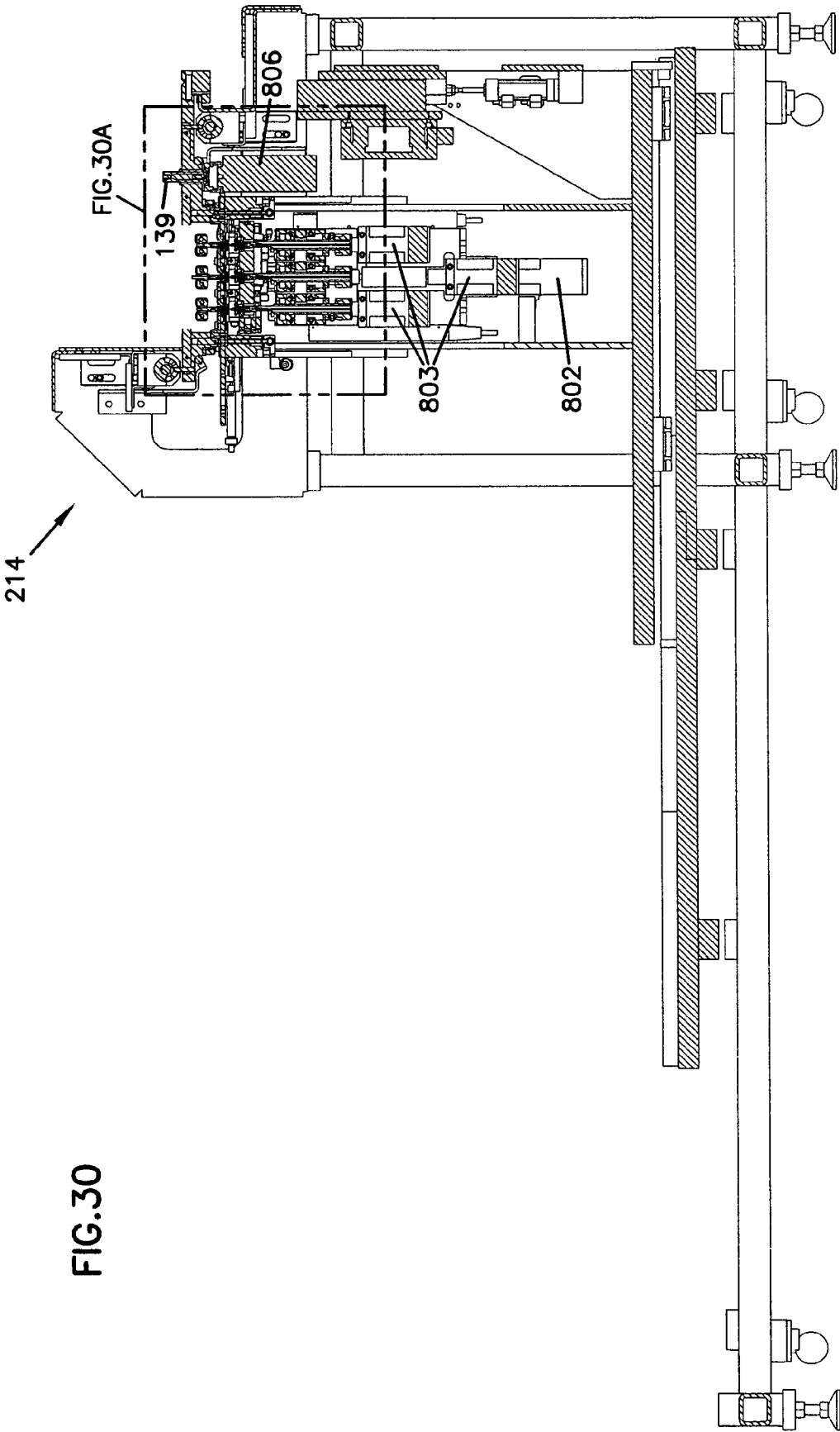


FIG. 30

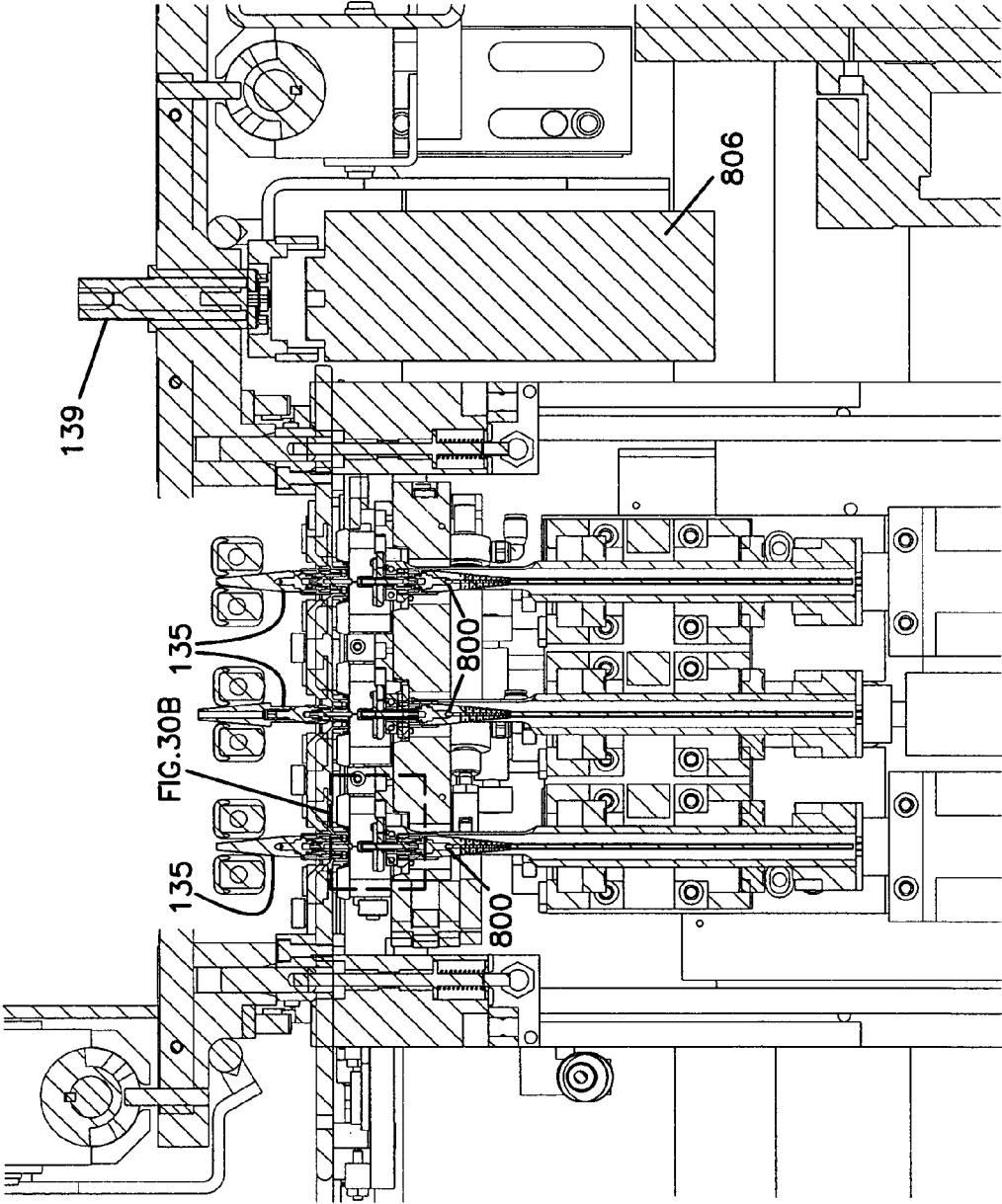


FIG. 30A

FIG.30B

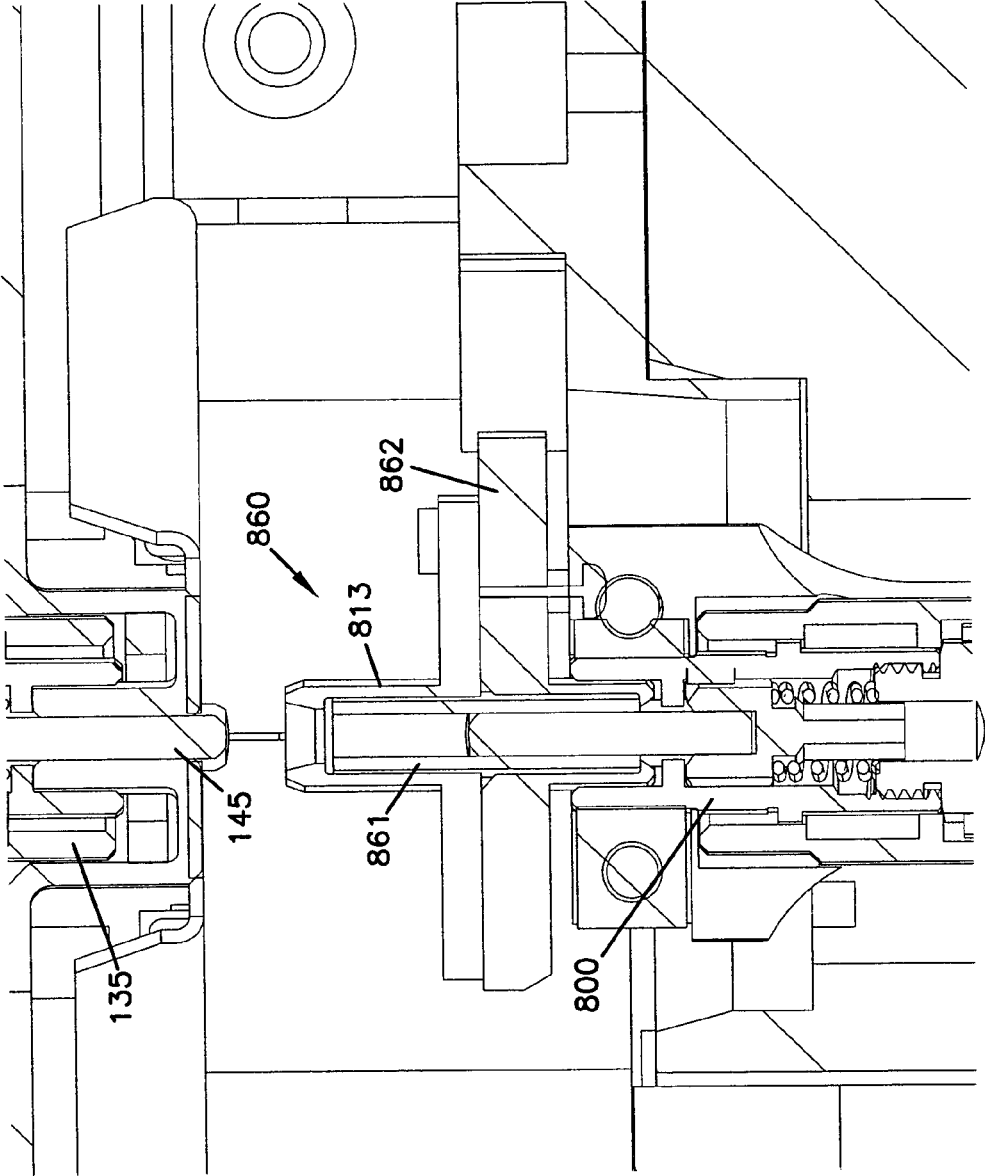




FIG.31

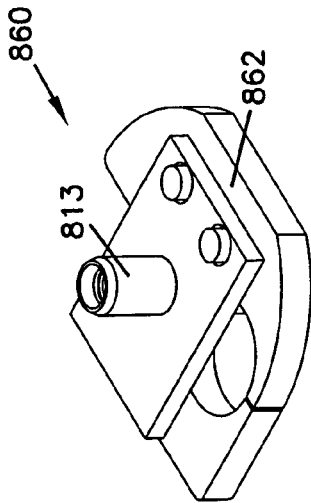
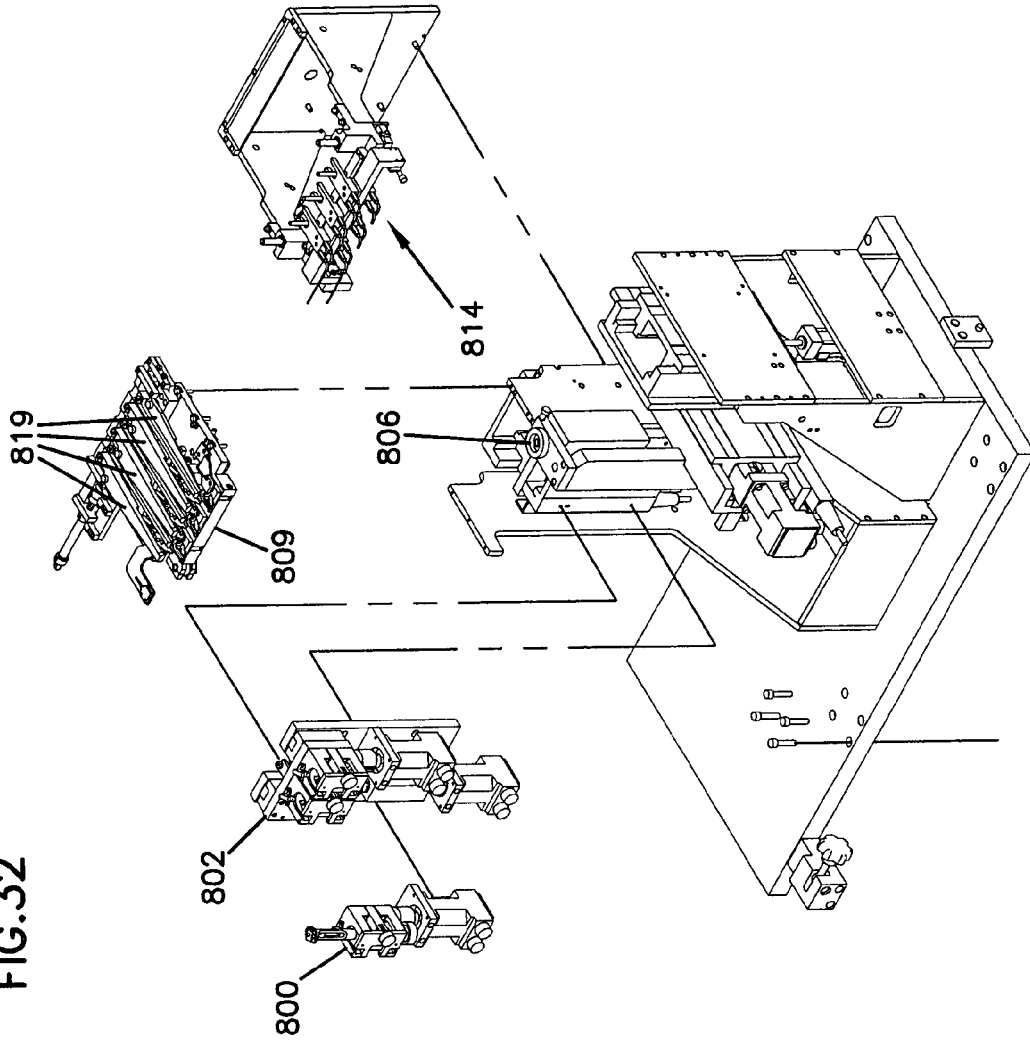


FIG.32



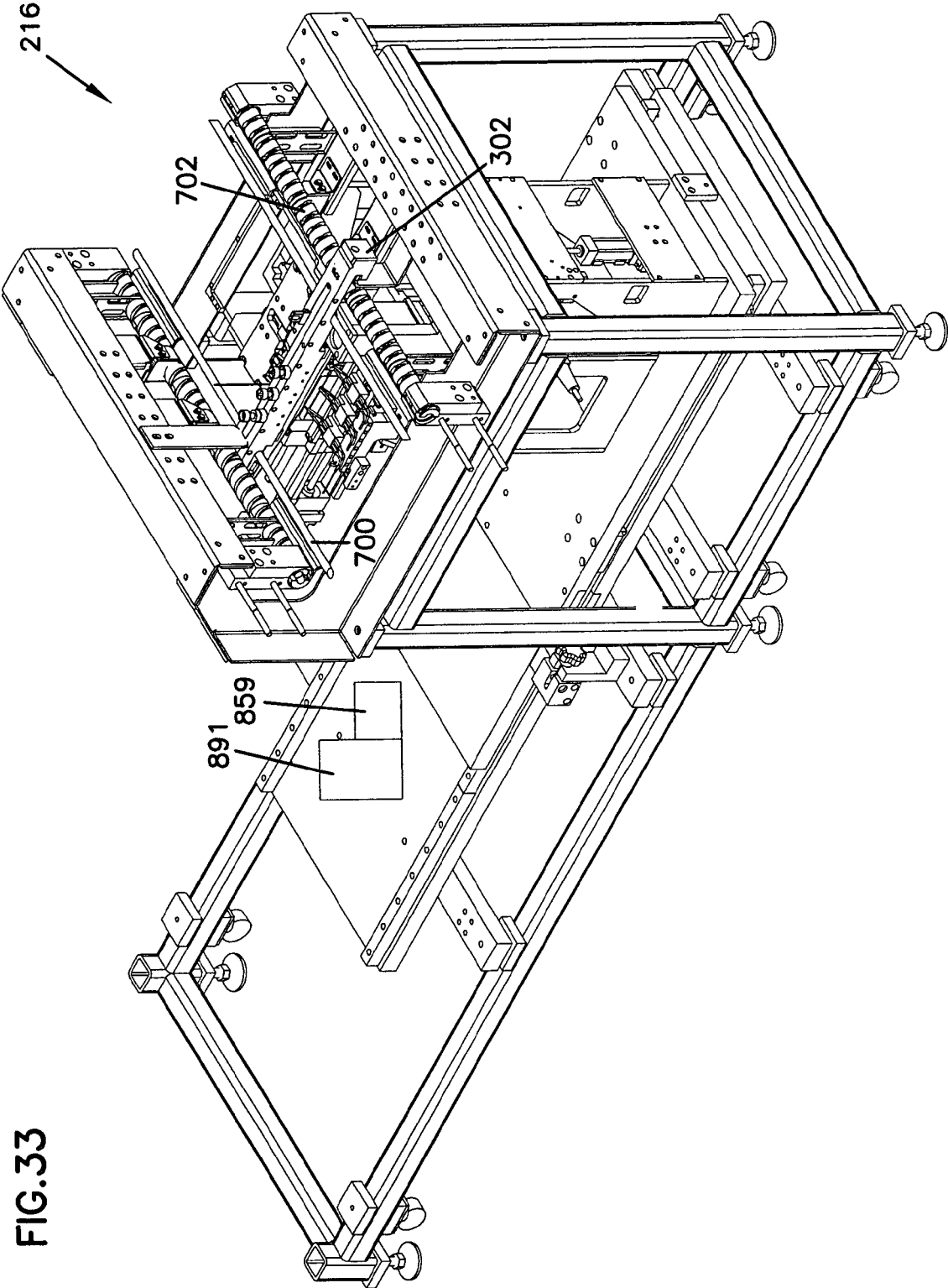


FIG. 33

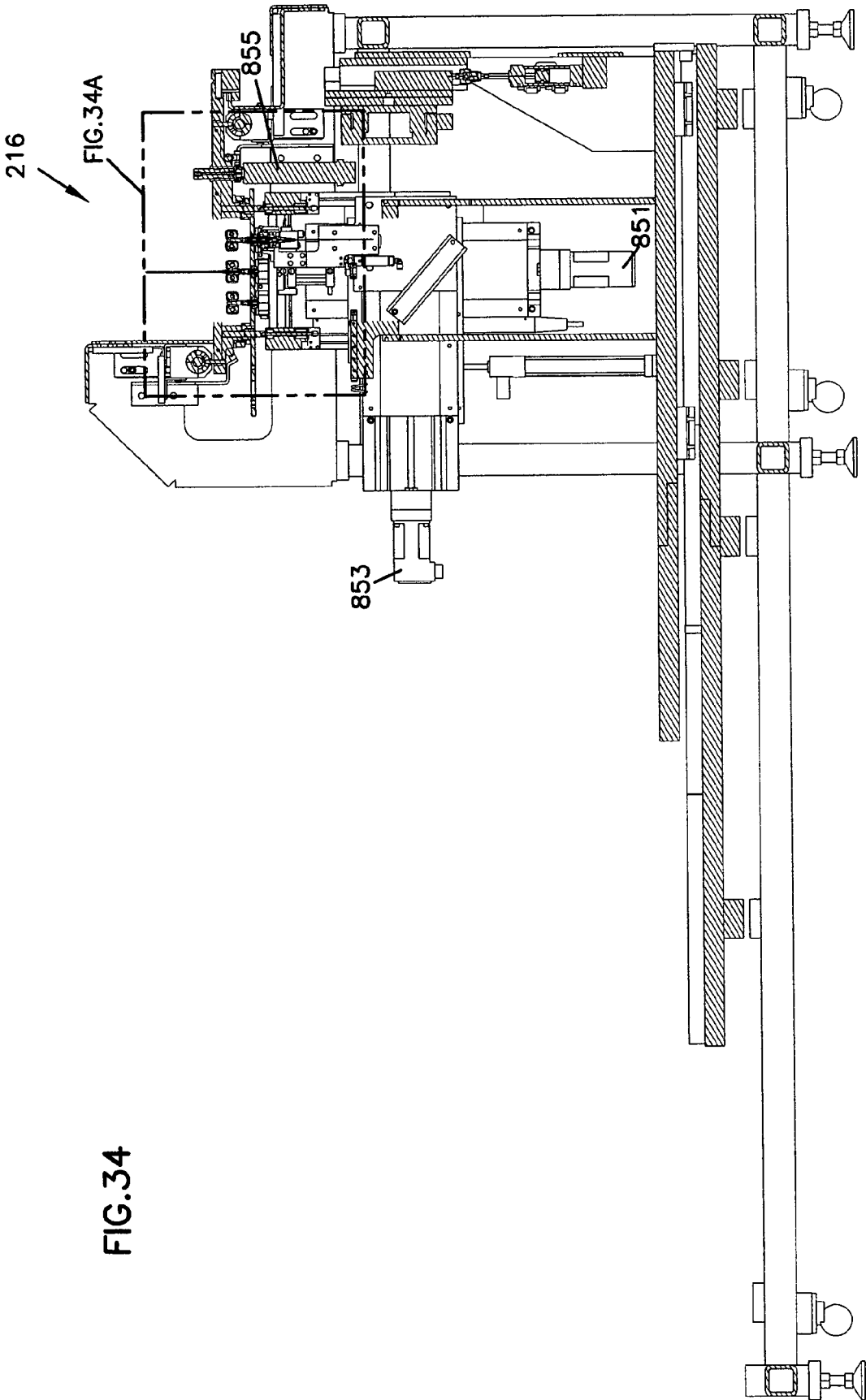


FIG. 34

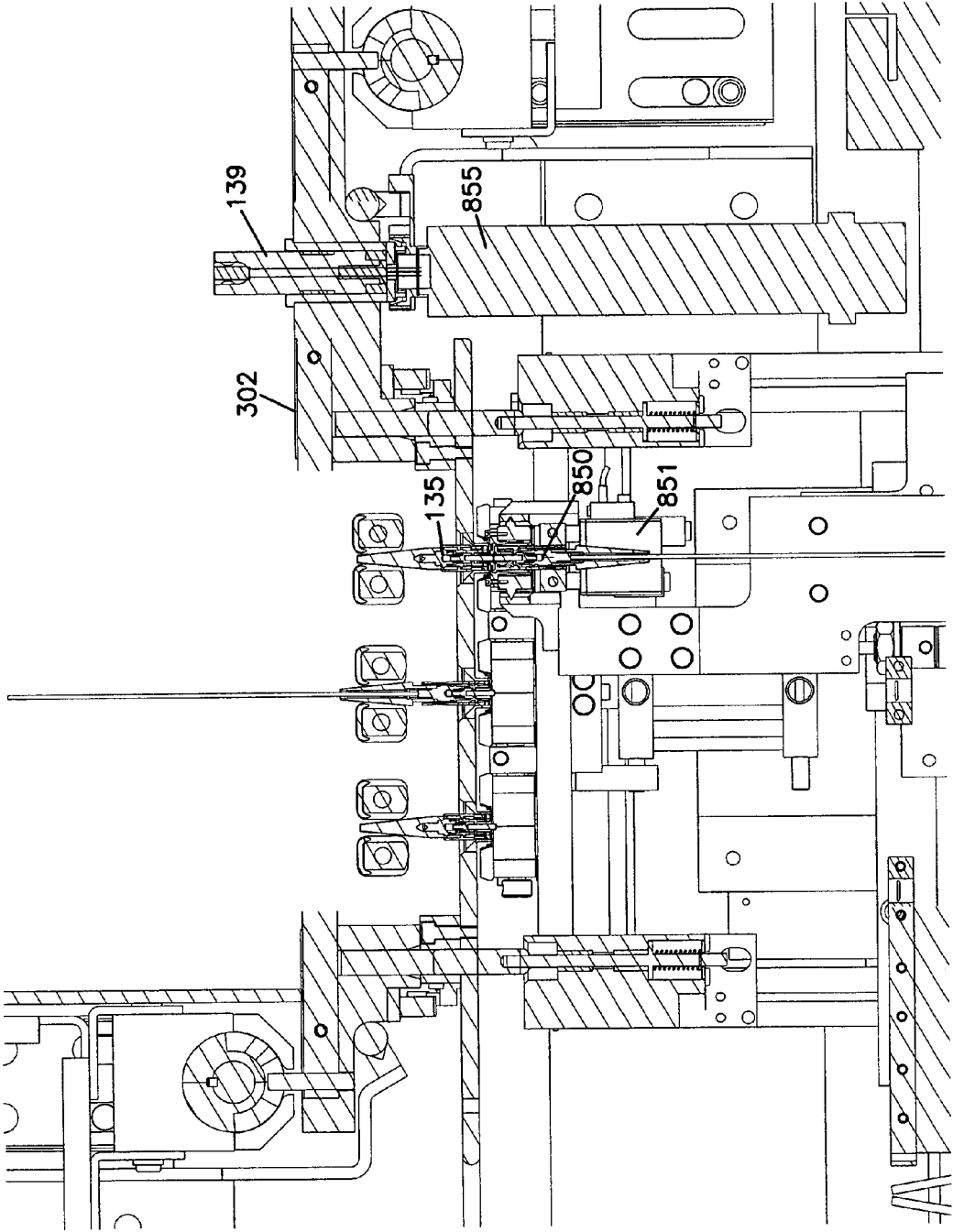


FIG. 34A

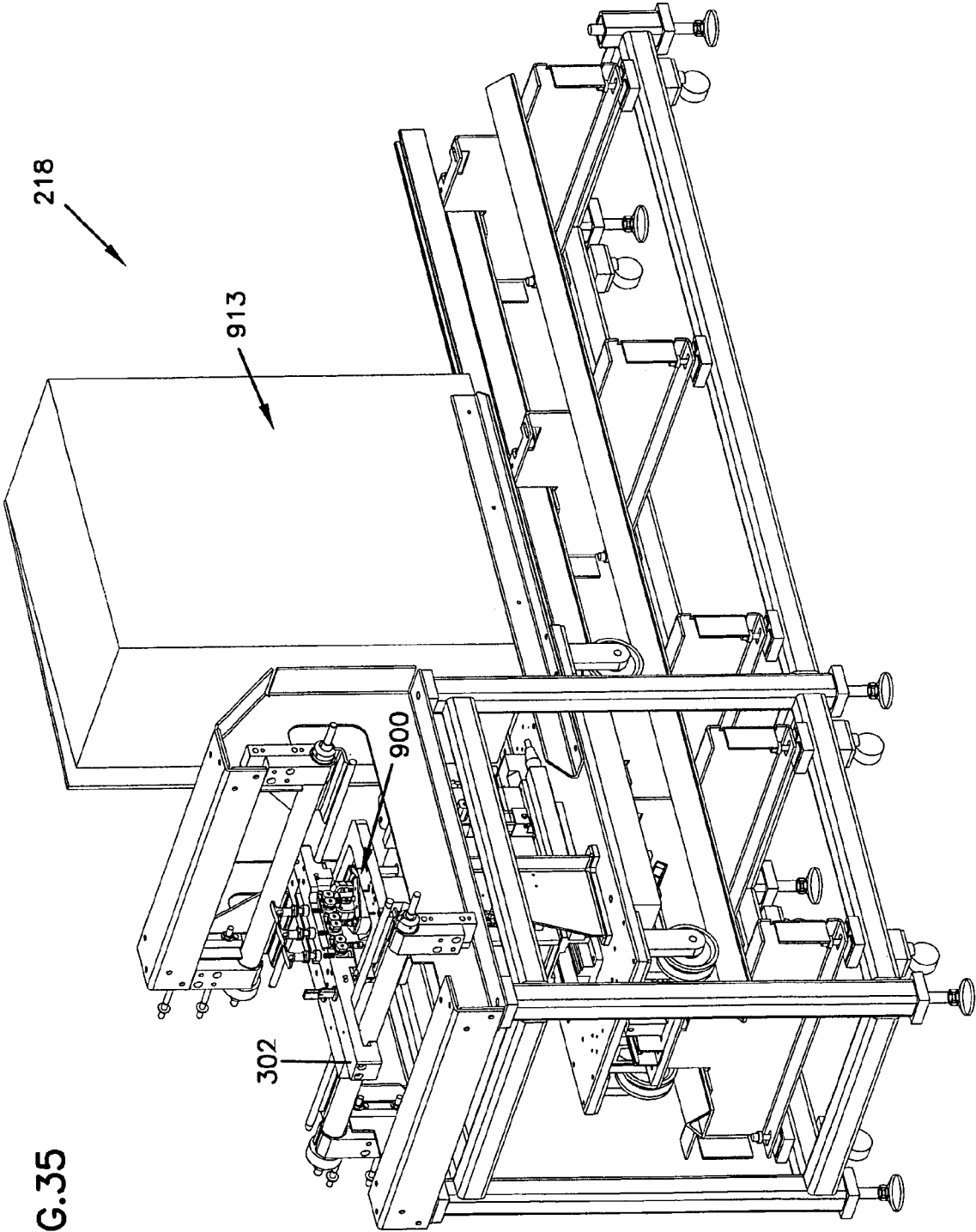


FIG.35

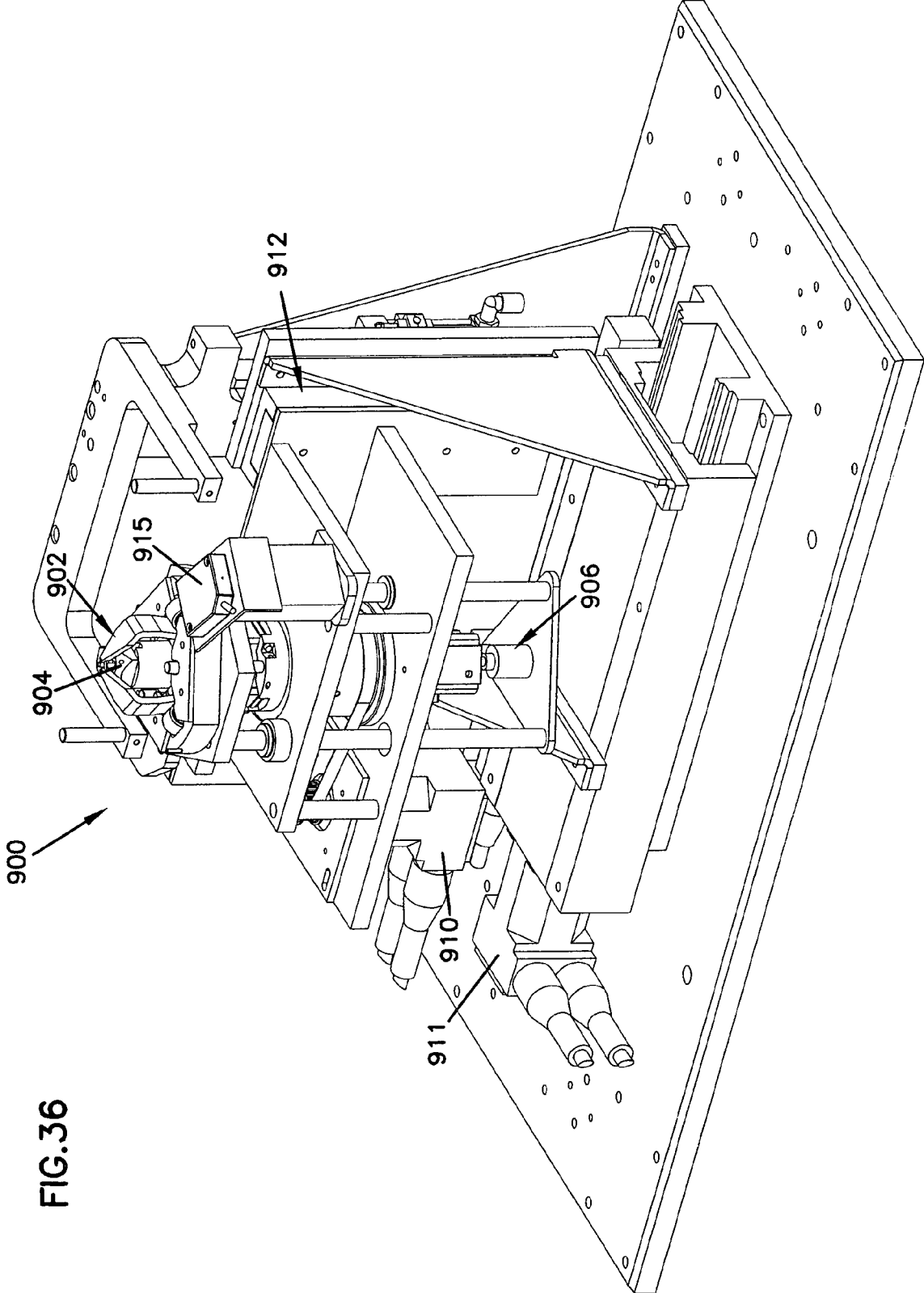


FIG.36

FIG.37

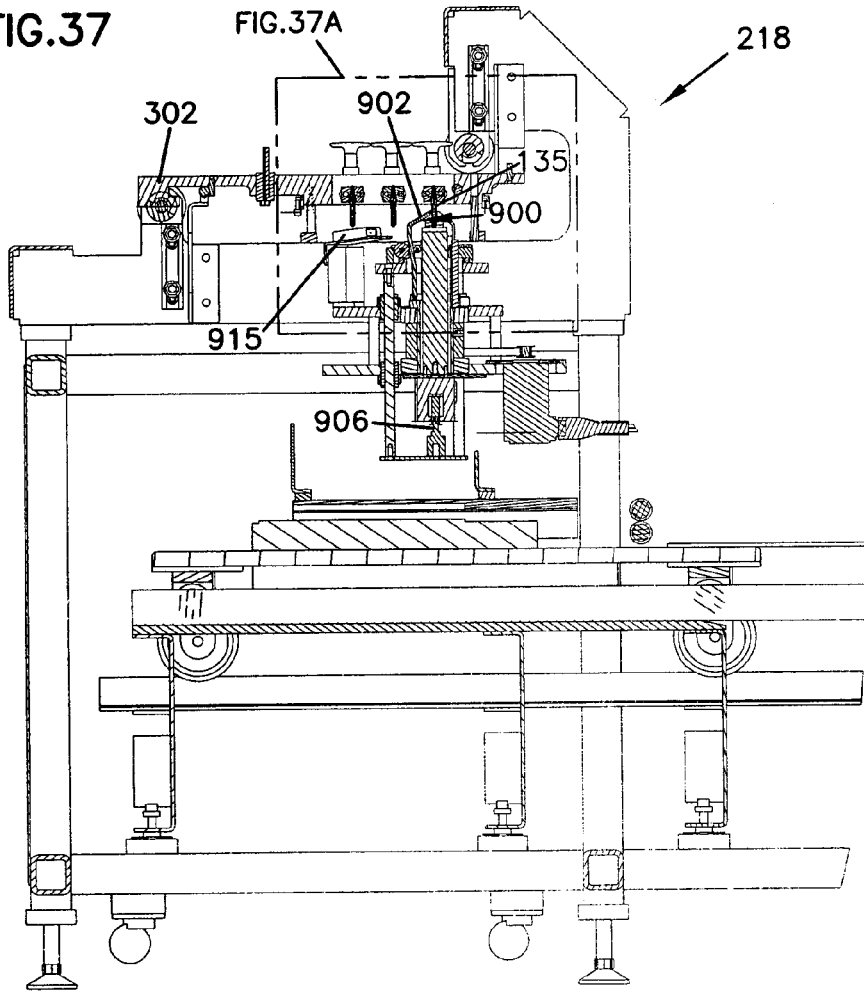
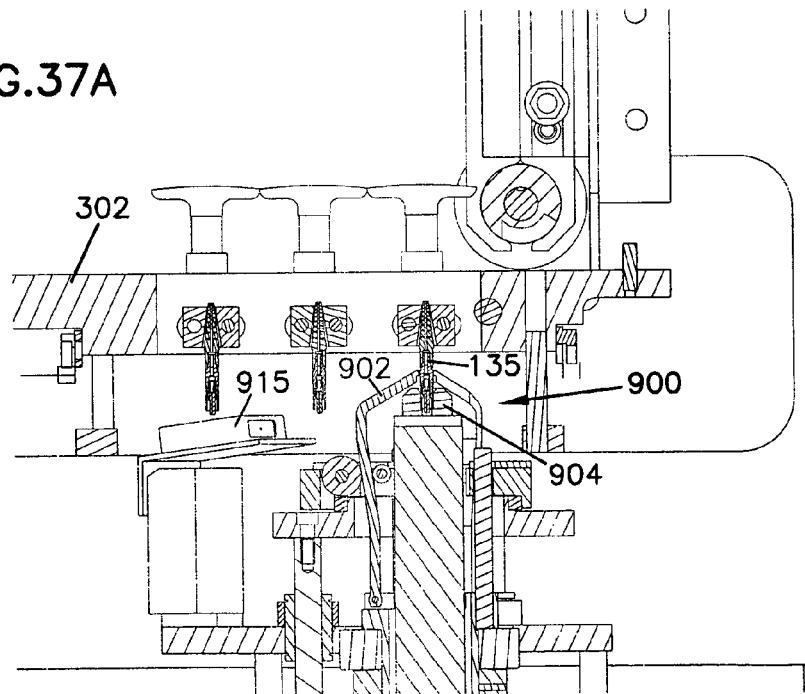


FIG.37A



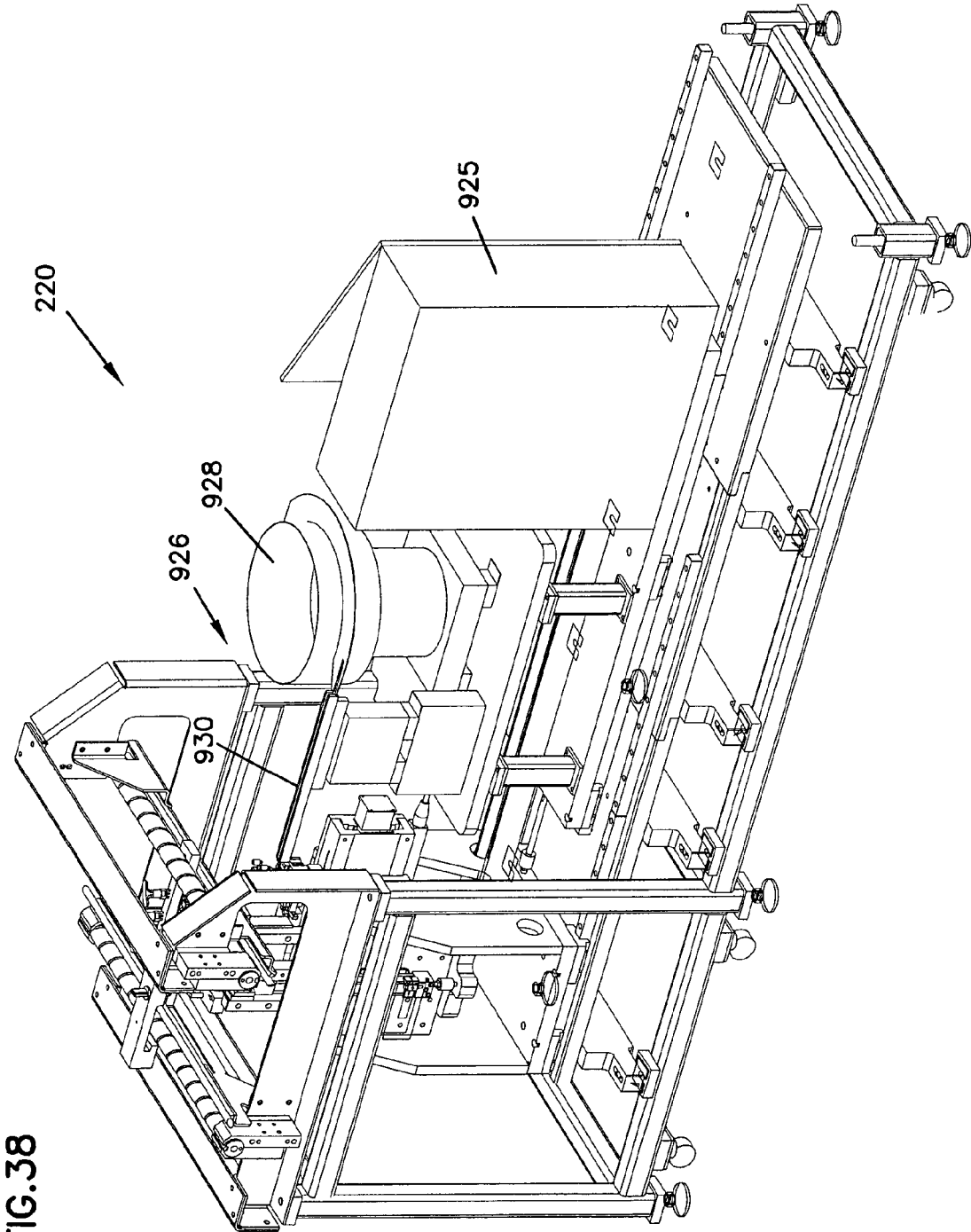


FIG. 38



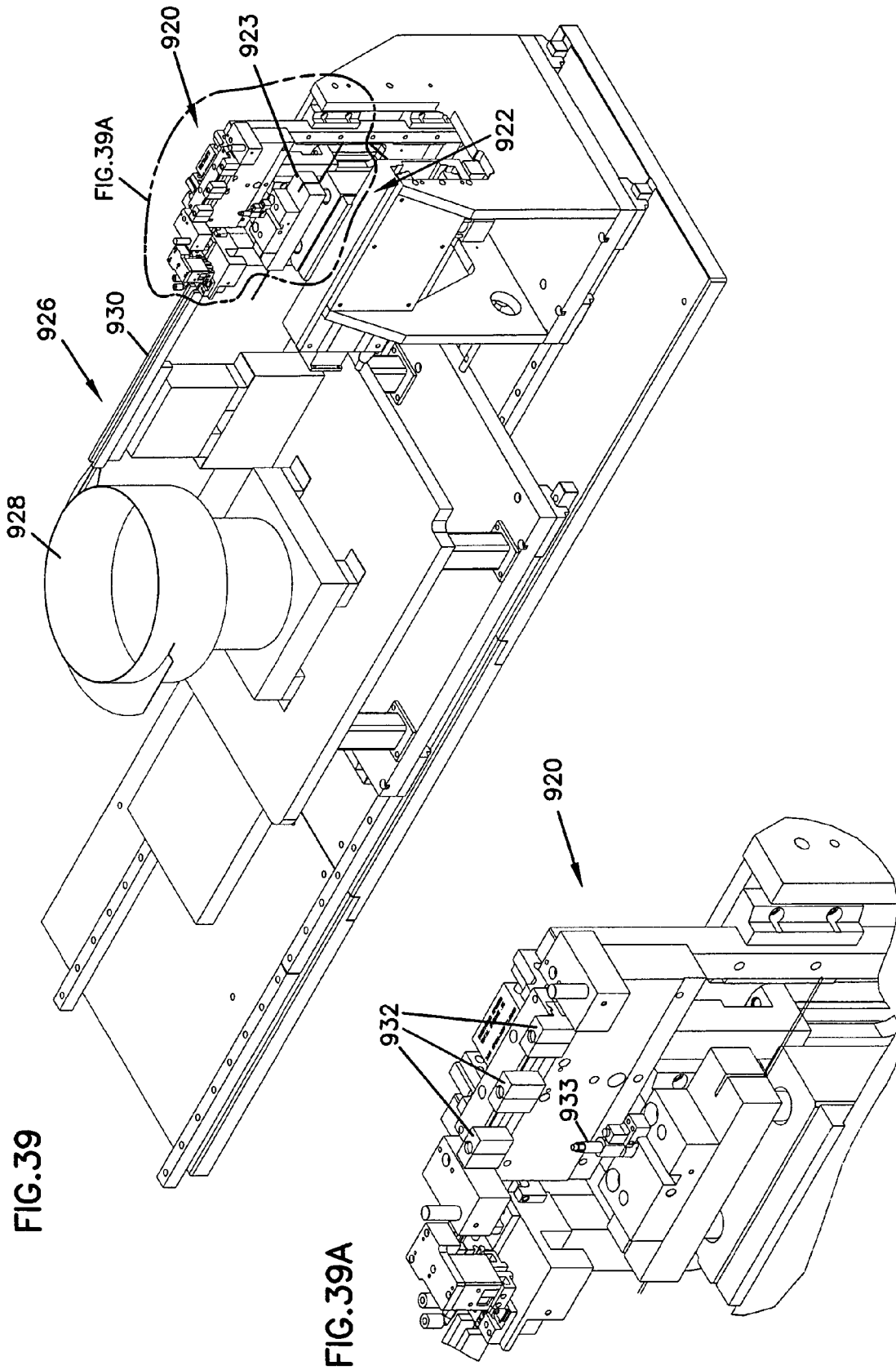


FIG. 39

FIG. 39A

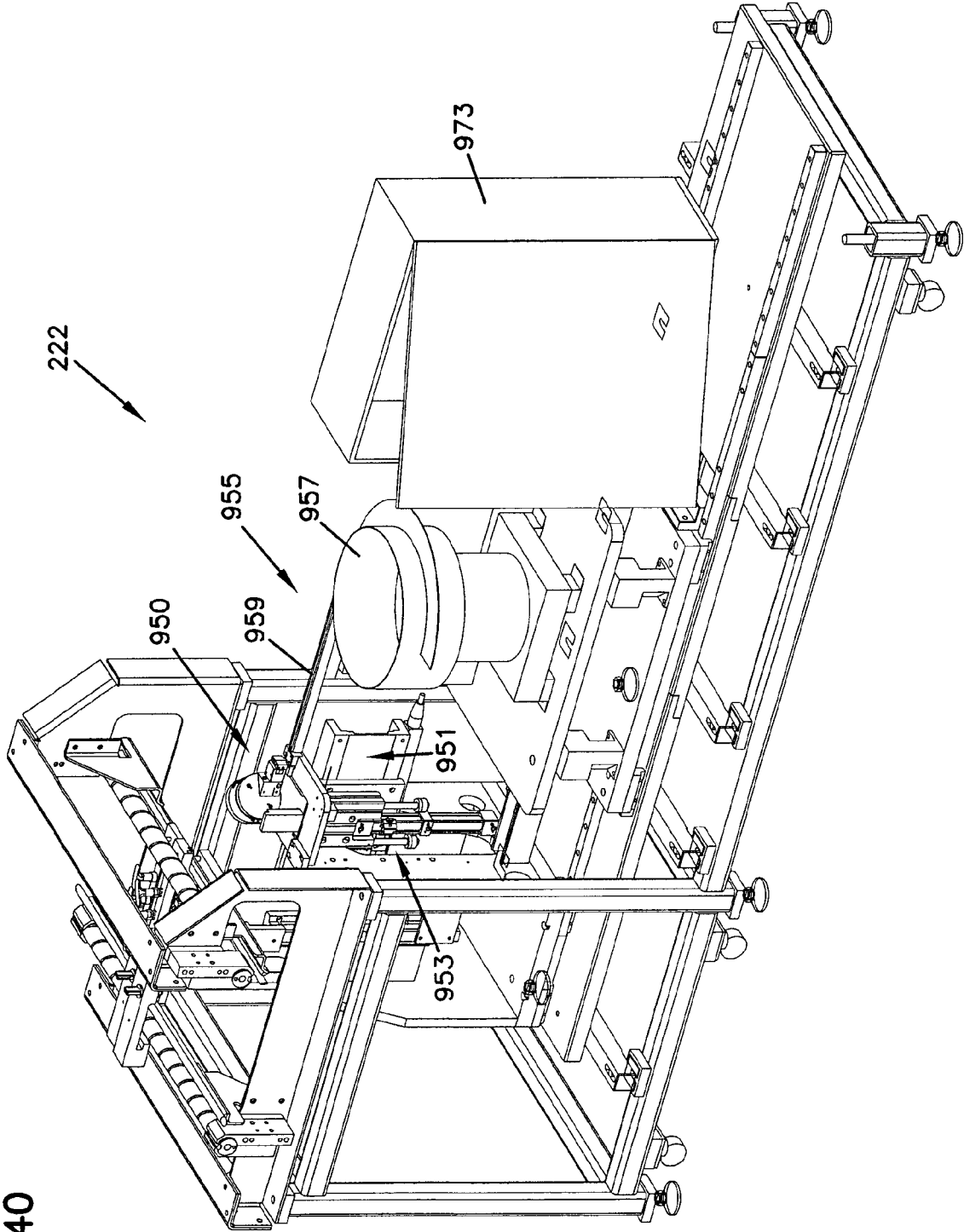


FIG.40

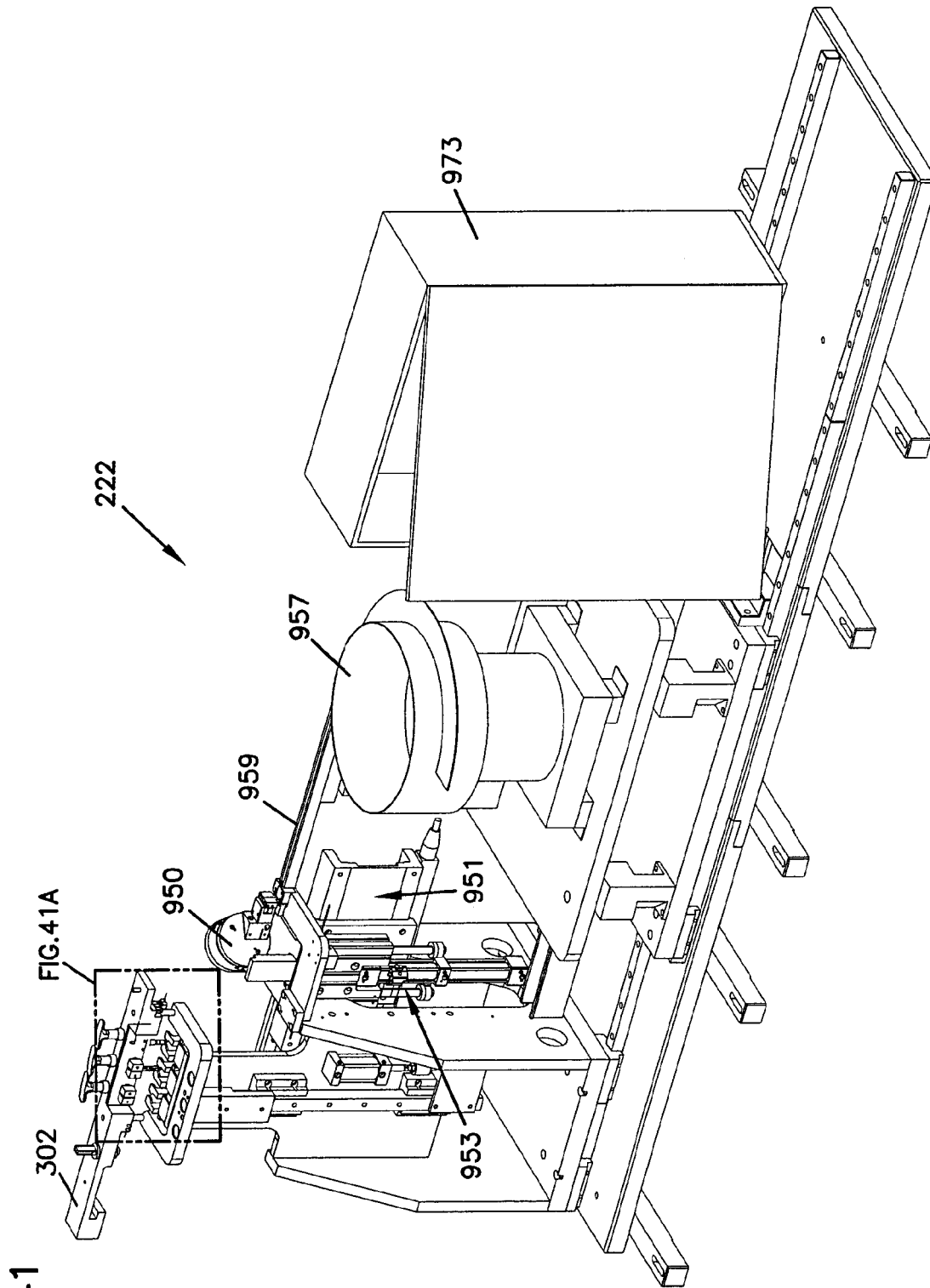


FIG.41

FIG.41A

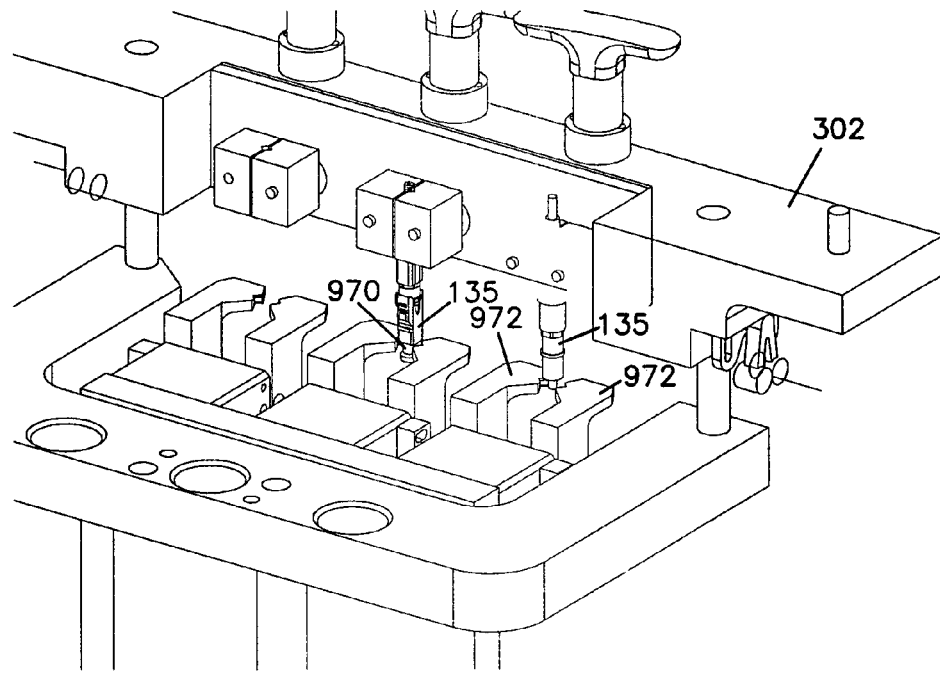
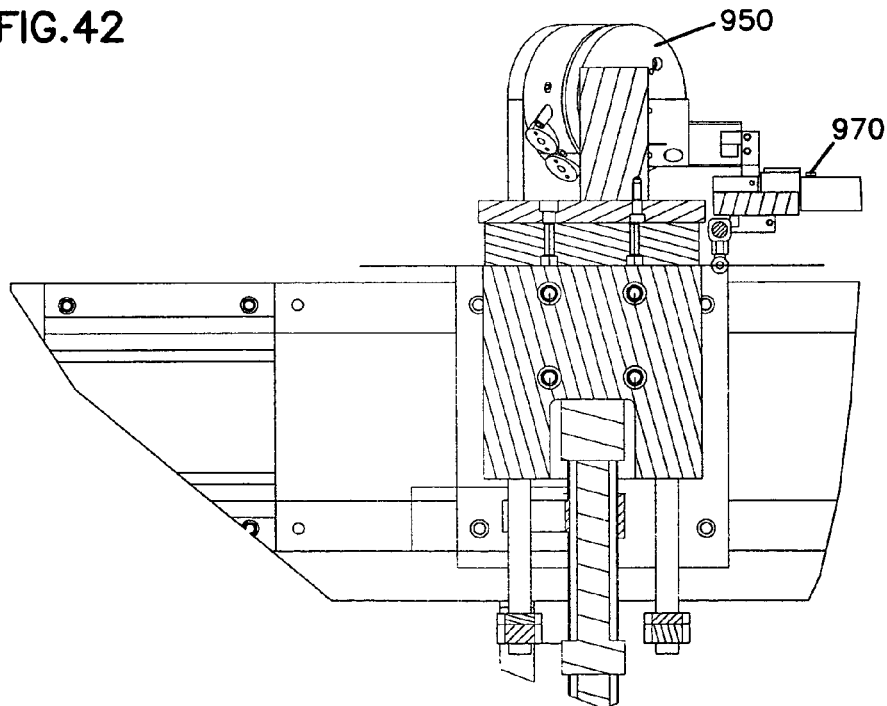


FIG.42



## DRIVE FOR SYSTEM FOR PROCESSING FIBER OPTIC CONNECTORS

### RELATED APPLICATION

The present application claims priority to U.S. Patent Provisional Application Ser. No. 60/579,755, entitled "System and Method for Processing Fiber Optic Connectors" and filed on Jun. 14, 2004, the entirety of which is hereby incorporated by reference.

### TECHNICAL FIELD

The present disclosure relates generally to systems and methods for processing fiber optic connectors.

### BACKGROUND

Fiber optic cables are used in the telecommunication industry to transmit light signals in high-speed data and communication systems. A standard fiber optic cable includes a fiber with an inner light-transmitting optical core. Surrounding the fiber typically is a reinforcing layer and an outer protective casing. A fiber terminates at a fiber optic connector. Connectors are frequently used to non-permanently connect and disconnect optical elements in a fiber optic transmission system. Connectors are typically coupled together through the use of an adaptor. An example adaptor is shown in U.S. Pat. No. 5,317,663, the disclosure of which is incorporated by reference.

There are many different fiber optic connector types. Some of the more common connectors are FC and SC connectors. Other types of connectors include ST and D4-type connectors.

FIG. 1 shows an example SC connector 10 that includes a ferrule 12. The ferrule 12 is a relatively long, thin cylinder preferably made of a material such as ceramic. Other materials such as metal or plastic can also be used to make the ferrule 12. The ferrule 12 defines a central opening 14 sized to receive a fiber of a given cladding diameter. An epoxy is typically placed into the opening 14 prior to inserting the fiber to hold the fiber in place. The ferrule 12 functions to align and center the fiber, as well as to protect it from damage.

Referring still to FIG. 1, the ferrule 12 is positioned within a ferrule housing 18 typically made of a material such as metal or plastic. An outer grip 19 is mounted over the ferrule housing 18. The housing 18 is externally keyed to receive the grip 19 at a single rotational orientation. A hub assembly 20 spring biases the ferrule 12 toward the front of the connector 10. A crimp sleeve 37 and boot 28 are located at the rear of the connector 10.

As described at U.S. Pat. No. 6,428,215, which is hereby incorporated by reference in its entirety, the connector 10 can be "tuned" by rotating the ferrule 12 relative to the ferrule housing 18 until an optimum rotational position is determined, and then setting the ferrule at the "tuned" or optimum rotational orientation. Connectors are tuned to ensure that when two connectors are coupled together via an adaptor, the ends of the fibers being connected are centered (i.e., aligned) relative to one another. Poor alignment between fibers can result in high insertion and return losses. Insertion loss is the measurement of the amount of power that is transferred through a coupling from an input fiber to an output fiber. Return loss is the measurement of the amount of power that is reflected back into the input fiber.

FIG. 2 shows an example FC connector 30 having a ferrule 32 mounted within a ferrule housing 34. A key 36 is fitted over the ferrule housing 34. The key 36 is positioned to correspond to a tuned orientation of the ferrule 32. An outer grip or connector 38 mounts over the ferrule housing 34. A hub assembly 40 is fixedly mounted to the ferrule 32. The hub assembly 40 spring biases the ferrule in a forward direction. The connector 30 also includes a dust cap 42 that covers the front of the ferrule 32, and a crimp sleeve 37 and boot 44 mounted at the rear of the connector 30.

In addition to tuning, insertion and return loss can be improved by polishing the end faces of the ferrules. During the polishing process, the ferrules are commonly held in a fixture, and the end faces are pressed against a rotating polishing wheel or disk. Frequently, the end faces are polished to form a polished surface oriented along a plane that is perpendicular with respect to the longitudinal axis of the fibers. However, for some applications, the end faces are polished to form a surface aligned at an oblique angle with respect to the longitudinal axis of the fibers.

Other process steps are also undertaken to complete the manufacture of fiber optic connectors. For example, after polishing, the end faces of the connector ferrules are often cleaned. Other steps include tuning the connectors, testing the connectors for insertion and return loss, and assembling the various components of the connectors.

Historically, the manufacture of fiber optic connectors has been quite labor intensive. Originally, connectors were individually manually polished and individually manually moved through the various processing steps. Manufacturing efficiency improved with the more prevalent use of multi-connector fixtures (e.g., see U.S. Pat. No. 6,396,996), which allowed multiple connectors to be simultaneously processed. While multi-connector fixtures have improved manufacturing efficiencies, further improvements in the area of automation are needed.

### SUMMARY

One aspect of the present disclosure relates to equipment having features adapted to facilitate automating various steps in the process of manufacturing a fiber optic connector.

A variety of advantages of the invention will be set forth in part in the description that follows, and in part will be apparent from the description, or may be learned by practicing the invention. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention as claimed.

### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate several aspects of the invention and, together with the description, serve to explain the principles of the invention. A brief description of the drawings is as follows:

FIG. 1 illustrates a typical prior art SC connector;

FIG. 2 illustrates another typical prior art FC connector;

FIG. 3 is a schematic diagram of an example embodiment of a connector processing system having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIG. 4 is a schematic diagram of another example embodiment of a connector processing system having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

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FIG. 4A is a schematic diagram of an example polishing station of the system of FIG. 4;

FIG. 4B is a schematic diagram of an example cleaning station of the system of FIG. 4;

FIG. 4C is a schematic diagram of an example tuning station of the system of FIG. 4;

FIG. 4D is a schematic diagram of an example testing station of the system of FIG. 4;

FIG. 4E is a schematic diagram of an example SC connector adjust station of the system of FIG. 4;

FIG. 4F is a schematic diagram of an example FC connector key press station of the system of FIG. 4;

FIG. 4G is a schematic diagram of an example dust cap station of the system of FIG. 4;

FIG. 5 is a perspective view of an example fixture;

FIG. 6 is a top view of the fixture of FIG. 5;

FIG. 7 is a side view of the fixture of FIG. 5;

FIG. 7A is another side view of the fixture of FIG. 7 with one control knob in a released position;

FIG. 8 is an end view of the fixture of FIG. 5;

FIG. 9 is an opposite end view of the fixture of FIG. 5;

FIG. 10 is a cross-sectional view taken along line 10-10 of the fixture of FIG. 6;

FIG. 10A is a cross-sectional view taken along line 10A-10A of the fixture of FIG. 6 with one control knob in the released position;

FIG. 10B is an enlarged view of a portion of the fixture of FIG. 10A;

FIG. 11 is a perspective view of an example stranded bare fiber support sleeve;

FIG. 12 is an exploded perspective view of the support sleeve of FIG. 11;

FIG. 13 is a perspective view of an example cart;

FIG. 14 is a side view of the cart of FIG. 13;

FIG. 15 is a front view of the cart of FIG. 13;

FIG. 16 is a top view of the cart of FIG. 13;

FIG. 17 is a perspective view of the front panel of the cart of FIG. 13;

FIG. 18 is a perspective view of the fixture mount of the cart of FIG. 13;

FIG. 19 is a perspective view of an example lead-in conveyor;

FIG. 19A is an enlarged view of a portion of the lead-in conveyor of FIG. 19;

FIG. 20 is a front view of the lead-in conveyor of FIG. 19;

FIG. 21 is a front view of an example lead-out conveyor;

FIG. 22 is a cross-sectional view of a portion of a fixture conveyor;

FIG. 23 is a perspective view of the fixture conveyor at the polishing station;

FIG. 23A is an enlarged view of a portion of the conveyor of FIG. 23;

FIG. 23B is an unwrapped view of the portion of the conveyor of FIG. 23A;

FIG. 24 is a front view of the conveyor of FIG. 23;

FIG. 24A is an enlarged view of a portion of the conveyor of FIG. 24;

FIG. 25 is a perspective view of an example cleaning station;

FIG. 26 is a perspective view of a portion of the cleaning station of FIG. 25;

FIG. 27 is a cross-sectional view of a portion of the cleaning station of FIG. 25;

FIG. 28 is another cross-sectional view of a portion of the cleaning station of FIG. 25;

FIG. 29 is a side view of an example tuning station;

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FIG. 30 is a cross-sectional view of the tuning station of FIG. 29;

FIG. 30A is an enlarged view of a portion of the tuning station of FIG. 30;

FIG. 30B is an enlarged view of a portion of the tuning station of FIG. 30A;

FIG. 31 is a perspective view of an example adaptor of the tuning station of FIG. 29;

FIG. 32 is an exploded perspective view of portions of the example tuning station of FIG. 29;

FIG. 33 is a perspective view of an example testing station;

FIG. 34 is a cross-sectional view of the testing station of FIG. 33;

FIG. 34A is an enlarged view of a portion of the testing station of FIG. 34;

FIG. 35 is a perspective view of an example SC connector adjust station;

FIG. 36 is a perspective view of a portion of the SC connector adjust station of FIG. 35;

FIG. 37 is a cross-sectional view of the SC connector adjust station of FIG. 35;

FIG. 37A is an enlarged view of a portion of the SC connector adjust station of FIG. 37;

FIG. 38 is a perspective view of an example FC connector key press station;

FIG. 39 is a perspective view of a portion of the FC connector key press station of FIG. 38;

FIG. 39A is an enlarged perspective view of a portion of the FC connector key press station of FIG. 39;

FIG. 40 is a schematic view of an example dust cap station;

FIG. 41 is another schematic view of the dust cap station of FIG. 40 with portions of the station removed;

FIG. 41A is an enlarged perspective view of a portion of the dust cap station of FIG. 41; and

FIG. 42 is a cross-sectional view of a portion of the dust cap station of FIG. 40.

While the invention is amenable to various modifications and alternative forms, the specifics there have been shown by way of example in the drawings and will be described in detail below. It is to be understood, however, that the intention is not to limit the invention to a particular embodiment. On the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the scope of the invention as defined by the appended claims.

#### DETAILED DESCRIPTION

In the following detailed description, references are made to the accompanying drawings that depict various embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized, and that structural and functional changes may be made without departing from the scope of the present invention.

#### I. First Embodiment of Automated Connectorization System

##### A. System Description

FIG. 3 schematically depicts a fiber optic connector processing system 100 having features that are examples of inventive aspects in accordance with the principles of the present disclosure. The system 100 is adapted for use in processing connectorized fiber optic cables 133 (e.g., ribbon or stranded cable). The connectorized cables 133 typically

include fiber optic connectors **135** (e.g., SC connectors, FC connectors, ST connectors, or D4) terminated at first ends of the cables **133**, and bare fibers **137** (e.g., fibers that have been stripped and cleaved) located at second ends of the cables **133**. The bare fibers **137** can be housed within bare fiber support sleeves **139** that protect and prevent bending of the bare fibers, and also facilitate optically coupling the bare fibers **137** to test equipment during processing of the cables **133**. After processing of the cables **133**, the bare fibers **137** can be used to provide field terminations or to provide splices with other cables.

Referring still to FIG. 3, the system **100** includes a plurality of modular processing stations arranged in an assembly line configuration. The processing stations shown include a polishing station **110**, a cleaning station **112**, a tuning station **114**, a test station **116**, an SC connector adjust station **118**, an FC connector key press station **120**, and a dust cap installation station **122**. The system **100** also includes a conveying system **124** for conveying the connectorized optical cables **133** through the various processing stations. One or more processing units (e.g., personal computers or other controllers) can be used to control the conveying system **124** and also to control the processes at each of the process stations.

The conveying system **124** includes a carrier **126** adapted for carrying any number of optical cables **133** ranging from a single optical cable up to hundreds of optical cables. The carrier **126** is shown carrying fixtures **132** for securing the connectors **135**. The fixtures **132** include clamps **141** for holding the connectors **135** as the connectors are processed at the various processing stations. The clamps **141** preferably hold the connectors **135** with ferrules **145** of the connectors exposed so that end faces **147** of the ferrules **145** can be readily accessed for processing. The fixtures **132** also include receiver sockets **143** for receiving the bare fiber support sleeves **139**. When mounted within the receiver sockets **143**, the ends of the bare fiber support sleeves **139** are exposed to facilitate optically coupling the bare fibers **137** to test equipment during processing. The fixtures of the carrier **126** are preferably adapted to hold a plurality of connectors **135** during processing. In one non-limiting embodiment, the fixtures of the carrier can have a capacity of least 72 connectors **135**.

The stations are preferably standalone units that are assembled together to form the assembly line. The modularity of the stations allows the stations to be readily removed, added, or rearranged along the assembly line. For example, each station can include wheels to allow for ease in the rearrangement of the different stations. While seven stations have been shown in the embodiment of FIG. 3, it will be appreciated that additional stations can be added, certain stations can be removed, and/or the order of the stations can be changed without departing from the principles of the present disclosure.

#### B. Description of System Operation

In use, the carrier **126** initially conveys the connectorized optical cables **135** to the polishing station **110**. The polishing station **110** preferably includes a plurality of substations each corresponding to a different polishing function. For example, the polishing substations can be configured with polishing mediums (e.g., films, disks, etc.) of different coarseness, and polishing pads of differing durometers, to achieve different polishing functions.

The polishing station **110** can include one or more drive mechanisms for moving the polishing mediums relative to the ferrule end faces **147** of the connectors **135** being

processed. For example, the drive mechanisms can spin, oscillate or otherwise move the polishing mediums relative to the ferrule end faces **147**. Alternatively, the end faces **147** of the connectors **135** can be moved relative to the polishing mediums. The polishing mediums and/or ferrules **145** of the connectors **135** can be biased to maintain contact between the end faces **147** and the polishing mediums.

After the ferrule end faces **147** of the connectors **135** have been polished, the carrier **126** conveys the connectorized cables **133** to the cleaning station **112**. At the cleaning station **112**, residue or other foreign material deposited on the ferrules **145** of during the polishing stage is preferably removed. In one embodiment, steam and blasts of air (e.g., carbon dioxide) can be used to clean the ferrules **145**.

After cleaning, the carrier **126** conveys the fixtures **132** to the tuning station **114**. At the tuning station **114**, the connectors **135** (e.g., SC and FC connectors) are tested for insertion and/or return loss at various incremental rotational positions (e.g., 60 degree increments). The connectors **135** are tuned by inputting light into the connectors **135** at each rotational increment, and comparing the relative amount of light that is output from the bare fiber ends **137** at each increment. The rotational orientation of the tuned position (i.e., "the key location") is selected to ensure that when two connectors are optically coupled together, the ferrules of the coupled connectors are relatively oriented to provide optimum optical performance. After tuning, FC connectors can be rotated within the fixtures to place the key locations at known rotational positions that are coordinated with subsequent processing steps (e.g., the key press step at the FC connector key press station **120**). Alternatively, in the case of SC connectors, the key locations can be stored in memory for use at the SC connector adjust station **118**.

From the tuning station **114**, the carrier **126** moves the connectorized cables **133** to the test station **116**. At the test station **116**, each of the connectors **135** is tested for insertion loss and return loss to ensure each of the connectors complies with predetermined insertion loss and return loss standards. The connectors **135** are tested by inputting light through the connectors **135** and measuring the quantity of light output through the bare fiber ends **137**. Information concerning connector failure is stored in memory for use during subsequent processing operations.

If SC connectors are being processed, the carrier **126** moves from the test station **116** to the SC connector adjust station **118**. If FC connectors are being processed, the carrier **126** moves from the test station **116**, past the SC connector adjust station **118**, to the FC connector key press station **120**. If ST or D4 connectors are being processed, the carrier moves from the test station **116**, past both the SC connector adjust station **118** and the FC connector key press station **120**, to the dust cap station **122**.

At the SC connector adjust station **118**, the ferrule of each SC connector (e.g., hub assembly **20** of SC connector **10** shown in FIG. 1) is rotated relative to its corresponding ferrule housing (e.g., housing **18**) until the keys of the ferrule housings align with the key locations previously determined at the tuning station **114** and stored in memory. After the SC connector adjustment process has been completed, the carrier **126** carries the SC connectors past the FC connector key press station **120** to the dust cap station **122**.

At the FC connector key press station **120**, keys (e.g., key **36** of FC connector **30** shown in FIG. 2) are pressed on to the bodies of FC connectors at the key mounting locations. The pre-orientation of the rotational positions of the FC connectors at the tuning station **114** ensures that the keys are

properly oriented at the optimal tuned or key locations. Thereafter, the carrier **126** moves the FC connectors to the dust cap station **122**.

At the dust cap station **122**, dust caps (e.g., dust cap **42** shown in FIG. **2**) are pressed over the ferrules of the connectors. In some embodiments, dust caps are only applied to those connectors that were successfully processed through system **100**. For example, dust caps can be placed on only those connectors that receive a passing rating at test station **116**. In this manner, during subsequent processing, the presence of a dust cap indicates that the connectors are ready for subsequent processing (e.g., installation of the outer grips). The absence of a dust cap alerts the operator that the connector has failed in some respect, and alerts the operator to remove the connector for re-processing.

## II. Second Embodiment of Automated Connectorization System

### A. System Description

FIGS. **4** and **4A-4G** show an alternative fiber optic connector processing system **200** having features that are examples of inventive aspects in accordance with the principles of the present disclosure. The system **200** includes a plurality of modular processing stations arranged in an assembly line. Similar to the previous embodiment, the processing stations include a polishing station **210**, a cleaning station **212**, a tuning station **214**, a test station **216**, an SC connector adjust station **218**, an FC connector key press station **220** and a dust cap station **222**, all of which are described further below.

The system **200** also includes a cart conveying unit **224** for conveying a cart **226** from station to station. See FIGS. **13-18** and accompanying description below. The cart **226** is adapted for carrying one or more connectorized fiber optic cables **133**.

The system **200** further includes fixture assemblies **300** that can be mounted to and detached from the cart **226**. See FIGS. **5-10B** and accompanying description below. For clarity, only a few of the fixture assemblies **300** are shown mounted to the cart **226**. The fixture assemblies **300** each include a tuning and test fixture **302** for clamping boots **149** of the connectors **135**, and a polishing fixture **304** having nests for supporting the ferrules **145** of the connectors **135**. The tuning and test fixtures **302** also define receptacles **342** for receiving the bare fiber support sleeves **139** mounted to bare fiber ends **137** of the cables **133**.

The system **200** further includes a fixture conveyor **240** for conveying the fixture assemblies **300** from station to station along the assembly line. See FIGS. **19-24A** and accompanying description below. The fixture conveyor **240** is a separate conveyor from the cart conveyor **224**. However, the operation of the fixture conveyor **240** is coordinated with the operation of the cart conveyor **224** such that the fixture assemblies **300** and their corresponding cart **226** move in a side-by-side relationship from station to station.

The system **200** includes a main system controller **250** that coordinates the operation of the fixture conveyor **240** with the operation of the cart conveyor **224**. The main system controller **250** interfaces with controllers at each of the stations to integrate each station into the overall system. In certain embodiments, the main systems controller **250** can include a personal computer with keyboard access.

### B. System Operation Overview

In general use of the system **200**, a spool **260** of fiber optic cable **133** is placed on the cart **226** while the cart is off-line

from the cart conveyor **224**. Connectors **135** of the fiber optic cables **133** are then clamped within the fixture assemblies **300**, and the bare fiber support sleeves **139** are inserted within receptacles **342** defined by the fixture assemblies **300**. The fixture assemblies **300** are then secured to the cart **226**.

After securing the fixture assemblies **300** to the cart **226**, the cart **226** is manually wheeled to the cart conveyor **224**. The cart **226** then engages the cart conveyor **224** and is conveyed toward the polishing station **210**. Prior to reaching the polishing station **210**, the fixture assemblies **300** are disconnected from the cart **226** and engaged with the fixture conveyor **240**. The fixture conveyor **240** then conveys the fixture assemblies **300** to the polishing station **210** for polishing of the ferrules **145**.

At the end of the polishing station, the polishing fixtures **304** of fixture assemblies **300** are stripped from the tuning and test fixtures **302** to provide more ready access to the connectors **135** during subsequent processing steps. The tuning and test fixtures **302** are then moved by the fixture conveyor **240** to subsequent processing stations to allow the connectors **135** to be processed (e.g., cleaned, tuned, tested, key adjusted, key pressed, fitted with dust caps or processed by other processing operations).

Typically, the tuning and test fixtures **302** are stopped at stations where processing is desired to provide sufficient time for processing. As described with respect to the embodiment of FIG. **3**, depending on the type of connector being processed, certain of the stations may be by-passed. The functions performed at each of the stations can be similar to those described with respect to the embodiment of FIG. **3**.

Movement of the cart **226** is preferably coordinated with the movement of the fixture on the conveyor **240**. The conveyor **240** preferably moves the fixtures in a stepwise motion (i.e., the movement is indexed or stepped in fixed increments). The cart conveyor **224** preferably moves the cart **226** in a stepwise motion that corresponds to the stepwise motion generated by the conveyor **240**. In this manner, the fixtures **300** (which carry the connectors **135**) and the cart **226** (which carries the bulk of the cable **133**) remain in a side-by-side relationship throughout the various processing steps.

After the dust cap station **222**, the fixtures **302** are disengaged from the conveyor **240** and re-connected to the cart **226**, and the cart **226** is disengaged from the cart conveyor **224** and manually wheeled to a location for further processing of the connectors **135**. For example, at a subsequent location, outer grips can be pressed on the connectors **135**. Thereafter, the connectors **135** can be removed from the fixtures **302**, and the fixture assemblies **300** can be re-assembled and reloaded with a next batch of connectors **135**. The cart **226** can then be wheeled back to the start of the cart conveyor **224** to initiate processing of the next batch of connectors **135**.

A plurality of carts **226**, each including a plurality of connectors **135** mounted in fixture assemblies **300**, can be processed by system **200**. For example, a plurality of carts **226** can be sequentially loaded into system **200** so that each station of system **200** is eventually occupied at a given point in time.

### C. System Component Descriptions

#### a. Fixture Assemblies

Referring now to FIGS. **5-10B**, the fixture assemblies **300** of the system **200** each include the tuning and test fixture **302** as well as the polishing fixture **304**. The polishing fixture **304** is detachably mounted to the underside of the



tuning and test fixture 302. A latching arrangement, such as a pair of spring latches 306, is used to secure the polishing fixture 304 relative to the tuning and test fixture 302. The polishing fixture 304 also includes alignment pins 308 that fit within openings 309 defined by the tuning and test fixture 302 to maintain alignment between the two fixtures 302, 304. See FIGS. 10 and 10A.

Referring to FIGS. 8 and 9, each of the spring latches 306 includes a pair of resilient arms 310 secured to the polishing fixture 304. The resilient arms 310 are biased together and interlocked with a retaining member 312 provided on the tuning and test fixture 302. The polishing fixture 304 can be detached from the tuning and test fixture 302 by pulling downwardly on the polishing fixture 304 with sufficient force to flex the arms 310 of the latches 306 apart such that the arms 310 disengage from the retaining member 312.

The polishing fixture 304 of the fixture assembly 300 includes three ferrule nests 314 sized to receive ferrules 145 of the connectors 135. See FIGS. 10, 10A, and 10B. The ferrules 145 protrude downwardly beyond the nests 314 such that the end faces 147 of the ferrules 145 are exposed for polishing. In addition, the ferrule nests 314 form a close tolerance fit as the ends 147 of ferrules 145 extend below the fixture 304.

Each ferrule nest 314 also includes a boss 319 with end 317. See FIG. 10B. The boss 319 functions to center the ferrule 145 of each connector 135 and is sized so that the end 147 of the ferrule 145 for both FC connectors and SC connectors extends an equal distance below the fixture 304. Specifically, as shown in FIG. 10B, ends 317 of boss 319 extend into and contact housing 18 of SC connector 135a. In contrast, an end 311 of housing 34 of FC connector 135b contacts the base of the nest 314. In this manner, end faces 147 of both the SC connector 135a and FC connector 135b extend an equal distance below fixture 304.

As shown in FIGS. 4, 6, and 10, the polishing fixture 304 also includes an extension 316 that extends beyond the end of the tuning and test fixture 302. The extension 316 provides a location where the polishing fixture 304 can be clamped by a polishing machine at the polishing station 212.

Referring to FIG. 8, the tuning and test fixture 302 includes an end opening 315 for receiving retractable retention pins of the cart 226 (see FIG. 18) to mount the fixture assembly to the cart 226. The tuning and test fixture 302 also includes a V-notch 320 (see FIGS. 6 and 7) for interlocking with resilient retention clips provided on the cart 226. The clips interlock with the V-notches 320 to prevent the fixture assemblies 300 from inadvertently rotating on or disengaging from the mounting pins of the cart 226.

The tuning and test fixture 302 also include three clamps 230 (best shown in FIGS. 5, 7, 10, 10A, and 10B) adapted for clamping boots 149 of the connectors 135 to hold the connectors 135 during processing. Each of the clamps 330 includes two clamp members 331 between which the boots 149 of the connectors 135 are clamped. Each of the clamp members 331 includes a recessed mid-region 333. The recessed mid-region 330 defines receptacles (e.g., channels or slots) in which the boots 149 of the connectors 135 can be clamped. The recessed mid-regions 333 have generally V-shaped cross-sections with the widths of the recessed mid-regions 333 enlarging as the recessed mid-regions 333 extend in a downward direction. A pair of resilient members 335 (e.g., O-rings) is mounted within each mid-region 333. The resilient members 335 facilitate gripping the boots 149 of the connectors 135.

The clamp members 331 are spring biased toward one another (i.e., toward a clamped orientation). The clamp

members 331 can pivot slightly to accommodate connectors with boots of differing dimensions and tapers. See, for example, FIG. 10B, which illustrates clamp members 331 clamped to boot 28 of SC connector 135a and boot 44 of FC connector 135b. In addition, when the clamp members 331 are moved from the closed to the open position, the clamp members 331 move slightly in an upward direction during the beginning of movement to the open position so that tension on the connector 135 is released prior to release of the boot of the connector.

The tuning and test fixture 302 further includes clamp control knobs 355 for manually opening and closing the clamps 230. In manual operation, as illustrated in FIGS. 7A and 10A, control knob 355a is pulled away from fixture 302 to open the clamp 230a to allow a connector 135 to be inserted into or removed from clamp 230a. Knob 355a can be rotated a quarter turn to temporarily lock clamp 230a in the open position. In an automatic operation, internal components of fixture 302 can be actuated to open clamps 230a, 230b, and 230c without requiring control knobs 355a, 355b, and 355c to be manually pulled upward.

The tuning and test fixture 302 further includes a receiver 340 defining the receptacle 342 for receiving one of the bare fiber support sleeves 139, which is illustrated in FIGS. 11 and 12 and described further below. The receiver 340 extends through the main body of the tuning and test fixture 302 and includes a lower portion that is accessible from the underside of the main body 302. See FIG. 10A. When the bare fiber support sleeve 139 is mounted within the receiver 340, the ends of the bare fibers are accessible from the underside of the tuning and test fixture 302 for allowing the fibers to be optically connected to a test structure such as a remote test head for use in insertion loss and return loss testing.

The tuning and test fixture 302 further includes upper and lower pins 344 and 346. See FIGS. 7 and 10. The upper pin 344 projects upwardly from the main body of the fixture 302, and the lower pin 346 projects downwardly from the main body of the fixture 302. The pins 344, 346 are adapted to engage the fixture conveyor 240. See FIG. 22.

As shown in FIGS. 11 and 12, the bare fiber support sleeves 139 include a top portion 151 that is pivotally mounted to a base portion 152. A fiber holder 156 including ferrules 153 is configured to receive and hold stranded bare fiber. In use, bare stranded fiber is extended through channel 154 formed in base portion 152 and into fiber holder 156. Previously stripped ends of the stranded fiber are positioned to extend through ferrules 153. Then, the top portion 151 is pivoted toward the base portion 152 until in the position illustrated in FIG. 11. Next, the stripped ends of the fibers that extend from ferrules 153 are cleaved. In one embodiment, a cleaver having product no. CT-107, manufactured by Fujikura Ltd. of Tokyo, Japan, is used to cleave the striped fiber. Once the fibers are cleaved, the bare fiber support sleeve 139 is positioned in the tuning and test fixture 302, as shown in FIGS. 5, 7, and 10A. In this position, the ferrules 153 of support sleeve 139 are accessible below the fixture 302.

If, instead of stranded fiber, ribbon fiber is being processed, a similar support sleeve can be used. However, for ribbon fiber, no ferrules are required because the ribbon structure provides adequate support for the fibers. In addition, for ribbon fiber, the fiber can be both stripped and cleaved once the fiber has been placed in the support sleeve.

#### b. Cart Assembly

FIGS. 13-18 show various views of the cart 226. The cart 226 includes a base 400. A rear portion of the base 400

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defines a platform **402** for supporting a spool of fiber optic cable. Rollers **403** are provided on the platform **402** for facilitating loading and unloading spools of fiber optic cable to or from the platform **402**. The sides of the platform **402** are enclosed by side walls **404** and the front of the platform **402** is enclosed by a front wall **406**. The back of the platform **402** is open to facilitate loading fiber optic spools onto the platform. Handles **408** are provided at the top sides of the side walls **404** for facilitating maneuvering of the cart **226**.

With respect to the spools carried by the cart **226**, the spools typically range in diameter from 12 inches to 36 inches. The spools can carry anywhere from one fiber optic cable to hundreds of fiber optic cables. In the case where a large number of fiber optic cables are wrapped about the spool, the fibers are typically bundled within one or more bundling sheathes. Sub-bundles can be provided within the main sheathed bundles. The fiber optic cables can range in length from a few feet to hundreds of feet. While the cables will typically be provided on spools, it will be appreciated that for short length cables, spools may not be needed.

Referring to FIGS. 13-16, casters **410** are mounted to the underside of the base **400**. The casters **410** include pivoting caster wheels **412**. The caster wheels **412** include central grooves **414**. See FIG. 14. A pair of racks or ladders **416** is also mounted to the underside of the base **400**. The ladders **416** provide structure for allowing the cart conveyor **224** to engage the cart **226**.

The cart **226** further includes a front cable management structure **420** that projects forwardly from the front wall **406**. The cable management structure **420** includes an upright front panel **422**. See FIGS. 13, 15, and 17. Cable management structures such as spools **424** for managing excess cable and clamps **426** for clamping cables are mounted to the front panel **422**. Two cable clamps **428** are mounted to the top of the upright panel **422**. The clamps **428** are adapted for clamping a sheathed portion of a bundle of fiber optic cables. The sheathed portion of the bundles is preferably clamped at the clamps **428**, and extensions of the fiber optic cables bundled within the sheath are typically fanned downwardly from the clamps **428** with connectorized ends **135** of the fiber optic cables being clamped within the fixture assemblies **300**. Excess length of cable corresponding to the connectors being processed, as well as extra cables having connectors that have already been processed or are soon to be processed, can be managed by wrapping such cables around the spools **424**.

The cart **226** further includes a fixture mount **450**. See FIGS. 14 and 18. The fixture mount **450** includes a plurality of mounting pins **452** adapted to be received within the rear openings **315** of the tuning and testing fixtures **302**. The depicted mount **450** is adapted for mounting **24** fixture assemblies **300**. However, it will be appreciated that the capacity of the mount **450** can be varied without departing from the principles of the disclosure.

The fixture mount **450** also includes resilient retention clips **454** that engage the notches **320** in the tuning and test fixtures **302** to prevent the fixtures **302** from inadvertently disengaging from the pins **452**. The fixture mount **450** further includes a handle **456** for retracting the fixture mount **450** to disengage the fixture assemblies **300** from the cart **226** after the fixture assemblies **300** have been engaged by the fixture conveyor **240**. By pivoting the handle **456**, the pins **452** are withdrawn from the rear openings **315** of the tuning and test fixtures **302** to disengage the fixture assemblies **300** from the cart **226**. As the fixture mount **450** is retracted, the retaining clips **454** flex upwardly to allow the fixture assemblies **300** to be disengaged from the cart **326**.

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The cart **226** further includes a bin **460** for receiving and storing the polishing fixtures **304**. See FIG. 14. As will be described below, after the polishing processes have been completed at the polishing station **212**, the polishing fixtures **304** are stripped from the tuning and test fixtures **302**. After the polishing fixtures **304** have been stripped, the polishing fixtures **304** slide by gravity down a ramp and into the bin **460** for storage. Subsequently, the polishing fixtures **304** are removed from the bin **460** and recoupled to fixtures **302** for processing the next batch of connectors.

## c. Cart Conveyor

The cart conveyor **224** is depicted in FIG. 4 as including a pair of parallel tracks **600** for receiving the caster wheels **412** of the cart **226**. Center guides **602** are located within each of the tracks **600**. When the cart **226** is conveyed along the tracks **600**, the grooves **414** of the wheels **412** ride along the center guides **602**. The cart conveyor **224** also includes a drive mechanism for moving the cart **226** along the tracks **600**. It will be appreciated that the drive mechanism can have any number of different configurations. In the depicted embodiment, the drive mechanism includes a pneumatically powered walking beam drive **661**. In other embodiments, the drive mechanism can include a chain drive, a stepper motor drive, a rack and pinion drive, or any other drive suitable for conveying the cart in a controlled manner.

The walking beam drive **661** includes a pair of parallel beams **662a**, **662b** having lugs **663** for engaging the ladders **416** on the underside of the cart **226**. Vertical pneumatic cylinders **665** raise and lower the beams **662a**, **662b** and horizontal pneumatic cylinders **667** move the rails horizontally. The left beam **662a** is preferably moved in a square pattern. For example, beam **662a** is raised (e.g., by cylinders **665**) such that the lugs **663** engage the left ladder **416** of the cart **226**, is moved horizontally forward (e.g., by cylinder **667**) to move the cart **226** forward one increment, is lowered (e.g., by cylinders **665**) to disengage the lugs **663** from the cart **336**, and is then horizontally returned to its initial position (e.g., by cylinder **667**) where it is ready to repeat the cycle. The right beam **662b** can be moved in a similar pattern.

Alternatively, the beam **662b** can simply be raised and lowered to selectively engage right ladder **416** the cart **226**. For example, the right beam **662b** can be raised when the left beam **662a** is lowered to prevent unintentional movement of the cart **226**, and then lowered when the lugs **663** of the left beam **662a** are in engagement with the cart **226**.

## d. Fixture Conveyor

Referring now to FIGS. 4 and 19-24A, the fixture conveyor **240** is shown including two generally parallel guide rails **700** and two generally parallel screw drives **702**. The screw drives **702** can be powered by a drive mechanism **707** (see FIG. 21) such as a pneumatic drive, a servo-motor drive, or any other drive suitable for rotating the screw drives **702**. The screw drives **702** are vertically offset from one another (i.e., set at different elevations) such that one of the screw drives **702** is adapted to engage the upper guide pins **344** of the fixtures **302**, and the other of the screw drives **702** is adapted to engage the lower pins **346** of the fixtures **302**. See FIGS. 20, 21, and 22.

As shown in FIG. 22, the pins **344**, **346** ride within slots **703** defined within the screw drives **702**. By rotating the screw drives **702**, the fixture **300**, including the tuning and test fixture **302** and polishing fixture **304**, is conveyed along the screw drives **702**.

The slots **703** of the screw drives **702** are generally arranged at an angled pitch configuration **709** for  $\frac{2}{3}$  of a turn and then a non-angled configuration **701** for the remaining

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$\frac{1}{3}$  of the turn. See FIGS. 23A and 23B. This configuration results in the fixture assemblies 300 being conveyed along the screw drives 702 for  $\frac{2}{3}$  of the turn (i.e., in angled pitch 709) and then dwelling at one spot for  $\frac{1}{3}$  of the turn (i.e., in non-angled configuration 701) for each revolution of the screw drives 702. The dwell times provided by the non-angled portions 701 of the slots 703 assist in preventing inertial bumping of the fixtures during conveying, as well as allow the screw drives 702 to reengage the fixture 300 after each polishing cycle, as described further below.

In one embodiment, the fixtures 300 are moved about 1 inch per revolution of the screw drives 702 and are typically moved in 2 inch increments between processing steps. To correspond with the fixture conveyor 240, the cart conveyor 224 preferably moves the cart 226 in the same 2 inch increments. While 2 inch increments are preferred, it will be appreciated that the size of the increments can be varied without departing from the principles of the disclosure.

As shown at FIGS. 23, 24, and 24A, the screw drives 702 also preferably include flat regions 348 located at the polishing station 210. The flat regions 348 are positioned to correspond with the non-angled portions 701 of the slots 703. The flat regions 348 allow the pins 344, 346 of the fixtures 302 to be disengaged from the screw drives 702 during polishing operations, as described further below. After polishing, the non-angled portions 701 of the slots 703 allow the pins 344, 346 to be reengaged with the screw drives 702 upon revolution of the screw drives.

The screw drives 702 also include regions of increased slot pitch 705 before and after entering the flat regions 348 of the polishing station 210. See FIG. 24A. The increased pitch regions 705 provide an increased spacing between the group of fixtures 300 being polished at the polishing station 210, and fixtures 300 located before and after the polishing station 210. This spacing allows the group of fixtures 300 at the polishing station 210 to be moved longitudinally during polishing without contacting adjacent fixtures.

While a screw drive arrangement is preferred for conveying the fixtures, it will be appreciated that other types of drive mechanisms such as rack and pinion drives, chain drives, belt drives or other drives could also be used.

The screw drives 702 can be powered by a drive mechanism 707 such as one or more servo-motors. If a single servo-motor is used, belts or other torque transfer arrangements can be used to transfer torque from the servo to the screw drives 702 for turning the screw drives 702.

The fixture conveyor 240 can also include a lead-in section 708 and a lead-out section 709. See FIGS. 19-21. The lead-in and lead-out sections 708, 709 preferably have a length generally equal to at least one cart length. At the lead-in and lead-out sections 708, 709, straight longitudinal slots 349 can be formed in screw drives 702 to allow pins 344, 346 of fixtures 300 to slide therein, thereby facilitating engaging the fixture pins 344, 346 with the screw drives 702 as the cart 226 is lead into the assembly line, and to facilitate disengaging the fixture pins 344, 346 from the screw drives 702 as the cart 226 is lead out of the assembly line. See FIG. 19A.

#### e. Polishing Station

Referring to FIGS. 4 and 4A, the depicted polishing station 210 includes a plurality of polishing substations 210a-210g. Each substation includes three polishing pads 750 that can be individually raised and lowered by separate lift mechanisms (e.g., pneumatic cylinders). Polishing films are positioned between the pads 750 and the ferrule end faces 147 of the ferrules 145 nested within the polishing fixtures 304 of the fixture assemblies 300.

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By lifting the polishing pads 750, the polishing films are pressed into contact with the ferrule end faces 147. The various polishing substations 210a-210g can provide various polishing functions. For example, the substation 210a can provide an epoxy and hackle removal function. Later substations can provide radius and apex shaping functions.

The substations can utilize polishing films having increasingly fine grit sizes to provide the final polished end faces. The substations can provide a chemical mechanical polishing effect by using polishing films having reactive components. An example film material includes cerium oxide. Example polishing steps are disclosed in U.S. Pat. No. 6,599,030 to Millmann, which is hereby incorporated by reference.

The polishing station 210 can include a fluid injection system for cleaning the polishing films between polishing cycles. For example, the fluid injection system can include one or more jets that sprays de-ionized water interspersed in a stream of high-pressure air to remove debris and other unwanted particles from the polishing films.

The polishing station 210 also includes a drive mechanism 755 for moving the fixture assemblies 226 along a horizontal plane relative to the polishing films. The drive mechanism 755 can include an X-Y table. A controller 756 can be used to program the polishing mechanism 755 to move or oscillate the fixture assemblies 300 along predetermined polishing patterns. The drive mechanism 755 includes clamps 757 adapted to clamp on the extensions 316 of the polishing fixtures 304 to secure the fixture assemblies 300 to the drive mechanism 755. The drive mechanism 755 preferably simultaneously moves all of the fixture assemblies 300 at the polishing station 210 along the preprogrammed polishing pattern.

Further details regarding aspects of the polishing system can be found in U.S. patent application Ser. No. 10/356,358 to Bianchi, filed on Jan. 31, 2003 and entitled "Apparatus and Method for Polishing a Fiber Optic Connector," which is hereby incorporated by reference.

In operation of the polishing station 210, the fixture assemblies 300 are moved from substation to substation by the screw drives 702. When the fixture assemblies 300 reach each substation, the clamp 757 corresponding to the given substation clamps down on the extension 316 of the polishing fixture 304. When the fixture assemblies 300 are aligned with the substations, the screw drives 702 are positioned with the flats 348 oriented to not interfere with the fixture pins 344, 346. See FIGS. 24 and 24A. Therefore, the drive mechanism 755 can readily move the fixture assemblies 300 without interference from the screw drives 702. After a polishing sequence has been completed, the clamps 757 are released, the screw drives 702 are rotated, causing the pins 344, 346 to re-engage the slots 703, and the fixture assemblies 300 are moved to the subsequent polishing substation. Thereafter, the process is repeated until the polishing process is complete.

When the fixtures are moved along the fixture conveyor 240, the fixtures 300 ride along guide rails 700. As shown, for example, at FIGS. 7, 10, and 22, the guide rails 700 are adapted to ride against shoulder portions 321 of the tuning and test fixture 302 such that a mid-portion of the test and tuning fixture 302 is captured between the rails 700. The rails 700 include portions that pivot about points 710 located at the polishing station 210 (see FIGS. 24 and 24A). During polishing, the portions of rails 700 pivot about points 710 outwardly toward the corresponding screw drives 702 to

provide clearance for allowing the fixtures **300** to be moved laterally by the drive mechanisms of **755** along the desired polishing pattern.

A stripping substation **760** is located at the end of the polishing station **210**. At the stripping station **760**, the polishing fixtures **304** are pulled downwardly from the tuning and test fixtures **302** to disengage the polishing fixtures **304** from the tuning and test fixtures **302** (e.g., by pulling downwardly on the polishing fixture **304** with sufficient force to flex the arms **310** of the latches **306** apart such that the arms **310** disengage from the retaining member **312**, as shown in FIGS. **8** and **9**). Once disengaged, the polishing fixtures **304** slide via gravity down a ramp into the storage bin for **460** of the cart **226**. See FIG. **14**. By removing the polishing fixture **304**, improved access is provided to the connectors **135** for subsequent processing. Since the connectors are clamped at the boot **149**, the lower ends of the connectors **135** are fully exposed and readily accessible from under the tuning and test fixtures **302**.

#### f. Cleaning Station

Referring to FIGS. **4**, **4B**, and **25-28**, the cleaning station **212** includes substations **212a**, **212b** for cleaning the ferrule end faces **147** of the connectors **135**. The substation **212a** includes steam recesses **790** into which the lower ends of the connectors **135** are inserted to expose the ferrules **145** to cleansing steam. Steam is provided to the steam recesses **790** by nozzles **791** that are connected to a steam source, and dry air is provided by nozzles **797**. The substation **212b** includes air stream recesses **795** into which the lower ends of the connectors **135** are inserted. The air stream recesses **795** are pneumatically coupled to a source of compressed gas. The source of compressed gas provides a pressurized gas stream to the recesses for cleaning the ferrules **145**. In one embodiment, the pressurized gas includes carbon dioxide. Operation of the cleaning module **212** can be controlled by a controller **799** that interfaces with the main system controller **250**.

In use, the fixture conveyor **240** advances a fixture **302** to substation **212a** and the fixture stops at a position where the connectors **135** align with the steam recesses **790**. The substation **212a** is then actuated towards the fixture **302** until end faces **147** of the connectors **135** are positioned to extend into the recesses **790**. See FIG. **27**. Steam (see arrows S) is applied to the ferrules **145** of the connectors **135** by nozzles **791**, and dry air is applied by nozzles **797** (see arrows A). Once the steam cleaning process is complete, fixture **302** is indexed to the substation **212b**, where the connectors **135** are cleaned with air in a similar manner.

Referring to FIG. **28**, in one embodiment, an air seal is used to seal the substations **212a**, **212b** when cleaning the connectors **135**. When steam, illustrated by arrows S, is applied to the end faces **147** of connector **135** during cleaning at substation **212a**, air is forced through passage **792** and out recess **790** surrounding the connector **135** (see arrows B). The air that is forced through passage **792** and out of recess **790** acts as a barrier to the steam and other debris removed from end faces **147** from exiting the substation **212a**. In this manner, the portions of connector **135** located outside of the substation **212a** are maintained in a clean condition.

After the air cleaning, the fixture **302** is moved to the tuning station **214**.

#### g. Tuning Station

Referring to FIGS. **4**, **4C**, and **29-32**, the tuning station **214** includes three master tuning connectors **800** and a remote test head **806** for use in inputting light into the connectors **135**, and monitoring the light output through the

bare fiber ends **137** held within the support sleeves **139**. The tuning connectors **800** can be raised and lowered by a lift mechanism **802**, and individually rotated by rotational drives **803**. A conventional optical testing apparatus **808** is optically connected to the master tuning connectors **800** and the remote head **806**. In one embodiment, the testing apparatus **808** includes a light member frame having product no. 8163A, a laser light source having product no. HP 81654A, a light meter having product no. 81618A, and a remote head having product no. 91623A, all being manufactured by Agilent Technologies of Palo Alto, Calif. In addition, a fiber optic switch (not shown) is used to switch the light signals entering the testing apparatus **808** so that the testing apparatus **808** can be used for all three master tuning connectors **800**.

Intermediate adapters **860** are positioned between the tuning connectors **800** and the connectors **135** being processed. See FIGS. **30B** and **31**. The adapters **860** include a boss **813** that surrounds a split sleeve **861** sized to receive the ferrules of the tuning connector **800** and connector **135**. A clamp **862** provides a compression force on the lower portion of the split sleeve **861** to retain the ferrule of the tuning connector **800** in the split sleeve **861** of the adapter **860**.

A module controller **810** interfaces with the testing apparatus **808** and various other components to control operation of the station **214**. The module controller **810** also interfaces with the main system controller **250**. In addition, a machine controller **811** interfaces with the structural components of the station **214** to control movement of the various components of the station **214**, such as lift mechanism **802** and rotational drives **803**.

In use of the tuning station **214**, the screw drive **702** conveys a fixture **302** to a position where the connectors **135** held by the fixture **302** are positioned directly above corresponding master tuning connectors **800**. An alignment mechanism **814** is used to align the fixture **302** with respect to the station **214**, and an alignment mechanism **809** is provided for retaining the ferrules of the connectors in direct alignment with the master tuning connectors **800**. See FIG. **32**. For SC connectors, fingers **819** are included on alignment mechanism **809** to prevent rotation of the connectors **135** during tuning.

Once the ferrules of the connectors **135** are aligned over the tuning connectors **800**, the tuning connectors **800** are raised to provide optical connections with the connectors being processed. Adapters **860** provide the connection between the tuning connectors **800** and the connectors **135** being processed. The bare fiber ends held within the support sleeve **139** mounted within the receiver **342** of the fixture **302** are also optically coupled to the remote head **806**.

Once the connectors **135** and the bare fiber ends **137** have been coupled to the test apparatus **808** respectively by the tuning connectors **800** and the remote head **806**, the test apparatus **808** injects light through the tuning connectors **800** and into the connectors **135** being processed. From the connectors **135**, the light travels through the optical fibers to which the connectors **135** are terminated and exits the fibers through the bare fiber ends **137** into the remote head **806**. In this manner, by detecting the amount of light that is transferred from the connectors **135** to the bare ends **137** of the fibers, the testing unit **808** can determine the insertion loss or return loss rating for the connectors **135**.

After testing the connectors **135** at a first rotational orientation, the master tuning connectors **800** are lowered by the lift mechanism **802**, rotated an increment (e.g., 60 degrees) by the rotational drives **803**, and then raised back

up by the lift mechanism **802** to reconnect the tuning connectors **800** with the connectors **135**. The testing device **808** is then used to test the connectors at the second rotational position. This process is repeated a plurality of times until each of the rotational positions of the connectors **135** have been tested for tuning purposes.

After this process has been completed, the various readings are compared to determine the appropriate key location. For SC connectors, the key locations of each of the connectors are stored in memory. For FC connectors, the boots **149** of the connectors **135** are released from the fixture clamps **330** while the connectors **135** remain in sleeves **861** of adapters **860**. The rotational drives **808** are then used to turn the master cables **800** and associated adapters **860**, which in turn causes the connectors **135** to individually rotate. Each connector **135** is rotated until the connector **135** is located at the tuned orientation, which is coordinated with subsequent processing at the FC connector key press station **270**. The fixture clamps **330** are then reengaged on boots **149** of the connectors **135** to maintain the connectors **135** in the desired rotational orientation.

#### h. Test Station

Referring now to FIGS. **4**, **4D**, and **33-34A**, the test station **216** includes a master test connector **850** that is moved up and down by a lift mechanism **851** and moved laterally by a lateral drive mechanism **853**. The test station **216** also includes a test unit including a remote test head **855** that optically couples to the bare fiber ends of the connectors **135** held by the fixture **302**. In one embodiment, the test unit **859** is an IQS-510P Industrial PC including an IQS-1700 laser, an IQS-3250 light meter, and an OHS-1700 remote head, all manufactured by EXFO of Quebec, Canada. The test station **216** further includes a fiber optic testing device **859** optically coupled to the master test connector **850** and the remote test head **855**. A controller **891** interfaces with the various components and also with the main controller **250**.

In use, the fixture conveyor **240** advances a fixture **302** to the test station **216**. The master connector **850** is then moved from connector **135** to connector **135** by the lift and lateral drive mechanisms **851**, **853**. At each connector **135**, the test unit is used to take return loss and insertion loss reading. The test results are stored in memory for use in identifying which connectors complied with acceptable return loss and insertion loss parameters.

#### i. SC Connector Adjust Station

As shown at FIGS. **4**, **4E**, and **35-37A**, the SC connector adjust station **218** includes an adjust arrangement **900** having a clamp **902** and a connector body receiver **904**. The SC connector adjust station **218** also includes a lateral drive **911** for moving the adjust arrangement **900** from connector to connector on a fixture **302**, and a lift mechanism **912** for raising and lowering the adjust arrangement **900**. See FIG. **36**. The SC connector adjust station **218** further includes a rotational drive **910** for turning the clamp **902** relative to the connector body receiver **904**, and a clamp actuator **906** for opening and closing the clamp **902**. A controller **913** interfaces with the various components of the station and also interfaces with the main controller **250**.

In use, the fixture conveyor **240** advances a loaded fixture **302** to the SC connector adjust station **218**. Once the fixture is positioned at the station **218**, the lateral drive **911** moves the adjust arrangement **900** laterally to a position beneath a first connector **135** held by the fixture **302**. The lift mechanism **912** then lifts the adjust arrangement **900** to a position where a lower end of the connector **135** (e.g., housing **18** shown in FIG. **1**) is nested within the connector body receiver **904** to prevent the housing from rotating, and the

clamp **902** is aligned with a ferrule hub (e.g., hub assembly **20**) of the connector **135**. The clamp **902** then clamps on the ferrule hub of the connector **135**. See FIGS. **37** and **37A**.

Thereafter, the rotational drive **910** rotates the claim **902** and associated clamped ferrule relative to the housing of the connector **135** to adjust the ferrule relative to the key position of the housing. Preferably, the ferrule of the connector is rotated to a position where the key aligns with the tuned key position determined at the tuning station **214**. Finally, once the ferrule of the connector **135** is in the desired rotational position, the clamp **902** releases the ferrule of the connector **135**, and the lift mechanism **912** lowers the adjust arrangement **900**. The adjust arrangement **900** is then moved by the lateral drive **911** from one to the other of the remaining two connectors **135** in fixture **302** and the same tuning process is repeated.

In the illustrated embodiment, a laser sensor **915** emits a laser that is trained on external features of the connector **135** such as the hub assembly **20**. See FIG. **1**. For example, the laser sensor **915** can be used to verify that the hub assembly **20** of the connector **135** has been rotated by the adjust arrangement **900**.

#### j. FC Connector Key Press Station

Referring to FIGS. **4**, **4F**, and **38-39A**, the FC connector key press station **220** includes a key holder **920** including clamps **932** for clamping each connector **135** prior to application of a key element (e.g., key **36** of FIG. **2**, and a pin **933** for holding each key element prior to application. The key holder **920** is moved laterally by a lateral drive **922** and is raised up and down by a lift **923**. The FC connector key press station **220** also includes a product handler **926** for feeding key elements to the key holder **920**. The product handler **926** includes a bin **928** for holding the key elements and a feed mechanism **930** for feeding the key elements to the key holder **920**. A controller **925** controls operation of the various components of the station and also interfaces with the main controller **250**.

In use, the fixture conveyor **240** advances a loaded fixture **302** to the station **220**. Prior to the fixture **302** reaching the station **220**, the key holder **920** is moved so that pin **933** can accept a key from the product handler **926**. When the fixture is positioned at the station **220**, clamps **932** are closed to capture a portion of the housing of each connector **135**. Lateral drive **922** moves the pin **933** of the key holder **920** to a position beneath a first FC connector **135** held by the fixture **302**. The lift **923** then lifts the pin **933** of the key holder **920** to press the key onto the connector **135**. Thereafter, the pin **933** of the key holder **920** returns to the product handler **926** to receive another key, and the process is repeated until all three connectors **135** held by the fixture **302** have been fitted with a key.

#### k. Dust Cap Installation Station

Referring to FIGS. **4**, **4G**, and **40-42**, the dust cap station **222** includes a cap holder **950** that is laterally moved by a lateral drive **951** and is raised and lowered by a lift **953**. The dust cap station **222** also includes a product handler **955** for conveying dust caps **970** (e.g., dust cap **42** of FIG. **2**) to the dust cap holder **950**. The product handler **955** includes a bin **957** for storing the dust caps **970** and a conveyor **959** for moving the dust caps from the bin **957** to a location where the dust caps can be picked up by the dust cap holder **950**. A controller **973** controls operation of the components of the station and also interfaces with the main controller **250**.

In use, the fixture conveyor **240** advances a loaded fixture **302** to the station **222**. Prior to the fixture **302** reaching the station **222**, the dust cap holder **950** is moved to accept a dust cap **970** from the product handler **955**. When the fixture **302**

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is positioned at the station 222, alignment fingers 972 close to align the connector 135 relative to the dust cap holder 950 (see FIG. 41A), and the lateral drive 951 moves the dust cap holder 950 to a position beneath a first connector 135 held by the fixture 302. The lift 953 then raises the dust cap holder 950 to press the dust cap 970 onto the connector 135. Thereafter, the dust cap holder 950 returns to the product handler 955 to receive another dust cap 970, and the process is repeated until all three connectors 135 held by the fixture 302 have been fitted with a cap 970.

In one embodiment, connectors 135 that fail at any station of system 200 (e.g., receive a failing rating at the test station 216) are not fitted with a dust cap 970. In this manner, the absence of a dust cap 970 functions as an indicator for allowing an operator to know which connectors 135 failed and which are in need of reprocessing.

What is claimed is:

1. An apparatus for moving a fiber including a plurality of fiber optic connectors through a system for processing the plurality of fiber optic connectors, the apparatus comprising:
  - a first drive mechanism for moving the fiber through the system, the first drive mechanism including:
    - a cart including a platform for holding a spool including the fiber; and
    - a cart drive for moving the cart and associated fiber through the system;
  - a second drive mechanism for moving the plurality of fiber optic connectors through the system; and

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a controller for coordinating movement of the first drive mechanism with the second drive mechanism.

2. The apparatus of claim 1, wherein the first drive mechanism further includes a track along which the cart is moved.
3. The apparatus of claim 2, wherein the cart drive is a walking beam drive.
4. The apparatus of claim 1, wherein the second drive mechanism includes a screw drive for moving the plurality of fiber optic connectors through the system.
5. The apparatus of claim 4, wherein the screw drive varies in pitch along at least a portion of a longitudinal length of the screw drive to vary a speed at which the plurality of fiber optic connectors are moved through the system.
6. The system of claim 4, wherein the screw drive includes a flat portion to allow the plurality of fiber optic connectors to be moved independently from the screw drive.
7. The apparatus of claim 1, wherein the second drive mechanism moves a fixture that is coupled to the plurality of fiber optic connectors.
8. The apparatus of claim 1, wherein the first drive mechanism includes a walking beam drive, and the second drive mechanism includes a screw drive.

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