(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 April 2015 (02.04.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/047574 A1

(51) International Patent Classification:
B21J 15/14 (2006.01) *F16B 31/02* (2006.01)
B23P 19/06 (2006.01)

(21) International Application Number:
PCT/US2014/050888

(22) International Filing Date:
13 August 2014 (13.08.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
14/036,495 25 September 2013 (25.09.2013) US

(71) Applicant: **THE BOEING COMPANY** [US/US]; 5301 Bolsa Avenue, Mailcode: H011-B171, Huntington Beach, California 92647 (US).

(72) Inventor: **BATT, Edward John**; 100 N. Riverside Plaza, Chicago, Illinois 60606 (US).

(74) Agents: **HALPERIN, Brett** et al.; 5301 Bolsa Avenue, Mailcode: H011-B171, Huntington Beach, California 92647 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: AUTOMATED INSTALLATION OF FRANGIBLE ELEMENTS

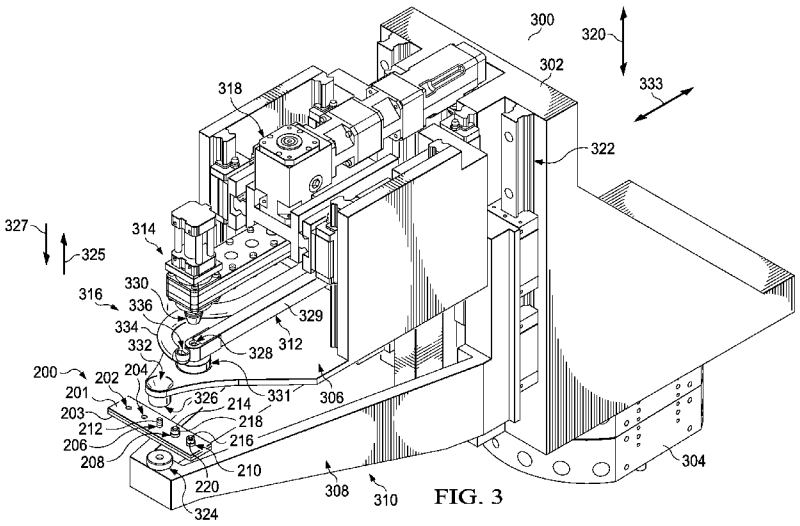


FIG. 3

(57) **Abstract**: A method and an end effector for installing an element over a member associated with an object. An end effector may be attached to the object. The element may be loaded onto an element installer by an element loader of the end effector. The element may be installed onto the member associated with the object by the element installer.

WO 2015/047574 A1

AUTOMATED INSTALLATION OF FRANGIBLE ELEMENTS

BACKGROUND INFORMATION

1. Field:

The present disclosure relates generally to the installation of fastener elements and, in particular, to automating the installation of fastener elements. Still more particularly, the present disclosure relates to a method and apparatus for automating the installation of frangible elements, such as frangible collars.

2. Background:

During manufacturing, different types of fastener elements may be installed in various types of objects. For example, without limitation, fastener elements, such as bolts, may be used to join a stackup of two or more parts together. Other fastener elements, such as collars, may then be used to secure and hold the parts together. In some cases, these collars may be referred to as nuts.

In some industries, such as the aerospace industry, fastener elements in the form of frangible collars may be used. As used herein, a "frangible collar" may be a collar having one portion of the collar that is designed to break off from another portion of the collar at a selected torque. The portion that is designed to break off may be referred to as the nut of the frangible collar, while the portion that remains may be referred to as the collar.

As one example, when a frangible collar is being threaded onto a threaded bolt, the nut portion of the frangible collar may break off once a selected torque has been reached to leave the collar portion of the frangible collar threaded onto the threaded bolt. The use of frangible collars may allow a collar and bolt to be assembled without having to control the torque

applied by a torque wrench to ensure that the applied torque is within specified tolerances.

With some currently available methods for installing frangible collars, the nuts that break off from the collars may become foreign object debris (FOD). This foreign object debris may cause undesired effects within a manufacturing environment. For example, without limitation, when the nut portion of a frangible collar breaks off from the collar portion of the frangible collar, the nut portion may break off in an uncontrolled manner and/or in an undesired direction. In particular, the nut portion may break off and impact a piece of equipment or machinery within the manufacturing environment in an undesired manner.

Further, some currently available methods for installing frangible collars require that the installation be performed manually. For example, without limitation, these methods may require that a human operator or human-operated machinery thread a frangible collar onto a bolt. However, performing this type of installation manually may be more time-consuming and labor-intensive than desired.

In certain industries, manufacturing is moving towards automated manufacturing. It may be desirable to have a system for automating the installation of frangible collars such that the integration of robotic automation and the manual installation of frangible collars may not be needed in future manufacturing environments. Therefore, it may be desirable to have a method and apparatus that take into account at least some of the issues discussed above, as well as other possible issues.

SUMMARY

In one illustrative example, an apparatus may comprise an attachment system, an element loader, and an element installer. The attachment system may be configured to attach the end

effector to an object. The element loader may be configured to hold a number of elements. The element installer may be configured to receive an element in the number of elements from the element loader. The element installer may be further configured to install the element onto a member associated with the object.

In another illustrative embodiment, an end effector may comprise an attachment system, an element loader, an element installer, and a removal system. The attachment system may be configured for use in attaching the end effector to an object. The element loader may be configured to hold a number of frangible collars in which a frangible collar in the number of frangible collars may include a nut portion and a collar portion. The element installer may be configured to receive the frangible collar from the element loader. The element installer may comprise a rotatable member and a retaining member. The rotatable member may be configured to rotate the frangible collar when the frangible collar is placed over a threaded fastener associated with the object to install the frangible collar onto the threaded fastener. The nut portion of the frangible collar may be configured to separate from the collar portion of the frangible collar when a torque being applied to the frangible collar by rotation of the frangible collar reaches a selected threshold. The retaining member may be configured to receive the frangible collar from the element loader and retain the frangible collar. The retaining member may retain the nut portion of the frangible collar after the nut portion separates from the collar portion of the frangible collar. The removal system may be configured for use in discarding the nut portion of the frangible collar that separates from the collar portion.

In yet another illustrative example, a method for installing an element over a member associated with an object may be provided. An end effector may be attached to the object. The element may be loaded onto an element installer by an

element loader of the end effector. The element may be installed onto the member associated with the object by the element installer.

In still yet another illustrative embodiment, a method for installing a frangible collar may be provided. An end effector may be clamped to a stackup of parts using a clamping system. A frangible collar held by an element loader of the end effector may be loaded onto an element installer of the end effector. The element installer may be moved such that the frangible collar is positioned over an installation feature of the clamping system. The frangible collar may be moved onto a threaded fastener installed through the stackup of parts through the installation feature. A torque may be applied to the frangible collar to thread the frangible collar onto the threaded fastener. A nut portion of the frangible collar may be separated from a collar portion of the frangible collar when the torque being applied to the frangible collar reaches a selected threshold. The nut portion may be moved away from the threaded fastener to leave the collar portion installed on the threaded fastener. The nut portion may be discarded using a removal system.

In summary, according to one aspect of the invention there is provided an apparatus including an attachment system configured for attachment to an object; an element loader configured to hold a number of elements; and an element installer configured to receive an element in the number of elements from the element loader and install the element onto a member associated with the object.

Advantageously the apparatus wherein the element installer is configured to apply a torque to the element to install the element onto the member.

Advantageously the apparatus wherein the element is a frangible element including a first portion; and a second portion, wherein the first portion is configured to break off

from the second portion when the torque being applied to the frangible element reaches a selected threshold.

Advantageously the apparatus further including a removal system configured for use in discarding the first portion of the frangible element.

Advantageously the apparatus wherein the element installer includes a rotatable member configured to rotate the frangible element when the frangible element is placed over the member to apply the torque to the frangible element.

Advantageously the apparatus wherein the element installer includes a retaining member configured to receive the frangible element from the element loader and retain the frangible element, wherein the retaining member retains the first portion of the frangible element after the first portion breaks away from the second portion of the frangible element.

Advantageously the apparatus wherein the frangible element is a frangible collar.

Advantageously the apparatus wherein the element installer includes an elongate member configured for use in aligning the element with the member; and an actuation system configured to actuate the elongate member.

Advantageously the apparatus wherein the member has a socket and the elongate member has a tip having a shape configured to fit within the socket.

Advantageously the apparatus wherein the element loader includes a holder configured to hold the number of elements; and a loading device configured to load the element onto the element installer.

Advantageously the apparatus wherein the element is a threaded fastener.

Advantageously the apparatus further including a movement system configured to move the element installer towards and away from the element loader.

Advantageously the apparatus wherein the attachment system is a clamping system including a first clamping device; and a second clamping device.

Advantageously the apparatus wherein the object comprises a first part and a second part and wherein the member is configured for use in joining the first part and the second part to each other.

According to another aspect of the invention there is provided an end effector including an attachment system configured for use in attaching the end effector to an object; an element loader configured to hold a number of frangible collars in which a frangible collar in the number of frangible collars includes a nut portion and a collar portion; an element installer configured to receive the frangible collar from the element loader and including a rotatable member configured to rotate the frangible collar when the frangible collar is placed over a threaded fastener associated with the object to install the frangible collar onto the threaded fastener in which the nut portion of the frangible collar is configured to separate from the collar portion of the frangible collar when a torque being applied to the frangible collar by rotation of the frangible collar reaches a selected threshold; and a retaining member configured to receive the frangible collar from the element loader and retain the frangible collar in which the retaining member retains the nut portion of the frangible collar after the nut portion separates from the collar portion of the frangible collar; and a removal system configured for use in discarding the nut portion of the frangible collar that separates from the collar portion.

According to yet another aspect of the invention there is provided a method for installing an element over a member associated with an object, the method including attaching an end effector to the object; loading, by an element loader of the end effector, the element onto an element installer; and installing,

by the element installer, the element onto the member associated with the object.

Advantageously the method wherein installing the element onto the member associated with the object includes applying a torque to the element to install the element onto the member, wherein the element is a frangible element.

Advantageously the method wherein installing the element onto the member associated with the object further includes separating a first portion of the frangible element from a second portion of the frangible element when the torque being applied to the frangible element reaches a selected threshold.

Advantageously the method further including discarding the first portion of the frangible element after the first portion has separated from the second portion of the frangible element using a removal system of the end effector.

Advantageously the method wherein loading the element onto the element installer includes moving the element from within a holder of the element loader towards a retaining member of the element installer using a loading device to load the element onto the element installer.

Advantageously the method wherein moving the element from within the holder of the element loader towards the retaining member of the element installer using the loading device to load the element onto the element installer includes moving the element from within the holder of the element loader towards the retaining member of the element installer using the loading device until an interface feature of the retaining member snaps into a groove on the element.

According to still another aspect of the invention there is provided a method for installing a frangible collar, the method including clamping an end effector to a stackup of parts using a clamping system; loading a frangible collar held by an element loader of the end effector onto an element installer of the end effector; moving the element installer such that the frangible

collar is positioned over an installation feature of the clamping system; moving the frangible collar onto a threaded fastener installed through the stackup of parts through the installation feature; applying a torque to the frangible collar to thread the frangible collar onto the threaded fastener; separating a nut portion of the frangible collar from a collar portion of the frangible collar when the torque being applied to the frangible collar reaches a selected threshold; moving the nut portion away from the threaded fastener to leave the collar portion installed on the threaded fastener; and discarding the nut portion using a removal system.

The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

Figure 1 is an illustration of a manufacturing environment in the form of a block diagram in accordance with an illustrative embodiment;

Figure 2 is an illustration of an object in accordance with an illustrative embodiment;

Figure 3 is an illustration of an isometric view of an end effector being positioned relative to an object in accordance with an illustrative embodiment;

Figure 4 is an illustration of an end effector clamped to an object in accordance with an illustrative embodiment;

Figure 5 is an illustration of a portion of an end effector with an element installer positioned over an element loader in accordance with an illustrative embodiment;

Figure 6 is an illustration of a cross-sectional view of a portion of an end effector in accordance with an illustrative embodiment;

Figure 7 is an illustration of an enlarged view of a portion of an end effector in accordance with an illustrative embodiment;

Figure 8 is an illustration of a frangible collar being held by a retaining member in accordance with an illustrative embodiment;

Figure 9 is an illustration of an element installer being moved away from an element loader in accordance with an illustrative embodiment;

Figure 10 is an illustration of a frangible collar held by a retaining member positioned over an opening in accordance with an illustrative embodiment;

Figure 11 is an illustration of a frangible collar in an installation feature in accordance with an illustrative embodiment;

Figure 12 is an illustration of a tip of an elongate member in contact with an end of a fastener in accordance with an illustrative embodiment;

Figure 13 is an illustration of a tip of an elongate member engaged with a socket of a fastener in accordance with an illustrative embodiment;

Figure 14 is an illustration of a first portion of a frangible collar separated from a second portion of a frangible collar in accordance with an illustrative embodiment;

Figure 15 is an illustration of an element installer moving a nut portion to a removal system in accordance with an illustrative embodiment;

Figure 16 is an illustration of a nut portion positioned over an opening into a vacuum tube in accordance with an illustrative embodiment;

Figure 17 is an illustration of an interface feature of an elongate member engaged with a nut portion in accordance with an illustrative embodiment;

Figure 18 is an illustration of a nut portion released from a retaining member in accordance with an illustrative embodiment;

Figure 19 is an illustration of an isometric view of an end effector unclamped from an object and a collar installed over a fastener in accordance with an illustrative embodiment;

Figure 20 is an illustration of a process for installing an element over a member associated with an object in the form of a flowchart in accordance with an illustrative embodiment;

Figure 21 is an illustration of a process for installing a frangible collar onto a threaded fastener in the form of a flowchart in accordance with an illustrative embodiment;

Figure 22 is an illustration of an aircraft manufacturing and service method in the form of a block diagram in accordance with an illustrative embodiment; and

Figure 23 is an illustration of an aircraft in the form of a block diagram in which an illustrative embodiment may be implemented.

DETAILED DESCRIPTION

The illustrative embodiments recognize and take into account different considerations. For example, the illustrative embodiments recognize and take into account that it may be desirable to have a system for automating the installation of frangible collars. Further, the illustrative embodiments

recognize and take into account that it may be desirable to have a system for automating the capture and discarding of the nut portions of frangible collars that break away from the collar portions of the frangible collars.

Referring now to the figures and, in particular, with reference to **Figure 1**, an illustration of a manufacturing environment is depicted in the form of a block diagram in accordance with an illustrative embodiment. In this illustrative example, manufacturing environment **100** may be an environment in which different types of parts may be manufactured and/or assembled. Manufacturing environment **100** may take the form of automated manufacturing environment **101** in this example.

As depicted, end effector **102** may be used within automated manufacturing environment **101**. End effector **102** may be configured to be moved and, in some cases, operated by, robotic device **104**. Robotic device **104** may be implemented in a number of different ways. Depending on the implementation, robotic device **104** may take the form of a robotic arm, a robotic vehicle, or some other type of robotic device.

End effector **102** may be associated with robotic device **104**. As used herein, when one component is "associated" with another component, the association is a physical association in the depicted examples.

For example, without limitation, a first component, such as end effector **102**, may be considered to be associated with a second component, such as robotic device **104**, by being secured to the second component, bonded to the second component, mounted to the second component, welded to the second component, fastened to the second component, and/or connected to the second component in some other suitable manner. The first component also may be connected to the second component using a third component. Further, the first component may be considered to be

associated with the second component by being formed as part of and/or as an extension of the second component.

In this illustrative example, end effector **102** may be configured to install fastener elements on object **106**. Object **106** may take a number of different forms. For example, without limitation, object **106** may be a single part, a sub-assembly, or an assembly of parts. In this illustrative example, object **106** may be a stackup of parts that includes, for example, without limitation, first part **108** and second part **110**. End effector **102** may be configured to install number of elements **112** onto number of members **114** already installed in object **106**.

As used herein, a "number of" items may be one or more items. In this manner, number of elements **112** may include one or more elements. Further, number of members **114** may include one or more members.

In one illustrative example, number of members **114** may be inserted through openings in both first part **108** and second part **110** to join these two parts together. Number of elements **112** may be installed onto number of members **114** to secure number of members **114** to first part **108** and second part **110** such that first part **108** and second part **110** may remain joined together.

Number of elements **112** may take the form of number of frangible elements **116** in this illustrative example. For example, frangible element **117** in number of frangible elements **116** may be an example of one implementation for element **115** in number of elements **112**. As used herein, a "frangible element," such as frangible element **117**, may have first portion **119** configured to break off from second portion **121** of frangible element **117** once a torque being applied to frangible element **117** has reached a selected threshold.

In one illustrative example, number of members **114** may be implemented as number of threaded fasteners **118**. In particular, a member in number of members **114** may be implemented as a threaded fastener in number of threaded fasteners **118**, such as

threaded fastener **143**. Threaded fastener **143** may take the form of a threaded bolt, a screw, or some other type of threaded fastener.

In this example, number of frangible elements **116** may be implemented as number of frangible collars **120** configured to be threaded onto number of threaded fasteners **118**. Frangible collar **145** may be an example of a frangible collar in number of frangible collars **120**. In particular, frangible collar **145** may be an example of one implementation for frangible element **117**. As depicted, frangible collar **145** may have nut portion **151** configured to break away from collar portion **160** of frangible collar **145** in response to torque **153** that is being applied to frangible collar **145** reaching selected threshold **162**. Nut portion **151** and collar portion **160** of frangible collar **145** may be examples of first portion **119** and second portion **121**, respectively, of frangible element **117**.

End effector **102** may be used to automate the process of installing number of frangible collars **120** on number of threaded fasteners **118**. As depicted, end effector **102** may include platform **122**, attachment system **124**, element loader **126**, element installer **128**, movement system **130**, and removal system **132**. Attachment system **124**, element loader **126**, element installer **128**, movement system **130**, and/or removal system **132** may be associated with platform **122**.

In this illustrative example, robotic interface feature **134** may be associated with platform **122**. Robotic interface feature **134** may be an interface for use in attaching end effector **102** to robotic device **104**. Robotic device **104** may be used to move end effector **102** relative to object **106**. For example, without limitation, robotic device **104** may move platform **122** of end effector **102** to position end effector **102** relative to object **106**.

Attachment system **124** may be used to attach end effector **102** to object **106** such that end effector **102** remains in a fixed

position relative to object **106** during the installation of number of frangible collars **120**. In one illustrative example, attachment system **124** may take the form of clamping system **136**. Clamping system **136** may include first clamping device **138** and second clamping device **140**. First clamping device **138** may engage first part **108** of object **106**, while second clamping device **140** may engage second part **110** of object **106**. In this manner, first clamping device **138** and second clamping device **140** may together clamp to object **106**.

In some cases, first clamping device **138** may include installation feature **142**. Installation feature **142** may be used to install a threaded fastener, such as threaded fastener **143**, in object **106**, while first clamping device **138** and second clamping device **140** are clamped to the stackup of first part **108** and second part **110**. Installation feature **142** may take the form of, for example, without limitation, a hollow portion, or channel, through which threaded fastener **143** may be inserted and then installed through first part **108** and second part **110**.

Once threaded fastener **143** has been installed, a frangible collar, such as frangible collar **145**, may be installed onto threaded fastener **143**. Element loader **126** and element installer **128** may be used to perform this installation.

As depicted, element loader **126** may include holder **144** and loading device **146**. In one illustrative example, holder **144** may be implemented as a structure configured to hold multiple frangible collars. In particular, holder **144** may hold a set of frangible collars, from which frangible collar **145** may then be selected for installation. Loading device **146** may be used to load frangible collar **145** held by holder **144** onto element installer **128**. Loading device **146** may include, for example, without limitation, loading member **147** that may be actuated to load frangible collar **145** onto element installer **128**.

Element installer **128** may include rotatable member **148**, retaining member **150**, actuation system **152**, and elongate member

154. Rotatable member 148 may be configured to receive frangible collar 145. Retaining member 150 may be configured to retain frangible collar 145 and secure frangible collar 145 to rotatable member 148. For example, without limitation, loading device 146 may be used to load frangible collar 145 onto rotatable member 148 through retaining member 150 such that retaining member 150 can form some type of fit with frangible collar 145. This fit may be, for example, without limitation, a snap-fit. In this illustrative example, retaining member 150 may be configured to hold nut portion 151 of frangible collar 145.

Movement system 130 may be used to move element installer 128 towards element loader 126 such that frangible collar 145 may be loaded onto rotatable member 148. Further, movement system 130 may be used to move element installer 128 away from element loader 126 and towards installation feature 142 once frangible collar 145 has been loaded onto rotatable member 148.

Movement system 130 may include any number of devices and/or components needed to move element installer 128 and/or other components of end effector 102. In one illustrative example, movement system 130 may include servo motor system 155 capable of moving element installer 128.

Movement system 130 may position element installer 128 over installation feature 142 such that retaining member 150 and rotatable member 148 holding frangible collar 145 may be positioned over installation feature 142. Element installer 128 may then be used to install frangible collar 145 onto threaded fastener 143 through installation feature 142.

In particular, actuation system 152 may be configured to move elongate member 154 of element installer 128 towards threaded fastener 143 through installation feature 142. Actuation system 152 may be comprised of one or more actuation devices and/or other types of components. For example, without limitation, actuation system 152 may include an actuated air

cylinder. Actuation system **152** may continue to push elongate member **154** until first end **156** of elongate member **154** comes into contact with threaded fastener **143**. First end **156** of elongate member **154** may be configured to engage second end **158** of threaded fastener **143**.

In one illustrative example, second end **158** of threaded fastener **143** may have a socket. In other words, threaded fastener **143** may have a depression at second end **158** of threaded fastener **143** that forms a socket configured to receive an object having substantially the same shape as the socket. In this example, the socket may have a hexagonal shape. Threaded fastener **143** may be a socket screw, also referred to as a socketed bolt.

First end **156** of elongate member **154** may have a shape configured to engage the socket at second end **158** of threaded fastener **143**. For example, first end **156** of elongate member **154** may have a hexagonal shape configured to fit within the hexagonal socket of threaded fastener **143**. First end **156** of elongate member **154** may be referred to as a hex key, an Allen wrench, or an Allen key.

In some cases, first end **156** of elongate member **154** may not readily engage second end **158** of threaded fastener **143** when elongate member **154** is moved towards second end **158** through installation feature **142**. In other words, first end **156** may not be properly aligned, rotationally, with second end **158**, such that first end **156** is not received within the hexagonal socket of second end **158**. However, in other cases, first end **156** may readily engage second end **158** when elongate member **154** is moved towards threaded fastener **143**.

Actuation system **152** may be configured to rotate rotatable member **148** in any number of directions to allow first end **156** of elongate member **154** to engage second end **158** of threaded fastener **143** and to allow collar portion **160** of frangible collar **145** to engage the threads on threaded fastener **143**. Once collar

portion **160** of frangible collar **145** has engaged the threads on threaded fastener **143**, actuation system **152** may rotate rotatable member **148** to thread collar portion **160** onto threaded fastener **143**.

This rotation may result in torque **153** being applied to frangible collar **145**. When selected threshold **162** for torque **153** has been reached, nut portion **151** may separate from collar portion **160** of frangible collar **145**. In other words, nut portion **151** may break away, or break off, from collar portion **160**. However, nut portion **151** may remain retained by retaining member **150**.

In this manner, collar portion **160** of frangible collar **145** may be installed onto threaded fastener **143**. Actuation system **152** may be programmed to apply pre-selected torque **163** to frangible collar **145**. Pre-selected torque **163** may be substantially equal to or greater than selected threshold **162** for torque **153**. In this manner, any undesired effects on threaded fastener **143** outside of selected tolerances caused by the threading of collar portion **160** onto threaded fastener **143** may be prevented.

Once collar portion **160** has been installed, movement system **130** may move element installer **128** away from installation feature **142** and towards removal system **132**. In this illustrative example, removal system **132** may be used to capture and discard nut portion **151** still being held by retaining member **150**. As depicted, removal system **132** may include vacuum tube **164**.

Movement system **130** may position element installer **128** over removal system **132** such that nut portion **151** is positioned over an opening in vacuum tube **164**. Actuation system **152** may be configured to move elongate member **154** in a direction towards vacuum tube **164** to cause nut portion **151** to be released from retaining member **150**. Once nut portion **151** is released from

retaining member **150**, nut portion **151** may enter vacuum tube **164** and be consequently discarded.

In this illustrative example, controller **166** may be configured to control the operation of at least one of actuation system **152**, movement system **130**, and robotic device **104**. As used herein, the phrase "at least one of," when used with a list of items, means different combinations of one or more of the listed items may be used and only one of the items in the list may be needed. The item may be a particular object, thing, or category. In other words, "at least one of" means any combination of items or number of items may be used from the list, but not all of the items in the list may be required.

For example, "at least one of item A, item B, and item C" may mean item A; item A and item B; item B; item A, item B, and item C; or item B and item C. In some cases, "at least one of item A, item B, and item C" may mean, for example, without limitation, two of item A, one of item B, and ten of item C; four of item B and seven of item C; or some other suitable combination.

Controller **166** may be implemented using hardware, software, or a combination of the two. Depending on the implementation, controller **166** may be implemented using at least one of a computer system comprised of one or more computers, a processor unit, an integrated circuit, a microprocessor, or some other type of data processing system or processor. Controller **166** may be considered part of end effector **102** in this illustrative example, and may be associated with platform **122**. However, in other illustrative examples, controller **166** may be considered separate from end effector **102**. For example, without limitation, controller **166** may be configured to control movement system **130** and actuation system **152** using wired and/or wireless connections.

For example, without limitation, controller **166** may use preprogrammed settings to control the number of rotations, the

different directions of rotation, and/or the number of degrees of rotation by which rotatable member **148** is rotated for the installation of each of number of frangible collars **120**. Further, controller **166** may control selected threshold **162** for torque **153**.

In this manner, the installation of number of frangible collars **120** may be automated. This type of installation system and method may increase the speed and efficiency with which frangible collars may be installed on threaded fasteners. Further, this type of installation system and method may reduce the amount of debris generated within automated manufacturing environment **101** when installing frangible collars.

The illustration of manufacturing environment **100** and end effector **102** in **Figure 1** is not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be optional. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

In some illustrative examples, end effector **102** may not be used to install number of members **114** in object **106**. Rather, a different end effector (not shown) may be used to install number of members **114**.

In other illustrative examples, attachment system **124** may be implemented using some other type of device other than clamping system **136**. For example, without limitation, attachment system **124** may attach end effector **102** to object **106** using a clasp, a locking mechanism, a combination of fastening devices, and/or other types of components.

With reference now to **Figure 2**, an illustration of an object is depicted in accordance with an illustrative embodiment. In this illustrative example, object **200** may be an

example of one implementation for object **106** in **Figure 1**. As depicted, object **200** may include first part **201** and second part **203**, which may be examples of implementations for first part **108** and second part **110**, respectively, in **Figure 1**. First part **201** and second part **203** may form a stackup of parts.

Object **200** may have holes **202**, **204**, **206**, **208**, and **210** configured to receive threaded fasteners. These holes may extend through both first part **201** and second part **203**. In this illustrative example, threaded fasteners **212**, **214**, and **216** have been installed in object **200**. Threaded fasteners **212**, **214**, and **216** may be examples of implementations for threaded fasteners in number of threaded fasteners **118** in **Figure 1**.

In this illustrative, collar **217**, collar **218**, and collar **220** may already be installed onto threaded fasteners **212**, **214**, and **216**, respectively. The process used to install collar **217** onto threaded fastener **212** may be described in **Figures 3-19** below.

With reference now to **Figures 3-19**, illustrations of the steps used to install collar **217** from **Figure 2** onto threaded fastener **212** from **Figure 2** may be depicted in accordance with an illustrative embodiment. In **Figures 3-19**, end effector **300** may be used to install collar **217** from **Figure 2** onto threaded fastener **212** from **Figure 2**. End effector **300** may be an example of one implementation for end effector **102** in **Figure 1**.

Turning now to **Figure 3**, an illustration of an isometric view of end effector **300** being positioned relative to object **200** is depicted in accordance with an illustrative embodiment. In this illustrative example, end effector **300** may be moved towards and positioned relative to object **200** from **Figure 2**. End effector **300** may be an example of one implementation for end effector **102** in **Figure 1**.

As depicted, end effector **300** may include platform **302** having robotic interface feature **304**. Robotic interface feature **304** may be used to attach end effector **300** to a robotic device

(not shown), such as robotic device **104** described in **Figure 1**. The robotic device (not shown) may be configured to move and manipulate end effector **300**.

End effector **300** may include first clamping device **306** and second clamping device **308**. First clamping device **306** and second clamping device **308** may be examples of implementations for first clamping device **138** and second clamping device **140**, respectively, in **Figure 1**. First clamping device **306** and second clamping device **308** may form clamping system **310**, which may be an example of one implementation for clamping system **136** in **Figure 1**. In this manner, clamping system **310** is an example of an attachment system, such as attachment system **124** in **Figure 1**.

In addition to clamping system **310**, end effector **300** may also include element loader **312**, element installer **314**, removal system **316**, and movement system **318**. Element loader **312**, element installer **314**, removal system **316**, and movement system **318** may be examples of implementations for element loader **126**, element installer **128**, removal system **132**, and movement system **130**, respectively in **Figure 1**. As depicted, clamping system **310**, element loader **312**, element installer **314**, removal system **316**, and movement system **318** may all be associated with platform **302**.

The robotic device (not shown) attached to end effector **300** may move end effector **300** such that first clamping device **306** and second clamping device **308** of end effector **300** are positioned relative to object **200**. In this illustrative example, first clamping device **306** may be positioned over first part **201**, while second clamping device **308** may be positioned over second part **203**. First clamping device **306** and second clamping device **308** may be moved along Z-axis **320** to allow end effector **300** to be clamped to and unclamped from object **200**.

As depicted, rail system **322** may be associated with platform **302** in this illustrative example. Rail system **322** includes rails along which each of first clamping device **306** and

second clamping device **308** may be moved in a direction along Z-axis **320**. For example, without limitation, first clamping device **306** may be moved along rail system **322** in the direction of arrow **327** towards first part **201**. Second clamping device **308** may be moved along rail system **322** in the direction of arrow **325** towards second part **203**. In this manner, first clamping device **306** and second clamping device **308** may be moved towards each other to clamp end effector **300** to object **200**.

In this illustrative example, second clamping device **308** may have engagement feature **324** configured to engage threaded fastener **212** on the side of second part **203**. Further, first clamping device **306** may have installation feature **326** configured to engage threaded fastener **212** on the side of first part **201**. Installation feature **326** may be an example of one implementation for installation feature **142** in **Figure 1**.

Installation feature **326** may be positioned over threaded fastener **212** such that installation feature **326** fits over threaded fastener **212** when first clamping device **306** is moved towards first part **201**. In other illustrative examples, installation feature **326** may be positioned over hole **206** such that threaded fastener **212** may be inserted through installation feature **326** into hole **206**.

As depicted, element loader **312** may include holder **329** and loading device **331**. Holder **329** and loading device **331** may be examples of implementations of holder **144** and loading device **146**, respectively, in **Figure 1**. Holder **329** may be configured to hold multiple frangible collars (not shown in this view). Loading device **331** may be used to load these frangible collars onto element installer **314**.

Element installer **314** may be configured to receive a frangible collar (not shown) at end **330** of element installer **314**. In particular, loading device **331** may be used to load the frangible collar (not shown) onto end **330** of element installer **314** through opening **328** in holder **329**.

Element installer **314** may then be moved by movement system **318** to position end **330** over opening **332** of installation feature **326** such that the frangible collar (not shown) held at end **330** may be installed over fastener **212** through installation feature **326**. Movement system **318** may be configured to move element installer **314** in the direction of X-axis **333** and/or the direction of Z-axis **320**.

When the frangible collar (not shown) has been fully installed over fastener **212**, the nut portion of the frangible collar may break away from the collar portion of the frangible collar. The nut portion may remain held at end **330**, while the collar portion may remain over the fastener. The nut portion of the frangible collar may then be discarded using removal system **316**.

Removal system **316** may include vacuum tube **334**. Vacuum tube **334** may be an example of one implementation for vacuum tube **164** in **Figure 1**. Movement system **318** may be used to move element installer **314** over opening **336** to vacuum tube **334**. Element installer **314** may then discard the nut portion by sending the nut portion into vacuum tube **334** through opening **336**.

Turning now to **Figure 4**, an illustration of end effector **300** from **Figure 3**, clamped to object **200** from **Figures 2-3**, is depicted in accordance with an illustrative embodiment. In this illustrative example, first clamping device **306** and second clamping device **308** have been used to clamp end effector **300** to object **200**. As depicted, installation feature **326** may fully cover fastener **212** seen in **Figures 2-3**.

Once end effector **300** has been clamped to object **200**, element installer **314** may be moved by movement system **318** towards element loader **312** such that a frangible collar (not shown in this view) may be loaded onto end **330** of element installer **314**. An enlarged view of portion **400** of end effector

300 with element installer **314** positioned over opening **328** in holder **329** is depicted in **Figure 5** below.

With reference now to **Figure 5**, an illustration of portion **400** of end effector **300** from **Figure 4** with element installer **314** positioned over element loader **312** is depicted in accordance with an illustrative embodiment. In this illustrative example, element installer **314** has been moved such that end **330** is positioned over loading device **331**.

Element installer **314** may include actuation system **500**, rotatable member **502**, and retaining member **504**. Actuation system **500**, rotatable member **502**, and retaining member **504** may be examples of implementations for actuation system **152**, rotatable member **148**, and retaining member **150**, respectively, in **Figure 1**. In this illustrative example, actuation system **500** and rotatable member **502** may be associated with base **501**. Base **501** may be moved and manipulated using movement system **318**.

With reference now to **Figure 6**, an illustration of a cross-sectional view of portion **400** of end effector **300** from **Figure 5** is depicted in accordance with an illustrative embodiment. In this illustrative example, a cross-sectional view of portion **400** of end effector **300** may be depicted taken with respect to lines **6-6** in **Figure 5**.

In this illustrative example, chamber **600** within holder **329** may be seen. Chamber **600** may hold frangible collars **602**. Frangible collars **602** may be an example of one implementation for number of frangible collars **120** in **Figure 1**. In this manner, frangible collars **602** may be an example of one manner in which number of frangible elements **116** in **Figure 1**, and thereby number of elements **112** in **Figure 1**, may be implemented.

Frangible collar **604** may be one of frangible collars **602**. Frangible collar **604** may be an example of a frangible element, such as frangible element **117** in **Figure 1**, and thereby an element, such as element **115** in **Figure 1**.

As depicted, frangible collar **604** may be the particular frangible collar that is next in line to be loaded onto end **330** of element installer **314**. Loading frangible collar **604** onto end **330** may include pushing frangible collar **604** towards retaining member **504** and rotatable member **502** of element installer **314**. An enlarged view of portion **610** of end effector **300** is depicted in **Figure 7** below. Further, the manner by which frangible collar **604** may be loaded onto end effector **300** is described in **Figures 7-9** below.

In **Figure 6**, actuation system **500** of element installer **314** may include piston device **606**. Piston device **606** may be configured to control the movement of elongate member **608** of element installer **314** along Z-axis **320**. Once frangible collar **604** has been loaded onto element installer **314**, piston device **606** and elongate member **608** may be used to install frangible collar **604** over fastener **212**.

Turning now to **Figure 7**, an illustration of an enlarged view of portion **610** of end effector **300** from **Figure 6** is depicted in accordance with an illustrative embodiment. As depicted, loading device **331** may include loading member **700** and cylinder **701**. Loading member **700** may be an example of one implementation for loading member **147** in **Figure 1**.

Cylinder **701** may be an air cylinder configured to exert a force on loading member **700** in the direction of arrow **702**. In other words, cylinder **701** may be used to move loading member **700** in the direction of arrow **702** such that frangible collar **604** may also be moved in the direction of arrow **702** towards element installer **314**.

As depicted, frangible collar **604** may have groove **706**. Groove **706** may separate the nut portion of frangible collar **604** from the collar portion of frangible collar **604**. Groove **706** may be used for loading frangible collar **604** onto element installer **314**.

In particular, frangible collar **604** may be moved in the direction of arrow **702** until interface feature **708** of retaining member **504** snaps into groove **706** of frangible collar **604**. Once interface feature **708** of retaining member **504** snaps into groove **706**, frangible collar **604** may be considered held by retaining member **504**.

In this illustrative example, rotatable member **502** of element installer **314** may be able to independently move relative to structure **704** of element installer **314** along Z-axis **320**. In other words, rotatable member **502** may be configured to float relative to structure **704**.

Turning now to **Figure 8**, an illustration of frangible collar **604** being held by retaining member **504** is depicted in accordance with an illustrative embodiment. In this illustrative example, interface feature **708** has snapped into groove **706** of frangible collar **604**.

Element installer **314** may be moved away from element loader **312** in the direction of arrow **800**. Further, loading member **700** may be moved back in the direction of arrow **802** such that the next frangible collar **804** may be moved into position over loading member **700**. In particular, frangible collar **804** may be moved in the direction of arrow **806** once frangible collar **604** has been moved away from element loader **312** and loading member **700** has moved back down in the direction of arrow **802**.

With reference now to **Figure 9**, an illustration of element installer **314** being moved away from element loader **312** is depicted in accordance with an illustrative embodiment. In this illustrative example, element installer **314** may be moved away from element loader **312** and then moved towards opening **332** in installation feature **326** in the direction of arrow **900**. In particular, element installer **314** may be moved in the direction of arrow **900** such that frangible collar **604** held by retaining member **504** may be positioned over opening **332**.

Turning now to **Figure 10**, an illustration of frangible collar **604** held by retaining member **504** positioned over opening **332** is depicted in accordance with an illustrative embodiment. Once frangible collar **604** has been positioned over opening **332**, actuation system **500** may be used to move frangible collar **604** into opening **332**. In particular, actuation system **500** may be used to move frangible collar **604** in the direction of arrow **1000** into opening **332**.

With reference now to **Figure 11**, an illustration of frangible collar **604** in installation feature **326** is depicted in accordance with an illustrative embodiment. In this illustrative example, actuation system **500** has moved frangible collar **604** through installation feature **326** such that frangible collar **604** may be placed over fastener **212**. In particular, end **1100** of frangible collar **604** may be placed over end **1102** of fastener **212**.

As depicted, fastener **212** may have socket **1104**. Elongate member **608** may have tip **1106** configured to be received within socket **1104** of fastener **212**. Tip **1106** may be an example of one implementation for first end **156** in **Figure 1**. Socket **1104** may be an example of one implementation for second end **158** in **Figure 1**.

In this illustrative example, socket **1104** may be a hexagonal socket and tip **1106** may have a hexagonal shape that fits within the hexagonal socket. Of course, in other illustrative examples, socket **1104** may be some other type of socket and tip **1106** may have some other type of shape.

Actuation system **500** may move elongate member **608** in the direction of arrow **1108** towards fastener **212** such that tip **1106** of elongate member **608** at least contacts end **1102** of fastener **212**. Tip **1106** of elongate member **608** may pass through opening **1110** in frangible collar **604** to reach fastener **212**.

In some cases, tip **1106** may engage socket **1104** when tip **1106** is moved in the direction of arrow **1108**. In other

examples, tip **1106** may not be rotationally aligned with socket **1104**. In other words, tip **1106** may contact end **1102** of fastener **212** but may be unable to engage socket **1104** when moved in the direction of arrow **1108**. Tip **1106** may need to be rotated in order for tip **1106** and socket **1104** to be properly aligned.

With reference now to **Figure 12**, an illustration of tip **1106** of elongate member **608** in contact with end **1102** of fastener **212** is depicted in accordance with an illustrative embodiment. As depicted, tip **1106** has not yet engaged socket **1104** but is in contact with end **1102** of fastener **212**.

Rotatable member **502** may be rotated about center axis **1200** through rotatable member **502** in the direction of, for example, without limitation, arrow **1202**. In particular, rotatable member **502** may be rotated according to preselected parameters. In other words, rotatable member **502** may be rotated a preselected number of turns.

Rotatable member **502** may be rotated while actuation system **500** is still applying force to elongate member **608** in the direction of arrow **1203** to move elongate member **608** in the direction of arrow **1203**. As a result, rotation of rotatable member **502** may cause tip **1106** of elongate member **608** to properly align with socket **1104** of fastener **212** and engage socket **1104**.

With reference now to **Figure 13**, an illustration of tip **1106** of elongate member **608** engaged with socket **1104** of fastener **212** is depicted in accordance with an illustrative embodiment. As depicted, tip **1106** has engaged socket **1104**.

Fastener **212** may have outer threads **1301**. Further, at least a portion of frangible collar **604** at end **1100** of frangible collar **604** may have inner threads (not shown) configured to engage outer threads **1301** of fastener **212**. Rotation of rotatable member **502** may cause frangible collar **604** to be threaded onto fastener **212**.

In this manner, rotation of rotatable member **502** according to preselected parameters may cause tip **1106** to engage socket

1104 and frangible collar **604** to be threaded onto fastener **212**. Threading frangible collar **604** onto fastener **212** may move frangible collar **604** relative to fastener **212** in the direction of arrow **1300** until end **1100** of frangible collar **604** reaches surface **1302** of first part **201**.

Further, the number of turns and speed by which rotatable member **502** is rotated may determine the torque applied to frangible collar **604**. Once the torque applied to frangible collar **604** reaches a selected threshold, first portion **1304** of frangible collar **604** may be configured to break away from second portion **1306** of frangible collar **604**.

With reference now to **Figure 14**, an illustration of first portion **1304** of frangible collar **604** separated from second portion **1306** of frangible collar **604** is depicted in accordance with an illustrative embodiment. In particular, first portion **1304** of frangible collar **604** has broken away from second portion **1306** of frangible collar **604**. First portion **1304** may be removed as nut portion **1400**, while second portion **1306** may remain installed over fastener **212** as collar **217**. Element installer **314** may then be moved away from installation feature **326** in the direction of arrow **1402** by actuation system **500** to move nut portion **1400** away from collar **217**.

Turning now to **Figure 15**, an illustration of element installer **314** moving nut portion **1400** to removal system **316** is depicted in accordance with an illustrative embodiment. In this illustrative example, actuation system **500** has moved nut portion **1400** away from collar **217**. Next, movement system **318** from **Figure 3** may move element installer **314** in the direction of arrow **1500** towards removal system **316**.

With reference now **Figure 16**, an illustration of nut portion **1400** positioned over opening **336** into vacuum tube **334** is depicted in accordance with an illustrative embodiment. In this illustrative example, nut portion **1400** has been positioned over

opening **336** into vacuum tube **334** such that nut portion **1400** may be discarded.

Elongate member **608** may be moved in the direction of arrow **1600** to push nut portion **1400** out of retaining member **504** and into vacuum tube **334**. In particular, nut portion **1400** may be pushed through opening **336** into channel **1602** inside vacuum tube **334**. As depicted, elongate member **608** has interface feature **1604** configured to engage end **1606** of nut portion **1400** and apply force to nut portion **1400** to move nut portion **1400** in the direction of arrow **1600**.

With reference now to **Figure 17**, an illustration of interface feature **1604** of elongate member **608** engaged with nut portion **1400** is depicted in accordance with an illustrative embodiment. In this illustrative example, interface feature **1604** has engaged with end **1606** of nut portion **1400**. Further application of force in the direction of arrow **1700** will cause nut portion **1400** to be released from retaining member **504** and pushed into channel **1602** within vacuum tube **334**.

Turning now to **Figure 18**, an illustration of nut portion **1400** released from retaining member **504** is depicted in accordance with an illustrative embodiment. In **Figure 18**, retaining member **504** may no longer be retaining nut portion **1400**. Nut portion **1400** may be further moved in the direction of arrow **1800** into channel **1602** by the pushing force being applied by elongate member **608** and the pulling force being applied by the vacuum pressure within channel **1602**.

Once nut portion **1400** enters channel **1602**, the vacuum pressure within channel **1602** may cause nut portion **1400** to be moved through vacuum tube **334** and discarded. In one illustrative example, nut portion **1400** may be discarded into a receptacle or container (not shown) located at the end of vacuum tube **334**.

With reference now to **Figure 19**, an illustration of an isometric view of end effector **300** unclamped from object **200** and

collar **217** installed over fastener **212** is depicted in accordance with an illustrative embodiment. In this illustrative example, first clamping device **306** and second clamping device **308** have been moved away from each other such that end effector **300** may unclamp from object **200**. Further, collar **217** is depicted installed over fastener **212**.

The illustrations of object **200** in **Figure 2** and end effector **300** in **Figures 3-19** are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be optional.

The different components shown in **Figures 2-19** may be illustrative examples of how components shown in block form in **Figure 1** can be implemented as physical structures. Additionally, some of the components in **Figures 2-19** may be combined with components in **Figure 1**, used with components in **Figure 1**, or a combination of the two.

With reference now to **Figure 20**, an illustration of a process for installing an element over a member associated with an object is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in **Figure 20** may be implemented using end effector **102** in **Figure 1**.

The process may begin by attaching end effector **102** to object **106** (operation **2000**). Object **106** may be, for example, without limitation, a stackup of first part **108** and second part **110**. Next, an element from number of elements **112** may be loaded onto element installer **128** of end effector **102** by element loader **126** of end effector **102** (operation **2002**). The element may take the form of, for example, without limitation, frangible collar **145**.

Thereafter, the element may be installed onto a member associated with object **106** by element installer **128** (operation **2004**), with the process terminating thereafter. The member

associated with object **106** may take the form of, for example, without limitation, threaded fastener **143** already installed in object **106**.

Turning now to **Figure 21**, an illustration of a process for installing a frangible collar onto a threaded fastener is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in **Figure 21** may be implemented using end effector **102** in **Figure 1**.

The process may begin by clamping end effector **102** to a stackup of parts using clamping system **136** of end effector **102** (operation **2100**). Next, frangible collar **145** held by element loader **126** of end effector **102** may be loaded onto element installer **126** of end effector **102** (operation **2102**).

Element installer **128** may then be moved such that frangible collar **145** is positioned over installation feature **142** of clamping system **136** (operation **2104**). Thereafter, element installer **128** may move frangible collar **145** onto threaded fastener **143** installed through the stackup of parts through installation feature **142** (operation **2106**).

Torque **153** may be applied to frangible collar **145** to thread frangible collar **145** onto threaded fastener **143** (operation **2108**). Nut portion **151** of frangible collar **145** may be separated from collar portion **160** of frangible collar **145** when torque **153** being applied to frangible collar **145** reaches selected threshold **162** (operation **2110**). Nut portion **151** may then be moved away from threaded fastener **143** to leave collar portion **160** installed on threaded fastener **143** (operation **2112**). Nut portion **151** may then be discarded using removal system **132** (operation **2114**), with the process terminating thereafter. In this manner, a collar may be installed on threaded fastener **143**.

Illustrative embodiments of the disclosure may be described in the context of aircraft manufacturing and service method **2200** as shown in **Figure 22** and aircraft **2300** as shown in **Figure 23**. Turning first to **Figure 22**, an illustration of an aircraft

manufacturing and service method is depicted in the form of a block diagram in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method **2200** may include specification and design **2202** of aircraft **2300** in **Figure 23** and material procurement **2204.**

During production, component and subassembly manufacturing **2206** and system integration **2208** of aircraft **2300** in **Figure 23** takes place. Thereafter, aircraft **2300** in **Figure 23** may go through certification and delivery **2210** in order to be placed in service **2212.** While in service **2212** by a customer, aircraft **2300** in **Figure 23** is scheduled for routine maintenance and service **2214**, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method **2200** may be performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

With reference now to **Figure 23**, an illustration of an aircraft is depicted in the form of a block diagram in which an illustrative embodiment may be implemented. In this example, aircraft **2300** is produced by aircraft manufacturing and service method **2200** in **Figure 22** and may include airframe **2302** with plurality of systems **2304** and interior **2306.** Examples of systems **2304** include one or more of propulsion system **2308**, electrical system **2310**, hydraulic system **2312**, and environmental system **2314.** Any number of other systems may be included. Although an aerospace example is shown, different illustrative

embodiments may be applied to other industries, such as the automotive industry.

Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **2200** in **Figure 22**. In particular, end effector **102** from **Figure 1** may be used to install elements, such as, for example, number of frangible elements **116** in **Figure 1** during any one of the stages of aircraft manufacturing and service method **2200**. For example, without limitation, end effector **102** from **Figure 1** may be used install number of frangible collars **120** onto number of threaded fasteners **118** during at least one of component and subassembly manufacturing **2206**, system integration **2208**, routine maintenance and service **2214**, or some other stage of aircraft manufacturing and service method **2200**. Further, number of frangible collars **120** may be installed to join together parts for different structures of airframe **2302** and/or interior **2306** in **Figure 23**.

In one illustrative example, components or subassemblies produced in component and subassembly manufacturing **2206** in **Figure 22** may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft **2300** is in service **2212** in **Figure 22**. As yet another example, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages, such as component and subassembly manufacturing **2206** and system integration **2208** in **Figure 22**. One or more apparatus embodiments, method embodiments, or a combination thereof may be utilized while aircraft **2300** is in service **2212** and/or during maintenance and service **2214** in **Figure 22**. The use of a number of the different illustrative embodiments may substantially expedite the assembly of and/or reduce the cost of aircraft **2300**.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and

methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, a segment, a function, and/or a portion of an operation or step.

In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, without limitation, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

The description of the different illustrative embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other desirable embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS:

What is claimed is:

1. An apparatus comprising:

an attachment system configured for attachment to an object;

an element loader configured to hold a number of elements; and

an element installer configured to receive an element in the number of elements from the element loader and install the element onto a member associated with the object.

2. The apparatus of claim 1, wherein the element installer is configured to apply a torque to the element to install the element onto the member.

3. The apparatus of claim 2, wherein the element is a frangible element comprising:

a first portion; and

a second portion, wherein the first portion is configured to break off from the second portion when the torque being applied to the frangible element reaches a selected threshold.

4. The apparatus of claim 3 further comprising:

a removal system configured for use in discarding the first portion of the frangible element.

5. The apparatus of either claim 3 or 4, wherein the element installer comprises:

a rotatable member configured to rotate the frangible element when the frangible element is placed over the member to apply the torque to the frangible element.

6. The apparatus of either claim 3 or 4, wherein the element installer comprises:

a retaining member configured to receive the frangible element from the element loader and retain the frangible element, wherein the retaining member retains the first portion of the frangible element after the first portion breaks away from the second portion of the frangible element.

7. The apparatus of either claim 3 or 4, wherein the frangible element is a frangible collar.

8. The apparatus of any preceding claim, wherein the element installer comprises:

an elongate member configured for use in aligning the element with the member; and

an actuation system configured to actuate the elongate member.

9. The apparatus of claim 8, wherein the member has a socket and the elongate member has a tip having a shape configured to fit within the socket.

10. The apparatus of any preceding claim, wherein the element loader comprises:

a holder configured to hold the number of elements; and

a loading device configured to load the element onto the element installer.

11. The apparatus of any preceding claim, wherein the element is a threaded fastener.

12. The apparatus of any preceding claim further comprising:

a movement system configured to move the element installer towards and away from the element loader.

13. The apparatus of any preceding claim, wherein the attachment system is a clamping system comprising:

a first clamping device; and

a second clamping device.

14. The apparatus of any preceding claim, wherein the object comprises a first part and a second part and wherein the member is configured for use in joining the first part and the second part to each other.

15. An end effector comprising:

an attachment system configured for use in attaching the end effector to an object;

an element loader configured to hold a number of frangible collars in which a frangible collar in the number of frangible collars includes a nut portion and a collar portion;

an element installer configured to receive the frangible collar from the element loader and comprising:

a rotatable member configured to rotate the frangible collar when the frangible collar is placed over a threaded fastener associated with the object to install the frangible collar onto the threaded fastener in which the nut portion of the frangible collar is configured to separate from the collar portion of the frangible collar when a torque being applied to the frangible collar by rotation of the frangible collar reaches a selected threshold; and

a retaining member configured to receive the frangible collar from the element loader and retain the frangible collar in which the retaining member retains the nut portion of the frangible collar after the nut portion separates from the collar portion of the frangible collar; and

a removal system configured for use in discarding the nut portion of the frangible collar that separates from the collar portion.

16. A method for installing an element over a member associated with an object, the method comprising:

attaching an end effector to the object;

loading, by an element loader of the end effector, the element onto an element installer; and

installing, by the element installer, the element onto the member associated with the object.

17. The method of claim 16, wherein installing the element onto the member associated with the object comprises:

applying a torque to the element to install the element onto the member, wherein the element is a frangible element.

18. The method of claim 17, wherein installing the element onto the member associated with the object further comprises:

separating a first portion of the frangible element from a second portion of the frangible element when the torque being applied to the frangible element reaches a selected threshold.

19. The method of claim 18 further comprising:

discarding the first portion of the frangible element after the first portion has separated from the second portion of the frangible element using a removal system of the end effector.

20. The method of either claim 16 or 17, wherein loading the element onto the element installer comprises:

moving the element from within a holder of the element loader towards a retaining member of the element installer using a loading device to load the element onto the element installer.

21. The method of claim 20, wherein moving the element from within the holder of the element loader towards the retaining member of the element installer using the loading device to load the element onto the element installer comprises:

moving the element from within the holder of the element loader towards the retaining member of the element installer using the loading device until an interface feature of the retaining member snaps into a groove on the element.

22. A method for installing a frangible collar, the method comprising:

clamping an end effector to a stackup of parts using a clamping system;

loading a frangible collar held by an element loader of the end effector onto an element installer of the end effector;

moving the element installer such that the frangible collar is positioned over an installation feature of the clamping system;

moving the frangible collar onto a threaded fastener installed through the stackup of parts through the installation feature;

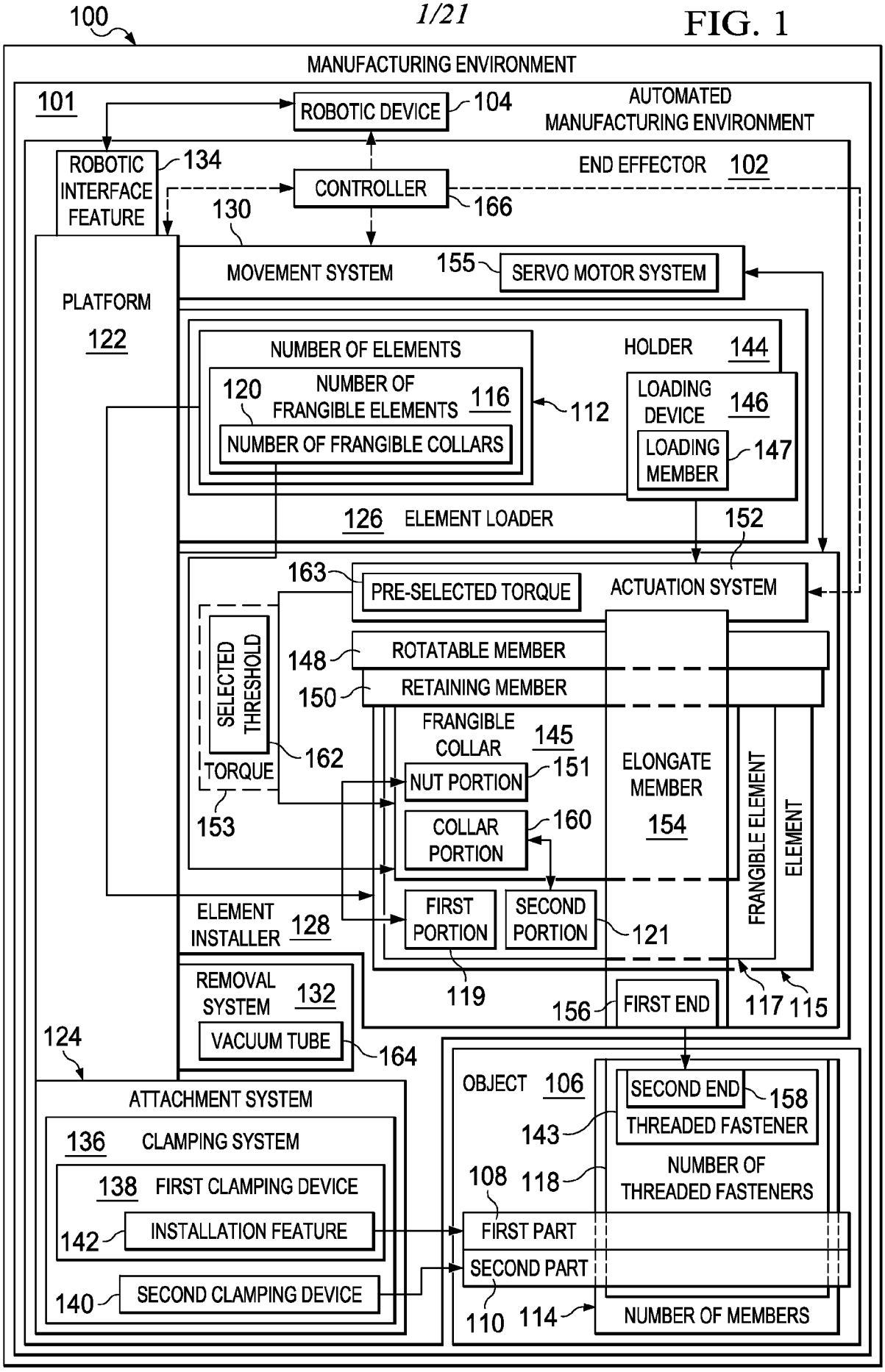
applying a torque to the frangible collar to thread the frangible collar onto the threaded fastener;

separating a nut portion of the frangible collar from a collar portion of the frangible collar when the torque being applied to the frangible collar reaches a selected threshold;

moving the nut portion away from the threaded fastener to leave the collar portion installed on the threaded fastener; and

discarding the nut portion using a removal system.

FIG. 1


100
MANUFACTURING ENVIRONMENT
101
ROBOTIC DEVICE
104
AUTOMATED MANUFACTURING ENVIRONMENT
ROBOTIC INTERFACE FEATURE
134
CONTROLLER
166
END EFFECTOR 102
130
MOVEMENT SYSTEM
155
SERVO MOTOR SYSTEM
PLATFORM 122
NUMBER OF ELEMENTS
120
NUMBER OF FRANGIBLE ELEMENTS
116
NUMBER OF FRANGIBLE COLLARS
112
HOLDER 144
LOADING DEVICE 146
LOADING MEMBER
147
126 ELEMENT LOADER
152
163
PRE-SELECTED TORQUE
ACTUATION SYSTEM
SELECTED THRESHOLD TORQUE
162
153
148
ROTATABLE MEMBER
150
RETAINING MEMBER
FRANGIBLE COLLAR 145
NUT PORTION
151
COLLAR PORTION
160
ELONGATE MEMBER 154
FRANGIBLE ELEMENT
ELEMENT
ELEMENT INSTALLER 128
FIRST PORTION
SECOND PORTION
121
REMOVAL SYSTEM 132
VACUUM TUBE
164
119
156
FIRST END
117
115
124
ATTACHMENT SYSTEM
136 CLAMPING SYSTEM
138 FIRST CLAMPING DEVICE
142
INSTALLATION FEATURE
140
SECOND CLAMPING DEVICE
OBJECT 106
SECOND END
158
143
THREADED FASTENER
NUMBER OF THREADED FASTENERS
108
118
FIRST PART
SECOND PART
110
114
NUMBER OF MEMBERS

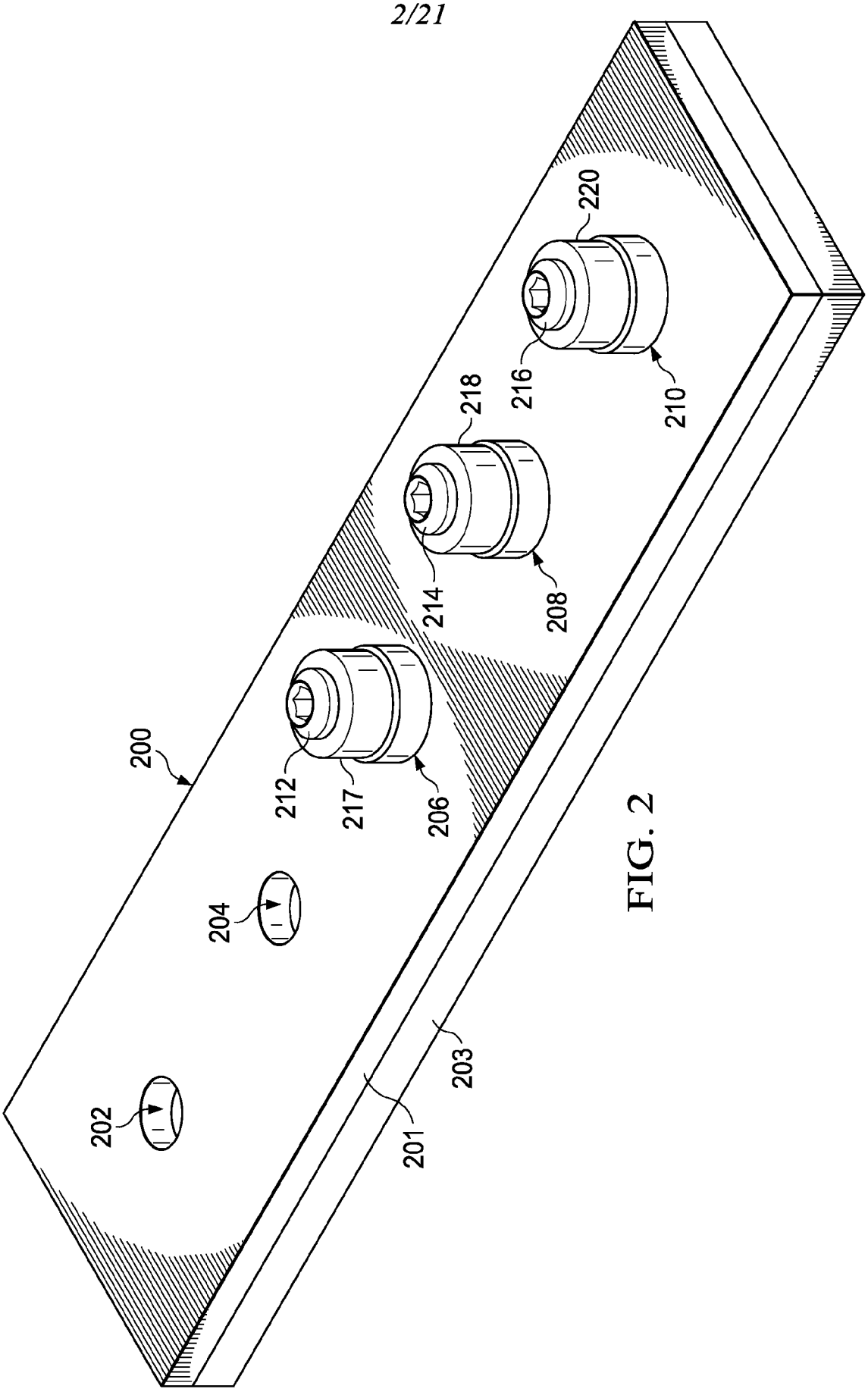


FIG. 2

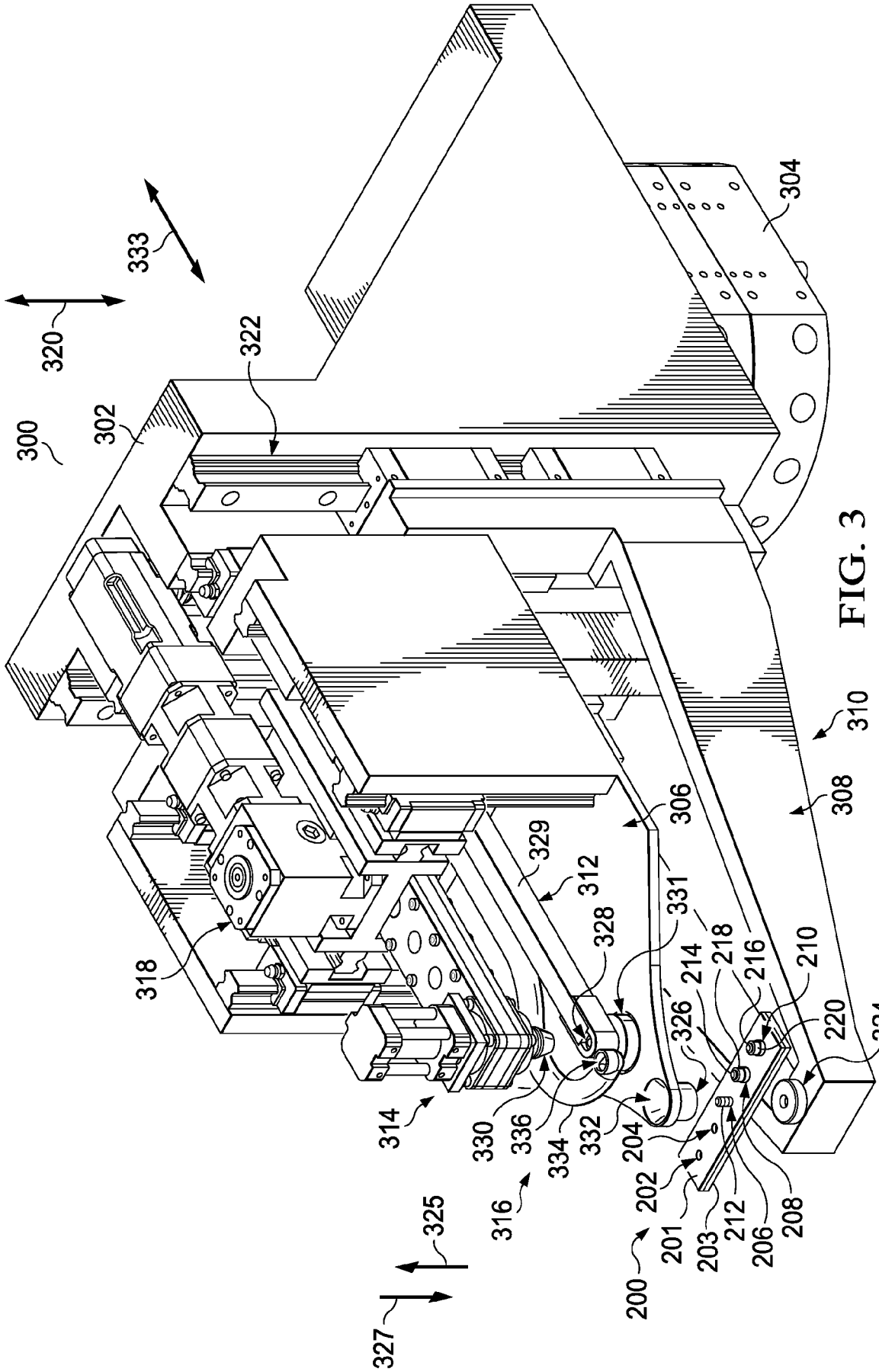

300
302
304
306
308
310
312
314
316
318
320
322
324
325
326
327
328
329
330
331
332
333
334
336
200
201
202
203
204
206
208
210
212
214
216
218
220

FIG. 3

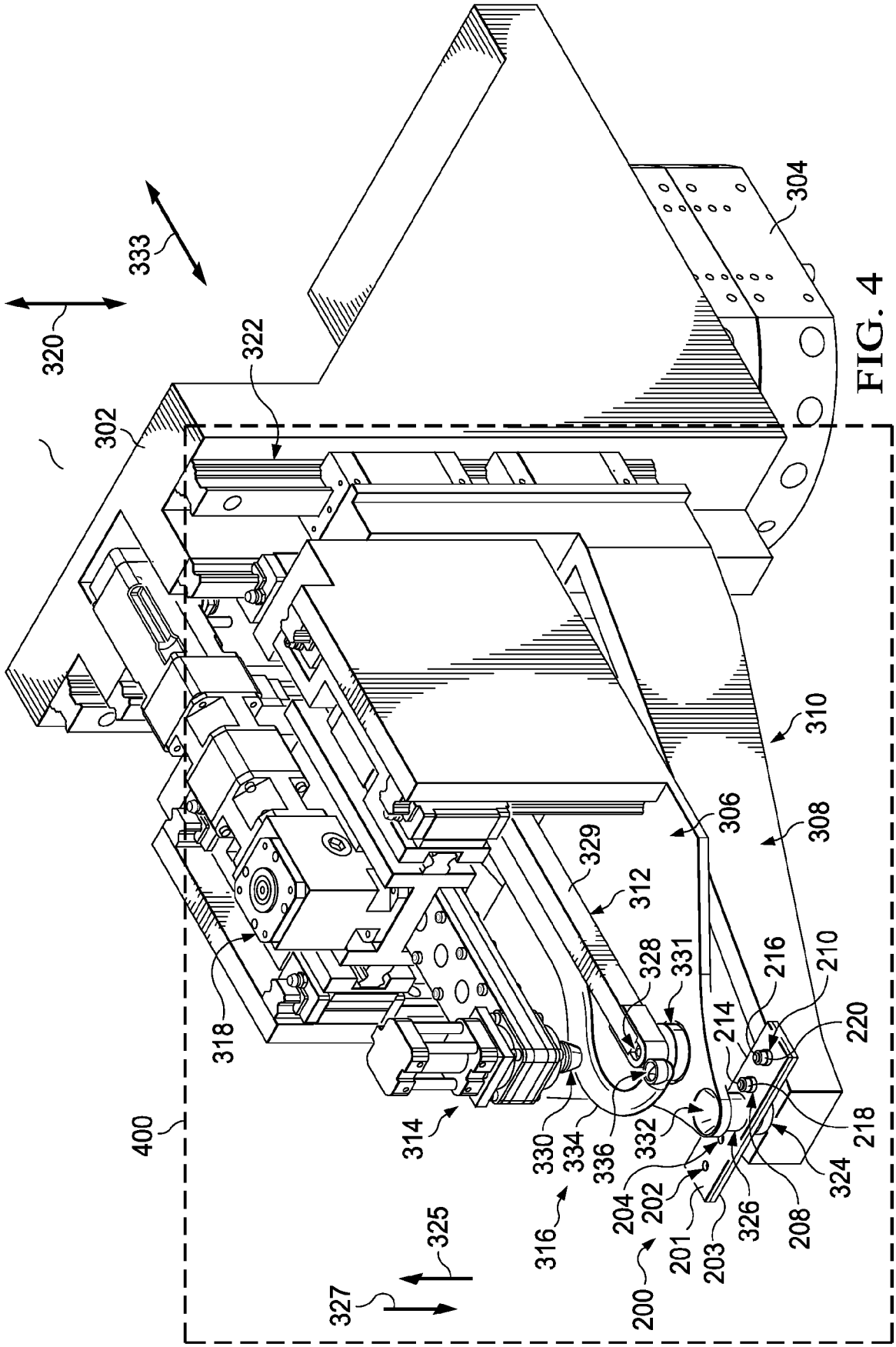

333
320
322
304
302
310
306
308
329
312
328
331
216
210
214
220
318
218
400
314
330
334
336
332
324
204
202
326
208
316
325
201
203
200
327

FIG. 4

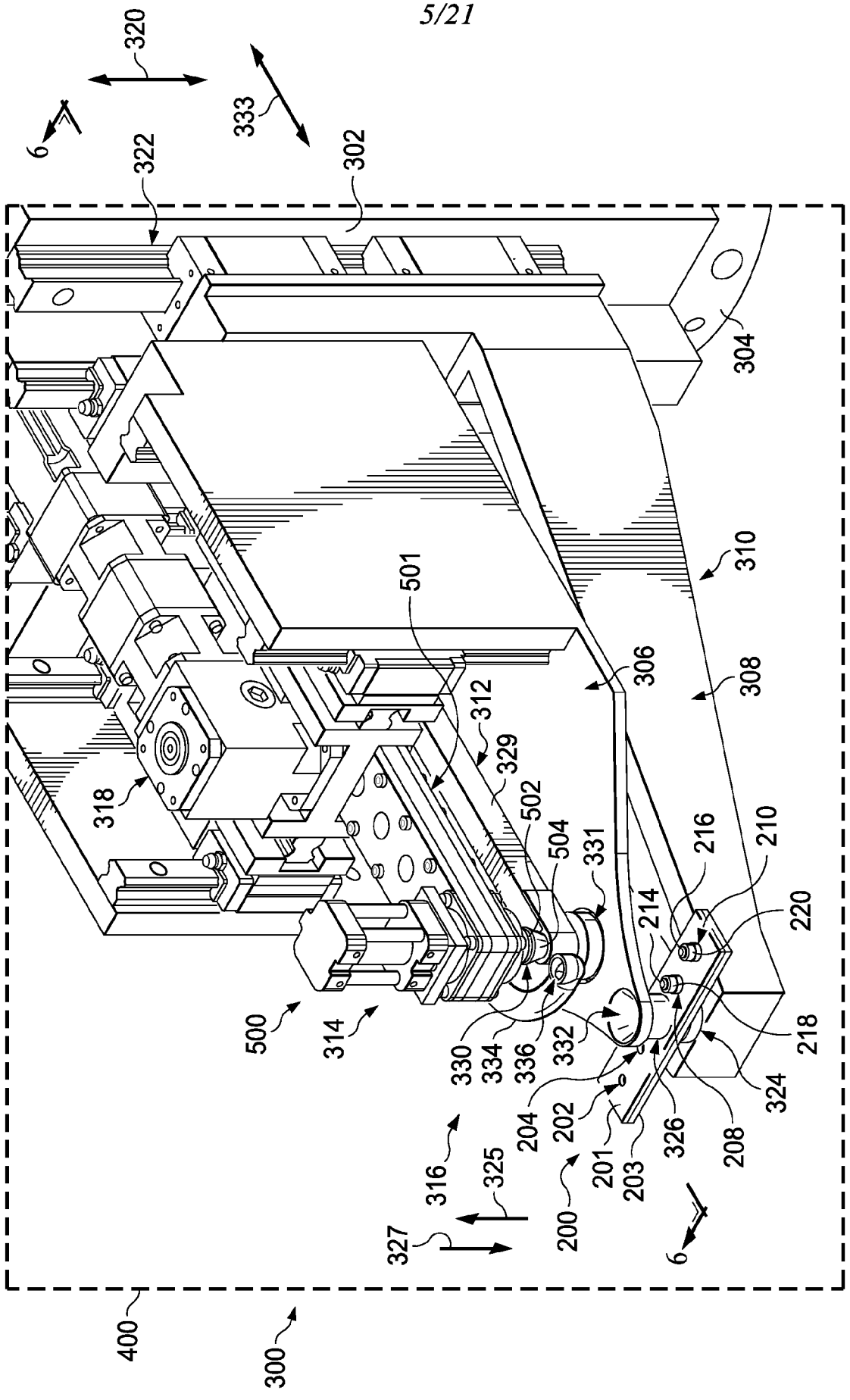

320
333
6
322
302
304
310
501
306
308
312
329
318
502
504
331
216
210
214
220
500
314
330
334
336
332
218
324
204
202
201
203
326
208
316
325
327
200
6
400
300

FIG. 5

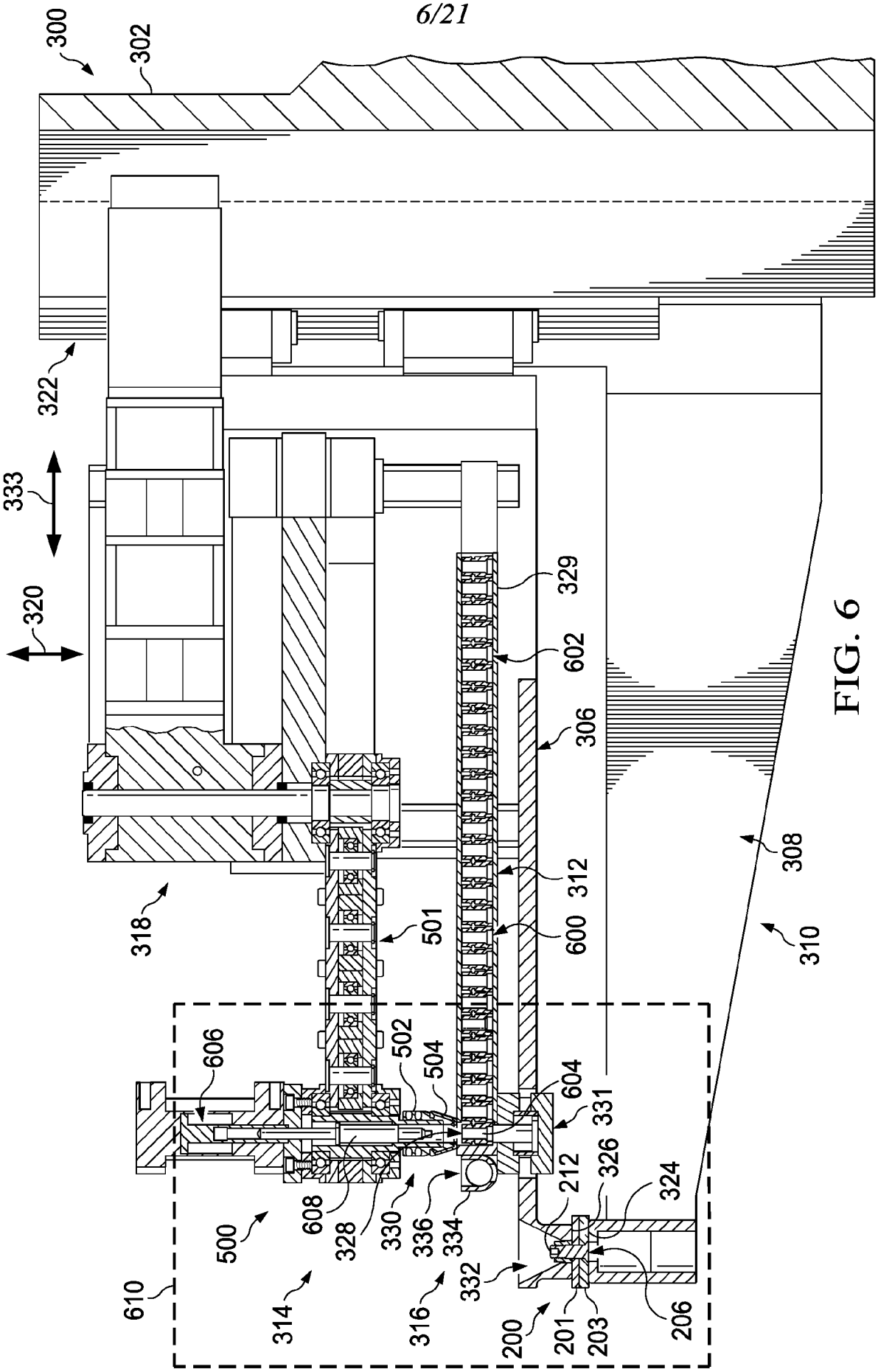

300
302
322
333
320
329
602
306
312
600
308
310
318
501
606
502
504
604
331
326
324
212
608
328
330
336
334
332
500
610
314
316
200
201
203
206

FIG. 6

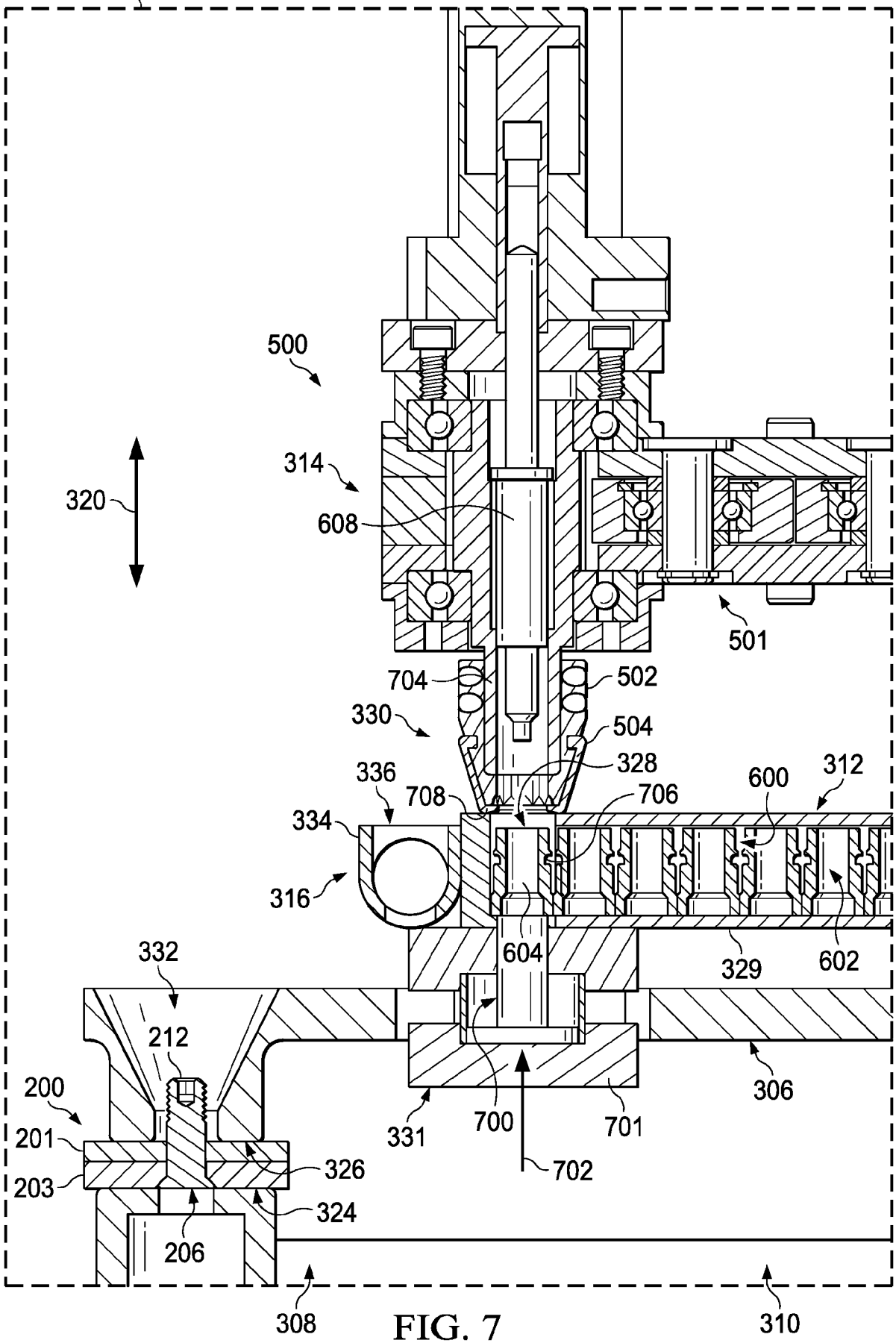

610
500
314
320
608
501
704
502
330
504
328
336
708
706
600
312
334
316
604
329
602
332
212
306
200
201
203
326
324
206
331
700
701
702
308
310

FIG. 7

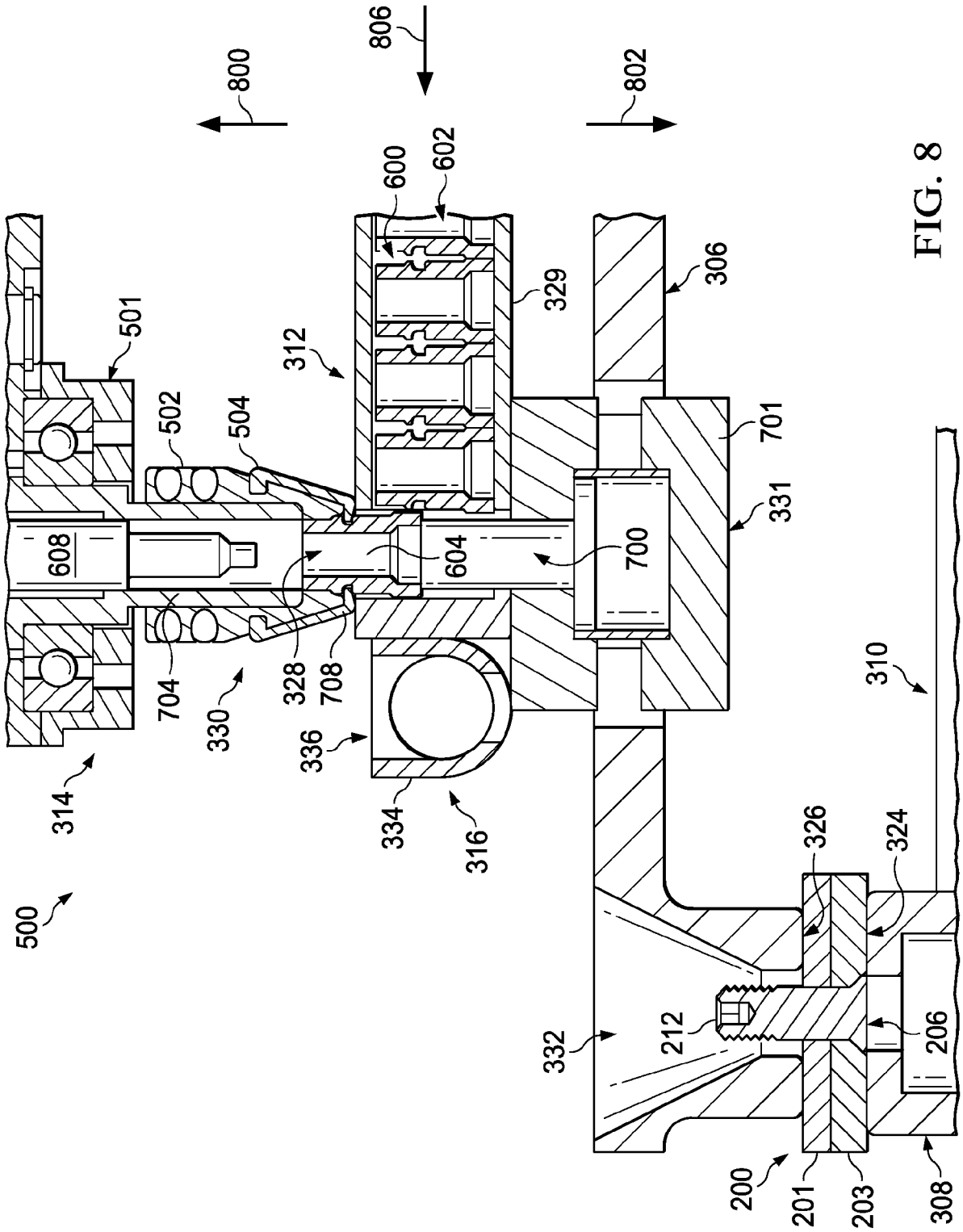

806
800
802
600
602
501
502
504
312
329
306
701
331
608
604
700
704
328
708
330
336
334
316
314
500
310
326
324
332
212
206
200
201
203
308

FIG. 8

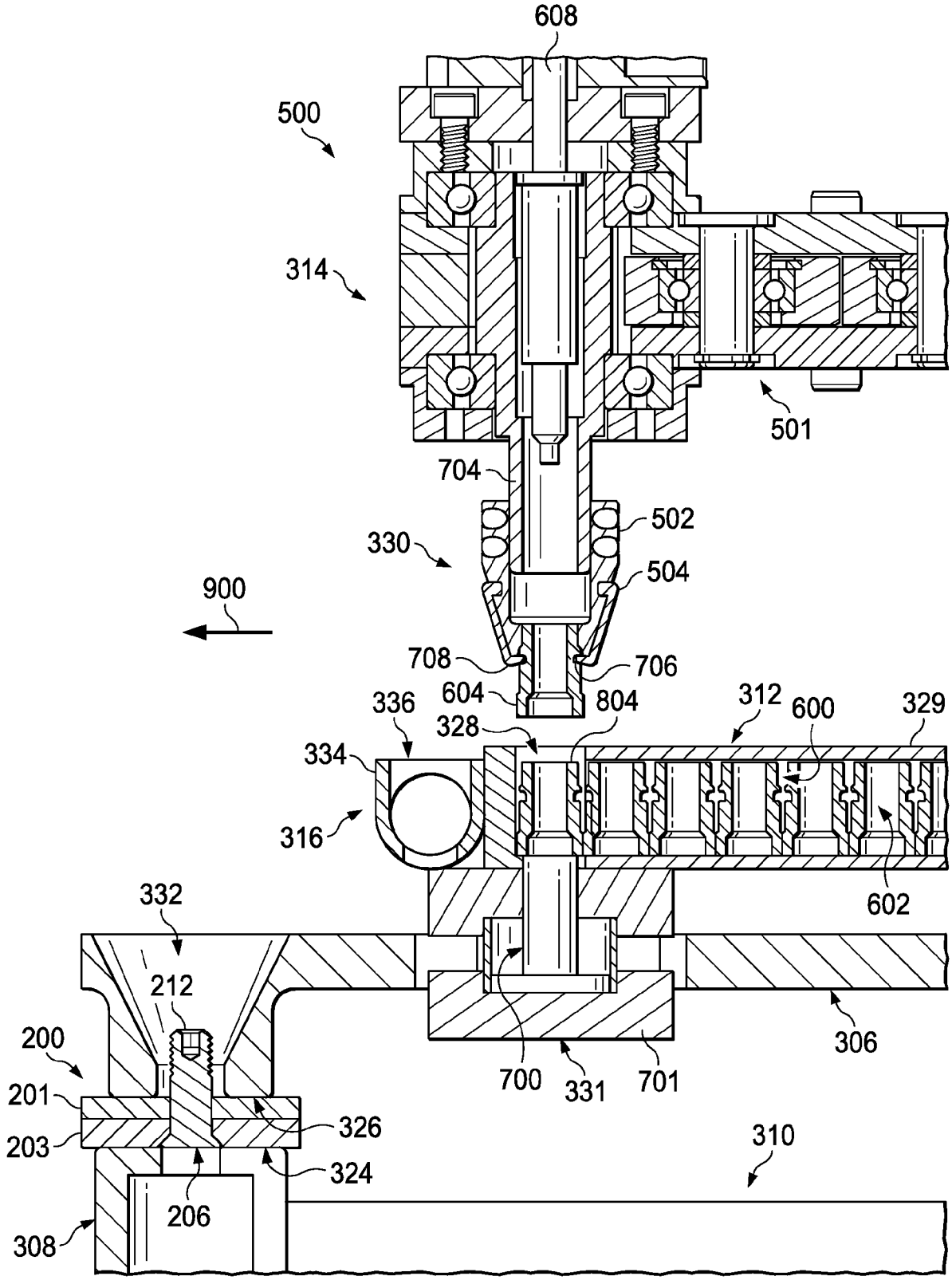

608
500
314
501
704
502
330
504
900
708
706
604
804
336
312
600
329
328
334
316
602
332
212
200
306
201
700
331
701
326
203
310
324
206
308

FIG. 9

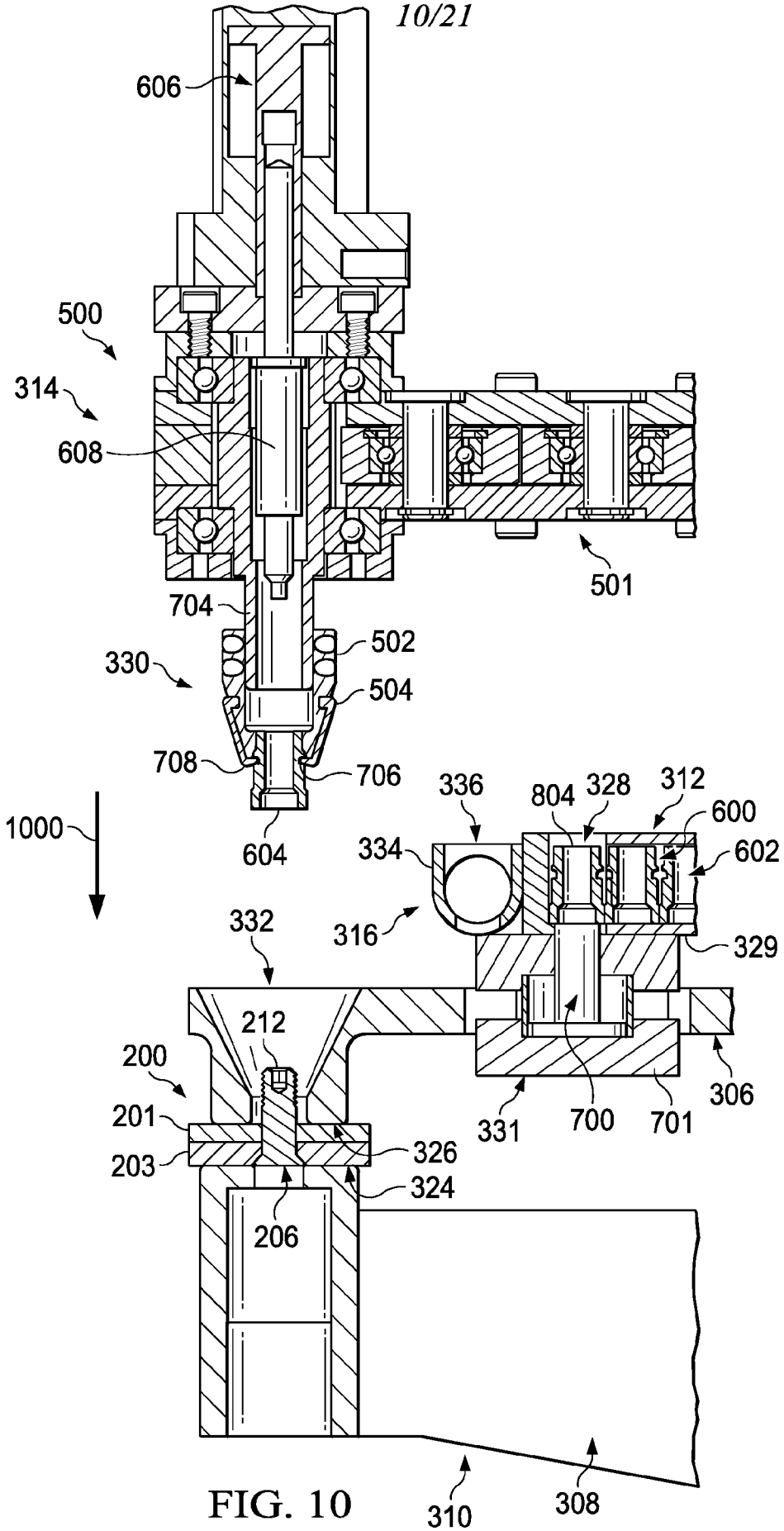

606
500
314
608
501
704
502
330
504
708
706
604
1000
336
804
328
312
600
334
602
316
329
332
212
200
306
201
331
700
701
203
326
324
206
310
308

FIG. 10

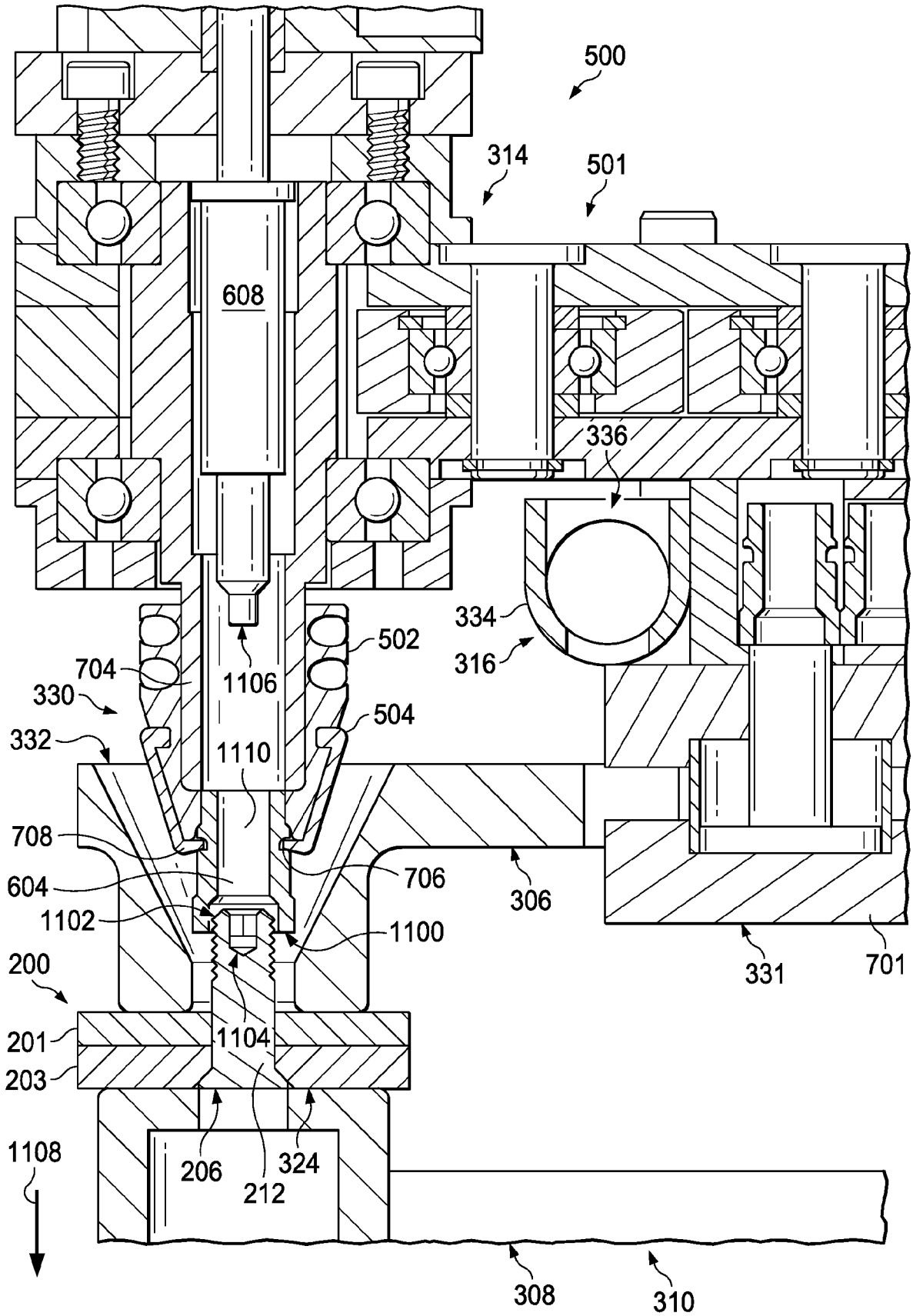

500
314
501
608
336
334
316
502
704
330
1106
504
332
1110
708
706
604
306
1102
1100
331
701
200
201
1104
203
1108
206
212
324
308
310

FIG. 11

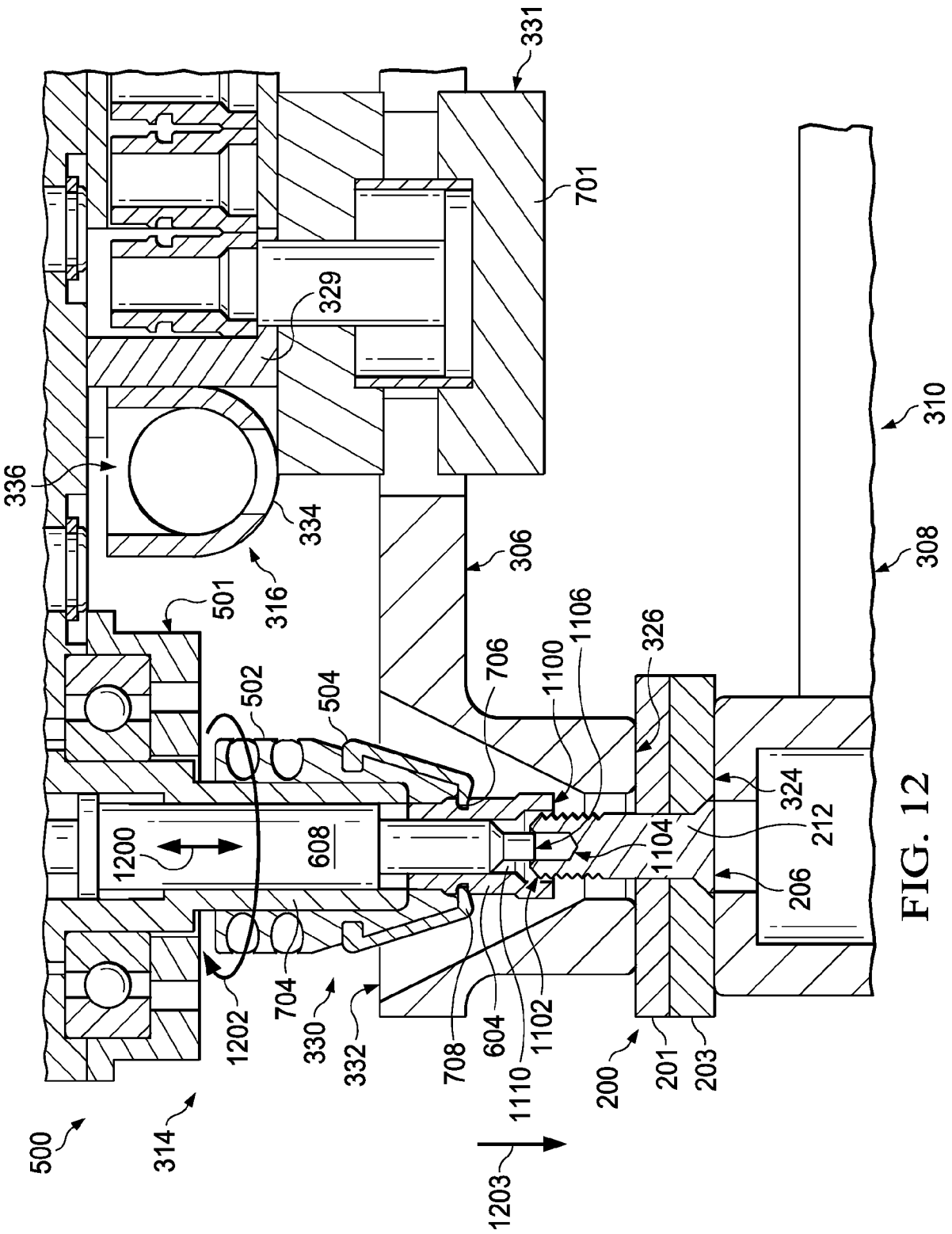

331
701
329
336
334
316
501
306
310
308
502
504
706
1100
1106
326
324
212
1104
206
1200
608
1202
704
330
332
708
604
1102
1110
200
201
203
500
314
1203

FIG. 12

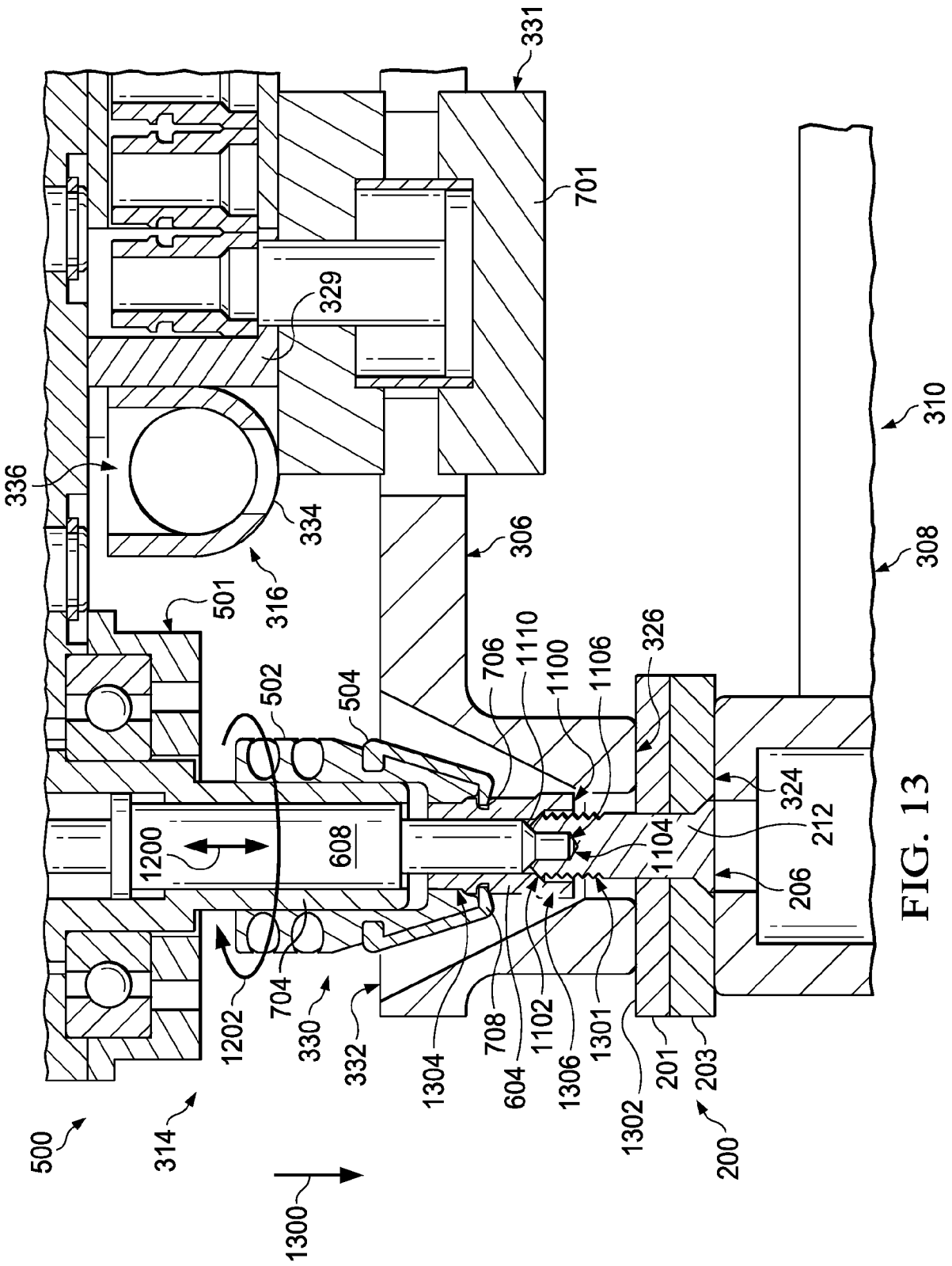

331
701
329
336
334
306
316
501
310
308
502
504
706
1110
1100
1106
326
324
212
1104
1200
608
206
704
1202
330
332
1304
708
604
1102
1306
1301
1302
201
203
200
500
314
1300

FIG. 13

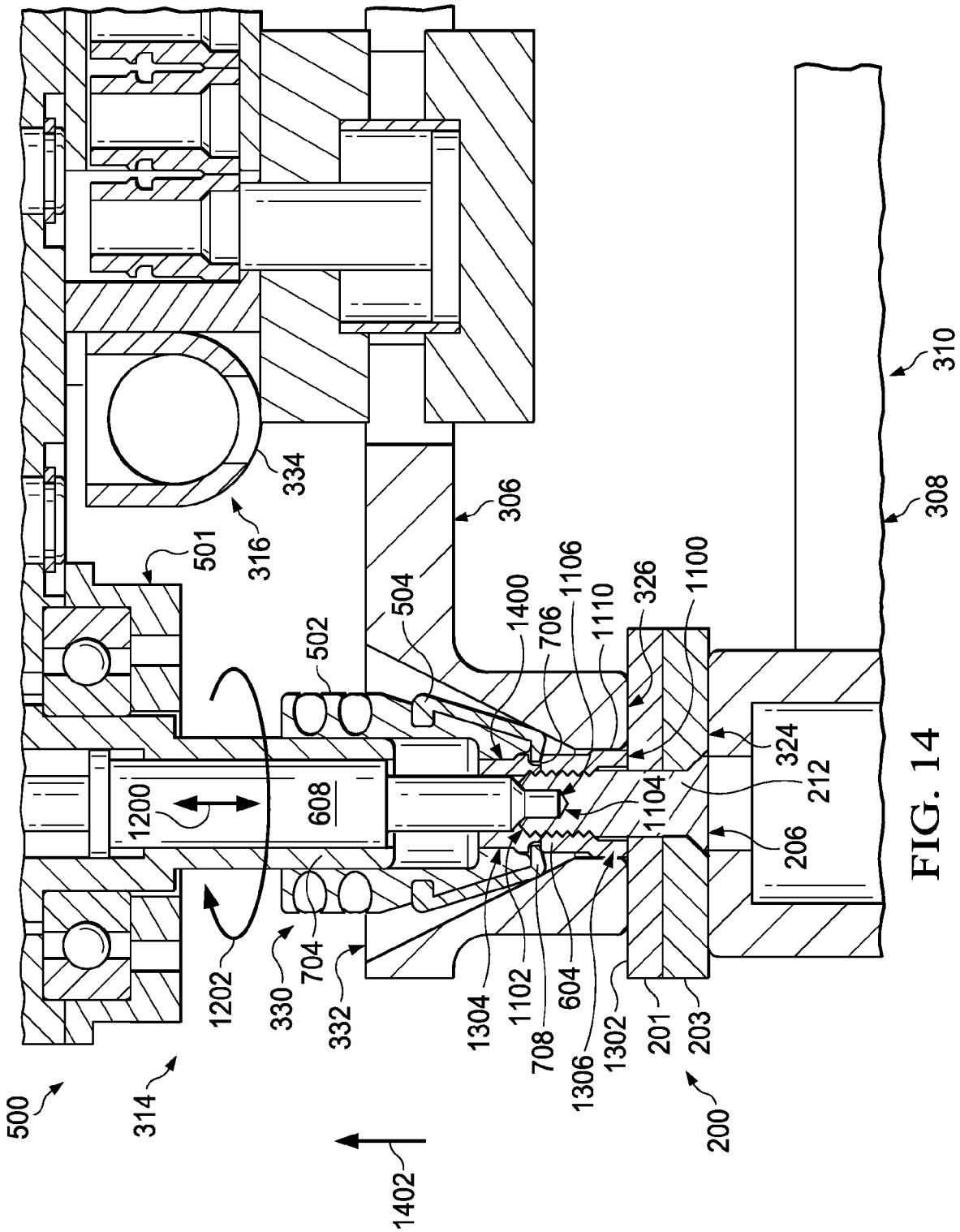

500
314
1402
1202
1200
608
330
704
332
1304
1102
708
604
1306
1302
201
203
200
502
504
501
316
334
306
1400
706
1106
1110
326
1100
1104
324
212
206
310
308

FIG. 14

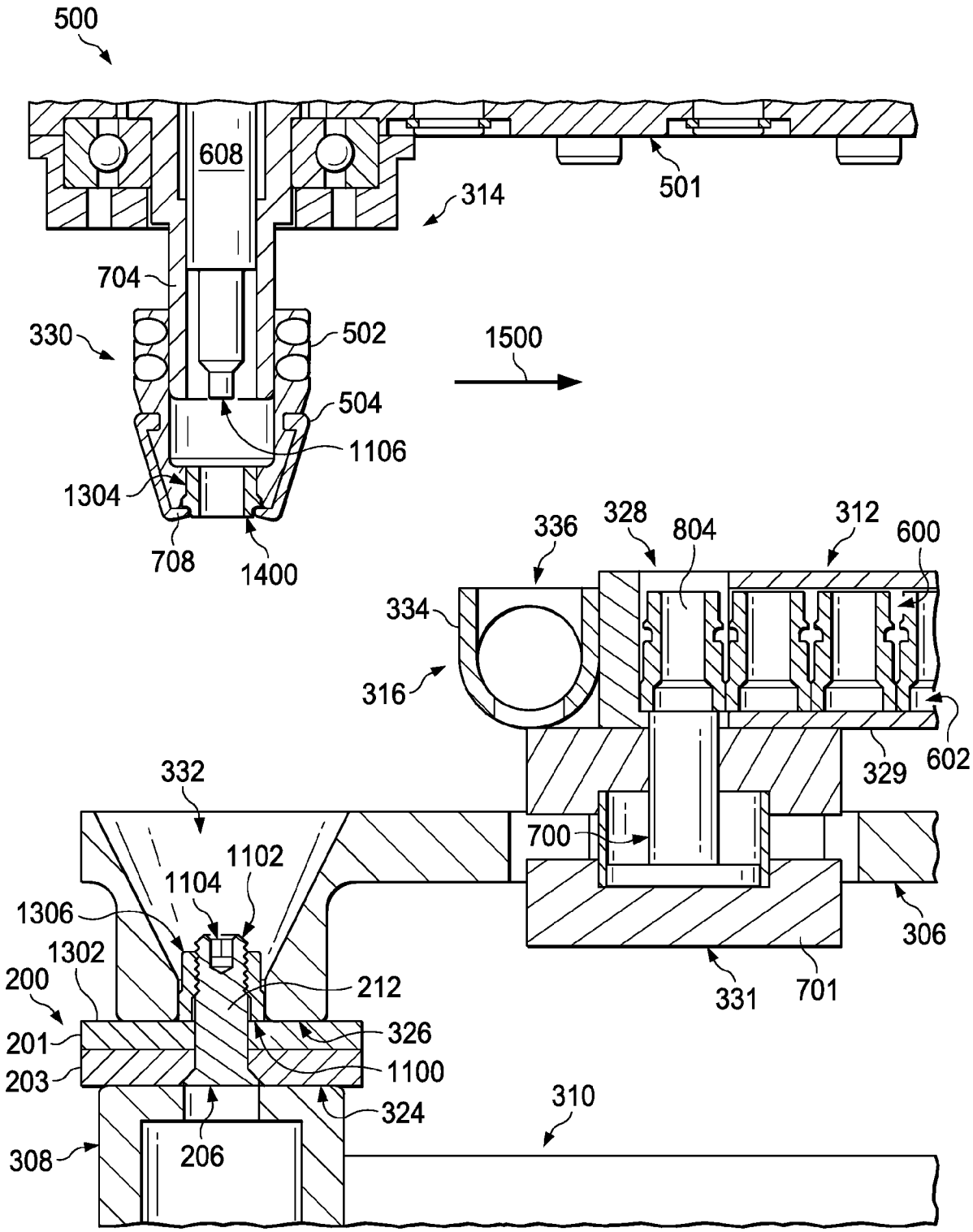

500
608
501
314
704
330
502
1500
504
1106
1304
708
1400
336
328
804
312
600
334
316
602
329
332
700
1102
1104
1306
1302
200
212
306
331
701
201
326
203
1100
324
310
308
206

FIG. 15

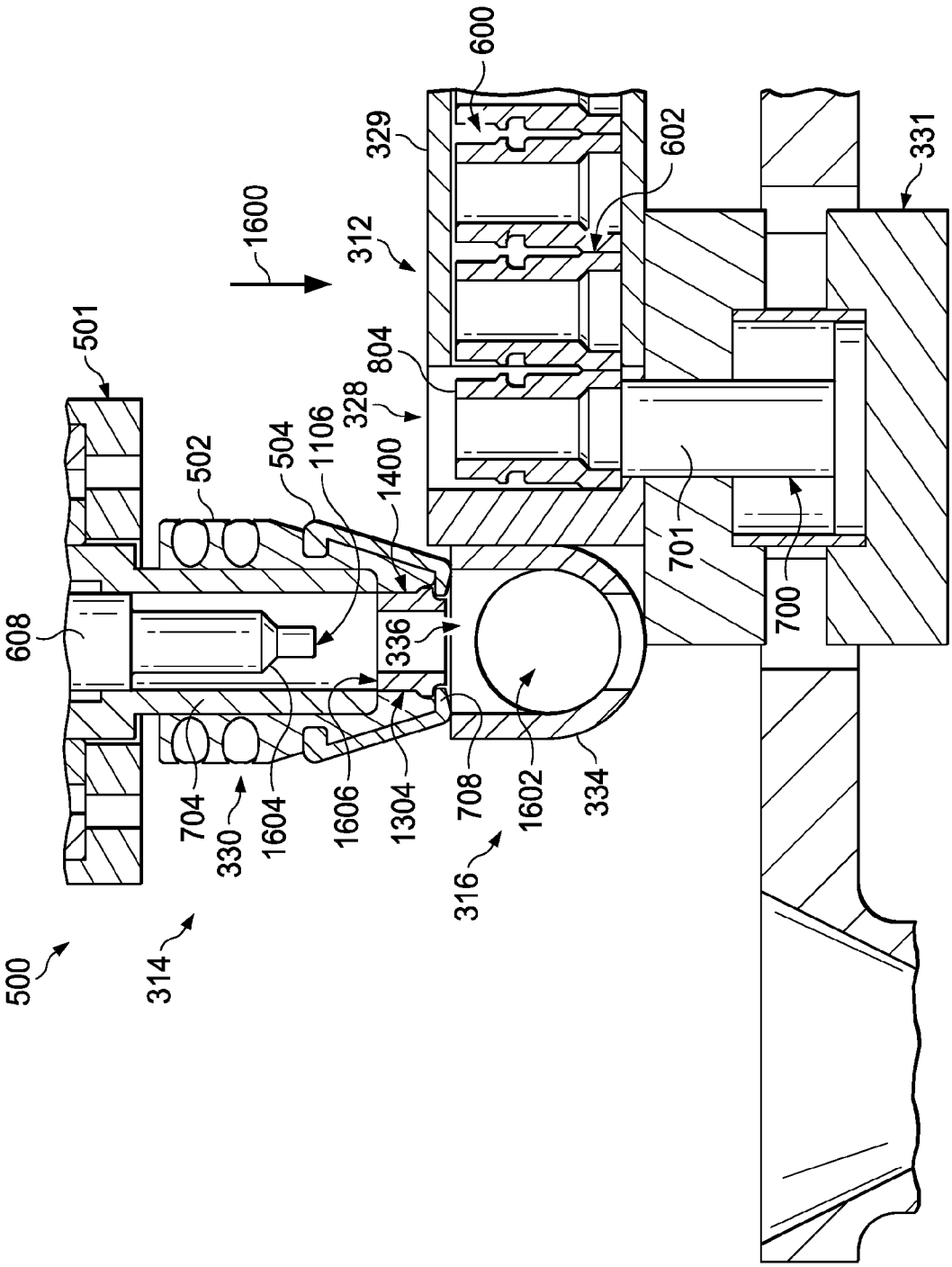

600
329
602
331
1600
312
501
804
328
502
504
1106
1400
608
336
701
700
704
330
1604
1606
1304
708
1602
334
316
500
314

FIG. 16

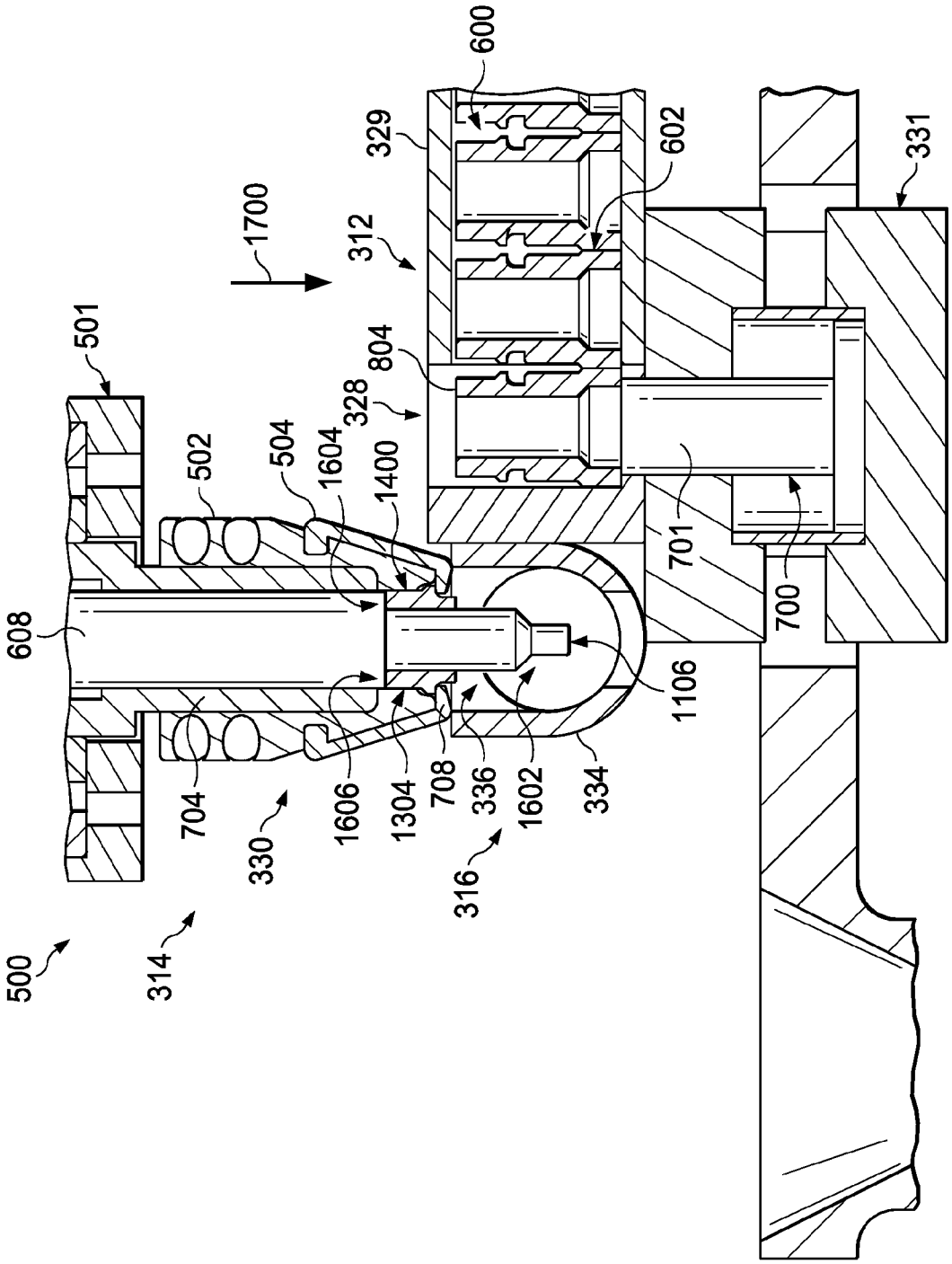

600
329
602
331
1700
312
501
804
328
502
504
1604
1400
608
701
700
1106
704
330
1606
1304
708
336
1602
334
316
500
314

FIG. 17

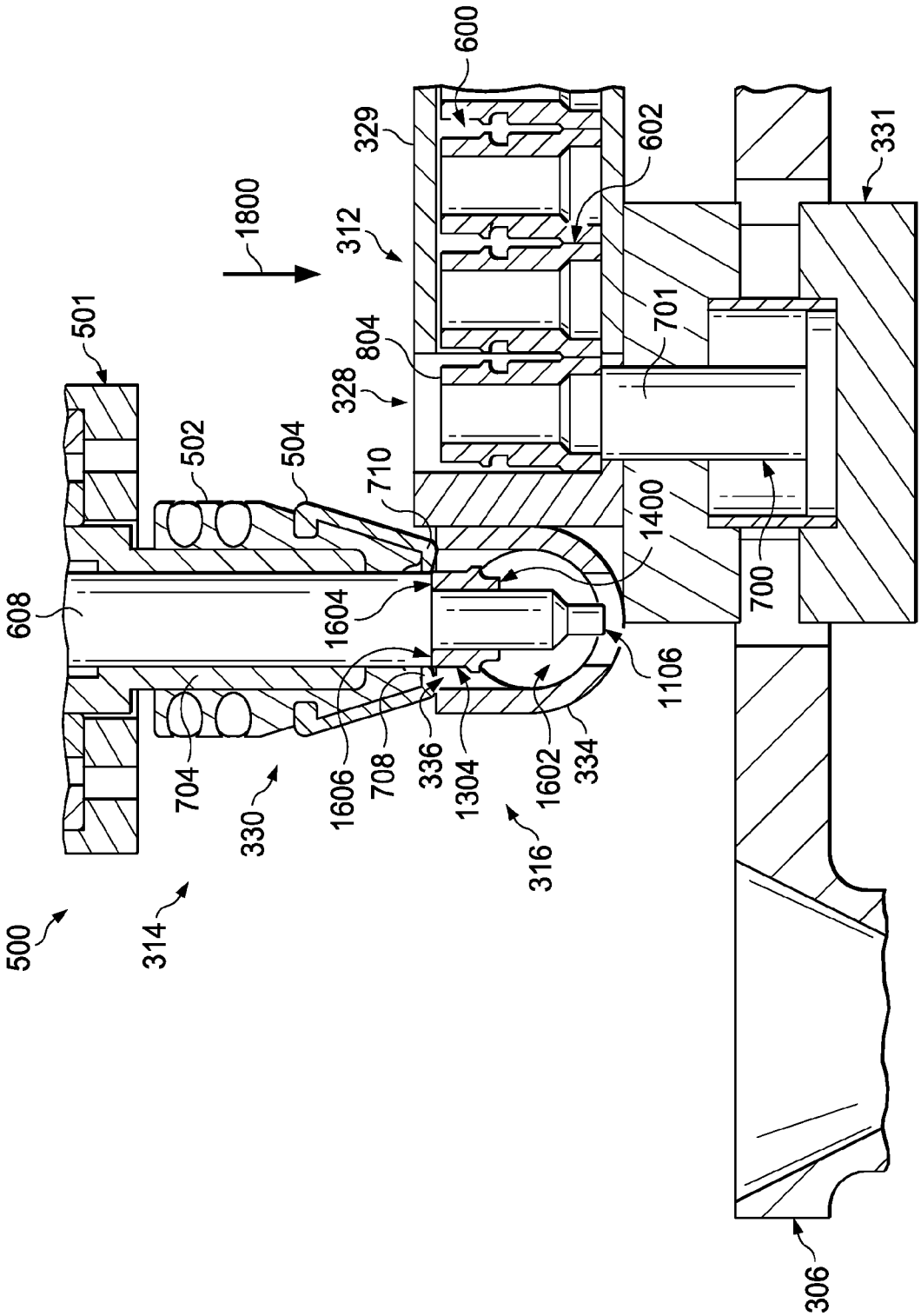

600
329
602
331
1800
312
501
804
701
328
502
504
710
1400
608
1604
700
1106
704
330
1606
708
336
1304
1602
334
316
500
314
306

FIG. 18

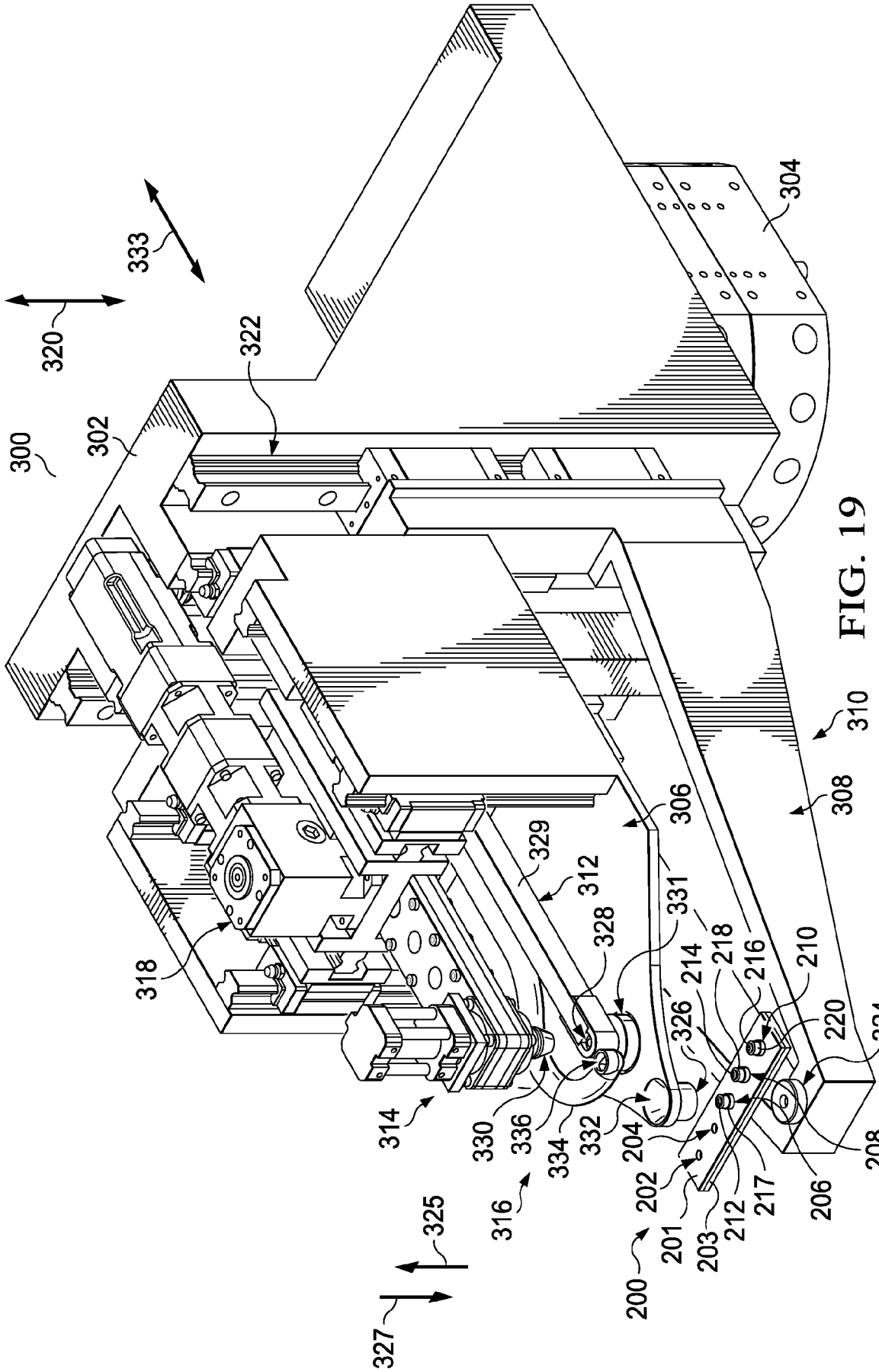

300
302
304
306
308
310
312
314
316
318
320
322
324
325
326
327
328
329
330
331
332
333
334
336
200
201
202
203
204
206
208
210
212
214
216
217
218
220

FIG. 19

FIG. 20

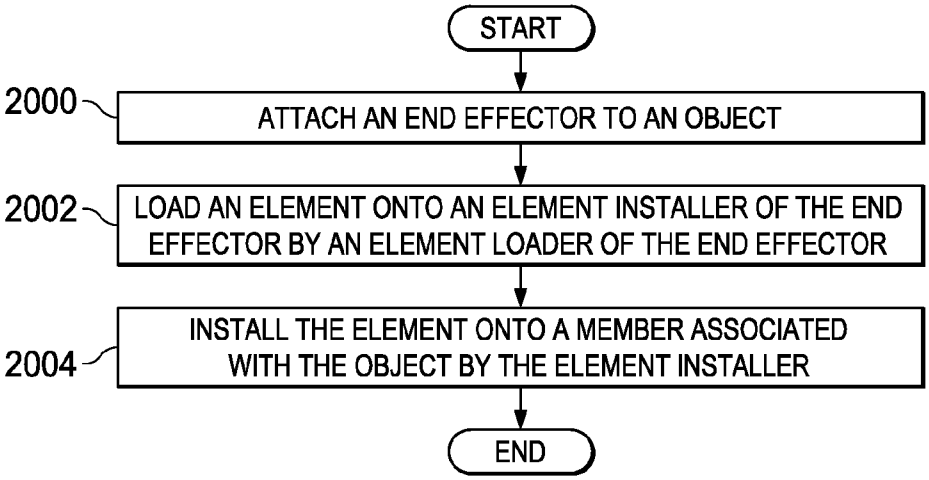
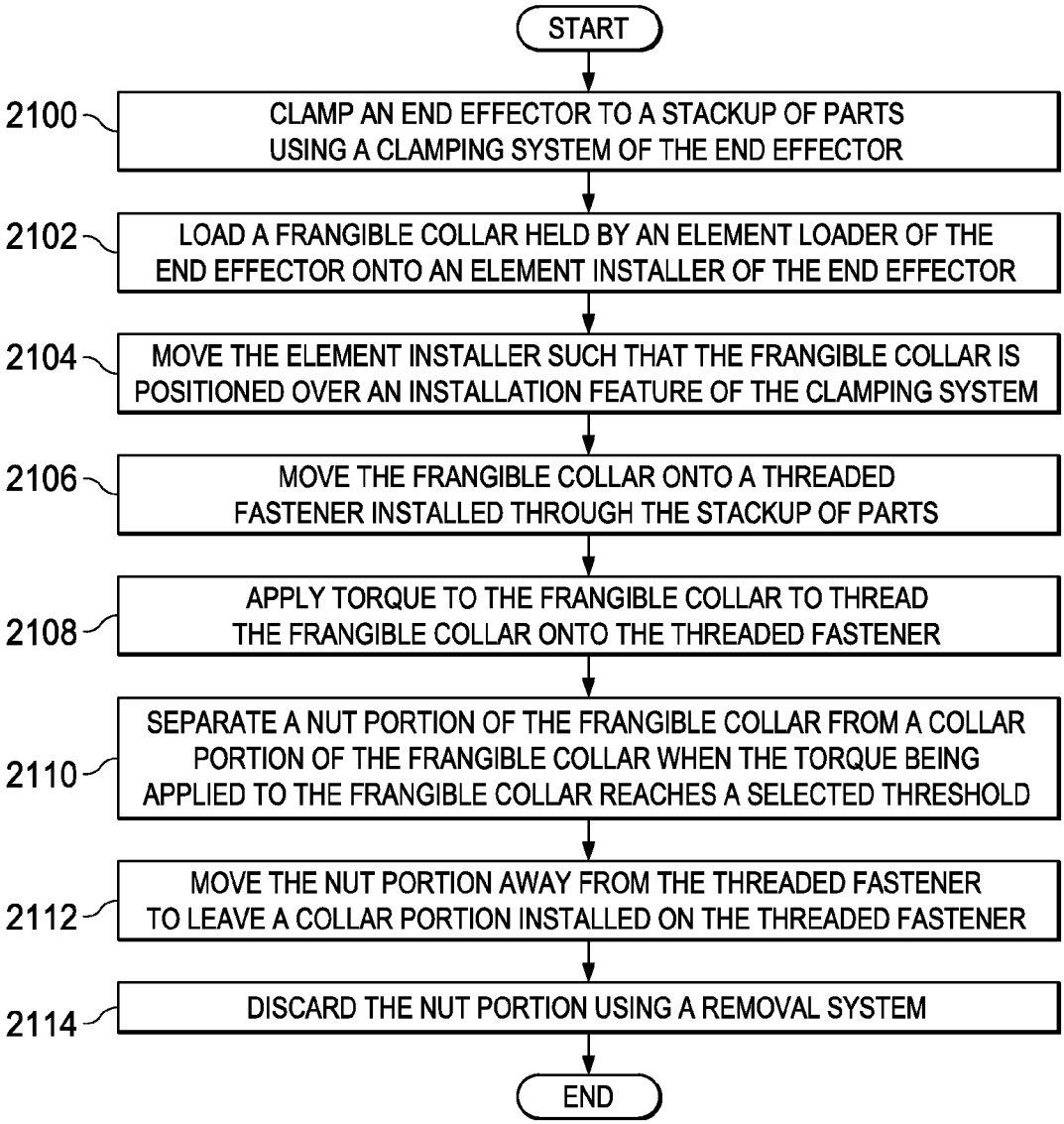

START
2000
ATTACH AN END EFFECTOR TO AN OBJECT
2002
LOAD AN ELEMENT ONTO AN ELEMENT INSTALLER OF THE END EFFECTOR BY AN ELEMENT LOADER OF THE END EFFECTOR
2004
INSTALL THE ELEMENT ONTO A MEMBER ASSOCIATED WITH THE OBJECT BY THE ELEMENT INSTALLER
END

FIG. 21


START
2100
CLAMP AN END EFFECTOR TO A STACKUP OF PARTS USING A CLAMPING SYSTEM OF THE END EFFECTOR
2102
LOAD A FRANGIBLE COLLAR HELD BY AN ELEMENT LOADER OF THE END EFFECTOR ONTO AN ELEMENT INSTALLER OF THE END EFFECTOR
2104
MOVE THE ELEMENT INSTALLER SUCH THAT THE FRANGIBLE COLLAR IS POSITIONED OVER AN INSTALLATION FEATURE OF THE CLAMPING SYSTEM
2106
MOVE THE FRANGIBLE COLLAR ONTO A THREADED FASTENER INSTALLED THROUGH THE STACKUP OF PARTS
2108
APPLY TORQUE TO THE FRANGIBLE COLLAR TO THREAD THE FRANGIBLE COLLAR ONTO THE THREADED FASTENER
2110
SEPARATE A NUT PORTION OF THE FRANGIBLE COLLAR FROM A COLLAR PORTION OF THE FRANGIBLE COLLAR WHEN THE TORQUE BEING APPLIED TO THE FRANGIBLE COLLAR REACHES A SELECTED THRESHOLD
2112
MOVE THE NUT PORTION AWAY FROM THE THREADED FASTENER TO LEAVE A COLLAR PORTION INSTALLED ON THE THREADED FASTENER
2114
DISCARD THE NUT PORTION USING A REMOVAL SYSTEM
END

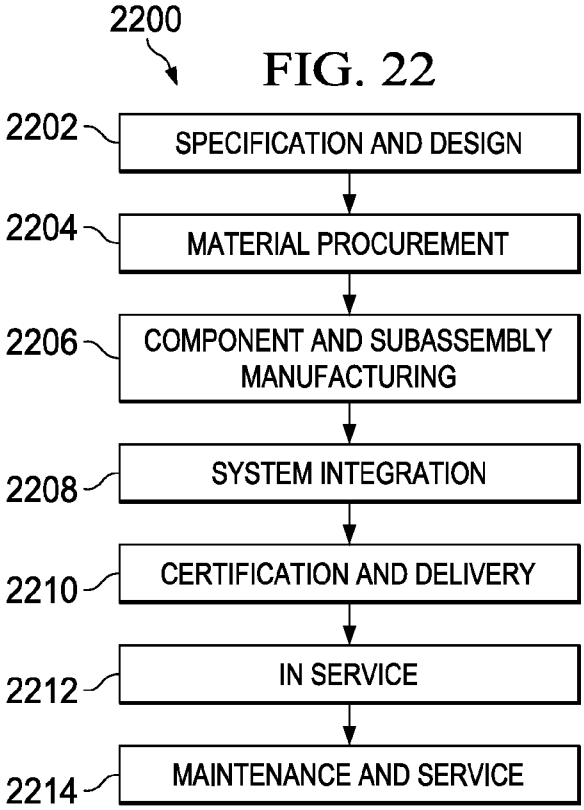

2200
2202
SPECIFICATION AND DESIGN
2204
MATERIAL PROCUREMENT
2206
COMPONENT AND SUBASSEMBLY MANUFACTURING
2208
SYSTEM INTEGRATION
2210
CERTIFICATION AND DELIVERY
2212
IN SERVICE
2214
MAINTENANCE AND SERVICE

FIG. 22

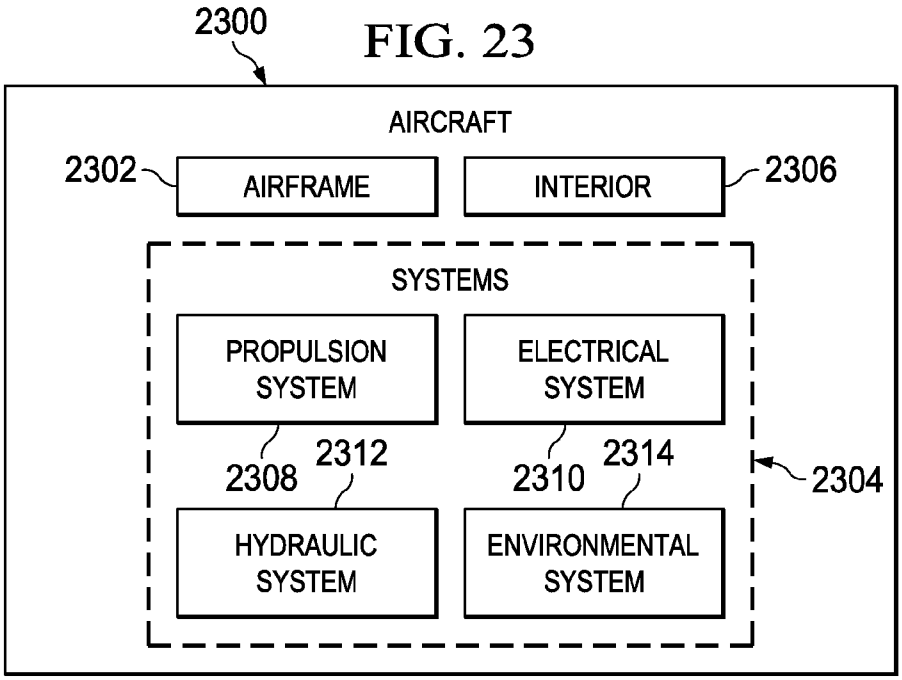

2300
AIRCRAFT
2302
AIRFRAME
INTERIOR
2306
SYSTEMS
PROPULSION SYSTEM
ELECTRICAL SYSTEM
2308
2312
2310
2314
2304
HYDRAULIC SYSTEM
ENVIRONMENTAL SYSTEM

FIG. 23

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/050888

A. CLASSIFICATION OF SUBJECT MATTER
INV. B21J15/14 B23P19/06
ADD. F16B31/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21J F16B B23P B25B B25J B64F

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 2 628 565 A1 (AIRBUS OPERATIONS SL [ES]) 21 August 2013 (2013-08-21) paragraphs [0003], [0007], [0027], [0032], [0035], [0036], [0037]; figures the whole document	1-12, 14-22 13
X	US 2008/155807 A1 (TOH CHIN H [US] ET AL) 3 July 2008 (2008-07-03) figures 2,6,10,11 paragraphs [0029], [0042], [0065] the whole document	1,2, 10-12, 14,16, 17,20,21
X	US 2009/260413 A1 (TOMCHICK SCOTT C [US]) 22 October 2009 (2009-10-22) the whole document	1,16

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 November 2014	20/11/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Sérgio de Jesus, E

2

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/050888

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 955 119 A (BONOMI GIOVANNI B [US] ET AL) 11 September 1990 (1990-09-11) the whole document	13
A	US 4 593 583 A (SINGLETON ARTHUR M [US]) 10 June 1986 (1986-06-10) the whole document	1-22
A	US 2012/186405 A1 (ORTIZ STEVEN A [US]) 26 July 2012 (2012-07-26) the whole document	1-22

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2014/050888

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2628565 A1	21-08-2013	CN 103252893 A	21-08-2013
		EP 2628565 A1	21-08-2013
		RU 2013106798 A	20-08-2014
		US 2013212883 A1	22-08-2013
US 2008155807 A1	03-07-2008	CA 2672302 A1	20-11-2008
		CA 2852191 A1	20-11-2008
		CN 101646512 A	10-02-2010
		EP 2125267 A2	02-12-2009
		US 2008155807 A1	03-07-2008
		US 2012030926 A1	09-02-2012
		WO 2008140614 A2	20-11-2008
US 2009260413 A1	22-10-2009	US 2009260413 A1	22-10-2009
		US 2011113623 A1	19-05-2011
		US 2013263415 A1	10-10-2013
		US 2013272805 A1	17-10-2013
US 4955119 A	11-09-1990	NONE	
US 4593583 A	10-06-1986	NONE	
US 2012186405 A1	26-07-2012	NONE	