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(54) **SYSTEMS AND METHODS FOR INSERTING AND REMOVING BUSHING ASSEMBLIES**

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(60) Provisional application No. 63/163,627, filed on Mar. 19, 2021, provisional application No. 63/070,759, filed on Aug. 26, 2020.

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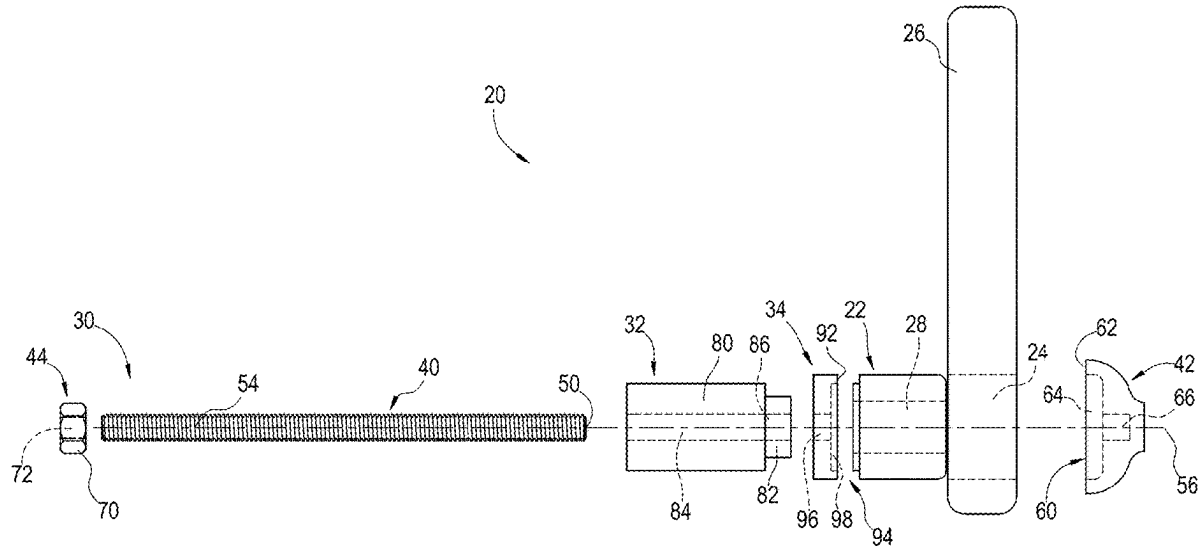
(52) **U.S. Cl.**

CPC ..... ***B25B 27/062*** (2013.01); ***F16C 43/02*** (2013.01); *B25B 27/28* (2013.01)

(57) **ABSTRACT**

An adapter system for a bushing displacing system for displacing at least a portion of a bushing assembly relative to an opening in a structural member, the bushing assembly comprising a bushing housing and a bushing pin, the adapter system comprising an extension tube defining first and second extension tube connecting portions, a cylinder adapter defining a cylinder adapter connecting portion, a cylinder tube cap defining a cylinder tube cap connecting portion, a cylinder tube cap adapter, a pullbar socket, and a push adapter. The first extension tube connecting portion is configured to engage the cylinder adapter connecting portion to detachably attach the cylinder adapter to the extension tube. The second extension tube connecting portion is configured to engage the cylinder tube cap connecting portion to detachably attach the cylinder tube cap adapter to the cylinder tube cap.



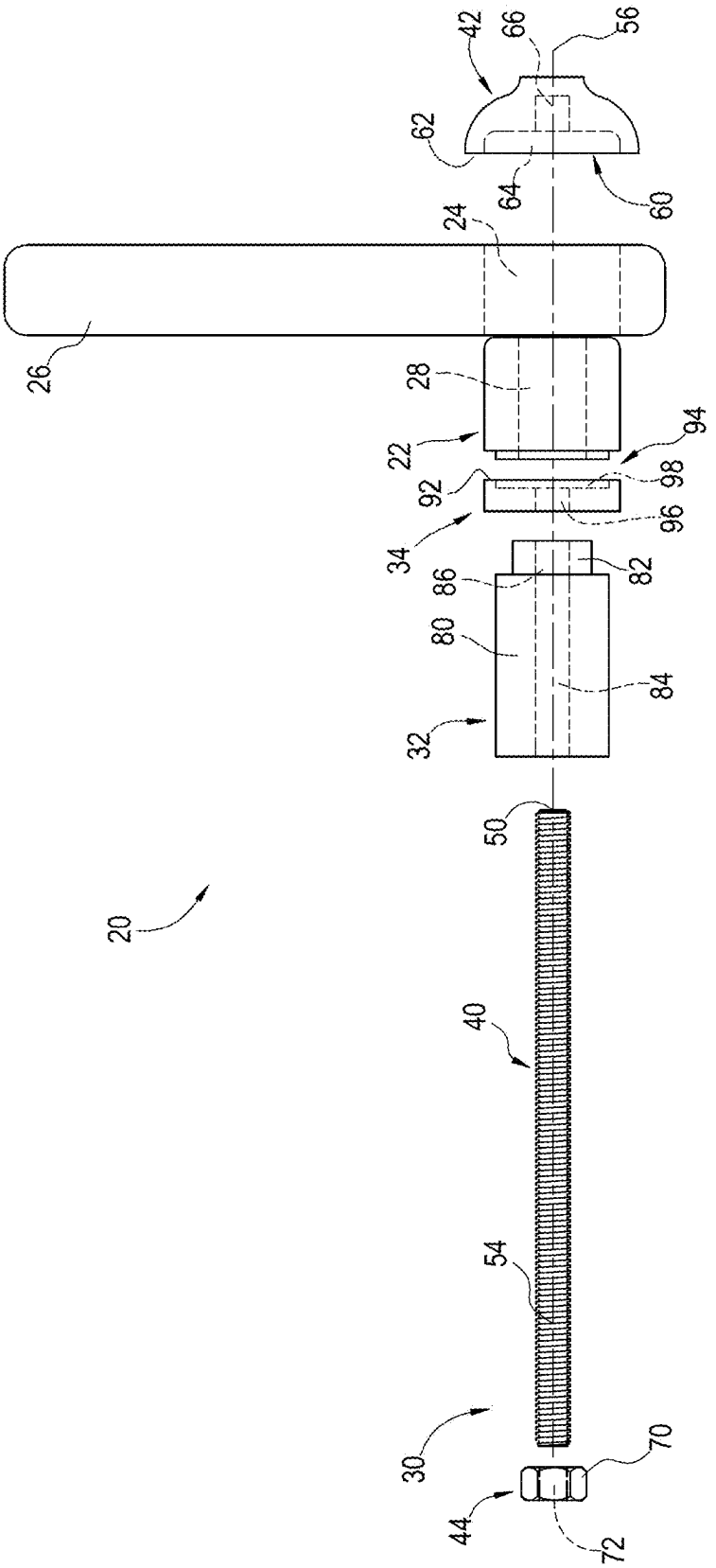

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FIG. 1

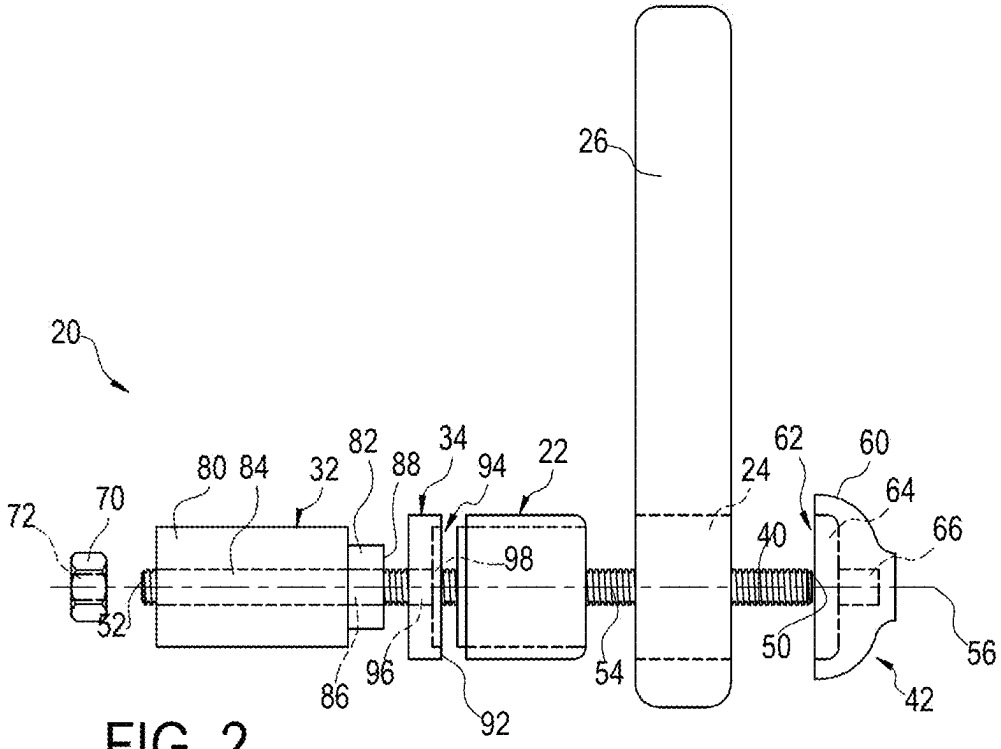
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FIG. 2

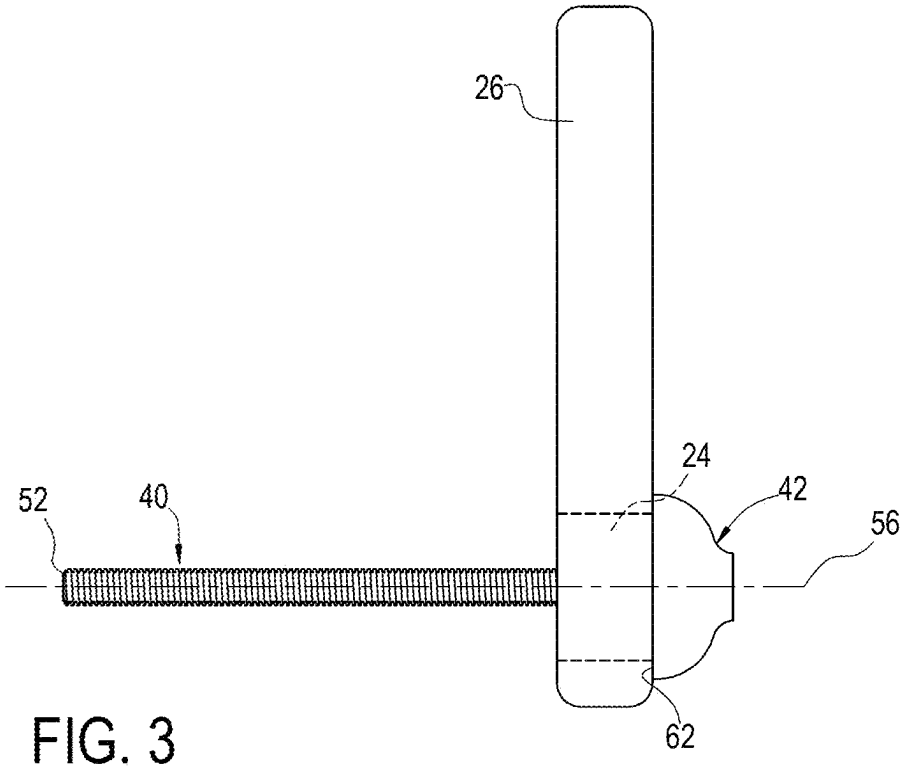
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FIG. 3

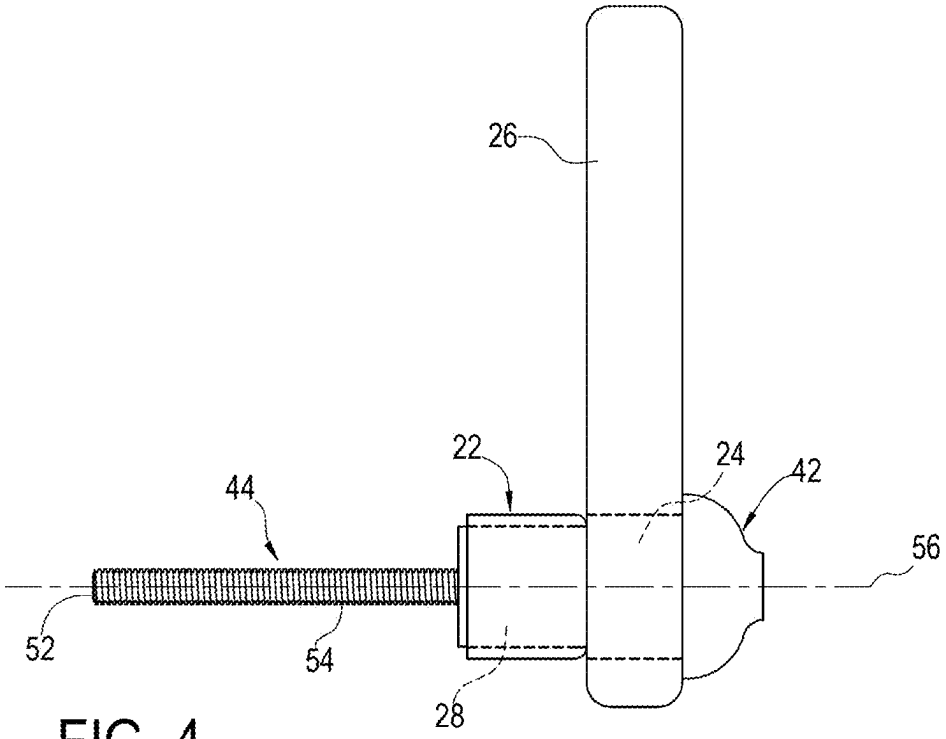


FIG. 4

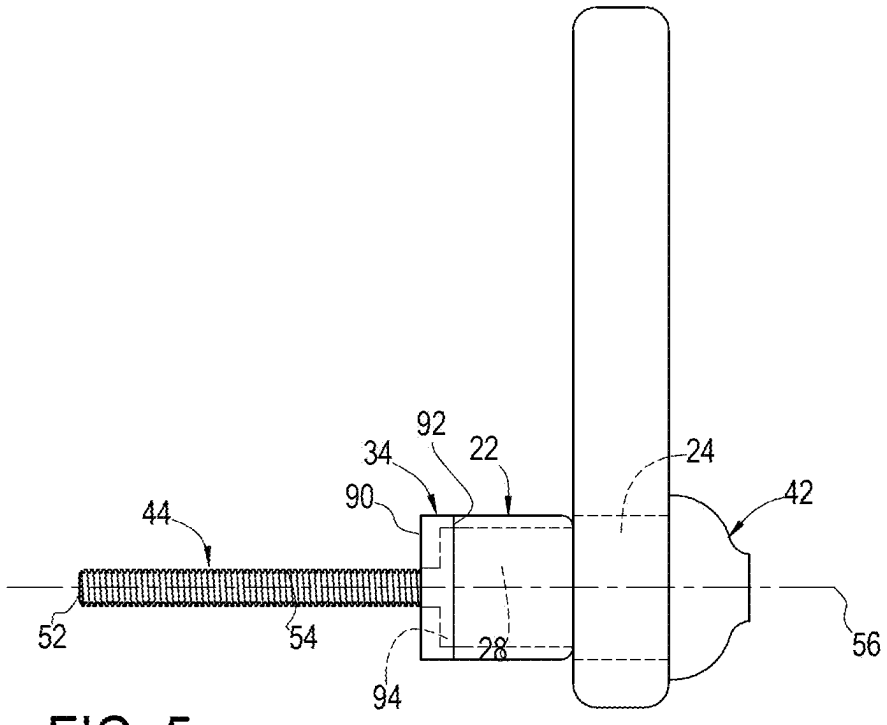


FIG. 5

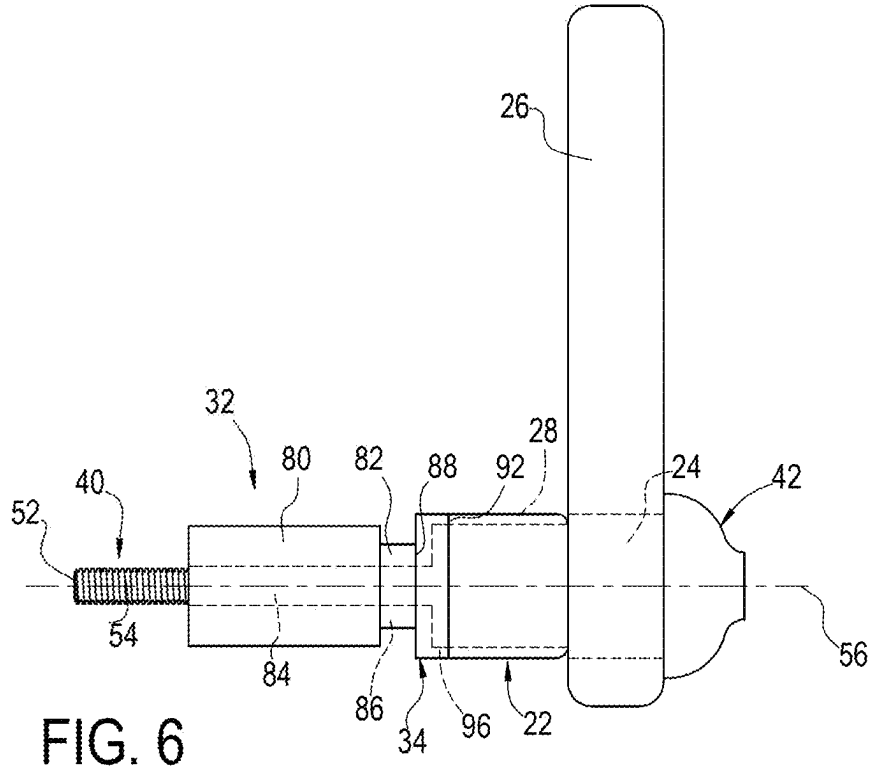
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FIG. 6

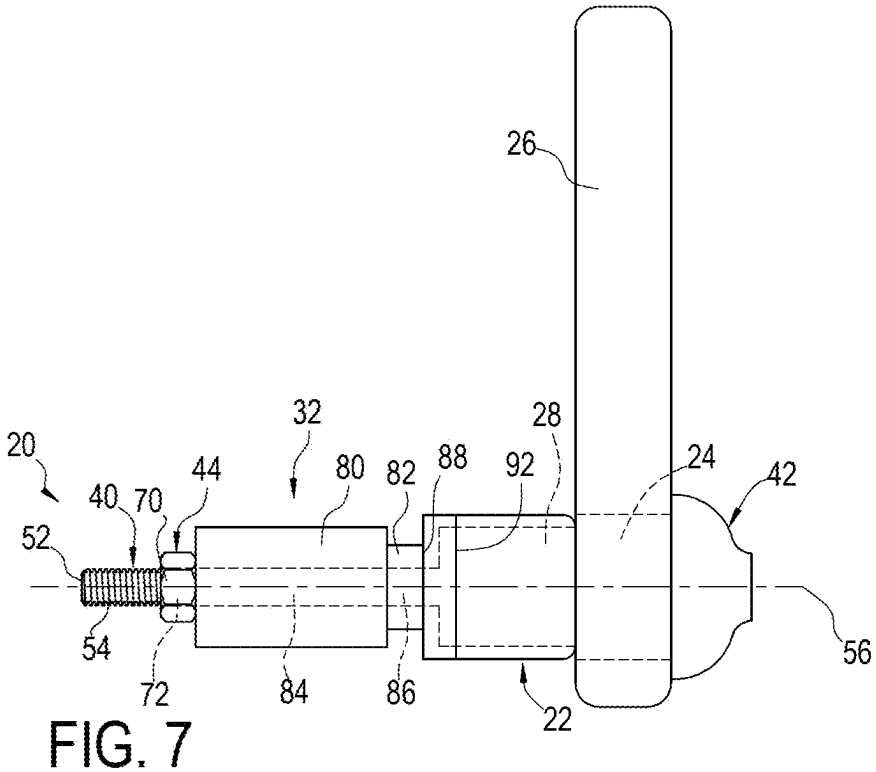
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FIG. 7

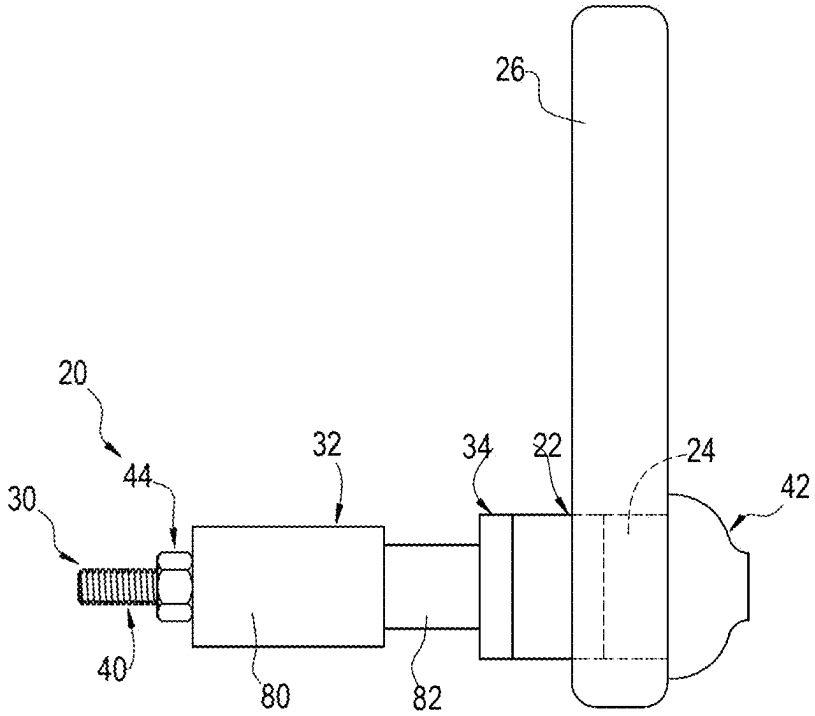


FIG. 8

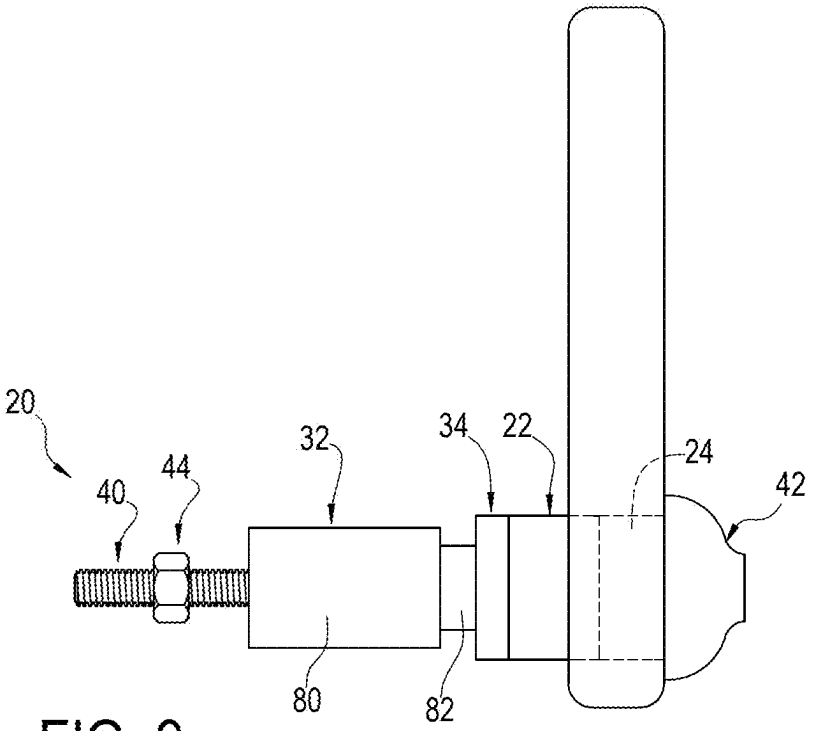


FIG. 9

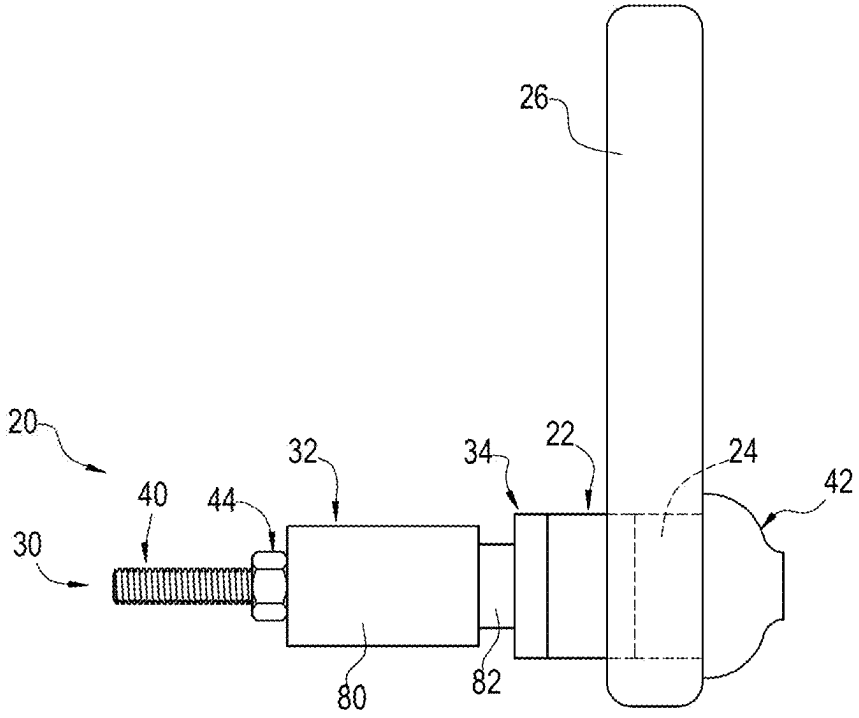


FIG. 10

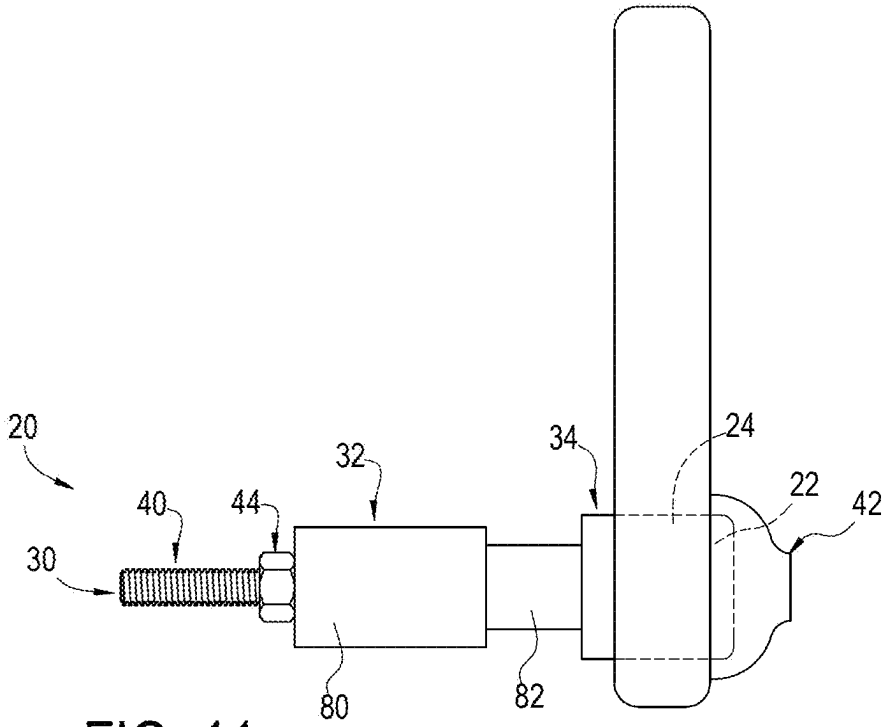


FIG. 11

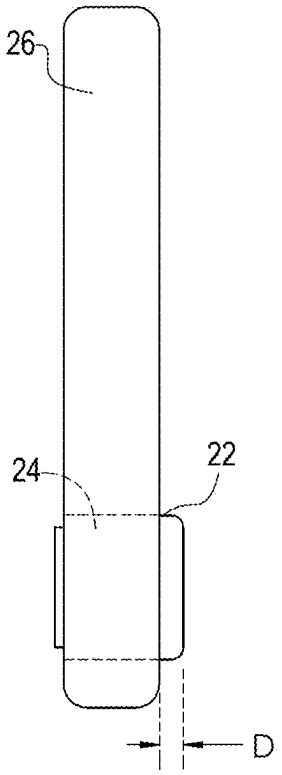


FIG. 12

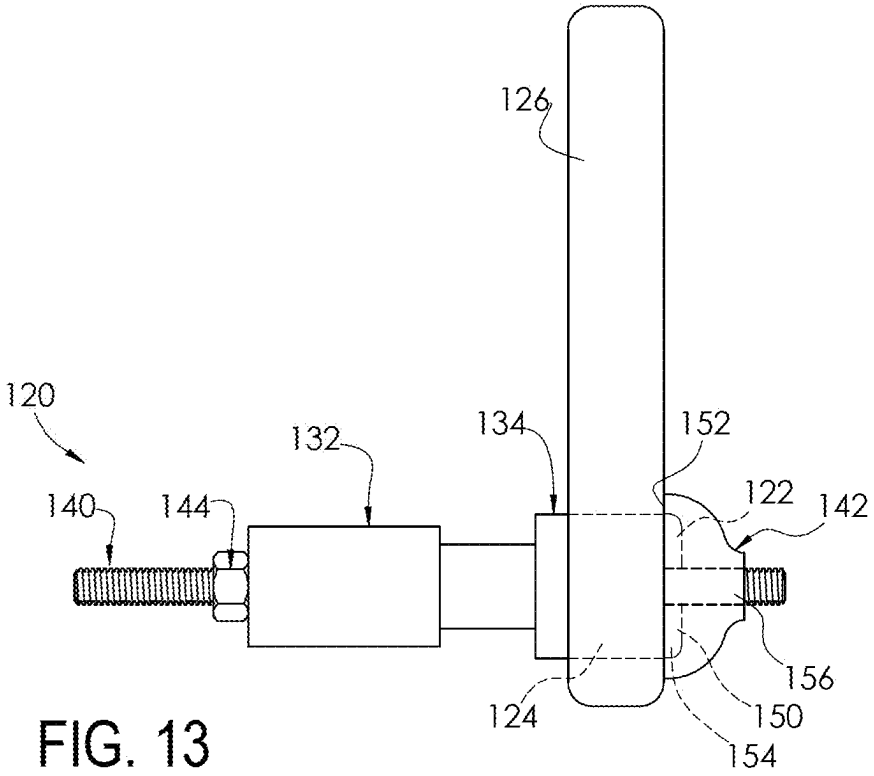


FIG. 13

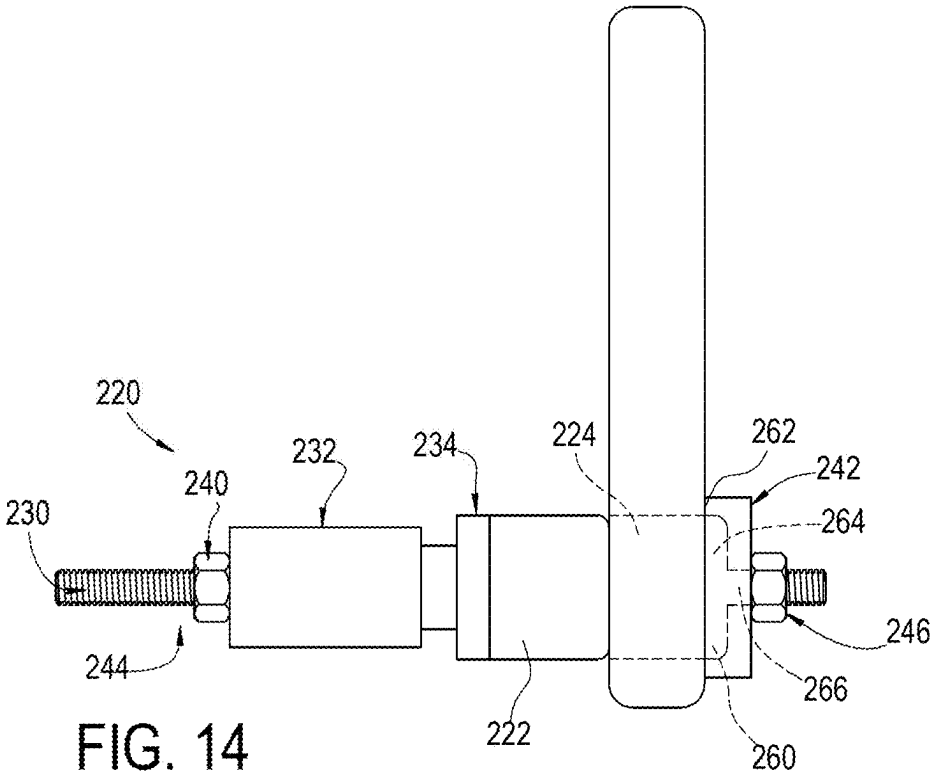


FIG. 14

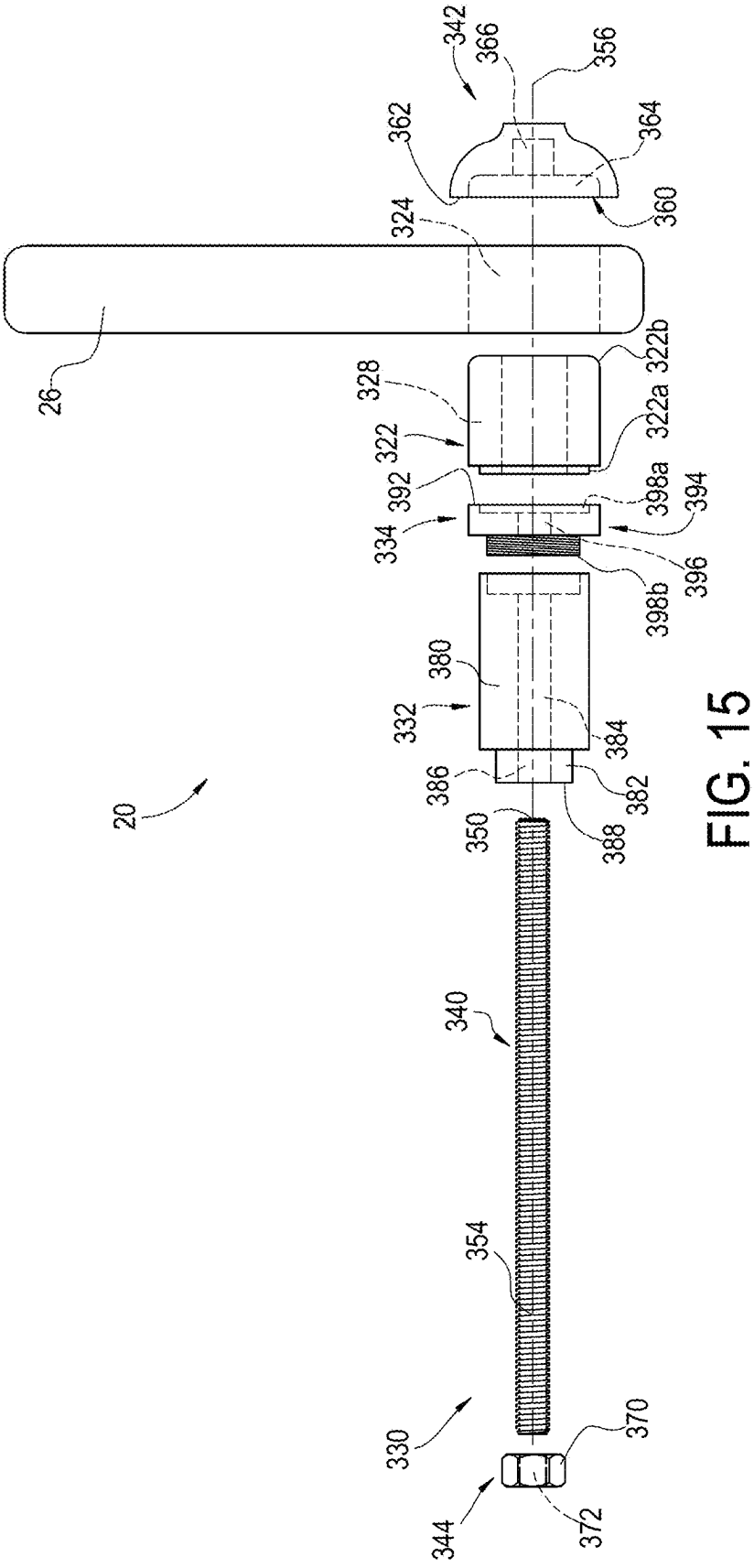
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FIG. 15

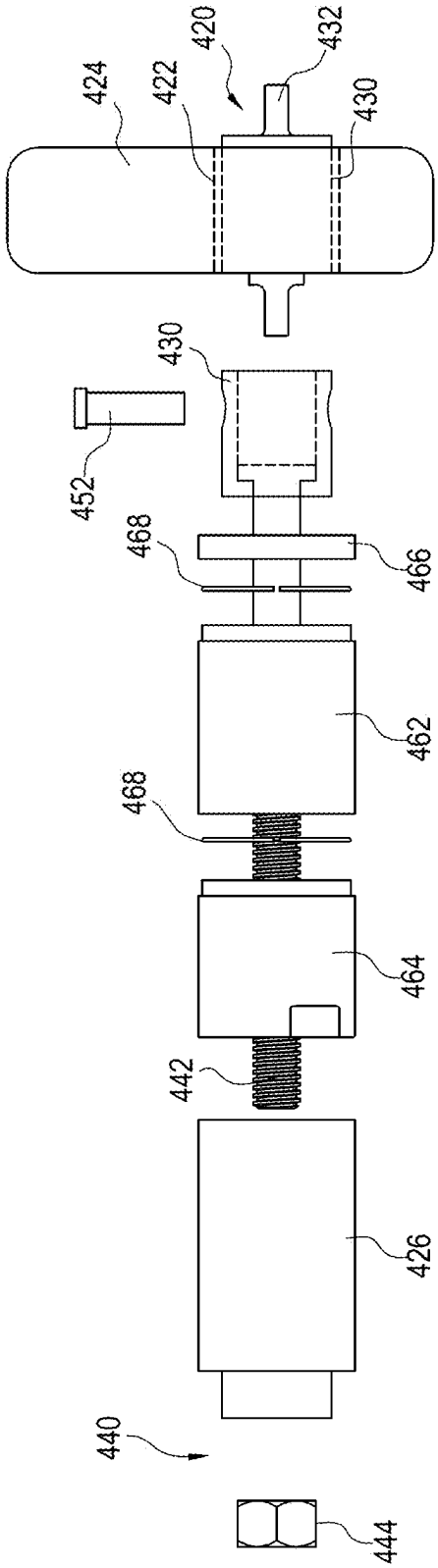


FIG. 16A

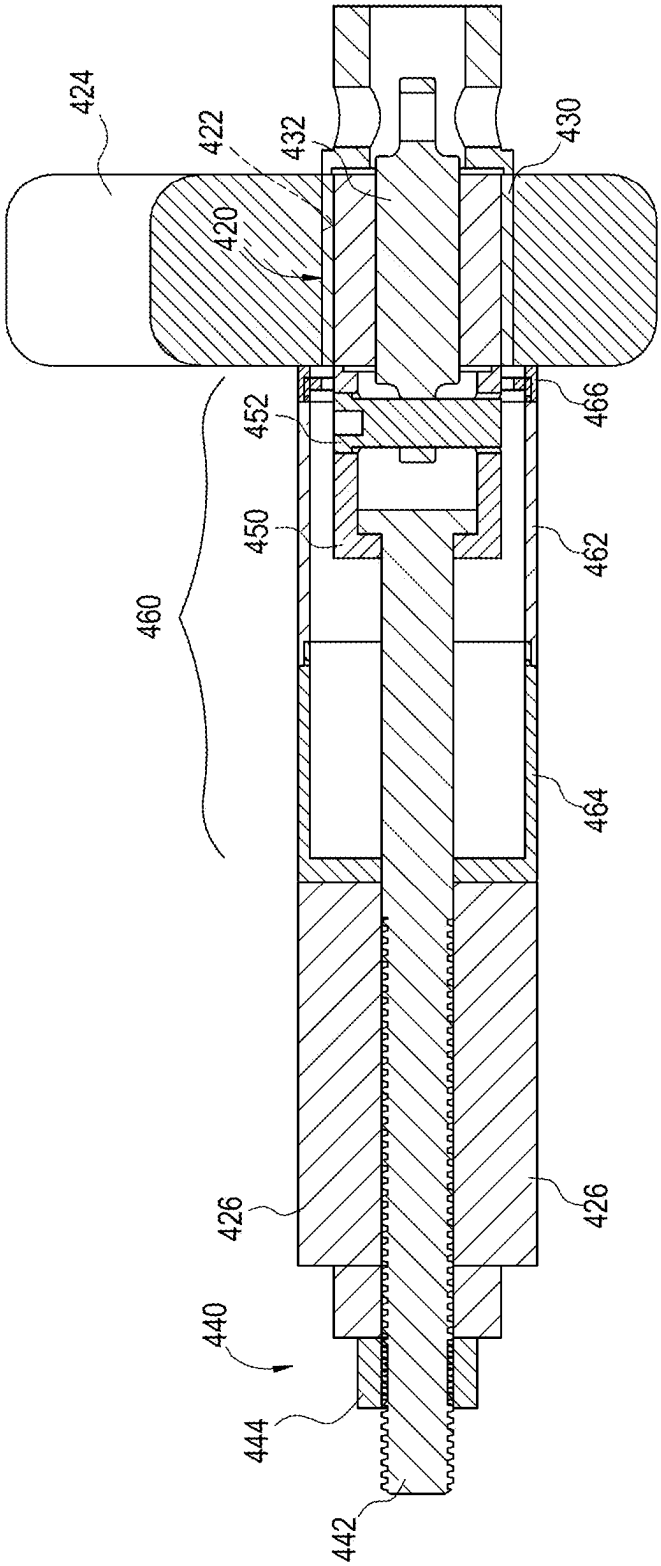


FIG.16B

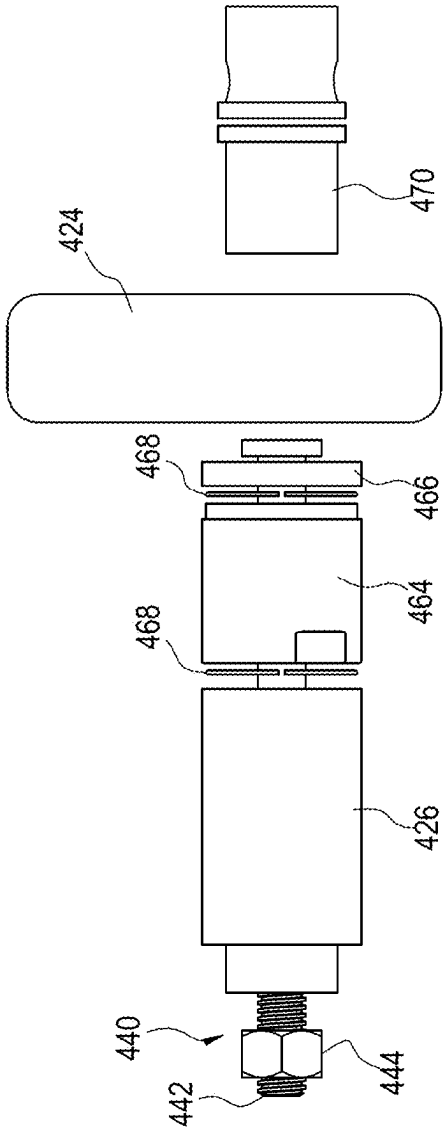


FIG. 17A

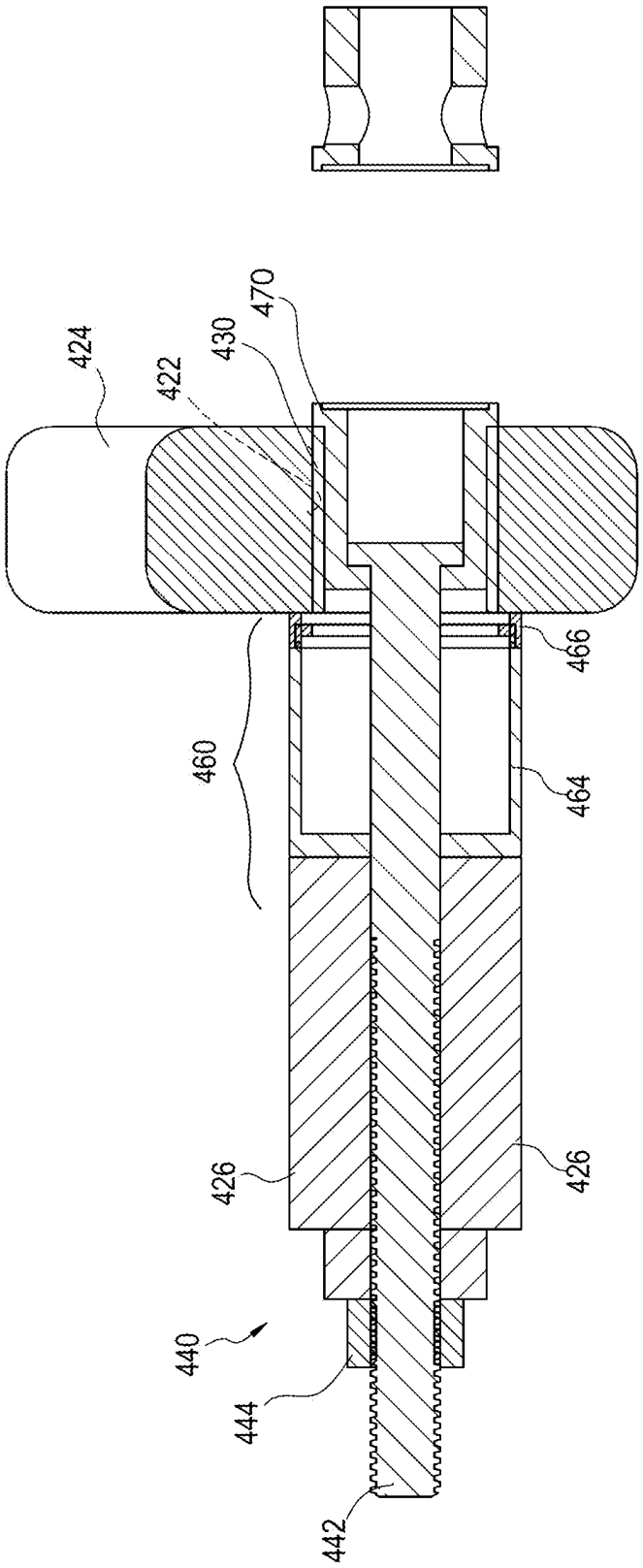


FIG.17B

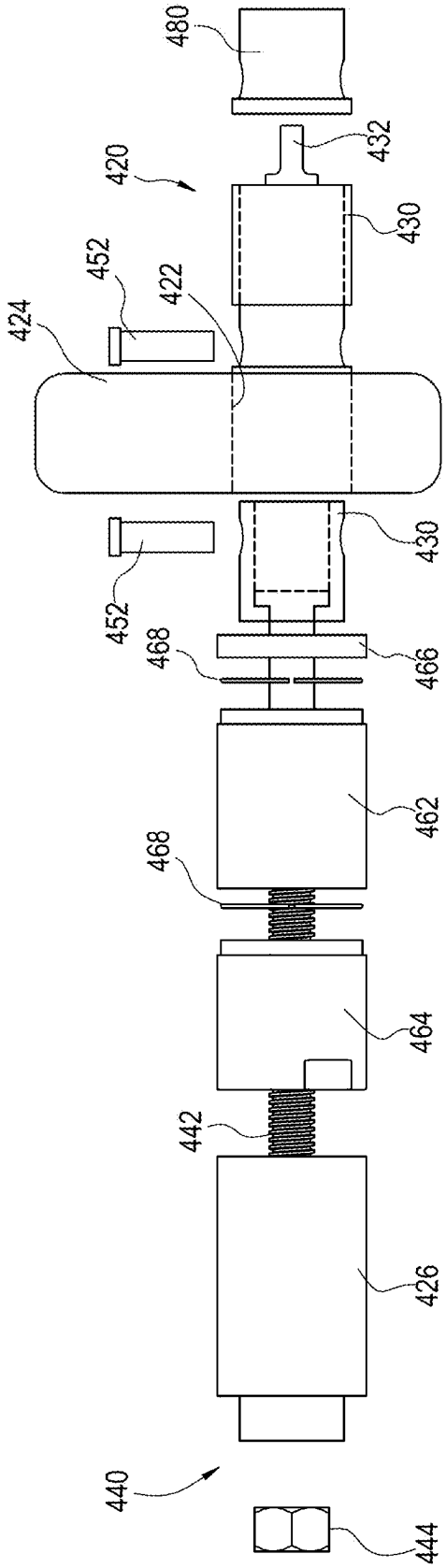
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FIG. 18A

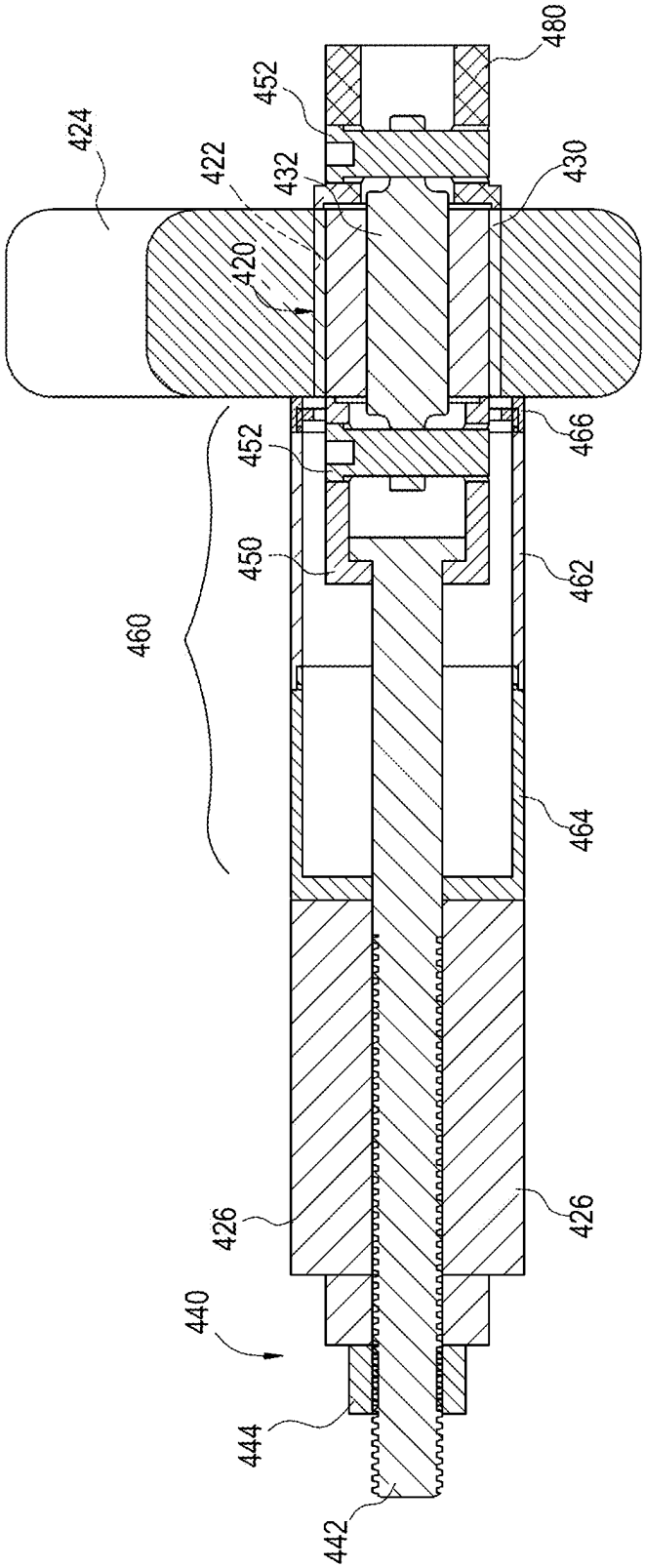
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FIG.18B

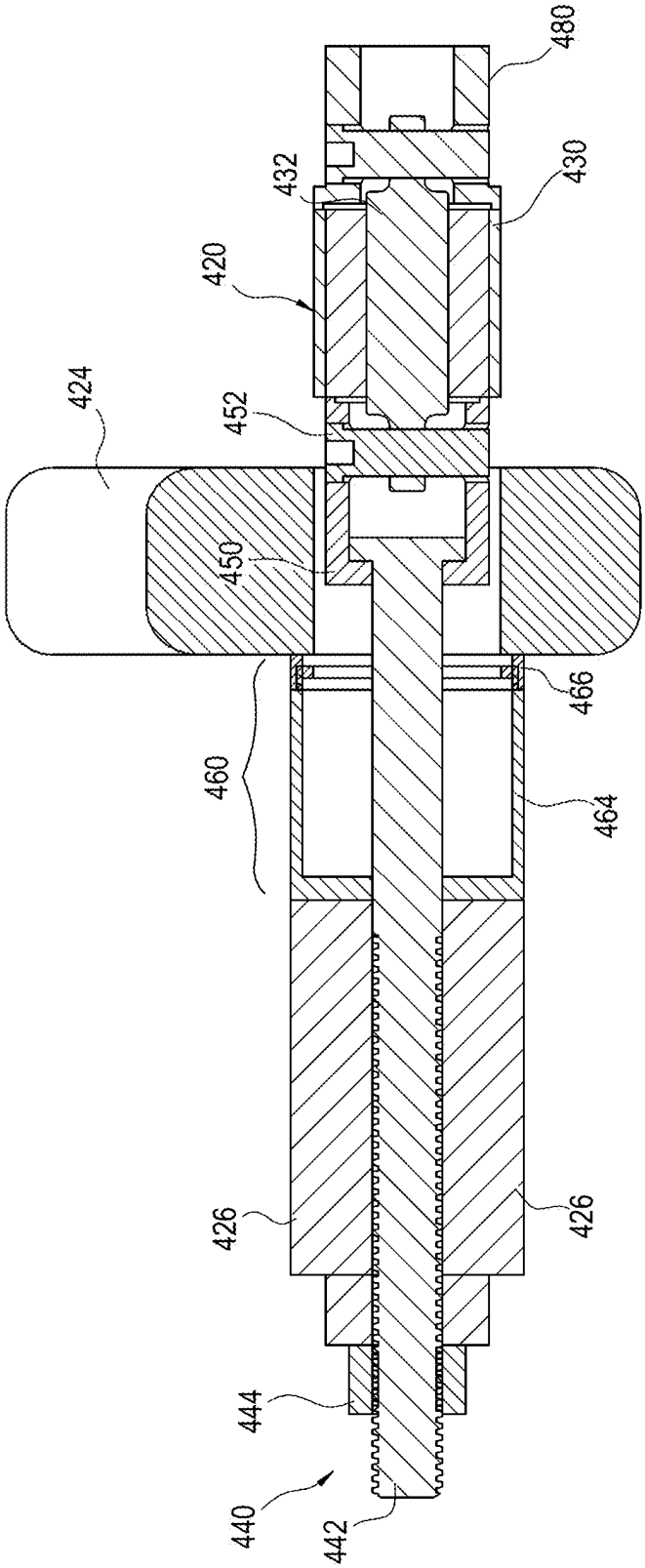


FIG.18C

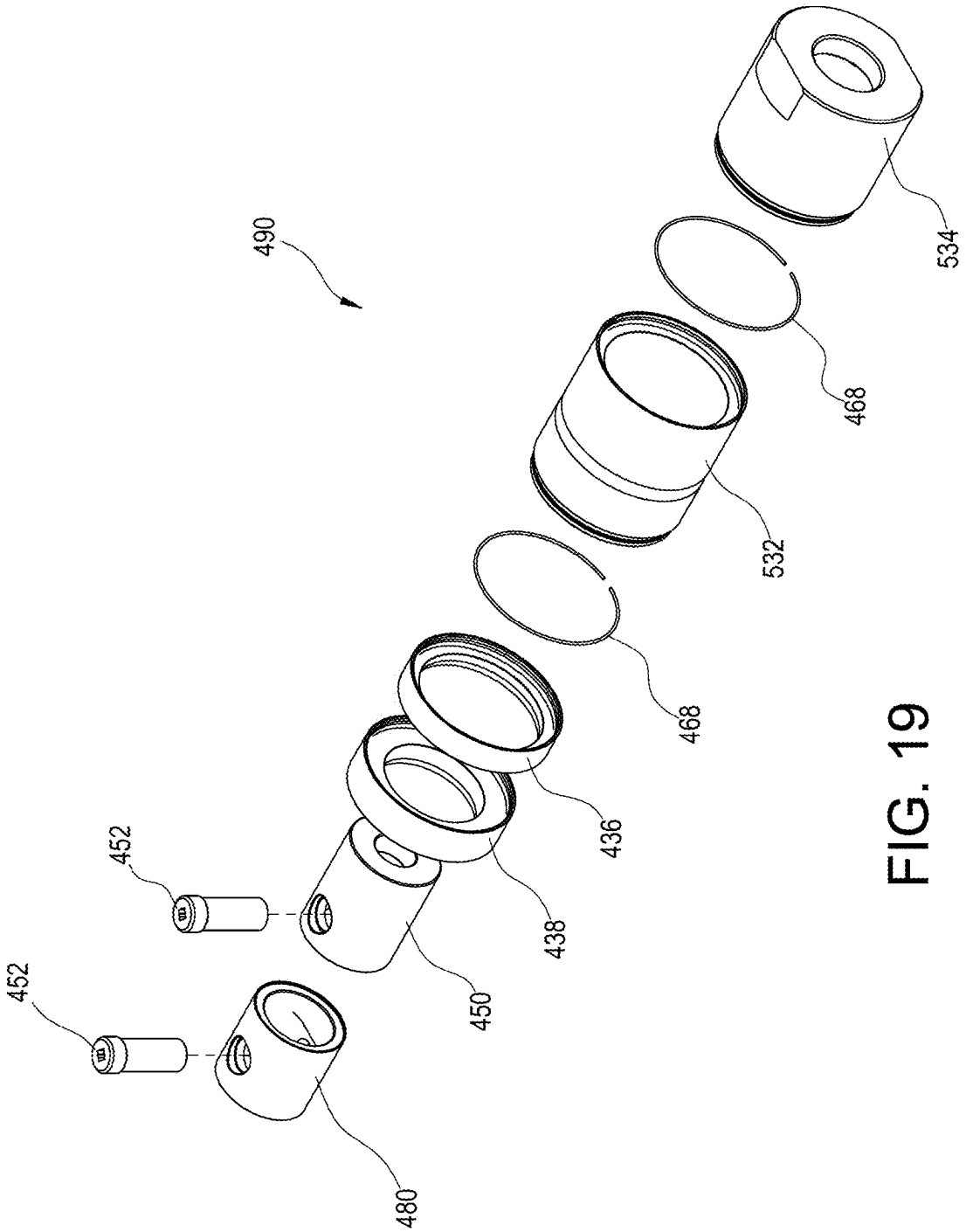


FIG. 19

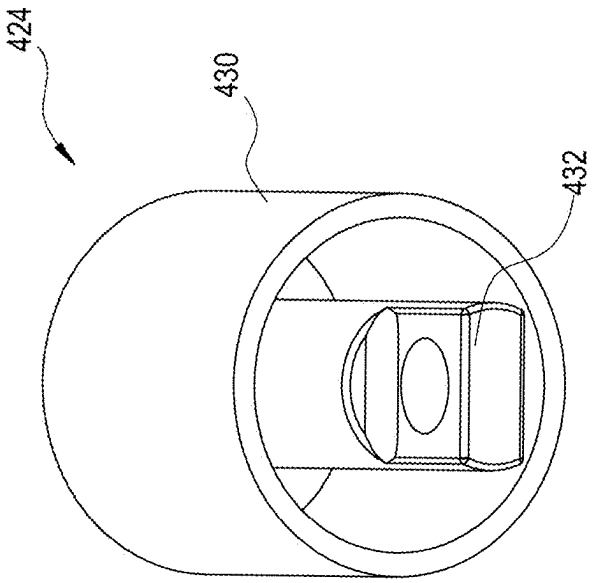


FIG. 20

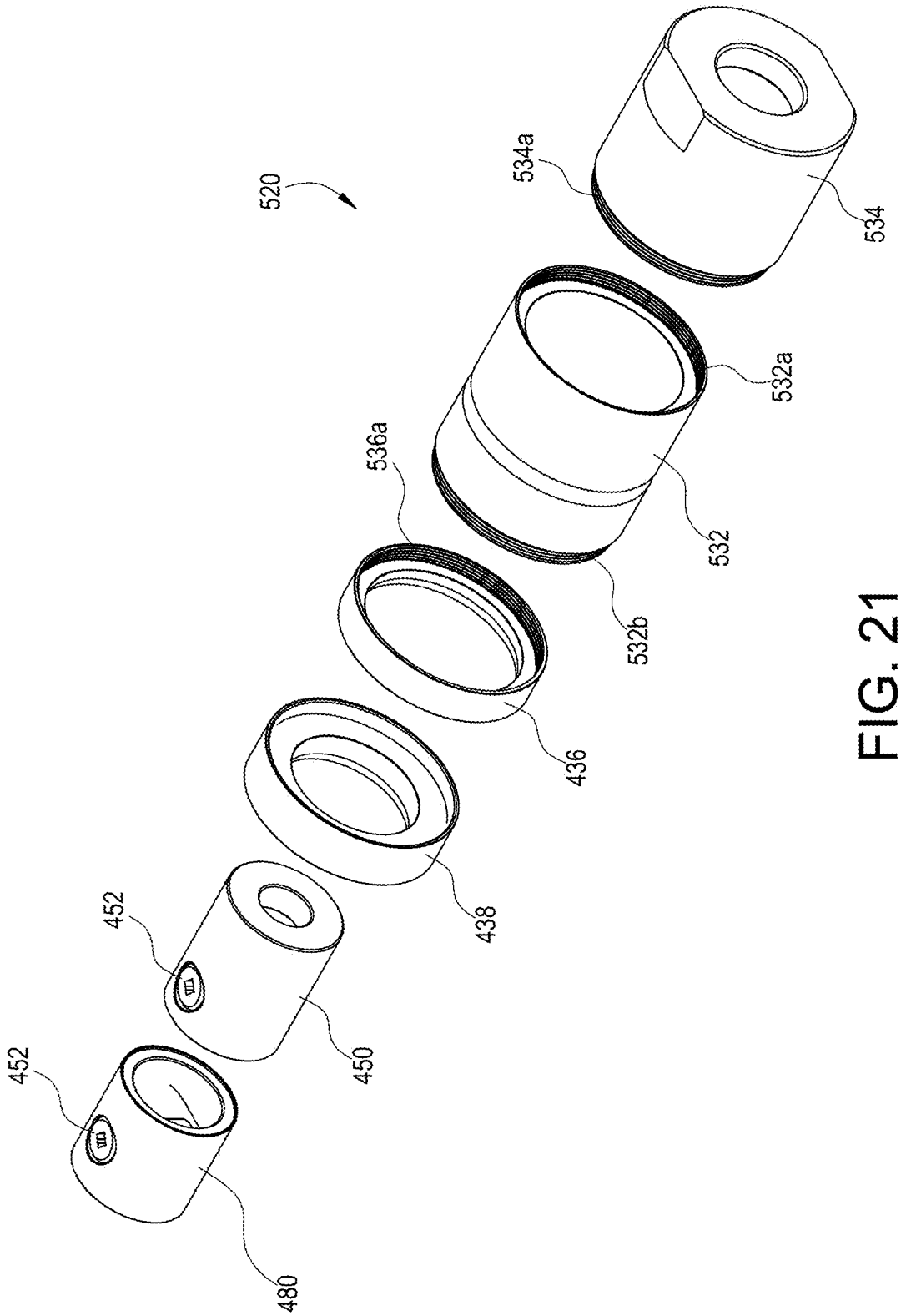


FIG. 21

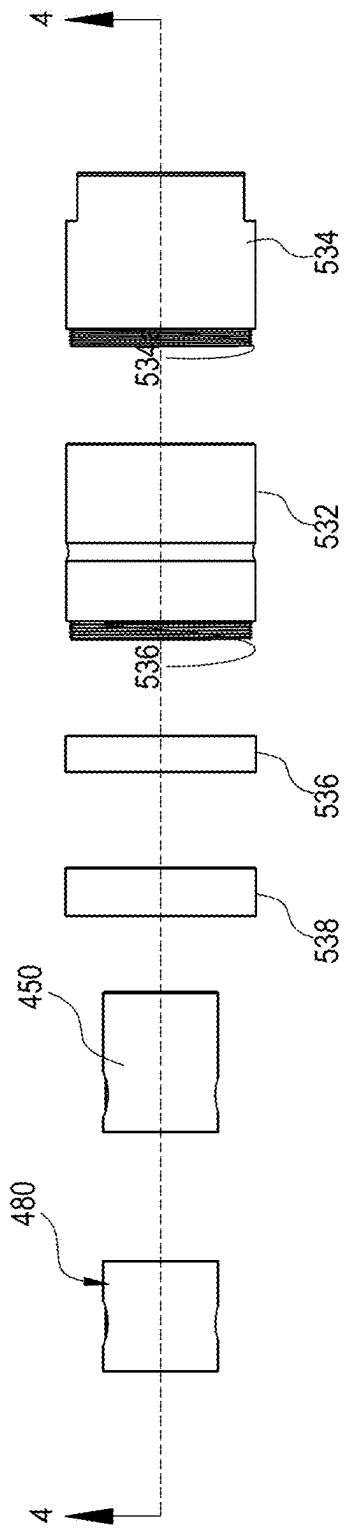
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FIG. 22

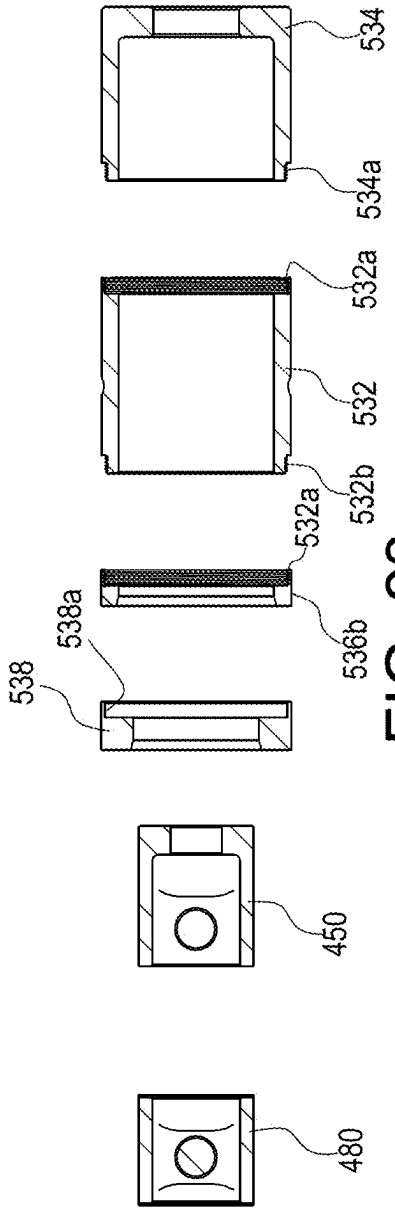
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FIG. 23

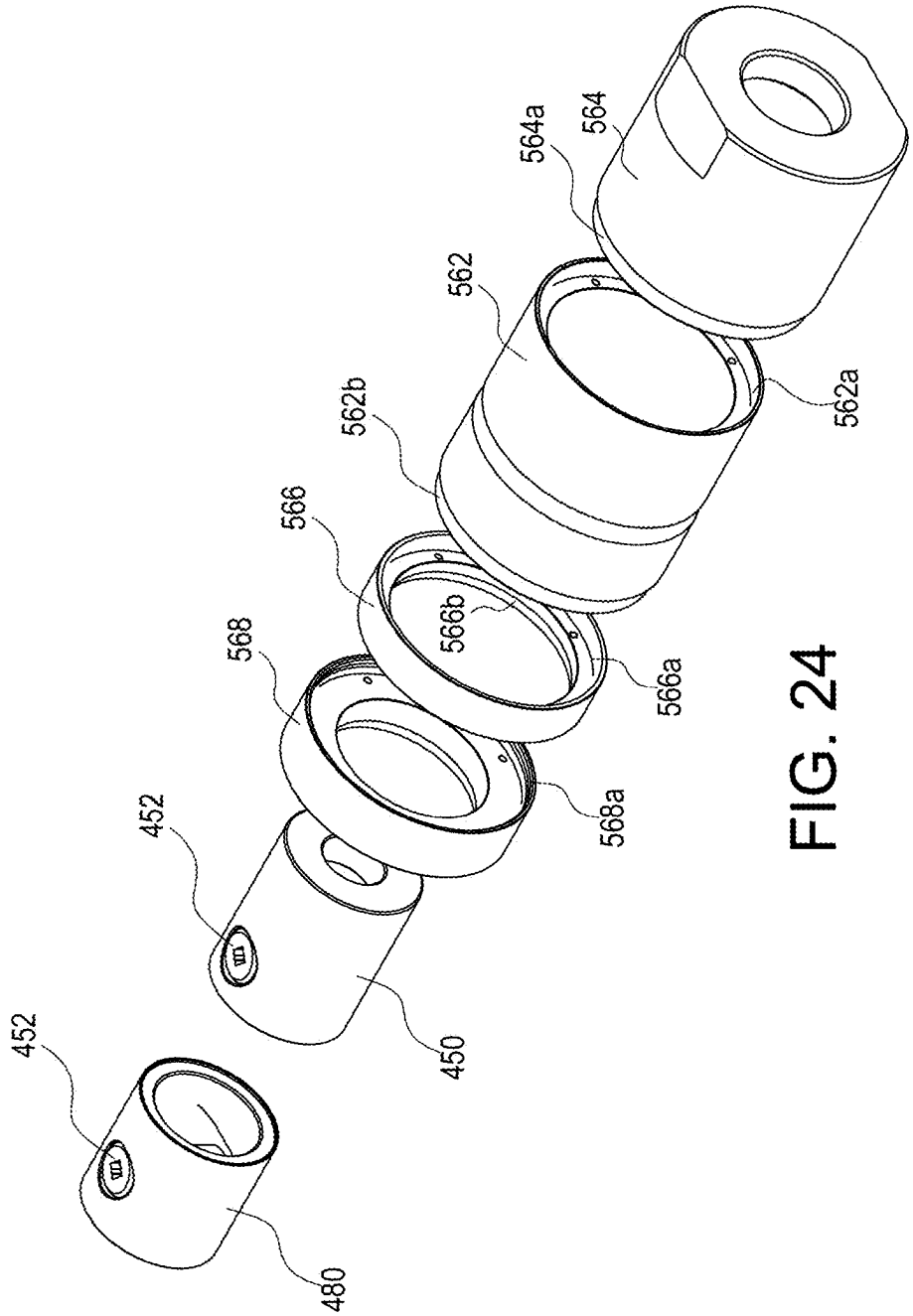


FIG. 24

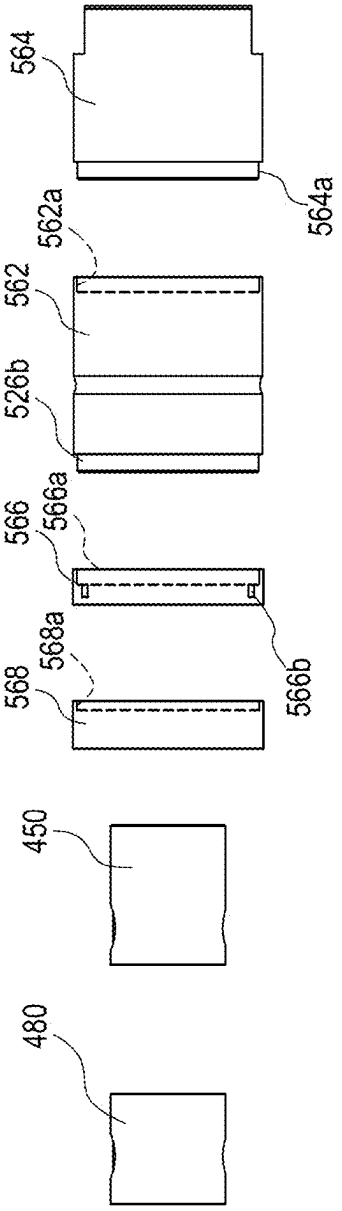
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FIG. 25

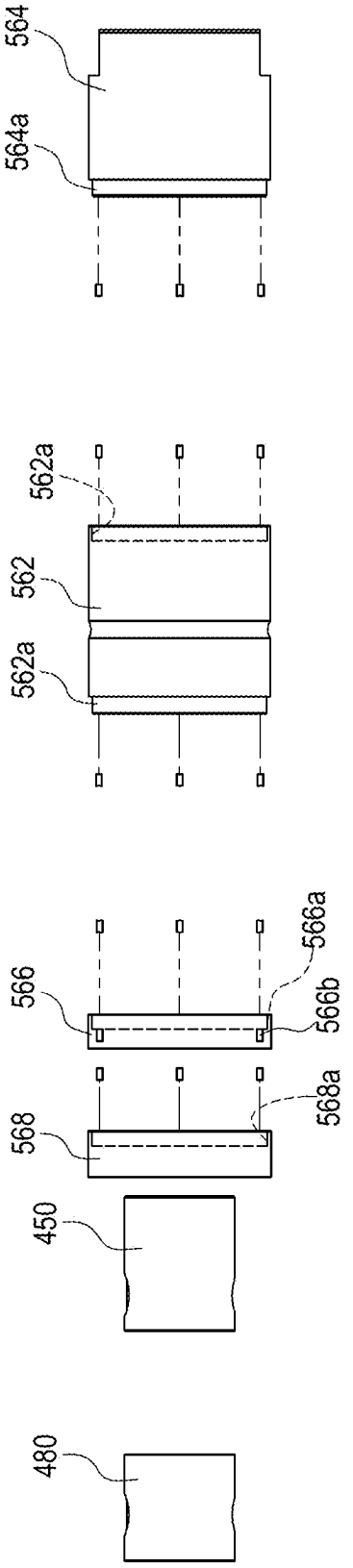
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FIG. 26

# SYSTEMS AND METHODS FOR INSERTING AND REMOVING BUSHING ASSEMBLIES

## RELATED APPLICATIONS

**[0001]** This application (Attorney's Ref. No. P220595) is a continuation of U.S. application Ser. No. 17/412,826 filed Aug. 26, 2021, currently pending.

**[0002]** U.S. application Ser. No. 17/412,826 filed Aug. 26, 2021, claims benefit of U.S. Provisional Application Ser. No. 63/070,759 filed Aug. 26, 2020, now expired.

**[0003]** U.S. application Ser. No. 17/412,826 filed Aug. 26, 2021, also claims benefit of U.S. Provisional Application Ser. No. 63/163,627 filed Mar. 19, 2021, now expired.

**[0004]** U.S. application Ser. No. 17/412,826 filed Aug. 26, 2021, is also a continuation-in-part of U.S. patent application Ser. No. 17/199,133 filed Mar. 11, 2021, now U.S. Pat. No. 11,815,732 issued on Nov. 14, 2023.

**[0005]** The contents of all related applications are incorporated herein by reference.

## TECHNICAL FIELD

**[0006]** The present invention relates to tool systems and methods for removing and/or installing bushings into a housing opening defined by a structural member.

## BACKGROUND

**[0007]** Bushings are a form of bearing that is used to support a rotating shaft relative to a structural member. Bushings can be removed and replaced when worn or damaged. Typically, a bushing defines an outer diameter sized and dimensioned to be snugly received within the housing opening and an inner diameter sized and dimensioned to snugly receive the rotating shaft.

**[0008]** The present invention relates to the insertion of solid sleeve bushings into a housing opening defined by the structural member.

**[0009]** To replace a worn bushing, the rotating shaft is first removed from the inner opening defined by the worn bushing. The worn bushing is then pressed out of the housing opening. The replacement bushing is then pressed into the housing opening such that the replacement bushing is rigidly supported by the structural member in a desired position relative to the structural member. The rotating shaft is next arranged within the inner opening of the replacement bushing.

**[0010]** The present invention is of particular significance when used as part of the step of inserting and/or removing bushing assemblies and in particular to the insertion and/or removal of a bushing assembly comprising a bushing pin, a bushing sleeve, and elastomeric material supporting the bushing pin within the bushing sleeve, and that application of the present invention will be described herein.

## SUMMARY

**[0011]** An adapter system for a bushing displacing system for displacing at least a portion of a bushing assembly relative to an opening in a structural member, the bushing assembly comprising a bushing housing and a bushing pin, the adapter system comprising an extension tube defining first and second extension tube connecting portions, a cylinder adapter defining a cylinder adapter connecting portion, a cylinder tube cap defining a cylinder tube cap connecting portion, and a cylinder tube cap adapter. The first extension tube connecting portion is configured to engage the cylinder adapter connecting portion to detachably attach the cylinder adapter to the extension tube. The second extension tube connecting portion is configured to engage the cylinder tube cap connecting portion to detachably attach the cylinder tube cap adapter to the cylinder tube cap.

**[0012]** The present invention may also be embodied as a method of configuring a bushing displacing system to displace at least a portion of a bushing assembly relative to an opening in a structural member, the bushing assembly comprising a bushing housing and a bushing pin, the method comprising the following steps. An extension tube defining first and second extension tube connecting portions is provided. A cylinder adapter defining a cylinder adapter connecting portion is provided. A cylinder tube cap defining a cylinder tube cap connecting portion is provided. A cylinder tube cap adapter is provided. The cylinder adapter is detachably attached to the extension tube by engaging the first extension tube connecting portion with the cylinder adapter connecting portion. The cylinder tube cap adapter is detachably attached to the cylinder tube cap by engaging the second extension tube connecting portion with the cylinder tube cap connecting portion.

**[0013]** The present invention may also be embodied as an adapter system for a bushing displacing system for displacing at least a portion of a bushing assembly relative to an opening in a structural member, the bushing assembly comprising a bushing housing and a bushing pin, the adapter system comprising an extension tube defining first and second extension tube connecting portions, a cylinder adapter defining a cylinder adapter connecting portion, a cylinder tube cap defining a cylinder tube cap connecting portion, a cylinder tube cap adapter, a pullbar socket, and a push adapter. The first extension tube connecting portion is configured to engage the cylinder adapter connecting portion to detachably attach the cylinder adapter to the extension tube. The second extension tube connecting portion is configured to engage the cylinder tube cap connecting portion to detachably attach the cylinder tube cap adapter to the cylinder tube cap.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0014]** FIG. **1** is an exploded side elevation view illustrating the components of a first example bushing assembly insertion system of the present invention that is adapted to insert a bushing assembly into bushing opening in a structural member;

**[0015]** FIG. **2** is partial exploded side elevation view of the first example bushing assembly insertion system, the bushing assembly, and the structural member;

**[0016]** FIGS. **3-11** are side elevation views depicting steps of an example process of using the first example bushing assembly insertion system to insert the bushing assembly into the bushing opening in the structural member;

**[0017]** FIG. **12** depicts the bushing assembly supported by the structural member in a desired position relative to the structural member;

**[0018]** FIG. **13** is a side elevation view illustrating the components of a second example bushing assembly insertion system of the present invention that is adapted to insert a bushing assembly into a bushing opening defined by a structural member;

**[0019]** FIG. **14** is a side elevation view illustrating the components of a third example bushing assembly insertion

system of the present invention that is adapted to insert a bushing assembly into a bushing opening defined by a structural member;

**[0020]** FIG. **15** is an exploded side elevation view illustrating the components of a fourth example bushing assembly insertion system of the present invention that is adapted to insert a bushing assembly into bushing opening in a structural member;

**[0021]** FIG. **16**A is an exploded view of a first step of a first example configuration and method of removing a bushing assembly from a housing;

**[0022]** FIG. **16**B is section view of the first step of the first example configuration and method of removing a bushing assembly from a housing;

**[0023]** FIG. **17**A is an exploded view of a second step of the first example method of removing a bushing assembly from a housing;

**[0024]** FIG. **17**B is section view of the second step of the first example configuration and method of removing a bushing assembly from a housing;

**[0025]** FIG. **18**A is an exploded view of an example configuration and method of inserting a bushing assembly into or removing a bushing assembly from a housing;

**[0026]** FIG. **18**B is section view of the example configuration and method of FIG. **18**A depicting the removal of a bushing assembly from a housing;

**[0027]** FIG. **18**C is section view of the example configuration and method of FIG. **18**A depicting the insertion of a bushing assembly into a housing;

**[0028]** FIG. **19** is an exploded, perspective view of components used in the first example removal method of FIGS. **16** and **17** and the example inserting method of FIG. **18**;

**[0029]** FIG. **20** is a perspective view of a portion of an example bushing assembly to be removed and/or inserted using the methods of FIGS. **16**-**18**;

**[0030]** FIG. **21** is an exploded, perspective view of another set of components that may be used in the first example removal method of FIGS. **16** and **17** and the example inserting method of FIG. **18**;

**[0031]** FIG. **22** is side elevation view of the set of components depicted in FIG. **21**;

**[0032]** FIG. **23** is side elevation section view of the set of components depicted in FIG. **21**;

**[0033]** FIG. **24** is an exploded, perspective view of yet another set of components that may be used in the first example removal method of FIGS. **16** and **17** and the example inserting method of FIG. **18**;

**[0034]** FIG. **25** is side elevation view of the set of components depicted in FIG. **24**; and

**[0035]** FIG. **26** is side elevation exploded view of the set of components depicted in FIG. **24**.

## DETAILED DESCRIPTION

**[0036]** Referring initially to FIG. **1** of the drawing, depicted therein is a first example bushing assembly insertion system **20** constructed in accordance with, and embodying, the principles of the present invention. FIG. **1** further illustrates that the first example bushing assembly insertion system **20** may be used to insert an example bushing assembly **22** into an example housing opening **24** defined by an example structural member **26**. FIG. **1** further illustrates that the example bushing assembly **22** defines a bushing assembly opening **28** sized and dimensioned to receive a shaft (not shown). The example bushing assembly **22** and structural member **26**, including the housing opening **24**, are or may be conventional and will not be described herein beyond that extent helpful for a complete understanding of the construction and operation of the first example bushing assembly insertion system **20**.

**[0037]** As shown in FIGS. **1** and **2**, the first example bushing assembly insertion system **20** comprises a brace assembly **30**, an actuator assembly **32**, and a drive plate **34**. The example brace assembly **30** comprises a brace rod **40**, an anchor member **42**, and a brace nut **44**. At least a portion of the example brace rod **40** is arranged to extend through bushing assembly opening **28** in the bushing assembly **22** and the housing opening **24** in the structural member **26** to support the brace nut **44**, the actuator assembly **32**, the drive plate **34** on a first side of the housing opening **24** and the anchor member **42** on a second side of the housing opening **24**. So arranged, operation of the actuator assembly **32** acts on the bushing assembly **22** through the drive plate **34** to force the bushing assembly **22** into the bushing assembly opening **24**. The example brace assembly **30** engages the structural member **26** to prevent the actuator assembly **32** from displacing itself away from the structural member **26** during operation of the actuator assembly **32**.

**[0038]** Given the foregoing general understanding of the construction and operation of the first example bushing assembly insertion system **20**, the details of construction and operation of the first example bushing assembly insertion system **20** of the present invention will now be described.

**[0039]** The example brace rod **40** defines a first rod end **50** and a second rod end **52**, and an outer surface **54** of the example brace rod **40** is threaded at least adjacent to the first rod end **52** and to the second rod end **54**. The example brace rod **40** as depicted is threaded along its entire length, but only a portion of the brace rod **40** need be threaded as will become apparent from the following discussion. The example brace rod **40** defines a brace rod axis **56**.

**[0040]** The example anchor member **42** defines an anchor cavity **60** and an anchor edge surface **62**. The anchor cavity **60** defines an anchor cavity spacing portion **64** and an anchor cavity threaded portion **66**. The anchor cavity threaded portion **66** is sized and dimensioned to receive the threaded outer surface **54** of the brace rod **40** adjacent to the first rod end **50**. Accordingly, axial rotation of the brace rod **40** and anchor member **42** relative to each other about the brace rod axis **56** with the threaded outer surface **54** within the anchor cavity threaded portion **66** prevents displacement of the anchor member **42** relative to the brace rod **40** along the brace rod axis **56** under predetermined tension loads exerted by the actuator assembly **32**.

**[0041]** The example brace nut **44** is or may be conventional and defines an external nut surface **70** and an internal threaded nut opening **72**. The internal threaded nut opening **72** is sized and dimensioned to receive the threaded outer surface **54** of the brace rod **40** adjacent to the second rod end **52**. Accordingly, axial rotation of the brace rod **40** and brace nut **44** relative to each other about the brace rod axis **56** with the threaded outer surface **54** within the internal threaded nut opening **72** prevents displacement of the brace nut **44** relative to the brace rod **40** along the brace rod axis **56** under predetermined tension loads exerted by the actuator assembly **32**. The example external nut surface **50** is a hex surface but other surface configurations may be used.

**[0042]** The example actuator assembly **32** comprises an actuator housing **80** and an actuator drive member **82**. The

example actuator assembly **32** is or may be conventional and will be described herein only to that extent helpful for a complete understanding of the construction and operation of the first example bushing assembly insertion system **20**. The example actuator housing **80** defines an actuator housing opening **84**, and the example actuator drive member **82** defines an actuator drive member opening **86**. The example drive member **82** defines a drive surface **88**. Operation of the example actuator assembly **32** causes displacement of the example actuator drive member **82** relative to the actuator housing **80**. The example actuator assembly **32** may be operated using an electrical drive system, pneumatic drive system, hydraulic drive system, or any other appropriate drive system. The drive system used to supply power to the example actuator system **32** is or may be conventional and is not depicted in the drawing for simplicity and clarity.

**[0043]** The example drive plate **34** defines a first drive plate surface **90**, a second drive plate surface **92**, and a drive plate opening **94**. The example drive plate opening **94** defines a drive plate opening first portion **96** and a drive plate opening second portion **98**. The drive plate opening **94** extends between the first drive plate first surface **90** and the second drive plate second surface **92**.

**[0044]** As perhaps best shown in FIG. **2**, the example brace rod **40** is sized and dimensioned such that the example brace rod **40** may be arranged to extend through the actuator housing opening **84**, the actuator drive member opening **86**, the adapter late opening **94**, and the bushing opening **28**. FIG. **2** further illustrates that the example brace rod **40** is sized and dimensioned to extend through the anchor cavity spacing portion **64** of the anchor cavity **60**. And as described above, the anchor rod **40** is further sized and dimensioned such that to be threaded into the anchor cavity threaded portion **66** and at least partly into the internal nut threaded opening **72**. As arranged in FIG. **2**, the rod axis **56** of the brace rod **40** defines a longitudinal axis of the first example bushing assembly insertion system **20**.

**[0045]** FIGS. **3-11** illustrate an example method of using the first example bushing assembly insertion system **20**. Initially, as shown in FIG. **3**, the anchor cavity threaded portion **66** is engaged with the external surface **54** of the brace rod **40** to fix a position of the anchor member **42** relative to the brace rod **40**. The brace rod **40** is then arranged such that the brace rod **40** extends through the housing opening **24** with the axis **56** of the brace rod **40** substantially aligned with a longitudinal axis of the housing opening **24**. At this point, the anchor edge **62** defined by the anchor member **42** is in contact with the structural member **26** around the housing opening **24**.

**[0046]** Next, as shown in FIG. **4** the bushing assembly **22** is arranged such that the brace rod **40** extends through the bushing opening **28** defined by the bushing assembly **22** with the axis **56** of the brace rod **40** substantially aligned with a longitudinal axis of the bushing assembly **22**.

**[0047]** As shown in FIG. **5**, the drive plate **34** is next arranged such that the brace rod **40** extends through the drive plate opening **94** and the drive plate second surface **92** is in contact with the bushing assembly **22**. In this position, a longitudinal axis of the drive plate **34** is substantially aligned with the brace rod axis **56**.

**[0048]** As shown in FIG. **6**, the actuator assembly **32** is next arranged such that the brace rod **40** extends through the actuator housing opening **84** and the actuator drive member opening **86**. At this point, the drive surface **88** of the actuator drive member **82** is in contact with the drive plate first surface **92**. With the actuator assembly **32** so arranged, a longitudinal axis of the actuator assembly **32** is substantially aligned with the brace rod axis **56**.

**[0049]** FIG. **7** illustrates that the brace nut **44** is next arranged such that the brace rod **40** engages the internal threaded opening **72** of the brace nut **44**. Axial rotation of the brace nut **44** relative to the brace rod **40** displaces the brace nut **44** along the axis **56** of the brace rod **40** until the brace nut engages the actuator housing **80**. At this point, the brace assembly **30** is formed, and a distance between the brace nut **44** and the anchor member **42** is substantially fixed. When the brace assembly **30** is formed, the first example bushing assembly insertion system **20** is formed.

**[0050]** With the brace assembly **30** formed as described above, operation of the actuator assembly **32** causes the actuator member **82** to be displaced away from the actuator housing **80** along the rod axis **56**. The actuator member **82** acts on and displaces the drive plate **34** which in turn acts on and displaces the bushing assembly **22**. The brace assembly **30** prevents movement of the anchor member **42** relative to the structural member **26**, so operation of the actuator assembly **32** forces the bushing assembly **22** into the housing opening **24** defined by the structural member **26** as shown by a comparison of FIGS. **7** and **8**.

**[0051]** The actuator assembly **32** defines a maximum "throw" distance that the drive member **82** may be forced out of the actuator housing **80**. If the throw distance is insufficient to fully drive the bushing assembly **22** into the housing opening, the actuator assembly **32** may be turned off and the actuator housing **80** may be displaced towards the bushing assembly **22** as shown in FIG. **9**. The brace nut **44** may be then rotated such that brace nut **44** is displaced along the brace rod **40** until the brace nut **44** contacts the housing as shown in FIG. **10**.

**[0052]** The actuator assembly **32** may then be operated to drive the bushing assembly **22** into the bushing assembly opening **24** until the bushing assembly comes into contact with the anchor plate **42** as shown in FIG. **11**. At this point, the anchor cavity spacing portion **64** defined by the anchor plate **42** is sized and dimensioned such that the bushing assembly **22** extends out of the housing opening **24** by a desired predetermined distance D as shown in FIG. **12**. Accordingly, the anchor plate **42** is configured to stop further movement as soon as the bushing assembly **22** is a desired position relative to the bushing assembly opening **24**.

**[0053]** Referring now to FIG. **13** of the drawing, depicted therein is a second example bushing assembly insertion system **120** constructed in accordance with, and embodying, the principles of the present invention. FIG. **13** illustrates that the first example bushing assembly insertion system **120** may be used to insert an example bushing assembly **122** into an example housing opening **124** defined by an example structural member **126**. The example bushing assembly **122** and structural member **126**, including the housing opening **124**, are or may be conventional and will not be described herein beyond that extent helpful for a complete understanding of the construction and operation of the second example bushing assembly insertion system **120**.

**[0054]** The second example bushing assembly insertion system **120** comprises a brace assembly **130**, an actuator assembly **132**, and a drive plate **134**. The example brace assembly **130** comprises a brace rod **140**, an anchor member **142**, and a brace nut **144**. During use of the second example

bushing assembly insertion system **120**, at least a portion of the example brace rod **140** is arranged to extend through a bushing assembly opening (not shown) in the bushing assembly **122** and the housing opening **124** in the structural member **126** to support the brace nut **144**, the actuator assembly **132**, the drive plate **134** on a first side of the housing opening **124** and the anchor member **142** on a second side of the housing opening **124**. So arranged, operation of the actuator assembly **132** acts on the bushing assembly **122** through the drive plate **134** to force the bushing assembly **122** into the bushing assembly opening **124**. The example brace assembly **130** engages the structural member **126** to prevent the actuator assembly **132** from displacing itself away from the structural member **126** during operation of the actuator assembly **132**.

**[0055]** The example brace rod **140** and brace nut **144** are or may be the same as the example brace rod **40** and brace nut **44** described above and will not be described herein again in detail.

**[0056]** The example anchor member **142** defines an anchor cavity **160** and an anchor edge **162**. The anchor cavity **160** defines an anchor cavity spacing portion **164** and an anchor cavity threaded portion **166**. The anchor cavity threaded portion **66** is sized and dimensioned to receive the threaded outer surface of the brace rod **140** adjacent to the first rod end. The example anchor cavity threaded portion **166** further allows the brace rod **140** to extend out of the anchor cavity **160** as shown in FIG. **13**. Axial rotation of the brace rod **140** and anchor member **142** relative to each other about a brace rod axis prevents displacement of the anchor member **142** relative to the brace rod **140** along the brace rod axis under predetermined tension loads exerted by the actuator assembly **132**.

**[0057]** The second example bushing assembly insertion system **120** is otherwise used in a manner similar to that of the first example bushing assembly insertion system **20** described above.

**[0058]** Referring now to FIG. **14** of the drawing, depicted therein is a third example bushing assembly insertion system **220** constructed in accordance with, and embodying, the principles of the present invention. FIG. **14** illustrates that the first example bushing assembly insertion system **220** may be used to insert an example bushing assembly **222** into an example housing opening **224** defined by an example structural member **226**. The example bushing assembly **222** and structural member **226**, including the housing opening **224**, are or may be conventional and will not be described herein beyond that extent helpful for a complete understanding of the construction and operation of the third example bushing assembly insertion system **220**.

**[0059]** The third example bushing assembly insertion system **220** comprises a brace assembly **230**, an actuator assembly **232**, and a drive plate **234**. The example brace assembly **230** comprises a brace rod **240**, an anchor member **242**, a first brace nut **244**, and a second brace nut **246**.

**[0060]** During use of the third example bushing assembly insertion system **220**, at least a portion of the example brace rod **240** is arranged to extend through a bushing assembly opening (not shown) in the bushing assembly **222** and the housing opening **224** in the structural member **226** to support the brace nut **244**, the actuator assembly **232**, the drive plate **234** on a first side of the housing opening **224** and the anchor member **242** on a second side of the housing opening **224**. So arranged, operation of the actuator assembly **232** acts on the bushing assembly **222** through the drive plate **234** to force the bushing assembly **222** into the bushing assembly opening **224**. The example brace assembly **230** engages the structural member **226** to prevent the actuator assembly **232** from displacing itself away from the structural member **226** during operation of the actuator assembly **232**.

**[0061]** The example brace rod **240** and brace nut **244** are or may be the same as the example brace rod **40** and brace nut **44** described above and will not be described herein again in detail.

**[0062]** The example anchor member **242** defines an anchor cavity **260** and an anchor edge **262**. The anchor cavity **260** defines an anchor cavity spacing portion **264** and an anchor cavity through portion **266**. The anchor cavity through portion **266** is sized and dimensioned to allow the threaded outer surface of the brace rod **240** adjacent to the first rod end to extend out of the anchor cavity **260** as shown in FIG. **14**. Axial rotation of the brace rod **240** relative to the first brace nut **244** and the second brace nut **246** about a brace rod axis prevents displacement of the anchor member **242** relative to the brace rod **240** along the brace rod axis under predetermined tension loads exerted by the actuator assembly **232**.

**[0063]** The third example bushing assembly insertion system **220** is otherwise used in a manner similar to that of the first example bushing assembly insertion system **20** described above.

**[0064]** Referring now to FIG. **15** of the drawing, depicted therein is a fourth example bushing assembly insertion system **320** constructed in accordance with, and embodying, the principles of the present invention. FIG. **15** further illustrates that the fourth example bushing assembly insertion system **320** may be used to insert an example bushing assembly **322** into an example housing opening **324** defined by an example structural member **326**. FIG. **15** further illustrates that the example bushing assembly **322** defines a bushing assembly opening **328** sized and dimensioned to receive a shaft (not shown). The example bushing assembly **322** and structural member **326**, including the housing opening **324**, are or may be conventional and will not be described herein beyond that extent helpful for a complete understanding of the construction and operation of the fourth example bushing assembly insertion system **320**.

**[0065]** Bushing assemblies such as the example bushing assembly **322** are sold in numerous shapes and sizes. The example bushing assembly **322** defines a first end configuration **322***a* and a second end configuration **322***b*. The end configurations **322***a* and **322***b* differ for differing bushing assemblies.

**[0066]** As shown in FIG. **1**, the fourth example bushing assembly insertion system **320** comprises a brace assembly **330**, an actuator assembly **32**, and a drive plate **334**. The example brace assembly **330** comprises a brace rod **340**, an anchor member **342**, and a brace nut **344**. At least a portion of the example brace rod **340** is arranged to extend through bushing assembly opening **328** in the bushing assembly **322** and the housing opening **324** in the structural member **326** to support the brace nut **344**, the actuator assembly **32**, the drive plate **334** on a first side of the housing opening **324** and the anchor member **342** on a second side of the housing opening **324**. So arranged, operation of the actuator assembly **32** acts on the bushing assembly **322** through the drive plate **334** to force the bushing assembly **322** into the bushing assembly opening **324**. The example brace assembly **330**

engages the structural member **326** to prevent the actuator assembly **32** from displacing itself away from the structural member **326** during operation of the actuator assembly **32**.

**[0067]** Given the foregoing general understanding of the construction and operation of the fourth example bushing assembly insertion system **320**, the details of construction and operation of the fourth example bushing assembly insertion system **320** of the present invention will now be described.

**[0068]** The example brace rod **340** defines a first rod end **350** and a second rod end **352**, and an outer surface **354** of the example brace rod **340** is threaded at least adjacent to the first rod end **352** and to the second rod end **354**. The example brace rod **340** as depicted is threaded along its entire length, but only a portion of the brace rod **340** need be threaded as will become apparent from the following discussion. The example brace rod **340** defines a brace rod axis **356**.

**[0069]** The example anchor member **342** defines an anchor cavity **360** and an anchor edge surface **362**. The anchor cavity **360** defines an anchor cavity recess portion **364** and an anchor cavity threaded portion **366**. The anchor cavity threaded portion **366** is sized and dimensioned to receive the threaded outer surface **354** of the brace rod **340** adjacent to the first rod end **350**. Accordingly, axial rotation of the brace rod **340** and anchor member **342** relative to each other about the brace rod axis **356** with the threaded outer surface **354** within the anchor cavity threaded portion **366** prevents displacement of the anchor member **342** relative to the brace rod **340** along the brace rod axis **356** under predetermined tension loads exerted by the actuator assembly **32**. The anchor cavity recess portion **364** is adapted to receive the second end **322***b* of the bushing assembly **322**.

**[0070]** The example brace nut **344** is or may be conventional and defines an external nut surface **370** and an internal threaded nut opening **372**. The internal threaded nut opening **372** is sized and dimensioned to receive the threaded outer surface **354** of the brace rod **340** adjacent to the second rod end **352**. Accordingly, axial rotation of the brace rod **340** and brace nut **344** relative to each other about the brace rod axis **356** with the threaded outer surface **354** within the internal threaded nut opening **372** prevents displacement of the brace nut **344** relative to the brace rod **340** along the brace rod axis **356** under predetermined tension loads exerted by the actuator assembly **32**. The example external nut surface **350** is a hex surface but other surface configurations may be used.

**[0071]** The example actuator assembly **32** comprises an actuator housing **380** and an actuator drive member **382**. The example actuator assembly **32** is or may be conventional and will be described herein only to that extent helpful for a complete understanding of the construction and operation of the fourth example bushing assembly insertion system **320**. The example actuator housing **380** defines an actuator housing opening **384**, and the example actuator drive member **382** defines an actuator drive member opening **386**. The example drive member **382** defines a drive surface **388** and a first connecting surface **388***a*. Operation of the example actuator assembly **32** causes displacement of the example actuator drive member **382** relative to the actuator housing **380**. The example actuator assembly **32** may be operated using an electrical drive system, pneumatic drive system, hydraulic drive system, or any other appropriate drive system. The drive system used to supply power to the example actuator system **32** is or may be conventional and is not depicted in the drawing for simplicity and clarity.

**[0072]** The example drive plate **334** defines a first drive plate surface **390**, a second drive plate surface **392**, and a drive plate opening **394**. The example drive plate **334** further defines a drive recess **398***a* and a connecting surface **398***b*. The example drive plate opening **394** defines a drive plate opening first portion **396** and a drive plate opening second portion **398**. The drive plate opening **394** extends between the first drive plate first surface **390** and the second drive plate second surface **392**. The drive recess **398***a* on the drive plate **334** is contoured to receive the first end configuration **322***a* of the bushing assembly **322** as will be described in further detail below.

**[0073]** The second connecting surface **398***b* is configured to engage the first connecting surface **388***a* to allow the drive plate **334** to be detachably attached to the actuator housing **380**. The example first drive surface **388***a* is internally threaded, and the example second drive surface **398***b* is externally threaded, but other connecting systems for detachably attaching the drive plate **334** to the actuator housing **380** may be used.

**[0074]** As perhaps best shown in FIG. **15**, the example brace rod **340** is sized and dimensioned such that the example brace rod **340** may be arranged to extend through the actuator housing opening **384**, the actuator drive member opening **386**, the adapter late opening **394**, and the bushing opening **328**. FIG. **15** further illustrates that the example brace rod **340** is sized and dimensioned to extend through the anchor cavity recess portion **364** of the anchor cavity **360**. And as described above, the anchor rod **340** is further sized and dimensioned such that to be threaded into the anchor cavity threaded portion **366** and at least partly into the internal nut threaded opening **372**. As arranged in FIG. **15**, the rod axis **356** of the brace rod **340** defines a longitudinal axis of the fourth example bushing assembly insertion system **320**.

**[0075]** The fourth example bushing assembly insertion system **320** is used in a manner similar to that of the first example bushing assembly insertion system **20** described above. However, in the fourth example bushing assembly insertion system **320**, the actuator assembly **332** is reversed such that the actuator drive member **382** engages the brace nut **344** and the actuator housing **380** supports the drive plate **334** as generally described above.

**[0076]** The example drive plate **334** and the example anchor member **342** are sold in a variety of configurations to accommodate a variety of configurations of bushing assemblies **322**. In particular, the anchor cavity recess portion **364** defined by the anchor member **342** and the drive recess **398***a* defined by the drive plate **334** are configured as necessary to accommodate a particular bushing assembly **322** and further to locate the particular bushing assembly **322** in a desired position relative to the example structural member **326**.

**[0077]** Referring now to FIGS. **16** and **17** of the drawing, depicted therein is a first example method of removing a bushing assembly **420** from a housing cavity **422** of a housing **424** using an actuator assembly **426**. As perhaps best shown in FIG. **20**, the example bushing assembly **420** comprises a bushing sleeve **430**, bushing pin **432**, and elastomeric material (not shown in FIG. **20** for clarity) that supports the bushing pin **432** relative to the bushing sleeve **430**. The bushing assembly **420**, housing cavity **422**, and housing **424** are not per se part of the present invention and are disclosed herein only to that extent helpful to a complete understanding of the present invention.

**[0078]** A first step of the first example method of removing the bushing assembly **420** from the housing cavity **422** is shown in FIGS. **16**A and **16**B. A brace assembly **440** comprising a threaded rod **442** and a nut **444** is provided. The threaded rod **442** is secured to a pullbar socket **450**, and the pullbar socket **450** is secured to the bushing pin **432** by a threaded pin **452**. A receiver assembly **460** is formed by assembling an extension tube **462**, cylinder adapter **464**, cylinder tube cap **466**, and first and second snap rings **468**. The receiver assembly **460** is arranged over the pullbar socket **450** and with the tube cap **466** thereof in contact with (engaging) the housing **424**.

**[0079]** An actuator assembly **444** is arranged between the receiver assembly **460** and a nut **446** such that extension of the actuator assembly **444** acts on the nut and the receiver assembly **460** to displace the threaded rod **442** such that the bushing pin **432** is removed from the bushing assembly **420**. The bushing sleeve **430** and elastomeric material remains in the housing cavity **422** at this point. When assembled, the actuator assembly **444**, nut **446**, and threaded rod **442** form a drive assembly in the form of the actuator assembly **426** for displacing the bushing pin **432** relative to the bushing assembly **420**.

**[0080]** The user of a receiver assembly **460** comprising a separate cylinder adapter **464** and cylinder tube cap **466** allows the receiver assembly **460** to be arranged in at least two configurations depending upon the specific function be performed. In the example depicted in FIG. **16**B, the receiver assembly **460** is in a long configuration. The tube cap **466** is sized and dimensioned relative to the structural housing member **420**, the housing cavity **422**, and the bushing assembly **420** to allow at least a portion of the bushing assembly **420** to enter the extension tube **462** when removed from the housing cavity **422**. In the first step depicted in FIG. **16**, the bushing pin **432** and at least a portion of the elastomeric material from the housing **420**, leaving the bushing sleeve **430** and perhaps a portion of the elastomeric material within the housing cavity **422**.

**[0081]** A second step of the first example method of removing the bushing assembly **420** from the housing cavity **422** is shown in FIGS. **17**A and **17**B. The threaded rod **442** is extended through an opening in the bushing assembly **420** formed by removal of the bushing pin **432** and secured to a sleeve remover **470**. The pullbar socket **450** is secured to the bushing pin **432** by a threaded pin **452**. The receiver assembly **460** is arranged over the threaded rod **442** in contact with the housing **426**. The actuator assembly **444** is arranged between the receiver assembly **460** and a nut **446** such that extension of the actuator assembly **444** acts on the nut and the receiver assembly **460** to displace the threaded rod **442** such that the sleeve remover forces the bushing sleeve **430** (and the elastomeric material within the bushing sleeve **430**) from the housing cavity **422**.

**[0082]** Again, the user of a receiver assembly **460** comprising a separate cylinder adapter **464** and cylinder tube cap **466** allows the receiver assembly **460** to be arranged in at least two configurations depending upon the specific function be performed. In the example depicted in FIG. **17**B, the receiver assembly **460** is in a short configuration. As described above, the tube cap **466** is sized and dimensioned relative to the structural housing member **420**, the housing cavity **422**, and the bushing assembly **420** to allow at least a portion of the bushing assembly **420** to enter the extension tube **462** when removed from the housing cavity **422**. The sleeve remover **470** is sized and dimensioned relative to bushing sleeve **430** and the housing cavity **422** in the the structural member **420** to engage the bushing sleeve **430** and enter the cavity **422** when the sleeve **430** is removed. In the second step depicted in FIG. **16**, the housing sleeve **430** and any remaining portion of the elastomeric material from is removed from the housing **420**. At this point, the entire bushing assembly **420** has been removed.

**[0083]** FIG. **18**A illustrates an example configuration that allows removal of an old bushing assembly **420** or insertion of a new bushing assembly **420** relative to the housing cavity **422**. The threaded rod **442** is secured to the pullbar socket **450**, and the pullbar socket **450** is secured to the bushing pin **432** by a threaded pin **452**. A push adapter **480** is connected to the other end of the bushing pin **432** by a threaded pin **452**. The receiver assembly **460** is arranged over the pullbar socket **450** in contact with the housing **424**. An actuator assembly **444** is arranged between the receiver assembly **460** and the nut **446** such that extension of the actuator assembly **444** acts on the nut and the receiver assembly **460** to displace the threaded rod **442** such that the bushing assembly **420** is pulled into the housing cavity **422**. FIG. **18**B illustrates removal of the entire spent bushing assembly **420** in one step, while FIG. **18**C illustrates insertion of a new bushing assembly **420**.

**[0084]** FIG. **19** illustrates a first example adapter kit **490** comprising the cylinder adapter **464**, the cylinder tube cap **466**, the extension tube **462**, the pullbar socket **450**, the push adapter **480**, and the sleeve remover **470** discussed above. The threaded pins **452** and snap rings **468** are or may be conventional and are also depicted in FIG. **19**. FIG. **19** also illustrates a conventional socket driver **492** that may be included in the example kit **490** and used to drive the threaded pins **452** as implicit in the discussion above. As generally discussed above, FIG. **20** illustrates an example bushing assembly **430** that may be displaced using the adapter components of FIG. **19**. The example kit **490** may include two or more of the tube caps **466**, sleeve removers **470**, and push adapters **480**, where each of these components **466**, **470**, and/or **480** is configured for a particular configuration of bushing assembly **420** and housing cavity **422** adapted to accommodate that particular bushing assembly **420**.

**[0085]** FIG. **21** illustrates details of a second example adapter kit **520** comprising an extension tube **532**, a cylinder adapter **534**, a cylinder tube cap **536**, a cylinder tube cap adapter **538**, a pullbar socket **450**, and a push adapter **480**. As with the first example kit **490**, threaded pins **452** depicted in FIG. **21** are sized and dimensioned to threadingly engage the pullbar socket **450** and the push adapter **480** and are or may be conventional. As with the first example kit **490**, the second example kit **520** may include two or more of the tube caps, sleeve removers, and/or push adapters configured for a particular configuration of bushing assembly and housing cavity adapted to accommodate that particular bushing assembly.

**[0086]** FIGS. **21**-**23** illustrate that a first threaded surface **534***a* is formed on the cylinder adapter **534**, second and third threaded surfaces **532***a* and **532***b* are formed on the extension tube **532**, and a fourth threaded surface **536***a* is formed on the cylinder tube cap **536**. The first and second threaded surfaces **534***a* and **532***a* are sized and dimensioned to engage each other to allow the cylinder adapter **534** to be detachably attached to the extension tube **532**. The third and fourth

threaded surfaces **432***b* and **536***a* are sized and dimensioned to engage each other to allow cylinder tube cap **536** to be detachably attached to the extension tube **532**. The cylinder tube cap **536** defines a first mating surface **536***b*. The cylinder tube cap adapter **538** defines a second mating surface **538***a*. The first and second mating surfaces **436***b* and **538***a* are sized and dimensioned to engage each other to allow the cylinder tube cap **536** to support the cylinder tube cap adapter **538**.

**[0087]** The second example adapter kit **520** may otherwise be used in the same manner as the first example adapter kit **490** described above.

**[0088]** FIG. **24** illustrates details of a third example adapter kit **550** comprising an extension tube **562**, a cylinder adapter **564**, a cylinder tube cap **466**M, a cylinder tube cap adapter **568**, a pullbar socket **450**, and a push adapter **480**. Threaded pins **452** depicted in FIG. **121** are sized and dimensioned to threadingly engage the pullbar socket **450** and the push adapter **480** and are or may be conventional. As with the first example kit **490** and second example kit **520**, the third example kit **550** may include two or more of the tube caps, sleeve removers, and/or push adapters configured for a particular configuration of bushing assembly and housing cavity adapted to accommodate that particular bushing assembly.

**[0089]** FIGS. **24-26** illustrate that a first engaging surface **564***a* is formed on the cylinder adapter **564**, second and third engaging surfaces **562***a* and **562***b* are formed on the cylinder adapter **562**, and a fourth engaging surface **566***a* is formed on the cylinder tube cap **566**. The first and second engaging surfaces **564***a* and **562***b* are sized and dimensioned to engage each other to allow the cylinder adapter **564** to be supported by the extension tube **562**. The third and fourth engaging surfaces **562***a* and **566***a* are sized and dimensioned to engage each other to allow cylinder tube cap **566** to be supported by the extension tube **562**. The cylinder tube cap **566** further defines a fifth engaging surface **566***b*. The cylinder tube cap adapter **568** defines a sixth mating surface **568***a*. The fifth and sixth mating surfaces **566***b* and **568***a* are sized and dimensioned to engage each other to allow the cylinder tube cap **566** to support the cylinder tube cap adapter **568**.

**[0090]** FIGS. **24** and **26** further illustrate that magnets **470** are supported by at least one, and in the example kit **450**, each of the extension tube **562**, the cylinder adapter **564**, the cylinder tube cap **566**, the cylinder tube cap adapter **568**, to detachably attach the various components as the kit is being arranged for use.

**[0091]** The third example adapter kit **550** may otherwise be used in the same manner as either of the first example adapter kit **490** and second example adapter kit **520** described above.

What is claimed is:

**1**. An adapter system for a bushing displacing system for displacing at least a portion of a bushing assembly relative to an opening in a structural member, the bushing assembly comprising a bushing housing and a bushing pin, the adapter system comprising:

an extension tube defining first and second extension tube connecting portions;

a cylinder adapter defining a cylinder adapter connecting portion;

a cylinder tube cap defining a cylinder tube cap connecting portion;

a cylinder tube cap adapter; whereby

the first extension tube connecting portion is configured to engage the cylinder adapter connecting portion to detachably attach the cylinder adapter to the extension tube;

the second extension tube connecting portion is configured to engage the cylinder tube cap connecting portion to detachably attach the cylinder tube cap adapter to the cylinder tube cap.

**2**. An adapter system as recited in claim **1**, in which:

the first and second extension tube connecting portions are threaded;

the cylinder adapter connecting portion is threaded; and

the cylinder tube cap connecting portion is threaded.

**3**. An adapter system as recited in claim **1**, in which:

the first extension tube connecting portion is internally threaded;

the second extension tube connecting portion is externally threaded;

the cylinder adapter connecting portion is externally threaded; and

the cylinder tube cap connecting portion is internally threaded.

**4**. An adapter system as recited in claim **1**, in which:

the first extension tube connecting portion is at least one of magnetic and magnetically attractable;

the second extension tube connecting portions is at least one of magnetic and magnetically attractable;

the cylinder adapter connecting portion is at least one of magnetic and magnetically attractable; and

the cylinder tube cap connecting portion is at least one of magnetic and magnetically attractable.

**5**. An adapter system as recited in claim **1**, in which:

the first extension tube connecting portion is magnetic;

the second extension tube connecting portions is magnetically attractable;

the cylinder adapter connecting portion is magnetically attractable; and

the cylinder tube cap connecting portion is magnetic.

**6**. A method of configuring a bushing displacing system to displace at least a portion of a bushing assembly relative to an opening in a structural member, the bushing assembly comprising a bushing housing and a bushing pin, the method comprising the steps of:

providing an extension tube defining first and second extension tube connecting portions;

providing a cylinder adapter defining a cylinder adapter connecting portion;

providing a cylinder tube cap defining a cylinder tube cap connecting portion;

providing a cylinder tube cap adapter;

providing a pullbar socket; and

providing a push adapter;

detachably attaching the cylinder adapter to the extension tube by engaging the first extension tube connecting portion with the cylinder adapter connecting portion; and

detachably attaching the cylinder tube cap adapter to the cylinder tube cap by engaging the second extension tube connecting portion with the cylinder tube cap connecting portion.

**7**. A method as recited in claim **6**, in which:

the first and second extension tube connecting portions are threaded;

the cylinder adapter connecting portion is threaded; and
the cylinder tube cap connecting portion is threaded.

**8**. A method as recited in claim **6**, in which:
the first extension tube connecting portion is internally threaded;
the second extension tube connecting portion is externally threaded;
the cylinder adapter connecting portion is externally threaded; and
the cylinder tube cap connecting portion is internally threaded.

**9**. A method as recited in claim **6**, in which:
the first extension tube connecting portion is at least one of magnetic and magnetically attractable;
the second extension tube connecting portions is at least one of magnetic and magnetically attractable;
the cylinder adapter connecting portion is at least one of magnetic and magnetically attractable; and
the cylinder tube cap connecting portion is at least one of magnetic and magnetically attractable.

**10**. A method as recited in claim **6**, in which:
the first extension tube connecting portion is magnetic;
the second extension tube connecting portions is magnetically attractable;
the cylinder adapter connecting portion is magnetically attractable; and
the cylinder tube cap connecting portion is magnetic.

**11**. An adapter system for a bushing displacing system for displacing at least a portion of a bushing assembly relative to an opening in a structural member, the bushing assembly comprising a bushing housing and a bushing pin, the adapter system comprising:
an extension tube defining first and second extension tube connecting portions;
a cylinder adapter defining a cylinder adapter connecting portion;
a cylinder tube cap defining a cylinder tube cap connecting portion;
a cylinder tube cap adapter;
a pullbar socket; and
a push adapter; whereby
the first extension tube connecting portion is configured to engage the cylinder adapter connecting portion to detachably attach the cylinder adapter to the extension tube;
the second extension tube connecting portion is configured to engage the cylinder tube cap connecting portion to detachably attach the cylinder tube cap adapter to the cylinder tube cap.

**12**. An adapter system as recited in claim **11**, in which:
the first and second extension tube connecting portions are threaded;
the cylinder adapter connecting portion is threaded; and
the cylinder tube cap connecting portion is threaded.

**13**. An adapter system as recited in claim **11**, in which:
the first extension tube connecting portion is internally threaded;
the second extension tube connecting portion is externally threaded;
the cylinder adapter connecting portion is externally threaded; and
the cylinder tube cap connecting portion is internally threaded.

**14**. An adapter system as recited in claim **11**, in which:
the first extension tube connecting portion is at least one of magnetic and magnetically attractable;
the second extension tube connecting portions is at least one of magnetic and magnetically attractable;
the cylinder adapter connecting portion is at least one of magnetic and magnetically attractable; and
the cylinder tube cap connecting portion is at least one of magnetic and magnetically attractable.

**15**. An adapter system as recited in claim **11**, in which:
the first extension tube connecting portion is magnetic;
the second extension tube connecting portions is magnetically attractable;
the cylinder adapter connecting portion is magnetically attractable; and
the cylinder tube cap connecting portion is magnetic.

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