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(12) **United States Patent**
Scotto d'Antuono et al.

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(45) **Date of Patent: *Jul. 23, 2024**

(54) **PYROTECHNIC LAUNCH UNITS AND SYSTEMS**

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(73) Assignee: **Strictly FX, LLC**, Nashville, TN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **18/192,898**

(22) Filed: **Mar. 30, 2023**

(65) **Prior Publication Data**

US 2023/0288176 A1 Sep. 14, 2023

Related U.S. Application Data

(63) Continuation of application No. 17/802,366, filed as application No. PCT/US2021/021707 on Mar. 10, 2021, now Pat. No. 11,898,832.
(Continued)

(51) **Int. Cl.**
F42B 4/24 (2006.01)
F41B 11/52 (2013.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F42B 4/24*** (2013.01); ***F41B 11/52*** (2013.01); ***F41B 11/80*** (2013.01); ***F42B 4/18*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC F42B 4/00; F42B 4/18; F42B 4/20; F42B 4/22; F42B 4/24; F41B 11/52; F41B 11/722; F41B 11/80; F41F 1/00
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,572,248 A 3/1971 Dardick
4,862,802 A 9/1989 Streifer et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2018331 C 5/1995
CA 2564823 A1 11/2005
(Continued)

OTHER PUBLICATIONS

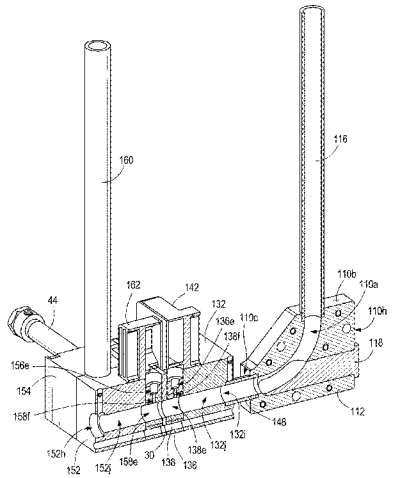
International Search Report for corresponding International Application No. PCT/US2021/021707, dated May 27, 2021 (6 pages).
(Continued)

Primary Examiner — Gabriel J. Klein
(74) *Attorney, Agent, or Firm* — Michael Best & Friedrich LLP

(57) **ABSTRACT**

A modular pyrotechnic launch unit includes a launch module, a first module, and a second module. The launch module includes a launch barrel. The first module is coupled in series to the launch module. The first module includes a first ignition state in which the first module ignites a pyrotechnic element that will then pass through the launch barrel. The first module also includes a first pass-through state in which the first module allows a pyrotechnic element ignited by another module to pass through the first module. The second module is coupled in series to the first module. The second module includes a second ignition state in which the second module ignites a pyrotechnic element that will then pass through the first module and through the launch barrel.

20 Claims, 28 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/987,991, filed on Mar. 11, 2020.

(51) **Int. Cl.**

F41B 11/80	(2013.01)
F42B 4/18	(2006.01)
F42B 4/20	(2006.01)
F42B 4/22	(2006.01)
F42B 4/26	(2006.01)

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

CPC ***F42B 4/20*** (2013.01); ***F42B 4/22*** (2013.01); ***F42B 4/26*** (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,892,037	A	1/1990	Betts	
5,282,455	A	2/1994	Adamson et al.	
5,339,741	A	8/1994	Craven et al.	
5,415,152	A	5/1995	Adamson et al.	
5,739,462	A	4/1998	Poor et al.	
6,393,990	B1	5/2002	Fagan	
8,157,169	B2	4/2012	Olden et al.	
10,948,271	B1 *	3/2021	Xiaowen	F42B 4/20
2003/0127010	A1	7/2003	O'Dwyer	
2010/0083552	A1 *	4/2010	Powers	F42C 19/0823 42/84

FOREIGN PATENT DOCUMENTS

CA	3093129	A1	10/2019
CN	203772152	U	8/2014
CN	103148743	B	6/2015
CN	110332856	A *	10/2019
CN	111121548	A *	5/2020
GB	2198815	A	6/1988
WO	2010149291	A1	12/2010

OTHER PUBLICATIONS

International Preliminary Report on Patentability for Application No. PCT/US2021/021707 dated Sep. 22, 2022 (6 pages).

Canadian Patent Office Action for Application No. 3,169,690 dated Nov. 18, 2022 (4 pages).

Extended European Search Report for Application No. 21768406.7 dated May 21, 2024 (9 pages).

* cited by examiner

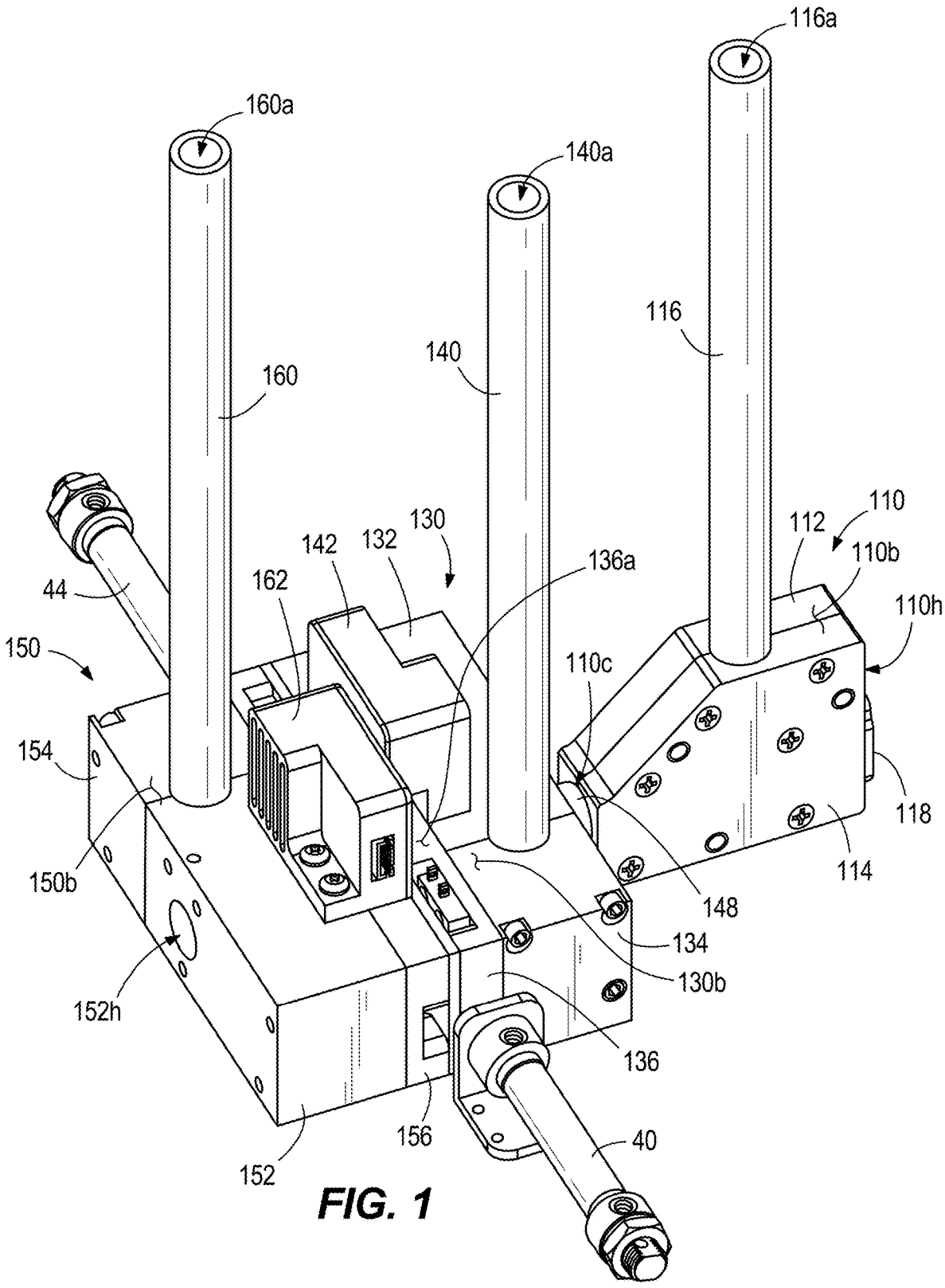

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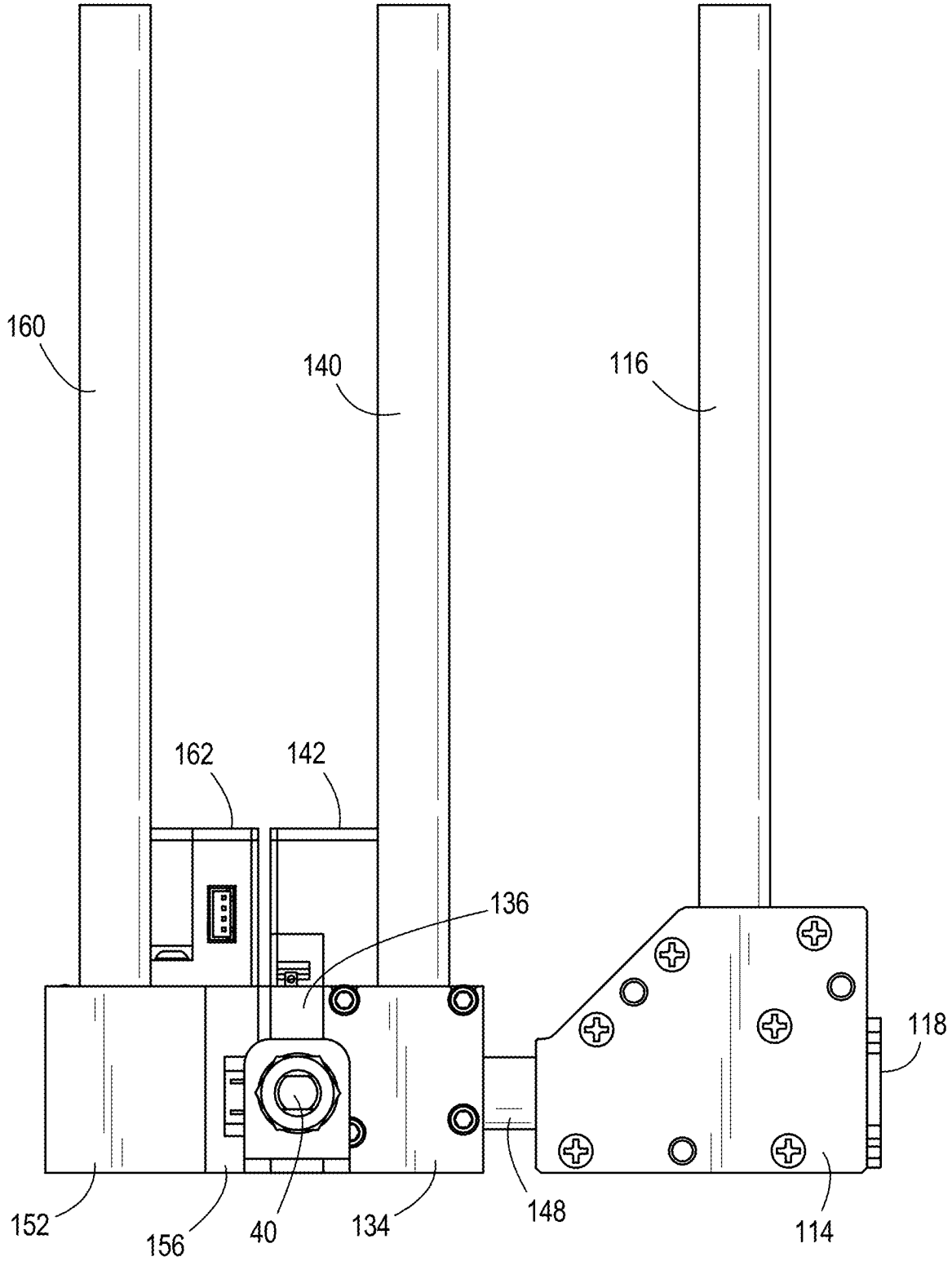
FIG. 1



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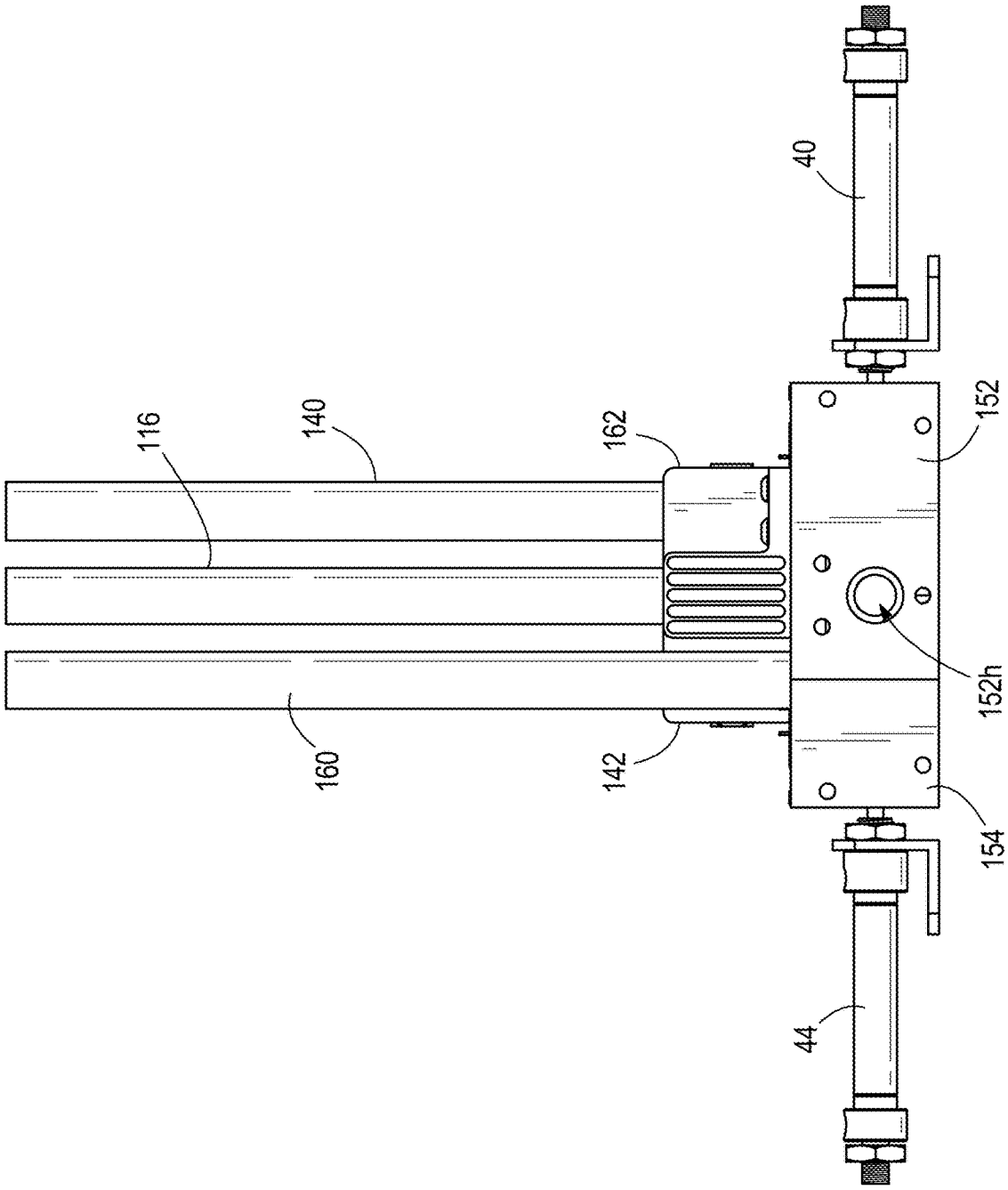

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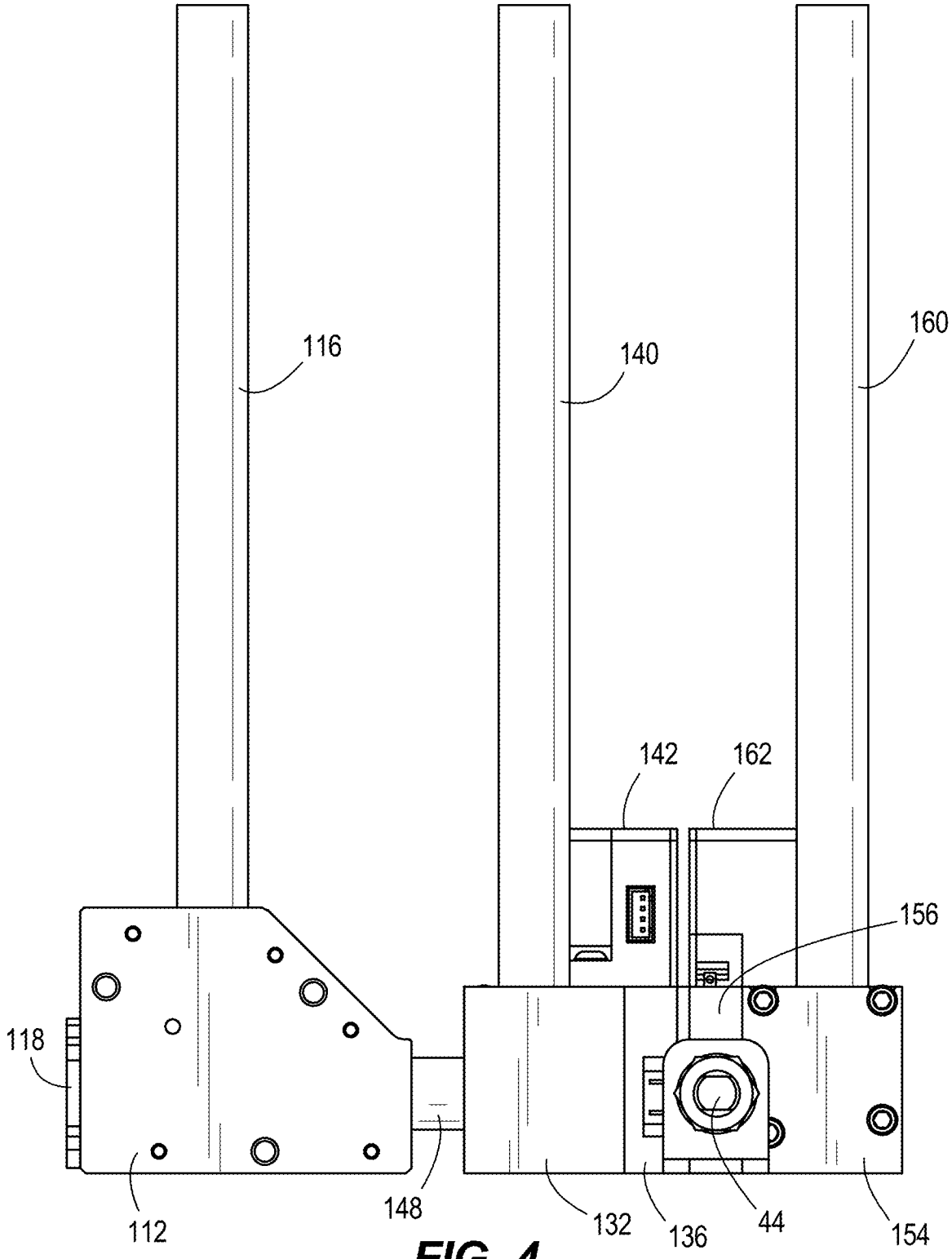

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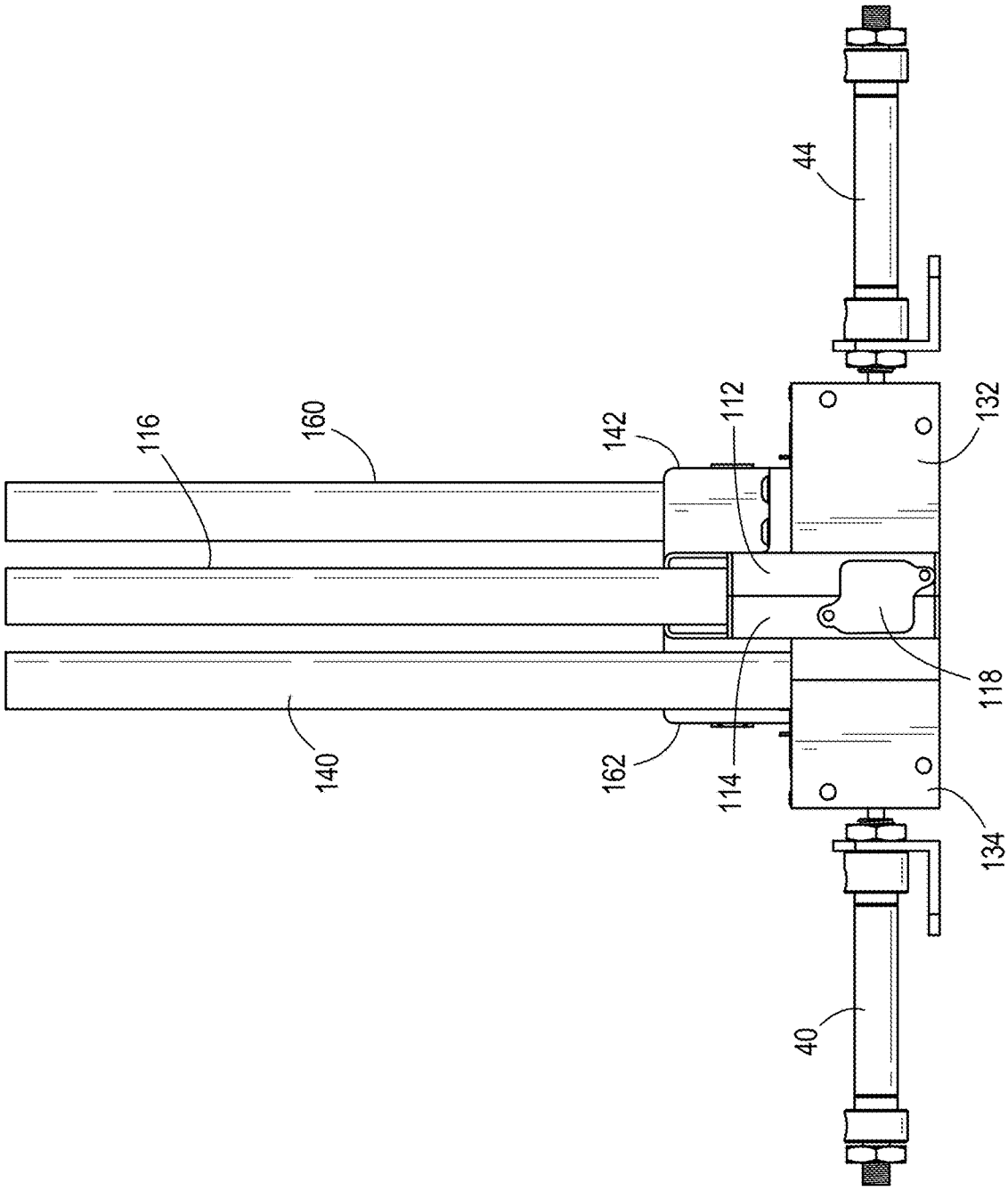

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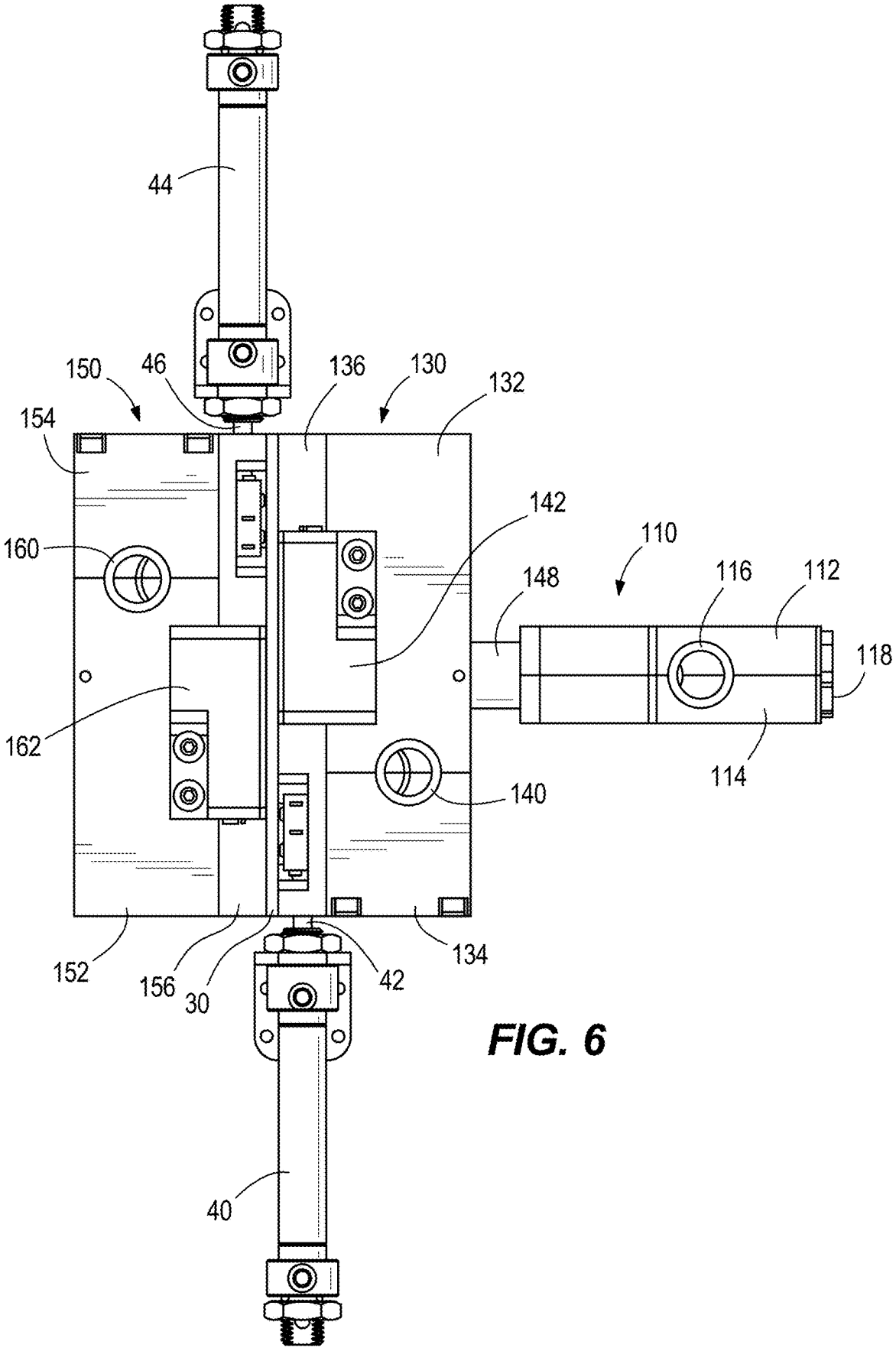
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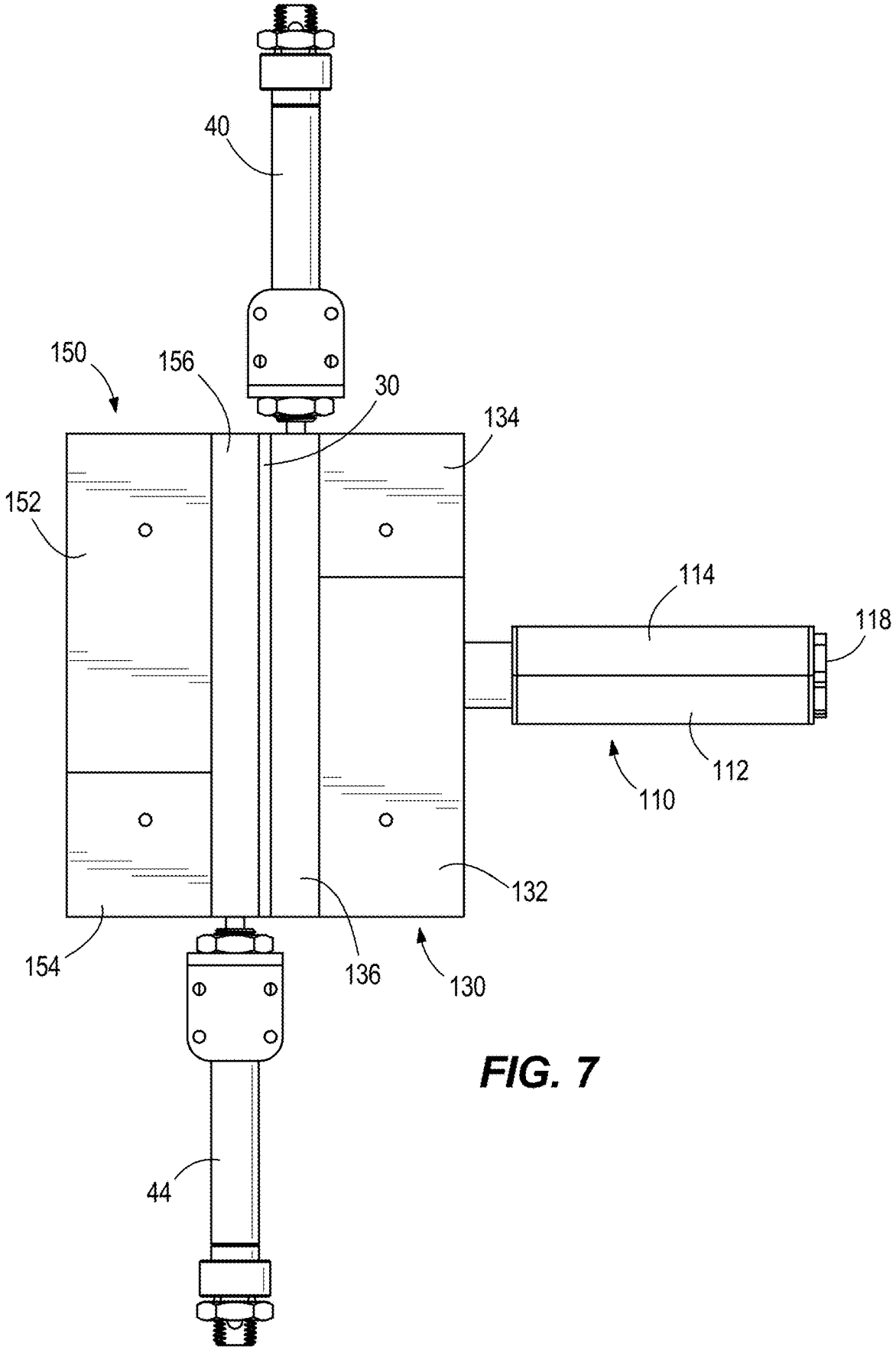
FIG. 6



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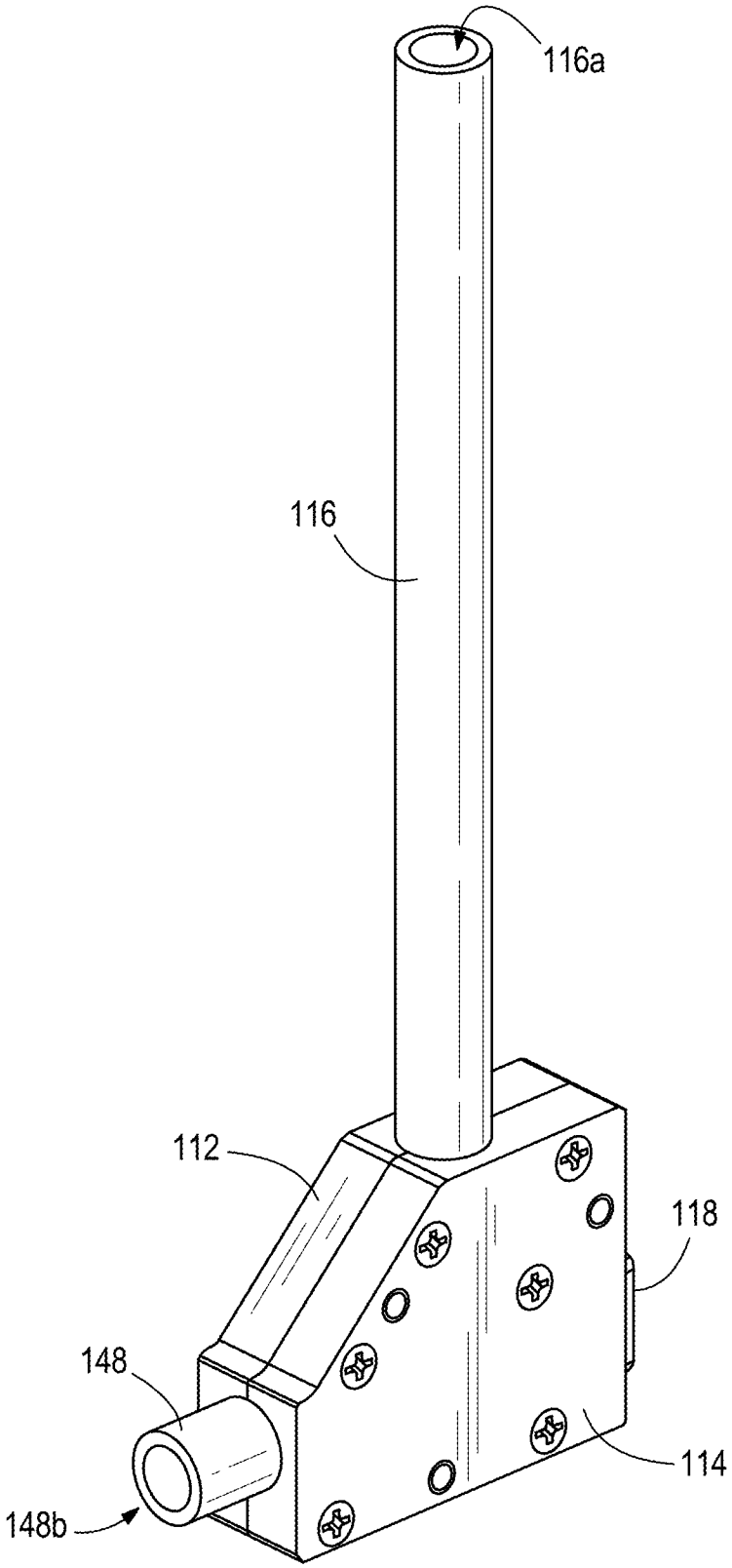

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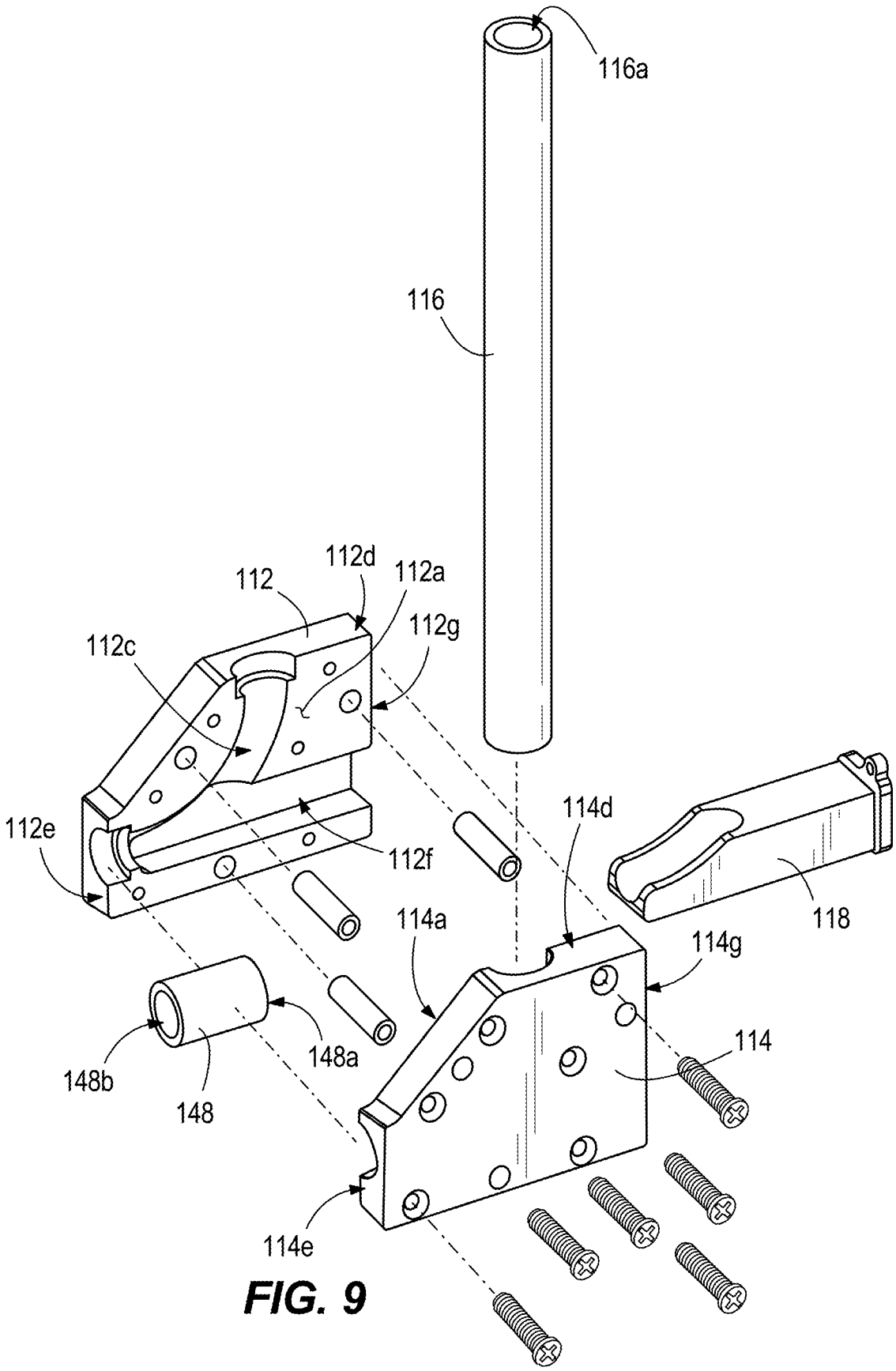
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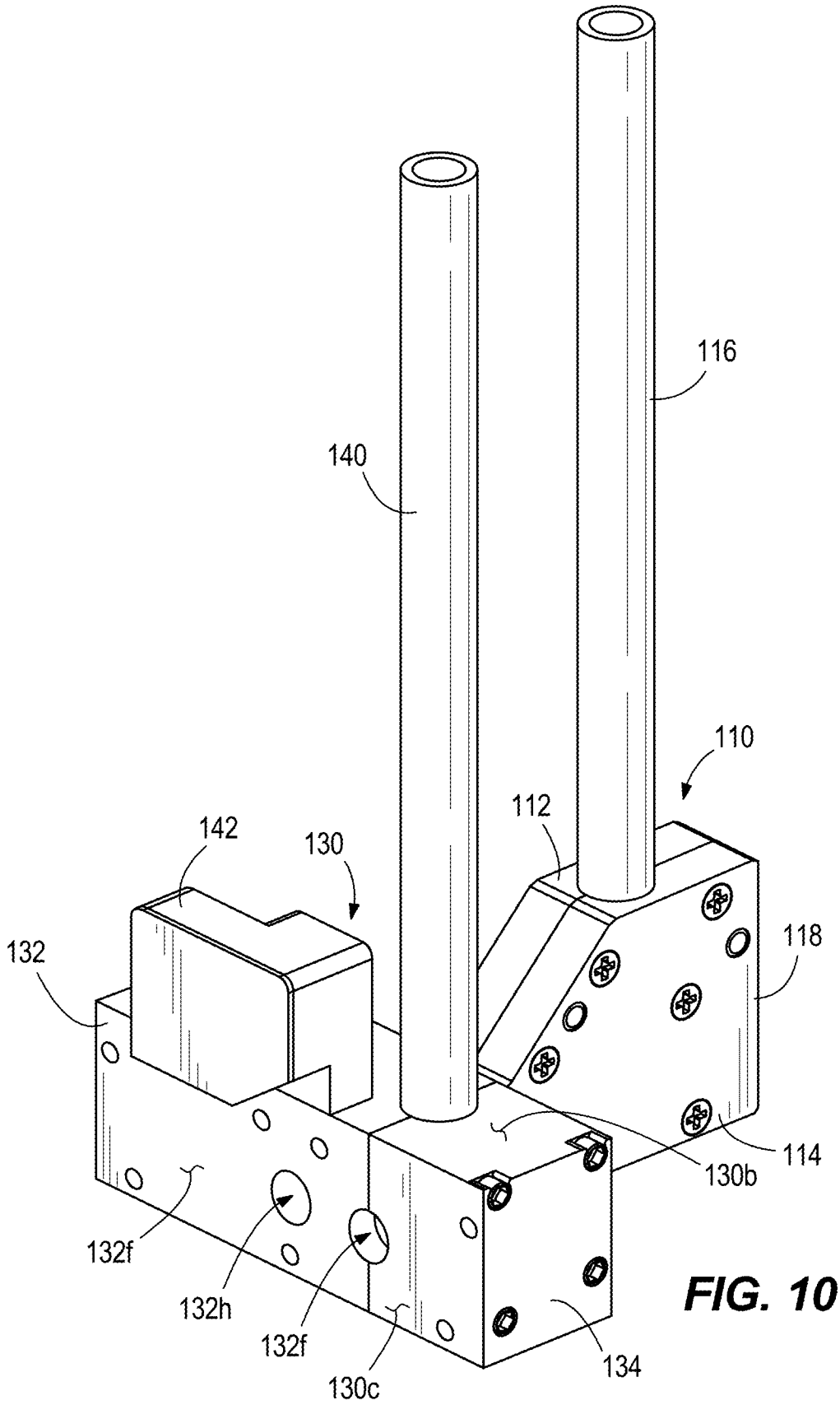
FIG. 9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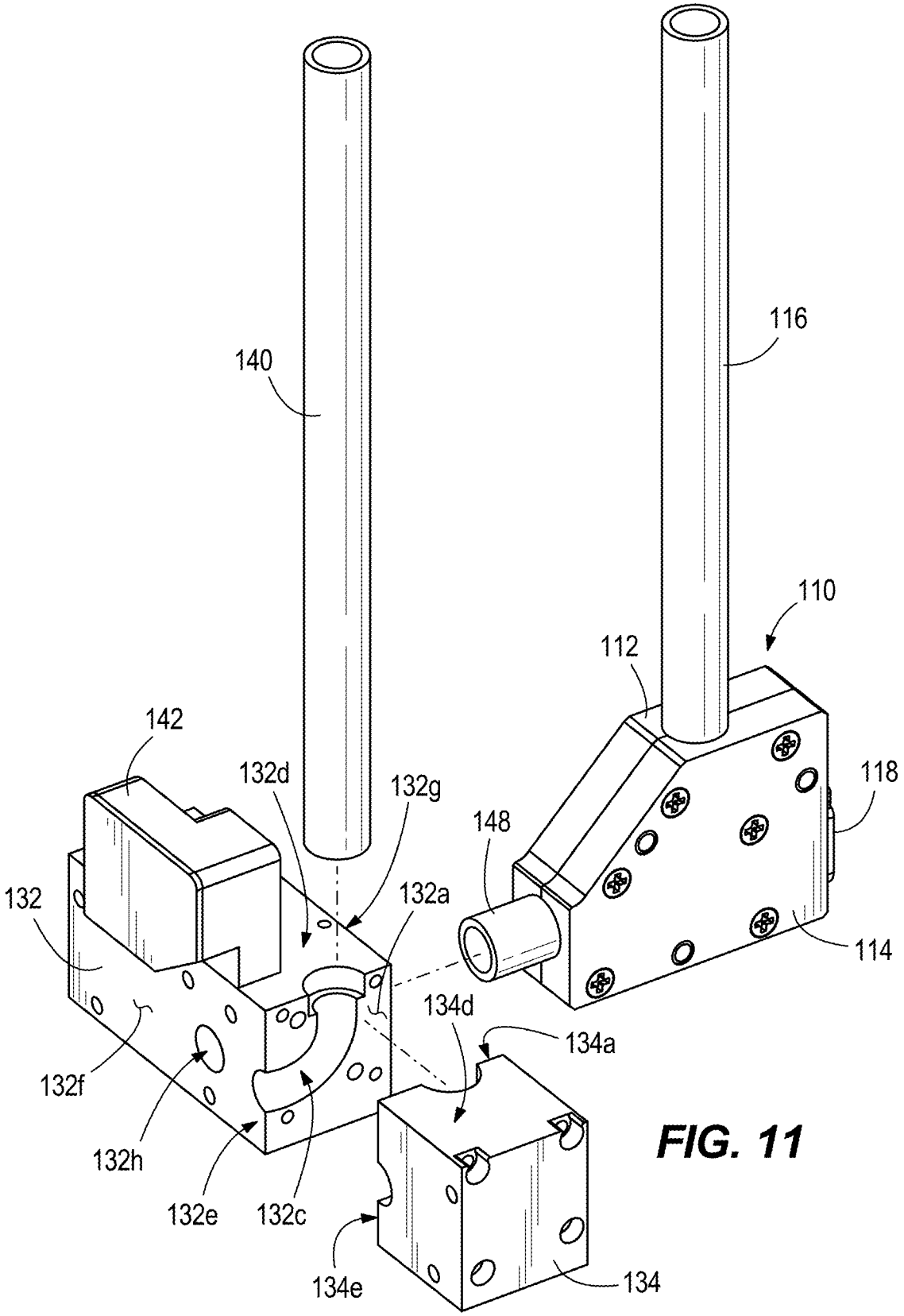
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FIG. 11

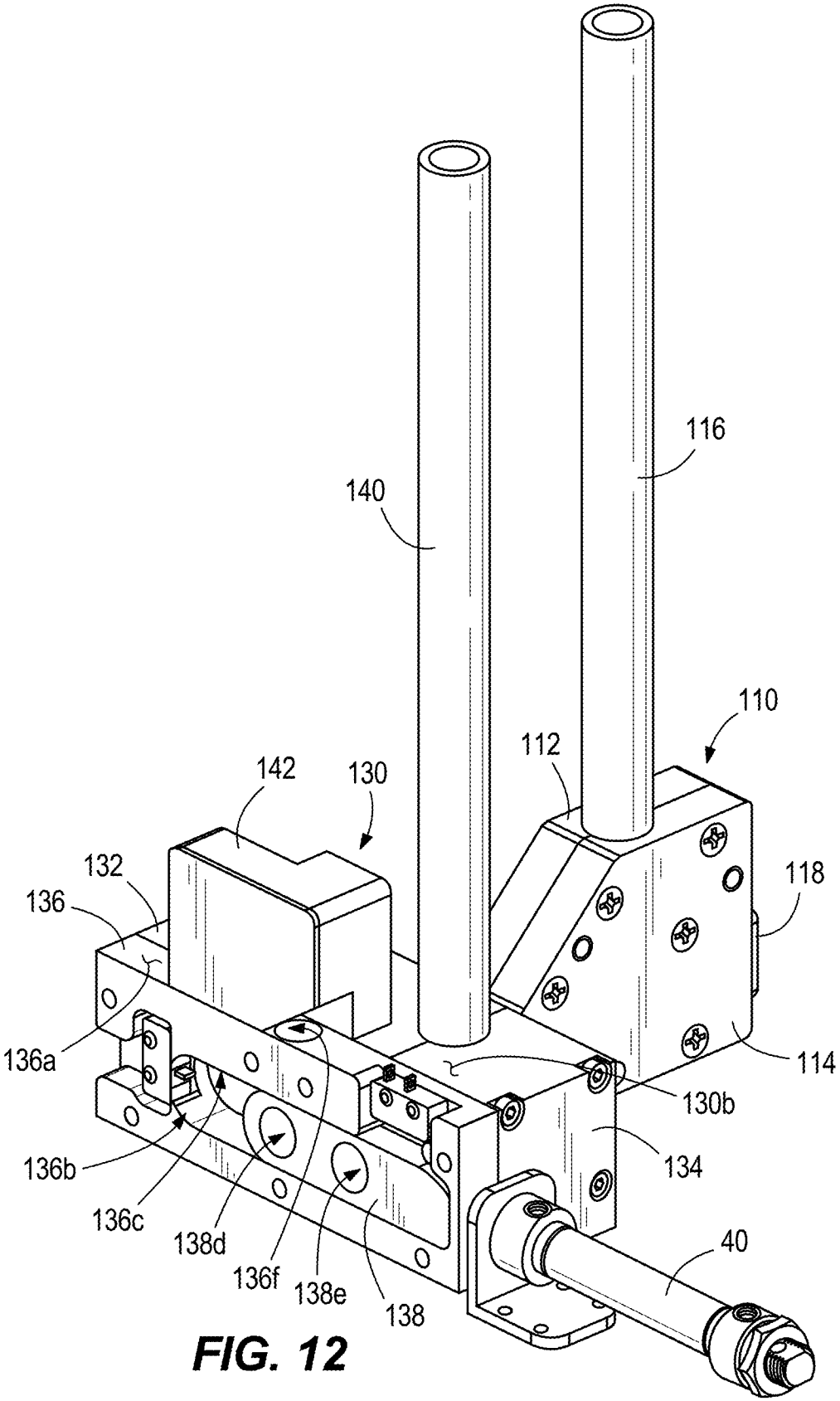
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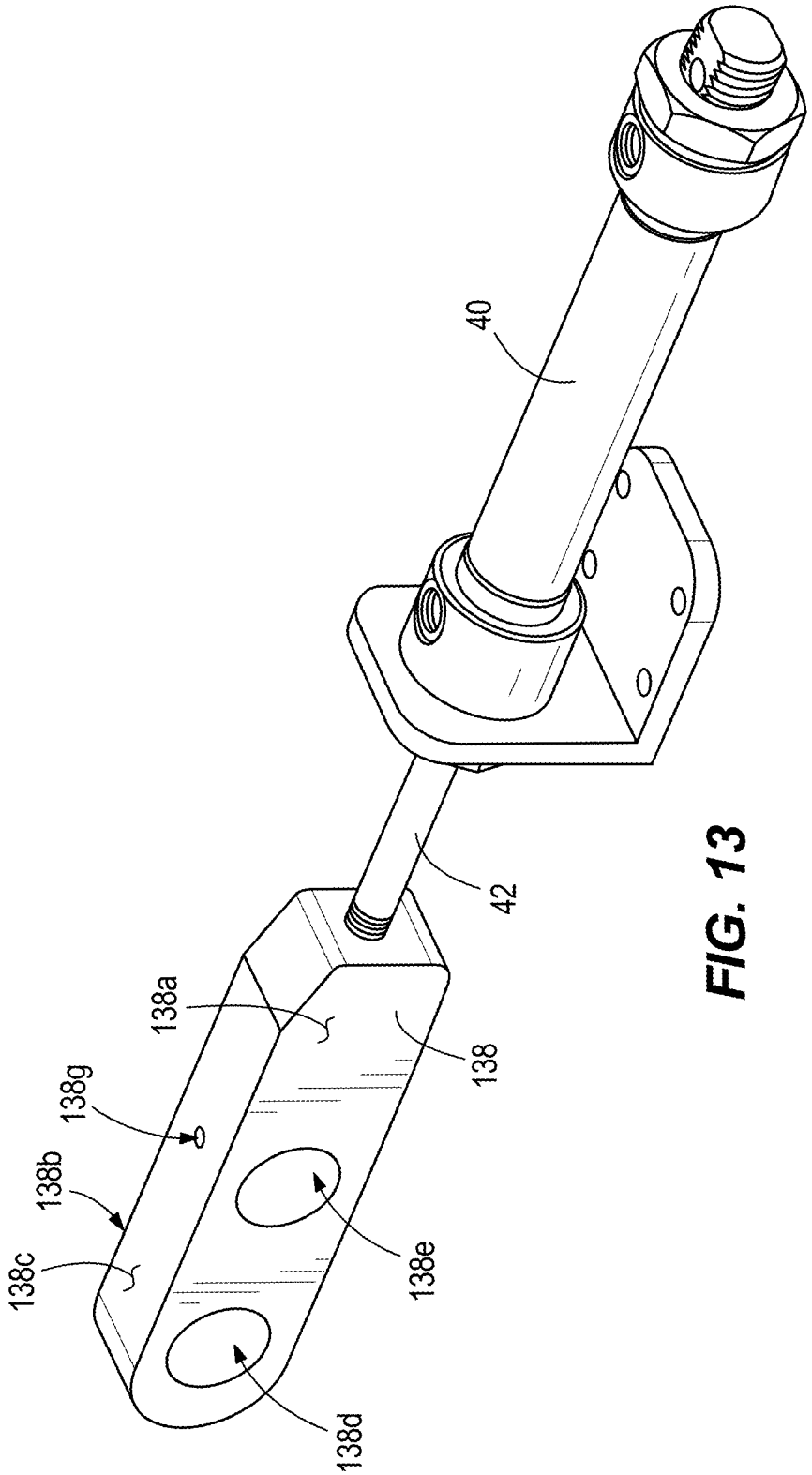
FIG. 12



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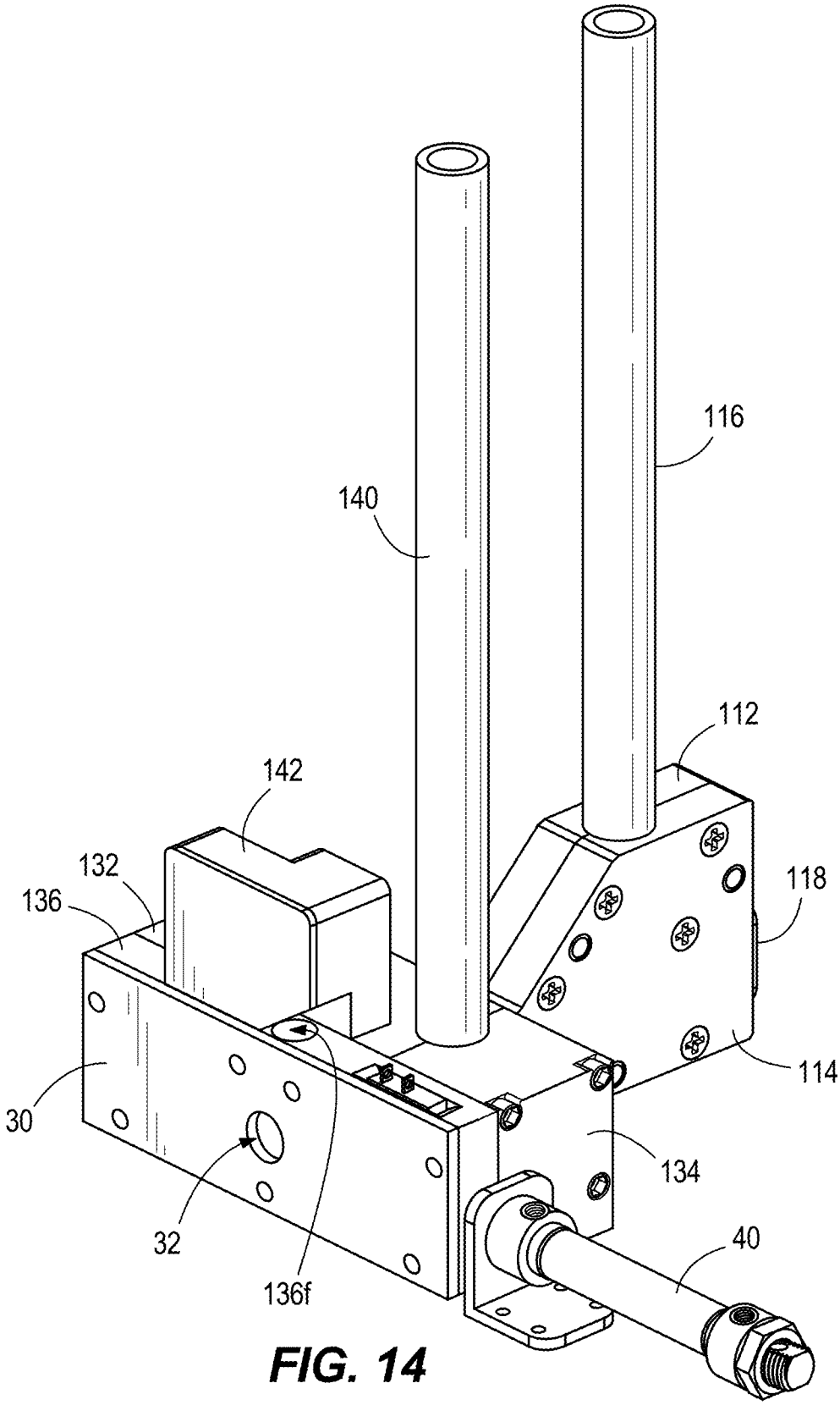

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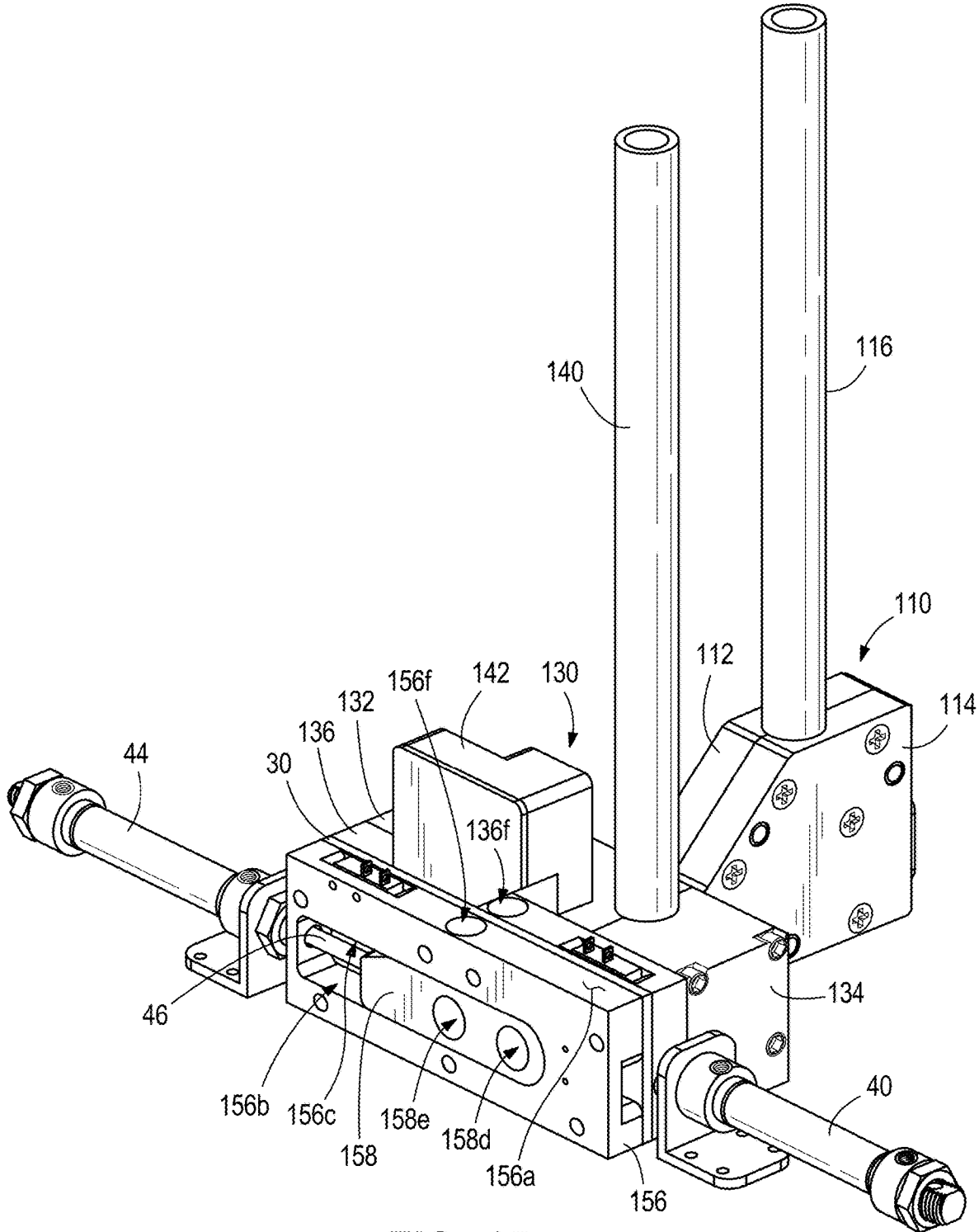
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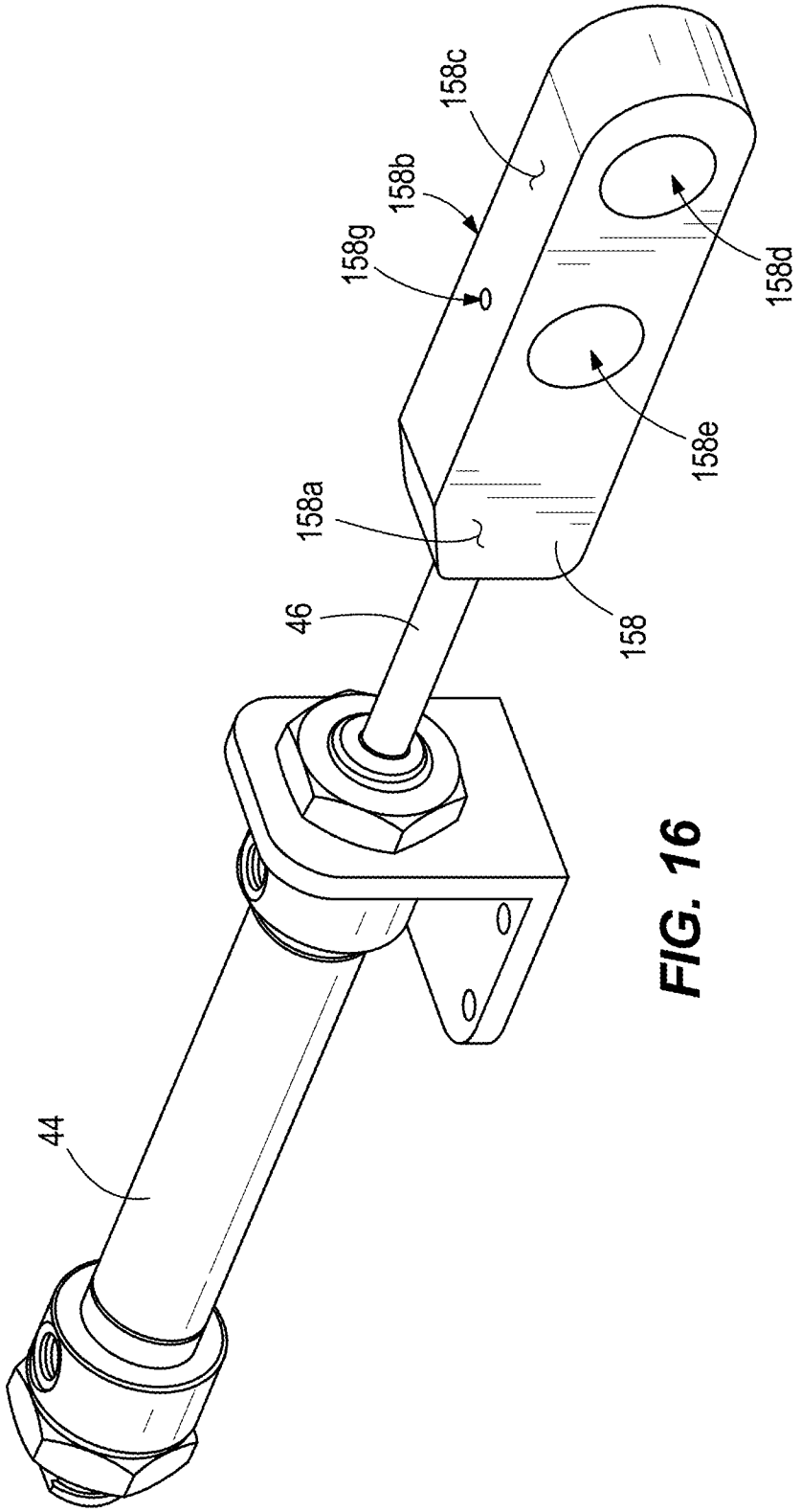
FIG. 15



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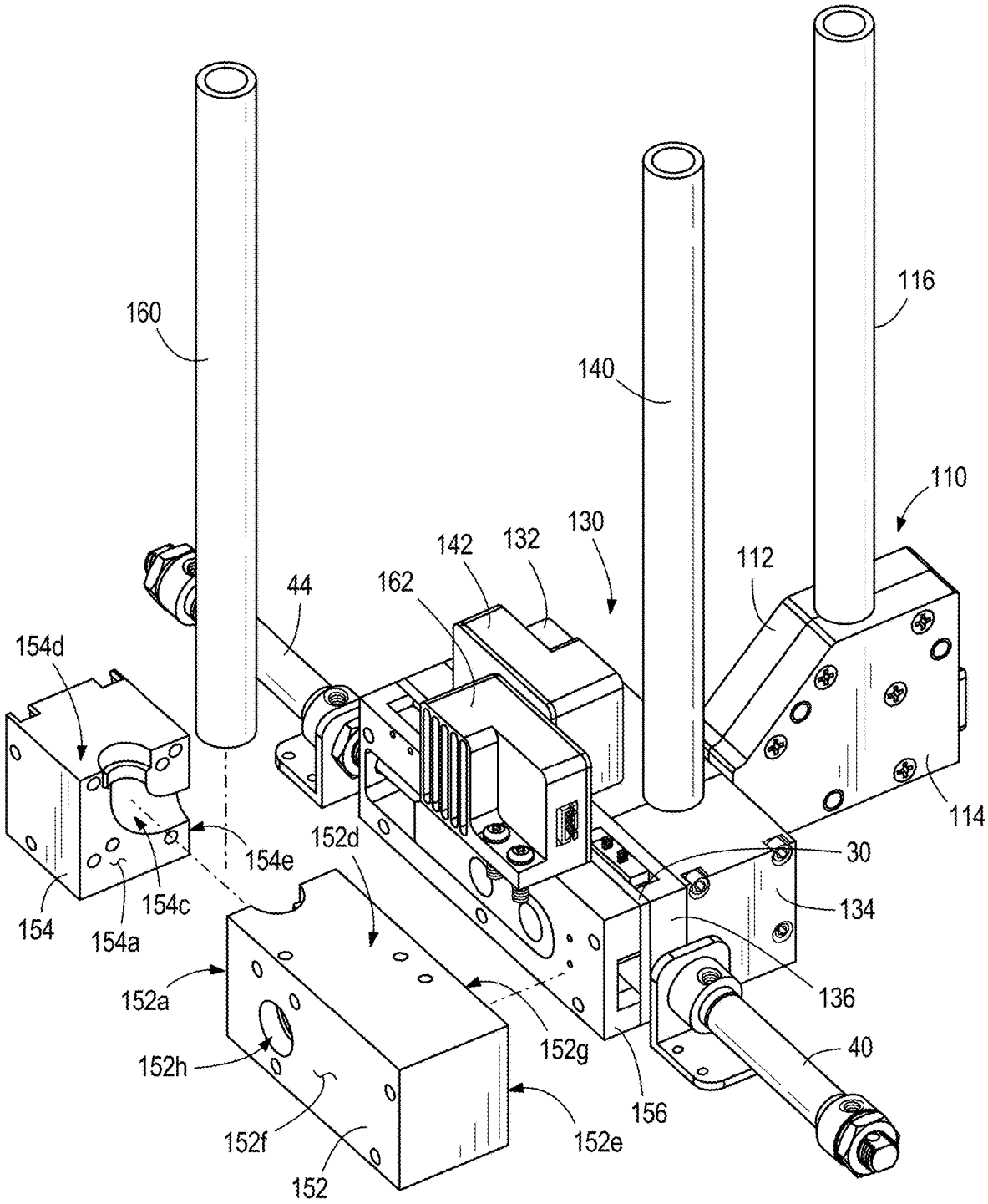
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FIG. 17

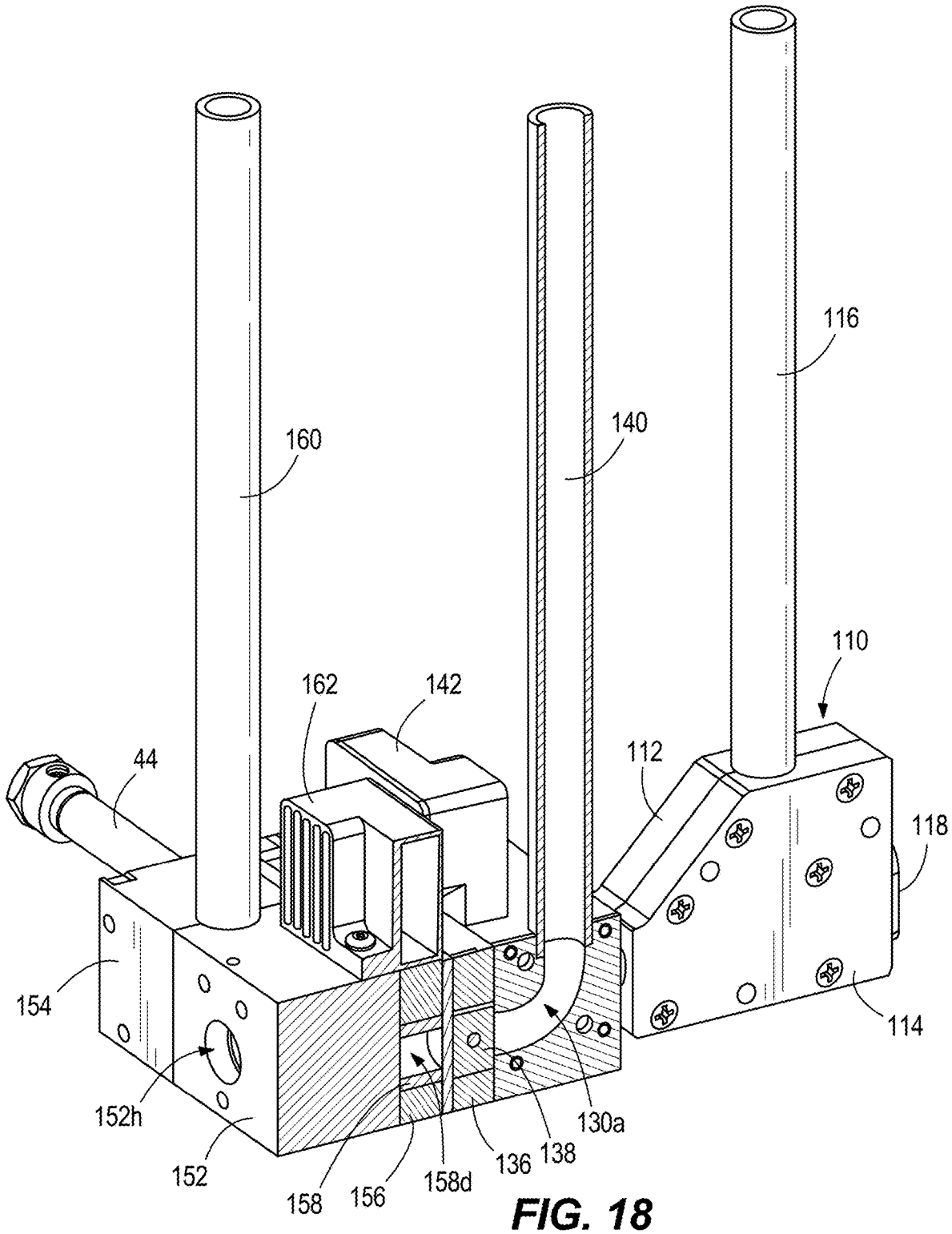
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FIG. 18

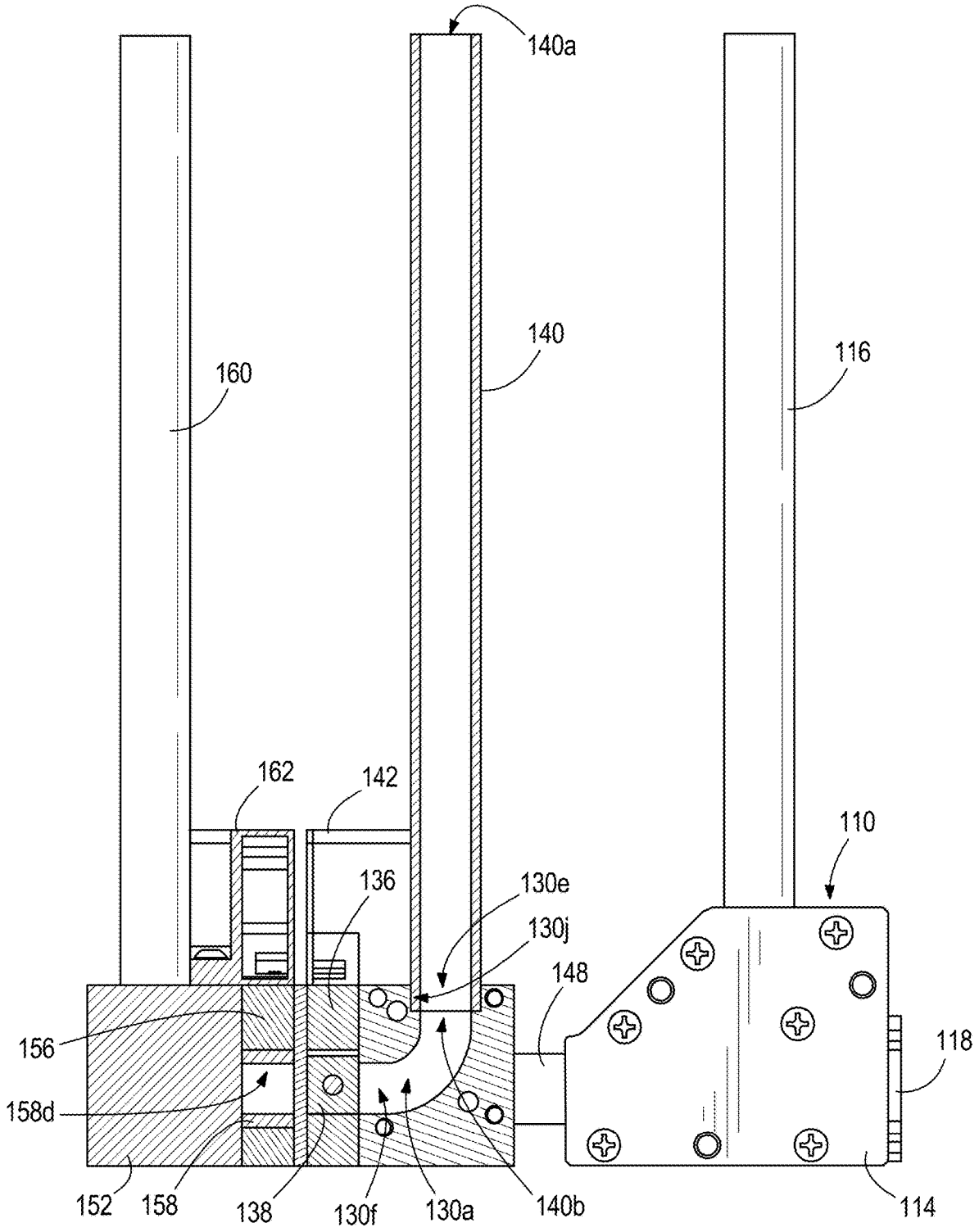
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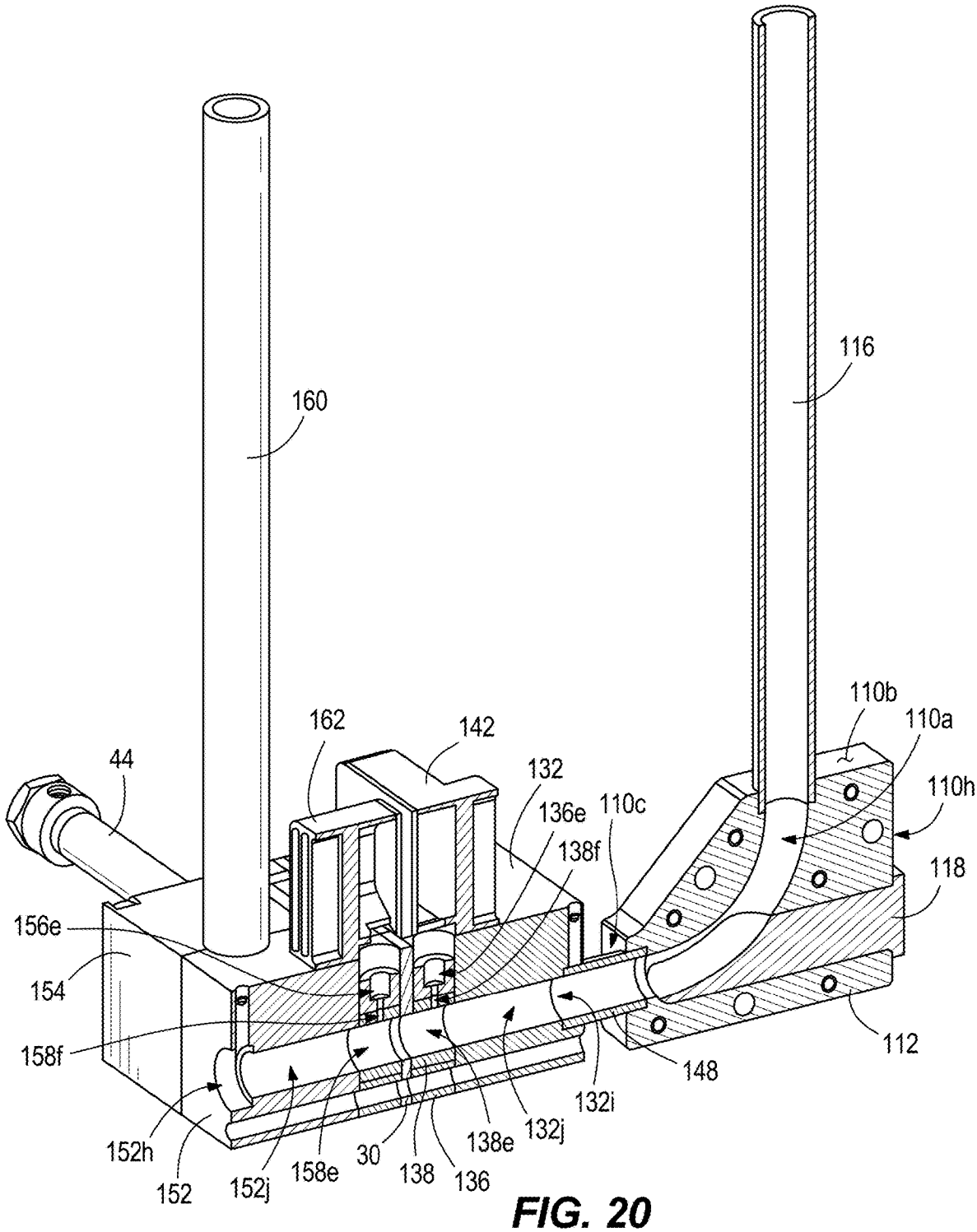
FIG. 19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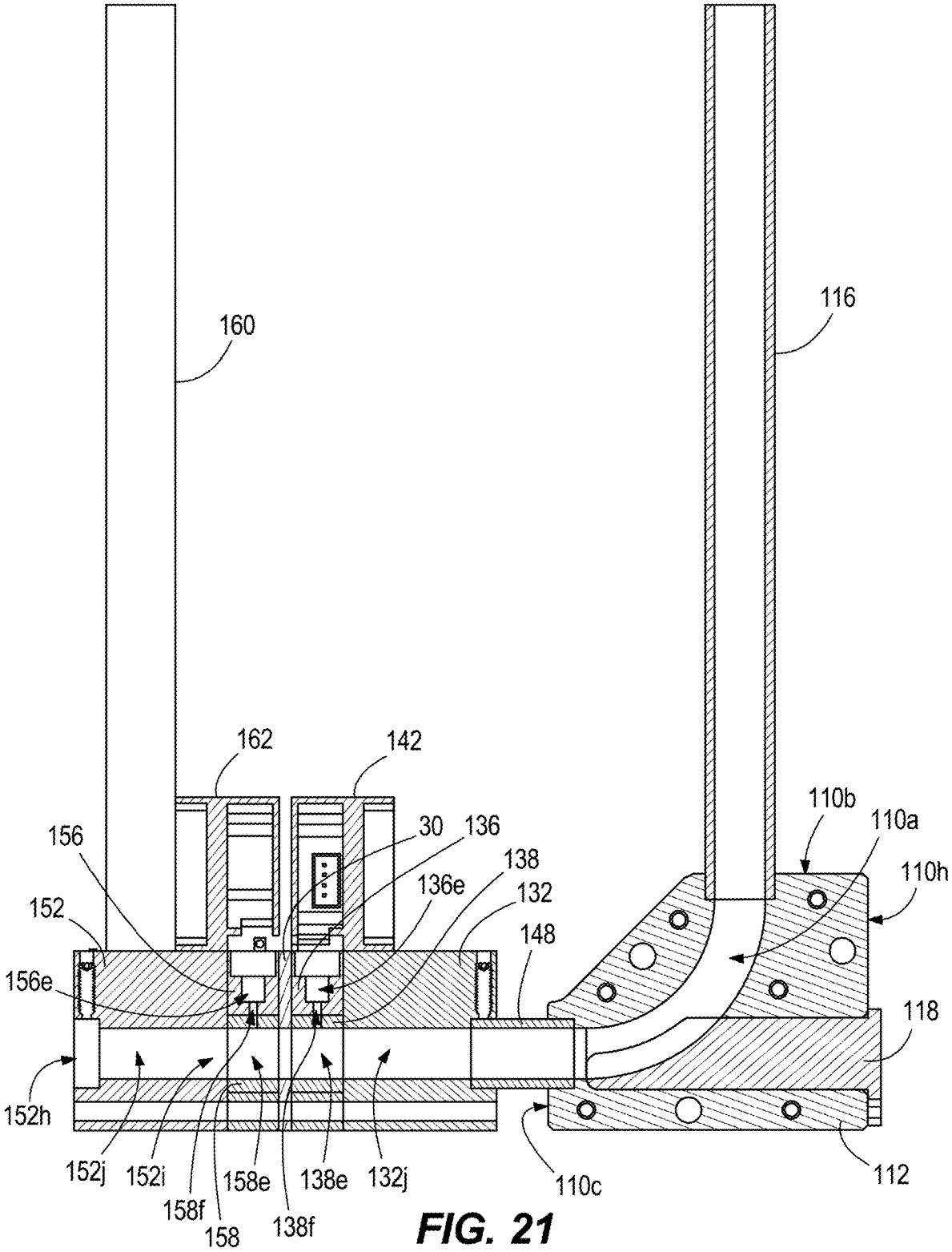
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FIG. 21

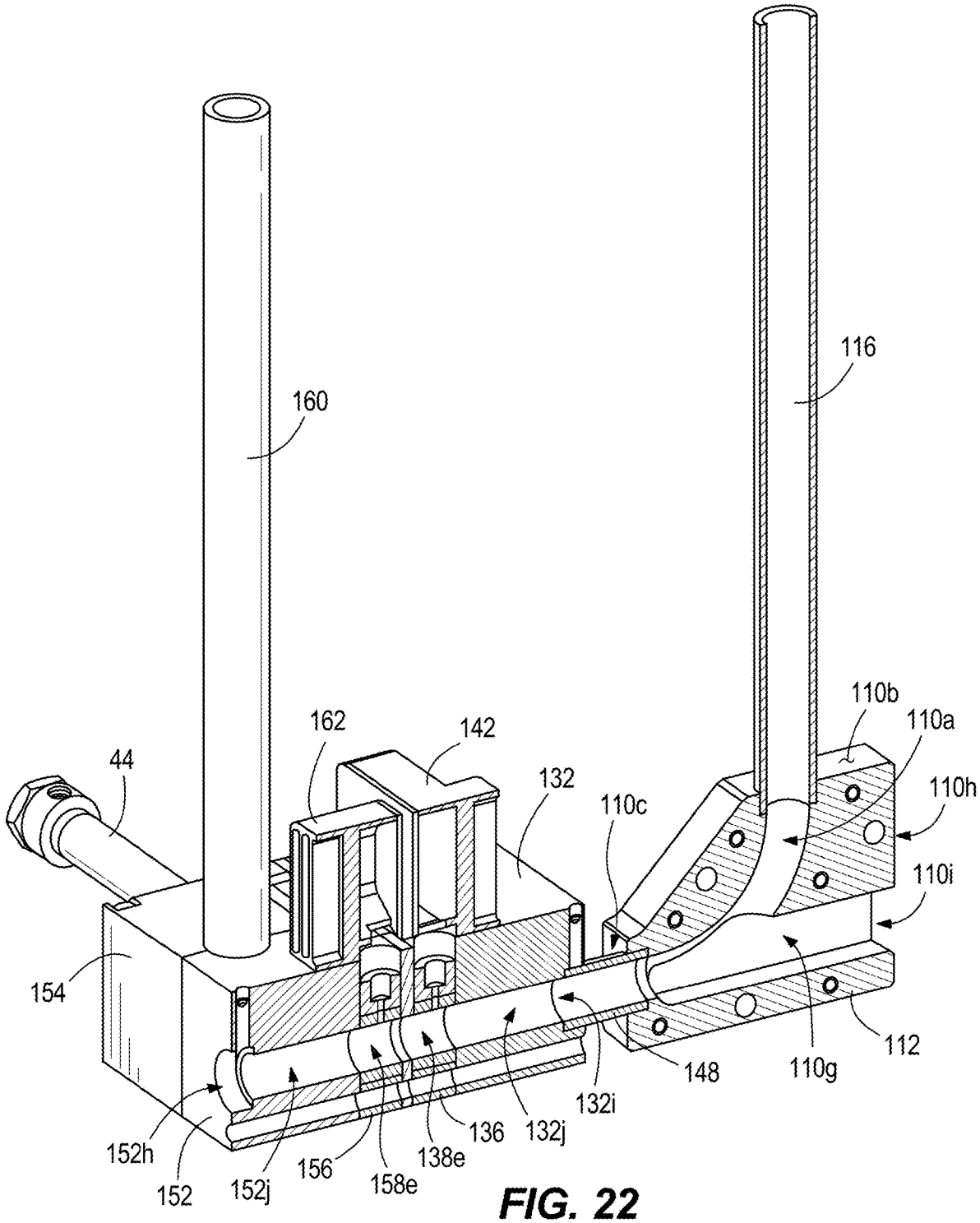
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FIG. 22

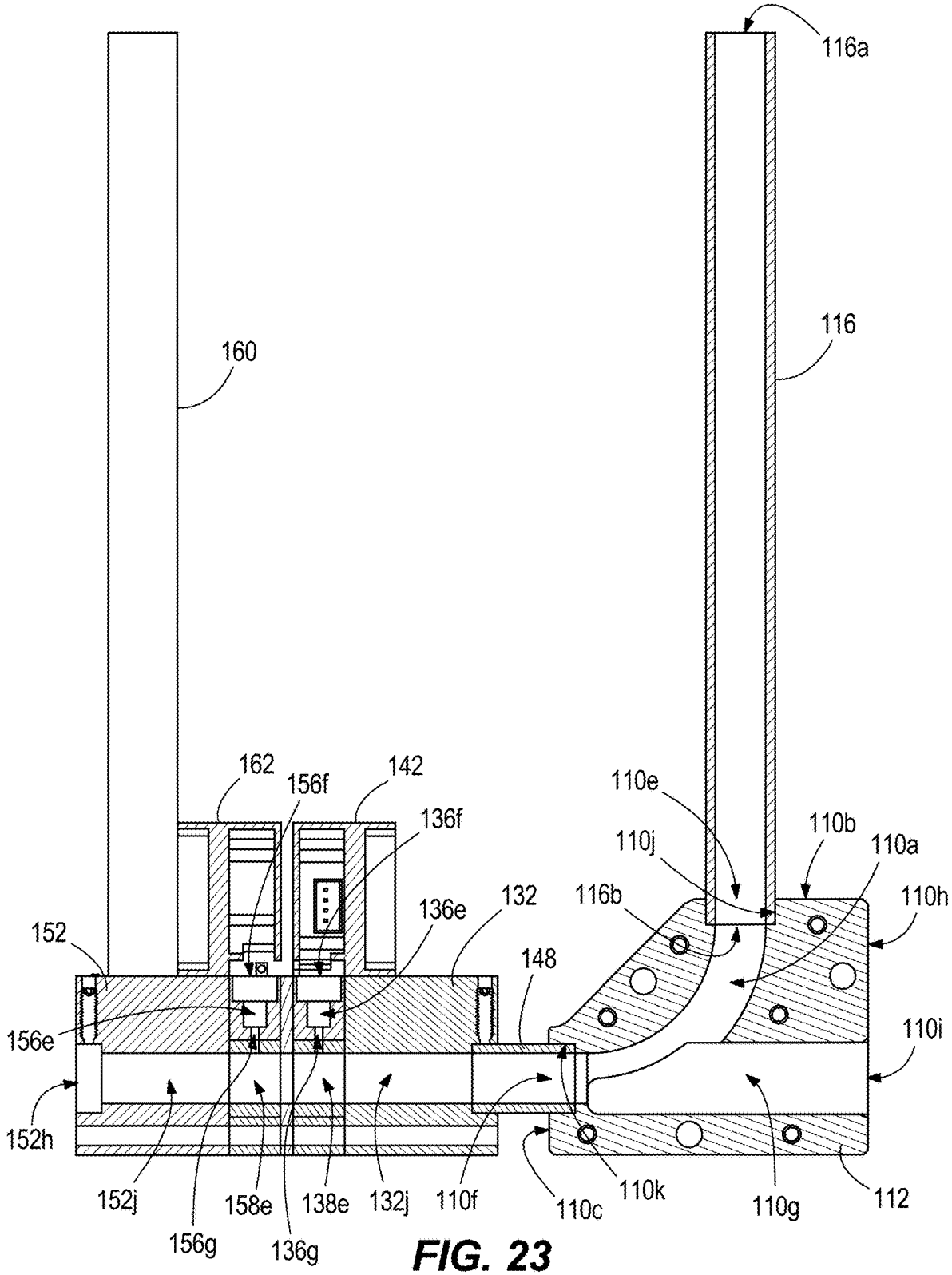
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FIG. 23

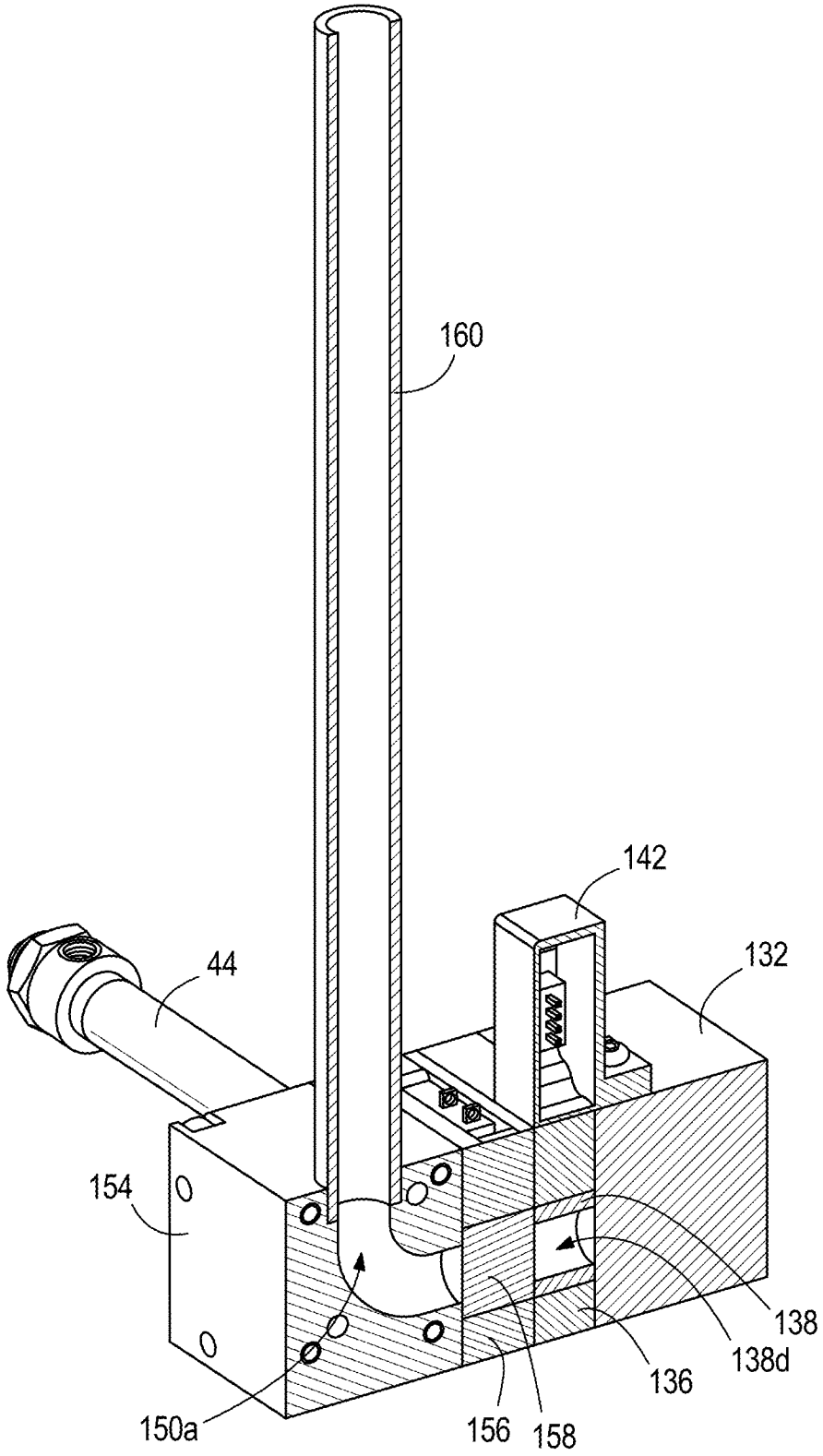
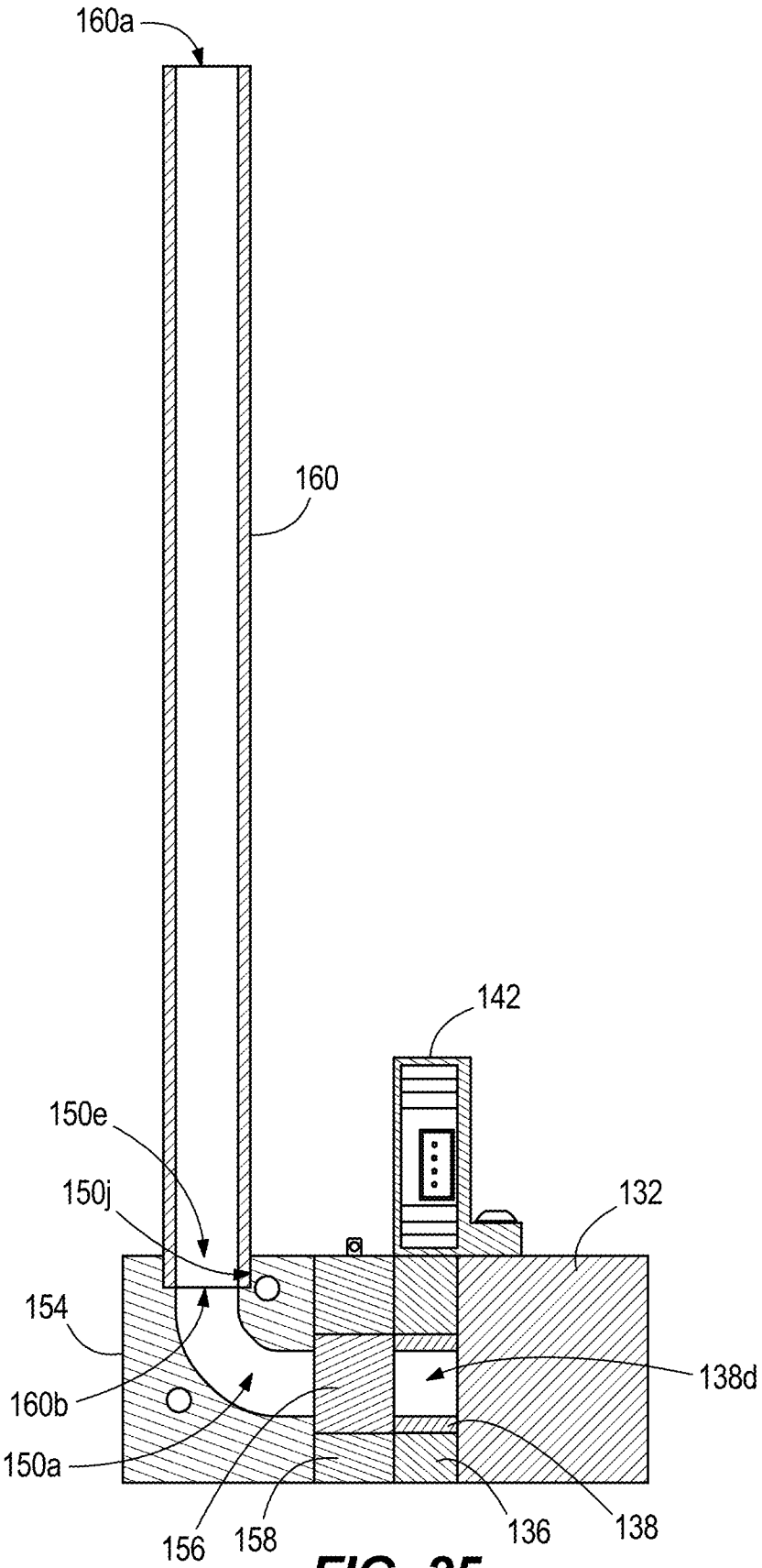


FIG. 24



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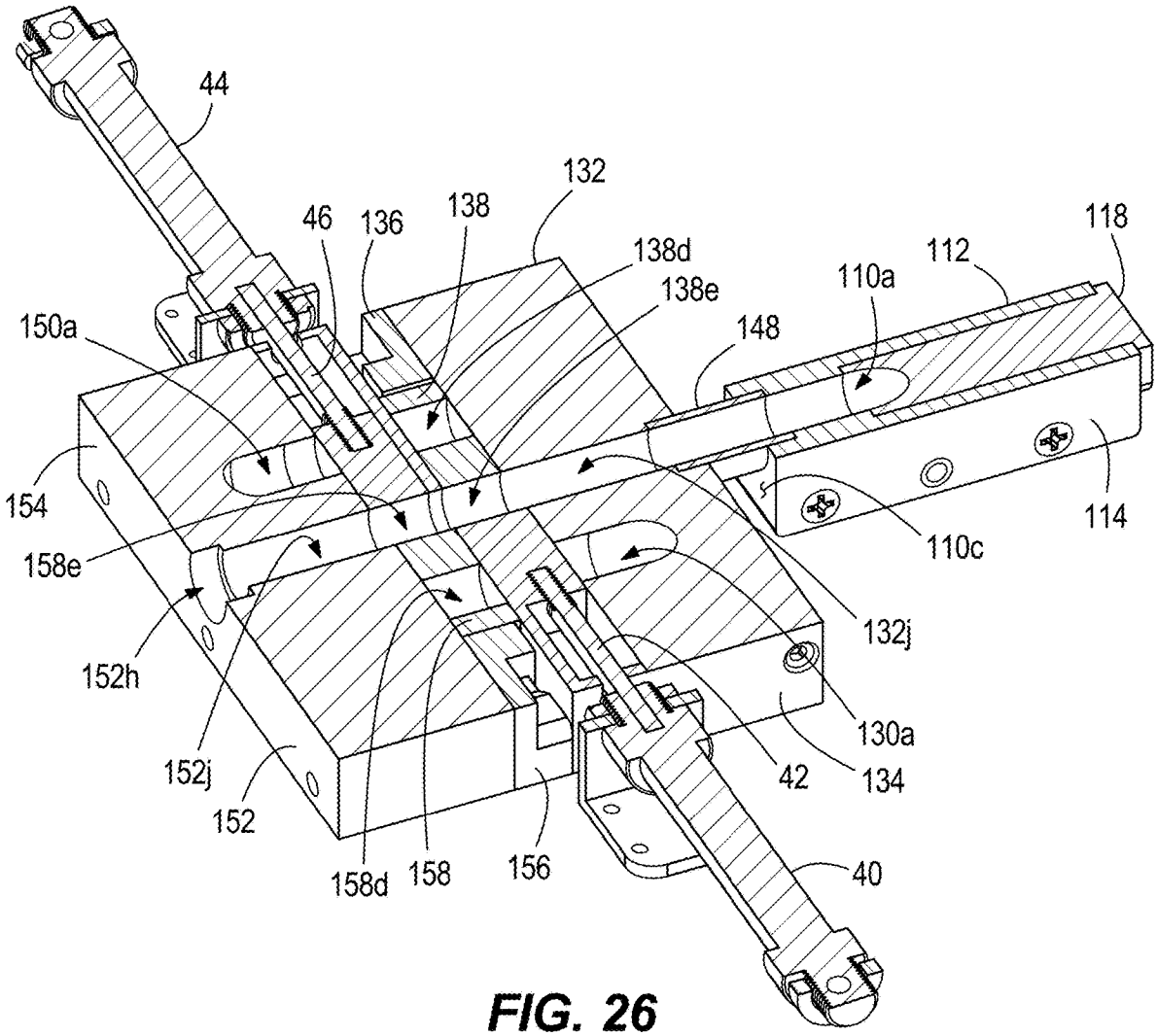
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FIG. 26

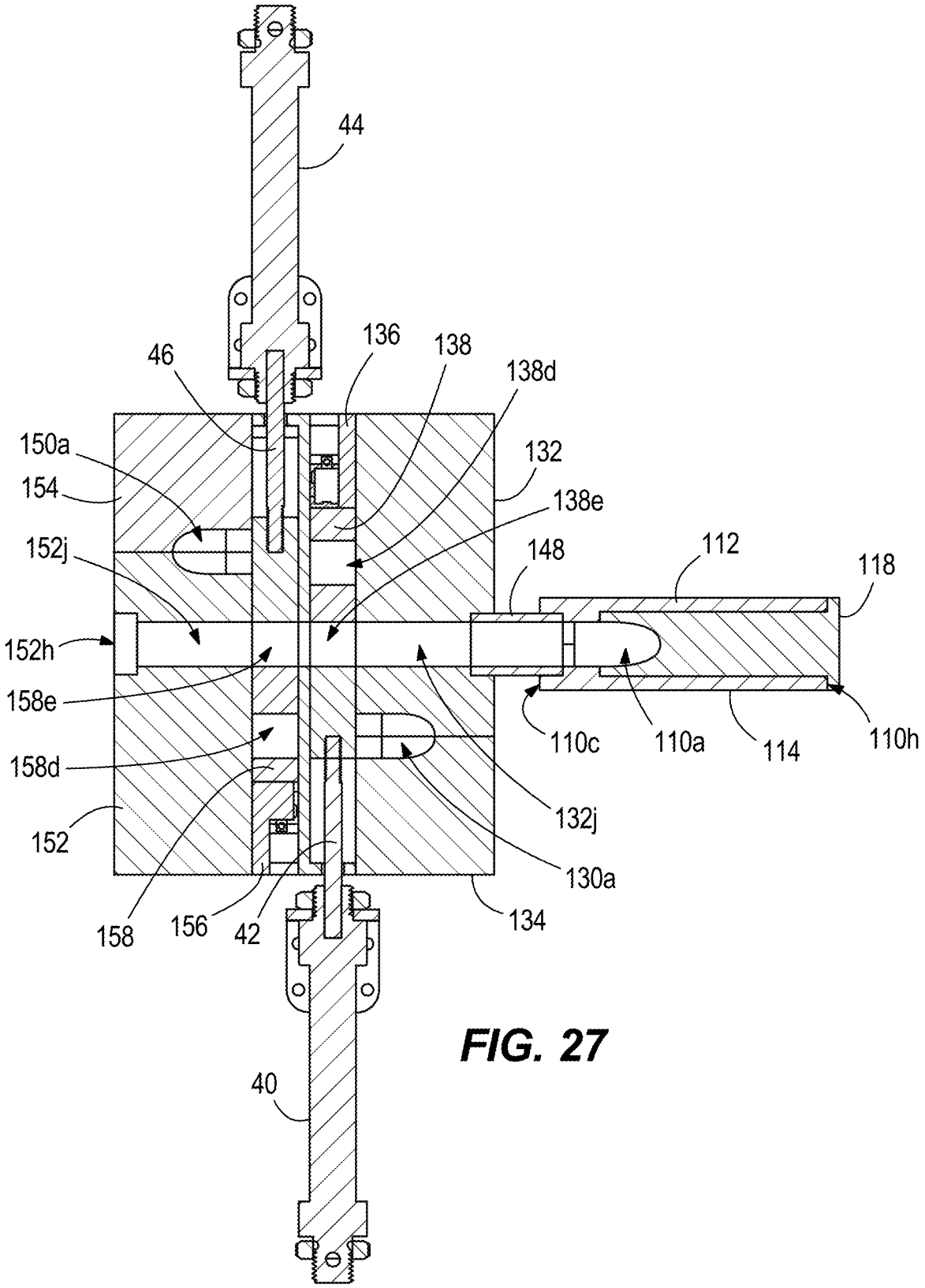
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FIG. 27

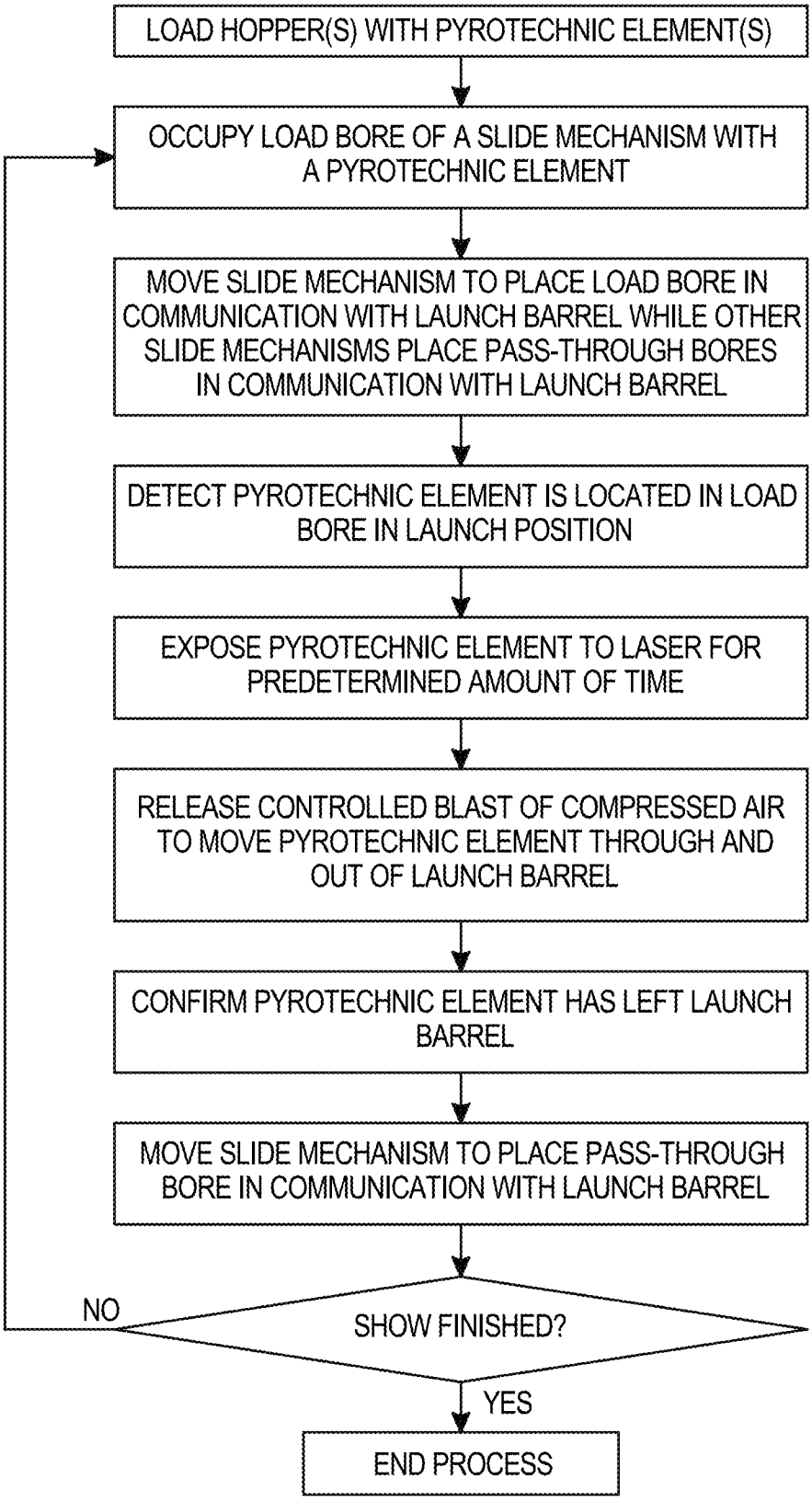
LOAD HOPPER(S) WITH PYROTECHNIC ELEMENT(S)
OCCUPY LOAD BORE OF A SLIDE MECHANISM WITH A PYROTECHNIC ELEMENT
MOVE SLIDE MECHANISM TO PLACE LOAD BORE IN COMMUNICATION WITH LAUNCH BARREL WHILE OTHER SLIDE MECHANISMS PLACE PASS-THROUGH BORES IN COMMUNICATION WITH LAUNCH BARREL
DETECT PYROTECHNIC ELEMENT IS LOCATED IN LOAD BORE IN LAUNCH POSITION
EXPOSE PYROTECHNIC ELEMENT TO LASER FOR PREDETERMINED AMOUNT OF TIME
RELEASE CONTROLLED BLAST OF COMPRESSED AIR TO MOVE PYROTECHNIC ELEMENT THROUGH AND OUT OF LAUNCH BARREL
CONFIRM PYROTECHNIC ELEMENT HAS LEFT LAUNCH BARREL
MOVE SLIDE MECHANISM TO PLACE PASS-THROUGH BORE IN COMMUNICATION WITH LAUNCH BARREL
SHOW FINISHED?
NO
YES
END PROCESS

FIG. 28

PYROTECHNIC LAUNCH UNITS AND SYSTEMS

PRIORITY CLAIM

The present application is a continuation of U.S. Non-Provisional application Ser. No. 17/802,366, filed on Aug. 25, 2022, which is a national phase application of International App. No. PCT/US2021/021707, filed on Mar. 10, 2021, which is based on and claims priority to U.S. Provisional App. No. 62/987,991 filed on Mar. 11, 2020, the entire contents of which are incorporated by reference herein.

FIELD

This disclosure pertains to units and systems for launching pyrotechnic elements and, more particularly, to units and systems for launching multiple laser-ignited pyrotechnic elements with precision and in rapid succession.

BACKGROUND

Pyrotechnics are often used for entertainment purposes. For example, brightly colored burning pyrotechnic elements are launched into the air to provide light shows associated with outside concerts, sporting events, and holiday celebrations such as the Fourth of July or New Year's Eve. These elements are made from pyrotechnic compositions including, for example, metallic powders, salts, and other compounds which, when ignited, burn with a predetermined color or with a sparking effect.

The pyrotechnic elements usually include priming elements such as black powder, which is typically applied to the surface of the pyrotechnic elements. Also, pyrotechnic elements for such applications are typically launched using a lifting charge. The lifting charge is ignited with sparks or flames, which light the priming elements, or the priming elements may be separately ignited.

Conventional pyrotechnic systems have a number of drawbacks including the smoke and debris produced by the priming elements and lifting charge, which may be distracting and physically irritating to spectators. Priming elements and lifting charges may also be environmentally undesirable particularly where the debris falls to the ground including soil or bodies of water in and around the launch site. Also, the launch and detonation of the pyrotechnic elements are subject to significant limitations arising from the use of the priming elements and lifting charges, making it difficult if not impossible to launch and ignite successive pyrotechnic elements in short precise periods of time. Finally, the use of black powder priming elements and lifting charges requires special care to avoid injury.

The trajectories and distances traversed by the pyrotechnic elements launched in prior art pyrotechnic systems are imprecise and not generally reproducible, particularly when multiple pyrotechnic elements are launched in succession with short intervals between launches. The lack of precision and repeatability in such prior art systems makes it difficult to produce optimal synchronized pyrotechnic displays.

SUMMARY

Embodiments of the invention comprise apparatuses and systems for launching multiple laser-ignited pyrotechnic elements with precision and in rapid succession.

In one embodiment, a pyrotechnic launch unit includes an elbow module, a first module, and a second module. The elbow module includes a launch barrel, an elbow passage, and a coupling tube. The elbow passage is in communication with the launch barrel. The coupling tube is in communication with the elbow passage. The first module is coupled to the elbow module. The first module includes an output passage, a first slide member, a first delivery passage, a first hopper tube, and a first laser ignition module. The output passage is in communication with the coupling tube. The first slide member includes a first pass-through bore, a first load bore, and a first laser opening. The first laser opening is in communication with the first load bore. Each of the first pass-through bore and the first load bore is in selective communication with the output passage. The first delivery passage is in selective communication with the first load bore. The first hopper tube is in communication with the first delivery passage. The first laser ignition module is configured to project a first laser through the first laser opening. The second module is coupled to the first module. The second module includes a second slide member, a second delivery passage, a second hopper tube, and a second laser ignition module. The second slide member includes a second load bore and a second laser opening. The second laser opening is in communication with the second load bore. The second load bore is in selective communication with the output passage. The second delivery passage is in selective communication with the second load bore. The second hopper tube is in communication with the second delivery passage. The second laser ignition module is configured to project a second laser through the second laser opening.

In one embodiment, a modular pyrotechnic launch unit includes a launch module, a first module, and a second module. The launch module includes a launch barrel. The first module is coupled in series to the launch module. The first module includes a first ignition state in which the first module is configured to ignite a pyrotechnic element that will then pass through the launch barrel. The first module also includes a first pass-through state in which the first module is configured to allow a pyrotechnic element ignited by another module to pass through the first module. The second module is coupled in series to the first module. The second module includes a second ignition state in which the second module is configured to ignite a pyrotechnic element that will then pass through the first module and through the launch barrel.

In one embodiment, a pyrotechnic launch unit includes an elbow module, a front module, a first slide retaining block, a second slide retaining block, and a rear module. The front module and the rear module each have a chamber for receiving a pyrotechnic element from a hopper loaded with pyrotechnic elements. A hopper is mounted to each of the front and rear modules to provide successive elements for loading and launching. A slide mechanism located in the slide retaining block receives the successive pyrotechnic elements and transports them to a launch position.

A laser ignition module is attached to each slide retainer. This module preferably is positioned so that the laser is about 0.75 to 1.0 inch above the pyrotechnic element in the slide mechanism after it has entered its launch position. The laser beam passes through a channel to minimize "blow-back" from the pyrotechnic elements once ignited and also to minimize air loss during the launch. The laser beam will be focused so that it contacts sufficient surface area of the pyrotechnic element to ensure proper ignition.

Preferably, the laser ignition module will have a fixed focal length. It should be mounted so that the laser beam stays in focus and remains aligned with the channel through which it is fired. Preferably the laser will be a pulsed laser

diode with a wavelength in the range of about 300 nm to 495 nm. Currently, the preferred wavelength is believed to be about 445 nm.

Embodiments also include a regulated air supply that is activated each time a pyrotechnic element is in the launch position to thrust the pyrotechnic element with a blast of air. The regulated air supply is variable so that the force of air may be adjusted as desired to launch the pyrotechnic element at as precise an altitude and as precise a velocity as desired. A launch apex of between 15 and 85 feet may, for example, be achieved with the current embodiments. Yet higher launches may also be achieved. The use of a blast of air to thrust the pyrotechnic element into the air in lieu of the more conventional black powder lifting charge is highly desirable because, among other things, it eliminates the smoke and debris produced by conventional systems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an isometric view of a pyrotechnic launch unit according to embodiments disclosed herein.

FIG. **2** illustrates a right side elevation view of the pyrotechnic launch unit of FIG. **1**.

FIG. **3** illustrates a rear elevation view of the pyrotechnic launch unit of FIG. **1**.

FIG. **4** illustrates a right side elevation view of the pyrotechnic launch unit of FIG. **1**.

FIG. **5** illustrates a front elevation view of the pyrotechnic launch unit of FIG. **1**.

FIG. **6** illustrates a top plan view of the pyrotechnic launch unit of FIG. **1**.

FIG. **7** illustrates a bottom plan view of the pyrotechnic launch unit of FIG. **1**.

FIG. **8** illustrates an isometric view of an elbow module of the pyrotechnic launch unit of FIG. **1**.

FIG. **9** illustrates an exploded isometric view of the elbow module of FIG. **8**.

FIG. **10** illustrates an isometric view of the elbow module and a portion of the first module of the pyrotechnic launch unit of FIG. **1**.

FIG. **11** illustrates an exploded isometric view of the elbow module and the portion of the first module of FIG. **10**.

FIG. **12** illustrates an isometric view of the elbow module and the first module of the pyrotechnic launch unit of FIG. **1**.

FIG. **13** illustrates an isometric view of a first slide member of the first module of FIG. **12**.

FIG. **14** illustrates an isometric view of the elbow module, the first module, and a retainer plate of the pyrotechnic launch unit of FIG. **1**.

FIG. **15** illustrates an isometric view of the elbow module, the first module, the retainer plate, and a portion of the second module of the pyrotechnic launch unit of FIG. **1**.

FIG. **16** illustrates an isometric view of a second slide member of the second module of the pyrotechnic launch unit of FIG. **1**.

FIG. **17** illustrates a partially exploded isometric view of the pyrotechnic launch unit of FIG. **1**.

FIG. **18** illustrates an isometric cross-sectional view of the pyrotechnic launch unit of FIG. **1**.

FIG. **19** illustrates a right side elevation view of the cross-section of FIG. **18**.

FIG. **20** illustrates another isometric cross-sectional view of the pyrotechnic launch unit of FIG. **1**.

FIG. **21** illustrates a right side elevation view of the cross-section of FIG. **20**.

FIG. **22** illustrates another isometric cross-sectional view of the pyrotechnic launch unit of FIG. **1**.

FIG. **23** illustrates a right side elevation view of the cross-section of FIG. **22**.

FIG. **24** illustrates another isometric cross-sectional view of the pyrotechnic launch unit of FIG. **1**.

FIG. **25** illustrates a right side elevation view of the cross-section of FIG. **24**.

FIG. **26** illustrates another isometric cross-sectional view of the pyrotechnic launch unit of FIG. **1**.

FIG. **27** illustrates a top plan view of the cross-section of FIG. **26**.

FIG. **28** illustrates a flow chart schematically representing a method of operating the pyrotechnic launch unit of FIG. **1**.

DETAILED DESCRIPTION

Features, objects, and advantages of embodiments may be best understood by reference to the following description, taken in connection with the drawings, in which like reference numerals identify like elements in the several figures.

The pyrotechnic elements, which are sometimes referred to as "stars," burn to produce various bright and vivid predetermined colors and/or sparking effects. The pyrotechnic elements burn but do not explode. The pyrotechnic elements have a burn rate that varies depending on the size, density, geometry, composition, and other properties of the pyrotechnic element. The burn rate of pyrotechnic elements is typically available from their manufacturers.

In some embodiments, the pyrotechnic elements are spherical in shape. In other embodiments, the pyrotechnic elements are cylindrical in shape. Whatever shape of pyrotechnic element is used, it is beneficial if the elements are substantially uniform in density and outer surface to ensure reproducible launch trajectories.

The pyrotechnic elements are made of, for example, metal powders, salts, and other compounds which, when ignited, burn with the desired color or colors and/or with a sparking effect. Pyrotechnic elements made with nitrocellulose compositions are particularly preferred since they do not produce significant amounts of smoke after launch.

Referring now to the Figures, an elbow module (or launch module) **110** includes a first block **112**, a second block **114**, a barrel (or launch barrel) **116**, and optionally a member **118**. First block **112** has an interior surface **112***a* and an exterior surface **112***b*. A first hollowed portion **112***c* extends from a top edge **112***d* to a first side edge **112***e* of the first block **112**. Optionally, a second hollowed portion **112***f* extends from the first hollowed portion **112***c* to a second side edge **112***g* located opposite first side edge **112***e*. Second block **114** has an interior surface **114***a* and an exterior surface **114***b*. A first hollowed portion **114***c* extends from a top edge **114***d* to a first side edge **114***e* of the second block **114**. The first hollowed portion **114***c* of second block **114** is the mirror image of the first hollowed portion **112***c* of first block **112**. Optionally, a second hollowed portion **114***f* extends from the first hollowed portion **114***c* to a second side edge **114***g* located opposite first side edge **114***e*. The second hollowed portion **114***f* of second block **114** is the mirror image of the first hollowed portion **112***f* of first block **112**.

First block **112** is fastened to second block **114** such that interior surface **112***a* abuts interior surface **114***a* and first hollowed portion **112***c* and first hollowed portion **114***c* form a chamber (or elbow passage) **110***a* that extends from a top surface **110***b* to a first side surface **110***c*. Chamber **110***a* has a cross-section **110***d*, an opening **110***e* at top surface **110***b*, and an opening **110***f* at first side surface **110***c*. Preferably,

openings **110***e* and **110***f* are circular openings. Chamber **110***a* is formed in the shape of an elbow having an angle θ between 90° and 135°. Preferably angle θ is 90°.

If second hollowed portions **112***f* and **114***f* are present, together they form a cavity **110***g* that extends from chamber **110***a* to a second side surface **110***h* opposite first side surface **110***c*. Cavity **110***g* provides access to chamber **110***a* to facilitate cleaning chamber **110***a* or removing any obstructions from chamber **110***a*. Cavity **110***g* has an opening **110***i* on a second surface **110***h*.

Member **118** is removably secured in cavity **110***g* and it is sized and shaped to complete the elbow shape of chamber **110***a*.

Barrel **116** is a cylindrical tube having a first opening **116***a* at one end and a second opening **116***b* at the opposite end. Barrel **116** is attached to opening **110***e* on top surface **110***b*. Preferably, barrel **116** is attached into a counterbore **110***j* located around opening **110***e*.

In some embodiments, a single block may replace first and second blocks **112**, **114**. The blocks in any of the embodiments can be machined to form chambers and cavities using methods such as drilling, CNC machining, electrochemical machining, electrochemical discharge machining, electric discharge machining, or other methods known to a skilled artisan.

A front module (or first module) **130** is coupled in series to the launch module **110**. The first module **130** includes a first front block **132**, a second front block **134**, a first slide retainer block **136**, a slide mechanism (or first slide member) **138**, a first hopper tube **140**, and a first laser ignition module **142**. First front block **132** has an interior surface **132***a* and an exterior surface **132***b*. A first hollowed portion **132***c* extends from a top edge **132***d* to a first side edge **132***e* of the first front block **132**. Second front block **134** has an interior surface **134***a* and an exterior surface **134***b*. A first hollowed portion **134***c* extends from a top edge **134***d* to a first side edge **134***e* of the second front block **134**. The first hollowed portion **134***c* of second block **134** is the mirror image of the first hollowed portion **132***c* of first front block **132**. First front block **132** has first side surface **132***f* and a second side surface **132***g* opposite first side surface **132***f*. First side surface **132***f* has a first opening **132***h* and second side surface **132***g* has a second opening **132***i*. A pass-through chamber (or output passage) **132***j* extends from first opening **132***h* to second opening **132***i*. Preferably, first opening **132***h* and second opening **132***i* are circular and pass-through chamber **132***j* is preferably cylindrical.

First front block **132** is fastened to second front block **134** such that interior surface **132***a* abuts interior surface **134***a* and first hollowed portion **132***c* and first hollowed portion **134***c* form a chamber (or first delivery passage) **130***a* that extends from a top surface **130***b* to a first side surface **130***c*. Chamber **130***a* has a cross-section **130***d*, an opening **130***e* at top surface **130***b*, and an opening **130***f* at first side surface **130***c*. Preferably, openings **130***e* and **130***f* are circular openings. Chamber **130***a* is formed in the shape of an elbow having an angle α between 90° and 135°. Preferably angle α is 90°.

Hopper tube **140** is a tube having a first opening **140***a* at one end and a second opening **140***b* at the opposite end. Hopper tube **140** is attached to opening **130***e* on top surface **130***b*. Preferably, hopper tube **140** is attached into a counterbore **130***j* located around opening **130***e*. Preferably, hopper tube **140** is cylindrical.

First slide retainer block **136** has a top surface **136***a*, an elongated cavity **136***b*, an inner surface **136***c*, and a side surface **136***d*. Inner surface **136***c* is opposite top surface **136***a*. A bore **136***e* extends from top surface **136***a* to inner surface **136***c* forming an opening **136***f* on top surface **136***a* and an opening **136***g* in inner surface **136***c*.

Slide mechanism **138** has front surface **138***a*, rear surface **138***b* opposite front surface **138***a*, and a top surface **138***c*. Slide mechanism **138** is slidably mounted in elongated cavity **136***b*. Preferably, front surface **138***a* and rear surface **138***b* are flat. Slide mechanism **138** includes a first pass-through bore **138***d* and a first load bore **138***e* each extending from front surface **138***a* to rear surface **138***b*. A bore **138***f* extends from top surface **138***c* to load bore **138***e* forming an opening (or first laser opening) **138***g* on top surface **138***c*.

First slide retainer block **136** is fastened to first front block **132** and second front block **134**. Preferably, first slide retainer block **136** is fastened with screws.

Slide mechanism **138** is driven by a first piston **40** that is attached to slide mechanism **138** by a first piston rod **42**. Piston **40** may be pneumatic or hydraulic; preferably, it is a pneumatic piston. Piston **40** moves slide mechanism **138** between a load position and a launch position.

In the load position (or first load state), load bore **138***e* is positioned to align with opening **130***f* of chamber **130***a* to receive successive pyrotechnic elements from hopper tube **140** and chamber **130***a* and pass-through bore **138***d* is positioned to align with pass-through chamber **132***j*. In this sense, the first load state coincides with a first pass-through state.

In the launch position (or first ignition state), load bore **138***e* is positioned to align with pass-through chamber **132***j* and bore **138***f* of slide mechanism **138** is positioned to align with bore **136***e* of first slide retainer block **136**. When bore **138***f* is aligned with bore **136***e*, they form a laser beam channel.

Laser ignition module **142** is disposed on top surface **136***a* of first slide retainer block **136**. Laser ignition module **142** includes a laser diode and a lens. Laser diode produces a laser beam to ignite the pyrotechnic element before launch. Laser beam passes through laser beam channel. Laser beam channel is intended to minimize "blowback" from the pyrotechnic element and therefore is dimensioned to allow laser beam to pass through the channel while minimizing loss of air pressure during launch. Preferably, laser beam channel has a diameter that is at least 2 millimeters and more preferably 5 millimeters. The laser ignition module **142** is programmed to project a laser for a predetermined amount of time, such as 10 milliseconds to 50 milliseconds.

In a preferred embodiment, a coupling tube **148** has an end **148***a* and an end **148***b* opposite end **148***a*. End **148***a* is attached into a counterbore **110***k* located around opening **110***f* and end **148***b* is attached into a counterbore **132***k* located around opening **132***i*.

A rear module (or second module) **150** is coupled in series to the first module **130**. The rear module **150** includes a first rear block **152**, a second rear block **154**, a second slide retainer block **156**, a slide mechanism (or second slide member) **158**, a second hopper tube **160**, and a second laser ignition module **162**. First rear block **152** has an interior surface **152***a* and an exterior surface **152***b*. A first hollowed portion **152***c* extends from a top edge **152***d* to a first side edge **152***e* of the first rear block **152**. Second rear block **154** has an interior surface **154***a* and an exterior surface **154***b*. A first hollowed portion **154***c* extends from a top edge **154***d* to a first side edge **154***e* of the second rear block **154**. The first hollowed portion **154***c* of second rear block **154** is the mirror image of the first hollowed portion **152***c* of first rear block **152**. First rear block **152** has first side surface **152***f* and a second side surface **152***g* opposite first side surface **152***f*

First side surface **152***f* has a first opening **152***h* and second side surface **152***g* has a second opening **152***i*. A pass-through chamber (or air input passage) **152***j* extends from first opening **152***h* to second opening **152***i*. Preferably, first opening **152***h* and second opening **152***i* are circular and pass-through chamber **152***j* is preferably cylindrical. In some embodiments, the pass-through chamber **152***j* receives pressurized air therethrough to launch the pyrotechnic elements.

First rear block **152** is fastened to second rear block **154** such that interior surface **152***a* abuts interior surface **154***a* and first hollowed portion **152***c* and first hollowed portion **154***c* form a chamber (or second delivery passage) **150***a* that extends from a top surface **150***b* to a first side surface **150***c*. Chamber **150***a* has a cross-section **150***d*, an opening **150***e* at top surface **150***b*, and an opening **150***f* at first side surface **150***c*. Preferably, openings **150***e* and **150***f* are circular openings. Chamber **150***a* is formed in the shape of an elbow having an angle β between 90° and 135°. Preferably angle β is 90°.

Hopper tube **160** is a tube having a first opening **160***a* at one end and a second opening **160***b* at the opposite end. Hopper tube **160** is attached to opening **150***e* on top surface **150***b*. Preferably, hopper tube **160** is attached into a counterbore **150***j* located around opening **150***e*. Preferably, hopper tube **160** is cylindrical.

Second slide retainer block **156** has a top surface **156***a*, an elongated cavity **156***b*, an inner surface **156***c*, and a side surface **156***d*. Inner surface **156***c* is opposite top surface **156***a*. A bore **156***e* extends from top surface **156***a* to inner surface **156***c* forming an opening **156***f* on top surface **156***a* and an opening **156***g* in inner surface **156***c*.

Slide mechanism **158** has front surface **158***a*, rear surface **158***b* opposite front surface **158***a*, and a top surface **158***c*. Slide mechanism **158** and is slidably mounted in elongated cavity **156***b*. Preferably, front surface **158***a* and rear surface **158***b* are flat. Slide mechanism **158** includes a pass-through bore **158***d* and a second load bore **158***e* each extending from front surface **158***a* to rear surface **158***b*. A bore **158***f* extends from top surface **158***c* to load bore **158***e* forming an opening (or second laser opening) **158***g* on top surface **158***c*.

Second slide retainer block **156** is fastened to first rear block **152** and second rear block **154**. Preferably, second slide retainer block **156** is fastened with screws.

Slide mechanism **158** is coupled to a driving mechanism. In one embodiment, the driving mechanism comprises a second piston **44** that is attached to slide mechanism **158** by a second piston rod **46**. Piston **44** may be pneumatic or hydraulic; preferably, it is a pneumatic piston. Piston **44** moves slide mechanism **158** between the load position and the launch position.

In another embodiment, the driving mechanism comprises a motor that is coupled to slide mechanism **158**. The motor can be a linear motor, a servo motor, a stepper motor, or any motor that can drive slide mechanism **158** in a linear motion.

In the load position (or second load state), load bore **158***e* is positioned to align with opening **150***f* of chamber **150***a* to receive successive pyrotechnic elements from hopper tube **160** and chamber **150***a* and pass-through bore **158***d* is positioned to align with pass-through chamber **152***j*. In this sense, the second load state coincides with a second pass-through state. In some embodiments, only pressurized air travels through the pass-through bore **158***d*. In other embodiments, however, pyrotechnic elements from upstream modules also travel through pass-through bore **158***d*.

In the launch position (or second ignition state), load bore **158***e* is positioned to align with pass-through chamber **152***j* and bore **158***f* of slide mechanism **158** is positioned to align with bore **156***e* of second slide retainer block **156**. When bore **158***f* is aligned with bore **156***e*, they form a laser beam channel **22**.

Laser ignition module **162** is disposed on top surface **156***a* of second slide retainer block **156**. Laser ignition module **162** includes a laser diode **162***a* and a lens **162***b*. Laser diode **162***a* produces a laser beam **62** to ignite the pyrotechnic element before launch. Laser beam **62** passes through laser beam channel **22**. Laser beam channel **22** is intended to minimize "blowback" from the pyrotechnic element and therefore is dimensioned to allow laser beam **62** to pass through the channel while minimizing loss of air pressure during launch. Preferably, laser beam channel **22** has a diameter that is at least 2 millimeters and more preferably 5 millimeters. The laser ignition module **162** is programmed to project a laser for a predetermined amount of time, such as 10 milliseconds to 50 milliseconds.

Some embodiments have one or more hopper tubes that feed the pyrotechnic elements. Pyrotechnic launch assemblies including one, two, three, eight, or the like number of hopper tubes are contemplated herein.

The elbow module, such as elbow module **110**, can be fixed or pivotably attached to the front module **130**. When pivotably attached, the elbow module **110** pivots between −90° and 90°, for instance. The elbow module **110** can be pivoted to a specified angle between each launch of a pyrotechnic element.

An air supply system may be attached to the pyrotechnic launch assembly to provide compressed air to actuate the pistons **40**, **44**. The air supply system may include an air compressor, air tank, power source, air delivery lines, air pressure regulator, or the like to provide a desired output pressure of air to actuate the pistons **40**, **44**.

In some embodiments, a retainer plate **30** disposed between the first module **130** and the second module **150**. In the illustrated embodiment, the retainer plate **30** is coupled to each of the first slide retainer block **136** and the second slide retainer block **156**. The retainer plate **30** includes a bore **32** defined therein. The bore **32** allows pyrotechnic elements and/or pressurized air to pass therethrough.

In accordance with embodiments disclosed herein, multiple pyrotechnic elements (or spherical capsules containing multiple pyrotechnic elements) are loaded into each hopper tube of the pyrotechnic launch assembly. In some embodiments, each hopper may be loaded with pyrotechnic elements of a particular color or other display feature. Other embodiments allow for a mix of colors for the pyrotechnic elements of each hopper. Each slide mechanism of the pyrotechnic launch assembly is in the load position. A first pyrotechnic element may be received in the load bore of the slide mechanism. Pyrotechnic elements are launched in succession by operating the slide mechanisms one at a time in a predetermined or random launch cycle. The launch cycle starts when the slide mechanism is moved by its associated piston to transport pyrotechnic element into the launch position. In the launch position, a pyrotechnic element is located in the launch channel. While the pyrotechnic element is in the launch channel for one particular slide mechanism, all other slide mechanisms are placed in the pass-through position. The laser ignition module is activated to emit a laser beam that ignites the pyrotechnic element. The air supply system supplies a regulated blast of air to propel the ignited pyrotechnic element through the launch channel (and the pass-through channels of the other down-

stream slide mechanisms, if any are present), into the elbow module, and into the air to the desired elevation and trajectory. The launch cycle ends when the slide mechanism is moved by its associated piston to the load position to receive the next pyrotechnic element, which places the pass-through channel of the slide mechanism in the launch channel so another module may fire and launch its respective pyrotechnic element. Some embodiments further include one or more sensors confirming whether the previous pyrotechnic element has left the launch channel prior to firing another pyrotechnic element with a laser. In some embodiments, each launch cycle may be completed within 100 milliseconds.

For example, a pyrotechnic launch assembly may have multiple hopper tubes with each supplying pyrotechnic elements of different colors that are launched in a predetermined order starting from the front module and continuing with one or more additional modules from closest to farthest relative to the elbow module. The first launch cycle launches the pyrotechnic element in the front module. The second launch cycle launches the pyrotechnic element in the module closest to the front module. Depending on the number of modules, additional launch cycles will proceed after the second launch cycle, if additional modules are present. Launch cycles may be repeated until the hopper tubes are empty.

The above process can be controlled by onboard circuitry which may receive commands from a conventional DMX-based lighting console to achieve a rapid repeatable multiple pyrotechnic element launch process. In some embodiments, the programming and timing need not be adjusted by the user. However, variables including air pressure and height may still be user-controlled.

In addition, sensors such as optical sensors and limit switches may be included in the pyrotechnic launch assembly to monitor for obstructions, such as jammed pyrotechnic elements or slide mechanisms, or to monitor the launch cycles. Other embodiments include one or more sensors detecting whether a pyrotechnic element has been loaded for firing.

The force (e.g., pressure) of the regulated blast of air may depend in part on the burn rate of the pyrotechnic element and the desired height to which the pyrotechnic element will be propelled. The higher the burn rate, the greater the force of the regulated blast of air to propel a pyrotechnic element to the same height as a pyrotechnic element with a lower burn rate.

In some embodiments, the regulated blast of air is set to a fixed pressure within an appropriate range. In another embodiment, the regulated blast of air may be varied between launches to different pressures within the appropriate range. By varying the pressure, a pyrotechnic launch assembly with two or more hoppers may launch pyrotechnic elements having the same burn rate to different heights or pyrotechnic elements having different burn rates to the same height. For example, a pyrotechnic launch assembly with two hoppers, each loaded with the same type of pyrotechnic element, can be operated with a variable regulated blast of air to launch the elements to different heights. In another example, a pyrotechnic launch assembly with two hoppers—one hopper loaded with a pyrotechnic element having a faster burn rate than the other hopper—may be operated with variable regulated blast of air to launch the elements to the same height. The elements with the faster burn rate would require a regulated blast of air at a relatively higher pressure, whereas the elements with the slower burn rate would require a regulated blast of air at a relatively lower pressure.

Although only first and second modules **130**, **150** have been described and illustrated herein, further modules are also contemplated. In some embodiments, the pyrotechnic launch assembly is a modular pyrotechnic launch assembly that can be expanded or condensed in number of modules depending on the needs of a particular display to be created. In some embodiments, a third module that is identical to the first module **130** can be coupled in series to the second module **150**. A fourth module that is identical to the second module **150** can be coupled in series to the third module. In the illustrated embodiment, the first module **130** and second module **150** face each other with the retainer plate **30** disposed therebetween. The third and fourth module may similarly face each other, and the third module may be removably coupled to the second module.

The use of the terms "a" and "an" and "the" and similar references in the context of describing embodiments (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable other unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (i.e., "such as") provided herein, is intended merely to illuminate embodiments and does not pose a limitation on the scope of the embodiments unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the embodiments.

Variations of the described embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the embodiments to be practiced otherwise than as specifically described herein. Accordingly, embodiments include all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed embodiments unless otherwise indicated herein or otherwise clearly contradicted by context.

What is claimed is:

1. A pyrotechnic launch unit comprising:

a launch barrel;

a first member including a first pass-through bore and a first load bore defined therein, the first pass-through bore and the first load bore alternatively placed in communication with the launch barrel, the first pass-through bore configured to allow a pyrotechnic element to pass therethrough;

a first hopper in selective communication with the first load bore, the first hopper configured to deliver a first pyrotechnic element to the first load bore;

a second member including a second load bore defined therein, the second load bore in selective communication with the first pass-through bore;

a second hopper in selective communication with the second load bore, the second hopper configured to deliver a second pyrotechnic element to the second load bore;

wherein the first member is movable relative to the first hopper to load the first pyrotechnic element into the first load bore; and

the second member is movable relative to the second hopper to load the second pyrotechnic element into the second load bore.

2. The pyrotechnic launch unit of claim **1**, further comprising a first actuator coupled to the first member, the first actuator configured to move the first member to alternatively place the first pass-through bore and the first load bore in communication with the launch barrel.

3. The pyrotechnic launch unit of claim **2**, wherein the first actuator includes a pneumatic actuator.

4. A pyrotechnic launch unit comprising:

a launch barrel;

a first member including a first laser opening, a first pass-through bore, and a first load bore defined therein, the first pass-through bore and the first load bore alternatively placed in communication with the launch barrel, the first pass-through bore configured to allow a pyrotechnic element to pass therethrough;

a first hopper in selective communication with the first load bore, the first hopper configured to deliver a pyrotechnic element to the first load bore;

a second member including a second load bore defined therein, the second load bore in selective communication with the first pass-through bore;

a second hopper in selective communication with the second load bore, the second hopper configured to deliver a pyrotechnic element to the second load bore; and

a first laser ignition module positioned to project a first laser through the first laser opening.

5. The pyrotechnic launch unit of claim **4**, further comprising

the second member further including a second laser opening defined therein, and

a second laser ignition module positioned to project a second laser through the second laser opening.

6. The pyrotechnic launch unit of claim **1**, wherein the launch barrel is rotatable relative to the first member.

7. A pyrotechnic launch unit comprising:

a launch assembly;

a first pyrotechnic element delivery assembly coupled in series to the launch assembly, the first pyrotechnic element delivery assembly including

a first member having a plurality of bores defined therein, and

a first actuator configured to move the first member between a first ignition position and a first pass-through position, the first ignition position allowing a pyrotechnic element to be ignited and subsequently delivered through the launch assembly; and

a second pyrotechnic element delivery assembly coupled in series to the first pyrotechnic element delivery assembly, the second pyrotechnic element delivery assembly including

a second member having a bore defined therein, and

a second actuator configured to move the second member to a second ignition position, the second ignition position allowing a pyrotechnic element to be ignited and subsequently delivered through the first pyrotechnic element delivery assembly when in the first pass-through position and through the launch assembly.

8. The pyrotechnic launch unit of claim **7**, wherein each of the first actuator and the second actuator includes a pneumatic actuator.

9. The pyrotechnic launch unit of claim **7**, wherein

the second pyrotechnic element delivery assembly further includes an input passage in selective communication with the bore, and

the input passage is configured to receive pressurized air therethrough.

10. The pyrotechnic launch unit of claim **9**, wherein the pressurized air received through the input passage can be adjusted such that pyrotechnic elements launched by the pyrotechnic launch unit have a launch apex of between 15 and 85 feet.

11. The pyrotechnic launch unit of claim **7**, wherein the first pyrotechnic element delivery assembly and the second pyrotechnic element delivery assembly are made of identical components.

12. The pyrotechnic launch unit of claim **7**, wherein each of the first actuator and the second actuator includes a piston and a piston rod coupled to a corresponding one of the first member and the second member.

13. The pyrotechnic launch unit of claim **7**, wherein

the first actuator translatably moves the first member, and

the second actuator translatably moves the second member.

14. The pyrotechnic launch unit of claim **7**, further comprising a retainer plate disposed between the first pyrotechnic element delivery assembly and the second pyrotechnic element delivery assembly.

15. A pyrotechnic launch unit comprising:

a launch barrel;

an elbow passage in communication with the launch barrel;

a coupling tube in communication with the elbow passage;

a first pyrotechnic element delivery assembly including an output passage in communication with the coupling tube; and

a second pyrotechnic element delivery assembly including an input passage in communication with the output passage;

wherein the second pyrotechnic element delivery assembly is connected in series with the first pyrotechnic element delivery assembly, the coupling tube, the elbow passage, and the launch barrel; and

the pyrotechnic launch unit is configured to launch a pyrotechnic element from the input passage through the output passage, the coupling tube, the elbow passage, and the launch barrel.

16. The pyrotechnic launch unit of claim **15**, wherein the first pyrotechnic element delivery assembly and the second pyrotechnic element delivery assembly are made of identical components.

17. A pyrotechnic launch unit comprising:

a launch barrel;

an elbow passage in communication with the launch barrel;

a coupling tube in communication with the elbow passage;

a first pyrotechnic element delivery assembly including an output passage in communication with the coupling tube; and

a second pyrotechnic element delivery assembly including an input passage in communication with the output passage;

wherein the first pyrotechnic element delivery assembly further includes a first member having a first pass-through bore and a first load bore defined therein, each of the first pass-through bore and the first load bore in selective communication with the output passage.

18. The pyrotechnic launch unit of claim **17**, wherein the second pyrotechnic element delivery assembly further includes a second member having a second load bore defined therein, the second load bore in selective communication with the output passage.

19. The pyrotechnic launch unit of claim **18**, wherein the second member further has a second pass-through bore defined therein, the second pass-through bore in selective communication with the output passage.

20. The pyrotechnic launch unit of claim **19**, further comprising a third pyrotechnic element delivery assembly including an output passage in communication with the input passage of the second pyrotechnic element delivery assembly.

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