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Voishvillo

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(54) **DUAL COMPRESSION DRIVERS AND PHASING PLUGS FOR COMPRESSION DRIVERS**

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Related U.S. Application Data

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(51) **Int. Cl.**

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H04R 1/20	(2006.01)
H04R 9/06	(2006.01)
H04R 11/02	(2006.01)

(52) **U.S. Cl.** **381/343**; 381/340; 381/398

(58) **Field of Classification Search** 381/337–343, 381/398, 423, 430; 181/152, 159, 177–195
See application file for complete search history.

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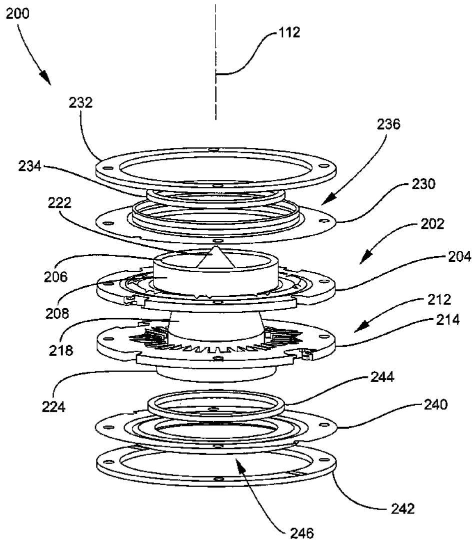
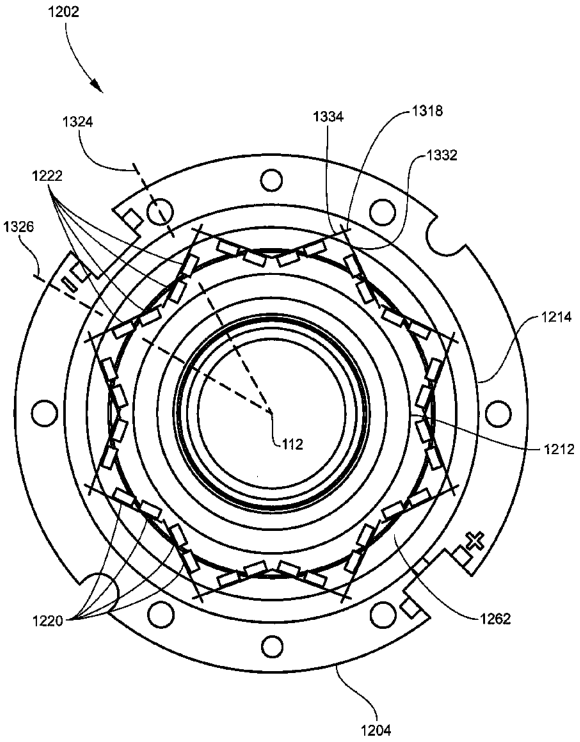
(57) **ABSTRACT**

A phasing plug includes a base portion including an input side, an output side, a plurality of entrances on the input side, a plurality of exits on the output side arranged about a central axis, and a plurality of channels fluidly interconnecting the entrances with the respective exits. Each corresponding entrance, channel and exit establish an acoustical path from the input side to the output side that is non-radial relative to the central axis. Two phasing plugs may be provided in a dual compression driver.

55 Claims, 28 Drawing Sheets





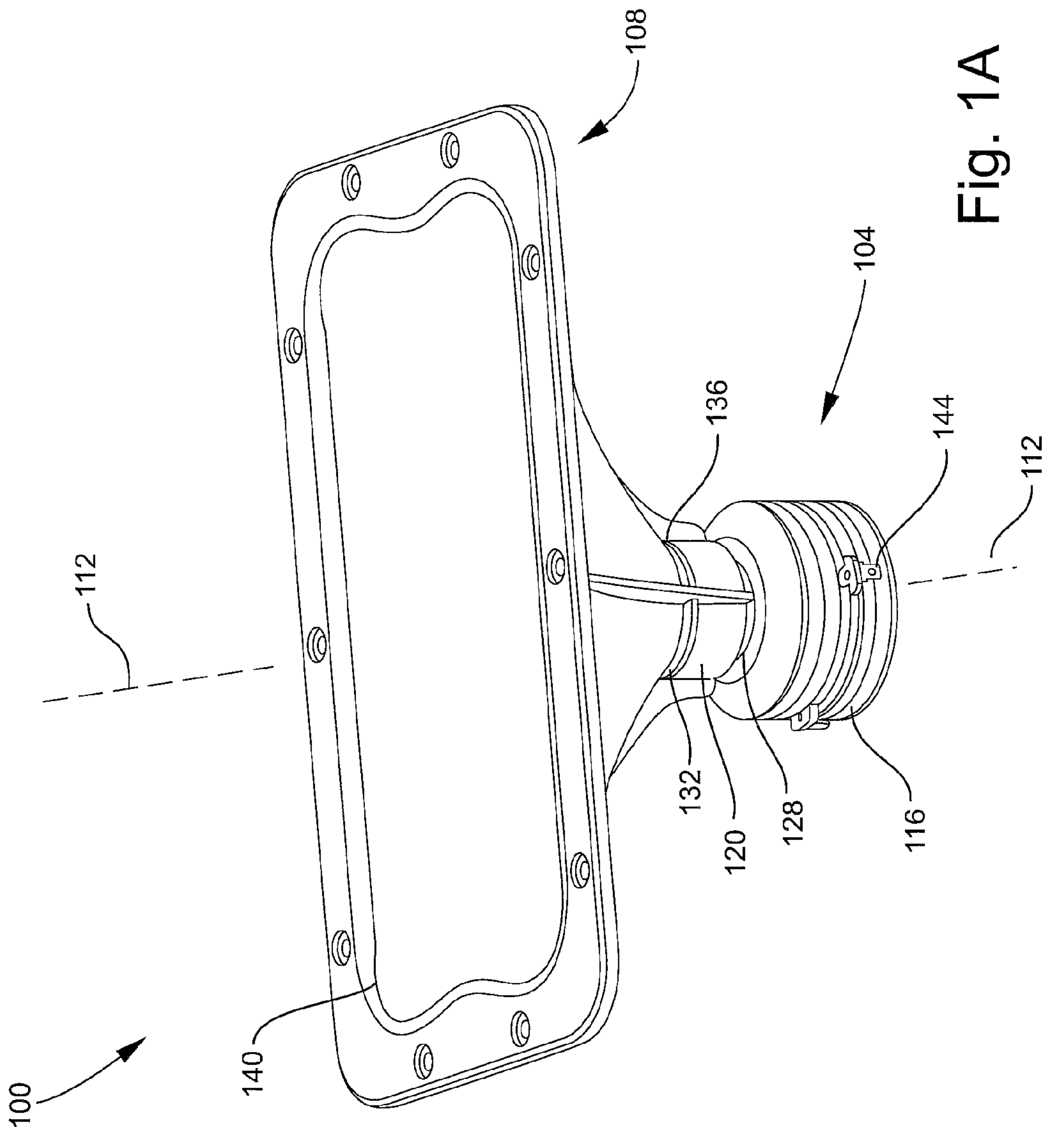


Fig. 1A

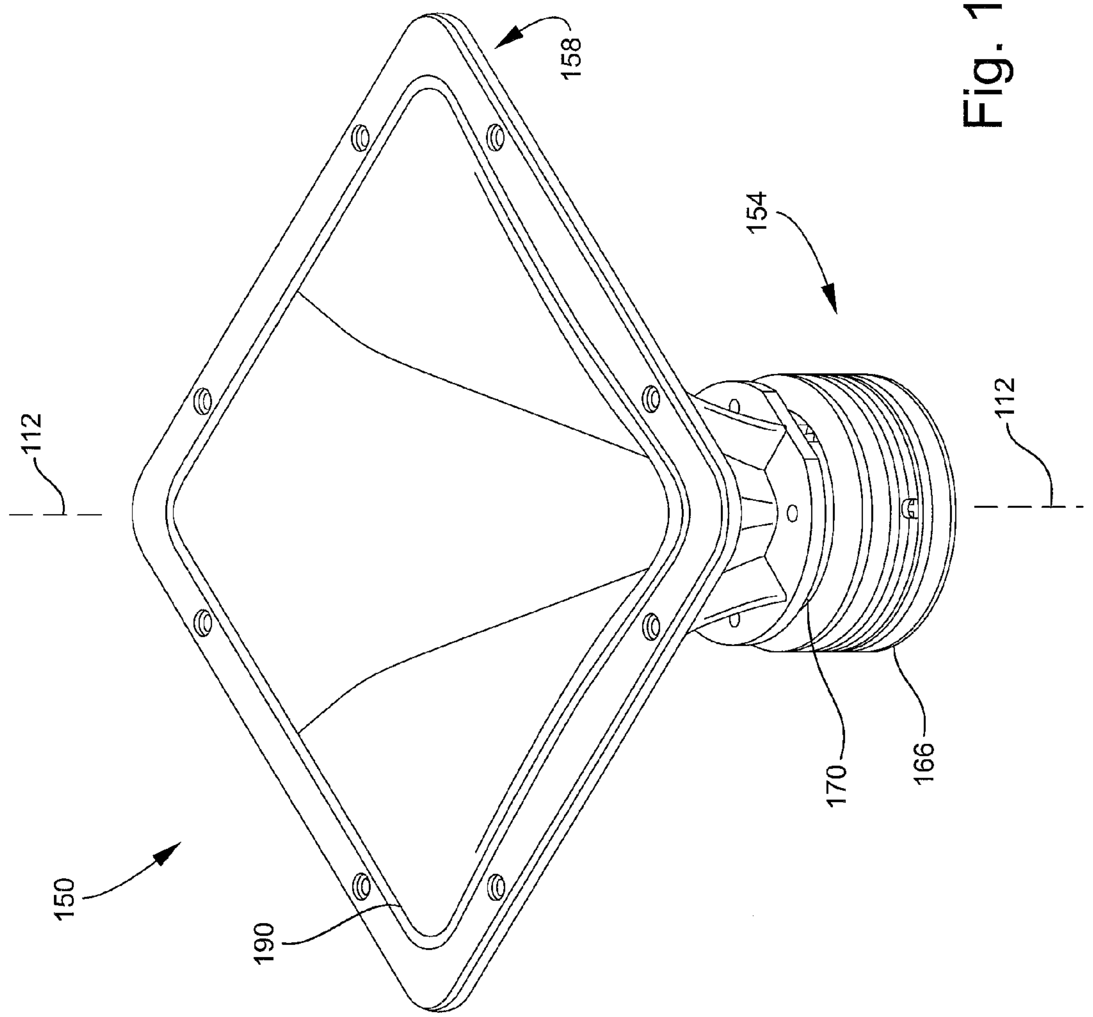


Fig. 1B

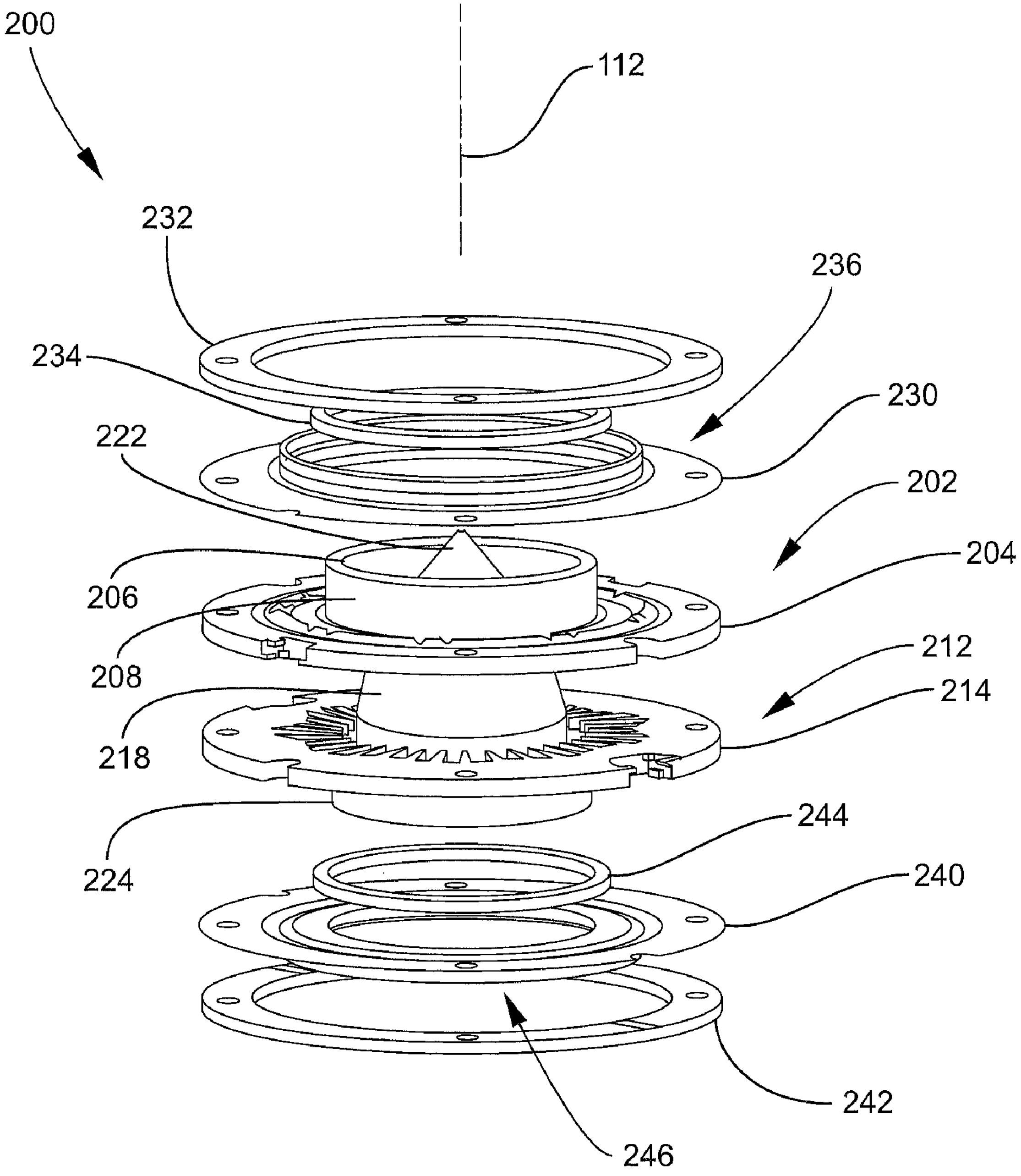

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Fig. 2

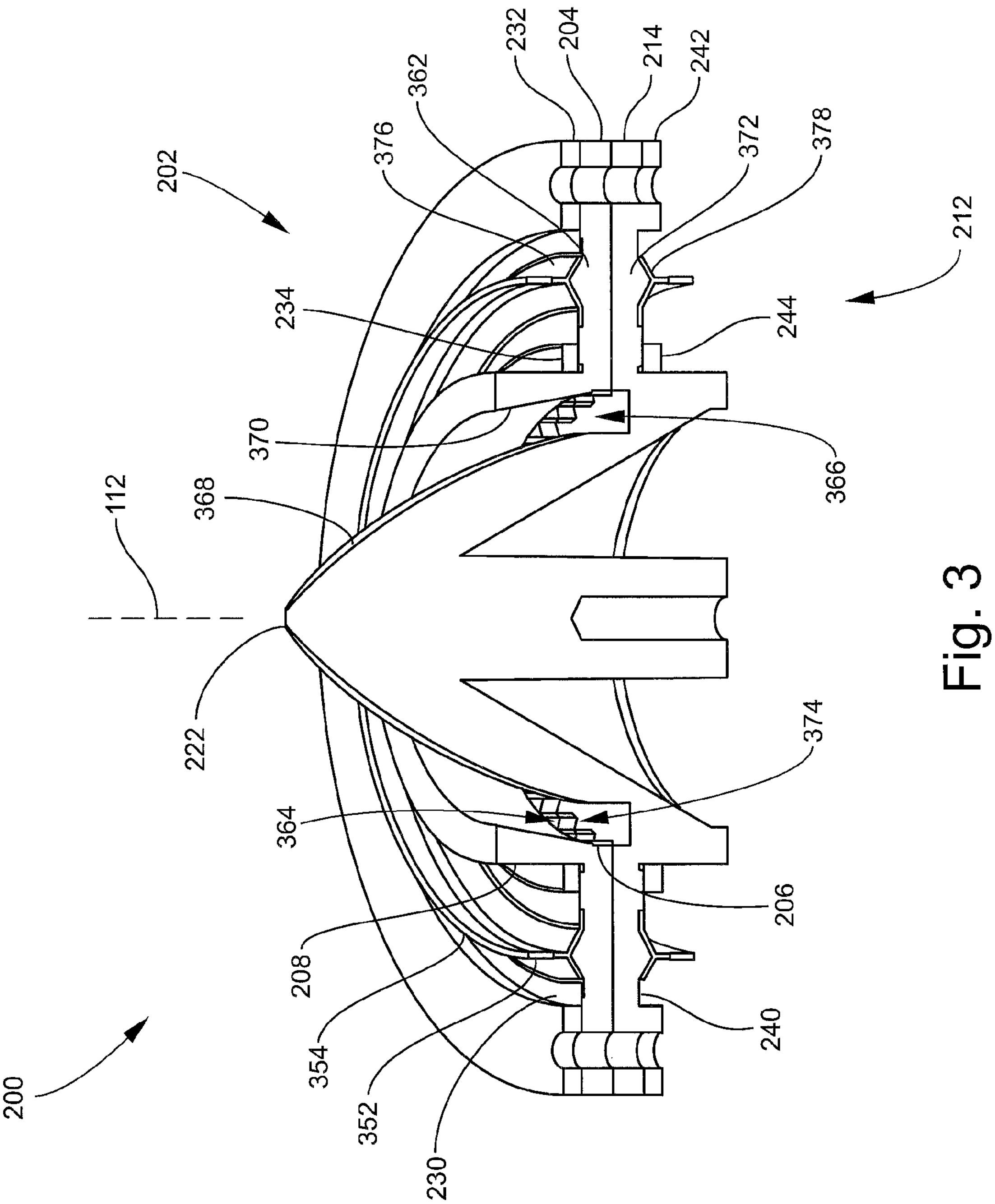
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Fig. 3

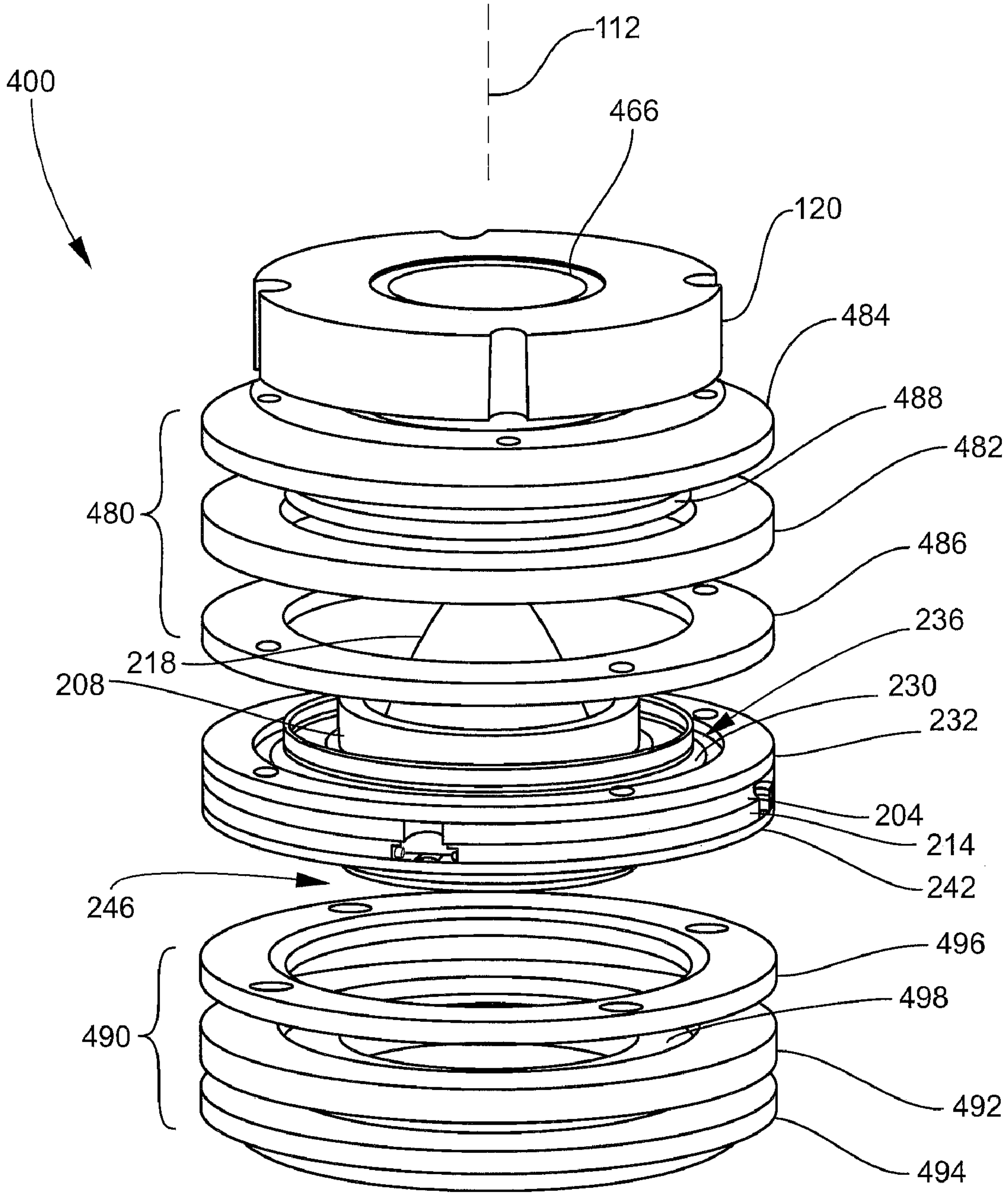
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Fig. 4

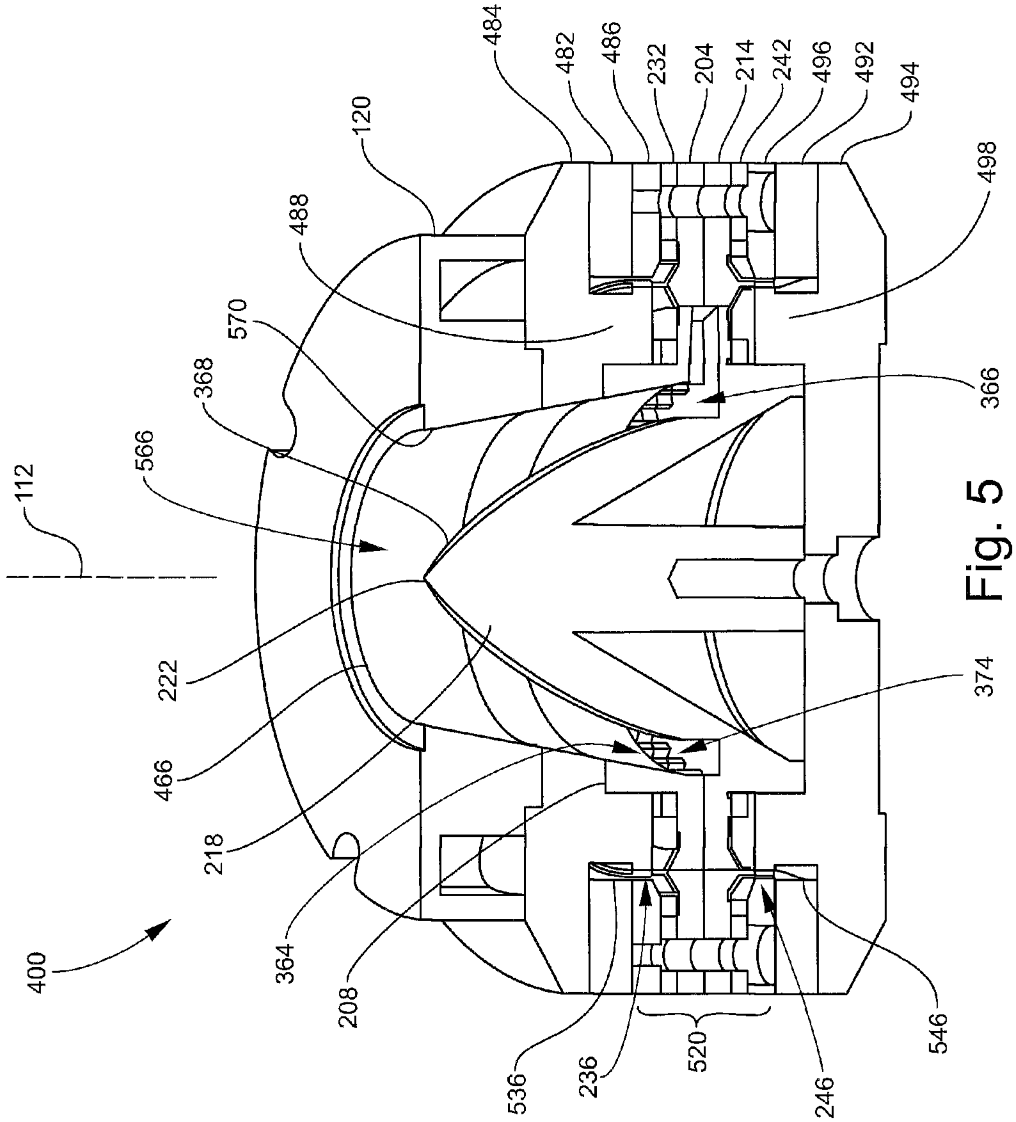
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Fig. 5

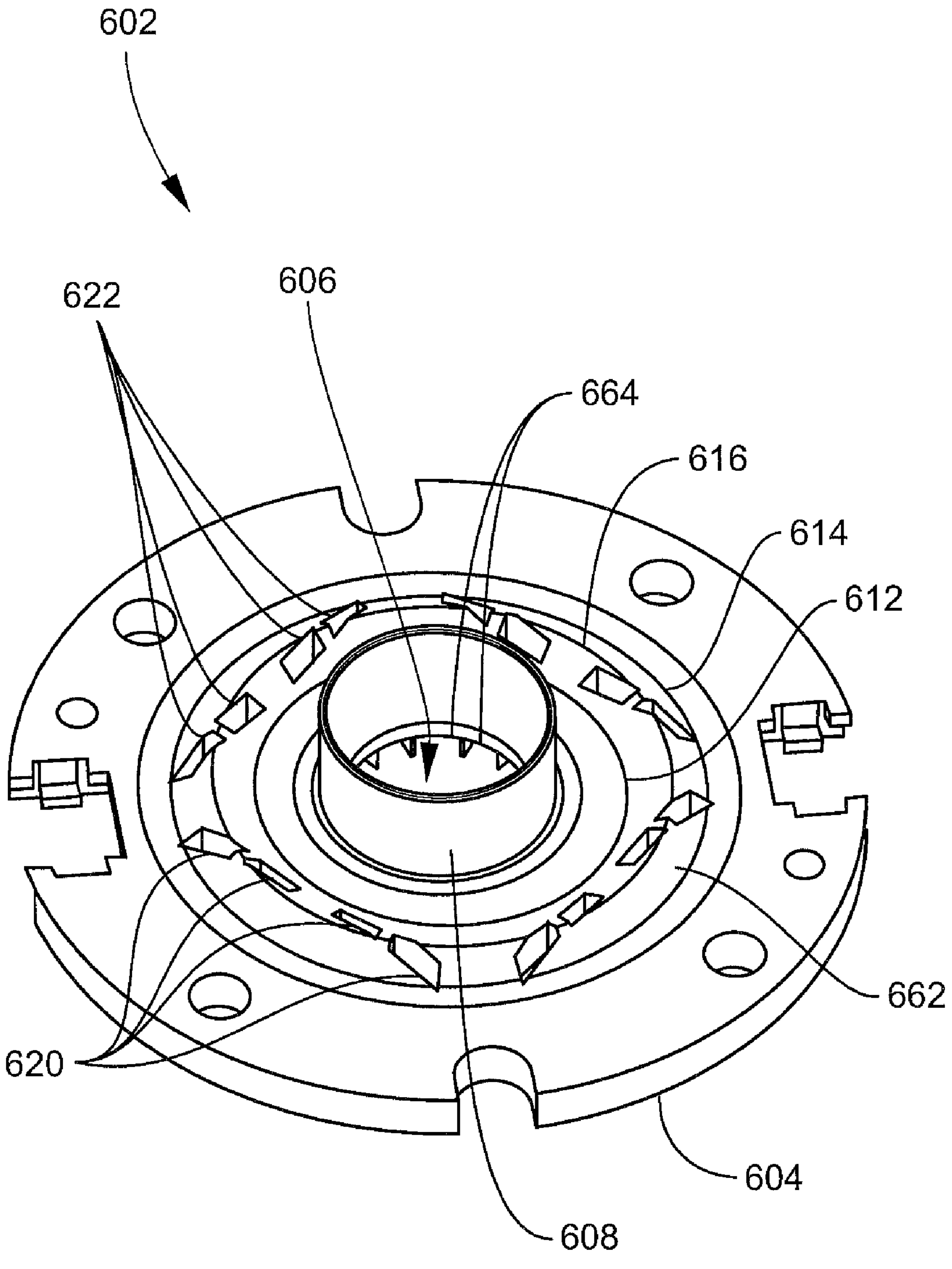

Fig. 6

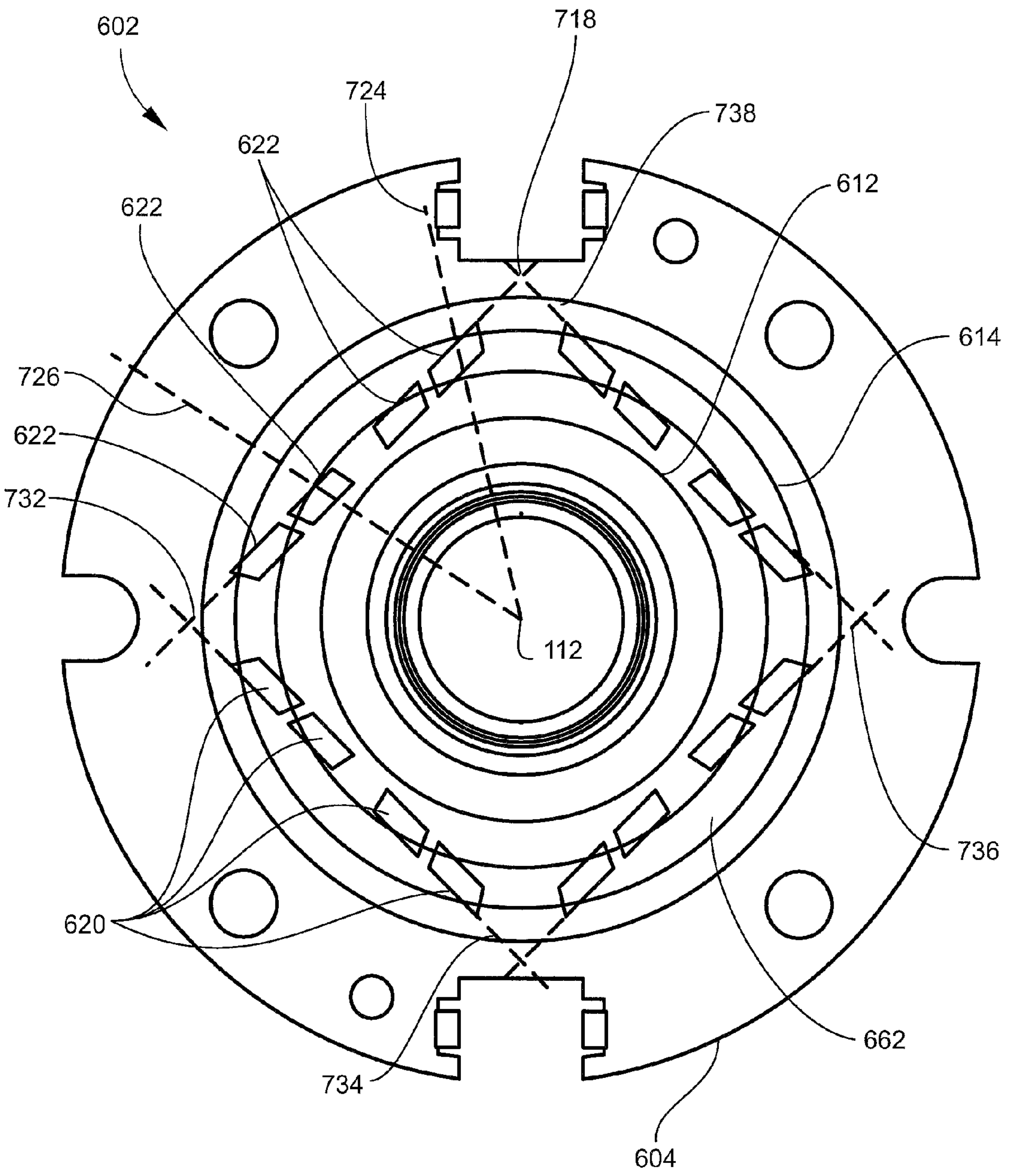
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Fig. 7

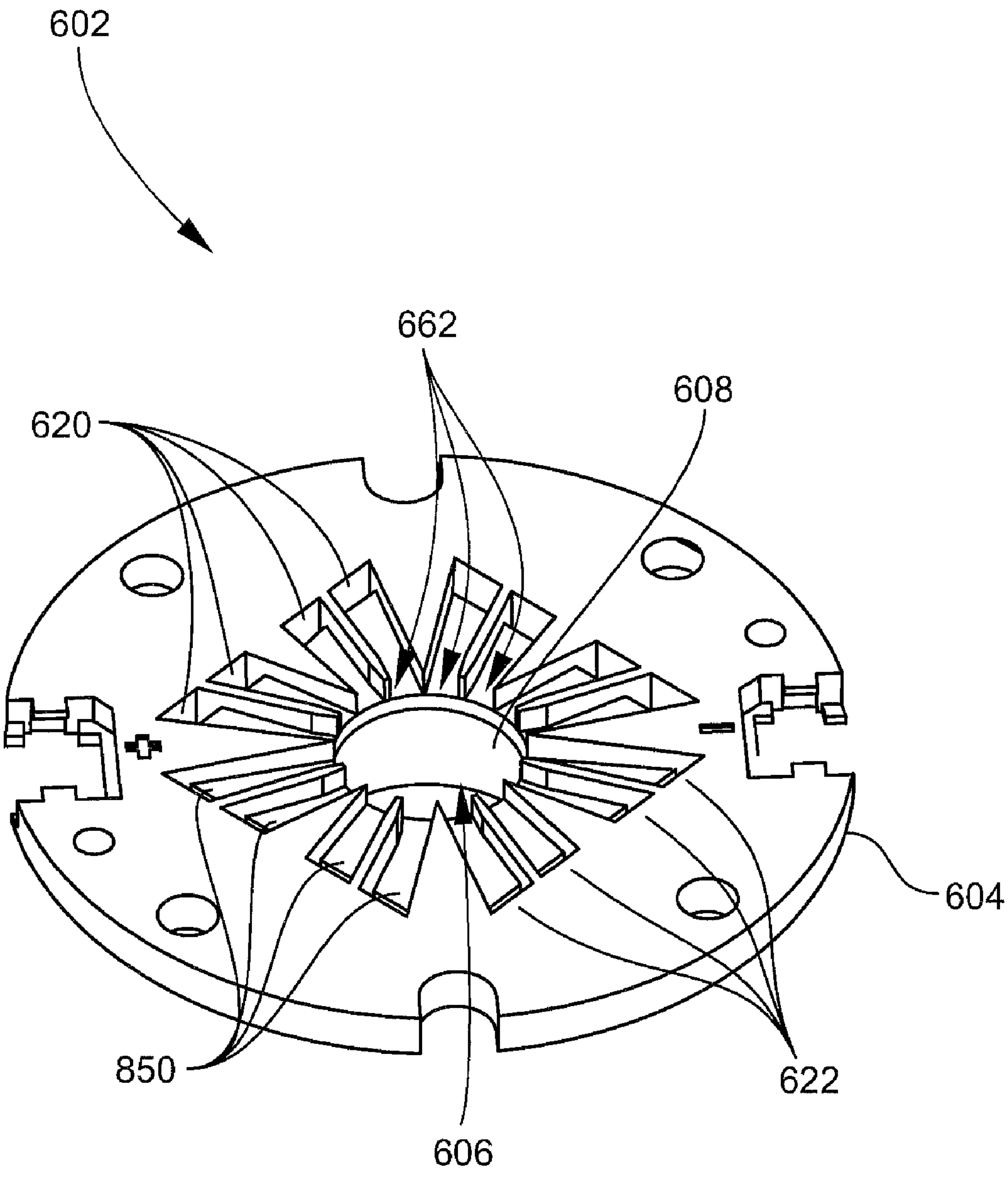

Fig. 8

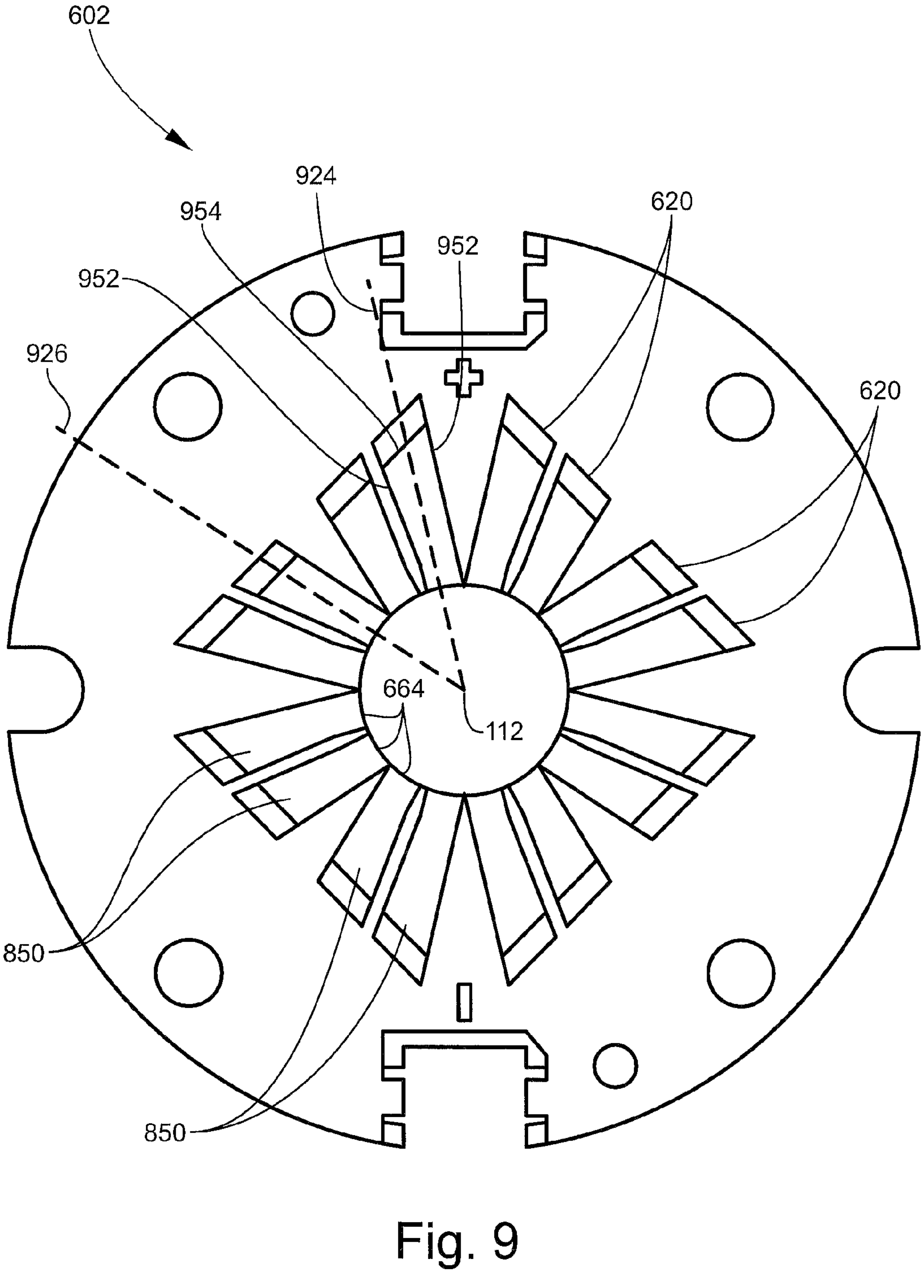

Fig. 9

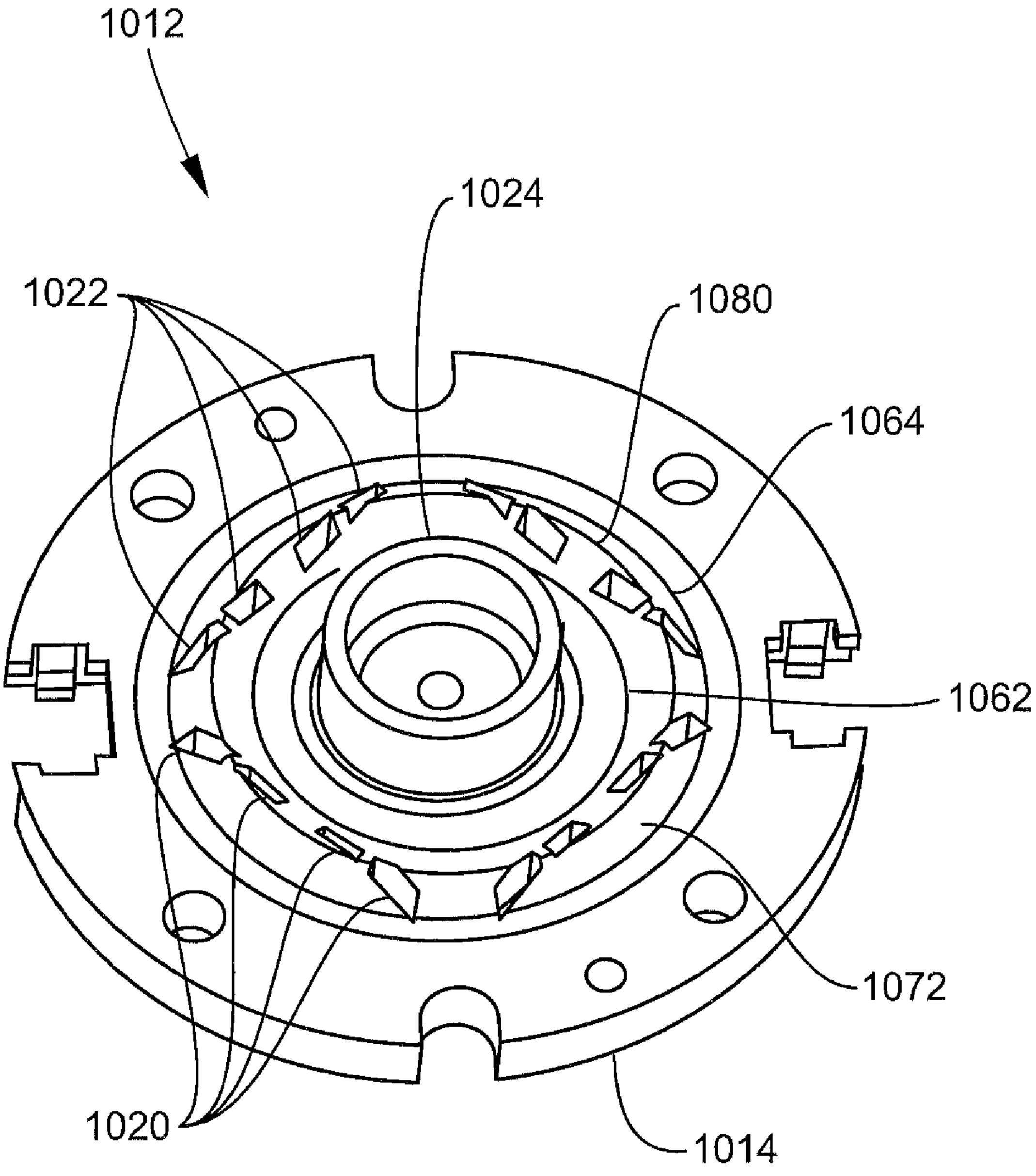

Fig. 10

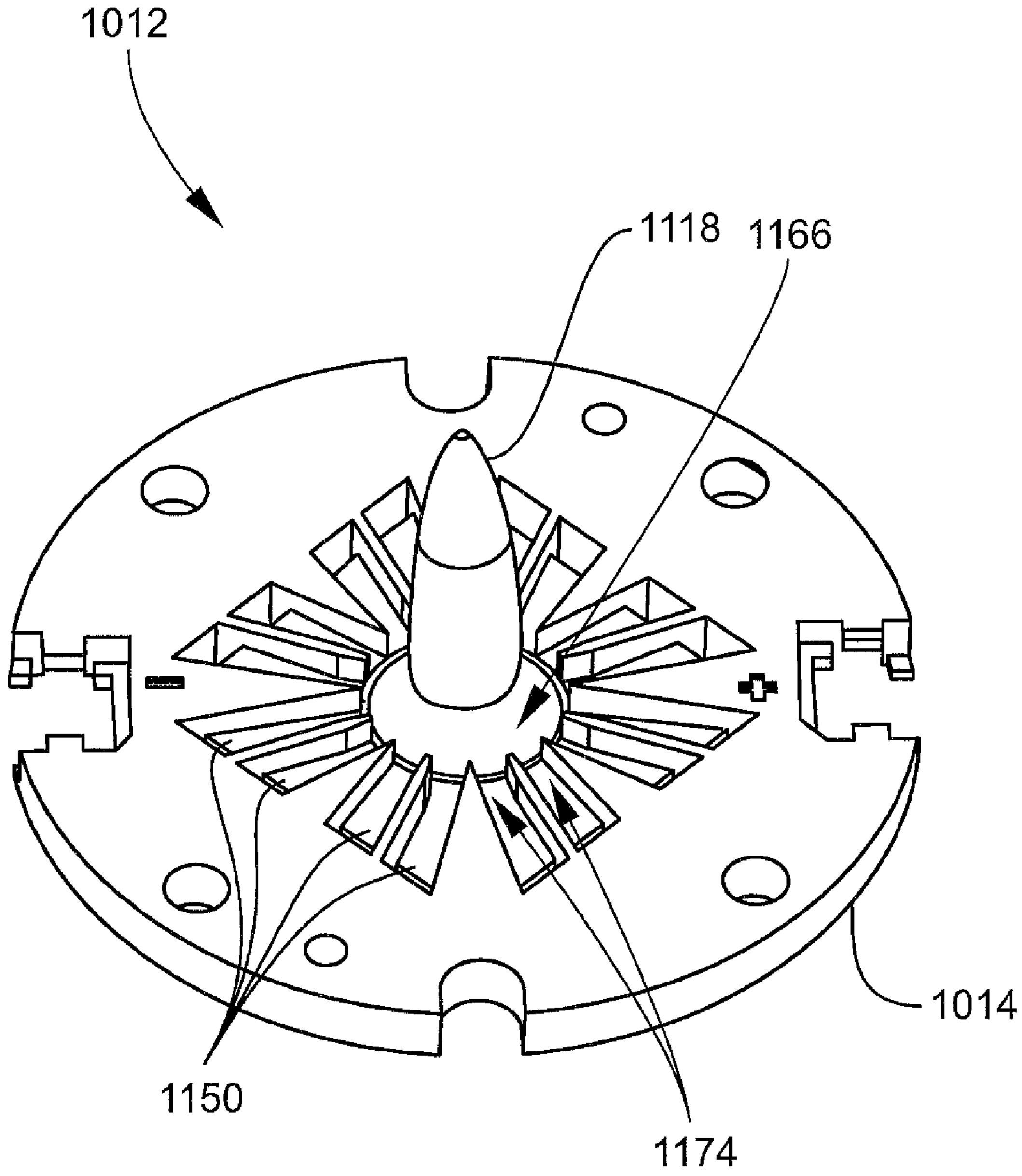

Fig. 11

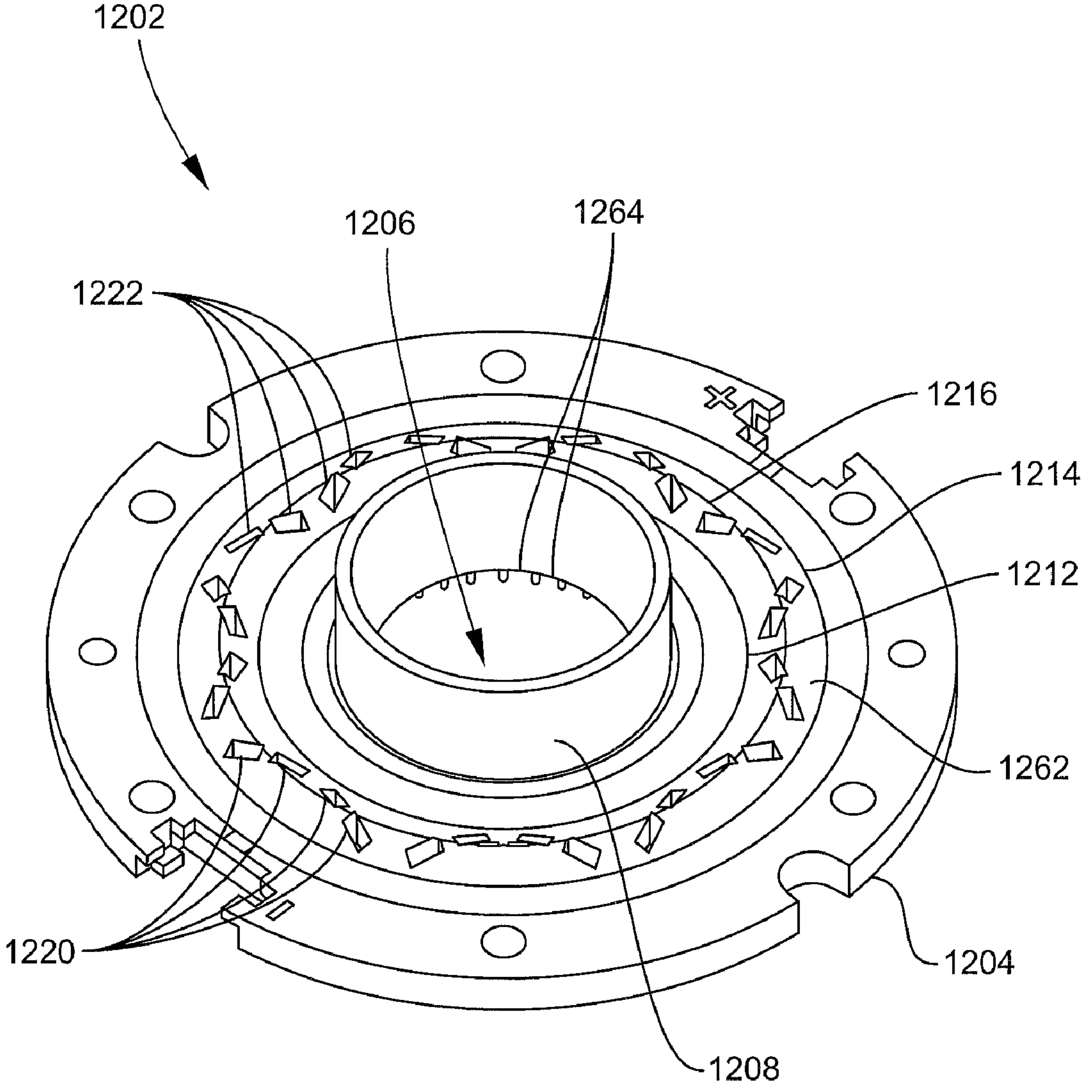

Fig. 12

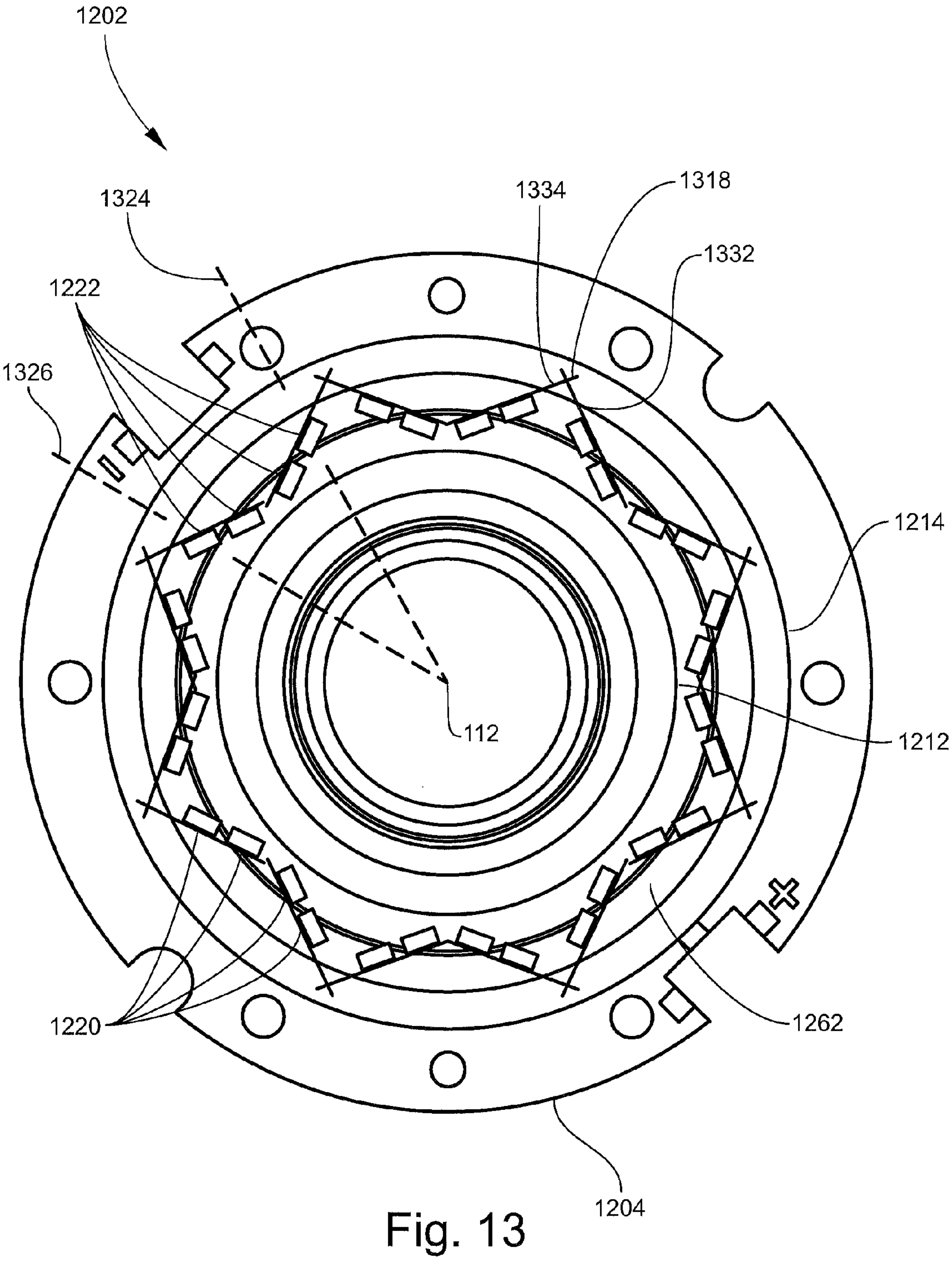
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Fig. 13

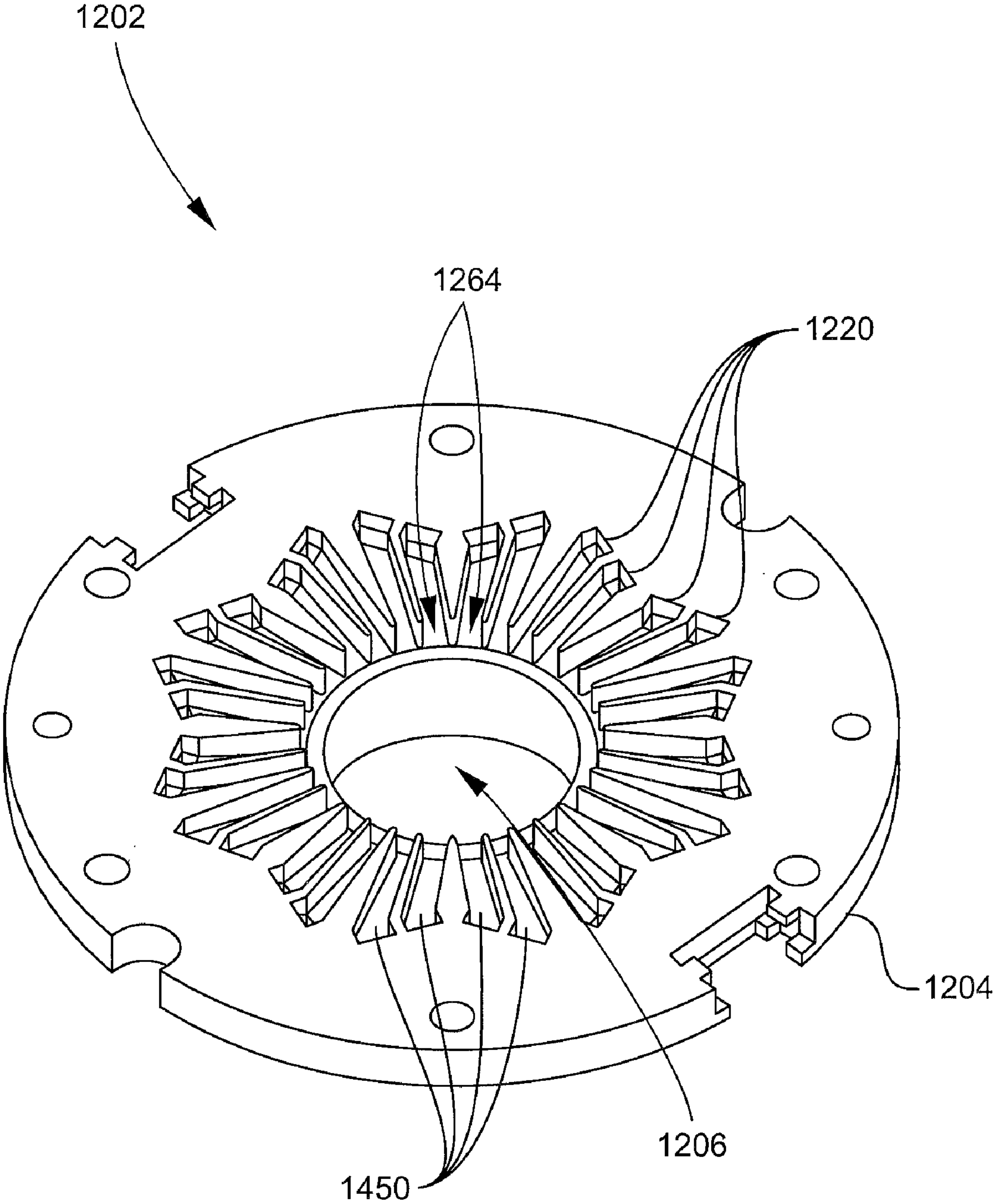

Fig. 14

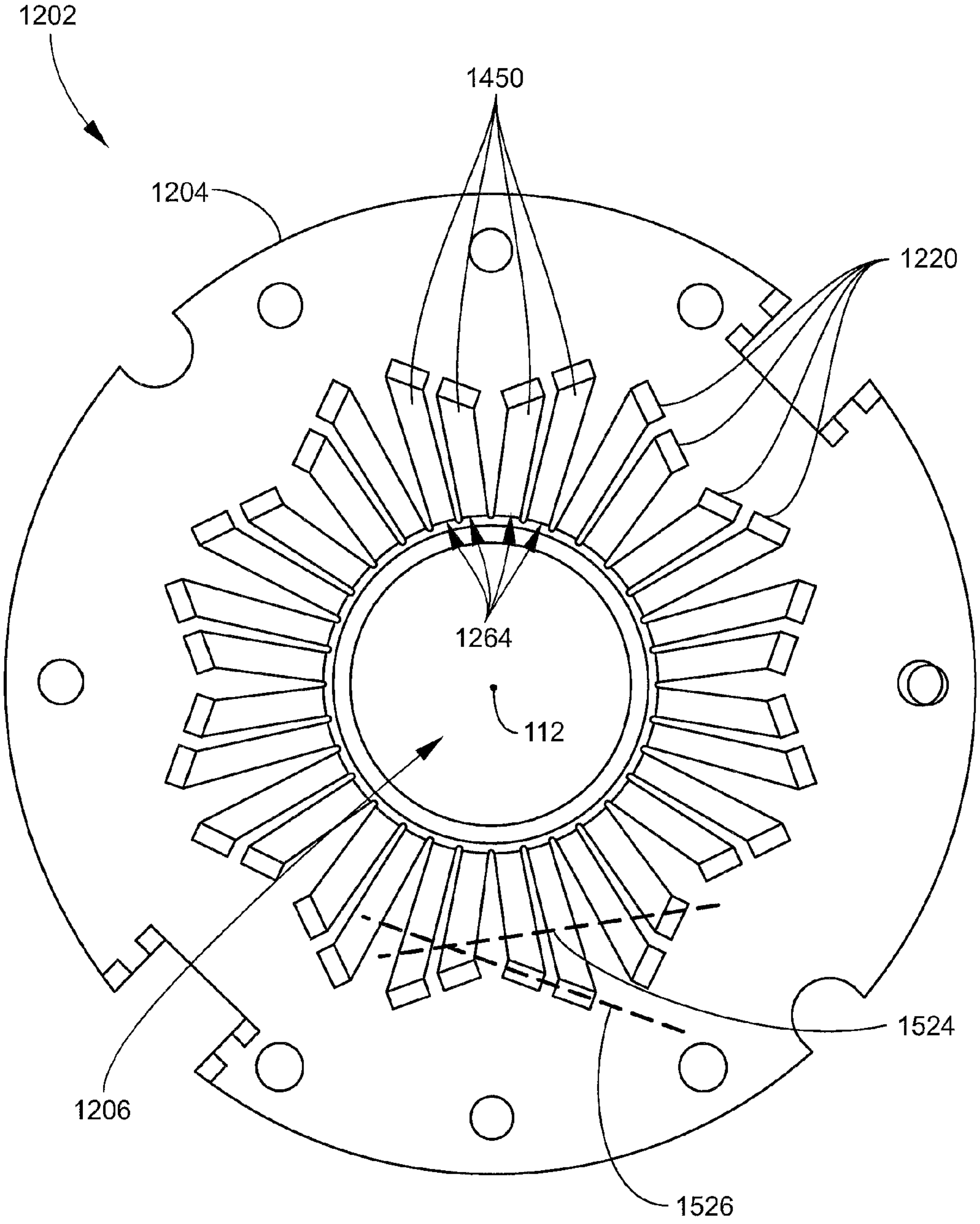

Fig. 15

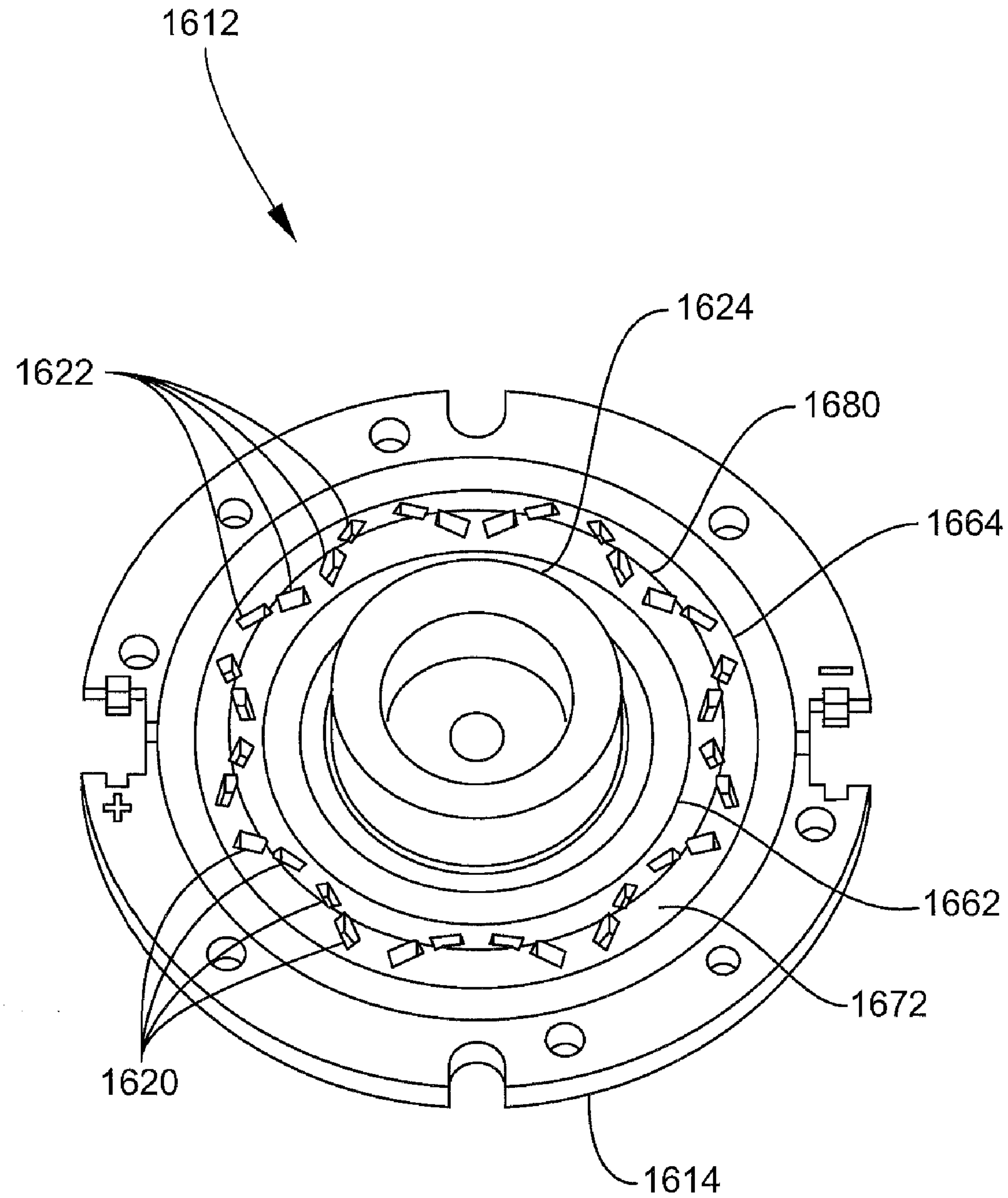

Fig. 16

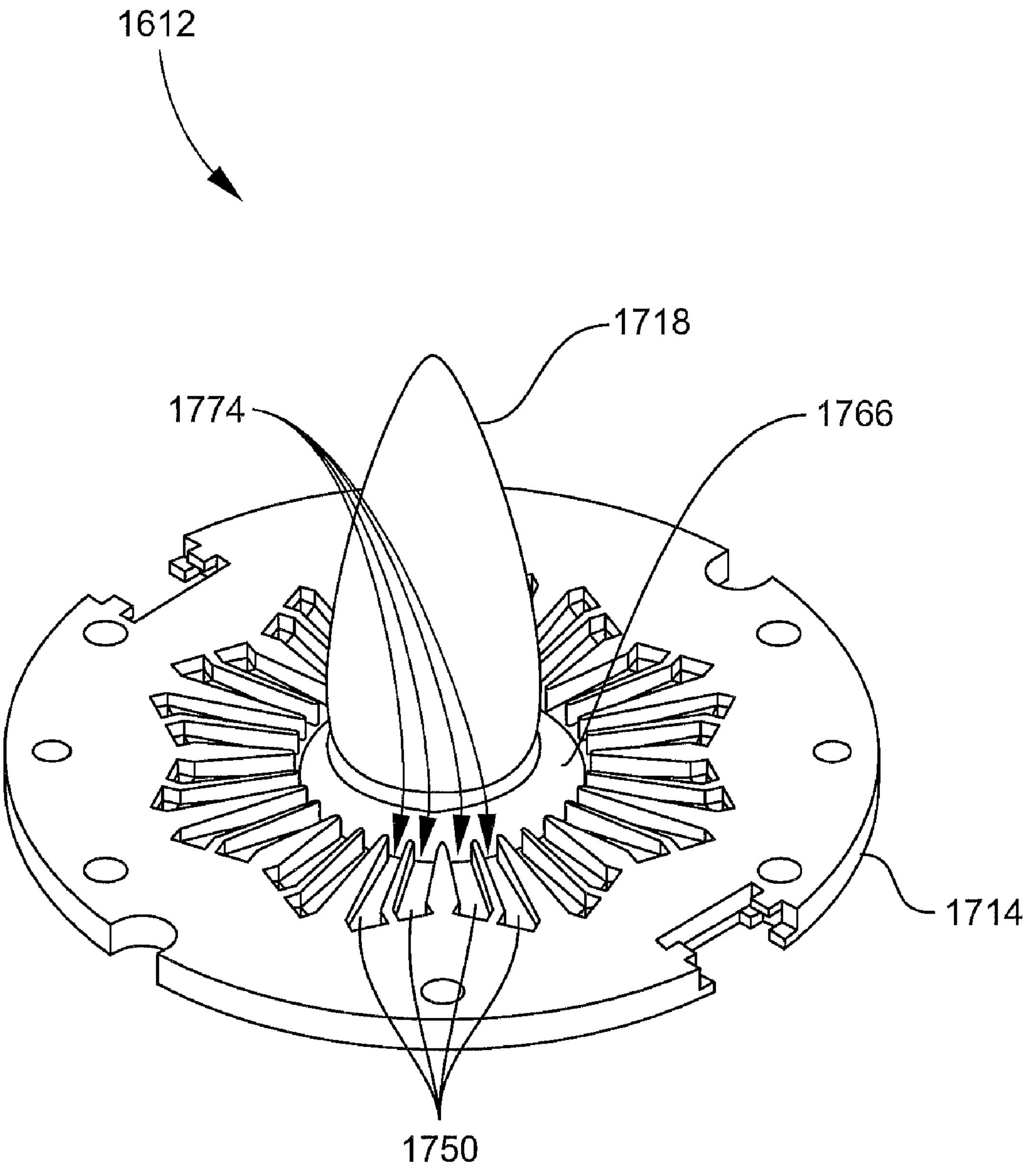

Fig. 17

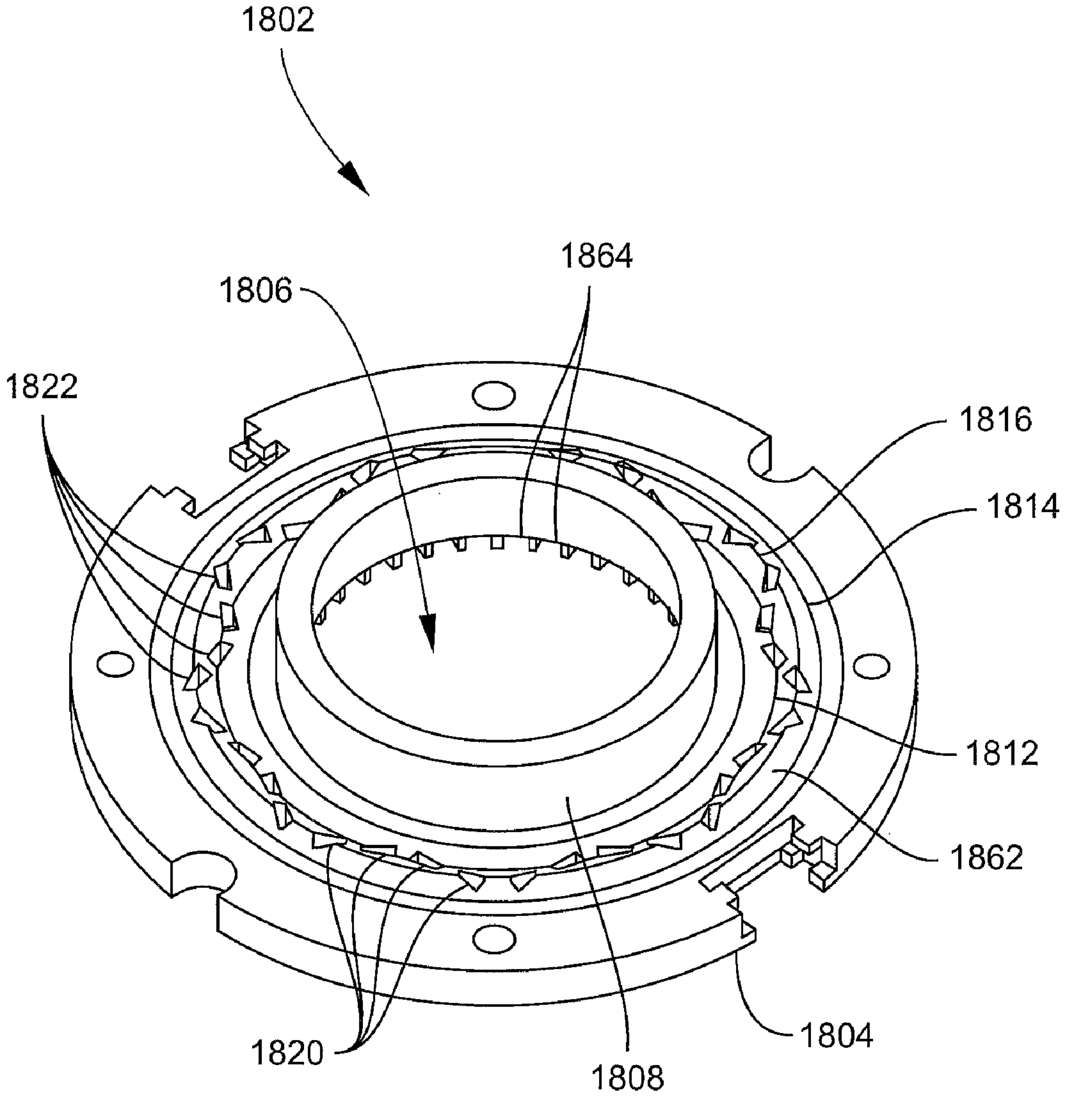

Fig. 18

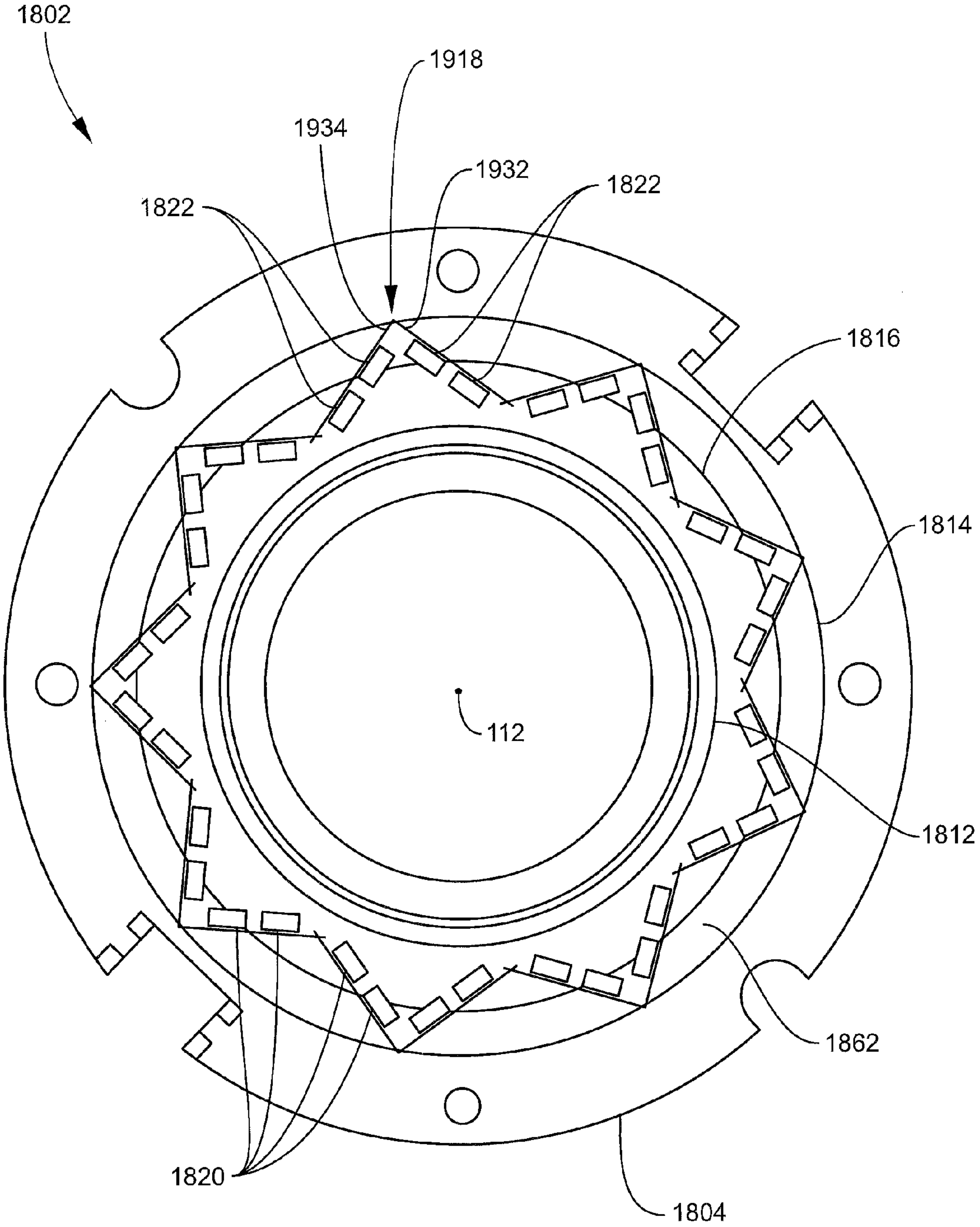
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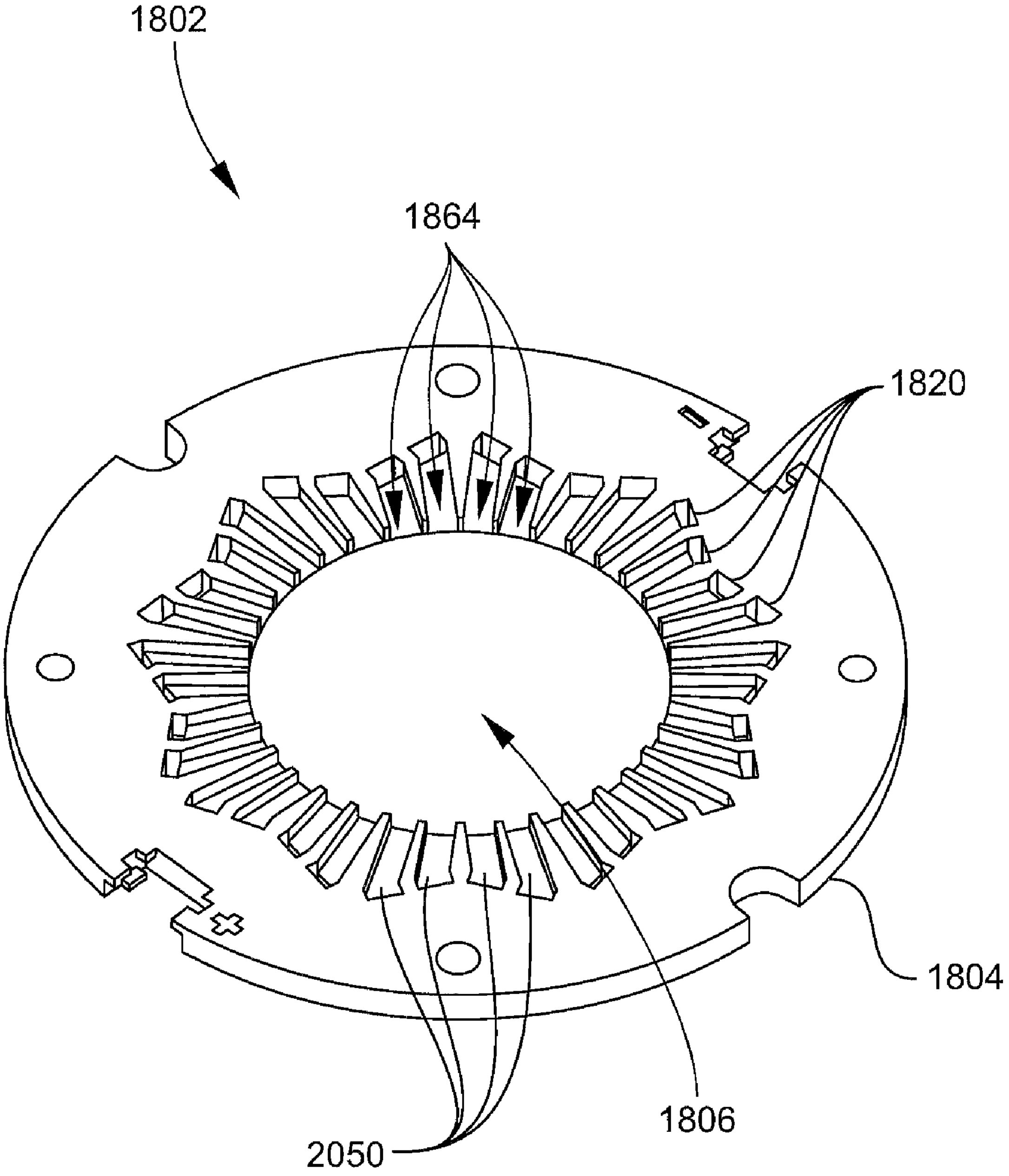
Fig. 19



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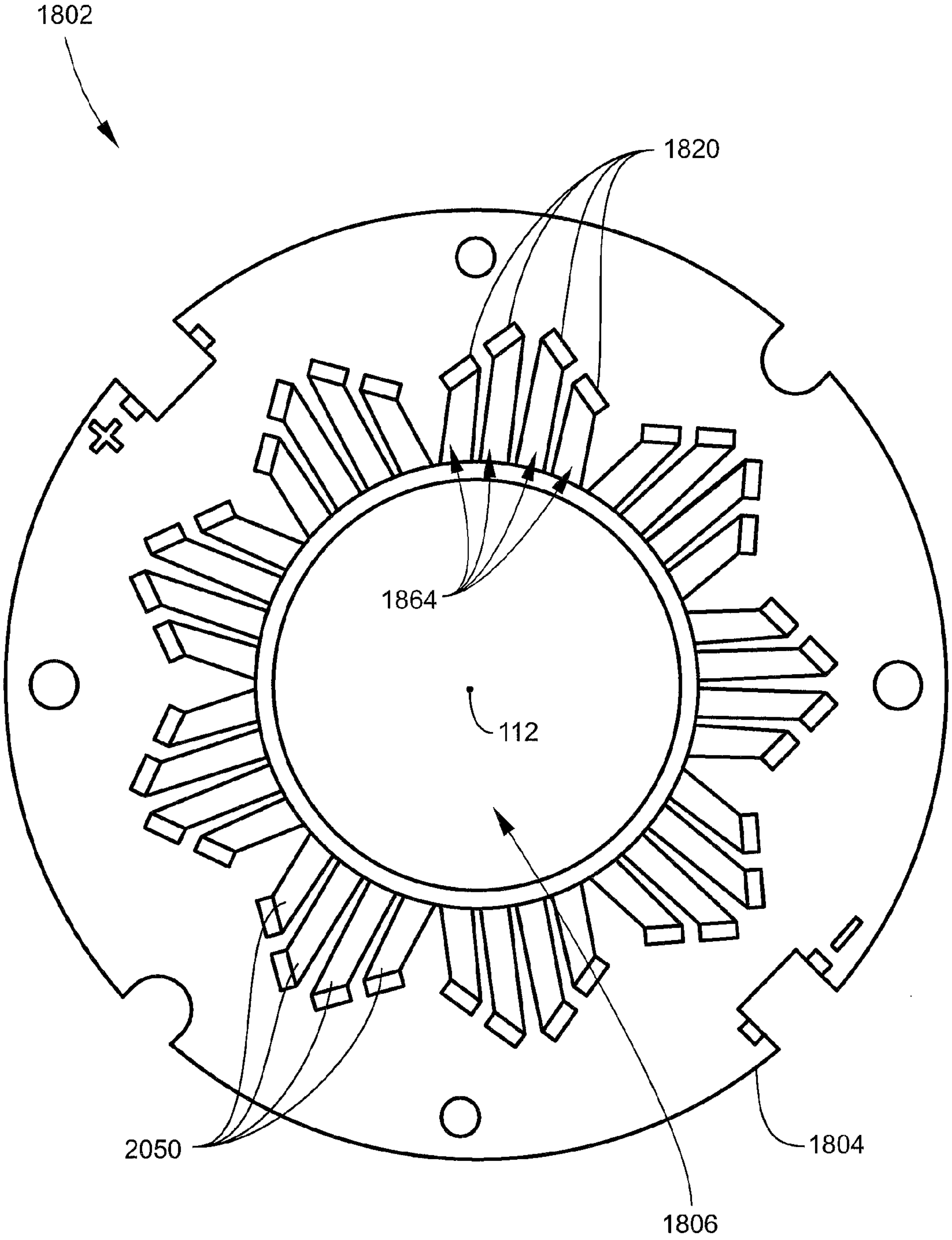

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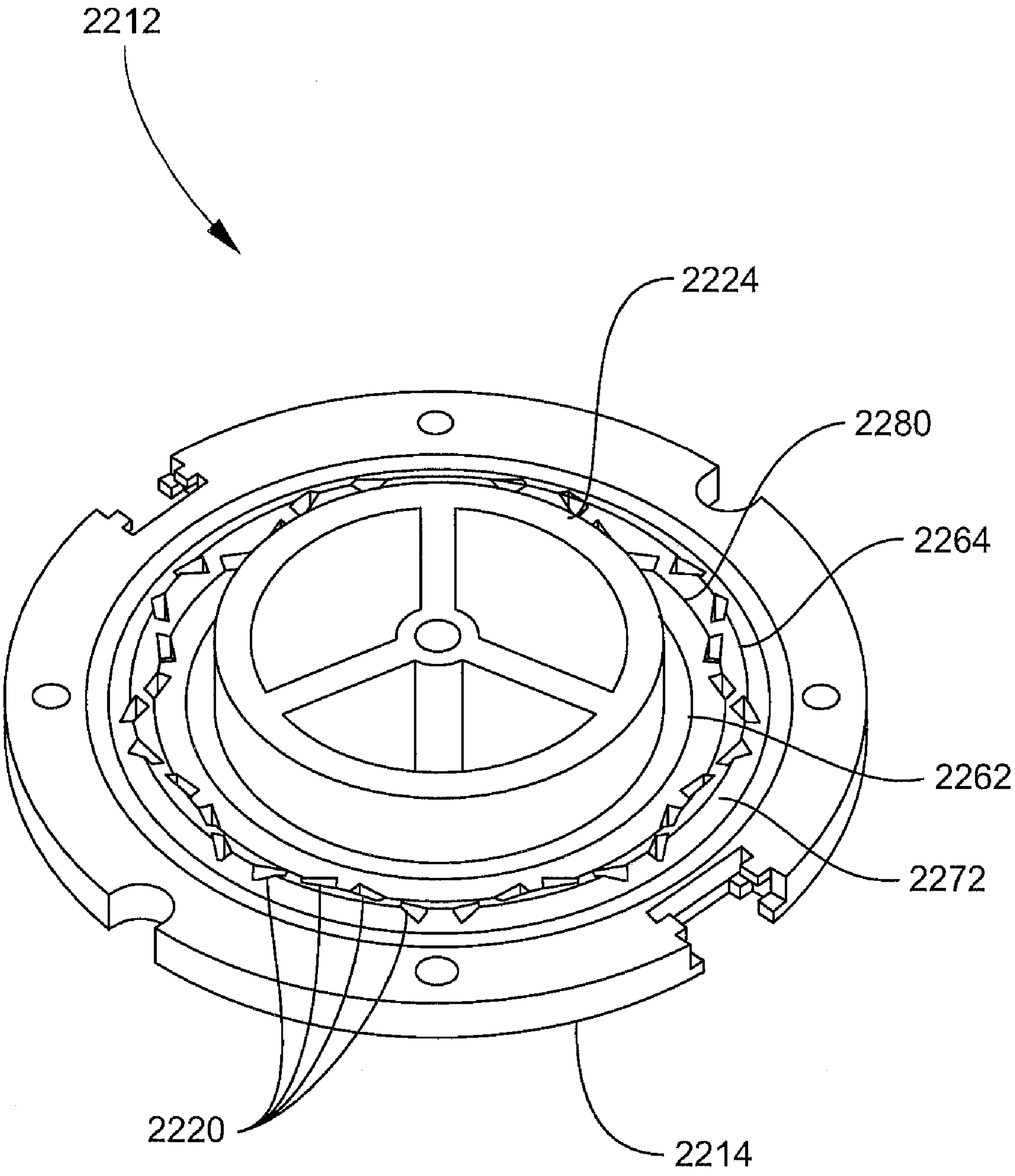

Fig. 22

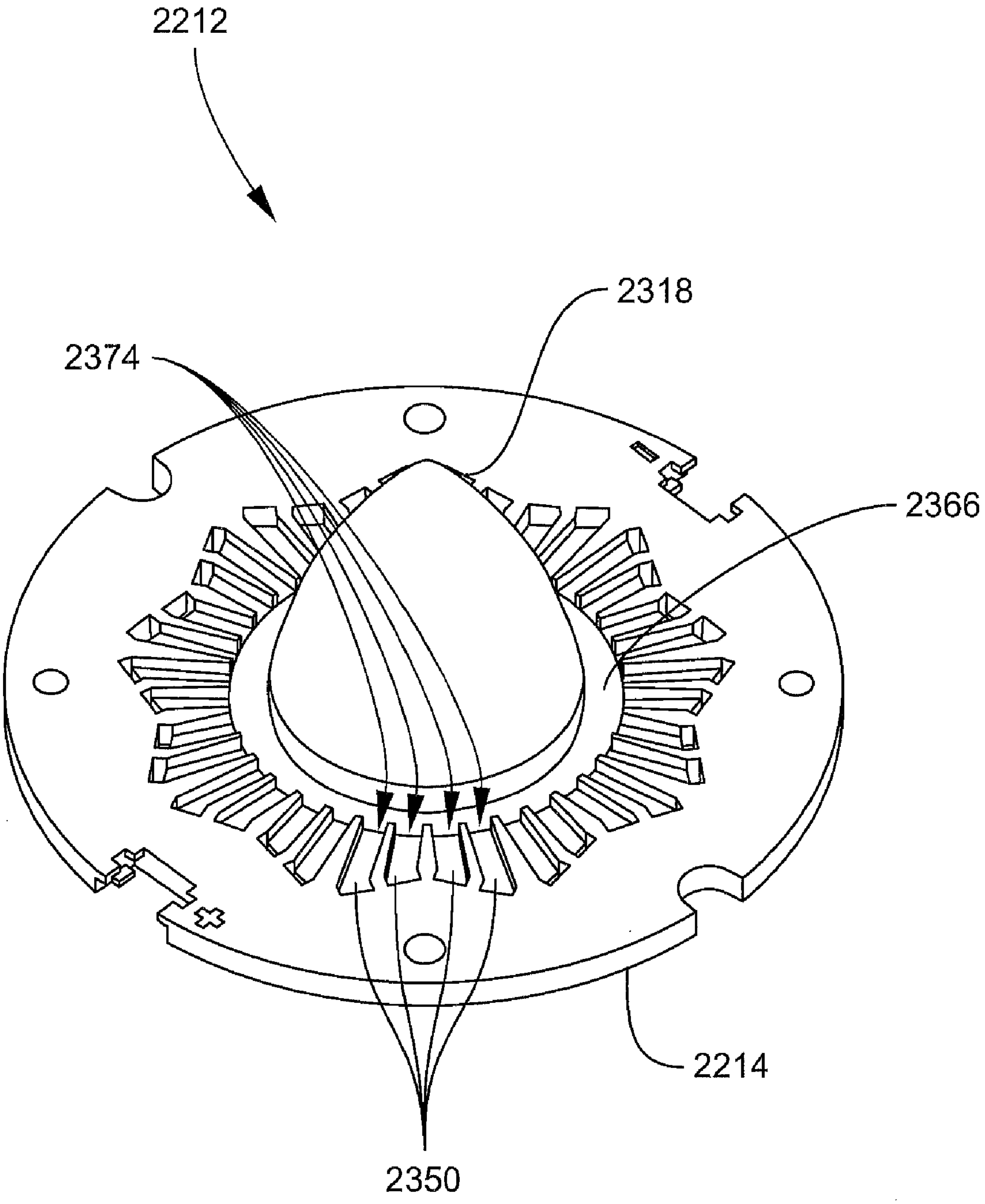

Fig. 23

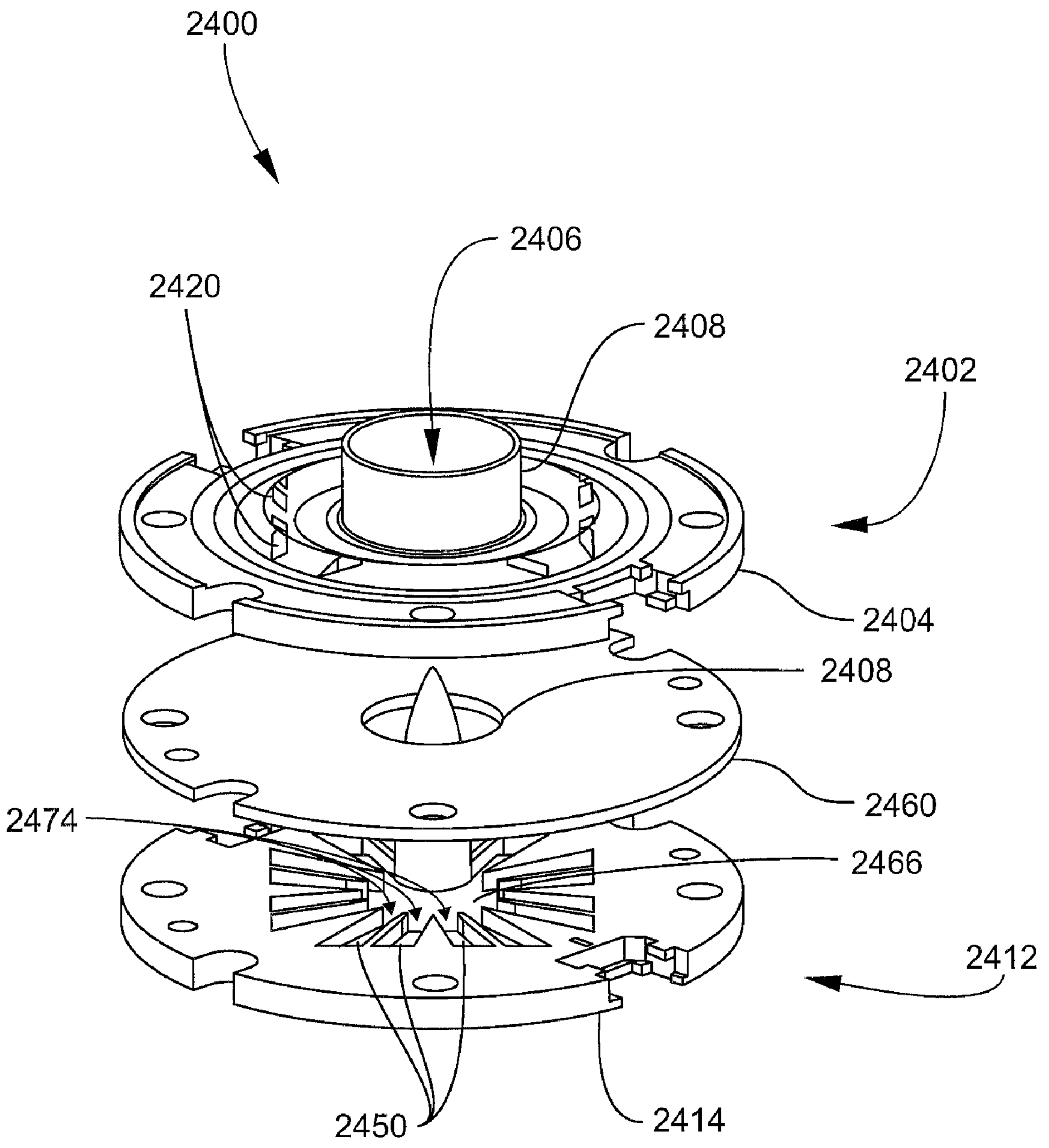
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Fig. 24

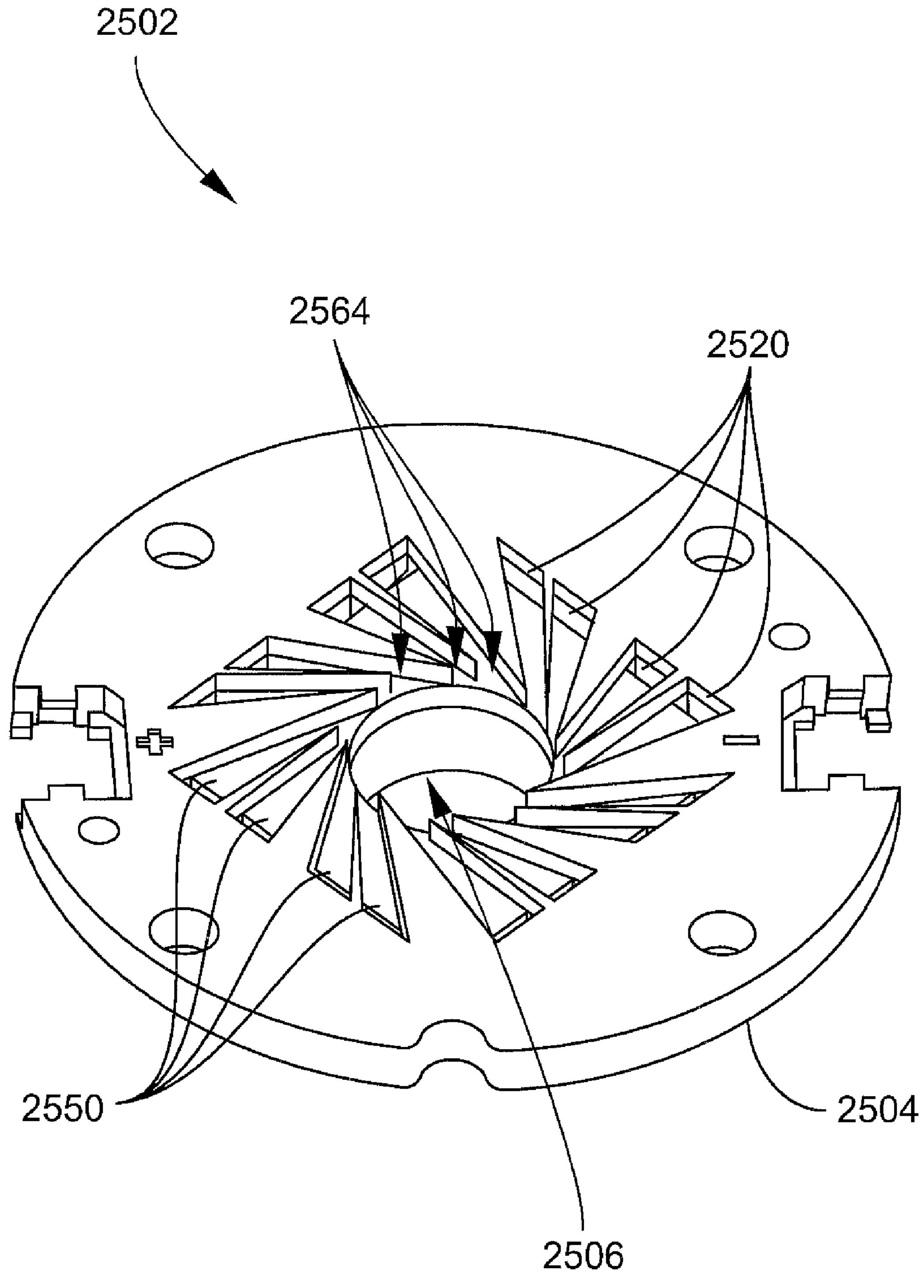

Fig. 25

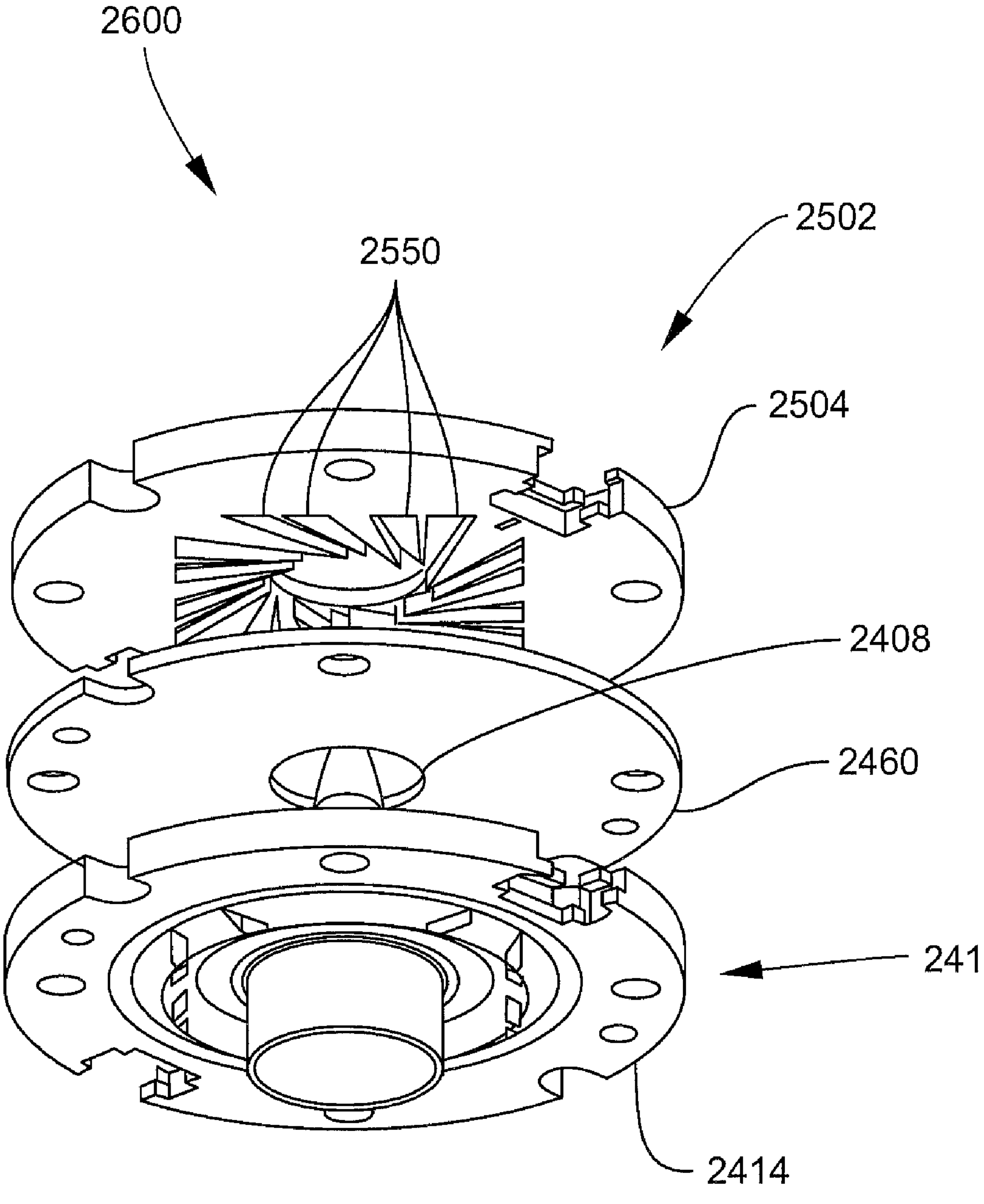

Fig. 26

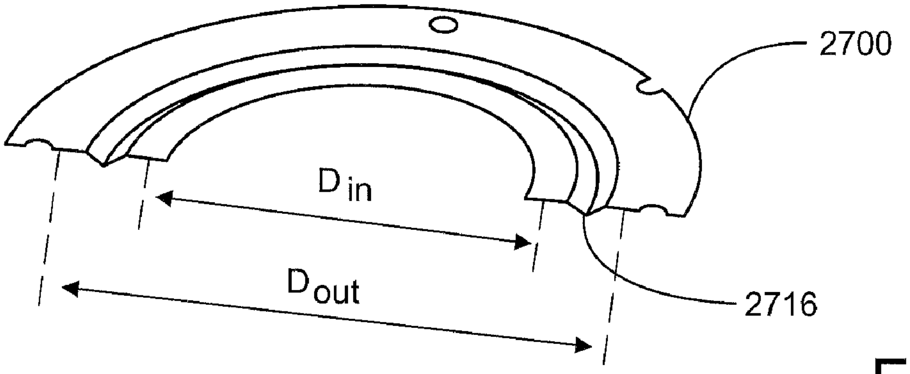

Fig. 27

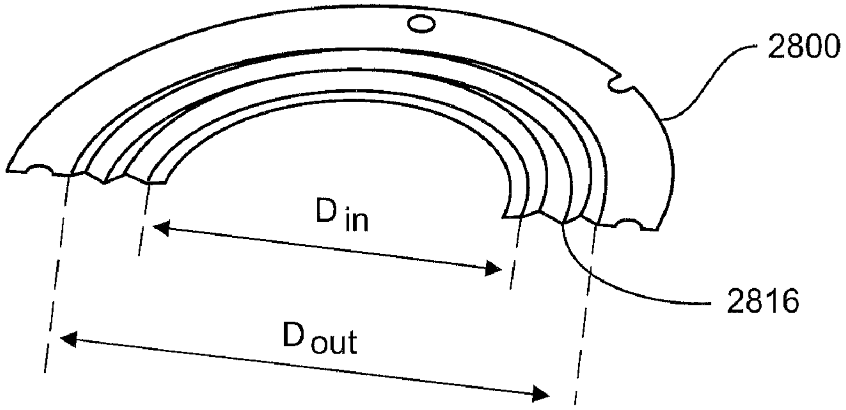

Fig. 28

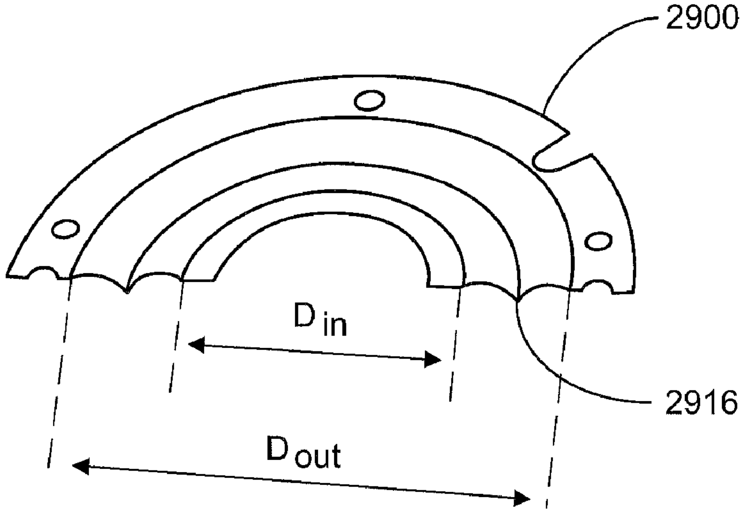

Fig. 29

DUAL COMPRESSION DRIVERS AND PHASING PLUGS FOR COMPRESSION DRIVERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. application Ser. No. 12/137,215, filed on Jun. 11, 2008, titled PHASING PLUG, which application is incorporated by reference in this application in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to electro-acoustical drivers and loudspeakers employing electro-acoustical drivers. More particularly, the invention relates to improved configurations for compression drivers and phasing plugs utilized in compression drivers.

2. Related Art

An electro-acoustical transducer or driver is utilized as a component in a loudspeaker system to convert electrical signals into acoustical signals. The driver includes mechanical, electromechanical, and magnetic elements to effect this conversion. For example, the electrical signals may be directed through a voice coil that is attached to a flexible diaphragm and positioned in an air gap. The voice coil is immersed in a radially oriented magnetic field provided by a permanent magnet and steel elements of a magnet assembly. Due to the Lorenz force affecting the conductor of current positioned in the permanent magnetic field, the alternating current corresponding to electrical signals conveying audio signals actuates the voice coil to reciprocate back and forth in the air gap and, correspondingly, move the diaphragm to which the coil is attached. The diaphragm may be suspended by one or more supporting elements (e.g., a surround, spider, or the like) such that at least a portion of the diaphragm is permitted to move. Accordingly, the reciprocating voice coil actuates the diaphragm to likewise reciprocate and, consequently, produce acoustic signals that propagate as sound waves through a suitable fluid medium such as air. Sound pressure differences in the fluid medium associated with these waves are interpreted by a listener as sound. The sound waves may be characterized by their instantaneous spectrum and level.

The driver at its output side may be coupled to an acoustic waveguide, which is a structure that encloses the volume of medium into which sound waves are first received from the driver. The waveguide may be designed to increase the efficiency of the driver and control the directivity of the propagating sound waves. The waveguide typically includes one open end coupled to the driver, and another open end or mouth downstream from the driver-side end. Sound waves produced by the driver propagate through the waveguide and are dispersed from the mouth to a listening area. The waveguide may be structured as a horn or other flared structure such that the interior defined by the waveguide expands or increases from the driver-side end to the mouth.

Electro-acoustical transducers or drivers may be characterized into two broad categories: direct-radiating types and compression types. A direct-radiating transducer produces sound waves and radiates these sound waves directly into open air (i.e., the environment ambient to the loudspeaker), whereas a compression driver first moves air in a radial direction in a high-pressure region, or compression chamber, and then produces sound waves that propagate in an axial direction to the typically much lower-pressure open-air environment. The compression chamber is open to a structure commonly referred as a phasing plug that works as a connector between the compression chamber and the horn. The area of the exit of the compression chamber (i.e., the entrance to the phasing plug) is smaller than the effective area of the diaphragm. This provides increased efficiency as compared to a direct-radiating loudspeaker. In a direct-radiating loudspeaker, the mechanical output impedance of the vibrating diaphragm is significantly higher than the loading impedance of the open air (the radiation impedance). This results in a mismatch between the “generator” (diaphragm) and the “load” (open air radiation impedance). In a compression driver, the loading impedance (entrance to the phasing plug) is significantly higher than the open air radiation impedance. This produces much better matching between the “generator” and the “load” and increases the efficiency of the compression driver as a transducer. Typically, it is considered ideal to attain 50% driver efficiency when the mechanical output impedance of the vibrating diaphragm is equal to the mechanical loading impedance of the phasing plug with the horn connected to it.

As noted, a compression driver utilizes a compression chamber on the output side of the diaphragm to generate relatively higher-pressure sound energy prior to radiating the sound waves from the loudspeaker. Typically, a phasing plug is interposed between the diaphragm and the waveguide or horn portion of the loudspeaker, and is spaced from the diaphragm by a small distance (typically a fraction of a millimeter). Accordingly, the compression chamber is bounded on one side by the diaphragm and on the other side by the phasing plug. The phasing plug is typically perforated in some fashion. That is, the phasing plug includes apertures (i.e., passages or channels) that extend between the compression chamber and the waveguide or horn portion of the loudspeaker to provide acoustic pathways from the compression chamber to the waveguide. The cross-sectional area of the apertures is small in comparison to the effective area of the diaphragm, thereby providing air compression and increased sound pressure in the compression chamber.

The compression driver, characterized by having a phasing plug and a compression chamber, may provide a number of advantages if properly designed. These advantages may include increasing the efficiency with which the mechanical energy associated with the moving diaphragm is converted into acoustic energy. Decreasing the parasitic compliance of air in the compression chamber prevents undesired attenuation of high-frequency acoustic signals. Properly positioning the apertures in the phasing plug and sizing the lengths of the associated passages may result in delivering sound energy in phase from all parts of the diaphragm, suppressing or canceling high-frequency standing waves in the compression chamber, and reducing or eliminating undesired interfering cancellations in the propagating sound waves. Particularly for high frequencies, compression drivers may be considered to be superior to direct-radiating drivers for generating high sound-pressure levels.

The diaphragm of a compression driver may have an annular shape and be coaxially disposed about central structures of the phasing plug. An annular diaphragm may have various configurations. As examples, the annular diaphragm may have a V-shaped cross-section (FIG. **27**), an M-shaped cross-section (FIG. **28**), a dual roll cross-section (FIG. **29**), or various combinations of the foregoing as well as other shapes. Different shapes of annular diaphragms have their own advantages and drawbacks. As examples, the V-shaped diaphragm has the lowest resonance frequency (in comparison to other diaphragms having similar voice coils) but its flat suspension is the most nonlinear. The suspension of the V-shaped diaphragm has the shape of internal and external flat rings, which is the softest configuration but has limited displacement capability, i.e., the stiffness of the V-shaped diaphragm rapidly increases with displacement. In comparison to other diaphragms having comparable attributes (e.g., similar inside diameter, voice coil diameter, thickness of diaphragm, and material composition of diaphragms, the M-shaped diaphragm and the dual roll diaphragm have higher resonance frequency (stiffer suspensions) but their suspensions are significantly more linear because of their geometry. The application of an annular diaphragm of a particular shape depends on the requirements of the desired frequency range, the linearity of displacement, and the shape of the frequency response.

Annular diaphragms may be fabricated out of different materials. For example V-shaped diaphragms made of aluminum foil have been manufactured since the early 1950s for high-frequency compression drivers. More recently, compression drivers based on annular diaphragms are typically made of thermoformed polymer films. The capability of the driver to efficiently reproduce high frequency signals depends predominantly on the diaphragm's moving mass and on its high frequency breakups (i.e. partial resonances). At high frequency range the diaphragm does not vibrate as a solid shell, but rather its parts vibrate with different amplitudes and phases. At the resonances (breakups) the diaphragm's overall surface exhibits an increase of displacement and, velocity, and therefore the upper part of the frequency range is increased as well. Due to the high internal damping of polymer films the frequency response of plastic diaphragms is typically much smoother than that of the diaphragms made of aluminum or titanium. There are several factors that limit high frequency signal, including the moving mass of the diaphragm assembly and the volume of the compression chamber. The higher the moving mass, the lower is the high-frequency roll-off (the frequency where the response starts to decrease). The larger the volume of the compression chamber, the lower is the roll-off of the frequency response. Acoustical compliance of air in the compression chamber acts as a low-pass filter, and a larger height of the compression chamber causes a higher compliance of the "air spring", and correspondingly, attenuation of high-frequency signals.

Extension of high frequency response could be obtained by decreasing the moving mass of the diaphragm assembly. However, this would require a smaller diaphragm and a smaller voice coil, which implies a smaller power handling capability. Attempts have been made to avoid this problem by manifolding compression drivers to make them work to a single acoustical load. In one example, several drivers have been mounted to the input ends of a Y-shaped or double Y-shaped tube, with a horn mounted to the single output end of the tube. In another example, several drivers have been stacked into a linear array, with circuitry provided on the input side of each driver to customize the individual frequency and directivity responses of the drivers. In another example, multiple drivers have been symmetrically mounted on opposing sides of a single horn structure, with the higher-frequency drivers being located behind the lower-frequency drivers relative to the mouth of the single horn. In another example, two compression drivers are arranged such that their respective diaphragms axially oppose each other and are coaxial with a central sound output bore. Each driver includes rotationally symmetric radial slots, all of equal length, across their respective compression chambers. The radial slots lead to radial channels that in turn lead to the central sound output bore. The radial slots of the one driver are interleaved with the radial slots of the other driver. That is, the circumferential positions of the radial slots of the one driver alternate with the circumferential positions of the radial slots of the other driver. None of these past approaches is considered to provide the performance criteria currently sought for compression drivers. For instance, the use of equal-length radial slots is disadvantageous in that they may fail to suppress circumferential resonances in the compression chamber, which may degrade the desired frequency response.

Accordingly, there exists an ongoing need for improved designs for compression drivers so as to more fully attain their advantages such as high-frequency efficiency, while ameliorating their disadvantages such as detrimental acoustical nonlinear effects, irregularity of frequency response, and limited frequency range.

SUMMARY

To address the foregoing problems, in whole or in part, and/or other problems that may have been observed by persons skilled in the art, the present disclosure provides methods, processes, systems, apparatus, instruments, and/or devices, as described by way of example in implementations set forth below.

According to one implementation, a dual phasing plug assembly for a compression driver includes a first phasing plug and a second phasing plug. The first phasing plug includes a first base portion. The first base portion includes a first input side, a first output side, a central bore coaxial with a central axis and extending from the first input side to the first output side, a plurality of first entrances on the first input side, a plurality of first exits communicating with the central bore on the first output side, and a plurality of first channels fluidly interconnecting the first entrances with the respective first exits. Each corresponding first entrance, first channel and first exit establish a first acoustical path that is non-radial relative to the central axis. The second phasing plug includes a second base portion. The second base portion includes a second input side, a second output side facing the first output side, a plurality of second entrances on the second input side, a plurality of second exits on the second output side, and a plurality of second channels fluidly interconnecting the second entrances with the respective second exits. Each corresponding second entrance, second channel and second exit establish a second acoustical path that is non-radial relative to the central axis. The second phasing plug further includes a hub portion extending along the central axis from the second output side through the central bore. The hub portion includes an outside surface having a diameter coaxial with the central axis. The first exits and the second exits communicate with an annular region between the central bore and the outside surface.

According to another implementation, a dual compression driver includes a first magnet assembly including an annular first air gap, a first voice coil assembly axially movable in the first air gap, a first diaphragm attached to the first voice coil assembly, a second magnet assembly including an annular second air gap, a second voice coil assembly axially movable in the second air gap, and a second diaphragm attached to the second voice coil assembly. The dual compression driver further includes a first phasing plug forming a first compression chamber with the first diaphragm, and a second phasing plug forming a second compression chamber with the second diaphragm. The first and second phasing plugs may be configured as summarized above.

According to another implementation, a phasing plug includes a base portion including an input side, an output side, a plurality of entrances on the input side, a plurality of exits on the output side arranged about a central axis, and a plurality of channels fluidly interconnecting the entrances with the respective exits. Each corresponding entrance, channel and exit establish an acoustical path from the input side to the output side that is non-radial relative to the central axis. The entrances lie along a plurality of lines collectively forming a polygon that includes greater than four vertices at which neighboring lines adjoin.

Other devices, apparatus, systems, methods, features and advantages of the invention will be or will become apparent to one with skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included within this description, be within the scope of the invention, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE FIGURES

The description of examples of the invention below can be better understood by referring to the following figures. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. In the figures, like reference numerals designate corresponding parts throughout the different views.

FIG. **1**A is a perspective view of an example of a loudspeaker in which dual compression drivers as described below may be implemented.

FIG. **1**B is a perspective view of another example of a loudspeaker in which dual compression drivers as described below may be implemented.

FIG. **2** is an exploded perspective view of an example of a dual phasing plug assembly that may be provided as part of a dual compression driver.

FIG. **3** is a cross-sectional perspective view of the dual phasing plug assembly illustrated in FIG. **2** with the components assembled.

FIG. **4** is an exploded perspective view of an example of a dual compression driver.

FIG. **5** is a cross-sectional perspective view of the dual compression driver illustrated in FIG. **4** with the components assembled.

FIG. **6** is a perspective view of an example of a phasing plug from an input side, which may, for example, be utilized as a front phasing plug in the dual compression driver illustrated in FIGS. **4** and **5**.

FIG. **7** is a plan view of the phasing plug illustrated in FIG. **6** from the perspective of the input side.

FIG. **8** is another perspective view of the phasing plug illustrated in FIGS. **6** and **7** from an output side opposite to the input side.

FIG. **9** is a plan view of the phasing plug illustrated in FIGS. **6**-**8** from the perspective of the output side.

FIG. **10** is a perspective view of an example of a phasing plug from an input side, which may, for example, be utilized as a rear phasing plug in the dual compression driver illustrated in FIGS. **4** and **5**.

FIG. **11** is another perspective view of the phasing plug illustrated in FIG. **10** from an output side opposite to the input side.

FIG. **12** is a perspective view of another example of a phasing plug from an input side, which may, for example, be utilized as a front phasing plug in the dual compression driver illustrated in FIGS. **4** and **5**.

FIG. **13** is a plan view of the phasing plug illustrated in FIG. **12** from the perspective of the input side.

FIG. **14** is another perspective view of the phasing plug illustrated in FIGS. **12** and **13** from an output side opposite to the input side.

FIG. **15** is a plan view of the phasing plug illustrated in FIGS. **12**-**14** from the perspective of the output side.

FIG. **16** is a perspective view of an example of a phasing plug from an input side, which may, for example, be utilized as a rear phasing plug in the dual compression driver illustrated in FIGS. **4** and **5**.

FIG. **17** is another perspective view of the phasing plug illustrated in FIG. **16** from an output side opposite to the input side.

FIG. **18** is a perspective view of another example of a phasing plug from an input side, which may, for example, be utilized as a front phasing plug in the dual compression driver illustrated in FIGS. **4** and **5**.

FIG. **19** is a plan view of the phasing plug illustrated in FIG. **18** from the perspective of the input side.

FIG. **20** is another perspective view of the phasing plug illustrated in FIGS. **18** and **19** from an output side opposite to the input side.

FIG. **21** is a plan view of the phasing plug illustrated in FIGS. **18**-**20** from the perspective of the output side.

FIG. **22** is a perspective view of an example of a phasing plug from an input side, which may, for example, be utilized as a rear phasing plug in the dual compression driver illustrated in FIGS. **4** and **5**.

FIG. **23** is another perspective view of the phasing plug illustrated in FIG. **22** from an output side opposite to the input side.

FIG. **24** is an exploded perspective view of another example of a dual phasing plug assembly that may be provided as part of a dual compression driver such as illustrated in FIGS. **4** and **5**.

FIG. **25** is a perspective view of another example of a phasing plug, specifically from the perspective of its output side.

FIG. **26** is an exploded perspective view of another example of a dual phasing plug assembly in which the phasing plug illustrated in FIG. **25** is utilized as a front phasing plug.

FIG. **27** is a cross-sectional perspective view of a diaphragm having a V-shaped profile.

FIG. **28** is a cross-sectional perspective view of a diaphragm having an M-shaped profile.

FIG. **29** is a cross-sectional perspective view of a diaphragm having a dual-roll profile.

DETAILED DESCRIPTION

According to certain implementations described by example below, a dual compression driver may be provided by positioning two drivers face-to-face in such a way that the drivers are loaded by the same acoustical load. The two drivers may be combined into a single unit that includes two motors, two diaphragms and two voice coils, but a single exit for sound output. The dual compression driver may include a dual phasing plug assembly configured in accordance with implementations described by example below. One or both phasing plugs may be configured in accordance with implementations also described by example below.

FIG. **1**A is a perspective view of an example of a loudspeaker **100** in which dual compression drivers as described below may be implemented. The loudspeaker **100** includes an electro-acoustical transducer section **104**. In some implementations, the loudspeaker **100** may also include a waveguide or horn **108**. The transducer section **104** and horn **108** are generally disposed about a longitudinal or central axis **112**. The transducer section **104** may include a rear section **116** and a housing or adapter **120**. The rear section **116** may be coupled to the housing **120** by any suitable means. The rear section **116** and housing **120** may enclose components for realizing a dual compression driver, an example of which is described below. The horn **108** may include a horn structure **124** such as one or more walls that enclose an interior **128** of the horn **108**. As illustrated, the horn structure **124** may be flared or tapered outwardly from the central axis **112** to provide an expanding cross-sectional area through which sound waves propagate. The housing **120** generally includes a first or input end **128** and a second or output end **132**. Likewise, the horn **108** generally includes a first or input end **136** and a second or output end commonly referred to as a mouth **140**. The output end **132** of the housing **120** may be coupled to the input end **136** of the horn **108** by any suitable means. In the present example, the horn **108** is attached to the housing **120** or rear section **116** via a screw-on connection. Generally, the loudspeaker **100** receives an input of electrical signals at an appropriate connection such as contacts **144** provided by the transducer section **104** (such as may be located at the rear section **116**) and converts the electrical signals into acoustic signals according to mechanisms briefly summarized above and readily appreciated by persons skilled in the art. The acoustic signals propagate through the interior of the housing **120** and horn **108** and exit the loudspeaker **100** at the mouth **140** of the horn **108**.

FIG. **1**B is a perspective view of another example of a loudspeaker **150** in which dual compression drivers as described below may be implemented. The loudspeaker **150** includes a transducer section **154** and a horn **158**. The transducer section **154** may include a rear section **166** and a housing or adapter **170**. In this example, the horn **158** includes a mouth **190** that is more square-shaped in comparison to the rectangular-shaped mouth of the example shown in FIG. **1**A. Also in this example, the horn **158** is attached to the housing **170** or rear section **166** via a bolt-on connection as an alternative to a screw-on connection.

As a general matter, the loudspeaker **100** or **150** may be operated in any suitable listening environment such as, for example, the room of a home, a theater, or a large indoor or outdoor arena. Moreover, the loudspeaker **100** or **150** may be sized to process any desired range of the audio frequency band, such as the high-frequency range (generally 2 kHz-20 kHz) typically produced by tweeters, the midrange (generally 200 Hz-5 kHz) typically produced by midrange drivers, and the low-frequency range (generally 20 Hz-200 Hz) typically produced by woofers. As appreciated by persons skilled in the art, loudspeakers **100**, **150** of the horn driver-type are typically utilized to process relatively high frequencies (i.e., midrange to high range), and compression drivers are typically more efficient at higher frequencies than non-compression driver configurations such as the direct-radiating type. However, the compression drivers described in the present disclosure are not limited to any particular frequency range.

FIGS. **2-29** illustrate examples of components that may be utilized in a loudspeaker such as illustrated in FIG. **1**A or **1**B. For convenience, the remainder of the description will refer primarily to the loudspeaker **100** associated with FIG. **1**A. It will be understood, however, that the description applies equally to the loudspeaker **150** associated with FIG. **1**B as a general matter, although some of the components shown in FIGS. **2-29** may be sized or otherwise configured more appropriately for the loudspeaker **100** while other components shown in FIGS. **2-29** may be sized or otherwise configured more appropriately for the loudspeaker **150**.

FIG. **2** is an exploded perspective view of an example of a dual phasing plug assembly **200** and associated components that may be provided as parts of a dual compression driver, which in turn may be provided as part of the transducer section **104** (FIG. **1**) of the loudspeaker **100**. Various components of the dual phasing plug assembly **200** may be disposed generally about the central axis **112**. For descriptive purposes, some components are described as being "front" components while other components are described as being "rear" components. Relative to "rear" components, "front" components are generally closer to the side of the dual phasing plug assembly **200** at which sound waves emanate and may further propagate through a waveguide such as, for example, the horn **108** shown in FIG. **1**. It will be understood, however, that the terms "front" and "rear" in this context are not intended to limit the dual phasing plug assembly **200** to any particular orientation in space.

The dual phasing plug assembly **200** includes a front (or first) phasing plug **202**. The front phasing plug **202** includes a front base portion or body **204**, which may be generally disk-shaped and lie in a plane orthogonal to the central axis **112**, and may be generally centered about the central axis **112**. A central bore **206** coaxial with the central axis **112** is formed through the thickness (axial direction) of the front base portion **204** to open at both an input side (facing upward from the perspective of FIG. **2**) and an output side (facing downward) of the front base portion **204**. The front phasing plug **202** may also include a hollow hub portion or conduit **208** axially extending from the input side. The conduit **208** may be provided as an annular wall coaxial with the central axis **112**. The inside diameter of the conduit **208** may be substantially the same as the inside diameter of the central bore **206**, at least at the juncture with the input side. The conduit **208** may be considered as an extension of the central bore **206**.

The dual phasing plug assembly **200** also includes a rear (or second) phasing plug **212**. The rear phasing plug **212** includes a rear base portion or body **214**, which likewise may be generally disk-shaped and lie in a plane orthogonal to the central axis **112**, and may be generally centered about the central axis **112**. The rear phasing plug **212** may also include a hub portion **218** axially extending from an output side of the rear base portion **214**. In the present example, the output side of the rear base portion **214** faces the output side of the front base portion **204**. The hub portion **218** is typically bullet-shaped and accordingly may be referred to as a bullet. That is, the diameter (coaxial with the central axis **112**) of the outside surface of the hub portion **218** typically tapers in the axial direction to an apex or tip **222** located on the central axis **112**. The tip **222** may be relatively sharp or may be domed. The diameter of the outside surface of the hub portion **218** at the rear base portion **214** is less than the inside diameter of the central bore **206**. When assembled, the hub portion **218** extends through the central bore **206**—and, if provided, through the conduit **208**—to an axial elevation above the front phasing plug **202**. The rear phasing plug **212** may also include an annular mounting structure **224** axially extending from an input side of the rear base portion **214**, which may facilitate mounting the rear phasing plug **212** to an underlying magnetic assembly (described below).

As further illustrated in FIG. **2**, an annular front diaphragm **230** may be mounted at the input side of the front base portion **204** such that the front diaphragm **230** is concentric to the central bore **206**. The front diaphragm **230** may be constructed of any flexible material suitable for loudspeakers, as appreciated by persons skilled in the art. An outer portion of the front diaphragm **230** may be mounted axially between the front base portion **204** and a front outer positioning ring **232**. An inner portion of the front diaphragm **230** may be mounted axially between the front base portion **204** and a front inner positioning ring **234**. A front voice coil assembly **236** may be attached to a movable portion of the front diaphragm **230** that is located at a transverse distance (i.e., in a direction orthogonal to the central axis **112**) between the front outer positioning ring **232** and the front inner positioning ring **234**. Similarly, an annular flexible rear diaphragm **240** may be mounted at the input side of the rear base portion **214** such that the rear diaphragm **240** is concentric to the mounting structure **224**. An outer portion of the rear diaphragm **240** may be mounted axially between the rear base portion **214** and a rear outer positioning ring **242**. An inner portion of the rear diaphragm **240** may be mounted axially between the rear base portion **214** and a rear inner positioning ring **244**. A rear voice coil assembly **246** may be attached to a movable portion of the rear diaphragm **240** that is located at a transverse distance between the rear outer positioning ring **242** and the rear inner positioning ring **244**.

FIG. **3** is a cross-sectional perspective view of the dual phasing plug assembly **200** illustrated in FIG. **2** with the components assembled. The front voice coil assembly **236** and the rear voice coil assembly **246** may have any configuration which, in response to electrodynamic excitation, respectively causes axial oscillation or translation of the front diaphragm **230** and the rear diaphragm **240** in a known manner. Accordingly, in the illustrated example the front voice coil assembly **236** includes a front voice coil **352** supported on a front voice coil former **354**, and the rear voice coil assembly **246** includes a rear voice coil **356** supported on a rear voice coil former **358**. The front and rear voice coil assemblies **236**, **246** may be assembled and respectively attached to the front and rear diaphragms **230**, **240** by any suitable means. As an example, the front and rear voice coils **352**, **356** may be respectively glued to the front and rear voice coil formers **354**, **358**, and the front and rear voice coil formers **354**, **358** may be respectively glued to the front and rear diaphragms **230**, **240**.

The front diaphragm **230** is clamped, on one side, between the front outer positioning ring **232** and the front base portion **204** and, on the other side, between the front inner positioning ring **234** and the front base portion **204**. The input side of the front base portion **204** includes an annular region **362** between the annular clamped boundaries provided by the front outer positioning ring **232** and the front inner positioning ring **234**. Within these boundaries, the front diaphragm **230** is free to translate axially toward and away from the annular region **362** in response to electromagnetic actuation of the front voice coil assembly **236** in a manner appreciated by persons skilled in the art. The front diaphragm **230** is spaced from the annular region **362** by an axial gap that varies in accordance with the axial translation of the front diaphragm **230**. This axial gap defines a front compression chamber. In practice, the height of the front compression chamber (i.e., the size of the axial gap when the front diaphragm **230** is not being driven) may be quite small (e.g., approximately 0.5 mm or less) such that the volume of the front compression chamber is also small. As also illustrated in FIG. **3**, a plurality of front exits **364** are formed on the output side of the front base portion **204** and are located at the central bore **206**. The front exits **364** may be circumferentially spaced relative to the central axis **112**.

As described further below, the front base portion **204** is configured to define a plurality of front (or first) acoustical paths that run from the front compression chamber, through the thickness of the front base portion **204** via entrances and associated channels (not shown), and to the respective front exits **364**. In operation, actuation of the front diaphragm **230** by the oscillating front voice coil assembly **236** (energized by the audio signal input) generates high sound-pressure acoustical signals within the front compression chamber, and the acoustical signals travel as sound waves through the front base portion **204** along the front acoustical paths. As further illustrated in FIG. **3**, an annular gap or region **366** is provided between the central bore **206** and an outside surface **368** of the hub portion **218**. Each front exit **364** communicates with the annular region **366**, whereby all front acoustical paths lead to and merge or sum at the common annular region **366**. The acoustical signal path then turns upward (from the perspective of FIG. **3**) and continues adjacent to the outside surface **368**. If the conduit **208** is provided, the acoustical signals propagate between an inside surface **370** of the conduit **208** and the outside surface **368** of the hub portion **218**. As further illustrated in FIG. **3**, the inside surface **370** may be tapered in the axial direction away from the input side of the front base portion **204**, but to a lesser degree than the outside surface **368**, whereby the annular region between the inside surface **370** and the outside surface **368** defines a waveguide of increasing cross-sectional area.

As also illustrated in FIG. **3**, the rear diaphragm **240** is clamped on one side between the rear outer positioning ring **242** and the rear base portion **214**, and on the other side between the rear inner positioning ring **244** and the rear base portion **214**. The input side of the rear base portion **214** includes an annular region **372** between the annular clamped boundaries provided by the rear outer positioning ring **242** and the rear inner positioning ring **244**. Within these boundaries, the rear diaphragm **240** is free to translate axially toward and away from the annular region **372** in response to electromagnetic actuation of the rear voice coil assembly **246**. The rear diaphragm **240** is spaced from the annular region **372** by an axial gap that varies in accordance with the axial translation of the rear diaphragm **240**. This axial gap defines a rear compression chamber. As also illustrated in FIG. **3**, a plurality of rear exits **374** are formed on the output side of the rear base portion **214** and are located at the central bore **206**. The rear exits **374** may be circumferentially spaced relative to the central axis **112**. As described further below, the rear base portion **214** is configured to define a plurality of rear (or second) acoustical paths that run from the rear compression chamber, through the thickness of the rear base portion **214** via entrances and associated channels (not shown), and to the respective rear exits **374**. Each rear exit **374** communicates with the annular region **366**, whereby all rear acoustical paths lead to and merge or sum at the common annular region **366**. The acoustical signal path then turns upward and continues adjacent to the outside surface **368**. As the annular region **366** is also common to the front acoustical paths, the rear acoustical paths may merge or sum with the front acoustical paths in, or in the vicinity of, the annular region **366**.

In the example illustrated in FIG. **3**, the front acoustical exits **364** are axially aligned with the rear acoustical exits **374**. That is, each front acoustical exit **364** is located at the same circumferential position as a corresponding rear acoustical exit **374** relative to the central bore **206**. Also in the example illustrated in FIG. **3**, the front base portion **204** abuts (is immediately adjacent to) the rear base portion **214**, such that each corresponding front acoustical exit **364** and rear acoustical exit **374** are in open communication with each other at the central bore **206** and open together into the annular region **366**. In other implementations described below, a divider (not shown) separates the front base portion **204** and the rear base portion **214**.

Also in the example illustrated in FIG. **3**, the movable portion of the front diaphragm **230** may include a raised section such as a V-shaped section **376**. The raised section may include a circular apex coaxial with the central axis **112**, and the front voice coil assembly **236** may be attached to the front diaphragm **230** at the circular apex. In this example, the annular region **362** may be complementarily V-shaped to form a V-shaped front compression chamber with the front diaphragm **230**. Similarly, the movable portion of the rear diaphragm **240** may include a V-shaped section **378** (or other type of raised section with a circular apex), and the annular region **372** may be complementarily V-shaped to form a V-shaped rear compression chamber with the rear diaphragm **240**. The rear voice coil assembly **246** may be attached to the rear diaphragm **240** at the circular apex. Other alternatively shaped profiles may be provided for the raised sections as described below.

FIG. **4** is an exploded perspective view of an example of a dual compression driver **400** that may be provided, for example, as part of the transducer section **104** (FIG. **1**) of the loudspeaker **100**. In this example the dual compression driver **400** may be realized by adding the front diaphragm **230**, the front voice coil assembly **236**, the rear diaphragm **240**, and the rear voice coil assembly **246** to the dual phasing plug assembly **200** in the manner described above and illustrated in FIGS. **2** and **3**, and by further adding a front magnet assembly **480** and a rear magnet assembly **490**. Generally, the front magnet assembly **480** and the rear magnet assembly **490** may have any configuration suitable for providing magnetic fields useful for respectively inducing the front voice coil assembly **236** to drive the front diaphragm **230** and inducing the rear voice coil assembly **246** to drive the rear diaphragm **240**, as necessary for converting inputted electrical signals into sound waves in accordance with principles understood by persons skilled in the art. In the illustrated example, the front magnet assembly **480** may include an annular front magnet **482** axially interposed between an annular front back plate **484** and an annular front top plate **486**. In this example, an annular front pole piece **488** of lesser diameter than the front magnet **482** is integrated with the front back plate **484**. The other components (e.g., plates/pole pieces) are typically composed of a soft magnetic material such as, for example, low-carbon steel. Likewise, the rear magnet assembly **490** may include an annular rear magnet **492** axially interposed between an annular rear back plate **494** and an annular rear top plate **496**. In this example an annular rear pole piece **498** of lesser diameter than the rear magnet **492** is integrated with the rear back plate **494**. The front and rear magnets **482**, **492** may be composed of any permanent magnetic material suitable for use in loudspeaker drivers. The other components (e.g., plates/pole pieces) are typically composed of a soft magnetic material such as, for example, low-carbon steel.

FIG. **4** also illustrates the annular adapter **120** that may be disposed on the front side of the uppermost front plate **484**. The adapter **120** circumscribes a central sound outlet **466**. Depending on the application of the dual compression driver **400** to a loudspeaker of a given design, the adapter **120** may be useful for providing a mechanical and/or acoustical connection to a sound radiator such as the horn **108** illustrated in FIG. **1**.

FIG. **5** is a perspective view in cross-section of the dual compression driver **400** illustrated in FIG. **4** with the components assembled. The front magnet **482** provides a magnetic field across an annular air gap **536** formed between the front top plate **486** and the pole piece **488** of the front back plate **484**, and the front voice coil assembly **236** is free to translate axially through the air gap **536** in a manner appreciated by persons skilled in the art. Likewise, the rear magnet **492** provides a magnetic field across an annular air gap **546** formed between the rear top plate **496** and the pole piece **498** of the rear back plate **494**, and the rear voice coil assembly **246** is free to translate axially through the air gap **546**. As also shown in FIG. **5**, inside surfaces **570** of various annular components disposed above the annular region **366**, such as the conduit **208**, the front back plate **484**, and the adapter **120**, may form a waveguide **566** in conjunction with the outside surface **368** of the hub portion **218**. The inside surfaces **570** may be tapered, but to a lesser degree than the outside surface **368**, whereby the waveguide **566** provides a cross-sectional area that increases in the axial direction to the central sound outlet **466**. Accordingly, the acoustical paths for sound waves generated by the dual compression driver **400** may be described as follows. First acoustical paths run from the annular front compression chamber, through the thickness of the front base portion **204** (in a manner described below) from its input side to its output side, through the respective front exits **364** and into the annular region **366**. Second acoustical paths run from the annular rear compression chamber, through the thickness of the rear base portion **214** (in a manner described below) from its input side to its output side, through the respective rear exits **374** and into the annular region **366** where the second acoustical paths may merge or sum with the first acoustical paths. The sound waves from the first and second acoustical paths then turn upward and propagate through the waveguide **566** and the central sound outlet **466**, and subsequently through the horn **108** (FIG. **1**) or any other sound radiator or waveguide attached to the dual compression driver **400** at the central sound outlet **466**. It will be noted that the horn **108** or other type of waveguide connected to the dual compression driver **400** may be considered to be part of, or an extension of, the waveguide **566** illustrated in FIG. **5**. The adapter **120** (if provided) may be considered to be an intermediate part between the dual compression driver **400** and the horn **108** (or other waveguide), or may be considered to be part of or an extension of the dual compression driver **400**, or may be considered to be part of or an extension of the horn **108**.

As an example of assembling the dual compression driver **400**, the front magnet assembly **480** may be assembled by gluing together the front back plate **484**, the front magnet **482** and the front top plate **486**. The rear magnet assembly **490** may be assembled by gluing together the rear top plate **496**, the rear magnet **492** and the rear back plate **494**. In this example, the front pole piece **488** is integral with the front back plate **484** and the rear pole piece **498** is integral with the rear back plate **494**, so the front and rear pole pieces **488**, **498** do not require separate mounting. The dual phasing plug assembly **200** may be assembled by threading bolts (not shown) through axially aligned bores of the various annular components of the dual phasing plug assembly **200**. Some of these bores are shown in FIGS. **4** and **5**. At least some of these bores may be threaded to mate with the threads of the bolts. The dual phasing plug assembly **200** may be secured to the front magnet assembly **480** by further threading the bolts through additional axially aligned bores formed in one or more annular components of the front magnet assembly **480**. In this example, the upper rear plate **496** includes blind holes axially aligned with the bores but of greater diameter to accommodate the heads of the bolts. Thus, after installing the bolts to secure the dual phasing plug assembly **200** to the front magnet assembly **480**, the rear magnet assembly **490** may be brought into abutment with the dual phasing plug assembly **200** such that the heads of the bolts are seated in these blind holes. A bolt outline **520** resulting from the axially aligned bores and corresponding blind hole is evident in FIG. **5**. Finally, the rear magnet assembly **490** may be secured to the dual phasing plug assembly **200** by threading another bolt (not shown) through centrally located, axially aligned bores of the lower rear plate **494** and the hub portion **218** of the rear phasing plug **212**, as shown in FIG. **5**. The adapter **120** may also be bolted between the upper front plate **484** and a sound radiator (e.g., the horn **108** of FIG. **1**) as appropriate.

FIG. **6** is a perspective view of an example of a phasing plug **602** that may, for example, be utilized as a front phasing plug in the dual compression driver **400** (FIGS. **4** and **5**). The perspective is from an input side that would face the front diaphragm **230** of the dual compression driver **400**. It will be noted that the phasing plug **602** is a smaller-sized version than the phasing plug **202** shown in FIGS. **2-5**, and thus in practice would be implemented in a driver utilizing a smaller-diameter voice coil. The phasing plug **602** includes a base portion **604**, a central bore **606**, and a conduit **608** aligned with the central bore **606**. The base portion **604** includes an annular compression region **662** located so as to be underneath the movable portion of the front diaphragm **230**. As noted above, the compression region **662** may have a raised profile (e.g., V-shape or other shape), which in FIG. **6** is generally demarcated by an inner circle (or circumference) **612**, an outer circle (or circumference) **614**, and a circular apex **616**. A plurality of acoustical entrances **620** is located on the input side in the compression region **662**. The entrances **620** extend as channels (not shown, but see FIG. **8**) through the thickness of the base portion **604** to respective acoustical exits **664** located on the output side, thus establishing acoustical paths as described above. The entrances **620** may have any suitable shapes. Each entrance **620** may have a dominant dimension in one direction as in the case of a slot or slit. In the illustrated example, the entrances **620** are shaped as slots with straight edges, including outermost edges **622** ("outermost" being relative to distance from the central axis). The plurality of entrances **620** may be arranged according to a desired pattern (such as from the perspective of a plane orthogonal to the central axis **112**). For this purpose, the plurality of entrances **620** may be arranged into groups or sets of similarly oriented entrances **620**. In the illustrated example, four groups are provided with each group including four entrances **620**. In the illustrated example, each set of four entrances **620** is linearly arranged. In other examples, a set of entrances may be arranged along an arcuate path that is either concave or convex relative to the central axis. In still other examples, an entrance may have a dominant dimension that is arcuate such that the entrance itself is shaped as an arcuate opening instead of a straight-edged opening.

The total number of entrances **620** and the cross-sectional areas of the entrances **620** may be selected according to the compression ratio desired for a particular application. Generally, the compression ratio is determined from the relationship between the effective area of the diaphragm and the effective area of the entrance into the phasing plug **602**. The effective area of the diaphragm is the portion of the diaphragm that serves as a boundary of, and hence partially defines, the compression chamber. The effective area of the entrance into the phasing plug **602** is the total cross-sectional area of all of the individual entrances **620**. The compression ratio affects the efficiency of the compression driver and influences the shape of the frequency response, and therefore the number and size of the entrances **620** should be carefully selected.

FIG. **7** is a plan view of the phasing plug **602** illustrated in FIG. **6** from the perspective of the input side. The plurality of entrances **620** may be patterned so as to have one or more of the following attributes. In one aspect, the orientation of each entrance **620** may be non-radial and non-circumferential relative to the central axis **112**. That is, the entrances **620** are not aligned with radii extending orthogonally from the central axis **112** and therefore are not circumferentially spaced from each other (e.g., along a circle) relative to the central axis **112**. For instance, in the illustrated example in which the entrances **620** are slot-shaped, if the entrances **620** were arranged in radial orientations their outermost edges **622** would intersect radii orthogonally, i.e., would be perpendicular to radii projecting through the entrances **620**. Instead, in the illustrated example the entrances **620** (and their outermost edges **622**) are oriented at non-ninety-degree acute angles to the radii. This configuration is illustrated in FIG. **7** by two radii **724**, **726** projecting from the central axis **112** through two arbitrarily selected entrances **620**. Despite the non-radial configuration, however, the pattern of entrances **620** as a whole may be symmetrical relative to the central axis **112**, as in the illustrated example. In another aspect, the entrances **620** may be arranged along one or more lines that run diagonally across the annular compression region **662**. In the illustrated example, each group of four entrances cuts diagonally across the compression region **662**. In another aspect, the entrances **620** may be arranged along one or more lines that are diagonal relative to the central axis **112**. In the present context, a diagonal line is collinear with a chord of a circle concentric with the central axis **112**, or is a line that is tangential to a circle concentric with the central axis **112**. In the illustrated example, using the outermost edge **622** of each entrance **620** as a datum, four lines **732**, **734**, **736**, **738** have been drawn coincident with the outermost edges **622** of the entrances **620** of the four respective groups. Each line **732**, **734**, **736**, **738** is a chord of the outer circle **614** or the circular apex **616** of the compression region **662**. In another aspect, the entrances **620** lie on the perimeter of a closed polygon associated with a plane (orthogonal to the central axis **112**) in which the base portion **604** resides. Typically, the closed polygon will have at least four corners or vertices, and may be centered about the central axis **112**. In the illustrated example, using the previously drawn lines **732**, **734**, **736**, **738**, the entrances **620** lay on the perimeter of a quadrangle (with four vertices), such as a rhomboid, parallelogram, rectangle, or as in the specific example, a square. As an example, a vertex **718** is designated at the intersection of the lines **732** and **738**.

FIG. **8** is another perspective view of the phasing plug **602** illustrated in FIGS. **6** and **7** from an output side opposite to the input side. A plurality of channels or grooves **850** is formed on the output side. The channels **850** respectively interconnect the entrances **620** with corresponding exits **664**. Accordingly, each acoustical path runs from the compression chamber on the input side, into one of the entrances **620**, through the thickness of the base portion **604** to the corresponding channel **850** communicating with that entrance **620**, through the corresponding exit **664** on the output side, and into the central bore **606**. Corresponding entrances **620**, channels **850** and exits **664** may be considered as respective acoustical connectors that extend through the thickness of the phasing plug **602**. The height and width of each channel **850** may be constant or may vary. The channels **850** may be provided in the form of recesses that extend into the thickness of the base portion **604** from the output side, as shown by example in FIG. **8**. The manner by which the channels **850** are bounded from above (from the perspective of FIG. **8**) depends on the implementation. In implementations such as illustrated in FIGS. **3** and **5** in which the rear phasing plug directly abuts the front phasing plug, the channels **850** of the front phasing plug **602** may be in open communication with complementary channels of the rear phasing plug. In other implementations such as described below, a dividing plate may abut the phasing plug **602** and consequently cover the channels **850**.

FIG. **9** is a plan view of the phasing plug **602** illustrated in FIGS. **6**-**8** from the perspective of the output side. The pattern of the channels **850** and the resulting acoustical paths may have the same or analogous attributes as those described above regarding the entrances **620**. For example, the orientation of each channel **850** and associated acoustical path may be non-radial relative to the central axis **112**. That is, the channels **850** do not radiate from the central axis **112** as spokes from the hub of a wheel. For instance, the boundaries of the channels **850**, such as side walls **952** and junctions **954** with the entrances **620**, are neither parallel with nor perpendicular to any radii (e.g., radii **924** and **926**) emanating from the central axis **112**. Instead, such boundaries are oriented at non-ninety-degree angles to the radii. In another aspect, the entrances **620** are non-parallel with (and not radially aligned with) the exits **664**. This may be further seen in FIG. **8** by looking at the cross-sectional area of one of the entrances **620** and comparing it to the cross-sectional area of the corresponding channel **850**, for example where the channel **850** adjoins the entrance **620**. As also shown in FIG. **9**, the lengths (i.e., in a general direction from the exits **664** to the entrances **620**) of one or more channels **850** may differ from the lengths of the other channels **850**. In the illustrated example, two of the channels **850** in each group are shorter than the other two channels **850** in the group. The pattern of entrances **620** and channels **850** as a whole, however, may be symmetrical relative to the central axis **112**, as in the illustrated example.

The non-radial, diagonal orientation of the entrances enables acoustical signals (sound pressure signals) to be picked up from the different parts of the compression chamber in both radial and circumferential directions. This configuration enables the "averaging" of acoustical signals that potentially have different phases. Moreover, the provision of channels **850** of different lengths mitigates possible resonances in the channels **850**. By contrast, the positions of equal-length radial slots and channels such as described in the Related. Art section above may coincide with the positions of circumferential resonances in the compression chamber, which may cause severe irregularity in the frequency response.

FIG. **10** is a perspective view of an example of a phasing plug **1012** that may, for example, be utilized as a rear phasing plug in the dual compression driver **400** (FIGS. **4** and **5**) in conjunction with the front phasing plug **602** described above and illustrated in FIGS. **6**-**9**. The perspective is from an input side that would face the rear diaphragm **240** of the dual compression driver **400**. The phasing plug **1012** includes a base portion **1014** and a mounting feature **1024** concentric with the central axis. The base portion **1014** includes an annular compression region **1072** located so as to be above (from the perspective of FIGS. **2**-**5**) the movable portion of the rear diaphragm **240**. As noted above, the compression region **1072** may have a raised profile (e.g., V-shape or other shape), which in FIG. **10** is generally demarcated by an inner circle **1062**, an outer circle **1064**, and a circular apex **1080**. A plurality of acoustical entrances **1020** is located on the input side in the compression region **1072**. The entrances **1020** extend as channels (not shown, but see FIG. **11**) through the thickness of the base portion **1014** to respective acoustical exits (not shown) located on the output side, thus establishing acoustical paths as described above. The entrances **1020** may have any suitable shapes. In the illustrated example, the entrances **1020** are shaped as slots with straight edges, including outermost edges **1022** ("outermost" being relative to distance from the central axis). The plurality of entrances **1020** may be arranged according to a desired pattern. For this purpose, the plurality of entrances **1020** may be arranged into groups or sets of similarly oriented entrances **1020**. In some implementations as in the illustrated example, particularly when the rear phasing plug **1012** is to be disposed in direct abutment with the front phasing plug **602**, the pattern of entrances **1020** of the rear phasing plug **1012** matches and is axially aligned with the pattern of entrances **620** of the front phasing plug **602**. Hence, in the illustrated example four groups are provided with each group including four entrances **1020**. The total number of entrances **1020** and the cross-sectional areas of the entrances **1020** may be selected according to the compression ratio desired for a particular application.

Particularly in matching implementations, the plurality of entrances **1020** of the rear phasing plug **1012** may be patterned so as to have one or more of the same attributes as described above in conjunction with the entrances **620** of the front phasing plug **602**. Thus, the orientation of each entrance **1020** may be non-radial and non-circumferential relative to the central axis. The entrances **1020** may be arranged along one or more lines (such as lines coincident with the outermost edges **1022**) that run diagonally across the annular compression region **1072**. The entrances **1020** may lie on the perimeter of a closed polygon associated with a plane in which the base portion **1014** resides, such as the same type of quadrangle as illustrated in FIG. **7**.

FIG. **11** is another perspective view of the phasing plug **1012** illustrated in FIG. **10** from an output side opposite to the input side. A plurality of channels or grooves **1150** is formed on the output side. The channels **1150** respectively interconnect the entrances **1020** with corresponding exits **1174**. The phasing plug further includes a centrally located hub portion **1118** that may be shaped as a bullet as described above. An annular region **1166** is defined between the hub portion **1118** and the surrounding exits **1174**. Accordingly, each acoustical path runs from the compression chamber on the input side, into one of the entrances **1020**, through the thickness of the base portion **1014** to the corresponding channel **1150** communicating with that entrance **1020**, through the corresponding exit **1174** on the output side, and into the annular region **1166**. The channels **1150** may be configured in the same manner as illustrated in FIGS. **8** and **9**. In implementations in which the rear phasing plug **1012** directly abuts the front phasing plug **602**, the channels **1150** of the rear phasing plug **1012** may be in open communication with corresponding channels **850** of the front phasing plug **602**. In this case, corresponding pairs of front channels **850** and rear channels **1150** may be considered as forming combined or common channels, and the front acoustical paths may be considered as merging or summing with the rear acoustical paths in the corresponding pairs of channels **850**, **1150**. In other implementations such as described below, a dividing plate may be positioned to axially separate the channels **1150** of the rear phasing plug **1012** from the channels **850** of the front phasing plug **602**. The pattern of the channels **1150** and the resulting acoustical paths may have the same or analogous attributes as those described above regarding the front phasing plug **602**. For example, the orientation of each channel **1150** and associated acoustical path may be non-radial relative to the central axis. The entrances **1020** may be non-parallel with (and not radially aligned with) the exits **1174**. The lengths of one or more channels **1150** may differ from the lengths of the other channels **1150**. The pattern of channels **1150** may or may not be symmetrical relative to the central axis.

FIG. **12** is a perspective view of another example of a phasing plug **1202** that may, for example, be utilized as a front phasing plug in the dual compression driver **400** (FIGS. **4** and **5**). The perspective is from an input side that would face the front diaphragm **230** of the dual compression driver **400**. The phasing plug **1202** includes a base portion **1204**, a central bore **1206**, and a conduit **1208** aligned with the central bore **1206**. The base portion **1204** includes an annular compression region **1262** located so as to be underneath the movable portion of the front diaphragm **230**. As noted above, the compression region **1262** may have a raised profile (e.g., V-shape or other shape), which in FIG. **12** is generally demarcated by an inner circle **1212**, an outer circle **1214**, and a circular apex **1216**. A plurality of acoustical entrances **1220** is located on the input side in the compression region **1262**. The entrances **1220** extend as channels (not shown, but see FIG. **14**) through the thickness of the base portion **1204** to acoustical exits **1264** located on the output side, thus establishing acoustical paths as described above. The entrances **1220** may have any suitable shapes. In the illustrated example, the entrances **1220** are shaped as slots with straight edges, including outermost edges **1222**. The plurality of entrances **1220** may be arranged according to a desired pattern. For this purpose, the plurality of entrances **1220** may be arranged into groups or sets of similarly oriented entrances **1220**. In the illustrated example, sixteen groups are provided with each group including two entrances **1220**. The total number of entrances **1220** and the cross-sectional areas of the entrances **1220** may be selected according to the compression ratio desired for a particular application.

FIG. **13** is a plan view of the phasing plug **1202** illustrated in FIG. **12** from the perspective of the input side. The plurality of entrances **1220** may be patterned so as to have one or more of the same or analogous attributes as described above in conjunction with the implementation illustrated in FIGS. **6-11**. As examples, the orientation of each entrance **1220** may be non-radial and non-circumferential relative to the central axis **112**. This configuration is illustrated in FIG. **13** by two radii **1324**, **1326** projecting from the central axis **112** through two arbitrarily selected entrances **1220**. Despite the non-radial configuration, however, the pattern of entrances **1220** as a whole may be symmetrical relative to the central axis **112**, as in the illustrated example. In another aspect, the entrances **1220** may be arranged along one or more lines that run diagonally across the annular compression region **1262**. In FIG. **13**, this configuration is illustrated by a line **1332** coincident with the outermost edges **1222** of one representative pair of entrances **1220** and a line **1334** coincident with the outermost edges **1222** of a neighboring or adjacent pair of entrances **1220**. The two lines **1332**, **1334** intersect at a vertex **1318**, and this pattern may be repeated for the rest of the entrances **1220** to form a closed perimeter. The lines **1332**, **1334** may be straight or arcuate (concave or convex). In the illustrated example, each group of two entrances **1220** cuts diagonally across the compression region **1262**, such as along one diagonal direction (e.g., line **1332**) or another diagonal direction (e.g., line **1334**). In another aspect, the entrances **1220** may be arranged along one or more lines that are diagonal relative to the central axis **112**. In another aspect, the entrances **1220** may lay on the perimeter of a closed polygon associated with a plane in which the base portion **1204** resides. In the illustrated example, the closed polygon has eight vertices (such as vertex **1318**) while in other examples may have more or less vertices. In the illustrated example, as partially represented by the previously drawn lines **1332**, **1334**, the entrances **1220** lay on the perimeter of an eight-pointed star, while in other examples the star may have more or less points (or vertices). Alternatively, the vertices may be considered as being the corners of a polygon. Hence, in the illustrated example the eight-pointed star may be considered as being inscribed by an octagon, with the points of the star being coincident with the corners of the octagon. Other patterns entailing more or less vertices or corners may be realized, such as a six-pointed star or hexagon, a ten-pointed star or decagon, etc.

FIG. **14** is another perspective view of the phasing plug **1202** illustrated in FIGS. **12** and **13** from an output side opposite to the input side. A plurality of channels or grooves **1450** is formed on the output side. The channels **1450** respectively interconnect the entrances **1220** with corresponding exits **1264**. Accordingly, each acoustical path runs from the compression chamber on the input side, into one of the entrances **1220**, through the thickness of the base portion **1204** to the corresponding channel **1450** communicating with that entrance **1220**, through the corresponding exit **1264** on the output side, and into the central bore **1206**.

FIG. **15** is a plan view of the phasing plug **1202** illustrated in FIGS. **12-14** from the perspective of the output side. The pattern of the channels **1450** and the resulting acoustical paths may have the same or analogous attributes as those described above regarding the entrances **1220**. For example, the orientation of each channel **1450** and associated acoustical path may be non-radial relative to the central axis **112**. In another aspect, the entrances **1220** may be non-parallel with (and not radially aligned with) the exits **1264**. In another aspect, the lengths of one or more channels **1450** may differ from the lengths of the other channels **1450**. The pattern of entrances **1220** and channels **1450** as a whole may be symmetrical relative to the central axis **112** as in the illustrated example, or alternatively may be non-symmetric. In another aspect, for one or more of the channels **1450**, the channel **1450** may be oriented at an angle relative to the corresponding entrance **1220**, as illustrated in FIG. **15** by a line **1524** passing through the main cross-sectional area (projecting outwardly from the corresponding exit **1264**) of a representative channel **1450** and a line **1526** passing through the cross-sectional area of its corresponding entrance **1220**.

FIG. **16** is a perspective view of an example of a phasing plug **1612** that may, for example, be utilized as a rear phasing plug in the dual compression driver **400** (FIGS. **4** and **5**) in conjunction with the front phasing plug **1202** described above and illustrated in FIGS. **12-15**. The perspective is from an input side that would face the rear diaphragm **240** of the dual compression driver **400**. The phasing plug **1612** includes a base portion **1614** and may also include a mounting feature **1624** concentric with the central axis. The base portion **1614** includes an annular compression region **1672** located so as to be above (from the perspective of FIGS. **2-5**) the movable portion of the rear diaphragm **240**. As noted above, the compression region **1672** may have a raised profile (e.g., V-shape or other shape), which in FIG. **16** is generally demarcated by an inner circle **1662**, an outer circle **1664** and a circular apex **1680**. A plurality of acoustical entrances **1620** is located on the input side in the compression region **1672**. The entrances **1620** extend as channels (not shown, but see FIG. **17**) through the thickness of the base portion **1614** to acoustical exits located on the output side, thus establishing acoustical paths as described above. The entrances **1620** may have any suitable shapes. In the illustrated example, the entrances **1620** are shaped as slots. The plurality of entrances **1620** may be arranged according to a desired pattern. For this purpose, the plurality of entrances **1620** may be arranged into groups or sets of similarly oriented entrances **1620**. In some implementations as in the illustrated example, particularly when the rear phasing plug **1612** is to be disposed in direct abutment with the front phasing plug **1202**, the pattern of entrances **1620** of the rear phasing plug **1612** matches and is axially aligned with the pattern of entrances **1220** of the front phasing plug **1202**. Hence, in the illustrated example sixteen groups are provided with each group including two entrances **1620**.

The total number of entrances **1620** and the cross-sectional areas of the entrances **1620** may be selected according to the compression ratio desired for a particular application.

Particularly in matching implementations, the plurality of entrances **1620** of the rear phasing plug **1612** may be patterned so as to have one or more of the same attributes as described above in conjunction with the entrances **1220** of the front phasing plug **1202**. Thus, the orientation of each entrance **1620** may be non-radial relative to the central axis. The entrances **1620** may be arranged along one or more lines (such as lines coincident with the outermost edges **1622**) that run diagonally across the annular compression region **1672**. The entrances **1620** may lay on the perimeter of a closed polygon associated with a plane in which the base portion **1614** resides, such as the eight-pointed star illustrated in FIGS. **12-15**.

FIG. **17** is another perspective view of the phasing plug **1612** illustrated in FIG. **16** from an output side opposite to the input side. A plurality of channels or grooves **1750** is formed on the output side. The channels **1750** respectively interconnect the entrances **1620** with corresponding exits **1774**. The phasing plug **1612** further includes a centrally located hub portion **1718** that may be shaped as a bullet as described above. An annular region **1766** is defined between the hub portion **1718** and the surrounding exits **1774**. Accordingly, each acoustical path runs from the compression chamber on the input side, into one of the entrances **1620**, through the thickness of the base portion **1614** to the corresponding channel **1750** communicating with that entrance **1620**, through the corresponding exit **1774** on the output side, and into the annular region **1766**. The channels **1750** may be configured in the same manner as illustrated in FIGS. **14** and **15**. In implementations in which the rear phasing plug **1612** directly abuts the front phasing plug **1202**, the channels **1750** of the rear phasing plug **1612** may be in open communication with corresponding channels **1450** of the front phasing plug **1202**. In other implementations such as described below, a dividing plate may be positioned to axially separate the channels **1750** of the rear phasing plug **1612** from the channels **1450** of the front phasing plug **1202**. The pattern of the channels **1750** and the resulting acoustical paths may have the same or analogous attributes as those described above regarding the front phasing plug **1202**. For example, the orientation of each channel **1750** and associated acoustical path may be non-radial relative to the central axis. The entrances **1620** may be non-parallel with (and not radially aligned with) the corresponding exits **1774**. The lengths of one or more channels **1750** may differ from the lengths of the other channels **1750**. The pattern of channels **1750** may or may not be symmetrical relative to the central axis.

FIG. **18** is a perspective view of another example of a phasing plug **1802** that may, for example, be utilized as a front phasing plug in the dual compression driver **400** (FIGS. **4** and **5**). The perspective is from an input side that would face the front diaphragm **230** of the dual compression driver **400**. The phasing plug **1802** includes a base portion **1804**, a central bore **1806**, and a conduit **1808** aligned with the central bore **1806**. The base portion **1804** includes an annular compression region **1862** located so as to be underneath the movable portion of the front diaphragm **230**. As noted above, the compression region **1862** may have a raised profile (e.g., V-shape or other shape), which in FIG. **18** is generally demarcated by an inner circle **1812**, an outer circle **1814**, and a circular apex **1816**. A plurality of acoustical entrances **1820** is located on the input side in the compression region **1862**. The entrances **1820** extend as channels (not shown, but see FIG. **20**) through the thickness of the base portion **1804** to acoustical exits **1864** located on the output side, thus establishing acoustical paths as described above. The entrances **1820** may have any suitable shapes. In the illustrated example, the entrances **1820** are shaped as slots with straight edges, including outermost edges **1822**. The plurality of entrances **1820** may be arranged according to a desired pattern. For this purpose, the plurality of entrances **1820** may be arranged into groups or sets of similarly oriented entrances **1820**. In the illustrated example, eighteen groups are provided with each group including two entrances **1820**. The total number of entrances **1820** and the cross-sectional areas of the entrances **1820** may be selected according to the compression ratio desired for a particular application.

FIG. **19** is a plan view of the phasing plug **1802** illustrated in FIG. **18** from the perspective of the input side. The plurality of entrances **1820** may be patterned so as to have one or more of the same or analogous attributes as described above in conjunction with the implementation illustrated in FIGS. **6-11** or FIGS. **12-17**. As examples, the orientation of each entrance **1820** may be non-radial and non-circumferential relative to the central axis **112**. Despite the non-radial configuration, however, the pattern of entrances as a whole may be symmetrical relative to the central axis **112**, as in the illustrated example. In another aspect, the entrances **1820** may be arranged along one or more lines that run diagonally across the annular compression region **1862**. In FIG. **19**, this configuration is illustrated by a line **1932** coincident with the outermost edges **1822** of one representative pair of entrances **1820**, and a line **1934** coincident with the outermost edges **1822** of a neighboring pair of entrances **1820**. The two lines **1932**, **1934** intersect at a vertex **1918**, and this pattern may be repeated for the other entrances **1820** to form a closed perimeter. The lines **1932**, **1934** may be straight or arcuate (concave or convex). In the illustrated example, each group of two entrances **1820** cuts diagonally across the compression region **1862**, such as along one diagonal direction (e.g., line **1932**) or another diagonal direction (e.g., **1934**). In another aspect, the entrances **1820** may be arranged along one or more lines that are diagonal relative to the central axis **112**. A diagonal line may or may not be tangential to a circle concentric with the central axis **112**. In another aspect, the entrances **1820** may lay on the perimeter of a closed polygon associated with a plane in which the base portion **1804** resides. In the illustrated example, the closed polygon has nine vertices such as vertex **1918**. In the illustrated example, as represented in part by the lines **1932**, **1934**, the entrances **1820** lay on the perimeter of a nine-pointed star. Alternatively, the vertices may be considered as being the corners of a polygon. Hence, in the illustrated example the nine-pointed star may be considered as being inscribed by a nonagon.

FIG. **20** is another perspective view of the phasing plug **1802** illustrated in FIGS. **18** and **19** from an output side opposite to the input side. A plurality of channels or grooves **2050** is formed on the output side. The channels **2050** respectively interconnect the entrances **1820** with corresponding exits **1864**. Accordingly, each acoustical path runs from the compression chamber on the input side, into one of the entrances **1820**, through the thickness of the base portion **1804** to the corresponding channel **2050** communicating with that entrance **1820**, through the corresponding exit **1864** on the output side, and into the central bore **1806**.

FIG. **21** is a plan view of the phasing plug **1802** illustrated in FIGS. **18-20** from the perspective of the output side. The pattern of the channels **2050** and the resulting acoustical paths may have the same or analogous attributes as those described above regarding the entrances **1820**. For example, the orientation of each channel **2050** and associated acoustical path may be non-radial relative to the central axis **112**. The entrances **1820** may be non-parallel with (and not radially aligned with) the corresponding exits **1864**. The lengths of one or more channels **2050** may differ from the lengths of the other channels **2050**. The pattern of entrances **1820** and channels **2050** as a whole may be symmetrical relative to the central axis **112** as in the illustrated example, or alternatively may be non-symmetric. For one or more of the channels **2050**, the channel **2050** may be oriented at an angle relative to the corresponding entrance **1820**.

FIG. **22** is a perspective view of an example of a phasing plug **2212** that may, for example, be utilized as a rear phasing plug in the dual compression driver **400** (FIGS. **4** and **5**) in conjunction with the front phasing plug **1802** described above and illustrated in FIGS. **18-21**. The perspective is from an input side that would face the rear diaphragm **240** of the dual compression driver **400**. The phasing plug **2212** includes a base portion **2214** and may also include mounting feature **2224** concentric with the central axis. The base portion **2214** includes an annular compression region **2272** located so as to be above (from the perspective of FIGS. **2-5**) the movable portion of the rear diaphragm **240**. As noted above, the compression region **2272** may have a raised profile (e.g., V-shape or other shape), which in FIG. **22** is generally demarcated by an inner circle **2262**, an outer circle **2264**, and a circular apex **2280**. A plurality of acoustical entrances **2220** is located on the input side in the compression region **2272**. The entrances **2220** extend as channels (not shown, but see FIG. **23**) through the thickness of the base portion **2214** to acoustical exits located on the output side, thus establishing acoustical paths as described above. The entrances **2220** may have any suitable shapes. In the illustrated example, the entrances **2220** are shaped as slots. The plurality of entrances **2220** may be arranged according to a desired pattern. For this purpose, the plurality of entrances **2220** may be arranged into groups or sets of similarly oriented entrances **2220**. In some implementations as in the illustrated example, particularly when the rear phasing plug **2212** is to be disposed in direct abutment with the front phasing plug **1802**, the pattern of entrances **2220** of the rear phasing plug **2212** matches and is axially aligned with the pattern of entrances **1820** of the front phasing plug **1802**. Hence, in the illustrated example eighteen groups are provided with each group including two entrances **2220**. The total number of entrances **2220** and the cross-sectional areas of the entrances **2220** may be selected according to the compression ratio desired for a particular application.

Particularly in matching implementations, the plurality of entrances **2220** of the rear phasing plug **2212** may be patterned so as to have one or more of the same attributes as described above in conjunction with the entrances **1820** of the front phasing plug **1802**. Thus, the orientation of each entrance **2220** may be non-radial relative to the central axis. The entrances **2220** may be arranged along one or more lines that run diagonally across the annular compression region **2272**. The entrances **2220** may lay on the perimeter of a closed polygon associated with a plane in which the base portion **2214** resides, such as the nine-pointed star illustrated in FIG. **19**.

FIG. **23** is another perspective view of the phasing plug **2212** illustrated in FIG. **22** from an output side opposite to the input side. A plurality of channels or grooves **2350** is formed on the output side. The channels **2350** respectively interconnect the entrances **2220** with corresponding exits **2374**. The phasing plug **2212** further includes a centrally located hub portion **2318** that may be shaped as a bullet as described above. An annular region **2366** is defined between the hub portion **2318** and the surrounding exits **2374**. Accordingly, each acoustical path runs from the compression chamber on the input side, into one of the entrances **2220**, through the thickness of the base portion **2214** to the corresponding channel **2350** communicating with that entrance **2220**, through the corresponding exit **2374** on the output side, and into the annular region **2366**. The channels **2350** may be configured in the same manner as illustrated in FIGS. **20** and **21**. In implementations in which the rear phasing plug **2212** directly abuts the front phasing plug **1802**, the channels **2350** of the rear phasing plug **2212** may be in open communication with corresponding channels **1820** of the front phasing plug **1802**. In other implementations such as described below, a dividing plate may be positioned to axially separate the channels **2350** of the rear phasing plug **2212** from the channels **2050** of the front phasing plug **1802**. The pattern of the channels **2350** and the resulting acoustical paths may have the same or analogous attributes as those described above regarding the front phasing plug **1802**. For example, the orientation of each channel **2350** and associated acoustical path may be non-radial relative to the central axis. The entrances **2220** may be non-parallel with (and not radially aligned with) the corresponding exits **2374**. The lengths of one or more channels **2350** may differ from the lengths of the other channels **2350**. The pattern of channels **2350** may or may not be symmetrical relative to the central axis.

A particular pattern of entrances and channels provided by a dual phasing plug assembly in accordance with the present teachings may be found to be appropriate or optimal based on one or more performance-related requirements and/or or design constraints associated with a given transducer, such as size, frequency response, etc. As a non-limiting example, at present the phasing plug set illustrated in FIGS. **6-11** is contemplated for a 1.5-inch voice coil format diaphragm, the phasing plug set illustrated in FIGS. **12-17** is contemplated for a 2-inch voice coil format diaphragm, and the phasing plug set illustrated in FIGS. **18-23** is contemplated for a 3-inch voice coil format diaphragm. More generally, however, any of the patterns encompassed by the present teachings may be scaled to any size practical for transducers having compression chambers.

FIG. **24** is an exploded perspective view of another example of a dual phasing plug assembly **2400**. The dual phasing plug assembly **2400** may be provided, for example, as part of the dual compression driver **400** (FIGS. **4** and **5**), which in turn may be provided, for example, as part of the transducer section **104** (FIG. **1**) of the loudspeaker **100**. The dual phasing plug assembly **2400** includes a front phasing plug **2402**. The front phasing plug **2402** includes a front base portion **2404** and a central bore **2406**. The front phasing plug **2402** may also include a conduit **2408** axially extending from the central bore **2406**. The front phasing plug **2402** includes a pattern of entrances **2420**, channels (not shown) and exits (not shown), which may be configured in accordance with any of the examples described above and illustrated in FIGS. **6-23**. The dual phasing plug assembly **2400** also includes a rear phasing plug **2412**. The rear phasing plug **2412** includes a rear base portion **2414** and a hub portion **2418** such as a bullet that extends through the central bore **2406** (and through the conduit **2408**, if provided) when the dual phasing plug assembly **2400** is assembled. The rear phasing plug **2412** includes a pattern of entrances (not shown), channels **2450** and exits **2474**, which may be configured in accordance with any of the examples described above and illustrated in FIGS. **6-23**. An annular region **2466** is defined generally between the exits **2474** and the hub portion **2418**.

Additionally, the dual phasing plug assembly **2400** includes a dividing plate (or divider) **2460** axially interposed between the respective output sides of the front phasing plug **2402** and the rear phasing plug **2412**. The dividing plate **2460** is sized large enough to cover the channels (not shown) of the front phasing plug **2402** and the channels **2450** of the rear phasing plug **2412**, and serves as a partition between the front channels and the rear channels **2450**. Hence, in the present implementation the front acoustical paths do not merge or sum with each other until they reach the annular region **2466**. The dividing plate **2460** includes a central aperture **2408** through which the hub portion **2418** extends and through which the acoustical signals outputted from the rear phasing plug **2412** pass. The dividing plate **2460** changes the acoustical impedance of the of the acoustical connectors (i.e. entrances, channels, exits) of the dual phasing plug assembly **2400**, and may be utilized as a means for fine tuning the overall frequency response of the dual phasing plug assembly **2400**. The diameter of the central aperture **2408** may be varied to provide extra flexibility in the fine tuning of the acoustical impedance of the acoustical connectors and, correspondingly, in the fine tuning of the frequency response. Accordingly, the diameter of the central aperture **2408** may be different from the diameter of the central bore **2406**. The dividing plate **2460** may also provide more flexibility in the design of the dual phasing plug assembly **2400**. For example, the dividing plate **2460** facilitates the use of respective entrance/channel patterns of the front phasing plug **2402** and rear phasing plug **2412** that are not necessarily matched to each other (i.e., are not mirror images of each other). Consequently, the dividing plate **2460** enables the provision of time-alignment or specific delay and corresponding phase shift in one of the phasing plugs **2402**, **2412** to vary and optimize high-frequency response. An example of implementing this feature is described below in conjunction with FIGS. **25** and **26**.

FIG. **25** is a perspective view of another example of a phasing plug **2502**, specifically from the perspective of its output side. The phasing plug **2502** includes a base portion **2504** in which entrances **2520**, channels **2550**, and exits **2564** are formed. The phasing plug **2502** in this example is a front phasing plug that includes a central bore **2506** such that the exits **2564** are located at the perimeter of the central bore **2506**. In this example, the entrance/channel pattern is generally similar to that illustrated in FIG. **8**. However, the lengths of the channels **2550** have been increased by changing the angles of the channels **2550** (relative to any reference line, such as a radius of the base portion **2504**). As a result, the channels **2550** (and hence the path lengths through the channels **2550**) are extended in comparison to those of FIG. **8**, which equalizes the time delay.

FIG. **26** is an exploded perspective view of another example of a dual phasing plug assembly **2600**. The dual phasing plug assembly **2600** includes the front phasing plug **2502** illustrated in FIG. **25** that features the extended-length channels **2550**, a rear phasing plug such as the rear phasing plug **2412** illustrated in FIG. **24**, and the intervening dividing plate **2460** illustrated in FIG. **24**. FIG. **26** is an example of providing different respective patterns in the front phasing plug **2502** and the rear phasing plug **2412** to obtain a desired acoustical effect. In the present example, the pattern of the front phasing plug **2502** is configured to provide time alignment as described above.

In other implementations, any of the front or rear phasing plugs described above and illustrated in FIGS. **2-26** may be utilized individually in a single compression driver.

As noted above, diaphragms of various configurations may be utilized in the implementations taught in the present disclosure. As examples, FIG. **27** is a cross-sectional perspective view of a diaphragm **2700** having a V-shaped profile, FIG. **28** is a cross-sectional perspective view of a diaphragm **2800** having an M-shaped profile, and FIG. **29** is a cross-sectional perspective view of a diaphragm **2900** having a dual-roll profile. The diaphragms **2700**, **2800**, **2900** have respective annular apices **2716**, **2816**, **2916** at which voice coil assemblies may be attached. As described above, the surface of a phasing plug utilized to form a compression chamber with the diaphragm may include a raised profile that is complementary (V-shaped, M-shaped, dual-roll, half-roll, etc.) to that of the diaphragm. In each of FIGS. **27-29**, D_{in} is the internal clamping diameter and p_{out} is the external clamping diameter. The clamping diameters may be determined by the means utilized to clamp or otherwise fix the diaphragm in a final-assembly position, such as for example by positioning rings **232**, **234**, **242**, **244** (FIGS. **2-5**).

The implementations described by example above offer significant flexibility in the specification of compression drivers for desired applications and frequency ranges in sound production. The compression ratio may be controlled by changing the geometry and dimensions of the acoustical connectors formed in the phasing plugs while, at the same time, preserving the continuity of the area of expansion defined by the waveguide of the phasing plug assembly. The patterns exhibited by the acoustical connectors may be configured to obtain a desired frequency response and/or optimize other operating parameters. Accordingly, the implementations disclosed herein provide flexible control over efficiency of the compression driver and over the shape of its frequency response.

In general, the term "communicate" (for example, a first component "communicates with" or "is in communication with" a second component) is used in the present disclosure to indicate a structural, functional, mechanical, electrical, optical, magnetic, ionic or fluidic relationship between two or more components (or elements, features, or the like). As such, the fact that one component is said to communicate with a second component is not intended to exclude the possibility that additional components may be present between, and/or operatively associated or engaged with, the first and second components.

The foregoing description of implementations has been presented for purposes of illustration and description. It is not exhaustive and does not limit the claimed inventions to the precise form disclosed. Modifications and variations are possible in light of the above description or may be acquired from practicing the invention. The claims and their equivalents define the scope of the invention.

What is claimed is:

1. A dual phasing plug assembly for a compression driver, the dual phasing plug assembly comprising:

a first phasing plug including:

a first base portion including a first input side, a first output side, a central bore coaxial with a central axis and extending from the first input side to the first output side, a plurality of first entrances on the first input side, a plurality of first exits communicating with the central bore on the first output side, and a plurality of first channels fluidly interconnecting the first entrances with the respective first exits, where each corresponding first entrance, first channel and first exit establish a first acoustical path that is non-radial relative to the central axis; and

a second phasing plug including:

a second base portion including a second input side, a second output side facing the first output side, a plurality of second entrances on the second input side, a plurality of second exits on the second output side, and a plurality of second channels fluidly interconnecting the second entrances with the respective second exits, where each corresponding second entrance, second channel and second exit establish a second acoustical path that is non-radial relative to the central axis; and

a hub portion extending along the central axis from the second output side through the central bore, the hub portion including an outside surface having a diameter coaxial with the central axis,

where the first exits and the second exits communicate with an annular region between the central bore and the outside surface.

2. The dual phasing plug assembly of claim **1**, where the outside surface is bullet-shaped and terminates at an apex on the central axis.

3. The dual phasing plug assembly of claim **1**, where the first phasing plug includes a conduit extending from the central bore along the central axis away from the first input side, the hub portion extends through the conduit, and the conduit and the outside surface form a waveguide extending from the annular region away from the first input side.

4. The dual phasing plug assembly of claim **1**, including a first diaphragm axially spaced from the first input side and forming with the first input side a first compression chamber communicating with the first entrances, and a second diaphragm axially spaced from the second input side and forming with the second input side a second compression chamber communicating with the second entrances.

5. The dual phasing plug assembly of claim **4**, where the first diaphragm includes a first raised portion and the first base portion includes a first annular region shaped complementarily with the first raised portion, and the second diaphragm includes a second raised portion and the second base portion includes a second annular region shaped complementarily with the second raised portion.

6. The dual phasing plug assembly of claim **4**, including a first voice coil assembly attached to the first diaphragm, and a second voice coil assembly attached to the second diaphragm.

7. The dual phasing plug assembly of claim **1**, where the first output side abuts the second output side, and each first exit adjoins a respective second exit forming a common exit at the annular region.

8. The dual phasing plug assembly of claim **1**, where the first exits and the second exits are concentric with the central axis.

9. The dual phasing plug assembly of claim **1**, where the first entrances are arranged in a first pattern in a plane orthogonal to the longitudinal axis, the second entrances are arranged in a second pattern in a parallel plane, and the first pattern matches the second pattern.

10. The dual phasing plug assembly of claim **1**, where each first entrance and each second entrance is arranged along a respective line that is diagonal relative to the central axis.

11. The dual phasing plug assembly of claim **1**, where each first entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective first exit, and each second entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective second exit.

12. The dual phasing plug assembly of claim **1**, where each first entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective first channel, and each second entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective second channel.

13. The dual phasing plug assembly of claim **1**, where at least one first channel has a length different from respective lengths of the other first channels, and at least one second channel has a length different from respective lengths of the other second channels.

14. The dual phasing plug assembly of claim **1**, where:

the plurality of first entrances lie along a plurality of lines, and the lines collectively form a first polygon including at least four vertices at which neighboring lines adjoin; and

the plurality of second entrances lie along a plurality of lines, and the lines collectively form a second polygon including at least four vertices at which neighboring lines adjoin.

15. The dual phasing plug assembly of claim **14**, where:

the plurality of first entrances is grouped into a plurality of sets of at least two first entrances and, for each set, the at least two first entrances lie along the same line; and

the plurality of second entrances is grouped into a plurality of sets of at least two second entrances and, for each set, the at least two second entrances lie along the same line.

16. The dual phasing plug assembly of claim **14**, where:

the plurality of first entrances is grouped into a plurality of sets of at least four first entrances and, for each set, the at least four first entrances lie along the same line; and

the plurality of second entrances is grouped into a plurality of sets of at least four second entrances and, for each set, the at least four second entrances lie along the same line.

17. The dual phasing plug assembly of claim **14**, where at least one of the first polygon and the second polygon is a quadrangle.

18. The dual phasing plug assembly of claim **14**, where at least one of the first polygon and the second polygon is a star.

19. The dual phasing plug assembly of claim **1**, including a dividing plate between the first base portion and the second base portion, the dividing plate including a central aperture through which the hub portion extends, where a first side of the dividing plate closes the first channels and a second side of the dividing plate closes the second channels.

20. The dual phasing plug assembly of claim **19**, where the central aperture has a diameter different from a diameter of the central bore.

21. The dual phasing plug assembly of claim **19**, where the first channels are arranged in a first pattern in a plane orthogonal to the longitudinal axis, the second channels are arranged in a second pattern in a parallel plane, and the first pattern is different from the second pattern.

22. A dual compression driver, comprising:

a first magnet assembly including an annular first air gap;

a first voice coil assembly axially movable in the first air gap;

a first diaphragm attached to the first voice coil assembly;

a second magnet assembly including an annular second air gap;

a second voice coil assembly axially movable in the second air gap;

a second diaphragm attached to the second voice coil assembly;

a first phasing plug including:

a first base portion including a first input side axially spaced from the first diaphragm to form a first compression chamber, a first output side, a central bore coaxial with a central axis and extending from the first input side to the first output side, a plurality of first entrances on the first input side communicating with the first compression chamber, a plurality of first exits communicating with the central bore on the first output side, and a plurality of first channels fluidly interconnecting the first entrances with the respective first exits, where each corresponding first entrance, first channel and first exit establish a first acoustical path that is non-radial relative to the central axis; and

a second phasing plug including:

a second base portion including a second input side axially spaced from the second diaphragm to form a second compression chamber, a second output side facing the first output side, a plurality of second entrances on the second input side communicating with the second compression chamber, a plurality of second exits on the second output side, and a plurality of second channels fluidly interconnecting the second entrances with the respective second exits, where each corresponding second entrance, second channel and second exit establish a second acoustical path that is non-radial relative to the central axis; and

a hub portion extending along the central axis from the second output side through the central bore, the hub portion including an outside surface having a diameter coaxial with the central axis,

where the first exits and the second exits communicate with an annular region between the central bore and the outside surface.

23. The dual compression driver of claim **22**, where the outside surface is bullet-shaped and terminates at an apex on the central axis.

24. The dual compression driver of claim **22**, where the first phasing plug includes a conduit extending from the central bore along the central axis away from the first input side, the hub portion extends through the conduit, and the conduit and the outside surface form a waveguide extending from the annular region away from the first input side.

25. The dual compression driver of claim **24**, including a sound radiator fluidly communicating with the waveguide.

26. The dual compression driver of claim **22**, including a sound radiator fluidly communicating with the annular region.

27. The dual compression driver of claim **22**, where the first diaphragm includes a first raised portion and the first base portion includes a first annular region shaped complementarily with the first raised portion, and the second diaphragm includes a second raised portion and the second base portion includes a second annular region shaped complementarily with the second raised portion.

28. The dual compression driver of claim **22**, where the first output side abuts the second output side, and each first exit adjoins a respective second exit forming a common exit at the annular region.

29. The dual compression driver of claim **22**, where the first exits and the second exits are concentric with the central axis.

30. The dual compression driver of claim **22**, where the first entrances are arranged in a first pattern in a plane orthogonal to the longitudinal axis, the second entrances are arranged in a second pattern in a parallel plane, and the first pattern matches the second pattern.

31. The dual compression driver of claim **22**, where each first entrance and each second entrance is arranged along a respective line that is diagonal relative to the central axis.

32. The dual compression driver of claim **22**, where each first entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective first exit, and each second entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective second exit.

33. The dual compression driver of claim **22**, where each first entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective first channel, and each second entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective second channel.

34. The dual compression driver of claim **22**, where at least one first channel has a length different from respective lengths of the other first channels, and at least one second channel has a length different from respective lengths of the other second channels.

35. The dual compression driver of claim **22**, where:

the plurality of first entrances lie along a plurality of lines, and the lines collectively form a first polygon including at least four vertices at which neighboring lines adjoin; and

the plurality of second entrances lie along a plurality of lines, and the lines collectively form a second polygon including at least four vertices at which neighboring lines adjoin.

36. The dual compression driver of claim **35**, where:

the plurality of first entrances is grouped into a plurality of sets of at least two first entrances and, for each set, the at least two first entrances lie along the same line; and

the plurality of second entrances is grouped into a plurality of sets of at least two second entrances and, for each set, the at least two second entrances lie along the same line.

37. The dual compression driver of claim **35**, where:

the plurality of first entrances is grouped into a plurality of sets of at least four first entrances and, for each set, the at least four first entrances lie along the same line; and

the plurality of second entrances is grouped into a plurality of sets of at least four second entrances and, for each set, the at least four second entrances lie along the same line.

38. The dual compression driver of claim **35**, where at least one of the first polygon and the second polygon is a quadrangle.

39. The dual compression driver of claim **35**, where at least one of the first polygon and the second polygon is a star.

40. The dual compression driver of claim **22**, including a dividing plate between the first base portion and the second base portion, the dividing plate including a central aperture through which the hub portion extends, where a first side of the dividing plate closes the first channels and a second side of the dividing plate closes the second channels.

41. The dual compression driver of claim **40**, where the central aperture has a diameter different from a diameter of the central bore.

42. The dual compression driver of claim **40**, where the first channels are arranged in a first pattern in a plane orthogonal to the longitudinal axis, the second channels are arranged in a second pattern in a parallel plane, and the first pattern is different from the second pattern.

43. A phasing plug, comprising:

a base portion including an input side, an output side, a plurality of entrances on the input side, a plurality of exits on the output side arranged about a central axis, and a plurality of channels fluidly interconnecting the entrances with the respective exits, where each corresponding entrance, channel and exit establish an acoustical path from the input side to the output side that is non-radial relative to the central axis, and the entrances lie along a plurality of lines collectively forming a polygon that includes greater than four vertices at which neighboring lines adjoin.

44. The phasing plug of claim **43**, where the base portion includes a central bore coaxial with the central axis and extending from the input side to the output side, and the exits communicate with the central bore on the output side.

45. The phasing plug of claim **44**, including a conduit extending from the central bore along the central axis away from the input side.

46. The phasing plug of claim **43**, including a hub portion extending along the central axis from the output side through the central bore, the hub portion including an outside surface having a diameter coaxial with the central axis.

47. The phasing plug of claim **46**, where the outside surface is bullet-shaped and terminates at an apex on the central axis.

48. The phasing plug of claim **43**, where the base portion includes an annular region including a raised profile, and the entrances are located in the annular region.

49. The phasing plug of claim **43**, where the exits are concentric with the central axis.

50. The phasing plug of claim **43**, where each entrance is arranged along a respective line that is diagonal relative to the central axis.

51. The phasing plug of claim **43**, where each entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective exit.

52. The phasing plug of claim **43**, where each entrance has a cross-sectional area non-parallel to a cross-sectional area of the respective channel.

53. The phasing plug of claim **43**, where at least one channel has a length different from respective lengths of the other channels.

54. The phasing plug of claim **43**, where the plurality of entrances is grouped into a plurality of sets of at least two entrances and, for each set, the at least two entrances lie along the same line.

55. The phasing plug of claim **43**, where the polygon is a star.

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