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(54) **SEAL IN COMBUSTOR NOZZLE OF GAS TURBINE ENGINE**

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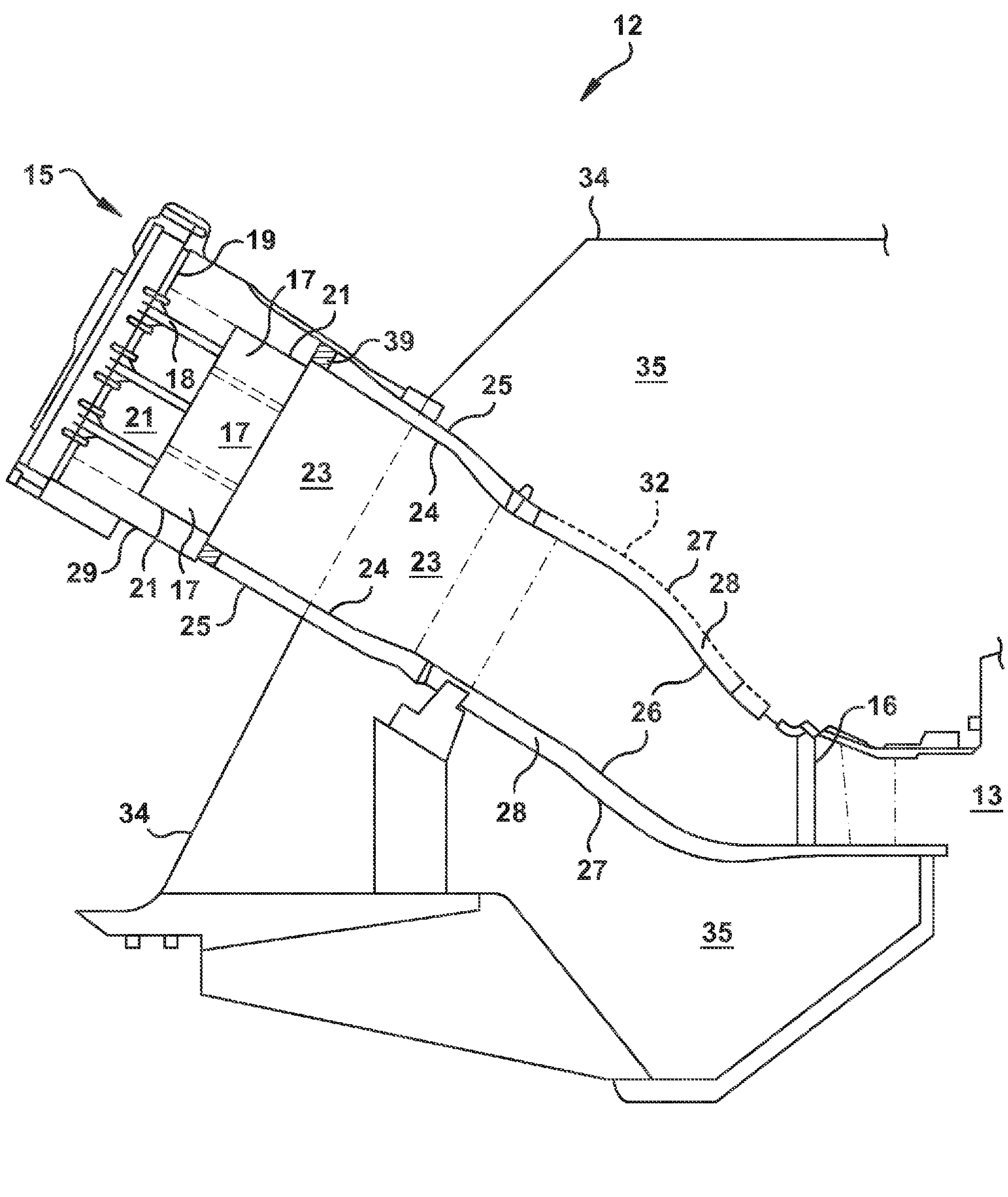
(57) **ABSTRACT**

A nozzle for use in a combustor of a combustion turbine engine, the nozzle including: radial sections defined by sidewalls; a gap formed between opposing sidewalls of adjacent ones of the radial sections; a groove formed on each of the sidewalls that define the gap, the grooves positioned correspondingly so to together form a pocket; and a seal having a zigzagging profile disposed within the pocket. The pocket may intercept the gap over a seal length, and the seal may extend longitudinally within the pocket such that the zigzagging profile intersects the gap over the seal length.



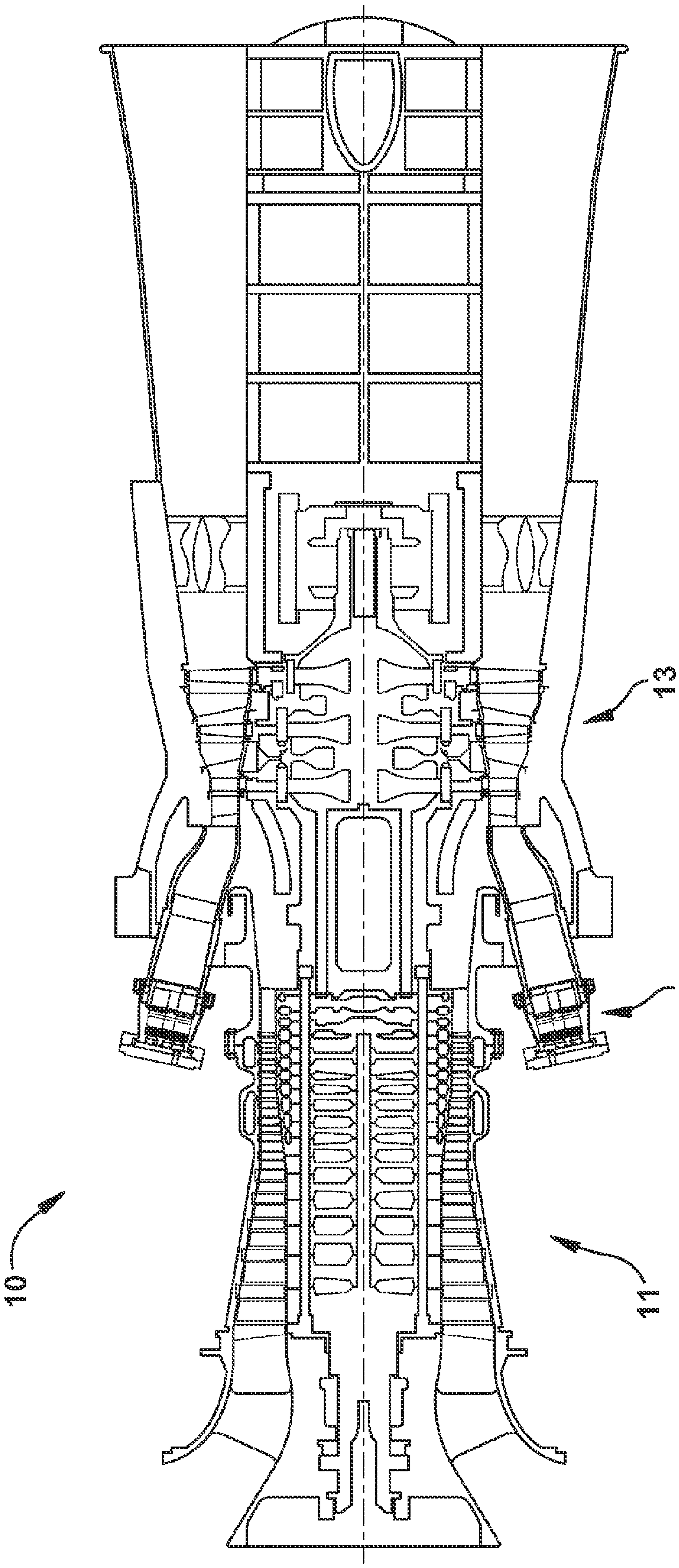


Figure 1
(Prior Art)

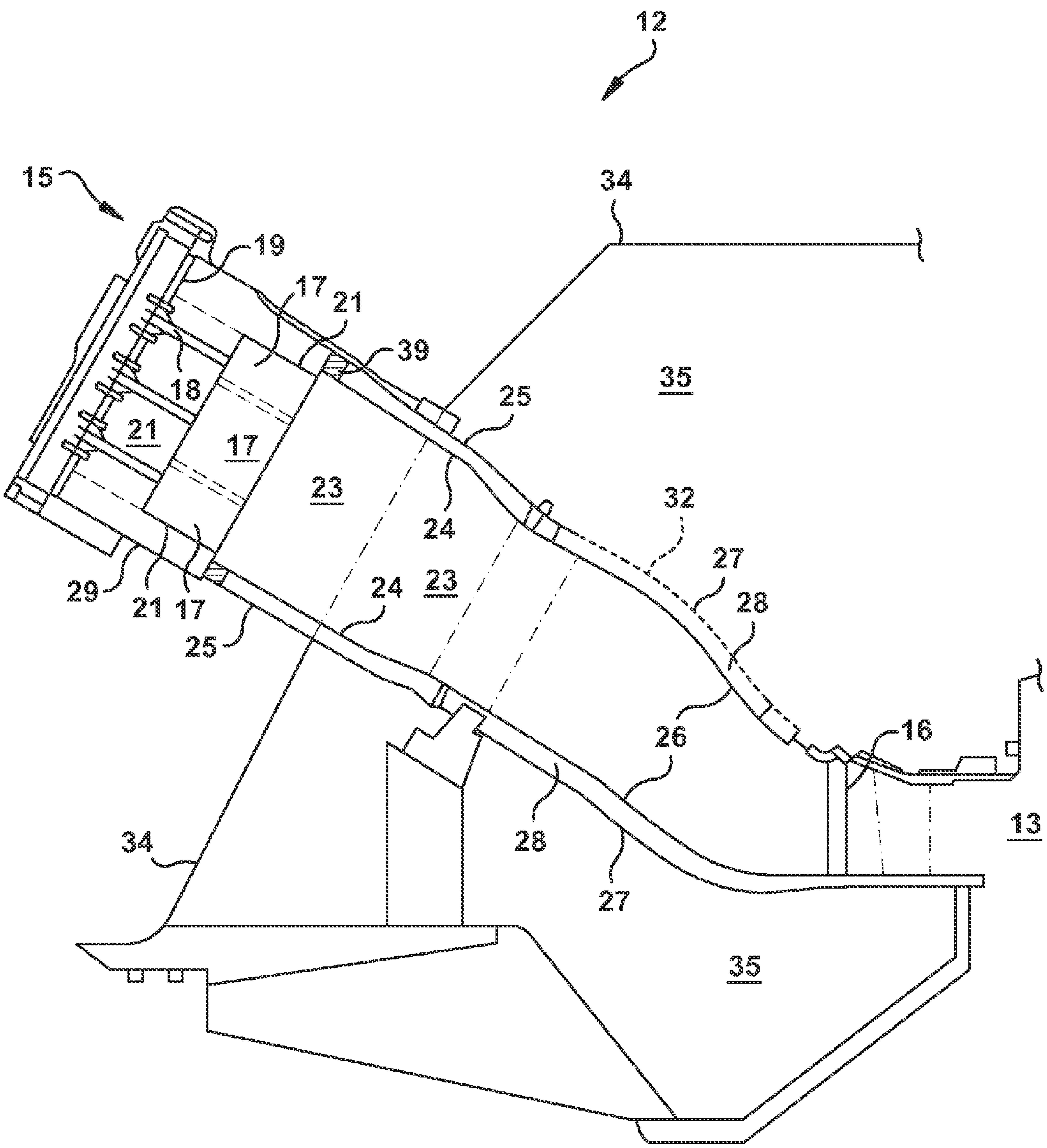

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Figure 2

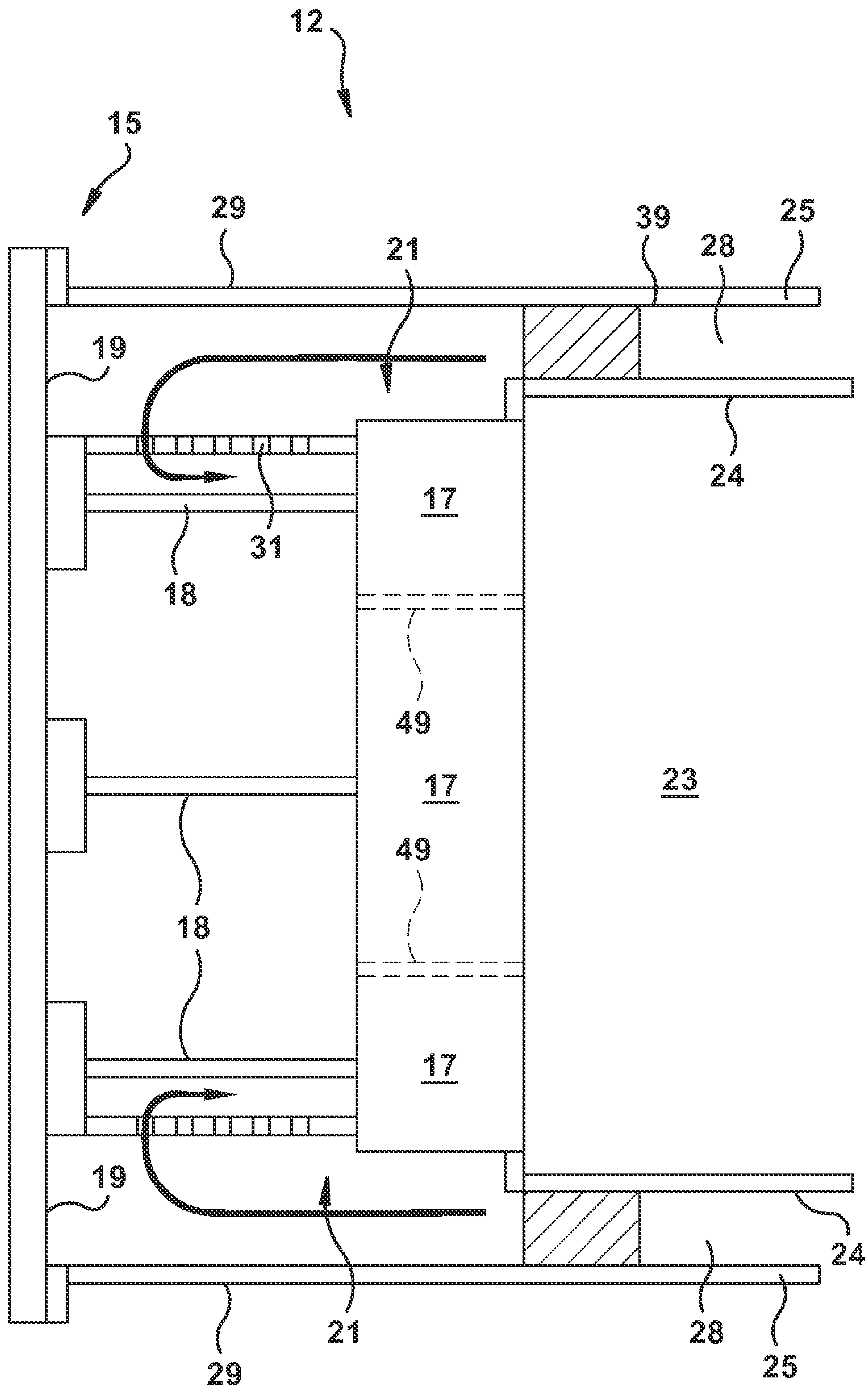

Figure 3

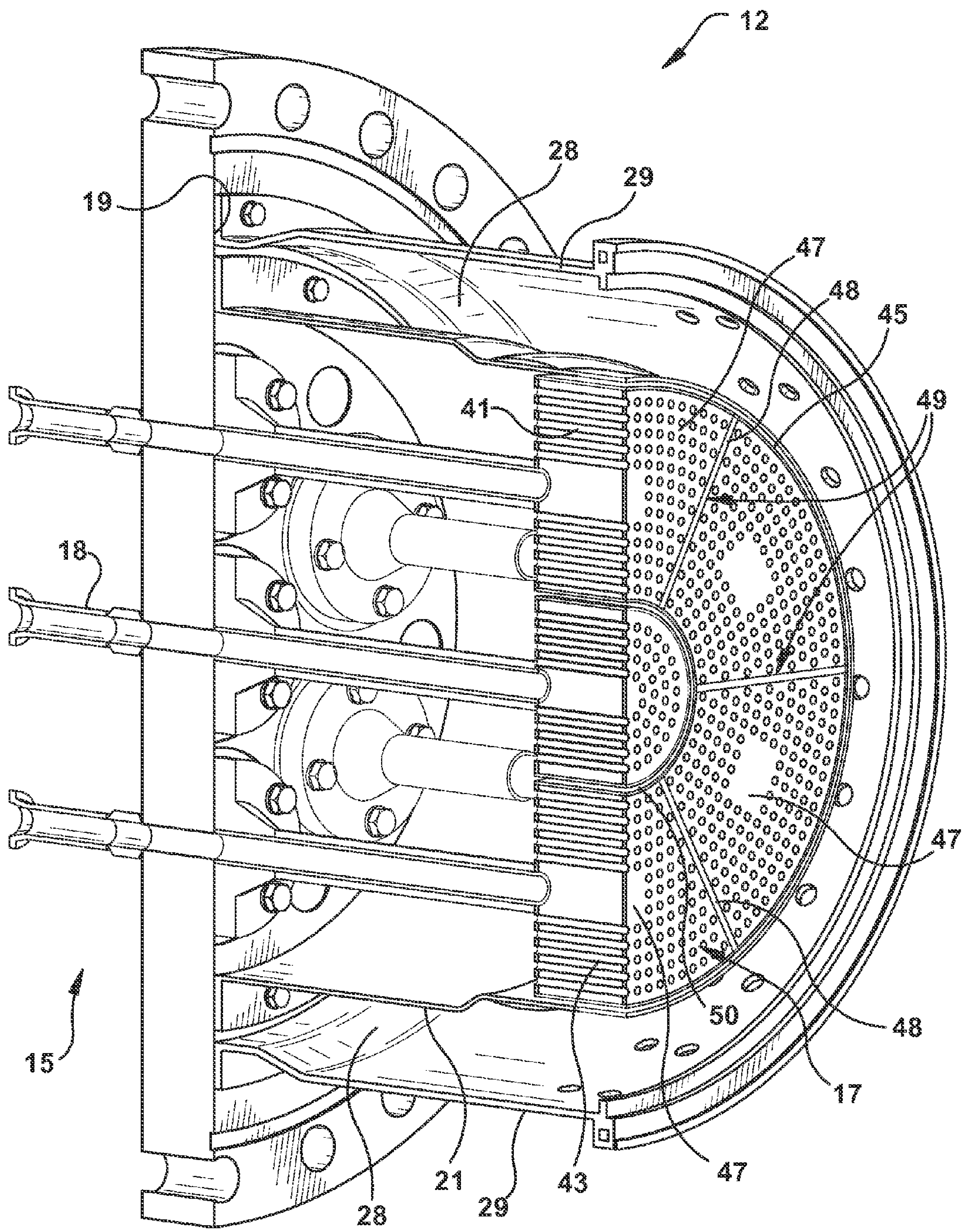

Figure 4

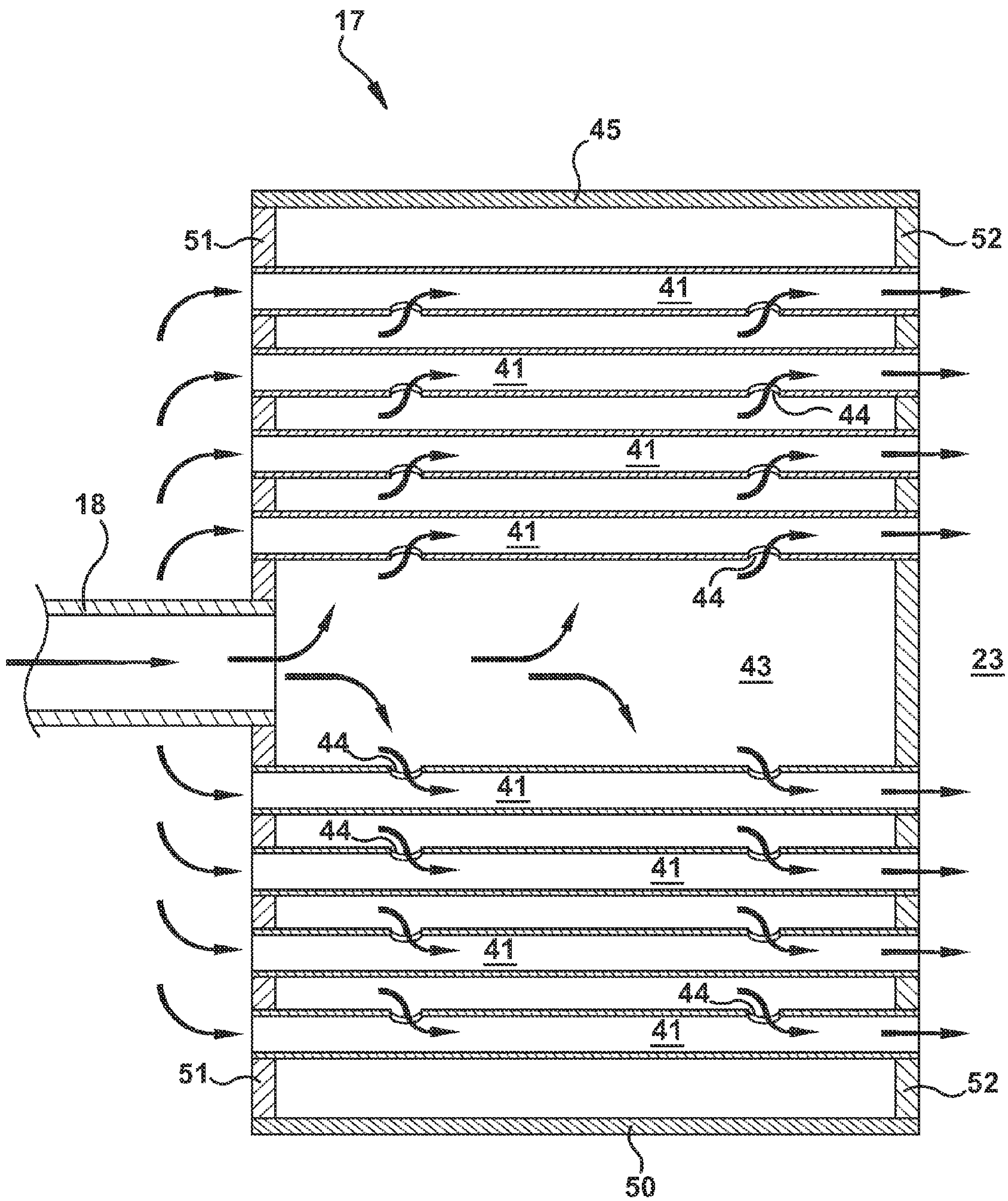

Figure 5

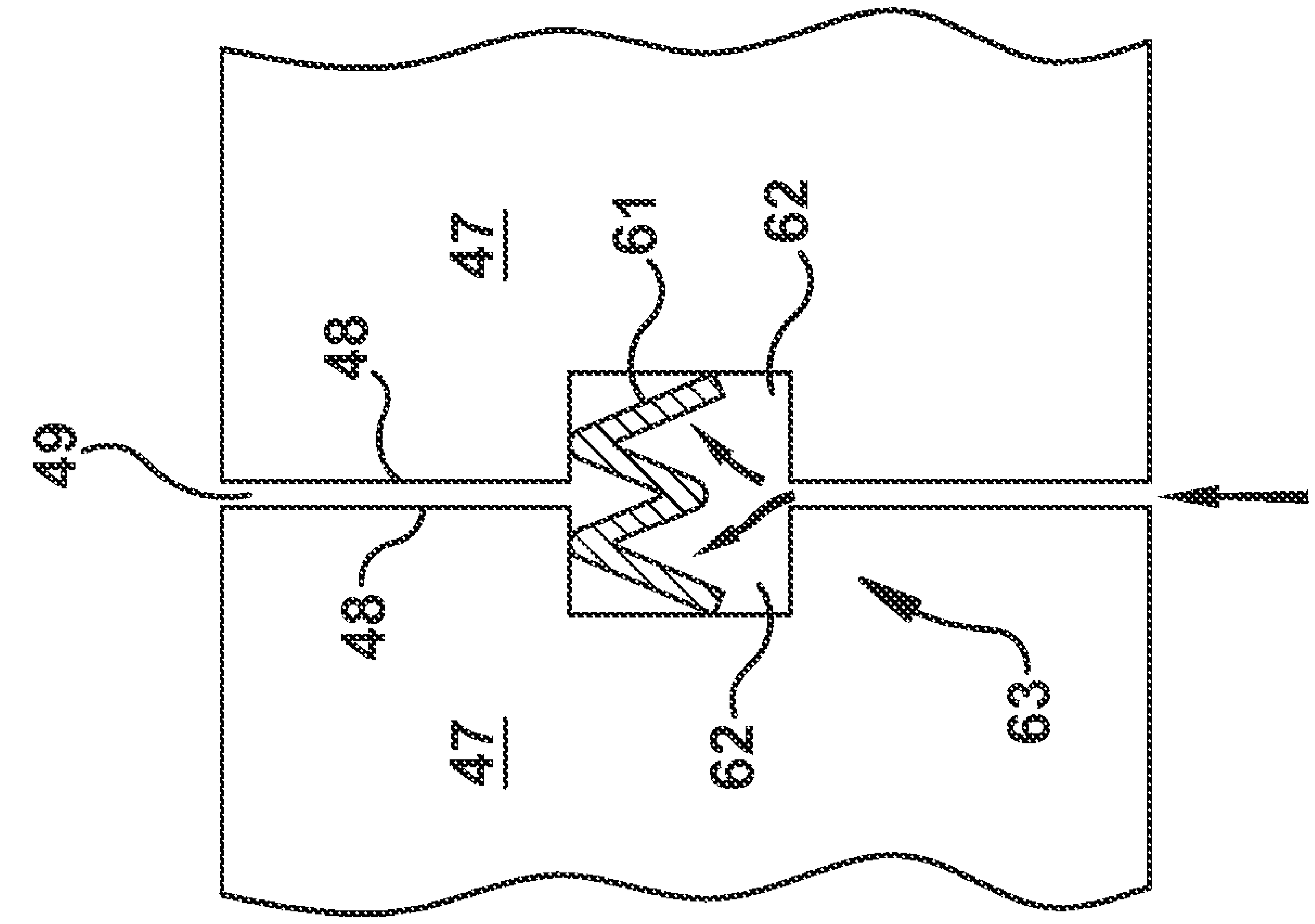

Figure 7

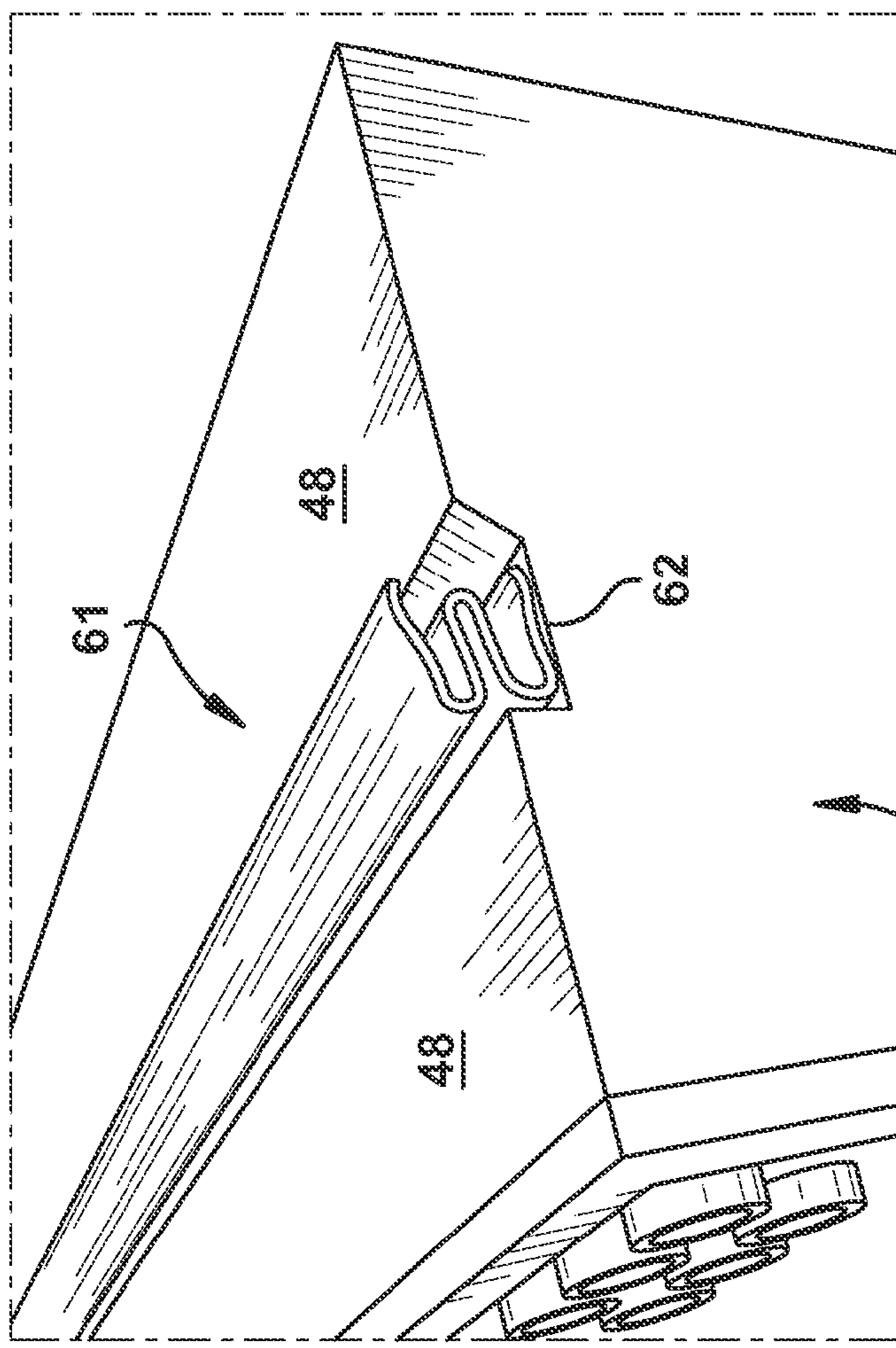

Figure 6

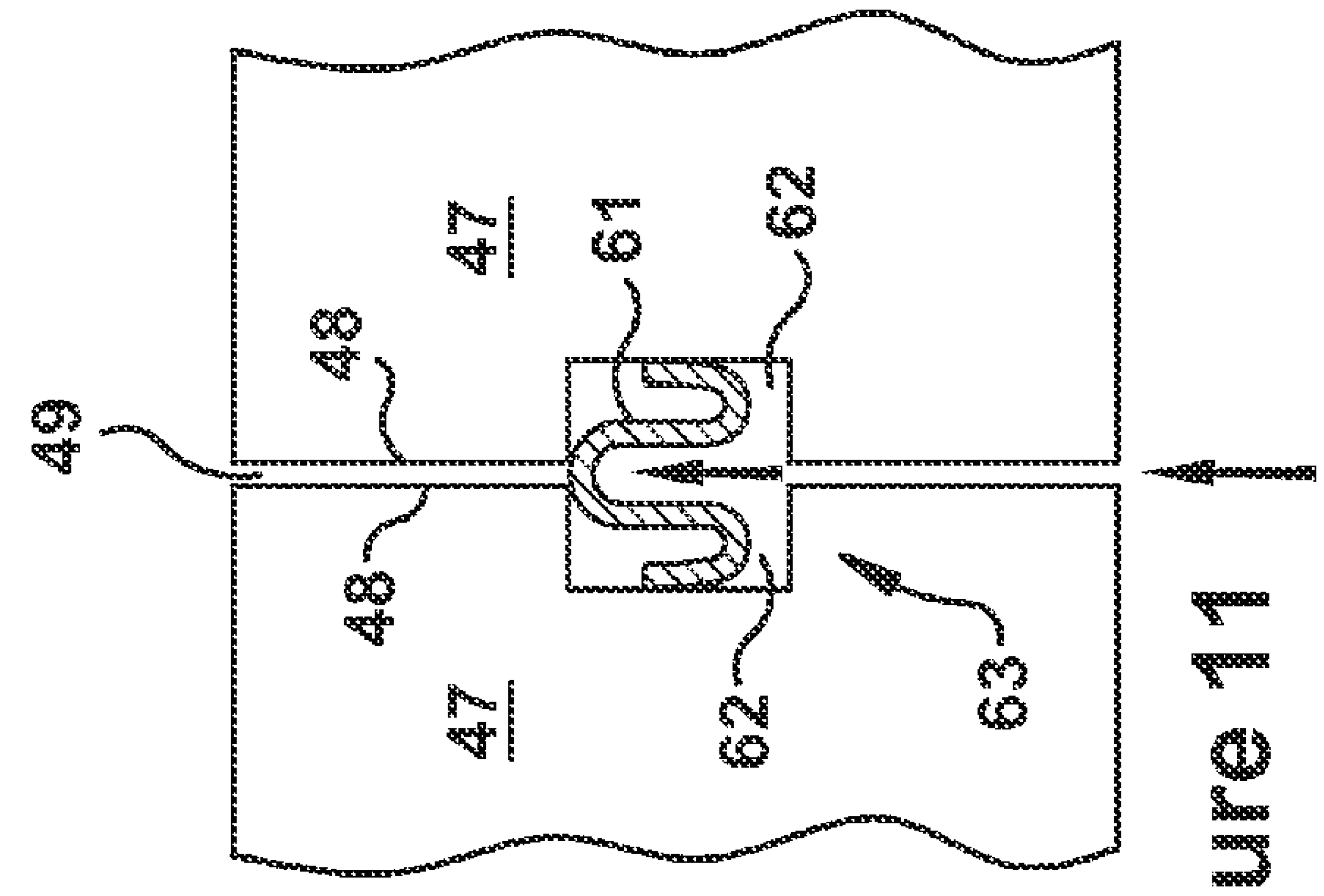

Figure 11

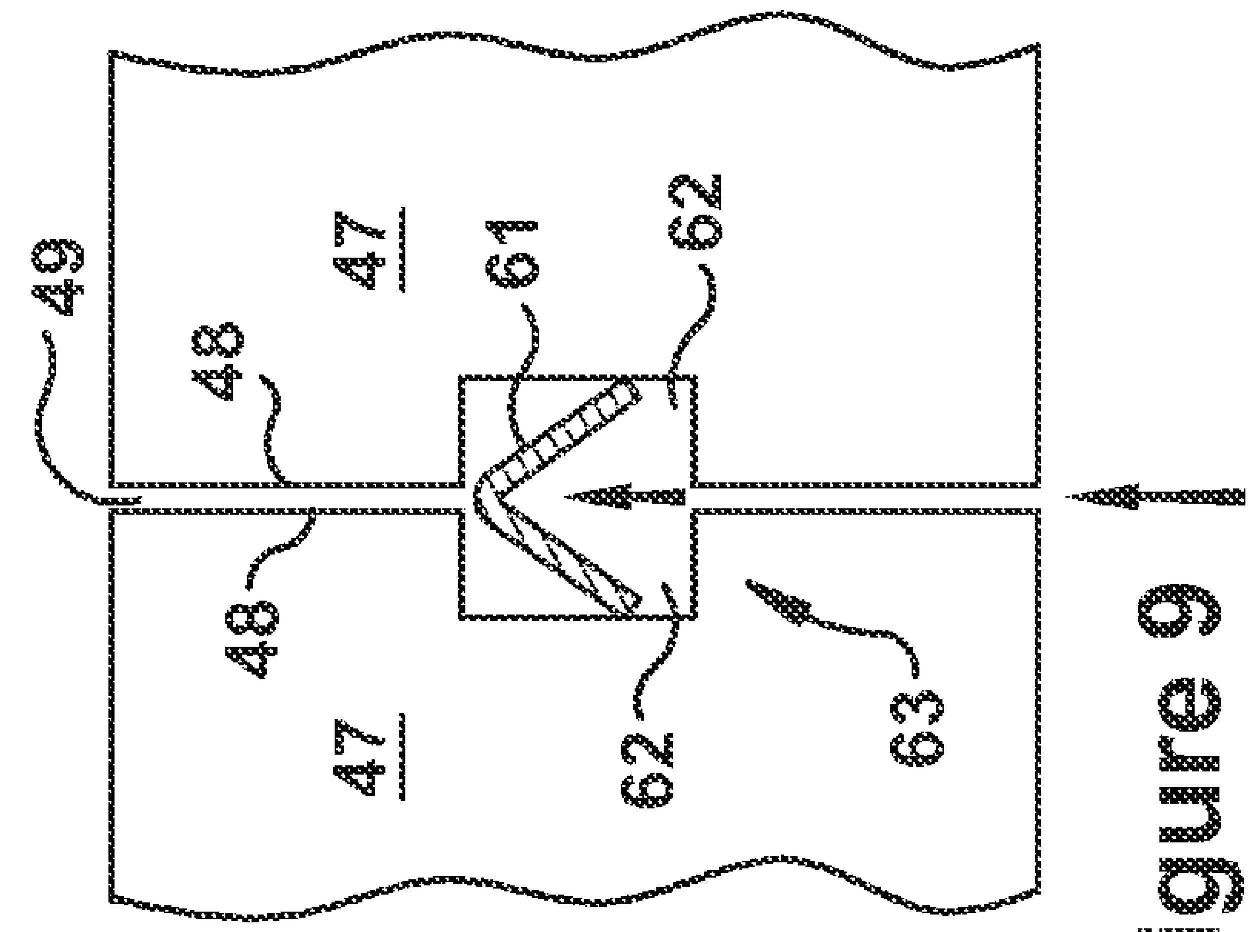

Figure 9

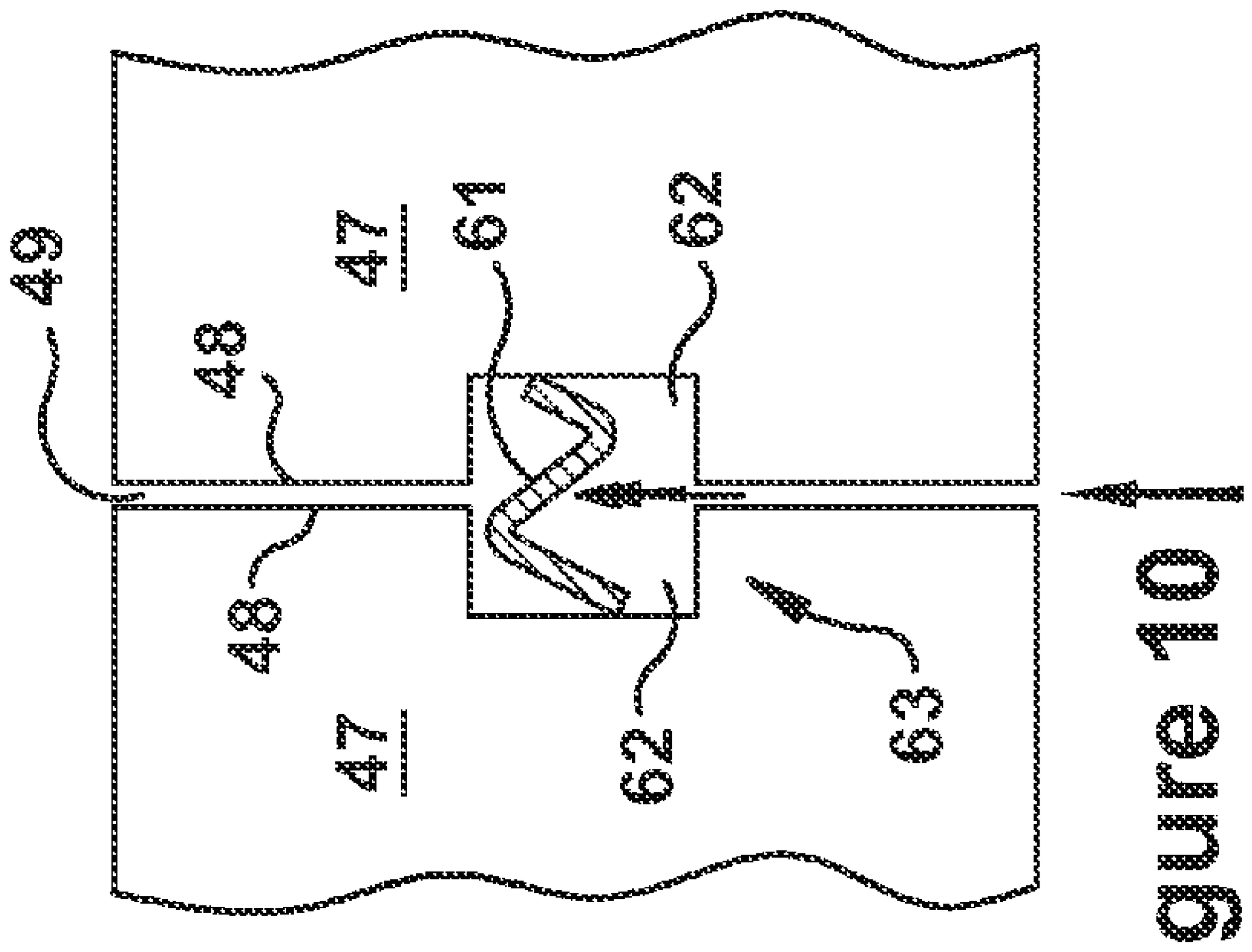

Figure 10

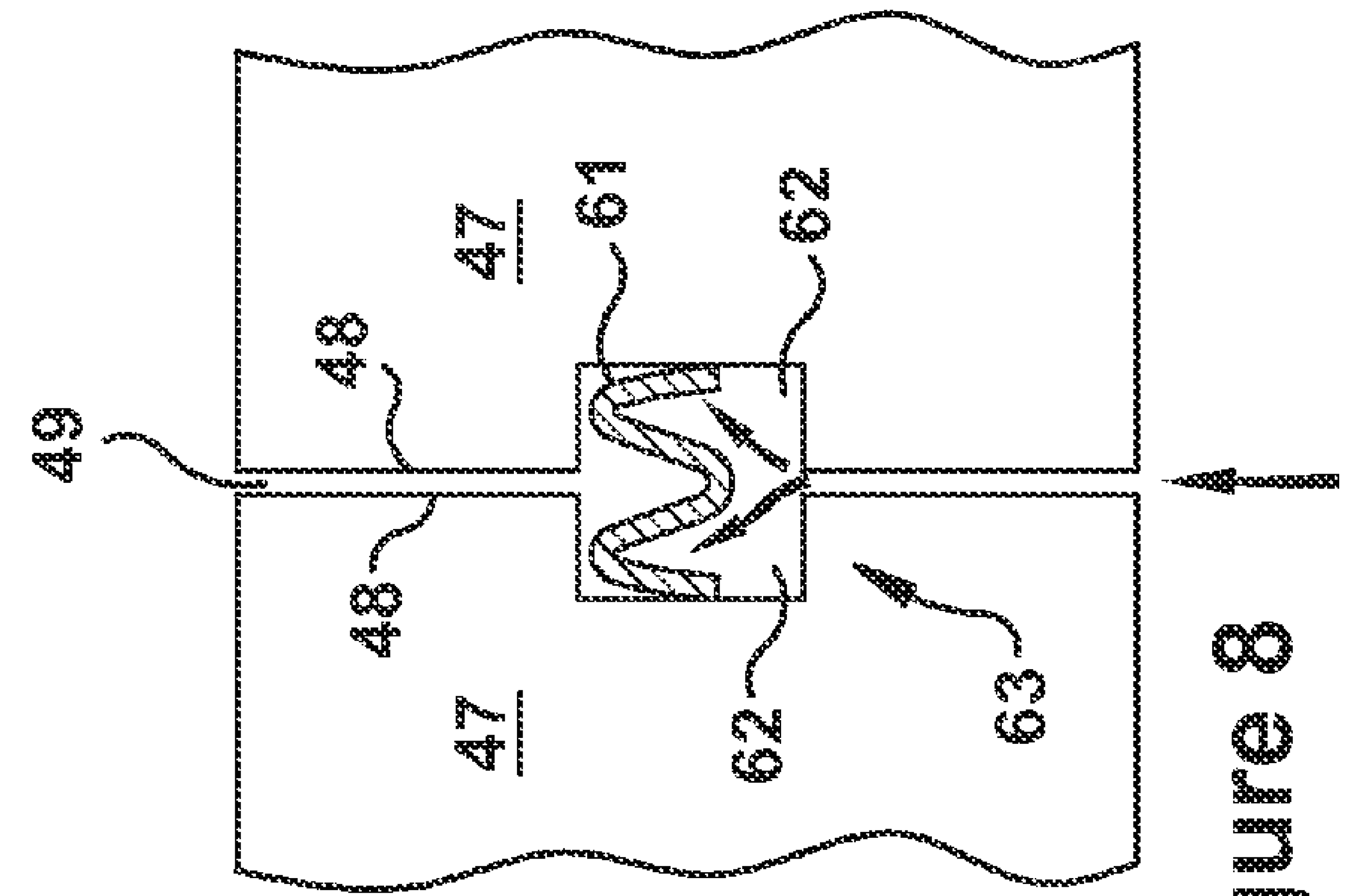

Figure 8

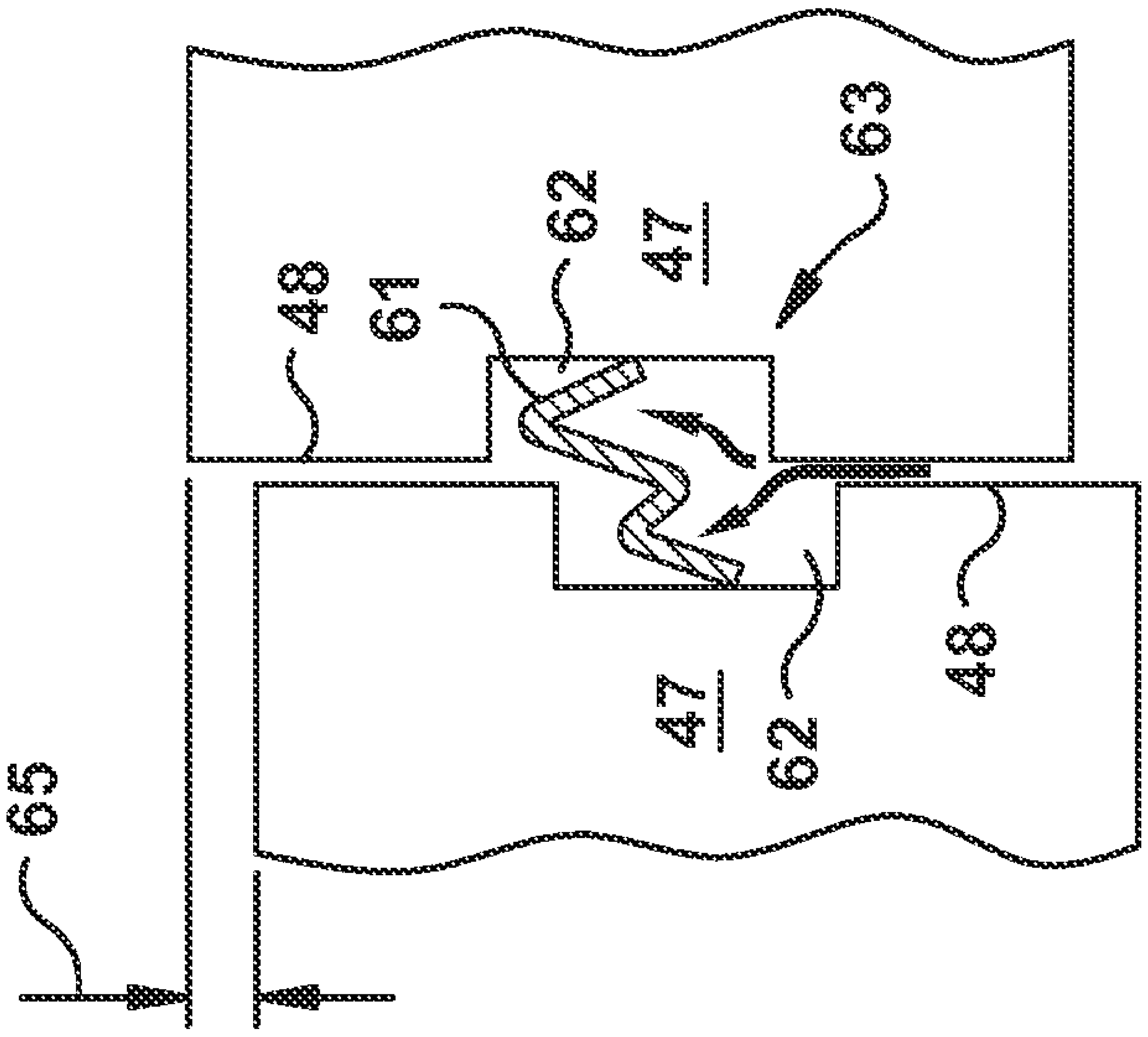

Figure 13

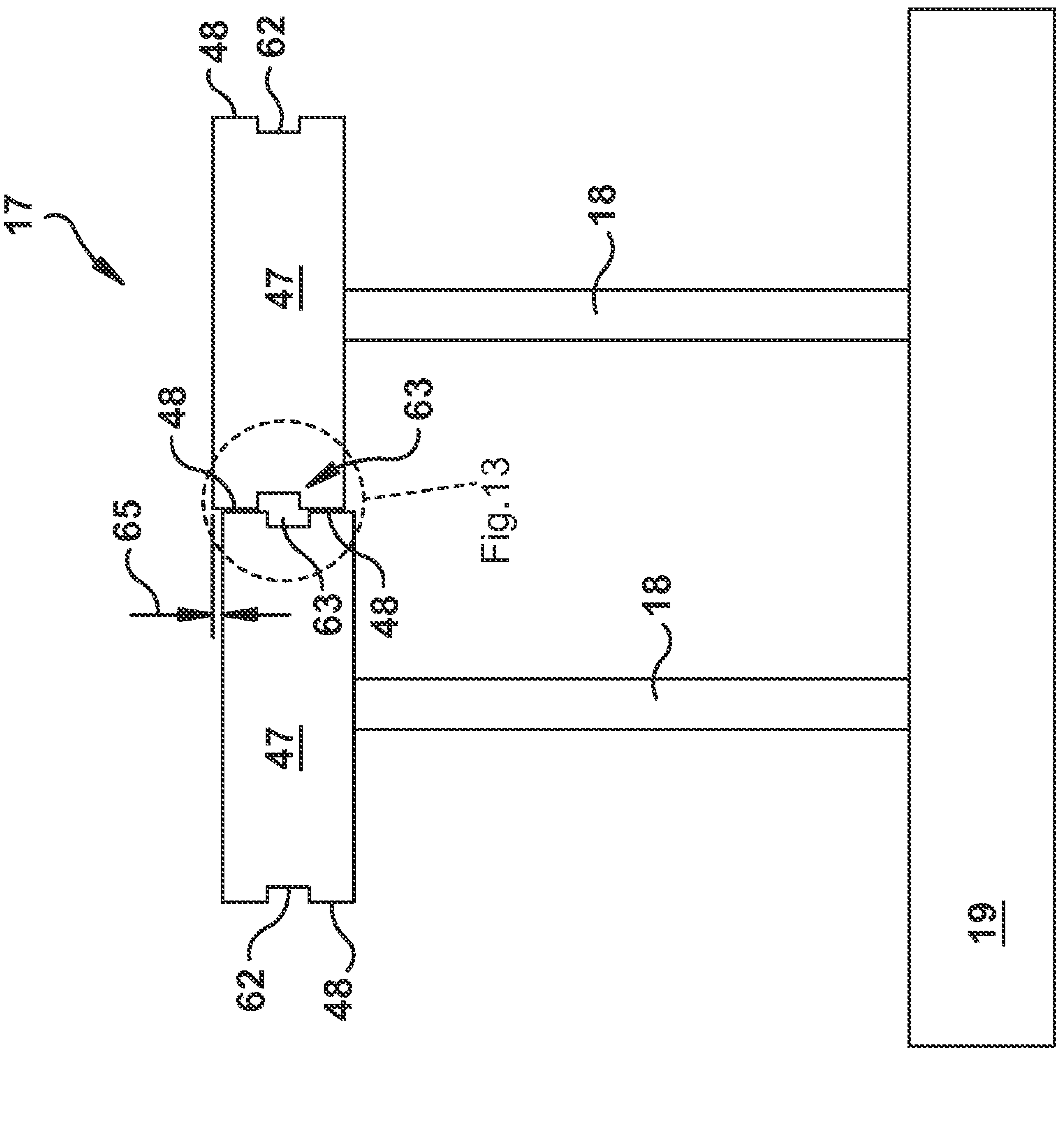

Figure 12

SEAL IN COMBUSTOR NOZZLE OF GAS TURBINE ENGINE

FEDERAL RESEARCH STATEMENT

[0001] This invention was made with Government support under Contract No. DE-FC26-05NT42643, awarded by the Department of Energy. The Government has certain rights in the invention.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to combustion systems in gas turbine engines, and more particularly, to apparatus and systems related to the configuration and design of combustor nozzles and fuel injectors.

[0003] Combustion turbine engines or "gas turbines" are widely used in industrial and power generating applications. As will be appreciated, typical gas turbines includes an axial compressor positioned at forward end, a turbine positioned at an aft end, and one or more combustors about the middle portion of the engine. In operation, ambient air enters the compressor, and rotating blades and stationary vanes in the compressor progressively impart kinetic energy so to produce a supply of compressed air. From the compressor, the compressed air is directed into the combustor where it is mixed with a supply of fuel. The air/fuel mixture is then ignited and combusted within the combustor, and the resulting highly energized flow or "working fluid" is then expanded through the rotating blades of the turbine so work may be extracted therefrom. For example, the rotation induced by the flow through the turbine may rotate a shaft that connects to a generator so to produce electricity.

[0004] Certain types of combustor nozzles—commonly referred to as "micro-mixer nozzles"—include an array of mixing tubes about which a fuel plenum is formed. The supply of compressed air from the compressor is brought to a forward wall of the fuel plenum and the created pressure boundary drives the air through the tubes toward a combustion chamber or zone. The mixing tubes include fuel ports that fluidly communicate with the interior of the fuel plenum, and via these ports fuel is injected into the air moving through the tubes. Brought together in this manner, the fuel and air are suitably mixed before being expelled into the combustion zone for combustion.

[0005] In combustors featuring micro-mixer nozzles, the nozzles themselves typically cover and seal the forward end of the combustion liner. A pressure drop is taken from one side of the nozzle to the other, and the pressure drop is what drives the air across the mixing tubes. Ideally all of the compressed air delivered to the head end is sent through the nozzle and mixed with the fuel that is injected in the nozzle from the fuel plenum. This typically achieves an uniform and balanced fuel-air mixture for combustion. Specifically, as will be appreciated, a given amount of fuel is supplied to the combustor to produce a specific amount of heat, and is controlled so to achieve a desirable fuel-air ratio. It will be appreciated that air that bypasses the nozzle—through gaps, leakage or otherwise—may result in a higher fuel to air ratio within the nozzle. This fuel rich mixture typically results in a locally higher flame temperatures, i.e., hotspots, and therefore produces more oxides of nitrogen, which is a regulated emission. Such leakage also negatively impacts engine efficiency. As a result, there is a continuing need for nozzle configurations that discourage such bypass air leakage. As will be appreciated, micro-mixer nozzles often include a seam formed between abutting nozzle sections that is highly susceptible to such leakage. A cost-effective and robust seal that prevented leakage through this seam would be commercially demanded.

BRIEF DESCRIPTION OF THE INVENTION

[0006] The present application thus describes a nozzle for use in a combustor of a combustion turbine engine, the nozzle including: radial sections defined by sidewalls; a gap formed between opposing sidewalls of adjacent ones of the radial sections; a groove formed on each of the sidewalls that define the gap, the grooves positioned correspondingly so to together form a pocket; and a seal having a zigzagging profile disposed within the pocket. The pocket may intercept the gap over a seal length, and the seal may extend longitudinally within the pocket such that the zigzagging profile intersects the gap over the seal length.

[0007] The present application further describes a combustor in a combustion turbine engine that includes a nozzle for mixing a supply of compressed air with a supply of fuel. The nozzle further includes: a fuel plenum having a cylindrical shape that is axially stacked between a first chamber and a second chamber, wherein the fuel plenum is defined between by a circumferentially extending shroud wall that extends axially between a planar forward tubesheet, which is adjacent to the first chamber, and a planar aft tube sheet, which is adjacent to the second chamber; a plurality of wedge-shaped nozzle sections formed by sidewalls that radially section the fuel plenum; and mixing tubes positioned within each of the plurality of nozzle sections, each of the mixing tubes including a tube extending between an inlet formed through the forward tubesheet and an outlet formed through the aft tubesheet and including a plurality of fuel ports connecting an interior of the tube with the fuel plenum formed about it. A first nozzle section and an adjacent second nozzle section may include, respectively, a first sidewall and a second sidewall opposed across a gap formed therebetween. A groove may be positioned on each of the first and second sidewalls so to together form a radially extending pocket that intercepts the gap over a seal length. And a seal having a zigzagging profile may extend longitudinally within the pocket such that the zigzagging profile intersects the gap over the seal length.

[0008] These and other features of the present application will become apparent upon review of the following detailed description of the preferred embodiments when taken in conjunction with the drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] These and other features of this invention will be more completely understood and appreciated by careful study of the following more detailed description of exemplary embodiments of the invention taken in conjunction with the accompanying drawings, in which:

[0010] FIG. **1** is a section view of a gas turbine engine in which embodiments of the present invention may be used.

[0011] FIG. **2** is a simplified cross-section of a combustor in which embodiments of the present invention may be used.

[0012] FIG. **3** is an enlarged sectional view of the head end of a combustor in which embodiments of the present invention may be used.

[0013] FIG. **4** is a sectional perspective view a head end and nozzle configuration in accordance with aspects of the present invention.

[0014] FIG. **5** is a side sectional view of a nozzle in accordance with aspects of the present invention.

[0015] FIG. **6** is a perspective view of a nozzle sidewall having a seal in accordance with exemplary embodiments of the present invention.

[0016] FIG. **7** is an outboard sectional view of adjacent nozzle sections in which the gap formed therebetween includes a seal in accordance with embodiments of the present invention.

[0017] FIG. **8** is an outboard sectional view of adjacent nozzle sections in which the gap formed therebetween includes a seal in accordance with an alternative embodiment of the present invention.

[0018] FIG. **9** is an outboard sectional view of adjacent nozzle sections in which the gap formed therebetween includes a seal in accordance with an alternative embodiment of the present invention.

[0019] FIG. **10** is an outboard sectional view of adjacent nozzle sections in which the gap formed therebetween includes a seal in accordance with an alternative embodiment of the present invention.

[0020] FIG. **11** is an outboard sectional view of adjacent nozzle sections in which the gap formed therebetween includes a seal in accordance with an alternative embodiment of the present invention.

[0021] FIG. **12** is sectional view of adjacent nozzle sections illustrating a typical axial shift between the nozzles during operation.

[0022] FIG. **13** is an enlargement of the axially shifted nozzle sections of FIG. **12** and how the shift may be accommodated according to an exemplary seal of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0023] In the following text, certain terms have been selected to describe the present invention. To the extent possible, these terms have been chosen based on the terminology common to the field. Still, it will be appreciate that such terms often are subject to differing interpretations. For example, what may be referred to herein as a single component, may be referenced elsewhere as consisting of multiple components, or, what may be referenced herein as including multiple components, may be referred to elsewhere as being a single component. In understanding the scope of the present invention, attention should not only be paid to the particular terminology used, but also to the accompanying description and context, as well as the structure, configuration, function, and/or usage of the component being referenced and described, including the manner in which the term relates to the several figures, as well as, of course, the precise usage of the terminology in the appended claims.

[0024] Because several descriptive terms are regularly used in describing the components and systems within turbine engines, it should prove beneficial to define these terms at the onset of this section. Accordingly, these terms and their definitions, unless specifically stated otherwise, are as follows. The terms "forward" and "aft", without further specificity, refer to directions relative to the orientation of the gas turbine. That is, "forward" refers to the forward or compressor end of the engine, and "aft" refers to the aft or turbine end of the engine. It will be appreciated that each of these terms may be used to indicate movement or relative position within the engine. The terms "downstream" and "upstream" are used to indicate position within a specified conduit relative to the general direction of flow moving through it. (It will be appreciated that these terms reference a direction relative to an expected flow during normal operation, which should be plainly apparent to anyone of ordinary skill in the art.) The term "downstream" refers to the direction in which the fluid is flowing through the specified conduit, while "upstream" refers to the direction opposite that.

[0025] Thus, for example, the primary flow of working fluid through a turbine engine, which consists of air through the compressor and then becoming combustion gases within the combustor and beyond, may be described as beginning at an upstream location at an upstream end of the compressor and terminating at an downstream location at a downstream end of the turbine. In regard to describing the direction of flow within a common type of combustor, as discussed in more detail below, it will be appreciated that compressor discharge air typically enters the combustor through impingement ports that are concentrated toward the aft end of the combustor (relative to the combustors longitudinal axis and the aforementioned compressor/turbine positioning defining forward/aft distinctions). Once in the combustor, the compressed air is guided by a flow annulus formed about an interior chamber toward the forward end of the combustor, where the air flow enters the interior chamber and, reversing it direction of flow, travels toward the aft end of the combustor. Coolant flows through cooling passages may be treated in the same manner.

[0026] Given the configuration of compressor and turbine about a central common axis as well as the cylindrical configuration common to many combustor types, terms describing position relative to an axis will be used. In this regard, it will be appreciated that the term "radial" refers to movement or position perpendicular to an axis. Related to this, it may be required to describe relative distance from the central axis. In this case, if a first component resides closer to the central axis than a second component, it will be described as being either "radially inward" or "inboard" of the second component. If, on the other hand, the first component resides further from the central axis than the second component, it will be described herein as being either "radially outward" or "outboard" of the second component. Additionally, it will be appreciated that the term "axial" refers to movement or position parallel to an axis. Finally, the term "circumferential" refers to movement or position around an axis. As mentioned, while these terms may be applied in relation to the common central axis that extends through the compressor and turbine sections of the engine, these terms also may be used in relation to other components or sub-systems of the engine. For example, in the case of a cylindrically shaped combustor, which is common to many machines, the axis which gives these terms relative meaning is the longitudinal central axis that extends through the center of the cross-sectional shape, which is initially cylindrical, but transitions to a more annular profile as it nears the turbine.

[0027] The following description provides examples of both conventional technology and the present invention, as well as, in the case of the present invention, several exemplary implementations and explanatory embodiments. However, it will be appreciated that the following examples are not intended to be exhaustive as to all possible applications the invention. Further, while the following examples are presented in relation to a certain type of turbine engine, the technology of the present invention also may be applicable to other types of turbine engines as would the understood by a person of ordinary skill in the relevant technological arts.

[0028] FIG. **1** is a cross-sectional view of a known gas turbine engine **10** in which embodiments of the present invention may be used. As shown, the gas turbine engine **10** generally includes a compressor **11**, one or more combustors **12**, and a turbine **13**. It will be appreciated that a flowpath is defined through the gas turbine **10**. During normal operation, air may enter the gas turbine **10** through an intake section, and then fed to the compressor **11**. The multiple, axially-stacked stages of rotating blades within the compressor **11** compress the air flow so that a supply of compressed air is produced. The compressed air then enters the combustor **12** and directed through a nozzle, within which it is mixed with a supply of fuel so to form an air-fuel mixture. The air-fuel mixture is combusted within a combustion zone portion of the combustor so that a high-energy flow of hot gases is created. This energetic flow of hot gases then becomes the working fluid that is expanded through the turbine **13**, which extracts energy from it.

[0029] FIG. **2** is a simplified cross-section of a combustor **12** in which embodiments of the present invention may be used, while FIG. **3** provides an enlarged sectional view of the forward portion of the combustor **12**. As one of ordinary skill in the art will appreciate, the combustor **12** is axially defined by a forward end, which typically is referred to as a head end **15**, and an aft end, which, as illustrated, may be defined by an aft frame **16** that connects the combustor to the turbine. A nozzle **17** may be positioned toward the forward end of the combustor **12**. It will be appreciated that the nozzle **17** is the primary component that brings together and mixes the fuel and air that is combusted within the combustor **12**. As discussed in more detail below, the nozzle **17** may be configured as a micro-mixer nozzle. As illustrated, the head end **15** generally provides various manifolds, apparatus, and/or fuel lines **18** that provide the fuel to the nozzle **17**. The head end **15** also may include an endcover **19** that forms the forward axial boundary of the large interior cavity that is defined in most combustors **12**.

[0030] The interior cavity of the combustor **12**, as illustrated, is divided into several chambers that are configured to direct the working fluid of the engine along a desired flow path. These include a first chamber that is typically defined by a component referred to herein as cap assembly **21**. The other chamber includes the combustion zone and is typically defined by a liner and/or transition piece, as discussed below. It will be appreciated that, given this arrangement, these chambers may be described as being axially stacked in their configuration.

[0031] The cap assembly **21**, as shown, may extend afterward from a connection it makes with the endcover **19**, and be surrounded by a combustor casing **29**, which is formed outboard of and in spaced relation to it. In this manner, the cap assembly **21** and the combustor casing **29** thereby form an annulus shaped flowpath between them. As discussed below, this annular flowpath—referred to herein as flow annulus **28**—continues in an aft direction. The cap assembly **29** may house and structurally support the nozzle **17**, which may be positioned at or near the aft end of the cap assembly **21**. Given this configuration, the cap assembly **21** may be described as including a two smaller chambers or sections that are axially stacked within it, with the first being the forward region that, as indicated by arrows in FIG. **3**, accepts a flow of compressed air from the flow annulus **28**. The second section within the cap assembly **28** is the region in which the nozzle **17** is defined.

[0032] The combustion zone **23** defined just aft of the nozzle **17** is circumferentially defined by a liner **24**. The combustion zone **23** is the region where the fuel-air mixture brought together in the nozzle **17** is combusted. From the liner **24**, this other chamber may extend through a transition section toward the connection the combustor **12** makes with the turbine **13**. Though other configurations are also possible, within this transition section, the cross-sectional area of the second chamber transitions from the circular shape of the liner **24** to a more annular shape that is necessary for directing the flow of combustion products onto the rotor blades of the turbine **13** in a desirable way.

[0033] Positioned about the liner **24** is a flow sleeve **25**. The liner **24** and flow sleeve **25** may be cylindrical in shape and arranged concentrically. In this manner, the flow annulus **28** formed between the cap assembly **21** and the combustor casing **29** may connect to a continuation of the flow annulus that extends toward the aft end of the combustor **12**. Similarly, as illustrated, an impingement sleeve **27** may surround the transition piece **26** so that the flow annulus **28** continues. According to the example provided, the flow annulus **28** loss may extend from approximately the endcover **19** of the head end **15** to the aft end of the combustor **12**. More specifically, it will be appreciated that the cap assembly **21**/combustor casing **29**, the liner **24**/flow sleeve **25**, and the transition piece **26**/impingement sleeve **27** pairings extend the flow annulus **28** a significant portion of the axial length of the combustor **12**. The concentrically arranged cylindrical walls that form the flow annulus **28** also may be referred to herein as inner and outer radial walls.

[0034] The flow sleeve **25** and/or the impingement sleeve **27** may include a plurality of impingement ports **32** that allow a flow of compressed air external to the combustor **12** into the flow annulus **28**. It will be appreciated that, as shown in FIG. **2**, a compressor discharge casing **34** may be define a compressor discharge cavity **35** about an aft section of the combustor **12**. According to conventional design, the compressor discharge cavity **35** may be configured to receive a supply of compressed air from the compressor **11** and the air may then enter the flow annulus **28** through the impingement ports **32**. The impingement ports **32** may be configured to impinge the flow of air entering the combustor **12** against the liner **24** and/or transition piece **26** so to convectively cool those components. Once in the flow annulus **28**, the compressed air is directed toward the forward end of the combustor **12**, where, via the inlets **31**, the flow enters the forward cavity of the cap assembly **21**. Within the cap assembly **21**, the compressed air is directed to the nozzle **17** where, as mentioned, it is mixed with fuel.

[0035] Referring now to FIGS. **4** and **5**, a nozzle having a micro-mixer configuration is shown that includes aspects of the present invention. FIGS. **4** shows a sectional perspective view of a combustor head end **15** having a cap assembly **21** and micro-mixer nozzle **17** (as well as nozzle sections, as discussed below) that includes elements of the present invention. FIG. **5** shows an enlarged cross-sectional side view of a micro-mix nozzle **17** and the typical components of this nozzle type. As illustrated, the fuel nozzle **17** includes a shroud wall **45** that circumferentially surrounds and defines a fuel plenum **43**. The fuel plenum **43** may be cylindrical in shape, though other shapes are also possible. The planar ends of the cylindrically shaped plenum **43** are defined by a forward tubesheet **51** and an aft tubesheet **52**. It will be appreciated that the fuel plenum **43** may be connected to a supply of fuel by a fuel line **18** that extends through the endcover **19**.

[0036] The nozzle **17** may include a number of mixing tubes **41** that are arranged in a parallel configuration. The mixing tubes **41** may extend across the axial thickness of the nozzle **17**. As will be appreciated, with the fuel plenum **43** defined about the mixing tubes **41**, a fuel, such as natural gas, may be injected into the mixing tubes **41** through fuel ports **44** defined therethrough. As shown in FIG. **4**, the nozzle **17** may be sectioned into radial sections, which will be referred to as "nozzle sections **47**". Given the circular cross-sectional shape of the nozzle **17**, the nozzle sections **47** may be wedge shaped in a preferred embodiment. Other configurations are also possible. The nozzle sections **47** are defined by sidewalls **48**. The sidewalls **48** of neighboring or adjacent nozzle sections **47**, as illustrated, may abut against each other so to form a seam or gap **49** therebetween. This gap **49** extends from an inner radial position that defines the inboard boundary of the nozzle suction **47** to the shroud wall **45**, which, as described, defines the outboard boundary of the nozzle suction **47**.

[0037] The mixing tubes **41** may be configured to extend through the fuel plenum **43** between the forward tubesheet **51** and aft tubesheet **52**. More specifically, the mixing tubes **41**, as illustrated, may be configured to form a passageway that connects an inlet formed through the forward tubesheet **51** to an outlet formed through the aft tubesheet **52**. It will be appreciated that, given this configuration, the inlet provides the means by which the compressed air within the cap assembly **21** enters the nozzle **17**. As mentioned, the mixing tube **41** may include one or more fuel ports **44**. The fuel ports **44** may be axially spaced along the length of the mixing tube **41**, and connect the interior passageway of the mixing tube **41** to the fuel plenum **43**. Thus arranged, compressed air fed into the mixing tubes **41** through the inlets on the forward tubesheet **51** is brought together with fuel injected into to the mixing tubes **41** through the fuel ports **44**. Within the mixing tubes **41**, the fuel and air is mixed and the mixture flows toward the outlet formed through the aft tubesheet **52**. In this manner, the outlets deliver an air/fuel mixture to the combustion chamber **23** where it then is combusted. Typically many separate mixing tubes **41** are positioned within the fuel nozzle **17**. Further, each of the nozzle sections **47** includes many mixing tubes **41**. The mixing tubes **41** may be aligned radially outward of an axial centerline **48** of the nozzle **12**, and be configured to extend in a parallel configuration across the axial thickness of the fuel plenum **43**.

[0038] It will be appreciated that the mixing tubes **41** may have a cross-section that is circular, oval, square, triangular, or any known geometric shape. In a preferred embodiment, as shown, the mixing tubes **41** have a round cross-sectional shape. The inlet and outlet of the mixing tube **41** may simply comprise openings formed through the forward and aft tubesheets **51**, **52**. The opening may be configured to correspond in a desired way with the size and shape of the interior passageway defined within the mixing tube **41**. The upstream and downstream ends of the mixing tubes **41** may be formed to permit air to freely flow through the mixing tubes **41** and mix with fuel injected into the mixing tubes **41** via the fuel ports **44**. The fuel ports **44** may simply comprise small openings or apertures in the wall of the mixing tube **41** that allow the fuel to flow from the fuel plenum **43** into the mixing tube **41** in a desired manner. The fuel ports **44** may be axially and circumferentially spaced so to encourage a more uniform mixing of fuel with the air supply moving through the mixing tubes **41**. It will be appreciated that the fuel ports **44** may be angled with respect to the axial centerline of the mixing tube **41** to vary the angle at which the fuel enters the mixing tube **41**, thus varying the distance that the fuel penetrates into the mixing tube **41** before mixing with the supply of air. In this manner a more uniform mixture of fuel and air may be achieved.

[0039] As mentioned, the nozzle **17** may be radially divided into sections, which are referred to herein as nozzle sections **47**. Each nozzle section **47** may be supplied by a separate fuel line **18** and include a plurality of the mixing tubes **41**. The nozzle sections **47** include sidewalls **48** that separate each from the nozzle sections **47** positioned to each side of it. As illustrated, the sidewalls **48** extends between the forward tubesheet **51** and the aft tubesheet **52**, as well as between the outer radial boundary defined by the shroud wall **45** and an inner radial boundary. The sidewalls **48** may be planar and, in a preferred embodiment in which the nozzle **17** is cylindrical in shape, the sidewalls **48** may have a rectangular shape.

[0040] As now described in further detail and with reference to FIGS. **6** through **13**, the present invention teaches a manner in which air leakage through the seam or gap **49** formed between adjacent nozzle sections **47** may be limited or substantially prevented. As mentioned, micro-mixer nozzles may include several wedge shaped nozzle sections which necessarily form gaps at the sidewall interfaces between them. (It will be appreciated that the present invention also may be applicable to other types of nozzles that include similar abutting sections that for seams or gaps such as described herein.) The gaps **49** form leakage paths and, as will be appreciated, air that leaks through these gaps bypasses the mixing tubes, which typically negatively impacts combustor performance. More specifically, leakage through these gaps may unbalance the air-fuel mixture within the nozzle, which may cause uneven combustion, the formation of localized hotspots, increased NOx emissions, as well as negatively impact engine efficiency. It will be appreciated that such leakage may quench the flame at low load conditions and thereby cause increases in CO emissions, such as during turn-down conditions. By preventing air from passing through these gaps, which are common to many nozzle types, more air is directed through the mixing tubes, proper mixing ratios maintained, and combustor performance improved.

[0041] In addition, the seal of the present invention prevents leakage while being compliant enough to accommodate the relative movement that typically occurs between adjacent nozzles. That is, the present invention provides a seal capable of maintaining its sealing effectiveness even when adjacent nozzle sections shift relative to each other. As will be appreciated, because this type of relative movement is common given of the dynamic thermal and mechanical loads within combustors, this is a significant feature. To achieve this, the seal of the present invention is made compliant and configured so that it is air loaded during operation. Having a "zigzagging profile", as defined below, the seal may be inserted radially into a pocket that is formed between two adjacent nozzle sections. As illustrated, the shape and size of the seal and the pocket may be configured so to prevent the seal from turning or rotating once installed. The seal thus maintains its orientation, and its zigzagging profile is made compliant enough so that air loading through the gap maintains the contact points that block flow through the gap. Given this configuration, it will be appreciated that the seal of the present invention may accommodate relative movement between the adjacent nozzle sections in both the radial and axial directions while still maintaining its sealing capabilities.

[0042] To operate most effectively, micro-mixer nozzles require a large number of relatively small mixing tubes, and it is challenging to position enough mixing tubes within the limited space of the combustor head end while also maintaining the necessary flow area through the nozzle. It is therefore desirable to dedicate as much space as possible for the placement of mixing tubes. Reducing flow area or the number of mixing tubes so to provide gap sealing would be detrimental to overall performance. The seal of the present invention, as described below, has an efficient design that requires substantially no additional space for implementation. This is not true of other types of possible sealing solutions, such as Hula seals. As will be appreciated, the seal configuration of the present invention features a low profile so that it does not take away area that might otherwise be used for mixing tube placement, thereby allowing a maximum number of mixing tubes within each nozzle section. The present seal also is relatively inexpensive compared to competing sealing schemes. Another advantage is that the present seal may be configured so to provide damping between nozzle sections. As will be appreciated, this is a desirable feature in lean pre-mixed combustors.

[0043] The seal **61** of the present invention may be used, for example, in the seams or gaps **49** formed between the radial sections of a cylindrically fuel plenum **43** of a nozzle **17**. The nozzle **17** may be axially stacked between a first chamber that receives a supply of compressed air (i.e., the cap assembly **21**) and a second chamber configured for combusting the fuel-air mix (i.e., combustion zone **23**). The fuel plenum **43** may be defined between a circumferentially extending shroud wall **45** that extends axially between a planar forward tubesheet **51**, which abuts the cap assembly **21**, and a planar aft tube sheet **52**, which abuts the combustion zone **23**. A plurality of wedge-shaped nozzle sections **47** may be formed by sidewalls **48**, which radially section the fuel plenum **43**. A plurality of mixing tubes **41** may be positioned within each of the plurality of nozzle sections **47**. The sidewalls **48** of adjacent nozzle sections **47** form the gap **49** in which the present seal may be used.

[0044] FIGS. **6** and **7** illustrate nozzle sidewalls **48** having a seal **61** in accordance with exemplary embodiments of the present invention. As illustrated, as part of the seal configuration, a groove **62** may be formed in the sidewall **48** of a nozzle section **47**. Between adjacent nozzle sections **47**, the sidewalls **48** that are opposed across the gap **49** may each include a groove **62** that are correspondingly positioned so that, as FIG. **7** shows, together a radially extending pocket **63** is formed. The pocket **63** may intercepts the gap **49** over what will be referred to herein as a seal length. The pocket **63** may extend longitudinally in the radial direction and, according to a preferred embodiment, the seal length may extend between an inner radial boundary **50** of the nozzle section **47** and the shroud wall **49**, which defines the outer radial boundary of the nozzle section **47**. The groove **62** formed in each sidewall **48** may be rectangular, though other shapes are possible. The pocket **63** may be rectangular in shape also. The depth of each of the grooves **62** may be approximately the same. In this manner, the gap **49** approximately bisects the pocket **63**. The seal **61** may include a zigzagging profile that extends longitudinally within the pocket **63** formed between opposing sidewalls **48**. The seal **61** may be positioned such that the zigzagging profile intersects the gap **49** over the seal length. As will be appreciated, the gap **49** may extend between a forward seam formed on the forward tubesheet and an aft seam formed on the aft tubesheet. The pocket **63** may be axially located between the forward and aft seams of the gap **49**. In certain embodiments, the pocked **63** is located approximately midway between the forward and aft seams formed on the tubesheets.

[0045] As will be appreciated, the "profile" of the seal **61** is the cross-sectional shape of the seal **61** shown in FIGS. **7** through **11** and **13**. The seal **61** may have a constant or substantially constant profile over the seal length. "Zigzagging", as used herein, is a path characterized by short and sharp turns, as further delineated below in relation to the several exemplary embodiments. As provided in the several figures, the zigzagging profile of the seal **61** may include a number of segments that are connected end-to-end at a sharp turn. According to a simplified version of the seal **61**, as illustrated in FIG. **9**, the zigzagging profile includes two segments connected at a sharp turn. According to preferred embodiments, the sharp turn is a turn of at least 90°. Alternatively, the sharp turn may be a turn of at least 120°, as well as, in another preferred embodiment, 150°. The segments may be linear in shape, as the "V" shape of FIG. **9** illustrates. According to other embodiments, the segments may be curved somewhat so that an related embodiment has more of a "U" shape.

[0046] According to an alternative embodiment, the zigzagging profile includes at least three segments connected end-to-end at alternating sharp turns. An example of this embodiment is provided in FIG. **10**. In this case, the sharp turns may be ones that includes at least a 90°, or 120°, or 150° change in direction. The segments may be linear or curved. Embodiments having linear segments may have a "N" shaped profile, as shown in FIG. **10**. As will be appreciated, curved segments may produce more of a sinusoidal shape.

[0047] According to certain other preferred embodiments, as illustrated in FIGS. **6** through **8**, **11** and **13**, the zigzagging profile includes at least four segments connected end-to-end at alternating sharp turns. As before, the sharp turns may be ones that includes at least a 90°, or 120°, or 150° change in direction, and the segments may be linear or curved. Embodiments having linear segments may have a "M" shaped profile, as shown in FIG. **7**. As will be appreciated, curved segments may produce more of a sinusoidal shape, such as the exemplary embodiment shown in FIG. **8**. According to another embodiment, as shown in FIG. **11**, the zigzagging profile having four segments may have an approximate "Ω" shape. As illustrated most clearly FIG. **8**, the "M" shape may be oriented within the pocket **63** in a preferred direction that enhances its sealing characteristics. As shown, the middle sharp turn of the "M" shaped embodiment may be directed toward an expected leakage flow through the gap **49**, which, given the configuration of the nozzle, corresponds with the forward direction of the gas turbine.

[0048] As will be appreciated the segments and the sharp turns that connect them may provide a compliant profile which may advantageously be air loaded by leakage moving through the gap **49**. Thus, for example, as indicated in FIG. **8**, the "M" shaped profile may have outer segments that the leakage forces against the surrounding walls of the pocket **63**, which would enhance the effectiveness of it. Along with having a profile that encourages such advantageous compliancy, the seal **61** may be made of a material selected for its compliancy. This material may be selected to allow a desired level of flexion during operation so that when the seal **61** is air loaded by leakage greater contact between the seal and the walls defining the grooves **62** is maintained. Additionally, the seal **61** and the pocket **63** may be correspondingly designed so to prevent rotation and misalignment of the profile within the pocket **63**. According to a preferred embodiment, the dimensions of the pocket **63** and dimensions of the zigzagging profile of the seal **61** may be designed so to mechanically prevent rotation of the seal **61** about its longitudinal axis. In a preferred embodiment, rotation greater than approximately 45° is prevented.

[0049] Finally, as illustrated in FIGS. **12** and **13**, the seal **61** of the present invention is shown accommodating the relative shifting that occurs between adjacent nozzles sections **47** during operation. Specifically, as illustrated in FIG. **12**, one nozzle selection **47** has shifted axially so to cause an axial offset **65** between it and a neighboring section **47**. In this case, as illustrated in FIG. **13**, the compliant profile of the seal **61** and the air loading of the segments of the seal **61**, allow the seal **61** to shift within the pocket **63** and bend so to maintain contact with the walls of the groove **62**. In this manner, the effectiveness of the seal is maintained.

[0050] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

1. A nozzle for use in a combustor of a combustion turbine engine, the nozzle comprising:

radial sections defined by sidewalls;

a gap formed between opposing sidewalls of adjacent ones of the radial sections;

a groove formed on each of the sidewalls that define the gap, the grooves positioned correspondingly so to together form a pocket; and

a seal having a zigzagging profile disposed within the pocket;

wherein the pocket intercepts the gap over a seal length; and

wherein the seal extends longitudinally within the pocket such that the zigzagging profile intersects the gap over the seal length.

2. The nozzle according to claim **1**, further comprising: a fuel plenum defined by a circumferentially extending shroud wall that extends axially between a forward tubesheet and an aft tubesheet, wherein the sidewalls radially section the fuel plenum so to form the radial sections; and

mixing tubes extending across each of the radial sections of the fuel plenum so to define a passageway connecting an inlet formed through the forward tubesheet to an outlet formed through the aft tubesheet.

3. The nozzle according to claim **2**, wherein the seal length extends between a first end positioned near an inboard boundary of the fuel plenum and a second end positioned near the shroud wall;

wherein a forward seam formed on the forward tubesheet and an aft seam formed on the aft tubesheet define forward and aft ends of the gap;

wherein the forward and aft seams each extend linearly between the inboard boundary of the fuel plenum and the shroud wall, and the gap extends planarly between the forward and aft seams.

4. The nozzle according to claim **3**, wherein the pocket comprises a position between the forward and aft seams of the gap, and wherein the pocket extends in a radially direction.

5. The nozzle according to claim **4**, wherein the pocket comprises a position approximately midway between the forward and aft seams; and

wherein each of the grooves and the pocket comprise rectangular profiles.

6. The nozzle according to claim **2**, wherein the grooves are formed so that the gap bisects the pocket; and

wherein the seal comprises a compliant material selected for air loading flexion during operation.

7. The nozzle according to claim **2**, wherein the zigzagging profile of the seal comprises at least two segments connected end-to-end at a sharp turn.

8. The nozzle according to claim **7**, wherein the sharp turn comprises one of at least 120°; and

wherein the zigzagging profile comprises at least one of a "V" or "U" shape.

9. The nozzle according to claim **2**, wherein the zigzagging profile comprises at least three segments connected end-to-end at alternating sharp turns.

10. The nozzle according to claim **9**, wherein the sharp turns each comprises one of at least 90°.

11. The nozzle according to claim **10**, wherein the segments are curved so that the zigzagging profile comprises a sinusoidal shape.

12. The nozzle according to claim **9**, wherein the sharp turns each comprises one of at least 120°; and

wherein the segments are linear and the zigzagging profile comprises a "N" shape.

13. The nozzle according to claim **2**, wherein the zigzagging profile comprises at least four segments connected end-to-end at alternating sharp turns.

14. The nozzle according to claim **13**, wherein the sharp turns each comprise one of at least 150°.

15. The nozzle according to claim **13**, wherein the zigzagging profile comprises an "Ω" shape.

16. The nozzle according to claim **13**, wherein the zigzagging profile comprises a "M" shape.

17. The nozzle according to claim **16**, wherein the "M" shape is oriented within the pocket such that the middle sharp turn is directed toward an expected leakage flow through the gap.

18. The nozzle according to claim **2**, wherein dimensions of the pocket and dimensions of the zigzagging profile of the seal are correspondingly sized so that rotation of the seal about a longitudinal axis beyond approximately 45° is mechanically prevented.

19. A combustor in a combustion turbine engine that includes a nozzle for mixing a supply of compressed air with a supply of fuel, wherein the nozzle further comprising:

a fuel plenum comprising a cylindrical shape that is axially stacked between a first chamber and a second chamber, wherein the fuel plenum is defined between by a circumferentially extending shroud wall that extends axially between a planar forward tubesheet, which is adjacent to the first chamber, and a planar aft tube sheet, which is adjacent to the second chamber;

a plurality of wedge-shaped nozzle sections formed by sidewalls that radially section the fuel plenum;

mixing tubes positioned within each of the plurality of nozzle sections, each of the mixing tubes including a tube extending between an inlet formed through the forward tubesheet and an outlet formed through the aft tubesheet and including a plurality of fuel ports connecting an interior of the tube with the fuel plenum formed about it;

wherein a first nozzle section and an adjacent second nozzle section comprise, respectively, a first sidewall and a second sidewall opposed across a gap formed therebetween;

wherein a groove is positioned on each of the first and second sidewalls so to together form a radially extending pocket that intercepts the gap over a seal length; and

wherein a seal having a zigzagging profile extends longitudinally within the pocket such that the zigzagging profile intersects the gap over the seal length.

20. The combustor according to claim **19**, wherein the first chamber is configured to receive a supply of compressed air and the second chamber is configured as a combustion zone;

wherein the seal length extends between a first end positioned near an inboard boundary of the fuel plenum and a second end positioned near the shroud wall; and

wherein the zigzagging profile comprises at least four segments connected end-to-end at alternating turns of at least 120°.

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