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(54) **IMPINGEMENT COOLING OF COMBUSTOR LINERS**

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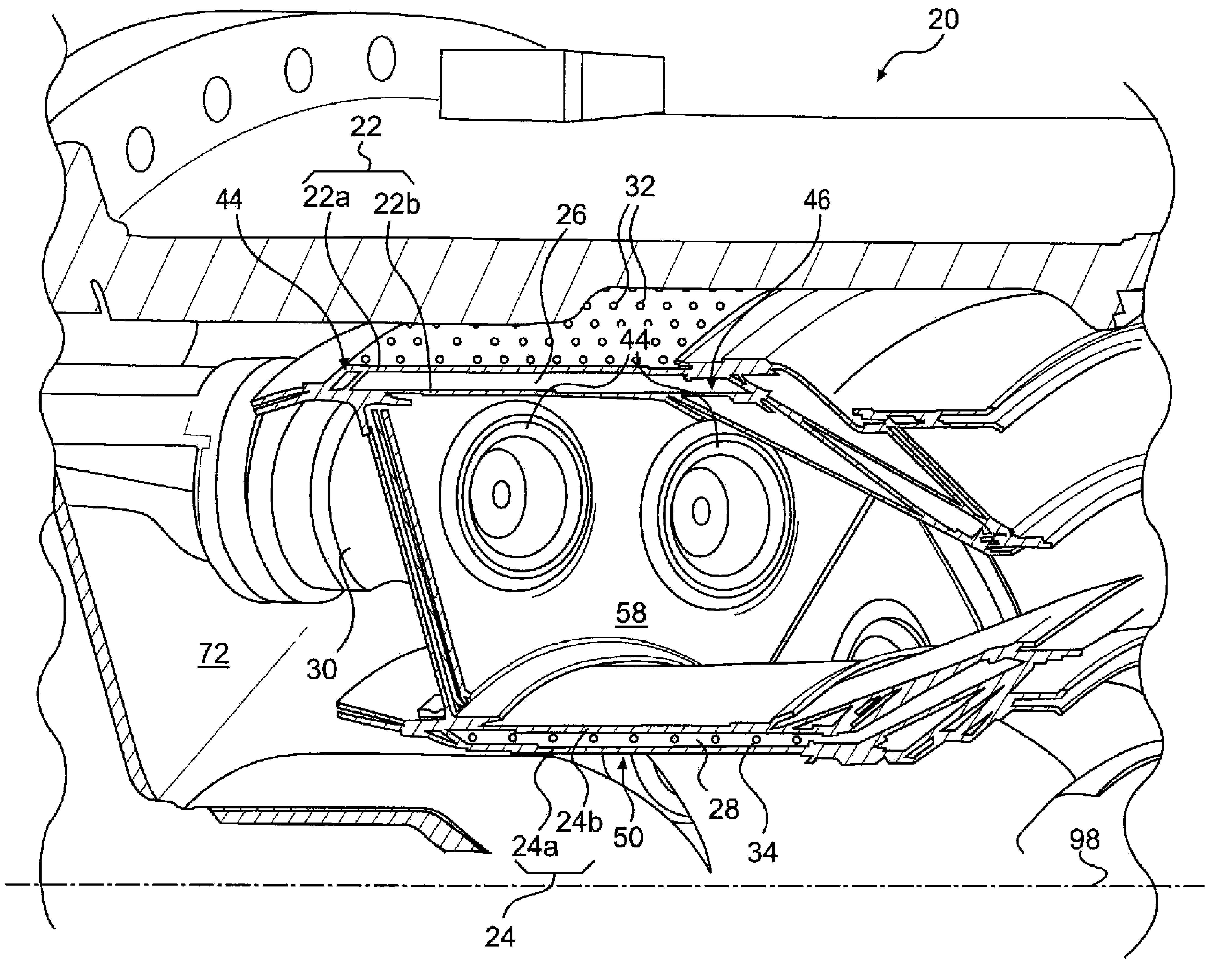
USPC **60/772**; 60/752

(57) **ABSTRACT**

A gas turbine engine may include an impingement cooled double-walled liner, having an inner liner and an outer liner, disposed around a combustion space of the turbine engine. The double-walled liner may extend from an upstream end to a downstream end. The gas turbine engine may also include a plurality of nozzles extending radially inwards through the outer liner to direct cooling air towards the inner liner. Each nozzle of the plurality of nozzles may extend radially inwards from a first distal end to a second proximal end. The plurality of nozzles may be arranged such that a radial gap between the second end of a nozzle and the outer liner decreases from the upstream end to the downstream end. The at least one nozzle of the plurality of nozzles may include multiple air holes at the second end.



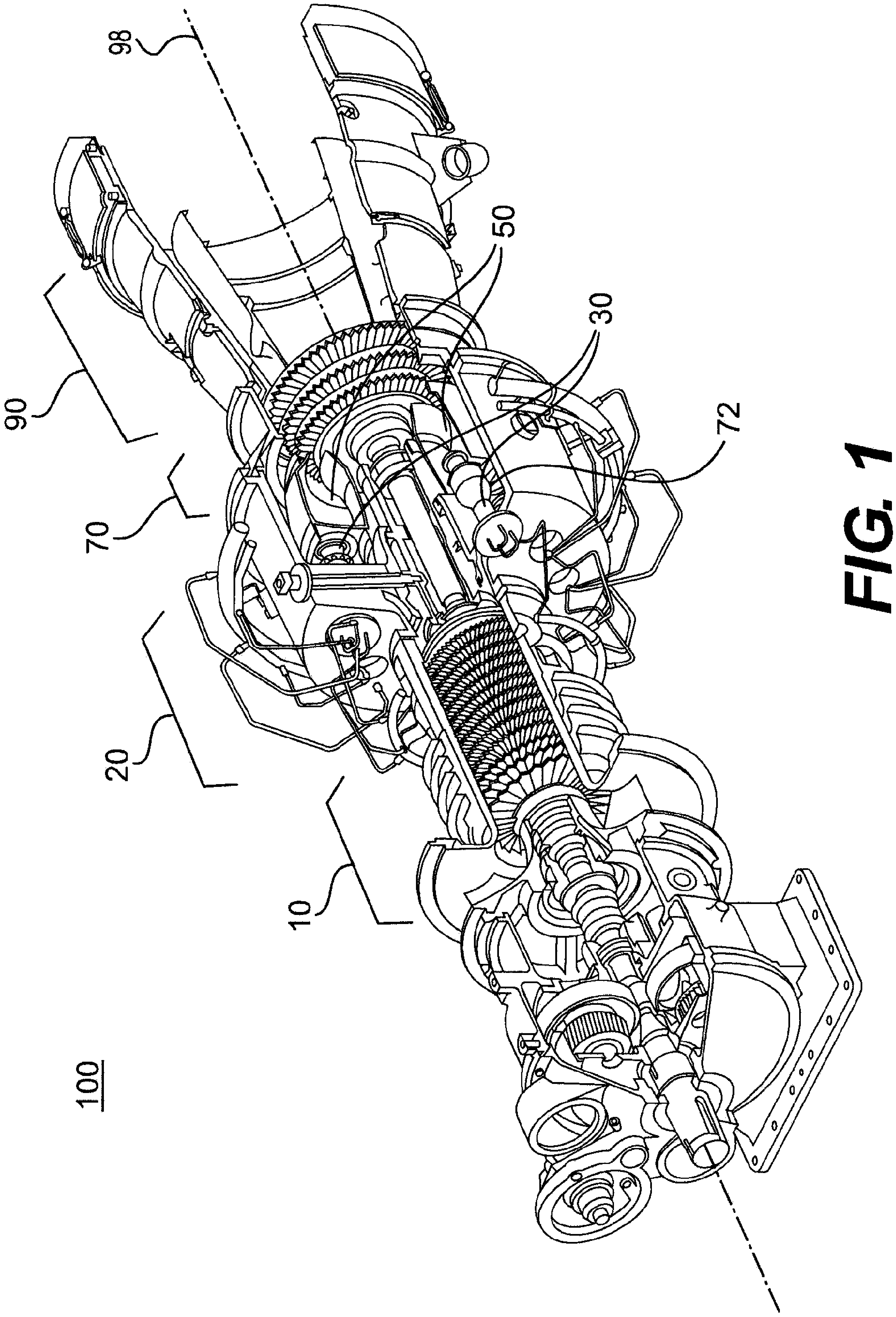


FIG. 1

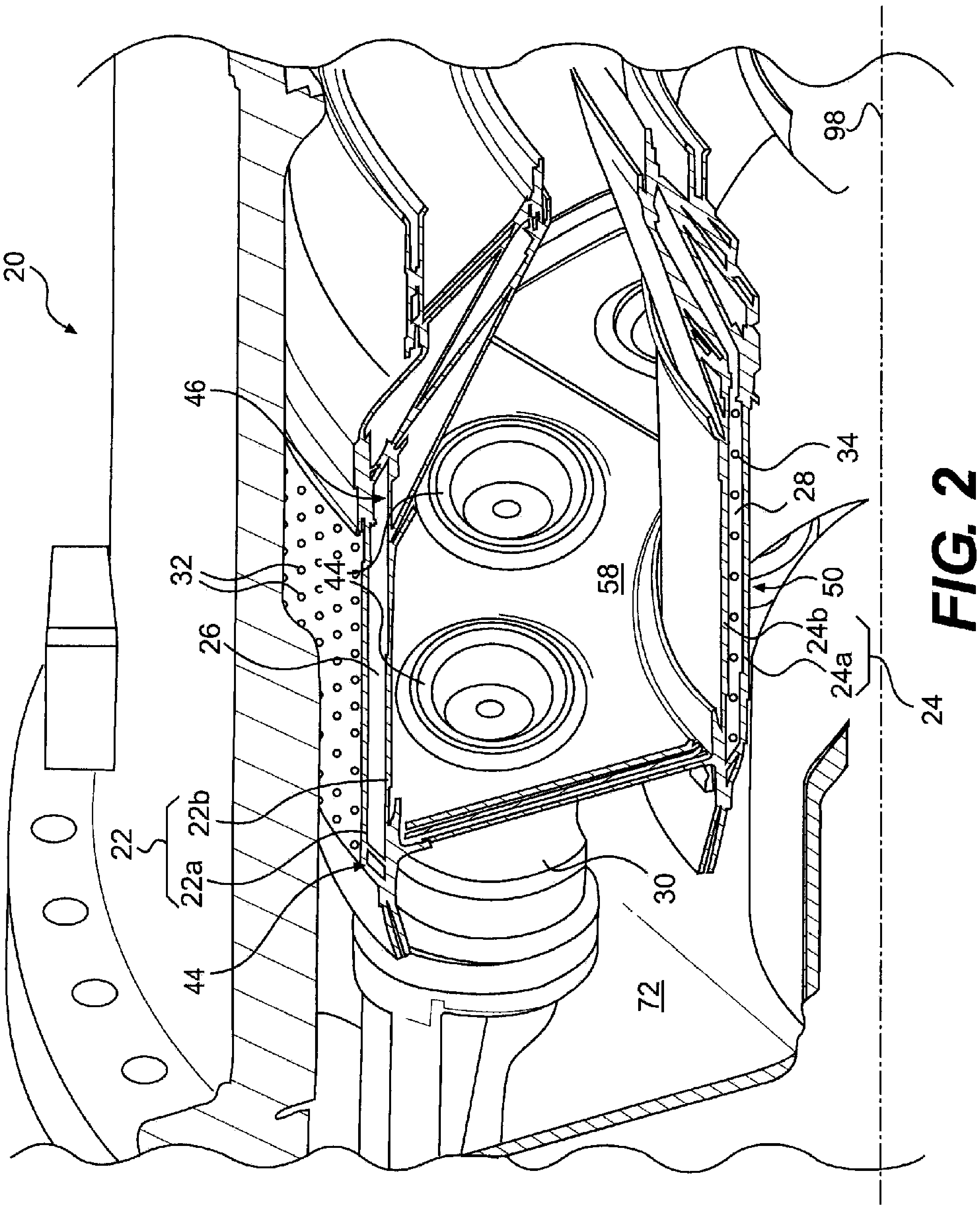


FIG. 2

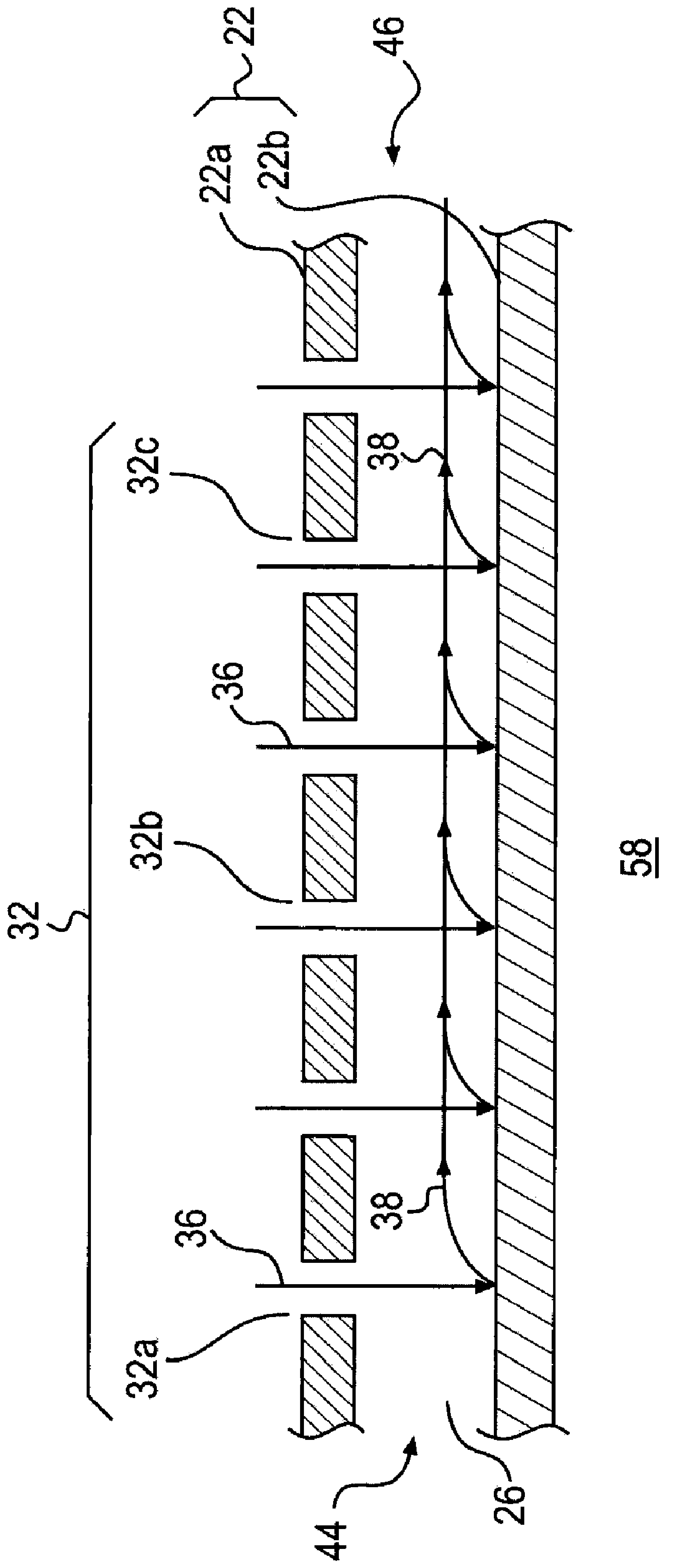


FIG. 3

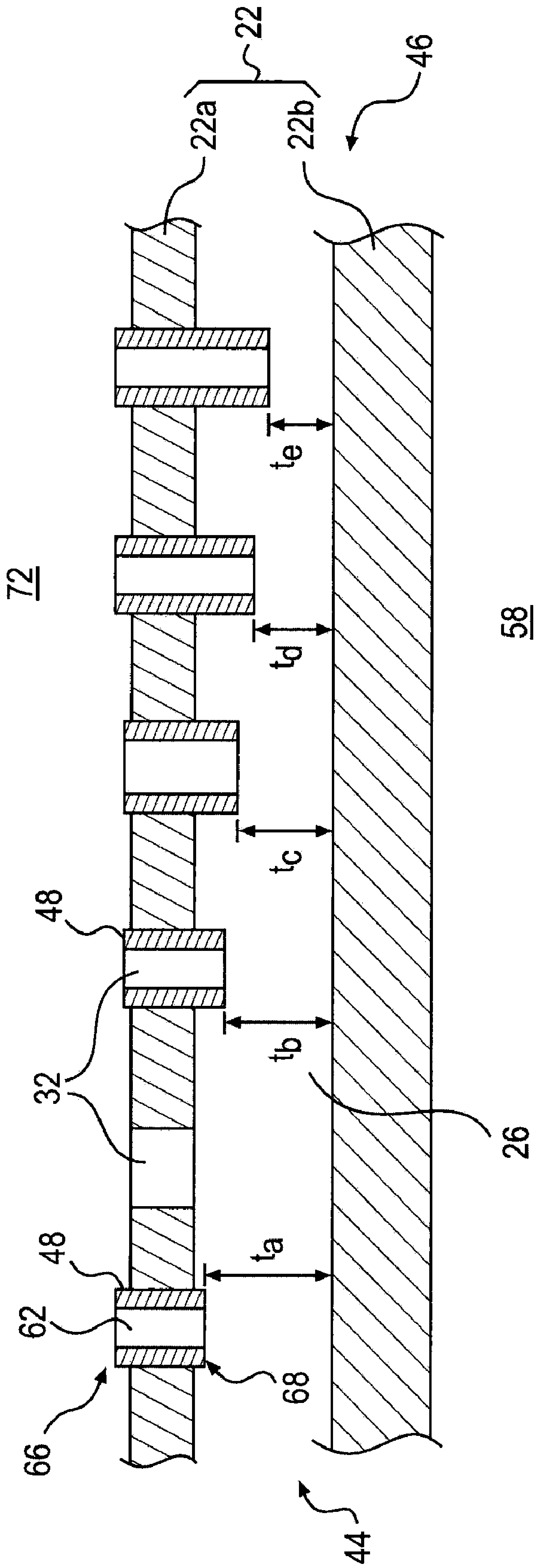


FIG. 4A

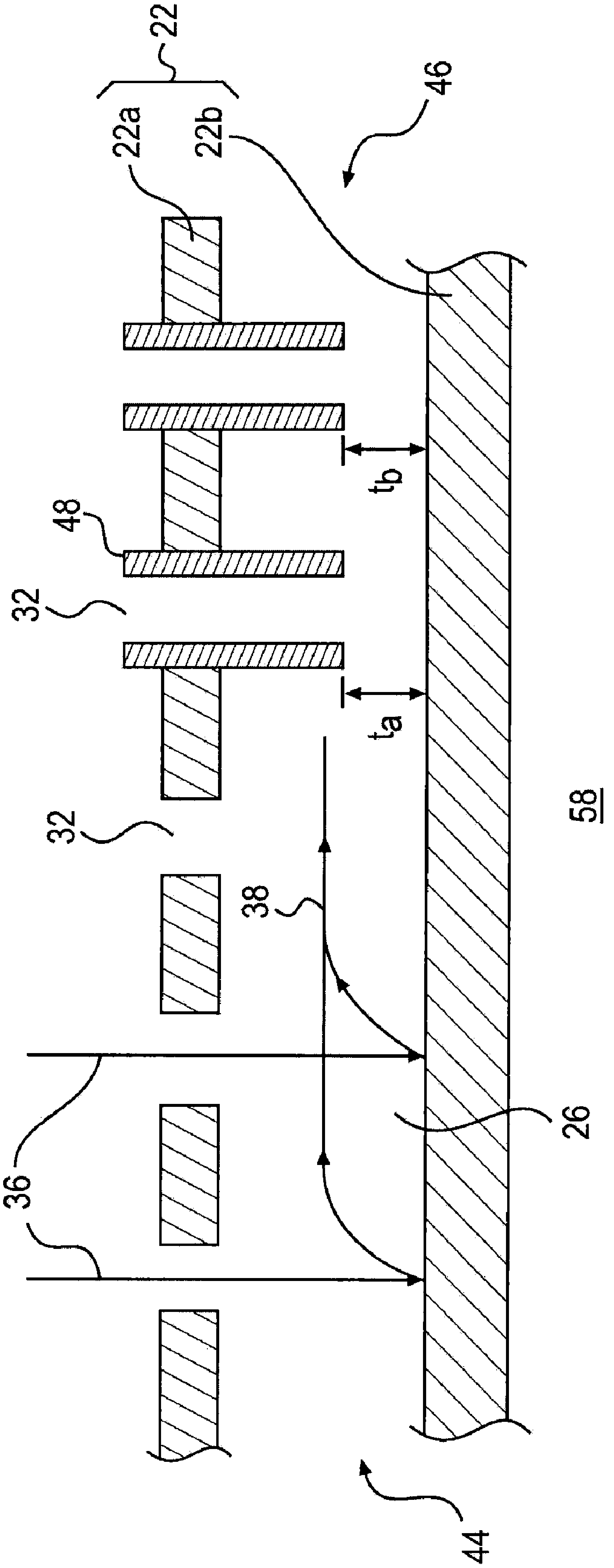


FIG. 4B

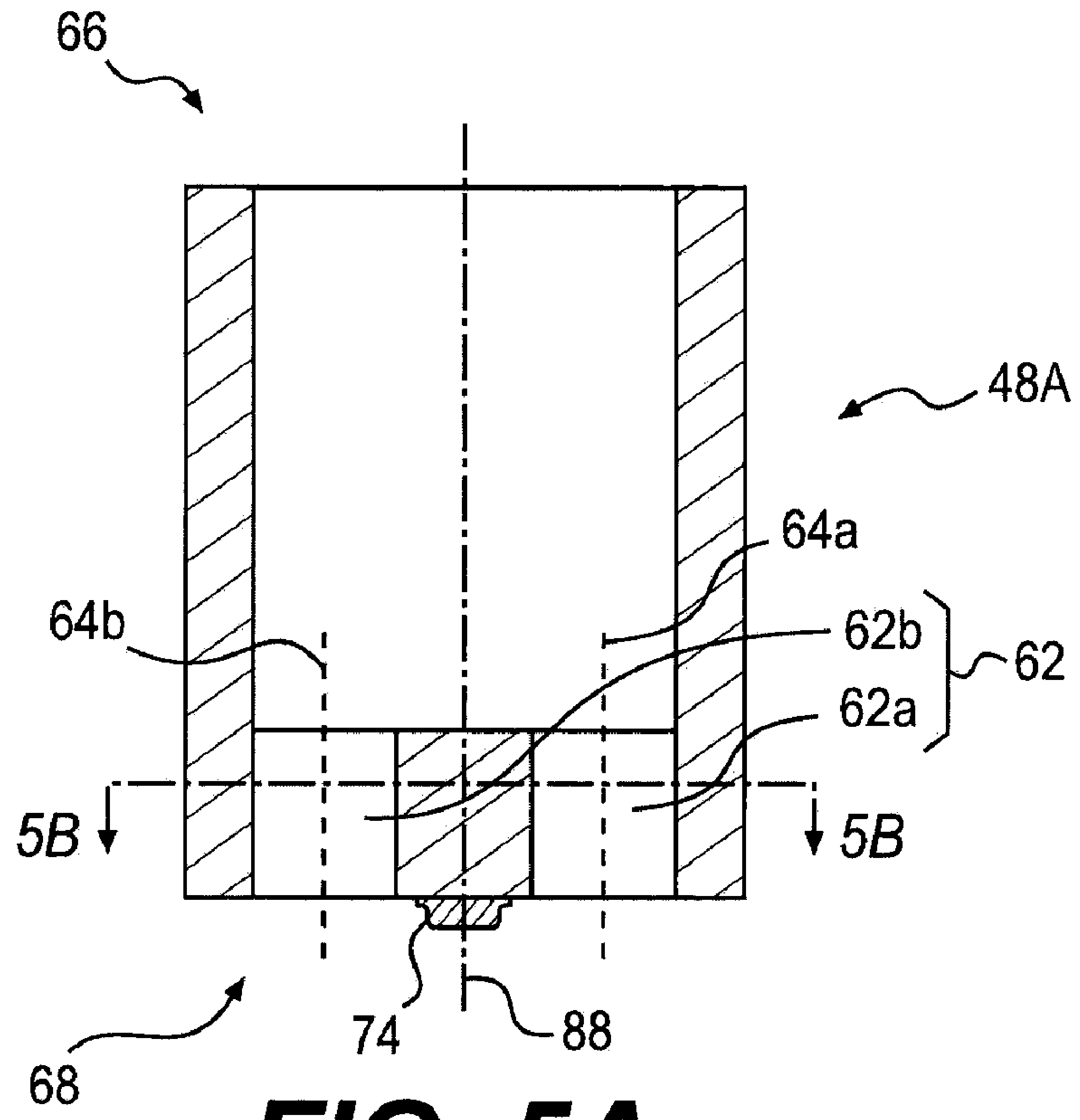

66
48A
64a
64b
62b
62
62a
5B
5B
68
74
88

FIG. 5A

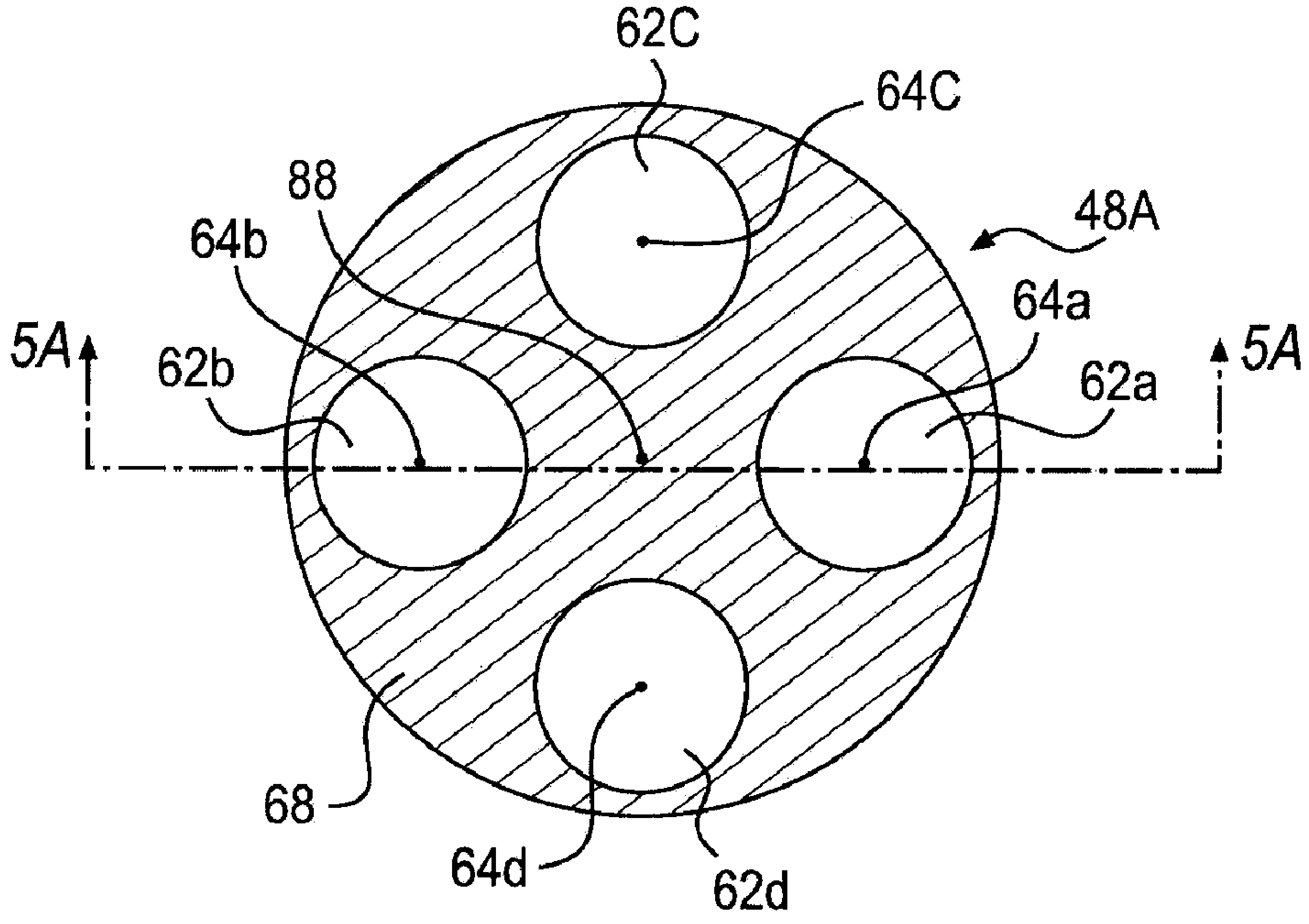

62C
64C
88
48A
64b
64a
5A
5A
62b
62a
68
64d
62d

FIG. 5B

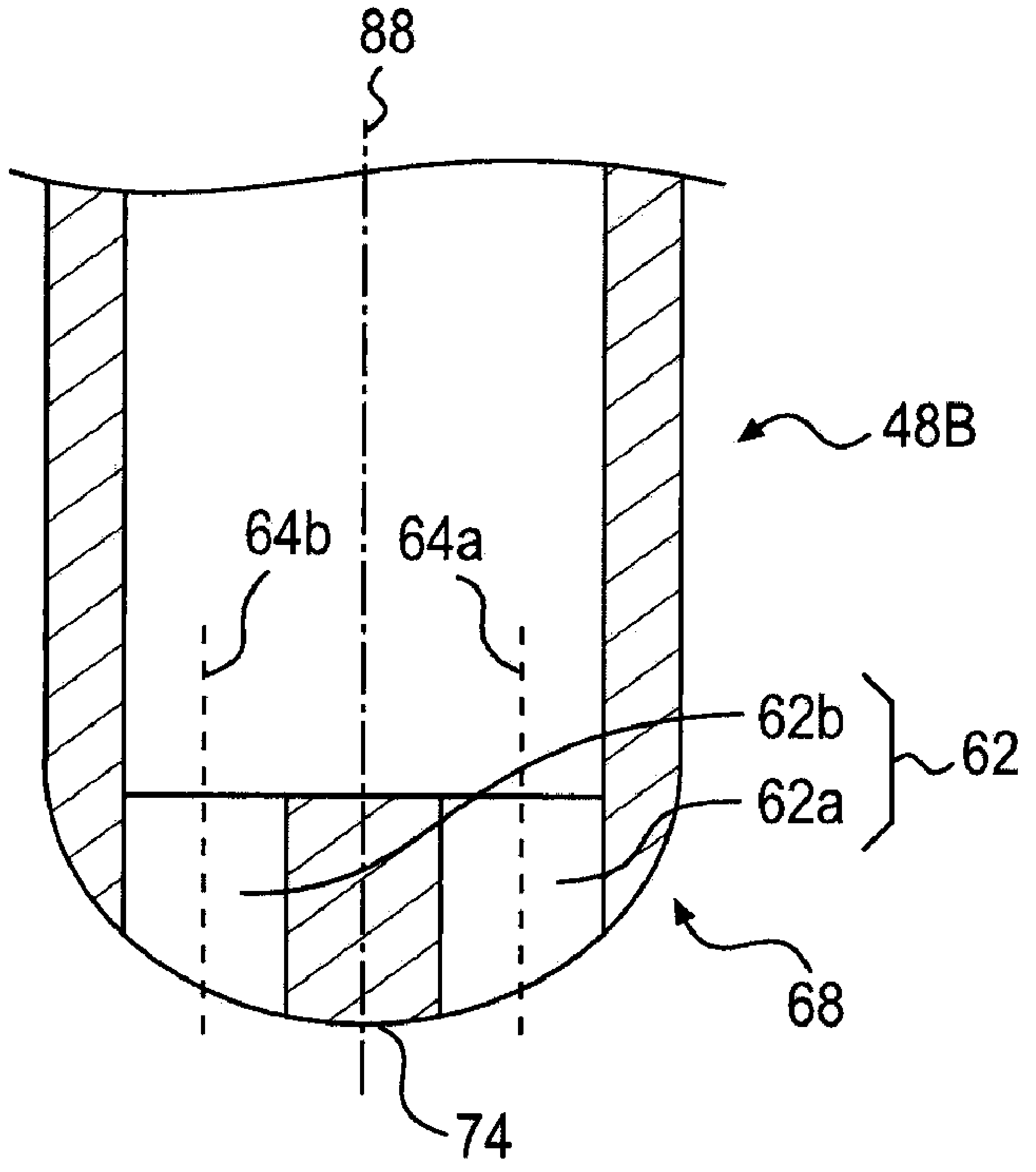

88
48B
64b
64a
62b
62
62a
68
74

FIG. 6

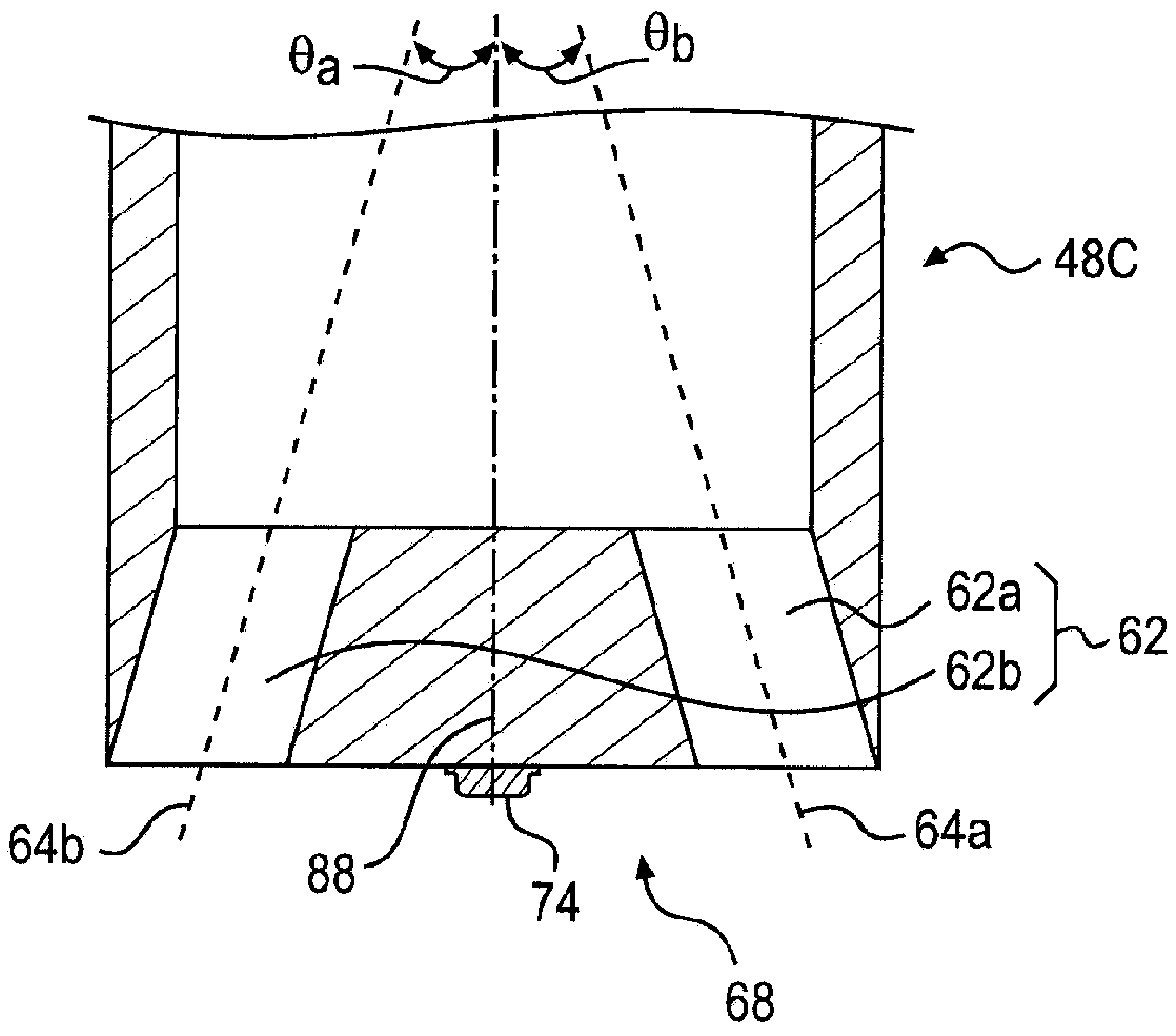

θa
θb
48C
62a
62
62b
64b
88
74
64a
68

FIG. 7

IMPINGEMENT COOLING OF COMBUSTOR LINERS

TECHNICAL FIELD

[0001] The present disclosure relates generally to systems and methods of impingement cooling a combustor liner of a gas turbine engine.

BACKGROUND

[0002] Combustor liners of gas turbine engines are exposed to high temperatures of combustion and therefore require cooling. A type of combustor liner, called a double-walled liner, includes an inner liner that encloses a volume where combustion occurs and an outer liner that surrounds the inner liner. An annular space between the inner liner and the outer liner assists in the cooling of the liner. There are various methods that are employed to cool combustion liners during operation of the engine. These method include film cooling and jet impingement cooling. In film cooling, air in the annular space is directed into the combustor through holes in the inner liner to mix with the hot combustion gases within. The air absorbs the heat from the inner liner as it flows therethrough. In jet impingement cooling, air jets impinge upon and cool the back surface of the inner liner. These air jets may be directed to the back surface of the inner liner through an array of holes on the outer liner. After impinging on the back surface of the inner liner, the spent cooling air flows downstream through the annular space. This spent air flow, called cross-flow, is known to degrade the cooling ability of downstream air jets.

[0003] U.S. Patent Application No. 2008/0271458 to Ekkad et al. (the '458 publication) describes an impingement cooled liner with ports extending from the outer liner to the inner liner to reduce the effects of cross-flow. While the extended ports of the '458 publication may reduce the effects of cross-flow, they may have limitations. For instance, dimensional changes during operation of the turbine engine may force portions of the inner liner against the extended ports preventing air flow therethrough. The systems and methods of the current disclosure are directed to overcoming one or more of the problems set forth above.

SUMMARY

[0004] In one aspect, a gas turbine engine is disclosed. The gas turbine engine may include an impingement cooled double-walled liner, having an inner liner and an outer liner, disposed around a combustion space of the turbine engine. The double-walled liner may extend from an upstream end to a downstream end. The gas turbine engine may also include a plurality of nozzles extending radially inwards through the outer liner to direct cooling air towards the inner liner. Each nozzle of the plurality of nozzles may extend radially inwards from a first distal end to a second proximal end. The plurality of nozzles may be arranged such that a radial gap between the second end of a nozzle and the outer liner decreases from the upstream end to the downstream end. The at least one nozzle of the plurality of nozzles may include multiple air holes at the second end.

[0005] In another aspect, a method of impingement cooling a double-walled combustor liner of a gas turbine engine is disclosed. The double-walled liner may extend from an upstream end to a downstream end and include an inner liner and an outer liner positioned radially outwards the inner liner. The method may include combusting a fuel in a combustor of the gas turbine engine, and directing cooling air through a plurality of nozzles that extend radially inwards through the outer liner to impinge upon and cool the inner liner. The cooling air may be directed such that the cooling air exits the plurality of nozzles closer to the inner liner at the downstream end than at the upstream end. The cooling air directed through at least one nozzle of the plurality of nozzles may exit the at least one nozzle through multiple air flow paths symmetrically arranged about a longitudinal axis of the at least one nozzle.

[0006] In yet another aspect, a gas turbine engine is disclosed. The gas turbine engine may include an impingement cooled double-walled liner. The double-walled liner may include an inner liner and an outer liner disposed around a combustion space of the turbine engine and extend from an upstream end to a downstream end. The gas turbine engine may also include a plurality of nozzles that extend radially inwards through the outer liner to direct cooling air towards the inner liner. Each nozzle of the plurality of nozzles may extend radially inwards from a first distal end to a second proximal end. Each nozzle of the plurality of nozzles may include multiple air holes arranged in a shower head pattern at the second end.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is an illustration of an exemplary disclosed gas turbine engine;

[0008] FIG. **2** is a cut-away illustration of an exemplary combustor system of the gas turbine engine of FIG. **1**;

[0009] FIG. **3** is a cross-sectional view of an embodiment of the outer combustor wall of the gas turbine engine of FIG. **1**;

[0010] FIG. **4**A is a cross-sectional view of another embodiment of the outer combustor wall of the gas turbine engine of FIG. **1**;

[0011] FIG. **4**B is a cross-sectional view of another embodiment of the outer combustor wall of the gas turbine engine of FIG. **1**;

[0012] FIG. **5**A is a cross-sectional view of an embodiment of a nozzle of the gas turbine engine of FIG. **1**;

[0013] FIG. **5**B is another cross-sectional view of the exemplary nozzle of FIG. **5**A;

[0014] FIG. **6** is a cross-sectional view of another embodiment of a nozzle of the gas turbine engine of FIG. **1**; and

[0015] FIG. **7** is a cross-sectional view of another embodiment of a nozzle of the gas turbine engine of FIG. **1**.

DETAILED DESCRIPTION

[0016] FIG. **1** illustrates an exemplary gas turbine engine (GTE) **100** having a compressor system **10**, a combustor system **20**, a turbine system **70**, and an exhaust system **90** arranged lengthwise along an engine axis **98**. The compressor system **10** may compress air and deliver the compressed air to an enclosure **72** of the combustor system **20**. The compressed air may be mixed with a fuel and directed into a combustor **50** through one or more fuel injectors **30**. The fuel-air mixture may ignite and burn in the combustor **50** to produce combustion gases that may be directed to the turbine system **70**. The turbine system **70** may extract energy from these combustion gases, and direct the exhaust gases to the atmosphere through the exhaust system **90**.

[0017] FIG. **2** is a cut-away view of combustor system **20** showing the combustor **50**. Combustor **50** includes an outer combustor wall **22** and an inner combustor wall **24** annularly disposed about the engine axis **98**. The outer and the inner combustor walls (**22**, **24**) are joined together at an upstream end by a dome assembly to define a combustion space **58** therebetween.

[0018] The combustion space **58** is fluidly coupled to turbine system **70** at the downstream end. The plurality of fuel injectors **30**, positioned on the dome assembly, direct the fuel-air mixture to the combustion space **58** for combustion. This fuel-air mixture burns in a combustion zone (proximate the upstream end) of the combustion space **58** to produce high pressure combustion gases that flow downstream towards the turbine system **70**. The combustion of fuel-air mixture within the combustion space **58** heats the outer and the inner combustor walls (**22**, **24**). For increased reliability and performance of GTE **100**, it is desirable to cool these walls. The outer combustor wall **22** includes an inner liner **22***b* and an outer liner **22***a*, and the inner combustor wall **24** includes an inner liner **24***b* and an outer liner **24***a*. The inner liners **22***b*, **24***b* are radially spaced apart from the outer liners **22***a*, **24***a* to define annular cooling spaces **26**, **28** between them. These cooling spaces **26**, **28** extend from an upstream end **44** to a downstream end **46** of the combustor **50**. The combustion in the combustion space **58** may create oscillations of pressure (pressure waves) within the combustion space **58** that causes radial expansion and contraction (bulging) of the inner liners **22***b*, **24***b* with respect to the outer liners **22***a*, **24***a*. The outer liners **22***a*, **24***a* include a plurality perforations **32**, **34** that direct high pressure air from the enclosure **72** to impinge on, and cool, the inner liners **22***b*, **24***b*. This technology of impingement cooling the combustor liners is referred to in the industry as Augmented Backside Cooled (ABC) technology. It is known that the use of ABC technology decreases the emission of pollutants into the atmosphere. It should be noted that the general configuration of combustor system **20** illustrated in FIG. **2** is exemplary only, and that several variations are possible.

[0019] FIG. **3** is a cross-sectional schematic of the outer combustor wall **22** illustrating the impingement cooling of the inner liner **22***b*. A high pressure stream of air ("air jets **36**") enters the cooling space **26** through perforations **32** on the outer liner **22***a*. These air jets **36** impinge on, and cool, the inner liner **22***b*. After impingement, the spent air stream flows towards the downstream end **46** to form the cross-flow air **38** that may be mixed with the combustion gases or discarded. It is known that cross-flow air **38** from the upstream end **44**, interacts with, and degrades the ability of the air jets **36** at the downstream end **46** to impinge on, and cool, the inner liner **22***b*. For instance, the cross-flow air **38** from a first perforation **32***a* may degrade the ability of the air jet **36** from a second perforation **32***b*, downstream of the first perforation **32***a*, to impinge on the region of the inner liner **22***b* under the second perforation **32***b*. Similarly, the cross-flow air **38** from the first and second perforations **32***a*, **32***b* may collectively further degrade the cooling ability of an air jet **36** from a third perforation **32***c*, further downstream of the first perforation **32***a*, to cool the inner liner **22***b* under the third perforation **32***c*. In some embodiments, some (or all) of the perforations **32** may include extended ports or nozzles **48** (see FIGS. **4A-7**) to reduce the impact of the cross-flow air **38** from an upstream perforation **32** on a downstream air jet **36**.

[0020] FIG. **4**A illustrates a cross-sectional view of the outer combustor wall **22** illustrating nozzles **48** attached to the perforations **32**. The nozzles **48** may include air holes **62** that extend from a first end **66**, positioned in the enclosure **72** outside the outer liner **22***a*, to a second end **68** positioned in the cooling space **26** inside the outer liner **22***a*. These air holes **62** may direct the compressed air in the enclosure **72** (air jets **36** of FIG. **3**) to impinge on the inner liner **22***b*. The nozzles **48** may be a separate part attached to the outer liner **22***a* (by any conventional attachment process, such as brazing, etc.) or may be a region of the outer liner **22***a* that is bent towards the inner liner **22***b* (such as for example, the rim of a perforation that is folded towards the inner liner **22***b*). The nozzles **48** may be arranged on the outer liner **22***a* such that a radial gap (t) between the second end **68** of a nozzle **48** and the inner liner **22***b* decreases from the upstream end **44** to the downstream end **46** (that is, $t_a>t_b>t_c>t_d>t_e$). To achieve this decreasing radial gap (t) from the upstream end **44** to the downstream end **46**, in some embodiments (as illustrated in FIG. **4**A), the length of the nozzles **48** may progressively increase from the upstream end **44** to the downstream end **46**. Because the air jets **36** enter the cooling space **26** closer to the inner liner **22***b* at the downstream end **46**, the effect of the cross-flow air **38** from the upstream air jets **36** on the downstream air jets **36** will be lower. In some embodiments, substantially all the rows of perforations on the outer liner **22***a* will include nozzles **48**, while in other embodiments, only selected rows of perforations along the length of the outer liner **22***a* will include nozzles **48**. In some embodiments, the perforations **34** on the inner combustor wall **24** (see FIG. **2**) will also include nozzles **48** so that the air jets **36** enter the cooling space **28** closer to the inner liner **24***b* at the downstream end **46** than at the upstream end **44**.

[0021] Although FIG. **4**A illustrates the radial gap (t) between the nozzles **48** and the inner liner **22***b* as decreasing substantially linearly from the upstream end **44** to the downstream end **46**, this is only exemplary. In general, the radial gap (t) may vary in any manner (such as, for example, decrease exponentially from the upstream end to the downstream end). In some embodiments, although the radial gap (t) may generally decrease from the upstream end **44** to the downstream end **46**, the radial gaps (t) of selected adjacent nozzles **48** may be substantially the same (such as, for example, $t_a \approx t_b>t_c>t_d \approx t_e$).

[0022] In some embodiments, as illustrated in FIG. **4**B, only perforations **32** in selected regions of the outer liner **22***a* may include nozzles **48** to direct the air jets **36** in these regions closer to the inner liner **22***b*. For example, in some embodiments, nozzles **48** may only be included in a few rows of perforations **32** at the downstream end **46** in applications where only the air jets **36** from those few rows are detrimentally affected by the cross-flow air **38** from the upstream end **44**. In some embodiments (as illustrated in FIG. **4**B), the radial gap (t) between these nozzles **48** and the inner liner **22***b* may be substantially the same (that is, $t_a \approx t_b$). Although FIGS. **4**A and **4**B illustrate embodiments, where nozzles **48** are used to decrease the radial gap (t) from the upstream end **44** to the downstream end **46**, it is contemplated that in some embodiments, the radial gap (t) may instead be decreased by decreasing the distance between the inner liner **22***b* and the outer liner **22***a* (that is, the thickness of the cooling space **26**) from the upstream end **44** to the downstream end **46**.

[0023] In some applications, the pressure pulses generated in the combustion space **58** during combustion may cause portions of the inner liner **22***b* to bulge outwards toward the nozzles **48** in corresponding portions of the outer liner **22***a*. Contact between the inner liner **22***b* and a nozzle **48** may restrict, or even block, air flow (air jets **36**) through the nozzle **48**, and result in uneven cooling of the liner. Some embodiments of the nozzles **48** of the current disclosure may be configured to allow the air flow to continue even when they are in contact with the inner liner **22***b*.

[0024] FIGS. **5**A and **5**B are cross-sectional illustrations of an exemplary embodiment of a nozzle **48**A of the current disclosure. FIG. **5**A illustrates a cross-sectional view along a plane parallel to a longitudinal axis **88** of nozzle **48**A, and FIG. **5**B illustrates a cross-sectional view along a plane transverse to the longitudinal axis **88**. In the discussion that follows, reference will be made to both FIGS. **5**A and **5**B. One or more air holes **62** may direct compressed air out of nozzle **48**A at second end **68**. In some embodiments, as illustrated in FIG. **5**A, the one or more air holes **62** may form a shower head pattern of air holes **62** at the second end **68**. In some embodiments, all the air holes **62** may extend from the first end **66** to the second end **68**, while in other embodiments (as illustrated in FIG. **5**A), a single air hole **62** that extends from the first end **66** may be divided into multiple air holes **62** to form a shower head pattern at the second end **68**. The single air hole may be divided into multiple air holes anywhere along the length of nozzle **48**A. In some embodiments, as illustrated in FIG. **5**A, the single air hole may be divided into multiple air holes proximate the second end **68**. In some embodiments, multiple (for example, 2, 3, 4, 5, 6 etc.) air holes **62** may be positioned symmetrically around the longitudinal axis **88** at the second end **68**. If the inner liner **22***b*, **24***b* bulges during operation, the bulging liner may contact a central portion (proximate longitudinal axis **88**) of the second end **68** of a nozzle **48**. And, since the air holes **62** are distributed around the central portion, some or all of the air holes **62** may remain unblocked by the bulging inner liner **22***b*, **24***b*. Even if flow through some of the air holes **62** is restricted (or even blocked) by the contacting inner liner **22***b*, **24***b*, the flow though the remaining air holes **62** may provide sufficient cooling for the inner liner **22***b*, **24***b*. Thus, a shower head pattern of air holes **62** in nozzle **48**A may allow air flow to continue through at least some of the air holes **62** when there is contact between the nozzle **48**A and the inner liner **22***b*, **24***b*.

[0025] In some embodiments, nozzle **48**A may include one or more projections **74** that project outwards from the second end **68**. In some embodiments, at least one of these projections **74** may be located between the outlets of the multiple air holes **62** at the second end **68**. Other projections (if any) may be located anywhere on, or proximate, the second end **68**. For instance, in some embodiments, the projections **74** may be substantially evenly distributed on the second end **68** of the nozzle **48**A. These projections **74** may contact a bulging inner liner **22***b*, **24***b* and act as a standoff to allow air flow through the air holes **62** of the nozzle **48**A. The projections **74** may have any shape and size. For instance, in some embodiments, arc-shaped projections may extend towards the inner liner **22***b*, **24***b* from the periphery of nozzle **48**A. In some embodiments, as illustrated in FIG. **5**A, the projections **74** may have a rounded edge to reduce bearing stresses on the inner liner **22***b*, **24***b* during contact. Although described as a projection, it is contemplated that other features (such as grooves, cutouts, etc.) that allow air from the air holes **62** to exit out of the nozzle **48**A when there is contact between the nozzle **48**A and the inner liner **22***b*, **24***b*, may be provided. In place of, or in addition to, discrete projections **74** on the second end **68**, in some embodiments, the shape of a nozzle **48**A may include a projecting region on the second end **68**. For example, as illustrated in FIG. **6**, the second end **68** of an exemplary nozzle **48**B may have a curved shape with a projecting central region. In these embodiments, the projecting central region may act as the projection **74** that contacts a bulging inner liner **22***b*, **24***b*. In addition to this projecting central region, in some embodiments, additional projections **74** may also be provided on second end **68** of nozzle **48**B.

[0026] In some embodiments (as illustrated in nozzles **48**A and **48**B of FIGS. **5**A-**6**), central axes (**64***a*, **64***b*, **64***c*, **64***d*, etc.) of the multiple air holes **62** may be substantially parallel to the longitudinal axis **88**. However, in other embodiments, the central axis of an air hole **62** may be inclined with respect to the longitudinal axis **88** of the nozzle. FIG. **7** illustrates an embodiment of a nozzle **48**C in with the central axes **64***a*, **64***b* of the air holes **62***a* and **62***b* make angles θ_a and θ_b, respectively, with respect to the longitudinal axis **88**. The angles θ_a and θ_b may have the same or different magnitudes. In these embodiments, a bulging inner liner **22***b*, **24***b* may contact the central portion of the second end **68** and allow air flow through the inclined air holes **62** even in the absence of a projection at the second end **68**. In some embodiments, one or more projections **74** may also be provided at the second end **68** of nozzle **48**C to act as a stand-off. The inclined air holes **62** may also allow the air flowing through them to diverge and impinge on a larger area of the inner liner **22***b*, **24***b*.

[0027] Any type of nozzle (such as, for example nozzles **48**, **48**A, **48**B, **48**C, etc.) may be used in an application. In some applications, a nozzle having one air hole **62** (such as nozzle **48** of FIGS. **4**A and **4**B) may be used in areas where the possibility of contact with the inner liner **22***b*, **24***b* is minimal, and a nozzle having multiple inclined air holes **62** (such as nozzle **48**C of FIG. **7**) may be used where the possibility of contact with the inner liner **22***b*, **24***b* exists. It should be noted that, although contact between a nozzle **48** and the inner liner **22***b*, **24***b* is described as being a result of a pressure wave in the combustor **50** that causes a portion of the inner liner **22***b*, **24***b* to bulge and contact one or more nozzles **48** on the outer liner **22***a*, **24***b*, this is only exemplary. In some applications, vibration of the combustor **50** may cause contact between the inner liner **22***b*, **24***b* and the nozzles **48**. Contact between a nozzle **48** and the inner liner **22***b*, **24***b* can occur for various other reasons, and the disclosed system can be used to provide continuous air flow through the nozzles **48** during contact that occurs for any reason.

INDUSTRIAL APPLICABILITY

[0028] The disclosed systems and methods of impingement cooling a cylinder liner may be applicable to any turbine engine to reliably and effectively cool the cylinder liner. The disclosed system of impingement cooling is configured to prevent the impingement air flow from being blocked as a result of dimensional changes of the combustor liner during operation of the turbine engine. The operation of a gas turbine engine using a disclosed system of impingement cooling will now be explained.

[0029] With reference to FIGS. **1** and **2**, during operation of GTE **100**, air may be drawn into compressor section **10** and compressed. This compressed air may then be directed to enclosure **72** around the combustor **50**. The combustor may enclose a combustion space **58** bounded by a double-walled liner (including inner liners **22***b*, **24***b* and outer liners **22***a*, **24***a*). A portion of the compressed air may be mixed with fuel and combusted in the combustion space **58**. The combustion heats the inner liners **22***b*, **24***b* of the combustor **50**. A portion of the compressed air in the enclosure **72** is directed though the perforations **32**, **34** on the outer liner **22***a,* **24***a* to impinge on, and cool, the hot inner liner **22***b,* **24***b* (FIGS. **3**). To reduce the impact of cross-flow air **38**, from upstream perforations, on the cooling effectiveness of downstream perforations, nozzles **48** are provided on some or all the perforations **32**, **34**. These nozzles **48** deliver the impingement air jets closer to the inner liner **22***b,* **24***b* at the downstream end **46** of the combustor **50** and thereby reduce the effect of the cross-flow air on the cooling effectiveness of the downstream air jets. To reduce the possibility of the air jets being blocked by dimensional variations of the liner walls during operation of the turbine engine (such as bulging of the inner liner **22***b,* **24***b*), the air jets may be provided in a shower head pattern at the tip of the nozzles **48**. A shower head pattern of air jets may allow some of the air jets to continue to impinge on, and cool, the inner liner **22***b,* **24***b* even when a bulging inner liner contacts and blocks some of the air jets.

[0030] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed impingement cooling system and method. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the disclosed cooling system. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

What is claimed is:

1. A gas turbine engine, comprising:

an impingement cooled double-walled liner, including an inner liner and an outer liner, disposed around a combustion space of the turbine engine and extending from an upstream end to a downstream end; and

a plurality of nozzles extending radially inwards through the outer liner to direct cooling air towards the inner liner, each nozzle of the plurality of nozzles extending radially inwards from a first distal end to a second proximal end, the plurality of nozzles being arranged such that a radial gap between the second end of a nozzle and the outer liner decreases from the upstream end to the downstream end,

wherein, at least one nozzle of the plurality of nozzles includes multiple air holes at the second end.

2. The gas turbine engine of claim **1**, wherein the at least one nozzle further includes a longitudinal axis extending from the first end to the second end and each air hole of the multiple air holes includes a central axis, the multiple air holes being symmetrically arranged about the longitudinal axis.

3. The gas turbine engine of claim **2**, wherein the central axis of each air hole is substantially parallel to the longitudinal axis.

4. The gas turbine engine of claim **2**, wherein the central axis of each air hole is inclined with respect to the longitudinal axis such that the cooling air exiting the at least one nozzle diverges.

5. The gas turbine engine of claim **1**, wherein the multiple air holes in the at least nozzle is arranged in a shower head pattern at the second end.

6. The gas turbine engine of claim **1**, wherein the second end of the at least one nozzle includes a projection that extends towards the inner liner.

7. The gas turbine engine of claim **6**, wherein the projection is centrally positioned on the second end and each air hole of the multiple air holes is symmetrically positioned about the projection.

8. The gas turbine engine of claim **1**, wherein the second end of the at least one nozzle is curved such that a central portion of the second end forms a proximal-most portion of the nozzle.

9. The gas turbine engine of claim **1**, wherein the radial gap decreases substantially linearly from the upstream end to the downstream end.

10. A method of impingement cooling a double-walled combustor liner of a gas turbine engine, the double-walled liner extending from an upstream end to a downstream end and including an inner liner and an outer liner positioned radially outwards the inner liner, comprising:

combusting a fuel in a combustor of the gas turbine engine; and

directing cooling air through a plurality of nozzles extending radially inwards through the outer liner to impinge upon and cool the inner liner, such that the cooling air exits the plurality of nozzles closer to the inner liner at the downstream end than at the upstream end, wherein the cooling air directed through at least one nozzle of the plurality of nozzles exit the at least nozzle through multiple air flow paths symmetrically arranged about a longitudinal axis of the at least one nozzle.

11. The method of claim **10**, wherein directing the cooling air includes directing the cooling air through the multiple air flow paths of the at least one nozzle such that the cooling air diverges.

12. The method of claim **10**, wherein directing the cooling air includes directing the cooling air though the multiple air flow paths of the at least nozzle such that the cooling air through each of the multiple air flow paths flow substantially parallel to one another.

13. A gas turbine engine, comprising:

an impingement cooled double-walled liner, including an inner liner and an outer liner, disposed around a combustion space of the turbine engine and extending from an upstream end to a downstream end; and

a plurality of nozzles extending radially inwards through the outer liner to direct cooling air towards the inner liner, each nozzle of the plurality of nozzles extending radially inwards from a first distal end to a second proximal end, wherein each nozzle of the plurality of nozzles include multiple air holes arranged in a shower head pattern at the second end.

14. The gas turbine engine of claim **13**, wherein the plurality of nozzles are arranged such that a radial gap of the second end of a nozzle to the inner liner decreases as a function of distance from the upstream end to the downstream end.

15. The gas turbine engine of claim **13**, wherein the multiple air holes are symmetrically positioned about a longitudinal axis of each nozzle.

16. The gas turbine engine of claim **15**, wherein each air hole of the multiple air holes are inclined with respect to the longitudinal axis such that the cooling air exiting each nozzle diverges.

17. The gas turbine engine of claim **16**, wherein an inclination of each air hole of the multiple air holes with respect to the longitudinal axis is substantially the same.

18. The gas turbine engine of claim **13**, wherein the second end of each nozzle includes a projection that extends towards the inner liner.

19. The gas turbine engine of claim **18**, wherein the multiple air holes are symmetrically arranged about the projection.

20. The gas turbine engine of claim **13**, wherein the second end of each nozzle is curved such that a central portion of the second end forms a proximal-most portion of the nozzle.

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