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[54] **FLUIDIC SEAL FOR SEGMENTED NOZZLE DIAPHRAGM**

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[52] **U.S. Cl.** **415/189,** 415/191, 415/217, 277/199

[51] **Int. Cl.** **F01d 1/02,** F01d 9/00, F16j 9/16

[58] **Field of Search**......................415/189, 190, 191, 415/216, 217, 172; 277/199

[56] **References Cited**

UNITED STATES PATENTS

3,112,915	12/1963	Morris	416/500
3,241,493	3/1966	Frey	415/191
3,393,894	7/1968	Redsell	415/217
3,266,771	8/1966	Morley	415/190
1,061,675	5/1913	Junggren	415/189
3,591,125	7/1971	Lewis	277/199

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[57] **ABSTRACT**

In a gas turbine engine, fluidic sealing is provided between the segments of a nozzle diaphragm in a manner that enables both the individual nozzle segments and the seal members to be brought together for joinder from directions that are generally radial in respect to the nozzle axis, thereby permitting assembly in areas where axial movement of the component parts is limited. The invention herein described was made in the course of or under a contract or subcontract thereunder (or grant) with the Department of the Army.

8 Claims, 9 Drawing Figures

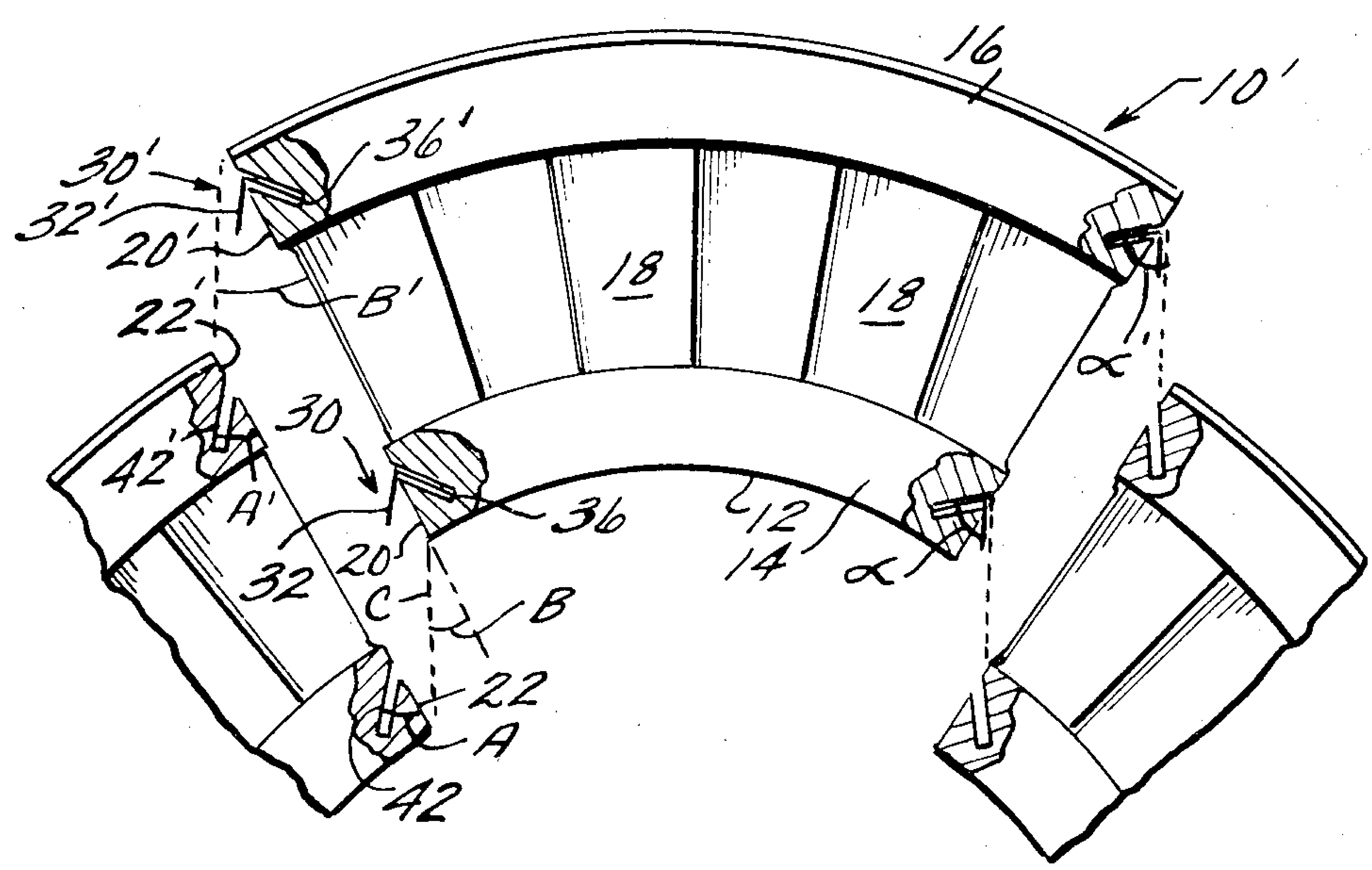
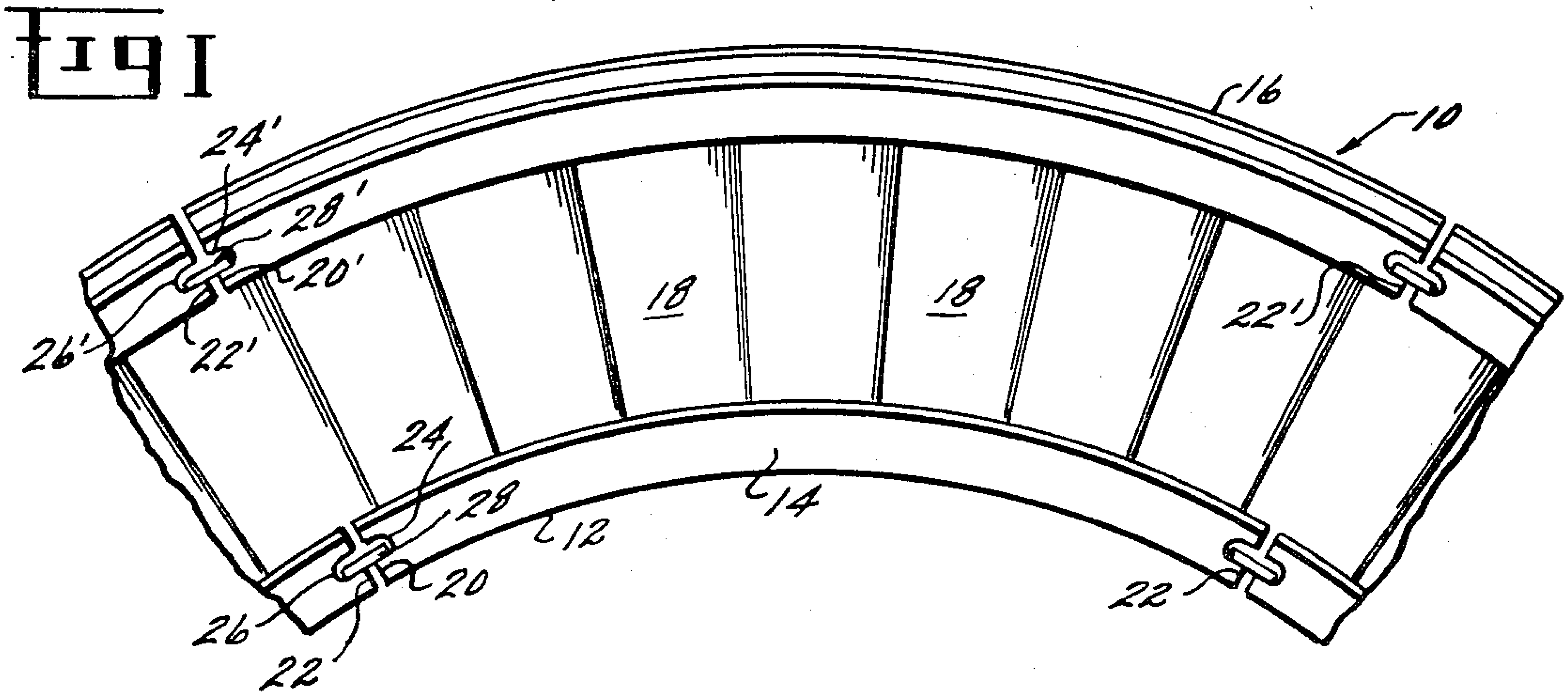


FIG 1



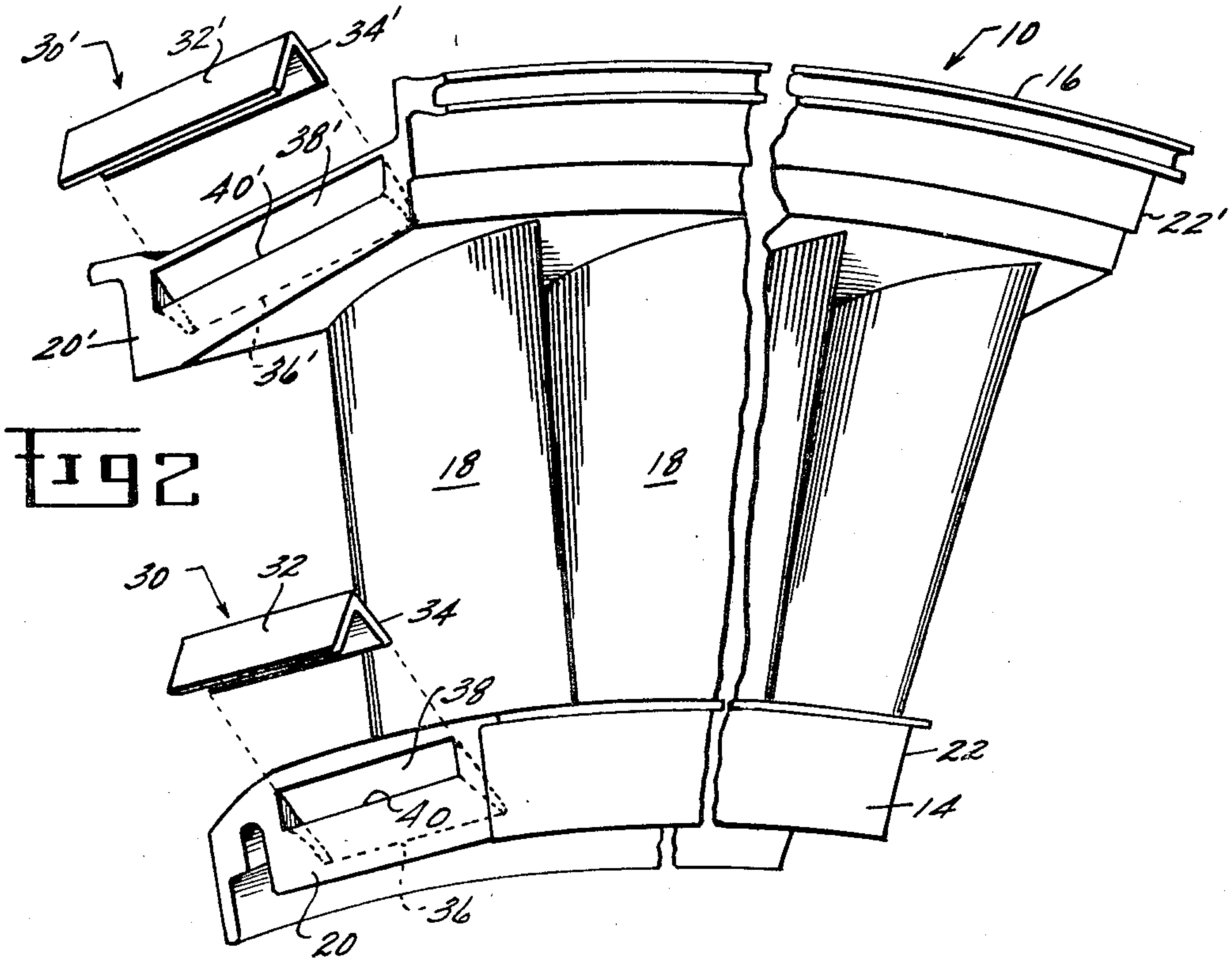


FIG 2

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Fig 3

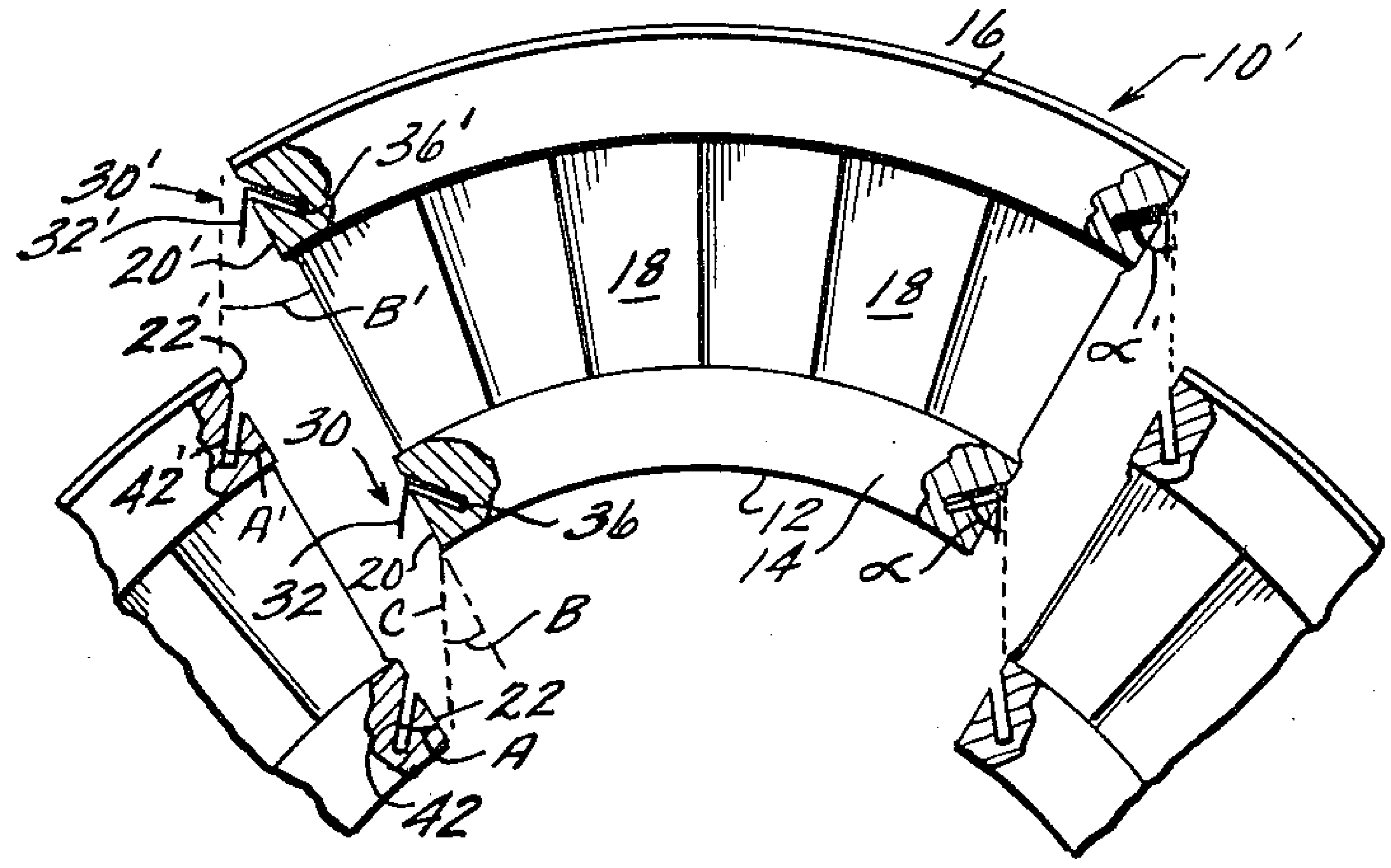

Fig 4

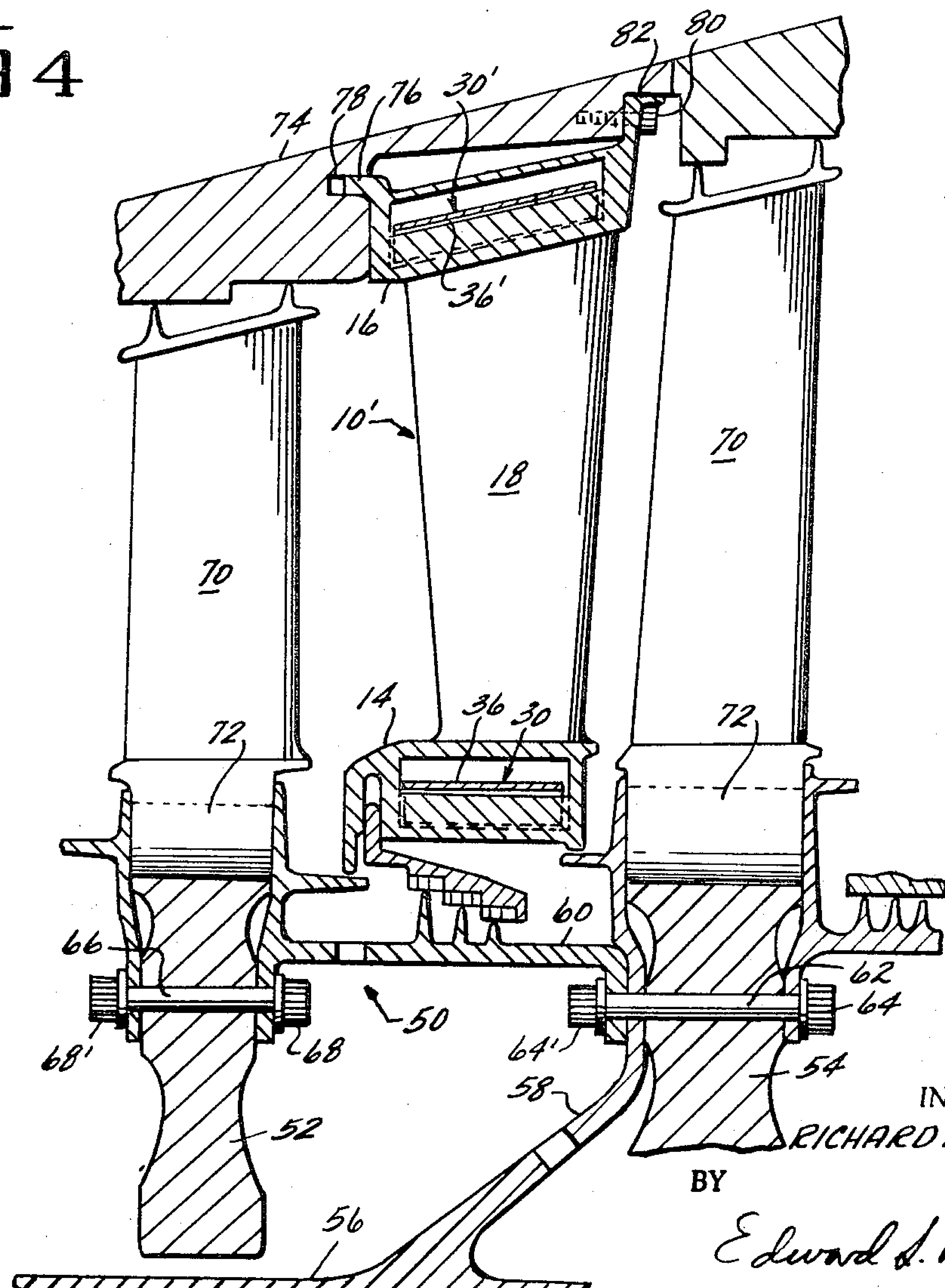

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FIG 5

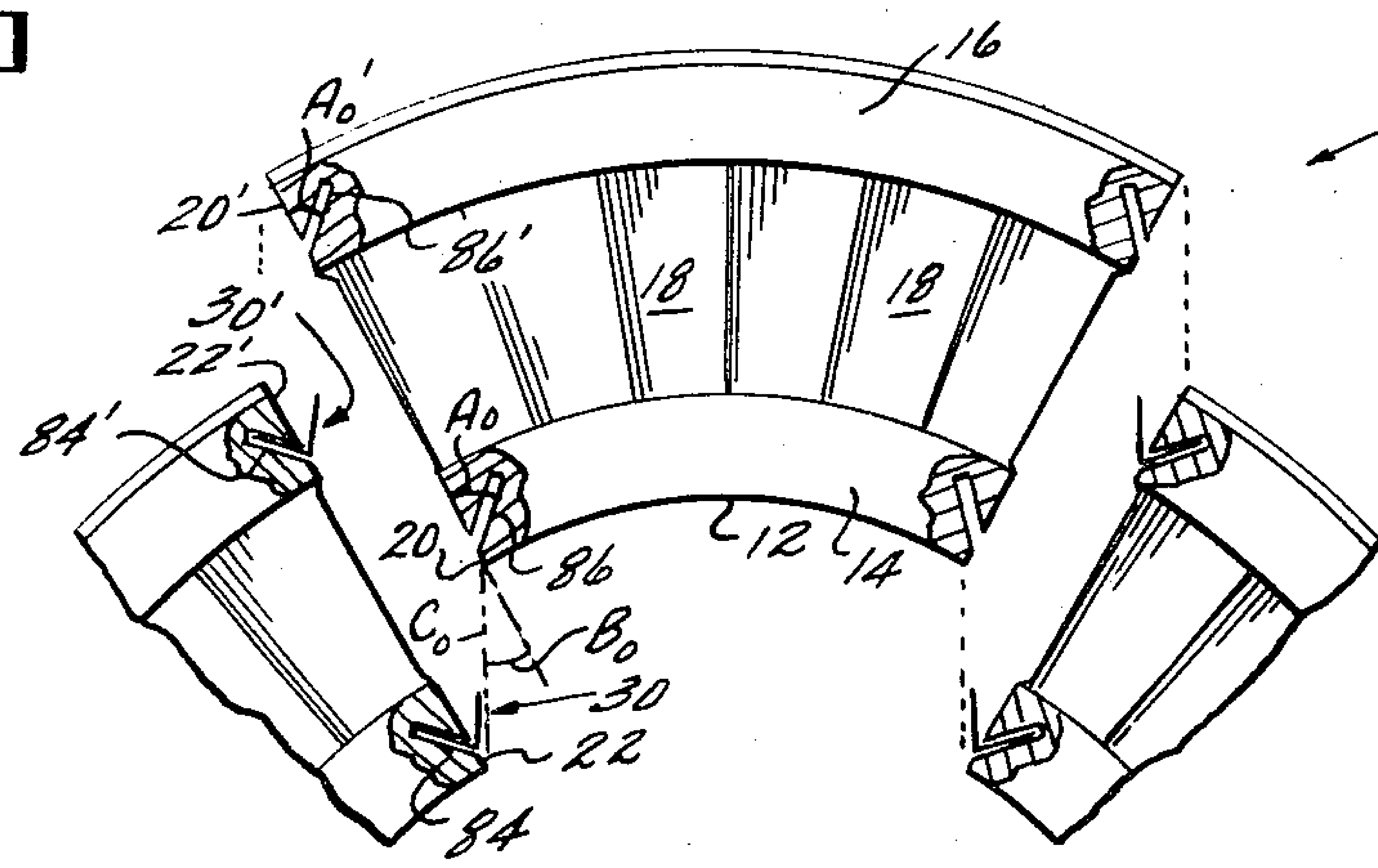


FIG 6a

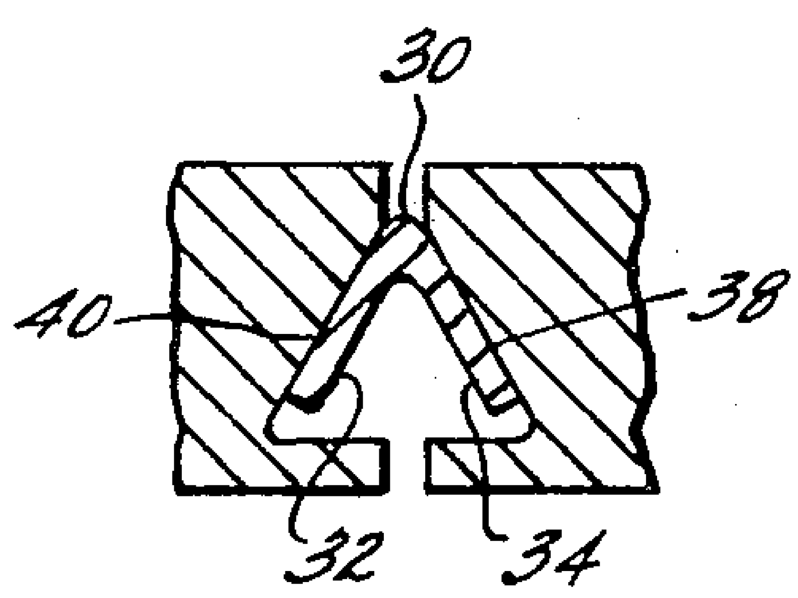


FIG 6b

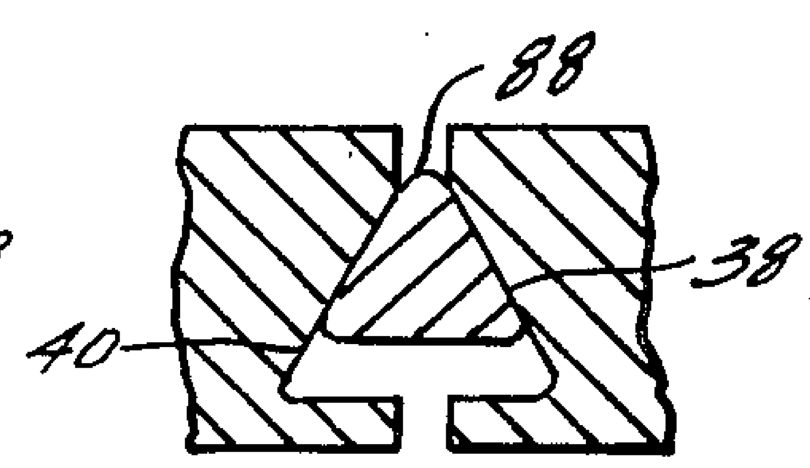


FIG 6c

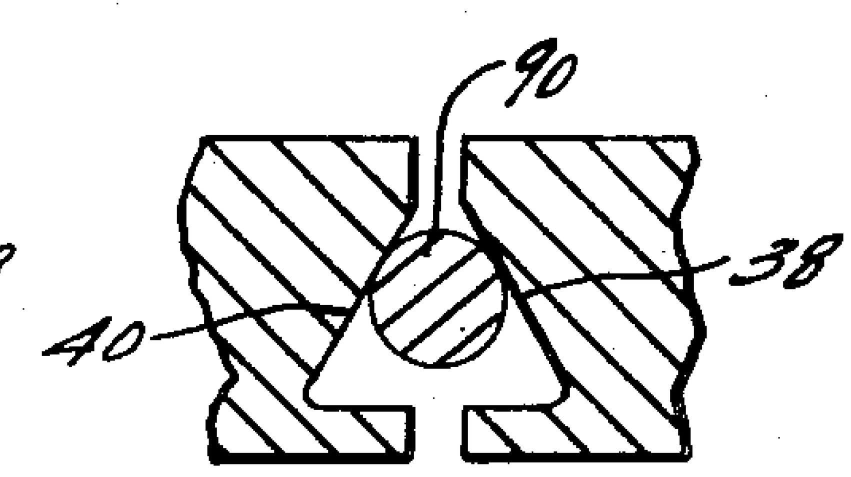
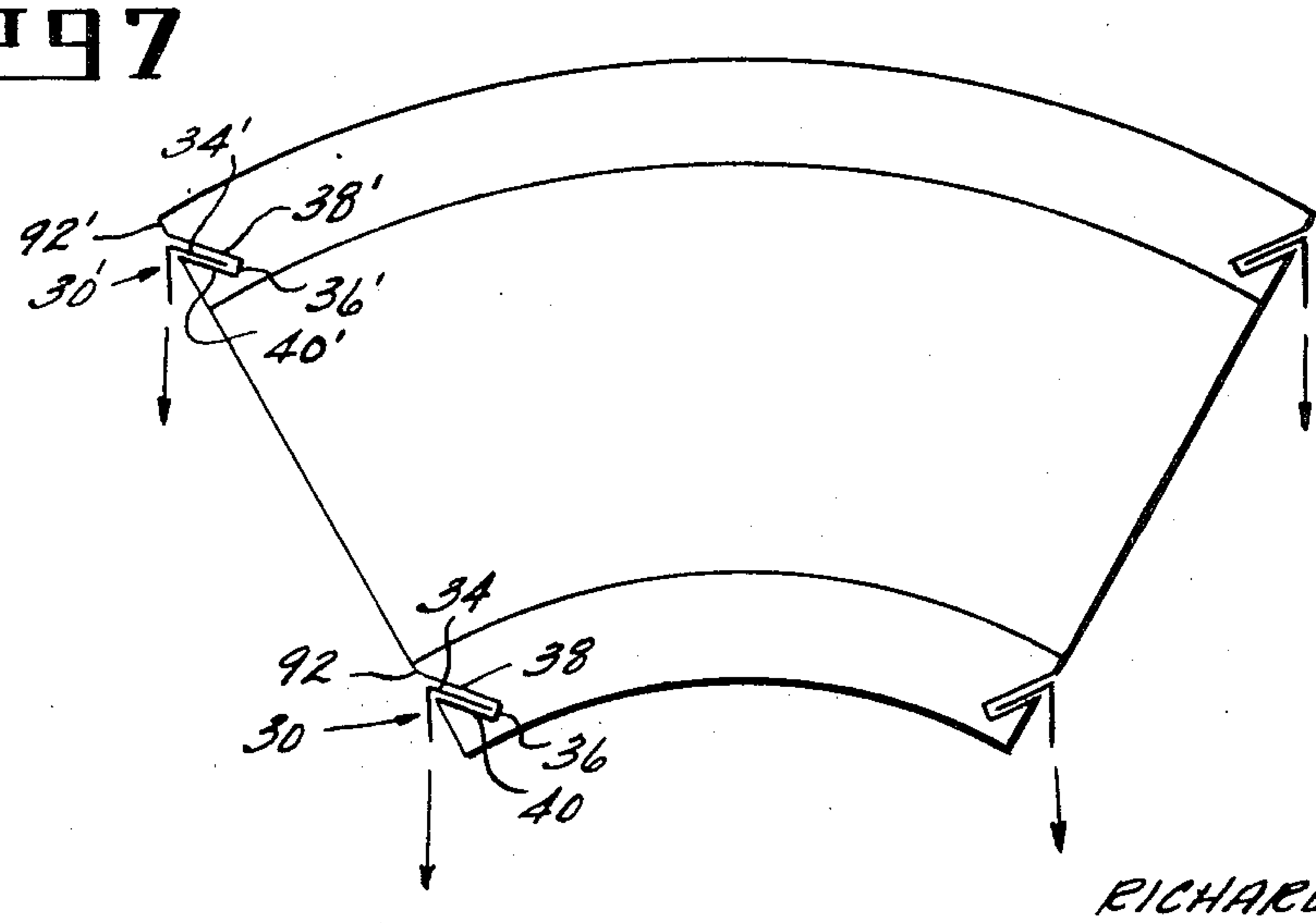


FIG 7



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FLUIDIC SEAL FOR SEGMENTED NOZZLE DIAPHRAGM

BACKGROUND OF THE INVENTION

In general, this invention relates to a fluidic seal for a segmented nozzle diaphragm and more particularly to a fluidic seal for a segmented nozzle diaphragm wherein the seal members and nozzle segments are adapted for assembly in an axially constrained space where only near radial movement of the individual nozzle components is possible.

Nozzle diaphragms of the type including a plurality of circumferentially spaced airfoil partitions extending in generally radial directions from an inner annular band to an outer annular band form an integral part of a gas turbine engine, and are well known to the turbine art. Such nozzle diaphragms are often formed of a plurality of arcuate nozzle segments circumferentially joined together to form a nozzle diaphragm annulus. It is desirable to provide fluidic sealing means between the nozzle segment interfaces so as to confine the motive fluid to the area of the nozzle flow path. Conventional sealing means are provided by axially extending straight slots at the interface between adjacent nozzle segments wherein straight sealing splines are axially inserted into the slots after the nozzle segments have been assembled into a completed nozzle annulus.

Difficulties with conventional sealing means arise when nozzle diaphragms are included intermediate two stages of a multiple stage turbine. Turbine assemblies often include two or more axially spaced and axially connected turbine wheels which are critically balanced during and after assembly. The segmented nozzle diaphragm must be disposed intermediate two turbine wheels; however, the interfering structure of the turbine wheels restricts axial movement during assembly of the nozzle annulus. Therefore, all the individual arcuate nozzle segments must converge together for assembly intermediate the turbine wheels from generally radial directions. Conventional sealing means then must be axially inserted after the nozzle segments have been assembled into a completed nozzle annulus. However, the interfering structure of the dual stage turbine prevents the axial insertion of seal splines. Alternatively, if the segmented nozzle diaphragm together with interface seals is preassembled apart from the turbine in a manner well known to the art, the interfering structure of the turbine would again prevent axial insertion of the preassembled nozzle diaphragm. Also, dual stage turbines cannot be disassembled to permit axial insertion of either the seal splines or of the preassembled nozzle diaphragm without disturbing the critical nature of the turbine balance.

Therefore, it is an object of this invention to provide a sealing arrangement between the interfaces of a segmented nozzle diaphragm wherein the sealing members and nozzle segments may be assembled in an area where axial movement of the component parts is severely limited.

It is also an object of this invention to provide a sealing arrangement between the interfaces of a segmented nozzle diaphragm wherein the sealing members and nozzle segments are assembled by insertion from generally radial directions.

It is another object of this invention to provide a sealing arrangement between the interfaces of a segmented nozzle diaphragm which is disposed intermediate the axially spaced turbine wheels of a preassembled multistage turbine.

It is a further object of this invention to provide a sealing arrangement between the interfaces of a segmented nozzle diaphragm which permits individual nozzle segment removal and replacement without rotor disassembly for ease of serviceability.

SUMMARY OF THE INVENTION

A segmented nozzle diaphragm having inner and outer annular bands with a plurality of circumferentially spaced partitions disposed therebetween includes a fluidic seal arrangement between adjacent nozzle segments. The fluidic seal arrangement comprises at least one pair of cavities extending in opposing directions into adjacent nozzle segments from the segment interface. In one embodiment of this invention each cavity includes a wall which is inclined to the segment interface and parallel to the plane of insertion for an adjacent nozzle segment. In another embodiment of the invention each cavity includes a wall which is inclined to the segment interface and parallel to the plane of insertion of that nozzle segment. For either embodiments, a seal member must be disposed within the opposing cavities for sealing engagement with the inclined walls of the opposing cavities. The inclined nature of the cavity walls allows unobstructed insertion and withdrawal of the nozzle segments and seal members in nominally radial directions to the nozzle diaphragm axis.

DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims distinctly claiming and particularly pointing out the invention described herein, it is believed that the invention will be more readily understood by reference to the discussion below and the accompanying drawings in which:

FIG. **1** is a front view showing a portion of a segmented nozzle diaphragm having conventional fluidic seals between the nozzle segments.

FIG. **2** is a fragmented pictorial view showing a nozzle segment including the fluidic seal arrangement of this invention.

FIG. **3** is a front view showing a portion of a segmented nozzle diaphragm having the fluidic seals of FIG. **2** between the nozzle segments.

FIG. **4** is a cross-sectional view of a dual stage turbine and segmented nozzle diaphragm having the fluidic seals of FIG. **2** between the nozzle segments.

FIG. **5** is a front view showing a portion of a segmented nozzle diaphragm having an alternate embodiment of the invention of FIG. **2**.

FIG. **6** *a*, *b*, and *c* are cross-sectional views of three alternate embodiments of the invention of FIG. **2**.

FIG. **7** is a front view showing one segment of a nozzle diaphragm including another alternate embodiment of the invention of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, there is shown at **10** a portion of a conventional nozzle diaphragm of the type suitable for incorporation within a gas turbine engine. The conventional segmented nozzle diaphragm **10** includes a plurality of individual arcuate nozzle segments **12** which are circumferentially arranged to form an annular ring, a portion of which is shown in the drawing. Each nozzle segment includes an inner band **14** and an outer band **16** which, when arranged adjacent the bands of other nozzle segments to form a completed nozzle diaphragm, compositely define inner and outer annular bands respectively. Circumferentially spaced partitions **18**, which typically approximate the shape of an airfoil, are disposed between bands **14** and **16**. The partitions **18** extend in generally radial directions and are fixedly attached to the bands **14** and **16**. The opposing ends of the bands **14** and **16** of each nozzle segment terminate in what are generally radial end faces shown at **20, 20′, 22** and **22′**. Fluidic sealing between adjacent end faces **20, 22** and **20′, 22′** is accomplished by means of opposing slots **24, 26** and **24′, 26′** respectively, wherein each pair of opposing slots extends from adjacent end faces into the bands in directions which are generally tangential to the circumference of the nozzle. Linear sealing splines **28, 28′** are axially inserted within opposing slots to provide the fluidic seal between the adjacent nozzle segments.

Often, however, a nozzle diaphragm must be disposed between two stages of a pre-assembled turbine in which case both axial insertion of linear sealing splines between radially inserted nozzle segments and axial insertion of a pre-assembled and sealed nozzle diaphragm would be prohibited by the interfering nature of the rotor structure. Disassembly of the rotor does not provide a practical solution due to the likelihood of disturbing the critical rotor balance.

Referring now to FIGS. **2** and **3** where like numerals refer to previously described elements, there is shown a novel scheme by which fluidic seal members may be provided between nozzle segments which are inserted from nominally radial directions. Nominally radial includes any direction of insertion for a nozzle segment wherein the predominant directional component is radial, although moderate axial and circumferential directional components may also be included. Referring particularly to FIG. **2**, inner and outer fluidic seal members are shown generally at **30** and **30′** respectively. Each seal member is formed by two intersecting generally planar elements, **32, 34** and **32′, 34′**, the perimeters of which may be configured as rectilinear although other irregular perimeters would be equally suited. Seal member receiving slots shown generally at **36, 36′** extend into the respective bands from the end faces **20, 20′** and are inclined so as to intersect the end faces at radially outward directed vertices. The slots are generally defined by two spaced apart sidewalls **38, 40** and **38′, 40′** wherein sidewalls **38, 38′** being closest to the midplane of the nozzle segment are designated as the inner sidewalls and sidewalls **40, 40′** being furthest from the midplane are designated as the outer sidewalls.

Referring now to FIG. **3** in conjunction with FIG. **2**, there is shown a portion of the nozzle diaphragm **10′** of the invention immediately prior to insertion of the nozzle segment **12** therein. The inner and outer bands of the waiting nozzle segments also include seal member receiving slots **42, 42′** extending from the end faces **22, 22′** respectively, and inclined to intersect the end faces at radially outward directed vertices. The seal elements are initially retained by the entering nozzle segment and inserted within the respective slots of the waiting assembly.

The lines of intersection formed by the dihedral walls of the slots and seal elements need not parallel the nozzle axis and may be skewed in relation thereto. Therefore, in order for the seals to engage the slots of adjacent segments without interference, any section orthogonal to the nozzle axis and through the dihedral angle formed by the intersection of the planes of the outer side walls of opposing slots must intersect an angle α equal to 360° divided by the total number of nozzle segments, assuming all nozzle segments to be of equal arc length. Also, the angle intersected by a section orthogonal to the nozzle axis and through the dihedral angle formed by the intersection of the seal elements **32, 34** must also conform to the previously described limitation in order to provide for unobstructed nominally radial insertion of the nozzle segments. For the more general situation where the nozzle segments may not be of equal arc length, or where the end faces of the bands **14, 16** may extend in non-radial directions, the essential requirement is illustrated by the following example. The inner walls of the slots **42, 42′** are inclined to the segment end faces **22, 22′** at angles A, A′ which are equal to or greater than the angles B, B′. Angles B, B′ are defined by the intersection of the plane of insertion C of the adjacent nozzle segments **10′** with the end faces **20, 20′** of that segment. Also the slots must be of sufficient clearance to permit radial translation of the seals as thermal growth alters the gap between adjacent end faces so as not to distort the shape and dihedral angle of the fluidic seals.

The inherent limitations of a conventional nozzle sealing means when compared with the novel seal arrangement of this invention may be further appreciated by reference to FIG. **4** where the seal and nozzle of this invention are shown as typically applied to the turbine of a gas turbine engine. A dual stage pre-assembled and pre-balanced turbine assembly is shown generally at **50**, wherein the turbine assembly includes two axially spaced rotor discs **52** and **54**. Rotor disc **54** is maintained for rotation with a center shaft **56** by attachment to a frusto-conical flange **58** extending from the shaft and formed integral therewith. Rotor disc **52** is maintained for rotation with the disc **54** by means of an axially extending circumferential flange **60**. Flange members **58** and **60** are attached to rotor disc **54** by means of elongated studs **62** extending through the flanges and disc, and threadably engaged at opposing ends by lock nuts **64, 64′**. Rotor disc **52** is attached to the other end of flange **60** by means of elongated studs **66** extending through the flange and disc and threadably engaged at opposing ends by lock nuts **68, 68′**. The rotor discs **52, 54** each include a plurality of air foil type blades **70** circumferentially spaced about the perimeter. Each blade **70** includes an inner root portion **72** for engagement with the respective rotor disc. A portion of a casing is shown generally at **74** and remains stationary with respect to rotation of the rotor assembly and shaft. A nozzle assembly **10′** is shown disposed between the dual stages of the turbine assembly and remains fixedly attached in relation to the housing. Attachment of the nozzle assembly **10'** to the housing **74** is accomplished by a circumferential flange **76** which axially extends from the outer band **16** of the nozzle diaphragm into engagement with an opposing slot **78** in the casing. The nozzle diaphragm is further secured to the casing by means of a plurality of circumferentially spaced bolts **80** passing through a radially extending flange **82** and threadably engaging the casing **74**. A stream of motive fluid as may be supplied from the gas generator (not shown) of a gas turbine engine impinges on the rotor blades of the turbine imparting rotational motion thereto. The nozzle diaphragm remains stationary with respect to the turbines in order that the partitions of the nozzle may circumferentially deflect the fluid stream into more efficient impingement on the second stage turbine rotor blades. The broken away portion of the shaft may extend forward to drive a compressor (not shown) which supplies compressed air to the gas generator of the gas turbine engine. The turbine and nozzle assembly so far described is conventional.

The dual turbine assembly **50** is assembled and installed on the shaft **56** whereupon the entire assembly is balanced. The individual nozzle segments must be inserted from nominally radial directions in order to assemble the nozzle diaphragm intermediate the dual turbine stages. As may be readily observed from the drawings, once the nozzle segments have been inserted, the interfering structure of the turbine stages no longer allows axial insertion of conventional type fluidic seals between adjacent segments. As previously mentioned, the turbine stages cannot be disassembled without disturbing the critical nature of the turbine balance. Therefore, the advantage of being able to insert fluidic seals in a nominally radial direction becomes readily apparent. In addition, radial insertion also allows independent removal and replacement of individual segments without disturbing other elements, thereby facilitating substantial ease of maintenance.

During turbine operation, the inner fluidic seal **30**, as shown in FIG. **4**, would be forced by an inwardly directed pressure differential into seating engagement with the outer sidewalls of the slots **36, 42** so as to provide an effective sealing interface. The outer fluidic seal **30'** would be forced by an outwardly directed pressure differential into seating engagement with the inner sidewalls of the slots **36', 42'** also providing an effective sealing interface. However, it is to be understood that the direction of pressure differential is arbitrary and may be reversed depending on the nozzle diaphragm mounting arrangement and other cooling considerations, in which case the seal would still perform equally satisfactorily. Any potential leakage around the seals is further reduced by the labyrinth effect of the serpentine leakage paths around the seals. The inclination of the sidewalls of the slot and seal in relation to the direction of fluid pressure produces an effect similar to that of an inclined plane, thereby increasing the unit loading and seal effectiveness. The fluidic seals of this invention may be applicable to any turbine segment size of less than 180°. However, practical mechanical size limitations likely limit the smallest segments to sizes greater than 20°. As becomes immediately obvious, segments of 180° would have straight seals similar to conventional sealing splines although fully capable of nominally radial insertion.

An inverted arrangement for the seals of FIGS. **2** through **4** is shown in FIG. **5** where like numerals refer to previously described elements. The seals are identical with those described above with only the spacial orientation being inverted such that the seal elements are inclined to intercept at radially inward directed vertices. Seal receiving slots **84, 84', 86, 86'** extend into the respective bands at inclined angles to the end faces so as to also intercept at radially inward directed vertices. The seal elements are initially retained by the waiting assembly and inserted within the respective slots of the entering nozzle segment. The essential requirement regardless of whether the nozzle segments are of equal arc length or whether the end faces of the bands **14, 16** extend in radial directions is that the inner walls of the slots from each nozzle segment interface must be inclined to the segment interface at angles A*o*, A*o'* which are equal to or greater than the angles B*o*, B*o'* of intersection of the plane of insertion C_o for that particular nozzle segment with that interface.

Referring now to FIG. *6a* there is shown an alternate embodiment for the sealing arrangement of this invention wherein the outer sidewalls of the slots have been removed leaving a triangular seal cavity. It is preferred that the outer sidewalls not be removed for sealing arrangements where the inner sidewall is inclined at an angle of greater than 30° to the end face. Removal of the outer sidewalls permits use of a triangular cross-sectional seal **88** as shown in FIG. *6b* or even a circular cross-sectional seal **90** as shown in FIG. *6c*. Seals of this type are more difficult to retain in position during insertion of the nozzle segment.

FIG. **7** shows a nozzle segment having non-radial faces **92, 92'** wherein the slots of each nozzle segment must be aligned parallel to the plane of insertion for the adjacent nozzle segment. Having above described preferred embodiments of the invention, though not exhaustive of all possible equivalents, what is desired to be secured by Letters Patent is distinctly claimed and particularly pointed out in the claims appearing below.

What is claimed is:

1. In a radially segmented cylindrical flow confining apparatus, a fluidic seal arrangement between adjacent arcuate segments comprises:

at least one pair of cavities extending in opposing directions into adjacent arcuate segments from the segment interface wherein each cavity includes a wall which is inclined to the segment interface at an angle not less than the angle of intersection of the plane of insertion for an adjacent arcuate segment with that interface and

a seal member disposed within the opposing cavities for sealing engagement with the inclined walls of the opposing cavities so as to allow unobstructed insertion and withdrawal of the segments and seal members in nominally radial directions to the assembly axis.

2. The devices of claim **1** wherein the cylindrical flow confining apparatus includes a segmented nozzle assembly having inner and outer annular bands with a plurality of circumferentially spaced partitions disposed therebetween.

3. The seal arrangement of claim **2** wherein the seal member includes a pair of intersecting substantially planar seal elements and wherein each cavity includes a slot for receiving a seal element and the inclined wall of each slot intersects the segment interface at a radially outward directed vertex with each slot having sufficient clearance to permit radial translation of the seals as a function of thermal growth of the nozzle assembly without distorting the seal member.

4. The seal arrangement of claim **2** wherein each nozzle segment is of equal arc length and any section orthogonal to the nozzle axis and through the dihedral angle formed by the intersection of the planes of the inclined walls of opposing slots intersects an angle equal to 360° divided by the total number of nozzle segments.

5. In a radially segmented cylindrical flow confining apparatus, a fluidic seal arrangement between adjacent arcuate segments comprises:

at least one pair of cavities extending in opposing directions into adjacent segments from the segment interface wherein each cavity includes a wall which is inclined to the segment interface at an angle not less than the angle of intersection of the plane of insertion of that nozzle segment with that interface and

a seal member disposed within the opposing cavities for sealing engagement with the inclined walls of the opposing cavities so as to allow unobstructed insertion and withdrawal of the segments and seal members in nominally radial directions to the assembly axis.

6. The device of claim **1** wherein the cylindrical flow confining apparatus includes a segmented nozzle assembly having inner and outer annular bands with a plurality of circumferentially spaced partitions disposed therebetween.

7. The seal arrangement of claim **6** wherein the seal member includes a pair of intersecting, substantially planar seal elements and wherein each cavity includes a slot for receiving a seal element and the inclined wall of each slot intersects the segment interface at a radially inward directed vertex with each slot having sufficient clearance to permit radial translation of the seals as a function of thermal growth of the nozzle assembly without distorting the seal member.

8. The seal arrangement of claim **6** wherein each nozzle segment is of equal arc length and any section orthogonal to the nozzle axis and through the dihedral angle formed by the interception of the inclined walls of opposing slots intercepts an angle equal to 360° divided by the total number of nozzle segments.

* * * * *