HOLLOW BLADE CONSTRUCTION

Filed Nov. 23, 1956 4 Sheets-Sheet 1

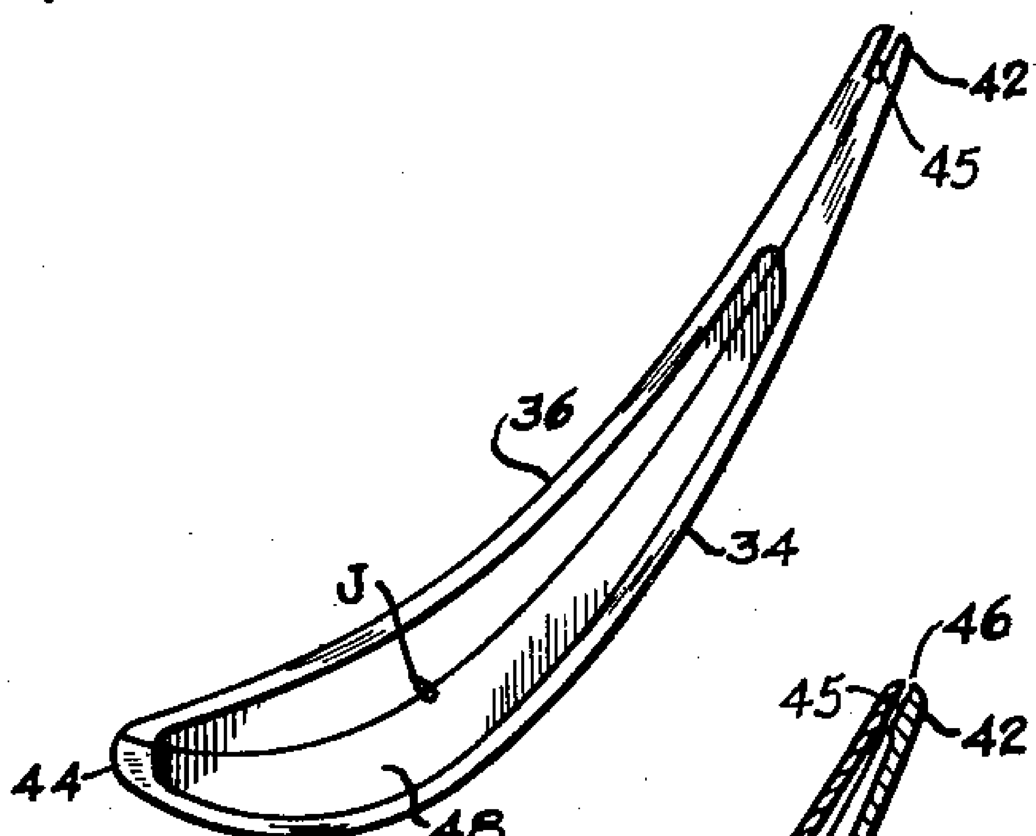

FIG. 4

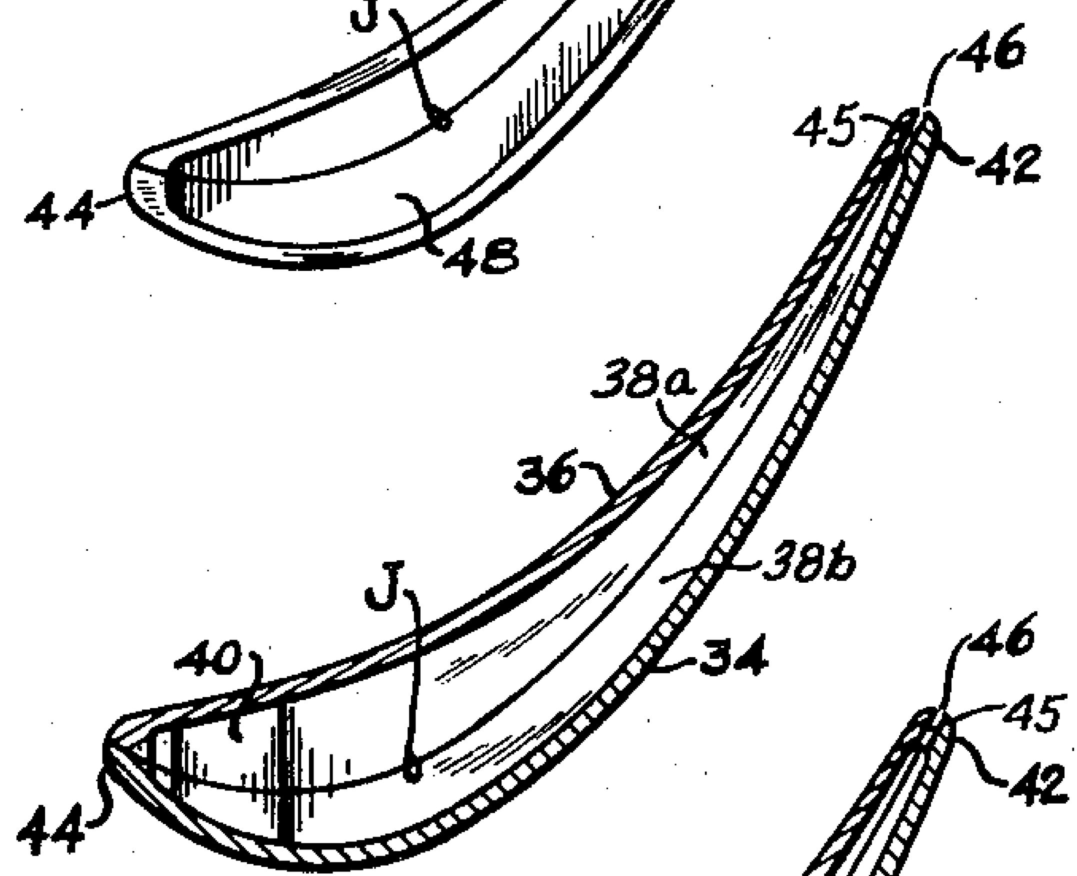

FIG. 5

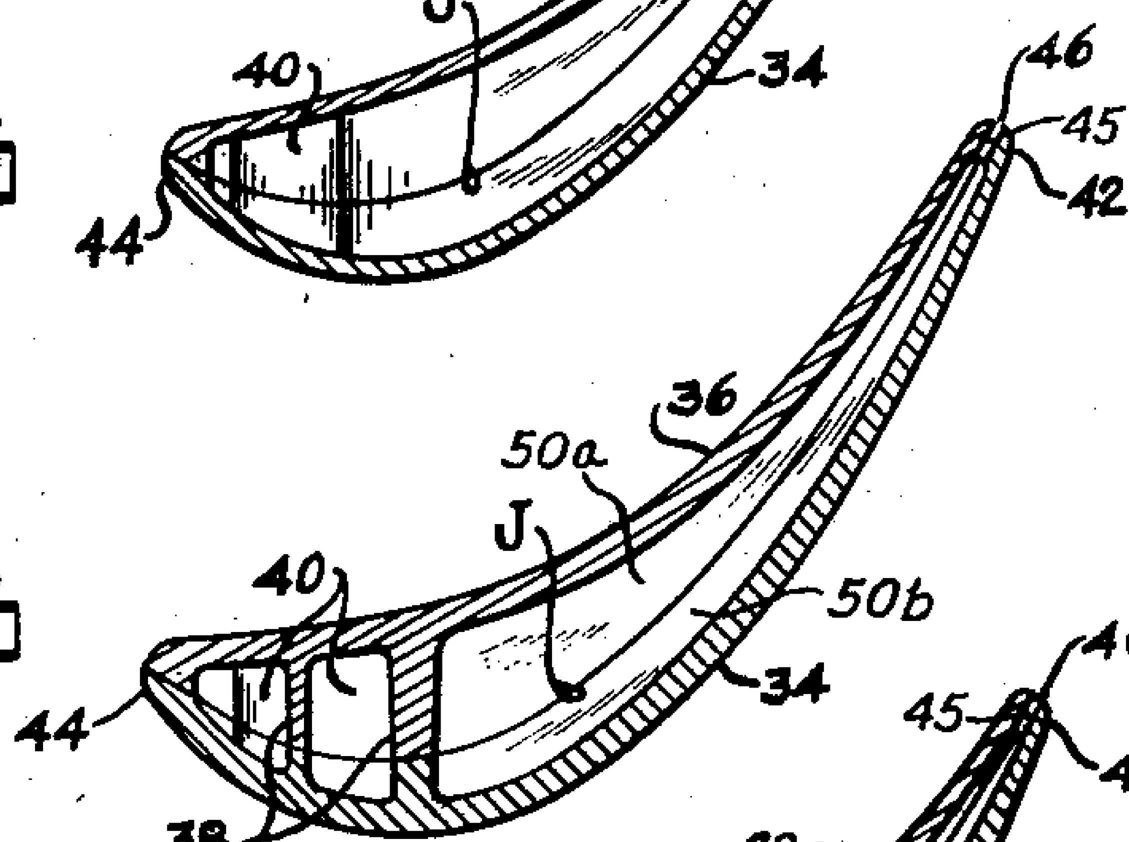

FIG. 6

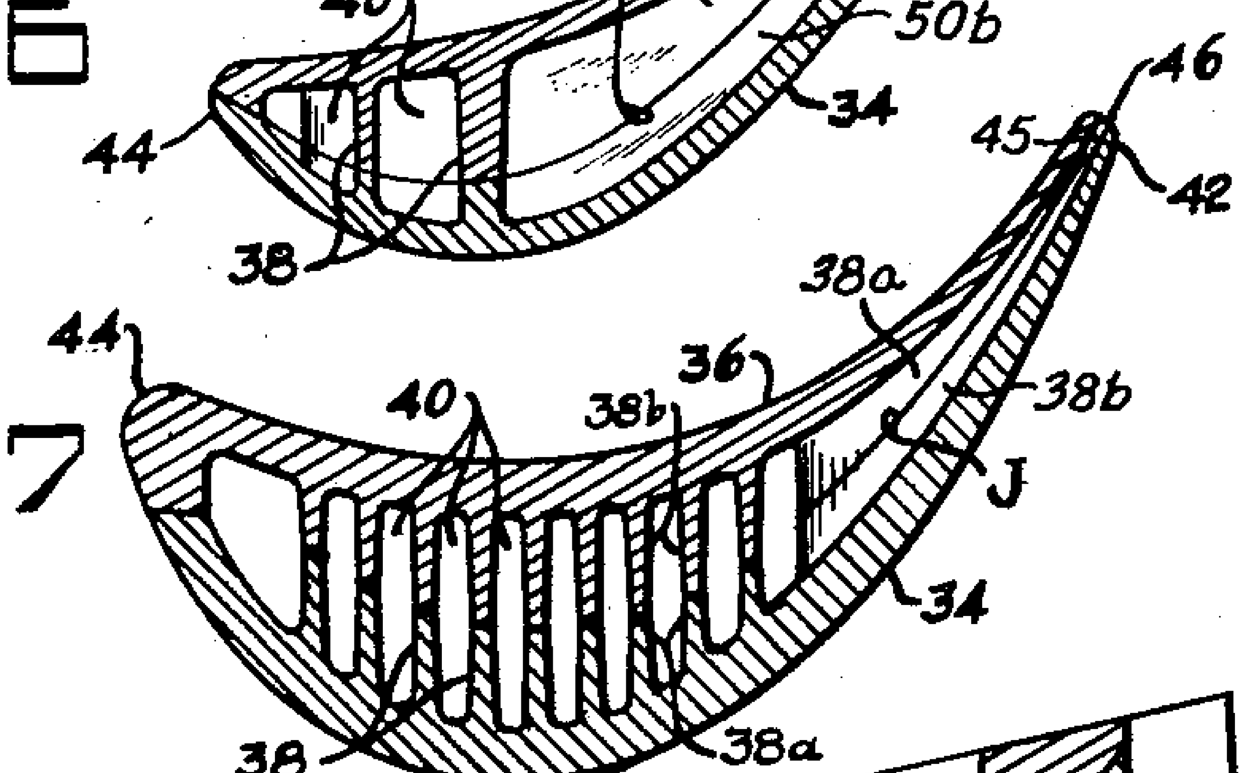

FIG. 7

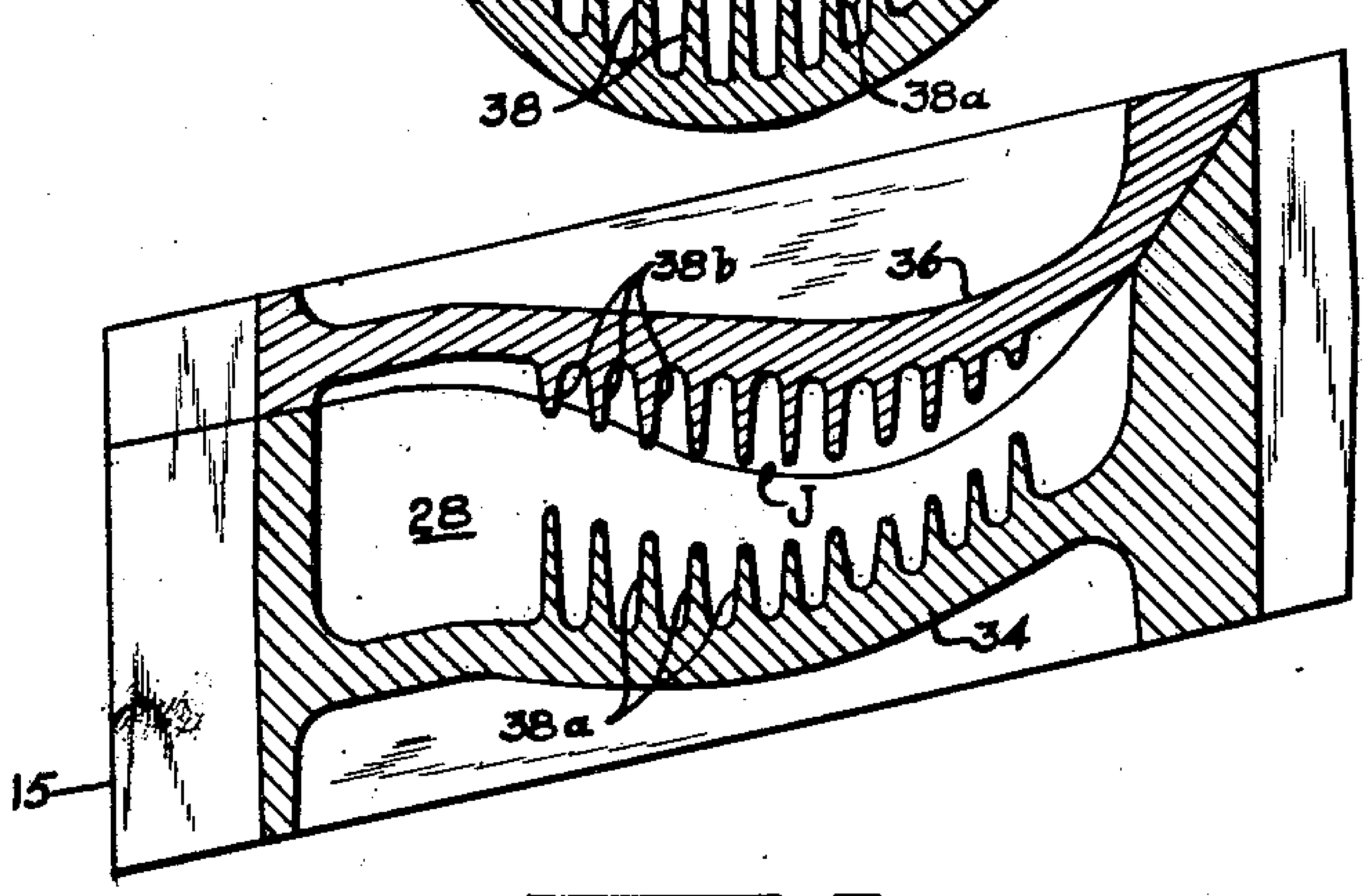

FIG. 8

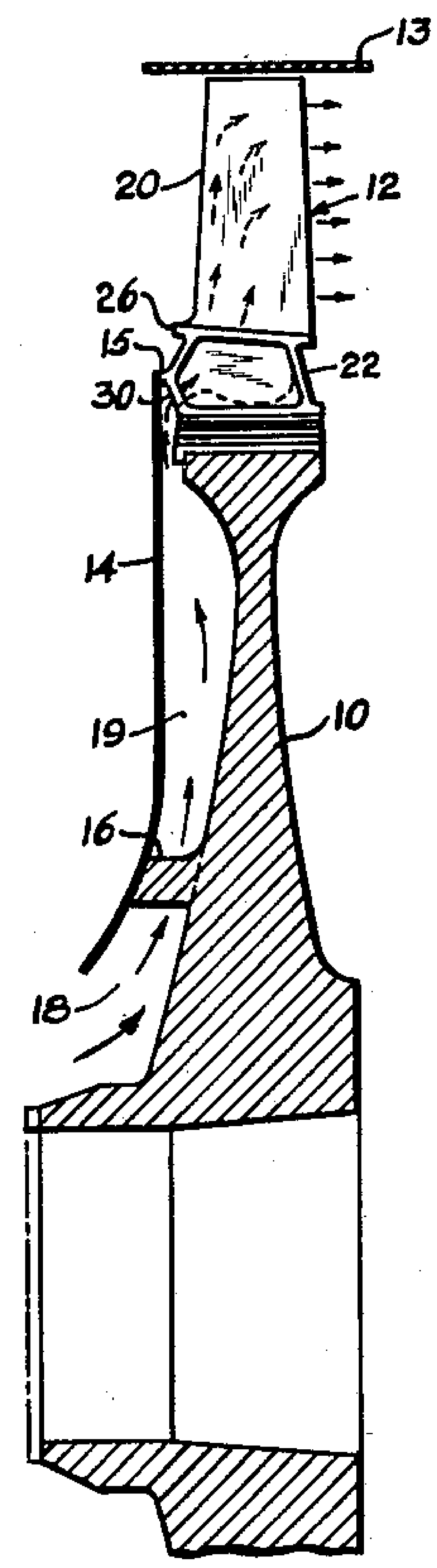

FIG. 1

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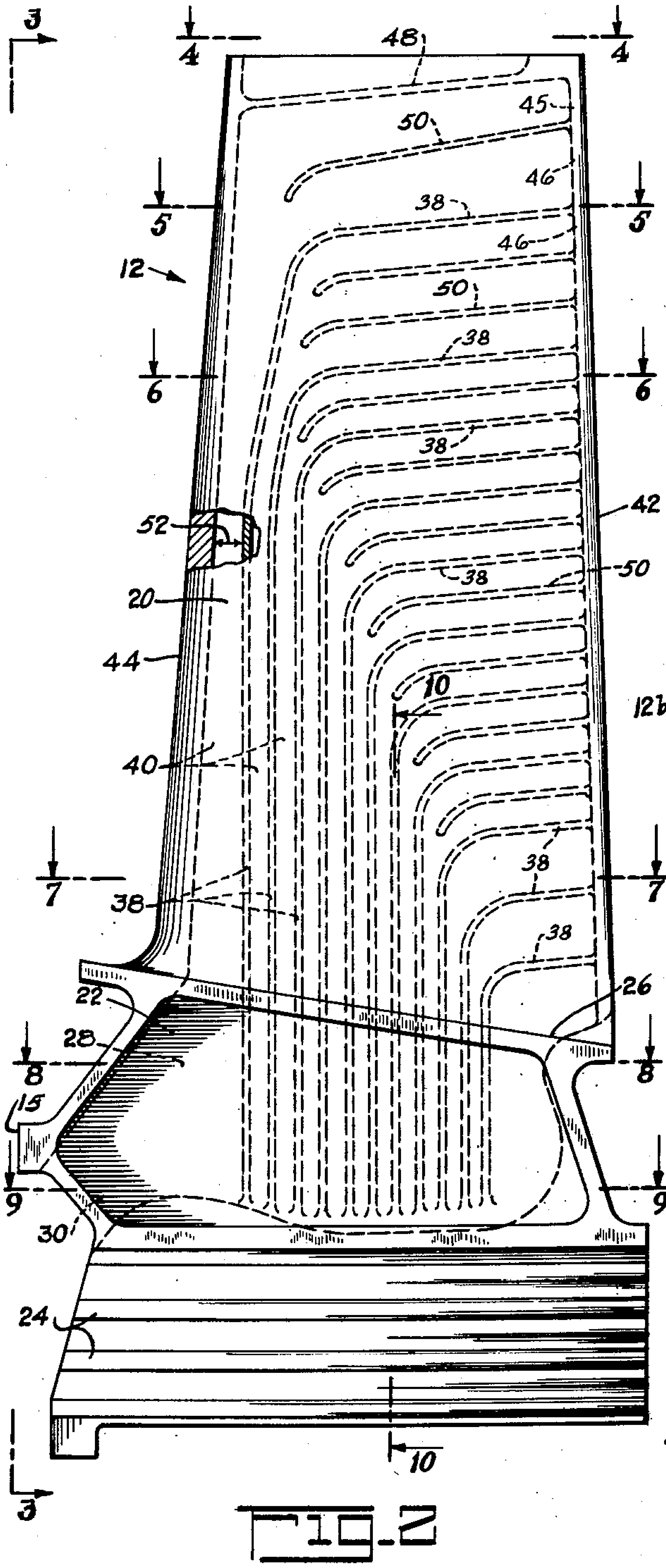

FIG. 2

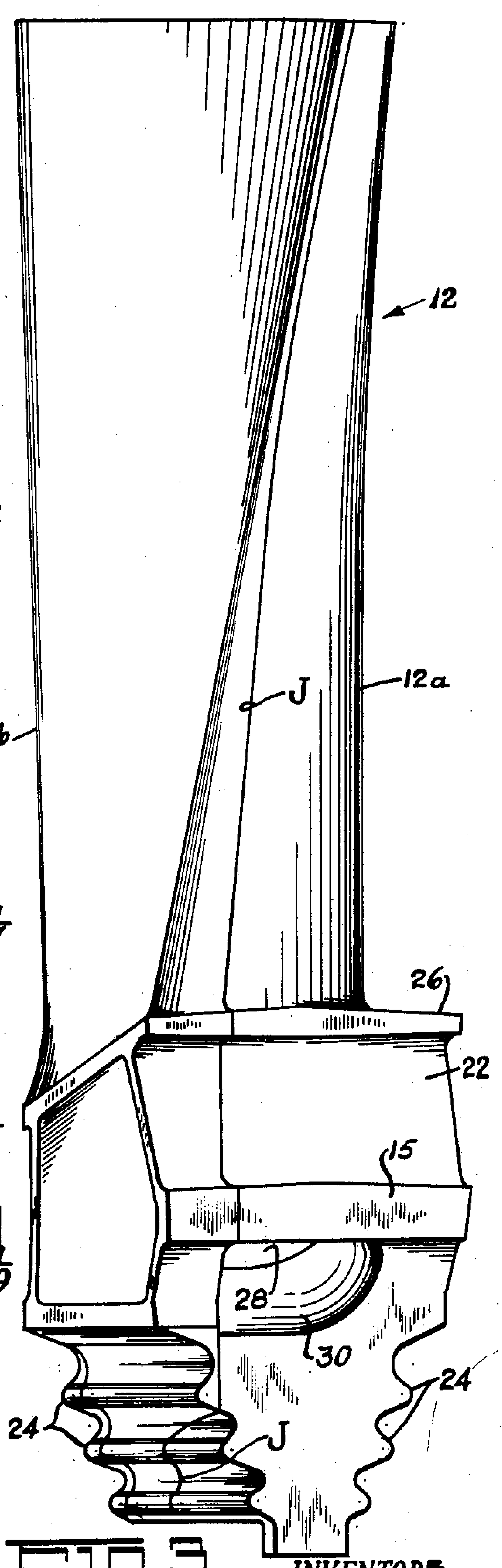

FIG. 3

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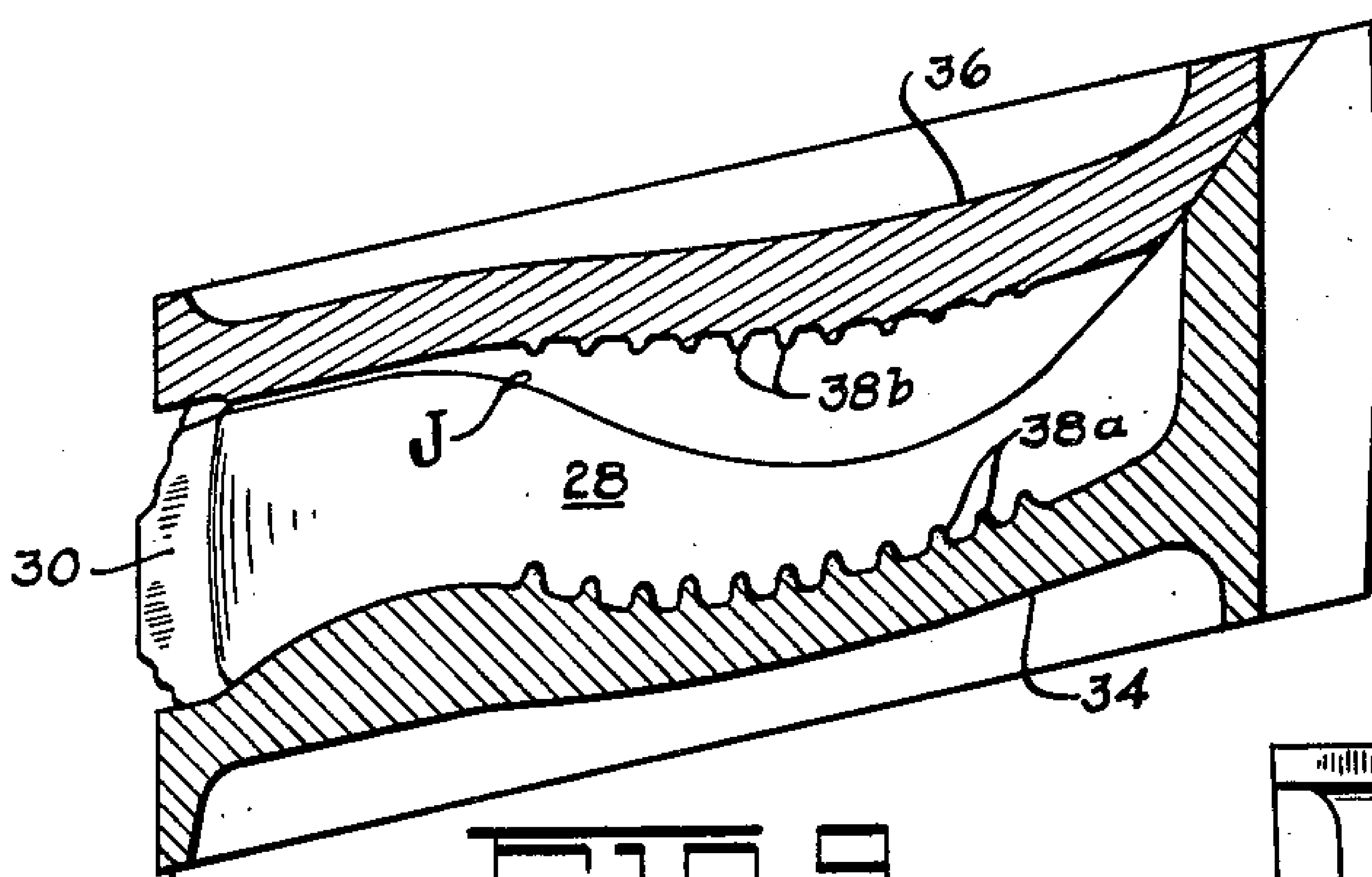

FIG. 9

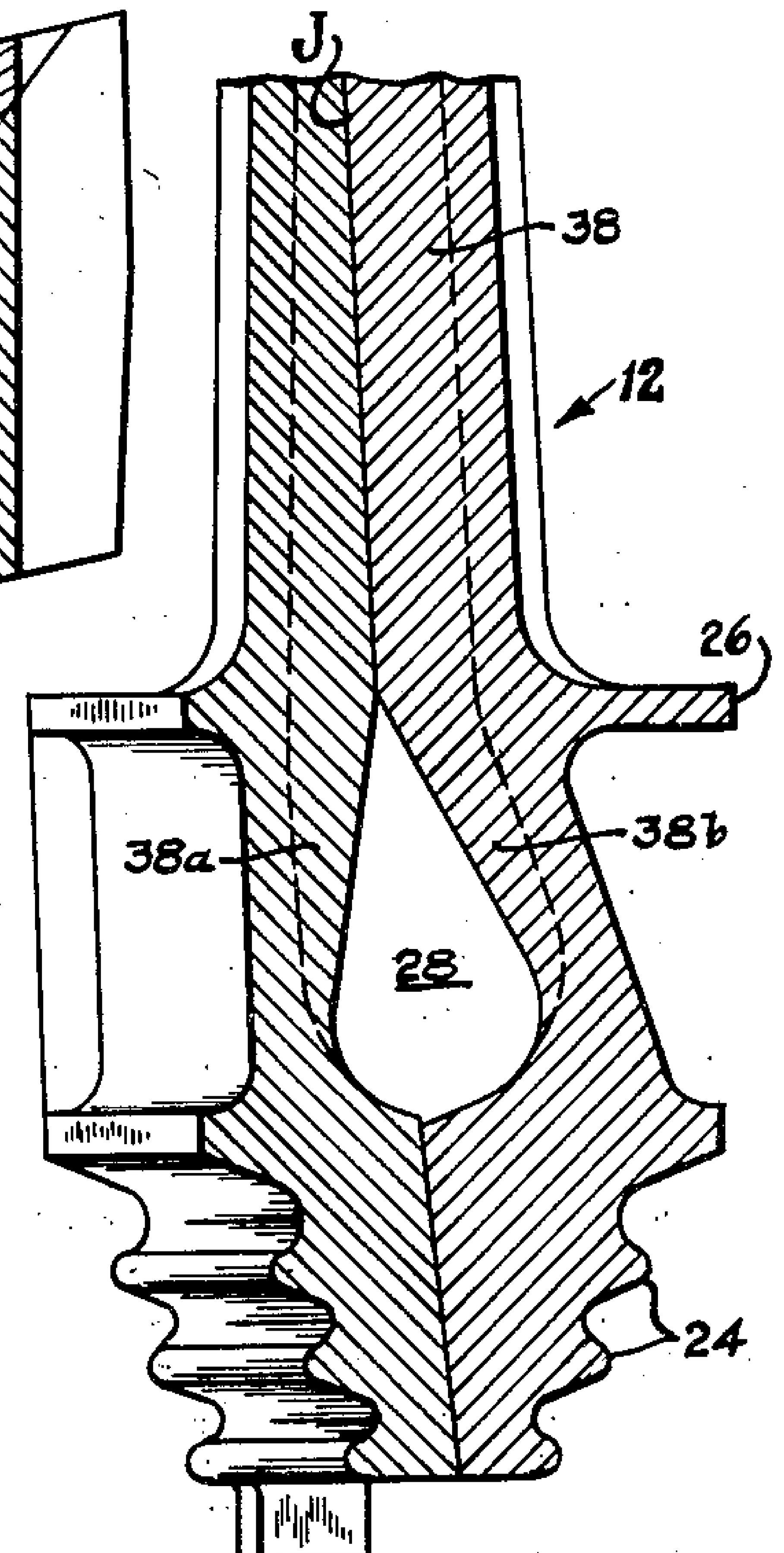

FIG. 10

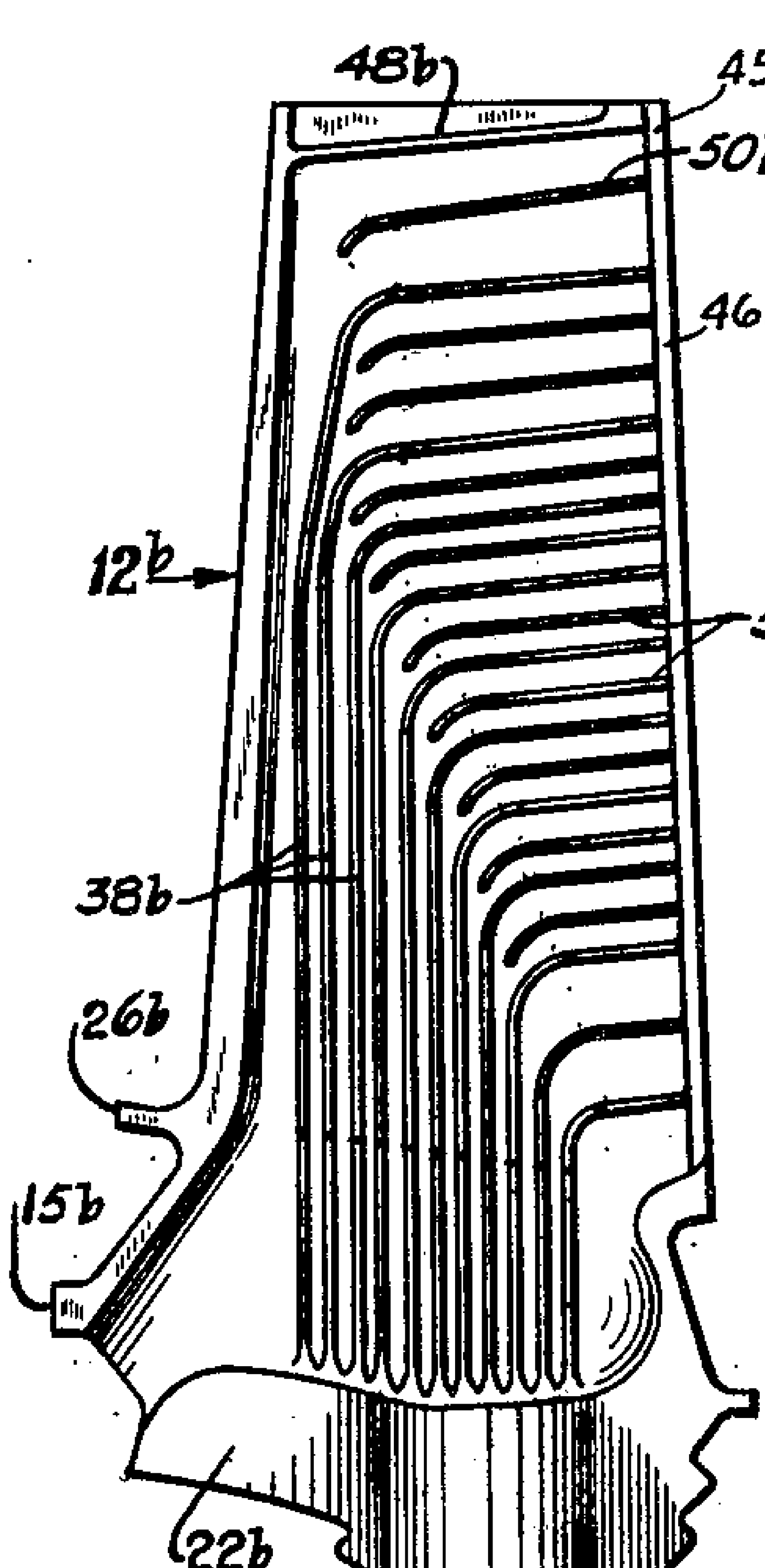

FIG. 11

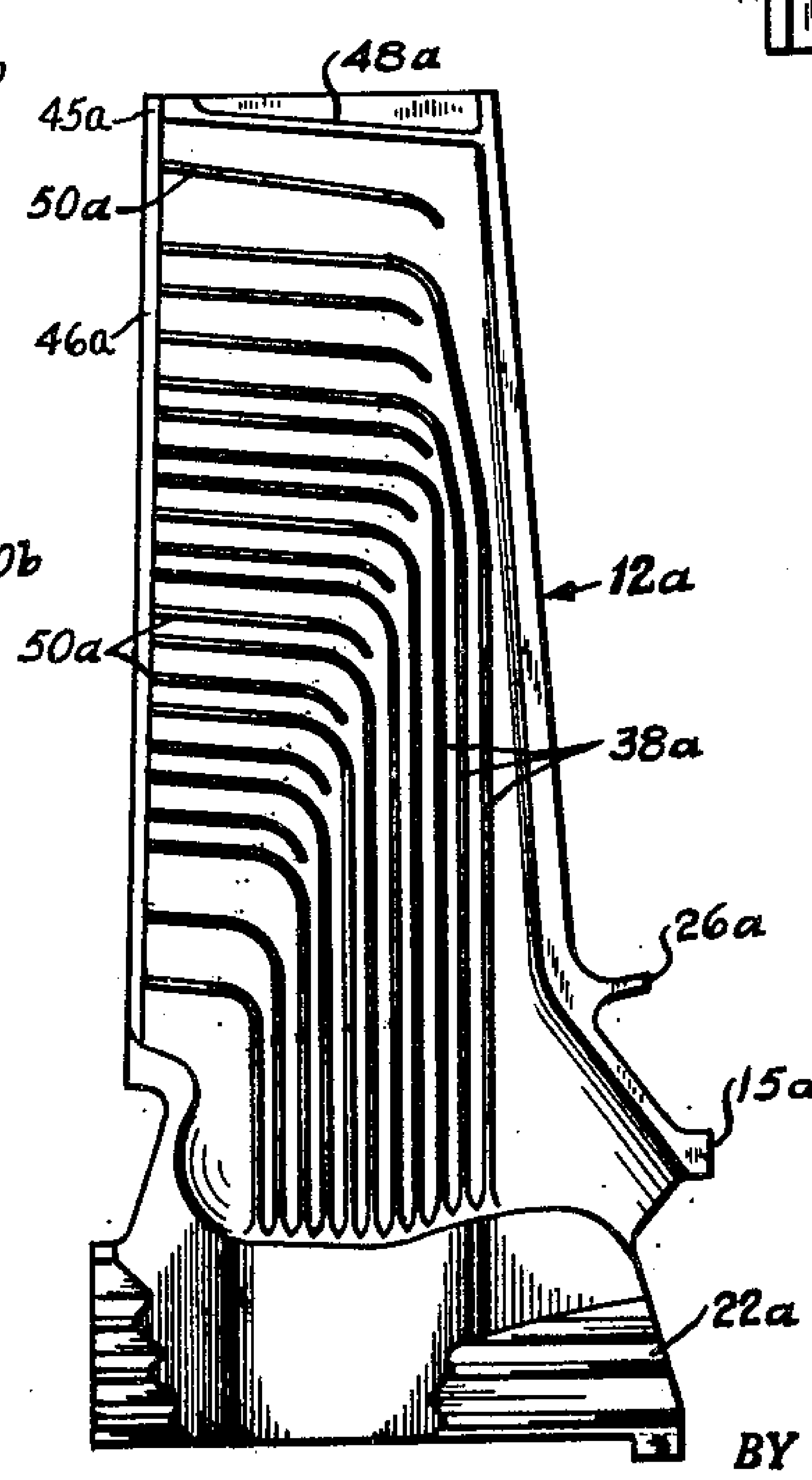

FIG. 12

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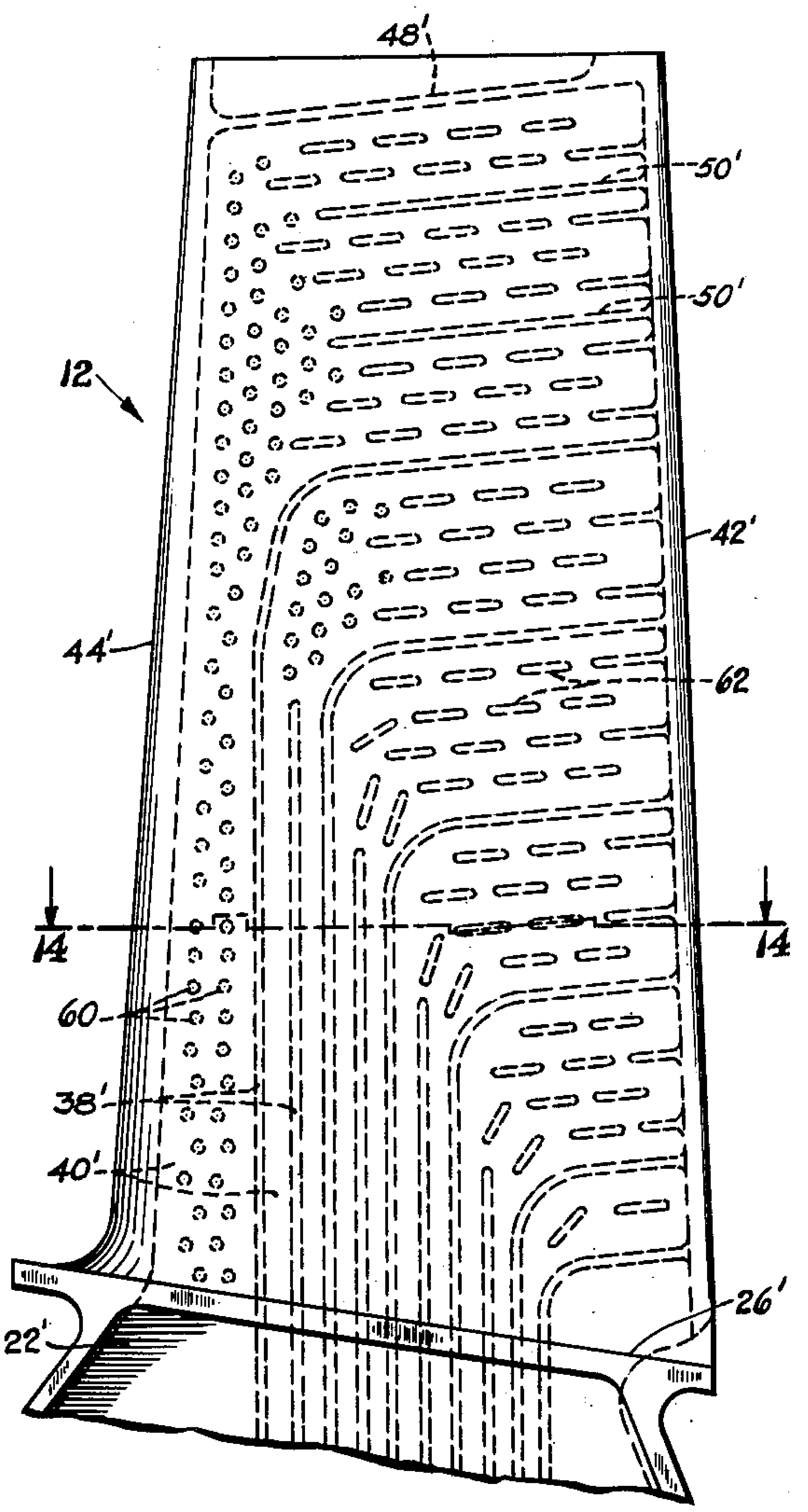

FIG. 13

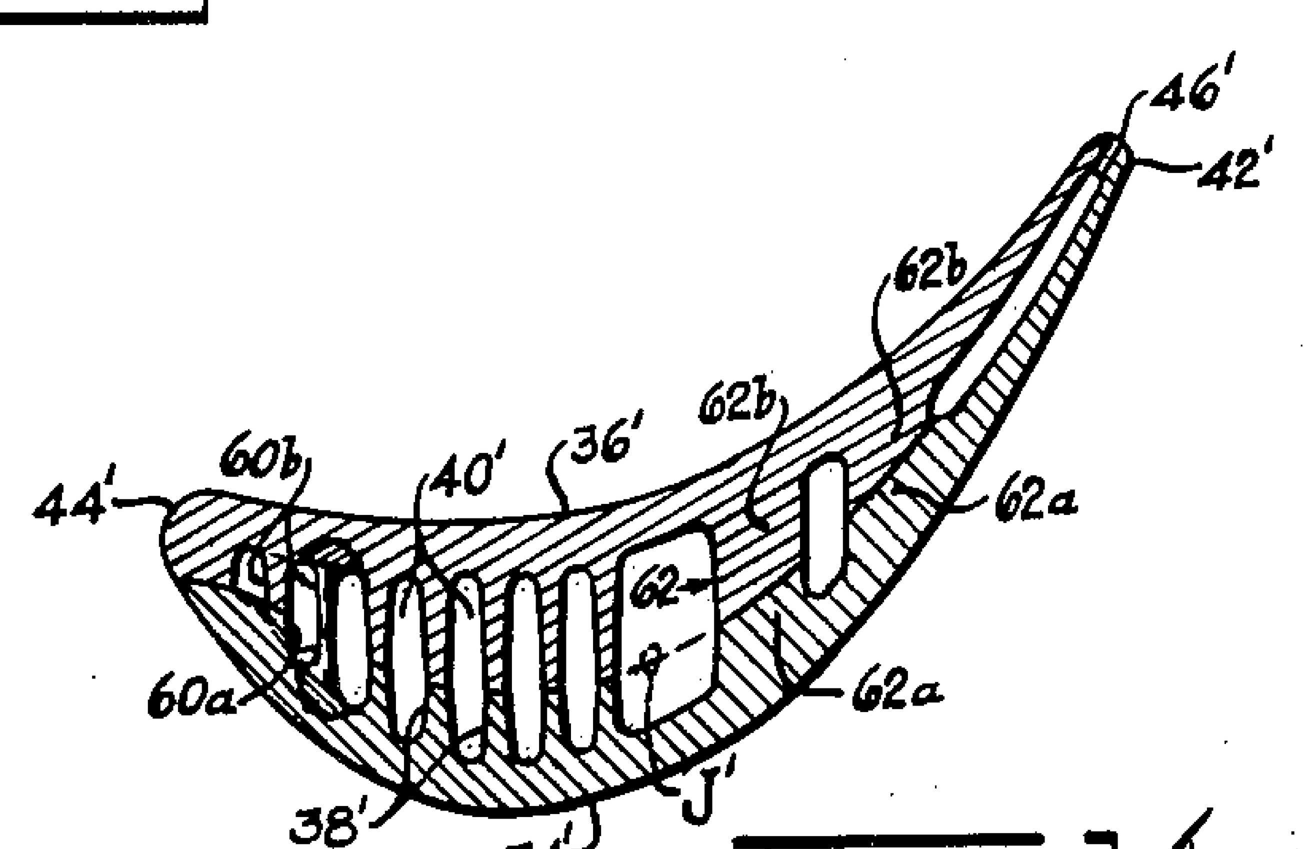

FIG. 14

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United States Patent Office

3,017,159
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3,017,159

HOLLOW BLADE CONSTRUCTION

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Filed Nov. 23, 1956, Ser. No. 623,943
3 Claims. (Cl. 253—39.15)

This invention relates to hollow blades for turbines, compressors or the like and is particularly directed to such blades designed for the flow of heat exchange fluid therethrough.

An object of the present invention comprises the provision of a novel hollow air-cooled blade for turbines, compressors or like apparatus such that high cooling efficiency of the blade is provided. A further object of the invention comprises the provision of a hollow air-cooled blade in which the blade is provided with a plurality of passages each controlled by a restricted discharge orifice disposed along the trailing edge of the blade. With this arrangement, the cooling air passages all discharge into the surrounding fluid in a region of substantially known pressure velocity and temperature thereby permitting accurate control of the cooling air flow through each passage. Also because of the restricted discharge orifices the cooling air discharges from the blade trailing edge at high velocity thereby insuring good cooling at the normally hot blade trailing edge. Furthermore, by properly proportioning the relative areas of the restricted discharge orifices of said blade passages any desired distribution of relative magnitudes of the mass air flow through the blade passages can be obtained. Thus with the present invention it is possible to provide for a substantial amount of cooling air flow along the normally hot leading edge of the blade.

Other objects of the invention will become apparent upon reading the annexed detailed description in connection with the drawing in which:

FIG. 1 is an axial sectional view through a gas turbine rotor having blades embodying the invention;

FIG. 2 is an elevation view of a blade embodying the invention;

FIG. 3 is a side view taken along line 3—3 of FIG. 2;

FIGS. 4, 5, 6, 7, 8, 9 and 10 are sectional views taken along lines 4—4, 5—5, 6—6, 7—7, 8—8, 9—9, 10—10 of FIG. 2, respectively;

FIGS. 11 and 12 are elevation views of the inner surface of the two halves of the blade prior to their assembly;

FIG. 13 is a view similar to FIG. 2 but illustrating a modified structure; and

FIG. 14 is a sectional view taken along line 14—14 of FIG. 13.

Referring first to FIG. 1 of the drawing, a gas turbine rotor **10** has a plurality of circumferentially-spaced blades **12** secured to and extending from the periphery of the disc portion of said rotor across the flow path of the turbine motive fluid. A shroud **13** forms the outer boundary of said flow path. For the purpose of supplying cooling air or other cooling fluid to the turbine blades, an annular shroud **14** is co-axially secured to a plurality of bosses **16** projecting axially from the disc portion of turbine rotor. The inner edge of the shroud **14** terminates short of the hub of the turbine rotor to leave an annular entrance **18** for cooling air flow into the space between the shroud

14 and the turbine rotor. A plurality of radially-disposed and circumferentially-spaced vanes **19** may be disposed between the shroud **14** and the turbine rotor **10** to help blow cooling air from said air entrance **18** to the periphery of the turbine rotor disc and thence into the root ends of the turbine rotor blades **12** for flow through said blades. The outer edge of the shroud **14** engages flanges **15** on the rotor blades **12** and projecting axially upstream therefrom for restricting said cooling air to flow into the root ends of said blades as hereinafter described. The structure so far described is largely conventional and, for example, is more fully illustrated in copending application Serial No. 557,051, filed January 3, 1956, now U.S. Patent No. 2,951,340, and the cooling air flow may be regulated in the manner described in said copending application.

The details of the rotor blades **12** are illustrated in FIGS. 2–12. As hereinafter described the blade **12** is fabricated in two halves **12***a* and **12***b* (see FIGS. 11 and 12) and the junction between said halves is indicated by the line J in FIGS. 3–10. Each blade **12** has a working portion **20** and a root portion **22**. The working portion **20** of the blade has an airfoil-like shape for co-action with the turbine motive fluid passing between the blades for driving the turbine. The root portion **22** of the blade is adapted for securement to the periphery of the turbine rotor disc. For this purpose, the root portion is illustrated as having ribs **24** formed thereon to form a fir tree shaped root portion arranged to be received in slots of complementary configuration in the turbine rotor disc. Each blade **12** also has a circumferentially-extending shelf **26** between its working or airfoil-like portion and root portion, said blade shelves being arranged to abut each other to form a continuous annular inner boundary for the turbine motive fluid, the blade airfoil or working portions **20** projecting across the flow path of said motive fluid from their respective shelves **26**. The blade shelves **26** are disposed outwardly of their previously described flanges **15**.

A cavity or chamber **28** is formed in the root portion of each blade between its shelf **26** and its fir tree configuration **24** and an opening **30** in the upstream side of the blade root portion communicates with this cavity. Each blade opening **30** is disposed on the radially inner side of its flange **15**. The blade flanges **15** form a substantially-continuous axially-extending annular flange which is engaged by the outer edge of the aforedescribed blower shroud **14** for causing the cooling air to flow into the turbine blade root openings **30**.

The working or airfoil portion **20** of each blade also has a hollow construction. Thus the working portion **20** of each blade comprises thin walls **34** and **36** forming the blade convex and concave faces, respectively, said walls preferably having a tapering thickness so that their thickness is a minimum at the outer ends of the blade. In addition a plurality of webs or partitions **38** extend across the hollow interior of the blade from one blade face to the other to divide said hollow blade interior into a plurality of passages **40**. As hereinafter described, each web **38** comprises a part **38***a* formed integral with convex blade face **34** and a part **38***b* formed integral with the concave blade face **36**, said web parts abutting and being joined together when the blade halves are joined. At the root end of the blade working portion, the webs **38** are spaced chordwise across the blade and said webs extend lengthwise of the blade from its root end for varying distances and then turn chordwise across the blade to its trailing edge **42**. The web **38**, disposed adjacent to the leading edge **44** of the blade, extends for substantially the entire length of the blade while the lengthwise extent of each of the other webs **38** progressively decreases chordwise across the blade so that the web **38** disposed adjacent to the trailing edge **42** of the blade has the shortest dimension lengthwise of the blade.

A narrow slot **45** is formed along the trailing edge of each blade and the webs **38** terminate at said slot **45** so that the portion **46** of said slot between each adjacent pair of webs **38** forms a restricted discharge opening or orifice **46** for the passage **40** formed by said pair of webs.

At the blade root portion the webs **38** extend into the root portion cavity or chamber **28** but each web separates into two spaced ribs **38*a*** and **38*b*** each formed on one face of the blade and each progressively decreasing in height as it extends farther into said cavity so that the root end of each said rib blends into the adjacent outer wall of the blade. With this arrangement, the cavity or chamber **28** in the root portion of the blade is in communication with each of the blade passages **40** so that cooling air supplied to said cavity through the opening **30** flows through the passages **40** and discharges from the trailing edge of the blade through the restricted openings **46**.

A web **48** extends chordwise across the blade working portion at its outer end to close said end in order that cooling air cannot discharge radially from the outer end of the blade. Also one or more short chordwise extending webs **50** divide the chordwise portion of certain of the passages **40** into a plurality of parallel passages to help distribute the cooling air across said passages **40**.

With the aforedescribed construction, the airflow through the blade is controlled by the restricted openings **46** disposed along the blade trailing edge **42** for each of the passages **40** so that said restricted openings **46** control the airflow distribution through the blade. Accordingly, the passages **40**, with their restricted discharge openings **46**, can be designed to provide any desired airflow distribution through the blade which distribution will be unaffected by change in operating conditions of the turbine. This is in contrast to hollow blades having passages discharging air at the outer ends of the blade since there obviously is a different pressure variation on the concave and convex faces of the airfoil and there is a pressure gradient chordwise across the outer end of a turbine blade, said pressures changing with changes in the operating conditions of the turbine. In addition, with air discharging from the outer end of a blade the air flow distribution in the blade will be affected by the small clearance between the blade and the adjacent stator wall which clearance is difficult to control accurately.

Because of the restricted openings **46**, the cooling air discharges at relatively high velocity from the trailing edge of the blade. The trailing edge of a turbine blade normally runs hot. The high velocity flow of the cooling air through the restricted openings **46** provides for high heat transfer from the adjacent portions of the blade thereby effectively cooling the blade trailing edge.

The leading edge of a turbine blade is the other region of such a blade which normally runs hot and therefore like the trailing edge requires more effective cooling than the portions of the blade between its said leading and trailing edges. In order to effectively cool the leading edge of the blade **12** the restricted openings **46** along the trailing edge are designed to provide for a relatively large amount of air flow through the passage **40** disposed along said leading edge. For this purpose, the length of the discharge opening **46**, as measured along the blade trailing edge **42**, for the leading edge passage **40** is relatively long compared to the discharge openings **46** for the other passages **40** whereby the area of the restricted opening **46** for said leading edge passage **40** is relatively large.

The temperature distribution pattern of the turbine motive fluid usually is such that the highest temperatures occur midway along the blade. To increase the cooling midway along the leading edge **44** of the blade **12** the passage **40** along said leading edge converges slightly in this region as indicated at **52** thereby increasing the velocity of the cooling air flow and hence the cooling in this region.

In order to fabricate a blade **12**, it is made in two halves **12*a*** and **12*b*** as previously mentioned and as best seen in FIGS. 11 and 12. The blade half **12*a*** includes the convex face **34** with part of the leading and trailing edges of the blade working or airfoil portion and the major portion **22*a*** of the blade root. In addition rib portions or halves **38*a***, **48*a*** and **50*a*** of the webs **38**, **48** and **50** respectively are formed integral with the blade half **12*a***. Likewise the blade half **12*b*** includes the concave face **36** with remaining part of the leading and trailing edges of the blade working portion and the remaining portion **22*b*** of the blade root. Also the other rib portions or halves **38*b***, **48*b*** and **50*b*** of the webs **38**, **48** and **50**, respectively, are formed integral with their blade half **12*b***. The rib halves **38*a*** and **38*b*** as well as the other of said rib halves all abut each other so that the portion of the junction J between the leading and trailing edges of the blades is defined by the abutting surfaces of said ribs.

Each blade half **12*a*** and **12*b*** preferably is a precision casting and the surfaces of each blade half to be joined to the complementary or mating surfaces of the other blade half are machined to provide an accurate fit with the other blade half. The shape and position of the mating surface junction J of the two halves is shown in FIGS. 3–10 and is so chosen that mating surfaces can be machined by a straight line pass of the cutter without any relative twisting of the blade or cutter. In other words the mating surface junction J of each blade half **12*a*** and **12*b*** is a cylindrical surface, although as illustrated, not necessarily a circular cylindrical surface, in that it can be defined by a straight line moving parallel to itself. In the blade illustrated the generating line of said cylindrical mating surface J is inclined to the longitudinal axis of the blade. The two blade halves are then brazed together at their mating surfaces. Following the brazing operation the fir tree ribs **24** and the shelf portions of the blade root are accurately machined. The trailing edge portions of the two blade halves are formed so as to provide the trailing edge slots **46** when the two halves are brazed together.

It is known that the heat transfer efficiency of a plurality of short webs is substantially better than that of a single long web having the same length as the combined length of the short webs. The heat transfer efficiency increases as the length of the webs along the flow path is decreased so that a short web having the shape of a pin-type projection has even superior heat transfer properties. Accordingly it is within the scope of the invention to add and/or substitute a plurality of short webs and/or pin-type projections within the airfoil portion of the hollow blade. Such a modification, illustrated in FIGS. 13 and 14, although superior from the standpoint of the cooling effectiveness of the air flowing through the blade is more complex from a fabrication standpoint. For ease of understanding the parts of FIGS. 13 and 14 corresponding to parts of FIGS. 1–12 have been designated by the same but primed reference numerals.

Referring to FIGS. 13 and 14 at least one of the lengthwise extending webs has been eliminated to widen the leading edge passage **40′** and a plurality of pin-type projections **60** of circular cross-section are spaced along the leading edge portion of this passage and along a portion of the adjacent passage in order to increase the cooling effectiveness of the cooling airflowing through said passages. Each of the projections **60** comprises two parts **60***a* and **60***b*. The parts **60***a* and **60***b* of each projection **60** are formed integral with the convex and concave blade faces **34'** and **36'** respectively with each part extending part way across its hollow blade passage into abutting engagement with the other part of its projection **60**.

A plurality of relatively short webs **62** are spaced along the chordwise portions of the various blade passages **40'** in the region of the trailing half of the blade to increase the cooling effectiveness of the air in this portion of the blade. For this purpose certain of the chordwise webs **50'** have been replaced by a plurality of short chordwise extending webs **62** and other webs **62** have been added. Short webs **62** are used along the trailing half of the blade instead of the pin-type projections because this half of the blade is relatively thin. Thus if pins **60** were used in this thin portion of the blade then because of the large fillets desired at the junction of each pin with its blade face the average width of each pin would be much greater in this thin portion of the blade.

Each of the webs **62** comprises two short ribs **62***a* and **62***b*. The ribs **62***a* and **62***b* are formed integral with the convex and concave blade faces **34'** and **36'** respectively with each rib extending part way across its hollow blade passage into abutting engagement with the other rib of its web **62**.

The two parts **60***a* and **60***b* of each pin type projection **60** and the two parts **62***a* and **62***b* of each short web **62**, like the halves of the various ribs between the blade faces, all abut each other along the aforementioned junction J'.

While we have described our invention in detail in its present preferred embodiment, it will be obvious to those skilled in the art, after understanding our invention, that various changes and modifications may be made therein without departing from theh spirit or scope thereof. We aim in the appended claims to cover all such modifications.

We claim as our invention:

1. A rotor blade for turbines, compressors or the like; said blade having a hollow airfoil portion and a root portion, said root portion having a cavity therein and an opening for the supply of a heat exchange fluid to said cavity for flow therefrom through said blade airfoil portion, said airfoil portion having opposed faces extending lengthwise of the blade and leading and trailing edges also extending lengthwise of the blade and joining said faces, said blade airfoil portion also having a plurality of spaced partitions dividing the hollow interior of said airfoil portion into a plurality of passages communicating at one end with said root portion cavity such that all of said heat exchange fluid flowing through said airfoil portion flows through said passages, said passages being spaced chordwise across the blade airfoil portion adjacent to the root portion of the blade and all of said passages extending lengthwise of the blade from the blade root portion but for varying distances and then turning toward and terminating in individual discharge openings spaced along the trailing edge of the blade airfoil portion, the passage adjacent to the leading edge of the blade airfoil portion extending lengthwise substantially the entire length of the blade airfoil portion and the lengthwise extent of the other of said passages progressively decreasing chordwise across the blade airfoil portion so that the passage adjacent to the blade trailing edge has its discharge opening disposed adjacent to the blade root portion and so that the discharge openings of said passages are disposed along substantially the entire length of said trailing edge, each of said passages having a restriction at its discharge opening and said leading edge passage having a reduced area region in its leading edge portion and disposed approximately midway along the blade leading edge.

2. A rotor blade for turbines, compressors or the like; said blade having a hollow airfoil portion and a root portion, said root portion having a cavity therein and an opening for the supply of a heat exchange fluid to said cavity for flow therefrom through said blade airfoil portion, said airfoil portion having opposed faces extending lengthwise of the blade and leading and trailing edges also extending lengthwise of the blade and joining said faces, said blade airfoil portion also having a plurality of spaced partitions dividing the hollow interior of said airfoil portion into a plurality of passages communicating at one end with said root portion cavity such that all of said heat exchange fluid flowing through said airfoil portion flows through said passages, said passages being spaced chordwise across the blade airfoil portion adjacent to the root portion of the blade and all of said passages extending lengthwise of the blade from the blade root portion but for varying distances and then turning toward and terminating in individual discharge openings spaced along the trailing edge of the blade airfoil portion, the passage adjacent to the leading edge of the blade airfoil portion extending lengthwise substantially the entire length of the blade airfoil portion and the lengthwise extent of the other of said passages progressively decreasing chordwise across the blade airfoil portion so that the passage adjacent to the blade trailing edge has its discharge opening disposed adjacent to the blade root portion and so that the discharge openings of said passages are disposed along substantially the entire length of said trailing edge, said blade having a narrow slot formed along the blade trailing edge and the blade partitions, separating the blade passages, terminating at said slot so that each portion of said slot between a pair of adjacent partitions forms the restricted discharge opening for the passage formed by said pair of partitions.

3. A rotor blade for turbines, compressors or the like; said blade having a hollow airfoil portion and a root portion, said root portion having a cavity therein and an opening for the supply of a heat exchange fluid to said cavity for flow therefrom through said blade airfoil portion, said airfoil portion having opposed faces extending lengthwise of the blade and leading and trailing edges also extending lengthwise of the blade and joining said faces, said blade airfoil portion also having a plurality of spaced partitions dividing the hollow interior of said airfoil portion into a plurality of passages communicating at one end with said root portion cavity such that all of said heat exchange fluid flowing through said airfoil portion flows through said passages, said passages being spaced chordwise across the blade airfoil portion adjacent to the root portion of the blade and all of said passages extending lengthwise of the blade from the blade root portion but for varying distances and then turning toward and terminating in individual discharge openings spaced along the trailing edge of the blade airfoil portion, the passage adjacent to the leading edge of the blade airfoil portion extending lengthwise substantially the entire length of the blade airfoil portion and the lengthwise extent of the other of said passages progressively decreasing chordwise across the blade airfoil portion so that the passage adjacent to the blade trailing edge has its discharge opening disposed adjacent to the blade root portion and so that the discharge openings of said passages are disposed along substantially the entire length of said trailing edge, the leading edge portion of the blade leading edge passage having a plurality of cylindrical projections spaced along and extending across said leading edge passage portion and the trailing edge portions of at least some of the blade passages having a plurality of short webs spaced along and extending across said trailing edge passage portions with the sides of each web being disposed substantially parallel to the sides of its passage, each of said cylindrical projections and webs being formed integral with at least one of the faces of the blade airfoil portion.

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