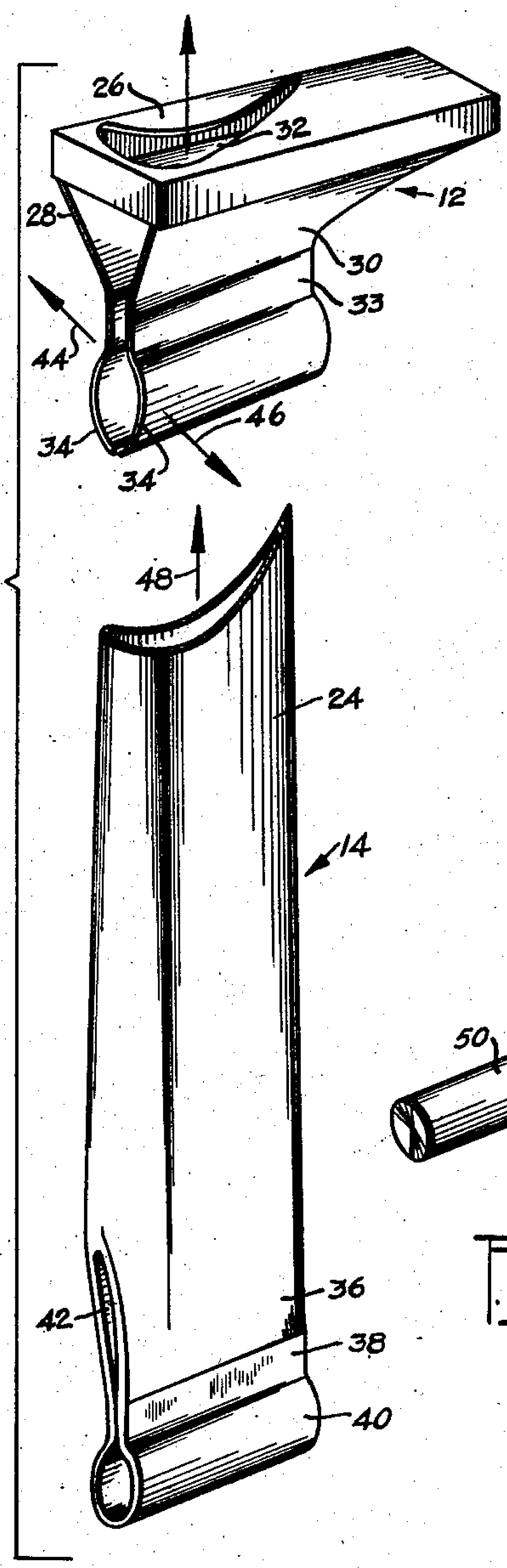
TURBINE BLADE CONSTRUCTION

Filed April 8, 1948 4 Sheets-Sheet 1

FIG. 2



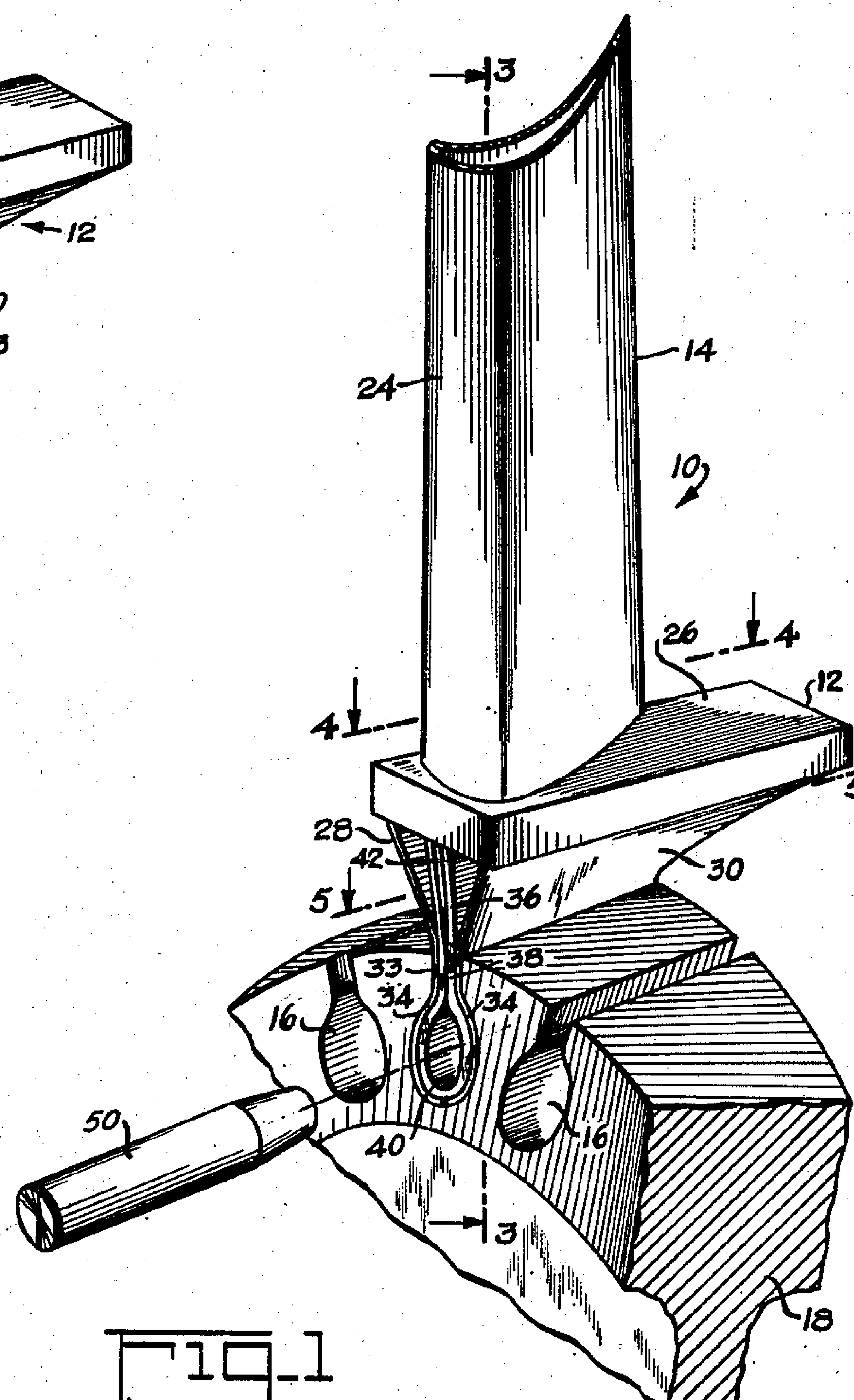


FIG. 1

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TURBINE BLADE CONSTRUCTION

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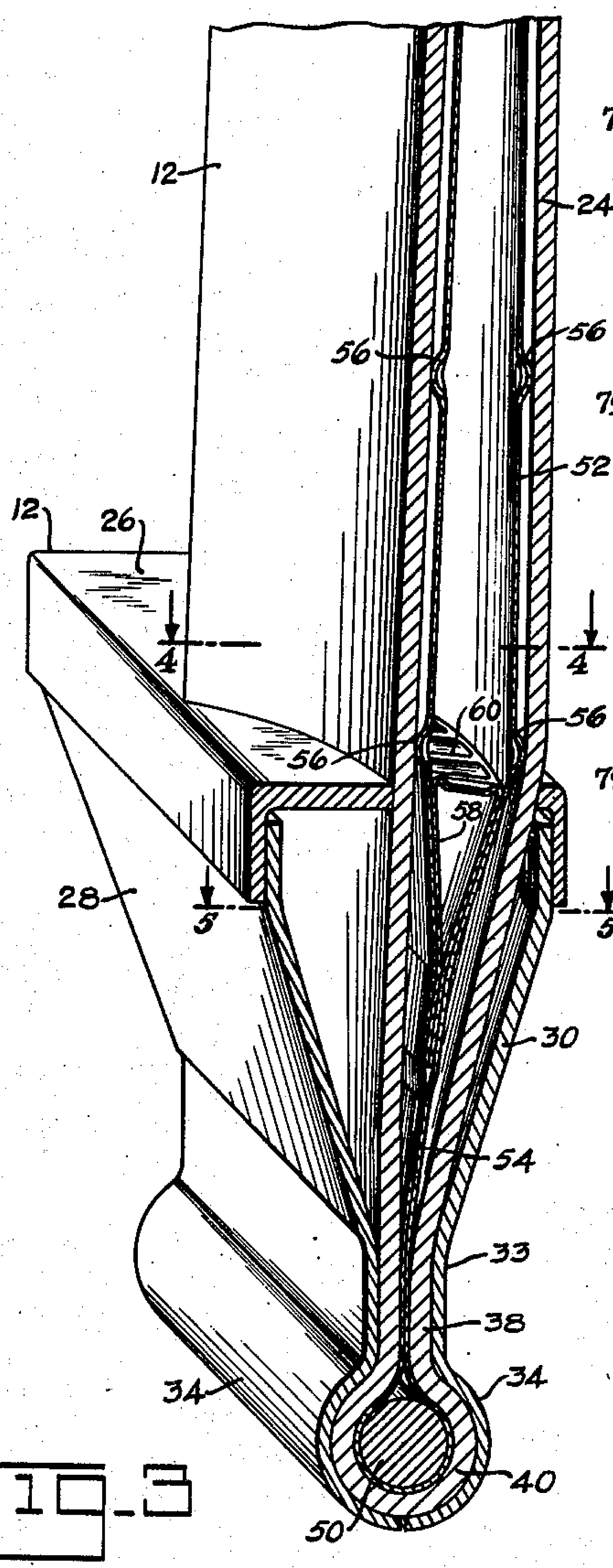

Fig. 3

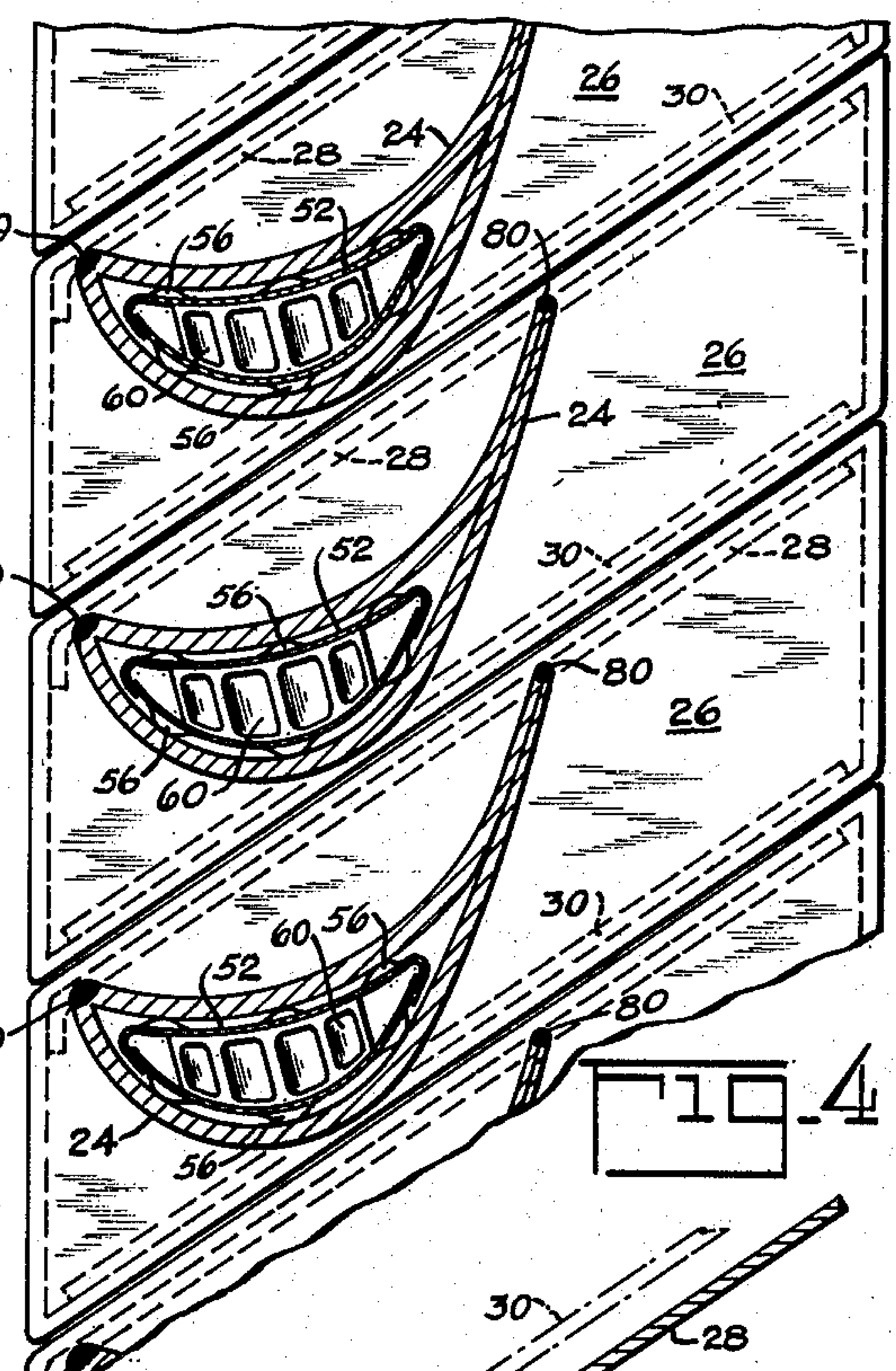

Fig. 4

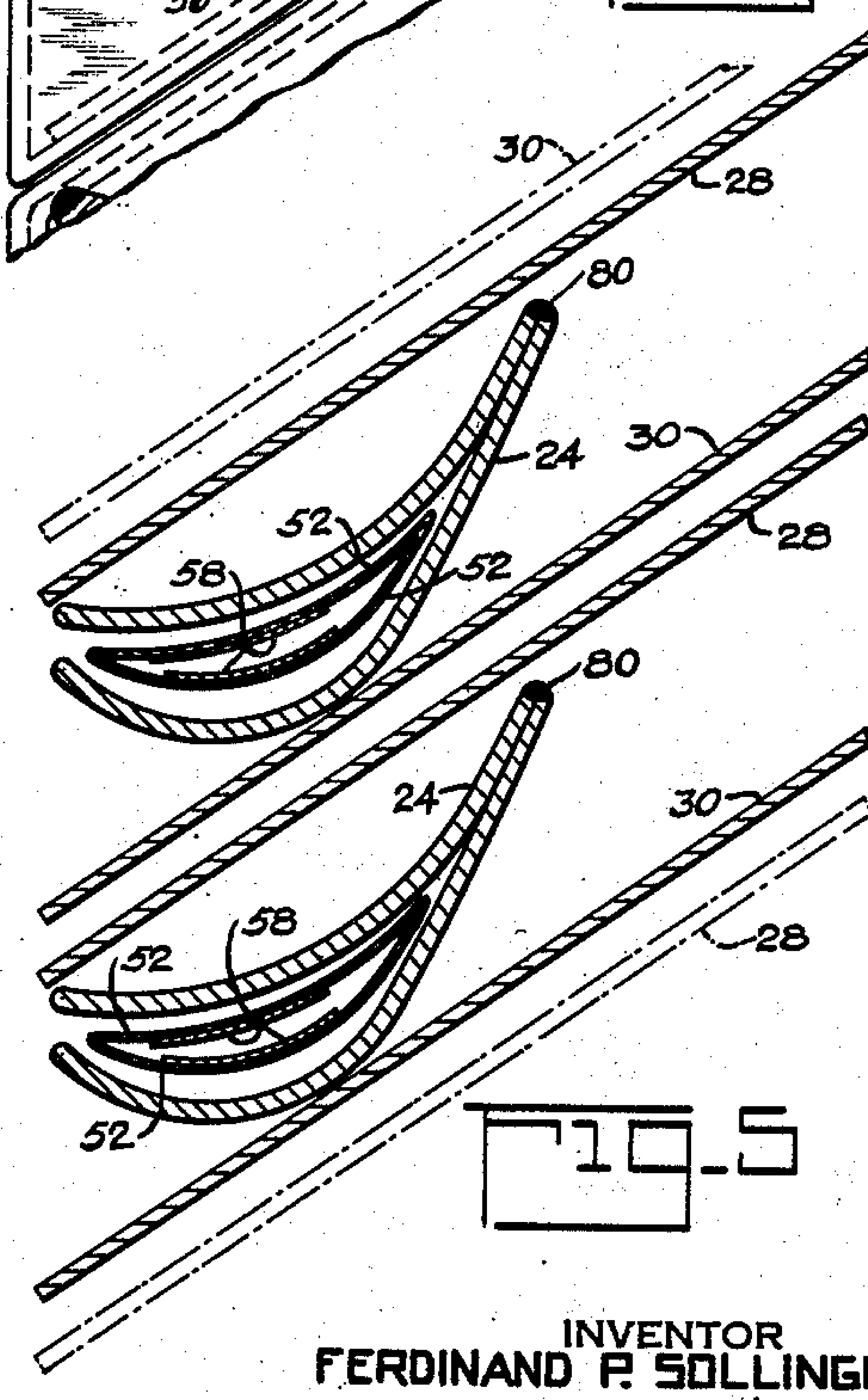

Fig. 5

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TURBINE BLADE CONSTRUCTION

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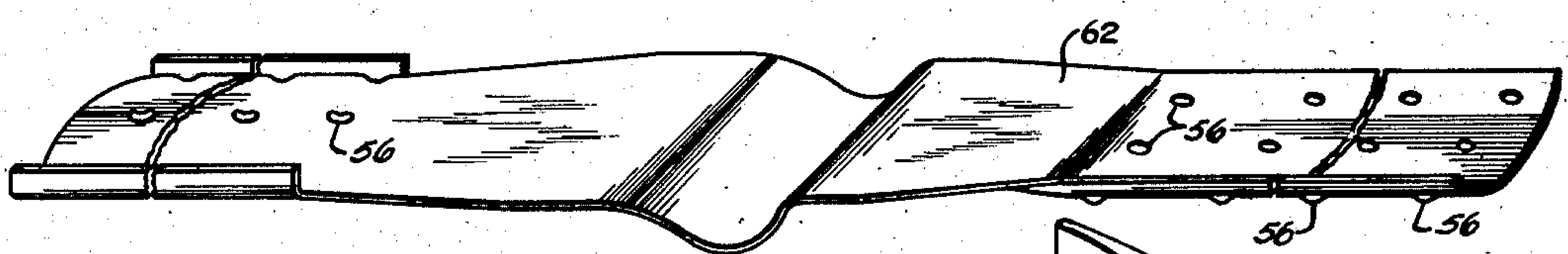

Fig. 7

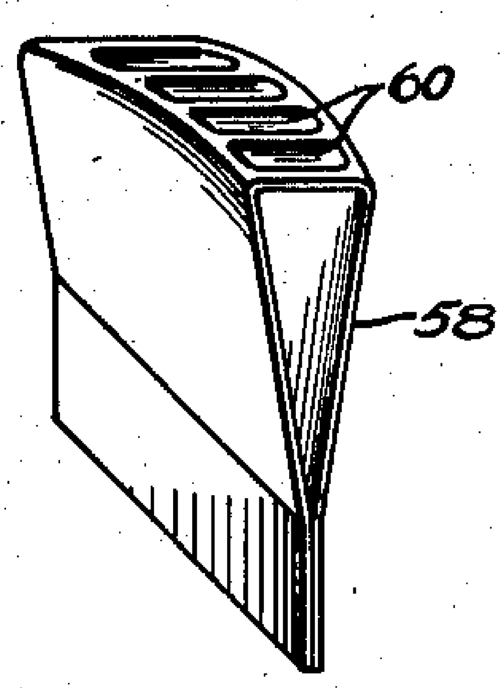

Fig. 6

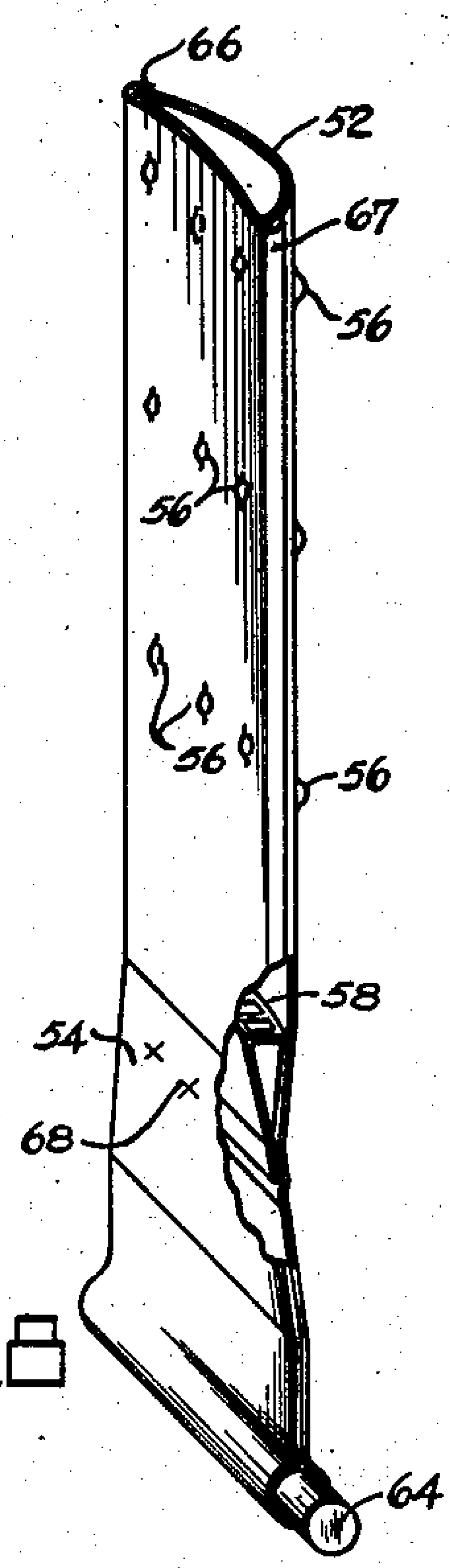

Fig. 8

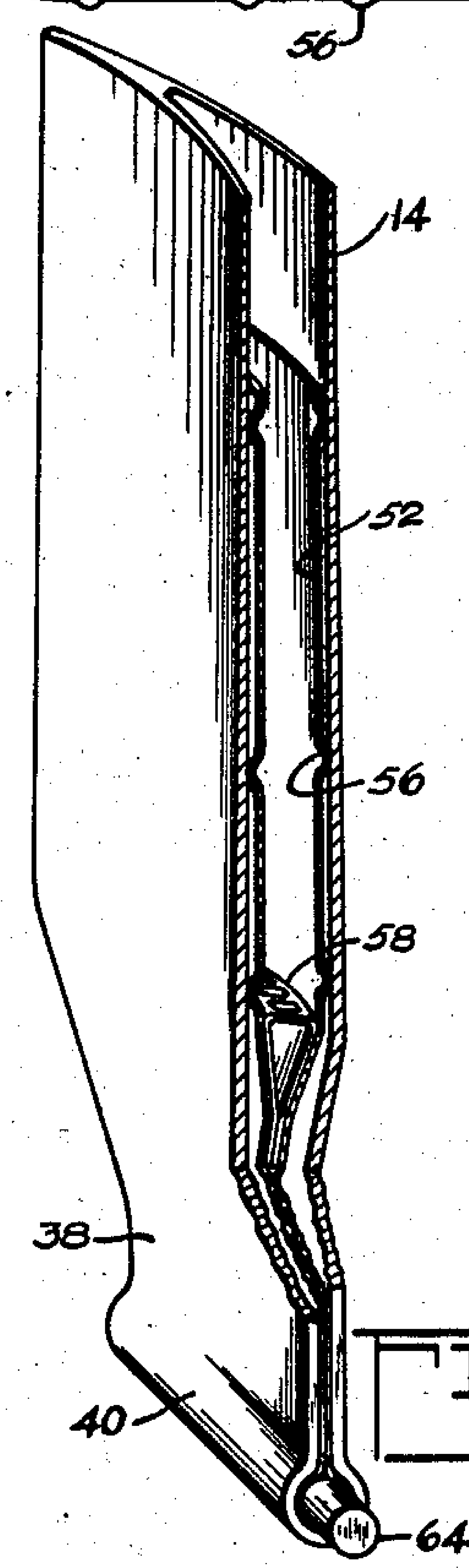

Fig. 13

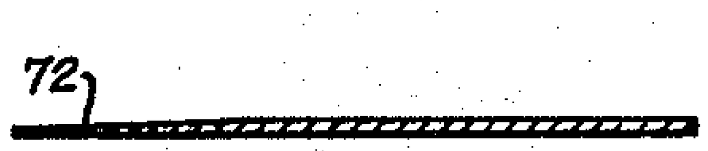

Fig. 10

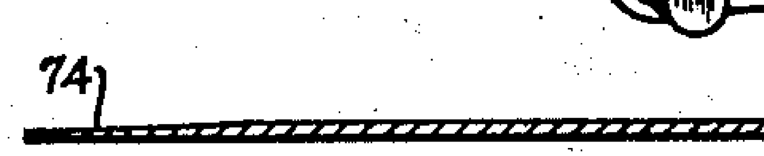

Fig. 11

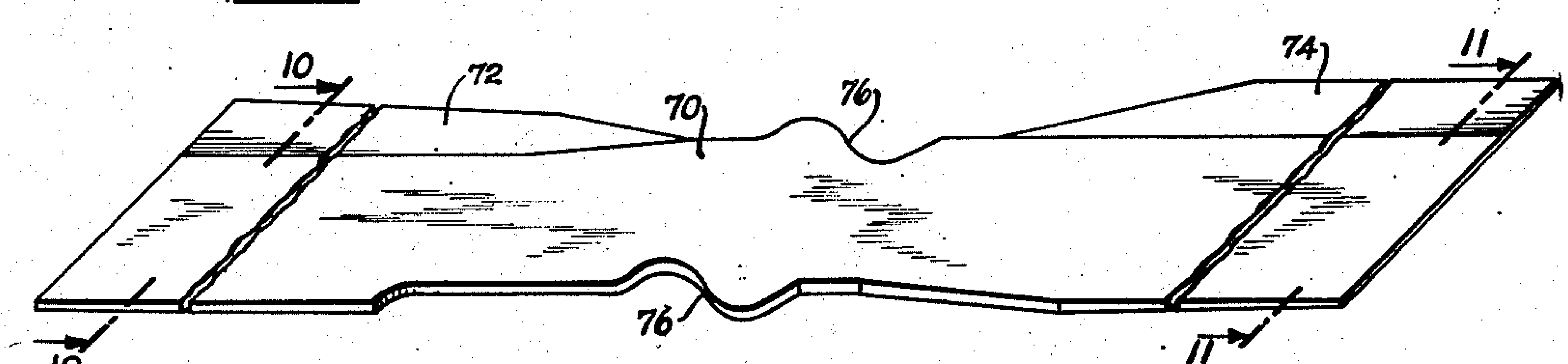

Fig. 9

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TURBINE BLADE CONSTRUCTION

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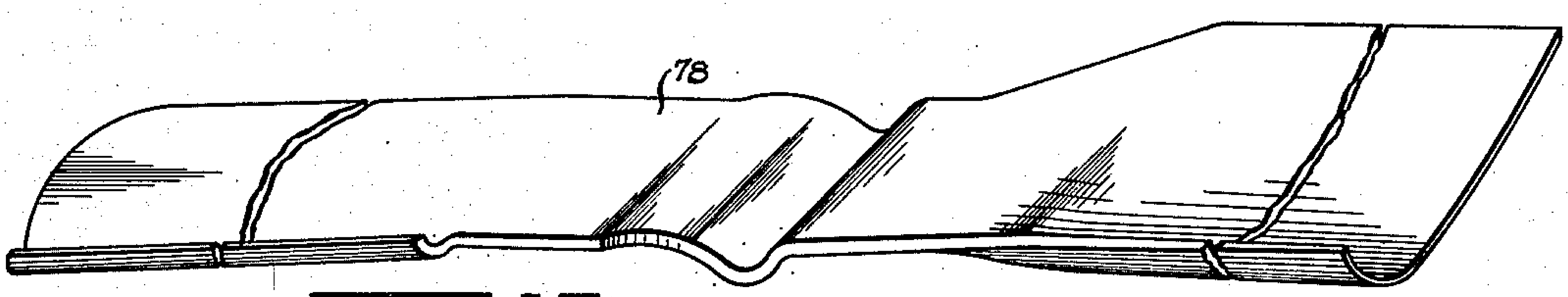

FIG. 12

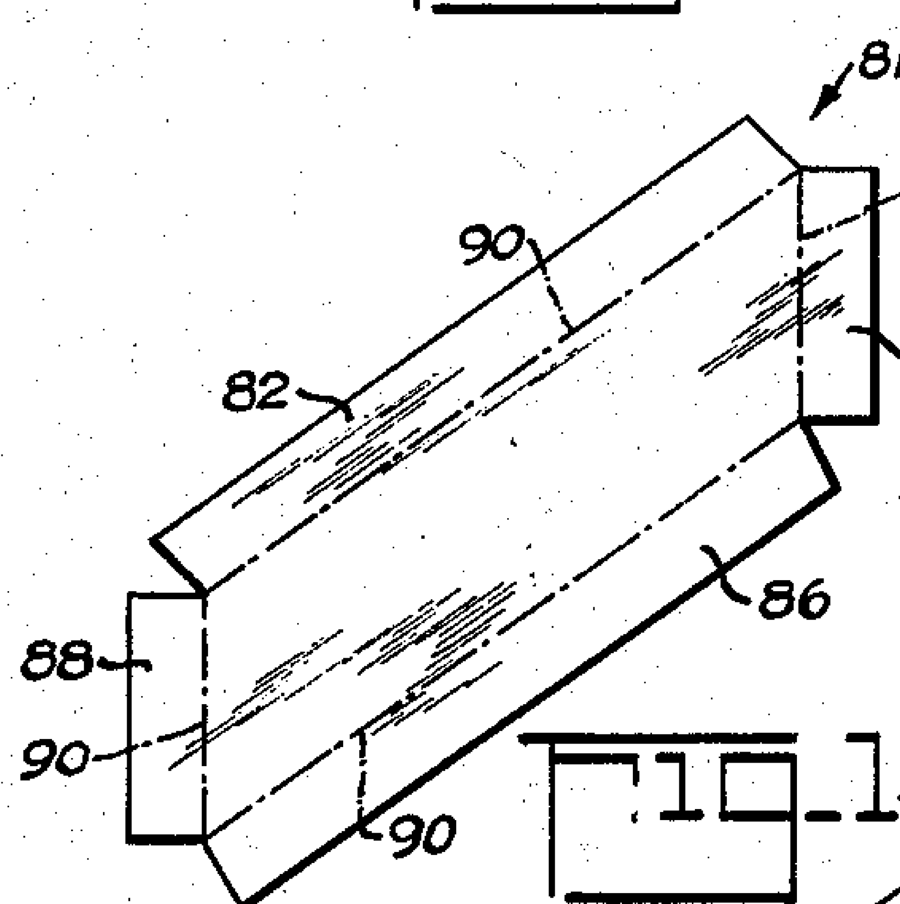

FIG. 14

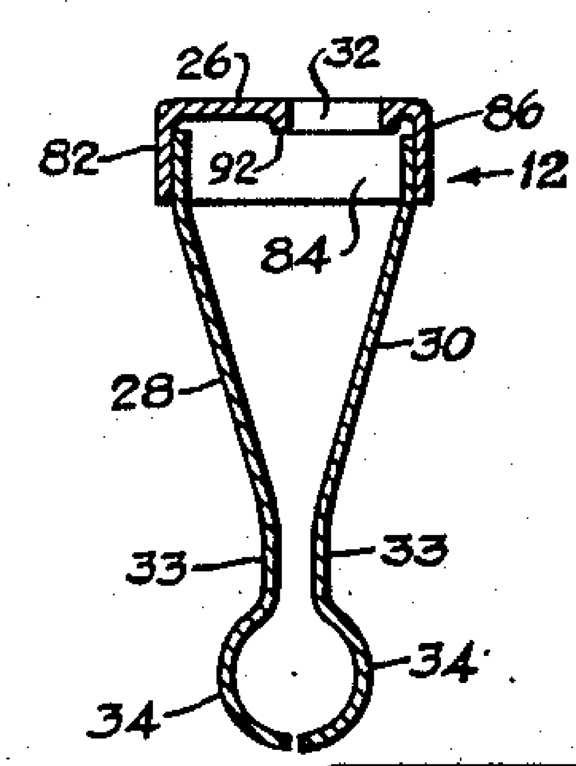

FIG. 17

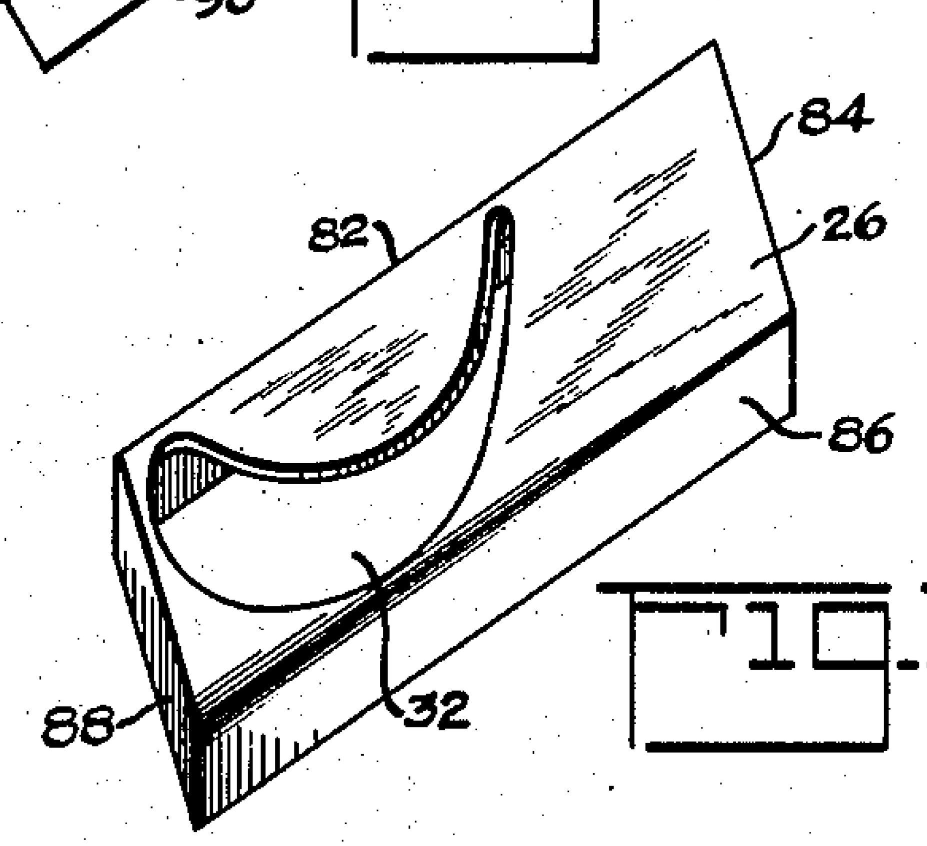

FIG. 15

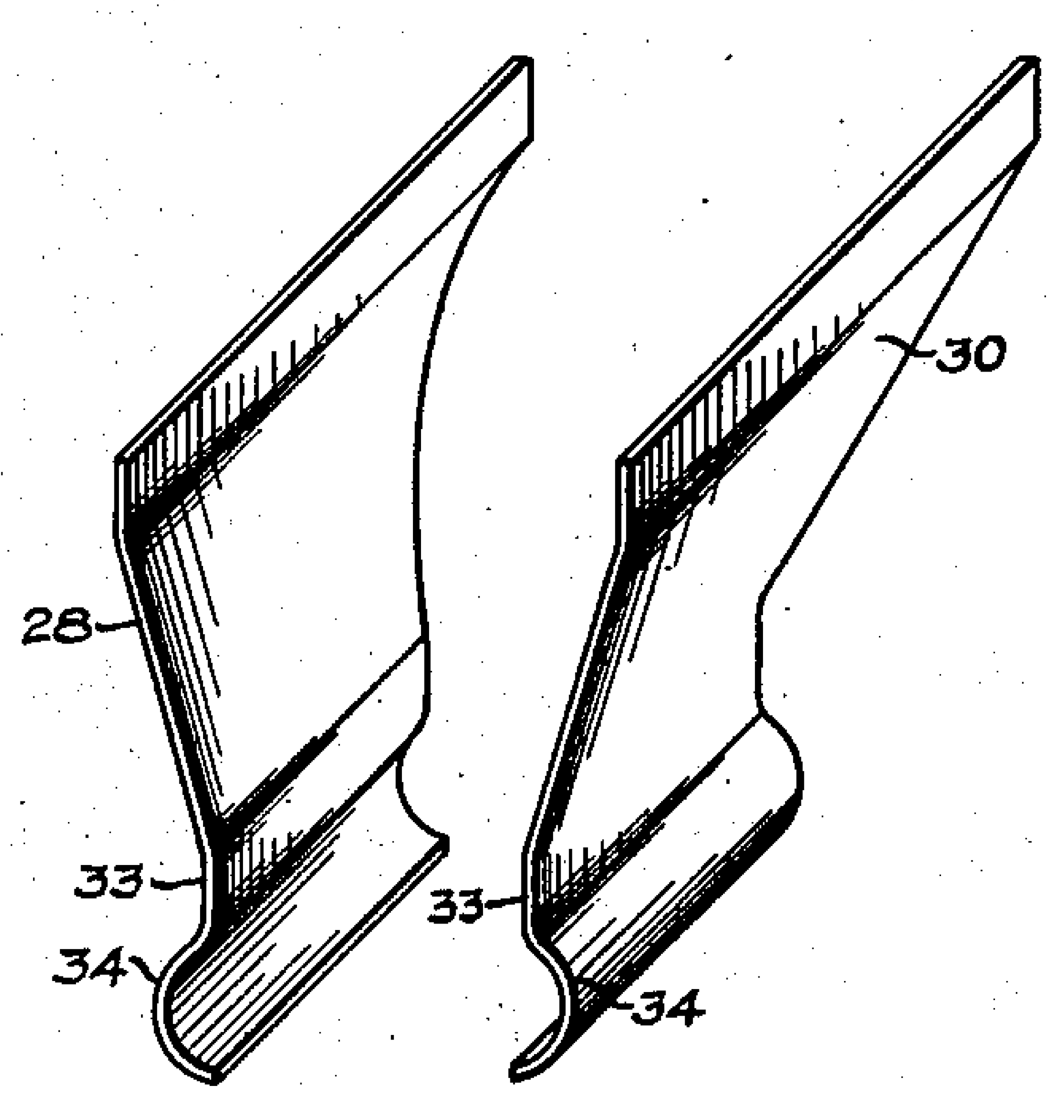

FIG. 16

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Patented Oct. 20, 1953

2,656,146

UNITED STATES PATENT OFFICE

2,656,146

TURBINE BLADE CONSTRUCTION

Ferdinand P. Sollinger, Paterson, N. J., assignor to Curtiss-Wright Corporation, a corporation of Delaware

Application April 8, 1948, Serial No. 19,743

10 Claims. (Cl. 253—39.15)

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This invention relates to rotor blades for turbines, compressors, blowers or the like, and to a method of making such blades. More particularly, the invention is directed to a novel sheet metal hollow blade and to a method of making said blades. The blade construction herein disclosed is designed for use as a turbine rotor blade. Obviously, however, the invention is also applicable to blades for compressors, blowers and like devices.

The blades of turbines are commonly provided with a shelf portion abutting the shelf portions of adjacent blades to define an annular boundary for the turbine motive fluid. An object of this invention comprises the provision of a blade construction and a method of fabricating same whereby the main and shelf parts of each blade are made separately and then assembled together. This procedure permits the construction of a strong and economical blade.

It is also common practice to make turbine blades hollow for reducing the weight of the blades and for permitting the flow of a cooling medium through the blades. A further object of this invention resides in the provision of a novel method of making a hollow blade and in the structure of the blade per se.

Specifically the invention comprises a hollow sheet metal blade made in two parts, a blade shelf part and a blade main part, both said parts being formed of sheet metal material. The shelf part of the blade is provided with a split shank to permit spreading of the sides of said shank so that the working portion of the blade main part may be inserted between said sides and through a hole in the deck of the shelf part, said hole being shaped to correspond to the profile of the adjacent working portion of the blade when said two parts are assembled. In addition, each blade main part is made from an elongate strip of sheet-like material by forming each end of said strip to the profile and shape of one face of the desired blade, and folding said strip about an axis disposed across the center of said strip and disposed transverse to the long dimension of said strip, so as to bring the longitudinal edges of one end of said strip adjacent the longitudinal edges of the other end of said strip. Said adjacent edges are then secured together, as by welding, to form the leading and trailing edges of the blade. This construction permits easy control of the grain flow lines in the blade material thereby permitting the construction of a blade which is both strong and light in weight. Preferably, the shank portion of each blade is formed so as to have an

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external key-hole-like profile thereby permitting said blade to be secured in a key-hole-like slot formed in the periphery of a turbine rotor.

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

Figure 1 is an exploded perspective view illustrating a portion of a turbine rotor with a turbine rotor blade embodying the invention, said figure also illustrating the method of securing said blade to said rotor;

Figure 2 is an exploded perspective view illustrating the main and shelf parts of a blade and the method of assembling said blade parts;

Figure 3 is a perspective view, partly in section, of the completed blade assembly;

Figures 4 and 5 are sectional views respectively taken along lines **4—4** and **5—5** of Figures 1 and 3 and also illustrating the adjacent blades;

Figure 6 is a perspective view of a spreader member for use in connection with an internal baffle member controlling the flow of a heat exchange medium through a blade;

Figure 7 is a perspective view of an elongate strip of sheet material cut and formed so that said strip can be folded about a cylindrical pin into a baffle member for disposition within a turbine rotor blade.

Figure 8 is a perspective view, partly in section, of a baffle member with its spreader member disposed therein;

Figure 9 is a perspective view of an elongate strip of sheet metal material from which the main part of the blade is formed, said material being cut and machined to the proper size;

Figures 10 and 11 are sectional views taken along lines **10—10** and **11—11** of Figure 9;

Figure 12 is a perspective view of the material of Figure 9 after each half of said material has been formed to the profile of one face of the blade;

Figure 13 is a perspective view, partly in section, illustrating the completed main part of a blade;

Figure 14 is a plan view of flat sheet metal material from which the deck of the shelf part of the blade can be formed therefrom;

Figure 15 is a perspective view of the deck of a blade shelf part;

Figure 16 is a perspective view illustrating, in side-by-side relation, the two halves of the shank of the blade shelf part; and

Figure 17 is a sectional view illustrating a completed shelf part of a blade.

Referring first to Figures 1 and 2 of the drawing, a blade 10 embodying the invention comprises a shelf part 12 and a main part 14 adapted to be assembled together and secured in key-hole-like slots 16 in a turbine rotor 18. Preferably and as illustrated, the slots 16 extend across the periphery of said rotor 18 in a direction inclined to the axis of said rotor such that said slots are substantially parallel to a line joining the leading and trailing edges 20 and 22 respectively at the inner end of the working portion 24 of the blade 10. Obviously, however, said slots 16 may be otherwise inclined, for example they may be disposed parallel to the axis of the rotor 18.

By "working portion" 24 of a blade 10 is meant that portion of said blade which reacts with the fluid. For example, in the case of a compressor or blower, the working portions of their blades act against the fluid while, in the case of a turbine, the working portions of the blades are acted against by said fluid.

The blade shelf part 12 of each blade 10 is formed as hereinafter described and comprises a deck 26 with a pair of spaced arms 28 and 30 extending from said deck to form the side walls of a split shank construction for said shelf part. As best seen in Figure 4, each deck 26 has a width and a shape such that it substantially abuts the decks 26 of the adjacent blades to form a continuous inner annular boundary for the fluid with which the blades 10 react. In addition, each deck 26 is provided with a hole 32 through which the working portion 24 of its associated blade main part 14 is inserted as hereinafter described. The shank arms or side walls 28 and 30 of each shelf part 12 converge to a reduced width portion 33 adjacent its shank end and each arm or side wall terminates in a hollow semi-cylindrical portion 34 facing a corresponding semi-cylindrical portion 34 on the end of the other arm or side wall. Accordingly, the split shank end of each blade shelf part has a hollow key-hole-like profile and said profile is such as to fit the key-hole-like slots 16 in the rotor 18.

The blade main part 14 of each blade 10 is formed as hereinafter described. Said main part 14 comprises an elongate strip of metal in which the two ends of said strip comprise the faces or working portion 24 of the blade and an intermediate length of said strip, between said ends, forms the shank 36 of said main part 14. Like the split shank of the shelf part of each blade 10, the shank 36 of its main part 14 also has a key-hole-like profile and said profile is adapted to fit within the internal key-hole-like profile formed by the facing sides of the ends of the arms 28 and 30. Thus, the shank 36 of each blade main part 14 has a reduced width section 38 and terminates in a hollow cylindrical or tubular end portion 40. The tubular end portion 40 of each blade main part 14 is adapted to be co-axially fitted between the semi-tubular ends 34 of the arms 28 and 30 of its shelf part 14 with the reduced width section 38 of said main blade part 14 fitted between the reduced width portion 33 of said arms 28 and 30. In addition, and as illustrated, each blade main part 14 of a turbine blade 10 is hollow and may have an opening 42 in the leading edge of its shank 36 for the admission of a suitable cooling medium into said turbine blade 10.

The shelf and main parts of a blade 10 are assembled as indicated in Figure 2. Thus the shank side walls or arms 28 and 30 of the blade shelf part 12 are spread apart, as indicated by the arrows 44 and 46, and the blade main part 14 is inserted between said side walls or arms and, as indicated by the arrow 48, said main part 14 is inserted through the hole 32 in the deck 26, until its tubular end 40 is received between the semi-tubular ends 34 of the blade shelf part 12. The profile of the hole 32 is such that when a blade 10 is thus assembled, the walls of said hole snugly fit about the adjacent portion of its blade main part 14. Although the pitch of the working portion 24 of each blade 10 progressively changes slightly from its deck 26 to its outer or tip end, as is conventional in turbine blades, the cross-section of said working portion progressively decreases from its deck 26 to its tip end, thereby permitting insertion of a blade main part 14 through the hole 32 in its deck 26.

After assembly of the shelf and main parts to form a completed blade 10, said blade is mounted on the rotor 18 by insertion of its composite shank end into a key-hole-like slot 16 in the rotor 18 and then a pin 50 is driven into the tubular end 40 to securely anchor the blade in position on the rotor 18. Each blade 10 is similarly constructed, assembled, and secured to the rotor 18. For simplicity, however, only one blade 10 is illustrated in Figure 1.

With the shank ends of the two parts 12 and 14 of each blade 10 secured and held together in a rotor slot 16, each said part tends to dampen resonant vibrations which may tend to occur in the other of said parts. If desired, the blade parts 12 and 14 of each blade 10 may be brazed, welded, or otherwise secured together along their abutting surfaces.

As previously mentioned, a suitable cooling medium may be introduced into the turbine blades through the openings 42 in their blade shanks. To facilitate cooling of the blades, a baffle member 52 is preferably disposed within each blade. For reasons of clarity, said baffle member is not illustrated in Figures 1 and 2 although it would be visible through the opening 42 in the shank of the blade.

Referring now to Figures 3 to 6 inclusive, the baffle members 52 have a profile similar to but smaller than the internal profile of the blade main parts 14 in order to leave a space therebetween for flow of the cooling medium radially outwardly through each blade. Like the blade main part 14, each of the baffle members 52 has a shank portion 54 with a tubular end disposed around the pin 50. In addition, dimples 56 are formed in the baffle members to keep them spaced from the internal walls of the working portions 24 of their blades. Also, the baffle members 52 do not have openings corresponding to the openings 42 in the shanks of their respective blades, whereby, when a cooling medium is introduced into the blades 10, through said shank openings 42, each baffle member 52 confines said medium to flow through its blade along the space between said baffle member and the adjacent internal wall of the working portion 24 of its blade. In this way the baffle members 52 provide intimate contact between said cooling medium and the walls of the blades 10. Said cooling medium may discharge from the open tip or outer ends of the blades 10 into the fluid with which said blades react or the tips of all the rotor blades 10 secured to the rotor 18 may be connected together by a ring into which said cooling medium discharges.

If the blades 10 are used as air compressor blades instead of turbine blades, it may be desirable to pass a heating medium, instead of a cooling medium, through at least some of the blades in order to prevent formation of ice thereon.

In addition to the baffle members **52**, a spreader member **58** may be disposed within each blade **10** between the shank ends of its baffle member **52**. The function of each spreader member **58** is to keep the two faces of its associated baffle member from collapsing against each other under the action of the centrifugal forces acting thereon during rotor rotation. Each spreader member **58** is secured in position within its baffle member—for example by spot welding thereto or in any other suitable manner. Preferably the spreader members **58** are also of sheet metal construction and the outer surface of said members is fluted as indicated at **60** to provide said member with sufficient strength and rigidity to keep apart the faces of the baffle member **52**.

The baffle members **52** are each formed from an elongate strip of sheet-like material **62**, as illustrated in Figures 7 and 8. The two end halves of said elongate strip are cut and formed by suitable dies to a profile similar to but somewhat smaller than the internal profile of one of the faces of a blade main part **14**. In addition, said strip **62** is provided with the dimples **56** previously mentioned.

Then, a cylindrical pin **64** is disposed across the middle of the strip **62** transverse to the long dimension of said strip. Thereupon, said strip is folded about said pin so as to wrap a small central length of said strip **62** approximately 360° about said pin with the two ends of said strip extending laterally from said pin and with the longitudinal edges of each end of said strip disposed adjacent to the corresponding longitudinal edges of the other end of said strip, thereby forming a baffle member **52**. Prior to said folding operation, a spreader member **58** is disposed adjacent the pin **64** so that, upon folding said strip, said spreader member is disposed in position between the sides of the shank end **54** of the resulting baffle member **52**. Also, the longitudinal edges of one end of the strip **62** are preferably folded over the longitudinal edges of its other half, as indicated at **66** and **67** in Figure 8. The engaged longitudinal edges at **66** and **67** are preferably only frictionally clamped together so that relative sliding movements of said engaged edges, in response to vibration of its blade, tend to dampen said vibration. In addition, the spreader member **58** may be spot welded into position as indicated at **68**, Figure 8, and as previously mentioned.

As illustrated in Figures 9 to 13, each blade main part **14** is formed from an elongate strip of sheet-like material **70** in a manner similar to the method of forming the baffle members **52**. In Figure 9, the strip **70** is flat except its longitudinal edges **72** and **74** are slightly tapered on one side as illustrated in Figures 10 and 11 respectively. This tapered edge construction facilitates the subsequent formation of the relatively thin trailing edge of each blade **10**. The reason for the ogee curved edge portions **76** at the center of the two longitudinal edges of the strip **70** is hereinafter explained.

The two ends of the elongate strip **70** are each now formed by suitable dies to the profile and shape of one of the faces of a blade main part **14**. The resulting strip is indicated at **78** in Figure 12. The elongate strip **78** is then folded about a baffle member **52** and a pin **64** (assembled as in Figure 8) with said pin disposed across the center of said elongate strip and disposed transverse to the long dimension of said strip. This folding of a strip **78** is similar to the previously described folding of a baffle member strip **62** about a pin **64** except a completed baffle member **52** is disposed between said pin **64** and said strip **78**. Thus, a small central length of a strip **78** is wrapped approximately 360° about said pin **64** with the two ends of said strip extending laterally from said pin and with the longitudinal edges of each end of said strip being disposed adjacent to the corresponding longitudinal edges of the other end of said strip. This latter folding operation forms a hollow blade main part **14** with a baffle member **52** disposed therein. A small length of an adjacent pair of said longitudinal edges are spaced apart to form the opening **42** in the shank of said blade part. The remainder of said longitudinal edges of the two ends of the strip **78** are then welded or otherwise secured together to form the leading and trailing edges of a blade main part **14**, the welds at the leading and trailing edges of a blade **10** being indicated at **79** and **80** in Figure 4.

The pins **52**, used for anchoring the blades **10** to the rotor **18**, have a slightly larger diameter than the pins **64** in order to provide a tight fit between each blade and the walls of the rotor slot **16**. With this construction, the pins **64** are removed before each blade main part **14** and its shelf part **12** are secured to the rotor **18**, as described in connection with Figures 1 and 2. Alternatively, however, the size of the rotor slots **16** may be such that each blade **10** with its pin **64** may be tightly driven into a rotor slot **16**. A blade main part **14** with its internal baffle construction is best illustrated in Figures 3 and 13.

The ogee curved edge portions **76**, at the center of the two longitudinal edges of a strip **70**, are provided in order that the end faces of its subsequently formed tubular shank end **38** are parallel to the plane of the rotor disc **18** when said tubular shank end is disposed in a slot **16** in said rotor, said slots being inclined to the rotor axis. Obviously, however, if the slots **16** are formed parallel to the rotor axis, the ogee curved edges **76** would be replaced by straight edges parallel to the long dimension of the strip **70**.

At this point it should be noted that instead of forming each end of an elongate strip **70**, to the profile and shape of one face of a blade main part **14**, prior to the folding operation about a pin **64**, said forming operation may be performed after at least part of said folding operation.

Figures 14 to 17 inclusive, illustrate a method of forming the shelf parts **12** of the blades **10**. The deck **26** of each blade shelf part is formed from a flat piece of sheet-like material **81** cut to the shape illustrated in Figure 14. The edge portions **82**, **84**, **86**, and **88** of said flat sheet **80** are then folded along the dot-and-dash lines **90** to form a downturned flange around a deck **26**. In addition, the hole **32** is cut in the deck **26** to permit insertion of the blade main part therethrough as hereinbefore described. The shank of each blade shelf part **12** has a split construction and comprises the two side walls **28** and **30**. As illustrated in Figure 16 each side wall **28** and **30** is separately formed from sheet metal stampings. The shank side walls **28** and **30** of a blade shelf part **12** are illustrated, in the exploded view of Figure 16, prior to their assembly with a deck **26**. The ends of the side walls **28** and **30**, remote from their semi-tubular ends **34**, are secured to the flanges **82** and

86, respectively, of their deck 26, for example by welding. With this construction, each blade shelf part 12 has a deck 26 and a split shank comprising side walls 28 and 30.

Preferably the hole 32 in the deck 26 of each blade is formed with an inturn flange 92, as illustrated in Figure 17. With this flange construction, the centrifugal forces acting on each deck 26, during rotor rotation, tend to cause said flange 92 to grip tightly the adjacent portion of its associated blade main part 14. This flange construction has not been illustrated in Figure 3.

Since the side walls 28 and 30 of each blade shelf part 12 constitute continuations of the deck flanges 82 and 86 of said shelf part, each shelf part can readily be formed from a single piece of sheet-like material instead of from the three pieces illustrated in Figures 14 and 15. With the construction illustrated, however, the junction between the side walls 28 and 30 and the deck flanges 82 and 86 increases the rigidity of said deck.

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

I claim as my invention:

1. A rotor for compressors, turbines, blowers or the like: said rotor having a rim with a plurality of circumferentially spaced slots, each said slot extending at least part way across the periphery of said rotor rim and having a relatively wide portion radially inwardly of the rotor periphery; a plurality of blades each secured in one of said slots and extending radially outwardly therefrom, each of said blades comprising a shelf part and a main part, each blade shelf part having a deck and a split shank extending inwardly from said deck and terminating in facing semi-tubular portions, the sides of said split shank being fitted between the sides of one of said slots, each blade main part having its working portion projecting through the deck of its associated shelf part and having a shank disposed between the sides of the shank of its associated shelf part, the shank of each blade main part terminating in a tubular portion disposed between the facing semi-tubular portions of its associated shelf part; and a pin tightly fitted within the tubular portion the shank of each blade main part.

2. A hollow blade for the rotor of a turbine, compressor, blower or the like in which said rotor has a slot extending at least part way across the rotor periphery and said slot has a relatively wide portion radially inwardly of the rotor periphery: said blade comprising a main part and a shelf part; said shelf part having a deck with a pair of spaced arms extending from said deck and terminating in facing semi-tubular portions adapted to be received within said rotor slot; said main part comprising a single elongate strip of material in which the two faces of the working portion of said blade are formed by the two ends of said strip and the shank of said main part includes a tubular end formed by a length of said strip intermediate said two ends; said main and shelf parts being arranged with the working portion of said main part extending through the deck of said shelf part and with the shank of said main part disposed between said arms so that said tubular end is disposed between said semi-tubular portions.

3. A hollow blade as described in claim 2 in which the shank of said blade main part has an opening for the admission of a heat exchange medium therein.

4. A hollow blade as described in claim 2 in which the shank of said blade main part has an opening for the admission of a heat exchange medium therein; and a hollow baffle member disposed within said main part for confining said medium to flow over the interior surface of the working portion of said blade, said baffle member having a profile generally similar to that of said main blade part and comprising a single strip of material with the intermediate portion of said strip forming a tubular end of said baffle member concentrically disposed within the tubular end of said main blade part.

5. The method of making a rotor blade for turbines, compressors, blowers or the like: said method comprising the steps of forming a blade shelf part with a deck having a hole therethrough and a pair of spaced arms extending from said deck; forming a blade main part with a working portion and a shank; and inserting the working portion of said main part between said arms and through said deck hole only so far as to leave the shank of said main part between the sides of said split shank.

6. The method of making and securing a blade for a compressor, turbine, blower or the like, to a rotor having a slot across its periphery with said slot having an enlarged cylindrical portion radially inwardly of the rotor periphery: said method comprising the steps of forming a blade shelf part with a deck having a hole therethrough and with a pair of spaced shank arms extending from said deck and having facing semi-cylindrical shank ends; forming a main blade part with a working portion and a shank portion having a hollow cylindrical end of enlarged width relative to the adjacent part of said shank; inserting the working portion of said main blade part between said arms and through said deck hole so as to leave the hollow cylindrical shank end of said main blade part embraced by said semi-cylindrical shank ends; inserting the shank ends of said main and shelf blade parts into said rotor slot with said hollow cylindrical end and the embracing semi-cylindrical ends received within the enlarged cylindrical portion of said slot; and then driving a cylindrical pin into said hollow cylindrical shank end of the main blade part.

7. The method of making and securing a blade for a compressor, turbine, blower or the like, to a rotor having a slot across its periphery with said slot having an enlarged width tubular portion radially inwardly of the rotor periphery; said method comprising the steps of forming a blade shelf part with a deck having a hole therethrough and with a pair of spaced shank arms extending from said deck and having facing semi-tubular shank ends; forming a main blade part with a working portion and a shank portion having a hollow tubular end of enlarged width relative to the adjacent part of said shank portion; assembling the main and shelf blade parts with the shank portion of the main blade part disposed between the shank arms of the shelf blade part so that said semi-tubular ends of the shelf blade part embrace the hollow tubular shank end of the main blade part and with the working portion

of said main blade part projecting through said deck hole; inserting the shank ends of said main and shelf blade parts into said rotor slot with said hollow tubular end and the embracing semi-tubular ends received within the enlarged width portion of said slot; and then driving a pin into said hollow tubular shank end of the main blade part.

8. A hollow rotor blade for turbines, compressors, blowers, or the like; said blade comprising a main part and a shelf part; said shelf part having a deck with a pair of spaced arms extending from said deck and terminating in facing semi-tubular end portions; said main blade part comprising a working portion and a shank with said shank being disposed between said arms and having an end portion disposed between said semi-tubular end portions and with said working portion projecting through an opening in said deck, said main blade part working portion being hollow and said main blade part shank having an opening providing communication between the outside of the blade and the interior of said hollow working portion.

9. A blade for the rotor of a turbine, compressor, blower or the like in which said rotor has a slot extending at least part way across the rotor periphery and said slot has a relatively wide portion radially inwardly of the rotor periphery: said blade comprising a main part and a shelf part; said shelf part having a deck with a pair of spaced arms extending from said deck and terminating in facing semi-tubular portions adapted to be received within said rotor slot; said main part having a working portion and a shank terminating in a tubular portion; said main and shelf parts being arranged with the blade working portion of said main part projecting through said deck and with the shank of said main part disposed between said arms so that said tubular portion is disposed between said facing semi-tubular portions.

10. The method of making a rotor blade for turbines, compressors or the like: said method comprising the steps of forming a blade shelf part with a deck having a hole therethrough and with a pair of arms extending from said deck and having facing semi-tubular ends; forming a hollow blade main part with a working portion and a shank having a tubular end; and inserting the working portion of said main part between

said arms and through said deck hole only so far as to leave the tubular shank end of said main part between the semi-tubular ends of said arms; said hollow blade main part being made by the steps of forming an elongate strip of sheet-like material so that each end portion of said strip has a profile corresponding to one face of said blade such that when viewed from one side one end of said strip is mainly concave and the other end of the strip is mainly convex, folding said strip about an axis disposed across an intermediate length of said strip and disposed transverse to the long dimension of said strip so as to form said intermediate length into a tubular portion with the two ends of said strip extending laterally from the same side of said tubular portion whereby the shank of said blade main part has an external key-hole-like profile, said folding operation being sufficient to bring at least the major portion of the longitudinal edges of one end of said strip adjacent to the longitudinal edges of the other end of said strip, and securing said adjacent longitudinal edges together to form the leading and trailing edges of the working portion of said blade.

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