# United States Patent [19]

**Kydd**

[11] **3,736,071**

[45] **May 29, 1973**


[54] **BUCKET TIP/COLLECTION SLOT COMBINATION FOR OPEN-CIRCUIT LIQUID-COOLED GAS TURBINES**


[75] Inventor: **Paul H. Kydd**, Scotia, N.Y.

[73] Assignee: **General Electric Company**, Schenectady, N.Y.



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[21] Appl. No.: **93,057**

[52] **U.S. Cl.** ......................**416/97,** 416/217, 415/168

[51] **Int. Cl.** .......................**F01d 5/18**

[58] **Field of Search**......................416/90, 91, 92, 93, 416/95, 96, 97, 215, 217, 219, 232; 415/168, 116; 60/39.66



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*Primary Examiner*—Everette A. Powell, Jr.
*Attorney*—Richard R. Brainard, Paul A. Frank, Charles T. Watts, Leo I. Malossi, Frank L. Neuhauser, Oscar B. Waddell and Joseph B. Forman



[57] **ABSTRACT**

Bucket tip designs are shown for manifolding fluid discharge from open-ended coolant passages in a liquid-cooled gas turbine. The manifolded fluid (e.g., steam and excess water in a water-cooled system) is discharged from the trailing edge of the bucket and liquid content thereof is thrown into a collection slot located in register therewith in the wall of the casing.


**5 Claims, 6 Drawing Figures**

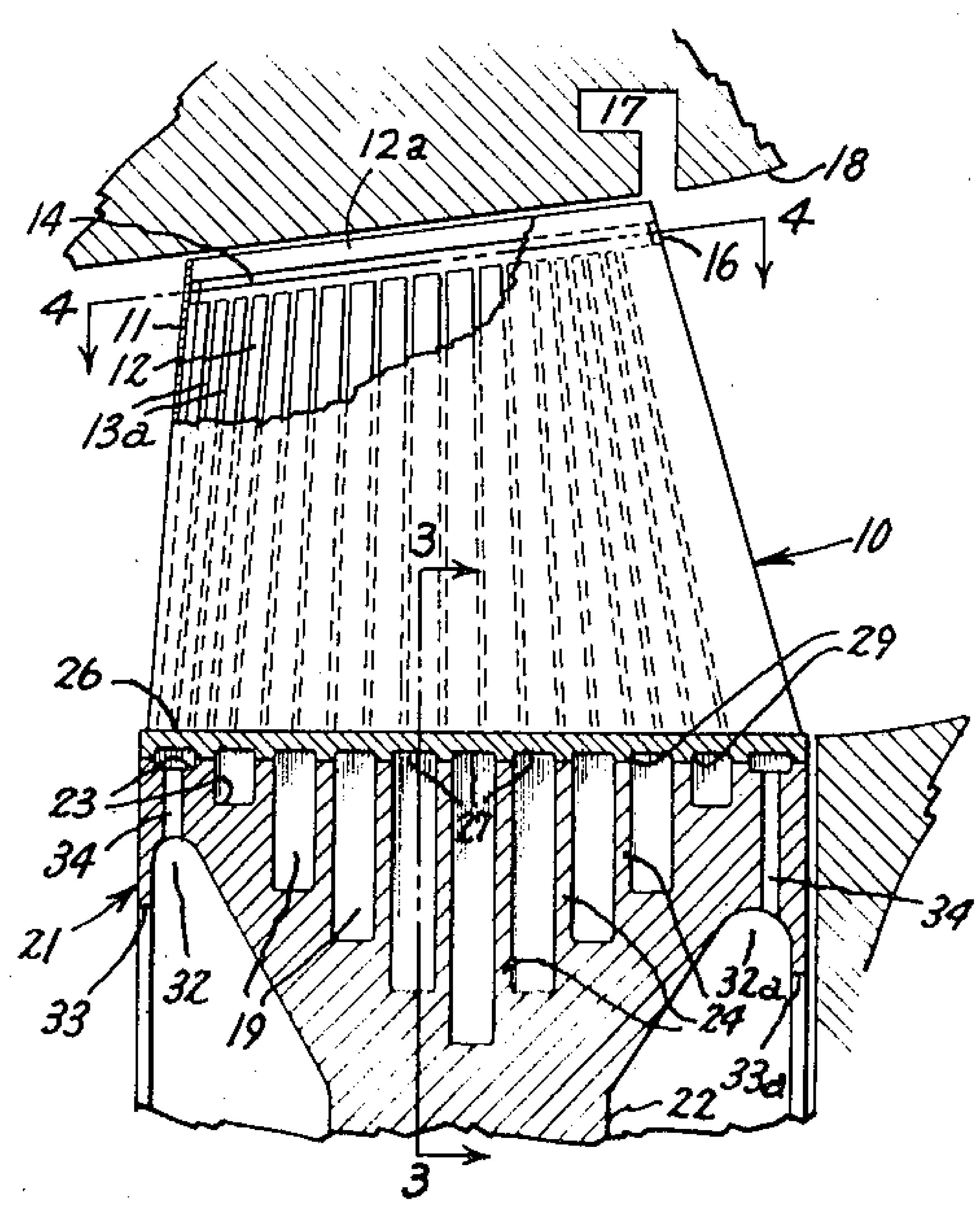


Fig. 1.

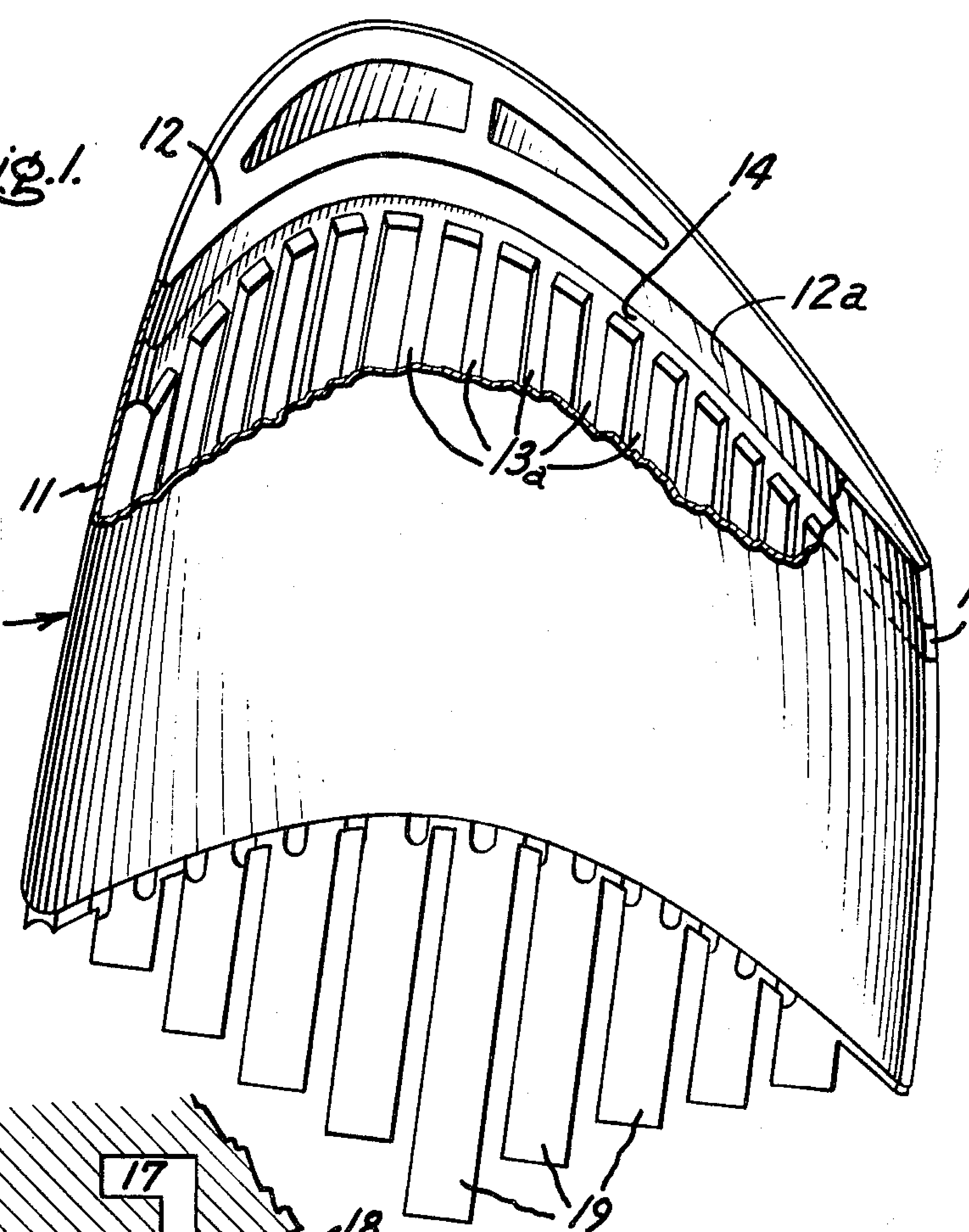
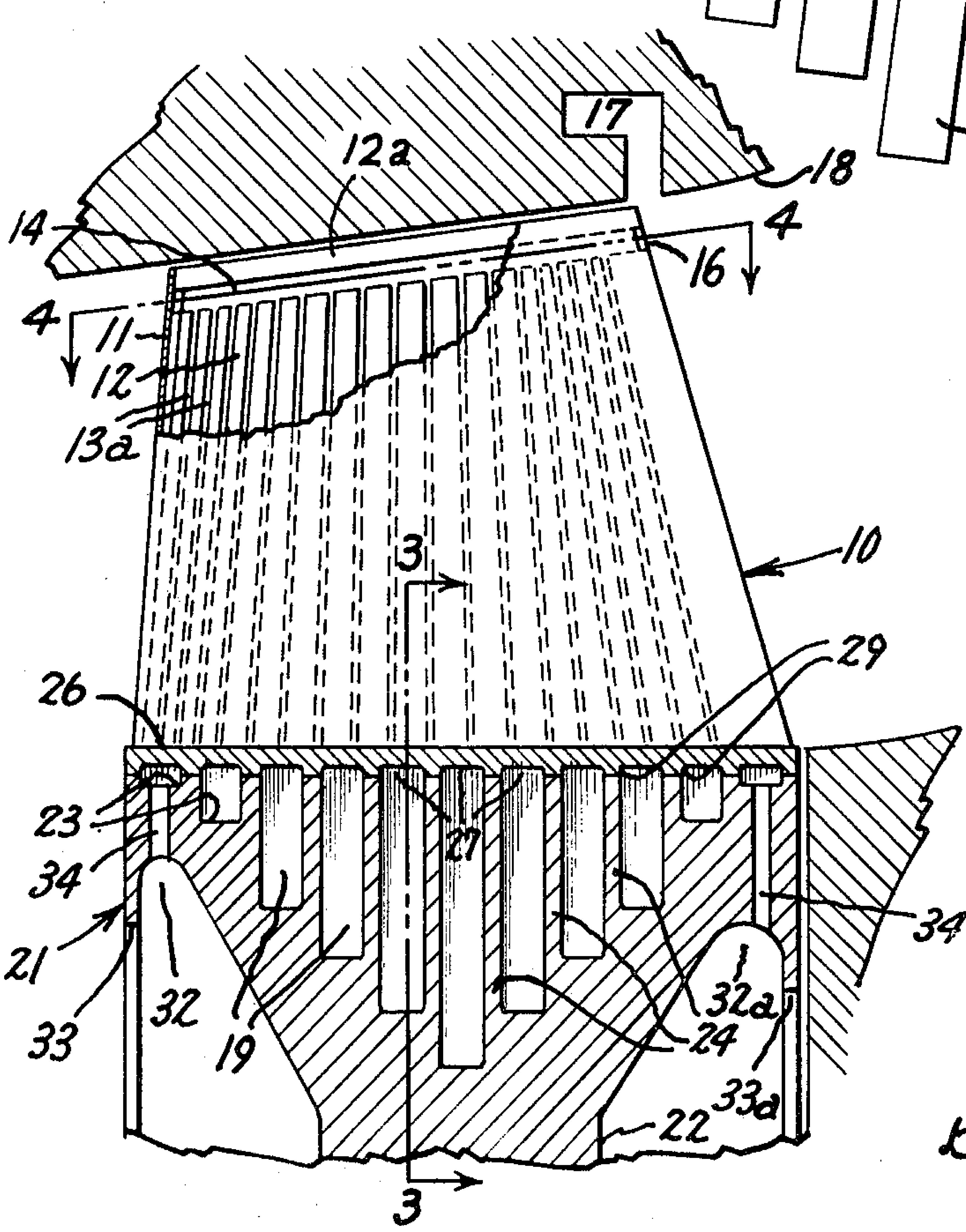



Fig. 2




Inventor:
Paul H. Kydd,
by Leo I. MaLossi
His Attorney.

Fig.3.

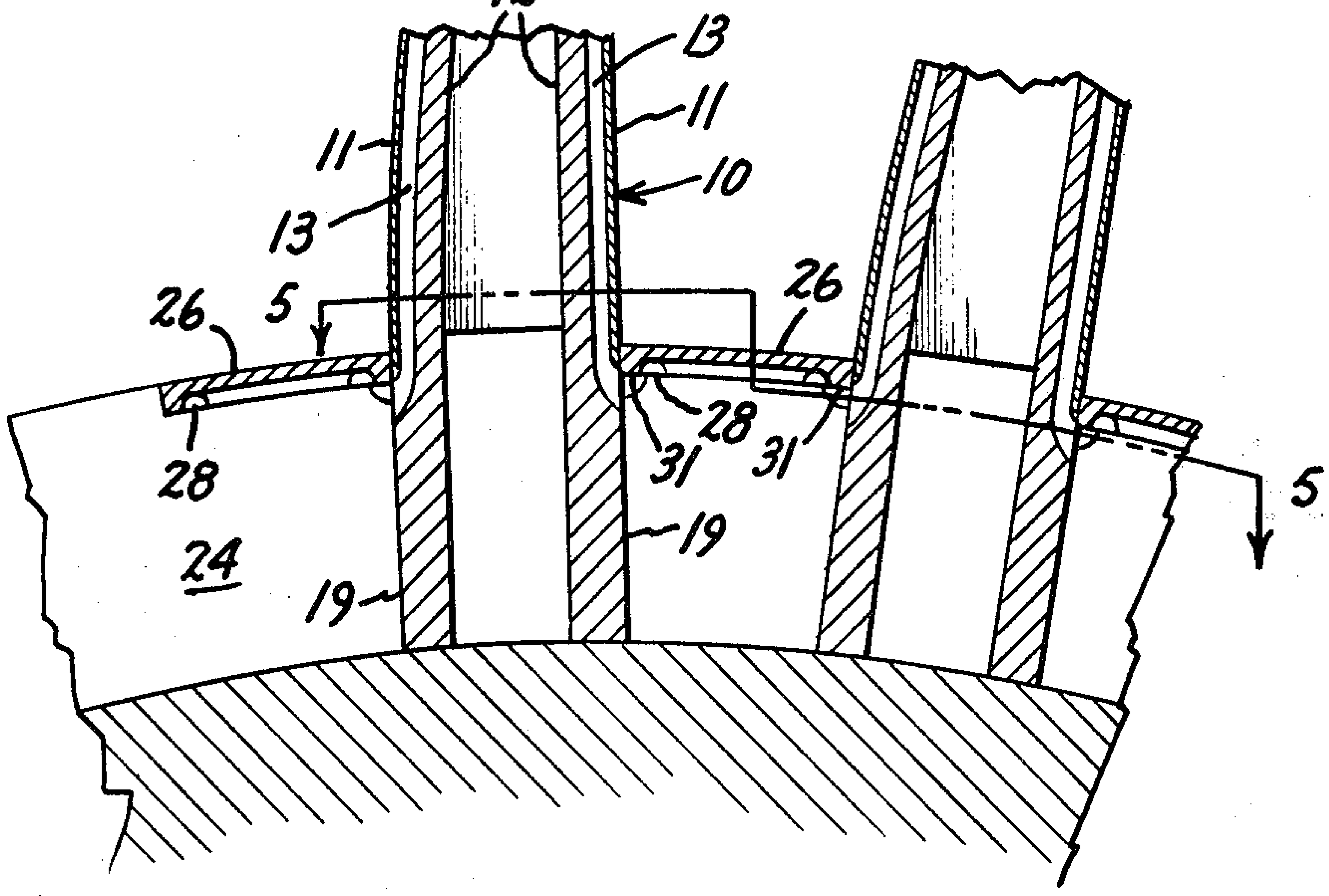
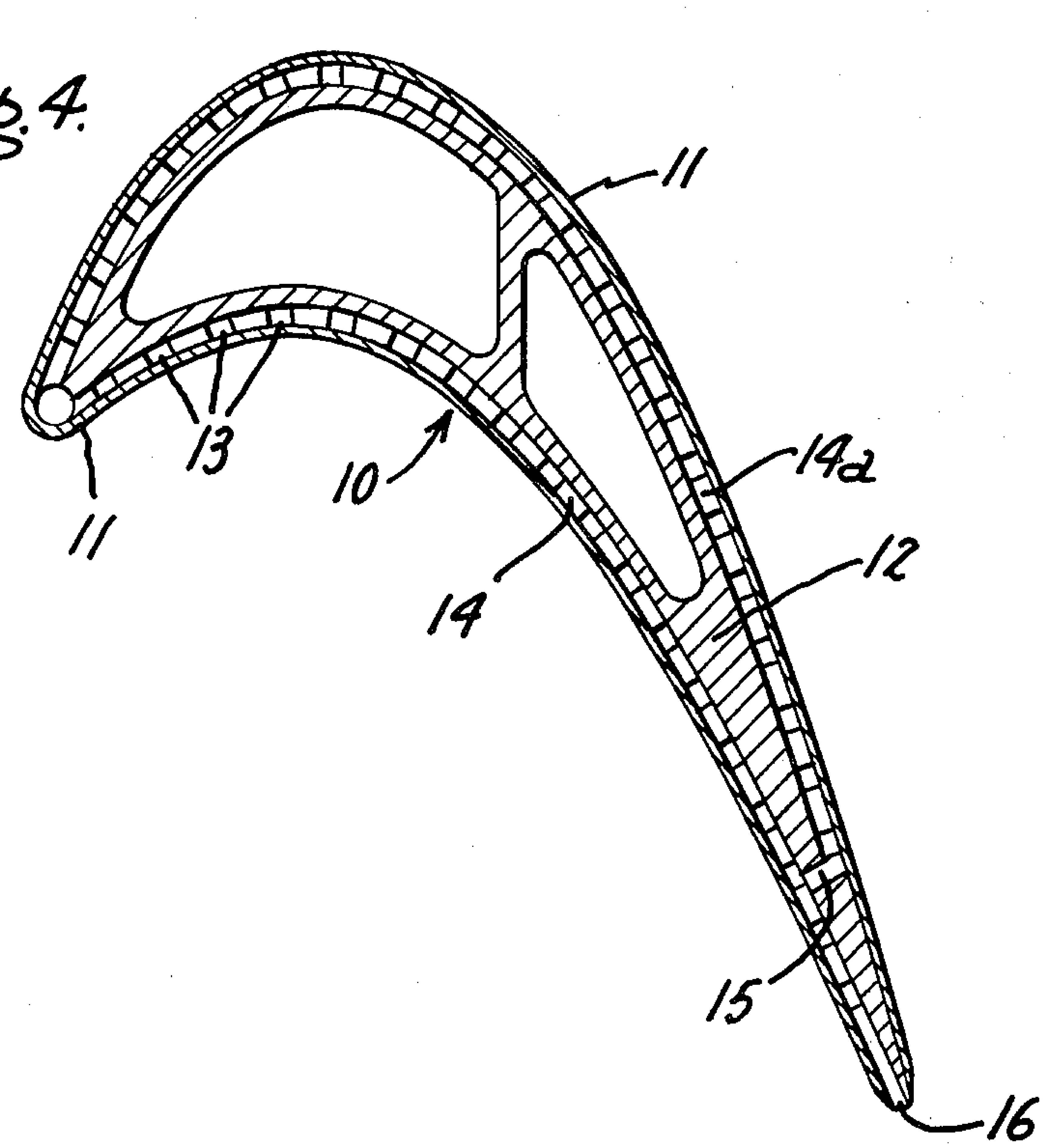



Fig.4.




Inventor:
Paul H. Kydd,
by Leo I. MaLossi
His Attorney.

Fig. 5.

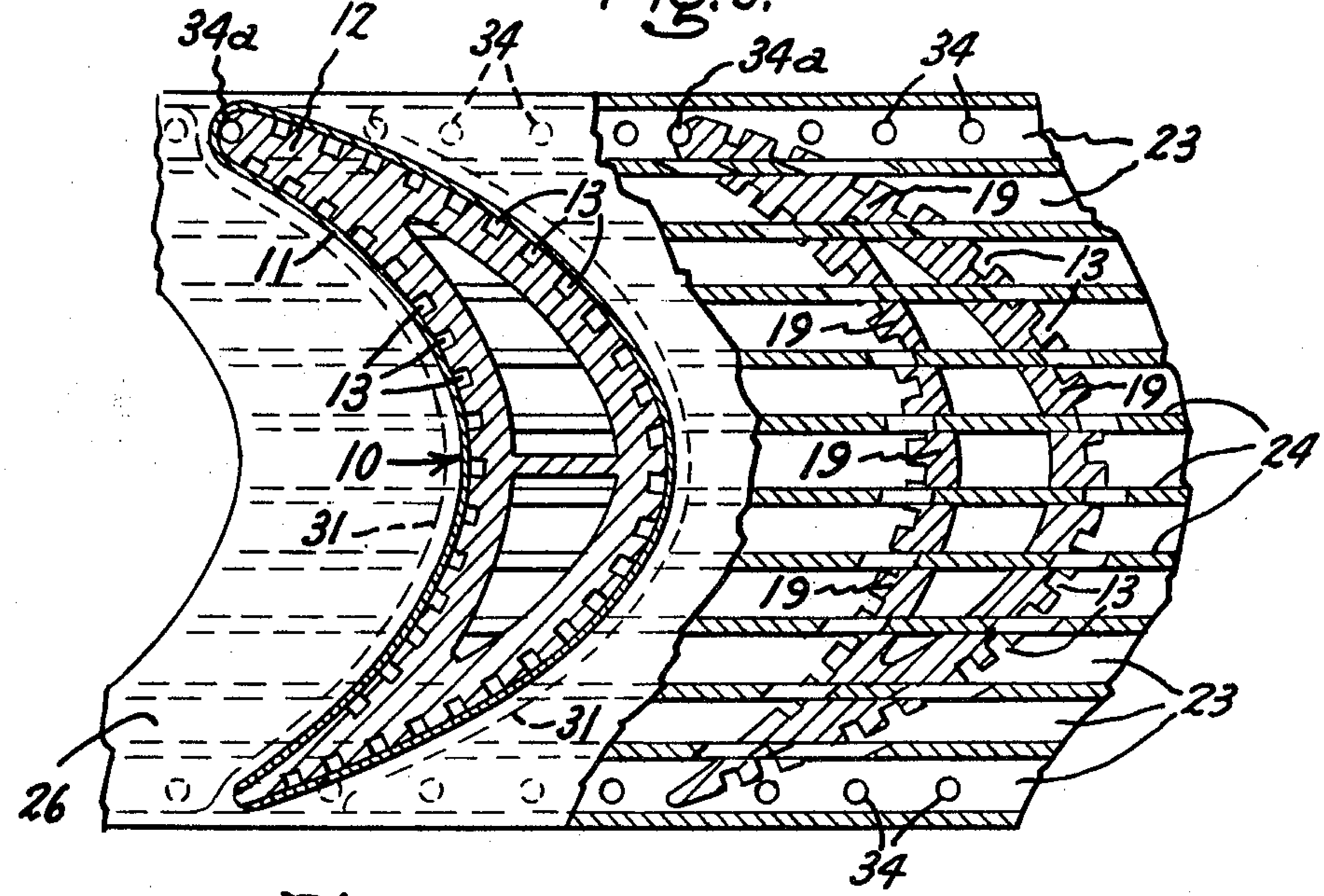
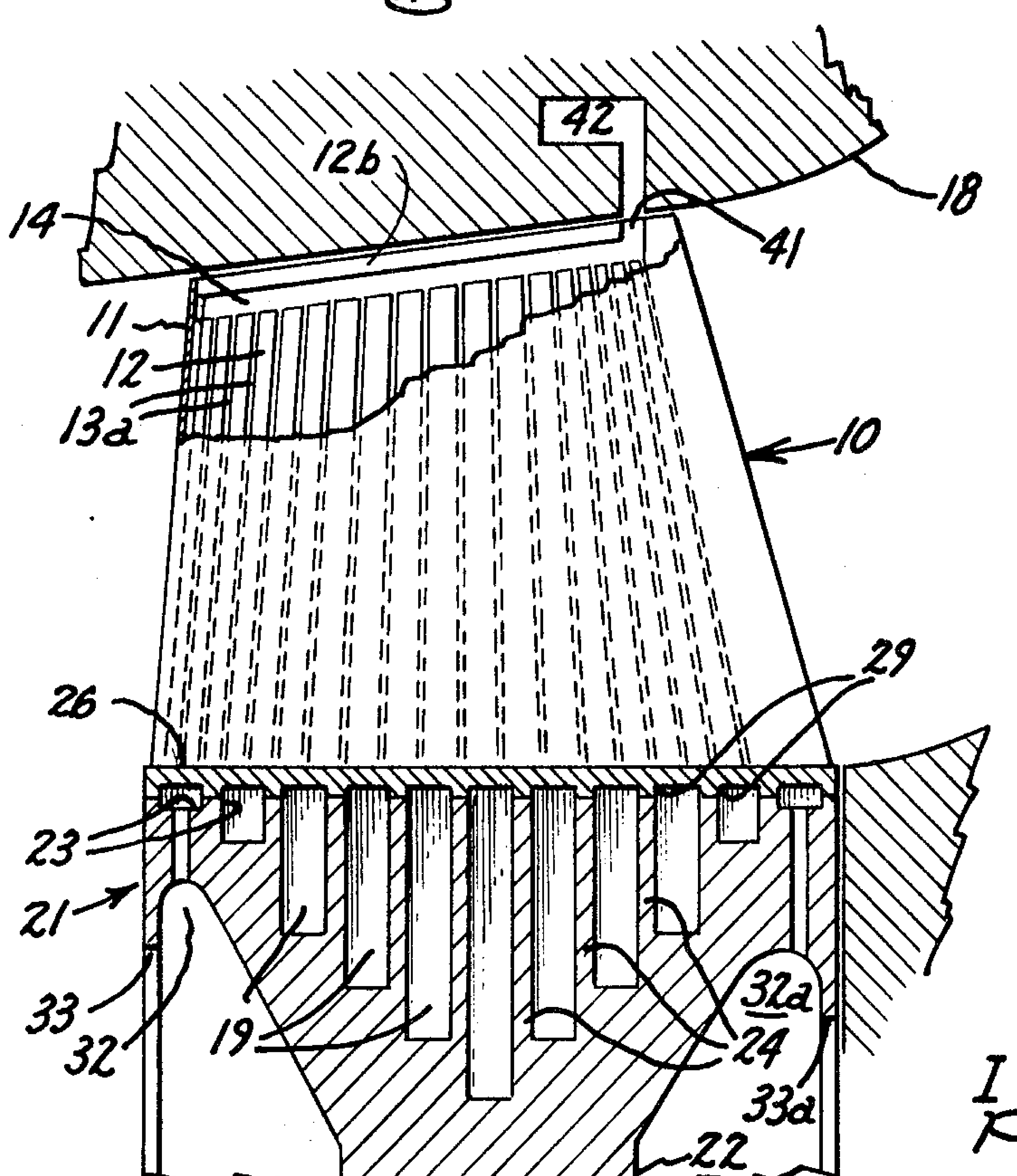



Fig. 6.




Inventor:
Paul H. Kydd,
by Leo I. MaLossi
His Attorney.

# BUCKET TIP/COLLECTION SLOT COMBINATION FOR OPEN-CIRCUIT LIQUID-COOLED GAS TURBINES

## BACKGROUND OF THE INVENTION

Structural arrangements for the liquid cooling of gas turbine buckets are shown in U. S. Pat. Nos. 3,446,481 — Kydd and 3,446,482 — Kydd. These patents are incorporated by reference.

The provisions for open-circuit liquid cooling disclosed therein are particularly importantfor the capability offered thereby for increasing the turbine inlet temperature to an operating range of from 2,500° F to at least 3,500° F thereby obtaining an increase in power output ranging from about 100 to 200 percent and in an increase in thermal efficiency ranging to as high as 50 percent. Such open-circuit liquid-cooled turbine structures are referred to as "ultra high temperature" gas turbines.

One problem arising in the operation of an unshrouded open-circuit liquid-cooled turbine in which there is a sizeable reaction at the bucket tip is that there is a substantial pressure difference (a) from inlet to outlet of the gas path (i.e., from bucket leading edge to bucket trailing edge] in the bucket tip region, (b) from one side of the bucket to the other and (c) from the root to the tip. The coolant passages shown in the Kydd patents extend radially of the buckets from below the surface of the platforms to the distal ends thereof and are open at both ends. During operation these coolant passages do not run full of liquid coolant due to centrifugal and coriolis forces. The problem that presents itself and that is solved by the instant invention is that since all of these coolant passages open at the inner ends thereof into a region of common pressure, when the outer ends of all of these same coolant passages open to the local ambient pressure at various locations around the bucket tip, hot gas will flow into some of these passages and this is hightly undesirable.

Although the problem can be minimized by making the tip clearance small enough, liquid coolant will pile up at the tip under certain conditions introducing an unwanted braking action and creating erosion problems. It would moreover be desirable to maintain tight clearances at the bucket tips.

## SUMMARY OF THE INVENTION

The instant invention provides a solution to the aforementioned problems while enabling operation of an open-circuit system with tight tip clearances at adequate liquid coolant flow. All the coolant passages are manifolded at each bucket tip placing a barrier between the open ends of the coolant passages and the hot gas stream and the hot colling fluids are redirected and discharged at the trailing edges of the buckets whereby liquid content thereof is thrown into an annular collection slot in register therewith in the casing wall to facilitate collection and recirculation of excess liquid coolant.

## BRIEF DESCRIPTION OF THE DRAWING

The exact nature of this invention as well as objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawings in which:

FIG. **1** is a three-dimensional view partially cut-away to display an open-circuit liquid-cooled turbine bucket having the manifolding and dischargeprovision of this invention;

FIG. **2** shows the manifolding and discharge features of this invention in combination with the annular collection slot;

FIG. **3** is a section taken on line **3—3** of FIG. **2**;

FIF. **4** is a section taken on line **4—4** of FIG. **2**;

FIG. **5** is an offset section taken on line **5—5** of FIG. **3** and

FIG. **6** is a second embodiment of the combination shown in FIG. **2**.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Turbine bucket **10** consists of a sheet metal skin **11** affixed (e.g., by brazing) to investment cast hollow core **12** having integral spanwise extending grooves **13*a*** formed therein. The rectangular cooling channels, or passages, **13** defined by skin **11** and grooves **13*a*** conduct cooling liquid therethrough at a uniform depth beneath skin **11**. At the upper ends thereof the rectangular cooling channels **13** on the pressure side of bucket **10** are in flow communication with and terminate at manifold **14**, which is shown recessed into core **12**. Manifold **14** (and, thereby, channels **13**) is separated from the tip of bucket **10** by the wall portion **12*a*** of core **12** extending chordwise thereof. On the suction side of bucket **10** rectangular cooling channels **13** are in flow communication with and terminate at manifold **14*a*** recessed into core **12**. A suction side wall portion (not shown) similar to wall portion **12*a*** separates manifold **14*a*** from the tip of bucket **10**. Near the trailing edge of bucket **10** the cross-over conduit **15** connects manifold **14*a*** to manifold **14**. Crossover **15** and the relation between manifolds **14**, **14*a*** is best seen in FIG. **4**.

Requisite open-circuit cooling from manifolds **14**, **14*a*** is insured by the presence of opening **16**, which provides for the exit of the heated cooling fluids (gas or vapor and excess liquid coolant) from manifold **14** at the trailing edge of bucket **10** as shown. Annular collection slot **17** formed in casing **18** receives the centrifugally directed ejected fluid for the eventual recirculation or disposal thereof.

By using this provision for manifolding and collecting of the coolant, the bucket tip/casing clearance can be made close and any excess liquid passing through bucket **10** will be thrown clear of the bucket into collection slot **17** avoiding any braking effect therefrom.

The trailing edge of the core **12** near the top is provided with cooling channels **13** on the pressure side only due to the thinness of the section. Several of the trailing edge cooling channels on the suction side are brought together at some point below manifolds **14**, **14*a***.

The root end of core **11** consists of a number of finger-like projections, or tines, **19** of varying length. These tines **19** may present a generally rectangular profile as shown or each tine may be tapered toward the distal end thereof to present a generally triangular profile. Rim **21** of turbine disk **22** has grooves **23** machined therein extending to various depths and having widths matching the different lengths and widths of bucket tines **19** such that tines **19** will fit snuggly into the completed grooves **23** in an interlocking relationship. Triangularly shaped bucket tine profiles provide for improved stress distribution of shear stresses in the joints between tines **19** and the walls of grooves **23** and of tensile stresses within the tines themselves.

Once the proper fit has been obtained, the appropriate amount of brazing alloy is placed in each groove **23** and the buckets are inserted and held in fixed position by a fixture. This fixture is biased to maintain a tight fit between tines **19** and grooves **23** regardless of thermal expansion. Conventional brazing alloys having melting points ranging from 700° to 1,100° C may be used. Single metals, such as copper, may also be used. This interlocking bucket/rotor disk construction is more completely described and claimed in U. S. Pat. application Ser. No. 93,058 — Kydd (incorporated by reference), filed Nov. 27, 1970 (now abandoned) and assigned to the assignee of the instant invention.

Thereafter, the assembly (the rim with all the buckets properly located) is furnace-brazed to provide an integral structure.

Steel alloys may be used for the skin and core, preferably those containing at least 12 percent by weight of chromium for corrosion resistance and heat treatable to achieve high strength.

The cutting of grooves **23** into rim **21** not only provides the requisite configuration for fastening the bucket root and lessens the weight of the rim, but in addition the ribs **24** between grooves **23** provide area on the upper surfaces thereof for attachment thereto of platform elements **26** having cooling channels **27** and **28** formed therein. The cooling channels **27** are in juxtaposition with grooves **23** and cooling channels **28** interconnect the cooling channels **27** as shown. The separating walls **29** between cooling channels **27** are dimensioned to coincide with the width of juxtaposed ribs **24**.

In preparing platform elements **26** the distal face of each wall **29** is ground to a radius common to the outer diameter of ribs **24** to enable the electron beam welding, or brazing, of separating walls **29** to the ribs **24**. Similarly, the distal face of each edge rib **31** is accurately ground to the radius of the outer diameter of the ribs **24** so that ribs **31** will provide a cylindrical surface facing radially inward, the elements of which extend in the axial direction. These cylindrical surfaces are presented alongside bucket **10** on each side thereof adjacent the cooling channels **13**. In operation these distal faces of edge ribs **31** will function as weirs over which the cooling fluid can distribute uniformly into the grooves **13*a*** leading to bucket cooling channels **13** of each bucket.

This weir construction, which is critical to effective metering of the coolant to the buckets is more fully described and is claimed in U. S. Pat. application Ser. No. 93,056 — Kydd (incorporated by reference) filed Nov. 27, 1970 (U.S. Pat. No. 3,658,439) and assigned to the assignee of the instant invention. As is explained therein all portions of those cylindrical surfaces receiving coolant from a common distribution path must be accurately located equidistant from the axis of rotation.

As is described in the aforementioned Kydd patents, cooling liquid (usually water) is sprayed at low pressure in a generally radially outward direction from nozzles (not shown but preferably located on each side of disk **22**) and impinges on disk **22**. The coolant thereupon moves into gutters **32, 32*a*** defined in part by downwardly extending lip portions **33, 33*a***. The cooling liquid accumulates in gutters **32, 32*a*** (cooling the rim portions with which it comes into contact) being retained therein until this liquid has been accelerated to the prevailing disk rim velocity.

After the cooling liquid in gutters **32, 32*a*** has been so accelerated, this liquid continually drains from gutters **32, 32*a*** passing radially outward through holes **34, 34*a*** of which holes **34** are in flow communication with the two outside grooves **23** (FIGS. **2** and **4**) in the regions between buckets **10**. As is shown in the aforementioned Kydd application Ser. NO. 93,056 holes **34*a*** communicate directly with the cooling channel at the leading edge of each of the buckets **10**, where the turbine buckets are exposed to the highest heat flux. Thus, some of the cooling liquid is provided directly to the leading edges of buckets **10** while the remainder of the coolant is introduced into the outside grooves **23** from which it is distributed via cooling channels **28** to the cooling channels **27**. As the coolant traverses all these surfaces of the platform elements **26**, these elements are kept cool. Thereafter, the coolant passes over the distal faces of edge ribs **31** in thin sheets into the radially inner ends of cooling channels **13** (via grooves **13*a*** projecting below the lower end of skin **11**) in adjacent buckets **10** and thence into and through the turbine buckets.

As the cooling liquid moves through cooling channels **13** of any given bucket **10** a large portion (or substantially all of the cooling fluid, depending upon the rate of flow) is converted to the gaseous or vapor state as it absorbs heat from the skin **11** and core **12** of the bucket. At the outer ends of cooling channels **13** the vapor or gas generated and any remaining liquid coolant pass into manifolds **14** and **14*a*** and is redirected to exit from the manifold system via opening **16** into collection slot **17** to complete the open-circuit cooling path.

FIG. **6** sets forth a modification of this invention wherein the fluid discharge is effected radially outward via hole **41** into annular collection slot **42**. In this embodiment as well the cross-over passage **15** is used to convey the fluid from manifold **14*a*** to manifold **14** in flow communication with slot **42**. Wall portion **12*b*** (and a similar wall portion, not shown, on the suction side) functions in the same way as wall portion **12*a*** serving to set apart the discharge ends of channel **13** from the hot gas stream and to direct the coolant flow to hole **41** for discharge therefrom.

What I claim as new and desire to secure by Letters Patent of the United States is:

**1.** In a gas turbine wherein a turbine disk is mounted on a shaft rotatably supported in a casing, said turbine disk extending substantially perpendicular to the axis of said shaft and having turbine buckets and platform means affixed to the outer rim thereof, said buckets receiving a driving force from a hot motive fluid confined within said casing and moving in a direction generally parallel to said axis of said shaft and the driving force being transmitted to said shaft via said turbine disk, means located radially inward of said platform adjacent said turbine disk for introducing liquid coolant within said turbine in a radially outward direction into open-circuit distribution paths by which said coolant traverses surface area of said rim and said platform means, passes into cooling channels in said buckets and exits from said channels in a radially outward direction, the improvement comprising:

a manifolding, discharge and collection system for the coolant fluid exiting from the coolant channels in the turbine buckets, said system consisting of

1. first and second interconnected manifolds located beneath the bucket surface near the tip of

each bucket in flow communication with the discharge ends of the coolant channels, said first and second manifolds being located on the pressure and suction sides of said bucket, respectively,

2. a single opening through the blade structure interconnecting said first manifold and the region of hot motive fluid flow within the casing near the trailing edge of said bucket, each of said manifolds being separated from the tip of said bucket by a wall formed in the bucket structure on the radially outward side of said manifold and extending generally chordwise of said bucket whereby coolant discharged radially from said coolant channels is redirected as required to reach said opening, and

3. liquid collection means located in the casing wall closely adjacent said trailing edge in register with said opening

whereby open-circuit flow conditions are maintained



with coolant fluid being discharged radially from said coolant channels into said manifolds, redirected and discharged from said first manifold through said opening into the hot motive fluid flow with excess liquid being thrown into said collection means.

**2.** The improvement of claim 1 wherein each of the manifolds consists of a slot formed in the bucket core and extending from leading edge to trailing edge, the two slots being interconnected near the opening by a passage extending through the separating bucket core material.

**3.** The improvement of claim 1 wherein the opening is in the trailing edge of the bucket.

**4.** The improvement of claim 1 wherein the opening is through the top of the bucket near the trailing edge.

**5.** The improvement in claim 1 wherein the root of each bucket is in the form of a plurality of spaced tines fitting between and bonded to the walls of annular grooves in the outer rim of the turbine disk.

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