May 8, 1956 M. S. ROUSH 2,744,723

CONTROLLED TEMPERATURE FLUID FLOW DIRECTING MEMBER

Filed Dec. 6, 1949

Fig. 1

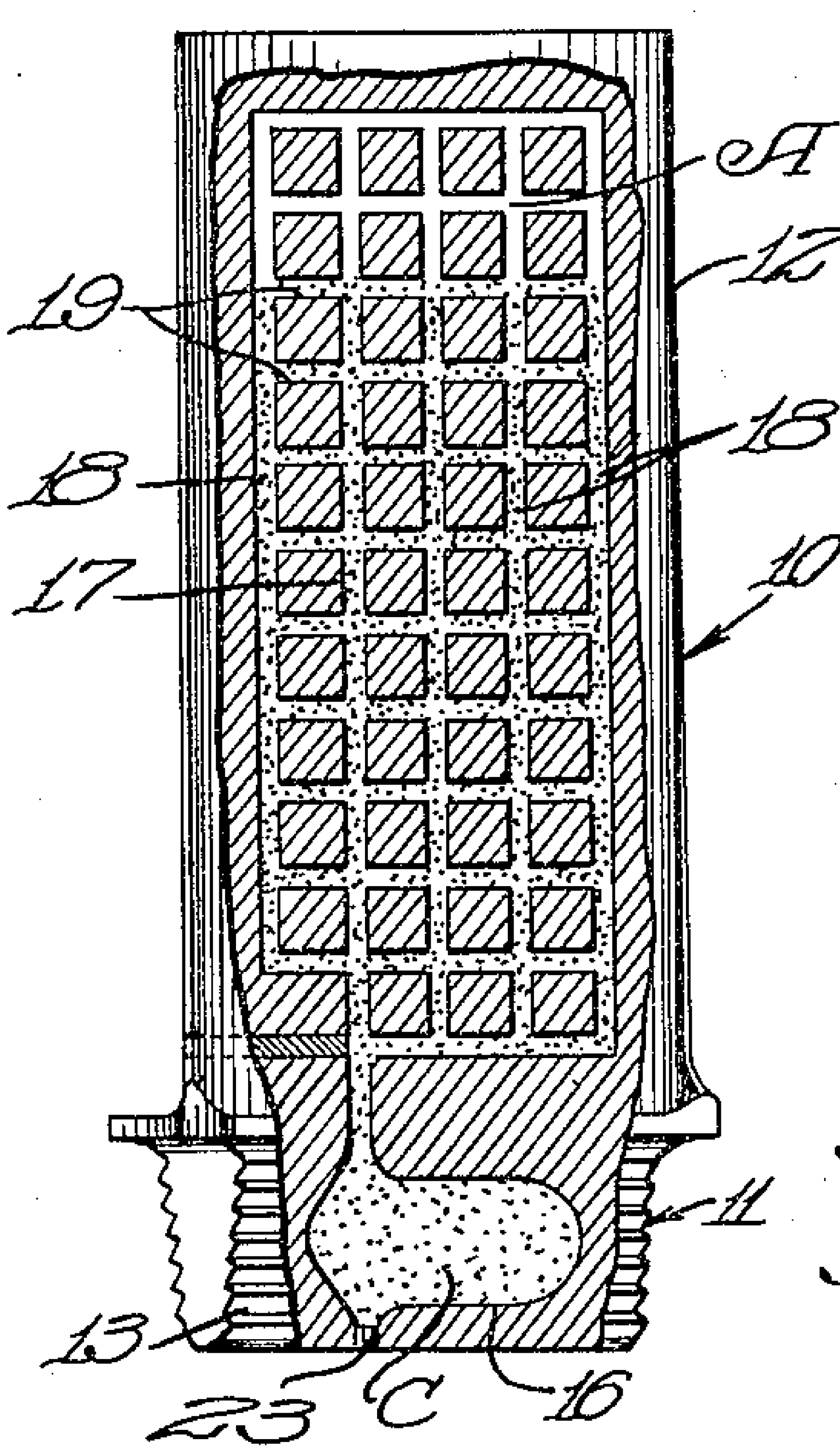


Fig. 2

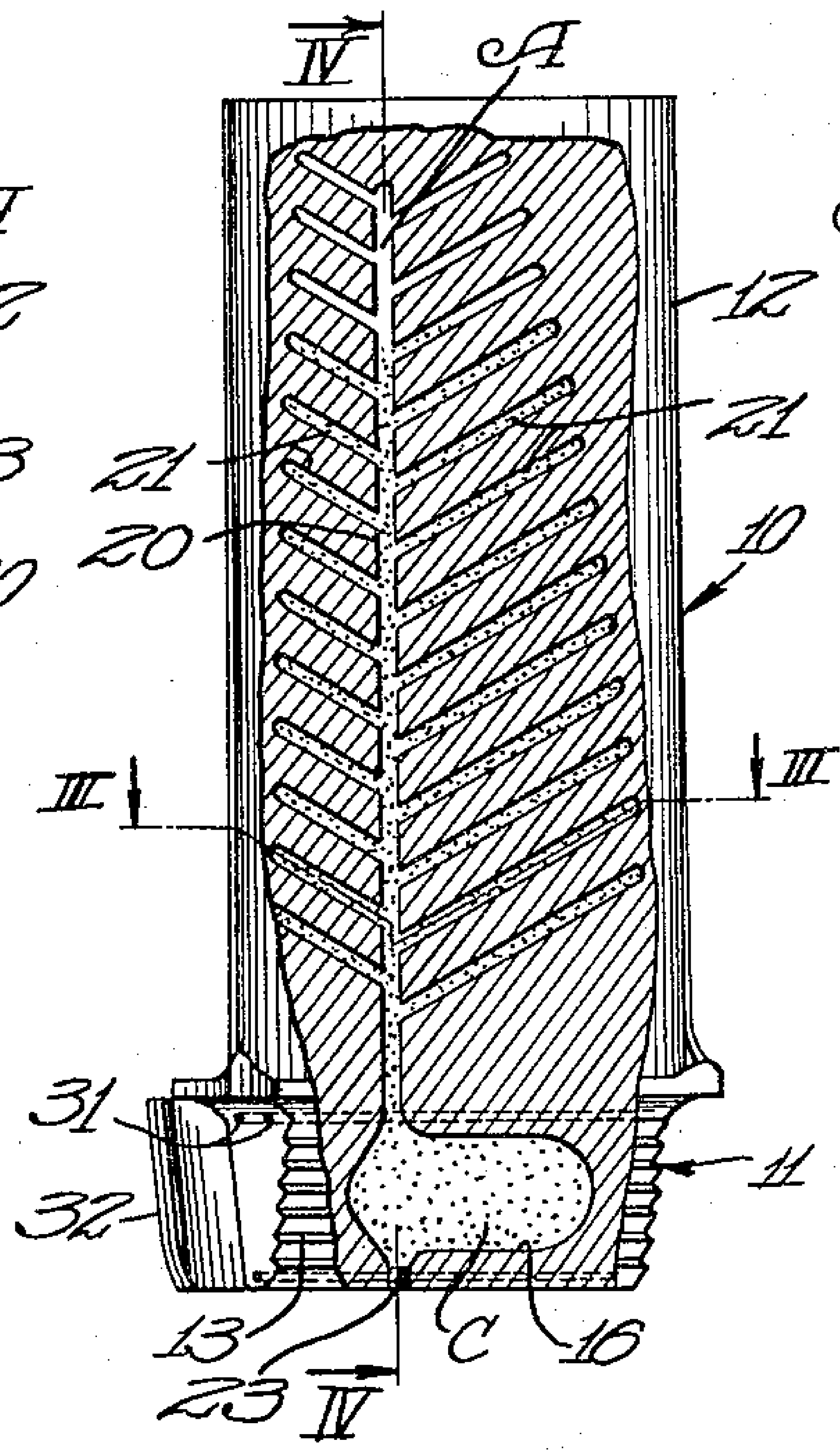


Fig. 4

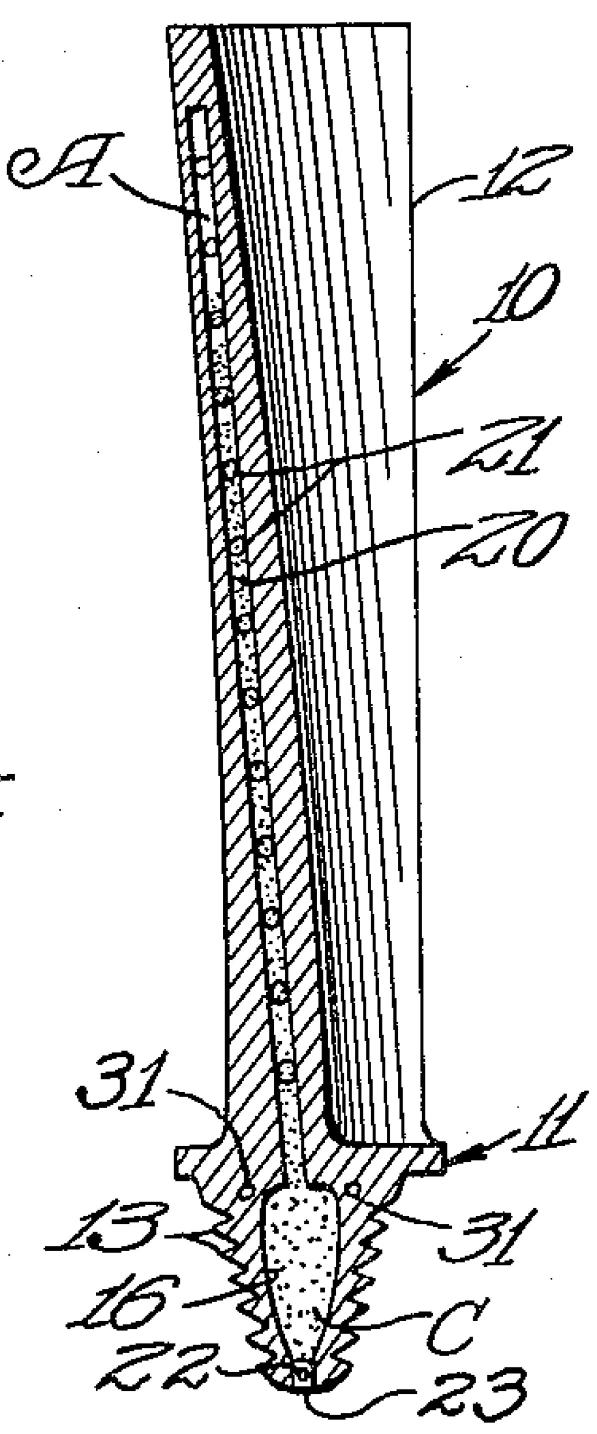


Fig. 3

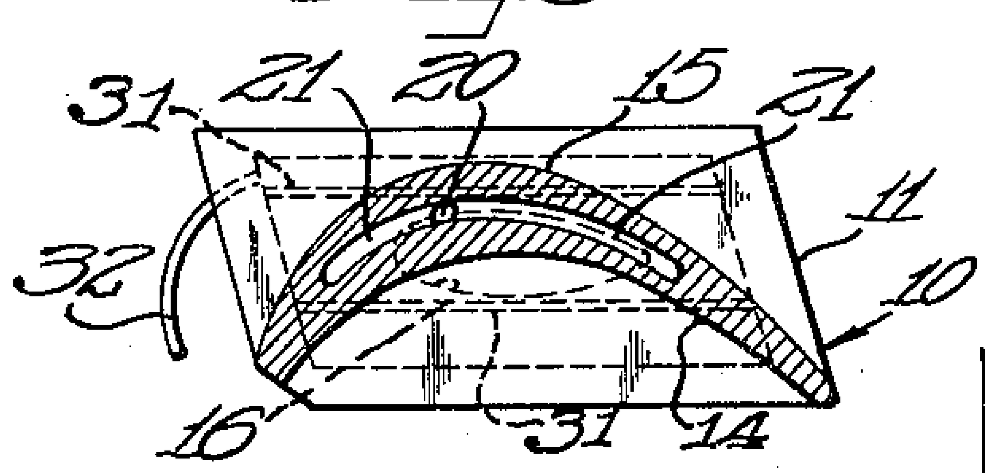


Fig. 5

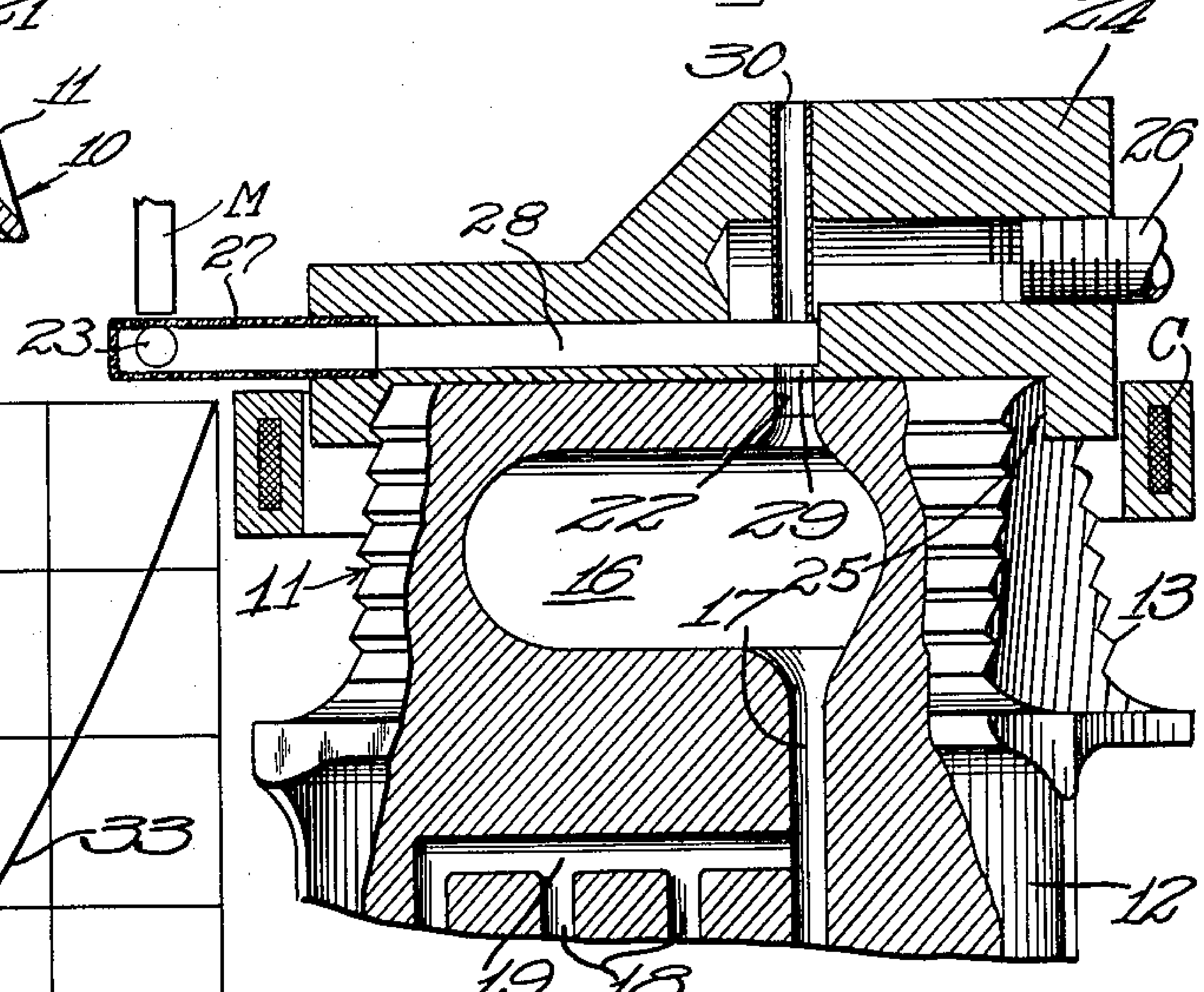
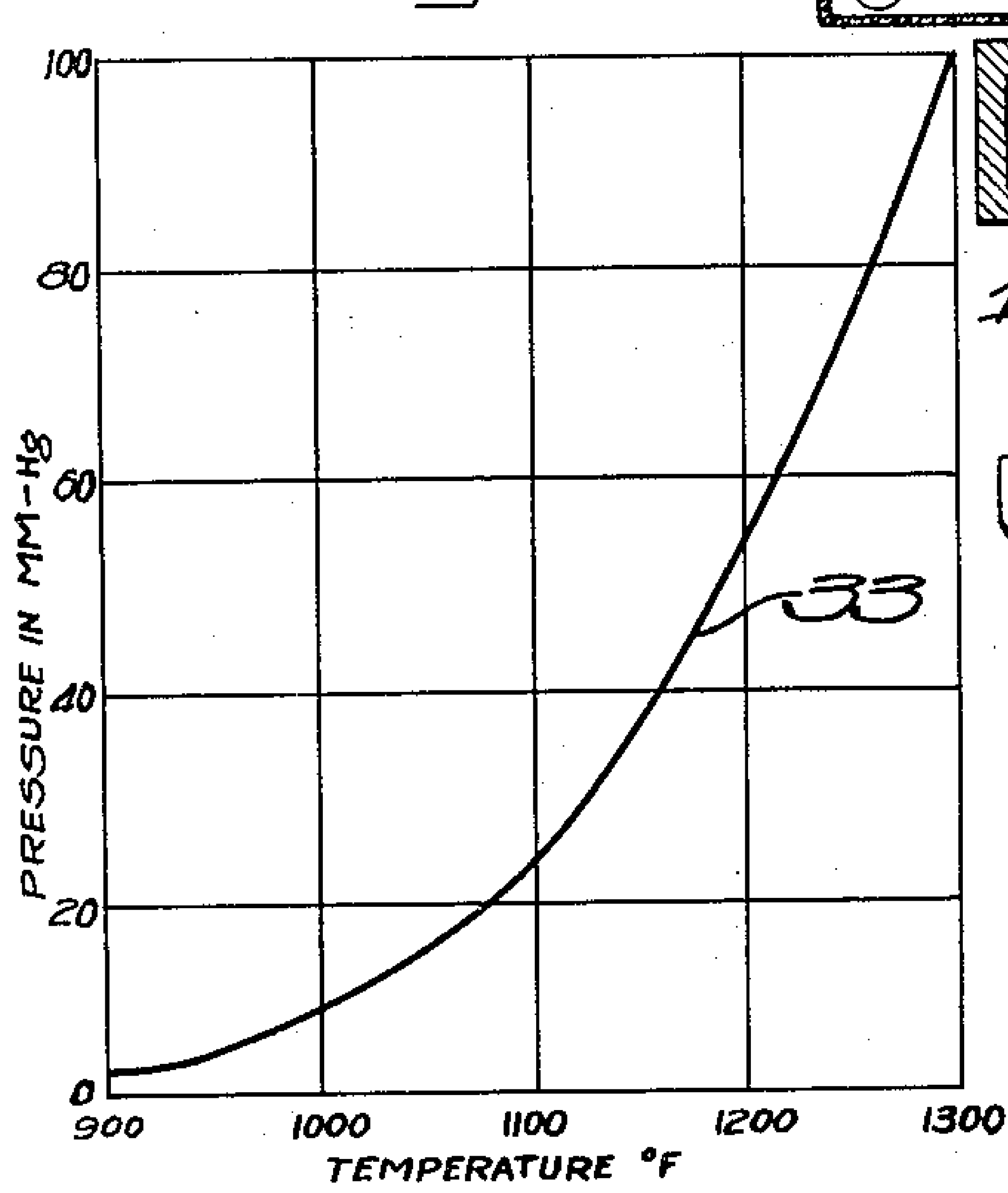


Fig. 6



Inventor
Milton S. Roush

By The Firm of Charles Hill Attys

United States Patent Office

2,744,723

Patented May 8, 1956

2,744,723

CONTROLLED TEMPERATURE FLUID FLOW DIRECTING MEMBER

Milton S. Roush, Painesville, Ohio, assignor to Thompson Products, Inc., Cleveland, Ohio, a corporation of Ohio

Application December 6, 1949, Serial No. 131,309

2 Claims. (Cl. 253—39.15)

The present invention relates to a controlled temperature fluid flow directing member and more particularly to a fluid flow directing member provided with means for controlling the temperature of the member when it is employed in a heated working fluid.

As is well known, the fluid flow directing members of a gas turbine, a jet turbine, a supercharger, or the like, are subjected to a heated working fluid, usually a burning gas, acting thereagainst. Since the efficiency of the turbine or supercharger increases with the heat content of the working fluid, it is desirable that the fluid contact the flow directing member at the maximum temperature at which the member is capable of functioning without excessive distortion and/or stress failure. Heretofore, the heat resistance properties of such members have limited the maximum temperature of the working fluid acting thereagainst, and even at such temperatures the occurrence of local "hot spots" has been a frequent reason for failure of the flow directing members.

The present invention now provides means whereby a fluid flow directing member, such as a turbine bucket or vane, is maintained at a uniform temperature throughout to prevent or immediately correct the occurrence of local hot spots. In general, the bucket or vane of the present invention includes a root portion for securing the bucket to its rotatable supporting means and a blade portion projecting beyond the root to direct the working fluid through the apparatus in which the bucket is employed. The bucket is provided with an interior cavity which may include a reservoir formed in the root and a branching passage formed in the blade, the reservoir and passage being adapted to receive a body of a suitable coolant, such as sodium, which is fluid at the temperatures developed on the blade during operation. In some instances the root reservoir can be omitted as, for example, where heat is not to be dissipated out of the root.

Upon the development of a local "hot spot" on the blade, that portion of the coolant contacting the hot spot is vaporized and passes to a cooler portion of the bucket for condensation, while relatively cool coolant under the tremendous centrifugal force created in the rapidly rotating turbine wheel fills the space vacated by the vaporized coolant. The vaporization of the coolant, due to its high latent heat of vaporization, creates a cooling effect, and the incoming coolant removes more heat by conduction and convection to reduce the temperature of surrounding portions of the blade. The maximum temperature which may be developed in the blade is predetermined by evacuation of the reservoir and the branched passage connected thereto, since for any given coolant the vaporizing or boiling temperature is directly proportional to the pressure to which it is subjected.

It is, therefore, an important object of the present invention to provide an improved controlled temperature fluid flow directing member.

Another important object of the present invention is to provide an improved controlled temperature fluid flow

directing member for disposition in a heated working fluid, the member including a coolant in efficient heat transfer relation to the portions thereof which are exposed to the working fluid to prevent the occurrence of local hot spots during operation.

It is a further important object of the present invention to provide a controlled temperature fluid flow directing member including a blade portion exposed to a heated working fluid and a root portion secured to rotatable means maintaining the blade in the working fluid; the root portion may have an interior coolant reservoir therein and the blade portion has a branched passageway which may communicate with the reservoir for conducting coolant from the reservoir into efficient heat transfer relation with substantially all of the exposed portions of said blade. The branched passageway above may be used as a heat transferring media.

Still another important object of the present invention is to provide a method for the cooling of a fluid flow directing member having portions exposed to a heated working fluid, including the steps of disposing a body of coolant in efficient heat transfer relation to heated portions of said member and determining the maximum temperatures to be developed in said member by controlling the pressure upon said coolant.

Other and further important objects of this invention will be apparent from the disclosures in the specification and the accompanying drawings.

On the drawings:

Figure 1 is a side elevational view, with parts broken away, of a fluid flow directing member of the present invention;

Figure 2 is an elevational view similar to Figure 1 illustrating a modified form of a fluid flow directing member of the present invention;

Figure 3 is a sectional view taken along the plane III—III of Figure 2;

Figure 4 is a sectional view taken along the plane IV—IV of Figure 2;

Figure 5 is a sectional view of an apparatus for filling a flow directing member of Figures 1–4 with coolant; and

Figure 6 is a graphical representation of the boiling point curve of a coolant suitable for use in a fluid flow directing member of the present invention.

As shown on the drawings:

In Figure 1, reference numeral **10** refers generally to a fluid flow directing member, specifically a turbine blade or bucket, of the present invention including a root portion **11** and an air foil section or blade portion **12**.

The root end portion **11** of the bucket **10** is massive and is provided with superimposed stepped notches **13** in the lateral faces thereof for mounting the bucket **10** in a conventional manner, as on a turbine wheel, a nozzle diaphragm, or the like. The blade or air foil portion **12** is appropriately shaped to efficiently direct the working fluid through the apparatus with which the bucket **10** is employed, as through a turbine wheel. The blade portion **12** has a concave face **14** and a convex face **15** designed and contoured to provide the desired aerodynamic characteristics of the blade, the blade being of relatively thin cross-sectional thickness. The bucket or vane **10** may be made of a suitable heat resistant alloy, such as Vitallium (30% Cr, 6% Mo, balance Co) or similar alloys in which a portion of the cobalt is replaced with nickel and/or in which the molybdenum is replaced with tungsten.

The root portion **11** is provided with an interior coolant reservoir **16** directly underlying the blade **12** for containing a body of a coolant C, and the blade portion **12** is provided with an interior cavity defined by a plurality of interconnected, branched channels arranged in a generally rectangular pattern. More particularly, the cavity is defined by a main vertical channel 17 communicating with the reservoir 16 and extending along the length of the blade 12 and auxiliary channels 18 extending parallel to the main channel 17 and transverse connecting channels 19 connecting the channels 17 and 18. The interconnecting channels 17, 18 and 19 thus define a grid network communicating with the reservoir 16 and closely underlying the concave and convex exterior surfaces of the blade 12.

A modified form of interior blade cavity is shown in Figures 2 and 3 of the drawing in which identical reference numerals refer to identical portions of the apparatus as hereinbefore described. In this form of the bucket 10, the cavity within the blade 12 takes the form of a main channel 20 extending interiorly of the blade 12 along the length thereof and branched auxiliary channels 21 extending from the main channel 20 toward the leading and trailing edges of the blade 12.

The grid network of channels 17 and the branched channels 21 terminate in spaced relation from the root portion 11 so as to leave a solid base section or area on the vane portion 12 adjacent the root portion 11. This solid base section or area is pierced only by a passage joining the channels with the reservoir chamber in the root portion.

The channels are arranged in the vane portion 12 to be separated by numerous solid vane areas which rigidify the opposed vane faces against collapse.

If desired, the reservoir 16 and the branching passages 17—19 and 20—21 may be zinc or silver coated to permit wetting of the coating with sodium or a similar coolant, thus enhancing heat transfer.

In Figure 5 of the drawings, an apparatus for filling the reservoir 16 and the connecting gridwork with a suitable coolant is shown. As shown in Figure 5, communication of the reservoir 16 with the exterior of the blade is provided through a port 22 which is adapted to be employed in filling the reservoir 16 with a suitable coolant, the port 22 being later closed by means of a ball shaped plug 23. A filling nipple 24 in the form of a generally rectangular block, recessed as at 25 to fit over the end of the root 11 of the blade 10, is provided with side conduits 26 and 27 communicating with a central chamber 28 adapted to overlie the port 22 when the block is positioned on the blade. The chamber 28 has a bottom opening 29 registering with the port 22 when the block 24 is positioned on the root 11. A tube 30 extends into the chamber 28 above the opening 29 to feed sodium or the like coolant through the opening into the port 22. The conduit 26 is connected to a suitable source of vacuum and the conduit 27 is closed and preferably made of glass. A magnet M is effective to hold the ball plug 23 at the closed end of the conduit until needed whereupon it can then be used to impel the ball into the port 22. An induction coil C surrounds the blade end to fuse the plug 23 to the port 22. If a nonmagnetic plug is used such as a copper plug a magnetic pusher in the tube 22 can be used to impel the ball.

To fill the reservoir 16 and the passage of the blade 12, the reservoir and the connecting passageways are first evacuated by means of the conduit 26 to a desired degree of vacuum and molten sodium is introduced through the conduit 30 under atmospheric pressures or under super-atmospheric pressures as desired. When the desired amount of sodium or of the coolant has been metered through the conduit 30 into the reservoir 16, the plug 23 is welded to the blade, to close the reservoir 16 and the communicating passageways of the blade 12.

The evacuation of the reservoir 16 and the connecting passageways not only insures the uniform introduction of molten coolant into the reservoir and the reduced connecting passages of the blade 12, but when regulated it also controls the maximum operating temperature for any portion of the blade 12. In Figure 6, applicant has illustrated the liquid-vapor phase diagram of sodium, which is employed as the preferred coolant in the bucket 10 of the present invention. From this diagram, in which reference numeral 33 refers to the boiling point curve of sodium, it will be seen that the boiling point of sodium decreases in proportion to a decrease in the pressure to which the sodium is subjected. The liquid-vapor diagrams of other suitable coolants, such as sodium-potassium eutectic, morganic salts, and the like, show the similar decrease in boiling point as a function of decreasing pressure.

The relation of pressure to boiling point of sodium, as illustrated in Figure 6, may also be expressed in tabulated form, as follows:

Table

Pressure—mm. Hg:	Temperature—°F.
2	900
9.7	1000
23.5	1100
54.0	1200
100.0	1300

The operation of the improved control temperature fluid flow directing member of the present invention will be readily understood from the foregoing description. If the temperature of the air foil exceeds the boiling temperature of sodium at the pressure to which the sodium is subjected, the resulting sodium vapors would immediately pass to a cooler portion of the bucket and condense and the centrifugal force will cause a flow of relatively cool molten sodium to the hot spot to reduce the temperature thereof with convection currents within the molten sodium still further dissipating the local heat developed. The very high latent heat of vaporization of sodium, namely, 1100 calories per gram at 880° C., insures the rapid removal of heat from the local hot spot and the immediate dissipation of this heat.

The reservoir if used serves to cool the entire bucket, inasmuch as it is located in the root out of the path of the heated working fluid and receives relatively cool fluid thereagainst, such as air from the axial flow compressor of a jet turbine. Cooling of the reservoir may be facilitated by the provision of a plurality of coolant air passages or bores 31 extending longitudinally of the root 11 alongside the reservoir 16, as illustrated in Figures 2–4 of the drawing. A further cooling effect may be obtained by providing an arcuate air scoop 32 extending across the leading edge of the root section of the bucket of Figure 2 to direct ambient fluid coolant into the bores 31.

When evacuating the coolant containing passages of the blade 12 and the reservoir 16, it is desirable to provide a small unfilled space A in the blade, and, during rotation of the turbine, centrifugal forces will maintain coolant in the passages 17—19 and 20—21 rather than in the root reservoir 16, so that efficient cooling of the blade portion 12 of the bucket 10 is insured. Further, in the branched passage design as embodied in Figure 2 of the drawings, centrifugal force tends to aid the movement of coolant fluid outwardly through the auxiliary passages 21 since they are inclined outwardly of the blade 12 from the reservoir 16. The unfilled evacuated space A will be substantially filled with coolant vapor when the blade is heated to a temperature greater than the boiling point of the coolant at the pressure within the space A. The unfilled space A is always desirable as an expansion chamber.

It will be understood that modifications and variations may be effected without departing from the scope of the concepts of the present invention.

I claim as my invention:

1. A turbine blade for disposition in the heated working fluid of a gas turbine engine or the like which comprises a vane portion of air foil shape and an integral an-

choring root portion at one end of the vane portion, said vane portion having vane faces exposed during operation to hot working fluid of the gas turbine engine, said root portion being thicker and more massive than the vane portion and in operation not being exposed to the hot working fluid of the gas turbine engine, a reservoir chamber in said root portion occupying the major volume of the root portion to accommodate a substantial charge of coolant, a plurality of interconnected small passages in the vane portion separated by numerous solid vane material areas rigidifying the opposed vane faces against collapse by the force of the working fluid, said interconnected passages terminating in spaced relation from the root portion to provide a solid base section adjacent the root portion, a single passage through said solid base section connecting the interconnected passages with the reservoir chamber, cooling passages in said root portion adjacent the periphery of the reservoir chamber, a scoop extending across an edge of the root portion adapted to direct adjacent ambient fluid into said cooling passages, a filling passage in the blade extending to the exterior of the blade and communicating with the reservoir chamber for introducing coolant to said reservoir chamber and said interconnected passages, and a closure for said filling passage to seal the coolant in the blade, whereby said colant will transfer heat from the vane portion exposed to the working fluid to the root portion and said ambient fluid directed into the cooling passages will dissipate heat from the coolant thereby eliminating local hot spots in the vane portion without reducing the collapse resistance of the vane portion.

2. A turbine bucket for a gas turbine engine which comprises a vane portion of air foil section and an

integral massive root portion at one end of the vane portion, said root portion being hollow to provide a reservoir chamber occupying substantially the entire volume of the root portion, said vane portion having a plurality of small interconnected passages therein, said passages terminating in spaced relation from the root portion to provide a solid base portion on the vane, a single small passage in said solid base portion connecting the interconnected passages with the reservoir chamber, said interconnected passages being separated by solid vane sections rigidifying the vane portion against collapse, a plurality of cooling passages extending through the root portion adjacent the periphery of the reservoir chamber therein, said passages adapted to receive cooling fluid therethrough for dissipating heat from the reservoir, a filling passage extending to the exterior of the bucket and communicating with the reservoir chamber, and a plug sealing said passage, whereby coolant encased in the reservoir can flow through the interconnected passages to dissipate heat from the vane and minimize development of local hot spots in the vane areas.

References Cited in the file of this patent

UNITED STATES PATENTS

2,407,164	Kimball	Sept. 3, 1946
2,407,531	Berimann	Sept. 10, 1946
2,501,038	Fransson	Mar. 21, 1950
2,565,594	Constant	Aug. 28, 1951

FOREIGN PATENTS

544,940	Germany	Feb. 26, 1932
594,931	Germany	Mar. 23, 1934
610,737	Great Britain	Oct. 20, 1948