June 29, 1965 F. B. POWELL ETAL 3,191,908

BLADES FOR FLUID FLOW MACHINES

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FIG. 1

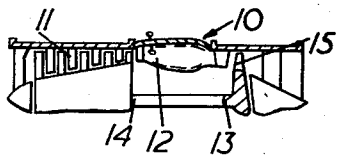

FIG. 2

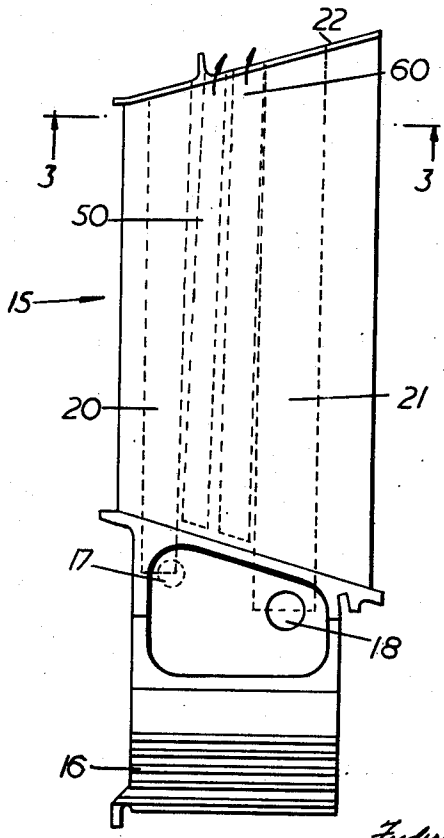

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FIG 3.

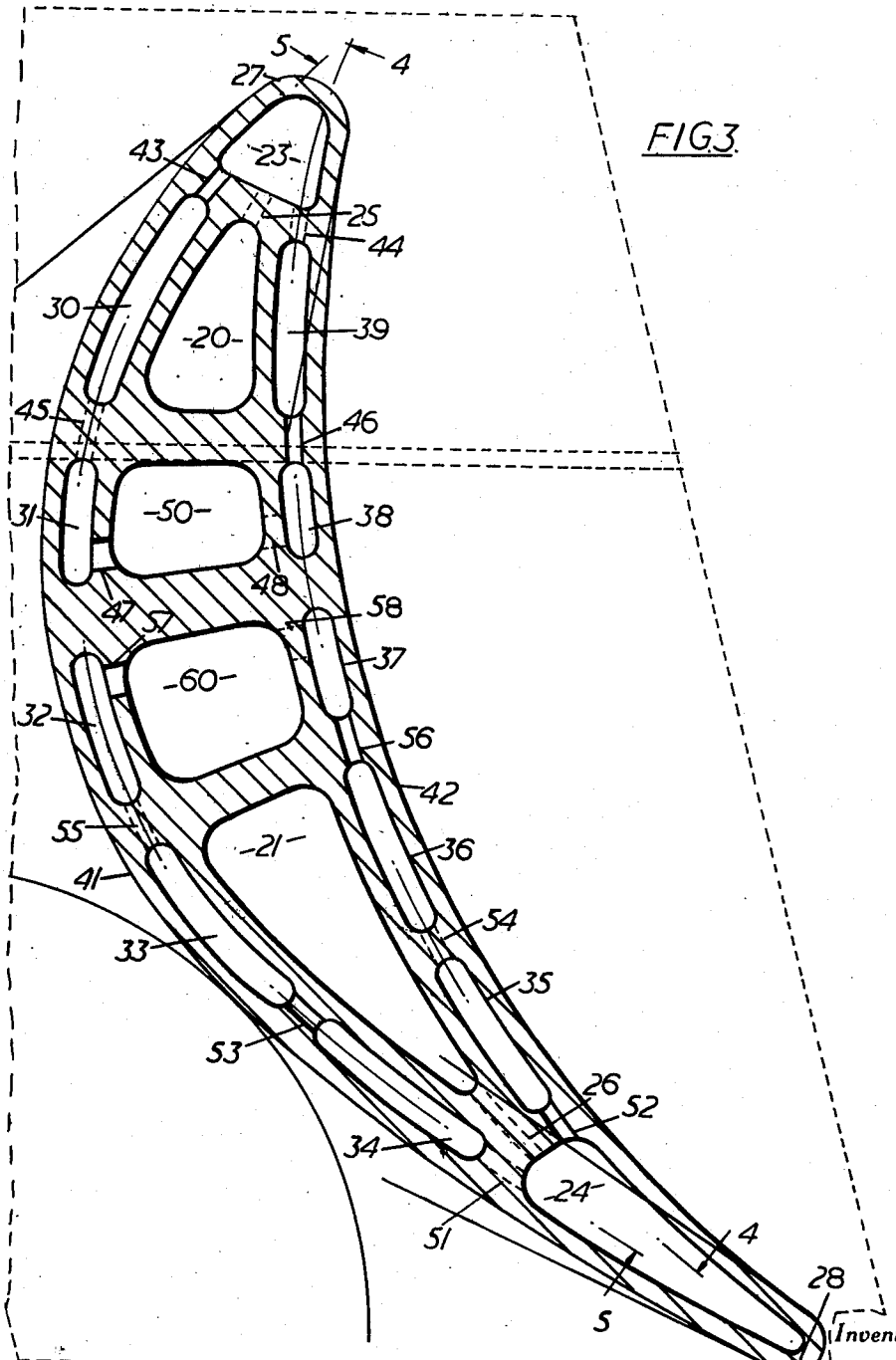

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FIG.4.

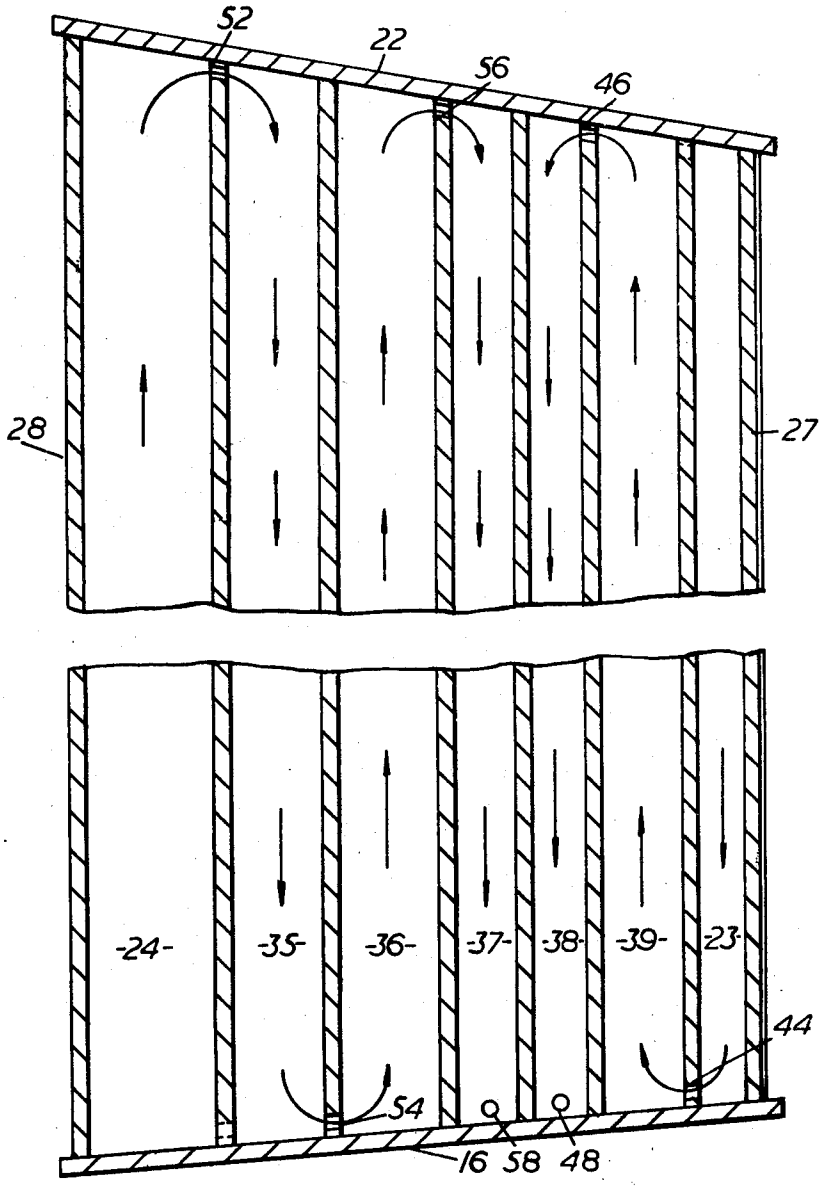

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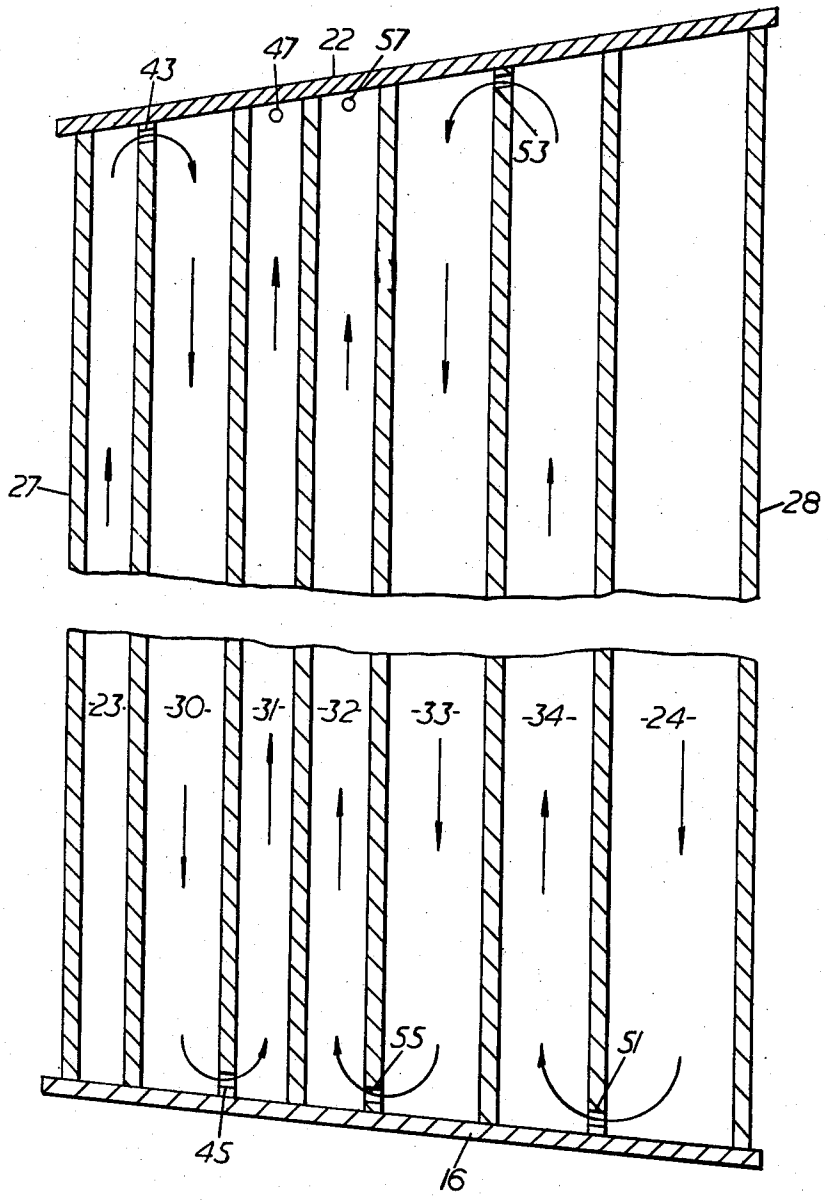
FIG.5.



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BLADES FOR FLUID FLOW MACHINES

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4 Claims. (Cl. 253—39.15)

This invention concerns blades for fluid flow machines e.g. turbine rotor blades for gas turbine engines.

The term "blade" is used in this specification in a broad sense to include blade-like members such as nozzle guide vanes.

According to the present invention, there is provided a blade adapted for use in a fluid flow machine and having formed therein a fluid conduit, said fluid conduit having an inlet through which a blade cooling fluid may be introduced into said fluid conduit and a sinuous fluid passageway which is formed in said blade and which is adapted to be supplied with a blade cooling fluid, the sinuous fluid passageway extending substantially completely around the fluid conduit and being so formed that blade cooling fluid flowing therethrough effects substantial heat-shielding of the blade cooling fluid flowing through the fluid conduit.

Preferably the sinuous fluid passageway is such that blade cooling fluid on entering the lattter first flows through leading and trailing portions of the blade and thereafter flows through the central portion of the blade. It will be appreciated that in such an arrangement the leading and trailing portions, i.e. the hottest portions of the blade will be cooled by the blade cooling fluid when the latter is at its coldest while the central portion of the blade, which does not require as much cooling, is cooled by the blade cooling fluid after the latter has picked up heat from the said leading and trailing portions.

Preferably the sinuous fluid passageway communicates with the fluid conduit so as to be supplied with blade cooling fluid therefrom.

Preferably the fluid conduit extends from substantially the root to the tip of the blade and the sinuous fluid passageway comprises a series of spaced fluid passages which also extend substantially from the root to the tip of the blade, said fluid passages being connected together by fluid paths which are alternatively arranged adjacent to the root and tip of the blade, one of the fluid passages communicating with the fluid conduit and another of the fluid passages having an outlet through which blade cooling fluid may pass out of the blade, whereby blade cooling fluid which has been introduced into the fluid conduit through said inlet will flow through adjacent fluid passages in opposite directions and will finally pass out of the blade through said outlet.

The said inlet is preferably disposed at the root of the blade, the said outlet being disposed at the tip of the blade.

One of the fluid passages is preferably disposed adjacent the leading or trailing edge of the blade and communicates with the fluid conduit by way of a drilling which is disposed adjacent the mid-height of the blade whereby blade cooling fluid passing through said drilling forms a jet which cools the said leading or trailing edge adjacent the mid-height of the latter.

The blade is preferably formed with two fluid conduits each of which is surrounded by a sinuous fluid passageway, the two sinuous fluid passageways respectively comprising fluid passages which are disposed adjacent the leading and trailing edges of the blade and which communicate with their respective fluid conduits by way of drilling disposed adjacent the mid-height of the blade.

The invention also comprises a gas turbine engine provided with a blade as set forth above.

The invention is illustrated, merely by way of example, in the accompanying drawings in which:

FIGURE 1 is a diagrammatic section through a gas turbine engine,

FIGURE 2 is a diagrammatic elevation of a turbine blade of the engine of FIGURE 1,

FIGURE 3 is a section taken on the line 3—3 of FIGURE 2, and

FIGURES 4 and 5 are sections taken respectively on the lines 4—4 and 5—5 of FIGURE 3.

In the following description, air which flows within the blade and towards the root thereof is, for ease of explanation, referred to as passing "downwardly" in the blade, while air which flows within the blade towards the tip thereof is referred to as passing "upwardly" in the blade.

Referring to the drawings, a gas turbine engine **10** comprises in flow series a compressor **11**, combustion equipment **12**, and a turbine **13**, the turbine **13** driving the compressor **11** through a shaft **14**.

The turbine **13** has turbine rotor blades **15** each of which has a "fir-tree" root **16** which is formed with air inlets **17**, **18** through which cooling air may be introduced into the blade **15**.

The air inlets **17**, **18** lead respectively to fluid conduits **20**, **21** which are formed within and extend longitudinally of the blade **15** from the root **16** to the tip **22** thereof. The fluid conduits **20**, **21** are blanked off at the tip of the blade, but are of course supplied at the root of the blade with cooling air from the air inlets **17**, **18**.

The fluid conduits **20**, **21** respectively communicate with fluid passages **23**, **24** by way of drillings **25**, **26**, the passages **23**, **24** being respectively blanked off at the root and tip of the blade. The drillings **25**, **26** are disposed at the mid-height of the blade i.e. halfway between the root and the tip of the blade.

The fluid passages **23**, **24** are respectively disposed adjacent the leading edge **27** and the trailing edge **28** of the blade. Accordingly jets of cooling air are directed through the drillings **25**, **26** into the fluid passages **23**, **24** so as to impinge, at mid-height, on the surfaces of the latter adjacent the leading and trailing edges **27**, **28**. The said jets thus effect cooling of what are, in operation, the hottest parts of the blade.

Extending longitudinally within the blade **15** from the root to the tip thereof are spaced apart fluid passages **30–39** all of which are blanked off at the root and at the tip of the blade. The fluid passages **30–34** are disposed adjacent the convex or upstream side **41** of the blade, while the fluid passages **35–39** are disposed adjacent the concave or downstream side **42** of the blade.

The fluid passages **30**, **39** respectively communicate with the fluid passage **23** by way of drilling **43**, **44** which are respectively disposed adjacent the tip and the root of the blade. The fluid passages **30**, **39** also respectively communicate with the fluid passages **31**, **38** by way of drillings **45**, **46** which are respectively disposed adjacent the root and the tip of the blade.

The fluid passages **31**, **38** respectively communicate, by way of drillings **47**, **48**, with a fluid passage **50** which extends longitudinally of the blade from the root to the tip thereof, the fluid passage **50** being blanked off at the root and being open at the tip of the blade. The drillings **47**, **48** are respectively disposed adjacent the tip and the root of the blade.

The fluid passages **34**, **35** respectively communicate with the fluid passage **24** by way of drillings **51**, **52** which are respectively disposed adjacent the root and the tip of the blade. The fluid passages **34**, **35** also respectively communicate with the fluid passages **33**, **36** by way of drill-

ings 53, 54, while the fluid passages 33, 36 respectively communicate with the fluid passages 32, 37 by way of drillings 55, 56. The fluid passages 32, 37 respectively communicate, by way of drillings 57, 58, with a fluid passage 60 which extends longitudinally of the blade from the root to the tip thereof, the fluid passage 60 being blanked at the root and being open at the tip of the blade.

The drillings 51, 54, 55 and 58 are disposed adjacent the root of the blade, while the drillings 52, 53, 56, and 57 are disposed adjacent the tip of the blade.

Accordingly, the cooling air which has passed into the fluid conduit 20 and has entered the fluid passage 23 through the drilling 25 first impinges on the surface of the passage 23 at mid-height and thereafter divides into two portions which respectively flow downwardly and upwardly through the passage 23 towards the root and the tip of the blade. The air which has flowed upwardly in the passage 23 passes through the drilling 43, flows down the passage 30, passes through the drilling 45, flows up the passage 31 and passes through the drilling 47 to the "upper" end of the passage 50.

The air which has flowed downwardly in the passage 23 passes through the drilling 44, flows up the passage 39, passes through the drilling 46, flows down the passage 38, and then passes through the drillings 48 to the "lower" end of the passage 50. The cooling air which is thus supplied to the passage 50 passes out of the blade through the tip thereof.

It will thus be noted that the fluid passages 23, 30, 31, 38, 39, 50, together with the drillings 43–48, collectively constitute a sinuous fluid pasasgeway the cooling air flowing through which effects substantial heat-shielding of the cooling air flowing through the fluid conduit 20.

Similarly, the cooling air which has passed into the fluid conduit 21 and has entered the fluid passage 24 through the drilling 26, impinges on the surface of the passage 24 at mid-height, and thereafter divides into two portions which respectively flow downwardly and upwardly through the passage 24 towards the root and the tip of the blade.

The air which has flowed upwardly in the passage 24 passes through the drilling 52, flows down the passage 35, passes through the drilling 54, passes up the passage 36, passes through the drilling 56, passes down the passage 37, and passes through the drilling 58 to the "lower" end of the passage 60.

The air which has flowed downwardly in the passage 24 passes through the drilling 51, flows up the passage 34, passes through the drilling 53, flows down the passage 33, passes through the drilling 55, flows up the passage 32, and passes through the drilling 57 to the "upper" end of the passage 60. The cooling air which is thus supplied to the passage 60 passes out of the blade through the tip thereof.

The fluid passages 24, 32–37, and 60, together with the drillings 51–58, collectively constitute a sinuous fluid passageway and the cooling air flowing through this sinuous fluid passageway will effect substantial heat-shielding of the cooling air flowing through the fluid conduit 21.

The blade, which may be a close forging, which is subsequently machined by an electrolytic or spark process, may be formed in two halves which abut at the mid-chord line of the blade and are secured together by brazing or electron beam welding. The conduits, passages and drillings in the blade may be formed by spark machining (e.g. carbon electrode spark machining) or by an electrolytic process.

It will be appreciated that the leading and trailing edges 27, 28, which are in operation the hottest portions of the blade, will be cooled by the cooling air when the latter is at its coldest, while the central portion of the blade, which does not require as much cooling, is cooled by the cooling air when the latter is at its coldest, while the central portion of the blade, which does not require as much cooling, is cooled by the cooling air after the latter has been heated by flowing through the blade. A substantially uniform temperature is therefore achieved throughout the blade.

We claim:

1. A blade adapted for use in a fluid flow machine said blade having a root and a tip, two fluid conduits formed in said blade and extending from substantially the root to the tip thereof, an inlet to each said fluid conduit, through which a blade cooling fluid may be introduced into said fluid conduits, two sinuous fluid passageways formed in said blade, each of said sinuous fluid passageways comprising a series of spaced fluid passages which also extend substantially from the root to the tip of the blade, fluid paths which are alternately arranged adjacent to the root and tip of the blade, connecting said fluid passages together, one fluid passage of each sinuous fluid passageway being disposed adjacent the leading and trailing edges of the blade respectively and communicating with their respective fluid conduits by way of drillings disposed adjacent the mid-height of the blade, blade cooling fluid passing through said drillings forming jets which cool the said leading and trailing edges adjacent the mid-heights of the blade, one fluid passage of each sinuous fluid passageway being provided with an outlet through which blade cooling fluid may pass out of the blade, each sinuous fluid passageway extending substantially completely around the respective fluid conduit.

2. A blade as claimed in claim 1 in which each said inlet is disposed at the root of the blade, each said outlet being disposed at the tip of the blade.

3. A blade adapted for use in a fluid flow machine, said blade having a root and a tip; a fluid conduit formed in the interior of said blade and extending from the root to the tip thereof and having an inlet at one end thereof through which a blade cooling fluid is introduced therein; a sinuous fluid passageway formed in said blade and extending completely around the fluid conduit, said sinuous fluid passageway comprising a plurality of spaced fluid passages, each extending substantially from the root to the tip of the blade, said plurality of spaced fluid passages defining a pair of sinuous paths, one path being disposed adjacent the upstream side of the blade and the other path being disposed adjacent the downstream side of the blade, with one of said fluid passages being common to both sinuous paths and disposed adjacent the leading edge of the blade; said one fluid passage disposed adjacent the leading edge of the blade communicating with said fluid conduit by a drilling disposed adjacent the mid height of the blade and forming a jet through which blade cooling fluid passes from the fluid conduit into the one passage and cools the leading edge of the blade from the mid height outwardly toward the root and tip respectively; drillings in said blade alternately arranged adjacent to the root and tip of the blade and connecting said fluid passages of each sinuous path together and with the one common fluid passage disposed adjacent the leading edge; and another of said fluid passages being common to both of the sinuous fluid paths and connected thereto by drillings respectively disposed alternately adjacent the root and tip of the blade, said another fluid passage being disposed on an opposite side of the fluid conduit with respect to the one fluid passage adjacent the leading edge and having an outlet for the blade cooling fluid at one end thereof.

4. A blade adapted for use in a fluid flow machine, said blade having a root and a tip, a first fluid conduit formed in the interior of said blade and extending from the root to the tip thereof and having an inlet at one end thereof through which a blade cooling fluid is introduced; a first sinuous fluid passageway formed in said blade and extending completely around said first fluid conduit, said first sinuous fluid passageway comprising a plurality of spaced fluid passages, each extending substantially from the root to the tip of the blade, said plurality of spaced fluid passages defining a pair of sinuous paths, one path of

said pair being disposed adjacent the upstream side of the blade and the other path of said pair being disposed adjacent the downstream side of said blade with one of said plurality of fluid passages being common to both sinuous paths and disposed adjacent the leading edge of the blade; the said one fluid passage disposed adjacent the leading edge of the blade communicating with said fluid conduit by a drilling disposed adjacent the mid height of the blade and forming a jet through which blade cooling fluid passes from the fluid conduit into the one passage and cools the leading edge of the blade from the mid height outwardly toward the root and tip respectively, drillings in said blade alternately arranged adjacent the root and tip of the blade and connecting said fluid passages of each sinuous path together and with the one common fluid passage disposed adjacent the leading edge, another of said fluid passages being common to both of the sinuous fluid paths and connected to one fluid passage of each of the sinuous fluid paths by drillings respectively disposed alternately adjacent the root and tip of the blade, said another fluid passage being disposed on an opposite side of the first fluid conduit with respect to the one fluid passage adjacent the leading edge and having an outlet for the blade cooling fluid at one end thereof; and a second fluid conduit formed in the interior of said blade and extending from the root to the tip thereof and having an inlet at one end thereof through which the blade cooling fluid is introduced therein; a second sinuous fluid passageway formed in said blade and extending completely around the second fluid conduit, said second sinuous passageway comprising a plurality of spaced fluid passages each extending substantially from the root to the tip of the blade, said second plurality of spaced fluid passages defining a second pair of sinuous paths with one path of the second pair being disposed adjacent the upstream side of the blade and the other path of the second pair being disposed adjacent the downstream side of the blade with one of the said plurality of fluid passages being common to both sinuous paths of the second pair and disposed adjacent the trailing edge of

the blade; said one fluid passage of the second pair of fluid passages being disposed adjacent the trailing edge communicating with said second conduit by a drilling disposed adjacent the mid height of the blade and forming a jet through which blade cooling fluid passes from the second fluid conduit into the one fluid passage and cools the trailing edge of the blade from the mid height outwardly toward the root and tip respectively, drillings in said blade alternately arranged adjacent to the root and tip of the blade and connecting the plurality of fluid passages of the pair of paths of said second sinuous passageway together with the one fluid passage disposed adjacent the trailing edge; and another of the said plurality of fluid passages of said seond sinuous passageway being common to both the sinuous fluid paths and connected thereto by drillings respectively disposed alternately adjacent the root and tip of the blade, said fluid passage of another of the said plurality of fluid passages being disposed on an opposite side of the second fluid conduit with respect to the one fluid passage adjacent the trailing edge and having an outlet for blade cooling fluid at one end thereof.

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