NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO ATTN OF: GP

June 30, 1971

MEMORANDUM

TO: KSI/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 2,956,772

Corporate Source : Lewis Research Center

Supplementary Corporate Source :

NASA Patent Case No.: XLE-00027

Gayle Parker

Enclosure:
Copy of Patent

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FACILITY FORM 602

Oct. 18, 1960 J. C. FRECHE 2,956,772

LIQUID-SPRAY COOLING METHOD

Filed Aug. 19, 1955

N71-29152

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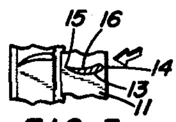

FIG. 3

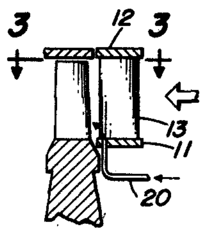

FIG. 2

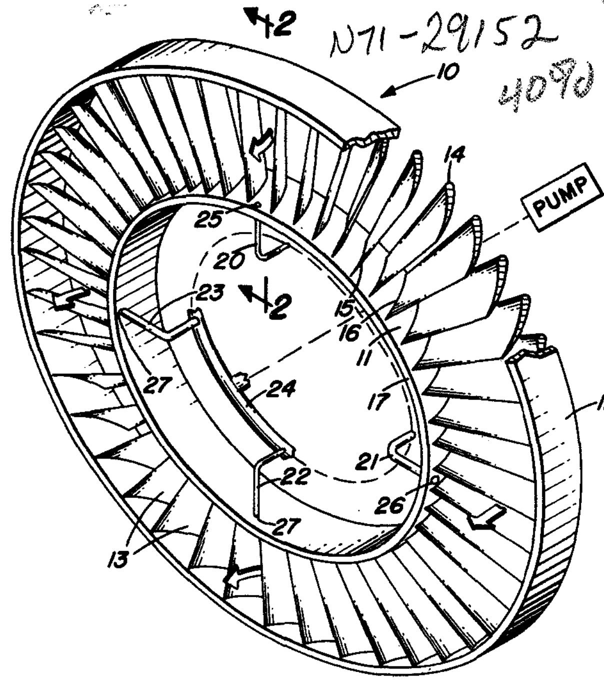

FIG. 1

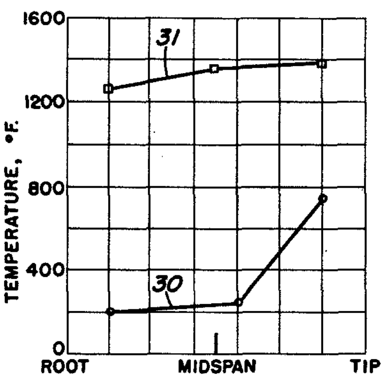

FIG. 4

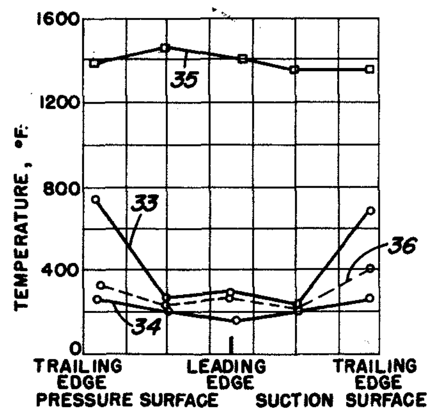

FIG. 5

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United States Patent Office 2,956,772
Patented Oct. 18, 1960

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2,956,772

LIQUID-SPRAY COOLING METHOD

John C. Freche, Fairview Park, Ohio, assignor to the United States of America as represented by the Secretary of the Navy

Filed Aug. 19, 1955, Ser. No. 529,594

5 Claims. (Cl. 253—39.1)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Goverment of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to apparatus for the cooling of gas turbine blades, and more particularly, to blade cooling employing liquid sprays.

Spray cooling of turbine blades has been heretofore employed but such cooling has usually involved costly and complex fabrication procedure, as, for example, to provide coolant passages within the stator blades. Other drawbacks to prior cooling methods of the spray type are partial blockage of gas flow passages by spray bars which may adversely affect the gas flow aerodynamics, spray bar failure after prolonged operation with attendant damage to blades downstream from the bar, and generally inadequate blade cooling.

The invention, in its broader aspect, consists of the use of free flowing spray tubes applied at spaced points around the stator diaphragm of the turbine with provision for varied mass flow from separate tubes to insure radial spread of coolant.

Objects contemplated in the use of the invention are to provide turbine blade spray cooling without the use of spray-bars; to provide spray cooling without use of spray ducts in the stator blade interior; and to provide blade spray cooling with simplified means of supply of coolant to the turbine structure.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a view in perspective of a turbine stator to which the spray structure is applied;

Fig. 2 is a detail view showing the relationship of the turbine stator to the rotor and to the gas flow, taken along lines 2—2 of Fig. 1;

Fig. 3 is a detail plan view taken along lines 3—3 of Fig. 2;

Fig. 4 is a view with curves showing spanwise turbine rotor blade temperatures with and without the disclosure cooling structure; and

Fig. 5 is a view similar to Fig. 4 but showing chordwise temperature variations.

The usual turbine structure includes a stator and rotor, each with radial blades shaped in cross-section to induce movement of the rotor on gas flow between the rotor blades from the stator. As shown in Fig. 1, the stator **10** includes an inner ring **11**, an outer concentric ring **12**, and, a plurality of radial blades **13** secured between these rings to form the stator diaphragm. These blades are simulated airfoils shaped with rounded leading edges **14** and thin trailing edges **15** and profiles **16** curved, as shown in Fig. 3, to transmit rotative forces to the rotor blades when gases flow through the turbine, in accordance with the well known theory of turbine structure and operation.

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At equally spaced circumferential intervals along the inner ring **11** of the stator, on the down stream edge **17** thereof and in line with the trailing edges of the stator blades, are a number of small openings **27**, four being shown by way of example, and in these openings are fitted the terminal orifices such as **25** and **26** of four coolant ducts **20**, **21**, **22** and **23**, each duct being connected to an appropriate common coolant source. The orifices of successive ducts, as **20** and **21**, are of different capacity so that the mass of coolant transmitted by the orifices may be varied. For example, orifice **25** of duct **20** may be of lesser area than that of orifice **26** of duct **21**, as in the ratio of about 0.078 inch to 0.135 inch diameters, so that for the same pressure the penetration of the jet from orifice **26** into the gas stream will be appreciably greater than the penetration of the jet from orifice **25**. This follows from the fact that the degree of penetration of the jet stream into the gas flow depends on the momentum of the jet, that is, the mass times the velocity, and since the velocity through both orifices is the same the penetration varies with the mass of fluid, or orifice cross-section. In operation, the jets from alternate ducts **20** and **22**, with lesser penetration, operate to spray the blade root region with coolant, whereas the jets from alternate ducts **21** and **23** serve to spray the mid-span and tip regions of the blades with coolant. It is noted that since the coolant orifices are positioned at the trailing edges of the stator blades, a minimum of evaporation of the coolant liquid particles occurs prior to impingement thereof on the rotor blades. On impingement, the coolant is vaporized, extracting latent heat of vaporization from the blades.

In installing the cooling apparatus on a turbine equipped with the usual stator diaphragm construction, it is necessary only to drill openings through the inner ring of the diaphragm at the desired locations and attach the coolant ducts from the liquid supply at these openings, as by welding or brazing. This may be done during the initial fabrication of the turbine stator or after the turbine construction has been completed. The number of openings with coolant connections as well as the diameters of the orifices thereof would be a function of the requirements of the particular installation. Water, with its relatively high latent heat of vaporization, is employed, preferably, as the spray coolant, connection of the supply ducts **20**, **21**, **22** and **23** being made through a manifold **24** to a pump and supply source, the pump permitting pressure variation at the orifices, as desired.

The utility of the cooling apparatus appears from the curves shown in Figs. 4 and 5 wherein the blade temperatures spanwise and chordwise are indicated with and without the spray application. In developing data for the curves, the spray apparatus was applied to the solid turbine blades of a turbojet engine having a rated speed of 11,500 revolutions per minute, an inlet-gas temperature of about 1568° F., a coolant-to-gas ratio of 0.0235 and small and large orifice diameters of 0.078 inch and 0.135 inch, respectively.

Fig. 4, in curve **30**, indicates a maximum temperature reduction of about 1000° F. at the root and midspan points on the midchord suction surface of the blade and a reduction of over 600° F. at the blade tip. Curve **31** indicates uncooled temperatures corresponding to the test points of curve **30**.

Fig. 5, in curve **33**, indicates chordwise temperature distribuion of the blade as applied to both suction and pressure surfaces at the midspan, and chordwise temperatures at the blade root are indicated by curve **34**. Curve **35** indicates corresponding uncooled temperatures for the chord test locations. Broken line **36** shows the effect of increasing the coolant-to-gas flow ratio to 0.0278 (7600 lb./hr.) with the larger orifice diameter increased from 0.135 inch to 0.150 inch. With these increased values the midspan chordwise temperature difference between the leading and trailing edges was reduced to about 100° F. with a maximum trailing edge temperature of 400° F. and an average midspan temperature of about 292° F. as compared with corresponding temperature values of about 450° F., 760° F. and 470° F. for a coolant-to-gas ratio of 0.0235 with a larger orifice diameter of 0.135.

In general, the curves of Figs. 4 and 5 clearly show a substantial reduction in temperature both spanwise and chordwise of the turbine blade through use of spray jets located at the downstream edge of the inner diaphragm ring between the stator blades. By using differently sized orifices, spanwise cooling is effectively accomplished. These results are made possible without complex modifications of the turbine structure and without addition of complicated equipment, the limited apparatus being readily installed and maintained with small danger of breakdown in use. Utilizing the described equipment, when applied to turbojet operation at sea level a 40 percent increase above rated thrust may be realized with a representative centrifugal-flow engine by operation at 2000° F. inlet-gas temperature and 10 percent overspeed.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A turbine blade spray apparatus comprising a stator blade diaphragm having an innerblade ring with a plurality of openings therein and adapted for positioning adjacent a turbine rotor, coolant ducts having terminal orifices fluidly attached to said openings in said ring, said openings spaced circumferentially around said ring; and means for supplying coolant under pressure to said coolant ducts, with the terminal orifices of some of said ducts having a cross-sectional area lesser than that of the terminal orifices of other of said ducts.

2. The turbine blade spray apparatus as defined in claim 1, the area of said terminal orifices alternately increasing and decreasing moving in sequence around said ring.

3. The turbine blade spray apparatus, as defined in claim 2, with the areas of adjacent terminal orifices being in the ratio of about 0.078 to 0.150.

4. The turbine blade spray apparatus, as defined in claim 2, with said openings being at least 4 in number and spaced equal distances in sequence, one from another around said blade ring.

5. A turbine blade spray apparatus comprising a stator blade diaphragm having an innerblade ring with a plurality of openings therein; coolant ducts having terminal orifices fluidly attached to said openings, said openings spaced circumferentially around said ring; a manifold, said ducts being fluidly connected to said manifold; and means for supplying coolant under pressure to said manifold, with adjoining openings being equally spaced one from another and at least one of said terminal orifices having a lesser cross-sectional area than another of said terminal orifices.

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UNITED STATES PATENT OFFICE

CERTIFICATION OF CORRECTION

Patent No. 2,956,772 October 18, 1960

John C. Freche

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, lines 2 and 3, for "assignor to the United States of America as represented by the Secretary of the Navy," read -- assignor to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration," lines 12 and 13, for "United States of America as represented by the Secretary of the Navy" read -- United States of America as represented by the Administrator of the National Aeronautics and Space Administration --; in the heading to the printed specification, lines, 3, 4, and 5, for "assignor to the United States of America as represented by the Secretary of the Navy" read -- assignor to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration --.

Signed and sealed this 18th day of April 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents