United States Patent [19]
Wilson
[11] 3,737,152
[45] June 5, 1973

[54] COOLING OF HOT FLUID DUCTS

[75] Inventor: **John Dennis Wilson**, Bristol, England

[73] Assignee: **Secretary of State for Defence in Her Britannic Majesty's Government of the United Kingdom of Great Britain and Northern Ireland**, London, England

[22] Filed: **Jan. 17, 1972**

[21] Appl. No.: **218,286**

[30] **Foreign Application Priority Data**

Jan. 25, 1971 Great Britain........................3,053/71

[52] **U.S. Cl.** **60/39.66**, 60/39.65, 432/222
[51] **Int. Cl.**..**F27d 9/00**
[58] **Field of Search** ....263/44, 19 A, 19 C

[56] **References Cited**

UNITED STATES PATENTS

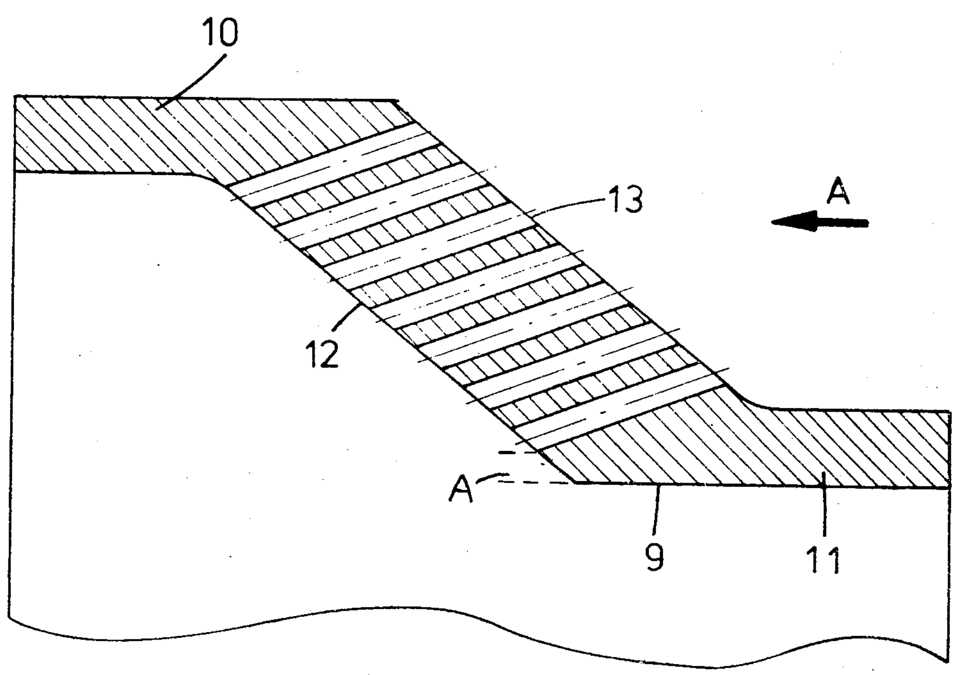
2,548,485	4/1951	Lubbock	263/44
3,623,711	11/1971	Thorstenson	263/19 A

Primary Examiner—John J. Camby
Attorney—Richard K. Stevens, Davidson C. Miller, Ellsworth H. Mosher

[57] **ABSTRACT**

A cooling ring for a gas turbine engine flame tube connects upstream and downstream wall sections, and includes a conical intermediate portion drilled with a large number of holes having diameters of the order of 0.010 ins. to 0.020 ins. through which cooling air passes to produce a cooling film over the hot surface of the flame tube.

5 Claims, 3 Drawing Figures



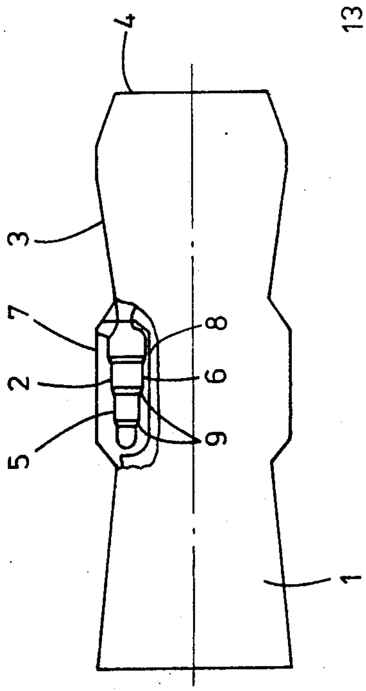


FIG.1

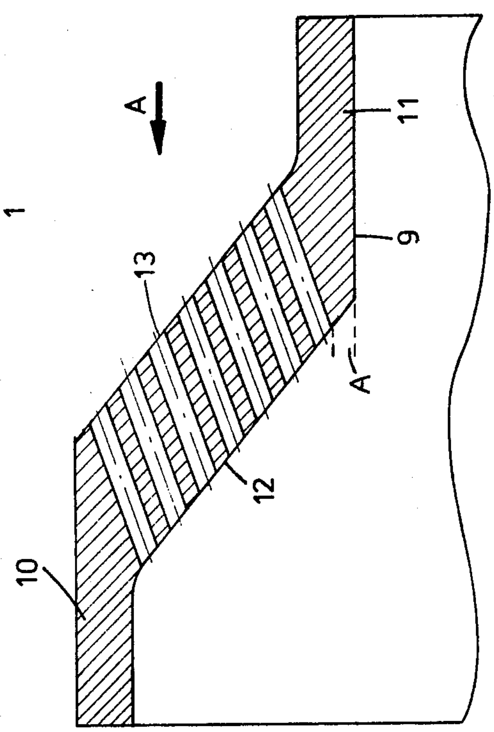


FIG.2.

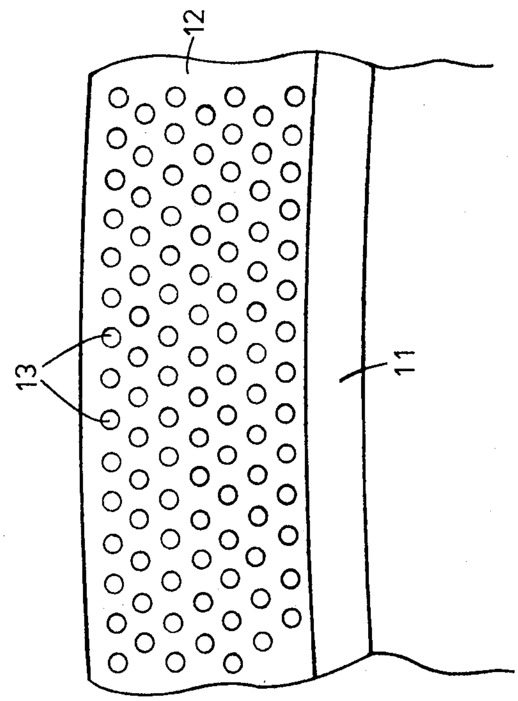


FIG. 3

COOLING OF HOT FLUID DUCTS

The present invention relates to ducts, one surface of which is exposed to a hot fluid, and relates particularly to means for providing film cooling for said surfaces. The invention has application, for example, in combustion chambers of gas turbine engines.

In combustion chambers the ducts, known as flame tubes, are provided with machined rings which separate upstream and downstream wall sections of the duct, and which are provided with a row of drilled holes circumferentially spaced around the ring.

The solid rings are made from high temperature resistant materials and are difficult to machine and drill, which makes them expensive to manufacture. In addition, the cooling air flow through the holes, which are usually about ⅛th inch diameter, takes time to coalesce into a continuous film and hot combustion gases can be induced into the spaces between the cooling air holes and overheat the ring.

According to the present invention a duct comprises coaxial upstream and downstream wall sections which lie at different distances from the duct axis, and a cooling section through which a cooling fluid can be passed to form a film over one of the surfaces of the duct, the cooling section having end portions connected to said wall sections and an intermediate portion which is provided with at least three spaced rows of holes therethrough, each hole in any one row being staggered with respect to the holes in an adjacent row, the diameter of the holes lying in the range from 0.005 to 0.030 ins.

The duct may have a circular cross-section and the cooling section is then in the form of a ring connecting two wall sections of the duct having different diameters.

The intermediate portion of the cooling section is preferably conical and may be convergent or divergent in an upstream direction to produce a cooling film on the exterior surface of a downstream wall section of reduced diameter, or to produce a cooling film on the interior surface of a downstream wall section of increased diameter respectively.

Although it is possible to produce holes of less than 0.005 in diameter on an electron beam pulse drilling machine, the lower practical limit of diameter of the holes is likely to be between 0.005 and 0.010 in order to maintain an adequate porosity and to reduce the possibility of blockage of the holes by dirt carried in the fluid stream.

The upper limit of the range of diameters is set inter alia by the power of the machine on which the holes are produced. A further consideration is the heat released during drilling on an electron beam or laser pulse drilling machine.

A preferred range of diameters of the holes is between 0.010 ins and 0.020.ins.

It has been found that such holes can be formed quickly and easily on an electron beam drilling machine which produces each hole by means of a single high powered pulse, and the cost of making cooling rings according to the invention on such machines offers considerable reduction in cost over the conventional cooling rings described above.

A second advantage comes from an improved performance in cooling the duct walls, because the air flow through a large number of tiny holes coalesces into a continuous film more quickly than in the conventional cooling rings.

The invention will now be more particularly described, merely by way of example, with reference to the accompanying drawings in which :

FIG. **1** is a diagrammatic view of a gas turbine engine, the combustion chamber of which includes a cooling ring of the present invention,

FIG. **2** shows a cooling ring of FIG. **1** in greater detail and,

FIG. **3** is a view on the arrow A of FIG. **2.**

Referring now to the drawings, there is shown in FIG. **1**, a gas turbine jet propulsion engine having a compressor **1**, combustion equipment **2**, and a turbine **3** all in flow series, the exhaust from the turbine being passed to atmosphere through an exhaust nozzle **4.**

The combustion equipment comprises outer and inner flame tubes **5** and **6**, radially spaced respectively from each other and from outer and inner casings **7** and **8** to form an annular flame chamber surrounded by annular cooling air passages. Each flame tube is constructed in a plurality of axially extending sections joined to each other by means of cooling rings **9.**

Air from the compressor **1** flows into the passages between the casings **7** and **8** and the flame tubes **5** and **6,** and some of said air passes into the flame tubes through the cooling rings **9,** each of which is adapted to direct said air in a substantially continuous circumferential film over the internal surface of the flame tube wall section downstream thereof.

One of the cooling rings **9** is shown enlarged in more detail in FIGS. **2** and **3.** Referring to these figures it will be seen that the cooling ring comprises axially extending end portions **10** and **11** which are dimensioned to be connected to the downstream end of an upstream wall section, and the upstream end of the adjacent downstream wall section respectively. The directions of cooling air and hot gas flows are shown by arrow A. The respective ends of the two adjacent wall sections are disposed at different radii from the axis of the engine so that an intermediate portion **12** of the cooling ring **9,** which connects the end portions **10** and **11,** lies at an angle to the engine axis. The angle may be as large as 90° but in the example shown it is 40°.

The intermediate portion **12** is drilled, by a high powered electron beam drilling machine, with a very large number of tiny holes **13** which pass completely through the portion to allow a flow of cooling air therethrough. Each hole is drilled using a single pulsed beam of electrons which makes the process very rapid. In the drawings, the example shown has seven rows of holes in which the holes are pitched 0.027 ins. apart and each hole in any one row is staggered with respect to the holes in an adjacent row, to cover the whole of the area of the intermediate portion **12.** The radial pitching and staggering of the holes is such that the centres of holes in any two rows lie on the apices of equilateral triangles. The diameter of the holes is 0.016 ins. and the total area of the holes is approximately two fifths of the area of the surface of the intermediate portion.

Each of the holes was drilled at an angle of 30° to the normal to the surface of the intermediate portion, so that the axis of each hole was at 20° to the axis of the engine. The angle of the intermediate portion, and of the holes, to the axis of the engine is a compromise between the ideal condition of a radially extending intermediate portion (i.e., at 90° to the engine axis) with holes whose axes are parallel to the engine axis, and the need to have an adequate number of rows of holes without making the intermediate portion of the cooling ring too deep radially, or without the axes of the holes departing too far from being parallel to the axis of the engine. With the axes of the holes at an angle of 20° to the engine axis, air flow flowing through the holes will be turned towards the wall of the duct in a very short time to form a film on the wall, and by having seven rows of holes, hot air inside the flame tube has to navigate a very tortuous path between the very many separate jets of cooling air from the holes, to reach the flame tube wall in the short length of wall between the cooling ring and the point where the separate jets become a continuous film. In addition, the base A (i.e., the radial depth) between the radially inner surface of the cooling ring and the first cooling air hole must be kept to a minimum. This may be achieved by varying the angles of the axes of the holes so that the radially inner row of cooling holes lie at a steeper angle to the axis of the engine than the radially outer row.

The holes are preferably as small as they can practicably be made, i.e., down to 0.005 ins. in diameter. Very small holes, however, can get blocked by dirt and debris in the cooling air so that 0.010 ins. should be considered as a minimum diameter for the holes in dirty environments such as gas turbine engines. In cleaner environments holes down to 0.005 ins. diameter may be used. The upper limit of diameter is reached by considerations of the increasing cost of the technique of drilling, due to increased power requirements, and the fall-off in cooling performance as the hole diameter increases. With single pulse electron beam drilling, which is the recommended technique because of the high speed and low cost, the rate of increase of cost with diameter increases steeply for diameters of holes above 0.020 ins. and this is recommended as a maximum, although the fall off in cooling performance is gradual and still shows an improvement over the conventional drilled cooling ring when holes up to 0.030 ins. are used. As the diameter of the holes increases, however, the number of rows in a given depth of cooling ring reduces, and it is considered that the minimum number of rows of holes which is required to produce a sufficiently tortuous path to significantly reduce the amount of hot gases reaching the duct wall is three rows.

Cooling rings made as described above are of basically simple shape, and using a high power, a single pulse electron beam drilling process, can be manufactured at a greatly reduced cost compared with a conventional drilled cooling ring, particularly when made from high temperature resisting alloys such as PK.24.

Use of an electron beam drilling machine, has the additional advantage, that as long as the voltage is maintained, once the machine is calibrated for a given size of hole in a given thickness of material, the electron beam will always produce the same hole size and cannot wear out, as is the case in any mechanical drilling operation. The calibration is done on a test-piece before drilling of the main component commences.

The invention has a further advantage in that areas of the combustion chamber wall, which for a given engine design are known to be hotter than others, can be cooled by varying the numbers of holes in the hot regions. In an automatic machine for drilling the holes using an electron beam, such variations can easily be made by altering the instructions to the machine on the punched tape or other controlled programme. Thus the most efficient use of cooling air can be obtained through cooling rings of the present invention.

The invention has been described with reference to an annular combustion chamber flame tube of a gas turbine engine, but clearly is applicable to the walls of other hot fluid ducts, for example, liners for reheat pipes, or to the walls of the separate annular array of flame tubes or cans, which are sometimes used in combustion equipment in gas turbine engines.

I claim :

1. A duct comprising coaxial upstream and downstream wall sections which lie at different distances from the longitudinal axis of the duct and a cooling section through which a cooling fluid can be passed to form a film over one of the surfaces of the duct, the cooling section having end portions connected to said wall sections and an intermediate portion which is provided with means defining at least three spaced rows of holes therethrough, each hole in any one row being staggered with respect to the holes in an adjacent row, the diameter of the holes lying in the range from 0.005 ins. to 0.030 ins.

2. A duct according to claim 1, having a circular cross section and wherein the cooling section is in the form of a ring connecting the upstream and downstream wall sections of the duct which have different diameters.

3. A duct according to claim 2 and wherein the downstream wall section has a greater diameter than the upstream wall section, and the intermediate portion of the cooling ring is conical and diverges in a downstream direction between the upstream and downstream wall portions, the holes in the intermediate portion of the cooling ring being arranged so that cooling fluid flowing over the radially outer surface of the upstream wall section of the duct passes through the holes to form a film of cooling fluid over the internal surface of the downstream wall section.

4. A duct according to claim 1 and wherein the centres of any two holes of one row form an equilateral triangle with the centre of a hole from an adjacent row.

5. A duct according to claim 1 and wherein the diameter of the holes lies in the range 0.010 ins. to 0.020 ins.

* * * * *