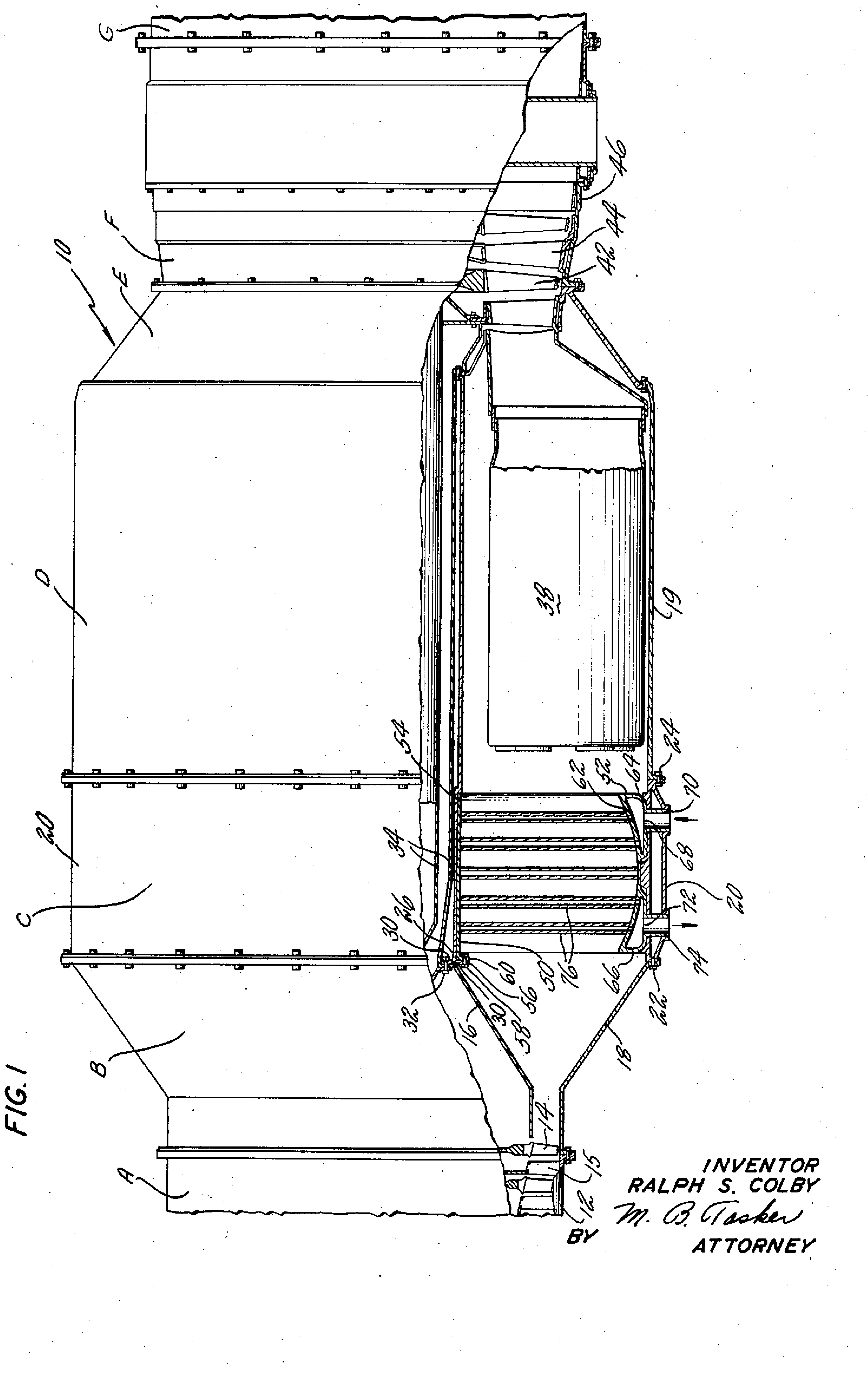
Jan. 31, 1961 R. S. COLBY 2,969,642

RADIATOR MATRIX DESIGN

Filed Dec. 4, 1957 2 Sheets-Sheet 1



INVENTOR
RALPH S. COLBY

BY M. B. Tasker

ATTORNEY

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FIG. 2

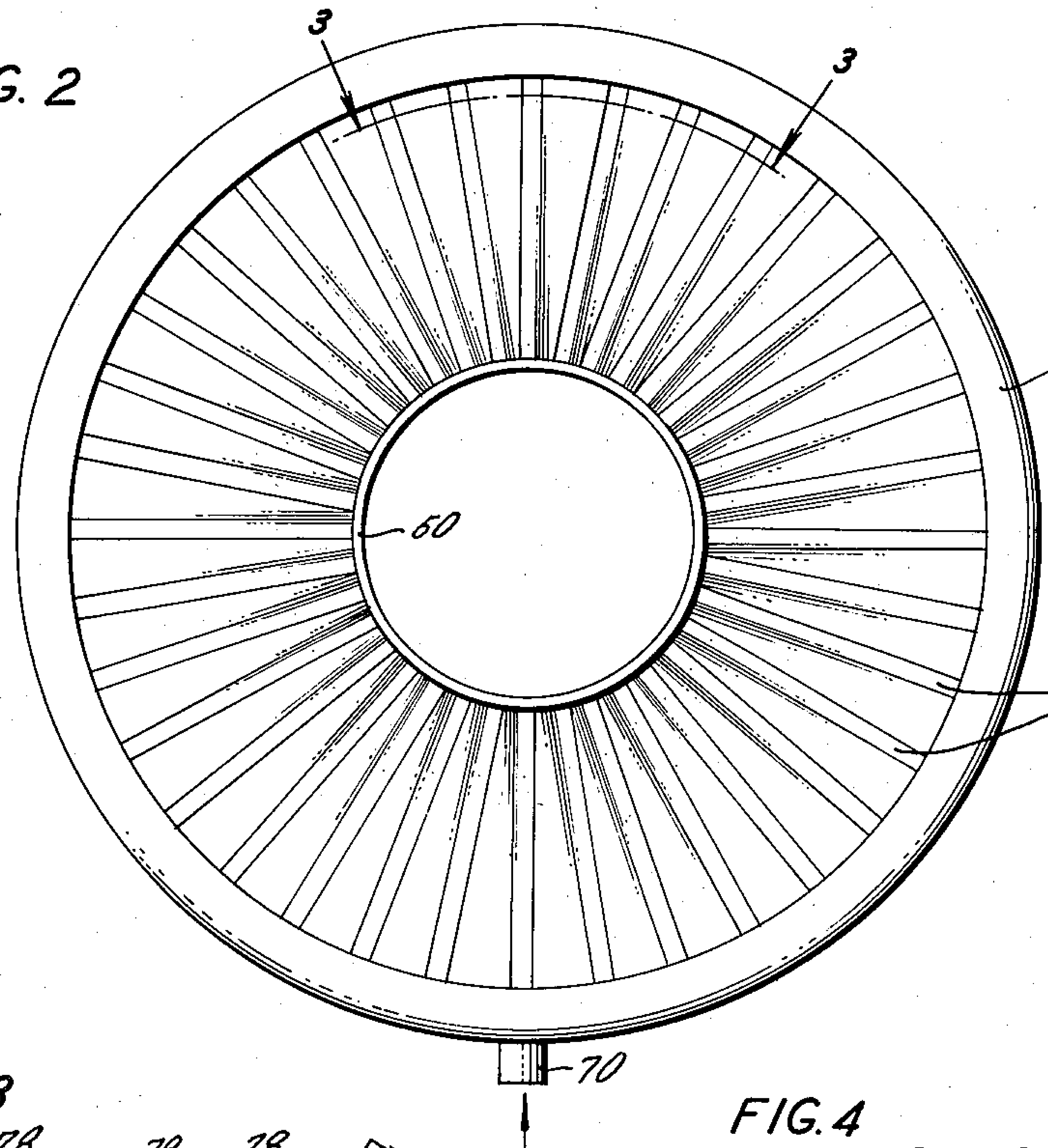


FIG. 3

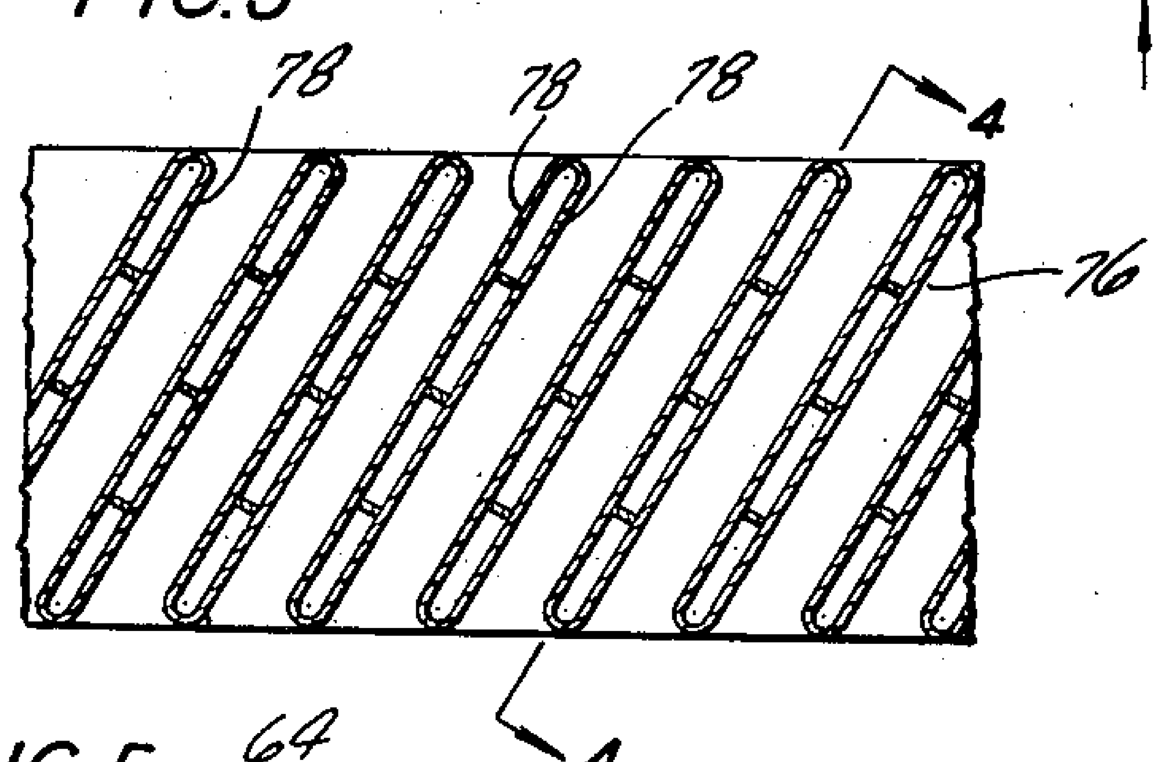


FIG. 4

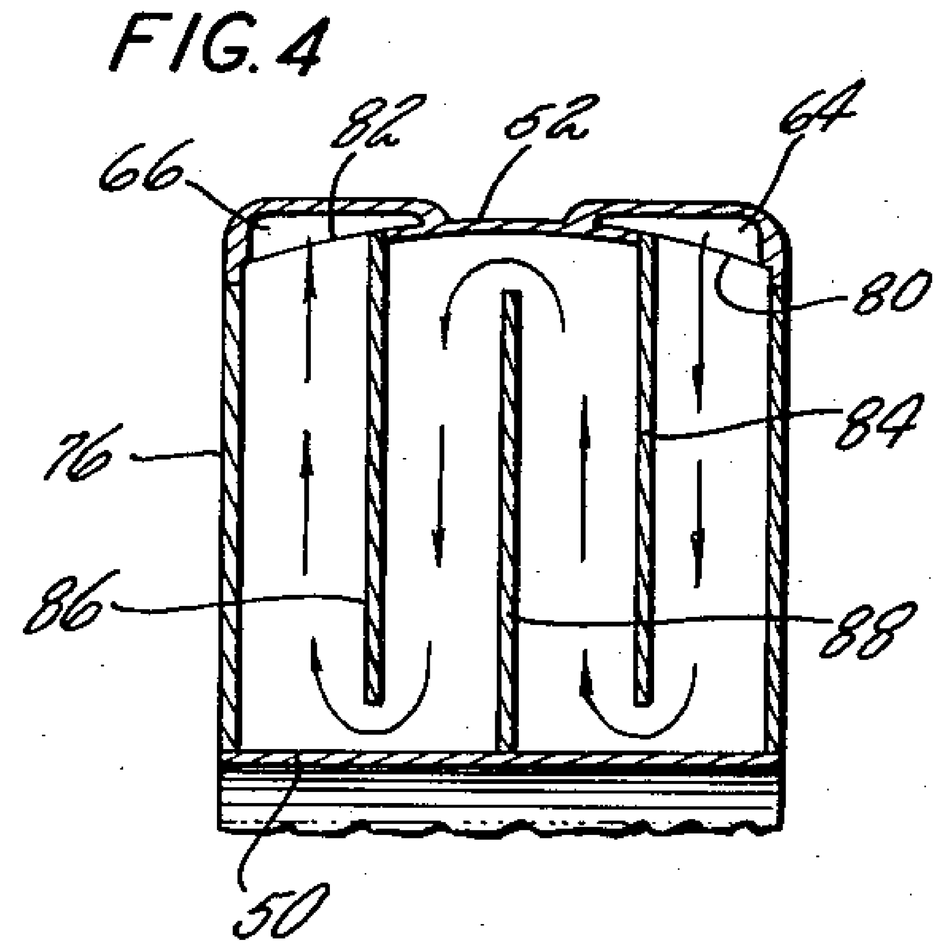
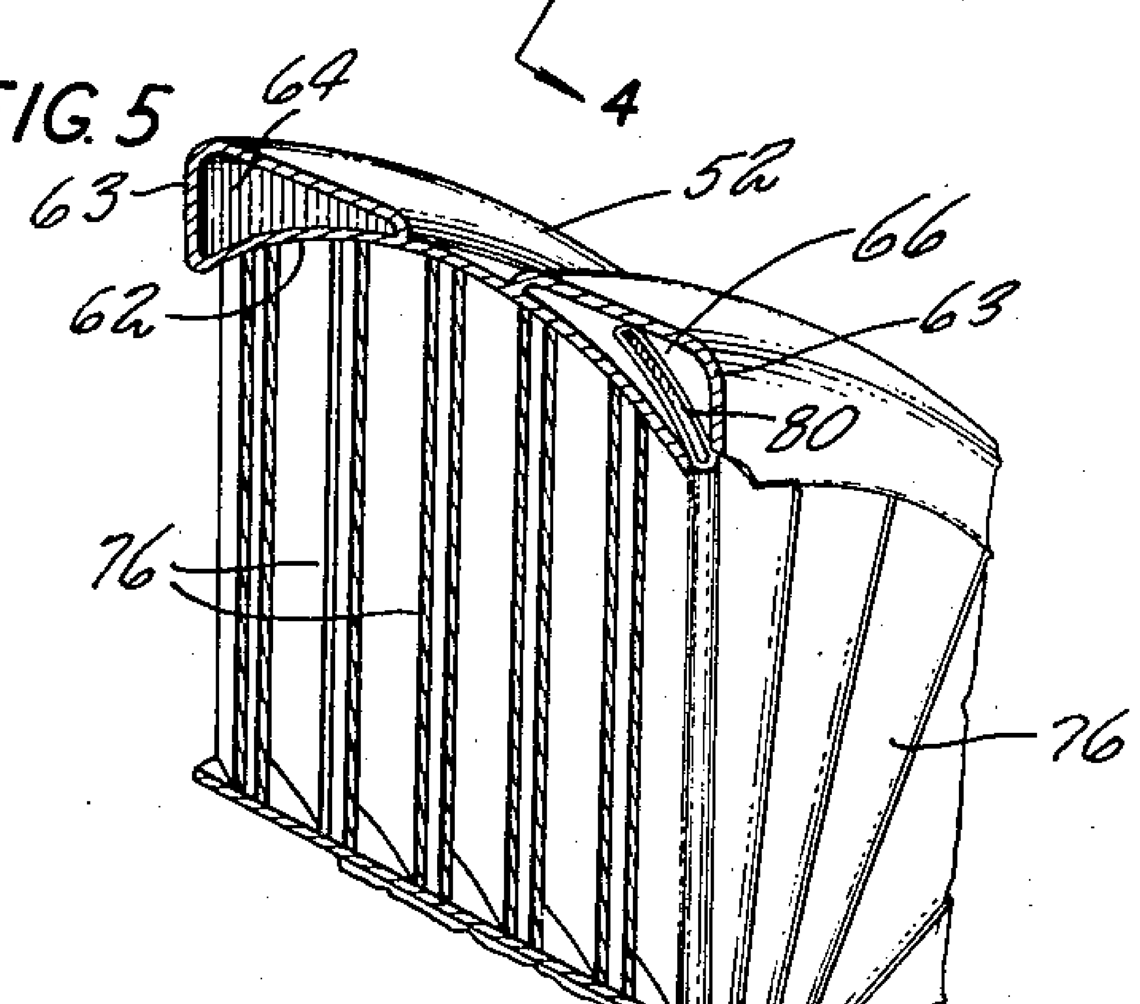


FIG. 5



INVENTOR
RALPH S. COLBY

BY M. B. Tasker
ATTORNEY

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RADIATOR MATRIX DESIGN

Ralph S. Colby, Merrimac, Mass., assignor to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware

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11 Claims. (Cl. 60—39.01)

This invention relates to gas turbine engines and more particularly to improvements in engines of this type which have a radiator in the engine housing downstream from the compressor discharge for heating the air prior to its introduction into the turbine.

Heretofore it has been the practice to provide stator vanes to straighten the flow of the swirling air emerging from the compressor in order to obtain a substantially axial flow of air as it passes through the radiator.

It is an object of this invention to provide an improved radiator construction for such an engine which is adapted to receive the swirling air directly from the rotating vanes of the compressor, thus eliminating the need for air flow straightening vanes between the compressor and the radiator with a consequent shortening and lightening of the engine.

A further object of the invention is to provide a radiator for such an engine in which hollow heat transfer vanes are provided which are inclined to the axial planes through the radiator in a direction to match the flow of the swirling air mass as discharged directly from the rotating blades of the compressor.

A further object of the invention is to provide a radiator of the cross-counterflow type having a reduced dimension between its upstream and downstream ends.

A still further object of the invention is to improve diffuser efficiency by preventing separation of the air flow from the diffuser wall by rotary flow.

These and other objects and advantages of the invention will be pointed out in connection with the following detailed description of a preferred embodiment of the invention shown in the accompanying drawings.

In the drawings,

Fig. 1 is a side elevation, partly in section, of a gas turbine engine embodying the invention;

Fig. 2 is an end view of the radiator as viewed from the downstream end;

Fig. 3 is a sectional view taken along line 3—3 of Fig. 2;

Fig. 4 is a sectional view taken along line 4—4 of Fig. 3; and

Fig. 5 is a perspective view, partly in section, showing a typical portion of the radiator.

In Fig. 1, 10 indicates generally an axial flow turbine engine including a compressor section A, a diffuser section B, a radiator section C, a combustor section D, a transition section E, a turbine section F, and an afterburner section G, the afterburner being largely broken away.

The compressor section includes an outer casing 12, which encloses a plurality of rotating compressor blades 14 and stator vanes 15. Air is discharged directly from the compressor blades through an annular diffuser having diverging inner and outer walls 16 and 18. The radiator section C includes a double-wall annular outer housing 20 which is connected by bolts 22 to the outer casing wall 18 of the diffuser section D and by bolts 24 to the outer wall 19 of the combustor section D. The

inner tubular wall 26 of the radiator section has a flange 30 which is secured to the inner wall 16 of the diffuser section by bolts 32. Annular casing walls 34 are also provided between the radiator and the engine shaft (not shown) and these as well as the inner casing wall 26 of the radiator section extend aft through the combustor section D. Burner cans 38 are provided around the casing walls 34 in combustor section and are enclosed by outer casing wall 19 of the combustor section. Chemical fuel is burned in the burner cans 38 in a usual manner and the hot gases are discharged therefrom through the transition section E into the turbine section F.

The turbine section F may include the usual rotating vanes 42 and stator vanes 44 which are enclosed in the annular outer housing 46 in the usual manner. Gases discharged from the turbine enter the afterburner G where additional fuel may be burned, if desired.

The radiator, with which this invention is particularly concerned, is located in the annular space between the inner wall 26 of the radiator section and the outer wall 20 thereof. As shown most clearly in Figs. 2 through 5, the radiator matrix includes an inner shell 50 and an outer shell 52 which are annular and concentric. The inner shell 50 is received in a shallow annular recess formed in the inner wall 26 between a shoulder 54 (Fig. 1) and an outstanding flange 56 which is welded to wall 26. A series of bolts 58 serve to connect the flange 56 to an outstanding flange 60 at the upstream end of the inner shell 50.

The outer shell 52 of the radiator matrix consists of a curved plate 62 (Fig. 5) having an inlet header 64 and an outlet header 66 formed integral therewith and extending around the outside of plate 62. As herein shown, the headers are formed by bending the edge portions 63 of plate 62 back over the outside of the plate in spaced relation thereto, and welding the edges of the plate adjacent to the center line thereof to form conduits which are of larger cross section at the upstream and downstream ends of the radiator and taper back toward the center of the radiator.

It will be obvious, however, that the headers may be made separate from the plate, if desired. The inlet header 64 has an external passage 68 therethrough (Fig. 1) which communicates with a header inlet conduit 70. The outlet header 66 has a similar passage 72 which communicates with an outlet header conduit 74. Herein, the inlet and outlet header conduits 70 and 74 extend through the double walled casing member 20 and are welded to the headers 64 and 66 over the passages 68 and 72 respectively.

Crossflow through the radiator between the inlet and outlet headers is provided by a plurality of generally radial, hollow vanes 76. Vanes 76 have generally parallel major surfaces 78 which extend from the upstream to the downstream ends of the radiator. These vanes extend radially from the inner shell 50 to the plate 62 of the outer shell 52. The inner ends of the hollow vanes are welded to the inner shell 50 which forms a complete closure for the open ends of these vanes at their inner ends. At their outer ends the vanes 76 are welded to the outer shell 62 about pairs of spaced openings 80 and 82 (Fig. 4). It will be noted that the opening 80 communicates with the inlet header 64 adjacent the downstream end of the shell 52, whereas the opening 82 communicates with the outlet header 66 adjacent the upstream end of the shell, the hollow vanes being otherwise closed at their outer ends by outer plate 62.

In accordance with this invention, the hollow vanes 76 are disposed at an angle to axial planes taken through the radiator. The angle of deflection of these vanes from the axial planes is such as to match the swirling gases discharged from the compressor. These gases pass through the diffuser and the vanes with a swirling flow, thus preventing separation of the flow from the passage walls.

In order to distribute the flow through the vanes over the entire surface of the vanes, a plurality of baffles are secured to inner and outer shells **50** and **52** which extend from one side to the other of the major surfaces of the vanes. These baffles are shown most clearly in Figs. 3 and 4. Two baffles, **84** and **86**, are welded to plate **62** and extend inwardly toward the inner shell **50** but terminate slightly short of this inner shell. An intermediate baffle **88** is welded to the inner shell **50** and extends outwardly between baffles **84** and **86** toward plate **62**, but terminates slightly short of the latter. In this way, the fluid entering the vanes from inlet header **64** is caused to pursue a tortuous path, as shown by the arrows in Fig. 4, before it reaches the outlet header **66** during which flow it has moved over all of both major surfaces of the vanes.

In operation, the swirling air discharged by the compressor blades **14** enters the diffuser section B directly without the usual straightening vanes and enters the radiator section C with a swirling motion. Because of the rotary motion of the air mass in the diffuser section and the resulting centrifugal force, a radial pressure gradient is created and separation difficulties are not encountered. Due to the inclination of the vanes **76**, high aerodynamic efficiency is maintained in the radiator with very little separation of the air from the vanes. As the air passes axially through the annular radiator section C it is heated by vanes **76** prior to its flow to the combustor section D. Liquid metal or other heat transfer medium entering the conduit **70** and header **64** flows through the passages **80** in plate **62** and flows inwardly between the sidewall of the vanes and the baffles **84** until it strikes the inner shell **50** and is deflected outwardly between the baffles **84** and **88**. It is then deflected by plate **62** and again flows inwardly between baffles **88** and **86** until it is caused by inner shell **50** to flow outwardly again between baffles **86** and the opposite sidewall of the vanes and finally through passages **82** into outlet header **66** and conduit **74**.

It will be evident that a very compact engine is provided. By omitting the turning vanes, the engine can be considerably shortened and lightened and also by reason of the resulting rotation of the air in the diffuser section problems of separation of the flow from the diffuser walls do not arise.

Further, as a result of the inclination of the vanes **76** relative to the axis of the engine, the radiator can be materially shortened with the same amount of radiating surface. Thus, the construction of this invention not only results in a weight saving and a reduction in overall engine length but also the pressure losses in the engine are lessened by the removal of the turning vanes and by the improved diffuser efficiency resulting from lack of separation of the air from the wall surfaces.

While only one embodiment of the invention has been shown for purposes of illustration, it will be understood that various changes in the construction and arrangement of the parts may be made without exceeding the scope of the invention.

I claim:

1. In an axial flow gas turbine engine, an axial compressor having rotating blades, a diffuser receiving the swirling air from said compressor having an annular diffuser passage coaxial with said shaft, an axial flow radiator receiving the swirling air from said diffuser comprising inner and outer shells concentric with said shaft, annular inlet and outlet headers associated with said outer shell, and a plurality of hollow radial vanes extending between said shells having their interiors in fluid communication with said headers, said vanes lying in planes inclined with respect to axial planes through said radiator.

2. In an axial flow gas turbine engine, an axial compressor having rotating blades, an annular diffuser receiving the swirling air directly from the rotating blades of said compressor, an annular radiator receiving the swirling air directly from said diffuser, said radiator having annular inner and outer shells and a plurality of hollow radial vanes extending from the upstream to the downstream ends of said radiator between said shells, annular inlet and outlet headers surrounding said outer shell having fluid communication with the interior of said vanes, said vanes lying in planes inclined with respect to axial planes through said radiator which intersect said vanes and in the direction of flow of the swirling air discharged from said compressor.

3. In an axial flow gas turbine engine, an axial compressor having rotating blades, an annular diffuser receiving the swirling air directly from the rotating blades of said compressor, an annular radiator receiving the air discharged from said diffuser comprising inner and outer concentric shells, annular inlet and outlet headers associated with said outer shell, and a plurality of hollow radial vanes extending between said shells having fluid communication through said outer shell with said headers, said vanes lying in planes inclined with respect to the axial planes through said radiator in a direction to match the flow of said swirling air discharged from said compressor.

4. In an axial flow gas turbine engine, an axial compressor having rotating vanes, an annular diffuser receiving the swirling air directly from the rotating blades of said compressor, an annular radiator receiving the air discharged from said diffuser comprising inner and outer concentric shells, annular inlet and outlet headers associated with said outer shell, a plurality of hollow radial vanes extending between said shells having fluid communication through said outer shell with said headers, said vanes lying in planes inclined with respect to axial planes through said radiator in a direction to match the flow of said swirling air discharged from said compressor, said inlet header being connected to the outer ends of said vanes adjacent their downstream edges and said outlet header being connected to the outer ends of said vanes adjacent their upstream edges, and baffle means in said hollow vanes for directing the fluid entering from said inlet header through a tortuous path within said hollow vanes to said outlet header.

5. In an axial flow gas turbine engine, an axial compressor having rotating blades, an annular radiator receiving the swirling air discharged from the rotating blades of said compressor, said radiator comprising annular inner and outer shells, annular inlet and outlet headers surrounding said outer shell at the downstream and upstream ends thereof respectively, said outer shell forming a wall of each header, a plurality of hollow vanes extending between said shells, said vanes having their inner ends closed by said inner shell and having their outer ends closed by said outer shell, means for establishing fluid communication between the interior of said hollow vanes and said headers including openings in said outer shell which register with the outer ends of said hollow vanes, said vanes lying in planes inclined out of the axial planes through said radiator in a direction to match the flow of the swirling air mass discharged from said compressor.

6. In an axial flow gas turbine engine, an axial compressor, a diffuser receiving the swirling air directly from said compressor, and a radiator receiving the air discharged from said diffuser, said radiator comprising an inner axial tubular shell, an outer axial tubular shell, a plurality of hollow radial heat transfer vanes extending between said shells, said vanes having their major surfaces in planes at an angle to the axial planes through said radiator, said inner shell forming a closure for the inner ends of said hollow vanes, said outer shell forming a closure for the outer ends of said hollow vanes, an annular inlet header surrounding said outer shell at the

downstream end of said radiator, said outer shell having openings providing fluid communication between said inlet header and the interior of said vanes, and an annular outlet header surrounding said outer shell at the upstream end of said radiator, said outer shell having openings providing for fluid communication between said outlet header and the interior of all of said vanes.

7. In a heat exchanger, an inner axial shell, an outer axial shell, annular inlet and outlet headers surrounding said outer shell at the downstream and upstream ends of said shell respectively, a plurality of hollow vanes extending between said shells, said vanes being disposed in planes at an angle to axial planes through said shells, and means for establishing fluid communication between the interior of each vane and each of said headers at the outer ends of said vanes.

8. In a heat exchanger, an inner axial shell, an outer axial shell, annular inlet and outlet headers surrounding said outer shell at the downstream and upstream ends of said shell respectively, a plurality of hollow vanes extending between said shells, said vanes being disposed in planes at an angle to axial planes through said shells, means for establishing fluid communication between the interior of each vane and each of said headers at the outer ends of said vanes, and baffle means in said vanes for directing the flow through a tortuous path within said vanes from said inlet header to said outlet header.

9. In a heat exchanger, an inner tubular shell, a concentric outer shell, hollow vanes extending between said shells, said shells forming closures for the open extremities of said vanes, annular inlet and outlet headers surrounding said outer shell at the downstream and upstream ends thereof respectively, said outer shell forming one wall of each of said headers, said outer shell having passages therein for establishing fluid communication between the interior of said vanes and said inlet header adjacent the upstream edge of each vane and between the interior of said vanes and said outlet header adjacent the upstream edge of each vane.

10. In a heat exchanger, an inner tubular shell, a concentric outer shell, hollow vanes extending radially between said shells, said vanes being inclined with respect to axial planes through said shells, said shells forming closures for the open extremities of said vanes, said outer shell having inlet and outlet headers formed therein which extend peripherally around said outer shell at the downstream and upstream ends respectively of said shell, said outer shell having passages therein for establishing fluid communication between said inlet header at the outer end of each vane adjacent its downstream edge and said outlet header at the outer end of each vane adjacent the downstream edge thereof, and baffles carried by said shells in the areas thereof enclosed by the open extremities of said vanes and extending into the spaces within said hollow vanes.

11. In a heat exchanger, an inner tubular shell, a concentric outer tubular shell, hollow vanes extending between said shells, said shells forming closures for the open extremities of said vanes, said outer shell having inlet and outlet headers formed therein which extend peripherally around said outer shell at the downstream and upstream ends thereof respectively, said vanes being disposed in planes oblique to axial planes of said shells and having their major surfaces generally parallel and extending from the upstream to the downstream ends of said shells, and baffles carried by said shells and extended into the hollow interior of said vanes, said baffles extending across the space between said major surfaces to divide said space into a plurality of intercommunicating compartments in series, the compartment at one end of the series being connected to said inlet header and the compartment at the other end of the series being connected with said outlet header.

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CERTIFICATION OF CORRECTION

Patent No. 2,969,642 January 31, 1961

Ralph S. Colby

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.

Column 3, line 64, after "engine," insert -- an axial shaft, --; column 5, line 3, after "of" insert -- all of --; line 37, for "upstream" read -- downstream --.

Signed and sealed this 27th day of June 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents