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(71) Applicant: GENERAL ELECTRIC COMPANY [US/US]; One River Road, Schenectady, NY 12345 (US).

(72) Inventor: RENTZ, Lawrence, Edward; 29 Gloucester Street, Clifton Park, NY 12065 (US).

(74) Agents: HARRINGTON, Mark, F. et al.; Harrington & Smith, LLP, 1809 Black Rock Turnpike, Fairfield, CT 06432-3504 (US).

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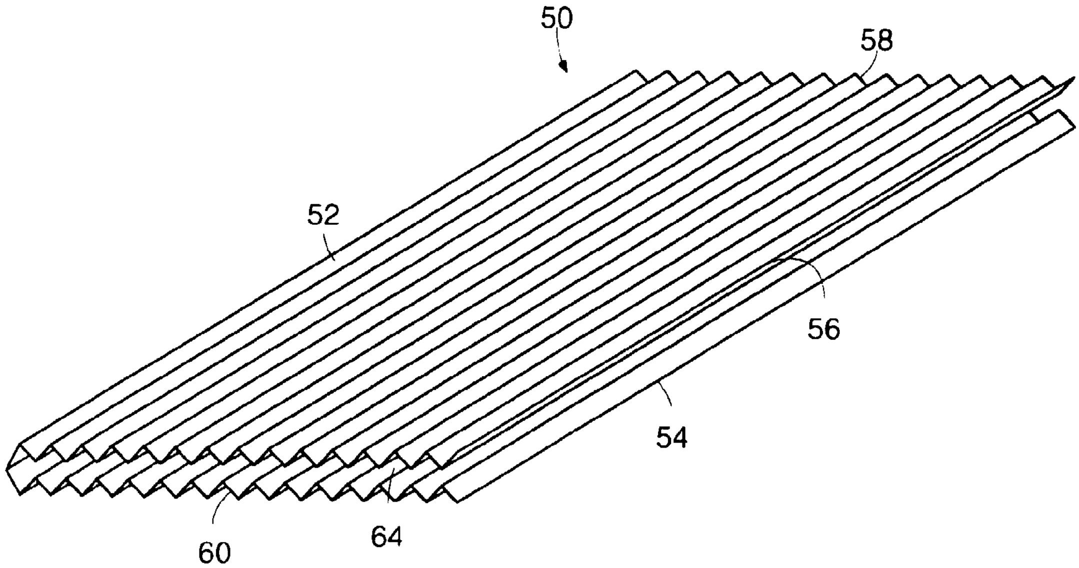

(57) Abstract: A turbine recuperator includes a housing (66) and a support member (62) positioned within the housing (66). A passage (67) extends between the housing (66) and the support member (62). A plurality of heat transfer cells (63) are secured to the support member (62). Each cell (63) includes a corrugated wheet (52) folded over onto itself, with the sides (54, 56) that are folded over being secured to the support member (62). The ends (58, 60) of the sheets (52) are sealed to define a chamber (64). An inlet header (68) is in fluid communication with each chamber (64) through a plurality of inlets (72) formed in the support header (62). An outlet header (74) is in fluid communication with each chamber (64) through a plurality of outlets (76) formed in the support header (62).

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TURBINE RECUPERATOR

BACKGROUND OF THE INVENTION

The present invention relates to turbine recuperators, and, more particularly, to turbine recuperators having improved heat transfer and ease of fabrication.

Small gas turbines and microturbines use recuperators to increase their efficiency. A recuperator takes heated exhaust air and uses it to preheat cold air that is to be introduced into the turbine. Recuperators typically include cold cells, through which cold air to be preheated passes, and hot cells, through which the heated exhaust air passes.

One example of a prior art recuperator design in shown in FIGS. 1-2. A recuperator 2 includes a cylindrical housing 4, within which a support member 6 is contained. A plurality of cold cells 8 and hot cells 10 extend outwardly from support member 6 in alternating fashion about the circumference of support member 6. Cold cells 8 and hot cells 10 preferably are curved along their radial length, to accommodate expansion and contraction of the cells. Cold air to be preheated passes through a header in support member 6 and then through cold cells 8, as described below in connection with Fig. 2. Heated exhaust air flows through annular channel 12, formed between housing 4 and support member 6, thereby passing over the surface of hot cells 10. As seen in FIG. 2. cold cell 8 includes a heat transfer fin 14, formed of a sheet of corrugated metal, encased in a shell 16, typically welded about its edges (shown in FIG. 2 with one end plate removed, and in a flat non-curved orientation for simplicity). Cold cell 8 is secured along side edge 21 to support member 6. Cold air 18 enters the interior of shell 16 through an inlet 20 that is in fluid communication via a header (not shown) with a cold air supply. Heated air 22 exits shell 16 through an outlet 24 into a header (not shown). As cold air 18 enters shell 16, it passes over the surface of heat transfer fin 14, gradually warming as it travels through shell 16 till it gets to outlet 24. As seen in FIG. 3, hot cell 10 is formed of a heat transfer fin 14, also formed of a sheet of corrugated metal (shown in a flat, non-curved orientation for simplicity). Hot turbine exhaust air 26 passes over the surface of heat transfer fin 14 of hot cell 10, cooling as it travels along fin 14 and exits hot cell 10 as cool exhaust air 28. In recuperator 2, as seen in FIG. 1, heat is transferred from the hot turbine exhaust air, that travels through channel 12 over hot cells 10, to cold cells 8, thereby preheating the air to be used in the turbine.

Such a recuperator design is limiting in that a significant amount of material must be used, and its assembly requires a significant amount of welding and handling of material. Further, the heat transfer between the hot and cold air primarily occurs between flat sheets, thereby failing to optimize the surface area used in the conduction of heat.

Another example of a recuperator 29 with cold and hot cells is shown in Fig. 4. A plurality of hot cells 30 are formed of tubes, or conduits. Cold cells 32 are also formed of tubes or conduits that extend alongside hot cells 30 in parallel fashion. Only a few hot cells 30 and cold cells 32 are shown here for purposes of clarity. Hot cells 30 are connected to one another through a set of headers 34, only one of which is shown. Cold cells 32 are similarly connected to one another via headers (not shown). Heated exhaust 34 enters an endmost hot cell 30 through an inlet, not visible, and passes in serpentine fashion through each of the hot cells by way of headers 34. Cooled exhaust 36 then exits at the opposite end through an outlet 38 in a hot cell 30. Similarly, cold air 40 enters cold cells 32 through an inlet (not shown), and passes in serpentine fashion through each cold cell 32 and associated headers (not shown) and heated air 42 exits cold cells 32 through an outlet (not shown). Although this design provides greater heat transfer than the prior art recuperator of FIGs. 1-3 due to the long path through which the air streams pass, this design consequently results in less than optimum pressure drops due to the serpentine path the air must follow. Excessive pressure drops reduce the overall turbine cycle efficiency. Such a design is also limiting in that it requires the use of a complex set of headers. thereby requiring costly tooling for fabrication and a labor intensive and expensive assembly process.

Such complex recuperator designs are costly. and, in fact, can make up between 25% to 40% of the overall cost of a microturbines. due to the complexity of the design and amount of material required in order to achieve the desired effectiveness.

Thus. there is a particular need to provide a turbine recuperator that reduces or wholly overcomes some or all of the difficulties inherent in prior known devices. Particular objects and advantages of the invention will be apparent to those skilled in the art, that is, those who are knowledgeable or experienced in this field of technology, in view of the following disclosure of the invention and detailed description of preferred embodiments.

BRIEF SUMMARY OF THE INVENTION

It is, therefore, seen to be desirable to provide a recuperator that optimizes effectiveness of the turbine cycle and minimizes the pressure drop across the recuperator, while at the same time minimizes the amount of material used and the number of manufacturing operations required to assemble the recuperator.

In accordance with a first aspect, a turbine recuperator includes a housing. A support member is positioned within the housing and defines a passage between the support member and the housing. A plurality of heat transfer cells are secured to the support member. Each heat transfer cell is formed of a sheet of corrugated material having two opposed ends and two opposed sides. The sheet is folded over upon itself such that the sides are proximate one another, and the sides are secured to the support member. The ends are sealed to define a chamber within the heat transfer cell. The cell further has an inlet header and an outlet header. A plurality of inlets are formed in the support member; with each inlet in fluid communication with the inlet header and a chamber. A plurality of outlets are formed in the support member, with each outlet in fluid communication with the outlet header and a chamber.

From the foregoing disclosure, it will be readily apparent to those skilled in the art that the present invention provides a significant advance. Preferred embodiments of the turbine recuperator of the present invention can provide improved heat transfer and improved manufacturability, while reducing the materials used and the steps required to assemble the recuperator. These and additional features and advantages of the invention disclosed here will be further understood from the following detailed disclosure of preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an end view of a prior art recuperator design

FIG. 2 is a perspective view of a cold cell of the prior art recuperator of FIG. 1;

FIG. 3 is a perspective view of a hot cell of the prior art recuperator of FIG. 1;

FIG. 4 is a perspective view of another prior art recuperator design, shown partially assembled;

FIG. 5 is a perspective view of a corrugated sheet of metal folded over upon itself to form a heat transfer cell of a recuperator of the present invention;

FIG. 6 is an end view of a recuperator of the present invention;

FIG. 7 is a section view of the recuperator of FIG. 6, taken along line A-A of FIG 6: and

FIG. 8 is a perspective view in cross-section, shown partially broken away, of the recuperator of FIG. 6.

The figures referred to above are not drawn necessarily to scale and should be understood to present a representation of the invention, illustrative of the principles involved. Some features of the turbine recuperator depicted in the drawings have been enlarged or distorted relative to others to facilitate explanation and understanding. The same reference numbers are used in the drawings for similar or identical components and features shown in various alternative embodiments.

DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of a recuperator 50 of the present invention is shown in FIGs. 5-8. A sheet 52 of corrugated material having side edges 54, 56 and end edges 58, 60 is folded over upon itself such that side edges 54, 56 are proximate one another. Sheet 52 is preferably metal, and may be, for example, formed of iron, or a nickel-based alloy. End edges 58, 60 are then crimped and sealed, preferably by welding, and sides edges 54, 56 are secured to support member 62, preferably by welding as well, forming a heat transfer cell 63. Since all three sides of folded over sheet 52 having exposed edges have been sealed, either to another portion of the sheet or to support member 62, a chamber 64 is defined within sheet 52. A plurality of heat transfer cells 63 are preferably secured around the circumference of support member 62. Heat transfer cells 63 are preferably curved along their radial dimension with respect to support member 62, as seen in FIGS. 6, 8, in order to accommodate thermal expansion and contraction.

Support member 62 is positioned within a housing 66, defining a passage 67 between support member 62 and housing 66. In a preferred embodiment, support member 62 and housing 66 are circular in cross-section, and are also co-axial with one another, such that passage 67 has an annular shape. An inlet header 68 is formed in one end of support member 62 and an outlet header 74 is provided in the other end of support member 62. Inlet header 68 is in fluid communication with a supply of cold air 70 to be preheated by recuperator 50. A plurality of inlets 72 are formed in support member 62, with each inlet 72 forming a fluid communication pathway between inlet header 68 and a respective chamber 64. A plurality of outlets 76 are formed in support member 62. with each outlet 76 forming a fluid communication pathway between a respective chamber 64 and outlet header 74.

In use, cold air 70 to be preheated flows into inlet header 68 and into chambers 64 through inlets 72. Hot turbine exhaust air 78 enters passage 67 and flows across the exterior surface of heat transfer cells 63. exiting passage 67 as cooled exhaust 79. As the cold air 70 to be preheated passes through chambers 64, heat transferred from hot exhaust air 78 warms the air in chambers 64, forming warm air 80 that exits chambers 64 via outlets 76 and exits recuperator 50 via outlet header 74. It is to be appreciated that, alternatively, exhaust air 78 could pass through heat transfer cells 63 and cold air 70 to be preheated could pass over the exterior surface of heat transfer cells 63. In the illustrated embodiment. hot exhaust air 78 flows counter to the flow of cold air 70. It is to be appreciated that the recuperator of the present invention can be configured to work in a parallel flow arrangement, or in any other flow arrangement that is desired, as well.

By forming the heat transfer cells 63 of a single piece of corrugated metal sealed along its edges, the amount of material used to form the cells is advantageously reduced, resulting in significant cost savings, as well as a reduction in the number of manufacturing steps required to build the heat transfer cells when assembling the recuperator. The corrugated surface of heat transfer cells 63 provides greater surface area than the flat surfaces found in certain prior art recuperator designs. thereby optimizing heat transfer from the hot turbine exhaust to the cold air to be preheated. The construction of the present invention also advantageously decreases the overall pressure drop across the recuperator as compared to some recuperators of the prior art. By providing such a simple construction with few parts, the recuperator of the present invention is well suited for high volume manufacturing and standardization of parts. reducing manufacturing and inventory costs.

The recuperator of the embodiment disclosed above is one in which the heat transfer cells extend radially outwardly from a central support member. It is to be appreciated that other configurations of the recuperator of the present invention are considered to be within the scope of the invention. The support member and housing could have other shapes, e.g., rectangular. In certain preferred embodiments, the microturbine is surrounded by the recuperator to minimize heat loss and pressure drop. In other preferred embodiments, the recuperator could be off-board, that is, detached from the microturbine and connected thereto only by necessary conduit or ductwork.

While the present invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A turbine recuperator comprising, in combination:

a housing (66);

a support member (62) positioned within the housing (66) and defining a passage (67) between the support member (62) and the housing (66);

a plurality of heat transfer cells (63) secured to the support member (62), each heat transfer cell (63) comprising a sheet (52) of corrugated material having two opposed ends (58, 60) and two opposed sides (54, 56), the sheet (52) being folded over upon itself such that the sides (54, 56) are proximate one another, the sides (54, 56) being secured to the support member (62) and the ends (58, 60) being sealed to define a chamber (64);

an inlet header (68);

a plurality of inlets (72) formed in the support member (62); each inlet (72) in fluid communication with the inlet header (68) and a chamber (64);

an outlet header (74); and

a plurality of outlets (76) formed in the support member (62), each outlet (76) in fluid communication with the outlet header (74) and a chamber (64).

2. The turbine recuperator of claim 1, wherein the chamber (64) defines a cold cell (63) through which air to be preheated passes.

3. The turbine recuperator of claim 1, wherein the housing (66) has a cylindrical cross-section.

4. The turbine of claim 3, wherein the support member (62) has a cylindrical cross-section and extends coaxially with the housing (66).

5. The turbine of claim 4. wherein the heat transfer cells (63) are curved along their radial dimension with respect to the support member (62).

6. The turbine of claim 1. wherein the passage (67) is configured to provide for a flow of hot exhaust air (78) in a direction counter to a flow of cold air (70) passing from the inlet header (68). through the inlets (72). the chamber (64) and the outlets (76) into the outlet header (74).

7. The turbine of claim 1. wherein the corrugated material (52) is metal.

8. The turbine of claim 7, wherein the sides (54, 56) are welded to the support member (62) .

9. The turbine of claim 7, wherein the ends (58, 60) are welded together to form a seal.

10. The turbine of claim 1, wherein the corrugated material (52) is iron.

11. The turbine of claim 1, wherein the corrugated material (52) is a nickel-based alloy.

12. A turbine recuperator comprising, in combination:

a cylindrical housing (66);

a cylindrical support member (62) positioned coaxially within the housing (66) and defining an annular passage (67) between the support member (62) and the housing (66) through which hot exhaust air travels (78);

a plurality of heat transfer cells (63) secured to the support member (62). each heat transfer cell (63) comprising a sheet of corrugated material (52) having two opposed ends (58, 60) and two opposed sides (54, 56). the sheet (52) being folded over upon itself such that the sides (54, 56) are proximate one another.

the sides (54, 56) being secured to the support member (62) and the ends (58, 60) being sealed to define a chamber (64);

an inlet header (68);

a plurality of inlets (72) formed in the support member (62); each inlet (72) in fluid communication with the inlet header (68) and a chamber (64) to introduce cold air (70) to be preheated into the chamber (64);

an outlet header (74); and

a plurality of outlets (76) formed in the support member (62), each outlet (76) in fluid communication with the outlet header (74) and a chamber (64).

13. The turbine recuperator of claim 12, wherein the heat transfer cells (63) are curved along their radial dimension with respect to the support member (62).

14. The turbine of claim 11, wherein the corrugated material (52) is metal.

15. The turbine of claim 11, wherein the corrugated material (52) is iron.

16. The turbine of claim 11, wherein the corrugated material (52) is a nickel-based alloy.

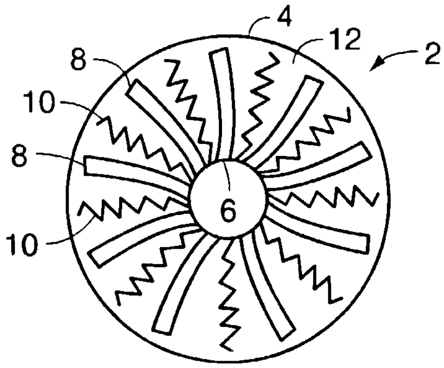
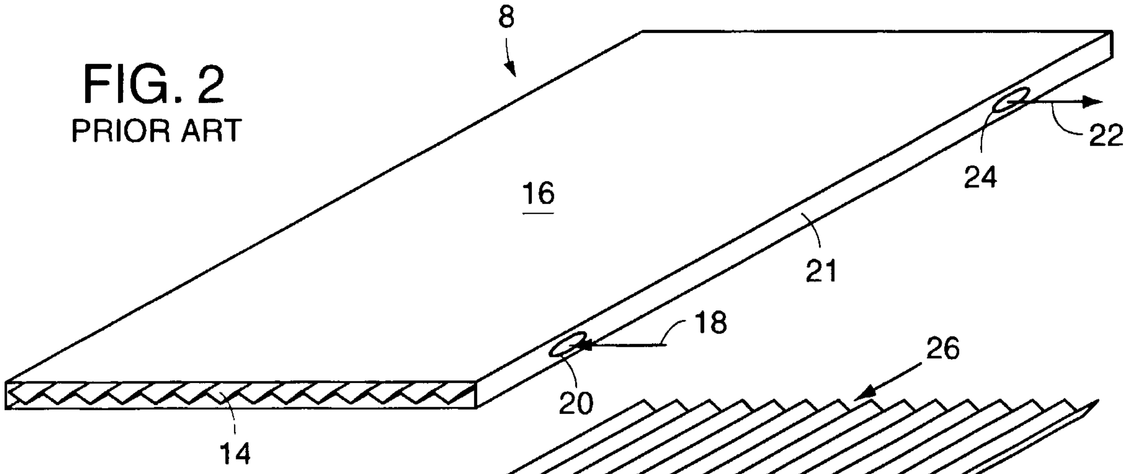


FIG. 1
PRIOR ART

FIG. 2
PRIOR ART



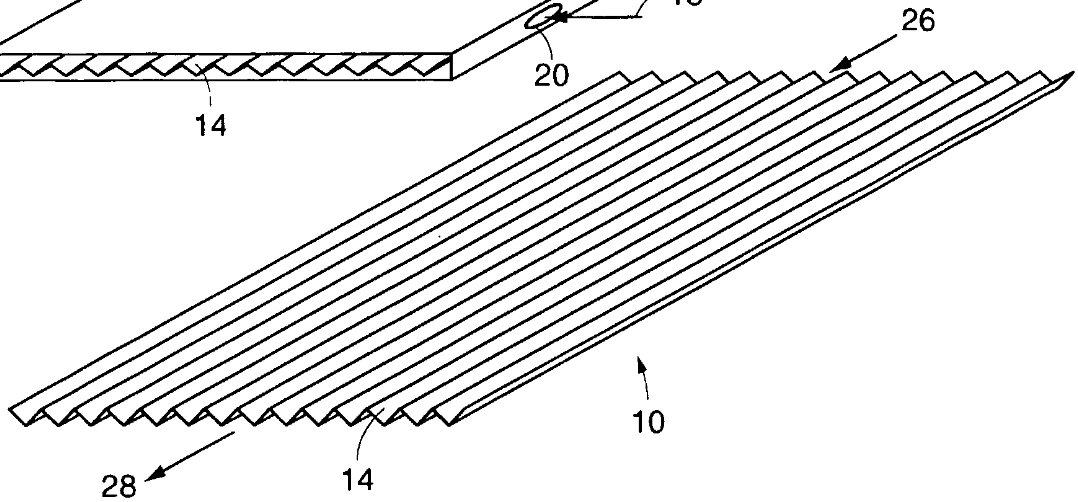


FIG. 3
PRIOR ART

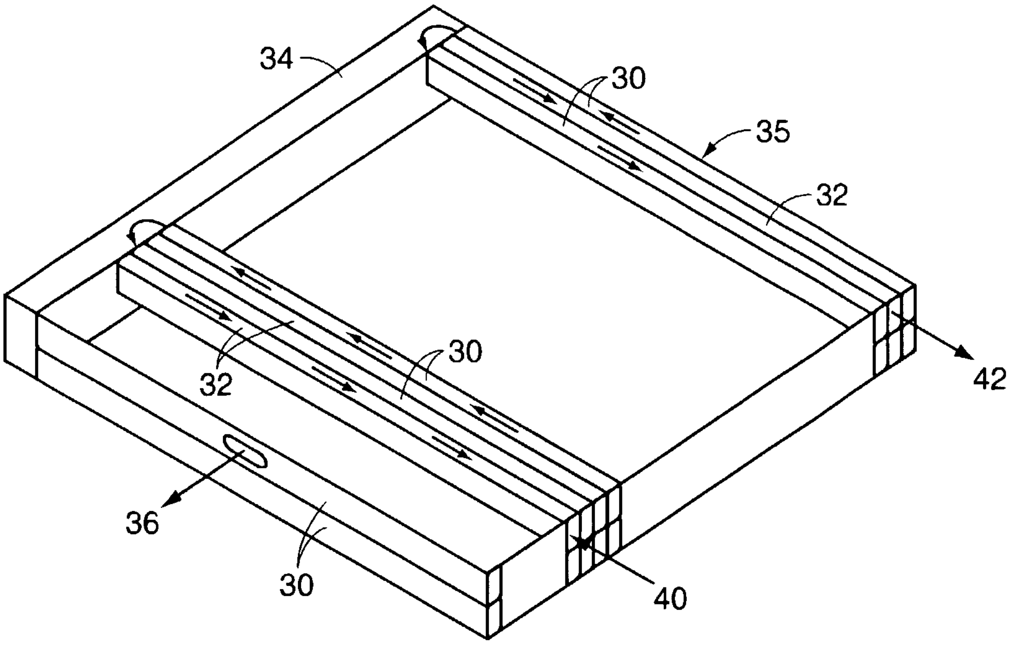


FIG. 4
PRIOR ART

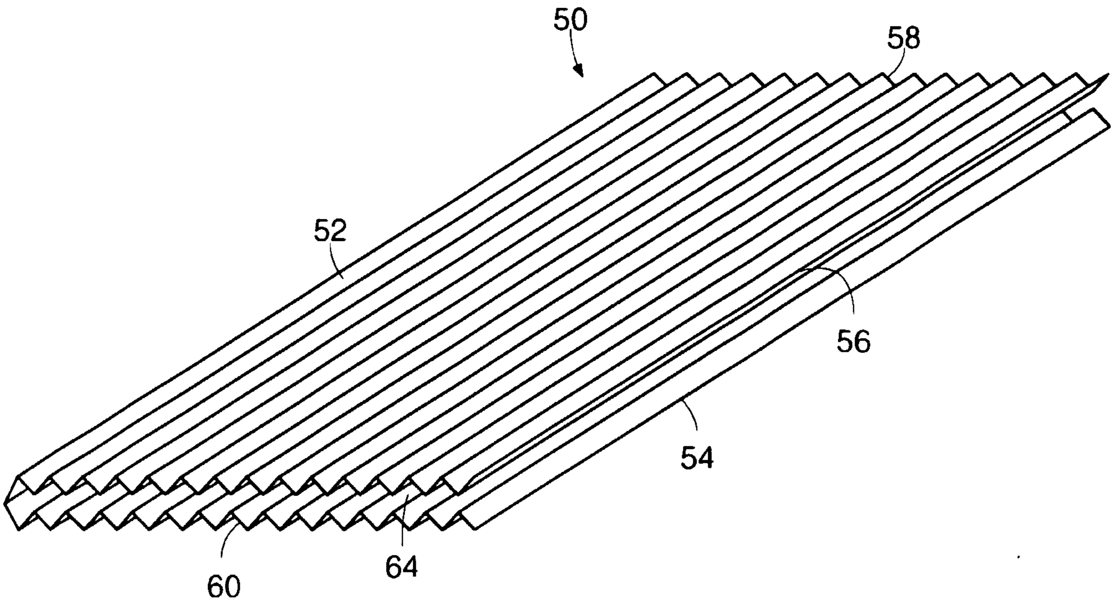


FIG. 5

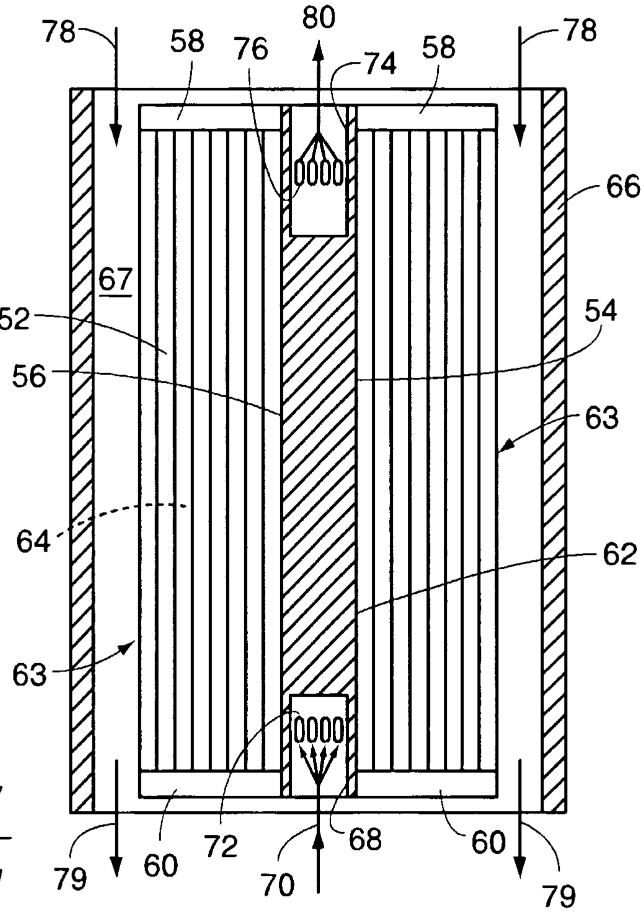


FIG. 7

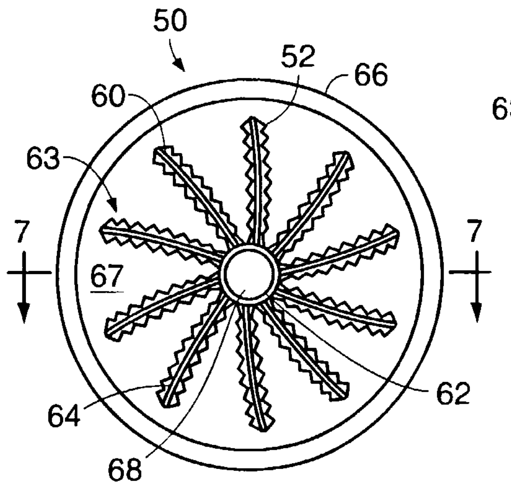


FIG. 6

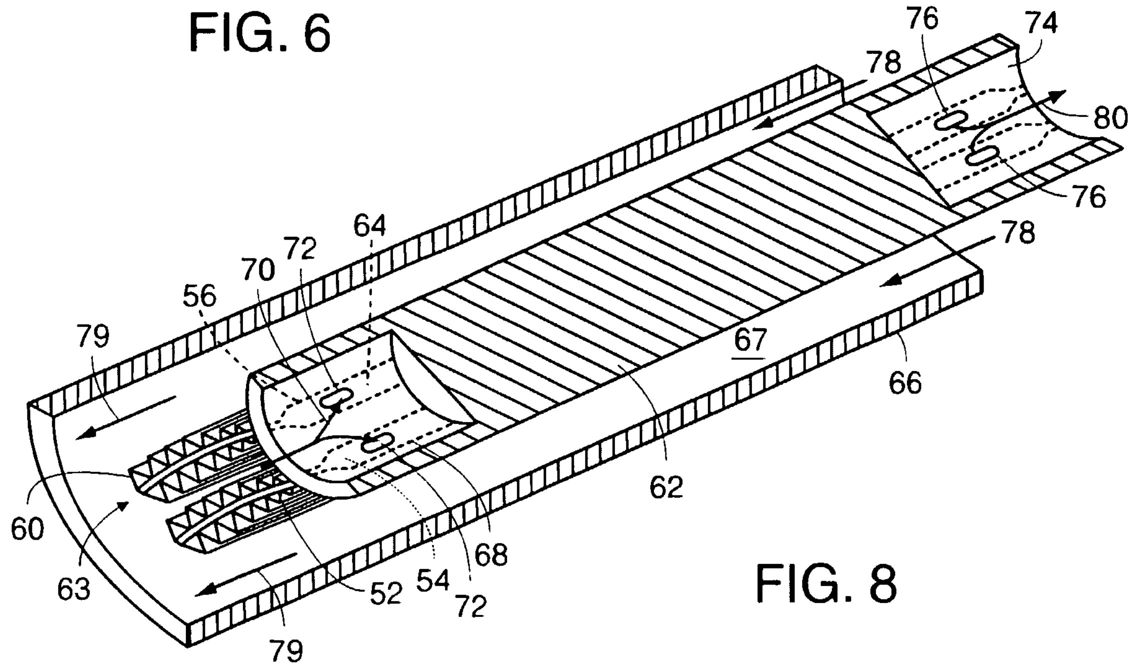


FIG. 8